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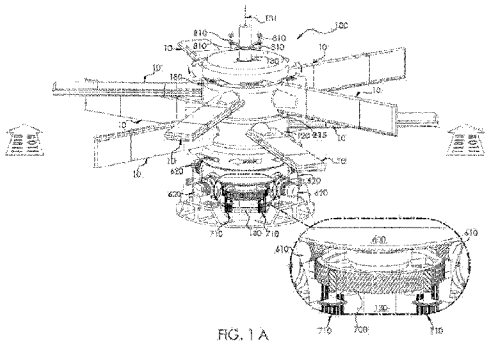


FIG. 1 A

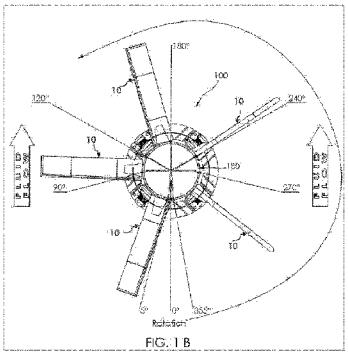


FIG. 1 B

(57) Abstract: A kinetic fluid energy conversion system comprises one or more hubs (120) which rotate about a central hub carrier, each including one or more independently controlled articulating energy conversion plates ("ECP"). An articulation control system rotates each ECP (10) independently of all others to control its orientation with respect to the fluid flow direction between an orientation of 90° perpendicular to the fluid flow, while traveling in the direction of the flow and 0° minimal drag parallel position to the flow, while traveling in the direction against the flow or blocked from it. Each hub (120) can be operably coupled to another hub to form one or more counter- rotating hub and ECP assemblies whereby the mechanical energy is transferred through the hubs, to one or more clutch/gearbox/ generator/pump assemblies thereby permitting such assemblies to be land-based when the system is air-powered, and above or near the surface, when the system is water-powered.

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KINETIC FLUID ENERGY CONVERSION SYSTEM

CROSS REFERENCE OF RELATED APPLICATION

[0001] This application claims the benefit under 35 U.S.C. § 119(e) of the filing date of provisional patent application Serial No. 62/687,554 filed June 20, 2018, the respective disclosure(s) of which is(are) incorporated herein by reference.

FIELD OF DISCLOSURE

[0002] This disclosure relates to kinetic fluid energy to mechanical energy conversion and integral counter-rotating transmission assemblies. In particular, this disclosure relates to a universal axis, counter-rotating arrangement of operationally coupled hubs, each rotating about an integral hub carrier, with each hub capable of supporting one or more independently controlled articulating energy conversion plates operationally connected to it. The energy conversion plates are automatically articulated, and at all times fully controlled by, components within the hub, from an orientation parallel to the fluid-flow position (slipstream) to an orientation perpendicular to the flow (working), and back to slipstream during any number of radians, or for any duration of travel, about the 360° hub rotation. Kinetic fluid energy is converted to mechanical energy via each energy conversion plate while in any orientation greater than parallel to the fluid flow while moving in the direction of the fluid flow. Mechanical energy is transferred from each energy conversion plate to the hub to which it is operationally connected, through the hubs, without a required driveshaft, to one or more clutches, gearboxes, electric generators, pumps, or other rotating mechanical devices ("Gearbox/Generator Assemblies") suitable for converting kinetic rotational energy from a rotating body into another form of energy, including without limitation, electricity or compressed fluid (gas or liquid). The unique design enables locating one or more Gearbox/Generator Assemblies on the ground, for land-based systems, and at the waterline, or above it, for water-based systems.

BACKGROUND

[0003] No document is admitted to be prior art to the claimed subject matter.

[0004] Machines used for converting kinetic fluid energy to mechanical energy are known in the art and include horizontal axis wind turbines ("HAWT"), vertical axis wind turbines ("VAWT"), and water turbines used to convert stored energy, for example water retained by a dam, or convert energy from a channeled flow, for example from a higher elevation to a lower elevation, to mechanical energy. Challenges exist within HAWTs whereby their blades are monolithic, industrial-scale units with blades weighing upwards of 30 tons each, and, in many cases, the blades require months to transport from their place of manufacture to their installation site. Up to a year of logistical planning for the transport of a single 32-ton blade is not uncommon. Another challenge exists with HAWTs whereby the gearbox/generator assembly, which can weigh more than 30 tons, is located within the nacelle upon a tower assembly. In addition, the high rotational tip speed of industrial-scale turbine blades can approach 200 mph, and, consequentially HAWTs kill an estimated 300,000 birds per year. Industrial scale HAWTs high rotational tip speed also produces what some describe as unbearable low-frequency noise for persons living within 3,200 feet of such machines and consequential related headaches, ear pain, nausea, blurred vision, anxiety, memory loss, and an overall feeling of unsettledness. These negative effects upon people have prompted legislators in the United States, Canada and Australia to seek minimum distance requirements for which industrial scale HAWTs can be located from residential housing. Challenges also exist with VAWTs, such as the Savonius Rotor, whereby energy converted by their airfoils, while moving in the direction of the wind, is largely canceled out when the airfoil completes its rotation while moving against the wind. With respect to the Darrieus Turbine (VAWT), which comprises vertical wing-like blades, challenges exist whereby the machine is not self-starting. Once started, however, the turbine also has a high rotational speed which can be fatal to birds. Additionally, the energy conversion of VAWTs is less than a HAWT relative to the volumetric area within which VAWTs operate as compared to HAWTs. Neither HAWTs nor VAWTs have designs or

features to effectively protect them from winds that far exceed their rated capacity and neither turbine type works in water. Likewise, water turbines do not work in wind.

SUMMARY

[0005] The following presents a simplified summary in order to provide a basic understanding of some aspects described herein. This summary is not an extensive overview of the claimed subject matter. It is intended to neither identify key or critical elements of the claimed subject matter nor delineate the scope thereof. Its sole purpose is to present concepts in a simplified form as a prelude to the more detailed description that is presented later.

[0006] Aspects of the disclosure are embodied in a system that may include a hub that is rotatable about a hub axis of rotation, one or more articulating plates extending radially from the hub and rotatable therewith, where each articulating plate is configured to be articulable about a plate articulation axis that is oriented radially with respect to the hub axis of rotation, and an articulation control system configured to independently control orientation of each plate with respect to the associated plate articulation control axis. Each plate is operably coupled to the articulation control system so that the articulation control system changes the orientation of the plate as the hub rotates about the hub axis of rotation.

[0007] According to other aspects, the hub axis of rotation may be oriented vertically, horizontally, or any angle therebetween.

[0008] According to other aspects, the system may include two or more hubs, each hub being axially adjacent with respect to the hub axis of rotation to at least one other hub, wherein each hub is rotatable about the same hub axis of rotation, and wherein each hub is configured to rotate in an opposite direction than the axially adjacent hub.

[0009] According to other aspects, the system may further include a separator plate disposed between each hub and at least one axially-adjacent hub, wherein the separator plate is fixed with respect to the hub axis of rotation and is configured so as

not to interfere with rotation of the articulating plates with the hub about the hub axis of rotation or articulation of the articulating plates about their respective axes of rotation.

[0010] According to other aspects, the separator plate is configured to prevent the fluid flow passing through each hub from affecting the fluid flow of the adjacent hub.

[0011] According to other aspects, the system may further include at least one counter-rotating transmission between each hub and an axially-adjacent hub to rotationally couple each hub to the axially-adjacent hub. The counter-rotating transmission may include a ring gear on each hub and the axially-adjacent hub, wherein each ring gear is coaxially arranged with respect to the hub axis of rotation and a plurality of pinon gears angularly spaced about the hub axis of rotation. Each pinion gear is rotatable about a pinion axis that is oriented radially with respect to the hub axis of rotation, and the pinion gears are disposed between the ring gears on each hub and the axially-adjacent hub, such that rotation of each hub about the hub axis of rotation in a first direction causes a corresponding rotation of the axially-adjacent hub in a second direction about the hub axis of rotation opposite the first direction.

[0012] According to other aspects, the system may include at least two counter-rotating transmissions between each hub and an axially-adjacent hub, wherein the ring gears of each of the counter-rotating transmissions have a different diameter.

[0013] According to other aspects, the system may include a non-rotating perimeter plate disposed between pairs of hubs rotating in opposite directions.

[0014] According to other aspects, the system may include a hub carrier comprising a tube that is coaxially arranged with respect to the hub axis of rotation, wherein each hub is rotationally mounted with respect to the hub carrier so as to be rotatable about the hub carrier, and the hub carrier is fixed against rotation with the hubs.

[0015] According to other aspects, the system may further include a float assembly to which the at least one hub, the one or more articulating plates, and the articulation control system are attached. The float assembly is configure to buoyantly

support the at least one hub, the one or more articulating plates, and the articulation control system within a body of water and with the at least one hub, the one or more articulating plates, and the articulation control system submerged below the surface of the body of water.

[0016] According to other aspects, the float assembly is anchored within the body of water by at least three cables connecting the float assembly to a ballast mounting attachment. The system may further include an automated winch assembly associated with each cable and configured to automatically control the length of the cable between the float assembly and the respective ballast mounting attachment so as to control the orientation of the float assembly and the at least one hub, the one or more articulating plates, and the articulation control system buoyantly supported thereby.

[0017] According to other aspects, the system may further include a perimeter plate fixed to the hub carrier and disposed between each hub and the axially-adjacent hub and thrust bearings disposed between the perimeter plate and the hub and between the perimeter plate and the axially adjacent hub.

[0018] According to other aspects, the system may further include a brake housing surrounding the hub carrier and fixed with respect to the hub carrier, wherein the brake housing is directly or indirectly coupled to an axially end-most one of the two or more hubs and thrust bearings between the brake housing and the axially end-most hub.

[0019] According to other aspects, each articulating plate comprises a shaft rotatably mounted to the hub and defining the articulation axis of the associated plate. The articulation control system may include a fixed track assembly having a continuous track about its perimeter, wherein the continuous track circumscribes the hub axis of rotation and a follower assembly coupled to each shaft, wherein the follower assembly traverses the continuous track as the hub and plate rotate about the hub axis of rotation to vary the orientation of the plate with respect to the articulation axis of the plate.

[0020] According to other aspects, the follower assembly is physically connected to an associated shaft.

[0021] According to other aspects, the follower assembly is magnetically coupled to an associated shaft.

[0022] According to other aspects, each articulating plate comprises a shaft rotatably mounted to the hub and defining the articulation axis of the associated plate, and the articulation control system may include a first magnetic array, a second magnetic array spaced apart from the first magnetic array and of opposite polarity than the first magnetic array, a magnetized follower coupled to the shaft and disposed at least partially in the space between the first magnetic array and the second magnetic array, and a controller adapted to selectively control the magnetic force of one or more portions of at least one of the first and second magnetic arrays to effect selective movement of the magnetic follower to cause rotation of the associated articulating plate.

[0023] According to other aspects, each articulating plate may include a shaft rotatably mounted to the hub and defining the articulation axis of the associated plate, and the articulation control system may include one or more motors operatively coupled to each of the shafts and controlled to effect selective rotation of the associated shaft.

[0024] According to other aspects, each articulating plate is mounted to an associated shaft defining the plate articulation axis, and may further include first and second stops attached to the shaft at angularly-spaced positions. The first stop is configured to prevent the associated articulating plate from rotating about the plate articulation axis beyond a first orientation, and the second stop is configured to prevent the associated articulating plate from rotating about the plate articulation axis beyond a second orientation.

[0025] According to other aspects, each articulating plate may include a shaft rotatably mounted to the hub and defining the articulation axis of the associated plate, and wherein the articulation control system may include a lubricant-filled chamber, a fixed track assembly disposed within the lubricant-filled chamber and having a

continuous track about its perimeter, wherein the continuous track circumscribes the hub axis of rotation, a follower assembly associated with each articulating plate and disposed within the lubricant-filled chamber and engaged with the continuous track, an outer magnetic coupling connected to each shaft and disposed outside of the lubricant-filled chamber, and an inner magnetic coupling connected to the follower assembly and disposed within the lubricant-filled chamber. The inner magnetic coupling is magnetically coupled to the outer magnetic coupling through a wall of the lubricant-filled chamber so that as the hub and articulating plate rotate about the hub axis of rotation the follower assembly traverses the continuous track and varies the orientation of the plate with respect to the articulation axis of the plate.

[0026] According to other aspects, the fixed track assembly may include a split track assembly including a stationary track member and a movable track member that is movable with respect to the stationary track member in an axial direction with respect to the hub axis of rotation, and the stationary track member is separable from the movable track member along the continuous track.

[0027] According to other aspects, one of the stationary track member and the movable track member includes a female conical mating surface and the other of the stationary track member and the movable track member includes a male conical mating surface, so that the stationary track member and the movable track member are self-aligning.

[0028] According to other aspects, the continuous track includes a first section, a second section, and first and second transition sections between the first and second sections and wherein, as the follower assembly traverses the first section of the track, engagement of the follower assembly with the first track section causes the associated plate to assume a first orientation with respect to the articulation axis of the plate, as the follower assembly traverses the second section of the track, engagement of the follower assembly with the second track section causes the associated plate to assume a second orientation with respect to the articulation axis of the plate, as the follower assembly traverses the first transition section of the track, engagement of the follower

assembly with the first transition section causes the associated plate to transition from the first orientation with respect to the articulation axis of the plate to the second orientation with respect to the articulation axis of the plate, and as the follower assembly traverses the second transition section of the track, engagement of the follower assembly with the second transition section causes the associated plate to transition from the second orientation with respect to the articulation axis of the plate to the first orientation with respect to the articulation axis of the plate.

[0029] According to other aspects, the first section of the track lies in a first plane that is perpendicular to the hub axis of rotation, the second section of the track lies in a second plane that is perpendicular to the hub axis of rotation, and the first and second sections of the track are axially spaced apart with respect to the hub axis of rotation.

[0030] According to other aspects, opposed sides of the continuous track have an opposite magnetic polarity and the follower assembly includes a follower head disposed within the continuous track and magnetized so that opposed sides of the follower head have a magnetic polarity opposite the magnetic polarity of the side of the continuous track facing that side of the follower head.

[0031] According to other aspects, the continuous track has a circular cross-sectional shape and the follower head has a spherical shape.

[0032] According to other aspects, each plate has opposed surfaces, a leading edge, and a trailing edge, and the articulation control system is configured to orient each plate in a slipstream orientation in which the opposed surfaces of the plate are parallel to the plane of rotation of the hub for a first portion of each rotation of the hub and in a working orientation in which the opposed surfaces are not parallel to the plane of rotation of the hub for a second portion of each rotation of the hub.

[0033] According to other aspects, the opposed surfaces are oriented perpendicular to the plane of rotation of the hub during the second portion of each rotation of the hub.

[0034] According to other aspects, the system may include a plurality of articulating plates disposed at angularly-spaced positions about the hub and wherein adjacent articulating plates that are in their slipstream orientations overlap one another, and each articulating plate has a leading edge pocket of reduced thickness on a first surface of the plate and a trailing edge pocket of reduced thickness on a second surface of the plate, and the leading edge pocket of one articulating plate nests with the trailing edge pocket of an adjacent overlapped articulating plate when the plates are in their slipstream orientations.

[0035] According to other aspects, the system may further include a hub orientation control system. The hub orientation control system may include a sensor detecting a direction of a fluid flow transverse to the hub axis of rotation; and one or more actuators configured to reposition the hub about the hub axis of rotation so that the articulating plates are in their slipstream orientations for the first portion of each rotation of the hub in a direction against the direction of fluid flow and so that the articulating plates are in their working orientations for the second portion of each rotation of the hub in a direction with the direction of fluid flow.

[0036] According to other aspects, the system may further include a cowling surrounding the at least one hub, wherein a part of the cowling associated with each hub is closed on a side of the cowling corresponding to the first portion of the hub's rotation and includes an intake port and an exhaust port on a side the cowling corresponding to the second portion of the hub's rotation.

[0037] According to other aspects, each plate has opposed surfaces, a leading edge, and a trailing edge, and the articulation control system is configured to orient each plate in a slipstream orientation in which the opposed surfaces of the plate are parallel to the plane of rotation of each hub for a first portion of each rotation of the hub and in a working orientation in which the opposed surfaces are not parallel to the plane of rotation of the hub for a second portion of each rotation of the hub. The system may further include a cowling surrounding the two or more hubs, wherein a part of the cowling associated with each hub is closed on a side of the cowling corresponding to

the first portion of the hub's rotation and includes an intake port and an exhaust port on a side the cowling corresponding to the second portion of the hub's rotation and a separator plate disposed within the cowling between each hub and at least one axially-adjacent hub, and the separator plate is fixed with respect to the hub axis of rotation and is configured so as not to interfere with rotation of the articulating plates with the hub about the hub axis of rotation or articulation of the articulating plates about their respective axes of rotation.

[0038] According to other aspects, the system may further include an articulation override system configured to override the articulation control system and cause each plate to assume a desired, unchanging orientation while the articulation override system is activated.

[0039] According to other aspects, the system may further include an articulation override system configured to override the articulation control system and orient each plate in its slipstream orientation at any angular position about the hub axis of rotation.

[0040] According to other aspects, each plate has opposed surfaces, a leading edge, and a trailing edge, and wherein the articulation control system is configured to orient each plate in a slipstream orientation in which the opposed surfaces of the plate are parallel to the plane of rotation of the hub for a first portion of each rotation of the hub and in a working orientation in which the opposed surfaces are not parallel to the plane of rotation of the hub for a second portion of each rotation of the hub. The system may further include an articulation override system configured to override the articulation control system and orient each plate in its slipstream orientation at any angular position about the hub axis of rotation. The articulation override system may include one or more linear actuators configured to axially separate the stationary track member from the movable track member to disengage the follower assembly of each articulating plate from the fixed track assembly, rocker arms coupling the movable track member to a primary override ring that is coaxially oriented with respect to the hub axis of rotation so that axial movement of the movable track member causes a corresponding axial movement of the primary override ring and an actuator cam

attached to the shaft of each articulating plate of a one of the hubs and configured to be contacted by the axially moving primary override ring and retain each articulating plate at its slipstream orientation.

[0041] According to other aspects, the system may further include a secondary override ring with lifters coupling the primary override ring to the secondary override ring, a tertiary override ring with lifters coupling the secondary override ring to the tertiary override ring, so that the primary override ring, the secondary override ring and the tertiary override ring move axially in unison, and an actuator cam attached to the shaft of each articulating plate of the axially adjacent one of the hubs and configured to be contacted by the axially moving tertiary override ring and retain each articulating plate of the axially adjacent hub at its slipstream orientation.

[0042] According to other aspects, the linear actuator comprises a ball screw actuator.

[0043] According to other aspects, the articulation override system may include one or more redundant actuators configured and controlled to cause axial movement of the primary override ring if the one or more linear actuators fail to axially separate the stationary track member from the movable track member.

[0044] According to other aspects, the redundant actuators comprise one or more actuators selected from the group consisting of pyrotechnic actuators, pneumatic actuators, hydraulic electronic solenoid actuators actuators, and piston actuators,

[0045] According to other aspects, the redundant actuator is configured to be actuated by an electrical device, explosive device, a pressure cartridge, a mechanical primer-initiated device, a linear detonation transfer line, or a laser actuated ordnance device.

[0046] According to other aspects, the system may further include a power take-off device operably coupled to the at least one hub and configured to receive mechanical energy from rotation of the at least one hub.

[0047] According to other aspects, the power take-off device may include one or more of a clutch, a gearbox, an electrical generator, and a pump.

[0048] Aspects of the disclosure are embodied in a method for converting kinetic fluid energy to mechanical energy with a hub that is rotatable about a hub axis of rotation and one or more articulating plates extending radially from the hub and rotatable therewith. The method may include the steps of A. selectively articulating each articulating plate about a plate articulation axis that is oriented radially with respect to the hub axis of rotation, and B. during step A, independently controlling an orientation of each plate with respect to the associated plate articulation control axis so that the orientation of the plate changes as the hub rotates about the hub axis of rotation.

[0049] According to other aspects, each plate has opposed surfaces, a leading edge, and a trailing edge, and wherein step B comprises orienting each plate so that the opposed surfaces of the plate are parallel to the plane of rotation of the hub for a first portion of each rotation of the hub and so that the opposed surfaces are not parallel to the plane of rotation of the hub for a second portion of each rotation of the hub.

[0050] According to other aspects, the opposed surfaces are oriented perpendicular to the plane of rotation of the hub during the second portion of each rotation of the hub.

[0051] According to other aspects, the method may further include placing the hub in a fluid flowing in a direction that is transverse to the hub axis of rotation, and wherein the plate is moving against the direction of fluid flow for the first portion of each rotation of the hub and the plate is moving with the direction of fluid flow for the second portion of each rotation of the hub.

[0052] According to other aspects, during first and second transition portions of each rotation of the hub, each plate transitions between its orientation during the first portion of the rotation and its orientation during its second portion of the rotation.

INCORPORATION BY REFERENCE

[0053] All publications, patents, and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication, patent, or patent application was specifically and individually indicated to be incorporated by reference.

BRIEF DESCRIPTION OF THE DRAWINGS

[0054] The novel features of the preferred embodiments are set forth with particularity in the claims. A better understanding of the features and advantages of the present embodiments will be obtained by reference to the following detailed description that sets forth illustrative embodiments, in which the principles of the preferred embodiments are utilized, and the accompanying drawings of which:

[0055] FIG. **1A** is an isometric view of a vertical axis embodiment of a kinetic fluid energy conversion system ("KFECS") with a broken-out section and enlarged partial isometric view of the hub orientation control motors and gears used to orient the KFECS toward the oncoming fluid flow or any other direction when used in a land-based application .

[0056] FIG. **1B** is a top view of the KFECS, configured with a single hub, with angular positions depicting where energy conversion plate articulations start and stop relative to the oncoming fluid flow.

[0057] FIG. **2A** is a partial isometric view of a hub, with a broken-out section which reveals one embodiment of an energy conversion plate articulation system, contained within a hub or enclosed by it.

[0058] FIG. **2B** is a partial front view of a hub, oriented nearest the fluid flow, with a broken-out section which reveals the portions of a cam track assembly that controls the energy conversion plates when they are in their orientations parallel and perpendicular to the fluid flow.

[0059] FIG. **2C** is a partial front view of a hub, with a broken-out section revealing a cross-sectional view of the cam track assembly, oriented nearest to the fluid flow, which reveals the portions of the cam track assembly that control the energy conversion plates when they are in their orientations parallel and perpendicular to the fluid flow.

[0060] FIG. **2D** is a partial front view of a hub, oriented nearest to the fluid flow, with a broken-out section which reveals the portions of the cam track assembly that controls the energy conversion plates when they are in their orientations parallel and perpendicular to the fluid flow.

[0061] FIG. **2E** is a partial front view of a hub, oriented nearest the fluid flow, with a broken-out section which reveals an energy conversion plate shaft, on the right, in its parallel to the flow orientation, rotating clockwise about a longitudinal axis of a hub carrier, immediately before it begins its 90° articulation to its perpendicular to the flow orientation, and an energy conversion plate shaft on the left, after it has articulated to its perpendicular to the flow orientation.

[0062] FIG. **2F** is a partial front view of a hub, oriented nearest the fluid flow, with a broken-out section which reveals an energy conversion plate shaft that is transitioning from a parallel to the fluid flow orientation to its perpendicular to the flow orientation.

[0063] FIG. **2G** is a partial front view of a hub, oriented nearest the fluid flow, with a broken-out section which reveals an energy conversion plate shaft cross-sectional view, that has completed its articulation from its parallel to the flow orientation, to its perpendicular to the flow orientation.

[0064] FIG. **3A** is a partial isometric view of two counter-rotating hub assemblies with a broken-out section revealing a counter-rotating transmission with a magnified detail partial isometric view of the counter-rotating transmission.

[0065] FIG. **3B** is a partial isometric view of two counter-rotating hub assemblies with a broken-out section revealing an alternate embodiment of (i) a counter-rotating transmission with a magnified detail partial isometric view of an additional counter-rotating transmission and (ii) outboard hub to perimeter plate thrust bearings.

[0066] FIG. **4** is a cropped isometric view of a vertical axis embodiment of the KFECS with a broken-out section revealing primary operationally linked components used to override the articulation of energy conversion plates from a working orientation to a position where all energy conversion plates are simultaneously in the slipstream orientation.

[0067] FIG. **5A** is a cross-sectional view of a vertical axis embodiment of the KFECS which depicts the flow of mechanical energy through the energy conversion system with detailed magnified cross-sectional views of (i) an operably coupled bevel gear and clutch/gearbox/electrical generator/pump assembly pinion gear (FIG. **5B**).and, (ii) the transmission's ring gears to pinion relationship (FIG. **5C**).

[0068] FIG. **6A** is an isometric view of a vertical axis embodiment of the KFECS with (i) a ¼ section removed to reveal the hub components and features used to transfer mechanical power to one or more clutch/gearbox/electrical generator/ pump assemblies or adjacent hub.

[0069] FIG. **6B** is a cross-sectional magnified view of a hub extension (Detail **6B** depicted on FIG. **6A**) revealing an energy conversion plate ("ECP") shaft and its operably supporting bearings.

[0070] FIG. **6C** is a cross-sectional and partial isometric view of the ECP shaft in its working orientation.

[0071] FIG. **6D** is a cross-sectional and partial isometric view of the ECP shaft in its slipstream orientation.

[0072] FIG. **7A** is a partial isometric view of two counter-rotating hub assemblies with (i) a broken-out section revealing a counter-rotating transmission and a portion of a perimeter plate that is fixedly linked to the hub carrier, and (ii) a second broken-out section revealing an isometric view of components within a hub orientation motor housing used to orient the KFECS toward the fluid flow or any other direction.

[0073] FIG. **7B** is a cross-sectional view of the hub carrier, counter rotating transmission's pinion carrier, perimeter plate, and hub to perimeter plate proximity sensors.

[0074] FIG. **7C** is a cross-sectional view of the hub carrier, and an alternate embodiment of the perimeter plate which embodies up to two counter-rotating transmissions and optional perimeter thrust bearings.

[0075] FIG. **8A** is a partial front view of two counter-rotating hub assemblies with a broken-out section of a hub, revolving in a clockwise rotation about the longitudinal axis of the hub carrier, and revealing the front of the cam track assembly. Angular positions are shown where the ECP articulation control for a clockwise-rotating hub begins its transition from a slipstream orientation, at the 0° position, and completes its articulation to its perpendicular to the fluid flow orientation at the 5° position.

[0076] FIG. **8B** is an isometric view of a follower assembly comprised of a connecting rod, connecting rod bearings, sacrificial shaft and spherical magnet.

[0077] FIG. **8C** is a front view (i.e., facing the oncoming fluid flow) of the hub carrier with two cam track assemblies that show the respective angular offsets of each cam track assembly relative to the other track assembly.

[0078] FIG. **8D** is a rear view (i.e., facing away from the oncoming fluid flow) of the hub carrier with two cam track assemblies that show the respective angular offsets of each cam track assembly relative to the other cam track assembly.

[0079] FIG. **8E – 8G** are front views (i.e., facing the oncoming fluid flow) which illustrate the progressive articulations of the ECPs of a counter rotating pair of hubs as the ECPs articulate from their slipstream orientations to their working orientations.

[0080] FIG. **8H – 8J** are rear views (i.e., facing away from the oncoming fluid flow) which illustrate the progressive articulations of an ECPs of a counter rotating pair of hubs as the ECPs articulate from their working orientations to their slipstream orientations.

[0081] FIG. **9A** is a front cross-sectional view of the cam track assembly located within a hub with a follower assembly within the track and an ECP shaft to which the follower assembly is attached, wherein the cam track is magnetic.

[0082] FIG. **9B** is a cross-sectional, magnified view of a portion of the magnetic cam track assembly of FIG. **9A** with a front view of a magnetic follower head levitating within the magnetic track, the follower linkage, and the ECP shaft.

[0083] FIG. **10** is front view of a cam track assembly disposed within a lubricant filled membrane with a portion of the membrane removed to reveal components within the membrane, and a isometric view (Detail A) of a magnetic coupling and an magnified cross-sectional detail view (Detail B) of the follower assembly.

[0084] FIG. **11A** is an isometric view an embodiment of independent energy conversion plate articulation via a computer-controlled electromagnetic array assembly.

[0085] FIG. **11B** is partial isometric view of the electromagnetic assembly controlling the ECP's working mode.

[0086] FIG. **11C** is partial isometric view of the electromagnetic assembly controlling the ECP's transition from working mode to slipstream mode.

[0087] FIG. **11D** is partial isometric view of the electromagnetic assembly controlling the ECP's slipstream mode.

[0088] FIG. **12A** is a front view of the ball screw and track portions of a triple cam track assembly, in its closed position, with a cross-sectional view of a triple follower FIG. **12B** is a cropped cross-sectional view of the ball screw and track portions of the triple split track assembly, in its closed position, with the triple follower assembly in its working orientation.

[0089] FIG. **12C** is a front view of the ball screw and track portions of the triple cam track assembly in its open position with the triple follower assembly in its slipstream orientation.

[0090] FIG. **12D** is a cropped cross-sectional view of the ball screw and track portions of the triple cam track assembly in its open position with the triple follower assembly in its slipstream orientation.

[0091] FIG. **12E** is a front view of a triple follower assembly, used in a triple cam track, in its slipstream orientation.

[0092] FIG. **13A** is an isometric view of the pinion carrier and perimeter plate fixedly linked to the hub carrier.

[0093] FIG. **13B** is a plan view of the pinion carrier and perimeter plate fixedly linked to the hub carrier with a dashed line depicting two of many paths that electric wiring, hydraulic lines, fiber optic cable and other similar support systems may be physically routed from a hub carrier chase to the perimeter plate without the need for rotatable couplings.

[0094] FIG. **13C** is an isometric view of an alternate embodiment of the perimeter plate configured to be fixedly linked to the hub carrier and which may be used with up to two counter-rotating transmissions and which may accommodate up to two optional perimeter thrust bearings.

[0095] FIG. **13D** is a plan view of the alternate embodiment of the perimeter plate and including dashed lines depicting two of many paths that electric wiring, hydraulic lines, fiber optic cable and other similar support systems may be physically routed from a hub carrier chase to the perimeter plate without the need for rotatable couplings.

[0096] FIG. **13E** is a transverse cross-section of the KFECS an alternate embodiment of brake housing and perimeter plate.

[0097] FIG. **14** is partial cross-sectional view, transverse to an axis of an ECP shaft, of articulation motors mounted to the interior perimeter of the hub and engaged with a ring gear attached to the ECP shaft.

[0098] FIG. **15A** is a cropped isometric view of vertical axis embodiment of the KFECS with a broken-out section revealing (i) redundant failsafe systems, while in their stand-by mode, that, when activated, cause all ECPs to rotate into and/or remain in a slipstream orientation, and (ii) two magnetic cam track assemblies in their working mode configurations.

[0099] FIG. **15B** is a cropped isometric view of the vertical axis embodiment of the KFECS hub assembly with a broken-out section revealing two magnetic cam track assemblies in their slipstream mode configurations.

[0100] FIG. **15C** is a partial isometric view of the vertical axis embodiment of the KFECS hub assembly with a broken-out section revealing a magnetic cam track assembly in its slipstream mode configuration.

[0101] FIG. **15D** is a front view of the cam track assembly in its slipstream mode configuration.

[0102] FIG. **15E** is a cross-sectional view of the cam track assembly in the direction 15E showing conical mating surfaces of a self-aligning track section mating embodiment.

[0103] FIG. **15F** is an isometric view of an embodiment of the KFECS upper hub with a broken-out section revealing (i) a cam track assembly that was opened by a fail-safe backup AOS operation with resulting uncoupled follower heads, and (ii) redundant AOS failsafe actuators in their working positions.

[0104] FIG. **15G** is a partial, side, cross-sectional view of an uncoupled follower head with a broken sacrificial shaft as a result of the operation of a fail-safe backup AOS operation.

[0105] FIG. **15H** is a partial, side, cross-sectional view of an uncoupled spherical bearing with a broken sacrificial shaft as a result of the operation of a fail-safe backup AOS operation.

[0106] FIG**. 15I** is a partial, side, cross-sectional view of an uncoupled triple follower assembly with a broken sacrificial shaft as a result of the operation of a fail-safe backup AOS operation.

[0107] FIG. **15J** is a front view of an uncoupled articulation motor pinion with a broken sacrificial shear pin as a result of the operation of a fail-safe backup AOS operation.

[0108] FIG. **16** is schematic of computerized functions' inputs from the KFECS and remote operations, and computer outputs that control the AOS, clutches, brakes, hub orientation motors and water-based KFECS buoyancy and depth operations.

[0109] FIG. **17A** is an isometric view of an embodiment of the KFECS with a broken-out section revealing components which orient the KFECS relative to the fluid flow, transfer mechanical energy to generators or pumps, and stop the KFECS's hub rotations.

[0110] FIG. **17B** is an isometric view of an embodiment of a base superstructure of the KFECS and components used to orient the KFECS toward the oncoming fluid flow or other computer directed orientation.

[0111] FIG. **17C** is a plan view of the base superstructure and components used to orient the KFECS toward the oncoming fluid flow or other computer directed orientation.

[0112] FIG. **17D** is a transverse cross section of FIG. **17C**, in the direction ***17D***, of the base superstructure and components used to orient the KFECS toward the oncoming fluid flow or other computer directed orientation.

[0113] FIG. **18A** is an isometric view of the rear side a non-nesting ECP in a working orientation.

[0114] FIG**. 18B** is an end view of a non-nesting ECP in a working orientation.

[0115] FIG. **18C** is an exploded side view of a non-nesting ECP in a working orientation with a broken away section revealing optional internal buoyancy chambers.

[0116] FIG. **18D** is a top plan view of a single hub with 5 ECPs, each with a rectangular configuration, with each ECP simultaneously in its slipstream orientation.

[0117] FIG. **18E** is a top plan view of a single hub with 5 ECPs, each with a trapezoidal configuration, with each ECP simultaneously in its slipstream orientation.

[0118] FIG. **18F** is a front view of a KFECS embodiment with elongated hubs that accommodate non-nesting ECPs that, while in their working mode, extend past their respective hub's swept area into the adjacent hub's swept area, and an elongated perimeter plate that can accommodate additional superstructure and cowling attaching area.

[0119] FIG. **19A** is a top view of rear side of a nested ECP in its slipstream orientation.

[0120] FIG. **19B** is an isometric view of the rear side of a nested ECP in its slipstream orientation, with enlarged leading edge details, in its slipstream orientation.

[0121] FIG. **19C** is a back-side view of a nested ECP in its slipstream orientation.

[0122] FIG. **19D** is a front-side view of a nested ECP in its slipstream orientation.

[0123] FIG. **19E** is a top plan view of a single hub with five nesting ECPs depicting each ECP overlapping the adjacent ECP while all ECPs are in their slipstream orientation.

[0124] FIG. **19F** is a front view of a KFECS embodiment with elongated hubs that accommodate nesting ECPs that, while in their working mode, extend past their respective hub's swept area into the adjacent hub's swept area, and an elongated perimeter plate that can accommodate additional superstructure and/or cowling attaching area.

[0125] FIG. **20A** is a partial top view of an aggregate coated ECP surface.

[0126] FIG. **20B** is a partial isometric view of an inverted dimpled ECP surface.

[0127] FIG. **21** is an isometric view of a KFECS superstructure used for a land-based application with the longitudinal axis of the hub carrier perpendicular to the land, or land-based structure, upon which it is operably supported.

[0128] FIG. **22A** is an isometric view of a KFECS superstructure used for a land-based application with the longitudinal axis of the hub carrier parallel to the land, or land-based structure, upon which it is operably supported.

[0129] FIG. **22B** is a front view of a KFECS superstructure used for a land-based application with the longitudinal axis of the hub carrier parallel to the land, or land-based structure, upon which it is operably supported.

[0130] FIG. **22C** is an isometric view of an alternate embodiment of a KFECS superstructure, for a land-based application with the longitudinal axis of the hub carrier parallel to the land, or land-based structure, upon which it is operably supported.

[0131] FIG. **22D** is a front view of the KFECS superstructure of FIG. **22C**.

[0132] FIG. **23A** is a top isometric view of an embodiment of a KFECS superstructure used for a water-based application with the longitudinal axis of the hub carrier oriented perpendicularly to the surface of the water within which the KFECS is tethered to the underwater bottom.

[0133] FIG. **23B** is a bottom isometric view of an embodiment of a KFECS superstructure of FIG. **23A**.

[0134] FIG. **23C** is an isometric view, partially in cross-section, of an embodiment of a KFECS superstructure used for a water-based application with the longitudinal axis of the hub carrier oriented perpendicularly to the surface of the water within which the KFECS is tethered to the underwater bottom.

[0135] FIG. **23D** is a cropped side view, partially in cross-section, of a KFECS superstructure used for a water-based application with the longitudinal axis of the hub carrier oriented perpendicularly to the water's surface, revealing the drive components operatively coupled to the clutch/gearbox/electrical generator and/or pump assemblies.

[0136] FIG. **24A** is an isometric view of a KFECS superstructure used for a water-based application with the longitudinal axis of the hub carrier is parallel to the water's surface within which the KFECS is tethered to the underwater bottom.

[0137] FIG. **24B** is a front view of a KFECS superstructure used for a water-based application with the longitudinal axis of the hub carrier is parallel to the water's surface within which the KFECS is tethered to the underwater bottom.

[0138] FIG. **25A** is a front view of a cowling surrounding the hubs of a KFECS when used in a land-based, vertical axis application.

[0139] FIG. **25B** is a rear view of the cowling and KFECS.

[0140] FIG. **25C** is a front isometric view of the cowling that shows intake ports, hub carrier attachment and a hub separator plate.

[0141] FIG. **25D** is a rear isometric view of the cowling.

[0142] FIG. **25E** is a plan view of the cowling with a top plate and the top of the cowling omitted to expose a hub separator plate located within the cowling.

[0143] FIG. **25F** is a front cross-sectional view of one configuration of the cowling that shows plates that can be used above, below and between the ECPs of two counter rotating hubs.

DETAILED DESCRIPTION

[0144] Unless defined otherwise, all terms of art, notations and other technical terms or terminology used herein have the same meaning as is commonly understood by one of ordinary skill in the art to which this disclosure belongs. If a

definition set forth in this section is contrary to or otherwise inconsistent with a definition set forth in the patents, applications, published applications, and other publications that are herein incorporated by reference, the definition set forth in this section prevails over the definition that is incorporated herein by reference.

[0145] Unless otherwise indicated or the context suggests other-wise, as used herein, "a" or "an" means "at least one" or "one or more."

[0146] This description may use relative spatial and/or orientation terms in describing an absolute or relative position and/or orientation of a component, apparatus, location, feature, or a portion thereof. Unless specifically stated, or otherwise dictated by the context of the description, such terms, including, without limitation, top, bottom, above, below, under, on top of, upper, lower, left of, right of, in front of, behind, next to, adjacent, between, horizontal, vertical, diagonal, longitudinal, transverse, radial, axial, etc., are used for convenience in referring to such component, apparatus, location, feature, or a portion thereof in the drawings and are not intended to be limiting.

[0147] Furthermore, unless otherwise stated, any specific dimensions mentioned in this description are merely representative of an exemplary implementation of a device embodying aspects of the disclosure and are not intended to be limiting.

[0148] As used herein, the terms “fixedly linked,” “operationally connected,” “operationally coupled,” “operationally linked,” “operably connected,” “operably coupled,” “operably linked,” “operably couplable” and like terms, refer to a relationship (mechanical, linkage, coupling, etc.) between elements whereby operation of one element results in a corresponding, following, or simultaneous operation or actuation of a second element. It is noted that in using such terms to describe inventive embodiments, specific structures or mechanisms that link or couple the elements are typically described. However, unless otherwise specifically stated, when one of such terms is used, the term indicates that the actual linkage or coupling take a variety of forms, which in certain instances will be readily apparent to a person of ordinary skill in the relevant technology.

[0149] As used herein, the term "KFECS", refers to any embodiment of a kinetic fluid energy conversion system described herein, including without limitation, embodiments used for converting wind energy or water energy to mechanical energy, irrespective of the orientation of the longitudinal axis (axis of rotation) of the hub carrier relative to the land or land-based structure upon which the KFECS is located, or the water surface under which the KFECS is located.

[0150] As used herein, the term "bearing" refers to a component used to support and/or guide a rotating, oscillating, articulating or sliding shaft, pivot, wheel or assembly. Irrespective of the bearing described or shown, it may take on numerous forms, including without limitation sealed, unsealed, roller, ball, angular, needle and thrust. However, unless otherwise specifically stated, when such term is used, the term indicates that the actual linkage or coupling take a variety of forms, which in certain instances will be readily apparent to a person of ordinary skill in the relevant technology.

[0151] As used herein, the terms "computer," "computer-controlled and like terms refer to a computer and/or redundant computer(s) within or connected to the KFECS irrespective of its physical location, that may include one or more uninterruptible power supplies.

[0152] As used herein, the term "land-based system" refers to a KFECS that is intended to convert kinetic fluid energy from a moving gas or gaseous mixture, including, without limitation, air, to mechanical energy.

[0153] As used herein, the term "water-based system" refers to a KFECS that is intended to convert kinetic fluid energy from a moving liquid, or liquid mixture, including without, limitation, water, to mechanical energy.

[0154] As used herein, the term "independent control" refers to the rotation of an energy conversion plate, relative to its axis, independent of, and unrelated to, any other energy conversion plate included within the KFECS.

[0155] As used herein, the term "clutch/gearbox/electrical generator/pump assembly" refers to any device or assembly of components that may be operably

coupled to the KFECS and which may be driven by mechanical energy that flows from the KFECS.

[0156] As used herein, the term "energy conversion plate" when used in a land-based system, are commonly known as airfoils, and when used in a water-based system, are commonly known as hydrofoils.

[0157] As used herein, the term "ECP" refers to an energy conversion plate.

[0158] As used herein, the term "nesting ECP" refers to an ECP that, when all ECPs are in their slipstream orientation, are configured such that the ECP's leading edge parallel to the ECP's axis overlaps and nests with the ECP that is immediately ahead of it in its direction of rotation about the longitudinal axis of the hub carrier.

[0159] As used herein, the term "working mode" refers to the orienting of an energy conversion plates whereby they are not parallel to – and may be perpendicular – to the fluid flow and will convert kinetic fluid energy to mechanical energy when subjected to an oncoming fluid flow.

[0160] As used herein, the term "slipstream orientation" refers to the orienting of energy conversion plates whereby they are parallel to an oncoming fluid flow and will not convert kinetic fluid energy to mechanical energy when subjected to an oncoming fluid flow.

[0161] As used herein, the term "AOS refers to an articulation override system that comprise multiple redundant systems that enable the KFECS to articulate all ECPs to their slipstream position and stop the rotations of the hubs.

[0162] As used herein, the term "AOS standby mode" refers to the operation of the AOS system whereby it (i) is monitoring the KFECS for conditions incompatible with the KFECS working mode, and (ii) has all moving parts retracted or otherwise in a position or state where such parts are not subjected to mechanical wear.

[0163] As used herein, the term "AOS active mode" refers to the operation of the AOS whereby all energy conversion plates are moved to and/or retained in their slipstream orientations.

[0164] As used herein, the term "stopped mode" refers to the reorienting of all energy conversion plates (i) to their parallel to the flow (slipstream) orientations whereby they will not convert kinetic fluid energy to mechanical energy when subjected to a fluid flow, (ii) to a position whereby the KFECS can withstand fluid speeds and pressures far in excess of its design limit, and (iii) whereby the rotation of the KFECS is stopped for maintenance or any other purpose.

[0165] As used herein, the term "AOS Triggering Event" refers to any event that causes an AOS primary, or failsafe operation to occur. Triggering events include, without limitation, a signal received by the computer indicating (i) the fluid speed exceeds the KFECS's design specification, (ii) an error condition is detected by one or more sensors within the KFECS where such error condition require the KFECS's rotations to cease, (iii) maintenance of, or relating to, the KFECS is required or requested by the AOS or a maintenance crew, or (iv) any other specified condition is met.

[0166] The preferred embodiments will now be described with reference to the accompanying figures, wherein like numerals, including those followed by the characters "-A" refer to like elements throughout. The terminology used in the descriptions below, including without limitation the words "upper" and "lower," are not to be interpreted in any limited or restrictive manner simply because it is used in conjunction with detailed descriptions of certain specific embodiments. Furthermore, the preferred embodiments include numerous novel features, no single one of which is solely responsible for its desirable attributes or which is essential to practicing the preferred embodiments described. Furthermore, many components described herein and shown within the drawings, and which are drawn as solid components, are done so for ease of understanding the drawings. Notwithstanding the crosshatch of such components, all such components may be manufactured using conventional (i)

assembly techniques whereby a single component may be split into multiple parts and, when reassembled, embody the characteristics of the component described herein and/or shown in the drawings, and (ii) weight saving methods, including without limitation designing all such components, including without limitation ECP **10**, ECP **20,** hub **120**, hub carrier **130**, hub **180**, perimeter plate **215**, brake housing **121**, base **900** and cowling **1000**, in multiple sub-assemblies, which can be assembled with conventional assembly techniques, into the particular component as shown. All components, at the designer's choice, may also have an interior lattice-like, or other non-solid interior design with strengthened and/or thickened areas where required, for example at areas in contact with bearings, and an external skin whereby such components may appear to be solid when in fact they need not be to achieve their desired functionality.

[0167] Provided herein and shown on accompanying figures are configurations of a kinetic fluid energy to mechanical energy conversion system (KFECS) based on one or more independently controlled energy conversion plates operationally coupled to one or more counter-rotating hubs, with all hubs operationally coupled to an integral hub carrier.

[0168] Provided herein and shown on accompanying figures are configurations of hubs capable of being operably coupled to one or more counter-rotating adjacent hubs, with each hub including one or more independently controlled articulating energy conversion plates.

[0169] Embodiments disclosed herein and shown on accompanying figures support the configuration of one or more clutch/gearbox/electric generator and/or pump assemblies on or near the ground, for a land-based KFECS, and near or above the water surface, for a water-based KFECS.

[0170] Embodiments disclosed herein and shown on accompanying figures permit positioning a longitudinal axis of a hub carrier as described herein in any orientation relative to the land or land-based structure upon which the KFECS is erected, or water in which the KFECS is erected, including without limitation, horizontal,

or vertical. Irrespective of the orientation of the hub carrier's axis to the land or water surface as the case may be, the operably coupled clutch/gearbox/electrical generator or pump assembly(ies) may be located at or near the ground, or floor as the case may be, for a land-based KFECS, and at or near the water surface, for a water-based KFECS.

[0171] Embodiments disclosed herein and shown on accompanying figures are also related to the independent control of an energy conversion plate by articulation of it about a rotational axis that is substantially parallel to the plane of the ECP to achieve optimal energy conversion, while an energy conversion plate is moving in the direction of the fluid flow and to encounter minimal drag while moving against the fluid flow. In some embodiments, adjustment of the energy conversion plate articulation can be automatically overridden by an Articulation Override System (AOS) which causes each energy conversion plate, irrespective of the angular position about the hub carrier where it is located or traveling, to articulate to a position parallel to the fluid flow, and then causes all hubs and to cease rotating about the hub carrier (KFECS stopped position).

[0172] Embodiments disclosed herein permit multiple configurations of size and shape of KFECS components, including without limitation (i) differing aspect ratios of ECPs, and (ii) KFECS vertical, horizontal or their orientations relative to the ground or water bottom. Moreover, the descriptions and drawings are not intended to be limiting with respect to a KFECS physical shape, size, installation location or fluid type in which a KFECS is operating.

System Overview Hub and Energy Conversion Plate Assemblies – FIG. 1A

[0173] The kinetic fluid energy conversion system ("KFECS") is based upon an integral hub carrier, with one or more rotating operationally coupled hubs rotating around the hub carrier, with each hub having equally-spaced, independently-articulating, fully controlled energy conversion plates ("ECP") located around the hub's perimeter. The hub carrier remains oriented directly to the oncoming fluid flow, or any other computer-controlled orientation, via hub orientation control system comprising, in an embodiment, one or more computer-controlled hub orientation control motors.

[0174] Each energy conversion plate is independently controlled from within its respective hub and synchronized with the system's revolutions, such that each energy conversion plate can be oriented for optimum overall energy conversion while moving in the direction of the fluid flow, and then articulated to be oriented for minimum drag, while the energy conversion plate is blocked from the fluid flow or moving against the flow.

[0175] Different numbers of hubs can be configured in different aspect ratios (height to width) to support a variable range of installation conditions and/or designer's choice, including without limitation fluid speed, fluid type, ECP types and shapes. Different numbers ECPs can be configured in multiple desired geometric shapes to achieve overall KFECS operating characteristics, including without limitation the desired aspect ratio of the energy conversion system, mechanical energy output desired, and the overall energy conversion system size. All KFECS hub embodiments may be operably coupled to one or more power take-offs, including without limitation clutch/gearbox/generator or pump assemblies. The operable couplings, including without limitation clutches, may be computer controlled to selectively and individually couple and decouple to the KFECS to achieve a range of loads enabling the KFECS to operate in a wide range of fluid speeds. For example, only one of the multiple gearbox/generator assemblies may be coupled, for example by an engaged clutch, to the KFECS during low fluid speed operating conditions while two or more or all of the gearbox/generator assemblies may be coupled to the KFECS during relatively high fluid speed operating conditions.

[0176] KFECS embodiments may have a lower cut-in speed (the minimum speed at which a fluid energy conversion system begins to convert energy, typically by rotating or moving, sufficiently to rotate a generator or pump). KFECS lower cut-in speed results from the much larger square area of fluid conversion surface (ECPs) that may be configured in a given volumetric area, and the time over which the ECPs are in contact with the fluid flow as described herein, as compared to traditional wind and water kinetic energy conversions systems configured within the same volumetric area.

[0177] KFECS embodiments may also have a higher cut-out speed (the speed at which wind powered kinetic energy conversion systems, such as conventional horizontal and vertical axis wind turbines, are either attempted to be brought to rest or otherwise subjected to a lesser amount of dynamic pressure in an attempt to prevent damage to such systems. The embodiments described herein permit higher cut-out speeds as a result of its integral internal supporting structure and hub design, the plurality of which may be configured to be greater than twenty percent of the total area exposed to an oncoming fluid flow.

[0178] Embodiments described herein include an ECP tip speed that may never exceed the fluid speed and consequently rotates at a low RPM thereby (i) reducing wear on energy conversion components and related parts, and (ii) possibly reducing the risk of moving parts injuring birds and other flying animals, when used in air, or marine life, when used in water.

[0179] The embodiment used in this summary, as shown in FIGS. **1A** and **1B** comprises a five ECP design, the axis of each ECP is configured at 72-degree intervals about the hub, with the 0 degree positioned located nearest the oncoming fluid flow. As the first ECP in this embodiment moves in a rotation about the hub carrier's longitudinal axis, in the direction of the fluid flow, it will begin to convert kinetic fluid energy to mechanical energy after it passes the 0-degree position, increasing its energy conversion output through the 90-degree position, and then decreasing its energy conversion output to the 120-degree position. After passing the 120-degree position, the fluid flow toward the ECP will be completely blocked by the following, adjacent, ECP. Consequently, the first ECP in this example is then articulated to its 0-degree (angle of attack) slipstream orientation where the surfaces of the ECP will be substantially parallel to the fluid flow. Once the ECP passes the 180-degree position, it will remain in its parallel to the flow (slipstream) orientation while it rotates against the oncoming fluid or until it otherwise reaches the angular position at which the articulation control system is configured to begin controlled articulation of the ECP to its perpendicular (90 degree angle of attack) to the fluid flow (working) orientation.

Articulation Control – FIG. 2A

[0180] The articulation and orientation of each energy conversion plate is controlled at all times by components within its respective hub. In an embodiment, as shown in FIG. **2A**, that articulation control system comprises a split track assembly comprised of a stationary section and a movable section joined together to form a continuous track. The track assembly is fixed to the hub carrier so that it acts as a part of the hub carrier, immovable from the hub carrier while the KFECS is its working mode, and rotating with the hub carrier when the hub carrier is rotated by the hub orientation control system.

[0181] The stationary and moveable sections of the track assembly are connected by splines around its circumference, as shown in FIGS. **2B** – **2C**, and are followed by a follower assembly operably linked to the energy conversion plate shaft of the respective energy conversion plate.

[0182] In one embodiment, each section of the track assembly, and the follower assembly that travel within it, are magnetically charged and arranged so a spherical magnetic assembly levitates within the spherical magnetic track. As the fluid pressure increases upon an energy conversion plate, while in an orientation perpendicular to the fluid flow and moving with it, the energy conversion plate will cause the operably coupled hub to rotate about the hub carrier in the direction of the fluid flow and consequently, the energy conversion plate, operably linked shaft and operably coupled hub will rotate around the track assembly. As the follower assembly moves into a spline within the magnetic track, in this example, FIG. **2E** – **2G**, from the lower track to the upper track, its path of travel will cause the operably linked shaft to articulate the operably linked energy conversion plate from its orientation parallel to the fluid flow, shown in FIG. **2E**, to an orientation perpendicular to the fluid flow position, shown in FIG. **2G**.

Counter-Rotating Hub – FIG. 3

[0183] Each hub may be operably coupled to one or more counter-rotating hubs thereby transferring mechanical energy between them to a clutch/gearbox/electrical generator or pump assembly. One coupling method is achieved via a synchronous gear mesh. In this embodiment, each hub is fitted with a ring gear, with pinion gears meshed between each ring gear. This arrangement embodies a counter-rotating transmission which enables an evenly distributed load across the hub carrier and a synchronized counter-rotation of the meshed hubs. The counter-rotating transmission is designed and configured to work in any hub carrier longitudinal axis orientation, including horizontal, and vertical. However, when used in a vertical axis orientation, all gear surfaces can be immersed in a reservoir suitable for holding liquid lubricant, while not requiring any seals about rotating shafts or between components located under the liquid lubricant level.

Articulation Override System – FIG. 4

[0184] A computer-controlled articulation override system ("AOS") provides a series of failsafe mechanisms to automatically override the articulation control of all energy conversion plates in the event the fluid speed exceeds the design specification, error conditions are detected, maintenance is required, or any other specified condition is met, and stop the rotation of the energy conversion system. Moveable and lockable rings, and related components, contained within each hub remain in their respective retracted position during normal operations whereby they are not subjected to any wear. When actuated, the rings travel along the hub carrier axis and engage, through the counter-rotating hubs, and may slide against and move against any cam operably linked to an energy conversion plate shaft that is not in a slipstream orientation. Simultaneously, the operationally coupled cam track separates to permit each follower assembly to travel to its slipstream orientation, irrespective of the radian about the hub carrier's longitudinal axis it is moving through or is at which it is stopped.

1. Hub & Energy Conversion Plate Assembly – Working Principles – FIGS. 1A and 1B

[0185] Referring now to FIG. **1A,** the kinetic fluid energy conversion system ("KFECS") **100** has an integral hub carrier **130**, which may comprise a central shaft, with

two or more counter-rotatable hubs **120** and **180** carried co-axially on the hub carrier **130** and mounted for rotation in opposite directions about a longitudinal axis of the hub carrier **130** (a hub axis of rotation **131**). A perimeter plate **215** is rotationally fixed to the hub carrier **130** and is disposed between hubs **120** and 1**80** (see FIGS. **7A** and **13A**). Each such hub **120** and **180** has equally-spaced, internally controlled, independently-articulating energy conversion plates **10** (ECP) located around the respective hub's **120** and **180** perimeter and each ECP **10** is operably coupled to the respective hub by an associated shaft **140** extending radially from the hub to effect fluid flow-powered rotation of the respective hub. As the fluid pressure increases upon an ECP **10**, while the ECP **10** is in an orientation perpendicular to the fluid flow and moving with the fluid flow, the ECP **10** will generate a torque applied to the respective hub **120**, or hub **180**, thereby causing the respective hub **120** or hub **180** to rotate about the hub carrier **130**. Hubs **120** and **180** may be provided in pairs of counter rotating hubs – one hub **120** or **180** of the pair rotating in a clockwise direction and the other hub **120** or **180** of the pair rotating in a counterclockwise direction – to balance torsional loads generated by each hub.

[0186] During rotation of a hub **120** or **180** and its corresponding ECPs **10** in the presence of a fluid flow in a direction transverse to the longitudinal axis of the hub carrier **130**, each hub/ECP assembly will be rotating with the direction of the fluid flow for half of its rotation and against the direction of the fluid flow for the other half of its rotation. To harness the motive power of the fluid flow, each ECP **10** is articulated so as to maximize the surface area exposed to the fluid flow during at least part of the rotation in the direction of the fluid flow and is articulated to minimize the surface area exposed to the fluid flow during at least part of the rotation in the direction against the fluid flow. In the embodiment illustrated in FIG. **1A**, to generate a clockwise rotation in the lower hub **120**, the ECPs **10** on the left side of the hub carrier **130** are articulated (about a plate articulation axis) so as to maximize the surface area exposed to the fluid flow while the ECPs **10** on the right side of the hub carrier **130** are articulated (about the plate articulation axis) to minimize the surface area exposed to the fluid flow. To generate a counterclockwise rotation in the upper hub **180**, the ECPs **10** on the right side of the hub carrier **130** are articulated so as to maximize the surface area exposed

to the fluid flow while the ECPs **10** on the left side of the hub carrier **130** are articulated to minimize the surface area exposed to the fluid flow.

[0187] In an embodiment, the hub carrier **130** and the KFECS **100** remain oriented directly toward the oncoming fluid flow while in its working mode via a hub orientation control system that may include one or more fluid direction sensors **810** and one or more computer-controlled hub orientation control motors ("hub orientation control motors") **710** having drive gears engaged with the orientation gear **700** attached to the hub carrier **130** (see FIG. **17A**).

[0188] The articulation of each ECP **10** about the longitudinal axis (plate articulation axis) of its respective shaft **140** (and thus the ECP's orientation) is independently, fully and continuously controlled by an articulation control system that, in various embodiments, is located within the respective hub **120** or **180**. Each ECP **10** is also synchronized with its respective hub's revolutions about the hub carrier **130**, such that each ECP **10** can be oriented by the articulation control system for energy conversion while such ECP **10** is moving in the direction of the fluid flow, and then articulated to be oriented by the articulation control system for minimum drag while such ECP **10** is blocked from the fluid flow or moving against the fluid flow.

[0189] Such a KFECS **100** converts kinetic fluid energy to positive mechanical energy when a fluid flow acts upon an ECP **10** that is (i) not parallel to the fluid flow, including without limitation perpendicular to it, and (ii) positioned and/or moving in the direction of the fluid flow, thereby causing the fluid pressure against the ECP **10** to rise. Such ECP **10** causes its respective hub **120** or hub **180**, as the case may be, to rotate about the longitudinal axis of the hub carrier **130**. Positive mechanical energy is transferred to the hub **120** and hub **180** during any period in which the angle of attack of one or more of its respective ECPs **10** is not parallel to the fluid flow and moving in the direction of the fluid flow referred to herein as "working mode."

[0190] In an embodiment, the articulation control system is configured so that when the fluid flow to an ECP **10** is blocked by a following, adjacent ECP **10**, or an ECP **10** reaches the 180° position about the hub carrier **130**, where the ECP **10** transitions

from moving with the fluid flow to moving against the fluid flow, the ECP **10** will be articulated by the articulation control system described in Sections **2** and **9** herein about its respective shaft **140** axis from its energy converting working orientation (e.g., the ECP **10** surface is not parallel to and may be perpendicular to the fluid flow, or not parallel, and possibly perpendicular to, the plane of rotation of the hub) to its parallel to the flow "slipstream" orientation (or parallel to the plane of rotation of the hub), independently of all other ECPs **10**, whereby the ECP **10** is oriented to generate minimal drag as it rotates about the longitudinal axis of the hub carrier **130** in a direction against the fluid flow.

[0191] Different numbers of (i) hubs **120** and **180** can be configured per hub carrier **130**, and (ii) different numbers of ECPs **10** can be configured per hub **120** and **180**, based upon the designer's choice for satisfying performance and installation requirements, including without limitation the desired aspect ratio (height to width) of the KFECS **100,** its mechanical energy output and overall size. The embodiment shown in FIG. **1A** comprises a configuration with five ECPs **10** per each of two hubs **120** and **180**. In such configuration, the axis of each ECP **10** (defined by shaft **140**) is spaced at 72° intervals around the respective hub's **120** and **180** perimeter. By way of example, if a six-ECP **10** embodiment was configured, the axis of each ECP **10** would be spaced at 60° intervals around the respective hub's **120** and **180** perimeter(s) such that the axis of each ECP **10** would be evenly spaced around such perimeter.

[0192] Referring now to FIG. **1B** and still referring FIG. **1A**, regardless of the number of ECPs **10** or hubs **120** and **180** configured within the KFECS **100**, in the context of the present disclosure, 0° relative to the oncoming fluid flow for the KFECS **100** is based upon the orientation of the hub carrier **130** to the oncoming fluid flow. For simplicity, FIG. 1B shows only the counter clockwise rotating hub **180**.

[0193] When a hub **180** is rotating in a counterclockwise rotation, as a first ECP **10** in this embodiment (i.e., a five-ECP hub) moves in a counterclockwise rotation about the longitudinal axis of the hub carrier **130**, after it passes the 0° position it will be traveling in the direction of the fluid flow. As the first ECP **10** passes the 0° position, the

articulation control system will orient the ECP so as to maximize surface exposure to the oncoming fluid by the time the ECP **10** reaches an angular position of about 355° (measuring backwards from 360°) and will begin to convert kinetic fluid energy to mechanical energy. As the ECP **10** approaches the 180° position transitioning from moving with the flow to moving against the flow, the ECP **10** is then articulated by the articulation control system, as described in Sections **2** and **9**, to its slipstream orientation where the ECP **10** will be parallel to the fluid flow. Once the ECP **10** passes the 180° position, it will remain in its parallel to the flow (slipstream) orientation while it rotates against the oncoming fluid flow or until it otherwise reaches the angular position where it is configured to begin its controlled articulation to its perpendicular to the fluid flow (working) orientation.

[0194] Clockwise rotating hub **120**, not shown in FIG. **1B**, will articulate to maximum surface exposure at an angular position of about 5° and will articulate to minimum surface exposure after an angular position of about 127°.

2. Articulation Control System – Working Principle FIGS. 2A-2G

[0195] Referring now to FIG. **2A**, the articulation and orientation of each ECP **10** is controlled at all times by components that may be enclosed within its respective hub **120** or hub **180**. In an embodiment, orientation of each ECP **10** is positively controlled by a follower mechanism engaged with a cam surface that effects articulation of the ECP **10** to varying predetermined orientations, relative to the fluid flow, as the ECP **10** rotates about the longitudinal axis of the hub carrier **130**. In another embodiment, orientation of each ECP **10** is positively controlled by computer-controlled motor that effects articulation of the ECP **10** to varying predetermined orientations, relative to the fluid flow, as the ECP **10** rotates about the longitudinal axis of the hub carrier **130**. In another embodiment, orientation of each ECP **10** is positively controlled by computer-controlled magnetic array that effects articulation of the ECP **10** to varying predetermined orientations, relative to the fluid flow, as the ECP **10** rotates about the longitudinal axis of the hub carrier **130**.

[0196] In the embodiment shown in FIG. **2A**, a cam track assembly **250** includes an upper stationary section **251** and a lower moveable section **252** (in alternate configurations, the cam track assembly **250** comprises a single, integral unit as well as multi-track variations). The cam track assembly **250** is fixed to the hub carrier **130** so that it acts as a part of the hub carrier **130**, immovable from it while the KFECS **100** is its working mode, and rotating with the hub carrier **130** when the hub carrier **130** is rotated by the hub orientation control system.

[0197] Referring now to FIGS. **2B** and **2C** and still referring to FIG. **2A**, the cam track assembly **250** includes a continuous track **255** disposed around its circumference that includes upper track portion or section **260** and a lower track portion or section **270** with an angled spline portion **261** forming a transition section connecting the upper and lower track portions on one side of the cam track assembly **250** (see FIG. **2B**) and an angled spline portion **262** forming a transition section connecting the upper and lower track portions on an opposite side of the cam track assembly **250** (see FIG. **2D**). A follower assembly **254** is operatively engaged with the continuous track **255**. One follower assembly **254** is operably linked to the energy conversion plate shaft **140** of each ECP **10**. As the ECP **10** and shaft **140** rotate with the associated hub **120** or **180** about the cam track assembly **250**, the follower assembly **254** traverses the continuous track **255** resulting in corresponding orientations of the ECP **10** as the ECP **10** completes a revolution about the longitudinal axis of the hub carrier **130**.

[0198] For example, as shown in FIGS. **2E**, **2F**, **2G**, when the follower assembly **254** is disposed within the upper track portion **260**, the corresponding ECP **10** is disposed in its working orientation perpendicular to the direction of fluid flow, and when the follower assembly **254** is disposed within the lower track portion **270**, the corresponding ECP **10** is disposed in its slipstream orientation parallel to the direction of fluid flow. As the follower assembly **254** traverses the spline portion **261** from the lower track portion **270** to the upper track portion **260** (FIG. **2F**), the corresponding ECP **10** transitions from its slipstream orientation parallel to the direction of fluid flow to its working orientation perpendicular to the direction of fluid flow. As the follower assembly **254** traverses the spline portion **262** on an opposite side of the cam track assembly **250**

from the upper track portion **260** to the lower track portion **270**, the corresponding ECP **10** transitions from its working orientation perpendicular to the direction of fluid flow, to its slipstream orientation parallel to the direction of fluid flow.

[0199] Features of an embodiment of the follower assembly **254** are shown in FIG. **8B.** Follower assembly **254** includes a connecting rod **145** connected to and extending radially from the shaft **140** of the ECP **10**. Follower head **253** is connected to the end of a shaft **256** mounted to the connecting rod **145** at a radial distance from the shaft **140**. Shaft **256** may be rotationally mounted, defining an axis of rotation that is generally parallel to an articulation axis defined by the shaft **140**.

[0200] In an alternate configuration, the ECP **10** is in its slipstream orientation when the follower assembly is in the upper track portion and is in its working orientation when the follower assembly is in the lower track assembly, depending on how the follower assembly is operatively attached to the shaft **140** of the ECP **10**.

[0201] The follower assembly **254** may include a linkage fixedly attached to the shaft **140** with a follower head **253** at a free end of the linkage disposed within the track **255** of the cam track assembly **250**. In an embodiment, the follower head **253** is spherical in shape and the track has circular transverse cross-sectional shape generally conforming to, but having a larger diameter than, the follower head **253**.

[0202] In an embodiment, the upper section **251** and the lower section **252** are magnetically charged with opposite poles facing each other, and together comprise a magnetic track. The upper and lower sections can be magnetically charged by any suitable means, such as machining the upper and lower sections from permanent magnetic materials, embedding magnetic materials within nonmagnetic sections **251** and **252**, or by application of electromagnetism. In this embodiment, the spherical follower head **253** is also magnetically charged and travels within the magnetic track whereby like poles of the follower head **253** are oriented nearest its like pole in the magnetic track, thereby resulting in the follower head **253** levitating within the magnetic track and forming a magnetic bearing.

3. Counter-Rotating Hub – Working Principle - FIG. 3

[0203] Referring now to FIG. **3A** and still referring to FIG. **1A**, each hub **120** and **180** may be operably coupled to one or more counter-rotating hubs **120** and **180** thereby enabling the transfer of mechanical energy between them and/or through them to one or more operably coupled power take-off devices, such as clutch/gearbox/electrical generator or pump assemblies **620**. One hub **120** to hub **180** counter-rotating coupling method is achieved via a counter-rotating transmission **240** which enables the transfer of mechanical energy between them and/or through them to one or more operably coupled power take-off devices, such as clutch/gearbox/electrical generator or pump assemblies **620**.

[0204] In an embodiment, transmission **240** comprises a ring gear **200** attached or otherwise operatively coupled to hub **120** and a ring gear **230** attached or otherwise operatively coupled to hub **180** (see Section **3** and FIG. **3A**). Transmission **240** further comprises radially oriented pinions **220** that are rotatably mounted to a pinion carrier **210**, which is fixed to the hub carrier **130**. This arrangement results in the center of the axis of each pinion **220** remaining at all times in the same angular position relative to the hub carrier **130**. Consequently, because the center of the axis of each pinion **220** is fixed at an angular position with respect to the hub carrier **130**, rotational movement of either hub **120** and **180** about the longitudinal axis of the hub carrier **130** results in its operably linked respective ring gear **200** and ring gear **230** rotating about the longitudinal axis of the hub carrier **130.**. Rotational movement of either ring gear **200** or ring gear **230** will cause the opposing ring gear to rotate in the opposite direction. Movement of either ring **200** or ring gear **230** will cause the operably coupled pinions **220** to rotate about their respective axes thereby causing an opposite rotation of the adjacent ring gear and operably coupled hub.

[0205] The transmission **240** will operate irrespective of the orientation of the longitudinal axis the hub carrier **130**, including without limitation, horizontal and vertical. However, when used in a KFECS **100** with a hub carrier **130** that has a vertical axis orientation, all gear surfaces can be immersed in a reservoir suitable for holding liquid

lubricant, while not requiring any seals about rotating shafts or between components located under the liquid lubricant level.

4. Articulation Override System Working Principle - FIG. 4

[0206] Referring now to FIG. **4**, and still referring to FIG. **1A**, a computer-controlled ECP **10** articulation override system ("AOS") provides a means to automatically override the primary articulation control of all ECPs **10** to protect the KFECS **100** from fluid flow that exceeds preset limits and/or to stop the KFECS **100** for maintenance or other purposes. When activated, the AOS articulates all ECPs **10** to, and/or retains them in, a slipstream orientation (AOS Active Mode) until the AOS determines it is safe to return ECP **10** articulation control to the Primary Articulation Control System.

[0207] While the KFECS **100** is in its working mode, the AOS is in its standby mode (AOS Standby Mode) whereby the AOS continuously monitors sensors for any AOS active mode triggering event. When the AOS detects such triggering event, the AOS changes its status to active mode (AOS Active Mode). Such triggering events include without limitation the computer's receipt of a signal indicating (i) the fluid flow speed exceeds the KFECS's **100** design specification, (ii) an error condition is detected by one or more sensors within the KFECS **100** where such error condition require the hub **120** and **180** rotations to cease, (iii) maintenance of, or relating to, the KFECS **100** is required or requested by the AOS or a maintenance crew, or (iv) any other specified condition is met. All AOS components, other than external kinetic fluid energy speed and direction sensors **810**, may be enclosed within the counter-rotating hubs **120** and **180**, hub carrier **130** or other areas of the KFECS 100 and do not come in contact with the fluid flow.

[0208] An embodiment of the AOS includes moveable and lockable rings (see Section **10** and FIG. **15A**) including a primary ring **560**, secondary ring **570** and tertiary override ring **580** contained within hub **120** and hub **180** which remain in their retracted positions during normal operations whereby they are not subjected to any wear. The shaft **140** of each ECP **10** includes a cam **590**. When the AOS active mode is triggered,

the primary ring **560**, secondary ring **570** and tertiary override ring **580** move in axial directions with respect to the hub carrier **130** and cause any cam **590** operably linked to an ECP **10** that is not in the AOS Slipstream Mode position to move into, and/or remain in, such position. Simultaneously, the stationary section **251** and moveable section **252** of the cam track assembly **250** separate to permit each follower assembly **254** to travel to (or remain in) its slipstream position, irrespective of the angular position about the longitudinal axis of the hub carrier **130** the follower assembly **254** is moving through or at which it is stopped. The ECPs **10** remain in their slipstream orientations and, optionally, each hub **120** and hub **180** remains stopped until the AOS resumes its standby mode.

[0209] Exemplary embodiments of an articulation control system are described below. All such embodiments are compatible with the AOS to achieve its functions of articulating the ECPs **10** to, and/or retaining them in, a slipstream orientation (AOS Active Mode) until the AOS determines it is safe return the ECP **10** articulation control to the Primary Articulation Control System. The AOS controls any embodiment of ECP, including, without limitation, nesting ECP **20** as described in Section **13.3**. The detailed operations of the AOS are described in Section **10**.

5. Energy Conversion and Flow – FIG. 5A

[0210] Referring now to FIG. **5A**, mechanical energy flow through the KFECS **100** while in its working mode is depicted with dashed arrows. While the KFECS **100** is in its working mode, kinetic fluid pressure upon any ECP **10** that is not parallel to the oncoming fluid flow is converted into mechanical energy by the resulting rotation of the corresponding hub **120**. The energy conversion begins when kinetic fluid energy converted from any ECP **10** is transferred as a distributed load over the ECP **10**, and then transferred into the operably linked shaft **140**, both of which act together as a lever thereby applying a torque to the associated hub **120** to rotate the hub. The mechanical energy of the rotating hub is transferred out of the hub **120** into an operably coupled device, such as a clutch/gearbox/electrical generator/pump assembly **620**.

[0211] Still referring to FIG. **5A**, when an adjacent counter-rotating hub **180** is included in a KFECS **100**, kinetic fluid energy is converted into mechanical energy from any ECP plate **10** that is not parallel to the oncoming fluid flow by the resulting rotation of the corresponding hub **120**. The mechanical energy is converted as a distributed load (pressure) across the ECP **10** and is transferred through its respective operably linked shaft **140**, both of which act together as a lever thereby applying a torque to the counter-rotating hub **180**, and causing the hub **180** to rotate. The mechanical energy is transferred out of the counter-rotating hub **180** through the transmission **240**, and as described in more detail below in Section **7**, into a operably coupled counter-rotating hub **120**. The combined mechanical energy from both hubs **120** and **180** is transferred to any operably coupled device, such as a clutch/gearbox/electrical generator/pump assembly **620**, for example, by means of bevel gear **600** and pinion gears **610**, as described in more detail in Section **12.3**.

6. Hub Assembly Detail – FIG. 6A

[0212] Referring to FIG. **6A**, the hub **120** and hub **180** and hub carrier **130** design may be scalable to include internal space to accommodate all of the bearings and primary articulation controls and related components necessary for the conversion of kinetic fluid energy to mechanical energy (collectively "Hub and Hub Carrier Components"). The Hub and Hub Carrier Components may include (i) multiple hub carrier bearings **135** between hubs **120** and **180** and hub carrier **130** that permit the respective hub **120** and hub **180** to rotate around the longitudinal axis of the hub carrier **130**, (see hub carrier longitudinal axis **131** on FIG **1A**) (ii) thrust bearings **190** for supporting the weight of the respective hub **120** or hub **180** when the hub carrier's **130** longitudinal axis is mounted vertically (the illustrated embodiment includes one thrust bearing **190** however, alternate embodiments may contain several), (iii) one or more ECP shaft bearings **175** supporting shaft **140** (see FIG. **6B**) which enable ECP **10** articulation within, and operable coupling to, the respective hub **120** and hub **180**, and which may comprise self-aligning bearing systems, such as, for example, bearing systems available from SKF Group, (iv) integral seal-less counter-rotating transmission well recess **235** formed in a top surface of lower hub **120** (see also FIG. **7B**) which

houses the transmission **240** comprising the ring gears **200** and **230** and the pinions **220**, (v) pinion carrier relief **185**, (vi) primary articulation control components, of multiple embodiments as described in Section **10**, including for example, a cam track assembly **250**, (vii) computer-monitored sensors used to monitor hub **120** and hub **180** and clutch/gearbox/brake housing **730** related components. Computer-monitored sensors may include, without limitation, proximity, temperature and fluid level sensors for monitoring and/or detecting, (a) ECP shaft **140** articulation position, (b) ECP shaft **140** angular position about the longitudinal axis of the hub carrier **130**, (c) counter-rotating operable coupling **240** fluid level, and (d) status and/or operating condition of the hub **120** and hub **180**. Hub status and operating conditions may include but are not limited to (1) bearing conditions, (2) speed of revolutions about the longitudinal axis of the hub carrier **130**, (3) KFECS **100** internal temperatures, (4) clearances between perimeter plate **215** and the hub **120** and hub **180**, (5) clearances within the transmission **240**, (6) transmission **240** rotations per minute, (7) bevel gear **600** and (8) operably coupled clutch/gearbox/electrical generator and/or pump assembly **620**. An embodiment of hub **120** includes an attached hub end **121** with recesses that accommodate hub carrier **130** bearings, AOS components further described in Section **10**, and brake components further described in Section **12.2**. An embodiment of hub **180** includes an attached hub end **181** with recesses that accommodate hub carrier **130** bearings and AOS components further described in Section **10**. An embodiment of hub **120** and hub **180** may include components which support operable counter-rotating coupling assemblies, similar to those described in Section **7**, on each end of hub **120** and hub **180** thus enabling additional hubs to be added to the KFECS **100** and thereby permitting an expanded range of KFECS **100** aspect ratios to serve a designer's choice.

[0213] Referring now to FIG. **6B** and still referring to FIG. **6A**, hub **120** and hub **180** have integral hub extensions **124** that house bearings **175** supporting shaft **140**. Hub extension **124** may be received within a conforming recess **17** formed in the end of the ECP **10** or nesting ECP **20** as described in Section **13.3**.

[0214] Referring now to FIGS. **6C** and **6D**, and still referring FIG. **6B**, each shaft **140** may include two stops **160** extending radially from the shaft **140** from angularly-

spaced positions and which contact corresponding shoulders **155** formed internally to the hub **120** (or hub **180**) at the limit of the shaft's **140** articulation from its working rotational position to its slipstream rotational position. Shoulders **155** and stops **160** also act as a failsafe method of preventing the shaft **140** from rotating past its designed maximum limits of rotation about the longitudinal axis of the shaft **140**.

7. Counter-Rotating Transmission – FIGS. 7A, 7B

[0215] Referring to FIGS. **7A**, **7B** and still referring to FIGS. **1A** and **3A**, hub **180** contains similar components found in hub **120** but rotates in the opposite direction due to the transmission **240**, i.e., the ring gears **200** and **230** and the pinions **220**. The pinions **220** are rotatably mounted to the pinion carrier **210,** which is fixed to the hub carrier **130** such that the pinions **220** act as an extension of the hub carrier **130** and move with it when it is rotated about its longitudinal axis by the hub orientation control system. Ring gear **230** is attached or otherwise coupled to hub **180**. Consequently, because the center of the axis of each pinion **220** is effectively linked to an angular position of the hub carrier **130**, rotational movement of either hub **120** and **180** about the longitudinal axis of the hub carrier **130** results in its respective ring gear **200** and ring gear **230** rotating about the longitudinal axis of the hub carrier **130.**. Rotational movement of either ring gear **200** or ring gear **230** will cause the opposing ring gear to rotate in the opposite direction. Movement of either ring gear **200** or ring gear **230** will cause the operably coupled pinions **220** to rotate about their respective axes thereby causing an opposite rotation of the adjacent ring gear and operably coupled hub. Consequently, mechanical energy is transferred between hub **180** and ring gear **230**, through the pinions **220**, into ring gear **200** and hub **120**.

[0216] The hub **180** has a conical pinion carrier relief **185** formed therein that accepts the pinion carrier **210** with sufficient clearance to rotate around the pinion carrier **210** without contacting it. The transmission well recess **235** housing the transmission **240** may be filled with a lubricating fluid, thereby permitting the transfer of mechanical energy between two counter-rotating hubs without the need for any fluid seals for rotating components or components located below the fluid level when the

longitudinal axis of the hub carrier **130** is oriented vertically, and consequently, all ECP **10** control shafts **140** can be articulated without the need for lubricant seals related to the ring gear and pinion assembly.

[0217] Proximity sensors **585** located on a perimeter plate **215** of the pinion carrier **210** can be used to determine KFECS **100** operations, including without limitation, the distance between hubs and potential wear of hub carrier bearings **135**. Exemplary proximity sensors **585** include digital inductive, **2**-wire amplified, digital CMOS laser, photo-electric, pattern matching and optical. Hub carrier bearing **135** wear can be detected when one or more proximity sensors **585** detect a distance between the perimeter plate **215** and its adjacent hub **120** or hub **180** that is out of a pre-determined tolerance.

8. Independent Energy Conversion Plate Articulation – Working Mode – FIG. 8A

[0218] Referring now to FIG. **8A** and still referring to FIG**. 1A**, the follower assembly **254**, which is operably connected to the shaft **140** of each ECP **10**, or nesting ECP **20** described in Section **13.3**, is rotated about the shaft axis **140**, e.g., by 90 degrees, by the splines portions **261**, **262** of the continuous track **255** of the cam track assembly **250** as the respective follower head **253** travels through the splines. Beginning at a given angular position about the longitudinal axis of the hub carrier **130** relative to the oncoming fluid flow, in one embodiment, where the 0° position is located nearest the oncoming fluid and the hub **120** is rotating clockwise about the longitudinal axis of the hub carrier **130**, the ECP **10** angle of incidence, relative to the oncoming fluid flow, begins as parallel to the oncoming fluid flow (slipstream orientation, or 0° angle of attack) while at the 355° position. As the follower head **253** travels through the splines, the follower assembly **254** rotates the associated ECP **10** from its slipstream orientation to its full articulation orientation of 90° perpendicular to the fluid flow (**90°** angle of attack). In this embodiment, the entire 90° articulation is completed by the 5° angular position. The articulation control independently articulates each ECP **10** such that its articulation is wholly independent of, unrelated to, and unconstrained by, any aspect of

any other ECP **10**. The articulation of each ECP **10** may be controlled by any of the embodiments described in Section **9**.

8.1. ECP Articulation Offsets

[0219] Referring now to FIG. **8A**, FIG. **2B**, FIG. **9A** - FIG. **9B** and still referring to FIG. **1A**, the articulations of the ECPs **10** of the counter-rotating hubs **120** and **180** are synchronized whereby the ECPs of the two hubs cannot collide with each other. The synchronizations are accomplished and controlled by the cam track assembly **250**, or other articulation control embodiment, within each hub **120** or hub **180**. This is demonstrated in FIGS. **8E-G** and **8H – J** where, for illustrative purposes, an ECP **10** on the lower hub has been renumbered as ECP **8** and shown as transparent, and ECP **10** on the upper hub has been renumbered as ECP **9** and shown as transparent to avoid obscuring the detail of the cam track assembly behind it.

[0220] As shown in FIG. **8E**, ECP **8** of a lower hub, disposed in a horizontal, slipstream orientation, moves clockwise with its follower control assembly **254** guided in the lower track **270**, and ECP **9** of an upper hub disposed in a horizontal, slipstream orientation moves counterclockwise toward the ECP **8** with its follower control assembly **254** guided in the upper track **260**. Each ECP **8** and **9** has rotated about the respective cam track assembly **250** to the same angular position (0° in FIG. **8E**) as the respective follower assembly begins to traverse the spline sections **261** of the upper and lower track assemblies. As shown in FIG. **8F**, as the follower assemblies of the ECPs **8** and **9** traverse the spline sections **261** of the respective upper and lower cam track assemblies **250**, the ECPs **8** and **9** synchronously articulate clockwise about their respective axes of rotation at angular positions that are offset with respect to each other. That is, as an example, the follower assembly of ECP **8** traverses spline section **261** from lower track section **270** to upper track section **260** between 0° and 5° angular position with respect to the lower cam track assembly **250**. Conversely, the follower assembly of ECP **9** traverses spline section **261** from upper track section **260** to lower track section **270** between 0° and 355° angular position with respect to the upper cam track assembly **250**. Accordingly, each ECP **8** and **9** has moved “past” the other in its

rotation about the respective track assembly **250** while being articulated about its axis of rotation through the spline section **261**. As shown in FIG. **8G**, by the time the ECPs **8** and **9** reach their vertical, working orientations, lower ECP **8** is at 5° angular position with respect to the lower cam track assembly **250** and moving clockwise away from ECP **9**, and upper ECP **9** is at 355° angular position with respect to the upper cam track assembly **250** and moving counterclockwise away from the lower ECP **8**. Thus, the ECPs **8** and **9** do not contact each other during the articulation from the horizontal, slipstream orientation to the vertical, working orientation.

[0221] As shown in FIG. **8H**, ECP **8** of the lower hub, disposed in the vertical, working orientation, is moving clockwise toward ECP **9** with its follower control assembly **254** guided in the upper track **260**, and ECP **9** of the upper hub disposed in the vertical, working orientation is moving counterclockwise toward the ECP **8** with its follower control assembly **254** guided in the lower track section **270**. Lower ECP **8** has rotated clockwise about the lower cam track assembly **250** to a position short of a full half rotation of 180° (e.g., 150°) as the ECP **8** enters the spline section **262** connecting upper track section **260** with lower track section **270**. Upper ECP **9** has rotated counterclockwise about the upper cam track assembly **250** to a position short of a full half rotation of 180° (e.g., 210°) as the ECP **9** enters the spline section **262** connecting lower track section **270** with upper track section **260**. As shown in FIG. **8I**, as the follower assemblies of the ECPs **8** and **9** traverse the spline sections **262** of the respective upper and lower cam track assemblies **250**, the ECPs **8** and **9** synchronously articulate counterclockwise about their respective axes of rotation at angular positions that are offset with respect to each other. That is, as an example, the follower assembly of ECP **8** traverses spline section **262** from upper track section **260** to lower track section **270** between 150° and 180° angular position with respect to the lower cam track assembly **250**. Conversely, the follower assembly of ECP **9** traverses spline section **262** from lower track section **270** to upper track section **260** between 210° and 180° angular position with respect to the upper cam track assembly **250**. Accordingly, each ECP **8** and **9** has not yet "met" the other in its rotation about the respective cam track assembly **250** while being articulated about its axis of rotation through the spline section **262**. As shown in FIG. **8J**, by the time the ECPs **8** and **9** reach their horizontal, slipstream

orientations, lower ECP **8** and upper ECP **9** are at the same angular position (180°). Thus, the ECPs **8** and **9** do not contact each other during the articulation from the vertical, working orientation to the horizontal, slipstream orientation.

[0222] Referring now to FIG. **1A**, FIG. **8C,** FIG. **8D** and FIG. **9A** and FIG. **9B**, the offsets of where the upper and lower ECP **10** or ECP **20** (see Section **13.3**) articulations begin and end, relative to its adjacent ECP **10** on hub **120** and hub **180**, are within a designer's choice for satisfying performance and installation requirements. The change in offset is accomplished, with respect to a cam track assembly **250**, by altering where each such assembly is attached to the hub carrier **130** relative to the cam track assembly **250** in the adjacent hub **120** or hub **180**. The change in offset is accomplished in embodiments using the magnetic array articulation or motorized articulation, described in Sections **9.3** and Section **9.6** respectively, by the computer. Increasing an articulation offset permits using ECPs **20** with aspect ratios that allow increased nesting capabilities as described in Section **13.3** and permits using ECPs **10** and ECPs **20** with differing materials properties. For example, stiffer materials require less offset because the respective ECP **10** or nesting ECP **20** will have less flex while in its working orientation and consequently can have a reduced offset, thereby converting more energy without colliding with the adjacent counter-rotating ECP **10** or nesting ECP **20** due to flexing.

[0223] The angle of the spline and angular extent over which it is applied are design parameters which can be set. For example, in the illustrated embodiment, on the back side (i.e., down flow side) of the hub **120** or **180** at which the ECPs **10** are substantially blocked from the fluid flow, the spline **262** of the cam track assembly **250** may be set at a relatively shallow angle, as there is no particular benefit to a rapid articulation of the ECP **10** and so as to minimize twisting moment applied to the follower assembly **254** and the ECP shaft **140**. On the other hand, on the front side (i.e., inflow side) of the hub **120** or **180** at which the ECPs **10** are exposed to maximum fluid flow, spline angle **261** may be set at a steeper angle to effect a rapid articulation of the ECP into its power generating orientation.

[0224] ECPs **10** could likewise be transitioned to their working position prior to 0°, and in fact, it has been determined mathematically that ECPs **10** produce more overall power through an entire 360° rotation if the articulation from slipstream mode to working mode begins at approximately 355° and has completed its transition to working mode by 5°. In this example, although the ECP **10** starts to encounter drag from 355° due to its working surface starting to transition while moving against the flow from 355° - 0° (half of its transition), the inventor has determined that the positive power from 0° - 5° more than offsets the negative power from 355°- 0°.

[0225] As each ECP rotates about its respective hub, its shaft **140** remains at a substantially fixed axial position with respect to the hub axis of rotation centered between the upper track section **260** and the lower track section **270**. While the follower head **253** of the follower assembly **254** of each ECP is traversing the upper track section **260** or the lower track section **270**, the radial distance between the hub axis of rotation and the position on the connecting rod **145** at which the shaft **256** is inserted or otherwise attached or coupled to the connecting rod **145** remains unchanged. Due to the offset of the follower ahead **253** with respect to the axis of rotation of shaft **140**, however, as the follower head 253 traverses the transition section **261** or transition section **262** while shaft **140** remains centered between the upper track section **260** and the lower track section **270**, the radial distance between the hub axis of rotation and the connecting rod **145** will change. In one example, the radial distance will increase until it reaches the midpoint of the transition section of the upper and lower track, and then it moves back in toward the hub axis as it nears the end of the transition section. To accommodate that radial variation, the shaft **256** and follower head **253** may be configured to be movable in an axial direction (relative to shaft **256**) with respect to the connecting rod **145**, thereby varying the distance between the follower head 253 and the connecting rod **145**, while the radial distance between the track 255 and the hub axis of rotation remains constant through the transition areas **261**, **262**. Alternatively, to accommodate that radial variation, the shaft **256** and follower head **253** may be fixed with respect to the connecting rod **145**, while the radial distance between the continuous track **255** and the hub axis of rotation varies through the transition areas **261**, **262**.

[0226] Other articulation control systems described in this disclosure may also include comparable provisions for accommodating variation in the radial positioning of a follower assembly with respect to the hub axis of rotation as the follower assembly traverses a transition section of a follower orientation control feature. These provisions may include alternate embodiments of connecting rod **145**, similar to connecting rod **146** (See FIG. **12E** and **15I**) that include bearings within an alternate embodiment of connecting rod **145**.

[0227] It should be appreciated that the articulation offsets and related synchronization described herein functions the same irrespective of if a KFECS **100** embodiment of nesting ECPs **20** as described in Section **13.3** are used in lieu of sets of ECP **10**.

9. Primary Articulation Control – Multiple Embodiments

[0228] Still referring to FIG. **1A**, ECP **10** articulation control may be accomplished by numerous methodologies. In each of the following articulation control embodiments that use a follower assembly **254** (see FIG. **8A** and **8B**) the torsion moment that such articulation control can support can be increased by increasing the length of the follower assembly **254** or the follower assembly's **254** functional equivalent.

[0229] It should be appreciated that primary articulation control embodiments described herein functions the same irrespective of if a KFECS **100** embodiment of nesting ECPs **20** as described in Section **13.3** are used in lieu of sets of ECP **10**.

9.1 Interior Magnetic Cam Track Assembly - FIGS. 9A and 9B

[0230] Referring now to FIGS. **9A** and **9B**, and still referring to FIG. **1A**, and as described above, one embodiment of ECP **10** articulation control is achieved via a magnetic spherical split cam track assembly **250** comprised of a stationary magnetic track section **251**, and moveable magnetic track section **252**, each with opposite magnetic poles nearest its respective spherical track half, with a spherical magnetic follower head **253** within the track **255**, for each operably coupled shaft **140**. The spherical magnetic follower head **253** is arranged such that its magnetic poles are

repelled by the magnetism of each track section **251** and **252**. This arrangement of magnetic components results in the spherical magnetic follower head **253** levitating within the magnetic spherical cam track assembly **250** thereby creating a magnetic bearing.

[0231] The spherical magnetic follower head **253** is operably coupled to, e.g., mounted on a shaft **256**, which may be a sacrificial shaft as described below, of the follower assembly **254**, which is operably linked to a shaft **140** of an ECP **10**. The geometry of the continuous track **255** controls the position of each ECP **10** relative to the fluid flow throughout the ECP's **10** entire 360° rotation about the longitudinal axis of the hub carrier **130**.

[0232] Referring now to FIG. **8A** and FIG. **8C**, and still referring to FIG. **9A**, FIG. **9B**, and FIG. **1A**, the geometry of the track **255** may be configured to control the start, end, and duration of each ECP **10** articulation, with the minimum duration between the start and end point of each such articulation limited only by the diameter of the spherical magnetic follower head **253** relative to the angle of the steepest splines **261** and **262** through which the spherical magnetic follower head **253** travels. The radius of the follower cannot be larger than the radius of the spline. To exaggerate, and illustrate, the concept, if the radius of the entire cam track assembly is 1 foot, and the radius of the follower was 1 inch, the radius of the spline would be less than the path of travel required by the 1-inch follower. Consequently, the follower would collide with the track. This can be further described as

[0233] C= S/(cos((90-Theta)/2)),

[0234] where

[0235] C is the circumference of the magnetic spherical cam track assembly **250**,

[0236] S is the diameter of the spherical magnetic follower head **253**, and

[0237] Theta is the angle of the spline **261** and **262**.

[0238] In this embodiment, as the spherical magnetic follower head **253** travels through the track **255** around the magnetic cam track assembly **250**, (i) while traveling through the upper track **260** it causes the operably coupled ECP **10** to remain in an orientation perpendicular to the fluid flow (working position), (II) while traveling through a spline it causes the operably coupled ECP **10** to articulate 90°, and (iii) while traveling through the lower track section **270** it causes the related ECP **10** to remain in an orientation parallel to the fluid flow (slipstream).

[0239] It should be appreciated the magnetic levitation method described herein will function regardless of which track section has a particular pole, North or South, nearest the track **255**, provided the spherical magnetic follower head **253** is assembled within the magnetic cam track assembly **250** with its poles facing like poles of the magnetic cam track assembly **250**, and each track section **251** and **252** has an opposing magnetic pole nearest the its respective track **255** half.

[0240] It should be further appreciated that the greater the circumference of the magnetic cam track assembly **250**, and follower head **253** and/or the greater length of the connecting rod **145** embodied, or alternate embodiments of these components, including without limitation as described in Sections **9.2** and **9.4**, the great twisting moment the respective follower head can support.

[0241] It should be further appreciated that the words “upper” and “lower” are used herein and throughout Section **9** to orient the reader to the related drawings contained herein but do not limit the relative positions in which the hub carrier **130** and magnetic cam track assembly **250** are configured within the KFECS **100** or relative to the ground, or bottom of body of liquid, as the case may be.

9.2 Interior Lubricant-Filled Cam Track Assembly - FIG. 10

[0242] Referring now to FIG. **10** and still referring to FIG. **1A**, another embodiment of ECP **10** articulation control is achieved via an internal liquid-lubricant filled cam track assembly **300** comprised of an stationary section **301** and moveable section **302**. In this embodiment, the track assembly **300** is split along the centerline of a

track **303** having an upper track **325** and a lower track **326**. The liquid-lubricant filled cam track assembly **300** includes membrane **322** that defines an interior chamber suitable for containing liquid lubricant.

[0243] A spherical bearing travels in a circular track **303** and is operably linked to a shaft **317** rotationally supported in a bearing **315**. The bearing **315** is operably coupled to an inner magnetic coupling **321** which glides over an interior surface of the membrane **322**, but does not contact it, during normal operations. An outer magnetic coupling **323** glides over the exterior of the membrane **322**, but does not contact it during normal operations, and is operably coupled to its associated inner magnetic coupling **321** via magnetic attraction of sufficient magnetic force, through the membrane **322** to permit the transfer of torque necessary to articulate the associated ECP **10**. It should be appreciated that this arrangement permits the transfer of torque through the magnetic field in a seal-less configuration. It should also be appreciated that the perimeter plate **215** may comprise computer monitored sensors, as further described in Sections **9.5** and **11**, that would detect a leak in the membrane **322** thereby resulting in one or more computer-controlled operations, including without limitation, triggering the AOS. The outer magnetic coupling **323** is operably linked via a shaft **317**, which may be a sacrificial shaft as described below, to a shaft **140** of the associated an ECP **10**.

[0244] Track **303** has a circular transverse cross-section to receive the spherical bearing **310.** The geometry of the track **303** controls the position of each ECP **10** relative to the fluid flow throughout its entire 360° rotation about the longitudinal axis of the hub carrier **130**. The track **303** geometry may be configured to control the start and end of each articulation, with the start, end and duration of each articulation limited only by the diameter of the spherical bearing **310** relative to the steepest angle of the splines **261** and **262** (see FIGS. **2B** and **2D**) through which the spherical bearing **310** travels. This can be further described as:

[0245] C= S/(cos((90-Theta)/2)),

[0246] where

[0247] C is the circumference of the internal liquid-lubricant filled cam track assembly **300**,

[0248] S is the diameter of the spherical bearing **310**, and

[0249] Theta is the angle of the spline **261** and **262**.

[0250] In this embodiment, as the bearing **310** moves through the track **303** around the cam track assembly **300**, (i) while traveling through the upper track **325** it causes the operably coupled energy conversion plate **10** to be articulated perpendicular to the fluid flow, and (ii) while traveling through the lower track section **326** causes the associated energy conversion plate **10** to rotate to an orientation parallel to the fluid flow.

9.3 Magnetic Array Assembly – FIGS. 11A – 11D

[0251] Referring now to FIG. **11A** – FIG. **11D** and to FIG. **8**, another embodiment of ECP **10** articulation control is achieved via a magnetic array assembly **370** which is installed in the same location as, and in lieu of, any type of cam track assembly, including a magnetic cam track assembly **250**. The magnetic array assembly **370** is comprised of two opposing computer-controlled electromagnetic arrays **371** and **372**. A magnetized follower **373** is operably linked to the shaft **140**, of each ECP **10**. Each magnetic array **371** and **372** has an opposing computer-controlled variable electromotive force, with the follower **373** also being magnetically charged, with its North pole side facing the North array **371** and its South Pole facing the South array **372**. The computer, not shown, can be located within the KFECS **100** or attached remotely to it by a wired or wireless connection. The computer, using inputs from one or more fluid speed and direction sensors **810** (see FIG. **1A**) causes the electromagnetic force to be increased on segments of one array **371** and decreased on segments of the opposing array **372** sequentially in the direction of rotation as desired as the magnetized follower **373** passes through the arrays, thereby causing the magnetized follower **373** to change its position relative to the array assembly **370**, and consequently, articulate the shaft **140** and associated plate **10**, relative to the fluid flow

throughout its entire 360° rotation about the longitudinal axis of the hub carrier **130**. That is, by increasing the relative attraction between magnetized follower **373** and upper array **371**, the follower moves closer to the upper array – analogous to the magnetized follower assembly being in an upper track of the embodiments described above. By increasing the relative attraction between the lower array **372** and the follower **373**, the follower moves closer to the lower array **372** – analogous to the magnetized follower assembly being in a lower track of the embodiments described above. This arrangement results in the magnetized follower levitating within the magnetic array field that exists between the upper array **371**, and the lower array **372** and comprising a magnetic bearing within a computer-controlled and infinitely variable path about the magnetic array assembly **370**. This computer-controlled articulation embodiment permits the KFECS **100** to remain constantly optimally oriented toward the fluid flow by changing the beginning, duration and end-point of each ECP **10** articulation thereby eliminating the need for hub orientation control motors **710** and related components (See FIG. **1A** Enlarged view).

[0252] It should be appreciated that magnetic array assembly **370**, during AOS slipstream mode, does not require any sacrificial parts due to mechanical failure, for example a failed split track operation as described in Section 10.4. Consequently, shaft **257** (see FIG. **11A**) is not sacrificial.

9.4 Triple Cam Track Assembly - FIG. 12A

[0253] Referring now to FIGS. **12A – 12E**, alternative embodiments of a cam track assembly include a triple cam track assembly **460**. Cam track assembly **460** may be implemented as a magnetic cam track assembly, similar to magnetic cam track assembly **250** (see FIG. **9A**) or a liquid lubricant filled cam track assembly **300** (see FIG. **10**). This embodiment is comprised of three continuous tracks assemblies that control the articulation of the ECP shafts **140**, an upper track assembly **463**, a center track assembly **473**, and a lower track assembly **483** – each with a lower track, and upper track, and two spline sections connecting the respective upper and lower tracks. In various embodiments, upper track assembly **463** comprises a fixed track section **461**

and a movable track section **462**, center track assembly **473** comprises a fixed track section **471** and a movable track section **472**, and lower track assembly **483** comprises a fixed track section **481** and a movable track section **482**

[0254] A triple follower assembly **490** is comprised of a linkage **491**, shafts **492**, follower heads **253**, one or more bearings **493** (see also FIG. **15I**), connecting rod **494** and shaft **495**, which may be a sacrificial shaft, as described below. The combination of the three track assemblies **463**, **473** and **483** and a triple follower assembly **490** coupled to the tracks **463**, **473**, **483** triples the torsion moment that the triple cam track assembly **460** supports as compared to single-track assemblies by tripling the surface area of the follower heads **253** or spherical bearings **310** (see FIG. **10**). The designer may increase or decrease the moment that a particular track assembly supports by reducing or increasing the number of tracks, e.g. a double or quadruple cam track assembly, while using the same fundamental design principles incorporated in the triple cam track assembly **460** and related triple follower assembly **490**.

[0255] In various embodiments, the triple cam track assembly **460** is fixedly linked to the hub carrier **130.** The ECP shaft **140**, the triple follower assembly **490**, and the center track assembly **473** are configured and arranged so that the axis of each ECP shaft **140** is equidistant from the upper track and lower track of the center track assembly **473** (i.e., the axis of each ECP shaft **140** bisects center track assembly **473**). The triple follower assembly **490** includes three follower heads **253** (or three spherical bearings **310** if the triple cam track assembly is configured as a liquid-lubricant filled cam track assembly (see FIG. **10**), each follower head **253** being disposed within one of the upper track assembly **463**, the center track assembly **473**, and the lower track assembly **483**. Furthermore, to prevent the triple follower assembly **490** from binding during rotation of the ECP shaft **140** about the hub, the triple follower assembly **490** is configured so that the follower heads **253** are all located at the same circumferential position within their respective tracks **463**, **473**, **483** as the ECP shaft **140** rotates about the hub, so that the follower heads **253** simultaneously enter and exit the splines of the respective tracks **463**, **473**, **483**.

[0256] The coplanar alignment is an essential element of the geometry necessary for proper operation of the triple follower assembly **490** and prevents it from binding within the respective tracks **463**, **473** and **483**.

[0257] The triple cam track assembly **460**, like the magnetic cam track assembly **250** and lubricant filled cam track assembly **300**, uses the splined hub **280** when it moves from its closed position, shown in FIGS. **12A** and **12B**, to its open position shown in FIGS. **12C** and **12D**.

9.5 Hub Carrier and Perimeter Plate Detail FIG. 13A

[0258] Referring now to FIG. **13A**, FIG. **13B**, and FIG. **5**, the hub carrier **130** of the KFECS **100** operates as a superstructure component. The hub carrier **130** may include an integral chase **132** that can be used for routing any type of electrical cable, hose or pipe for transporting mixed fluids, gases, such as pneumatic or hydraulic lines (collectively "Transport System") or similar components (collectively "Transport System") through the entirety of the KFECS **100**, and routing such Transport System through the counter-rotating hubs **120** and **180** without the need for rotatable couplings.

[0259] The perimeter plate **215** is fixed to the pinion carrier **210** (connected to each other or a single, integral component) which is fixed to the hub carrier **130**. Consequently, any Transport System that runs through the hub carrier chase **132** may branch off through the perimeter plate **215** to serve numerous systems, including without limitation, electronic sensors, motor, vacuum, and pressure lines. Additionally, rotatable electrical couplings, including without limitation brush slip rings may be configured between the perimeter plate **215** and the adjacent hubs **120** and **180** thereby permitting the transfer of high voltage routed from the hub chase **132** to each ECP shaft **140** that serves a respective ECP **10** or **20**. This provides a means of energizing heating elements within the ECPs that could be controlled by computer, as described in Section **9.6**, to reduce potential icing of the ECPs **10** and **20** during icing conditions that sometimes occur. A KFECS **100** embodiment with more than two hubs **120** and **180** may include an additional perimeter plate **215**, and related transmission as described in Section **7**, between each additional hub.

[0260] Referring now to FIG. **13B**, Transport Systems may be routed over numerous physical routes between the hub carrier chase **132** and the circumference of the perimeter plate **215**. Several such physical routes are shown with a dashed line.

[0261] As shown in FIGS. **13A** and **13B**, the perimeter plate **215** and fixedly linked pinion carrier **210** have numerous features integral to the counter-rotation transmission described in Section **7** and the AOS described in Section **10**. Pinion shaft receiver bores **211** are formed at angularly spaced positions about an outer wall of the pinon carrier **210** and receive the shafts of the pinions **220**. Perimeter plate **215** includes an annular support flange **216** at its inner periphery at which the perimeter plate **215** connects to the pinion carrier **210**. Pinion openings **217** are formed in the annular support flange at angularly spaced positions corresponding to the positions of the pinion shaft receiver bores **211** and receive the pinions **220**. An annular hub receiver ring **218**, bordering the annular support flange **216** nests with hub **120** below the perimeter plate **215** and nests with hub **180** above the perimeter plate **215**. Annular support flange **216** is axially recessed with respect to the annular hub receiver ring **218** and the pinion carrier **210**, thereby forming an annular trough that nests within the transmission well recess **235**. The annular trough formed by flange **216** and the transmission recess **235** of the adjacent hub form a reservoir that can contain a liquid lubricant within which the pinions **220** positioned within the openings **217** are immersed. The reservoir does not require seals for retaining the liquid lubricant within the reservoir when the hub is operated in configuration in which the hub carrier **130** is oriented substantially vertically. An annular rib **221** projects axially above annular hub receiver rib **218** and the outer perimeter of the perimeter plate **215** and defines a recess beneath it which accepts a secondary ring **570** of an articulation override system as described in Section **10**. Tertiary ring lifter slots **219** formed in the annular rib **221** permit movement of a tertiary ring of the articulation override system as described in Section **10**. Proximity sensors **585** may be located on both sides of the perimeter plate in the locations shown, however, the locations and numbers of proximity sensors are not intended to be limiting an are shown as described as an embodiment. The words “below” and “above” as used herein are not intended to be limiting and are merely used to orient the reader to the drawing.

9.5.1 Perimeter Plate – Multi-function Alternate embodiment

[0262] Referring now to FIG. **13C** and **13D**, an alternate embodiment of a perimeter plate **215-A** includes all of the features and functionality embodied within perimeter plate **215** and further includes attachment points and/or supporting areas for (i) a second and/or additional counter-rotating transmission **245** (See FIGS. **3B** and **7C**), and (ii) a thrust bearing **227** extending circumferentially about the perimeter plate **215-A** near its outer perimeter**.**

[0263] Perimeter plate **215-A** includes outer pinion openings **222** formed in an annular support flange **228** at angularly spaced positions about the perimeter plate **215-A**. A pinion shaft receiver bore **223** is aligned with each outer pinion opening **222**. Each shaft receiver bore **223** receives a shaft of an outer pinion **224** having a gear head that is disposed in an associated outer pinion opening **222**.

[0264] Perimeter plate **215-A** is configured to be used with alternate embodiments of hub **120 (120-A)** and hub **180** (**180-A)**, whereby the counter rotating hubs **120-A** and **180-A** are rotationally coupled by the outer pinions **224**, optionally in combination with pinions **220** (inner pinions) of transmission 240.

[0265] In an embodiment, transmission **245** comprises a ring gear **225** attached or otherwise operatively coupled to hub **120-A** (to the top of hub **120-A** as shown in FIGS. **3B** and **7C**) and a ring gear **226** attached or otherwise operatively coupled to hub **180-A** (to the bottom of hub **180-A** as shown in FIGS. **3B** and **7C**). The radially oriented outer pinions **224** rotatably mounted within the receiver bores **223** of the perimeter plate **215-A** are disposed between the outer ring gears **225**, **226**. This arrangement results in the center of the axis of each outer pinion **224** remaining at all times in the same angular position relative to the hub carrier **130**. Consequently, because the center of the axis of each outer pinion **224** is fixed at an angular position with respect to the hub carrier **130**, rotational movement of either hub **120-A** or **180-A** about the longitudinal axis of the hub carrier **130** results in its operably linked respective outer ring gear **225** or outer ring gear **226** rotating about the longitudinal axis of the hub carrier **130**. Rotational movement of either outer ring gear **225** or outer ring gear **226** will cause the

opposing ring gear to rotate in the opposite direction via the coupling of the outer pinions **224**. In addition, if an (inner) transmission **240** is also used, movement of either ring gear **200** or ring gear **230** of transmission **240** will cause the operably coupled pinions **220** (inner pinions) to rotate about their respective axes thereby causing an opposite rotation of the adjacent ring gear and operably coupled hub.

[0266] Two thrust bearings **227**, referred to herein as perimeter hub bearings, may be provided and located against the perimeter plate **215**-A, with one thrust bearing **227** positioned between the top of the perimeter plate **215-A** and the bottom of top hub **180-A**, and another thrust bearing **227** positioned between the bottom of the perimeter plate **215-A** and the top of bottom hub **120-A** (see FIG. **7C**).

[0267] As shown in FIG. **13E**, an alternate embodiment of brake housing **730,** (**730-A**) includes a brake housing thrust bearing **731** disposed circumferentially within an annular groove or channel formed in the top of the brake housing **730-A** between the brake housing **730-A** and an alternate embodiment of the hub end **121-A**.

[0268] The brake housing thrust bearing **731** permits rotation of the hub end **121-A** and the hubs **120-A** and **180-A** with respect to the brake housing **730-A** about the hub carrier **130**. Brake housing thrust bearing **731** at the outer radial periphery of the of the brake housing 730-A and hub end 121-A also transfers lateral and vertical loads acting upon the hubs **120-A** and **180-A** through the hub end **121-A** to the brake housing **730-A**. Because the brake housing thrust bearing **730-A** is located at the outer radial periphery of the of the brake housing **730-A** and hub end **121-A**, it is able to withstand a greater lateral moment than only the hub carrier bearings **135** positioned between the hub end **121-A** and the hub carrier **130**.

[0269] Similarly, perimeter hub bearings **227** positioned on opposite sides of the perimeter plate **215-A** between the hubs **180-A**, **120-A** and at the outer radial periphery of the of the perimeter plate **215-A** and hubs **180-A**, **120-A**, transfers lateral and vertical loads acting upon the hubs **120-A** and **180-A** through the hubs and to the hub end **121-A**. Because the perimeter hub bearings **227** are at the outer radial periphery of the of the perimeter plate **215-A** and hubs **180-A**, **120-A**, they are able to withstand a greater

lateral moment than only the hub carrier bearings **135** positioned between the hubs **120-A**, **180-A** and the hub carrier **130**.

[0270] Thus, the hubs **120-A, 180-A**, hub end **121-A**, and hub carrier **130**, and all components operably or fixedly linked to the hub carrier **130**, are able to withstand greater vertical and lateral loads than could be withstood without brake housing thrust bearing **731** disposed between the brake housing **730-A** and the hub end **121-A**.

[0271] In addition, because the perimeter plate **215-A** and counter-rotating transmission **245** provides support points near the radially outer peripheries of the perimeter plate and hubs **120-A** and **180-A** (i.e., radially outer support points provided by outer pinions **224** and ring gears **225** and **226**), whereas transmission **240** (See FIG. **3B**) only provides support points located near the radial center of the perimeter plate **215** and hubs **120** and **180** (i.e., radially inner support points provided by pinions **220** and ring gears **200** and **230**), transmission **245** can transfer greater lateral torque than transmission **240** and would be subject to less stress than transmission **240**. Transmission **240** and transmission **245** can be used alone or in combination. That is, transmission **240** can be provided between one pair of counter rotating hubs **120-A**, **180-A** and transmission **245** can be provided between the same pair of counter rotating hubs **120-A**, **180-A**.

[0272] Unless otherwise noted or evident from the context, one or more of hubs **120-A**, **180-A**, perimeter plate **215-A**, hub end **121-A**, and/or brake housing **730-A** could be substituted for one or more of hubs **120**, **180**, perimeter plate **215**, hub end **121**, and brake housing **730**, as applicable, in any descriptions in this disclosure.

9.6 Perimeter Motor Driven Assembly – FIG. 14

[0273] Referring now to FIG. **14** and to FIG. **1A**, another embodiment of ECP **10** articulation control is achieved via one or more computer-controlled motors **400** and operably coupled ring gear **408**. In this embodiment, the ring gear **408** is operably coupled (e.g. fixedly and coaxially attached to) an ECP shaft **140** of an ECP **10** and is part of a computer controlled articulation control assembly **400**, comprising at least one

motor **402**, which rotates a pinion **404**, which is operably coupled to and rotates the ring gear **408** that is fixedly attached to an ECP shaft **140**. The perimeter plate **215** is operably connected to, and remains aligned with, the hub carrier **130** at all times, acts as an extension of it, and moves with it when it is rotated about its longitudinal axis by hub orientation control system. All power and computer control signals related to the operation of any articulation motor assembly **400** may be transmitted through the hub carrier chase **132** and routed from the hub carrier chase **132** through the perimeter plate **215** and thereafter transferred and/or transmitted into the hubs **120** and **180** by rotatable couplings between the perimeter plate **215** and the hubs **120** and **180**. The computer, not shown, can be located within KFECS **100** or attached remotely to it by a wired or wireless connection. The computer, using inputs from one or more fluid speed and direction sensors **810**, causes the motorized pinions **404** to articulate the associated ECP shaft **140** and each operably linked ECP **10**, to its optimal position relative to the fluid flow throughout its entire 360° rotation about the longitudinal axis of the hub carrier **130**. This computer-controlled articulation embodiment permits the KFECS **100** to remain constantly optimally oriented toward the fluid flow by changing the beginning, duration and end-point of each ECP **10** articulation thereby eliminating the need for hub orientation control motors **710** and related components.

10. Articulation Override System – Standby Mode - FIG. 15A.

[0274] Referring now to FIG. **15A**, and still referring to FIG. **1A**, the KFECS **100** in some embodiments includes a computer-controlled articulation override system ("AOS") configured to rotate all ECPs **10**, or ECPs **20** as described in Section **13**, to their slipstream orientation (active mode) irrespective of their orientation to the oncoming fluid flow or their angular position about the longitudinal axis of the hub carrier **130**. The AOS may be include redundant actuator groups, such as, for example, pyrotechnic, pneumatic, hydraulic and electronic solenoid actuators, any one of which, when activated, cause all ECPs **10** to be rotated to their slipstream orientation all as more fully described in Section **10.3**. Such redundant actuators may comprise piston actuators that can be actuated by multiple means, including without limitation, an electrical device, explosive device (pressure cartridge), a pneumatic device, a spring-

loaded device, mechanical primer-initiated device (gas generator), a linear detonation transfer line (SMDC, FCDC, ETL, RDC), or a laser actuated ordnance device (laser-initiated squib or detonator).

[0275] One of the sections **251**, **252** of the magnetic cam track assembly **250**, for example, the moveable track section **252**, is designed to move with respect to the other stationary track section **251** when directed by the AOS to go into AOS active mode to thereby decouple the follower assembly **254** and ECP **10** from the magnetic cam track assembly **250**.

[0276] As shown in FIGS. **15B – 15E**, during AOS active mode, moveable cam track section **252**, which, in the illustrated embodiment, is the lower track section of the cam track assembly **250** of lower hub **120** and is the upper track section of the cam track assembly **250** of the upper hub **180**, engages with rocker arms **550** configured to engage a primary override ring **560**. As the moveable cam track section **252** separates from the stationary section **251** of the lower hub **120** (moving axially downwardly in the illustrated embodiment), the moveable cam track section **252** actuates the rocker arms **550**, which in turn engage and move the primary override ring **560** in an axial direction (upward in the illustrated example). As the primary override ring **560** moves axially, it contacts actuator cams **590** of the ECP shafts **140** of the lower hub **120**, thereby moving or maintaining each ECP **10** of the lower hub **120** in a slipstream orientation. The primary override ring **560** is also coupled to a secondary override ring **570**, for example, by means of axially-oriented lifters **565** extending between the primary override ring **560** and the secondary override ring **570**. Thus, axial movement of the primary override ring **560** is transferred into a corresponding axial movement of the secondary override ring **570**. A tertiary override ring **580** includes integral lifters **581** which operably couple to the secondary override ring **570**. Thus, the axial movement of the secondary override ring **570** is transferred into a corresponding axial movement of the tertiary ring **580**. As the tertiary override ring **580** moves axially, it contacts actuator cams **590** of the ECP shafts **140** of the upper hub **180**, thereby moving or maintaining each ECP of the upper hub **180** in a slipstream orientation.

[0277] In an embodiment, none of the operably coupled AOS components move or are subjected to any mechanical wear at any time other than when the AOS switches into active mode. In an embodiment, all operably coupled parts that come in contact with an actuator cam **590** or any other movable AOS components are constructed of materials with inherent low friction properties designed to slide without lubricant, such as Delrin®, or low friction coatings, such as Tungsten Disulfide. In an embodiment, the AOS is designed to rotate all ECPs **10** to their slipstream orientation in less time than is required for a hub **120** or **180** to make one revolution about the longitudinal axis of the hub carrier **130**.

[0278] During normal KFECS **100** operations, the AOS remains in a standby mode whereby linear actuators, such as motorized ball-screw assemblies **530** (which may be computer controlled, as described in further detail below), apply pressure to the moveable cam track section **252** in the direction of the stationary cam track section **251** causing both sections to act as a single contiguous track **255**. Similarly, in embodiments with a triple cam track assembly **460**, motorized ball screw assemblies **534** apply pressure to the movable track sections **462**, **472** and **482** causing all three sections, in combination with their associated fixed track section **461**, **471**, and **481**, respectively, to act as contiguous tracks **463**, **473** and **483**, respectively.

[0279] It should be appreciated that the it is the designer's choice as to the lifter style that may be used, lifters **565** or **581**, in alternate embodiments of the (i) AOS, (ii) perimeter plate **215** or **215-A** (see Section **9.5**), and (iii) hubs **120** and **180** as adequate space exists in all components that may be operably coupled to either lifters **565** or 581.

10.1 Active Mode – Primary System - FIG. 15A – FIG. 15F

[0280] Referring now to FIG. **15A**- FIG. **15F**, FIG. **12C**, and FIG. **12D** and still referring to FIG. **1A**, the AOS when activated is designed to rotate all energy conversion plates **10** to their slipstream orientations irrespective of their orientation to the oncoming fluid flow or their angular location about the longitudinal axis of the hub carrier **130**. The AOS primary activation system is comprised of the electromechanical actuator system **505** which, when activated as shown, cause all ECPs **10** to be rotated to their

slipstream position. In an embodiment, the computer-controlled electromechanical actuator system **505** does so by means of one or more computer controlled motors **506**, which rotate operably coupled dual right-angle gearboxes **518**, which rotate operably coupled right angle gear boxes **520**, which rotate operably coupled linear actuators attached to the moveable track section **252**, such as ball-screw assemblies **530**, causing the cam track assembly **250** to separate at the centerline of the continuous track **255** thereby providing clearance for the follower head **253** of the follower assembly **254** to move to its slipstream orientation irrespective of its angular position (i.e., to decouple the follower head **253** and follower assembly **254** from the continuous track **255**). For a magnetic track assembly, the linear actuators, e.g., ball screw assemblies **530**, must be able to overcome the magnetic attraction between sections **251**, **252**. The moveable cam track section **252** is operably coupled to the one or more rocker arms **550** and, as the moveable cam track section **252** separates from track section **251**, moving axially with respect to the hub carrier, the movable track simultaneously actuates the rocker arms, which causes the operably coupled primary override ring **560** to move toward and operably couple with the primary lifters **565**, which move toward, and operably couple with, the secondary override ring **570**, which operably couples with, and moves toward the tertiary override ring **580**. As the secondary override ring **570** moves toward the energy conversion plate control shafts **140**, the primary override ring **560** engages each actuator cam **590** in the hub **120** that is not in the slipstream orientation. Simultaneously, as the tertiary override ring **580** moves toward its end of travel, all actuator cams **590** in the hub **180** that it engages rotate the associated energy conversion plate shaft **140** and ECP **10** to its slipstream orientation.

[0281] The mechanical movement of the moveable magnetic cam track section **252**, and the parts to which it is operably coupled, are conceptually identical in function to the splitting movement of the liquid-lubricant filled cam track assembly **300**, and triple cam track assembly **460**, irrespective of whether or not the triple cam track assembly is used in a magnetic embodiment or liquid lubricant embodiment.

10.2 Self-Aligning Track Hub Assembly - FIG. 15B

[0282] Referring now to FIG. **15B** – **FIG. 15E** and still referring to FIG. **15A**, in various embodiments that include a track assembly fixed to the hub carrier **130**, such as magnetic cam track assembly **250**, lubricant filled cam track assembly **300,** or triple cam track assembly **460**, such assemblies are operably coupled to a splined hub **280** which is fixedly attached to the hub carrier **130**. In various embodiments, each split track assembly, irrespective of type, includes a male conical mating surface **274** on one of the track sections (fixed or movable) and a female conical mating surface **272** on the other track section (movable or fixed) that faces and mates with surface **274**. When the motorized ball-screws **530**, or other linear actuators, move the track section with the female conical mating surface **272** toward the male conical mating surface **274**, the cam track sections will self-align, relying in part upon the mating male and female frusto-conical surfaces of the splined hub **280** for its continually aligned path of travel, thereby assuring a uniformly mated and aligned split track assembly, e.g., magnetic cam track assembly **250** lubricant filled cam track assembly **300,** or triple cam track assembly **460** as the case may be.

10.3 Redundant Active Modes 1 – 3 - FIG. 15F

[0283] Referring now to FIG. **15F** and still referring to and FIG. **15A**, in an embodiment when one or more computer-controlled sensors, for example, a proximity sensor, detect an incomplete AOS operation, e.g. partial or failed cam track separation, one or more backup systems comprised of redundant actuator groups may be activated whereby all ECPs **10** will be rotated to their slipstream orientations. Rotation of the ECPs will occur irrespective of the ECP's **10** angular position about the longitudinal axis of the hub carrier **130** and regardless of articulation control system embodiment, including without limitation (i) magnetic cam track assembly **250**, (ii) lubricated cam track assembly **300**, (iii) triple cam track assembly **460** or (iv) ring and pinion positions, with respect to articulation via motorized articulation control assembly **400**.

[0284] Each actuator group may be supported on an actuator plate **500**, which may comprise a circular plate arranged coaxially with, oriented radially to, and

rotationally fixed to the hub carrier **130**. Accordingly, the actuator plate **500** may act as an extension of the hub carrier and move with the hub carrier when the hub carrier is rotated about its longitudinal axis by hub orientation control system. Actuator groups may be comprised of multple actuator types, including without limitation, pneumatic **508**, pyrotechnic **510**, hydraulic and electronic solenoid actuators, each capable of extending an integral actuator element, such as a piston, when activated.

[0285] When activated, each actuator of a backup actuator group, such as one comprising pneumatic actuators **508** and/or pyrotechnic actuators **510**, will simultaneously extend its respective actuator piston toward the primary articulation control ring **560**, and function as a backup to, and replacement for, the rocker arms **550** that failed to operate or fully operate as a result of a failed split-track operation. In an embodiment, the extent of axial movement of the primary articulation control ring **560** caused by the actuator group is equal or substantially equal to the movement of primary articulation control ring **560** caused by rocker arms **500**, and primary articulation control ring **560** thereafter actuates secondary articulation control ring **570** and the tertiary control ring **580,** as described above. Consequently, during any redundant AOS mode one or more sacrificial parts will break or become de-coupled as further described in Section **10.4.**

[0286] It should be appreciated that the AOS functions described herein operate on any ECP **10** type, including without limitation, nesting-ECPs **20** as described in Section **13.3**.

10.4 Sacrificial Parts FIGS. 15D – 15J

[0287] Referring now to FIGS. **15D - 15J**, FIG. **9A**, FIG. **9B**, FIG. **10**, FIG. **12A** and FIG. **14**, when any redundant AOS mode is activated (e.g., due to failure of the sections of the cam track assembly to fully separate and thereby decouple the ECP shaft **140** articulation control system), sacrificial components of the articulation control system will systematically fail to decouple the articulation control system from the ECP shaft **140**. The redundant backup actuator systems are designed to prevent catastrophic damage to the KFECS **100** from one or more ECPs **10**, or any other ECP embodiments,

including but not limited to all ECPs **20** as described in Section **13**, being in an orientation that exceeds design specifications, for example, exceeding the fluid speed for which a particular KFECS **100** is rated. One or more redundant backup actuator systems may be triggered when the AOS detects a failed ball screw assembly **505** operation or motorized articulation control assembly **400** failure. The redundant backup actuator systems incorporate follower assemblies having sacrificial shafts **256** for an embodiment with a track follower assembly **254**, such as magnetic cam track assembly **250** (or sacrificial shaft **495** for triple cam track **460** (see FIG. **12D** and FIG. **15I**) or sacrificial shafts **317** for an embodiment with a lubricant filled cam track assembly **300** (see FIG. **10**). For a motor-driven articulation **400,** a sacrificial shear pin **406** connects each pinion **404** to the shaft of its corresponding motor **402** (see FIG. **15J**). In the event of a failed cam track separation operation, as a redundant backup system causes the primary articulation control ring **560** to move through its length of travel, any sacrificial shaft **256,** sacrificial shaft **317** or sacrificial shaft **495** that is not in its slipstream orientation will be sacrificed and broken to decouple the associated follower assembly from the track and permit all ECPs **10** to be articulated into their slipstream orientations. The sacrificial parts allow all cams **590** to be moved into, or remain in, their slipstream positions irrespective of the failed cam track separation operation. In an embodiment with motorized articulation control, in the event of a failed motorized articulation to a slipstream orientation, the shear pin **406** will be sacrificed and broken to decouple each ring gear **408** and associated ECP shaft **140** from the motor(s) **402**, thereby allowing all ECPs **10** to be moved to or remain in, their slipstream orientation irrespective of the orientation of the motorized ECP shaft **140** orientation.

11. Computer Controlled Functions and Sub-Systems FIG. 16.

[0288] Referring now to FIG. **16**, in various embodiments, the KFECS **100** embodies redundant failsafe systems, which may be monitored and controlled by an onboard or remote computer and which may be protected by one or more uninterruptible power supplies. In a computer-controlled failsafe system, a computer may receive inputs from sensors that monitor conditions internal and external to the KFECS **100**. Sensor-monitored conditions include, but are not limited to, fluid speed and

direction, internal clearances between mechanical components, temperatures internal and external to the KFECS **100**, revolutions per minute of any rotating shaft, fluid levels, lubricant levels, brake states (brakes on or off), and clutch/gearbox/electrical generator/pump assembly service hours.

[0289] Using inputs from the sensors, the computer controls numerous KFECS **100** functions, irrespective if it is a land-based KFECS **100** or water-based KFECS **100**, including without limitation, the KFECS's **100** orientation to the fluid flow, the ECP's working and slipstream orientations during AOS operations and motorized articulation control, braking operations of the KFECS **100**, and equalizing the time that each clutch/gearbox/electrical generator/pump assembly is engaged and converting mechanical energy to electricity, a compressed gas, or pressurized fluid.

[0290] In various embodiments, computer monitored conditions and operations that are exclusive to KFECS **100** water-based installations include but are not limited the KFECS' **100** yaw, pitch, and depth relative to the water surface. Using these inputs, the computer controls numerous functions, as further described below.

12. Orientation Control and Conversion Unit – FIG. 17A – FIG. 17D

12.1 Hub Orientation Control

[0291] Referring now to **FIG. 17A – FIG. 17D**, in an embodiment, a hub orientation control system comprises one or more computer-controlled hub orientation control motors **710** engaged with the orientation gear **700** coaxially mounted to the hub carrier **130** and supported by a superstructure **900** located at or near the ground, or ground-based structure, as the case may be, for a vertical axis land-based KFECS **100.**

[0292] Exemplary hub orientation motor locations on other KFECS **100** embodiments are shown in FIG. **22A -** FIG. **22D**, FIG. **23C**, FIG. **23D** and FIG. **24A**. As shown in FIG. **17A**, FIG. **17B** and FIG. **17D**, hub orientation control motors **710** may be mounted to or carried by a plate **902** within a hub orientation motor housing **750**, or a functional equivalent, which is supported by the superstructure **900**, or a functional equivalent, including without limitation a (i) turn table style base assembly **908** (see FIG.

22A and **22C**), (ii) superstructure **960** (see FIG. **23C** and **23D**) and (iii) superstructure **972** (see FIG. **24A** and **24B**).

[0293] The computer receives input from any number of sensors and sources, including without limitation a fluid direction indicator **810** (see FIG. **1A**), and causes the hub orientation control motors **710** to turn associated pinions **720**, which turn the orientation gear **700,** or other gears in other embodiments described in Section **14,** thereby rotating the KFECS **100** to its optimal orientation relative to the oncoming fluid flow, or any other position, as directed by the computer. Suitable flow direction and speed indicator sensors are known in the art.

12.2 Brakes - FIG. 17A

[0294] Still referring to FIG. **17A**, one or more computer-controlled brake assemblies **760** are mounted within a clutch/gearbox/brake housing **730** supported by the superstructure **900** and, when actuated, are operably coupled with one or more brake discs **770.** The brake assemblies **760**, may comprise calipers that, when actuated, create resistance between their respective pads and the brake disc **770**, which is connected or otherwise operably linked to the hub **120**, or hub **180** in some embodiments, thereby stopping the rotations of all hubs **120** and hub **180** about the longitudinal axis of the hub carrier **130**.

12.3 Mechanical Energy Transfer to Gearbox/Electrical Generator/Pump Assemblies - FIG. 5A

[0295] Referring to FIGS. **5A – 5C** and FIG. **6A**, mechanical energy is transferred from the hub **120**, to the operably linked bevel gear **600** (coupled, e.g., to hub end **121**), to the operably coupled pinion gear **610**, to the operably linked clutch/gearbox/electrical generator/pump assembly **620.** Other embodiments of the KFECS **100** may transfer mechanical energy to the one or more respective operably linked clutch/gearbox/electrical generator/pump assembly **620** using additional components. For example, referring now to FIG. **22A** and FIG. **22 B**, a land-based KFECS **100** with the longitudinal axis of the hub carrier **130** that is approximately parallel to the land, or

land-based structure upon which it fixedly attached, one or more ring gears **602** and hub extensions **122** (see Fig. **22A**) are used to transfer mechanical energy from the hub **120** and/or hub **180** and their respective extensions, for example hub end **121**, to one or more operably coupled pinions **621** and operably linked clutch/gearbox/electrical generator/pump assemblies **620**.

[0296] Referring now to FIG. **22 C** and FIG. **22D,** another embodiment for a land-based KFECS 100 with the longitudinal axis of the hub carrier **130** that is approximately parallel to the land, or land-based structure upon which it fixedly attached, provides for the transfer of mechanical energy from hubs **120** and **180** to clutch/gearbox/electrical generator/pump assemblies **620** through one or more operably coupled driveshaft and gear sets as described in Section **14.2**.

[0297] FIG. **23C** shows a water-based KFECS **100** with a longitudinal axis of the hub carrier **130** (see also **131** on FIG. **1A**) that is transverse to (e.g., generally perpendicular to) the surface of the water in which the KFECS **100** is tethered to the bottom or otherwise submerged below the surface of the body of water, and which includes a gearbox/brake housing **740**. As shown in FIG. **23D**, gearbox/brake housing **740** enables the clutch/gearbox/electrical generator/pump assembly **620** to be oriented with its longitudinal axis co-planer to the vertical axis of the hub carrier **130** (vertical position), whereby it can more easily located above the water surface, all as more fully described in Section **14.3**.

[0298] FIG. **24A** shows a water-based KFECS **100** with the longitudinal axis of the hub carrier **130** that is approximately parallel to surface of the water in which the KFECS **100** is tethered to the bottom or otherwise submerged beneath the surface of the body of water. One or more hub extensions **122** supporting ring gears **606** that are rotationally coupled to the hubs **120** and **180** are used to transfer mechanical energy from hub **120** and/or hub **180** to one or more operably coupled clutch/gearbox/electrical generator/pump assemblies **620**, all as more fully described in Section **14.4**.

13. Energy Conversion Plates - FIG. 18A - FIG. 18F and FIG. 19A – FIG. 19F

13.1. General

[0299] Referring now to FIG. **18A – 18F**, FIG. **19A-19F** and still referring to FIG. **1A**, the ECP **10** and nesting ECP **20** include leading edges that are designed to reduce drag coefficient for all leading surfaces that are oriented toward oncoming fluid flow. The term "leading" means the forward most edge of an ECP **10** and nesting ECP **20** that is nearest to, or first to encounter, an oncoming fluid flow. All leading edges, irrespective of the embodiment, may be tapered or beveled. Each ECP **10** has a leading edge **14**, a trailing edge **18**, and opposed, planar surfaces **19-A** and **19-B** (see Figs. **A, B, D-F**), extending between the leading and trailing edges **14**, **18**, and which planer surface **19-A** defines the fluid impingement surface when the ECP **10** is in its working mode orientation. Each ECP **20** has a leading edge **24**, a trailing edge **29**, and opposed, planar surfaces **33** and **34** (see Figs. **19A, 19C-19F**), extending between the leading and trailing edges **24**, **29**, and which planer surface **33** defines the fluid impingement surface when the ECP **20** is in its working mode orientation.

[0300] In the embodiments shown, each ECP **10** leading horizontal (X coordinate) edge **14**, and the leading vertical (Y coordinate) edge **15** may be tapered or beveled. Similarly, each ECP **20** leading horizontal (X coordinate) edge **24**, and the leading vertical (Y coordinate) edge **29** may be tapered or beveled. Each ECP **10** and nesting ECP **20** may also be comprised of one or more sections, each connected to its adjacent section(s). The non-nesting ECP **10** may include an inboard section **11**, an extension section **12**, and an outboard section **13**, each of which, may include on or more integral air chambers **16**, that when used in a water-based KFECS **100** may be used to obtain a neutral buoyancy for the ECP **10**, thereby reducing the radial load on the ECP **10** and operably coupled and fixedly linked components. All ECP sections, when assembled, act as a single ECP **10** or nesting ECP **20** as described in Section **13.3**. The design of the ECP **10** and nesting ECP **20**, including without limitation, its aspect ratio (width to height), number of sections used to comprise it, and surface finish, are within a designer's choice for satisfying performance and installation requirements.

It should be appreciated that the aspect ratios are only constrained by the overall size of the KFECS **100**, the dimensions of its hubs **120** and **180**, and material's properties. It should also be appreciated that any ECP **10** referenced within Sections **1** – **12** could be replaced by a nesting ECP **20**.

13.2. Non-Nesting Energy Conversion Plate – FIG. 18A and FIG. 18D

[0301] Still referring to FIG. **18A** and FIG. **18D**, in one embodiment of a hub **180** comprising multiple ECPs, when all ECPs **10** are simultaneously in a position parallel to the fluid flow (slipstream) as shown, do not contact nor overlap any adjacent ECP **10**.

13.3. Nesting Energy Conversion Plate – FIGS. 19A – 19D

[0302] FIG. **19A** – FIG. **19D** shows one embodiment of a nesting ECP **20**. Each nesting ECP **20** includes a leading edge pocket **30** (section of reduced plate thickness) extending along the leading edge **24** and a trailing edge pocket **26** (section of reduced plate thickness) extending along the trailing edge **29** and disposed on the opposite side of the ECP from the leading edge pocket **30**. As shown in **FIG. 19E**, ECPs **20** are configured so that when all ECPs **20** of hub **180** are simultaneously in a position parallel to the fluid flow (slipstream), the leading edge pocket **30** of each nesting ECP **20** nests with the trailing edge pocket **26** of the following nesting ECP **20** (relative to the direction of hub rotation). Trailing edge pocket **26** includes edges **27** and **28** that are contoured to nest with the leading edges **31** and **32** of an adjacent nesting ECP **20**. This embodiment enables the surface area of the nesting ECP **20** to be increased over the surface area of non-nesting ECPs. The size of the nesting ECP **20** is limited only by the distance between the axis of articulation "A" of the nesting ECP **20** and the axis of articulation "A" of the adjacent nesting ECP **20**. The nesting ECP **20** has leading edges **24**, **25**, **31** and **32,** to reduce drag coefficient while the nesting ECP **20** is rotated through various orientations of its slipstream position. Each ECP **20** may be assembled of any number of operably linked subassemblies, for example the three ECP subassemblies **21**, **22** and **23** (see FIG. **19A** -**19B**) that, when operably linked, may comprise an entire ECP **20**. The ECP **20** assemblage may be similar in all respects to that of an ECP **10** (see FIG. **18C**).

[0303] Referring now to FIG. **19E** and still referring to FIG. **19A** – FIG. **19D**, leading edge nesting pockets **30** and trailing edge nesting pockets **26** permit all ECPs **20** to simultaneously be in their slipstream position as seen in FIG. **19E**. FIG. **19F** shows only two counter-rotating ECPs **20** - one per hub **120** and **180** – although each hub may have one, two, three, four, five, or more ECPs **20**.

[0304] Referring now to FIG. **19F** and still referring to FIG. **19A** – FIG. **19D**, an embodiment of the KFECS **100** that supports nesting ECPs **20** includes elongated hub extensions **215** coupled to hubs **120** and **180**, all of which provide working area (sufficient clearance) for ECPs **20** with a larger surface area.

13.4. Energy Conversion Plate – Surface Detail FIG. 20A – FIG. 20B

[0305] Referring now to FIG. **20A**, the surface of non-nesting ECP **10** (see **FIG. 18A – FIG. 18D**) and nesting ECP **20** (see FIG. **19A** -- FIG. **19D**) may be textured, or dimpled (see FIG. **20A** - **20B,** or any combination thereof**,** to increase its drag coefficient on any of its surface area used to convert kinetic fluid energy to mechanical energy, and consequently increase the KFECS's **100** total amount of fluid energy converted to mechanical energy. Any surface area may also have a surface finish designed to minimize drag coefficient as the surface moves against the fluid flow. Such surfaces include, but are not limited to leading edges **14**, **15**, **24**, **25**, **31** and **32**, which may beveled or otherwise shaped to minimize fluid dynamic drag.

14. Superstructure Embodiments – General - FIG. 21

[0306] Referring now to FIG. **21**, and FIG. **1A**, and FIG. **1B**, the hub carrier **130** serves as the central structural component in all embodiments of the KFECS **100**. That is, in various embodiments, the hub carrier **130** may function as an alignment axis that coaxially aligns the hub(s) and other components, and all components that are radially oriented are radially oriented with respect to the hub carrier.

[0307] The hub carrier **130** can be supported and/or stabilized at its ends and/or at one or more positions intermediate to the ends, for example at the perimeter plate **215**. The hub carrier **130**, together with the overall design of the KFECS **100**, permits

the KFECS **100** to be mounted with the longitudinal axis **131** of the hub carrier **130** (see FIG. **1A**) in any orientation, including but not limited to, horizontal, vertical and diagonal.

[0308] In various embodiments, irrespective of the non-nesting ECP **10** or nesting ECP **20** embodiment used, all ECP types may be in their slipstream orientation between 130° and 210° (see FIG. **8J**). Consequently, superstructure components can be connected to the perimeter plate **215** at and near the 180° position without being in the path of an ECP **10** or nesting ECP **20** in its working position when the KFECS **100** is operably connected to a turn-table style base, thereby enabling the superstructure to be connected to the perimeter plate **215** at the point nearest the maximum moment exerted upon hub carrier **130** (the point furthest from the oncoming fluid flow). In other words, the system will be exposed to a load, perpendicular to the hub carrier, from the fluid pressure. In some embodiments, the entirety of the lateral load would be on the hub carrier. However, because the ECPs articulate to their slipstream position as they approach and leave the 180° position, an additional superstructure component including without limitation a structural tube, beam or cable, could be fixed between the base and the perimeter plate at or near the 180° without colliding with the plates, thereby reducing the moment on the hub carrier.

[0309] It should be appreciated that in various embodiments it is the designer's choice as to when an ECP **10** or nesting ECP **20** may be in its slipstream, transition, or working orientation to the flow throughout the ECP's 360° rotation about the longitudinal axis **131** of the hub carrier **130** as further described in Section **9**.

14.1. Superstructure - Land-Based Vertical - FIG. 21

[0310] Still referring to **FIG. 21**, where the KFECS **100** is used to convert wind energy to mechanical energy, one embodiment is as shown with the longitudinal axis of the hub carrier **130** oriented perpendicular to the land or land-based structure upon which it is located. In this orientation, the KFECS **100** may be entirely supported by the hub carrier **130** and operably coupled base **900** when the base **900** is operably linked to the ground or a ground-based structure such as a building.

14.2. Superstructure - Land-Based Horizontal - FIGS. 22A – 22D

[0311] Referring now to FIGS. **1A**, **22A**, **22B**, where the KFECS **100** is used to convert wind energy to mechanical energy, one embodiment is as shown with the longitudinal axis of the hub carrier **130** oriented parallel to the ground or a ground-based structure. In this orientation, the KFECS **100** may be entirely supported by a superstructure **905** supporting the hub carrier **130** and perimeter plate **215** and supported on a turntable-style base assembly **908**. One or more clutch/gearbox/electrical generator/pump assemblies **620** may be supported on a turntable mounting plate **910** and are operably coupled by a pinion **621** to a ring gear **602**, which is supported on hub extension spokes **122**, and which is (i) operably coupled to the hub carrier **130,** and (ii) fixedly linked to respective hub **120** or hub **180**.

[0312] The orientation of the turntable style base assembly **908** may be varied by one or more hub orientation control motors **710** which are operably linked to a turntable-style base assembly **908** and are also operably coupled to the turntable ring gear **912** by a operably coupled pinion **720**. The turntable-style base assembly **908** is also operably linked to the ground or ground-based structure. This configuration enables the computer-controlled hub orientation motors **710** to cause the KFECS **100** to be continuously optimally oriented relative to the oncoming fluid flow, or any other computer-controlled direction, based upon the inputs received by one or more fluid speed and direction sensors **810** or any other computer input.

[0313] In an embodiment electricity, high pressure fluid and/or high pressure gaseous mixture converted by, or compressed by, as the case may be, the clutch/gearbox/electrical generator/pump assembly(ies) **620** do not require rotatable coupling as the computer controlled hub orientation control motors **710** are configured so that KFECS **100** is never rotated about the center point of the turn-table style base assembly **908** by more than a 360° rotation in either a clockwise or counterclockwise movement. If necessary to accommodate KFECS **100** reorientation due to fluid flow direction change, the AOS may be temporarily activated to avoid an overspeed condition while the KFECS **100** is being reoriented to the changed fluid flow direction.

[0314] Referring now to FIGS. **1A**, **22C**, **22D**, where the KFECS **100** is used to convert wind energy to mechanical energy, in one embodiment the longitudinal axis of the hub carrier **130** (i.e., the axis of rotation of the hubs **120**, **180**) is oriented parallel to the ground or a ground-based structure. In this orientation, the KFECS **100** may be entirely supported by a superstructure **905** supporting the hub carrier **130** and perimeter plate **215** and supported on a turntable-style base assembly **908**. One or more clutch/gearbox/electrical generator/pump assemblies **620** may be supported on a turntable mounting plate **910**. Each assembly **620** includes a bevel gear **607**. A bevel gear **607-A** is operably linked to, and rotatable with, the hub **120** and/or hub **180**. A transmission comprising a drive shaft **609**, an upper bevel gear **608-A** connected to one end of drive shaft **609** and coupled to bevel gear **607-A**, and a lower bevel gear **608** connected to an opposite end of drive shaft **609** and coupled to bevel gear **607** transmits rotation of the hubs **120**, **180** to rotation of the assembly **620**. A superstructure mount **905-A** may be provided to stabilize the drive shaft **609**.

[0315] The orientation of the turntable mounting plate **910** may be varied by one or more hub orientation control motors **710**. Hub orientation control motors **710** are mounted to the turntable-style base assembly **908** and are also operably coupled to a turntable ring gear **912** surrounding turntable mounting plate **910** by a operably coupled pinion **720**. The turntable-style base assembly **908** may be mounted or otherwise supported by the ground or ground-based structure. This configuration enables the hub orientation control motors **710** to cause the KFECS **100** to be continuously optimally oriented relative to the oncoming fluid flow, or any other desired direction. Hub orientation control motors **710** may be computer controlled in accordance with a control algorithm and computer-monitored sensor inputs, including, for example, one or more fluid speed and direction sensors **810** or any other sensor or computer input.

[0316] In an embodiment, electricity, high pressure fluid and/or high pressure gaseous mixture converted by, or compressed by, as the case may be, the clutch/gearbox/electrical generator/pump assembly(ies) **620** do not require rotatable coupling to external electric or fluid transmission components as the hub orientation control motors **710** are configured so that KFECS **100** is never rotated about the center

point of the turn-table style base assembly by more than a 360° rotation in either a clockwise or counterclockwise movement. If necessary to accommodate KFECS **100** reorientation due to fluid flow direction change, the AOS may be temporarily activated to avoid an overspeed condition while the KFECS **100** is being reoriented to the changed fluid flow direction.

14.3. Superstructure - Water-Based Vertical - FIGS. 23A – 23D

[0317] Referring now to FIGS. **23A – 23D**, and FIG. **1A,** where the KFECS **100** is used to convert kinetic water energy to mechanical energy, one embodiment is as shown with the longitudinal axis of the hub carrier **130** oriented relatively perpendicular to the surface of the body of water in which it is located. In this embodiment, the KFECS **100** can be entirely supported by a superstructure **960** which may comprise baffles 955 and **956** containing air or other buoyant material) and operably linked and protective cover **950.** Gearbox/winch assemblies **962** and pulleys **963** are operably linked to superstructure **960**. Each gearbox/winch assembly **962** may be computer controlled and is also operably linked to a respective cable **964**, which is operably coupled to pulley **967-A**, which is operably linked to a respective ballast **966** and the cable **964** is operably linked to a hub carrier stabilizer plate **968**, which is operably coupled to the hub carrier **130** where the hub carrier **130** extends past hub carrier **180 (**see FIG. **1A**). The gearbox/winch assemblies **962** control the tension of each respective operably linked cable **964**. The gearbox/winch assemblies **962** consequently can control (i) the X and Y orientation of the KFECS **100** relative to a plumb position and (ii) the depth of the KFECS **100** relative to the water surface by increasing or decreasing the amount cable **964** contained within any or all gearbox/winch assemblies **962**. The gearbox/winch assemblies **962** enable releasing sufficient cable **964** to permit the KFECS **100** to raise in the water to a point that the KFECS's **100** gearbox/brake assembly **740** is above water surface, or optionally, to permit raising and/or removing the KFECS **100** out of the water by conventional lifting equipment.

[0318] The gearbox/winch assemblies, **962**, pullies **963**, cables **964**, pulleys, **967-A**, ballasts **966,** and components fixedly and/or operably linked or operably coupled

thereto comprise an example of a deep water mounting system, capable of being computer controlled, with a depth limited only by the (i) gearbox/winch assemblies' **962** capacity to store cables **964**, (ii) length and physical characteristics of cables **964**, and (iii) space between the cover **950** and the superstructure **960** (see Figs. **23A** and **23C**).

[0319] Referring now to FIG. **23C** and FIG. **23D**, one or more clutch/gearbox/electrical generator/pump assemblies **620** are also (i) operably linked to the superstructure **960** and (ii) operably coupled, for example, via a pinion and shaft **611**, to a gear **604** which is operably coupled to the hub **120** (as is bevel gear **600** as described in Section **5**.

[0320] The superstructure **960** is also operably linked to the fluid orientation motor housing **750-A**, which is operably linked to plate **902**, which is operably linked to hub orientation control motors **710,** which are operably coupled to pinions **720**, which are operably coupled to the linked to the plate **902,** which is operable linked to and are also operably coupled to the orientation gear **700**, which is operably linked to the hub carrier **130**. This configuration enables the hub orientation control motors **710** to cause the KFECS **100** to be continuously optimally positioned relative to the oncoming fluid flow, or any other computer-controlled direction, based upon the inputs received by one or more fluid speed and direction sensors **810** or any other computer input.

[0321] The brake disc **770** (see FIG. **23-D**) and braking system that may stop the rotations of the hubs **120** and **180** about the longitudinal axis of carrier **130** are further described in Section **12.2**.

[0322] Electricity, high pressure fluid and/or high pressure gaseous mixture converted by, or compressed by, as the case may be, the clutch/gearbox/electrical generator/pump assembly(ies) **620** (See FIG. **23D**) flows through the hub carrier **130** and operably linked umbilical cord **970** (see FIG. **23C**) to their respective destination, including but not limited to a land-based connection points such as an electrical grid, hydraulic pump(s) and/or compressed air tank(s) (not shown). The hub carrier **130** design, including the hub carrier chase **132** (see FIG. **5A**) enables the connection of electric harness, fiber optic cable, electric transmission cable, hydraulic, pneumatic or

other similar systems to connect from the clutch/gearbox/electrical generator/pump assembly(ies) **620** and from within the clutch/gearbox/brake housing to the umbilical cord **970** without the need for any rotary couplings.

14.4. Superstructure - Water-Based Horizontal - FIGS. 24A, 24B

[0323] Referring now to FIGS. **1A**, **24A** and **24B**, where the KFECS **100** is used to convert kinetic water energy to mechanical energy, one embodiment is as shown with the longitudinal axis of the hub carrier **130** oriented relatively parallel to the surface of the body of water in which it is located. In this embodiment, the KFECS **100** includes a protective cover **950**, and can be entirely supported by the superstructure **972** (which may comprise baffles **955-A, 955-B and 957** containing air or other buoyant material). The superstructure **972** is operably linked to the hub carrier superstructure **980**, which is operably linked to the (i) hub carrier **130** and **(ii)** generator mounting plate **978.**

[0324] The superstructure **972** is also operably linked to (i) gearbox/winch assemblies **962**, which may be computer controlled, and pulleys **963**. Each gearbox/winch assembly **962** is also operably coupled to each respective pulley **963**, by a respective cable **964**, which is operably linked to ballast mounting attachment **967,** such as a pulley as shown**,** which is operably linked to a respective ballast **966**.

[0325] The computer controlled gearbox/winch assemblies **962** control the tension of each respective operably linked cable **964**. The computer controlled gearbox/winch assemblies **962** consequently can control (i) the X and Y orientation of the KFECS **100** relative to a plumb position and (ii) the depth of the KFECS **100** relative to the water surface by selectively increasing or decreasing the amount cable **964** contained within any or all gearbox/winch assemblies **962**. The computer controlled gearbox/winch assemblies **962** enable releasing sufficient cable **964** to permit the KFECS **100** to raise in the water to a point that the superstructure **972** of the KFECS **100** is at or above the water surface, or optionally, to permit raising and/or removing the KFECS **100** out of the water by conventional lifting equipment.

[0326] The plurality of the KFECS **100** gearbox/winch assemblies, **962**, cables **964**, ballasts **966** and components fixedly and/or operably linked or operably coupled thereto, comprise another embodiment of a deep water mounting system with a depth limited only by the gearbox/winch assemblies' **962** capacity to store cables **964**, the length and physical characteristics of cables 964, and the space between the cover **950** and the superstructure **972.**

[0327] One or more hub orientation control motors **710** are operably linked to the superstructure **972** and are also linked to a pinion **720**, which is operably coupled to turntable ring gear **974**, which is operably linked to generator mounting plate **978**. The generator mounting plate **978**, is located upon a low friction perimeter bearing **973-A** (see FIG. **24B**), extending circumferentially about flange **973** which is formed within superstructure **972**. This configuration enables the computer-controlled hub orientation motors **710** to cause the KFECS **100** to be continuously optimally oriented relative to the oncoming fluid flow, or any other computer-controlled direction, based upon the inputs received by one or more fluid speed and direction sensors **810** (see FIG. **1A**) or any other computer input.

[0328] Mechanical energy is transferred from hub **120** and hub 1**80** via one or more hub extension spokes **122** which are operably linked to a ring gear **606**, which is operably linked to pinion **606-A**, which are operably coupled with one or more clutch/gearbox/electrical generator/pump assemblies **620**.

[0329] Electricity, high pressure fluid and/or high pressure gaseous mixture converted by, or compressed by, as the case may be, the clutch/gearbox/electrical generator/pump assembly(ies) **620** flows through the hub carrier **130** and operably linked umbilical cord **970** to their respective destination, including but not limited to land-based connection points such as an electrical grid, hydraulic pump(s) and/or compressed air tank(s) (not shown). The hub carrier **130** design, including the hub carrier chase **132** (see FIG. **5A**) enables the connection of electric harness, fiber optic cable, electric transmission cable, hydraulic, pneumatic or other similar systems to connect from the clutch/gearbox/electrical generator/pump assembly(ies) **620** and from

within the clutch/gearbox/brake housing to the umbilical cord **970** without the need for any rotary couplings.

15. Cowling

[0330] Referring now to FIGs. **25A-25D**, and FIG. **1A**, the KFECS **100** may be configured with a cowling **1000** to improve the characteristics of fluid flow that contacts the ECPs **10**, or **20** when using nesting ECPs, including without limitation by acting as a concentrator, and to isolate aspects of the KFECS **100** from exposure to the elements in which it is located, including without limitation, water, debris or wildlife. The cowling **1000** may be fixedly linked to (i) the hub carrier **130** via a connection boss **1150** and (ii) either embodiment of the perimeter plate **215** or **215-A** (see FIGs. **13A** and **13C),** thereby causing the cowling **1000** to at all times to remain optimally oriented to the fluid flow as the cowling **1000** will rotate with the hub carrier **130** when reoriented by the hub orientation control system. The cowling **1000** may include a lower intake port **1010** and an upper intake port **1020** aligned with the respective ECPs **10,** or **20** (when using nesting ECPs), of the upper and lower hubs **120-A**, **180-A** (see FIG. **13E**) when the ECPS **10**, or **20** are primarily in their working mode behind the intake ports. Conversely, the cowling **1000** is closed on the side of each hub **120-A** and **180-B** opposite the side of the working ECPs **10** or **20** and largely blocks the oncoming fluid flow from contacting an ECP **10** or **20** while in its respective slipstream mode. The cowling may also include a lower hub exhaust port **1015** and an upper hub exhaust port **1025** opposite their respective intake ports **1010** and **1020**. The intake ports **1010** and **1020**, and exhaust ports **1015** and **1025** may also be shaped to increase the flow that reaches the working ECPs **10** or **20.** The cowling **1000** may further include a base **1005** that may include (i) ventilation louvers **1120** located on the side of the hub optimally oriented to the fluid flow to permit incoming ventilation to the clutch/gearbox/generator assemblies **620**, (ii) exhaust louvers **1130** on an opposite side (FIG. **25B**) to further ventilate the clutch/generator/gearbox assemblies **620,** and (iii) sufficient area for multiple penetrations, for numerous purposes, including but not limited to access panels and doors.

[0331] Referring now to FIGs. **25E-25F** and still referring to **25A-25D**, and FIG. **1A,** cowling 1000 may include a separator plate **1070** that may be fixedly linked via a boss **1100** to (i) either embodiment of the perimeter plate **215**, or **215-A**, and/or (II) the cowling **1000** so that separator plate **1070** (i.e., separator plate **1070** may be employed without the cowling **1000**) always remains optimally oriented to the oncoming fluid flow and prevent any ECPs **10 or 20** from coming in contact with separator plate **1070**. The separator plate **1070** may be located between any two counter-rotating hub assemblies, for example hubs **120** and **180**, and extends from intake port **1010** to exhaust port **1015** and from intake port **1020** to exhaust port **1025**. The separator plate **1070** improves the characteristics of the oncoming fluid flow that contacts the counter-rotating ECPs **10** or **20** in part by preventing the fluid flow that contacts ECPs **10** or **20** attached to hub **120** from disturbing the flow that contacts ECPs **10** or **20** attached to hub **180**, and vice versa (e.g., separator plate **1070** prevents the turbulence from one hub interfering with the axially adjacent hub).

[0332] Referring now to **FIG. 25 F**. the cowling **1000** may also include a top plate **1105** located near the top of the cowling **1110** and bottom plate **1050** that is located near the ECP **10** or **20** that rotates past it (above and below, respectively). The separator plate **1070**, top plate **1105,** bottom plate **1050,** and cowling **1000** each have the additional benefit of increasing the dynamic pressure on the ECPs **10** or **20** while in their working mode positions (e.g., by concentrating flow impinging on the working ECPs **10** or **20**) and lowering the dynamic pressure on the ECPs **10** or **20** while in their slipstream mode positions (by blocking flow from impinging on the ECPs **10** or **20** while in their slipstream orientations). The cowling **1000** may also include external collectors at the intake ports **1010** and **1020** areas where the fluid flow enters them it thereby further increasing the dynamic pressure on the ECPs **10** or **20**, and consequently increasing the total horsepower and related energy conversion output of the KFECS **100.**

[0333] It should be appreciated that the cowling 1000 provides sufficient area to support embodiments that could block the fluid flow from intake ports 1010 and 1020, and exhaust ports **1025** and **1015**, thereby supporting another embodiment of

overspeed protection or maintenance purposes whereby its desirable to control, restrict or block the fluid flow from contacting **ECPs 10** or **20.**

[0334] Separator plate **1070** may be disposed at different axial positions (relative to the hub axis of rotation) for adjacent hubs to accommodate the width of the respective ECPs **10** or **20** while in their working modes. For example, as shown in FIG. **25A**, the top edge of left intake port **1010** (which corresponds to the bottom surface of separator plate **1070** extending from the intake port **1010**) is above the bottom edge of right intake port **1020** (which corresponds to the top surface of separator plate **1070** extending from the intake port **1020**). Thus, the separator plate **1070** on the right-hand side **(1070-A)** of the cowling **1000**) in FIG. **25A** will be at a different axial location than the separator plate **1070** on the left-hand (**1070-B**) side of the cowling **1000**. Separator plate **1070** may include a transition area **1090** between the right-hand and left-hand sides of the separator plate. In an embodiment, the angle of the transition area may generally conform to the path of the upper edge of the lower hub ECP or the lower edge of the upper hub ECP, as applicable, as the respective ECP transitions from its working orientation perpendicular to the oncoming flow to its slipstream orientation parallel to the oncoming flow.

[0335] While the subject matter of this disclosure has been described and shown in considerable detail with reference to certain illustrative embodiments, including various combinations and sub-combinations of features, it will be obvious to those skilled in the art that such embodiments are provided by way of example only. Numerous variations, changes, and substitutions will now occur to those skilled in the art without departing from the preferred embodiments. It should be understood that various alternatives to the embodiments described herein may be employed in practicing the preferred embodiments. It is intended that the following claims define the scope of the preferred embodiments and that methods and structures within the scope of these claims and their equivalents be covered thereby.

EXEMPLARY EMBODIMENTS

[0336] One or more of the following features and benefits may be encompassed by or achievable by embodiments described herein.

[0337] 1. A system comprising:

[0338] at least one hub rotatable about a hub axis of rotation;

[0339] one or more articulating plates extending radially from the hub and rotatable therewith, wherein each articulating plate is configured to be articulable about a plate articulation axis that is oriented radially with respect to the hub axis of rotation; and

[0340] an articulation control system configured to independently control orientation of each plate with respect to the associated plate articulation axis, wherein each plate is operably coupled to the articulation control system so that the articulation control system changes the orientation of the plate as the hub rotates about the hub axis of rotation.

[0341] 2. The system of embodiment 1, wherein the hub axis of rotation is oriented vertically, horizontally, or any angle therebetween.

[0342] 3. The system of embodiment 1, comprising two or more hubs, each hub being axially adjacent with respect to the hub axis of rotation to at least one other hub, wherein each hub is rotatable about the same hub axis of rotation, and wherein each hub is configured to rotate in an opposite direction than the axially adjacent hub.

[0343] 4. The system of embodiment 3, further comprising a separator plate disposed between each hub and at least one axially-adjacent hub, wherein the separator plate is fixed with respect to the hub axis of rotation and is configured so as not to interfere with rotation of the articulating plates with the hub about the hub axis of rotation or articulation of the articulating plates about their respective axes of rotation.

[0344] 5. The system of embodiment 14, wherein the separator plate is configured to prevent the fluid flow passing through each hub from affecting the fluid flow of the adjacent hub.

[0345] 6. The system of embodiment 3, further comprising at least one counter-rotating transmission between each hub and an axially-adjacent hub to rotationally couple each hub to the axially-adjacent hub, wherein the counter-rotating transmission comprises:

[0346] a ring gear on each hub and the axially-adjacent hub, wherein each ring gear is coaxially arranged with respect to the hub axis of rotation; and

[0347] a plurality of pinon gears angularly spaced about the hub axis of rotation, wherein each pinion gear is rotatable about a pinion axis that is oriented radially with respect to the hub axis of rotation, and wherein the pinion gears are disposed between the ring gears on each hub and the axially-adjacent hub, such that rotation of each hub about the hub axis of rotation in a first direction causes a corresponding rotation of the axially-adjacent hub in a second direction about the hub axis of rotation opposite the first direction.

[0348] 7. The system of embodiment 6, comprising at least two counter-rotating transmissions between each hub and an axially-adjacent hub, wherein the ring gears of each of the counter-rotating transmissions have a different diameter.

[0349] 8. The system of any one of embodiment s 3 to 7, further comprising a non-rotating perimeter plate disposed between pairs of hubs rotating in opposite directions.

[0350] 9. The system of any one of embodiment s 3 to 7, further comprising a hub carrier comprising a tube that is coaxially arranged with respect to the hub axis of rotation, wherein each hub is rotationally mounted with respect to the hub carrier so as to be rotatable about the hub carrier, and the hub carrier is fixed against rotation with the hubs.

[0351] 10. The system of any one of embodiment s 1 to 9, further comprising a float assembly to which the at least one hub, the one or more articulating plates, and the articulation control system are attached, and wherein the float assembly is configure to buoyantly support the at least one hub, the one or more articulating plates, and the articulation control system within a body of water and with the at least one hub, the one

or more articulating plates, and the articulation control system submerged below the surface of the body of water.

[0352] 11. The system of embodiment 10, wherein the float assembly is anchored within the body of water by at least three cables connecting the float assembly to a ballast mounting attachment, wherein the system further comprises an automated winch assembly associated with each cable and configured to automatically control the length of the cable between the float assembly and the respective ballast mounting attachment so as to control the orientation of the float assembly and the at least one hub, the one or more articulating plates, and the articulation control system buoyantly supported thereby.

[0353] 12. The system of embodiment 11, further comprising:

[0354] a perimeter plate fixed to the hub carrier and disposed between each hub and the axially-adjacent hub; and

[0355] thrust bearings disposed between the perimeter plate and the hub and between the perimeter plate and the axially adjacent hub.

[0356] 13. The system of embodiment 12, further comprising:

[0357] a brake housing surrounding the hub carrier and fixed with respect to the hub carrier, wherein the brake housing is directly or indirectly coupled to an axially end-most one of the two or more hubs; and

[0358] thrust bearings between the brake housing and the axially end-most hub.

[0359] 14. The system of any one of embodiment s 1 to 13, wherein each articulating plate comprises a shaft rotatably mounted to the hub and defining the articulation axis of the associated plate, and wherein the articulation control system comprises:

[0360] a fixed track assembly having a continuous track about its perimeter, wherein the continuous track circumscribes the hub axis of rotation; and

[0361] a follower assembly coupled to each shaft, wherein the follower assembly traverses the continuous track as the hub and plate rotate about the hub axis of rotation to vary the orientation of the plate with respect to the articulation axis of the plate.

[0362] 15. The system of embodiment 14, wherein the follower assembly is physically connected to an associated shaft.

[0363] 16. The system of embodiment 14, wherein the follower assembly is magnetically coupled to an associated shaft.

[0364] 17. The system of any one of embodiment s 1 to 16, wherein each articulating plate comprises a shaft rotatably mounted to the hub and defining the articulation axis of the associated plate, and wherein the articulation control system comprises:

[0365] a first magnetic array;

[0366] a second magnetic array spaced apart from the first magnetic array and of opposite polarity than the first magnetic array;

[0367] a magnetized follower coupled to the shaft and disposed at least partially in the space between the first magnetic array and the second magnetic array; and

[0368] a controller adapted to selectively control the magnetic force of one or more portions of at least one of the first and second magnetic arrays to effect selective movement of the magnetic follower to cause rotation of the associated articulating plate.

[0369] 18. The system of any one of embodiments 1 to 17, wherein each articulating plate comprises a shaft rotatably mounted to the hub and defining the articulation axis of the associated plate, and wherein the articulation control system comprises one or more motors operatively coupled to each of the shafts and controlled to effect selective rotation of the associated shaft.

[0370] 19. The system of any one of embodiment s 1 to 18, wherein each articulating plate is mounted to an associated shaft defining the plate articulation axis, and further comprising first and second stops attached to the shaft at angularly-spaced positions, wherein the first stop is configured to prevent the associated articulating plate from rotating about the plate articulation axis beyond a first orientation, and wherein the second stop is configured to prevent the associated articulating plate from rotating about the plate articulation axis beyond a second orientation.

[0371] 20. The system of any one of embodiments 1 to 19, wherein each articulating plate comprises a shaft rotatably mounted to the hub and defining the articulation axis of the associated plate, and wherein the articulation control system comprises:

[0372] a lubricant-filled chamber;

[0373] a fixed track assembly disposed within the lubricant-filled chamber and having a continuous track about its perimeter, wherein the continuous track circumscribes the hub axis of rotation;

[0374] a follower assembly associated with each articulating plate and disposed within the lubricant-filled chamber and engaged with the continuous track;

[0375] an outer magnetic coupling connected to each shaft and disposed outside of the lubricant-filled chamber; and

[0376] an inner magnetic coupling connected to the follower assembly and disposed within the lubricant-filled chamber, wherein the inner magnetic coupling is magnetically coupled to the outer magnetic coupling through a wall of the lubricant-filled chamber so that as the hub and articulating plate rotate about the hub axis of rotation the follower assembly traverses the continuous track and varies the orientation of the plate with respect to the articulation axis of the plate.

[0377] 21. The system of embodiment 14, wherein the fixed track assembly comprises a split track assembly including a stationary track member and a movable track member that is movable with respect to the stationary track member in an axial direction with respect to the hub axis of rotation, and wherein the stationary track member is separable from the movable track member along the continuous track.

[0378] 22. The system of embodiment 21, wherein one of the stationary track member and the movable track member includes a female conical mating surface and the other of the stationary track member and the movable track member includes a male conical mating surface, so that the stationary track member and the movable track member are self aligning.

[0379] 23. The system of any one of embodiments 14 to 16, wherein the continuous track includes a first section, a second section, and first and second transition sections between the first and second sections and wherein,

[0380] as the follower assembly traverses the first section of the track, engagement of the follower assembly with the first track section causes the associated plate to assume a first orientation with respect to the articulation axis of the plate,

[0381] as the follower assembly traverses the second section of the track, engagement of the follower assembly with the second track section causes the associated plate to assume a second orientation with respect to the articulation axis of the plate,

[0382] as the follower assembly traverses the first transition section of the track, engagement of the follower assembly with the first transition section causes the associated plate to transition from the first orientation with respect to the articulation axis of the plate to the second orientation with respect to the articulation axis of the plate, and

[0383] as the follower assembly traverses the second transition section of the track, engagement of the follower assembly with the second transition section causes the associated plate to transition from the second orientation with respect to the articulation axis of the plate to the first orientation with respect to the articulation axis of the plate.

[0384] 24.. The system of embodiment 23, wherein the first section of the track lies in a first plane that is perpendicular to the hub axis of rotation, the second section of the track lies in a second plane that is perpendicular to the hub axis of rotation, and the first and second sections of the track are axially spaced apart with respect to the hub axis of rotation.

[0385] 25. The system of any one of embodiments 14 to 16, wherein opposed sides of the continuous track have an opposite magnetic polarity and the follower assembly includes a follower head disposed within the continuous track and magnetized so that opposed sides of the follower head have a magnetic polarity opposite the

magnetic polarity of the side of the continuous track facing that side of the follower head.

[0386] 26. The system of embodiment 25, wherein the continuous track has a circular cross-sectional shape and the follower head has a spherical shape.

[0387] 27. The system any one of embodiments 1 to 26, wherein each plate has opposed surfaces, a leading edge, and a trailing edge, and wherein the articulation control system is configured to orient each plate in a slipstream orientation in which the opposed surfaces of the plate are parallel to the plane of rotation of the hub for a first portion of each rotation of the hub and in a working orientation in which the opposed surfaces are not parallel to the plane of rotation of the hub for a second portion of each rotation of the hub.

[0388] 28. The system of embodiment 27, wherein the opposed surfaces are oriented perpendicular to the plane of rotation of the hub during the second portion of each rotation of the hub.

[0389] 29 The system of embodiment 27 or embodiment 28, comprising a plurality of articulating plates disposed at angularly-spaced positions about the hub and wherein adjacent articulating plates that are in their slipstream orientations overlap one another, wherein each articulating plate has a leading edge pocket of reduced thickness on a first surface of the plate and a trailing edge pocket of reduced thickness on a second surface of the plate, and wherein the leading edge pocket of one articulating plate nests with the trailing edge pocket of an adjacent overlapped articulating plate when the plates are in their slipstream orientations.

[0390] 30. The system of any one of 27 to 29, further comprising a hub orientation control system comprising:

[0391] a sensor detecting a direction of a fluid flow transverse to the hub axis of rotation; and

[0392] one or more actuators configured to reposition the hub about the hub axis of rotation so that the articulating plates are in their slipstream orientations for the first

portion of each rotation of the hub in a direction against the direction of fluid flow and so that the articulating plates are in their working orientations for the second portion of each rotation of the hub in a direction with the direction of fluid flow.

[0393] 31. The system of any one of embodiments 27 to 30, further comprising a cowling surrounding the at least one hub, wherein a part of the cowling associated with each hub is closed on a side of the cowling corresponding to the first portion of the hub's rotation and includes an intake port and an exhaust port on a side the cowling corresponding to the second portion of the hub's rotation.

[0394] 32. The system of embodiment 3, wherein each plate has opposed surfaces, a leading edge, and a trailing edge, and wherein the articulation control system is configured to orient each plate in a slipstream orientation in which the opposed surfaces of the plate are parallel to the plane of rotation of each hub for a first portion of each rotation of the hub and in a working orientation in which the opposed surfaces are not parallel to the plane of rotation of the hub for a second portion of each rotation of the hub, and wherein the system further comprises:

[0395] a cowling surrounding the two or more hubs, wherein a part of the cowling associated with each hub is closed on a side of the cowling corresponding to the first portion of the hub's rotation and includes an intake port and an exhaust port on a side the cowling corresponding to the second portion of the hub's rotation; and

[0396] a separator plate disposed within the cowling between each hub and at least one axially-adjacent hub, wherein the separator plate is fixed with respect to the hub axis of rotation and is configured so as not to interfere with rotation of the articulating plates with the hub about the hub axis of rotation or articulation of the articulating plates about their respective axes of rotation.

[0397] 33. The system of any one of embodiments 1 to 31, further comprising an articulation override system configured to override the articulation control system and cause each plate to assume a desired, unchanging orientation while the articulation override system is activated.

[0398] 34. The system of any one of embodiments 8 to 10, further comprising an articulation override system configured to override the articulation control system and orient each plate in its slipstream orientation at any angular position about the hub axis of rotation.

[0399] 35. The system of embodiment 21, wherein each plate has opposed surfaces, a leading edge, and a trailing edge, and wherein the articulation control system is configured to orient each plate in a slipstream orientation in which the opposed surfaces of the plate are parallel to the plane of rotation of the hub for a first portion of each rotation of the hub and in a working orientation in which the opposed surfaces are not parallel to the plane of rotation of the hub for a second portion of each rotation of the hub, and wherein the system further comprises an articulation override system configured to override the articulation control system and orient each plate in its slipstream orientation at any angular position about the hub axis of rotation, wherein the articulation override system comprises:

[0400] one or more linear actuators configured to axially separate the stationary track member from the movable track member to disengage the follower assembly of each articulating plate from the fixed track assembly;

[0401] rocker arms coupling the movable track member to a primary override ring that is coaxially oriented with respect to the hub axis of rotation so that axial movement of the movable track member causes a corresponding axial movement of the primary override ring; and

[0402] an actuator cam attached to the shaft of each articulating plate of a one of the hubs and configured to be contacted by the axially moving primary override ring and retain each articulating plate at its slipstream orientation.

[0403] 36. The system of embodiment 35, further comprising:

[0404] a secondary override ring with lifters coupling the primary override ring to the secondary override ring;

[0405] a tertiary override ring with lifters coupling the secondary override ring to the tertiary override ring, so that the primary override ring, the secondary override ring and the tertiary override ring move axially in unison; and

[0406] an actuator cam attached to the shaft of each articulating plate of the axially adjacent one of the hubs and configured to be contacted by the axially moving tertiary override ring and retain each articulating plate of the axially adjacent hub at its slipstream orientation.

[0407] 37. The system of embodiment 35 or 36, wherein the linear actuator comprises a ball screw actuator.

[0408] 38. The system of any one of embodiments 35 to 37, wherein the articulation override system further comprises one or more redundant actuators configured and controlled to cause axial movement of the primary override ring if the one or more linear actuators fail to axially separate the stationary track member from the movable track member.

[0409] 39 The system of embodiment 38, wherein the redundant actuators comprise one or more actuators selected from the group consisting of pyrotechnic actuators, pneumatic actuators, hydraulic electronic solenoid actuators actuators, and piston actuators,

[0410] 40 The system of embodiment 38 or 39, wherein the redundant actuator is configured to be actuated by an electrical device, explosive device, a pressure cartridge, a mechanical primer-initiated device, a linear detonation transfer line, or a laser actuated ordnance device.

[0411] 41. The system of any one of embodiments 1 to 40 further comprising a power take-off device operably coupled to the at least one hub and configured to receive mechanical energy from rotation of the at least one hub.

[0412] 42. The system of embodiment 41, wherein the power take-off device comprises one or more of a clutch, a gearbox, an electrical generator, and a pump.

[0413] 43. A method for converting kinetic fluid energy to mechanical energy with a hub that is rotatable about a hub axis of rotation and one or more articulating plates extending radially from the hub and rotatable therewith, the method comprising:

[0414] A. selectively articulating each articulating plate about a plate articulation axis that is oriented radially with respect to the hub axis of rotation; and

[0415] B. during step A, independently controlling an orientation of each plate with respect to the associated plate articulation control axis so that the orientation of the plate changes as the hub rotates about the hub axis of rotation.

[0416] 44. The method of embodiment 43, wherein each plate has opposed surfaces, a leading edge, and a trailing edge, and wherein step B comprises orienting each plate so that the opposed surfaces of the plate are parallel to the plane of rotation of the hub for a first portion of each rotation of the hub and so that the opposed surfaces are not parallel to the plane of rotation of the hub for a second portion of each rotation of the hub.

[0417] 45. The method of embodiment 44, wherein the opposed surfaces are oriented perpendicular to the plane of rotation of the hub during the second portion of each rotation of the hub.

[0418] 46. The method of embodiment 44, further comprising placing the hub in a fluid flowing in a direction that is transverse to the hub axis of rotation, and wherein the plate is moving against the direction of fluid flow for the first portion of each rotation of the hub and the plate is moving with the direction of fluid flow for the second portion of each rotation of the hub.

[0419] 47. The method of any one of embodiments 43 to 46, wherein, during first and second transition portions of each rotation of the hub, each plate transitions between its orientation during the first portion of the rotation and its orientation during its second portion of the rotation.

[0420] 48 The energy conversion plates may be textured to increase its drag coefficient.

[0421] 49 Each hub is operably coupled to any adjacent hub via a counter-rotating transmission.

[0422] 50 The hub may include a lubricant reservoir suitable for containing one or more components of the counter-rotating transmission.

[0423] 51 The energy conversion system of embodiment **50**, wherein each lubricant reservoir includes a counter-rotating coupling configured to effect a mechanical energy transfer between two adjacent hubs.

[0424] 52 The energy conversion system of embodiment **50**, wherein each lubricant reservoir is constructed and arranged to enable the counter-rating transmission to operate in a radial seal-less configuration.

[0425] 53 T Each hub is hermetically sealed whereby all components located within the hub are protected from the fluid flow.

[0426] 54 In various embodiments, all components required to maintain positive control of the orientation and articulation of all energy conversion plates may be contained within each hub assembly].

[0427] 55 In various embodiments, the ECP articulation controls are isolated from the fluid flow to prevent all such controls from contacting the fluid low.

[0428] 56 The articulation control system is mechanical, magnetic or electro-mechanical.

[0429] 57 The articulation of each energy conversion plate is controlled by components that are contained within the ECP's respective operably connected hub or that are enclosed by the respective operably connected hub.

[0430] 58 The articulation control system includes a stop at the end of each limit of travel of each ECP(s) articulation as a failsafe method of preventing the ECP from articulating past its specified limit of travel.

[0431] 59 The stops are located at 0° and 90°.

[0432] 60 The articulation control system includes a spherical magnetic cam track, with each track halve having a magnetic charge of equal polarity and magnetic force.

[0433] 61 The articulation control system includes an equal magnetic force on opposing track halves, with each track halve repelling a magnetic sphere coupled to the ECP, so that the sphere levitates between the two halves.

[0434] 62 The magnetic sphere is connected to each ECP actuator arm and causes the articulation of the shaft and ECP attached to it achieved via internal magnetic spherical track.

[0435] 63 Mechanical energy is transferred through the entirety of the counter-rotating hub system to one or more power take-offs, including without limitation a Clutch/Gearbox/Electrical Generator or Pump assembly(ies).

[0436] 64 Secondary articulation system, which may be contained entirely within the hub assemblies, permits moving all ECPs to their slipstream orientation for maintenance mode and/or overspeed protection.

[0437] 65 All mechanical secondary articulation system components are subject to wear only when secondary articulation system is activated due to switching to maintenance mode or overspeed mode.

[0438] 66 The entirety of all secondary articulation system's mechanical components can be actuated from internal hub components and transfer mechanical movement of AOS components through all adjacent counter-rotating hubs.

[0439] 67 Hub design permits multiple redundant secondary articulation actuators, including pyrotechnic, pneumatic, hydraulic and electronic solenoid actuators.

[0440] 68 Self-aligning bearing system for rotationally supporting each ECP shaft within an associated hub.

[0441] 69 Central hub carrier enables all control components, such as, electrical harnesses, pneumatic lines, hydraulic lines, fiber optic cables and any other support hub support system, to be routed to each hub.

[0442] 70 Aspect ratio - details configured in numerous aspect ratios (width to height) to accommodate desired overall system dimensions. The aspect ratios are only constrained by the overall size of the machine and material's properties.

[0443] 71 ECP – The portion of the surface area oriented perpendicular to the oncoming fluid flow can be textured to increase its drag coefficient. The portion of the surface area that will be oriented parallel to oncoming fluid flow has a smooth surface, and/or leading edge to minimize the drag coefficient.

[0444] 72 A spherical liquid lubricant-filled cam track assembly controls the movement of a linkage attached to each energy conversion plate shaft, and consequently, its articulation. Each track half is closed during working mode thereby making a track with a circular cross section, similar to a ball race. A spherical metal ball, with a bearing insert, is operably coupled to a sacrificial linkage, which is operably that is of sufficient strength to articulate the related energy conversion plate. The track geometry may be configured to control the start, end and duration of each articulation, with minimum duration between the start and end point of each such articulation limited only by the diameter of the spherical magnetic follower head **253** relative to the angle of the steepest splines **261** and **262** through which the spherical magnetic follower head **253** travels. This can be further described as C= S/(cos((90-Theta)/2)) where C is the circumference of the magnetic spherical cam track assembly **250**, S is the diameter of the spherical magnetic follower head **253**, and Theta is the angle of the spline **261** and **262**. In this embodiment, as the ball moves around the track, the track geometry causes the spherical magnetic follower head **253** to move to the lower portion of the track and consequently causes the related energy conversion pressure plate to rotate to an orientation parallel to the fluid flow.

[0445] 73 Articulation track assembly **250** may include a neodymium spherical magnet, with a positive charge above its centerline (like the equator) and a

negative charge below its centerline. The spherical magnet travels within a spherical (circular) race which is comprised of two halves – an upper half with a positive charge, and a lower half with a negative charge. The spherical magnetic control (or follower head) is operably coupled to a linkage as shown and consequently remains oriented throughout its travel around the race that is parallel to the opposing magnetic forces, thereby resulting in a magnetic bearing requiring no lubrication and virtually no drag.

[0446] 74 Battery backup AOS – will work during power failure.

[0447] 75 KFECS **100** configuration enables the transfer of power, including, without limitation, electricity, computer signals, hydraulic fluid, and compressed air and from virtually any area within the KFECS **100** that is adjacent to the hub carrier **130**, to the perimeter plate **215**, and consequently to ancillary systems, e.g. proximity sensors **585**, without the need for any form of rotating coupling.

[0448] 76 In various embodiments operably coupled parts that come in contact with an actuator cam **590** or any other movable AOS components are constructed of materials designed to slide without lubricant. In various embodiments the AOS is designed to rotate all ECPs **10** and **20** to their slipstream orientation in less time than is required for a hub to make one revolution about the longitudinal axis of the hub carrier **130**.

[0449] 77 The energy conversion system of embodiment 1 further comprising one or more Gearbox/generator Assemblies, each of which may be computer-controlled to engage or disengage based upon fluid flow-speed, and number of hours that each such assembly has run, thereby balancing the service hours used among multiple Gearbox/generator Assemblies.

[0450] 78 The energy conversion system encompasses a universal axis orientation capability, permitting the energy conversion system to be mounted and operated horizontally, vertically or in any orientation to the surface over or under which it is installed.

CLAIMS

1. A system comprising:

at least one hub rotatable about a hub axis of rotation;

one or more articulating plates extending radially from the hub and rotatable therewith, wherein each articulating plate is configured to be articulable about a plate articulation axis that is oriented radially with respect to the hub axis of rotation; and

an articulation control system configured to independently control orientation of each plate with respect to the associated plate articulation axis, wherein each plate is operably coupled to the articulation control system so that the articulation control system changes the orientation of the plate as the hub rotates about the hub axis of rotation.

2. The system of claim 1, wherein the hub axis of rotation is oriented vertically, horizontally, or any angle therebetween.

3. The system of claim 1, comprising two or more hubs, each hub being axially adjacent with respect to the hub axis of rotation to at least one other hub, wherein each hub is rotatable about the same hub axis of rotation, and wherein each hub is configured to rotate in an opposite direction than the axially adjacent hub.

4. The system of claim 3, further comprising a separator plate disposed between each hub and at least one axially-adjacent hub, wherein the separator plate is fixed with respect to the hub axis of rotation and is configured so as not to interfere with rotation of the articulating plates with the hub about the hub axis of rotation or articulation of the articulating plates about their respective axes of rotation.

5. The system of claim 4, wherein the separator plate is configured to prevent the fluid flow passing through each hub from affecting the fluid flow of the adjacent hub.

6. The system of claim 3, further comprising at least one counter-rotating transmission between each hub and an axially-adjacent hub to rotationally couple each hub to the axially-adjacent hub, wherein the counter-rotating transmission comprises:

a ring gear on each hub and the axially-adjacent hub, wherein each ring gear is coaxially arranged with respect to the hub axis of rotation; and

a plurality of pinon gears angularly spaced about the hub axis of rotation, wherein each pinion gear is rotatable about a pinion axis that is oriented radially with respect to the hub axis of rotation, and wherein the pinion gears are disposed between the ring gears on each hub and the axially-adjacent hub, such that rotation of each hub about the hub axis of rotation in a first direction causes a corresponding rotation of the axially-adjacent hub in a second direction about the hub axis of rotation opposite the first direction.

7. The system of claim 6, comprising at least two counter-rotating transmissions between each hub and an axially-adjacent hub, wherein the ring gears of each of the counter-rotating transmissions have a different diameter.

8. The system of any one of claims 3 to 7, further comprising a non-rotating perimeter plate disposed between pairs of hubs rotating in opposite directions.

9. The system of any one of claims 3 to 7, further comprising a hub carrier comprising a tube that is coaxially arranged with respect to the hub axis of rotation, wherein each hub is rotationally mounted with respect to the hub carrier so as to be rotatable about the hub carrier, and the hub carrier is fixed against rotation with the hubs.

10. The system of any one of claims 1 to 9, further comprising a float assembly to which the at least one hub, the one or more articulating plates, and the articulation control system are attached, and wherein the float assembly is configure to buoyantly support the at least one hub, the one or more articulating plates, and the articulation control system within a body of water and with the at least one hub, the one or more articulating plates, and the articulation control system submerged below the surface of the body of water.

11. The system of claim 10, wherein the float assembly is anchored within the body of water by at least three cables connecting the float assembly to a ballast mounting attachment, wherein the system further comprises an automated winch assembly

associated with each cable and configured to automatically control the length of the cable between the float assembly and the respective ballast mounting attachment so as to control the orientation of the float assembly and the at least one hub, the one or more articulating plates, and the articulation control system buoyantly supported thereby.

12. The system of claim 9, further comprising:

a perimeter plate fixed to the hub carrier and disposed between each hub and the axially-adjacent hub; and

thrust bearings disposed between the perimeter plate and the hub and between the perimeter plate and the axially adjacent hub.

13. The system of claim 12, further comprising:

a brake housing surrounding the hub carrier and fixed with respect to the hub carrier, wherein the brake housing is directly or indirectly coupled to an axially end-most one of the two or more hubs; and

thrust bearings between the brake housing and the axially end-most hub.

14. The system of any one of claims 1 to 13, wherein each articulating plate comprises a shaft rotatably mounted to the hub and defining the articulation axis of the associated plate, and wherein the articulation control system comprises:

a fixed track assembly having a continuous track about its perimeter, wherein the continuous track circumscribes the hub axis of rotation; and

a follower assembly coupled to each shaft, wherein the follower assembly traverses the continuous track as the hub and plate rotate about the hub axis of rotation to vary the orientation of the plate with respect to the articulation axis of the plate.

15. The system of claim 14, wherein the follower assembly is physically connected to an associated shaft.

16. The system of claim 14, wherein the follower assembly is magnetically coupled to an associated shaft.

17. The system of any one of claims 1 to 16, wherein each articulating plate comprises a shaft rotatably mounted to the hub and defining the articulation axis of the associated plate, and wherein the articulation control system comprises:

a first magnetic array;

a second magnetic array spaced apart from the first magnetic array and of opposite polarity than the first magnetic array;

a magnetized follower coupled to the shaft and disposed at least partially in the space between the first magnetic array and the second magnetic array; and

a controller adapted to selectively control the magnetic force of one or more portions of at least one of the first and second magnetic arrays to effect selective movement of the magnetic follower to cause rotation of the associated articulating plate.

18. The system of any one of claims 1 to 17, wherein each articulating plate comprises a shaft rotatably mounted to the hub and defining the articulation axis of the associated plate, and wherein the articulation control system comprises one or more motors operatively coupled to each of the shafts and controlled to effect selective rotation of the associated shaft.

19. The system of any one of claims 1 to 18, wherein each articulating plate is mounted to an associated shaft defining the plate articulation axis, and further comprising first and second stops attached to the shaft at angularly-spaced positions, wherein the first stop is configured to prevent the associated articulating plate from rotating about the plate articulation axis beyond a first orientation, and wherein the second stop is configured to prevent the associated articulating plate from rotating about the plate articulation axis beyond a second orientation.

20. The system of any one of claims 1 to 19, wherein each articulating plate comprises a shaft rotatably mounted to the hub and defining the articulation axis of the associated plate, and wherein the articulation control system comprises:

a lubricant-filled chamber;

a fixed track assembly disposed within the lubricant-filled chamber and having a continuous track about its perimeter, wherein the continuous track circumscribes the hub axis of rotation;

a follower assembly associated with each articulating plate and disposed within the lubricant-filled chamber and engaged with the continuous track;

an outer magnetic coupling connected to each shaft and disposed outside of the lubricant-filled chamber; and

an inner magnetic coupling connected to the follower assembly and disposed within the lubricant-filled chamber, wherein the inner magnetic coupling is magnetically coupled to the outer magnetic coupling through a wall of the lubricant-filled chamber so that as the hub and articulating plate rotate about the hub axis of rotation the follower assembly traverses the continuous track and varies the orientation of the plate with respect to the articulation axis of the plate.

21. The system of claim 14, wherein the fixed track assembly comprises a split track assembly including a stationary track member and a movable track member that is movable with respect to the stationary track member in an axial direction with respect to the hub axis of rotation, and wherein the stationary track member is separable from the movable track member along the continuous track.

22. The system of claim 21, wherein one of the stationary track member and the movable track member includes a female conical mating surface and the other of the stationary track member and the movable track member includes a male conical mating surface, so that the stationary track member and the movable track member are self aligning.

23. The system of any one of claims 14 to 16, wherein the continuous track includes a first section, a second section, and first and second transition sections between the first and second sections and wherein,

as the follower assembly traverses the first section of the track, engagement of the follower assembly with the first track section causes the associated plate to assume a first orientation with respect to the articulation axis of the plate,

as the follower assembly traverses the second section of the track, engagement of the follower assembly with the second track section causes the associated plate to assume a second orientation with respect to the articulation axis of the plate,

as the follower assembly traverses the first transition section of the track, engagement of the follower assembly with the first transition section causes the associated plate to transition from the first orientation with respect to the articulation axis of the plate to the second orientation with respect to the articulation axis of the plate, and

as the follower assembly traverses the second transition section of the track, engagement of the follower assembly with the second transition section causes the associated plate to transition from the second orientation with respect to the articulation axis of the plate to the first orientation with respect to the articulation axis of the plate.

24. The system of claim 23, wherein the first section of the track lies in a first plane that is perpendicular to the hub axis of rotation, the second section of the track lies in a second plane that is perpendicular to the hub axis of rotation, and the first and second sections of the track are axially spaced apart with respect to the hub axis of rotation.

25. The system of any one of claims 14 to 16, wherein opposed sides of the continuous track have an opposite magnetic polarity and the follower assembly includes a follower head disposed within the continuous track and magnetized so that opposed sides of the follower head have a magnetic polarity opposite the magnetic polarity of the side of the continuous track facing that side of the follower head.

26. The system of claim 25, wherein the continuous track has a circular cross-sectional shape and the follower head has a spherical shape.

27. The system any one of claims 1 to 26, wherein each plate has opposed surfaces, a leading edge, and a trailing edge, and wherein the articulation control system is configured to orient each plate in a slipstream orientation in which the opposed surfaces of the plate are parallel to the plane of rotation of the hub for a first portion of each rotation of the hub and in a working orientation in which the opposed surfaces are not

parallel to the plane of rotation of the hub for a second portion of each rotation of the hub.

28. The system of claim 27, wherein the opposed surfaces are oriented perpendicular to the plane of rotation of the hub during the second portion of each rotation of the hub.

29 The system of claim 27 or claim 28, comprising a plurality of articulating plates disposed at angularly-spaced positions about the hub and wherein adjacent articulating plates that are in their slipstream orientations overlap one another, wherein each articulating plate has a leading edge pocket of reduced thickness on a first surface of the plate and a trailing edge pocket of reduced thickness on a second surface of the plate, and wherein the leading edge pocket of one articulating plate nests with the trailing edge pocket of an adjacent overlapped articulating plate when the plates are in their slipstream orientations.

30. The system of any one of 27 to 29, further comprising a hub orientation control system comprising:

a sensor detecting a direction of a fluid flow transverse to the hub axis of rotation; and

one or more actuators configured to reposition the hub about the hub axis of rotation so that the articulating plates are in their slipstream orientations for the first portion of each rotation of the hub in a direction against the direction of fluid flow and so that the articulating plates are in their working orientations for the second portion of each rotation of the hub in a direction with the direction of fluid flow.

31. The system of any one of claims 27 to 30, further comprising a cowling surrounding the at least one hub, wherein a part of the cowling associated with each hub is closed on a side of the cowling corresponding to the first portion of the hub's rotation and includes an intake port and an exhaust port on a side the cowling corresponding to the second portion of the hub's rotation.

32. The system of claim 3, wherein each plate has opposed surfaces, a leading edge, and a trailing edge, and wherein the articulation control system is configured to orient each plate in a slipstream orientation in which the opposed surfaces of the plate are parallel to the plane of rotation of each hub for a first portion of each rotation of the hub and in a working orientation in which the opposed surfaces are not parallel to the plane of rotation of the hub for a second portion of each rotation of the hub, and wherein the system further comprises:

a cowling surrounding the two or more hubs, wherein a part of the cowling associated with each hub is closed on a side of the cowling corresponding to the first portion of the hub's rotation and includes an intake port and an exhaust port on a side the cowling corresponding to the second portion of the hub's rotation; and

a separator plate disposed within the cowling between each hub and at least one axially-adjacent hub, wherein the separator plate is fixed with respect to the hub axis of rotation and is configured so as not to interfere with rotation of the articulating plates with the hub about the hub axis of rotation or articulation of the articulating plates about their respective axes of rotation.

33. The system of any one of claims 1 to 32, further comprising an articulation override system configured to override the articulation control system and cause each plate to assume a desired, unchanging orientation while the articulation override system is activated.

34. The system of any one of claims 8 to 10, further comprising an articulation override system configured to override the articulation control system and orient each plate in its slipstream orientation at any angular position about the hub axis of rotation.

35. The system of claim 21, wherein each plate has opposed surfaces, a leading edge, and a trailing edge, and wherein the articulation control system is configured to orient each plate in a slipstream orientation in which the opposed surfaces of the plate are parallel to the plane of rotation of the hub for a first portion of each rotation of the hub and in a working orientation in which the opposed surfaces are not parallel to the plane of rotation of the hub for a second portion of each rotation of the hub, and wherein

the system further comprises an articulation override system configured to override the articulation control system and orient each plate in its slipstream orientation at any angular position about the hub axis of rotation, wherein the articulation override system comprises:

one or more linear actuators configured to axially separate the stationary track member from the movable track member to disengage the follower assembly of each articulating plate from the fixed track assembly;

rocker arms coupling the movable track member to a primary override ring that is coaxially oriented with respect to the hub axis of rotation so that axial movement of the movable track member causes a corresponding axial movement of the primary override ring; and

an actuator cam attached to the shaft of each articulating plate of a one of the hubs and configured to be contacted by the axially moving primary override ring and retain each articulating plate at its slipstream orientation.

36. The system of claim 35, further comprising:

a secondary override ring with lifters coupling the primary override ring to the secondary override ring;

a tertiary override ring with lifters coupling the secondary override ring to the tertiary override ring, so that the primary override ring, the secondary override ring and the tertiary override ring move axially in unison; and

an actuator cam attached to the shaft of each articulating plate of the axially adjacent one of the hubs and configured to be contacted by the axially moving tertiary override ring and retain each articulating plate of the axially adjacent hub at its slipstream orientation.

37. The system of claim 35 or 36, wherein the linear actuator comprises a ball screw actuator.

38. The system of any one of claims 35 to 37, wherein the articulation override system further comprises one or more redundant actuators configured and controlled to cause axial movement of the primary override ring if the one or more linear actuators fail to axially separate the stationary track member from the movable track member.

39 The system of claim 38, wherein the redundant actuators comprise one or more actuators selected from the group consisting of pyrotechnic actuators, pneumatic actuators, hydraulic electronic solenoid actuators actuators, and piston actuators,

40 The system of claim 38 or 39, wherein the redundant actuator is configured to be actuated by an electrical device, explosive device, a pressure cartridge, a mechanical primer-initiated device, a linear detonation transfer line, or a laser actuated ordnance device.

41. The system of any one of claims 1 to 40 further comprising a power take-off device operably coupled to the at least one hub and configured to receive mechanical energy from rotation of the at least one hub.

42. The system of claim 41, wherein the power take-off device comprises one or more of a clutch, a gearbox, an electrical generator, and a pump.

43. A method for converting kinetic fluid energy to mechanical energy with a hub that is rotatable about a hub axis of rotation and one or more articulating plates extending radially from the hub and rotatable therewith, the method comprising:

A. selectively articulating each articulating plate about a plate articulation axis that is oriented radially with respect to the hub axis of rotation; and

B. during step A, independently controlling an orientation of each plate with respect to the associated plate articulation control axis so that the orientation of the plate changes as the hub rotates about the hub axis of rotation.

44. The method of claim 43, wherein each plate has opposed surfaces, a leading edge, and a trailing edge, and wherein step B comprises orienting each plate so that the opposed surfaces of the plate are parallel to the plane of rotation of the hub for a first portion of each rotation of the hub and so that the opposed surfaces are not parallel to the plane of rotation of the hub for a second portion of each rotation of the hub.

45. The method of claim 44, wherein the opposed surfaces are oriented perpendicular to the plane of rotation of the hub during the second portion of each rotation of the hub.

46. The method of claim 44, further comprising placing the hub in a fluid flowing in a direction that is transverse to the hub axis of rotation, and wherein the plate is moving against the direction of fluid flow for the first portion of each rotation of the hub and the plate is moving with the direction of fluid flow for the second portion of each rotation of the hub.

47. The method of any one of claims 43 to 46, wherein, during first and second transition portions of each rotation of the hub, each plate transitions between its orientation during the first portion of the rotation and its orientation during its second portion of the rotation.

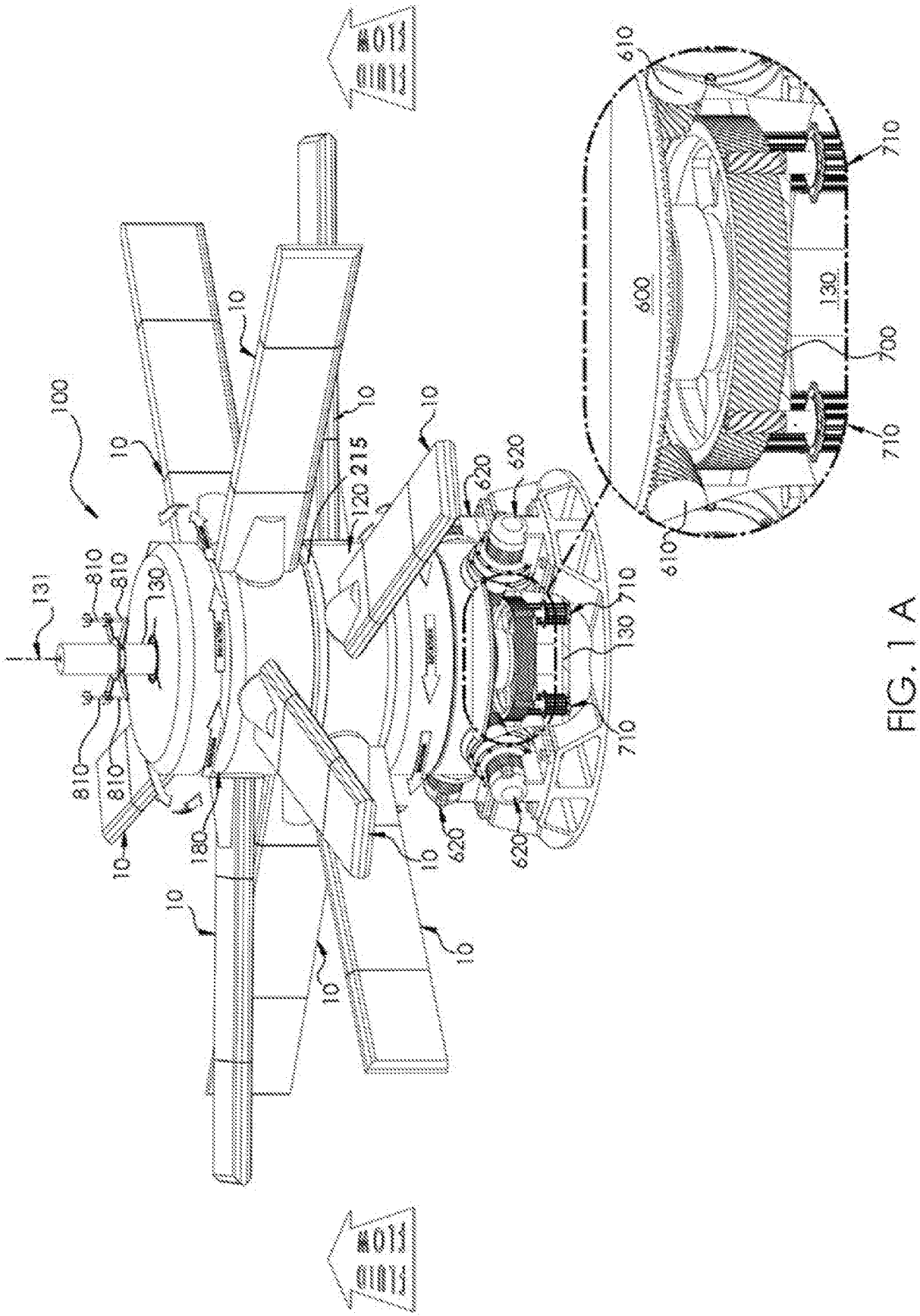


FIG. 1A

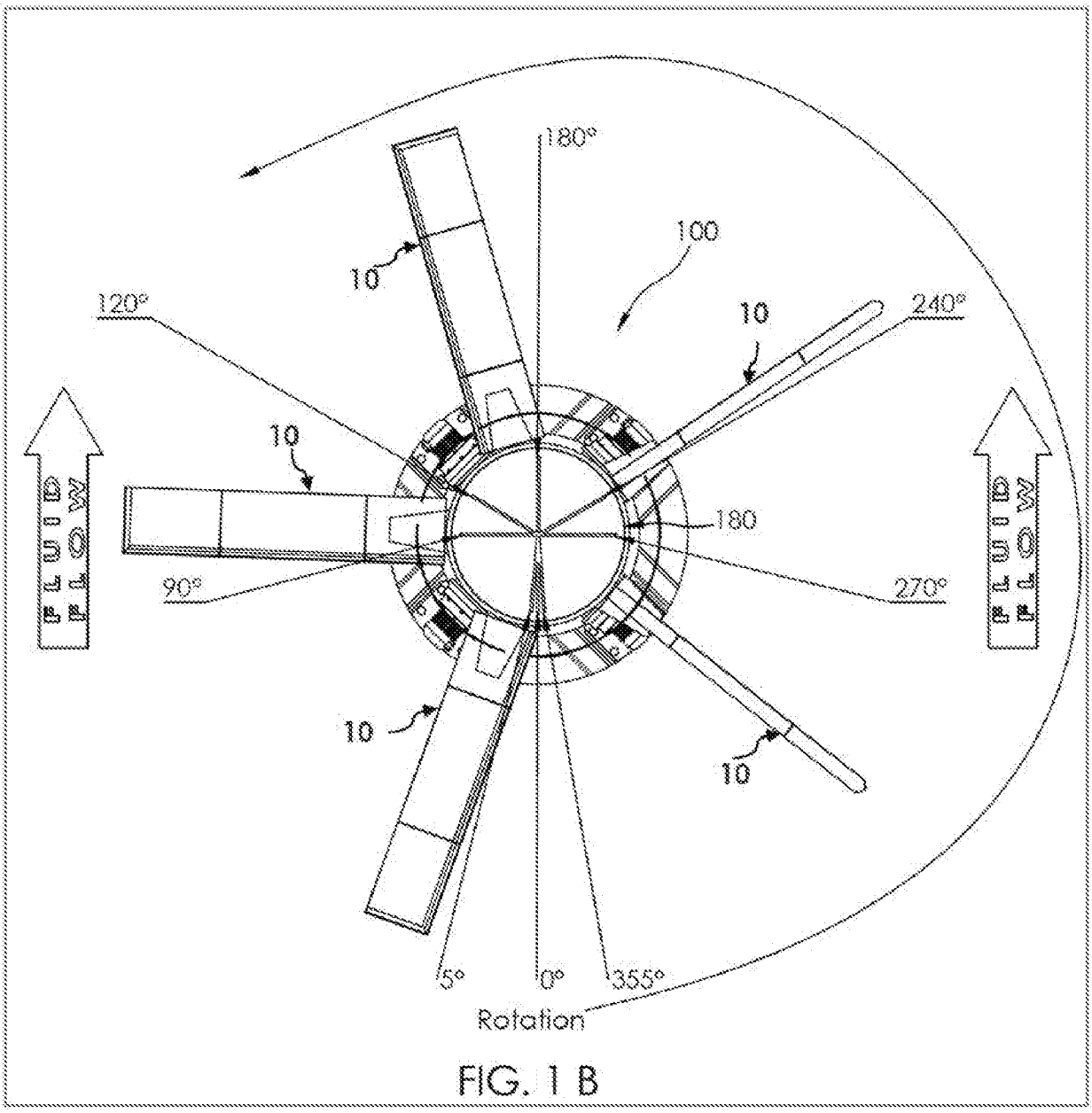

180°
100
10
120°
10
240°
10
FLUID FLOW
180
90°
270°
FLUID FLOW
10
10
10
5°
0°
355°
Rotation

FIG. 1 B

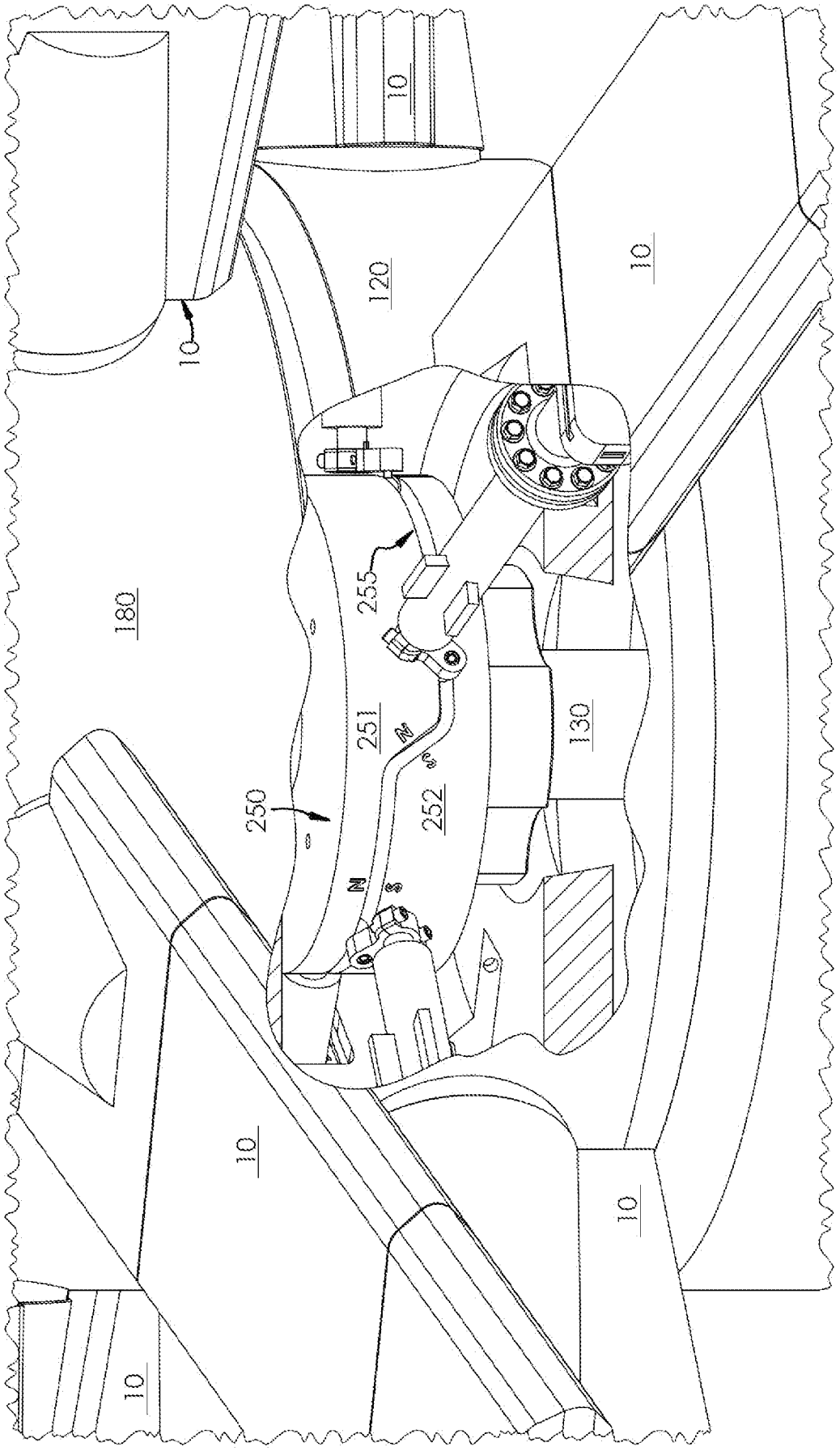


FIG. 2 A

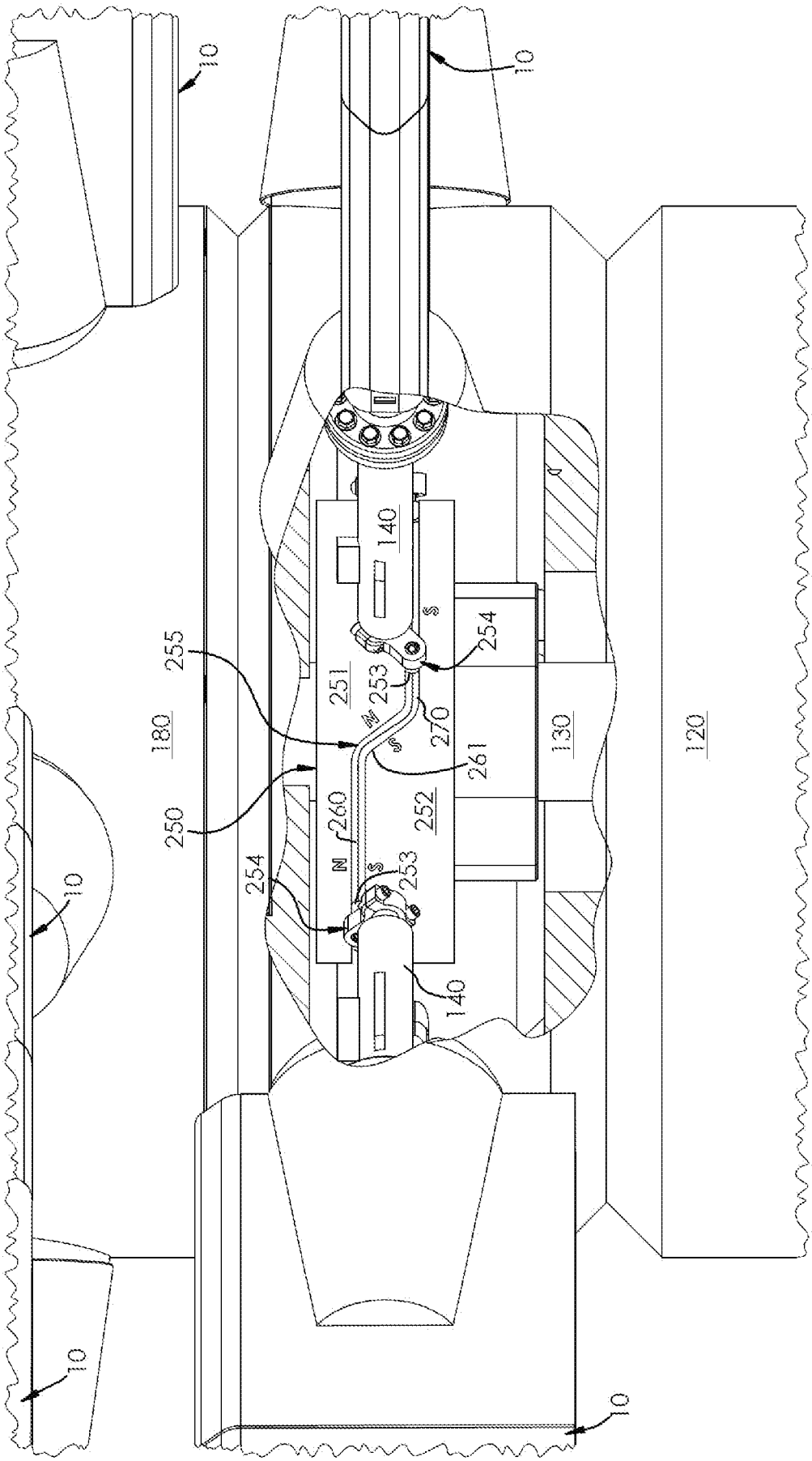

10
10
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180
270
130
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261
260
252
254
253
140
10
10
10

FIG. 2 B

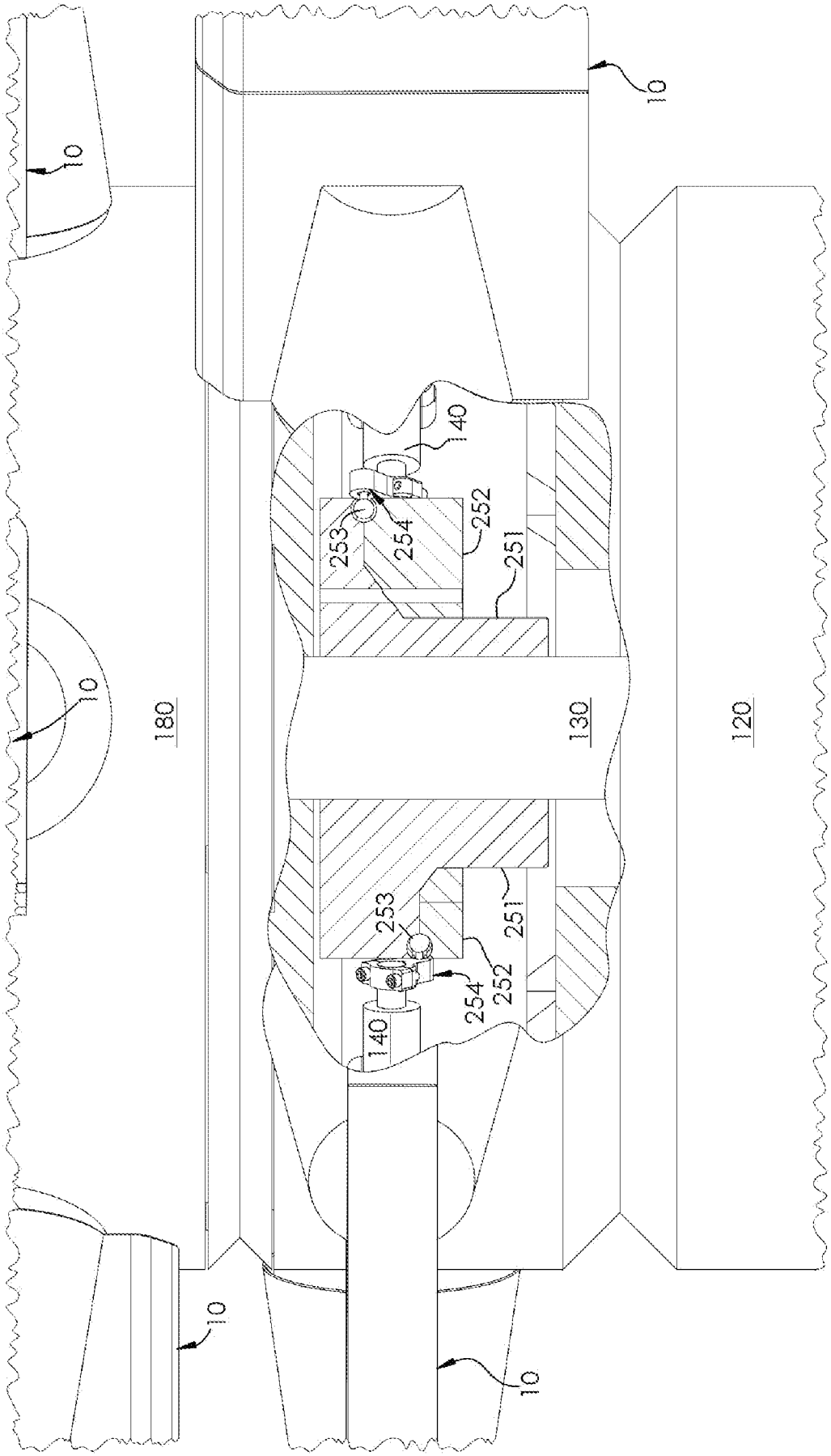


FIG. 2C

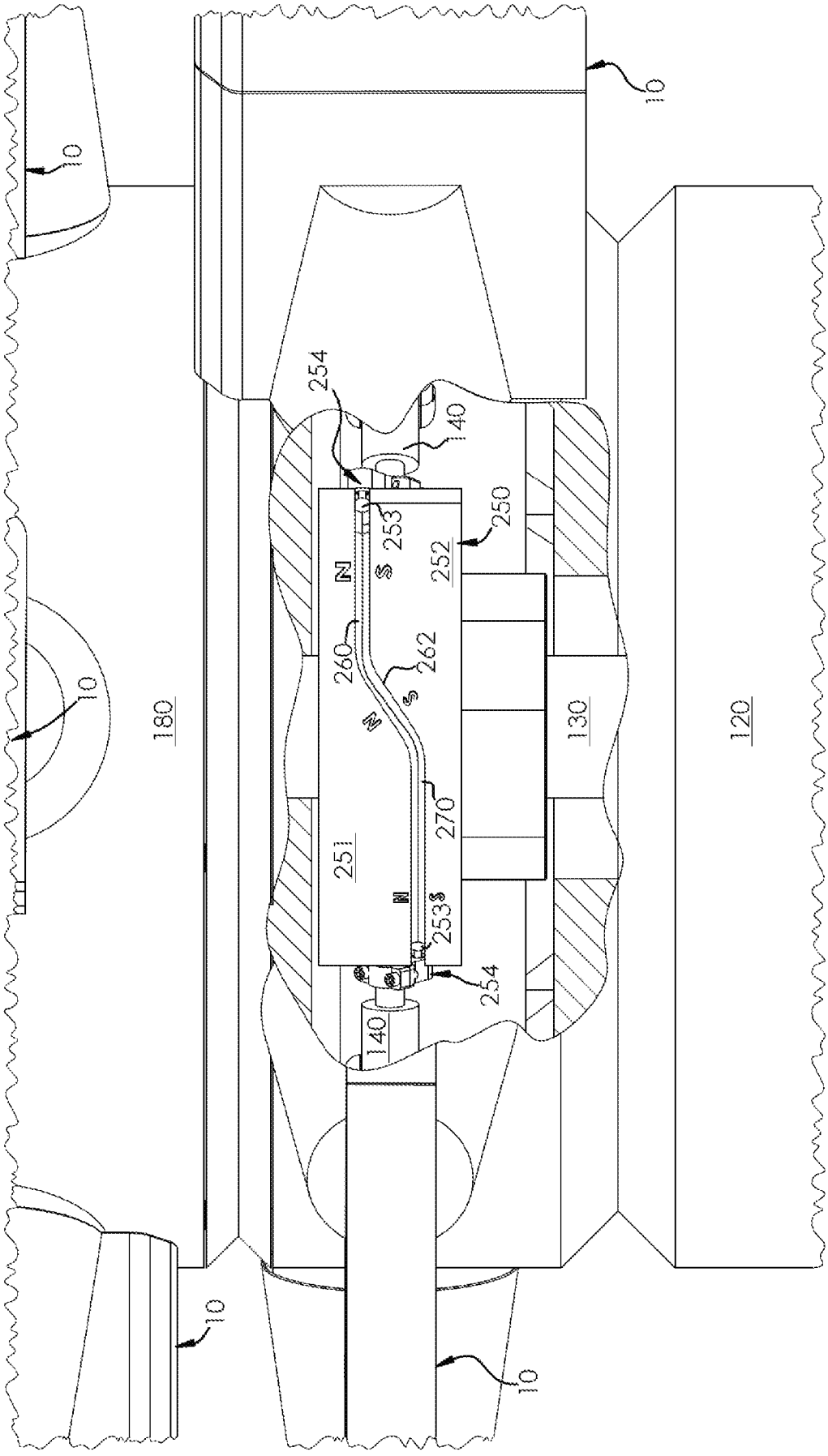

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10
10
10
10
254
140
250
253
252
N
S
260
262
S
N
180
130
120
270
251
N
253S
254
140

FIG. 2D

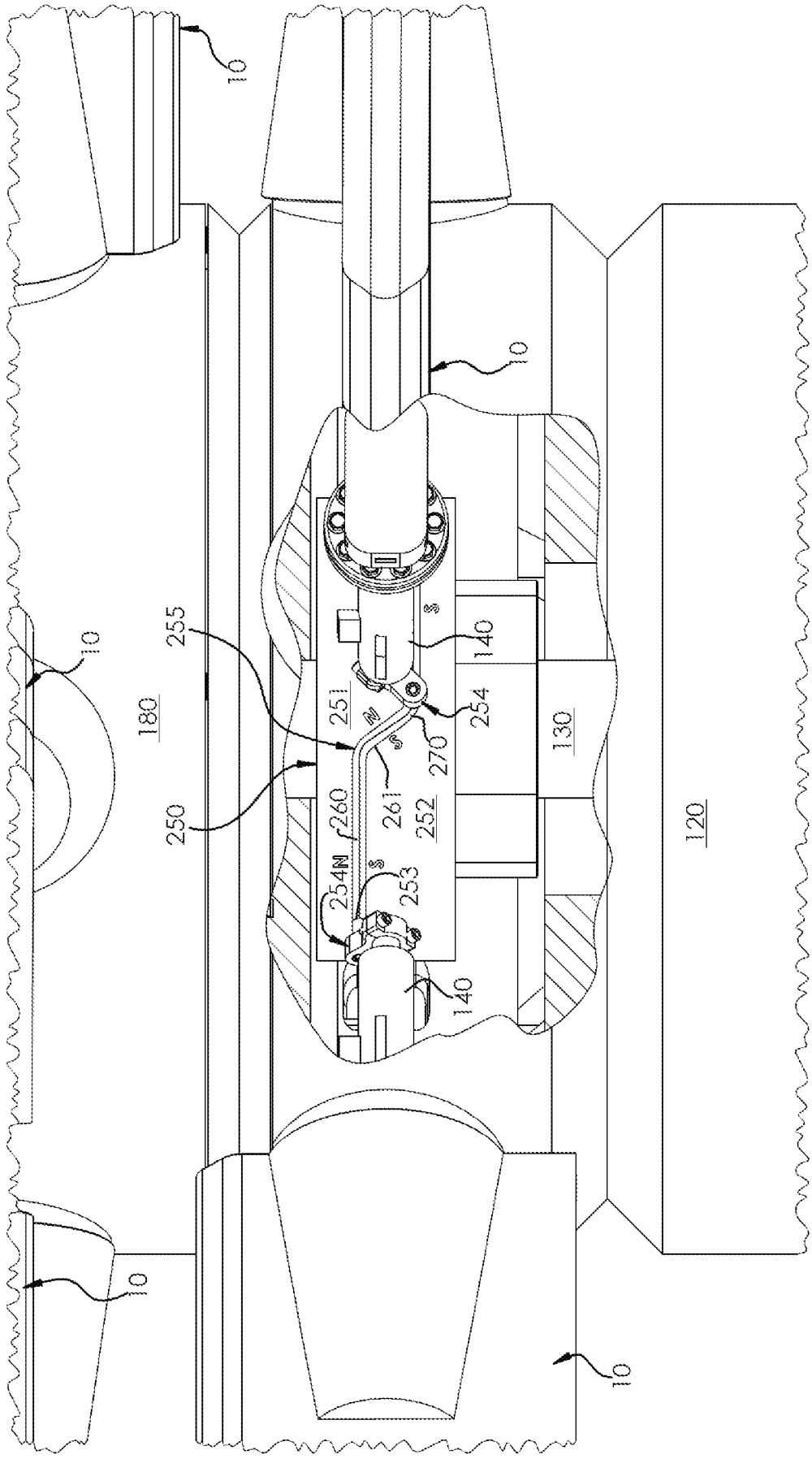

10
10
10
10
255
250
180
251
260
261
252
254N
253
254
270
140
140
130
120

FIG. 2 E

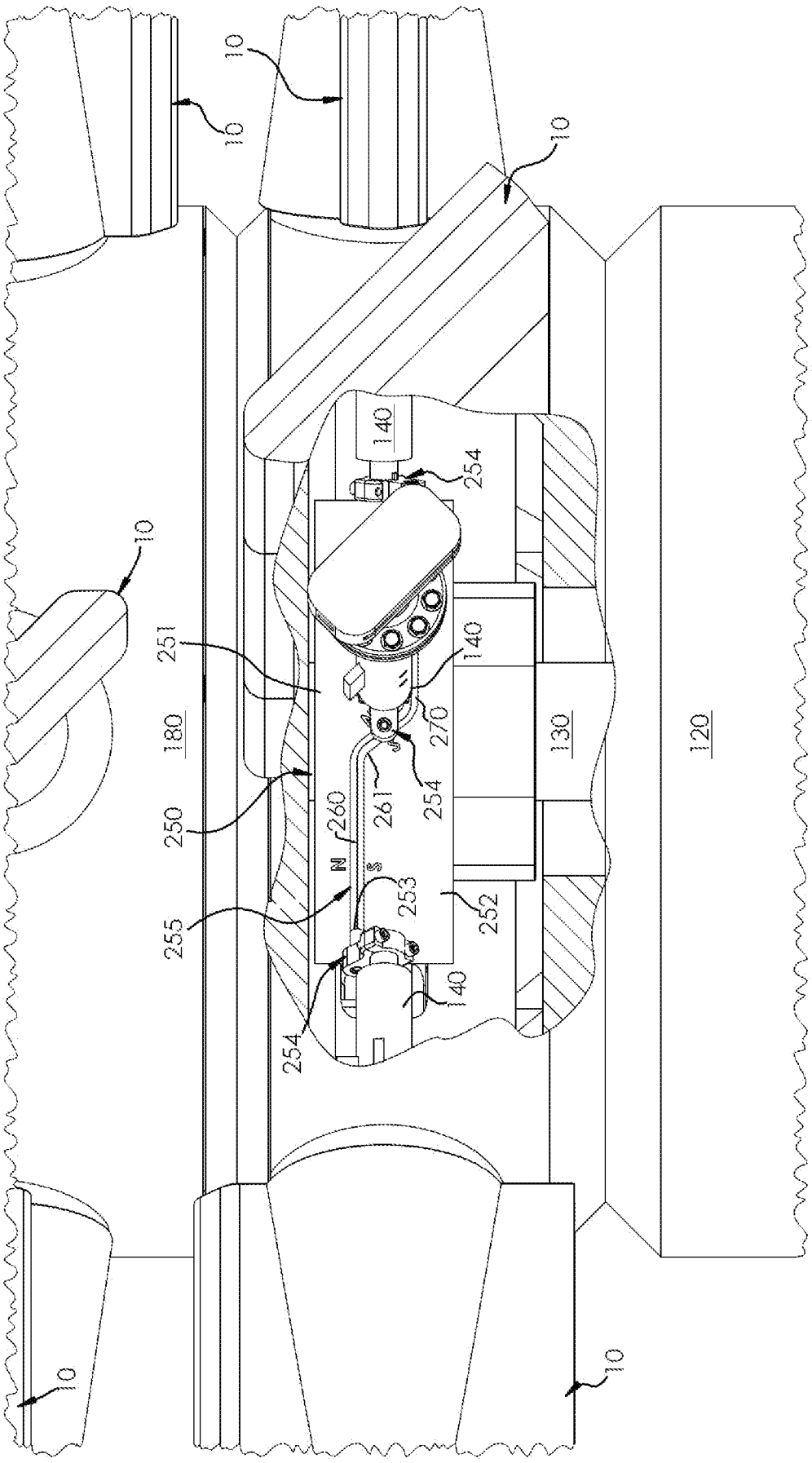

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10
10
10
10
10
140
254
140
251
180
270
254
250
260
261
130
120
N
S
253
252
255
140
254

FIG. 2 F

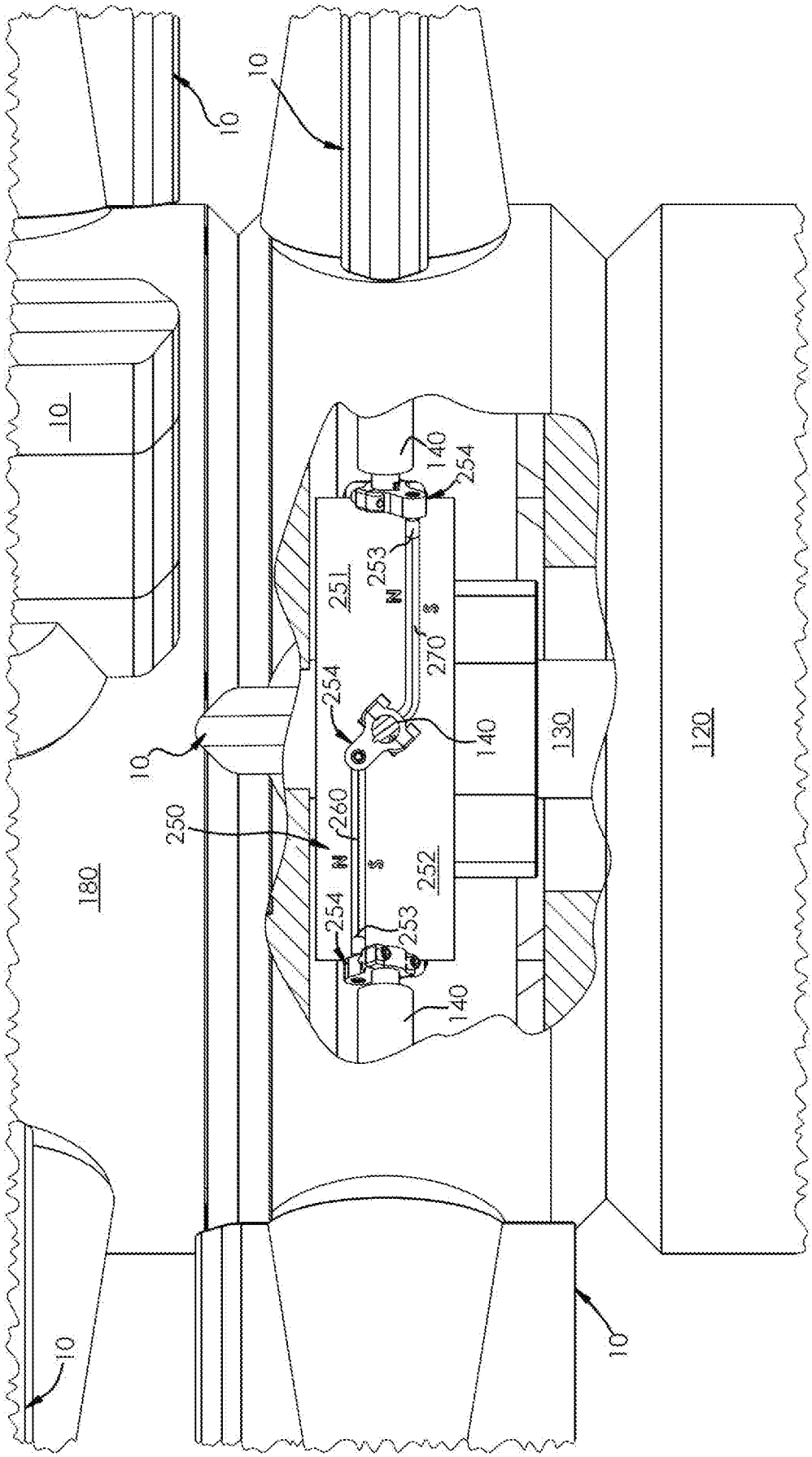

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10
10
10
10
10
140
254
253
N
S
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254
140
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120
10
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260
N
S
252
180
254
253
140

FIG. 2G

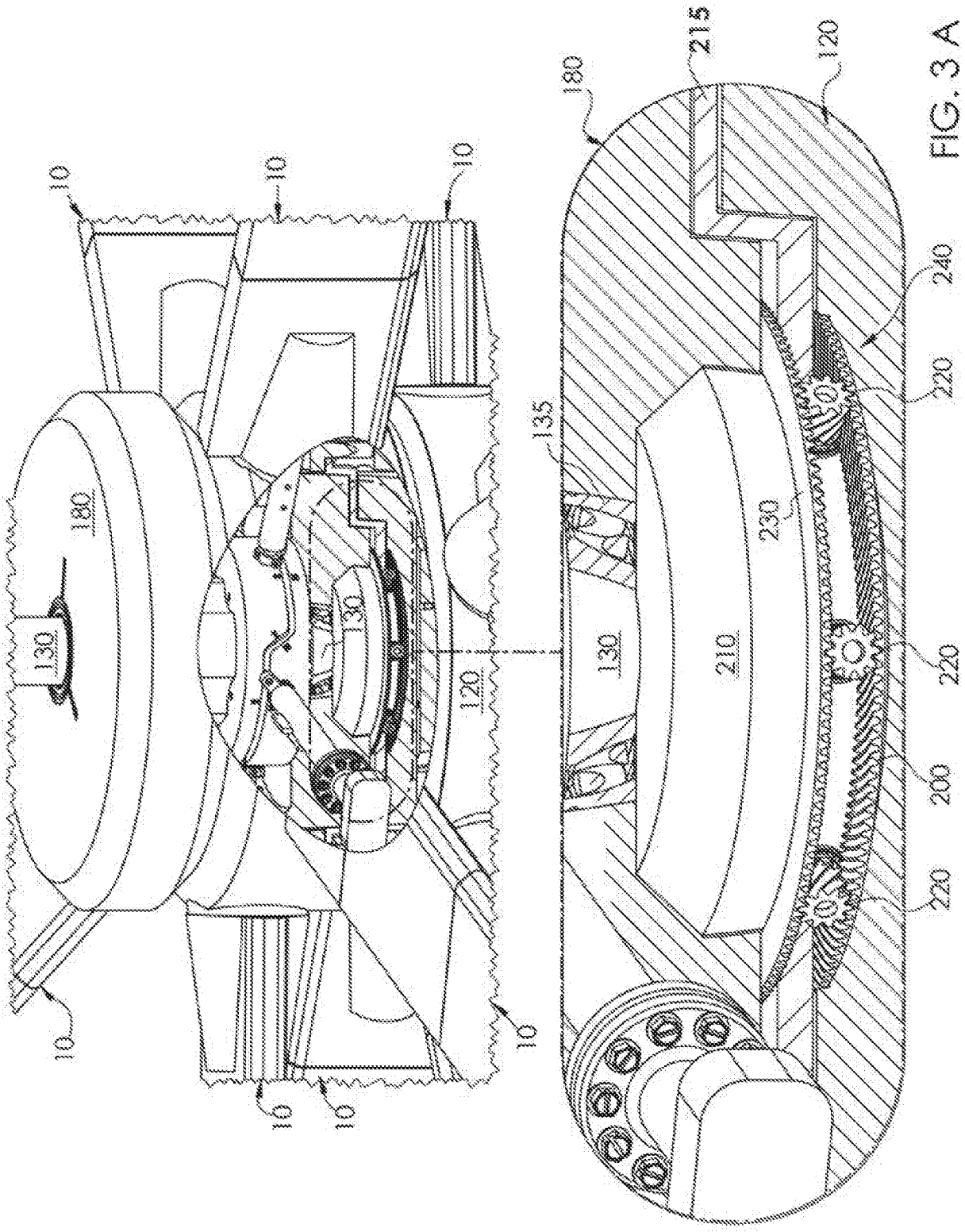

10
10
10
180
130
120
135
215
120
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220
230
210
130
220
200
220
10
10
10
10

FIG. 3A

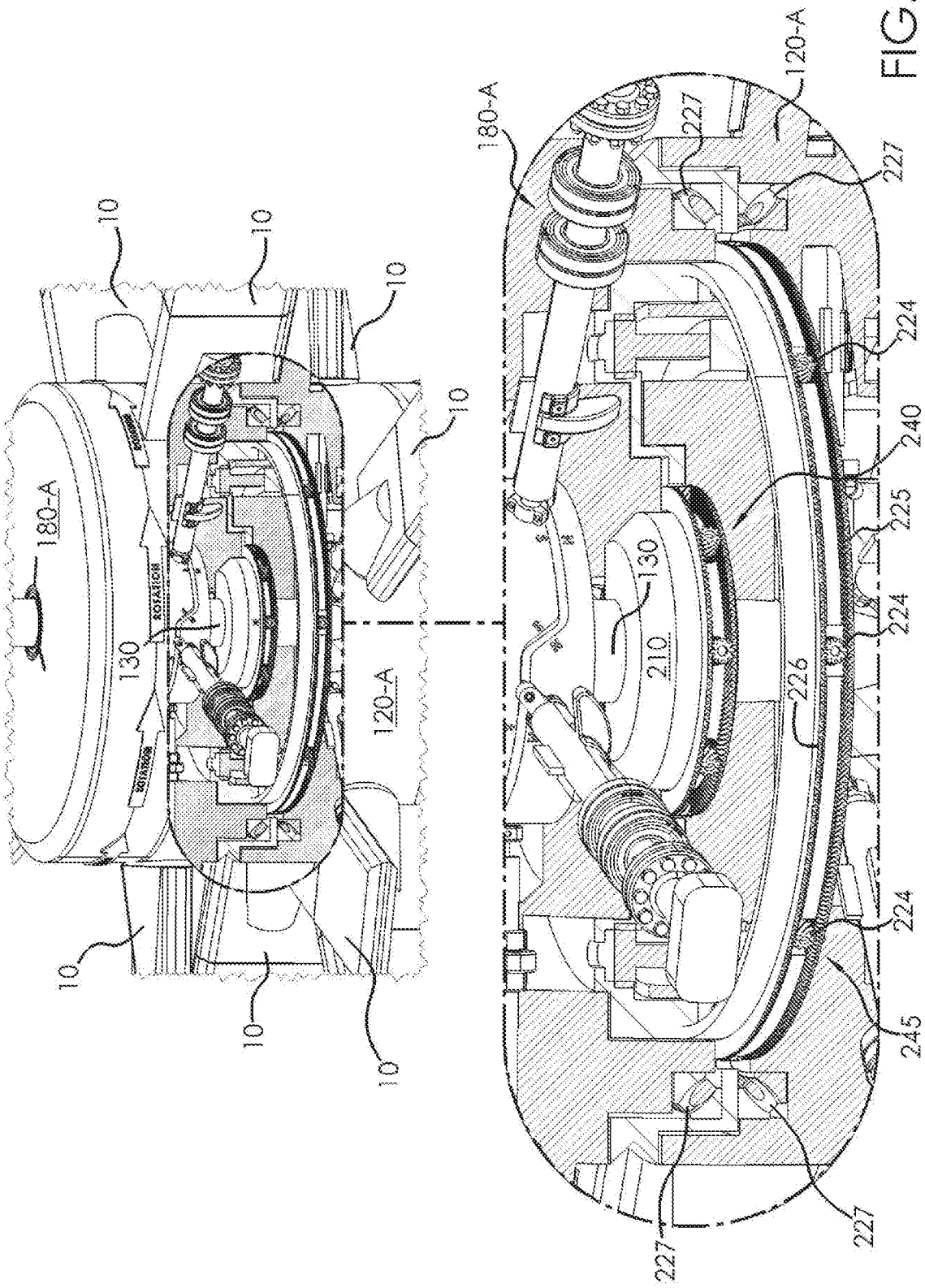

10
10
10
10
10
10
10
10
180-A
130
120-A
180-A
120-A
227
227
224
240
225
130
210
224
226
224
245
227
227

FIG. 3B

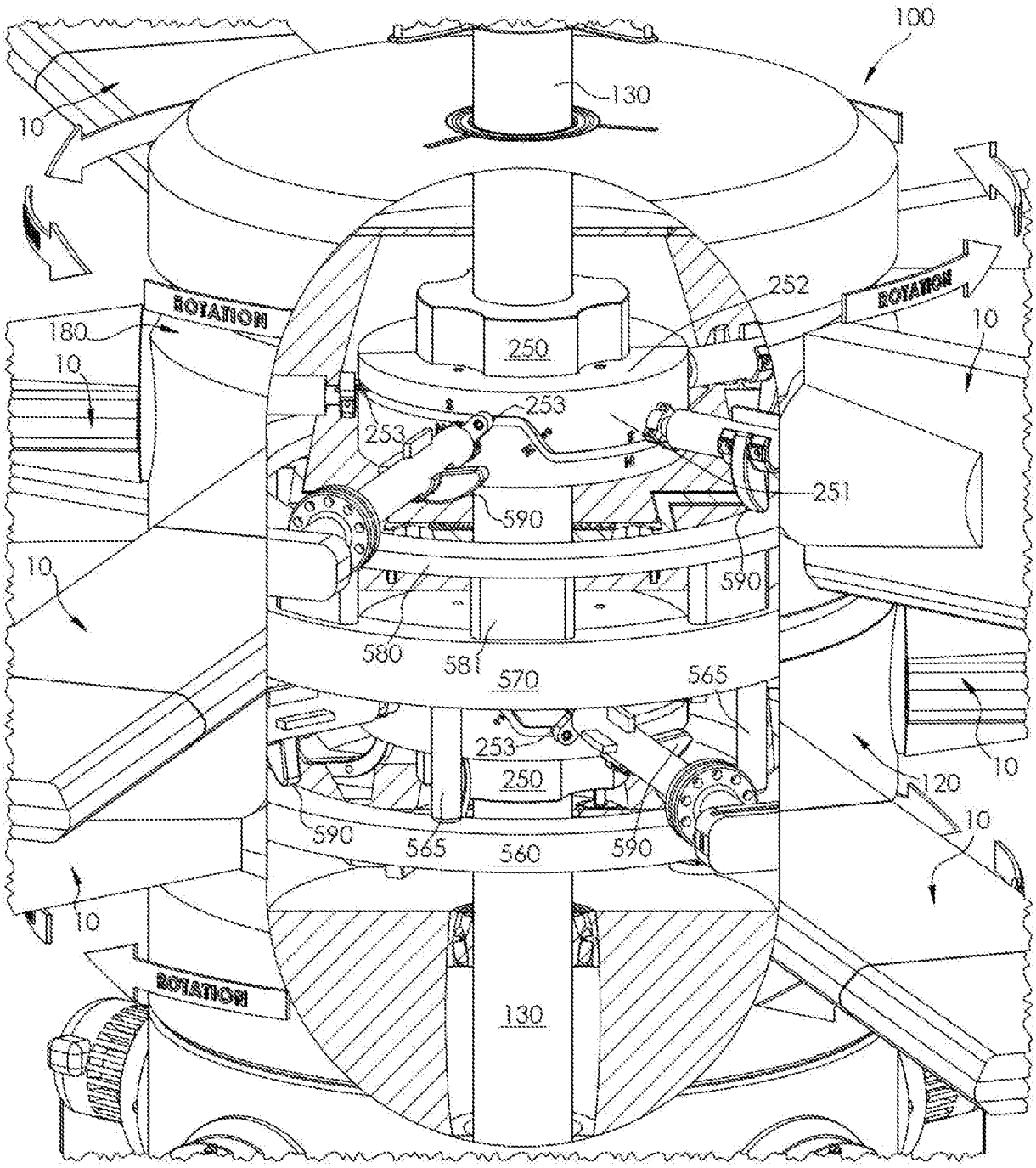

100
130
10
ROTATION
252
180
250
253
251
590
580
581
570
565
560
120
130

FIG. 4

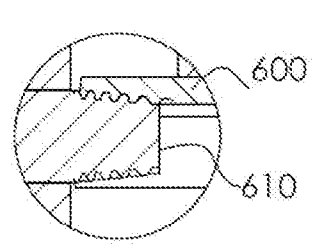


FIG. 5 B

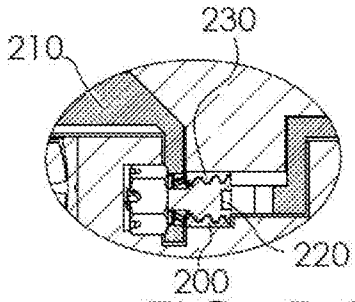


FIG. 5 C

FIG. 5 A

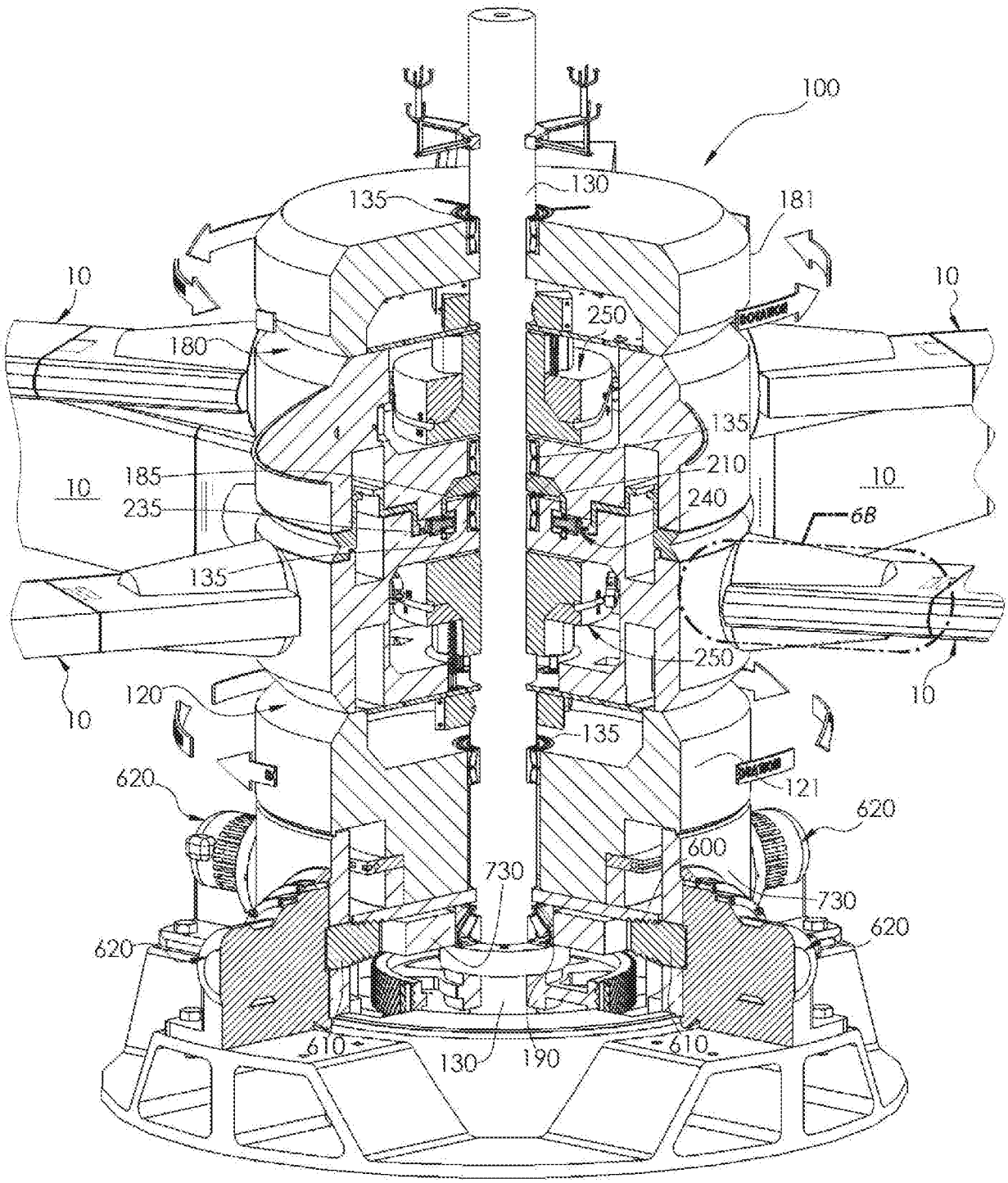

100
130
135
181
10
250
180
135
210
185
240
235
6B
135
120
135
620
121
620
600
730
730
620
620
610
610
130
190

FIG. 6 A

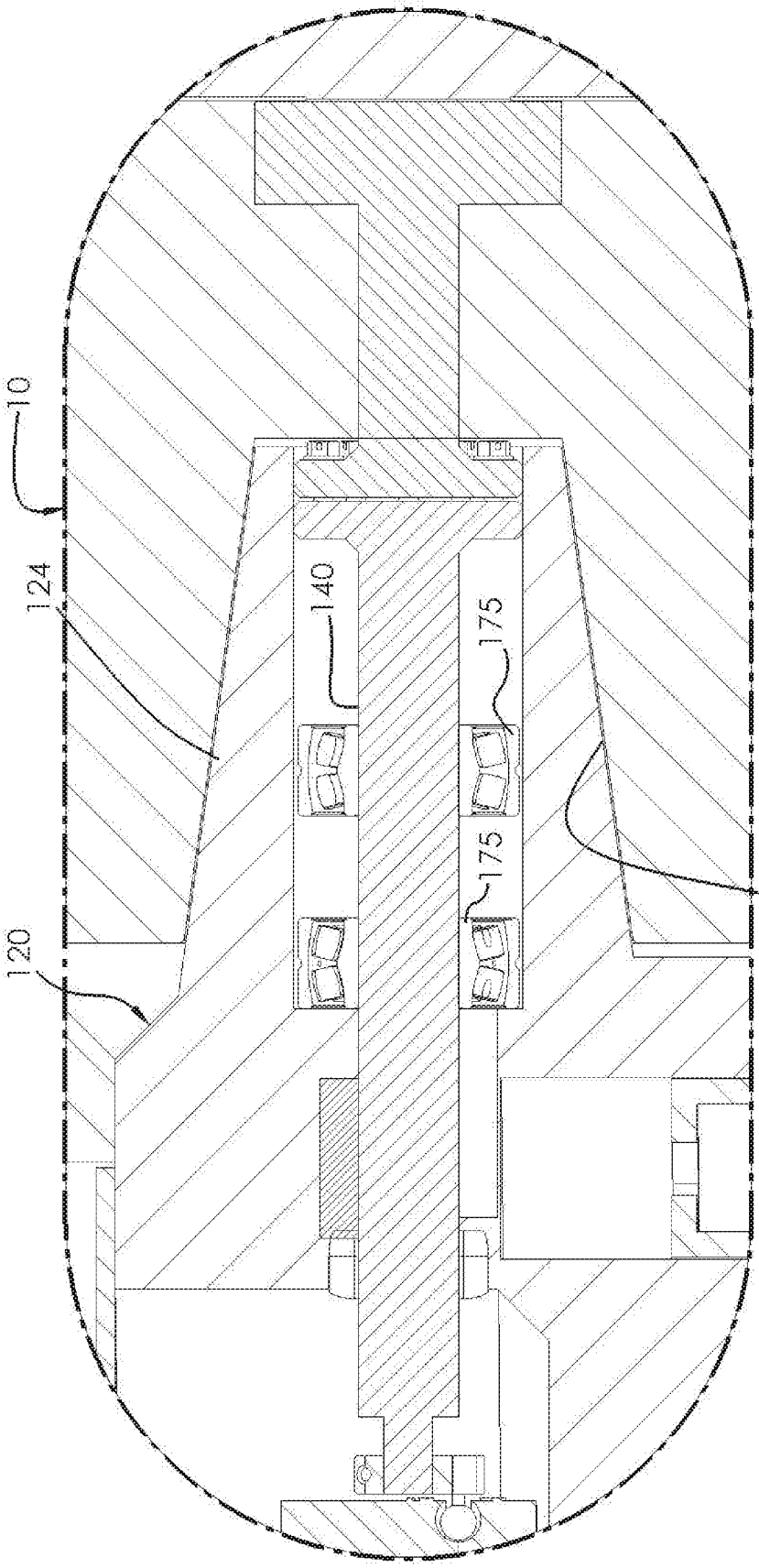


FIG. 6B

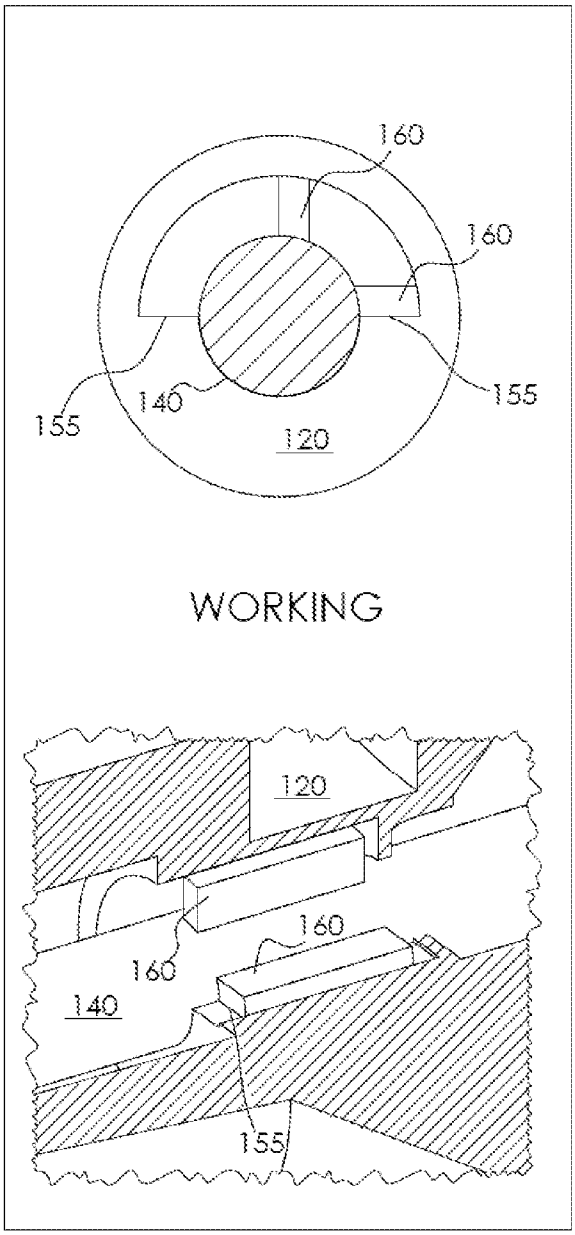

160
160
155
140
155
120
WORKING
120
160
160
140
155

FIG. 6C

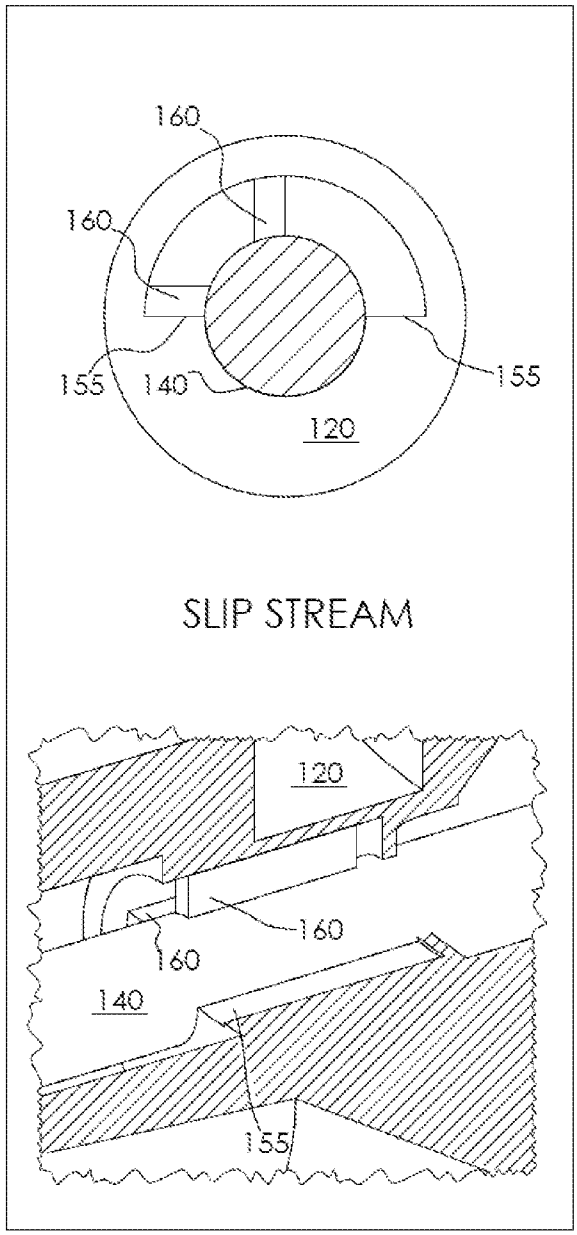

160
160
155
140
155
120
SLIP STREAM
120
160
160
140
155

FIG. 6D

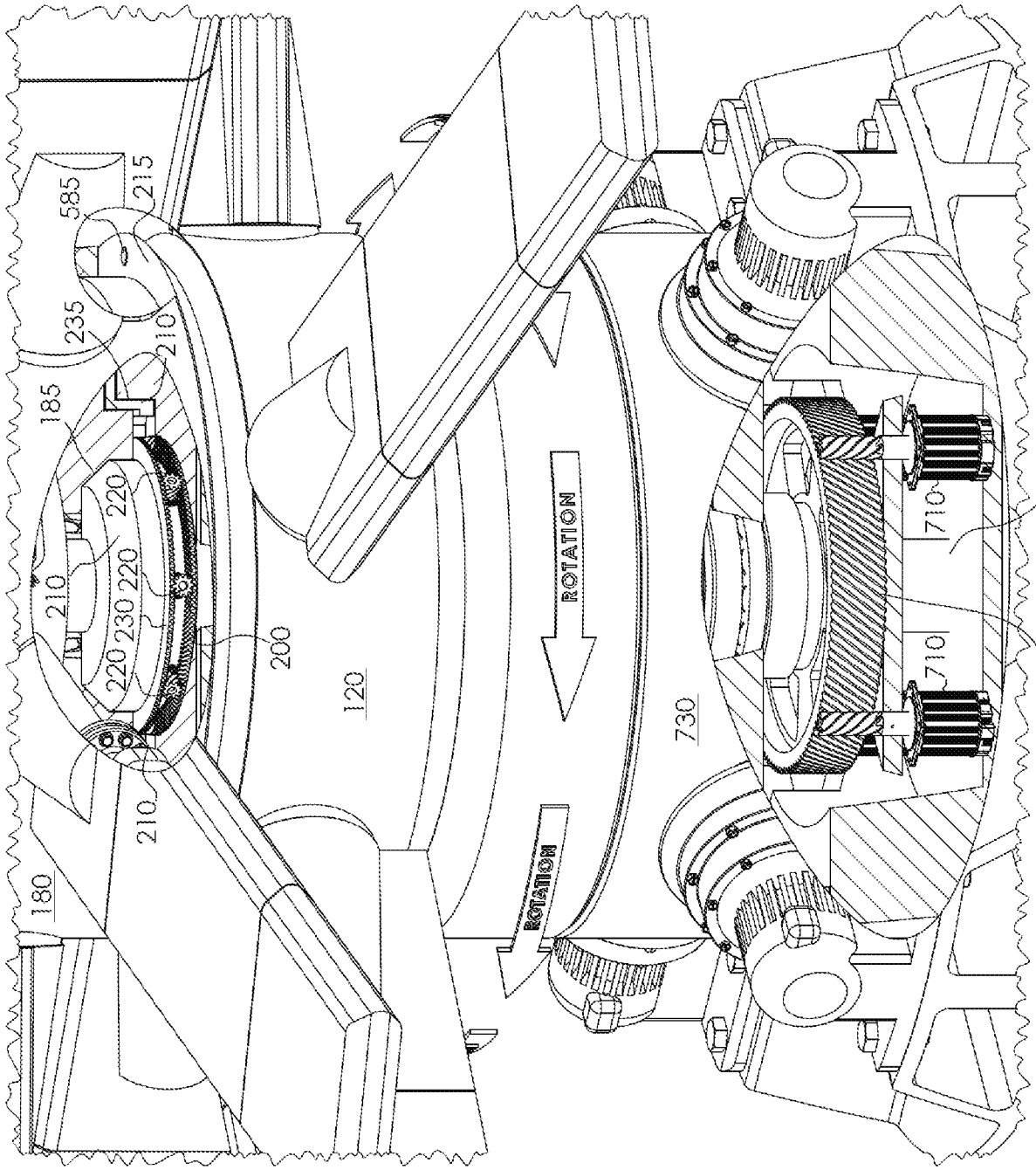

585
215
235
210
185
220
210
220
230
220
200
210
180
120
ROTATION
ROTATION
730
710
710
130
700

FIG. 7A

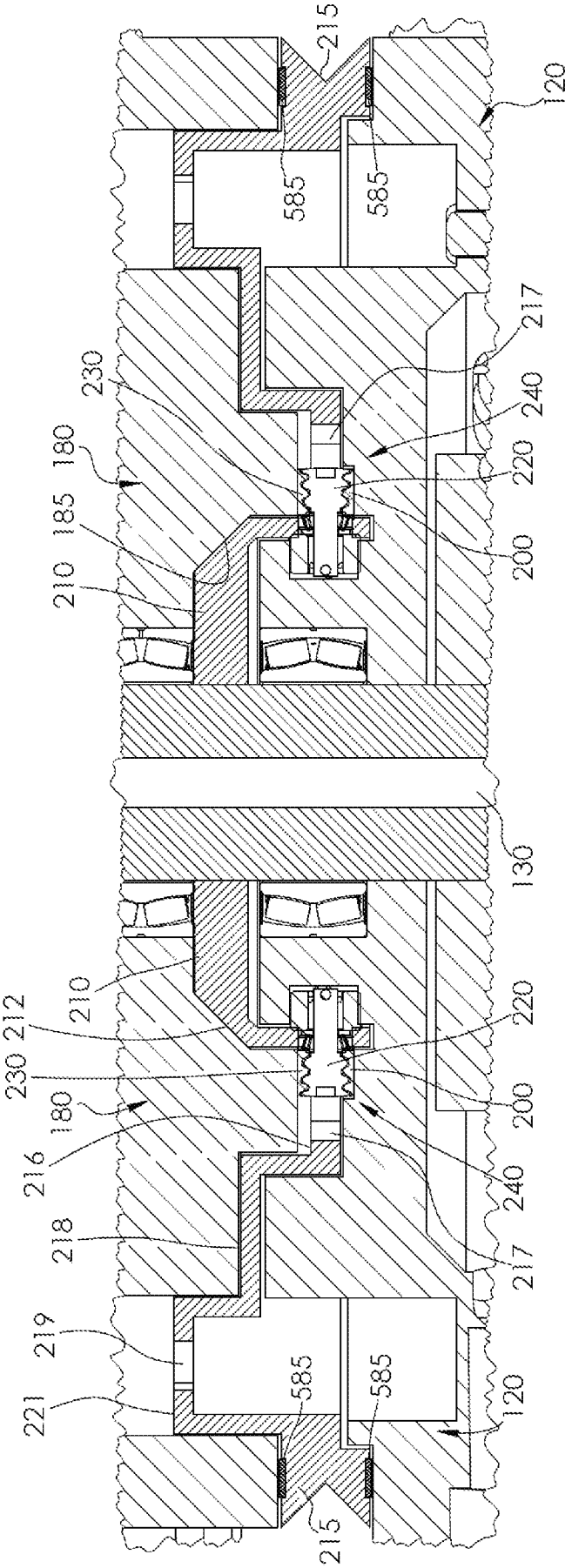

215
120
585
585
217
230
240
180
220
185
200
210
130
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212
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200
180
216
240
218
217
219
221
585
585
120
215

FIG. 7B

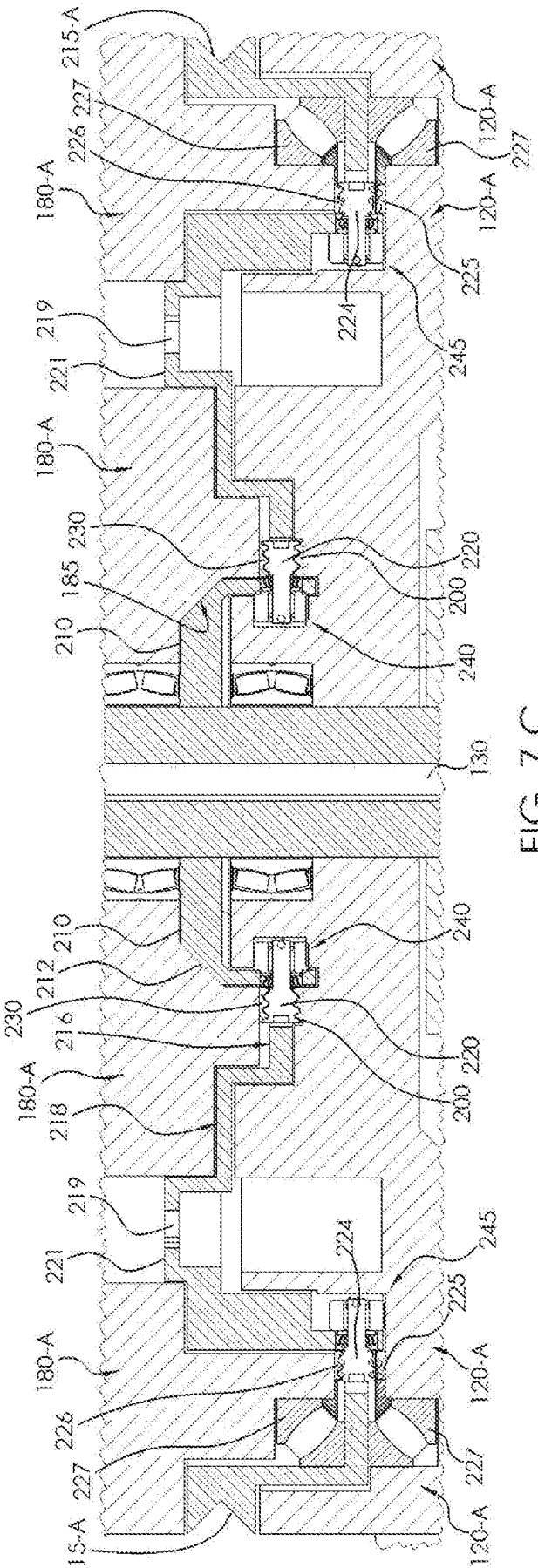

215-A
227
226
180-A
219
221
230
185
210
212
216
218
120-A
225
224
245
220
200
240
130

FIG. 7 C

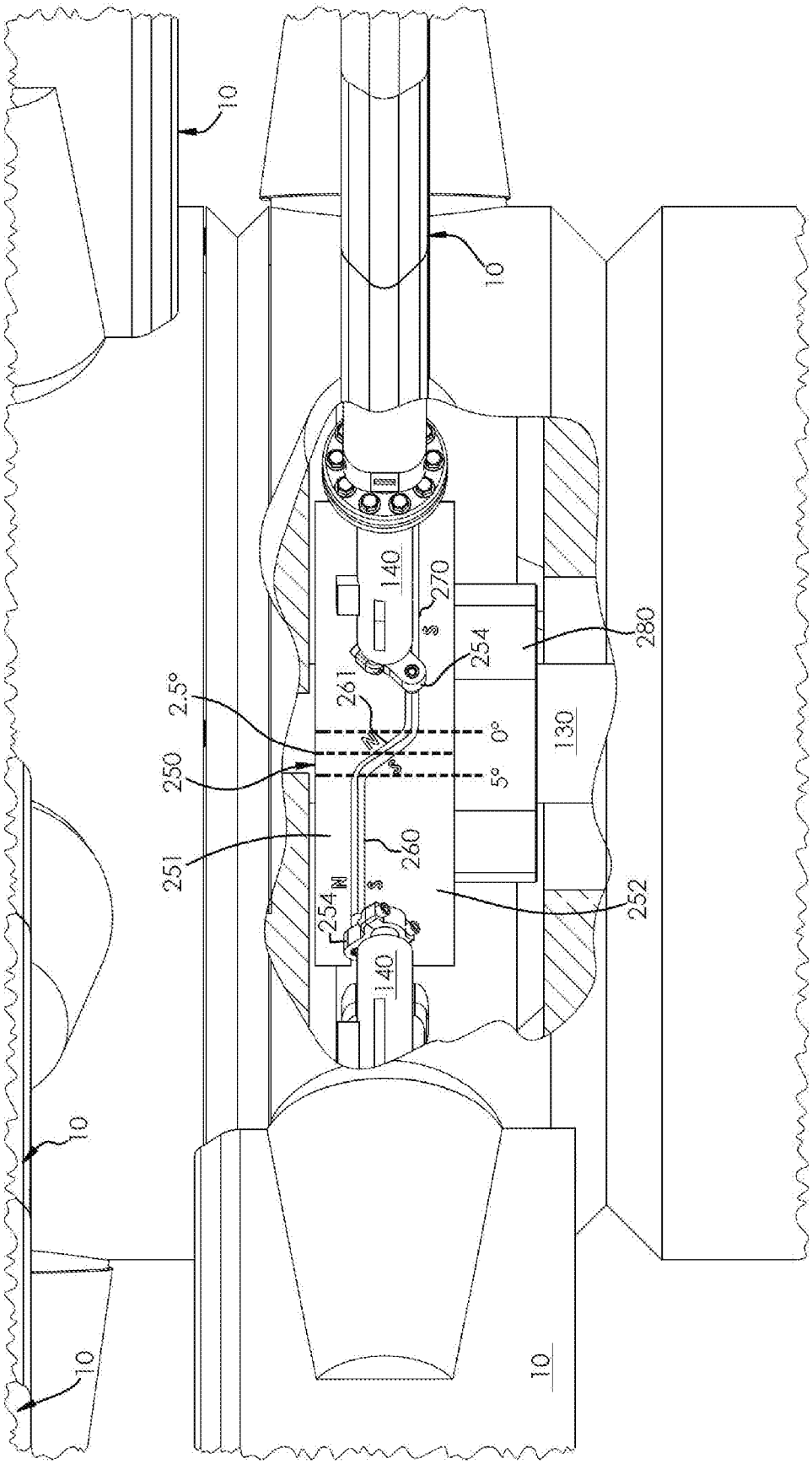

10
10
140
270
S
254
280
261
2.5°
0°
130
250
5°
251
260
N
S
254
252
140
10
10
10

FIG. 8A

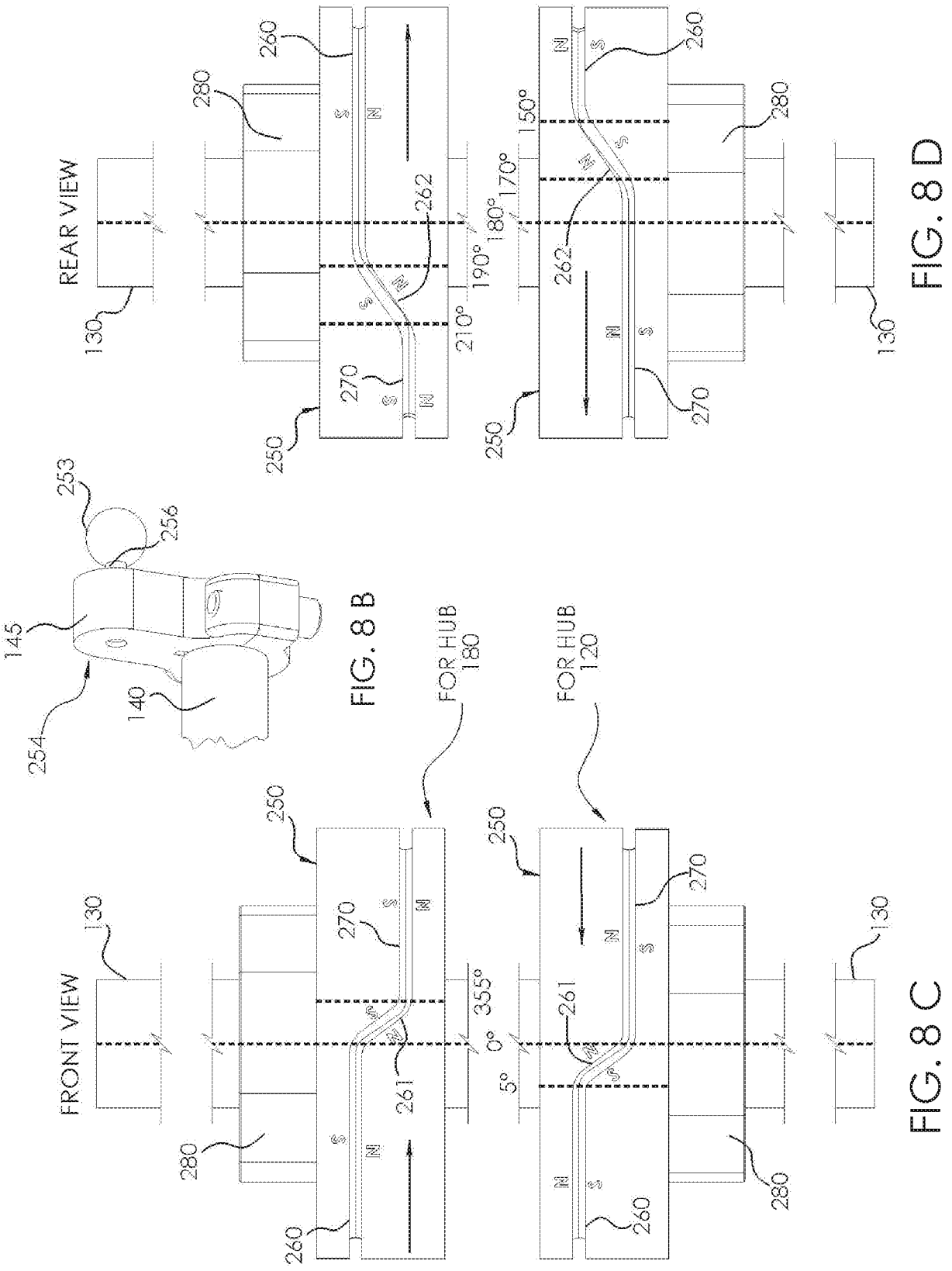
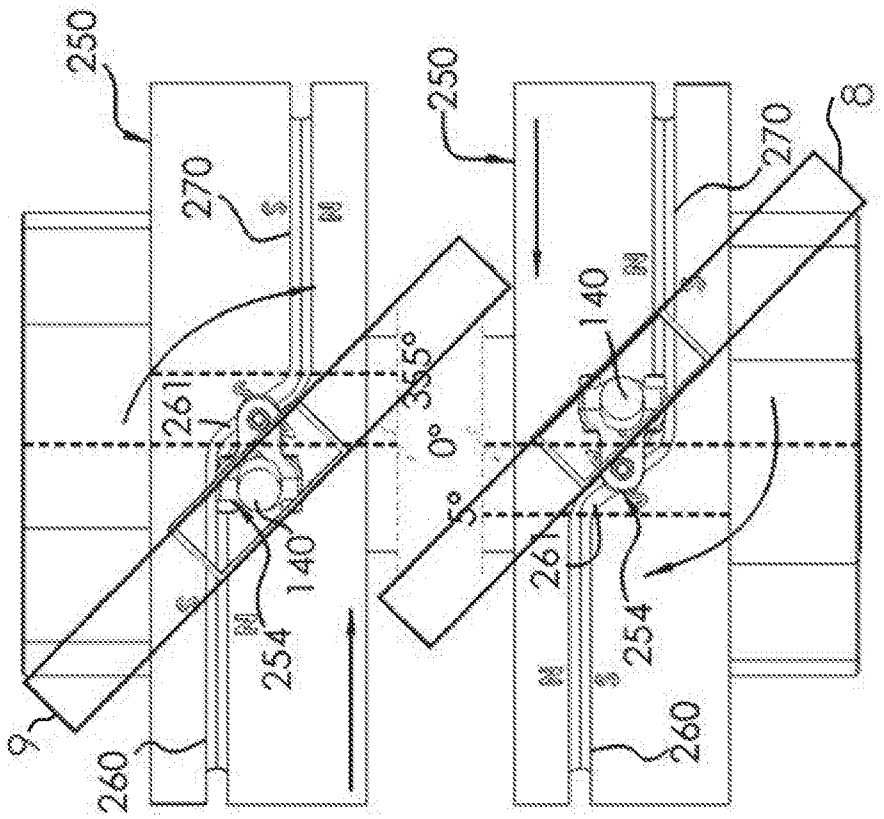


FIG. 8 B

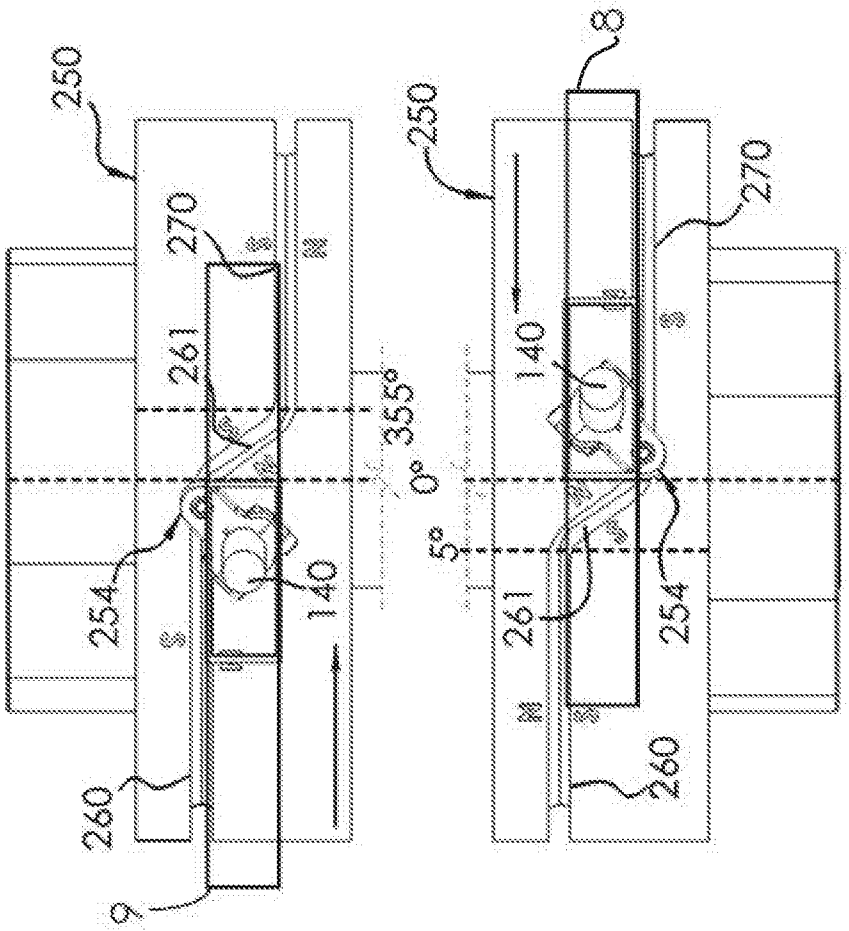
FIG. 8 C

FIG. 8 D



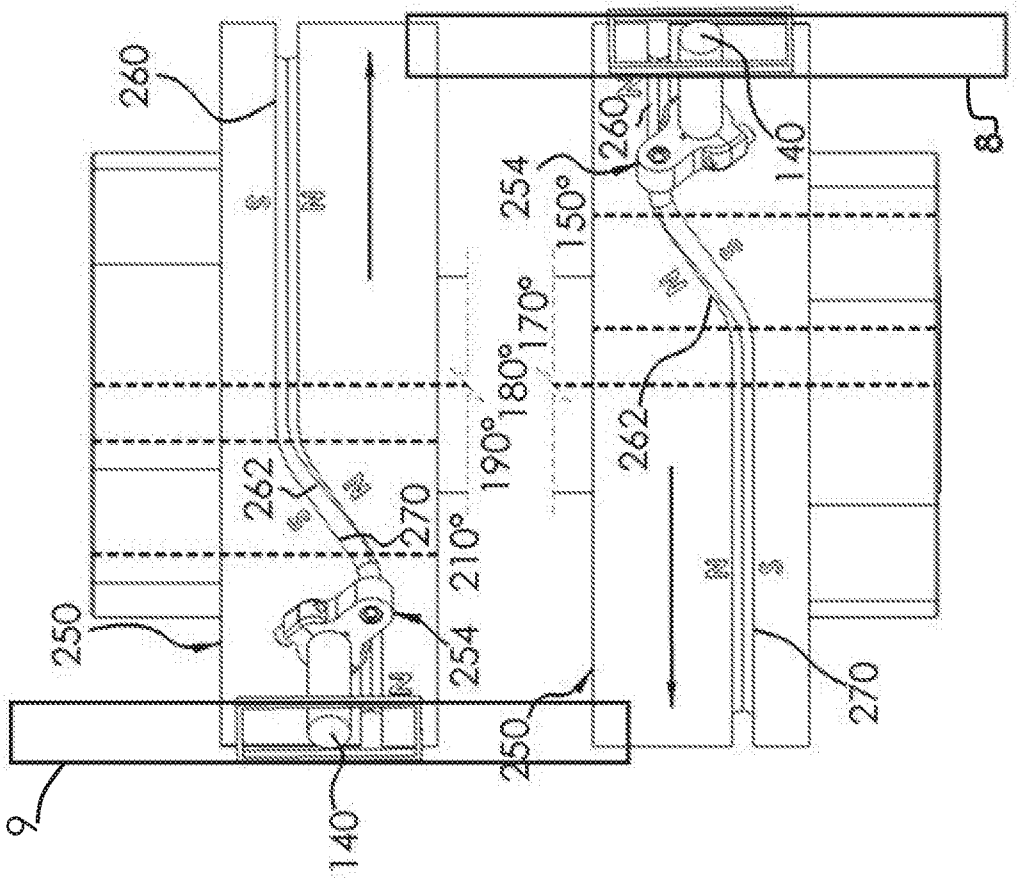
FRONT VIEW

FIG. 8 F



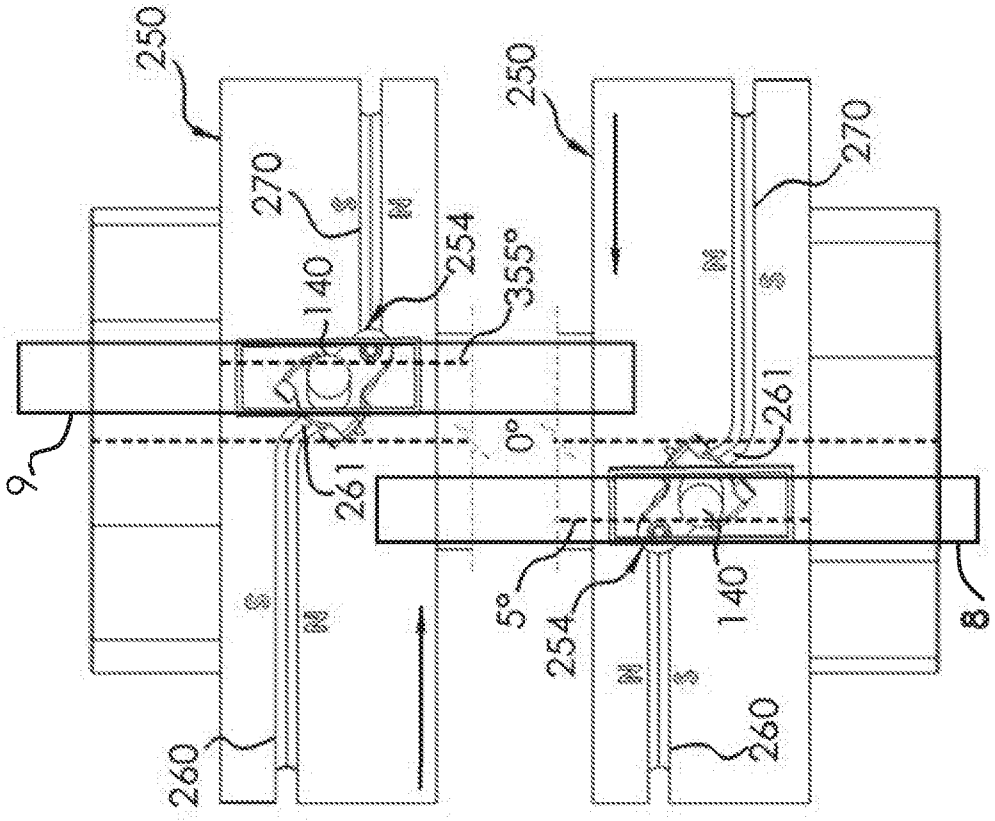
FRONT VIEW

FIG. 8 E



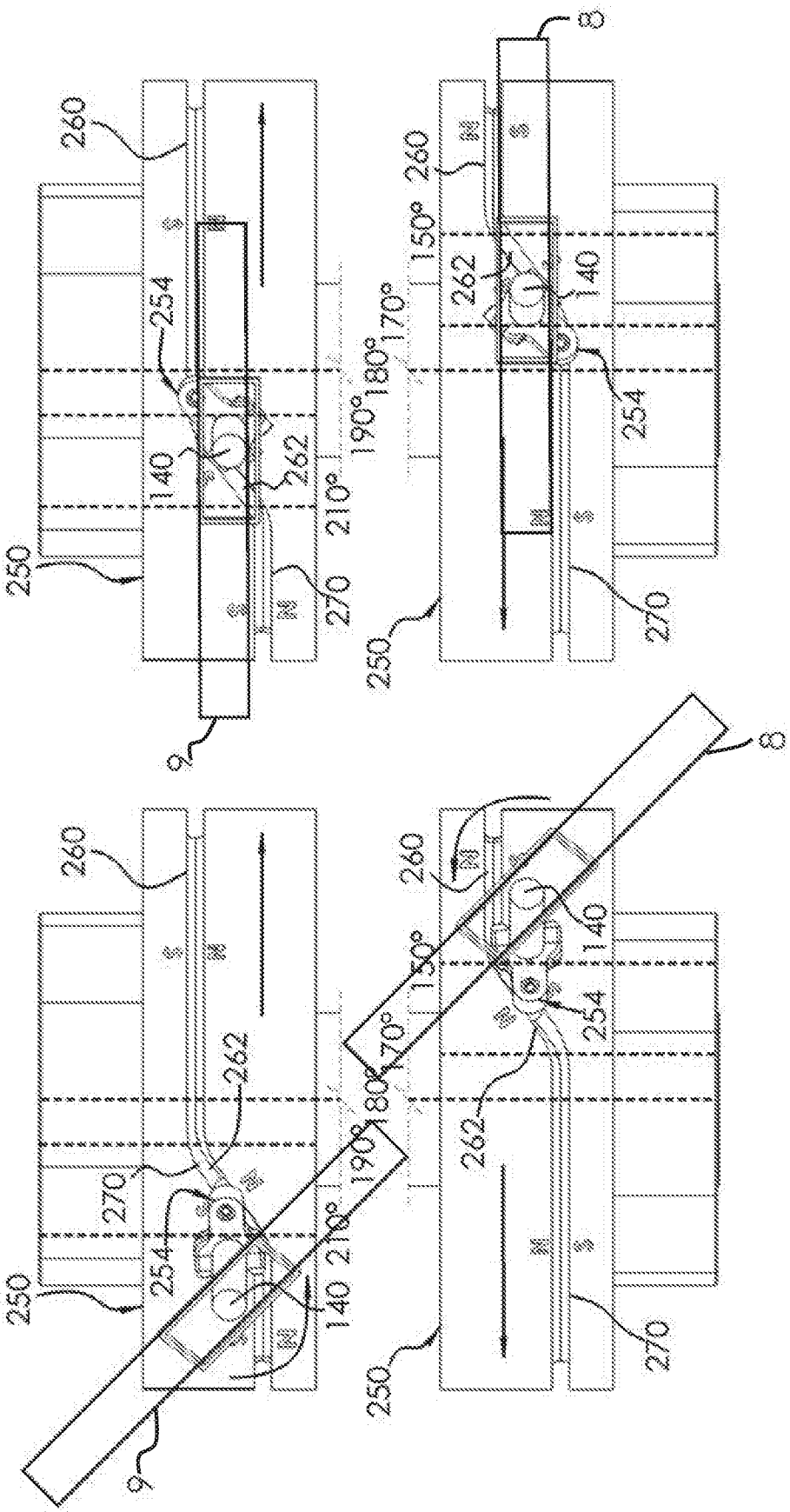
REAR VIEW

FIG. 8H



FRONT VIEW

FIG. 8G



REAR VIEW
FIG. 8 J

REAR VIEW
FIG. 8 I

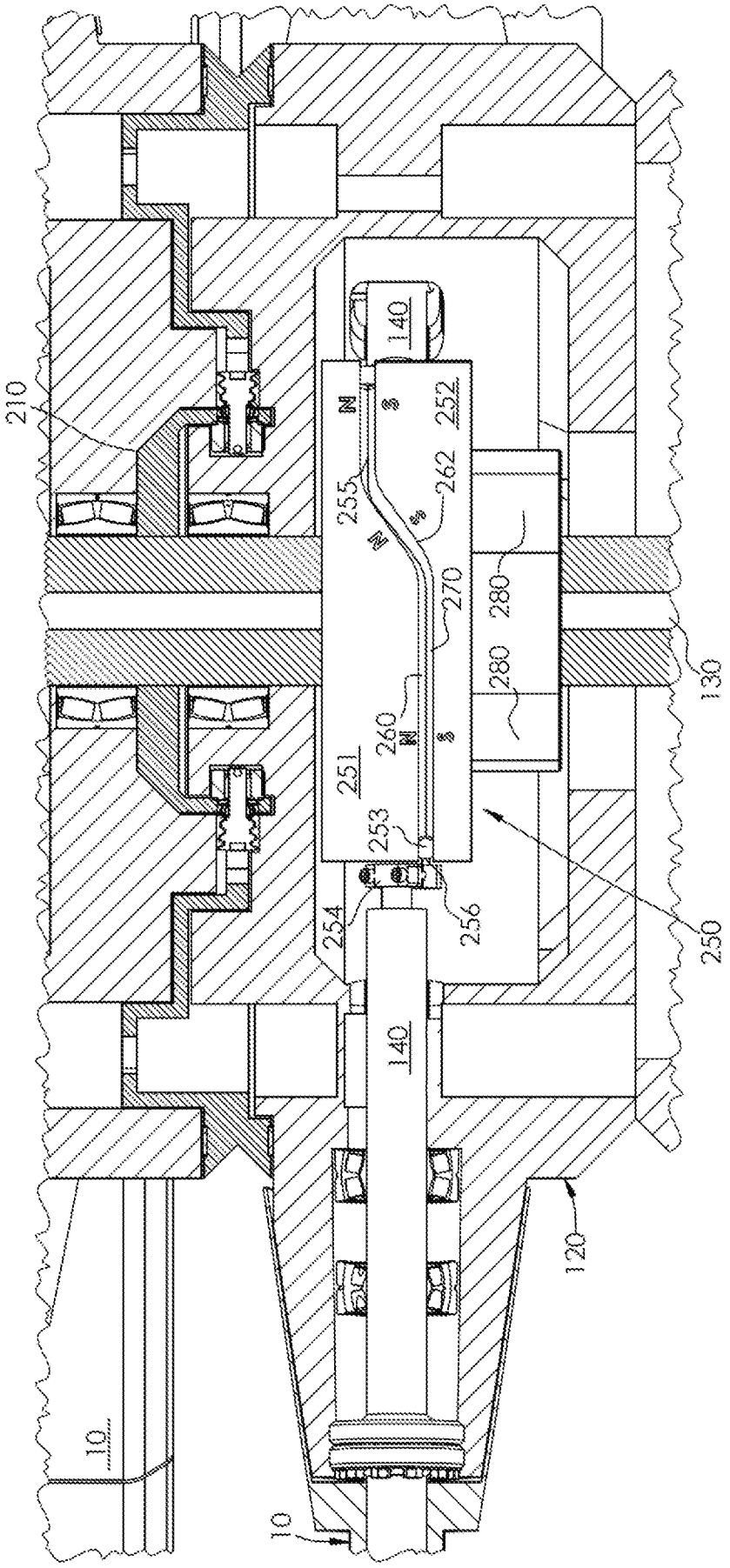

210
140
252
262
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270
280
280
260
251
253
254
256
250
130
140
120
10
10

FIG. 9A

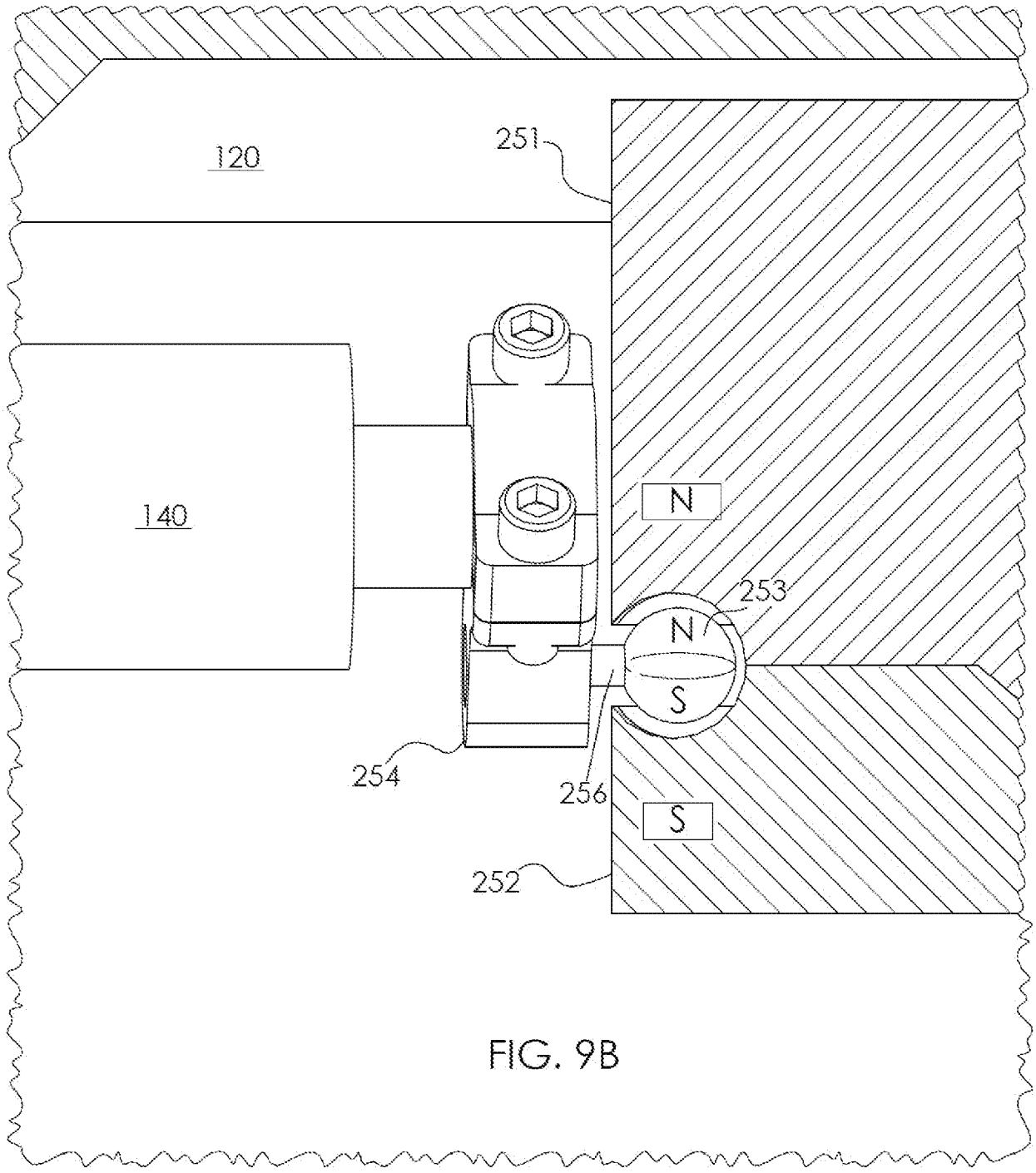


FIG. 9B

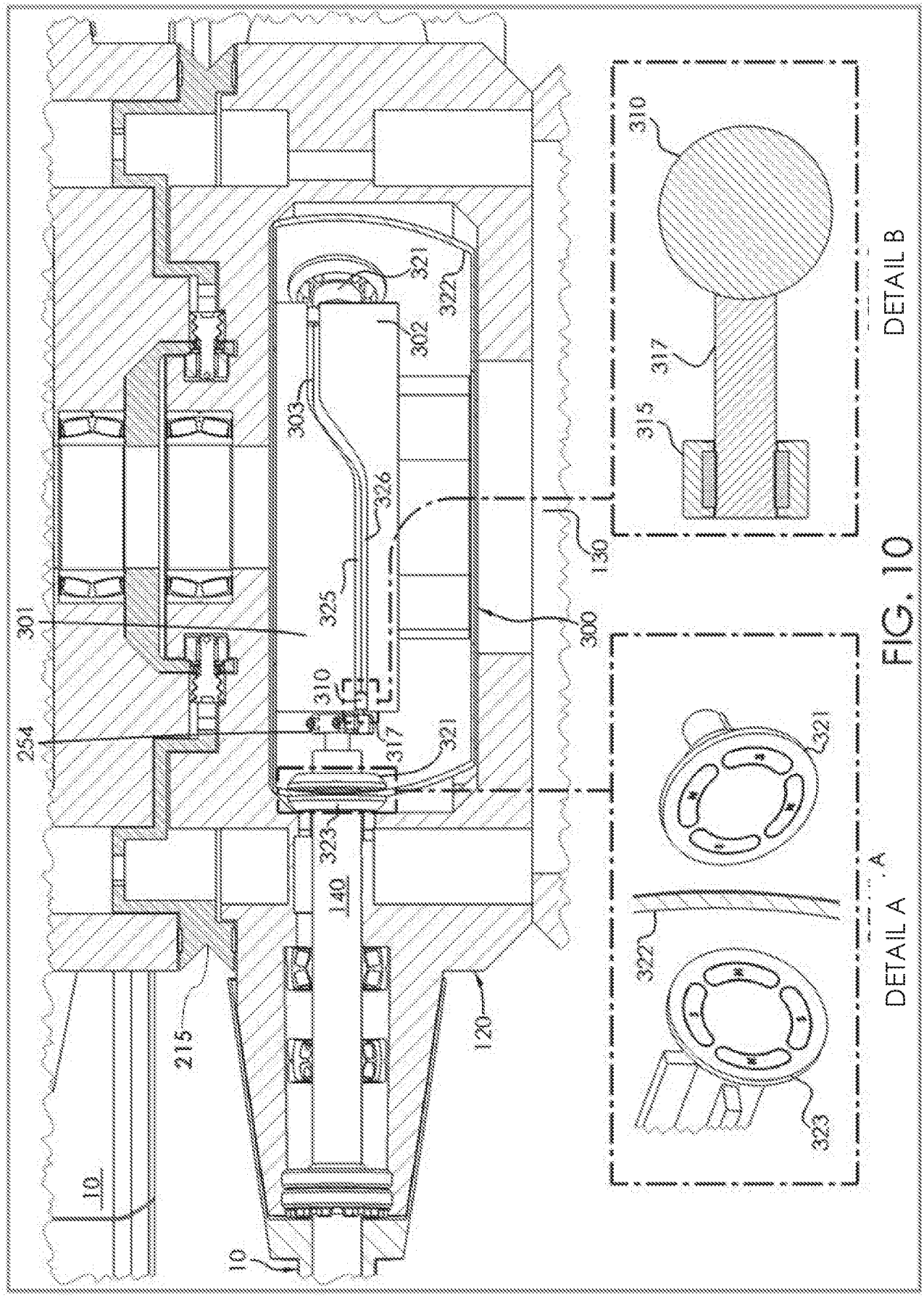

301
254
215
10
10
140
120
323
321
322
302
303
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325
310
317
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300
130
DETAIL A
DETAIL B
310
317
315
321
322
323

FIG. 10

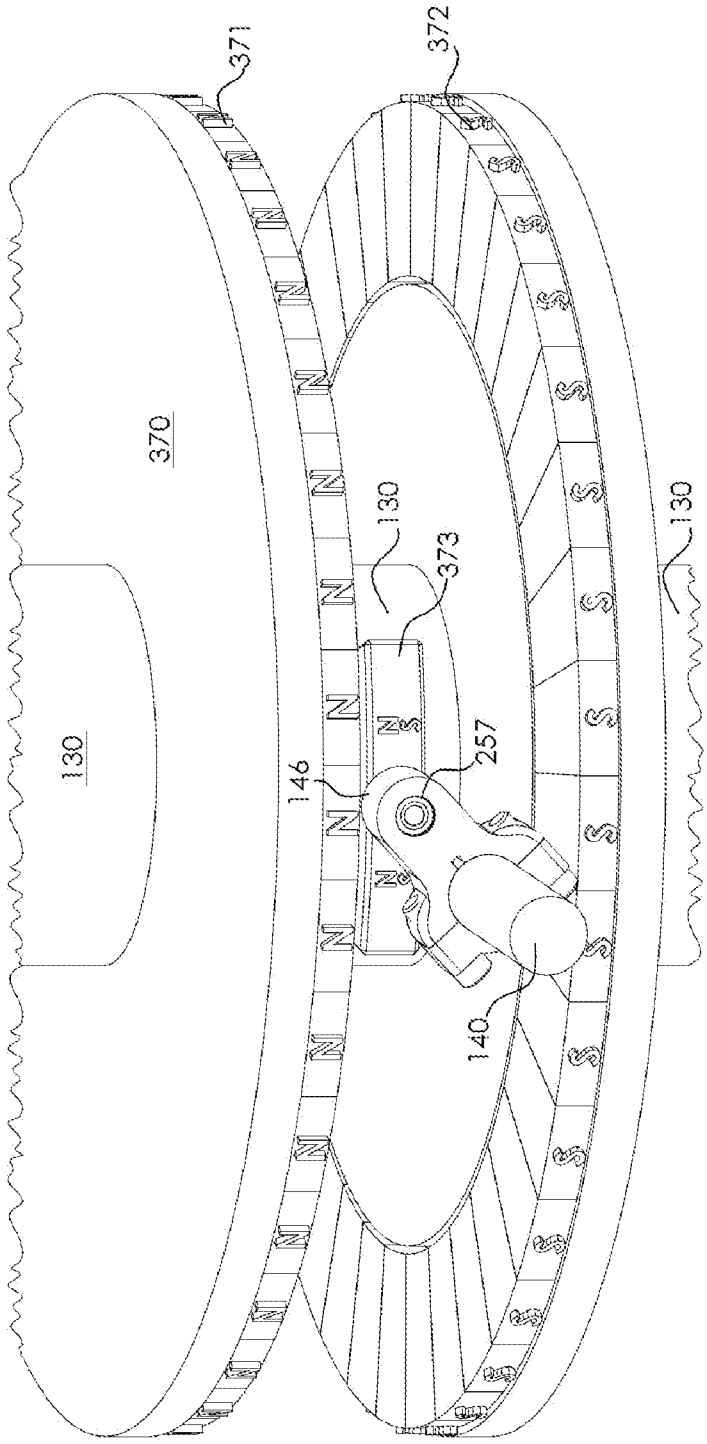


FIG. 11A

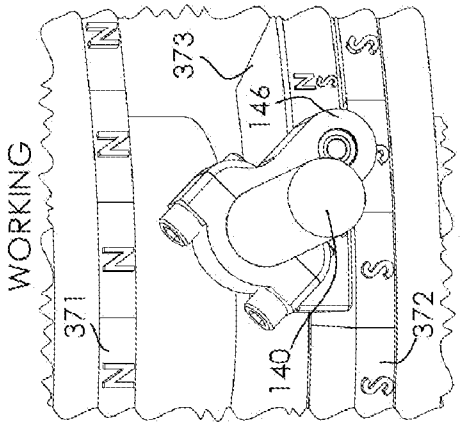


FIG. 11D

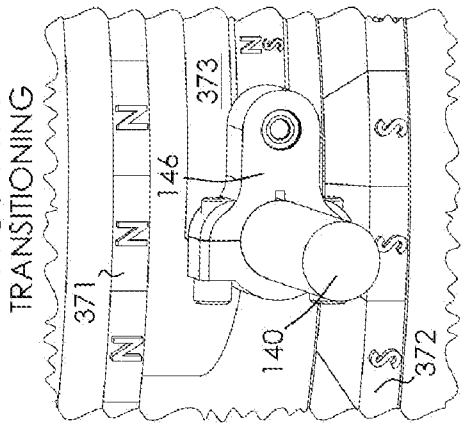


FIG. 11C

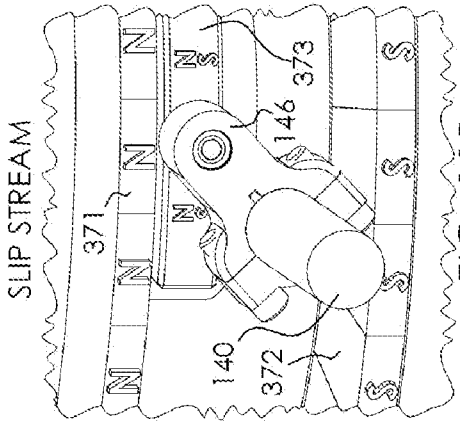


FIG. 11B

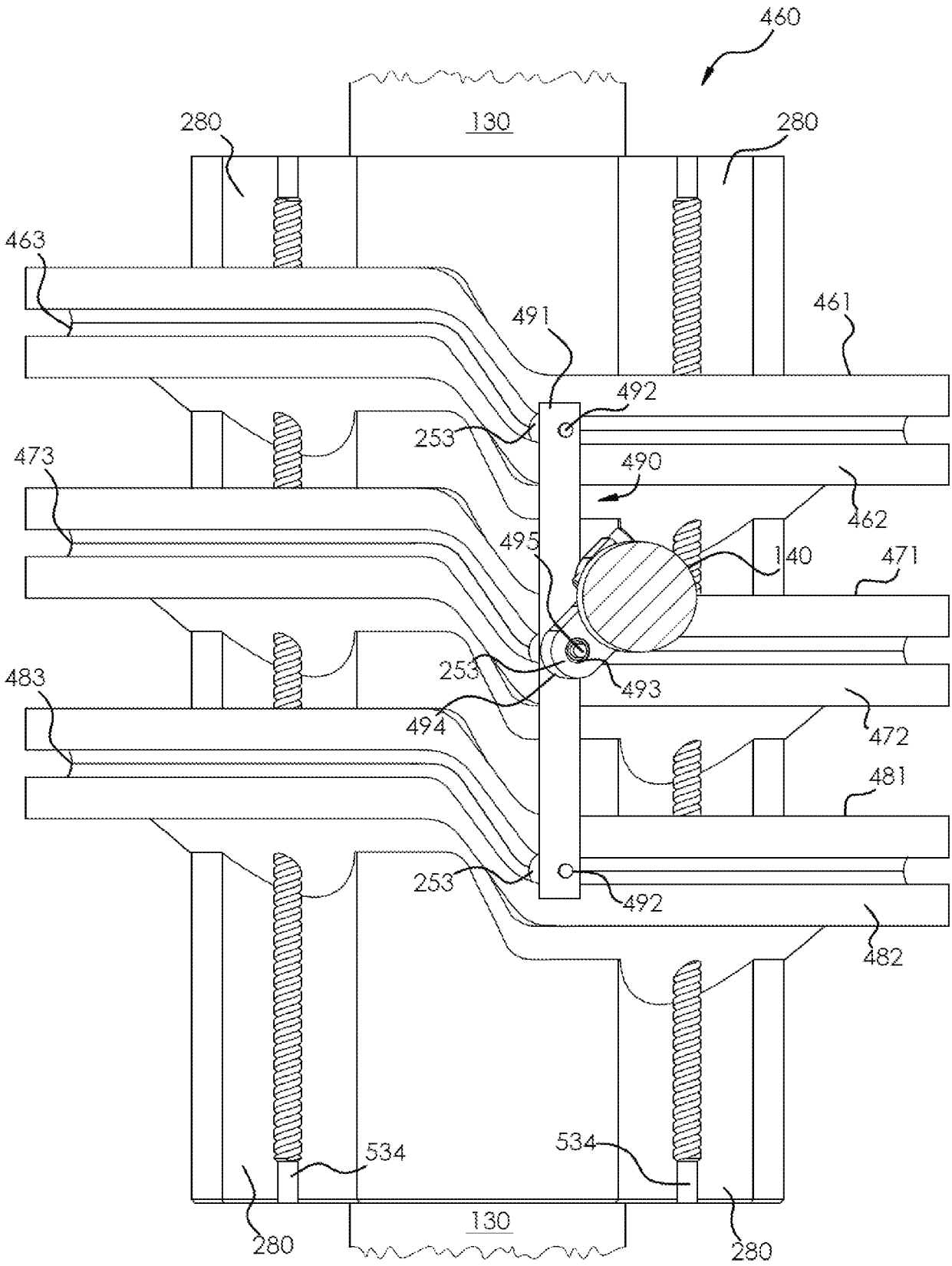

460
130
280
280
463
491
461
492
253
473
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495
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253
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494
472
481
253
492
482
534
534
280
130
280

FIG. 12A

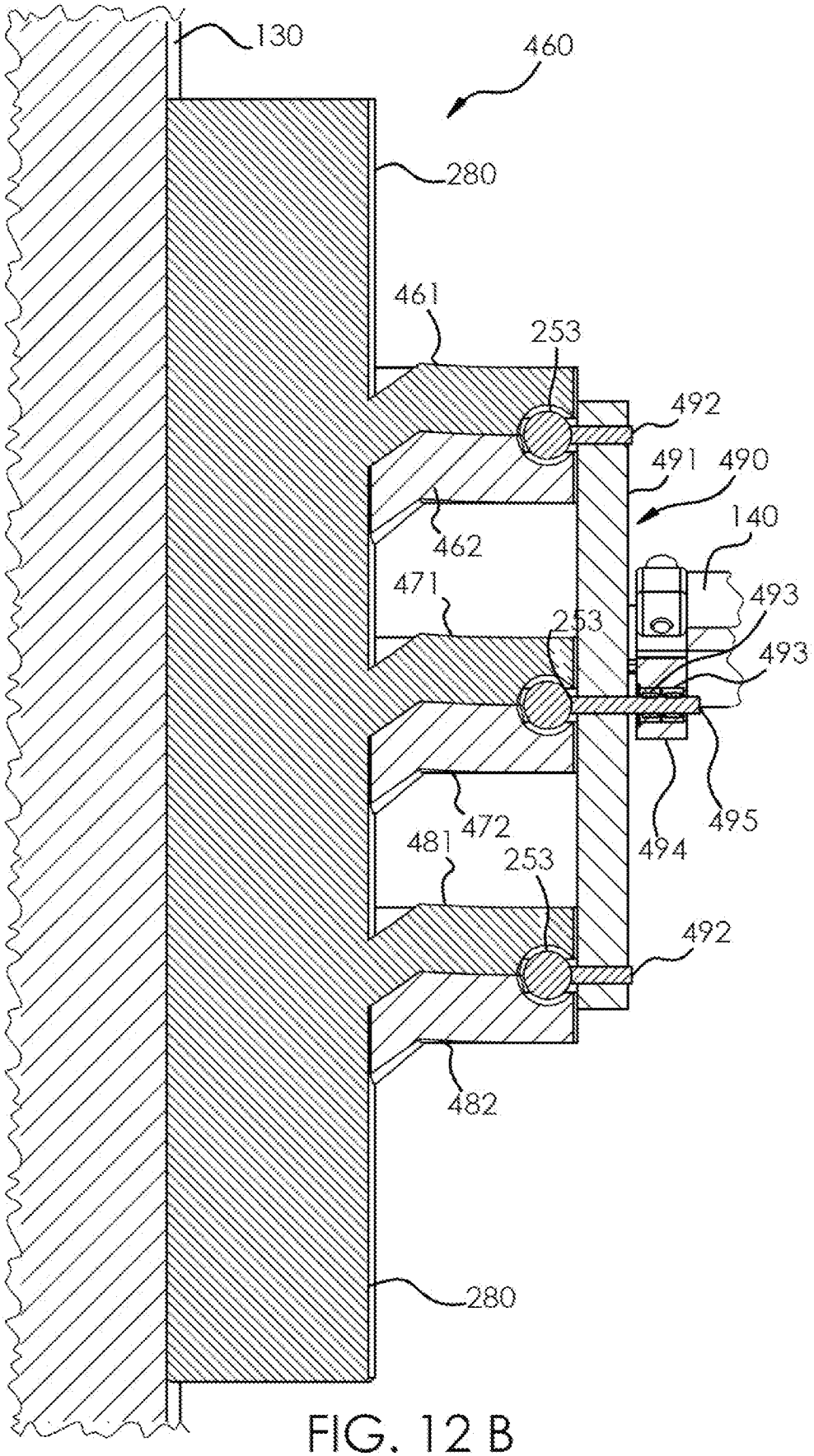

130
460
280
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140
462
471
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253
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472
495
494
481
253
492
482
280

FIG. 12 B

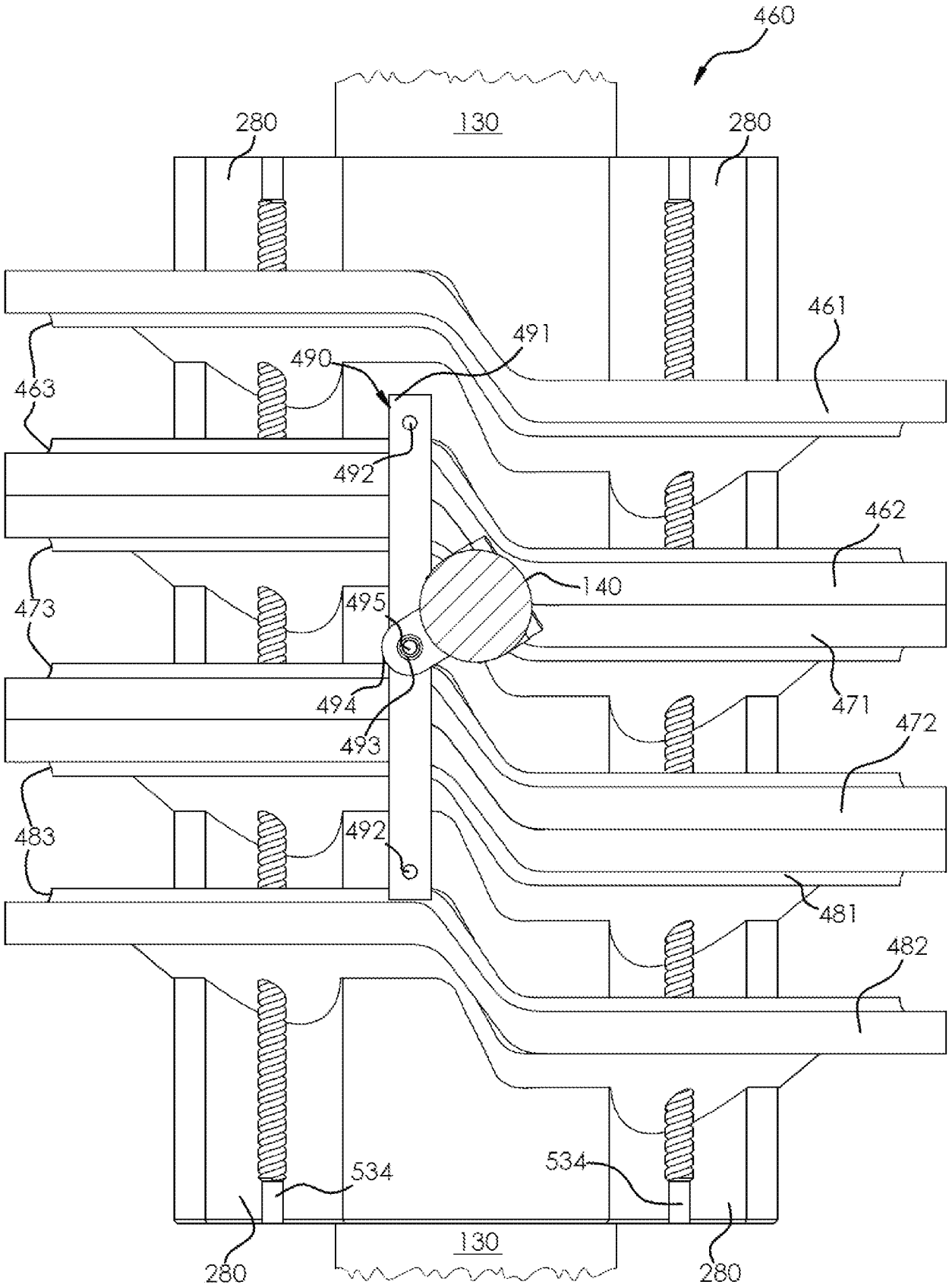

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280
130
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461
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490
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493
472
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481
482
534
534
280
130
280

FIG. 12C

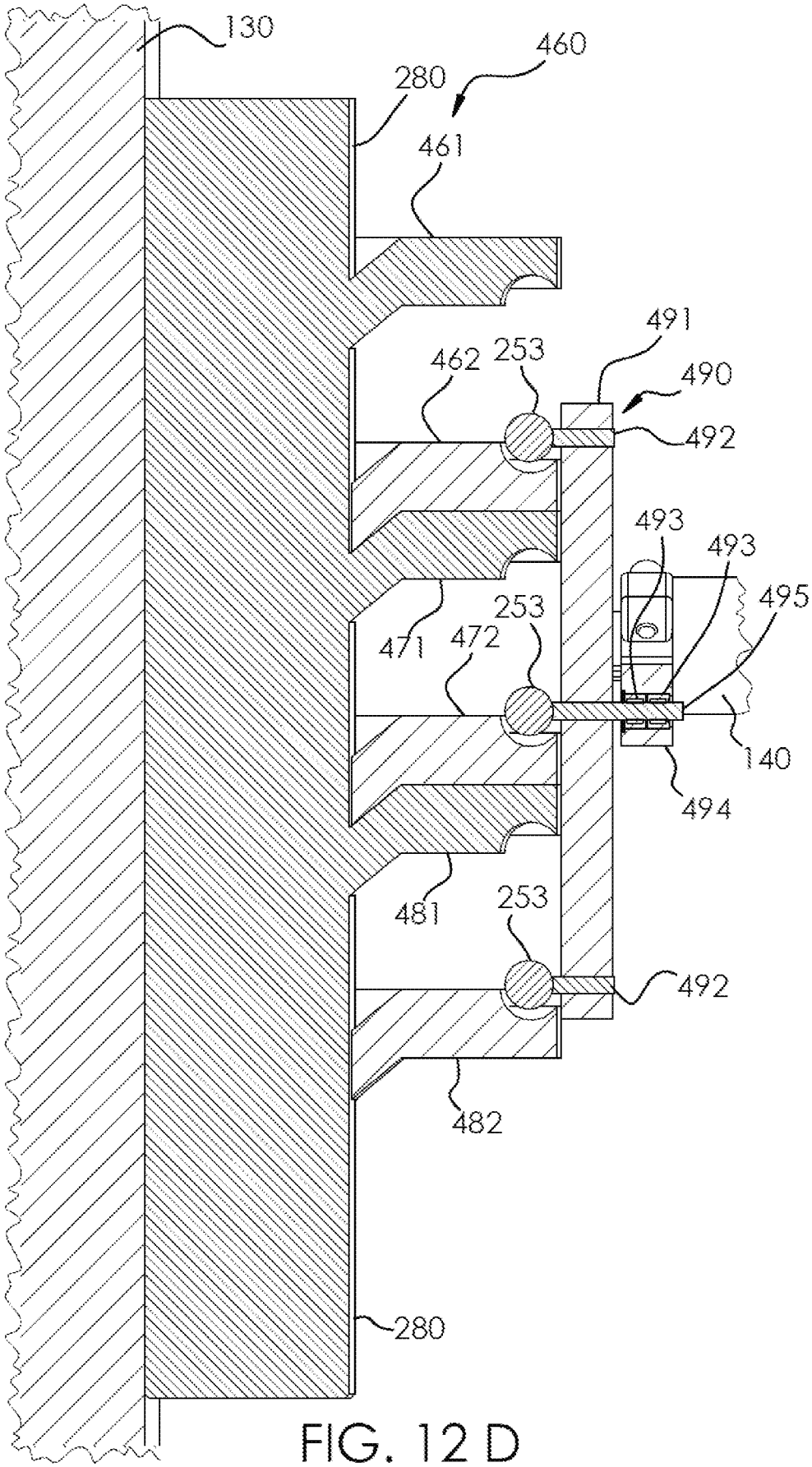

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460
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492
482
280

FIG. 12 D

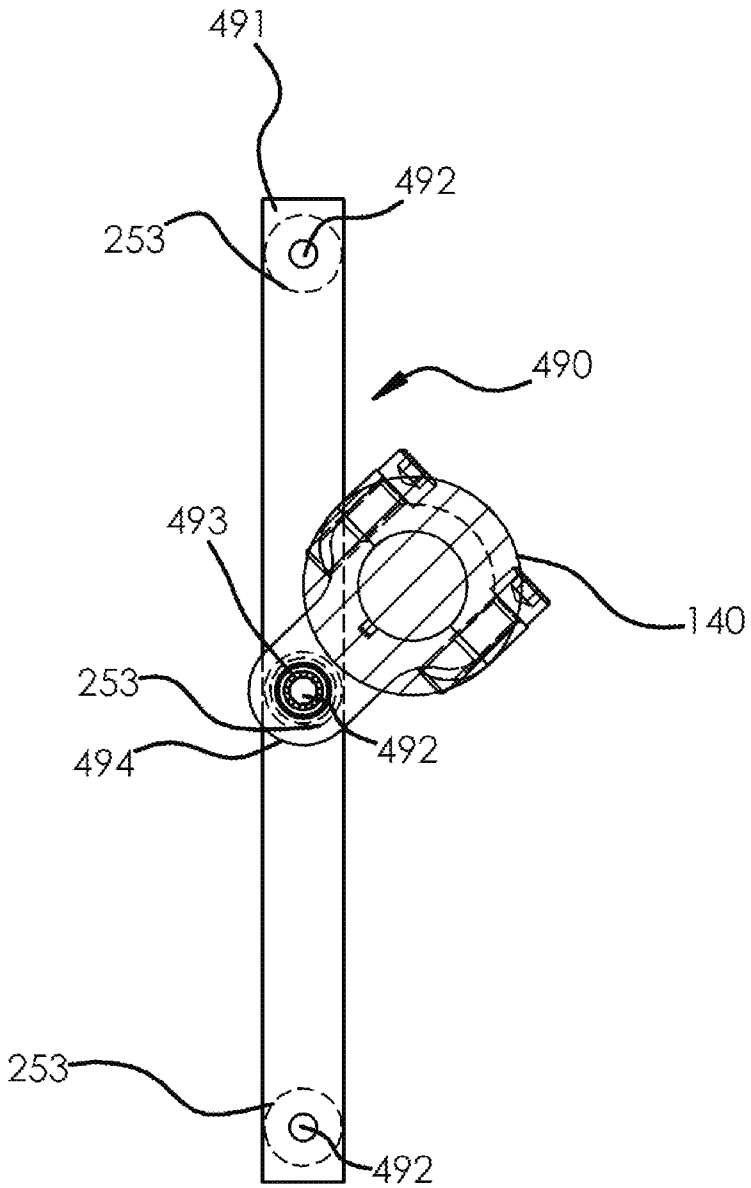


FIG. 12E

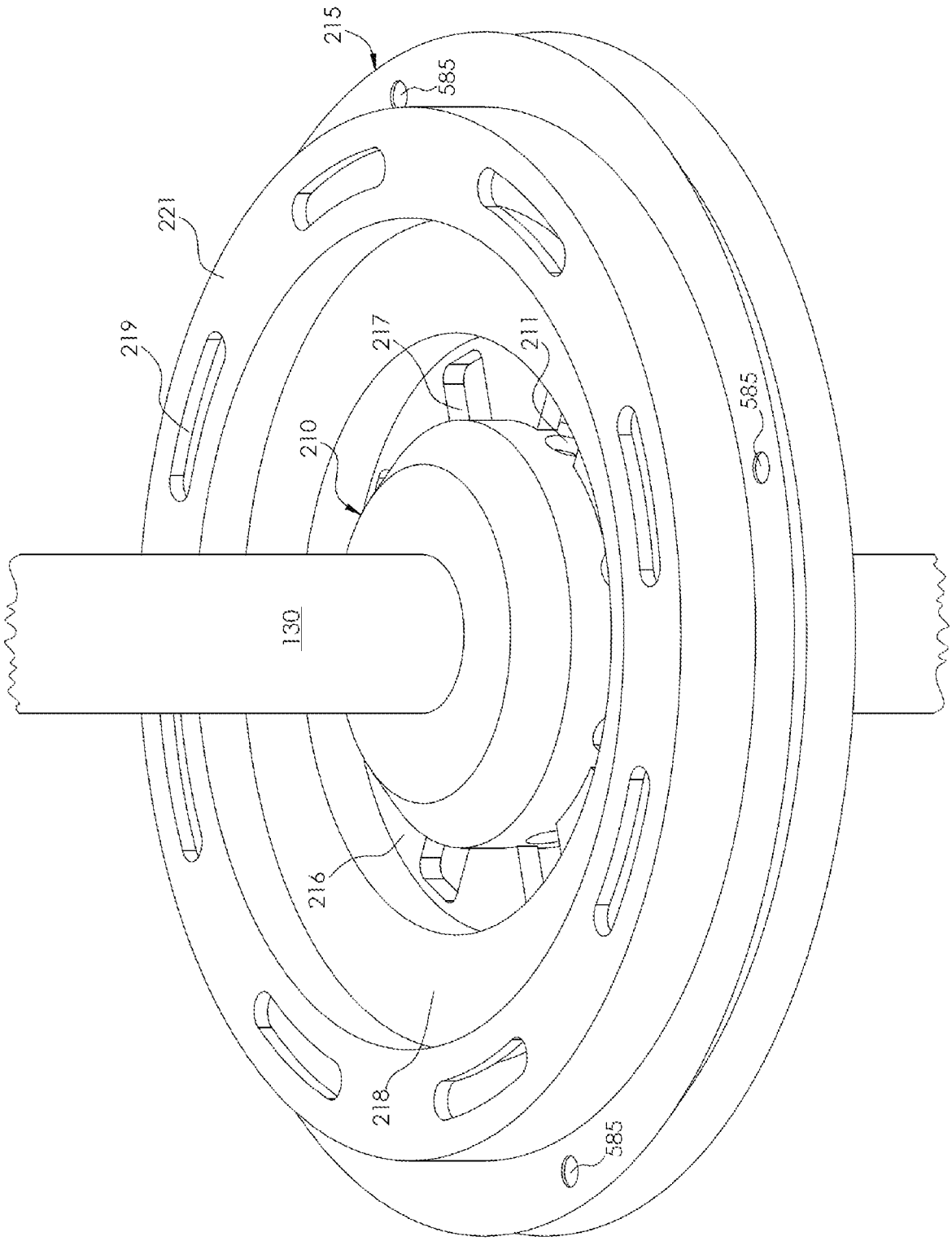


FIG. 13A

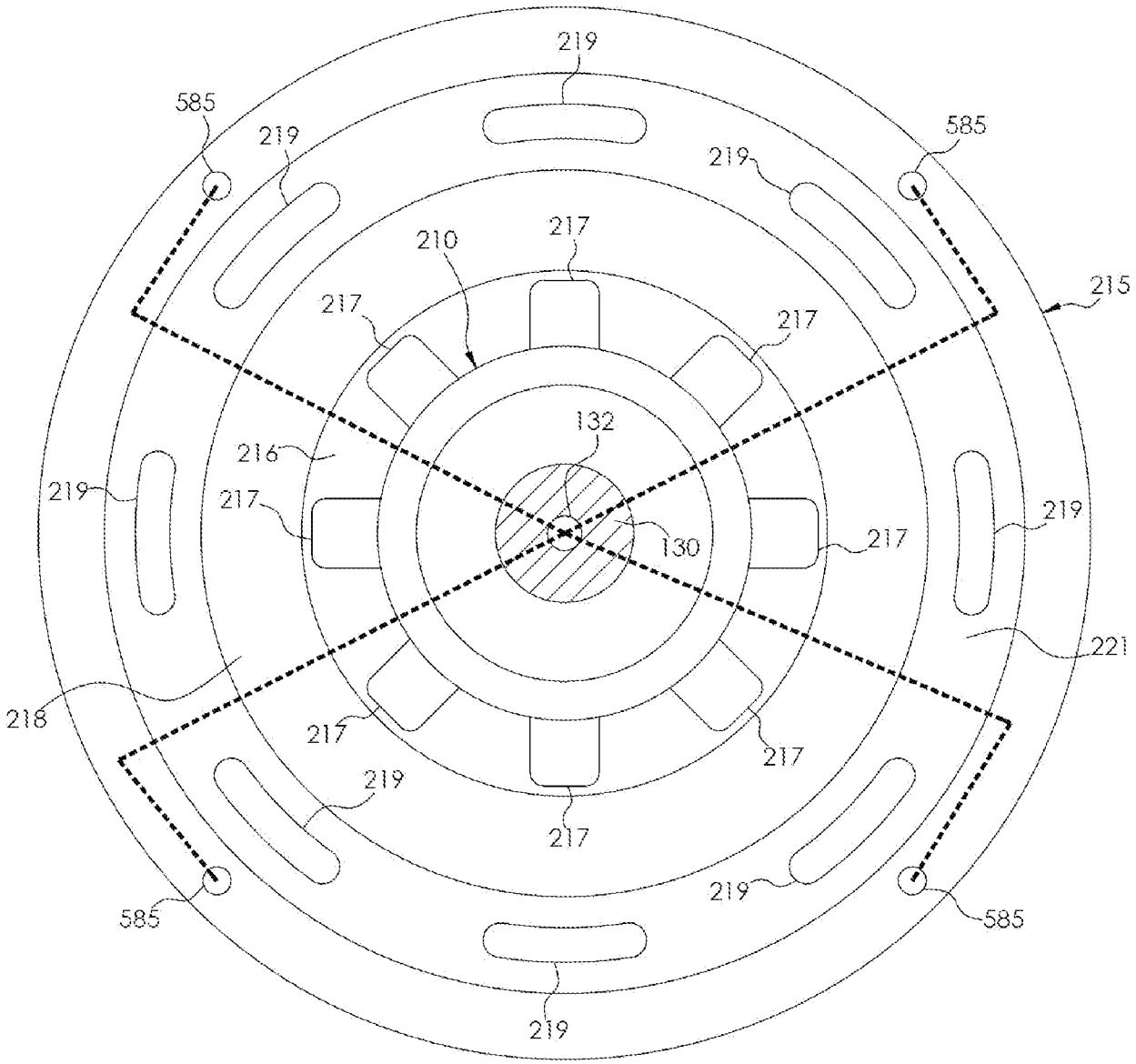

219
585
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585
219
210
217
215
217
217
132
216
219
217
217
219
130
221
218
217
217
219
217
219
585
585
219

FIG. 13 B

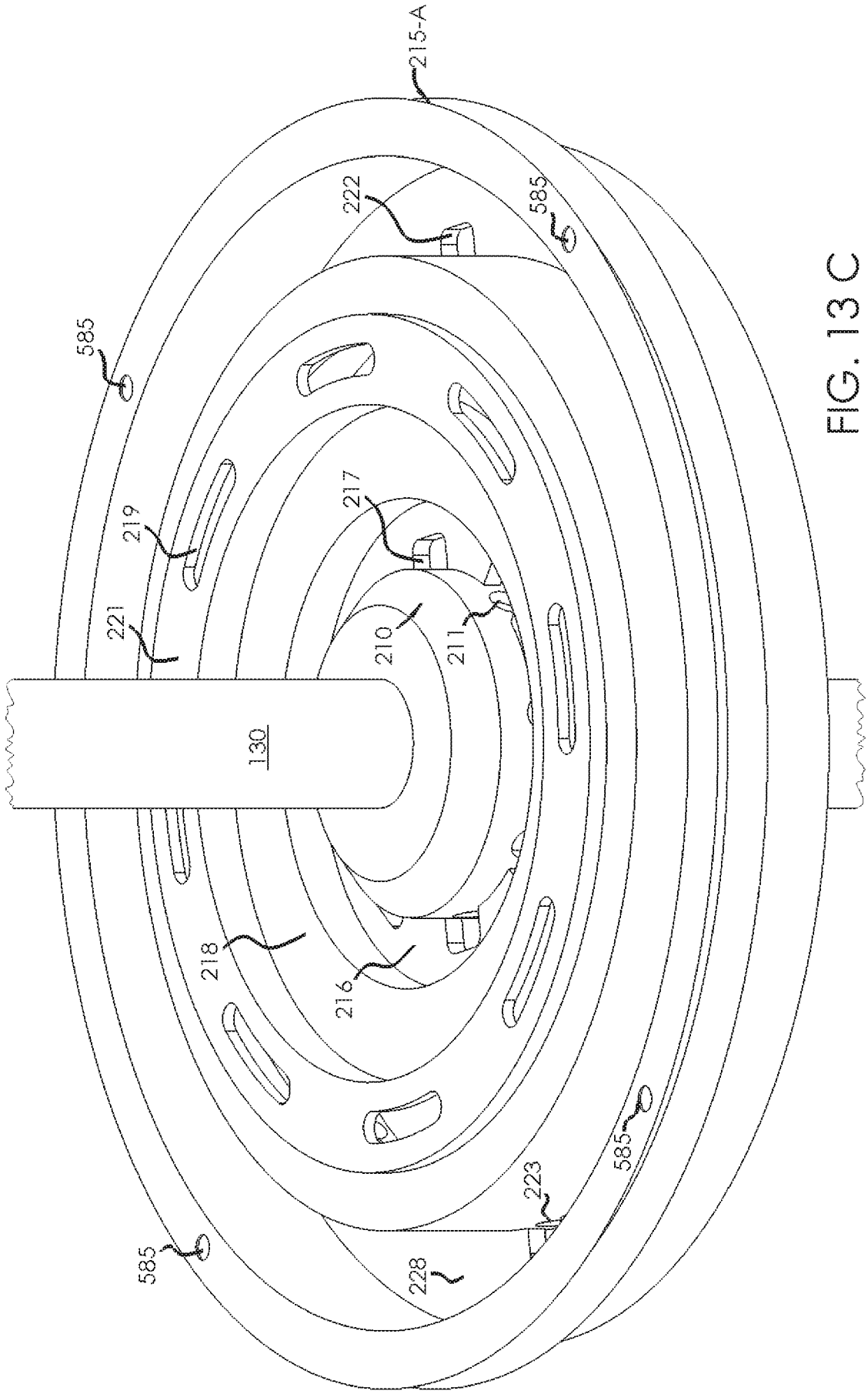


FIG. 13C

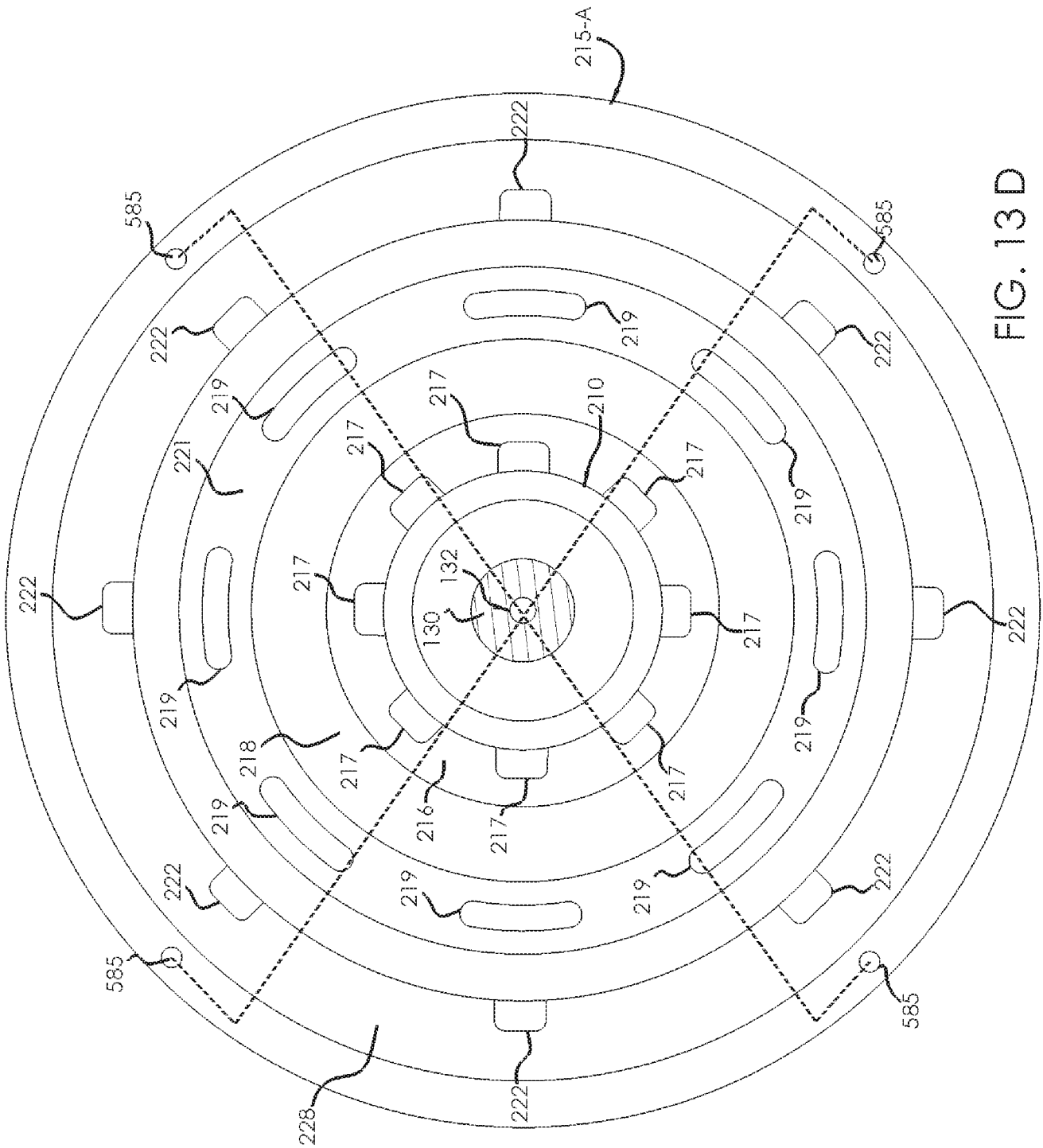


FIG. 13D

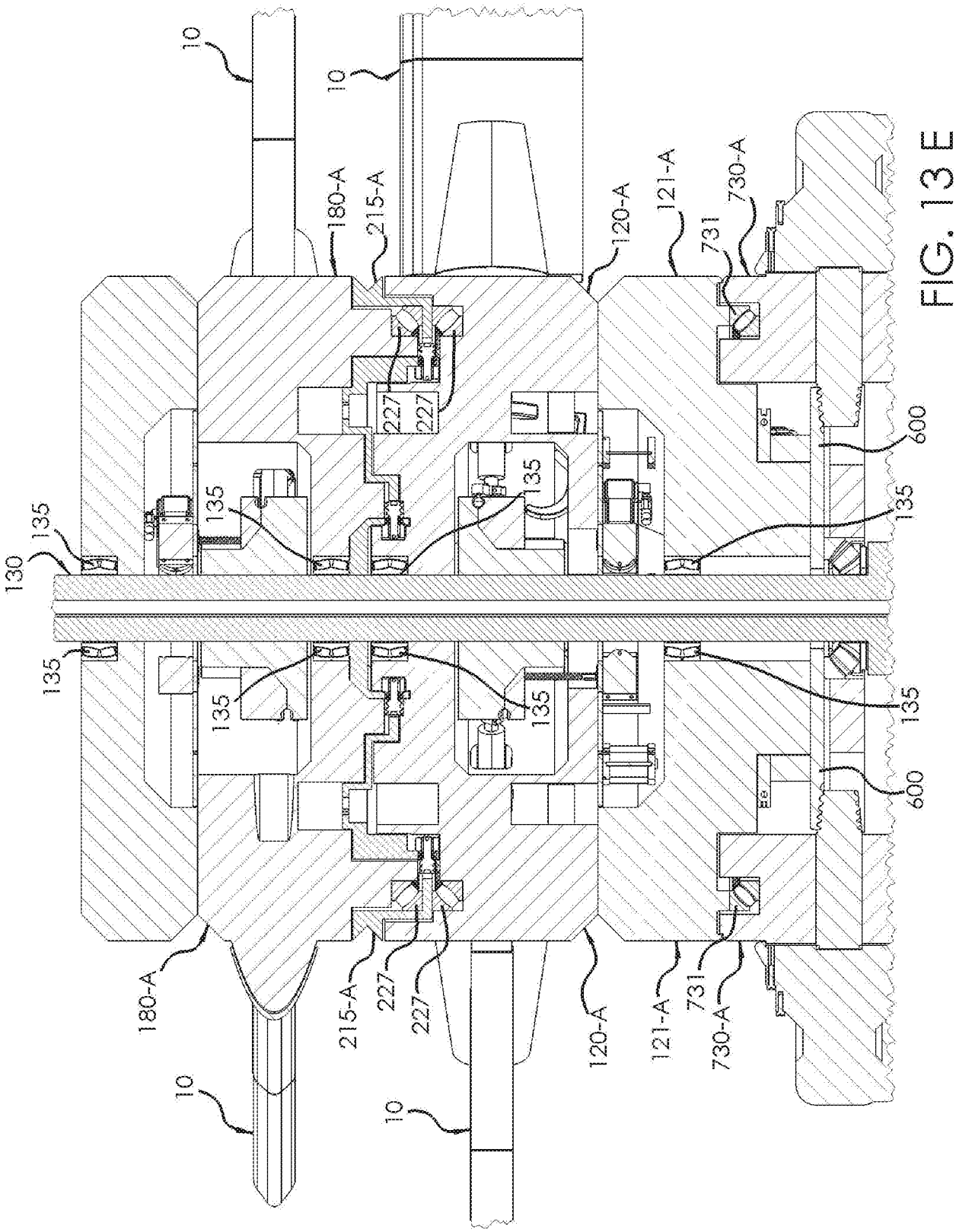

10
10
180-A
215-A
120-A
121-A
731
730-A
227
227
135
135
135
135
600
130
135
135
135
135
135
600
180-A
215-A
227
227
120-A
121-A
731
730-A
10
10

FIG. 13 E

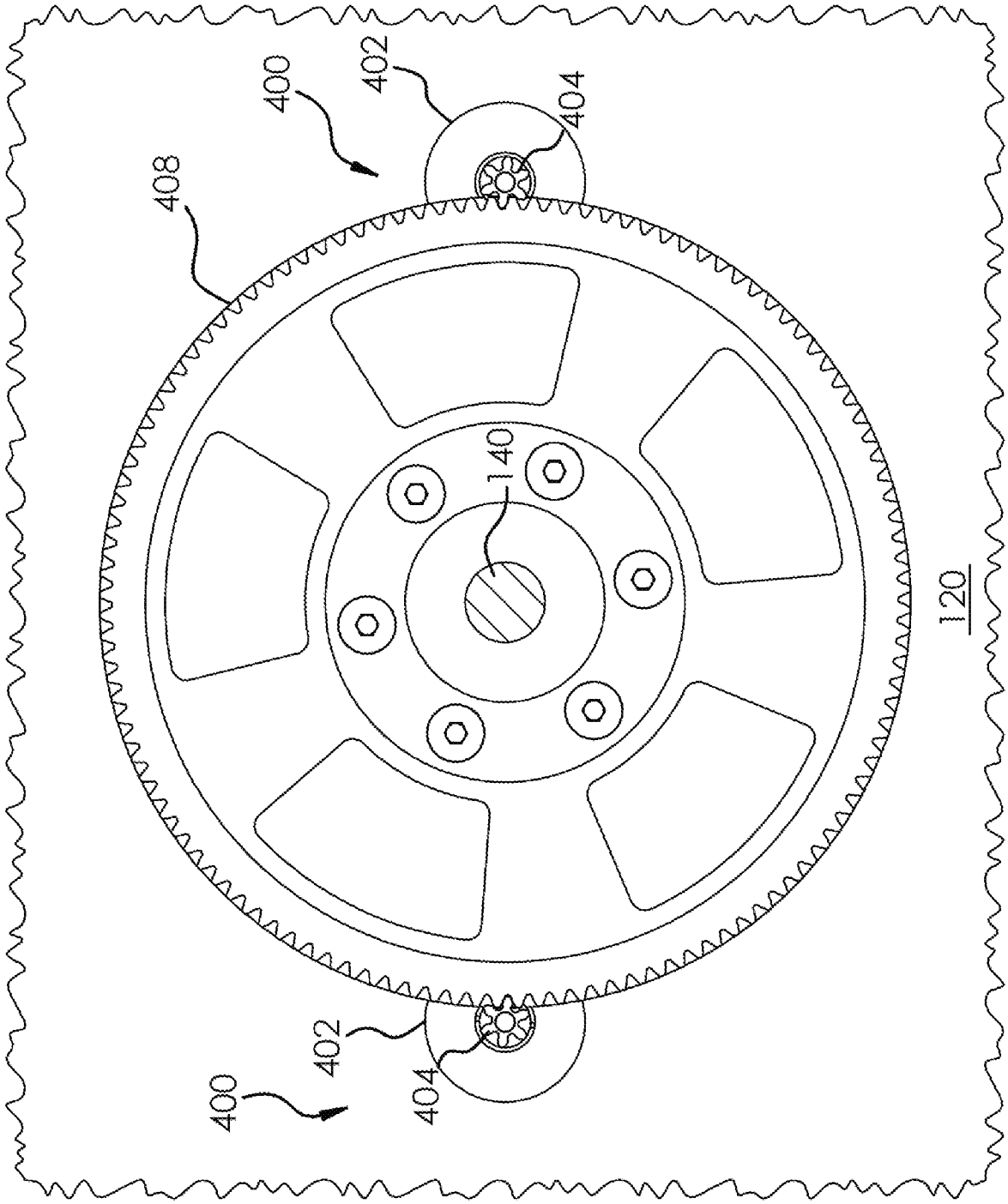


FIG. 14

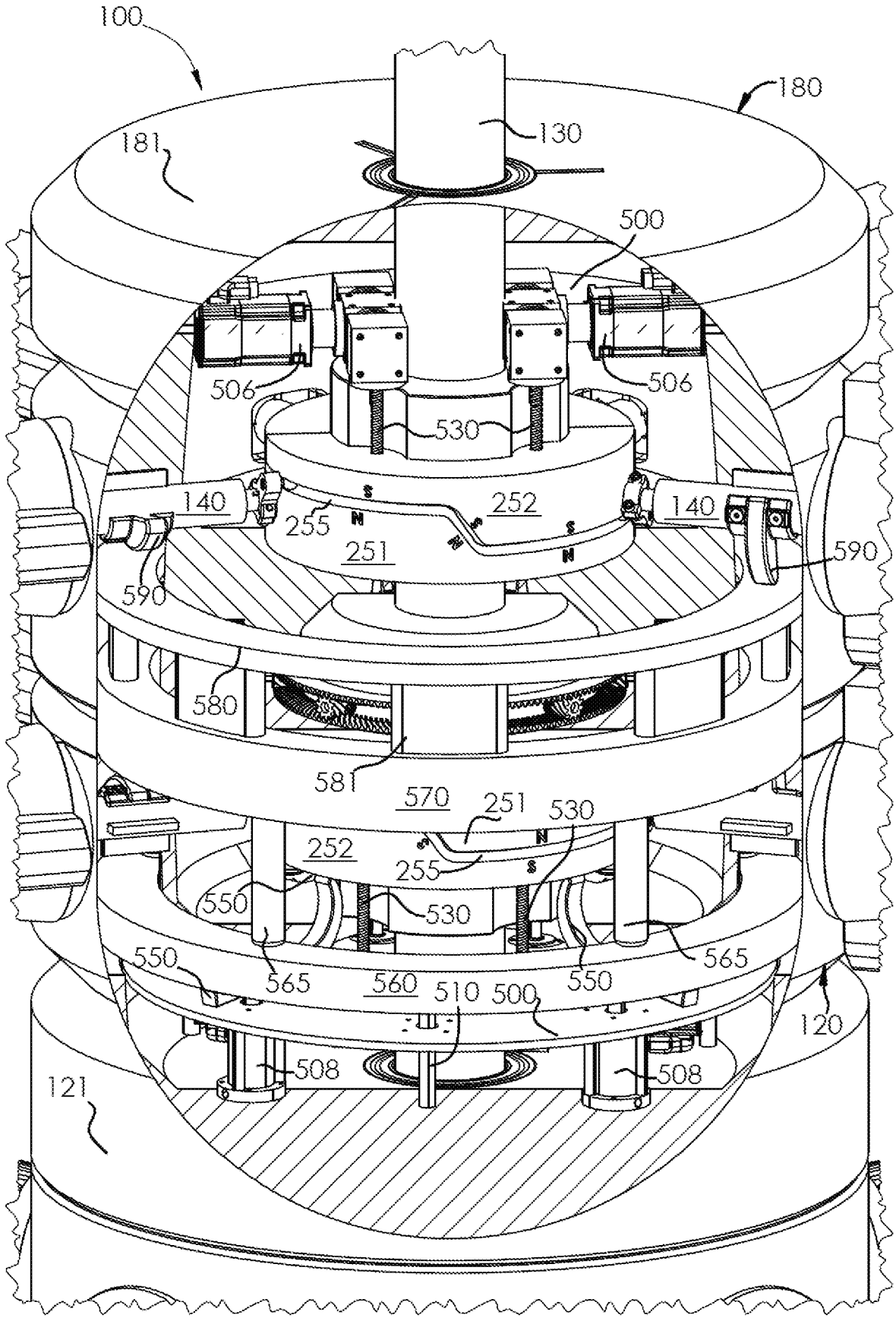

100
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181
130
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506
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140
255
252
140
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590
590
580
581
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565
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510
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550
120
508
508
121

FIG. 15A

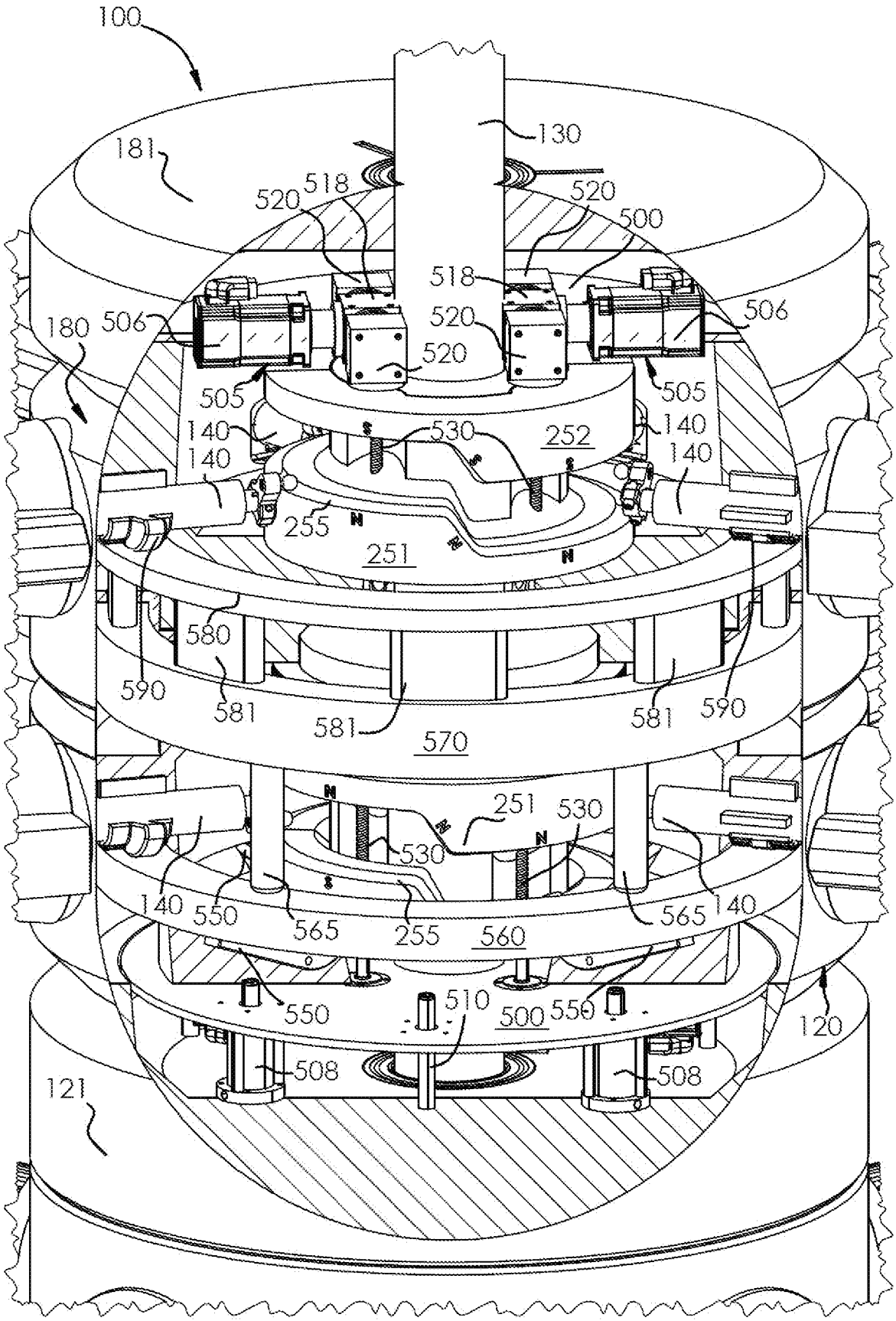

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581
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581
590
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500
550
120
508
508
121

FIG. 15B

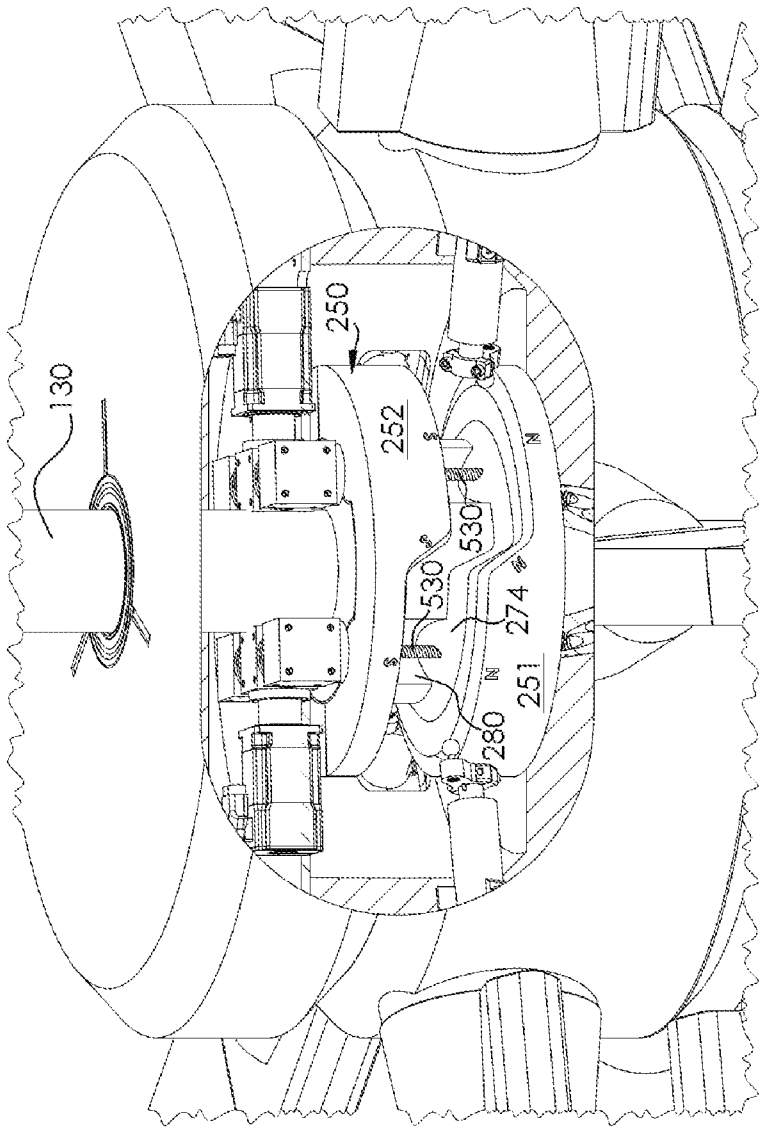


FIG. 15 C

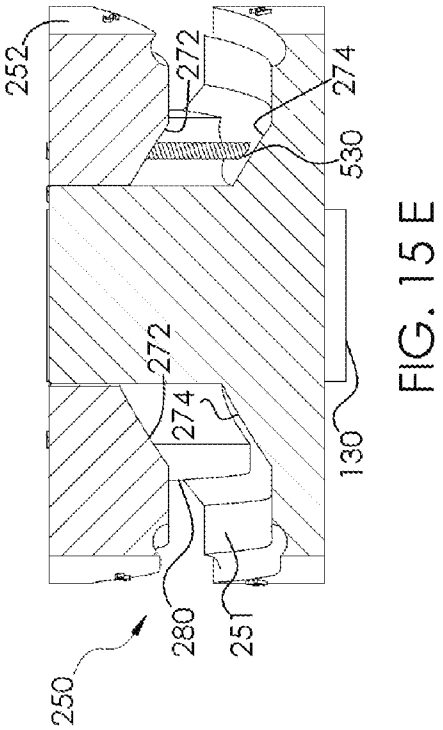


FIG. 15 E

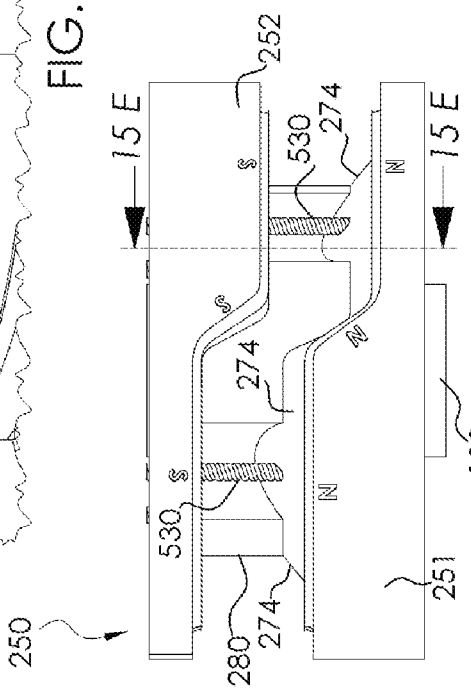


FIG. 15 D

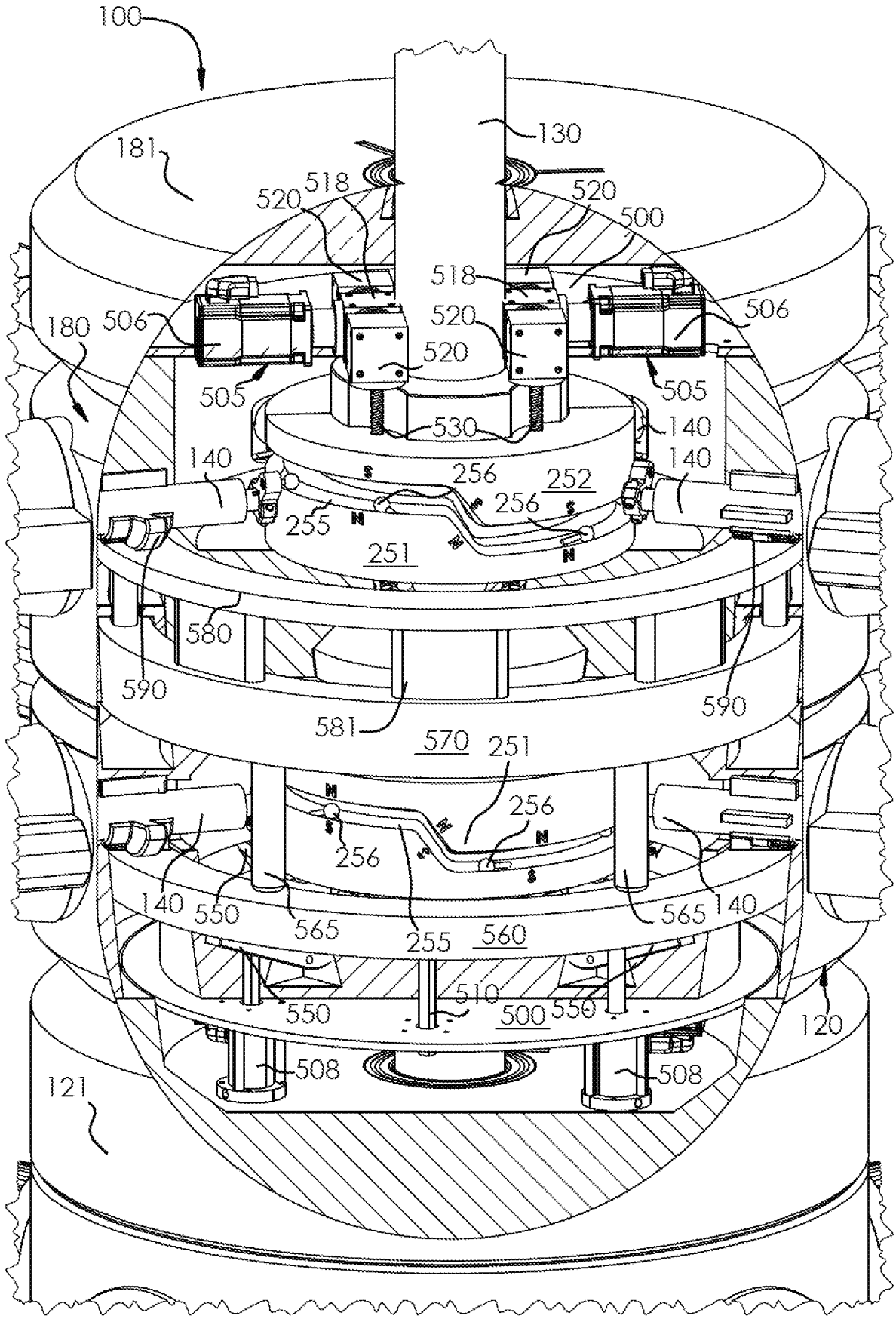

100
181
130
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520
518
500
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520
505
505
530
140
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140
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255
251
580
590
590
581
570
251
256
256
140
550
565
565
140
255
560
510
550
500
550
120
508
508
121

FIG. 15F

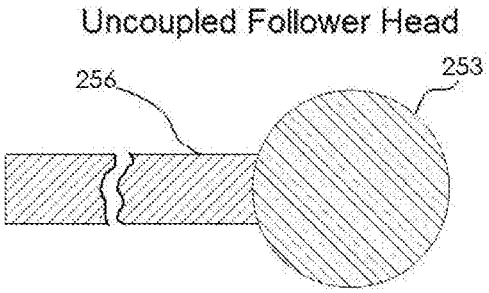


FIG. 15 G

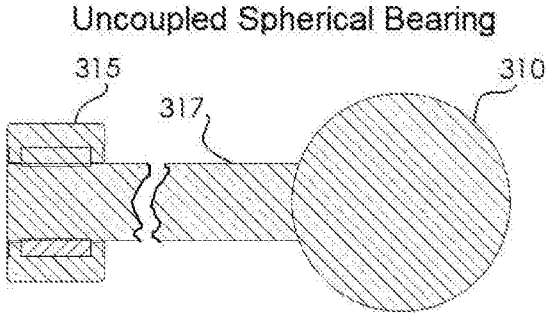


FIG. 15 H

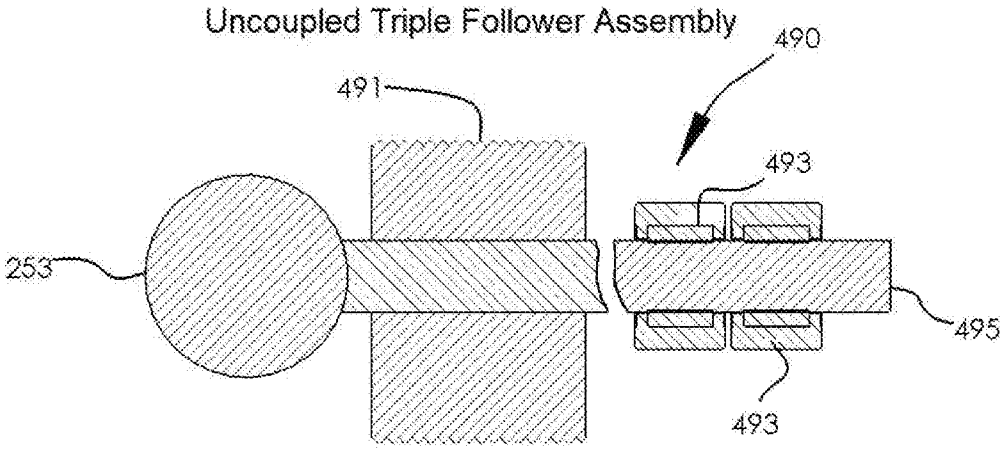


FIG. 15 I

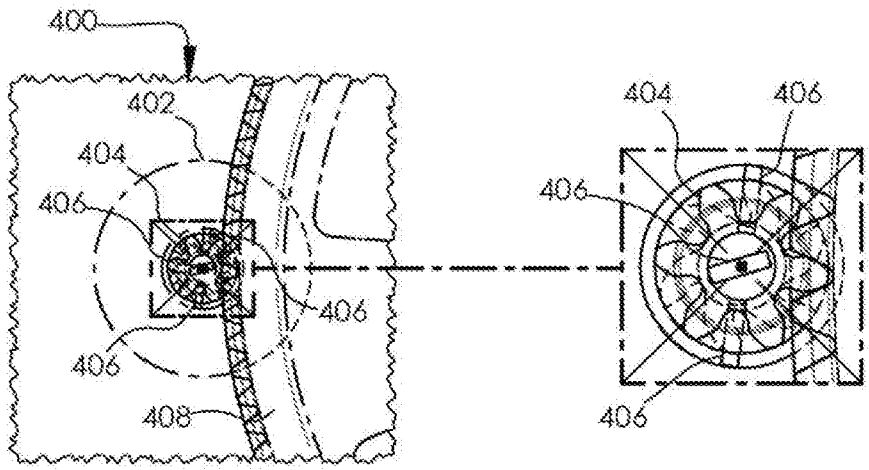


FIG. 15 J

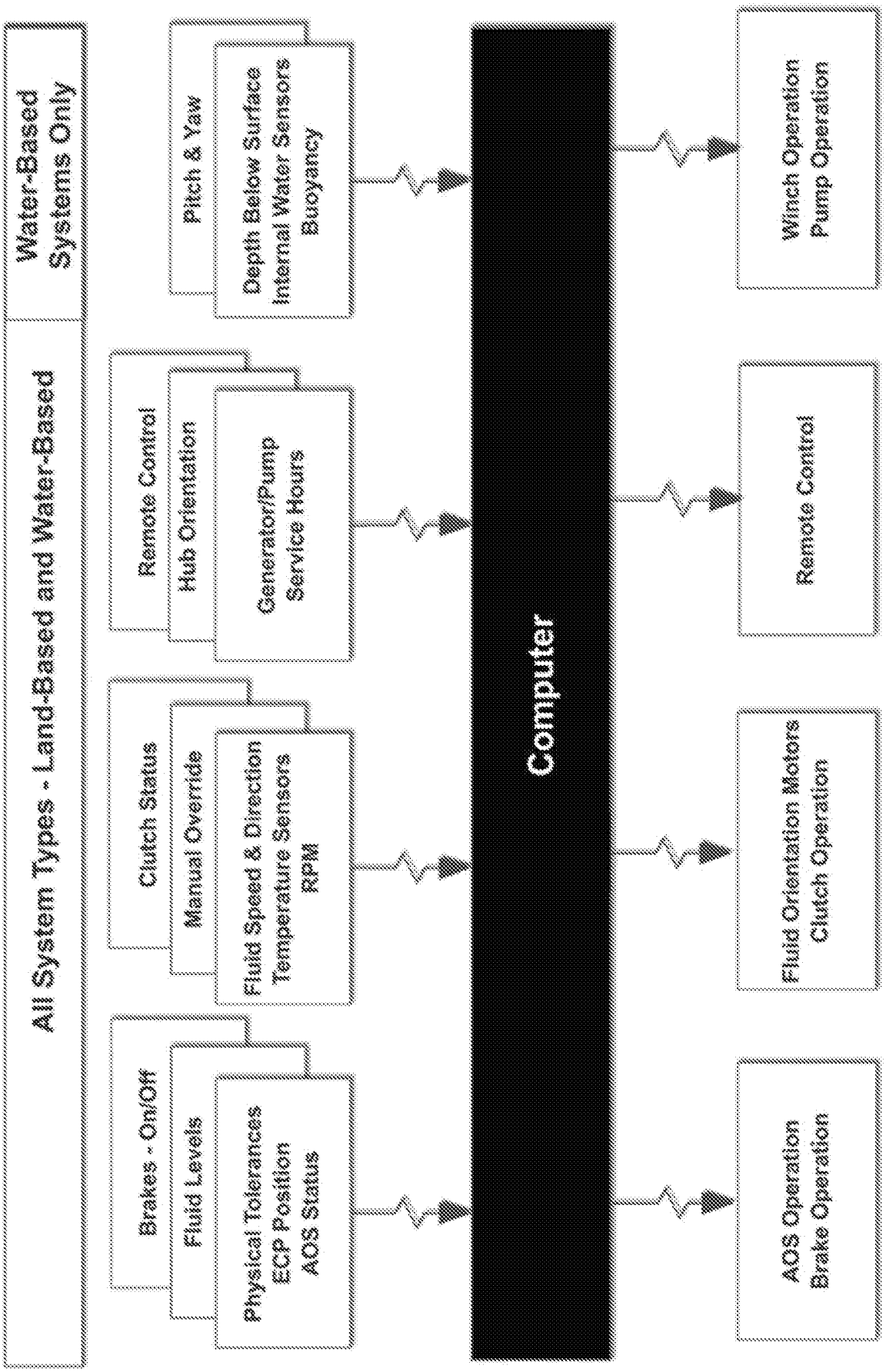

All System Types - Land-Based and Water-Based
Water-Based Systems Only
Brakes - On/Off
Fluid Levels
Physical Tolerances
ECP Position
AOS Status
Clutch Status
Manual Override
Fluid Speed & Direction
Temperature Sensors
RPM
Remote Control
Hub Orientation
Generator/Pump
Service Hours
Pitch & Yaw
Depth Below Surface
Internal Water Sensors
Buoyancy
Computer
AOS Operation
Brake Operation
Fluid Orientation Motors
Clutch Operation
Remote Control
Winch Operation
Pump Operation

FIG. 16

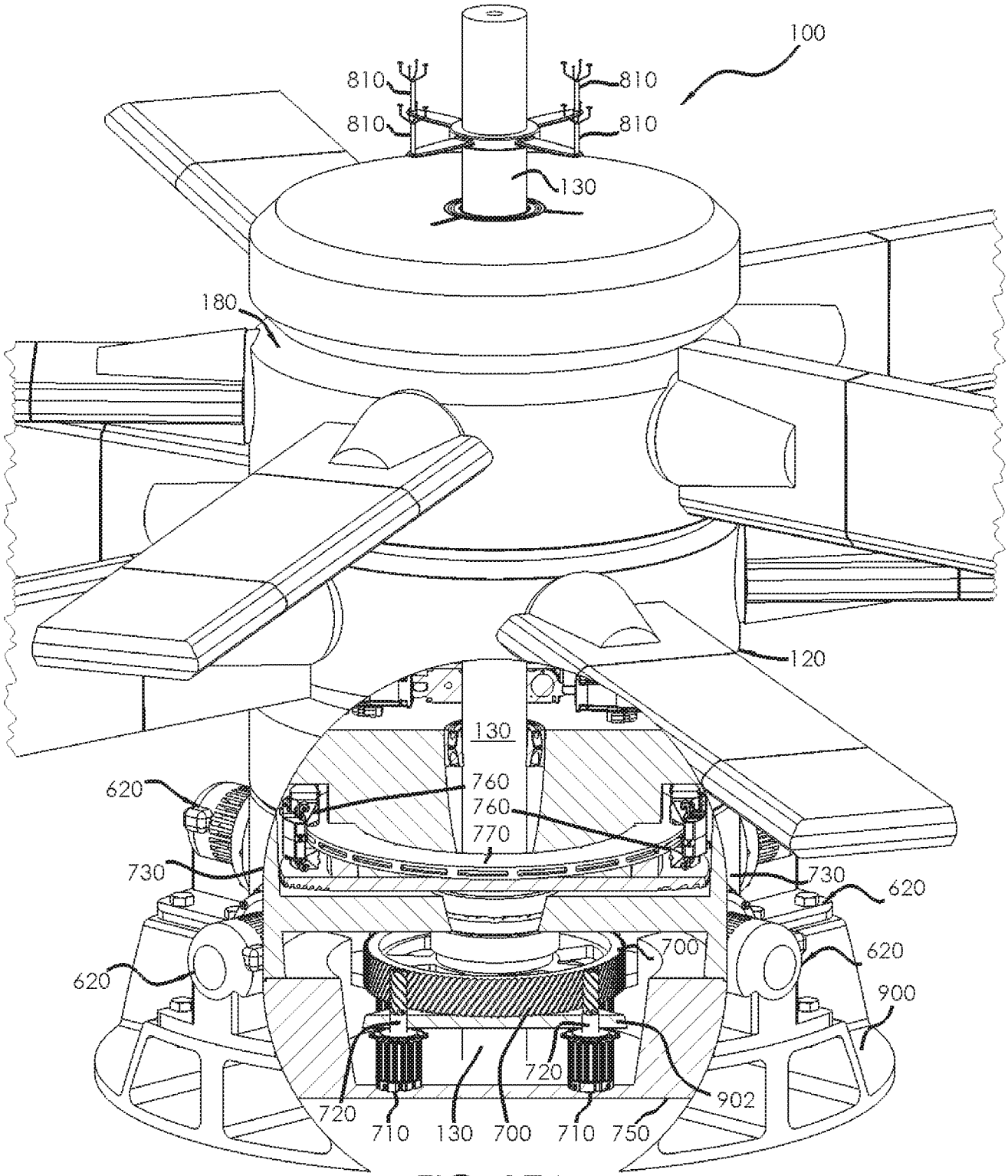

100
810
810
810
810
130
180
120
130
760
760
770
620
730
730
620
620
620
700
900
720
720
902
710
130
700
710
750

FIG. 17A

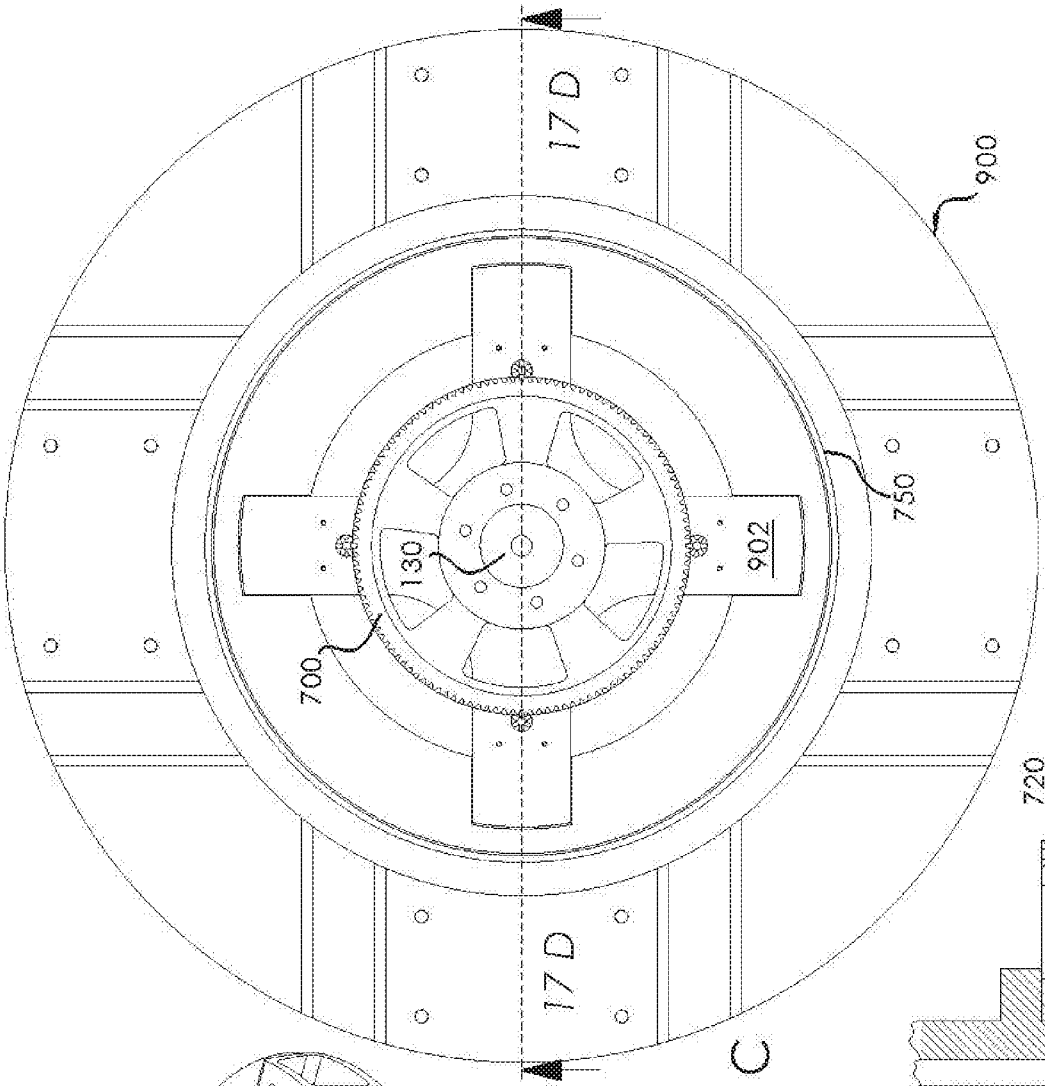


FIG. 17 C

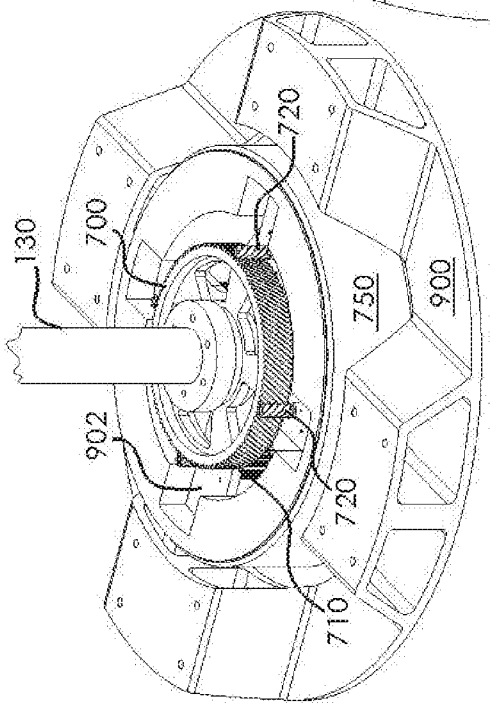


FIG. 17 B

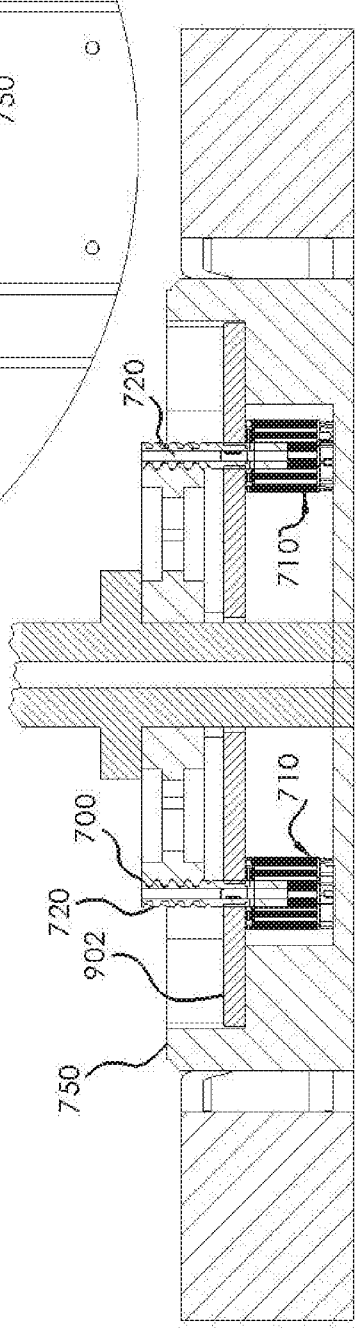


FIG. 17 D

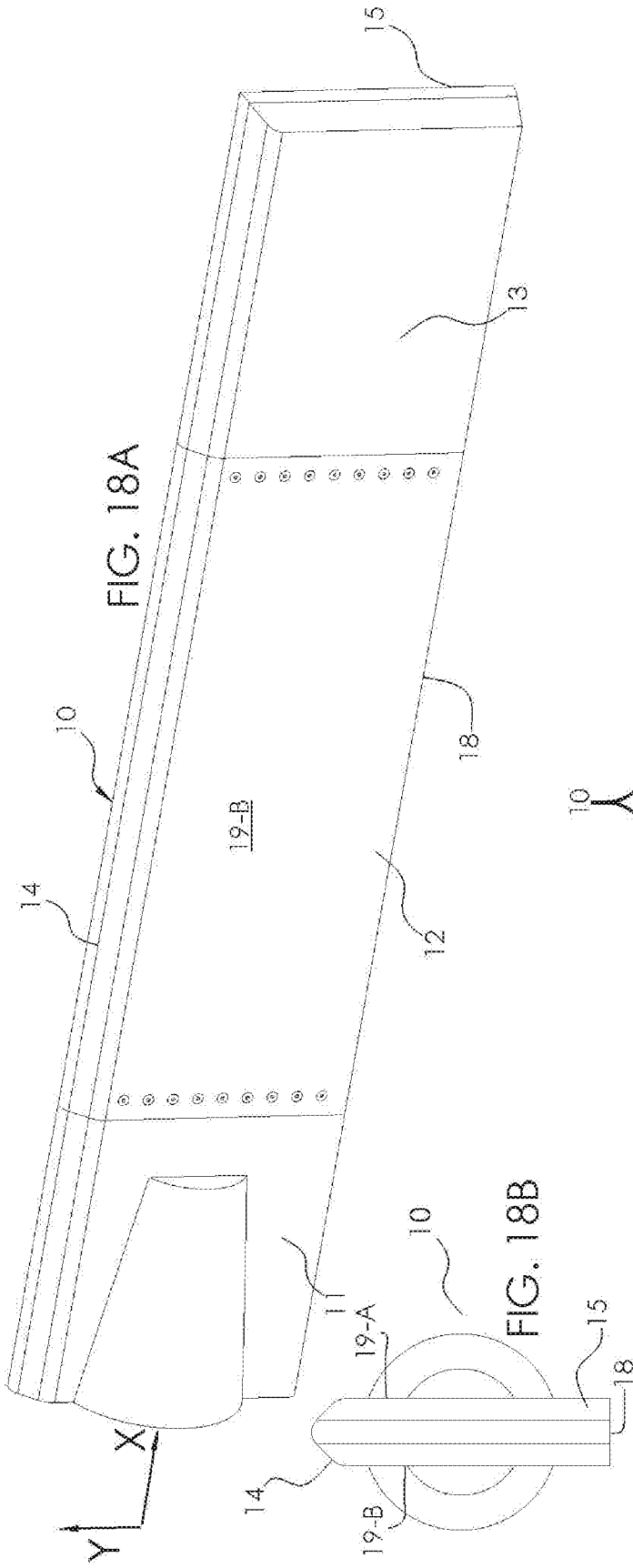


FIG. 18A

FIG. 18B

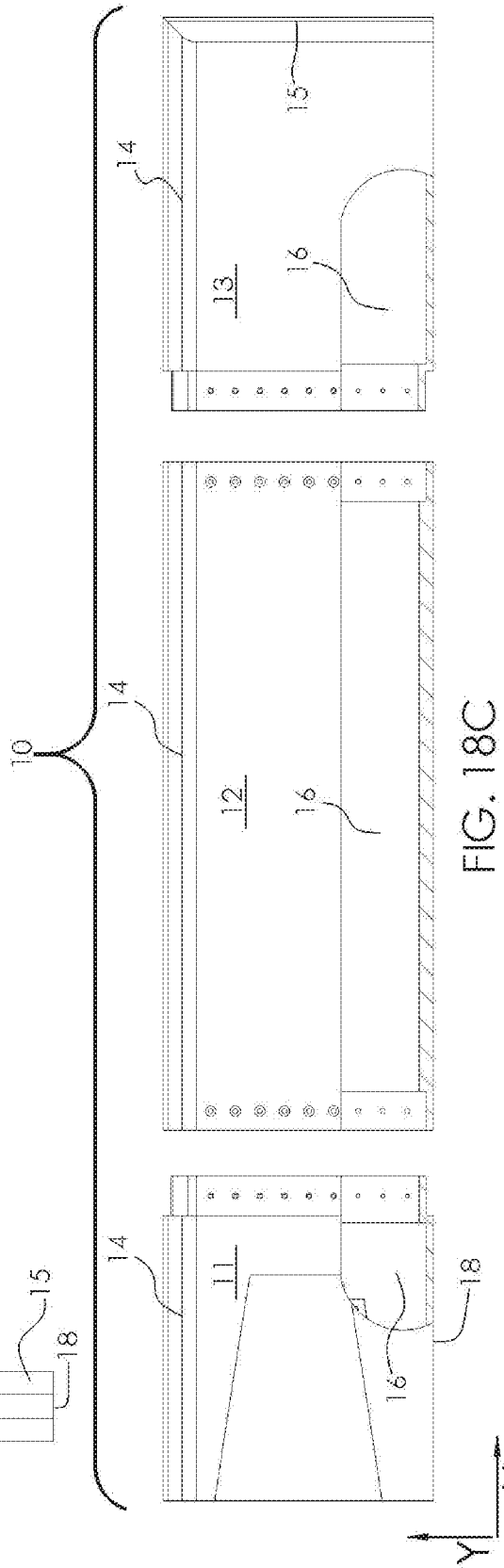


FIG. 18C

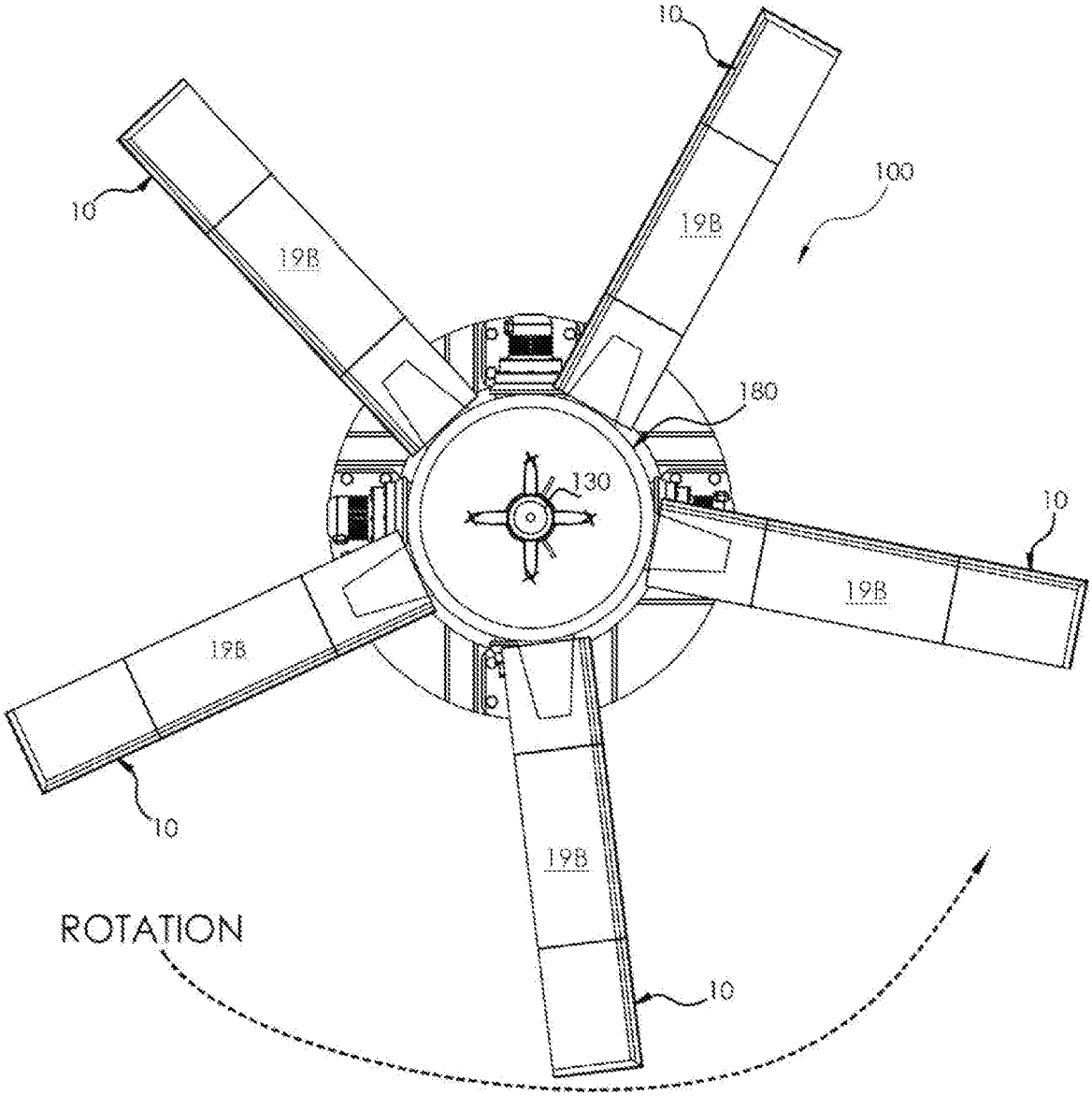


FIG. 18D

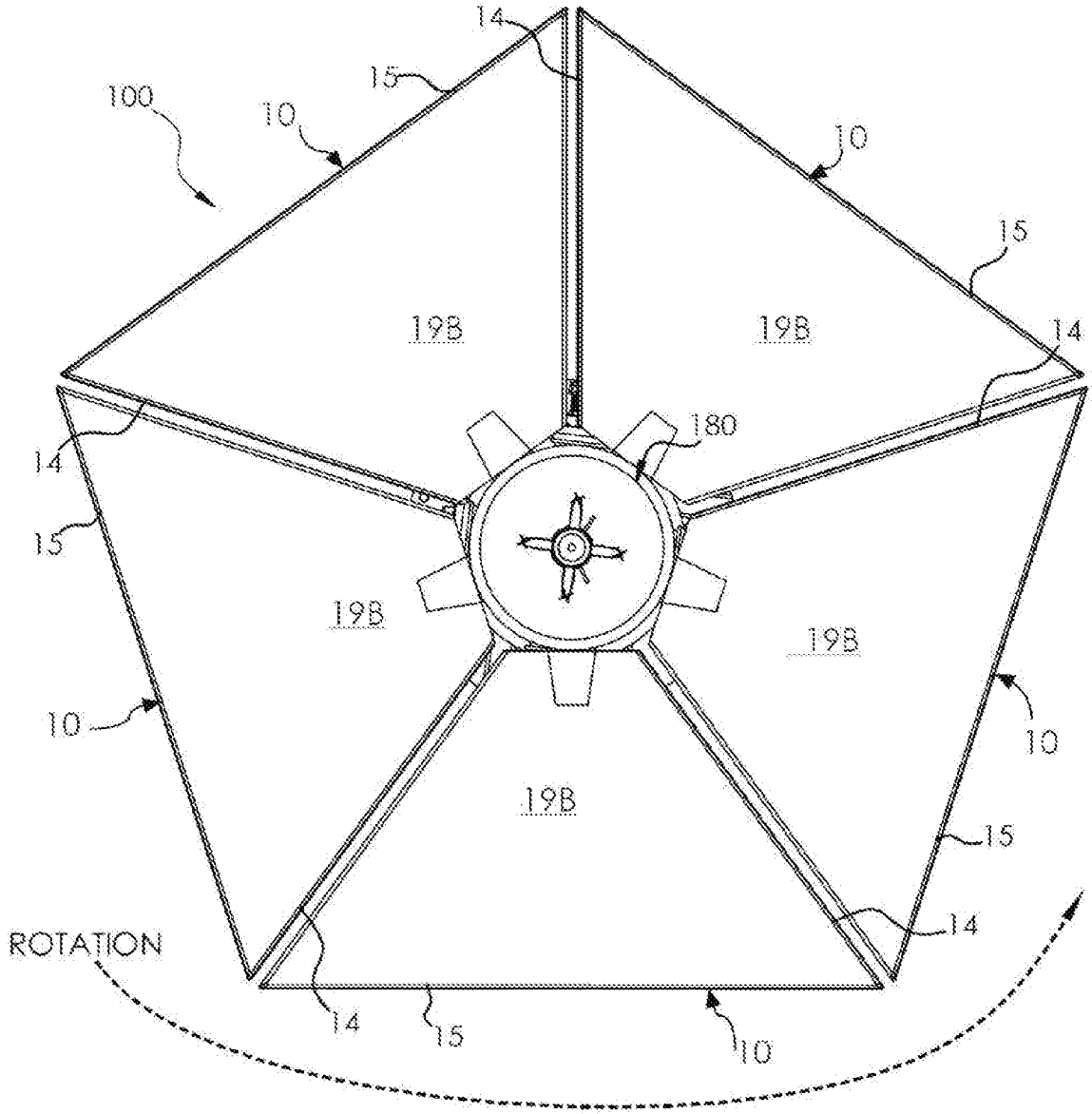

14
15
100
10
10
15
19B
19B
14
180
14
15
19B
19B
10
10
19B
15
14
ROTATION
14
15
10

FIG. 18E

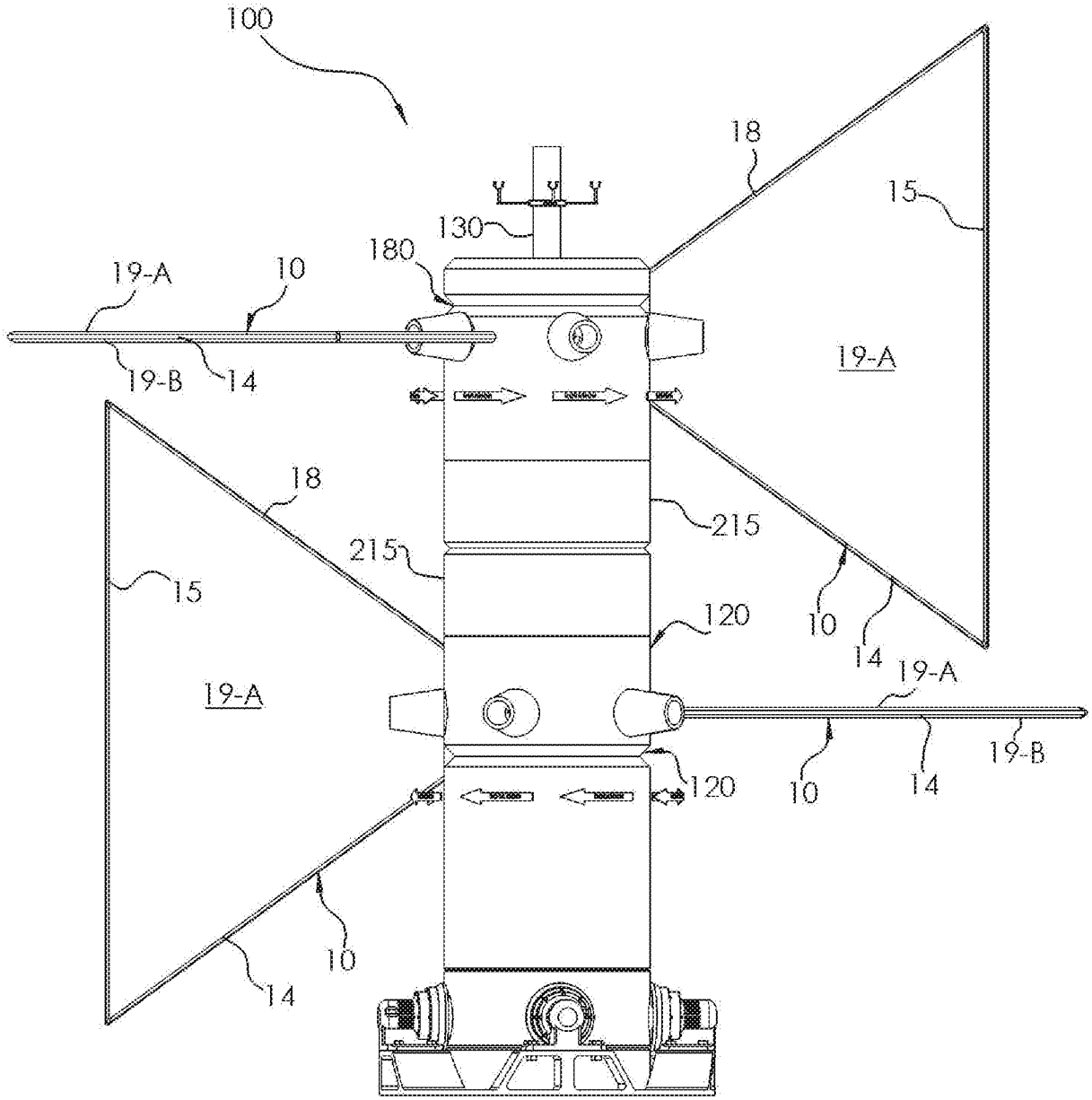
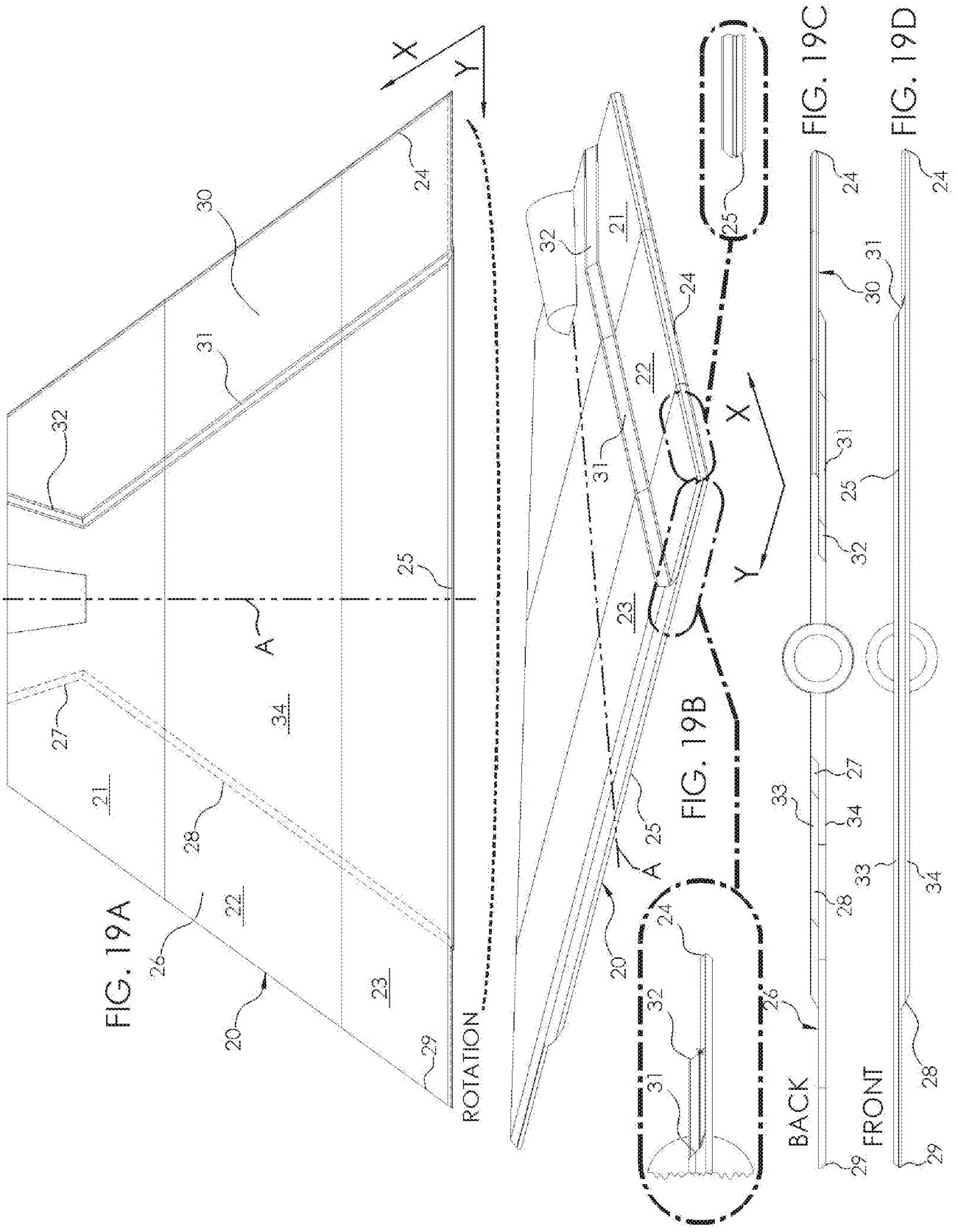

100
18
15
130
180
19-A
10
19-A
19-B
14
18
215
215
15
120
10
14
19-A
19-A
19-B
120
10
14
10
14

FIG. 18F


FIG. 19A
FIG. 19B
FIG. 19C
FIG. 19D
ROTATION
BACK
FRONT
X
Y
A
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34

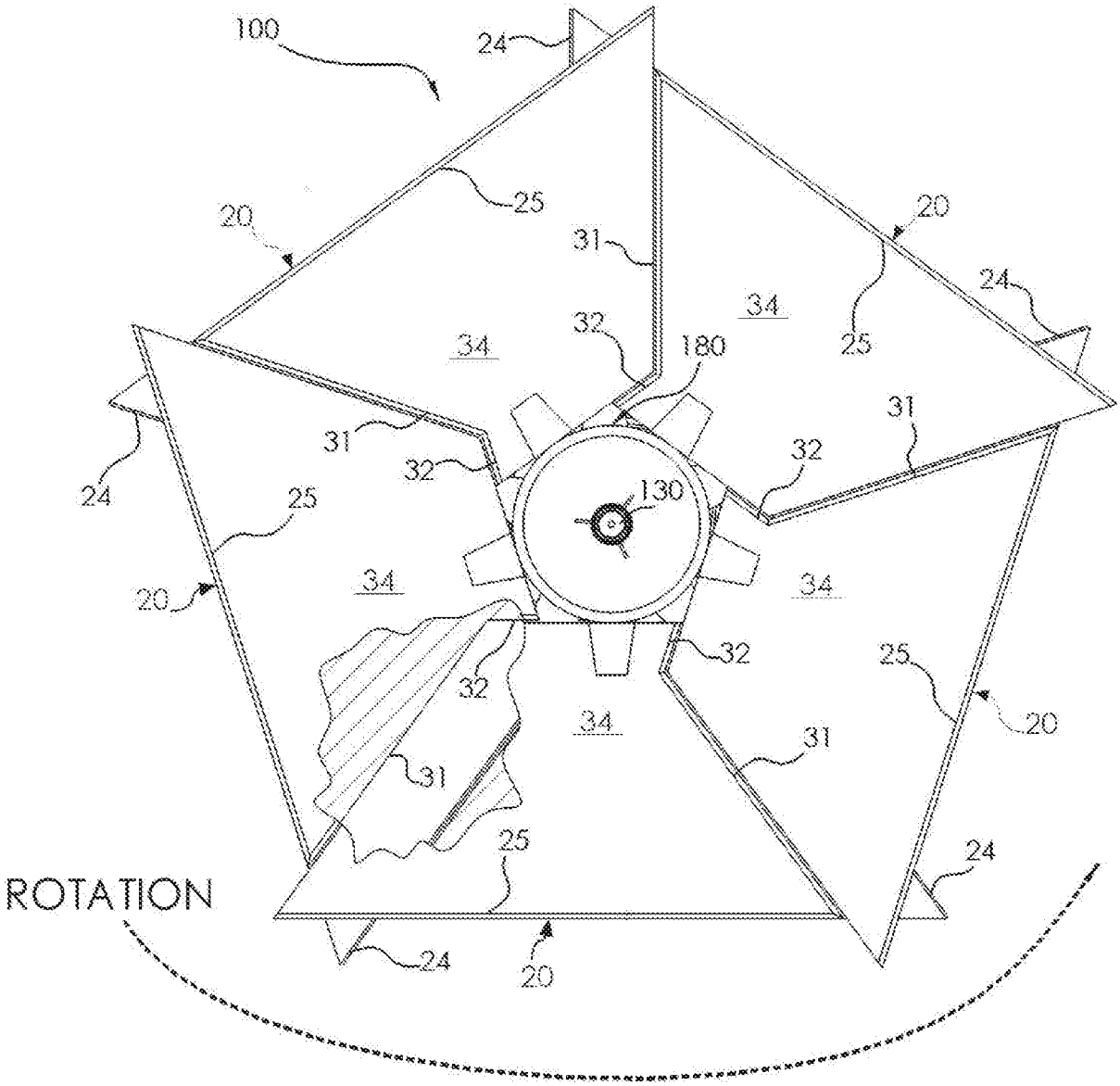


FIG. 19E

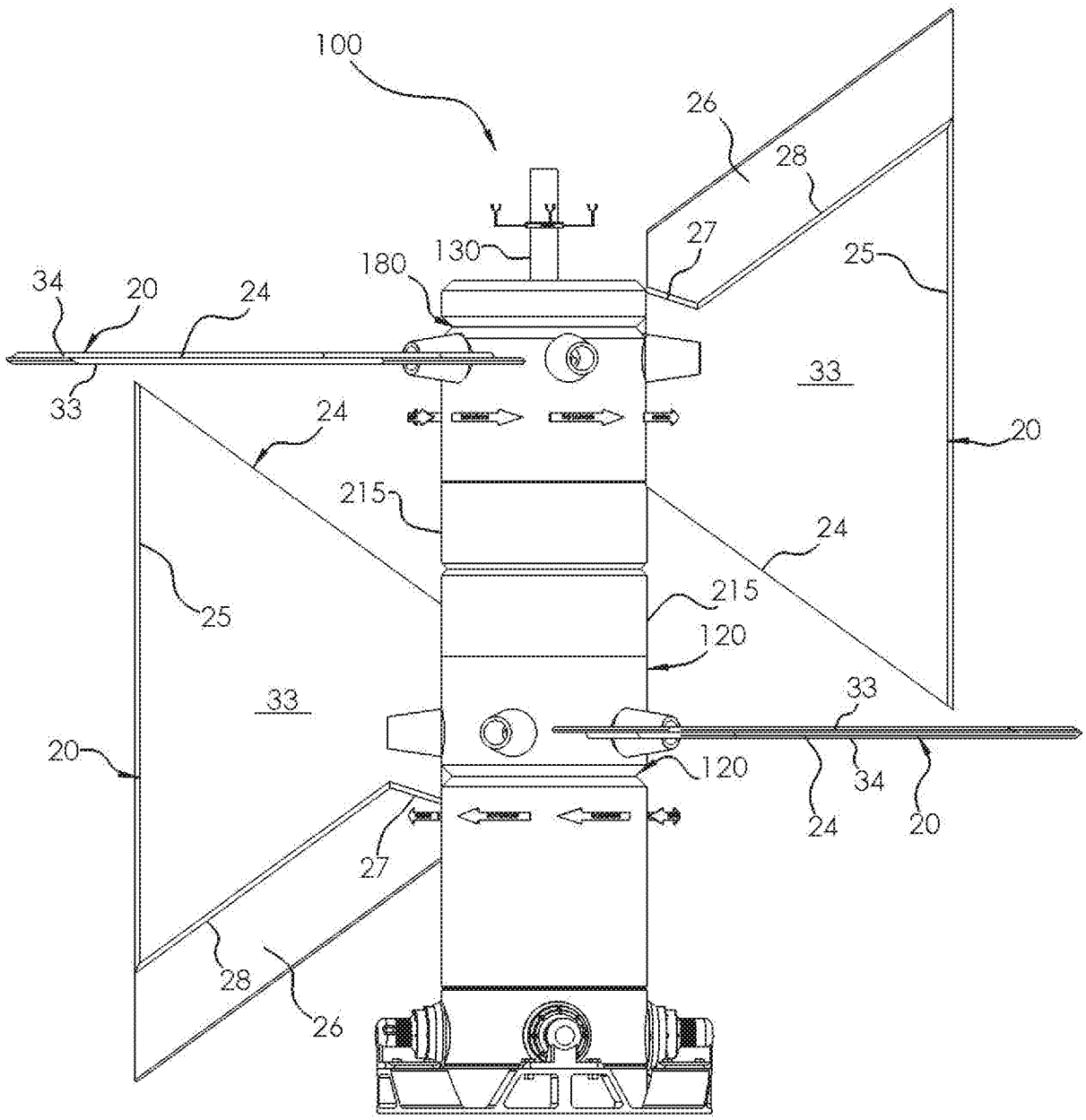

100
26
28
27
25
180
130
34
20
24
33
33
24
20
215
24
25
215
120
33
33
20
120
34
24
20
27
28
26

FIG. 19F

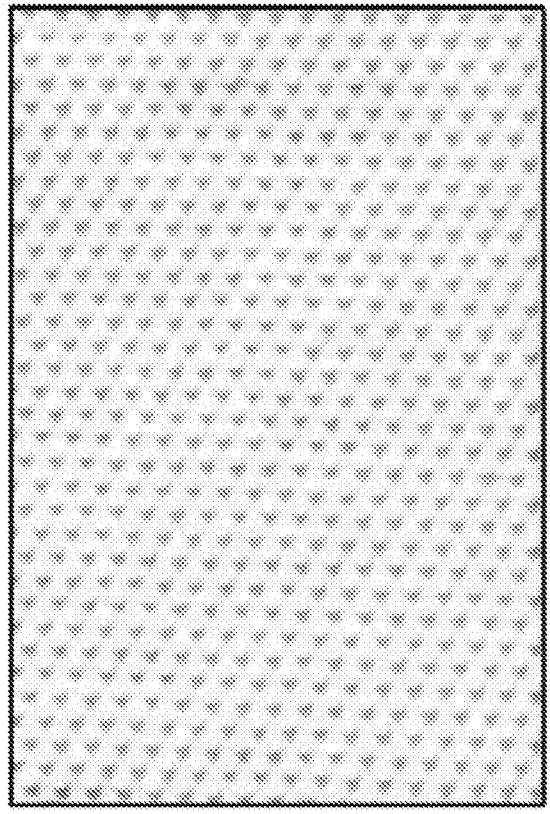


FIG. 20B

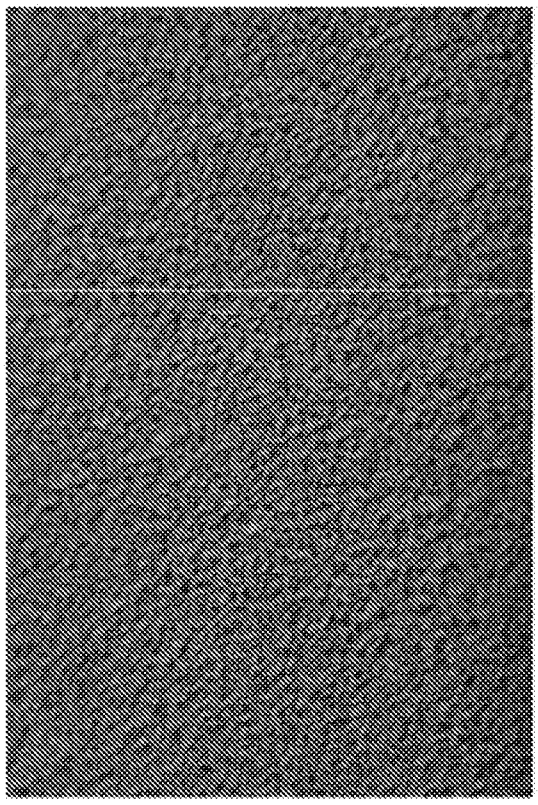


FIG. 20A

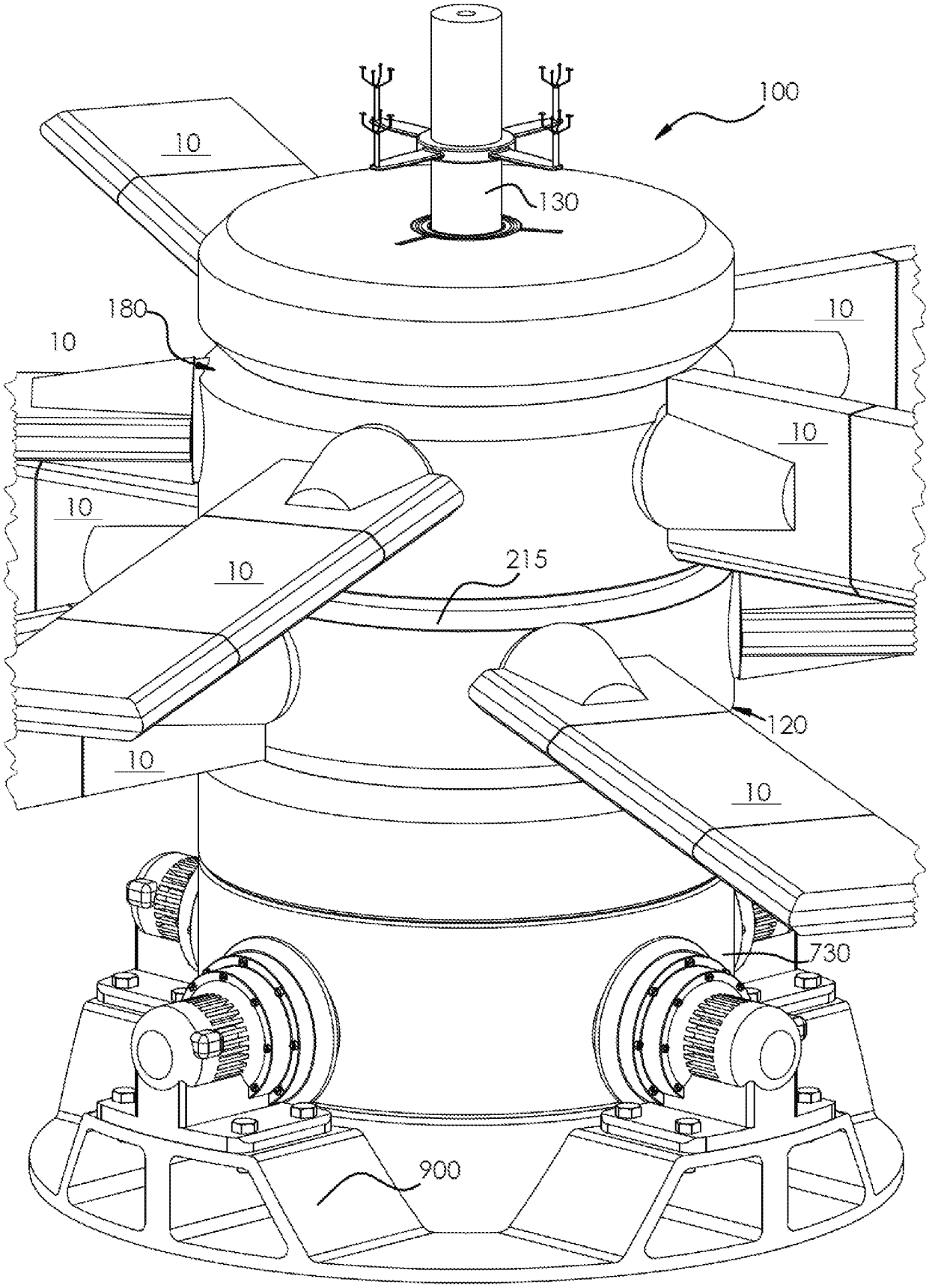


FIG. 21

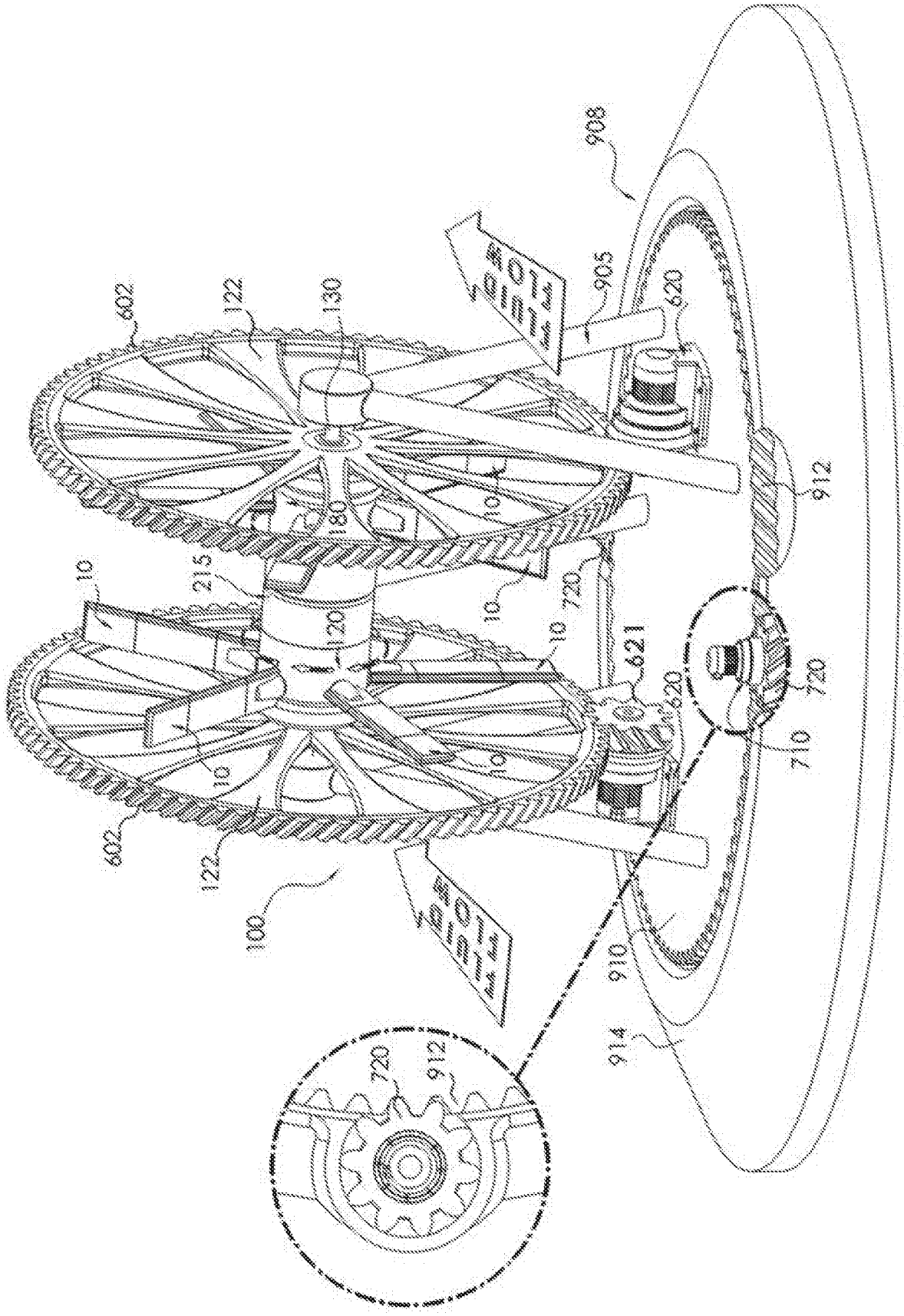

908
905
620
912
602
122
130
180
215
120
10
720
621
710
100
910
914

FIG. 22 A

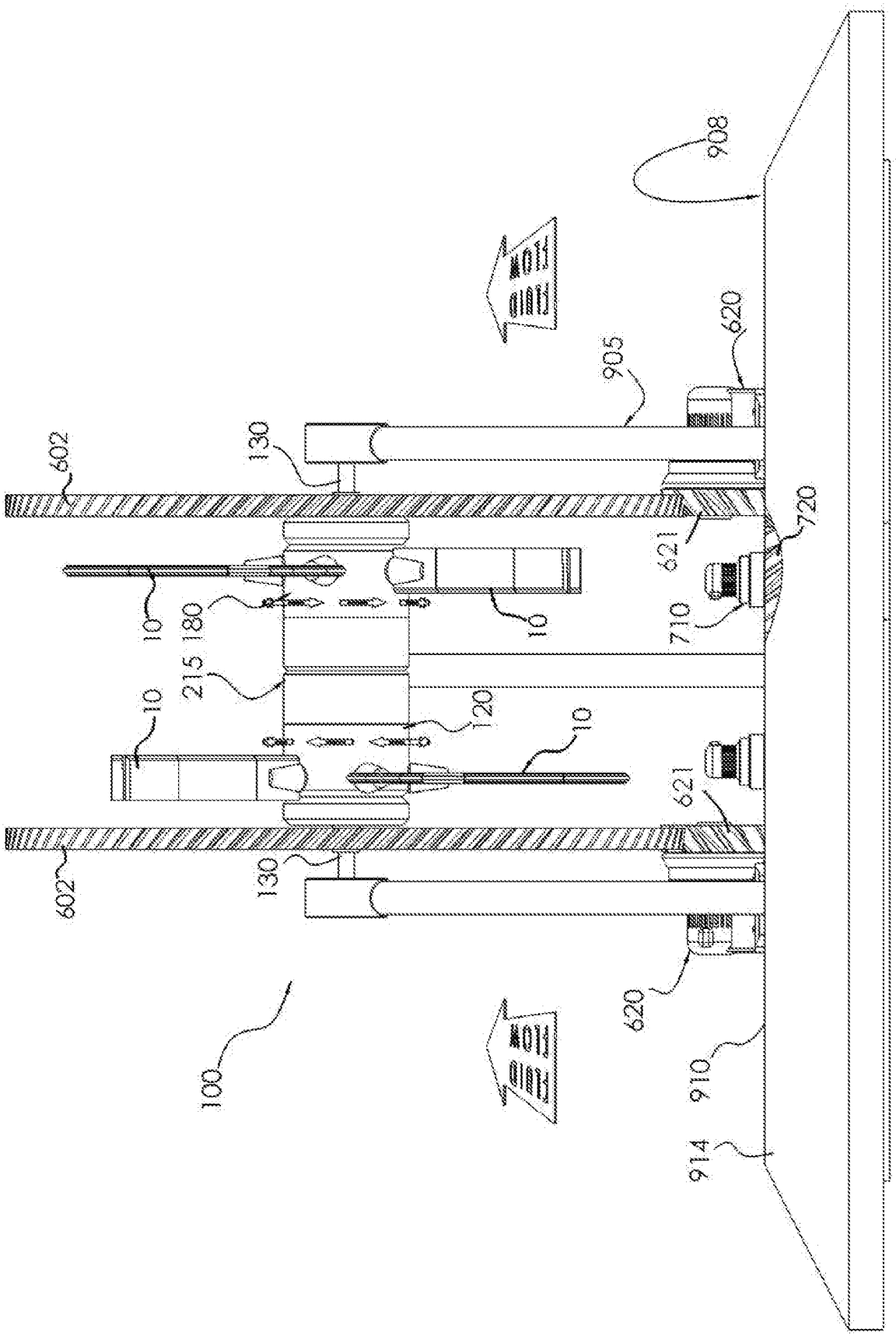


FIG. 22 B

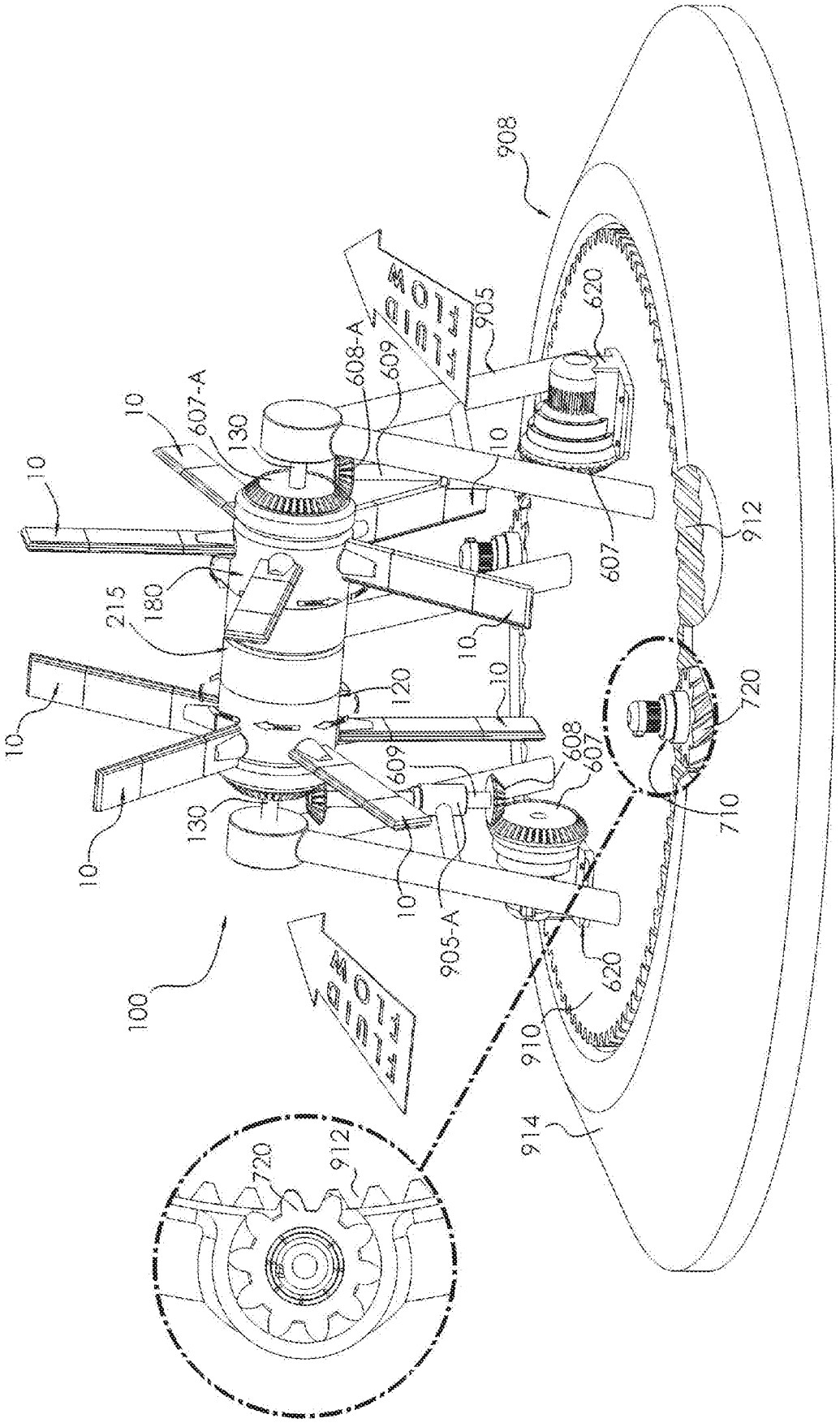

908
620
905
608-A
609
607-A
130
10
215
180
120
607
912
720
608
710
905-A
100
910
914

FIG. 22 C

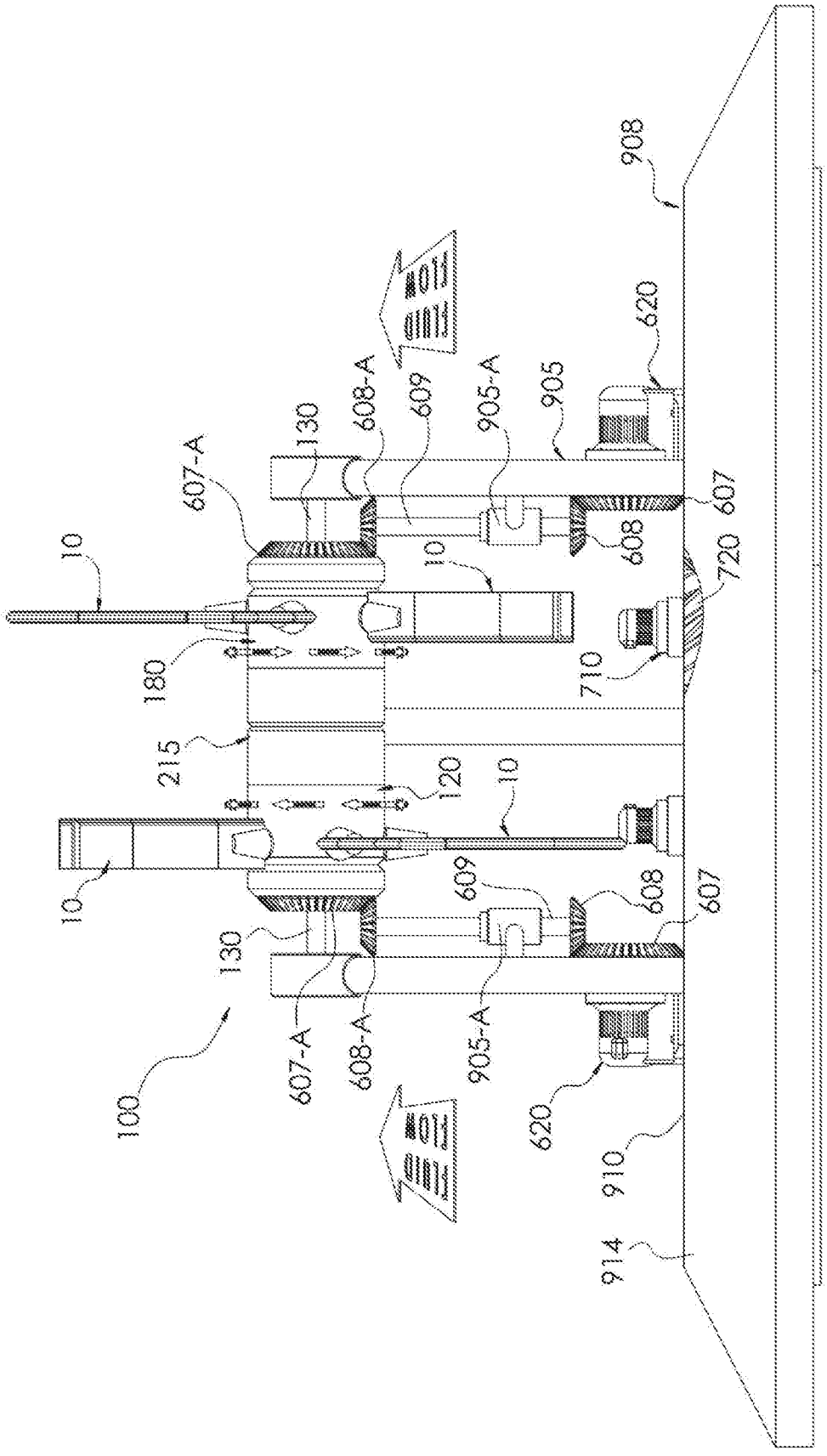

908
620
905
905-A
609
608-A
130
607-A
607
608
720
10
180
710
215
120
100
910
914

FIG. 22 D

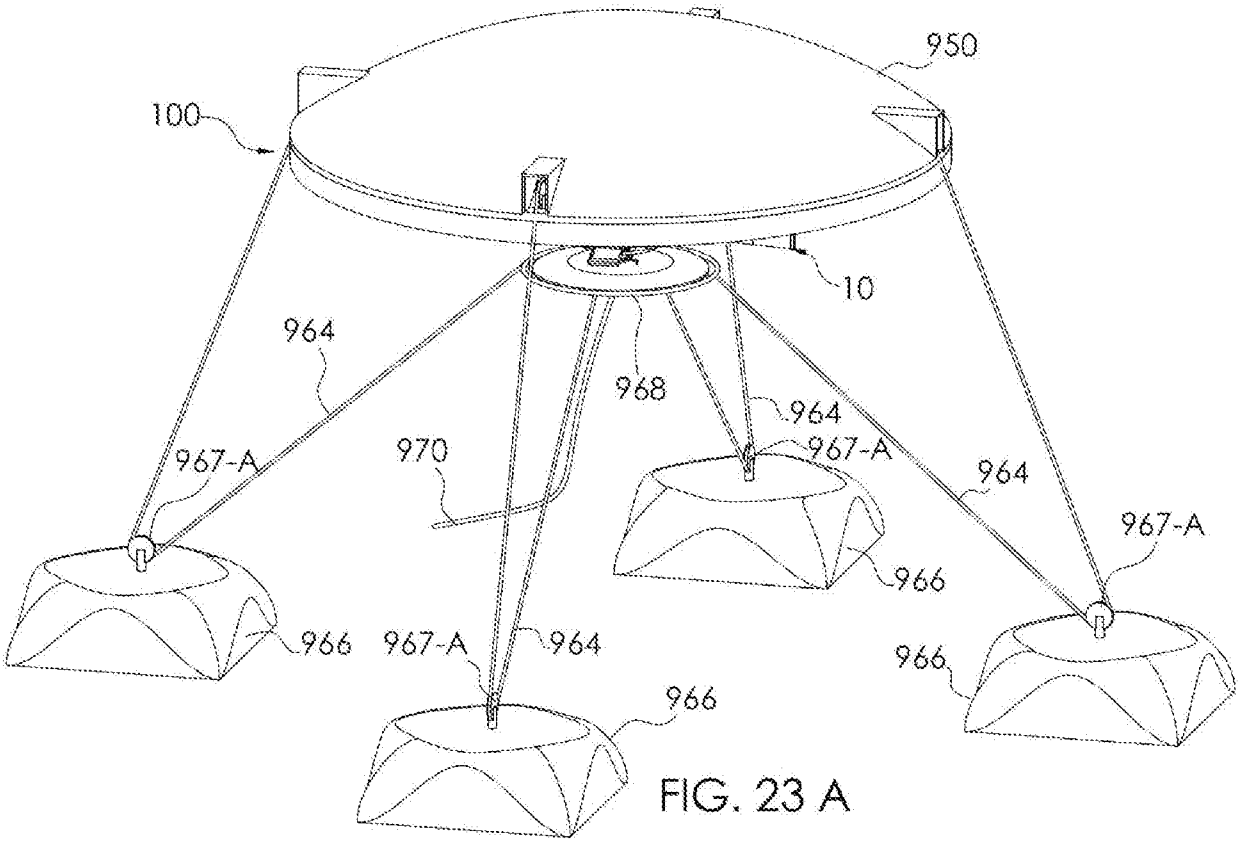


FIG. 23 A

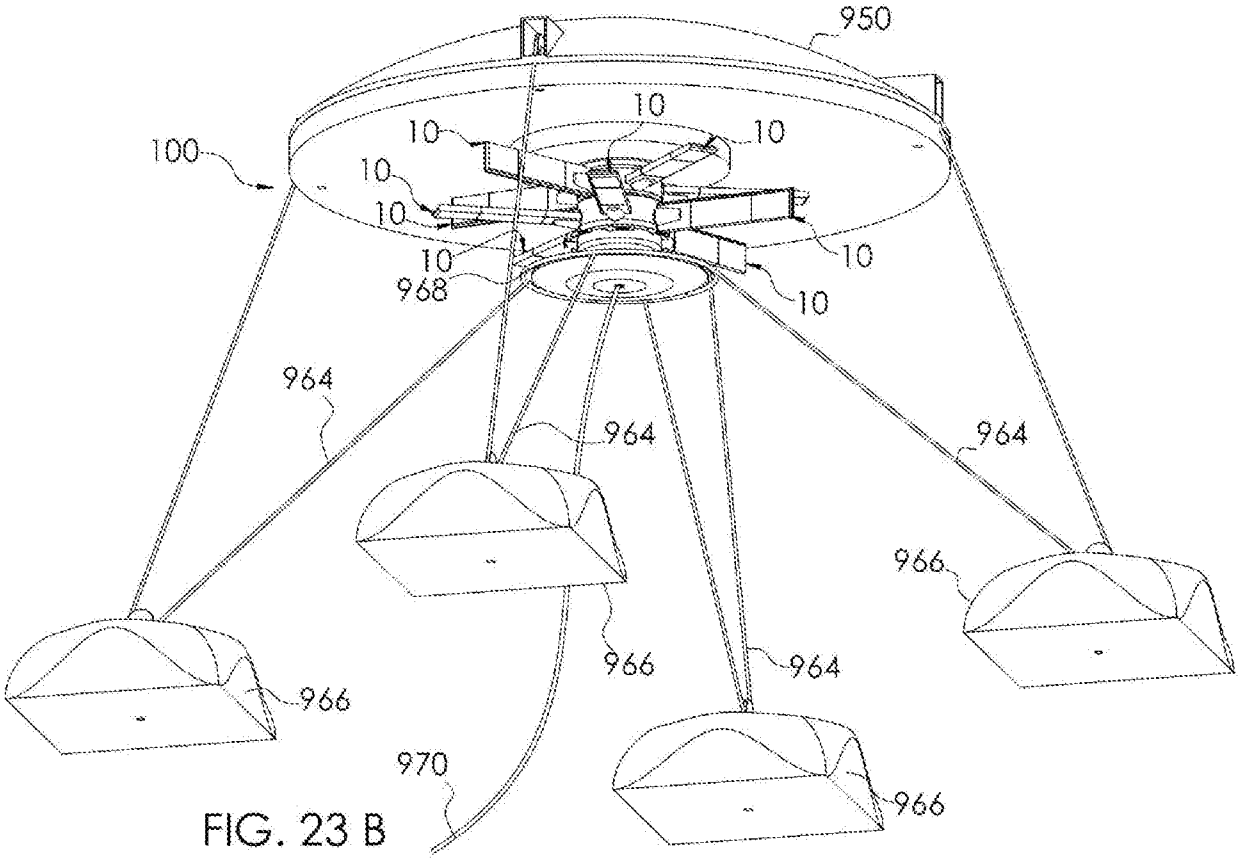


FIG. 23 B

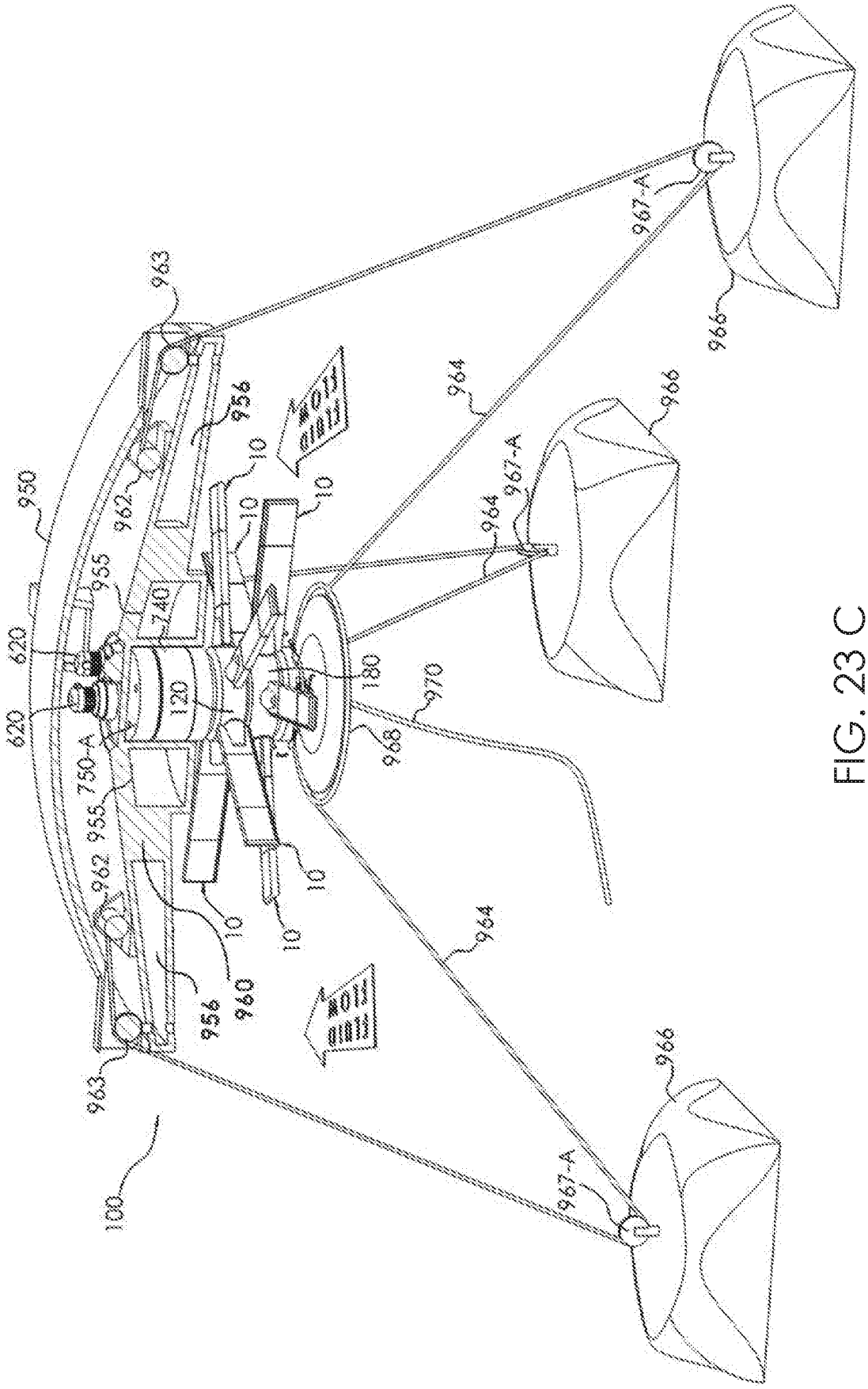

100
963
950
620
620
750-A
955
962
956
960
963
956
962
955
740
120
10
10
10
10
10
10
180
970
968
964
964
964
967-A
967-A
967-A
966
966
966

FIG. 23 C

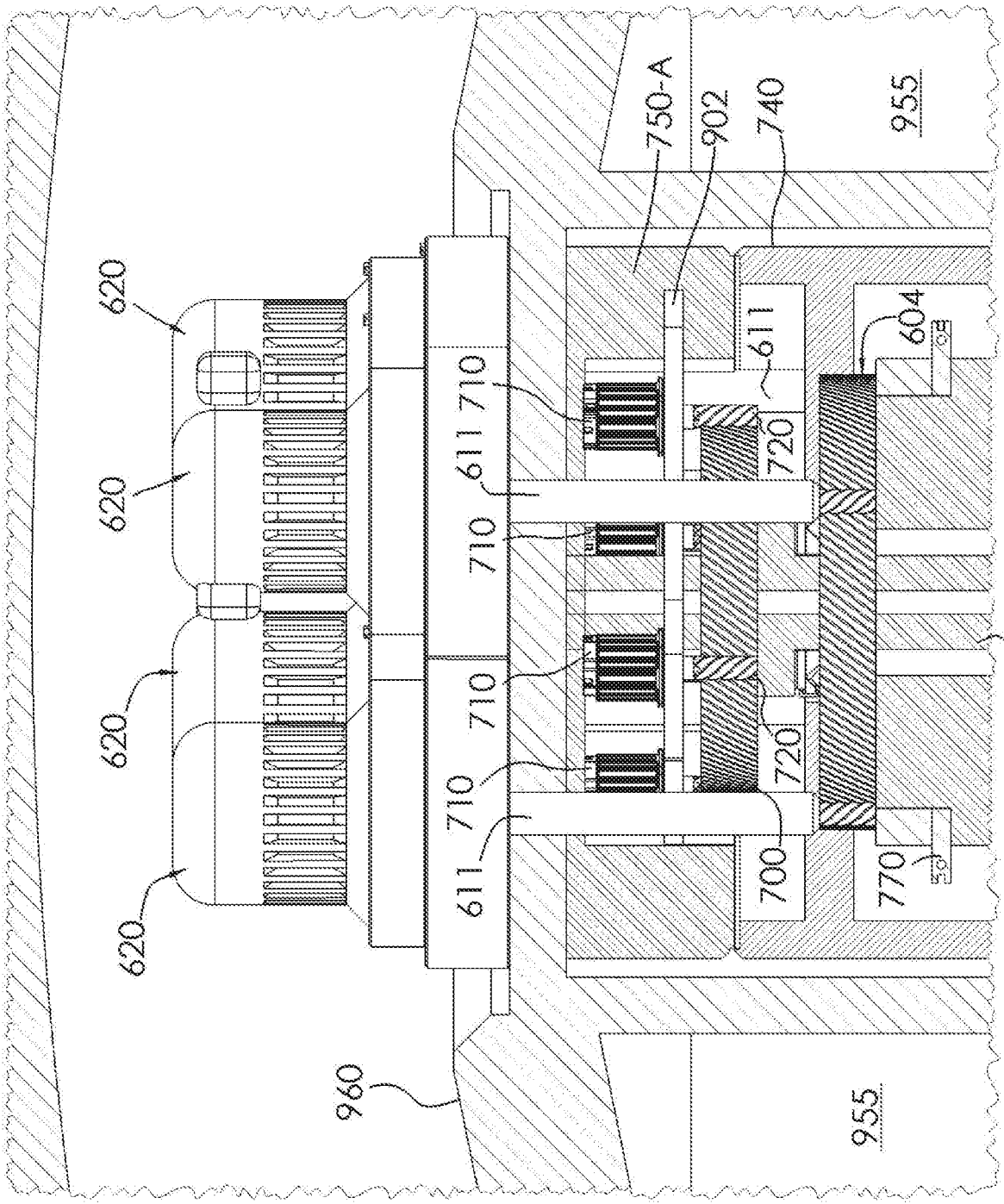

750-A
902
740
955
620
620
620
620
611
710
710
710
710
611
720
720
700
604
770
130
960
955

FIG. 23 D

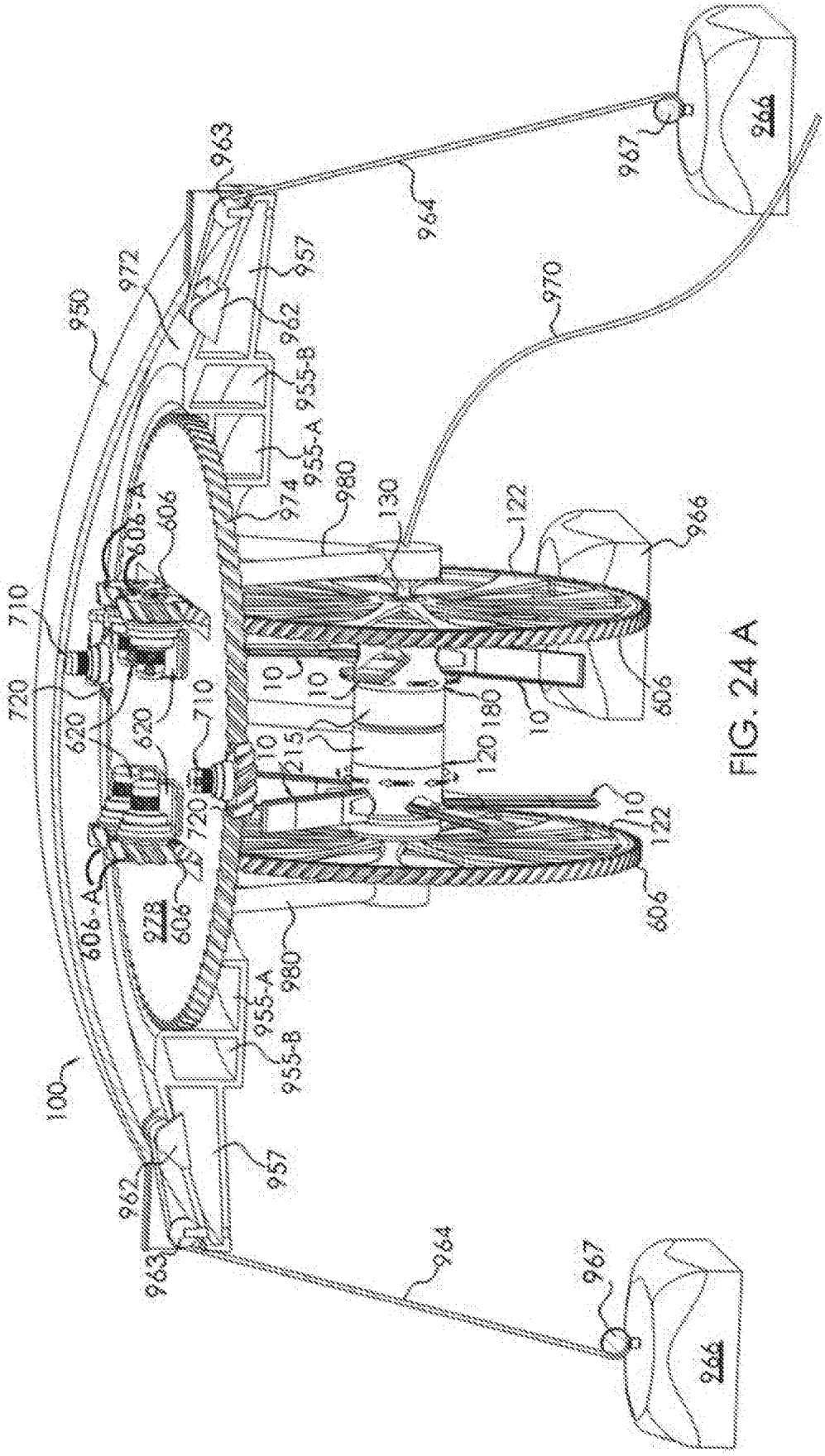

963
964
967
266
957
972
950
962
955-B
955-A
974
980
130
122
966
606
606-A
710
720
620
180
120
215
228
100

FIG. 24 A

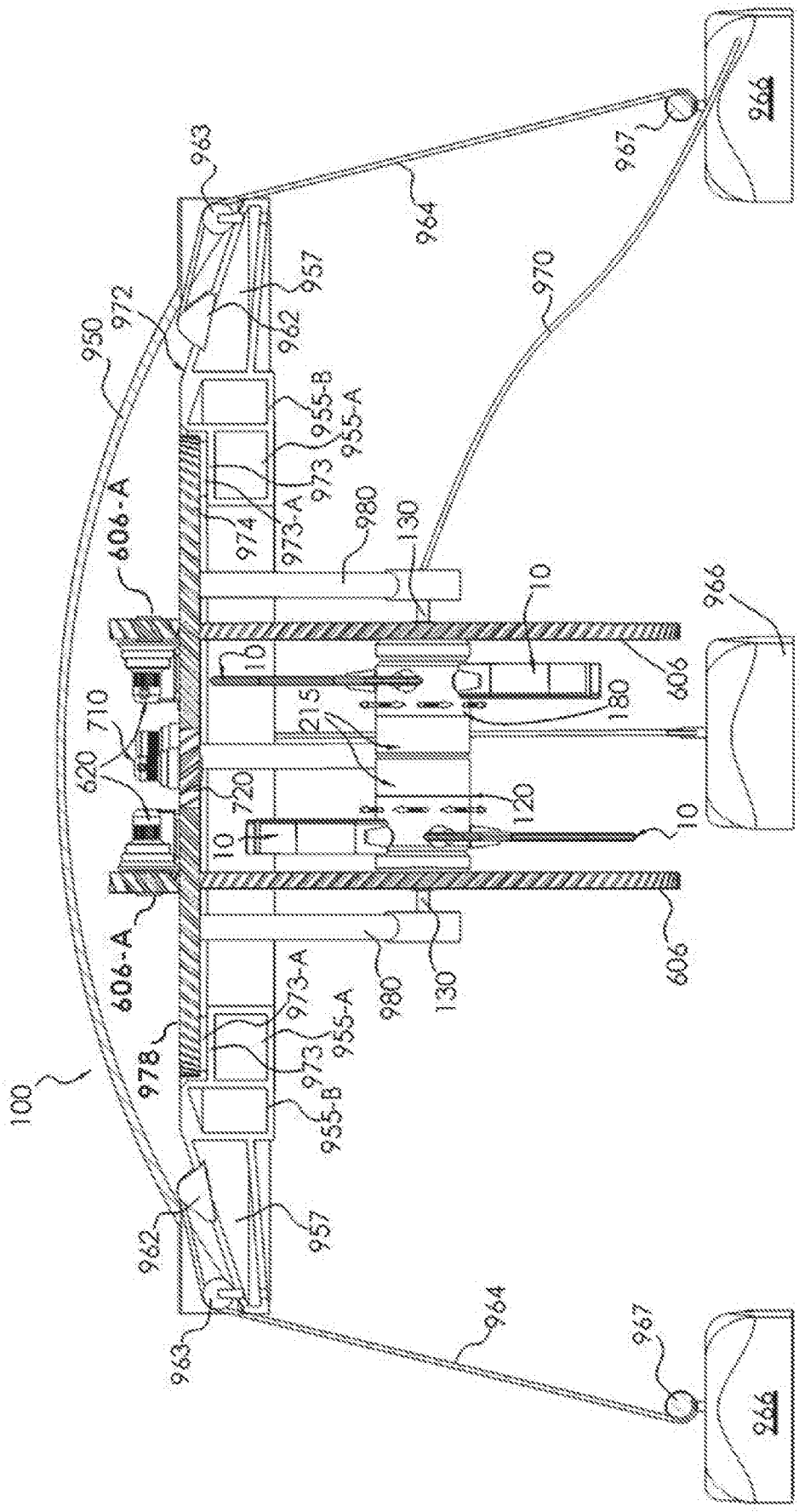

100
950
972
963
962
957
964
967
966
970
955-B
955-A
973
973-A
974
980
130
606-A
606
10
180
215
710
620
720
120
978

FIG. 24 B

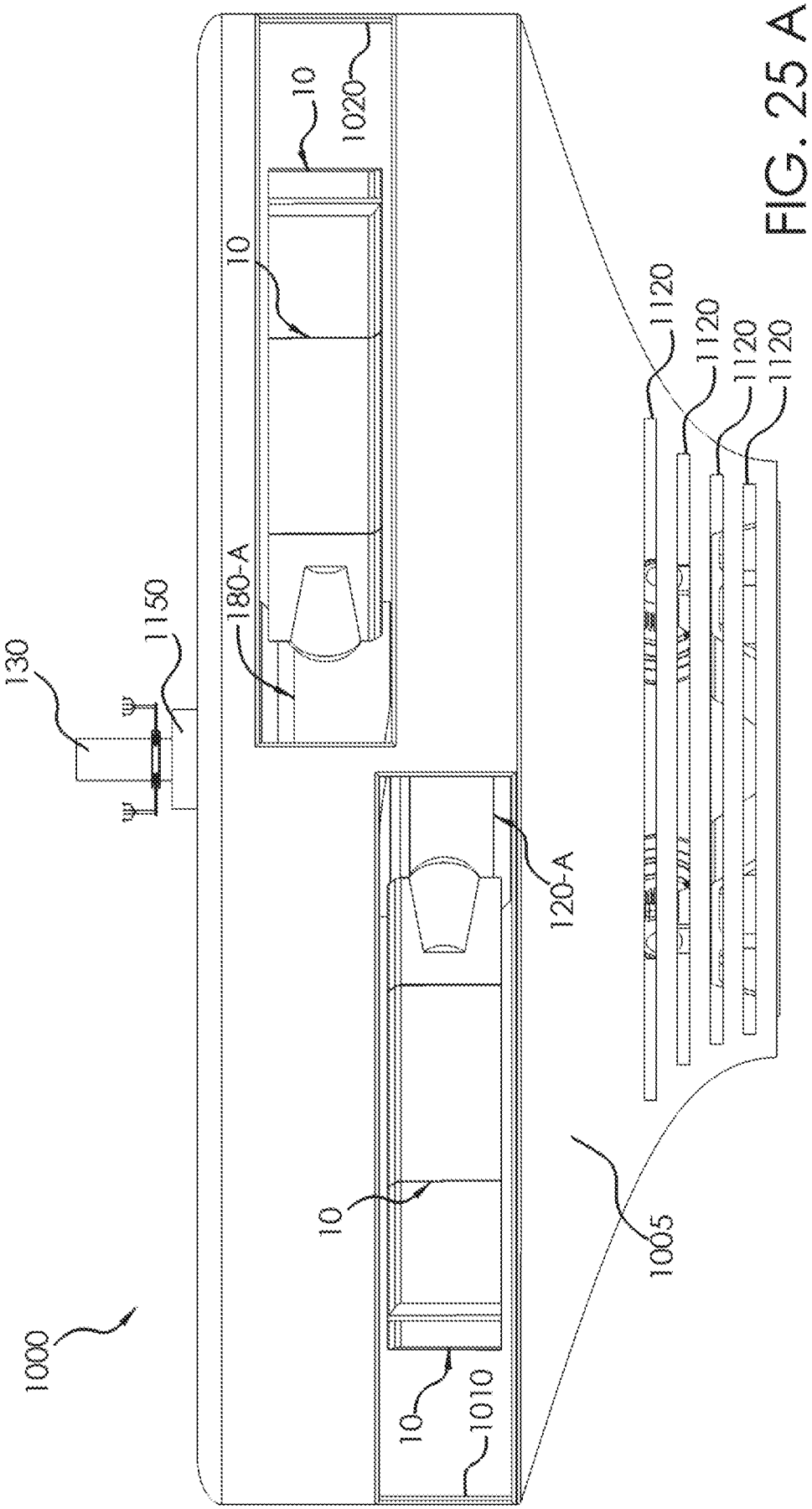

1000
1010
10
120-A
1005
10
180-A
1150
130
10
1020
1120
1120
120
120

FIG. 25 A

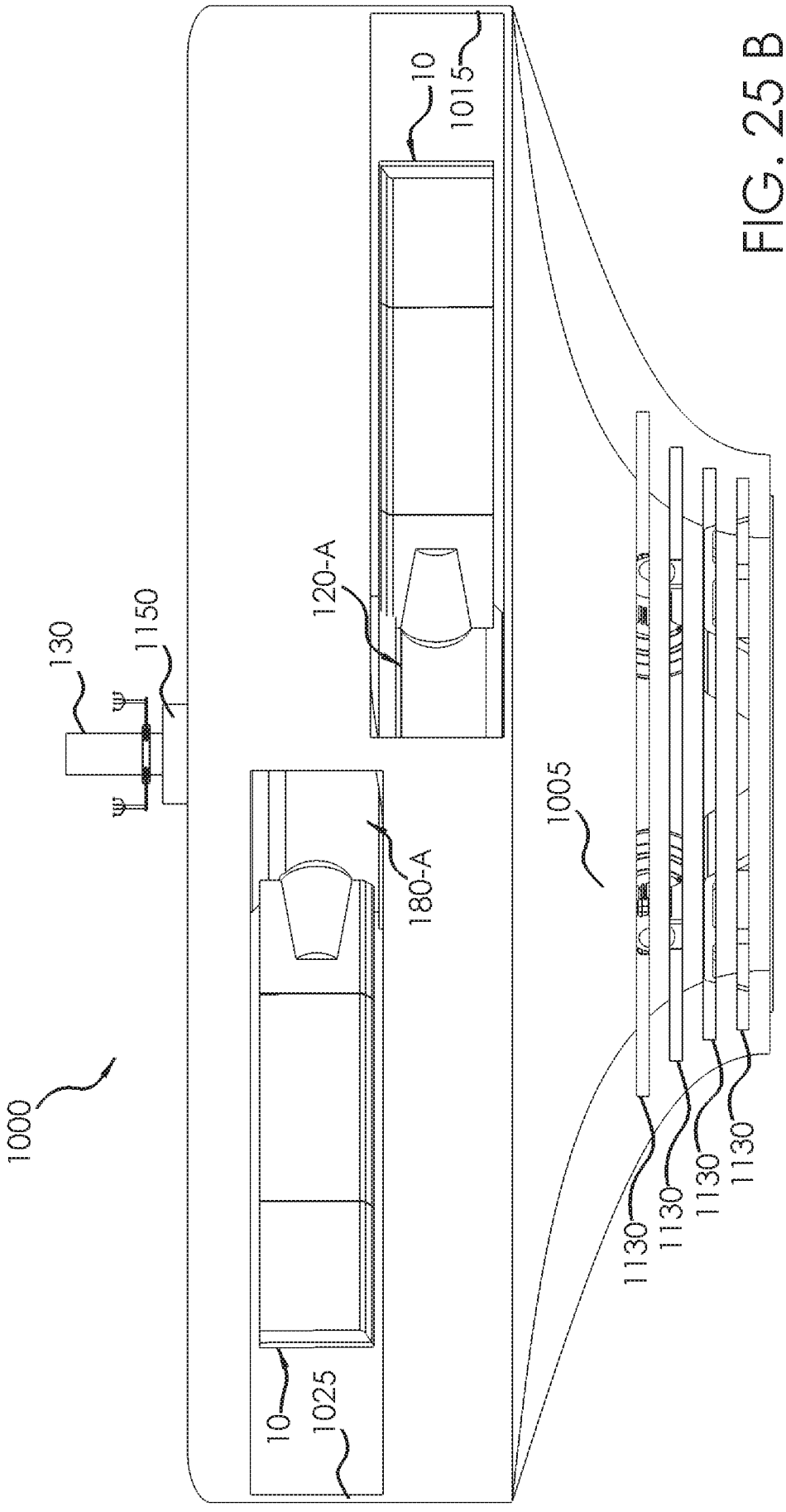

1000
130
1150
120-A
10
1015
180-A
1005
10
1025
1130
1130
1130
1130

FIG. 25B

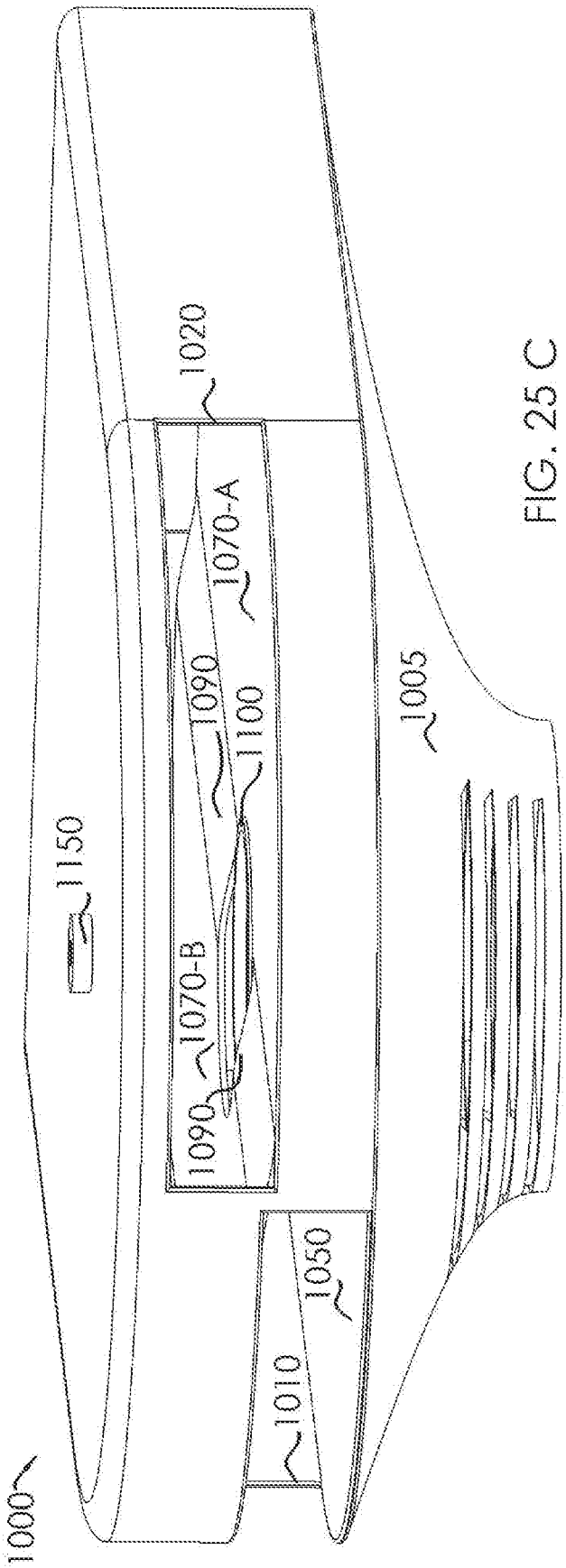


FIG. 25 C

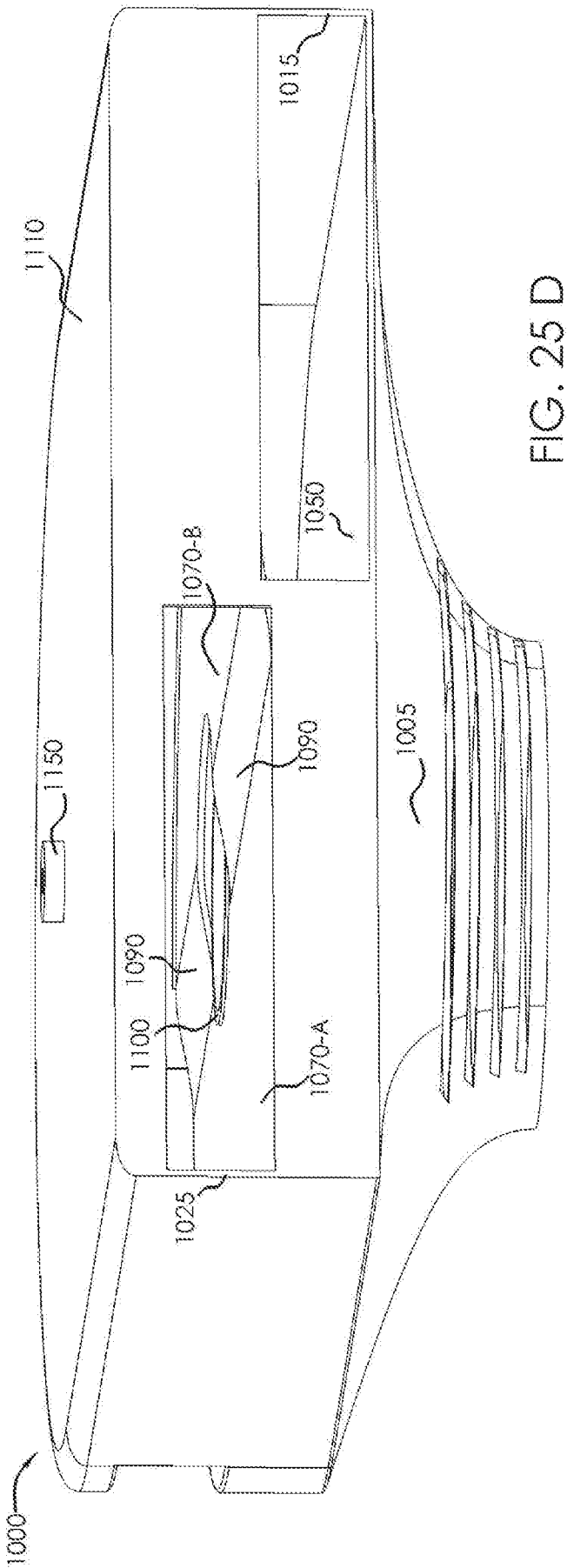

1015
1110
1050
1070-B
1090
1005
1150
1090
1100
1070-A
1025
1000

FIG. 25 D

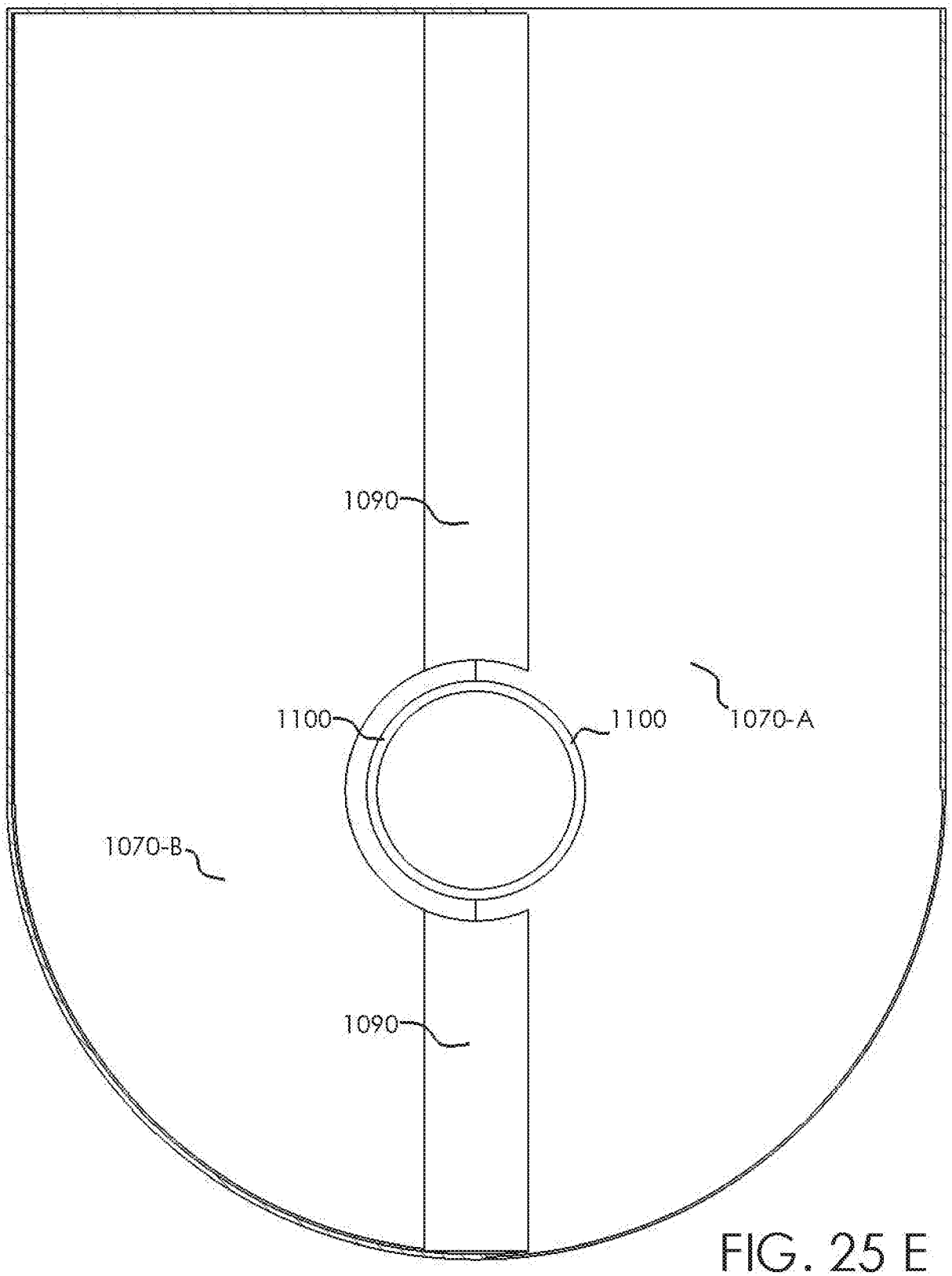


FIG. 25 E

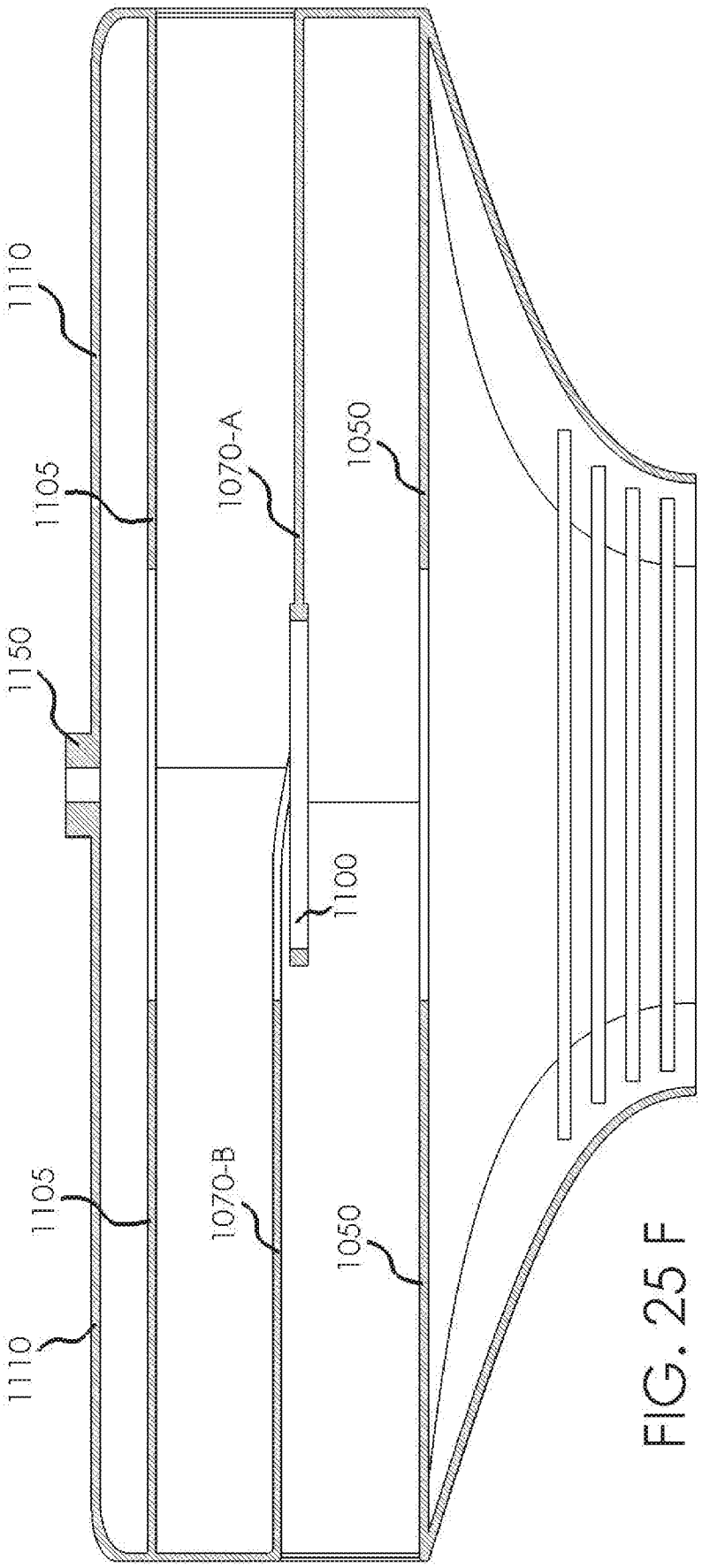


FIG. 25 F

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2019/038219

A. CLASSIFICATION OF SUBJECT MATTER
INV. F03D3/06
ADD.

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)
F03D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	GB 2 463 957 A (MICROGEN TECH LTD [GB]) 7 April 2010 (2010-04-07) pages 3,4,7,8 figures 1-10	1-9,12, 13,18, 19,32, 34,43

X	US 2011/223023 A1 (CARDEN MELVIN DON [US]) 15 September 2011 (2011-09-15) paragraphs [0072] - [0095] figures 1-8	1,2,10, 11,18, 19,43

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
8 August 2019	20/08/2019

Name and mailing address of the ISA/	Authorized officer
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INTERNATIONAL SEARCH REPORT

International application No
PCT/US2019/038219

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2015/292482 A1 (SHEOREY MUKUND MANOHAR [US]) 15 October 2015 (2015-10-15) paragraphs [0020] - [0024] figures 1-10 -----	1,2, 14-16, 18,19, 21-31, 33,35-47
X	US 2010/080706 A1 (LAM CHI HUNG LOUIS [HK] ET AL) 1 April 2010 (2010-04-01) paragraphs [0079], [0083], [0084], [0093], [0110] figures 1,2 -----	1,2, 17-20, 27,28, 30,31,33

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INTERNATIONAL SEARCH REPORT

Information on patent family members

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