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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
8 July 2010 (08.07.2010)

PCT

(10) International Publication Number
WO 2010/077640 A1

(51) International Patent Classification:
E02F 3/88 (2006.01) *E02F 5/00* (2006.01)

(21) International Application Number:
PCT/US2009/067114

(22) International Filing Date:
8 December 2009 (08.12.2009)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
12/330,462 8 December 2008 (08.12.2008) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PE, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

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

Published:

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

(54) **Title**: UNDERWATER EXCAVATION TOOL

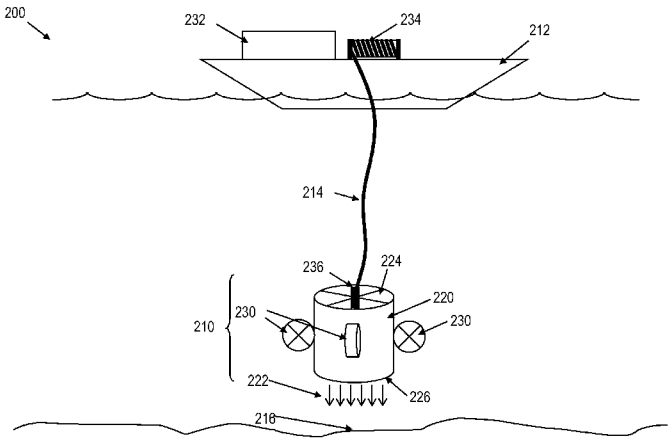


Fig. 2

(57) **Abstract**: An underwater excavating tool can generate a downward directed jet of water from a propeller in a main thruster body connected to a surface vessel by an umbilical. The umbilical can include an outer armored sheath that supports an underwater weight of the excavating apparatus, a data cable carrying signals from a controller unit on a surface vessel, and a power cable that supplies electrical power to operate the propeller and other functions of the excavating apparatus. One or more of the orientation, position, and rotation of the main thruster body can be controlled remotely by adjusting two or more positional thrusters mounted radially on the main thruster body. Remote control can be provided using the signals carried via the data cable. Related systems, apparatus, methods, and/or articles are also described.

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UNDERWATER EXCAVATION TOOL

FIELD

[0001] The subject matter described herein relates to excavation of material in a submerged environment, potentially including oceans, lakes, seas, and the like.

BACKGROUND

[0002] Underwater excavation can be a complicated and expensive endeavor, particularly in situations that require excavation over substantial distances or at substantial water depths. One example of excavation over long distances involves burying of a pipeline, a cable, or some other extended apparatus between two or more locations. For example, a pipeline for transporting oil or some other petroleum product between an oil rig and an onshore terminal might advantageously be buried beneath the ocean or sea floor to minimize the risk of damage to the pipeline. Special equipment is required to efficiently and cost-effectively bury the pipe below the surface of the ocean or sea floor. One means of performing underwater excavation is via generation of a stream or jet of water that is used to displace material on the floor of the ocean, sea, lake, or the like and thereby create a hole, trench, or other underwater excavation. Other means of underwater excavating can include physical digging, cutting, or scraping devices that generally involve mechanical contact between such a device and the area of the underwater floor to be excavated. Such mechanical methods and apparatus can be undesirable in applications involving equipment such as pipes or cables that might become fouled or otherwise damaged by inadvertent contact with a mechanical digging, cutting, or scraping tool.

SUMMARY

[0003] Currently available underwater excavating apparatus typically use hydraulic power generated on a surface vessel and transmitted to the underwater apparatus via hydraulic hoses. Because of the pressure drop in the hoses such apparatus are limited to depths of about 200 meters. The position of the excavating apparatus is generally controlled by two or more cables which are attached to the surface vessel

and/or clump weights. This arrangement limits the maneuverability of the apparatus and the range it can be controlled. The current subject matter can advantageously address these and other limitations of currently available underwater excavation technologies.

[0004] In one aspect, an apparatus according to the current subject matter includes a main thruster body having an inlet for water intake and an outlet through which water is discharged. An umbilical junction that is structurally integral to the main thruster body is configured to connect to an umbilical at a first end of the umbilical. The umbilical connects at a second end to a surface vessel such that an outer armored sheath of the umbilical supports an underwater weight of the apparatus. The umbilical also provides electrical power to the apparatus via an electrical cable that runs from the surface vessel to the apparatus within the outer armored sheath. The apparatus also includes a main thruster propeller that is housed within the main thruster body and powered by the electrical power to generate a flow of water in through the inlet and out through the outlet of the main thruster body, a main hydraulic motor that drives the main thruster propeller, and a main thruster pump that is driven by the one or more electric motors. The main thruster pump drives the main thruster propeller by providing hydraulic pressure to the main hydraulic motor. Two or more adjustable positional thrusters are mounted outboard of the central axis on the main thruster body. Each thruster includes a thruster propeller that produces thrust. The two or more adjustable positional thrusters act in response to signals received from the controller unit via the data cable to provide thrust at one or more angles relative to the main axis to maintain a desired orientation, position, rotation, and/or depth of the main thruster body and to provide rotational thrust to counter torque produced by rotation of the main thruster propeller. Two or more positional thruster hydraulic pumps that are driven by the electric motors provide pressurized hydraulic fluid to drive the two or more positional thruster propellers.

[0005] In a second interrelated aspect, a method includes generating a downward directed jet of water from a single propeller in a main thruster body of an excavating apparatus whose underwater weight is supported by an umbilical connected to a surface vessel. The method also includes controlling one or more of the orientation, position, and rotation of the main thruster body by adjusting

two or more positional thrusters mounted on the main thruster body. The umbilical includes an outer armored sheath that supports an underwater weight of the excavating apparatus, a data cable carrying signals from a controller unit on a surface vessel, and a power cable that supplies electrical power to operate the single propeller and other functions of the excavating apparatus. The controlling occurs remotely via the signals carried via the data cable.

[0006] In a third interrelated aspect, a system includes a control and power unit configured to be carried on a surface vessel and an umbilical that includes at least one electrical power cable, at least one data cable, and a weight-bearing outer sheath. The umbilical is configured to be connected at a first end to a winch on the surface vessel and also has a second end. The electrical power cable carries high voltage electricity from the control and power unit, and the data cable carries signals to and from the control and power unit. The system also includes an underwater excavation tool that includes a main thruster body having an inlet disposed at a top end of the main thruster body, an outlet disposed at a bottom end, and a central axis running from the top end to the bottom end. An umbilical junction is located on the central axis and connected to the second end of the umbilical such that a weight of the underwater excavation tool is supported by the weight-bearing outer sheath. A plurality of power packs each include an electrical motor and a positional thruster hydraulic fluid pump and one or more main thruster hydraulic fluid pumps driven by the electrical motor. A power junction receives power from the electrical power cable and distributes it to the electrical motors in each of the plurality of power packs. A main hydraulic motor receives pressurized hydraulic fluid from the one or more main thruster hydraulic fluid pumps of each of the plurality of power packs and drives, in a single radial direction, a single main thruster propeller mounted about the central axis within the main thruster body. A plurality of adjustable positional thrusters are mounted outboard of the central axis on the main thruster body and each supplied with pressurized hydraulic fluid by the positional thruster hydraulic fluid pump of one of the plurality of power packs. Each thruster includes a thruster propeller that produces thrust. The plurality of adjustable positional thrusters act in response to signals received from the control and power unit via the data cable to provide

thrust at one or more angles relative to the main axis to maintain a desired orientation, position, and/or rotation of the main thruster body and to provide rotational thrust to counter torque produced by rotation of the main thruster propeller.

[0007] One or more of the following optional features can also be included in these and other aspects of the current subject matter. The apparatus or system can optionally include exactly four adjustable positional thrusters and/or exactly one main thruster propeller within the main thruster body. Alternatively, one or more second main thruster propellers can be included on the central axis. The main thruster propeller or propellers can optionally rotate in only one radial direction about the central axis. The apparatus or system can optionally include two main hydraulic motors that drive the main thruster propeller, four positional thrusters, four electric motors, four positional thruster fluid pumps, and eight main thruster fluid pumps. One of the four motors, one of the four positional thruster fluid pumps, and two of the eight main thruster fluid pumps can be housed in one of four power packs secured outboard of the main thruster body. The electric motor of each power pack can drive the one positional thruster fluid pump that drives one of the four positional thrusters and also drive the two main thruster pumps of the power pack that provide pressurized hydraulic fluid to the two main hydraulic motors. One or more surveying devices can be mounted on the main thruster body. The surveying devices can include one or more of a multi-beam sonar unit, an obstacle avoidance sonar unit, and a video camera.

[0008] The apparatus can further include the controller unit, the umbilical, and/or the power supply that is connected to a surface vessel power source and that includes one or more electrical transformers that provide a stepped up high voltage current to the at least one electrical cable in the umbilical. The controller unit can include an interlock that causes shutdown of the main thruster propeller if rotation of the main thruster body beyond a threshold angle about the umbilical is detected. One or more sensors can be included that monitor one or more parameters selected from a group consisting of: input and output pressure of the adjustable positional thrusters, input and output pressure of the main thruster body, pressure of one or more auxiliary hydraulics systems, ambient water pressure, differential

pressure between the main thruster body inlet and ambient water pressure, differential pressure between the main thruster body outlet and ambient water pressure, rotation of the main thruster body about the umbilical, and position and orientation of the main thruster body.

[0009] The single propeller can be driven by one or more main hydraulic motors that are provided with hydraulic fluid pressure from one or more main thruster pumps that are driven by one or more electric motors powered by the electric power. The electrical power supplied by the power cable can power one or more electric motors that drive at least one main thruster hydraulic fluid pump that drives the single propeller and one or more positional thruster hydraulic fluid pumps that provide pressurized hydraulic fluid to drive the one or more positional thrusters. Data can be transmitted from one or more sensors on the excavating apparatus to the controller unit via the data cable, the one or more sensors monitoring one or more parameters selected from a group consisting of: input and output pressure of the adjustable positional thrusters, input and output pressure of the main thruster body, fluid pressure of one or more auxiliary hydraulics systems, ambient water pressure, differential pressure between the main thruster body inlet and ambient water pressure, differential pressure between the main thruster body outlet and ambient water pressure, rotation of the main thruster body about the umbilical, position and orientation of the main thruster body, and the revolutions per minute. The controller unit can command an automatic shutdown of the single propeller if rotation of the main thruster body beyond a threshold angle about the umbilical is detected by a rotational sensor on the excavating apparatus.

[0010] Various implementations of the currently described subject matter can include one or more advantageous or beneficial features relative to currently available underwater excavation technologies. Excavation of material can be accomplished solely using hydraulic action generated by water currents generated by one or more main propellers. No cutting devices or other mechanical features that could prove hazardous to the integrity of the object being buried need be employed. The device can be maintained with regards to its orientation, position, depth, and direction of travel through a combination of support via an umbilical to a surface vessel and through the action of its main thruster device and plurality of

positional thruster devices mounted outboard of the main thruster. Improved maneuverability and access to greater depths than currently available devices is also possible using the current subject matter. Whereas conventional excavating apparatus are limited to approximately 200 meters excavating apparatuses consistent with the current subject matter can be used at depths of up to 3000 meters and more.

[0011] The terms "upward" or "top" or "upper" and "downward" or "bottom" or "lower" as used in this disclosure are intended to refer to relative orientations and generally apply in an absolute directional sense when an apparatus or system, according to the various implementations of the current subject matter, is oriented so as to be actively operated. For example, a top or upper feature would be positioned relative to a bottom or lower feature such that when an apparatus or system is in operation, the top or upper feature is further from the surface being excavated. The terms "outboard" and "inboard" describe relative positioning of features on a device. Outboard refers to positioning of one feature farther from a core or center of a device relative to another, and inboard refers to positioning of one feature closer from a core or center of a device relative to another. In the case of a cylindrically shaped apparatus or device, an inboard feature is closer to a central axis or rotation than an outboard feature. In the case of a non-cylindrical device, an inboard feature could be closer to a central plane and/or a central point or axis relative to an outboard feature. The term "surface vessel" as used throughout this disclosure is intended to refer to any platform positioned above a body of water and can include a boat or ship, a barge, a permanently or temporarily fixed platform, or even a pier, bridge, or other over water structure.

[0012] The details of one or more variations of the subject matter described in this disclosure are set forth in the accompanying drawings and the description below. Any examples provided are intended to be illustrative of possible features that could be included in an implementation of the inventive subject matter and should not be interpreted as restricting the scope of the inventive subject matter. Other features and advantages of this subject matter will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

[0013] The accompanying drawings, which are incorporated in and constitute a part of this specification, show certain aspects of the subject matter disclosed herein and, together with the description, help explain some of the principles associated with the disclosed embodiments. In the drawings,

[0014] FIG. 1 is a process flow diagram illustrating features of a method for underwater excavation;

[0015] FIG. 2 is a schematic diagram showing features of an underwater excavation system;

[0016] FIG. 3 is a perspective diagram showing an example of an underwater excavation apparatus;

[0017] FIG. 4 is a perspective diagram showing a cutaway section of the main thruster body of an underwater excavation tool;

[0018] FIG. 5 is a perspective diagram showing an assembled power pack;

[0019] FIG. 6 is a perspective diagram showing a power pack with the pump enclosures removed to show the pumps;

[0020] FIG. 7 is a perspective diagram showing a power pack with the main propeller pump enclosure removed;

[0021] FIG. 8 is a perspective diagram showing a cutaway view of an underwater excavation tool;

[0022] FIG. 9 is a perspective diagram showing a lower main thruster body with a connection ring for a nozzle for use at the outlet of an underwater excavation tool; and

[0023] FIG. 10 is a perspective diagram showing a section of the upper main thruster body of an underwater excavation tool.

DETAILED DESCRIPTION

[0024] Prior underwater excavation systems and methods using water jetting or fluid flow to displace solid material underwater tend to be limited by difficulties in maneuvering --for example steering, positioning, orienting and achieving and maintaining a desired depth -- of an excavation apparatus and in dealing with the substantial rotational torque produced by the propeller, turbine, or other rotating

means for producing the water jet. Previous systems have addressed the torque issue by providing two impellers aligned in parallel with contrary rotating directions, by arranging pairs of motors that drive such propellers so that the motors are out of phase with each other, or by providing a pair of opposed or angled inlets via which water is drawn into an impeller chamber before being forced out via a single outlet.

[0025] The current subject matter provides methods, techniques, systems, apparatuses, articles of manufacture, and the like that can be used to perform underwater excavations controlled from a surface vessel. FIG. 1 shows a flow chart 100 that illustrates a method for underwater excavation according to the currently disclosed subject matter. At 102, a downward directed jet of water is generated from a single propeller in a main thruster body of an excavating apparatus that is connected to a surface vessel by an umbilical. The umbilical includes an outer armored sheath that is capable of supporting an underwater weight of the excavating apparatus, a data cable carrying signals from a controller unit on a surface vessel, and a power cable that supplies electrical power to operate the single propeller and other functions of the excavating apparatus. One or more of the orientation, position, depth, and rotation of the main thruster body is controlled at 104 by adjusting two or more positional thrusters mounted radially on the main thruster body and outboard of the axis of the main thruster propeller. The controlling can be performed remotely via the signals carried via the data cable. The method can also optional include transmitting data from one or more sensors on the excavating apparatus to the controller unit via the data cable at 106 and commanding an automatic shutdown of the single propeller if rotation of the main thruster body beyond a threshold angle about the umbilical is detected by a rotational sensor on the excavating apparatus at 110.

[0026] An example of a system 200 according to the current subject matter is illustrated in FIG. 2. The system can include an underwater excavation tool 210 connected to and controlled from a surface vessel 212 via an umbilical 214. The underwater excavation tool 210 includes a main thruster body 220 that creates a jet or stream 222 of water to be directed at a site 216 that is to be excavated. The main thruster body 220 includes an inlet 224 through which water is drawn into the

thruster body 220 and an outlet 226 via which the stream or jet of water 222 is directed toward the excavation site 216 by a main thruster propeller 228 (not shown in FIG. 2). The underwater excavation tool 210 also includes one or more, and in some implementations four, hydraulically driven positional thrusters 230 disposed radially about and outboard of the main thruster body 220 that can provide thrust at one or more angles to assist with positioning, both laterally in the X-Y plane, and orientation of the tool, steering, and compensating for the torque of the propeller in the main thruster body 220. Control and power systems for the underwater excavation tool 210 can be housed in one or more transportable containers 232 positioned on the surface vessel 212. An umbilical winch 234 on the surface vessel 212 controls payout of the umbilical 214 which is connected at a mounting junction or lifting point 236 to the underwater excavation tool 210. The main thruster body 220 can be axially symmetric about a main vertical axis about which the main thruster propeller 228 rotates. The mounting junction 236 for the umbilical 214 can lie on the main axis.

[0027] The control system, that can optionally be housed in the one or more transportable containers 232 on the surface vessel 212, can provide one or more of auto heading control, which can in some implementations have a static accuracy of ± 1 degree or better; manual X, Y, and/or Z directional thrust control via a user interface device, such as for example one or more joysticks; control of an auto swing function (in the X-direction, for example lateral to the direction of travel of the surface vessel and/or the underwater excavation tool 210); and pre-thrust control in the X, Y, and/or Z directions. Auto heading control can be applied to adapt a maximum allowable spin angle of the tool about the main vertical axis. This maximum allowable spin angle can be based on the paid out length of the umbilical 214 connecting the underwater excavation tool 210 to the surface vessel 212, so that the umbilical 214 will not be twisted beyond the limits of its design parameters.

[0028] FIGS. 3 to 10 are perspective diagrams showing features of an underwater excavation tool 210 according to a possible implementation of the current subject matter. The underwater excavation tool 210 includes a main thruster body 220 as described above. The main thruster body 220 has an inlet port 224 oriented

upward and a jet outlet port 226 oriented downward. Each of the inlet port 224 and the outlet port 226 can be tapered or have other physical features designed to improve the flow of water into and out of the main thruster body 220, to stabilize the underwater excavation tool 210, and/or to improve or modify the flow of water 222 produced from the outlet port 226. A number of positional thrusters 230 are positioned outboard of the main vertical axis of the main thruster body 220. The umbilical 214 is structurally connected at a first end to the main thruster body 220 at the umbilical mounting junction 236. In some variations, the main thruster body 220 includes exactly one main thruster propeller 228 that is driven by one or more main hydraulic motors 250 that can be powered by one or more hydraulic pumps. The motors and pumps can be housed in one or more power packs 240 that include electric motors and hydraulic pump enclosures 242, 244, and 246 as described in greater detail below.

[0029] FIG, 3 is a perspective diagram of a fully assembled underwater excavation tool and FIG. 4 is a perspective diagram of a central section of an underwater excavation tool 210 that includes power packs 240, the propeller 228, and one or more main hydraulic motors 250 that are supplied with pressurized hydraulic fluid from one or more main hydraulic thruster pumps. In addition to four positional thrusters 230 (three are shown in FIG. 3 and one is hidden on the back side of the tool 210) mounted symmetrically about the main thruster body 220, four power packs 240, each including one or more electric motors housed in an electric motor enclosure 242, one or more main thruster propeller pumps housed in a main thruster propeller pump enclosure 244, and one or more positional thruster pumps housed in a positional thruster pump enclosure 246. These power packs 240 are also arrayed outboard of the main thruster body 220 (again, due to perspective, only three of the power packs 240 are visible). Each of the electric motor enclosures 242, the main thruster propeller pump enclosures 244, and the positional thruster pump enclosures 246 can be constructed of a corrosion resistant material such as for example stables steel or brass. In the implementations discussed herein, four positional thrusters 230 are provided with a corresponding four power packs 240. In other implementations, more or fewer of the positional thrusters 230 and/or power packs 240 can be included.

[0030] FIGS. 5-7 show detail views of the power packs 240 according to one implementation. In FIG. 5, a power pack 240 is shown from the exterior. The electric motor enclosure 242 further includes a power supply connection 245 and a revolutions per minute indicator connection 247. The electric motor enclosure 242, the main thruster propeller pump enclosure 244, and the positional thruster pump enclosure 246 are connected along a central power pack axis. As shown in FIG. 5, the three enclosures 242, 244, 246 can be cylindrical. Other geometries are also possible. FIG. 6 shows a power pack 240 with the electric motor enclosure 242 in place but the main thruster propeller fluid pump enclosure 244 and positional thruster fluid pump enclosure 246 removed to reveal two main thruster propeller fluid pumps 252 and an auxiliary fluid pump 254 that are enclosed in the main thruster propeller fluid pump enclosure 244 during operation of the underwater excavation tool 210 and a the opposite end one positional thruster fluid pump 256 that is enclosed in the positional thruster fluid pump enclosures 246 during operation of the underwater excavation tool 210. In the exemplary implementation, each of four power packs 240 includes two main thruster propeller fluid pumps 252 that provide hydraulic pressure to the main hydraulic motor 250 and one positional thruster fluid pump that provides hydraulic pressure to one of four positional thrusters 230. One electric motor in each power pack drives a main shaft (not shown) that couples to and drives all of the pumps 252, 254, and 256 in each power pack 240. The auxiliary fluid pump can be a constant displacement gear pump 254. FIG. 7 shows a perspective diagram of exposed main thruster propeller fluid pumps 252, an auxiliary fluid pump 254, and a swash plate drive motor via which a swash plate in main thruster fluid pumps 252 can be controlled to meter hydraulic pressure to the main hydraulic motors 250 to control the rotational velocity of the main thruster propeller 228.

[0031] FIG. 8 shows a side view cutaway diagram of an implementation of the underwater excavation tool 210. As shown, the main hydraulic motors 250 are housed within a main hydraulic motor enclosure 260 directly connected to the main thruster propeller 228 via a drive shaft 262. In one implementation, the outer diameter of the blades 264 of the main thruster propeller 228 can be approximately 72 inch (1.82 m) and the hub 266 of the main thruster propeller 228

can have a diameter of approximately 0.7 m. The main thruster propeller 228 can be direct driven by one or more, or in some implementations two main hydraulic motors 250 that are operated in series. In one example, model CBP 140-80 motors that are available from Hägglunds (Mellansel, Sweden) and having a displacement volume for each motor of approximately 5024 cm^3 per revolution can be operated at approximately 270 $\pm$ 15 revolutions per minute. In some implementations, the main thruster propeller 228 within the main thruster body 220 can rotate in only one direction. Return valves can be mounted in both feed lines. The propeller drive shaft 262 can optionally have one section with two taper roller bearings. The fluid-filled interior of the drive mechanism including the main hydraulic motor enclosure 260, the propeller drive shaft 262 and the main hydraulic motor or motors 250 can be separated from seawater using one or more mechanical seals.

[0032] Hydraulic connections to the main hydraulic motors 250 from the main thruster hydraulic fluid pumps 252 can be via one or more, and in some implementations four spokes 268 in an internal tunnel of the main thruster body 220. The spokes 268 can also provide structural support and/or mechanical strength for the main thruster propeller 228 mounting. The feed and the return lines of the main hydraulic motors 250 can be combined in a manifold block. Piping running through the spokes 268 can optionally be fitted with a metric hexagon section for easy fitting. Some or all of the connections coming out of the spokes 268 can optionally have an "O"-ring sealing face and can use, for example, standard SAE split-flanges so that the position of the piping coming out of the spokes 268 is not critical when it comes to connecting the hoses/piping on the outside of the tool.

[0033] On the underside of an underwater excavation tool 210 as currently described, the water outlet port or jet 226 can be equipped with a nozzle, which converts the energy from the main thruster propeller 228 into a water column with the desired flow and speed. Different shapes of such nozzles can be used to adapt the system to specific soil or sea floor conditions. In some implementations, an underwater excavation tool 210 can be provided with two nozzles, one for low velocity (for example approximately 6 m s^{-1}) and one for high velocity (for example approximately 10.5 m s^{-1}). Attachment of the nozzle to the tool 210 can optionally

be performed on deck of the surface vessel, using a bolted-on construction. The funnel design can be optimized for water flow through a funnel. To protect the main thruster propeller 228 from damage due to floating objects such as rope or plastics, an easily dismountable grid can be installed above the water inlet 224 to the main thruster body 220.

[0034] The main thruster propeller fluid pumps 252 can optionally have a maximum displacement of approximately 250 cm^3 per revolution. Larger displacement is also possible. The positional thruster fluid pumps 256 can optionally have a displacement of approximately 100 cm^3 per revolution. Auxiliary pumps 254 can optionally have displacements of approximately 10 cm^3 per revolution units. All fluid pumps can in some implementations be similar to those available from Sauer-Danfoss (Ames, Iowa). The power pack electric motors can be equipped with water ingress detection sensors and one or more or optionally two temperature sensors such as the PT 100 available from Pico Technologies (St Neots, Cambridgeshire, England). Power cables between the motors and a power junction box 270 (see e.g. FIGS. 3, 4, and 8) on the underwater excavation tool 210 can be fixed at the motor end, and fitted with underwater connectors, such as those available from Gisma (Neumuenster, Germany) at the junction box end. The PT100 and water sensors can be interfaced using electrical connectors such as those available from Burton Electrical Engineering (Gardena, California). Seals can be provided between the pump housings and the motor housings. The electric motor enclosures 242 can have their own compensators 272 so that in case of water ingress in the hydraulics the HV electric motors will not be affected.

[0035] The one or more positional thrusters 230 as shown in the partial perspective diagram of FIG. 10 can in some implementations have a diameter of approximately 32 inches and can rotate inside a nozzle that can optionally be constructed of a metal or a high impact plastic such as for example Pa6G. The thruster frame can be constructed of stainless steel, such as AISI 316, or some other comparable material. As noted above, the positional thrusters can be driven by Sauer Danfoss 100 cm^3 per revolution hydraulic motors via, for example, a 3:1 gearbox.

[0036] Each of the electrical power packs within the electrical motor enclosures 242 can optionally drive three variable displacement fluid pumps as discussed above, one positional thruster fluid pump 256 for providing hydraulic power to a positioning thruster 230, and the two main thruster propeller fluid pumps 252 to provide hydraulic pressure to drive the main hydraulic motors 250 for the main thruster propeller 228. All these fluid pumps can be operated in a closed loop. A swash plate control pump 258 can control the flow of the fluids to the motor can be steered electronically and controlled from the control room on board the service vessel 212 Small auxiliary fluid pumps 254 fitted on, for example two out of four power packs can be constant displacement gear fluid pumps. Pressure compensation can be configured as follows. The main hydraulic system can optionally include one or more, and possibly four, hydraulic compensators 274 (optionally 15 L) with level measurement. The power pack electric motors can each be equipped with their own compensator 272 as described above (optionally 6 L) with level measurement. A valve/survey junction box 270 (described below) can be compensated with its own compensator (optionally 15 L) with level measurement. The umbilical and power junction box 280 (described below) can have its own compensator (optionally 6 L) with level measurement. The system can also be equipped with various filters. One filter can be installed in the leak/flushing oil line from the main thruster propeller 228 drive. This leak line can carry leak oil from the main hydraulic motors 250, but also the flush-oil for these motors. The same oil can be used to flush the main prop bearings. One filter can be provided in the combined thruster motor leak lines. All filters can be equipped with a clogged filter detection switch. Where practically possible, stainless steel piping can optionally be used for hydraulic connections. The remaining connections can be made using hoses, optionally with stainless steel fittings. All hydraulic connections can be made using BSP-P fittings. Hoses can be Parker HDPE coated high-pressure hoses. The fluid temperature of the system can in some implementations be assumed to be below the safe working temperature of the fluid. If higher oil temperatures are expected based on a specific design, an fluid/seawater cooler can also be implemented in the hydraulic system.

[0037] In some variations, an umbilical 214 with a length of approximately 1000 m can be used. Other umbilical lengths, such as for example 3000 m, can also be used. The length of the umbilical 214 generally determines the maximum depth at which an excavation tool can operate as well as the width of the horizontal footprint over which the underwater excavation tool 210 can be deployed from a surface vessel 212. The operational footprint of an underwater excavation tool can in some implementations be approximately 20% of the water depth. For large horizontal excursions, some reduction of power to the main thruster propeller 228 may be necessary.

[0038] For an underwater weight of an underwater excavation tool 210 of about 15.5 tons, an umbilical 214 can in some implementations have the following features and functions: twelve power conductors with 16 mm^2 current flow cross sectional area that are electrically isolated for 4.5 kV input voltage, two power conductors with 2.5 mm^2 current flow cross sectional area that are electrically isolated for 1 kV input voltage, three signal conductors with 0.5 mm^2 current flow cross sectional area that are electrically isolated for 240 V input voltage, six multi-mode fibers with 50/125 μm diameter, six single-mode fibers with 9/125 μm diameter, and an outer steel armor layer. The safe working load (SWL) can be defined as the maximum momentary load at any one time, resulting from the combination of the underwater excavation tool 210 underwater weight, umbilical 214 underwater weight, drag and accelerations, and can be approximately 330 kN for the aforementioned 17.5 ton (175 kN) device. In general, the system can be engineered to support a SWL on the umbilical of at least 1.25 times the maximum expected weight of the underwater excavation tool 210 and fully played out umbilical 214. The bending diameter of the umbilical 214 can in some implementations be 1.5 meter or more. The umbilical can be connected to the underwater excavation tool 210 using a strain relief junction 236 that can also be the lifting point for the underwater excavation tool 210 out of the water. From the strain relief junction 236, the electrical and electronics links 282 within the umbilical 214 can continue as shown in FIG. 8 (optionally without its outer armor) to an umbilical junction box 280 which can be oil filled and pressure compensated. Cables can depart from the umbilical junction box 280 to the power junction box

270 and then to the electrical motors in the power packs 240 and an electronics pod (E-pod) 290 (see below) and can optionally be connected via GISMA connectors and/or Subconn metal shell connectors. The power junction box 270 and umbilical junction box 280 can optionally be equipped with one or more water ingress sensors. This can be of particular importance for the umbilical junction box 280 which may be opened to connect and disconnect power and electronics links between the surface vessel 212 and the underwater excavation tool 210 prior to and after each use. The power junction box 270 can also house a toroidal transformer which converts the power for control and lighting from a higher voltage (i.e. 880 V) carried on the umbilical to a local voltage (i.e. 240 V).

[0039] Electrical power for operating an underwater excavation tool 210 can optionally be provided via a transformer system that can convert power from the surface vessel 212 to the necessary voltages for running the on-tool power packs. In one example, the transformer system can be housed in a commercially available 20-foot container 232 that can be equipped with a door, an escape hatch, lighting, air-conditioning, standstill heating, and other convenience, safety, and or ergonomic features. Inside the power container can be housed one or more main transformers that convert the ship's power supply into the HV supply that is provided to the on-tool power packs 240 via the umbilical 214. Each of the transformers can also optionally include a switchgear cabinet (section) with starter relays and protection circuits. In general, the power supply container can be operated as an unmanned area with access necessary only for maintenance, inspection, or repair.

[0040] The container 232 housing the transformer system can include a fence or other safety barrier that separates a personnel-accessible inspection area from the HV transformers area. The fence or some hatch or access panel to the transformer section can be interlocked to shut down power for safe access. The switchgear cabinet inside the power container can also house the following equipment: starters and protection circuits for the winch hydraulic power pack, starters and protection circuits for the LARS hydraulic power pack, starters and protection circuits for the winch chiller unit, UPS for the control system, and starters for air-conditioning,

heating and lighting for both the transformer container and the control system container.

[0041] As discussed above, in some implementations the main thruster propeller 228 can be powered by electrical motors in power packs 240 with two main propeller pumps 252 directly connected to one side and located on the exterior of the main thruster body 220 of the underwater excavation tool 210 and the positional thrusters 230 can be powered by the same electrical motors with positional thruster pumps 254 directly connected to one side and located on the exterior of the main thruster body 220 of the underwater excavation tool 210. An underwater excavation tool 210 can in some implementations be equipped with four identical power packs Fig 240. Each electric motor in the power packs 240 can optionally be driven by a 4160 VAC / 60Hz 400 hp fluid filled electric motor within an electric motor enclosure 242. The electric motors can be such as those available from Sun Star Electric (Lubbock, Texas). In the implementation described above, each electric motor drives three variable displacement hydraulic pumps (two for the main thruster propeller 228, one for each of the positional thrusters 230). Two of the power packs 240 can also drive a fixed displacement pump for auxiliary purposes, such as a cooling water pump and operation of forward and aft survey frames. Other configurations are within the scope of the current subject matter.

[0042] The underwater excavation tool 210 can optionally include one or more types of survey equipment, including but not limited to multibeam sonar units; obstacle avoidance sonar units; black and white cameras, optionally with integrated pan & tilt unit. In one implementation, two multibeam sonar units, two obstacle avoidance sonar units, and four black and white cameras can be included. A survey junction box and/or electronics pod (E-pod) 290 that is optionally made of stainless steel can be attached to the exterior of the main thruster body 220 to house hydraulic valves of the tool and also to act as a junction box for survey equipment included with the underwater excavation tool 210. In some examples, the survey junction box and/or e-pod 290 can have approximate dimensions of approximately 1000 × 500 × 150 mm. A transparent cover can be included to allow visual inspection of the contents of the box, which can optionally include

terminal strips for survey equipment with individual fuses and led indicators, main thruster propeller pump swash plate angle proportional control valves, positional thruster pump swash plate angle proportional control valves (which can be bidirectional), spare positions for additional valves, a water ingress sensor, and the like. The survey junction box and/or e-pod 290 can have hydraulic and electric connections on the sides for ready connections to other devices on the underwater excavation tool 210. Connections to survey equipment from the survey junction box and/or e-pod 290 can optionally be made using multi-pole metal shell connectors such as the 10-pole connector available from Subconn in Florida USA and Denmark Europe.

[0043] The ends of the survey junction box and/or E-pod 290 can be sealed, for example with stainless steel flanges and covers in stainless steel 431. In some implementations, the survey junction box and/or E-pod 290 cover can be provided with hoist-eyes and guide pins for easy handling and positioning despite their weight. The survey junction box and/or E-pod 290 can optionally house one or more of a gyro compass (for example the Octans available from Ixsea, Marly-le-Roi, France); a multiplexer with capabilities for video cameras, control and survey equipment; power supplies for one or more controls; power supplies for survey equipment; dimmers for lamps, a water ingress sensor, and a controller or processor. The survey junction box and/or E-pod 290 can also have conduits for one or more of a penetrator for power supplies and valve controls to a survey junction and valve box (described in greater detail below), a penetrator for data to the survey junction and valve box, lamps, power connector cable(s) from the umbilical junction box, fiber penetrator(s) from the umbilical junction box, cables to differential pressure sensors, cable to pressure sensor pod, compensator level signals, a tachometer for the main thruster propeller RPM, power pack temperature and water ingress measurements, fluid temperature measurements (i.e. fluid to main motors, fluid to thruster motors, filter clogged signals, sensor(s) to detect leak/flush fluid return from the main thruster propeller drive, sensor(s) to detect leak/flush fluid return from the combined thruster drive leak/flush lines, connection to the backup fluxgate compass, and a vacuum plug.

[0044] An atmospheric, stainless steel pressure sensor pod can optionally be installed on the underwater excavation tool 210 to house pressure sensors that monitor one or more of the following: positional thrusters input and output pressure, main thruster input and output pressure, auxiliary hydraulics system pressure, and ambient water pressure. Differential pressure sensors can also be installed to allow monitoring of the main thruster propeller performance. These differential pressure sensors can measure differential pressure between the main thruster propeller inlet 224 and ambient water pressure and differential pressure between the main thruster propeller outlet 226 and ambient water pressure. The differential pressure sensors can be mounted in housings separate from the pressure sensor pod.

[0045] An underwater excavation tool 210 can optionally be constructed so that it can be transported in units that fit inside a transportable container, such as for example a standard 20 foot container footprint. The main thruster body 220, including power packs 240, main thruster propeller 228 and other equipment, can be transported as one unit in such a container. The positional thrusters 230 and additional parts can be transported in a second container. In some variations, one or more of the underwater excavation tool 210 components might not fit inside a 20 foot container. As an alternative, one or more open top frames can be used for transport.

[0046] A control system and/or power system for the underwater excavation tool 210 can be provided in one or more containers 232 in which the excavation tool is transported to a work site or to an embarkation point for a waterborne transport vessel. In some variations, the control system can include a screen or other display device featuring a user graphical user interface as well as one or more user input devices such as for example a joystick, a roller ball, or the like. On-screen graphical user interface controls of various systems on the underwater excavation tool that a user can manipulate via an input device such as a mouse, a trackpad, a keyboard, and/or one or more action buttons or control can also be included. Among other functions, the control system can apply the underwater excavation tool's positional thrusters 230 (in some examples there are four as noted above) to automatically compensate for torque generated by the main thruster propeller 228 and thereby

maintain a stable orientation without physical contact of the tool with a solid surface. Such compensation can in some examples be based on one or more of an auto heading control based on gyro compass, feed forward based on pressure difference across hydraulic motors, and feed forward based on operator adjustment of main thruster propeller power.

[0047] Although the control system can generally keep the tool at the prescribed heading, the main thruster power can in some situations be sufficient to spin the tool around multiple turns, thereby potentially damaging its own umbilical 214. To mitigate this potential hazard, one or more of the following measures can be implemented. The twist angle of the umbilical 214 can be automatically limited based on a gyrocompass installed on the tool. In this manner, the operator can be prevented from over-rotating the underwater excavation tool 210 when performing a heading adjustment. Automatic shutdown of the main thruster propeller 228 can be programmed to occur in the event that the auto heading controller cannot maintain the desired heading (error > 5 degrees,). A redundant fluxgate compass can also or alternatively be installed to shut the system down in case the gyro compass fails (difference between gyro and fluxgate more than 30 degrees).

[0048] The underwater excavation system 200 as shown in FIG. 2 can optionally further include a launch and recovery system (LARS) with various additional components to facilitate moving the tool between the surface vessel 212 and the water. The LARS can be designed such that during in-water operations the underwater excavation tool 210 is suspended on its own umbilical 214. When the underwater excavation tool 210 is handled on deck however, the load of the underwater excavation tool 210 can be carried by a separate steel cable (or cables). A catcher mechanism can be provided to connect the underwater excavation tool 210 to the LARS. The process of 'catching' can be performed in stages. First, a mechanical connector can be lowered onto the swiveling strain-relief junction 236 on the underwater excavation tool 210. A male/female mechanical latch (male on the tool side) can provide a failsafe connection of the steel cable to the underwater excavation tool 210. The latch can allow hydraulic opening and be operated from the surface vessel 212 (not from the tool), and provided that there is no tension in the steel cable. Once the load of the underwater excavation tool 210 has thus been

transferred from the umbilical 214 to the steel cable, the underwater excavation tool 210 can be hoisted until it is to-blocks with the LARS. In this situation the LARS can dampen swing motions, supporting against the inlet bell-mouth of the underwater excavation tool 210.

[0049] As noted, in normal in-water operation, the underwater excavation tool 210 can be suspended on its umbilical 214, which is routed via a sheave at the end of the LARS boom. This sheave can be capable of pivoting in order to accommodate surface vessel 212 motions as well as the maximum thruster-induced excursion of the tool (in one example up to 20 degrees). If the LARS cannot accommodate the combined departure angle of the umbilical 214 resulting from thruster-induced sideways excursions in combination with drag and vessel motions, an alarm can be provided to help prevent mal-operations.

[0050] In one example, the LARS can be designed for the combined load of the underwater weight of the "dead" (i.e. main and positional thrusters off) underwater excavation tool 210 (estimated 17.5 tons), underwater weight of the umbilical 214 (max 1000 m at 7 kg/m), maximum 5 tons sideways force from the positional thrusters 230, sideways load due to local water current acting on underwater excavation tool 210 and umbilical 214, and heave motions that result in drag and acceleration forces on the underwater excavation tool 210 and the umbilical 214. A load cell in the end-sheave can provide an indication of the actual load on the LARS.

[0051] The underwater excavation tool 210 umbilical winch 234 can be constructed in steel or some comparable material with adequate strength and can optionally include a grooved drum with a capacity of 1000 m of 50 mm steel armored umbilical 214. The umbilical 214 can optionally be stored in three layers on a drum with diameter 1800 mm and width 2750 mm. The winch 234 can be used on board of a surface vessel 212 for deployment of a underwater excavation tool 210. The storage drum can be hydraulically driven and equipped with a hydraulically driven spooling device. The winch 234 can be installed on a frame with a 20-foot container footprint together with a dedicated 250 kW hydraulic power pack in some implementations. Nominal speed of the winch 234 can optionally be 60 m/min at a force of 175 kN or 30 m/min at 250 kN. Because the

underwater excavation tool 210 may be fitted with optional extras, the winch can be rated for hoisting an additional weight beyond the typical out of water weight of the underwater excavation tool 210, in one example for a maximum 25 ton at the top layer.

[0052] The grooved drum can be constructed in steel. For heat transfer, instead of using lebus shells, the drum itself can be grooved. The drum can be hydraulically driven, in some implementations with a hydraulically operated fail-safe band brake. An extra motor-brake is optional. The storage drum can also be equipped with a multi turn encoder measuring drum revolutions, to be used for calculating paid out length. A hydraulically driven spooling device can also be fitted. Spooling can performed done via a traveling sheave that is fitted above the drum. The winch frame can also be constructed in steel. It can have a 20 foot container footprint and adequate sea-fastening provisions with sacrificial welding plates bolted onto the frame. A hydraulic power pack can be fitted on the winch frame. It can be a self contained unit suitable for continuous operation. Cooling should be designed for operation with seawater of 32 degrees Celsius. The winch 234 power supply can optionally be 440 V, 60 Hz, connected via a deck cable in a terminal box on the winch frame. The starter can be external to the winch 234. The winch 234 can be equipped with a local control station, mounted on the winch 234, which apart from allowing control of the winch 234 can also be equipped with a full diagnostics screen. In addition to the local station a remote control station can be provided and located in the control container 232. The interface between the remote control station and the winch control system can be based on a modbus or similar protocol. The winch 234 can optionally be fitted with a Focal slip ring unit, one stainless steel rotary junction box and one stainless steel static junction boxes. The winch 234 can also be equipped with water-cooling on the inside of the drum. The cooling system will be based on a chiller unit that is installed on the winch base-frame. From the chiller a closed loop circuit can circulate cooling liquid through the drum via a rotary joint. The chiller itself can transfer heat to seawater. The chiller can be powered from the power container 232. For cooling capacity calculations it can in one example be assumed that the dissipation in the umbilical will not exceed 40 kW. Power supply can in some examples be 440 V, 60 Hz,

connected via a deck cable in a terminal box on the winch frame. The starter can be external to the winch.

[0053] The subject matter described herein may be embodied in systems, apparatus, methods, and/or articles depending on the desired configuration. In particular, various aspects or features of the subject matter described herein may be realized in digital electronic circuitry, integrated circuitry, specially designed ASICs (application specific integrated circuits), computer hardware, firmware, software, and/or combinations thereof. These various implementations may include implementation in one or more computer programs that are executable and/or interpretable on a programmable system including at least one programmable processor, which may be special or general purpose, coupled to receive data and instructions from, and to transmit data and instructions to, a storage system, at least one input device, and at least one output device. These computer programs (also known as programs, software, software applications, applications, components, or code) include machine instructions for a programmable processor, and may be implemented in a high-level procedural and/or object-oriented programming language, and/or in assembly/machine language. As used herein, the term "machine-readable medium" refers to any computer program product, apparatus and/or device (e.g., magnetic discs, optical disks, memory, Programmable Logic Devices (PLDs)) used to provide machine instructions and/or data to a programmable processor, including a machine-readable medium that receives machine instructions as a machine-readable signal. The term "machine-readable signal" refers to any signal used to provide machine instructions and/or data to a programmable processor.

[0054] The implementations set forth in the foregoing description do not represent all implementations consistent with the subject matter described herein. Instead, they are merely some examples consistent with aspects related to the described subject matter. Wherever possible, the same reference numbers will be used throughout the drawings to refer to the same or like parts. Although a few variations have been described in detail above, other modifications or additions are possible. In particular, further features and/or variations may be provided in addition to those set forth herein. For example, the implementations described

above may be directed to various combinations and subcombinations of the disclosed features and/or combinations and subcombinations of several further features disclosed above. In addition, the logic flow depicted in the accompanying figures and/or described herein do not require the particular order shown, or sequential order, to achieve desirable results. Other embodiments may be within the scope of the following claims.

WHAT IS CLAIMED:

1. A system comprising:

a control and power unit configured to be carried on a surface vessel;

an umbilical comprising at least one electrical power cable, at least one data cable, and a weight-bearing outer sheath, the umbilical configured to be connected at a first end to a winch on the surface vessel and having a second end, the electrical power cable carrying high voltage electricity from the control and power unit, the data cable carrying signals to and from the control and power unit; and

an underwater excavation tool comprising:

a main thruster body comprising an inlet disposed at a top end of the main thruster body and an outlet disposed at a bottom end and a central axis running from the top end to the bottom end;

an umbilical junction located on the central axis and connected to the second end of the umbilical such that a weight of the underwater excavation tool is supported by the weight-bearing outer sheath;

a plurality of power packs each comprising an electrical motor and a positional thruster hydraulic fluid pump and one or more main thruster hydraulic fluid pumps driven by the electrical motor;

a power junction that receives power from the electrical power cable and distributes the electrical power to the electrical motors in each of the plurality of power packs;

a hydraulic motor that receives pressurized hydraulic fluid from the one or more main thruster hydraulic fluid pumps of each of the plurality of power packs;

a main thruster propeller mounted about the central axis within the main thruster body and driven in a single radial direction by the main hydraulic motor;

a plurality of adjustable positional thrusters mounted on the main thruster body and each supplied with pressurized hydraulic fluid from the positional thruster hydraulic fluid pump of one of the plurality of power packs, each thruster comprising a thruster propeller that produces thrust, the

plurality of adjustable positional thrusters acting in response to signals received from the control and power unit via the data cable to provide thrust at one or more angles relative to the main axis to maintain one or more of a desired orientation, position, and rotation of the main thruster body and to provide rotational thrust to counter torque produced by rotation of the main thruster propeller.

2. A system as in claim 1, comprising four adjustable positional thrusters and four power packs.

3. A system as in claim 1 in which there is only one main thruster propeller.

4. A system as in claim 1, further comprising a second main thruster propeller mounted about the central axis within the main thruster body and driven in the same single radial direction by the main hydraulic motor.

5. An apparatus comprising:

a main thruster body comprising an inlet for water intake and an outlet through which water is discharged;

an umbilical junction that is integral to the main thruster body and configured to connect to an umbilical at a first end of the umbilical, the umbilical connecting at a second end to a surface vessel such that an outer armored sheath of the umbilical supports an underwater weight of the apparatus, the umbilical further providing electrical power to the apparatus via an electrical cable that runs from the surface vessel to the apparatus within the outer armored sheath;

a main thruster propeller housed within the main thruster body and powered by the electrical power to generate a flow of water in through the inlet and out through the outlet; and

two or more adjustable positional thrusters mounted on the main thruster body, each thruster comprising a thruster propeller that produces thrust to counteract torque produced by rotation of the main thruster propeller within the

main thruster body and to maintain one or more of a desired orientation, position, and rotation, of the main thruster body.

6. An apparatus as in claim 5, further comprising a connection module mounted to the main thruster body, the connection module comprising an electrical connection configured to connect to the electrical cable within the umbilical to provide the electrical power to the apparatus from a power supply on the surface vessel; and a data connection configured to connect to a data cable within the umbilical to transmit data and commands between the apparatus and a controller module on the surface vessel.

7. An apparatus as in claim 5, further comprising an electric motor that is supplied with electrical power via the electrical cable, a main thruster hydraulic fluid pump that is driven by the electric motor, and a main hydraulic motor that is supplied with pressurized hydraulic fluid from the main hydraulic fluid pump and that drives the main thruster propeller.

8. An apparatus as in claim 5, wherein the main thruster body comprises a central passage leading between the inlet and the outlet, the central passage being rotationally symmetrical about a central axis, and wherein the main thruster propeller is disposed within the central passage and rotates about the central axis.

9. An apparatus as in claim 8, wherein the main thruster propeller can rotate in only one radial direction about the central axis.

10. An apparatus as in claim 5, comprising exactly four adjustable positional thrusters.

11. An apparatus as in claim 5, further comprising two main hydraulic motors that drive the main thruster propeller, four positional thrusters, four electric motors, four positional thruster fluid pumps, and eight main thruster fluid pumps, wherein one of the four motors, one of the four positional thruster fluid pumps, and two of the eight main thruster fluid pumps are housed in one of four power packs

secured outboard of the main thruster body, the electric motor of each power pack driving the one positional thruster fluid pump of the power pack that provides pressurized hydraulic fluid to drive one of the four positional thrusters and also driving the two main thruster fluid pumps of the power pack that provide pressurized hydraulic fluid to the two main hydraulic motors.

12. An apparatus as in claim 5, further comprising one or more surveying devices mounted on the main thruster body.

13. An apparatus as in claim 12, wherein the surveying devices comprise one or more of a multibeam sonar unit, an obstacle avoidance sonar unit, and a video camera.

14. An apparatus as in claim 5, further comprising an interlock that causes shutdown of the main thruster propeller if rotation of the main thruster body beyond a threshold angle about the umbilical is detected.

15. An apparatus as in claim 5, further comprising one or more sensors that monitor one or more parameters selected from a group consisting of: input and output pressure of the adjustable positional thrusters, input and output pressure of the main thruster body, pressure of one or more auxiliary hydraulics systems, ambient water pressure, differential pressure between the main thruster body inlet and ambient water pressure, differential pressure between the main thruster body outlet and ambient water pressure, rotation of the main thruster body about the umbilical, and position and orientation of the main thruster body.

16. An apparatus as in claim 5, further comprising the power supply that is connected to a surface vessel power source and that comprises one or more electrical transformers that provide a stepped up high voltage current to the at least one electrical cable in the umbilical.

17. A method comprising:

generating a downward directed jet of water from a single propeller in a main thruster body of an excavating apparatus whose underwater weight is supported by an umbilical connected to a surface vessel, the umbilical comprising an outer armored sheath that supports the underwater weight, a data cable carrying signals from a controller unit on a surface vessel, and a power cable that supplies electrical power to operate the single propeller and other functions of the excavating apparatus; and

controlling one or more of the orientation, position, and rotation of the main thruster body by adjusting two or more positional thrusters that are mounted on the main thruster body, the controlling occurring remotely via the signals carried via the data cable.

18. A method as in claim 17, further comprising driving the single propeller by one or more main hydraulic motors that are provided with pressurized hydraulic fluid from one or more main thruster fluid pumps that are driven by one or more electric motors powered by the electric power.

19. A method as in claim 17, wherein the electrical power supplied by the power cable powers one or more electric motors that drive at least one main thruster hydraulic fluid pump that drives the single propeller and two or more positional thruster hydraulic fluid pumps that drive the two or more positional thrusters.

20. A method as in claim 17, further comprising transmitting data from one or more sensors on the excavating apparatus to the controller unit via the data cable, the one or more sensors monitoring one or more parameters selected from a group consisting of: input and output pressure of the adjustable positional thrusters, input and output pressure of the main thruster body, pressure of one or more auxiliary hydraulics systems, ambient water pressure, differential pressure between the main thruster body inlet and ambient water pressure, differential pressure between the main thruster body outlet and ambient water pressure, rotation of the main thruster body about the umbilical, and position and orientation of the main thruster body.

21. A method as in claim 17, wherein the controller unit commands an automatic shutdown of the single propeller if rotation of the main thruster body beyond a threshold angle about the umbilical is detected by a rotational sensor on the excavating apparatus.

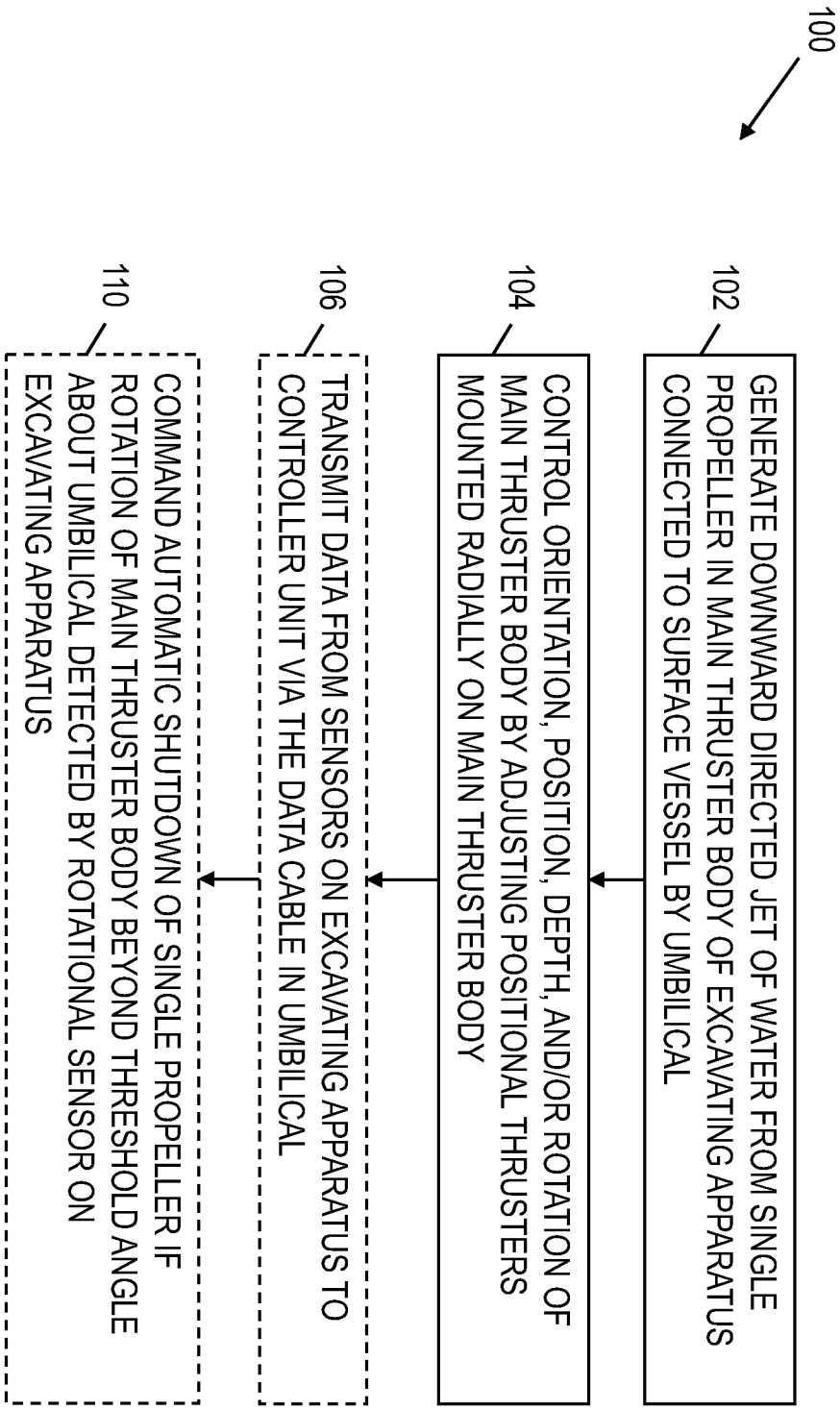

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102
GENERATE DOWNWARD DIRECTED JET OF WATER FROM SINGLE PROPELLER IN MAIN THRUSTER BODY OF EXCAVATING APPARATUS CONNECTED TO SURFACE VESSEL BY UMBILICAL
104
CONTROL ORIENTATION, POSITION, DEPTH, AND/OR ROTATION OF MAIN THRUSTER BODY BY ADJUSTING POSITIONAL THRUSTERS MOUNTED RADIALLY ON MAIN THRUSTER BODY
106
TRANSMIT DATA FROM SENSORS ON EXCAVATING APPARATUS TO CONTROLLER UNIT VIA THE DATA CABLE IN UMBILICAL
110
COMMAND AUTOMATIC SHUTDOWN OF SINGLE PROPELLER IF ROTATION OF MAIN THRUSTER BODY BEYOND THRESHOLD ANGLE ABOUT UMBILICAL DETECTED BY ROTATIONAL SENSOR ON EXCAVATING APPARATUS

Fig. 1

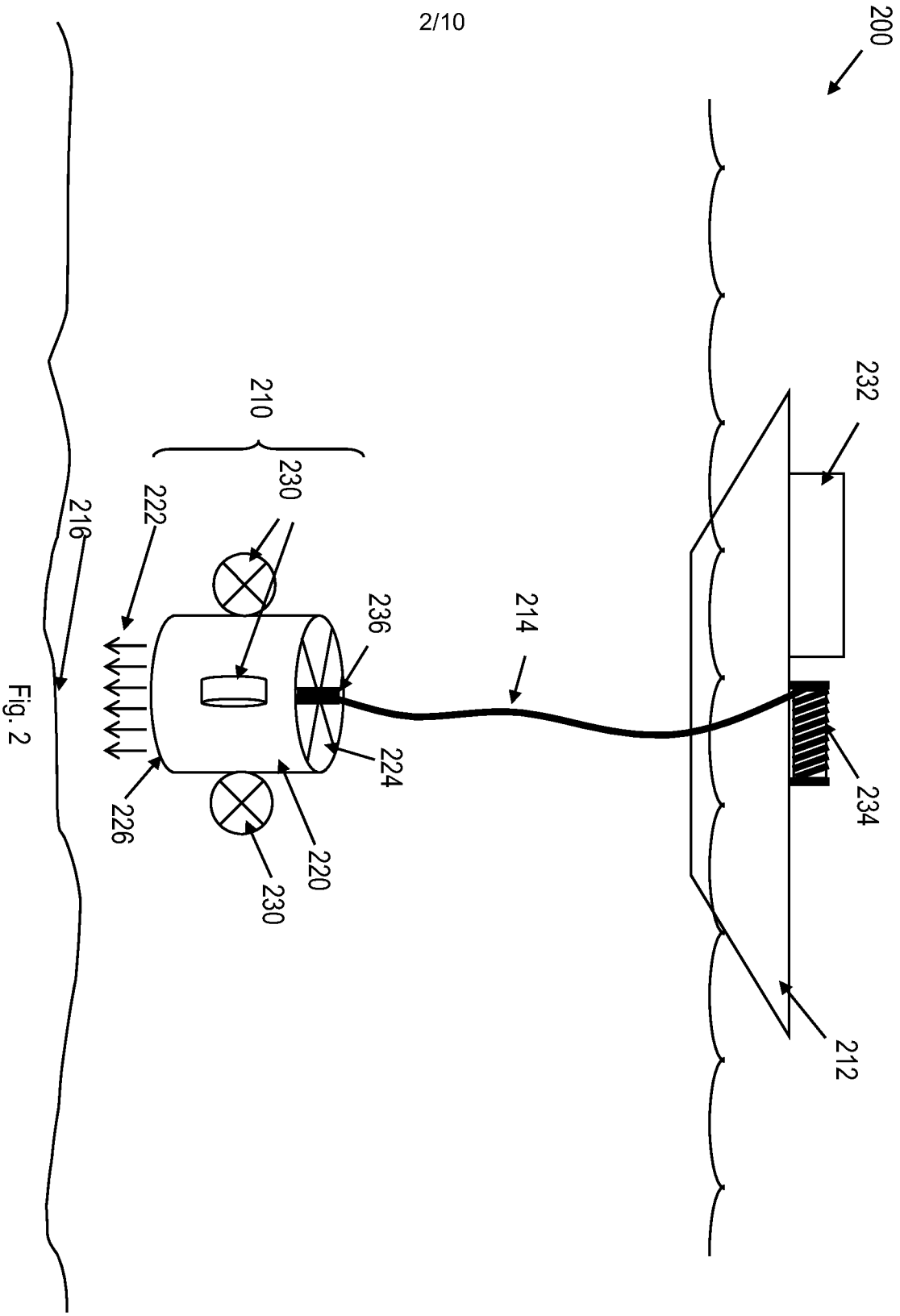
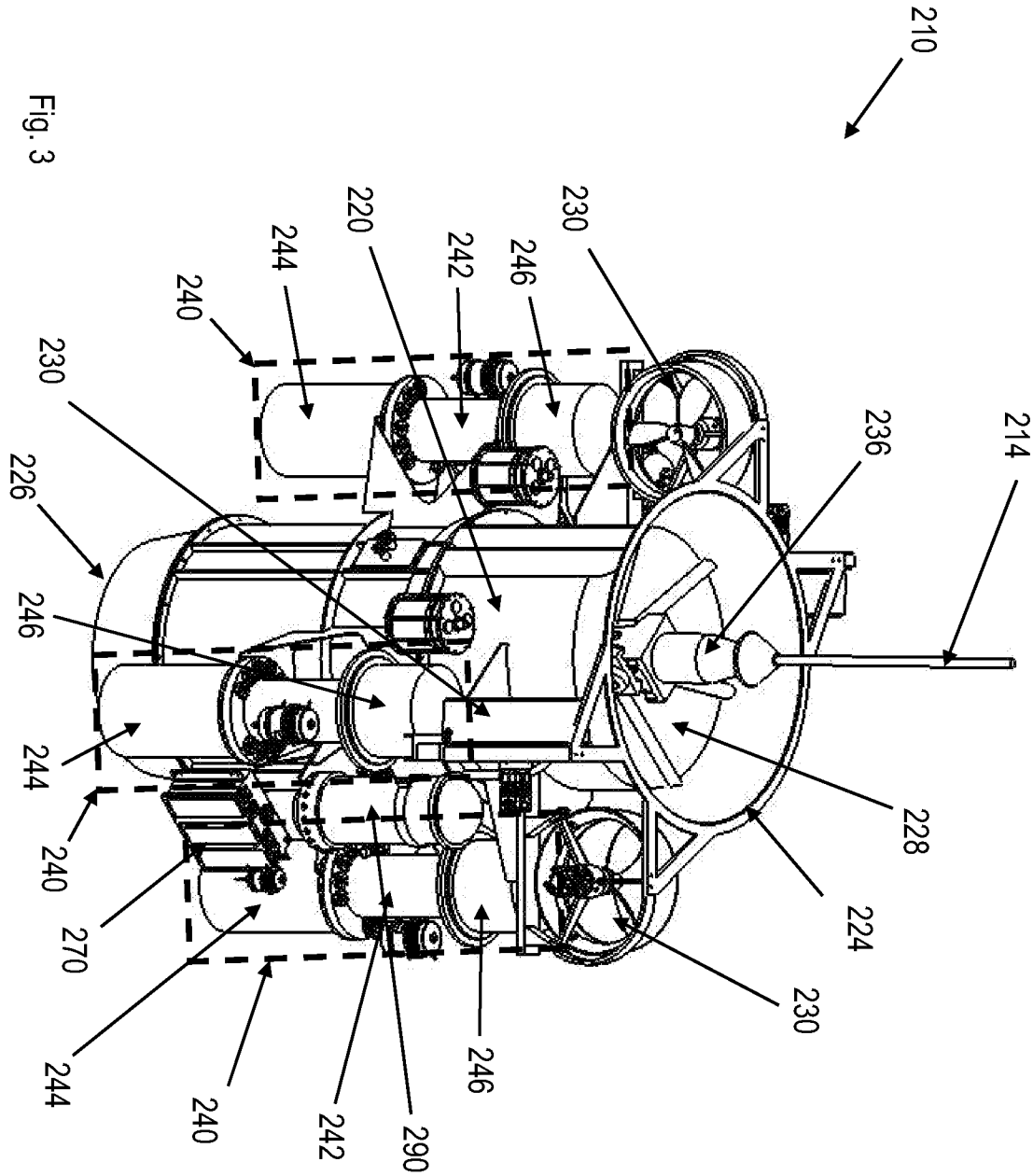


Fig. 2

Fig. 3


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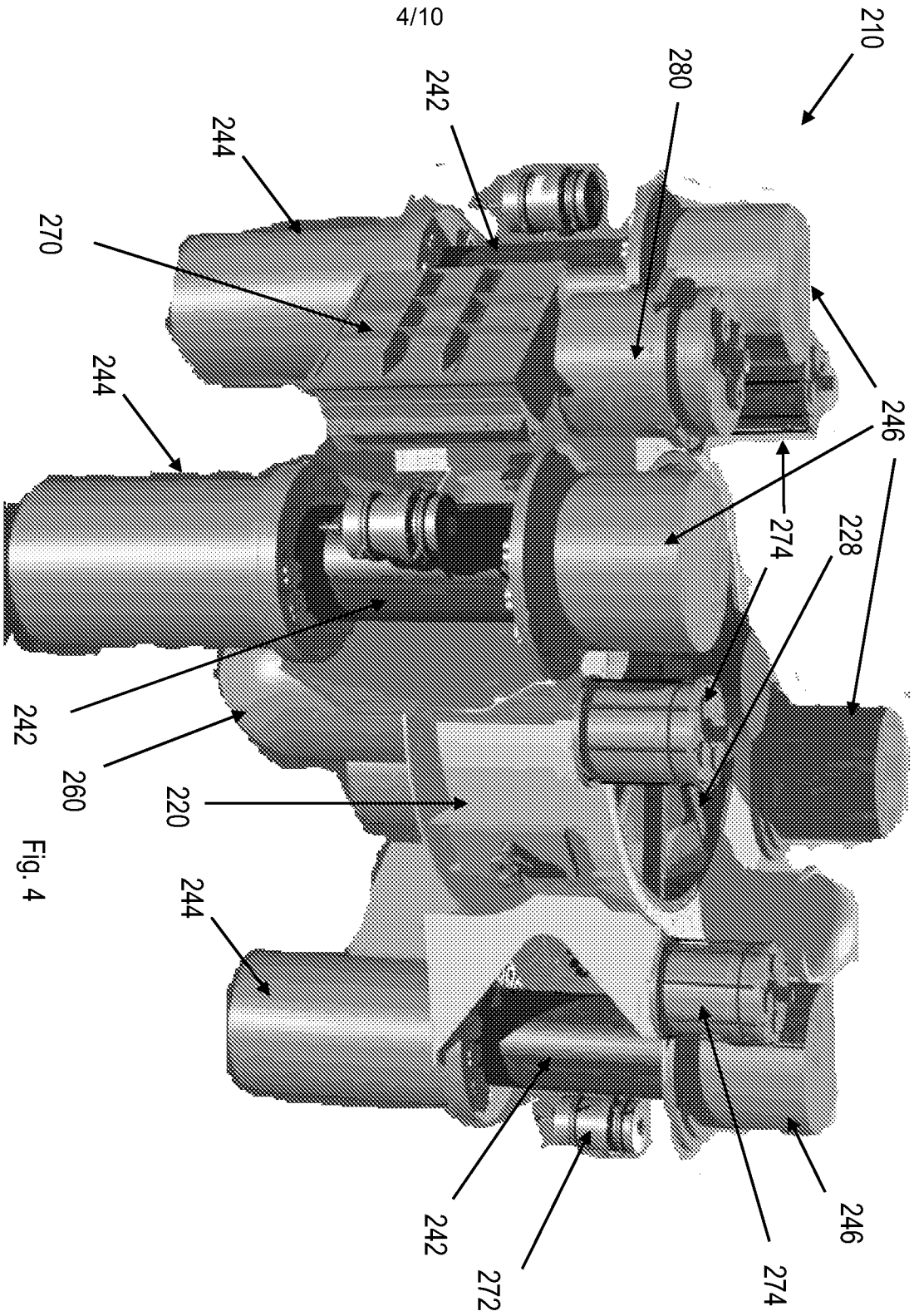

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Fig. 4

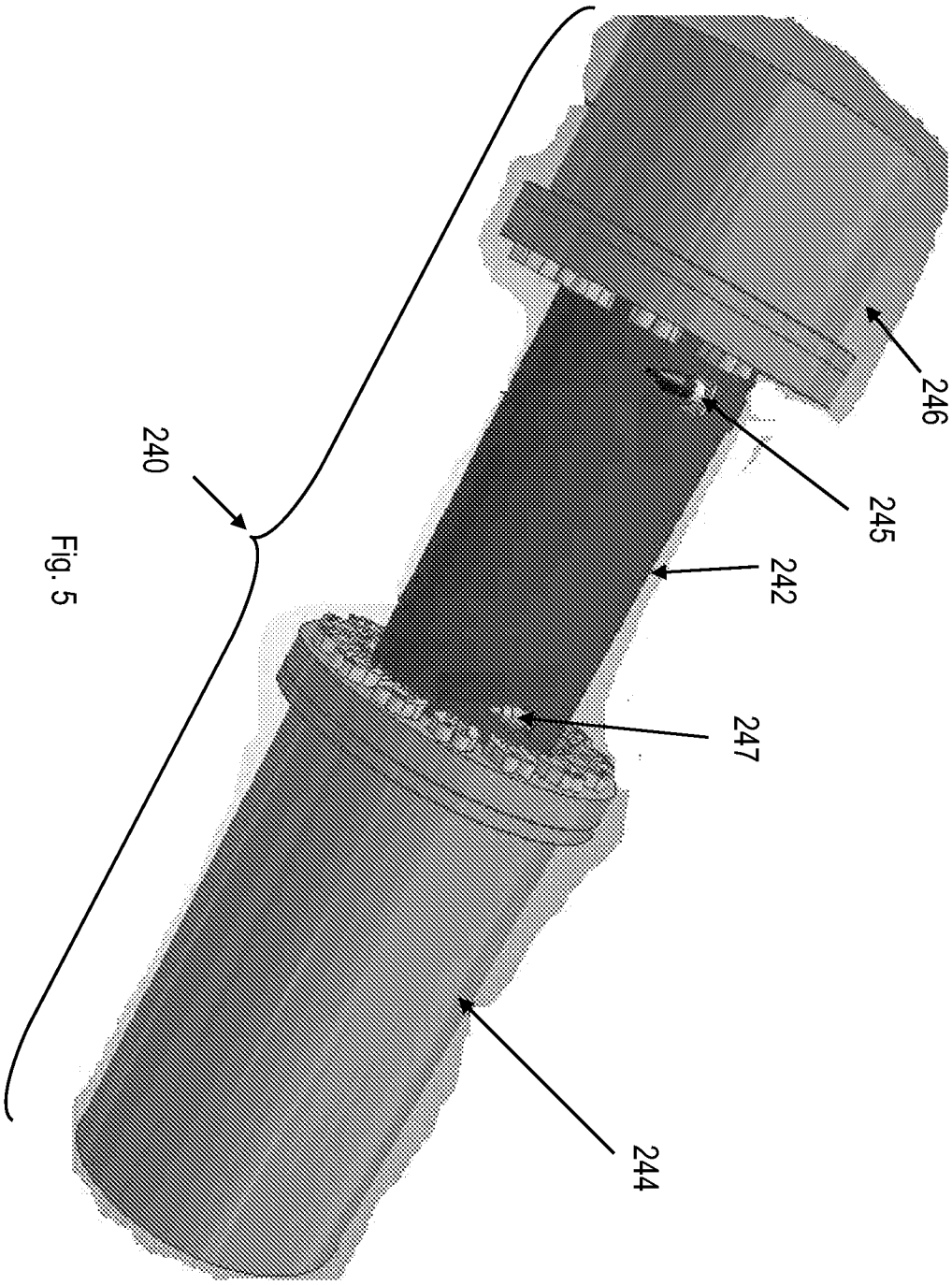


Fig. 5

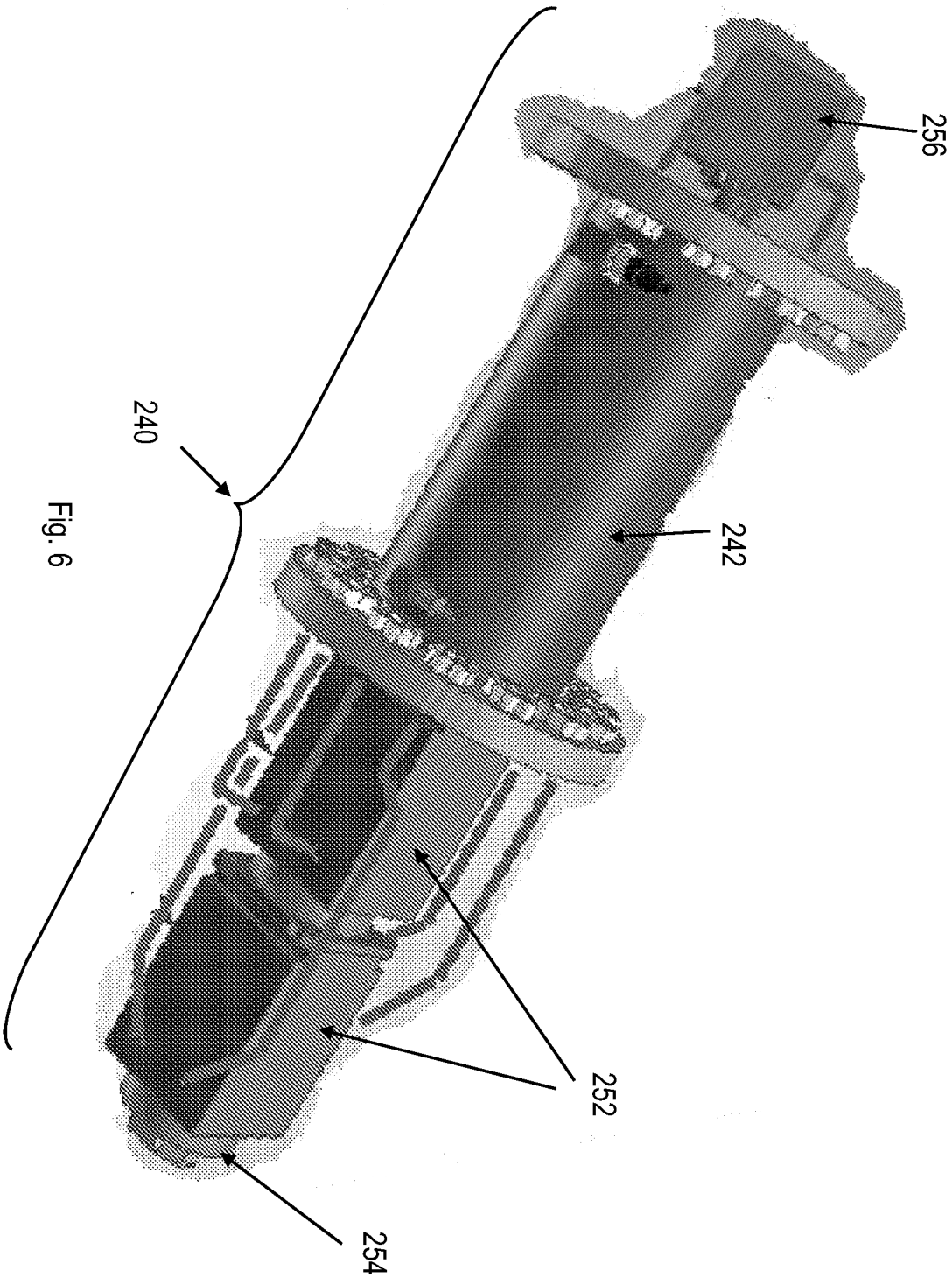


Fig. 6

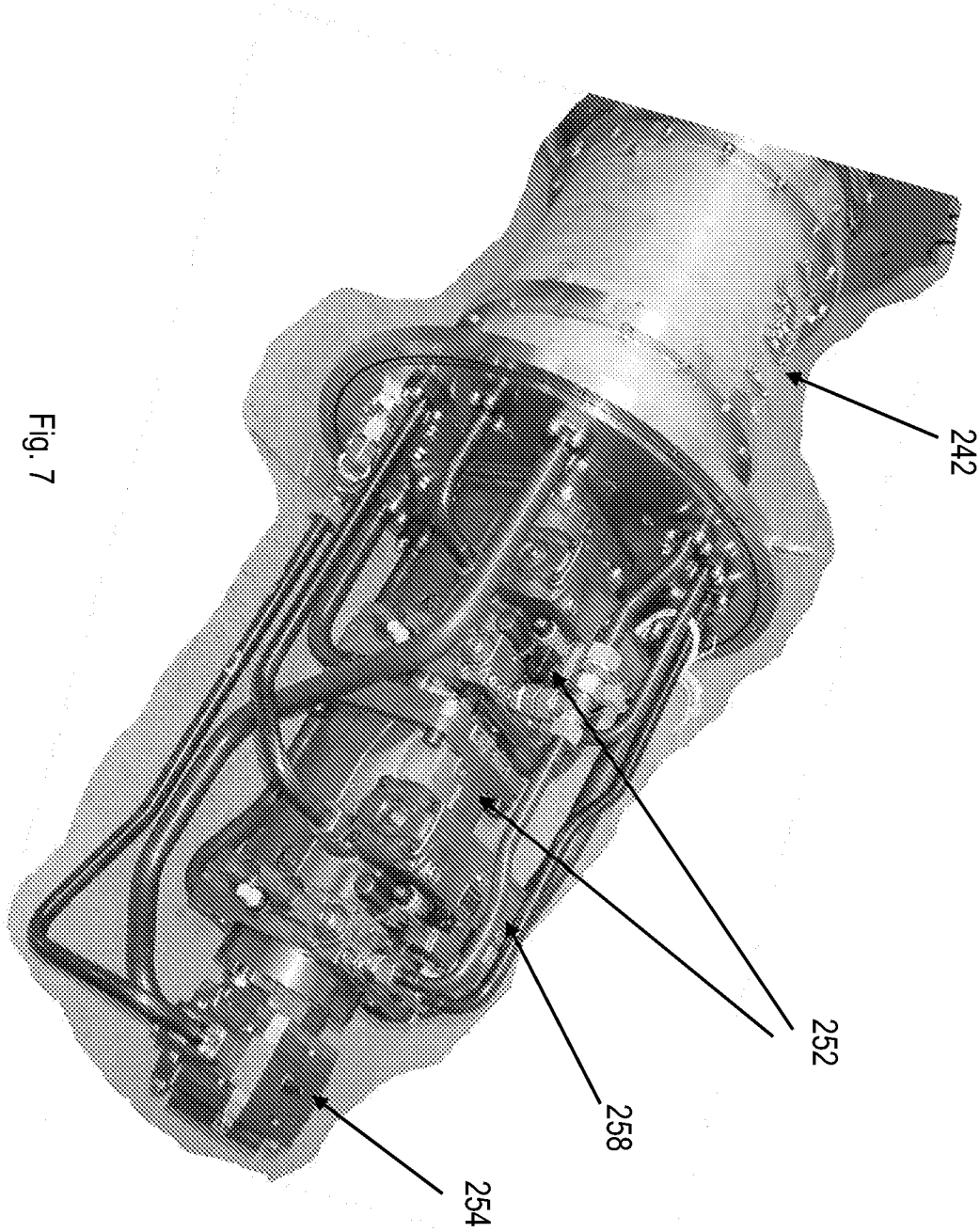


Fig. 7

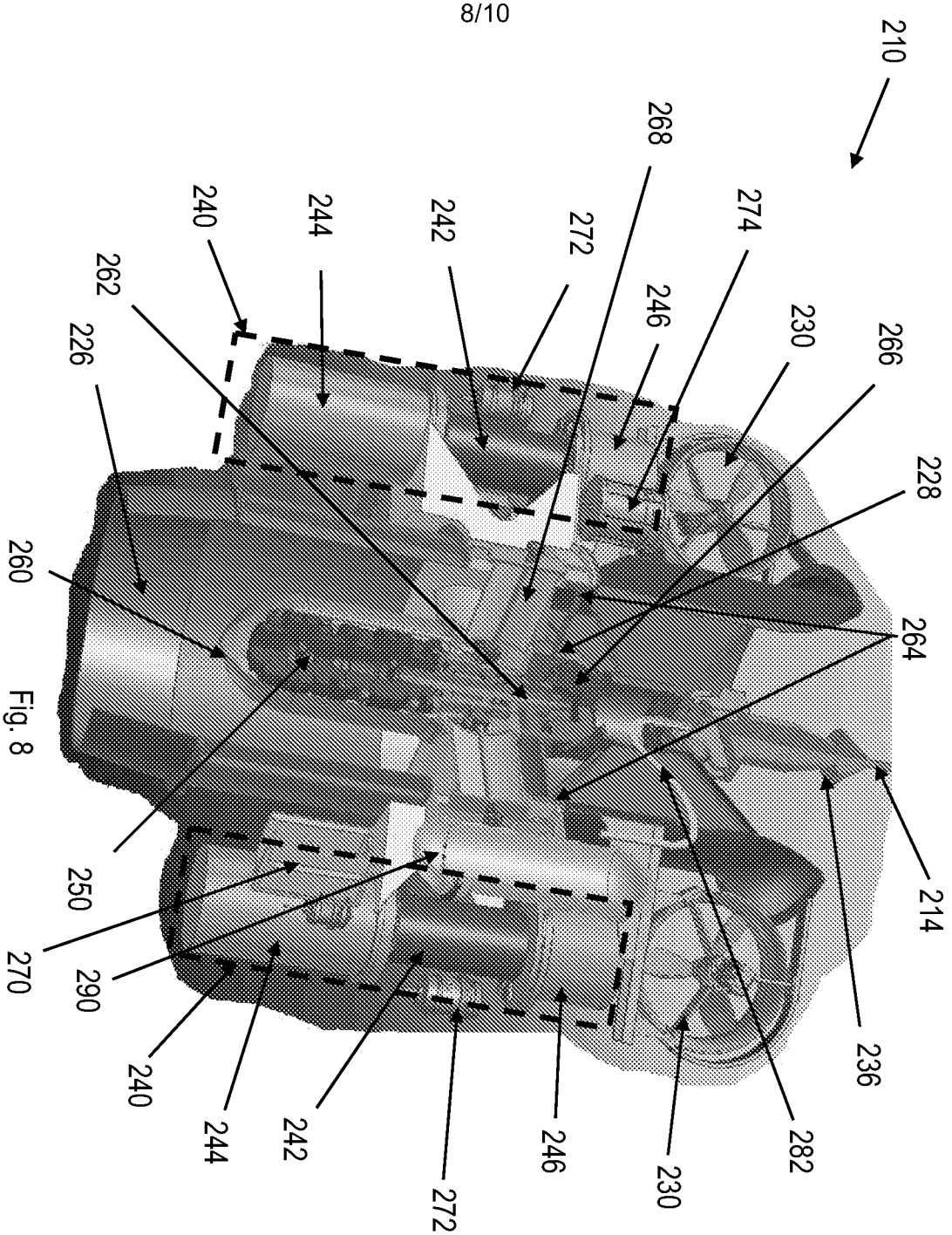

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Fig. 8

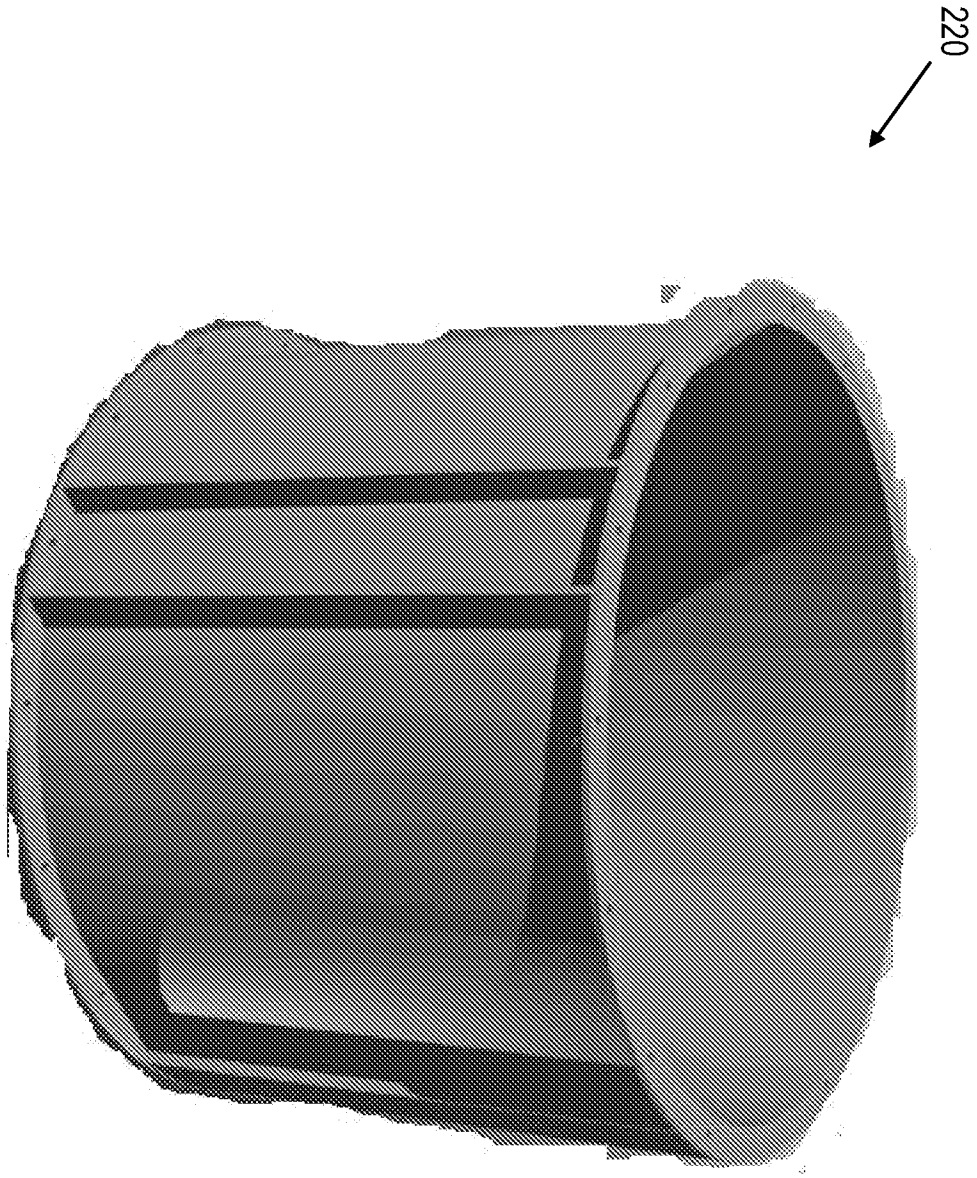


Fig. 9

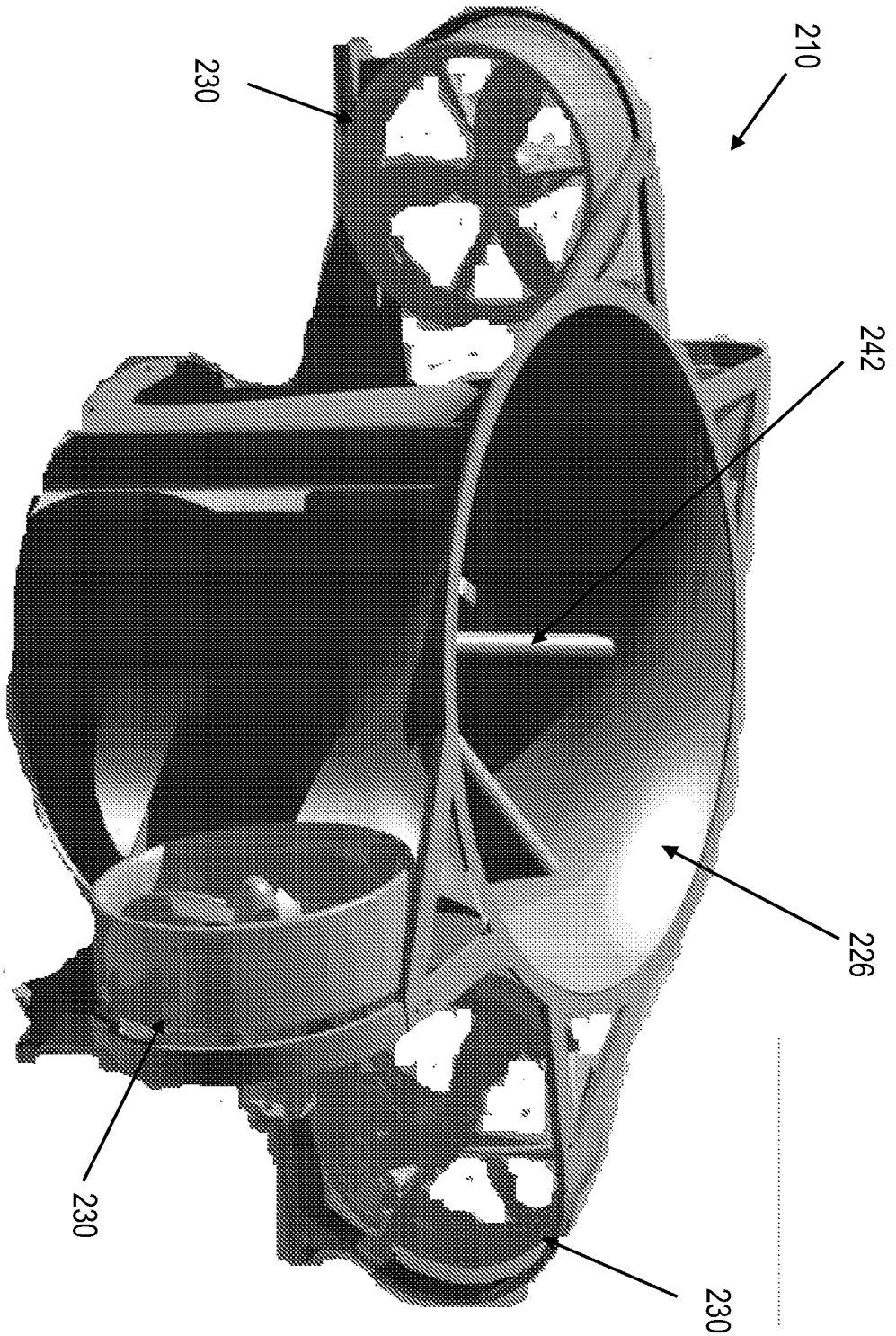


Fig. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2009/067114

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - E02F 3/88, E02F 5/00 (2010.01)
USPC - 37/195, 114/312, 37/321
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)
IPC(8) - E02F 3/88, E02F 5/00 (2010.01)
USPC - 37/195, 114/312, 37/321

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)
MicroPatent, Freepatentsonline, Google, Google Scholar

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 2008/065360 A1 (SUSMAN et al) 05 June 2008 (05.06.2008) entire document	1-21
Y	US 6,223,675 B1 (WATT et al) 01 May 2001 (01.05.2001) entire document	1-21
Y	EP 1997567 A1 (OSAKA et al) 03 December 2008 (03.12.2008) entire document	1-21
Y	GB 2301128 A (SUSMAN et al) 27 November 1996 (27.11.1996) entire document	1-16
A	US 5,016,553 A (SPENCER) 21 May 1991 (21.05.1991) entire document	1-21

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

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

Date of the actual completion of the international search	Date of mailing of the international search report
25 January 2010	14 APR 2010
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Authorized officer: Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

Form PCT/ISA/210 (second sheet) (July 2009)