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(54)	Title	**Autonomous power battery exchange system for a marine vessel.**
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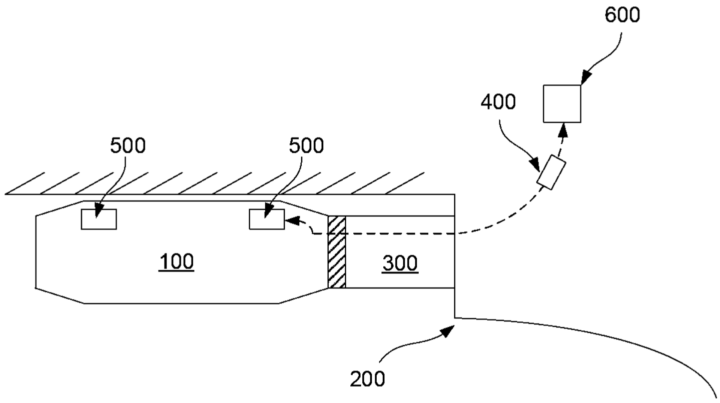
(57)	Abstract	

Autonomous power battery exchange system for a marine vessel (100) comprising self-driving battery assemblies (400), docking station (500) onboard the marine vessel (100) and charging station (600) on shore, wherein the self-driving battery assemblies (400) are arranged for autonomous movement between the docking station (500) and charging station (600) or vice versa.



Autonomous power battery exchange system for a marine vessel

The present invention is related to an autonomous power battery exchange system for a marine vessel, according to the preamble of claim 1.

Background

There is an increasing focus in the marine industry to develop environmentally friendly propulsion systems for marine vessels, where the main goal is to achieve zero emissions or close to zero emissions from the marine vessel. Propulsion systems driven electrically or hybrid electric (electric and fuel) are increasingly being used. Such systems enable the marine vessel to be driven entirely or in part by electrical energy stored in energy storage devices usually in the form of multiple batteries or battery packs.

For marine vessels with integrated energy storage device(s) (batteries) this requires a shore connection for charging of the energy storage devices.

There is further an increasing focus on reducing emission when marine vessels are at shore, by providing shore supply power/charging power for avoiding the marine vessel to use combustion engines for powering the marine vessel when at shore.

The main disadvantage with marine vessels that are driven electrically is that this requires time for charging of the energy storage devices/batteries. For marine vessel with short port time, such as ferries, this results in that the energy storage devices/batteries will not be charged enough for the marine vessel to leave the port with fully charged energy storages/batteries.

For, e.g., for an electrically powered ferry, to ensure that the energy storage device/batteries provide electric power the entire time the ferry is in operation this will require frequent charging at charging station at different ferry terminals the ferry sails to. Ferries usually lies alongside the port for as short time as ten minutes for loading/unloading. In this short period, the energy storage device of the ferry will have to be charged as much as possible. To be able to do this there is usually used a very high charging current, resulting in a heavy demand on the shore power grid that is to supply the charging current. Further, the use of this high charging current over time deteriorates the energy storage device/batteries due to high stress during the charging process.

It should further be mentioned that the charging might also be performed in combination with energy storages/batteries arranged on shore under constant charging from a shore power supply grid.

Further, this also requires the use of an advanced and expensive connection system for enabling electric power supply for charging of the energy storage device/batteries.

These connection systems will be a weak element in such a system, as any connection error will result in that the energy storage cannot be charged, and which could result in delays or cancelation of the departure of the marine vessel.

Further, even with large energy storage devices/batteries charged with high charging current, the energy storage device/batteries will gradually discharge over time during the day, and, e.g., a ferry will thus not be able to operate 24 hours without one or more periods with extended charging. To be able to charge over a longer time this will result in that the ferry will have to be taken out of operation.

Increasing the capacity of the energy storage device/batteries or arranging several energy storages/battery packs would result in higher weight on the marine vessel, as well as this would be space demanding and expensive.

Moreover, providing an infrastructure for supply of even higher charging current will be expensive and in many cases not possible due to the power grid will not be designed for this.

Accordingly, there is a desire to provide solutions that enable near continuous operation of electrically powered marine vessels. Some attempts to provide a solution have been made, which will be discussed below.

From NO20161753 A1 and WO2018084716 A1 it is known a transport system comprising a seagoing vessel with a battery room for at least one swappable battery pack for providing power for at least propulsion of the vessel, at least two battery packs, of which at least one battery pack is arranged on the vessel when the vessel is in operation, a charging station for charging the battery packs, which charging station is located outside the vessel, such that the vessel can be positioned close to the charging station for transfer of one or more battery packs between the vessel and the charging station, and a transfer device for transferring the battery packs back and forth between the vessel and the charging station when the vessel is positioned close to the charging station. A drawback of this solution is that it requires space-demanding permanent infrastructure on the port in the form of a charging station for charging the batteries and further a transfer device for transferring the batteries back and forth between the vessel and charging station. Having such a permanent infrastructure at the port will reduce the ability for using the occupied port area for other operations. Available space at ports is already limited and the introduction of a further space-demanding infrastructure is not desirable. A further disadvantage is that the solution requires adaption of the vessel to the transport device and battery pack by arranging access from exterior, i.e. the transfer device, for transferring batteries back and forth between the vessel and the charging station. This solution will thus be both expensive and complicated, as well as occupying space on the vessel and port that may be used for other purposes. Further, if the vessel is at a port where there is no such charging station and transfer device, the battery pack cannot be charged/exchanged. Similarly, if there is an error of the transfer device, the battery pack cannot be charged, as the battery pack cannot be removed from the vessel.

Further, the movements of a vessel (roll and pitch) when at shore, due to affections of weather, waves, other vessels passing in the area, as well as affection from heavy vehicles driving onboard or off the vessel, will set demands and limitations to the more or less high port tower-based battery transfer device, as regards adapting and compensating/following such movements of the vessel. It is likely that the system of NO20161753 A1 and WO2018084716 A1 will have to stop the battery exchange if the movements of the vessel are over a certain amount.

A further disadvantage is that this solution can only serve one marine vessel at time, such that if the transfer device is occupied, there are no possibilities for making battery exchange of a different marine vessel.

NL2001854 A1 describes a solution where a battery assembly arranged in a container is arranged to be transported to and from a ship by a vehicle, e.g. a truck. Containers holding the battery assembly may be fixed to a vehicle or be removably arranged to the vehicle. In the case where the containers are fixed to the vehicle, several vehicles are required for the replacement of the battery assembly. In the case where the containers are removably arranged to the vehicle, a lifting device is required on the vehicle for loading and unloading the containers to/from the vehicle. This solution accordingly requires a separate vehicle at each location for transport of the battery assembly in the case where the containers are removably arranged to the vehicle. In the case where the container is fixed to the vehicle, one separate vehicle will be required for each battery assembly. In the case with fixed containers, this will require that the vehicle is positioned on the vessel when traveling, occupying space that could be used for transport of goods or other vehicles, as well as adding weight. This solution is thus space-demanding, expensive and further requires the use of personnel driving the vehicle on and off the vessel when the battery assembly is to be replaced. Further, in the case where the containers are removably arranged to the vehicle, this will be time consuming due to the fact that both the container already arranged in the vessel will have to be uploaded and transported of the vessel and unloaded before a new container is uploaded and transported on the vessel before being unloaded.

In cases where the vessel is only at port for a short time this will be a problem. Further, this will also result in that the loading/unloading of other vehicles/goods will have to be delayed during the loading/unloading of the container.

From US2017151881 A1 is known a battery replacement system for replacing battery for an electric vehicle that includes a control system, a first self-propelled battery module and a second self-propelled battery module in communication with the control system. The first self-propelled battery module is configured to detach from the electric vehicle upon receiving an appropriate command from the control system, and the second self-propelled battery module is configured to be mounted to the electric vehicle upon receiving an appropriate command from the control system. The first self-propelled battery module and the second self-propelled battery module are capable of moving automatically to a predetermined position. A method for use of the battery replacement system is also described. The solution is not designed for autonomous movement and requires a control system for movement of the self-propelled battery modules along a predefined path.

There is accordingly a need for an autonomous power battery exchange system for marine vessel capable of operating with minimal manual interaction.

Object

The main object of the present invention is to provide an autonomous power battery exchange system for a marine vessel partly or entirely solving the mentioned drawbacks and lacks of prior art solutions.

It is further an object of the present invention to provide an autonomous power battery exchange system for a marine vessel wherein exchange of batteries may be performed approximately autonomous with minimal manual interaction.

An object of the present invention is to provide an autonomous power battery exchange system for a marine vessel enabling approximately continuous operation of electrically power marine vessels with frequent arrivals and departures.

A further object of the present invention is to provide an autonomous power battery exchange system for a marine vessel providing approximately continuous charging of battery assemblies.

It is an object of the present invention to provide an autonomous power battery exchange system for a marine vessel reducing the time and costs for performing a battery exchange on a marine vessel.

An object of the present invention is to provide an autonomous power battery exchange system for a marine vessel reducing the need for high charging current.

It is an object to provide an autonomous power battery exchange system for a marine vessel that does not require any infrastructure on the port for performing a battery exchange.

An object of the present invention is to provide an autonomous power battery exchange system for a marine vessel that meets the requirement of providing energy supply to the vessel propulsion system and energy demand onboard also when exchange of battery assemblies from/to a charging station is performed.

It is an object of the present invention to provide an autonomous power battery exchange system for a marine vessel comprising self-driving battery assemblies arranged for movement onto or off the marine vessel via a loading ramp of the marine vessel or port in a rapid, safe and stable manner without being substantially affected by vessel movements, weather conditions or waves.

Further objects of the present invention will appear from the following description, claims and attached drawings.

The invention

An autonomous power battery exchange system for a marine vessel according to the present invention is disclosed in claim 1. Preferable features of the system are disclosed in the dependent claims.

The present invention is related to an autonomous power battery exchange system for a marine vessel that is based on electrical power for operation of propulsion system and control systems.

The present invention is especially suitable for marine vessels in approximately continuous operation with frequent arrivals and departures, such as ferries.

Such energy systems are usually required to deliver 400 kWh electrical power for each crossing, i.e. between departure from one port to arrival at another port.

This electrical power will thus have to be “refilled” when the marine vessel is at the port, i.e. between arrival and departure at the same port, which time could be as short as 5-6 minutes in many ferry services.

The autonomous power battery exchange system according to the present invention is based on self-driving battery assemblies capable of autonomous movement between a charging station on shore and a docking station onboard the marine vessel and vice versa.

The self-driving battery assembly will comprise a number of batteries forming one or more battery packs for storage of electrical energy.

The present invention is based on the use of multiple such self-driving battery assemblies, and where at least one such self-driving battery assembly is arranged for approximately continuous charging at each destination for the marine vessel, and at least one self-driving battery assembly arranged on the marine vessel during a crossing to provide electrical power to the marine vessel during the crossing.

The present invention is further based on autonomous replacement of the at least one self-driving battery assembly onboard the marine vessel when the marine vessel is at its destination, i.e. lying at the port, with the at least one self-driving battery assembly that is approximately continuously charged.

Accordingly, when the marine vessel is at port, the at least one self-driving battery assembly onboard the marine vessel will disconnect from the connection to a power grid of the marine vessel and start moving off the marine vessel, while the at least one self-driving battery assembly connected to the charging station will disconnect from the connection to the charging station and move towards the marine vessel. The self-driving battery assemblies will thus use the loading ramp of the marine vessel/port for loading and unloading, respectively.

The self-driving battery assembly leaving the marine vessel will then move to the charging station and connect for being charged, while the fully charged self-driving battery assembly will enter the marine vessel and connect to the power grid of the marine vessel.

By activation manually or automated when the marine vessel is at port, the self-driving battery assembly on the marine vessel will be exchanged with the fully charged self-driving assembly in a minimum of time.

If it is required, the fully charged self-driving battery assembly may start to move towards the landing area at the port for the marine vessel before the marine vessel has finished its arrival to save even further time, as the marine vessel may departure as soon as the discharged self-driving battery assembly has moved off the marine vessel and the fully-charged driving battery assembly is connected to the power grid of the marine vessel.

As the self-driving battery assemblies according to the present invention are approximately continuously charged when connected to the charging station, this requires a substantially lower available charging effect than existing system. By that one do not need to use high charging current over a short time, this will increase the operation life of the batteries.

According to a further embodiment of the present invention the charging stations may be arranged to charge two or more self-driving battery assemblies at the time or the system may comprise several charging stations arranged to charge one or more self-driving battery assemblies at time. In this way, redundancy may be achieved as well as the system may handle several marine vessels.

The marine vessel will be provided with at least one docking station for connection to at least one self-driving battery assembly to the power grid of the marine vessel. According to a further embodiment, the docking station may be arranged for connection to two or more self-driving battery assemblies at time, or the marine vessel is provided with two or more docking stations for connection to at least one self-driving battery assemblies. In this way, redundancy may be achieved, as well as the use of several lower dimensioned self-driving battery assemblies.

For ferries, that typically will land the port from opposite sides, depending on the driving direction of vehicles thereon, there will be preferable to have at least one docking station at each side of the marine vessel to make the time for self-driving battery assembly exchange as short as possible, as well as ensuring that the exchange of the self-driving battery assemblies as little as possible is interfering with the unloading or loading of vehicles and goods from/to the marine vessel.

Accordingly, the design of the system according to the present invention may be altered from one to multiple charging stations on shore of each destination and one to multiple docking stations onboard the marine vessel.

According to a further embodiment of the docking station it is arranged for securing the self-driving battery assemblies in the docking station and thus to the marine vessel.

The charging station will further be provided with at least one electrical connection for electrical connection to the self-driving battery assemblies and at least one electrical connection for electrical connection to a power supply grid for charging.

The docking station will further be provided with at least one electrical connection for electrical connection to the self-driving battery assemblies and at least one electrical connection for electrical connection to the power grid of the marine vessel.

According to a further embodiment, the charging station and docking station are provided with means for cooling of the connected self-driving battery assemblies.

In accordance with a further embodiment of the present invention, the charging station and docking station are arranged for autonomous electrical connection and connection for cooling, if present, to the self-driving battery assemblies.

According to a further embodiment of the present invention, the charging station and docking station are provided with a monitoring system for monitoring one or more of the following: fire, temperature, battery status, correct connection of electrical connection and connection for cooling, etc. The monitoring system of the charging station may further be monitoring charging current.

The self-driving battery assemblies will be formed by a housing for accommodating the batteries/battery packs, provided with electrical connection and connection for cooling exterior of the housing.

The self-driving battery assemblies are further provided with transport means, such as wheels or belts, at lower side of the housing, enabling the self-driving battery assemblies to move between the docking station and charging station or vice versa. The transport means are driven by at least one electrical motor powered by the chargeable batteries or by a separate chargeable battery.

The self-driving battery assemblies according to the present invention is further provided with a positioning system and a sensor system enabling positioning in relation to the docking station and charging station.

According to a further embodiment of the present invention, also the charging station and docking station are provided with positioning means for enabling enhanced positioning of the self-driving battery assemblies in relation to the docking station and charging station, respectively.

In accordance with a further embodiment of the present invention, the self-driving battery assembly, docking station and charging station are provided with communication means for mutual communication and external communication.

The self-driving battery assemblies may according to a further embodiment be arranged for remote controlling by an operator if required.

According to a further embodiment of the autonomous power battery exchange system for a marine vessel, it comprises at least one fully charged self-driving battery assembly positioned onboard the marine vessel at all time to meet the requirement of providing energy supply to the vessel propulsion system and energy demand onboard also when exchange of battery assemblies from/to a charging station is performed.

By the present invention is accordingly provided an autonomous battery exchange system for a marine vessel comprising multiple self-driving battery assemblies that will be able to use existing infrastructure, i.e. loading ramp of the marine vessel or port, and which will not be affected by vessel movements, waves or other exterior disturbances, that further enables the exchange of battery assemblies in a rapid and safe manner.

The present invention further provides a solution that reduces the time required for performing an exchange of battery assemblies that make sure that the marine vessel may departure at correct time.

The present invention further provides a solution that does not require expensive and space-demanding infrastructure at port or the marine vessel.

The present invention further provides a solution where a high degree of redundancy may be achieved by increasing the number of self-driving battery assemblies.

The present invention also provides a solution that may be used to serve several marine vessel, unlike prior art systems that require a one-to-one mapping. By the present invention, several self-driving battery assemblies may go to and from different marine vessels at the same time.

Further preferable features and advantageous details of the present invention will appear from the following example description, claims and attached drawings.

Example

The present invention will below be described in further detail with references to the attached drawings, where:

Fig. 1 is a principle drawing of an autonomous power battery exchange system for marine vessel according to the present invention,

Fig. 2a-b are principle drawings of a self-driving battery assembly according to the present invention,

Fig. 3a-b are principle drawings of a docking station according to the present invention,

Fig. 4a-b are principle drawings a charging station according to the present invention, and

Fig. 5 is a principle drawing of a connection assembly that may constitute electrical connections in the system.

Reference is first made to Fig. 1 which is a principle drawing of an autonomous battery exchange system for a marine vessel 100 based on electrical power for operation of propulsion system and control systems.

In the example is shown a marine vessel 100 in the form of a ferry positioned at a port 200. The marine vessel 100 or port 200 will be provided with a loading ramp 300 enabling loading and unloading of vehicles and goods to and from the marine vessel 100.

The main components of the system according to the present invention are multiple self-driving battery assemblies 400, at least one docking station 500 arranged on the marine vessel 100 and at least one charging station 600 arranged on shore in the vicinity of the port 200.

Reference is now made to Figures 2a-b showing principle drawings of a self-driving battery assembly 400 according to the present invention. According to the present invention the self-driving battery assembly 400 is formed by a housing 410 for accommodating multiple chargeable batteries 420 (battery packs), provided with at least one electrical connection 430 and connection for cooling 440 of the batteries 420. The at least one electrical connection 430 is connected to the chargeable batteries 420 via a battery management system 421 (BMS) via power cables 422. BMS 421 is well known for a skilled person and requires no further explanation herein.

The self-driving battery assembly 400 according to the present invention is further provided with transport means 450 in the form of wheels 451 or belts, arranged at lower side of the housing 410 enabling the self-driving battery assemblies 400 to move between the docking station 500 and charging station 600 or vice versa. The transport means 450 are preferably powered by several electrical motors 452 enabling separate and mutual control of the respective wheels or belts, to enable controlled movement of the self-driving battery assemblies 400. The electric motors 452 powering the transport means 450 are powered from the chargeable batteries 420 or at least one separate chargeable battery 423 arranged for powering the self-driving battery assembly 400 when not connected to the docking station 500 or charging station 600.

The self-driving battery assembly 400 according to the present invention is further provided with a control unit 460, positioning system 470, sensor system 480 and communication means 490.

The positioning system 470 comprises a short-range positioning module 471 enabling short-range positioning in relation to the charging station 600 and docking station 500, respectively. Such a short-range (local) positioning will be required to achieve precise maneuvering in relation to the charging station 600 and docking station 500.

The positioning system 470 may further be provided with a global positioning system 472 that may be used for controlling of the self-driving battery assembly 400 when on shore.

The sensor system 480 of the self-driving battery assembly 400 will provide input to the control unit 460 for safe controlling of the self-driving battery assemblies 400 between the charging station 600 and docking station 500 or vice versa. The sensor system 480 is provided with sensors to monitor the surroundings of the self-driving battery assemblies 400, such as one or more of: radar, computer vision, Lidar, sonar, GPS, odometry, inertial measurement units, etc.

The control unit 460 is provided with means and/or software for interpreting sensor information from the sensor system 480 and information from the positioning system 470 to identify appropriate navigation paths from the charging station 600 to the docking station 500 and vice versa, as well as detecting and avoiding obstacles, and controlling movement of the self-driving battery assembly 400 by controlling the transport means 450.

The self-driving battery assembly 400 will according to a further embodiment be provided with required brakes and emergency brake systems, as well as light and sound systems that are required for autonomous vehicles, to satisfy demands to both the surroundings and regulations for vehicles, and road traffic act, also known as national requirements for slow-moving or self-driving vehicles without registration requirements.

According to a further embodiment, the self-driving battery assembly 400 is provided with a control interface (not shown) enabling the self-driving battery assembly 400 to be manually controlled if desired or required.

In accordance with a further embodiment of the self-driving battery assembly 400, the transport means 450 are arranged to be disconnected from the electrical motors 452 such that the self-driving battery assembly 400 may be towed if required.

The communication means 490 will be arranged for communication with the docking station 500 and charging station 600, as well as external communication with a superior control system.

Reference is now made to Figure 3a which is a principle drawing of a docking station 500 with a self-driving battery assembly 400 according to the present invention received and connected therein, as well as Figure 3b which is a block diagram of the docking station 500. According to the present invention the marine vessel 100 is provided with at least one docking station 500, and in the shown example the marine vessel 100 is provided with two docking stations 500 one at each side of the deck of the marine vessel 100. The docking station 500 is formed by a housing 510 adapted for receiving and accommodating the self-driving battery assemblies 400 via an opening 511 at one side of the housing 510.

The docking station 500 according to the present invention is provided with an electrical connection 520 adapted the electrical connection 430 of the self-driving battery assembly 400 and a connection 530 for cooling adapted the connection 440 for cooling of the self-driving battery assembly 400. The connections 430, 440 and 520, 530, respectively, are preferably arranged as quick snap connections. The connections 520, 530 may be fixed arranged in the docking station 500 and where one use the moving force of the self-driving battery assembly 400 for connection and disconnection. In the shown embodiment in Figure 3a, the connections 520 and 530 are arranged to a manipulator 540 arranged for movement of the connections 520 and 530 in relation to the connections 430 and 440, respectively, of the self-driving battery assembly 400 for connection thereto. The connections 430, 440 may be arranged on any side of the housing 410 of the self-driving battery assembly 400 and the manipulator 540 arranged in corresponding position in the housing 510. In the shown example there is shown an example of manipulator 540 arranged movable at least in longitudinal direction or vertical direction, or both, of the housing 510 for connection, depending on where on the housing 410 of the self-driving battery assembly 400 the connections 430, 440 are arranged. In yet at further embodiment, the connections 520 and 530 are arranged on a tiltable and/or rotatable platform (not shown) arranged to the manipulator 540 providing further degrees of freedom for movement of the connections 520 and 530. In this way, any irregularities on the surface of the housing 510 or wheels/belts 451 may be compensated for.

According to a further embodiment of the docking station 500, it is provided with fastening means 550 arranged for securing the self-driving battery assembly 400 to the housing 510 and thus the marine vessel 100 to prevent the self-driving battery assembly 400 moving due to movement of the marine vessel 100. The fastening means 550 will be arranged for autonomous connection to the housing 410 of the self-driving battery assembly 400 by comprising a manipulator 551 being at least movable in longitudinal or vertical direction, or both, of the housing 510, and wherein the housing 410 of the self-driving battery assembly 400 and manipulator 551 are provided with corresponding attachment means 552. The attachment means 552 may be arranged on any side of the housing 410 of the self-driving battery assembly 400 and the manipulator 551 arranged in corresponding position in the housing 510. In yet at further embodiment, the attachment means 552 is arranged on a tiltable and/or rotatable platform arranged to the manipulator 551 providing further degrees of freedom for movement of the attachment means 552 relation to the attachment means 552 on the self-driving battery assembly 400. In this way, any irregularities on the surface of the housing 510 or wheels/belts 451 may be compensated for.

In an alternative embodiment, the self-driving battery assembly 400 is relying on brakes and the friction of the wheels 451 or belts and wherein the manipulator 540 is arranged to compensate for any possible movement of the self-driving battery assembly 400 in relation to the housing 510 due to vessel movements.

The docking station 500 will further be provided with a cooling unit 531, e.g. an air-cooling unit or fluid cooling unit, arranged to the connection 530 for cooling of the batteries 420 of the self-driving battery assembly 400 when connected to the docking station 500.

The docking station 500 will further preferably be provided with at least one short-range (local) positioning unit 560 for enabling accurate positioning of the self-driving battery assembly 400 in relation to the docking station 500.

According to a further embodiment, the docking station 500 is provided with communication means 570 for external communication, such as a superior control system, as well as communication with the self-driving battery assembly 400.

According to a further embodiment of the docking station 500, it further comprises a monitoring system 580 for monitoring one or more of the following: fire, temperature, battery status, correct connection of electrical connection and connection for cooling, etc.

The docking station 500 will further be provided with a control unit 590 provided with means and/or software for controlling the connection to the self-driving battery assembly 400 by controlling the manipulator 540, if present, for connection of the connections 520, 530 to the connections 430, 440, as well as controlling the fastening means 550, if present.

The docking station 500 will be connected to the power grid 700 of the marine vessel 100 via power cables 710.

The docking station 500 may further be provided with a closable lid or door(s) (not shown) for opening or closing the opening 511 in the housing 510. The housing 510 may further be provided with one or more open sides if desired.

Reference is now made to Figure 4a which is a principle drawing of a charging station 600 with a self-driving battery assembly 400 according to the present invention received and connected therein, as well as Figure 4b which is a block diagram of the charging station 600. According to the present invention, at least one such charging station 600 is arranged at an appropriate location on shore, close to the port 200. The charging station 600 is formed by a housing 610 adapted for receiving and accommodating the self-driving battery assemblies 400 via an opening 611 at one side of the housing 610.

The charging station 600 according to the present invention is provided with an electrical connection 620 adapted the electrical connection 430 of the self-driving battery assembly 400 and a connection 630 for cooling adapted the connection 440 for cooling of the self-driving battery assembly 400. The connections 620, 630 and 430, 440, respectively, are preferably arranged as quick snap connections. The connections 620, 630 may be fixed arranged in the charging station

600 and where one use the moving force of the self-driving battery assembly 400 for connection and disconnection. In the shown embodiment in Figure 4a, the connections 620 and 630 are arranged to a manipulator 640 arranged for movement of the connections 620 and 630 in relation to the connections 430 and 440, respectively, of the self-driving battery assembly 400 for connection thereto. The connections 430, 440 may be arranged on any side of the housing 410 of the self-driving battery assembly 400 and the manipulator 640 arranged in corresponding position in the housing 610. In the shown example there is shown an example of a manipulator 640 arranged movable in at least longitudinal direction or vertical direction, or both, of the housing 610 for connection, depending on where on the housing 410 of the self-driving battery assembly 400 the connections 430, 440 are arranged. In yet at further embodiment, the connections 620 and 630 are arranged on a tiltable and/or rotatable platform (not shown) arranged to the manipulator 640 providing further degrees of freedom for movement of the connections 620 and 630. In this way, any irregularities on the surface of the housing 610 or wheels 451/belts may be compensated for.

The charging station 600 will further be provided with a cooling unit 631, e.g. an air-cooling unit or fluid cooling unit, arranged to the connection 630 for cooling of the batteries 420 of the self-driving battery assembly 400 when connected to the charging station 600.

The charging station 600 will further preferably be provided with at least one short-range (local) positioning unit 650 for enabling accurate positioning of the self-driving battery assembly 400 in relation to the charging station 600.

According to a further embodiment, the charging station 600 is provided with communication means 660 for external communication, such as a superior control system, as well as communication with the self-driving battery assembly 400.

According to a further embodiment of the charging station 600, it further comprises a monitoring system 670 for monitoring one or more of the following: fire, temperature, battery status, correct connection of electrical connection and connection for cooling, charging current, etc.

The charging station 600 will further be provided with a control unit 680 provided with means and/or software for controlling the connection to the self-driving battery assembly 400 by controlling the manipulator 640, if present, for connection of the connections 620, 630 to the connections 430, 440.

The charging station 600 will be connected to a shore supply power grid 800 via power cables 810.

The charging station 600 may further be provided with a closable lid or door(s) (not shown) for opening or closing the opening 611 in the housing 610. The housing 610 may further be provided with one or more open sides if desired.

The short-range (local) positioning means 471, 560 and 650, respectively of the self-driving battery assembly 400, docking station 500 and charging station 600, thus form a positioning network with three nodes, wherein the position of the charging station 600 will be fixed, and the position of the docking station 500 will be fixed due to fixed position on the marine vessel 100 and the fixed position of the marine vessel 100 in relation to the port 200. Additional nodes (beacons) may be arranged at fixed positions on the port 200 or the marine vessel 100 to further increase the accuracy of the short-range (local) positioning of the self-driving battery assembly 400.

Examples of short-range positioning units 560, 650 may e.g. be active or passive retroreflectors, transponders, laser-based systems, RFID-systems, optical systems or similar, suitable for cooperating with the short-range positioning module 471 of self-driving battery assembly 400 or the sensor system 480 of the self-driving battery assembly 400.

Reference is now made to Figure 5 showing a principle drawing of an example of an electrical connection plug assembly 900 that may be used in the present invention formed by a male assembly 910 and a female assembly 920, wherein one of the assemblies is arranged on the self-driving battery assembly 400 and constituting the electrical connection 430 and the other assembly is arranged in the docking station 500 and the charging station 600 and constituting the electrical connection 520 and 620, respectively. In the shown embodiment the male assembly 910 and female assembly 920, respectively, have been arranged in a housing 911 and 921, respectively, preferably formed by a non-conductive material, such as composite or similar casting materials, which housings 911 and 921, respectively, are arranged in the housings 410, 510, 610 of self-driving battery assembly 400, docking station 500 and charging station 600, respectively. It will also be preferable that the housing 911, 921 are water resistant. Preferably, the female housing 921 is designed to exhibit a funnel shape to ease the insertion of the male assembly 910 in the female assembly 920.

The male assembly 910 is in the shown embodiment formed by a mainly disc-shaped main body 912. The male assembly 910 is further at one side of the main body 912 provided with mainly cylinder-shaped protruding parts 913 adapted for accommodating and enclosing male electrical connectors 914. The protruding parts 913 may also exhibit a mainly conical shape. The protruding parts 913 accordingly constitute an isolator for the male electrical connectors 914 and will be formed by a non-conductive material. The male electrical connectors 914 are fixed at distal end of the mainly cylinder-shaped protruding parts 913 and preferably exhibit a protruding part 915 extending out of the mainly cylinder-shaped protruding parts 913. At the opposite side of the protruding part 915, the male electrical connector 914 is provided with a connection 916, such as a crimp connection/housing, for connection to power cables 810 of the electrical shore power supply grid 800 or power cables 710 of the vessel power grid 700 power or power cables 422 of the battery management system 421 of the self-driving battery assembly 400, wherein the main body 912 is provided with through holes 917 corresponding with the mainly cylinder-shaped protruding part 913 for receiving and accommodating the power cables 422, 710, 810, respectively. After the power cables 422, 710, 810, respectively are connected to the male electrical connectors 914, the holes 917 are preferably sealed by the same non-conductive material as is used for the protruding parts 913 to ensure a sealed cable gland.

The mainly cylinder-shaped protruding parts 913 is further provided with an annular recess 918 with an extension in longitudinal direction of outer wall of the mainly cylinder-shaped protruding parts 913, the function of which will be further described below.

The female assembly 920 is in the shown embodiment formed by a mainly cylinder-shaped main body 922 with one open end and one closed end.

The female assembly 920 is further at one side of the main body 922 provided with mainly cylinder-shaped protruding parts 923 adapted for accommodating and enclosing female electrical connectors 924. The protruding parts 923 may also exhibit a mainly conical shape. The female assembly 920 further comprises female electrical connectors 924 fixed at lower part of the mainly cylinder-shaped protruding parts 923. The protruding parts 923 accordingly constitute an isolator for the female electrical connectors 924 and will be formed by a non-conductive material. In the shown embodiment of the female assembly 920, the female electrical connectors 924 are formed by a main body 925 with a disc shape, wherein the main body 925 is provided with an elevation 926 at a part of the side of the main body 925 facing the open end of the mainly cylinder-shaped protruding parts 923. To the elevation 926 is arranged connector fingers 927, extending in a parallel horizontal plane of the main body 925, wherein the connector fingers 927 are fixed at one side to the elevation 926 by means of a fixation element 928 and are free at the other end. The connector fingers 927 are preferably made of a material exhibiting spring properties, such as Beryllium copper or a similar material, which in addition to spring properties also is corrosion resistant. In a preferred embodiment, the connector fingers 927 at the free end thereof, at the side facing the open end of the mainly cylinder-shaped projections 923, are provided with silver contacts 929 for enhanced connection with the male electrical connectors 927.

The design of the protruding parts 913 and 923 of the male assembly 910 and female assembly 920, respectively, ensures that the creep current length becomes large. In the shown examples, the creep current length satisfies the requirements for 24 kV in harsh environments.

The female electrical connector 920 is further provided with a power cable connectors 930 extending from the main body 925 of the electrical connector 924 and to the exterior of the female assembly 920 via holes arranged in the main body 922 of the female assembly 930, for connection with power cables 810 of the electrical shore power supply grid 800 or power cables 710 of the vessel power grid 700 power or power cables 422 of the battery management system 421 of the self-driving battery assembly 400, respectively. In the shown embodiment, the power cable connectors 930 are extending in a horizontal direction out of the main body 922.

The mainly cylinder-shaped protruding parts 923 of the female assembly 920 are further provided with an annular recess 931 with an extension in longitudinal direction of outer wall of the mainly cylinder-shaped protruding parts 923, the function of which will be further described below.

The mainly cylinder-shaped protruding parts 923 and annular recesses 931 of the female assembly 930 and the mainly cylinder-shaped protruding parts 913 and annular recesses 918 of the male assembly 910 are adapted to each other, such that the mainly cylinder-shaped protruding parts 913 of the male assembly 910 are received and accommodated in the mainly cylinder-shaped protruding parts 923 of the female assembly 920.

According to the shown embodiment of the electrical connection plug assembly 900, the female assembly 920 is further provided with seals 932, such as an O-ring, at bottom of the annular recesses 931, such that when the mainly cylinder-shaped protruding parts 913 of the male assembly 910 are received and accommodated in the mainly cylinder-shaped protruding parts 923 of the female assembly 920, a sealing is provided between the male assembly 910 and female assembly 920.

The female assembly 920 is further, at the open end, provided with an annular seal 933, such as an O-ring, arranged in an annular recess extending along the open end of the main body 922, such that when the male assembly 910 is arranged to the female assembly 920, the inner space of the female assembly 920, and thus electrical connection plug assembly 900, is sealed by that the main body 913 of the male assembly 910 is in contact with main body 922 of the female assembly 920 via the annular seal 933.

The female assembly 920 is further provided with means for providing vacuum in the sealed inner space of the electrical connection plug assembly 900, when the male 910 and female 920 assemblies are arranged to each other. According to the present invention, this is achieved by that there are arranged channels, tubes or hoses 940 extending from a vacuum generating device 950, such as a vacuum pump, and into each of the mainly cylinder-shaped protruding parts 923 of the female assembly 920 via through holes 941 arranged in the main body 922 corresponding with the mainly cylinder-shaped protruding parts 923, which are capable of providing a vacuum in the sealed inner space of the electrical connection plug assembly 900. After the channels, tubes or hoses 940 are arranged in the female assembly 920, as well as the female electrical connectors 924, the holes 941 are preferably sealed by the same non-conductive material as is used for the protruding parts 923 to ensure a sealed channel, tube or hose gland.

If necessary or desired, also the male assembly 910 can be provided with channels, tubes or hoses 940 extending from a vacuum generating device 950 and into the mainly cylinder-shaped protruding parts 913 of the male assembly 910.

At the use of the above disclosed electrical connection assembly 900 for the electrical connections 430, 520, 620, the control unit 460, 590, 680 of the self-driving battery assembly 400, docking station 500 or charging station 600, respectively, will be provided with means and/or software for controlling the vacuum generating device 950 at connection.

Accordingly, when the male assembly 910 is received and accommodated in the female assembly 920, wherein the seals 932 and 933 ensure that the inner space of the electrical connection plug assembly 900, formed by the male assembly 910 and the female assembly 920, is sealed, whereupon the vacuum generating device 950, can be activated to ensure that necessary pulling force is achieved between the male assembly 910 and the female assembly 920. The use of vacuum will provide a safe retention force of the male assembly 910 to the female assembly 920 together with the mechanical connection, and ensure safe connection/contact force between the electrical connectors 914, 924 of the male assembly 910 and female assembly 920, respectively.

Accordingly, by using the male assembly 910 for the electrical connections 520 and 620 of the docking stations 500 and charging station 600, respectively, and the female assembly 920 for the electrical connections 430 of the self-driving battery assembly 400, or vice versa, the connection described above may be used for improved efficiency for connection, as well as improved safety by reducing the opportunities for electrical flashover and risk of electrical creep current in the electrical connection. The solution is further suitable for autonomous connection by the described manipulators 540, 640, due to the connection will be mainly self-plugging.

According to a further embodiment of the autonomous power battery exchange system for a marine vessel 100, it comprises arranging at least one fully charged self-driving battery assembly 400 onboard the marine vessel 100 at all times such that the vessel propulsion system and energy demand onboard can be provided with energy also when exchange of the self-driving battery assemblies 400 from/to the charging station 600 is performed. By that, the docking station 500 is arranged for connection to several self-driving battery assemblies 400 at the time or that the marine vessel 100 is provided with several docking stations 500 this may be achieved.

Features of the above described embodiments may be combined to form modified embodiments within the scope of the enclosed claims.

Claims

1. Autonomous power battery exchange system for a marine vessel (100), wherein the marine vessel (100) is based on electrical power for operation of propulsion system and control systems, wherein the system comprises:

- multiple self-driving battery assemblies (400) provided with transport means (450),

- at least one docking station (500) arranged on the marine vessel (100) in electrical connection with a vessel power grid (700),

- at least one charging station (600) arranged in vicinity of a port (200) in electrical connection with a power supply grid (800), and

wherein the self-driving battery assemblies (400), at least one docking station (500) and charging station (600) are provided with corresponding electrical connections (430, 520, 620) for electrical connection therebetween,

characterized in that the self-driving battery assemblies (400) are arranged for autonomous movement between the docking station (500) and charging station (600) or vice versa when the marine vessel (100) is at a port (200), by that the self-driving battery assemblies (400) are provided with a control unit (460), positioning system (470) and sensor system (480) monitoring the surroundings of the self-driving battery assembly (400), wherein the control unit (460) is provided with means and/or software for interpreting sensor information from the sensor system (480) and information from the positioning system (470) to identify appropriate navigation paths from the charging station (600) to the docking station (500) and vice versa, as well as detecting and avoiding obstacles, and controlling movement of the self-driving battery assembly (400) by controlling the transport means (450).

2. Autonomous power battery exchange system for a marine vessel (100) according to claim 1, **characterized in** that the transport means (450) comprises wheels (451) or belts powered by at least one electric motor (452).

3. Autonomous power battery exchange system for a marine vessel (100) according to claim 1, **characterized in** that the sensor system (480) is provided with sensors to monitor the surroundings of the self-driving battery assembly (400).

4. Autonomous power battery exchange system for a marine vessel (100) according to claim 1, **characterized in** that the positioning system (470) is arranged for positioning the self-driving battery assembly (400) in relation to the docking station (500) and charging station (600).

5. Autonomous power battery exchange system for a marine vessel (100) according to claim 1, **characterized in** that the self-driving battery assembly (400) is provided with a connection for cooling (440) and the docking station (500) and charging station (600) are provided with means (521, 621) for cooling as well as connections (530, 630) for connection to the connection (440) for cooling in the self-driving battery assembly (400).

6. Autonomous power battery exchange system for a marine vessel (100) according to any preceding claim, **characterized in** that the docking station (500) and charging station (600) are provided with means (560, 650) for short-range positioning for positioning of the self-driving battery assembly (400).

7. Autonomous power battery exchange system for a marine vessel (100) according to any preceding claim, **characterized in** that docking station (500) and charging stations (600) are provided with a manipulator (540, 640) for autonomous connection of the connections (520, 530; 620, 630) to the connections (430, 440) of the self-driving battery assembly (400).

8. Autonomous power battery exchange system for a marine vessel (100) according to claim 1, **characterized in** that the self-driving battery assembly (400), docking station (500) and charging station (600) are provided with communication means (490, 570, 660) for mutual communication and external communication.

9. Autonomous power battery exchange system for a marine vessel (100) according to claim 1, **characterized in** that the docking station (500) is provided with fastening means (550) for securing the self-driving battery assembly (400) to the docking station (500).

Patentkrav

1. Autonomt energibatteri-utskiftingssystem for et maritimt fartøy (100), hvori det maritime fartøyet (100) er basert på elektrisk energi for drift fremdriftssystem og styringssystemer, hvori systemet omfatter:

- et flertall selvkjørende batterisammenstillinger (400) forsynt med transportmidler (450),

- minst en dokkingstasjon (500) innrettet på det maritime fartøyet (100) i elektrisk forbindelse med et strømnett (700) for fartøyet,

- minst en ladestasjon (600) innrettet i nærheten av en havn (200) i elektrisk forbindelse med et kraftforsyningsnett (800), og

hvori de selvkjørende batterisammenstillingene (400), minst ene dokkingstasjonen (500) og ladestasjonen (600) er forsynt med samsvarende elektriske koblinger (430, 520, 620) for elektrisk kobling derimellom,

karakterisert ved at de selvkjørende batterisammenstillingene (400) er innrettet for autonom bevegelse mellom dokkingstasjonen (500) og ladestasjonen (600) eller omvendt når det maritime fartøyet (100) er ved en havn (200), ved at de selvkjørende batterisammenstillingene (400) er forsynt med en styringsenhet (460), et posisjoneringssystem (470) og et sensorsystem (480) hvilket overvåker omgivelsene til den selvkjørende batterisammenstillingen (400), hvori styringsenheten (460) er forsynt med midler og/eller programvare for å tolke sensorinformasjon fra sensorsystemet (480) og informasjon fra posisjoneringssystemet (470) for å identifisere egnede navigasjonsbaner fra ladestasjonen (600) til dokkingstasjonen (500) og omvendt, samt deteksjon og unngåelse av hindringer, og styring av bevegelse av den selvkjørende batterisammenstillingen (400) ved styring av transportmidlene (450).

2. Autonomt energibatteri-utskiftingssystem for et maritimt fartøy (100) i samsvar med krav 1, **karakterisert ved** at transportmidlene (450) omfatter hjul (451) eller belter drevet av minst en elektrisk motor (452).

3. Autonomt energibatteri-utskiftingssystem for et maritimt fartøy (100) i samsvar med krav 1, **karakterisert ved** at sensorsystemet (480) er forsynt med sensorer for overvåkning av omgivelsene til den selvkjørende batterisammenstillingen (400).

4. Autonomt energibatteri-utskiftingssystem for et maritimt fartøy (100) i samsvar med krav 1, **karakterisert ved** at posisjoneringssystemet (470) er innrettet for posisjonering av den selvkjørende batterisammenstillingen (400) i forhold til dokkingstasjonen (500) og ladestasjonen (600).

5. Autonomt energibatteri-utskiftingssystem for et maritimt fartøy (100) i samsvar med krav 1, **karakterisert ved** at den selvkjørende batterisammenstillingen (400) er forsynt med en kobling for kjøling (440) og dokkingstasjonen (500) og ladestasjonen (600) er forsynt med midler (521, 621) for kjøling samt koblinger (530, 630) for tilkobling til koblinger (440) for kjøling i den selvkjørende batterisammenstillingen (400).

6. Autonomt energibatteri-utskiftingssystem for et maritimt fartøy (100) i samsvar med et av de foregående krav, **karakterisert ved** at dokkingstasjonen (500) og ladestasjonen (600) er forsynt med midler (560, 650) for kortdistanseposisjonering for posisjonering av den selvkjørende batterisammenstillingen (400).

7. Autonomt energibatteri-utskiftingssystem for et maritimt fartøy (100) i samsvar med et av de foregående krav, **karakterisert ved** at dokkingstasjon (500) og ladestasjoner (600) er forsynt med en manipulator (540, 640) for autonom tilkobling av koblingene (520, 530; 620, 630) til koblingene (430, 440) for den selvkjørende batterisammenstillingen (100).

8. Autonomt energibatteri-utskiftingssystem for et maritimt fartøy (100) i samsvar med krav 1, **karakterisert ved** at den selvkjørende batterisammenstillingen (400), dokkingstasjonen (500) og ladestasjonen (600) er forsynt med kommunikasjonsmidler (490, 570, 660) for innbyrdes kommunikasjon og ekstern kommunikasjon.

9. Autonomt energibatteri-utskiftingssystem for et maritimt fartøy (100) i samsvar med krav 1, **karakterisert ved** at dokkingstasjonen (500) er forsynt med festemidler (500) for sikring av den selvkjørende batterisammenstillingen (400) til dokkingstasjonen (500).

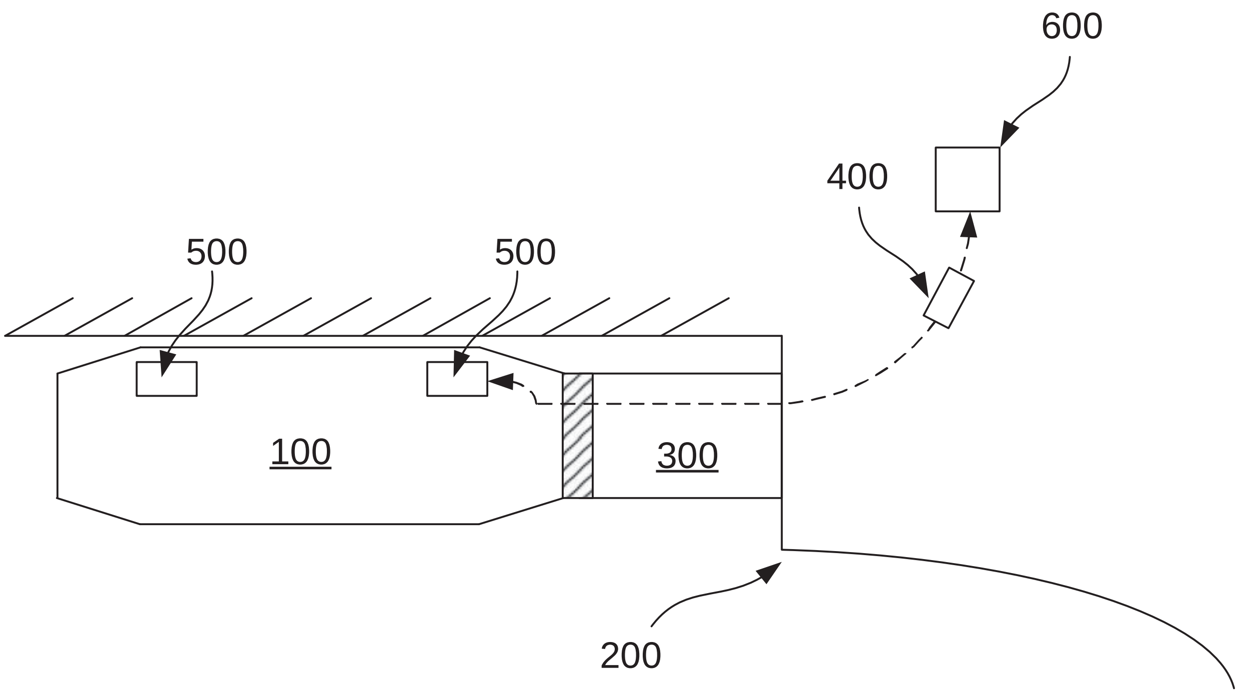
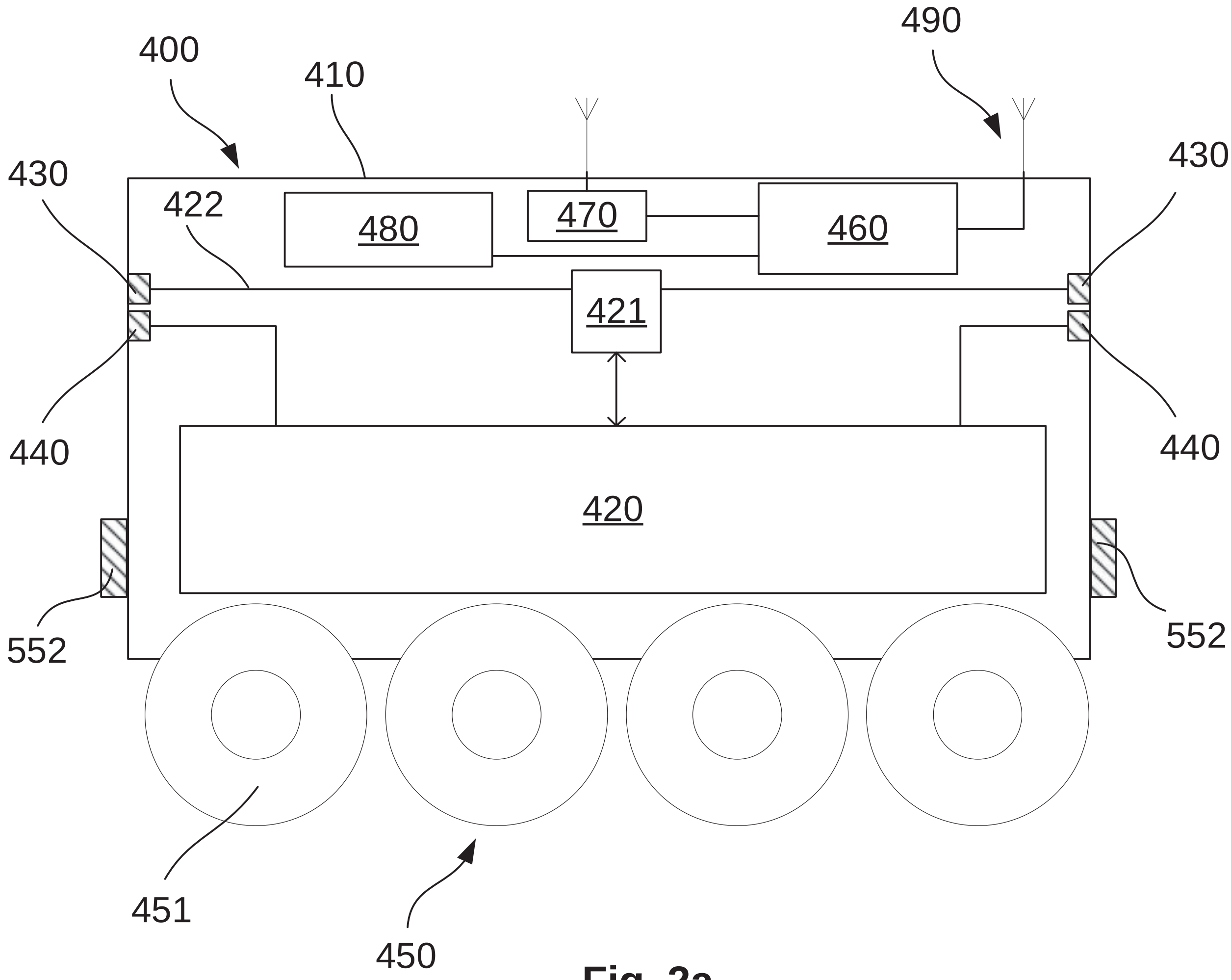


Fig. 1.


400
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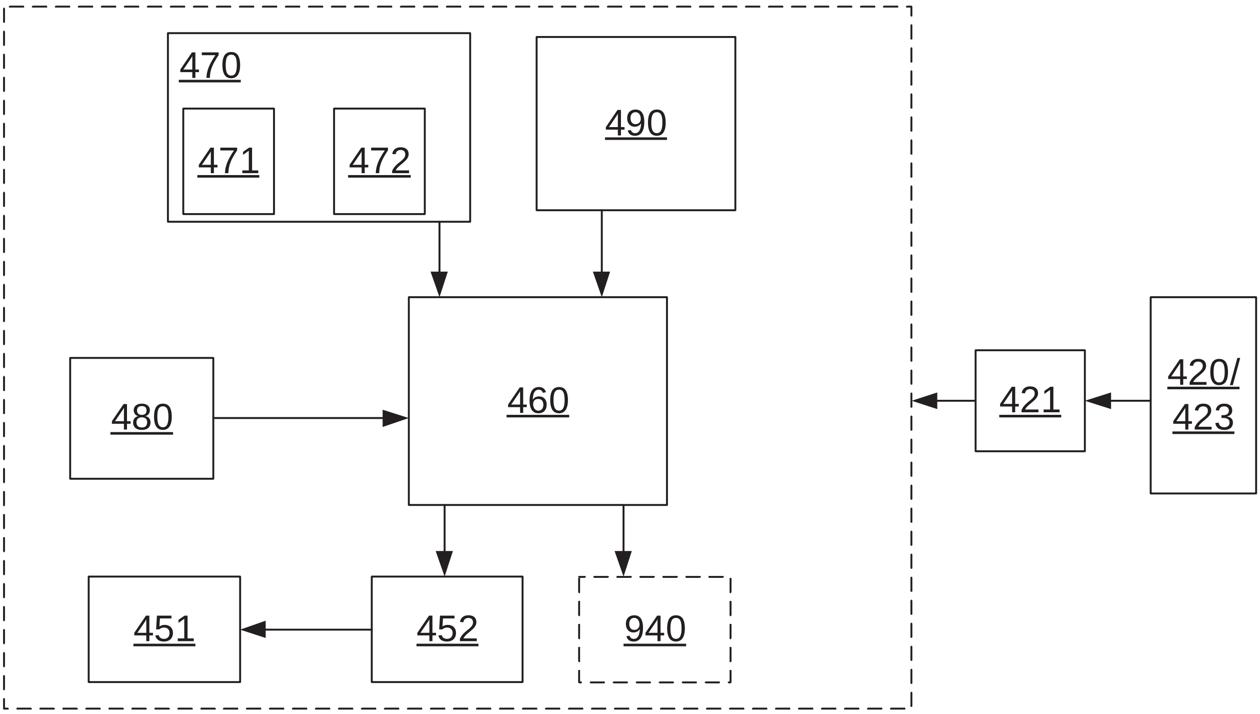
490
430
422
480
470
460
430
421
440
440
420
552
552
451
450

Fig. 2a.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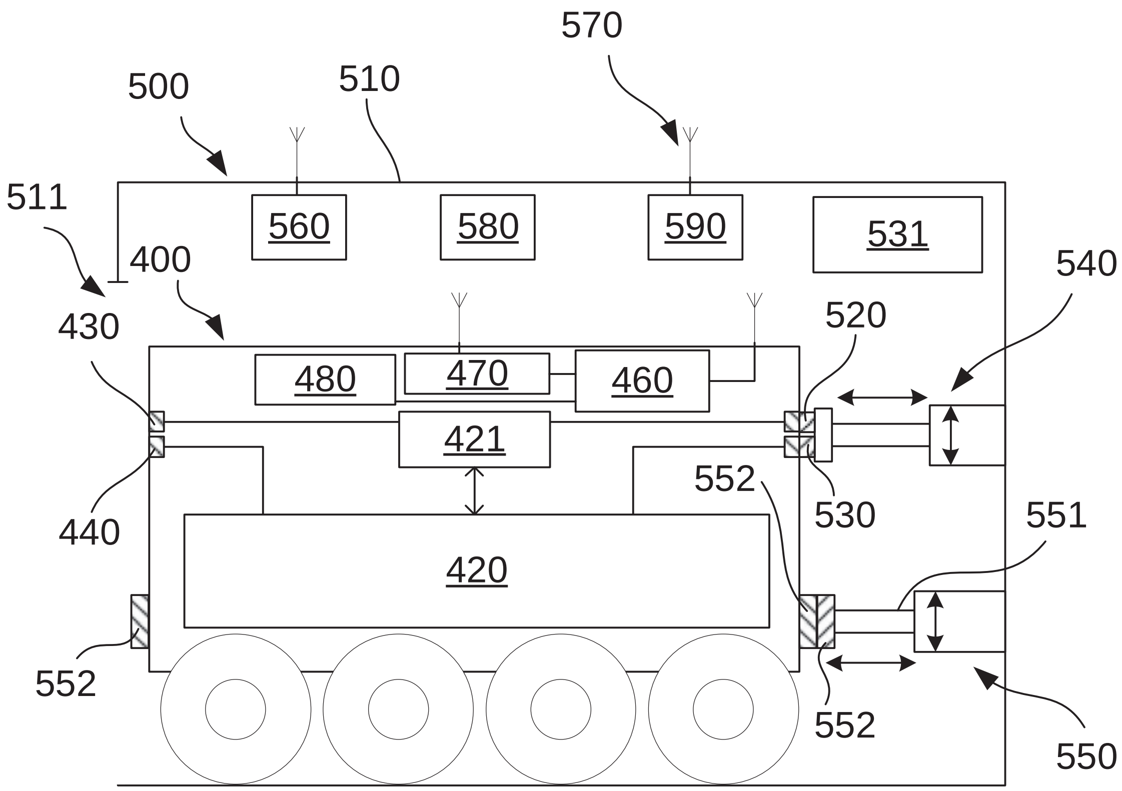
471
472
490
480
460
421
420/
423
451
452
940

Fig. 2b.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510
511
560
580
590
531
400
540
430
520
480
470
460
421
552
530
551
440
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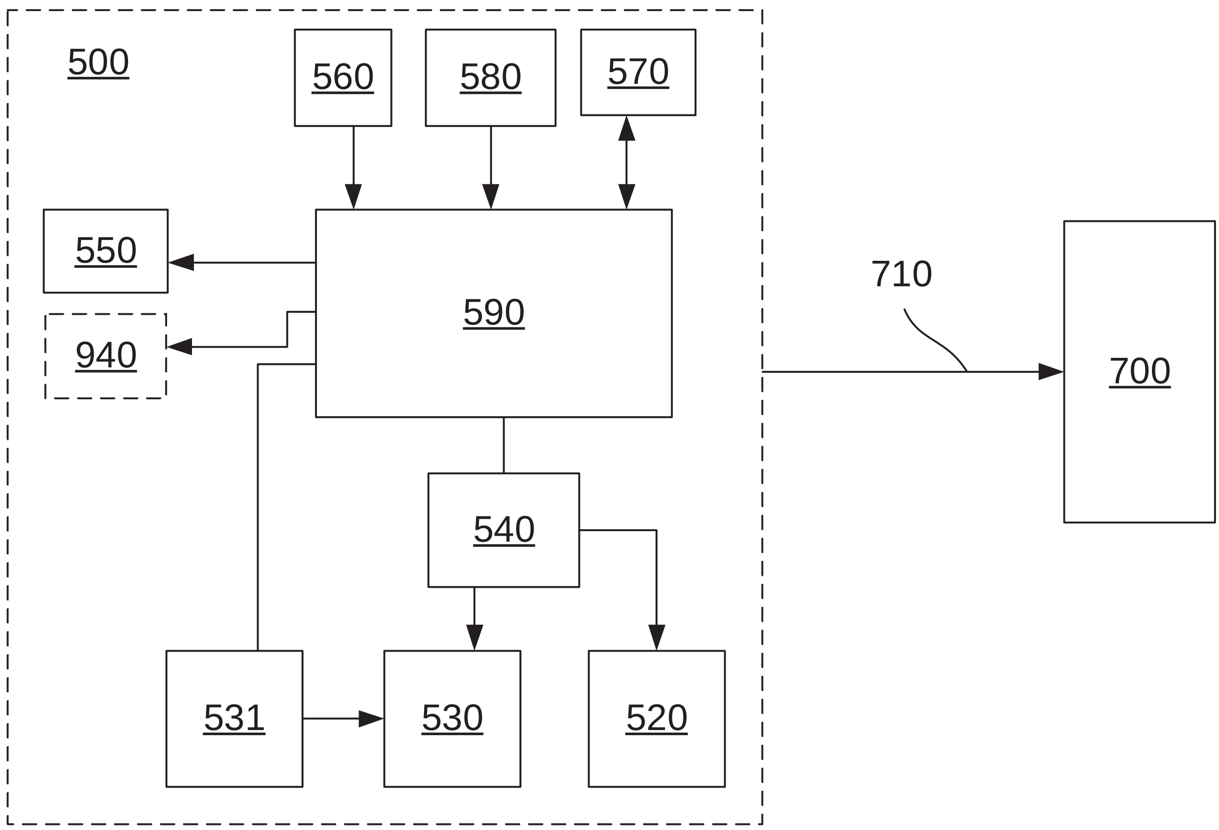
552
552
550

Fig. 3a.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560
580
570
550
590
710
700
940
540
531
530
520

Fig. 3b.

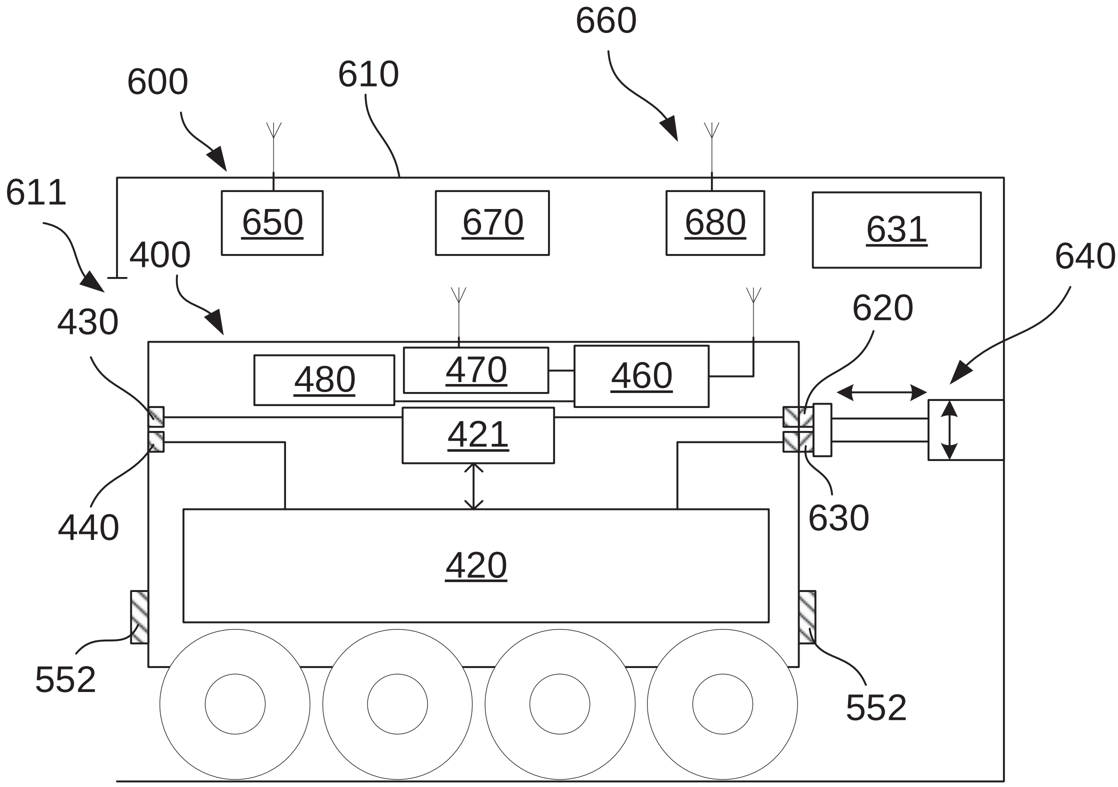
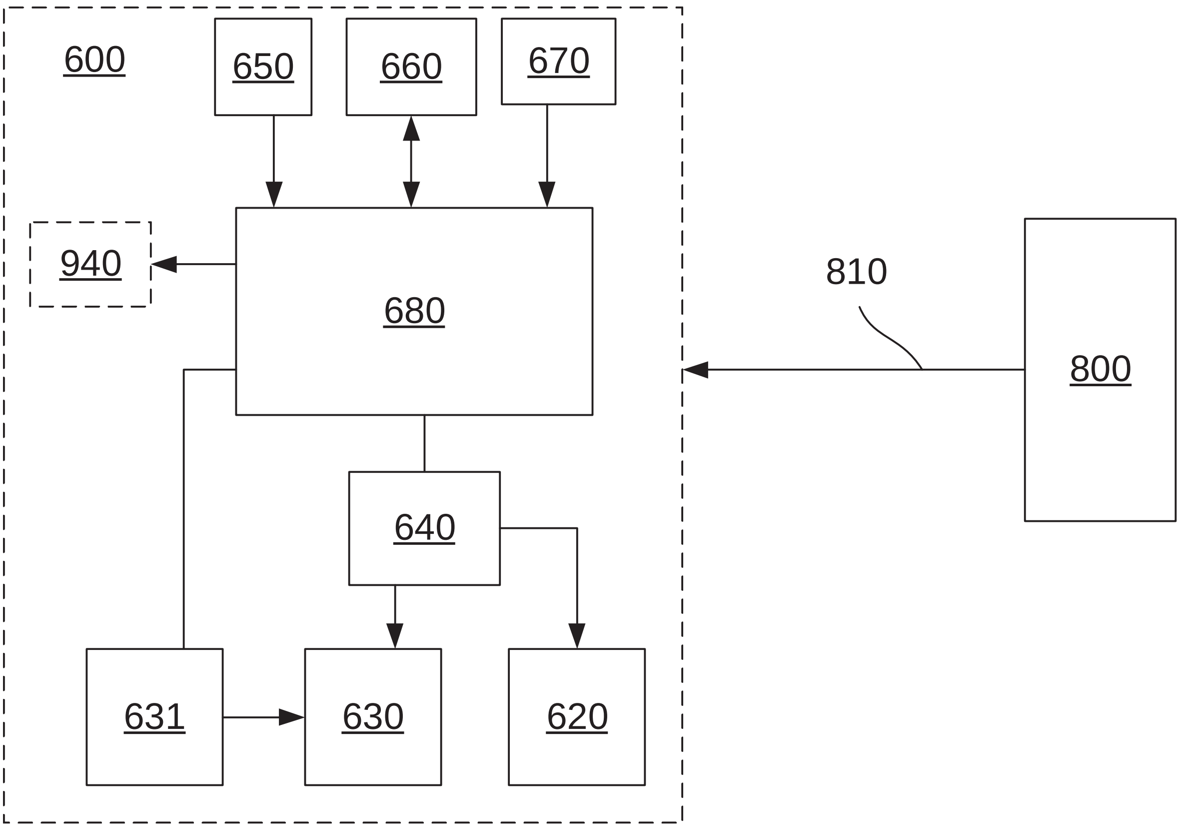

660
600
610
611
650
670
680
631
400
640
620
430
480
470
460
421
630
440
420
552
552

Fig. 4a.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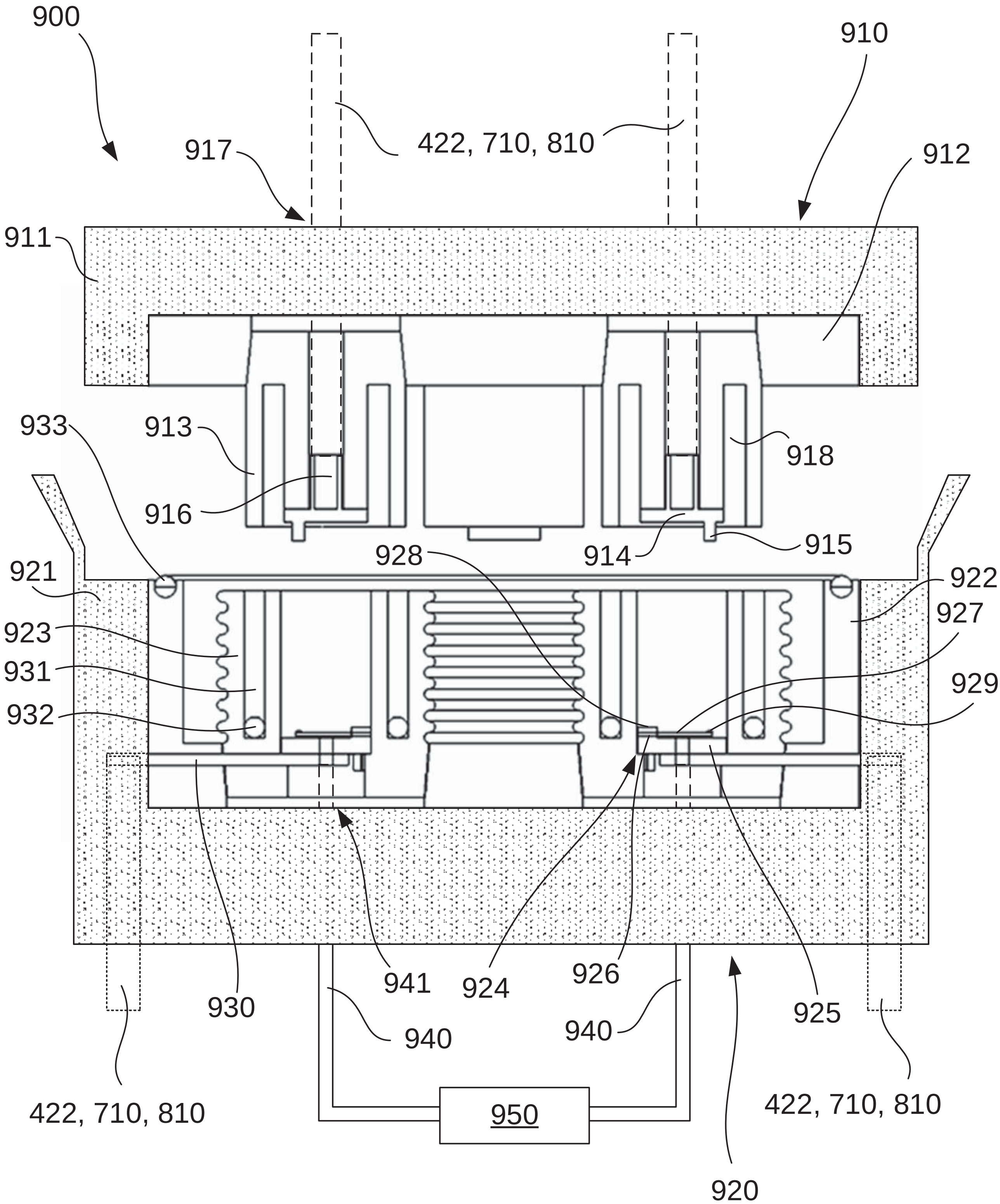
650
660
670
940
680
810
800
640
631
630
620

Fig. 4b.


900
910
917
422, 710, 810
912
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927
931
929
932
930
941
924
926
925
940
940
950
422, 710, 810
422, 710, 810
920

Fig. 5