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(72) Inventors:  
• **HÖRLÉN, Per**  
**121 34 ENSKEDEDALEN (SE)**  
• **MÖKANDER, Jürgen**  
**192 78 SOLLENTUNA (SE)**  
• **BRATTHÄLL, Johan**  
**132 37 SALTSJÖ BOO (SE)**

(71) Applicant: **Xylem IP Management S.à.r.l.**  
**1259 Senningerberg (LU)**

(74) Representative: **Brann AB**  
**P.O. Box 3690**  
**Drottninggatan 27**  
**103 59 Stockholm (SE)**

(54) **SUBMERSIBLE ELECTRIC MACHINE ASSEMBLY**

(57) The invention relates to a submersible electric machine assembly comprising a submersible electric machine (2) having an integrated control unit (12) configured for monitoring and controlling the operation of the submersible electric machine (2), an electric power connector (3), and an electric power cable (4) interconnecting the electric power connector (3) and the submersible electric machine (2), and comprising at least one power wire for supplying power from the electric power connector (3) to the control unit (12) of the submersible electric machine (2). The submersible electric machine assembly is characterized in that the electric power cable (4) comprises at least one communication wire and the electric power connector (3) comprises an operating panel, wherein the operating panel is connected to the control unit (12) of the submersible electric machine (2) via said at least one communication wire.

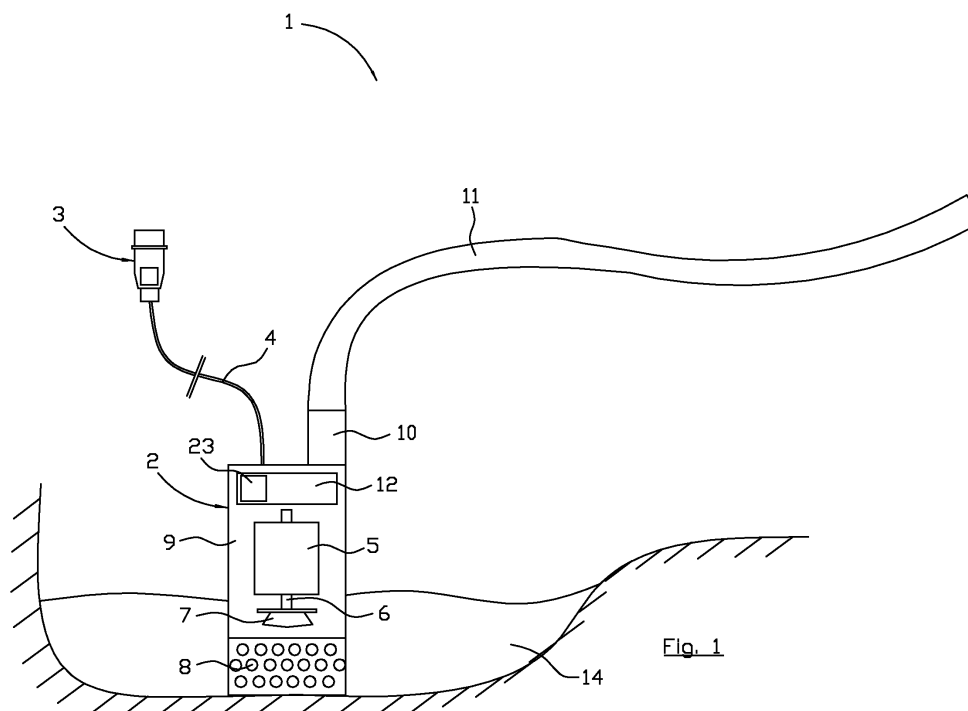
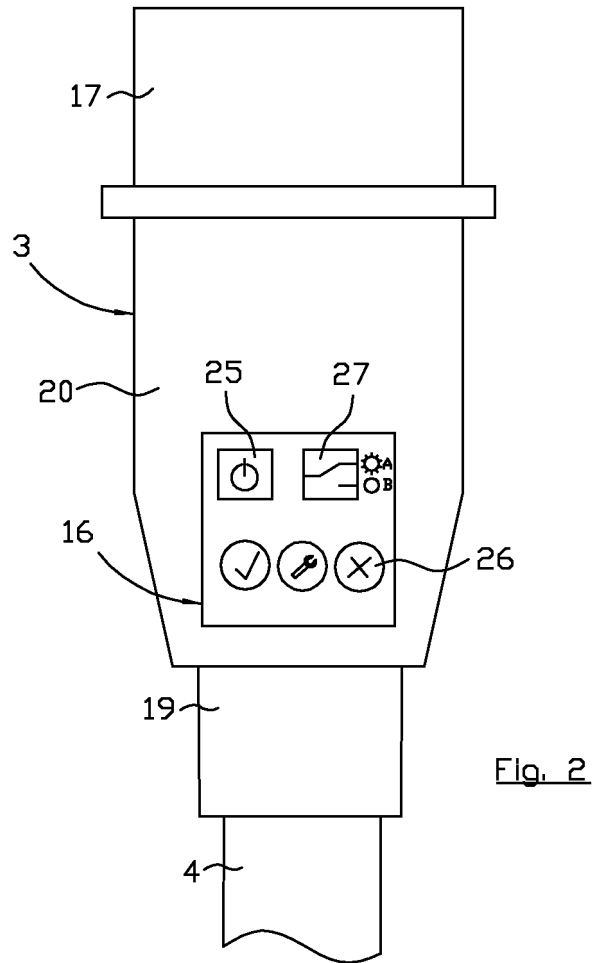


Fig. 1



## Description

### Technical field of the Invention

**[0001]** The present invention relates generally to the field of submersible electric machine assemblies especially configured for handling liquid, preferably liquid comprising solid matter. Further, the present invention relates specifically to the field of submersible electric machine assemblies especially configured and intended for treatment applications, transport applications and/or dewatering applications, and comprises submersible electric machines such as pumps and mixers.

**[0002]** The submersible electric machine assembly comprises a submersible electric machine having an integrated control unit configured for monitoring and controlling the operation of the submersible electric machine, an electric power connector, and an electric power cable interconnecting the electric power connector and the submersible electric machine and comprising at least one power wire for supplying power from the electric power connector to the control unit of the submersible electric machine.

### Background of the Invention

**[0003]** Submersible electric machines having an integrated control unit, also known as intelligent drive, which monitors and controls the operation of the submersible electric machine, are conventionally powered via an electric power cable. Usually said electric power cable is rigidly connected, i.e. hardwired, to an external control cabinet located between the submersible electric machine and the power mains. The control cabinet is necessary for the operator to be able to control the submersible electric machine by sending control signals from the control cabinet to the submersible electric machine via a power/phase wire/conductor of the electric power cable. The operator is able to turn the submersible electric machine ON and OFF, respectively, at the control cabinet, and conventionally the operator is also able to control at least one of the functions of the electric machine and/or monitoring the operating condition of the electric machine. The control cabinet is more or less stationary. Thereto, the control cabinet must be adapted to serve the specific submersible electric machine, and thereto only personnel having a certificate qualifying them to connect the electric power cable of the electric machine to the control cabinet are allowed to install the electric machine.

**[0004]** However, some applications such as drainage/dewatering pumps intended for use at a mining/tunneling/construction site, i.e. configured for pumping liquid comprising sand and stone material, such as drilling water in mining/tunneling applications or surface water on construction sites, require that the pump is truly mobile and configured to be moved and connected to any suitable power supply by personnel not having electric certificate.

**[0005]** Thereto, the operator is usually not able to reach the submersible electric machine during operation in order to control the operation of submersible electric machine or to interact with the submersible electric machine, i.e. in order to change operational mode of the submersible electric machine. In some applications there is a need to be able to change between different operational modes of the submersible electric machine, for instance a constant operation operational mode and an automatic ON/OFF operational mode, respectively.

**[0006]** In mines, on construction sites, and the like applications, there is almost always a need to remove water in order to secure a dry enough environment at the working site. In mining/tunneling applications a lot of drilling water is used when preparing for charging before blasting and if the drilling water is not removed at least the lower parts of the mine will become flooded. Surface water and groundwater will also add up to accumulation of water to be removed.

**[0007]** Generally the personnel, as well as the actual process at the working site, requires a constant low liquid level and therefor it is often decided that the drainage pump should be in constant operation even though there is sometimes only little water available. Thus, in many applications the drainage pumps are in constant operation, irrespective of water being pumped or not by the drainage pump. Constant operation of the drainage pump may damage the drainage pump and result in excessive energy consumption. If there is no or little inflow of water to the pit/dent housing the drainage pump, the drainage pump will start to heat the water, an operational mode referred to as boiling. During boiling, the elevated temperature in the drainage pump and in the water is especially harmful for the seals, and eventually all water will become evaporated. The combination of high operational speed and snoring accelerates pump wear and significantly shortens the operative life of the drainage pump. Constant operation is good and inevitable when there is a constant inflow of liquid to the pit/dent housing the drainage pump.

**[0008]** In other applications, the drainage pump is operated in an automatic ON/OFF operation, i.e. the pump is stopped when the water level surrounding the pump is low, for instance the drainage pump is stopped when the drainage pump is snoring or is stopped by means of a level sensor. The drainage pump is snoring when a mixture of air and water is sucked into the drainage pump. The drainage pump is stopped to decrease the use of energy when the drainage pump is not able to perform any positive duty, and to spare the pump from additional wear.

**[0009]** An external and mobile control unit for controlling the operation of a pump is disclosed in EP2660474. The operator is able to change between a few predetermined operational modes of the pump and is able to obtain alarms via an operating panel of the control unit. The electric power plug belonging to the pump and located at the end of the electric power cable of the pump is de-

tachably connectable to an electric power socket of the control unit, and an electric power plug of the control unit is detachably connected to the power mains. Thus, the control unit is configured not to be part of the pump and the control unit has the obvious drawback that it easily can get lost. The electric power cable of the pump is constituted by three power/phase wires/conductors and a ground/earth wire, wherein the signal transfer between the control unit and the pump is performed via one or more of the phase wires at the same time as power transfer.

#### Object of the Invention

**[0010]** The present invention aims at obviating the aforementioned disadvantages and failings of previously known submersible electric machine assemblies, and at providing an improved submersible electric machine assembly. A primary object of the present invention is to provide an improved submersible electric machine assembly of the initially defined type that comprises a Human-Machine-Interface (HMI) fixedly connected to the submersible electric machine and at the same time always accessible for the operator. It is another object of the present invention to provide a submersible electric machine assembly, wherein the operator may interact with the control unit of the submersible electric machine in order to control and monitor the operation of the pump.

#### Summary of the Invention

**[0011]** According to the invention at least the primary object is attained by means of the initially defined submersible electric machine assembly having the features defined in the independent claim. Preferred embodiments of the present invention are further defined in the dependent claims.

**[0012]** According to the present invention, there is provided a submersible electric machine assembly of the initially defined type, which is characterized in that the electric power cable comprises at least one communication wire and the electric power connector comprises an operating panel, wherein the operating panel is connected to the control unit of the submersible electric machine via said at least one communication wire.

**[0013]** Thus, the present invention is based on the insight of using a HMI constituted by an operating panel that is fixedly connected to the electric power connector of the submersible electric machine, whereby the operator can interact by means of two-way communication with the control unit that is integrated into the submersible electric machine.

**[0014]** In a preferred embodiment of the present invention, the electric power connector comprises a wireless communication unit operatively connected to a microcontroller unit that is operatively arranged between the operating panel and the communication wire, wherein the wireless communication unit is configured for wireless

communication between the microcontroller unit and a remote operator device. Thereby at least any possible alarm from the submersible electric machine can be provided to an operator situated remote from the specific submersible electric machine assembly.

**[0015]** According to a preferred embodiment of the present invention, the control unit of the submersible electric machine comprises a master communication unit and the microcontroller unit of the electric power connector comprises a slave communication unit, wherein said master communication unit and said slave communication unit are operatively connected to each other via two communication wires of the electric power cable. Therefore, it is preferable that said slave communication unit comprises a capacitor, the master communication unit being configured to transfer DC-power charge pulses to said capacitor of the slave communication unit via the two communication wires. Thereby, the operating panel is powered by the submersible electric machine and the power/phase wires of the electric power cable are only used to power the submersible electric machine, including the integrated control unit.

**[0016]** According to a preferred embodiment of the present invention, the master communication unit and the slave communication unit are configured for two-way data communication via the two communication wires.

**[0017]** Further advantages with and features of the invention will be apparent from the other dependent claims as well as from the following detailed description of preferred embodiments.

#### Brief description of the drawings

**[0018]** A more complete understanding of the above-mentioned and other features and advantages of the present invention will be apparent from the following detailed description of preferred embodiments in conjunction with the appended drawings, wherein:

- Fig 1 is a schematic illustration of an inventive submersible electric machine assembly,
- Fig. 2 is a schematic illustration of one embodiment of an electric power connector, and
- Fig. 3 is a schematic illustration of the inside of the electric power connector disclosed in figure 2.

#### Detailed description of preferred embodiments of the invention

**[0019]** The present invention relates generally to the field of submersible electric machine assemblies especially configured for handling liquid, preferably liquid comprising solid matter. The present invention relates specifically to the field of submersible drainage/dewatering pumps especially configured for pumping liquid comprising solid matter, such as water comprising sand and stone material.

**[0020]** Reference is initially made to figure 1, disclosing

a schematic embodiment of a submersible electric machine assembly, generally designated 1. The inventive submersible electric machine assembly 1 comprises a submersible electric machine, generally designated 2, an electric power connector, generally designated 3, and an electric power cable, generally designated 4, wherein the electric power cable 4 interconnects the electric power connector 3 and the submersible electric machine 2. Thus, the electric power cable 4 is hardwired to the electric power connector 2 and to the submersible electric machine 2, in order to provide a united/aggregated system or assembly.

**[0021]** The submersible electric machine 2 is preferably constituted by a pump or a mixer, i.e. machines specifically configured and intended for treatment application, transport applications and/or dewatering applications. In the disclosed embodiment the submersible electric machine 2 is constituted by a drainage/dewatering pump. Hereinbelow, for sake of clarity, the term pump will be used as fully equivalent with the generic term submersible electric machine, and it shall be realized that also mixers are concerned, if nothing else is indicated.

**[0022]** The submersible electric machine 2 comprises a drive unit having an electric motor 5 and a drive shaft 6 and comprises a hydraulic unit having an impeller 7 connected to said electric motor 5 via said drive shaft 6. In the disclosed embodiment the pump 2 comprises an inlet 8, a pump housing 9 and an outlet 10, wherein an outlet conduit 11 is connected to the outlet 10 of the pump 2. The outlet conduit 11 is releasably connected to the pump 2, and the pump 2 is preferably of centrifugal pump type. In a conventional way the hydraulic unit of the disclosed pump 2 has a pump chamber (not disclosed) arranged in the pump housing 9 and connecting the inlet 8 and the outlet 10. The electrical motor 5 is arranged in a liquid tight part of the pump housing 9, and the drive shaft 6 extends from the electrical motor 5 and into the pump chamber. The impeller 7 is arranged in the pump chamber and is connected to and driven in rotation by the drive shaft 6 during operation of the pump 2, wherein liquid is sucked into said inlet 8 and pumped out of said outlet 10 when the pump 2 is active. The pump housing 9 and the impeller 7, and other essential components, are preferably made of metal, such as aluminum and/or iron/steel.

**[0023]** The submersible electric machine 2 comprises an integrated control unit 12, also known as intelligent drive, configured for monitoring and controlling the operation of the submersible electric machine 2, wherein the electric power cable 4 comprises at least one power/phase wire 13 for supplying power from the electric power connector 3 to the control unit 12 of the submersible electric machine 2. The control unit 12, including a Variable Frequency Drive (VFD) of the control unit 12, is located inside a liquid tight part of the pump housing 9 and is operatively connected to the electric motor 5. The submersible electric machine 2 comprises a liquid tight lead-through receiving the electric power cable 4.

**[0024]** Thus, the pump 2 is configured to be operated at a variable operational speed [rpm], by means of said control unit 12 that is configured to control the operational speed of the pump 2. The operational speed of the pump 2 is more precisely the rpm of the electrical motor 5 and of the impeller 7, and correspond/relate to a control unit 12 output frequency.

**[0025]** The components of the submersible electric machine 2 are usually, directly or indirectly, cold down by means of the liquid/media surrounding the submersible electric machine 2. The submersible electric machine 2 is designed and configured to be able to operate in a submerged configuration/position, i.e. during operation be located entirely under the liquid surface. However, it shall be realized that the submersible electric machine 2 during operation must not be entirely located under the liquid surface but may continuously or occasionally be partly located above the liquid surface. The pump 2 is in the disclosed embodiment located in a basin 14 and is intended to transport/pump liquid comprising solid matter from said basin 14. The basin 14 may be a natural recess/cavity/pit or a prepared recess/cavity/pit.

**[0026]** Reference is now also made to figures 2 and 3, disclosing a preferred embodiment of the electric power connector 3. The electric power cable 4 comprises at least one communication wire 15, preferably two communication wires, besides said at least one power wire 13. The electric power connector 3 comprises an operating panel, generally designated 16, wherein the operating panel 16 is connected to the control unit 12 of the submersible electric machine 2 via said at least one communication wire 15 in order to transmit signals and instructions between the control unit 12 and the operating panel 16, i.e. two-way communication.

**[0027]** The electric power connector 3 may be constituted by a plug assembly, as in the disclosed embodiment, or may be constituted by a joint assembly, not disclosed embodiment. In both embodiments the electric power connector 3 is hardwired to the terminal end of the electric power cable 4 that is hardwired to the submersible electric machine 2.

**[0028]** The electric power connector 3 when realized by a plug assembly, comprises in a conventional way a sleeve 17 surrounding a set of pins 18, some of which are connected to the power/phase wires 13 of the electric power cable 4 inside the electric power connector 3. Such an electric power connector 13 is a so-called male plug and is preferably based on a standardized electric power plug, such as 3P+E, 3P+N+E, 2P+E, etc., for instance a CEE plug. Adapters are available that are arranged to fit the standardized electric power plug and thereto comprises another standardized electric power plug or a local electric power plug, in order for the submersible electric machine assembly 1 to be used at different locations/markets of the world. The adapters may alternatively be arranged to fit the standardized electric power plug and thereto comprise a short cable configured for post-mounting of another standardized electric power

plug or a local electric power plug. Said short cable does not comprise any signal wire, unlike the electric power cable 4. The electric power connector 3 of the disclosed embodiment comprises only one cable inlet 19 that is arranged to prevent the electric power cable 4 from being pulled out of the electric power connector 3 and that is arranged to prevent liquid from entering the electric power connector 3.

**[0029]** The electric power connector 3 when realized by a joint assembly, comprises a second cable inlet instead of the sleeve 17 and set of pins 18 of the disclosed embodiment. A short cable configured for post-mounting of a standardized electric power plug or a local electric power plug, or a short cable having a standardized electric power plug or a local electric power plug, is arranged at the second cable inlet. The second cable inlet is arranged to prevent the short cable from being pulled out of the electric power connector 3 and is arranged to prevent liquid from entering the electric power connector 3. Said short cable does not comprise any signal wire, unlike the electric power cable 4. The power/phase wires of the short cable are connected to the power/phase wires 13 of the electric power cable 4 inside the electric power connector 3.

**[0030]** The electric power connector 3 comprises in both embodiments an intermediate housing 20 wherein the operating panel 16 is attached to said housing 20.

**[0031]** The electric power connector 3 comprises a microcontroller unit 21 operatively arranged between the operating panel 16 and the at least one communication wire 15. Thereto, the electric power connector 3 may comprise a wireless communication unit 22 operatively connected to said microcontroller unit 21 and configured for wireless communication between the microcontroller unit 21 and a remote operator device (not disclosed). Thus, the remote operator device may comprise an imaginary operating panel having the same or at least some of the abilities of the operating panel 16 of the electric power connector 3. The remote operator device may be constituted by for instance a mobile phone, a tablet or a computer.

**[0032]** According to the disclosed and preferred embodiment the control unit 12 of the submersible electric machine 2 comprises a master communication unit 23 and the microcontroller unit 21 of the electric power connector 3 comprises a slave communication unit 24. The master communication unit 23 and said slave communication unit 24 are operatively connected to each other via the two communication wires 15. Signals and instructions are transmitted between the master communication unit 23 and the slave communication unit 24, i.e. two-way communication. According to the disclosed embodiment, the slave communication unit 24 comprises a capacitor, the master communication unit 23 being configured to transfer DC-power charge pulses to said capacitor of the slave communication unit 24 via the two communication wires 15. Alternatively, the electric power connector 3 comprises a power supply unit operatively

connected to the slave communication unit 24 of the microcontroller unit 21. Said power supply unit may be constituted by a battery or the like, or may be configured to branch current from one of the power wires 13.

**[0033]** According to an alternative embodiment (not disclosed) the microcontroller unit 21 of the electric power connector 3 comprises a master communication unit and the control unit 12 of the submersible electric machine 2 comprises a slave communication unit, wherein said master communication unit and said slave communication unit are operatively connected to each other via the two communication wires 15. In this embodiment the master communication unit arranged in the microcontroller unit 21 of the electric power connector 3 may comprise a capacitor, the slave communication unit of the control unit 12 being configured to transfer DC-power charge pulses to said capacitor of the master communication unit via the two communication wires 15. Alternatively, the electric power connector 3 comprises a power supply unit operatively connected to the master communication unit of the microcontroller unit 21. Said power supply unit may be constituted by a battery or the like, or may be configured to branch current from one of the power wires 13.

**[0034]** The communication between the control unit 12 and the operating panel 16 over the communication wires 15 is executed when no DC-power charge pulse is transmitted over the communication wires 15, and vice versa. The master communication unit 23 and the slave communication unit 24 are configured for two-way data communication via the two communication wires 15, independently of which of the two units that is located in the control unit 12 and in the microcontroller unit 21, respectively.

**[0035]** The operating panel 16 of the electric power connector 3 comprises a power supply switch 25, i.e. a main switch for the submersible electric machine 2. The operating panel 16 comprises at least one indicator 26 configured for indicating the condition of the submersible electric machine 2, i.e. a status indicator. In the disclosed embodiment the indicator 26 is constituted by three elements which can be individually lit, i.e. indicate that the submersible electric machine 2 is OK, need service or is out of order. Thereto the operating panel 16 may also comprise a mode selector switch 27. By means of the mode selector switch 27 the operator may choose between preset operating modes, for instance mode A and mode B in the disclosed embodiment. The submersible electric machine 2 may be configured to be driven in more operating modes.

**[0036]** A first mode is constant operation. During this mode the operational speed may be constant or adaptive/varying. A second mode is automatic ON/OFF operation, i.e. the pump 2 is controlled by level sensors to start pumping at a liquid start level and stop pumping at a liquid stop level, or the pump 2 is controlled to stop pumping when the pump 2 is snoring, or the pump 2 is controlled to start at preset time intervals, or a combina-

tion thereof. Also in the automatic ON/OFF operation, and when the pump 2 is active, the operational speed may be constant or adaptive/varying. Any level sensor is operatively connected to the control unit 12 of the pump 2.

**[0037]** The term "snoring" entails that the drainage pump 2 sucks a mixture of air and liquid into the inlet 8. The step of detecting whether the pump 2 is snoring or not, may be performed using different techniques, independently or in combination with each other. A preferred embodiment to detect snoring is to monitor the power or current consumption of the pump 2 using the control unit 12. If the power or current consumption of the pump 2 starts to widely fluctuate outside a predetermined range and/or decrease below a predetermined threshold, the pump 2 has started to snore and the control unit 12 detects a snoring condition. An alternative embodiment to detect snoring is to monitor the torque of the pump 2 using the control unit 12. If the torque of the pump 2 starts to widely fluctuate outside a predetermined range and/or decrease below a predetermined threshold, the pump 2 has started to snore and the control unit 12 detects a snoring condition. Other alternative embodiments to detect snoring constitute monitoring one or more of sounds, vibrations, pressure at the outlet 10, etc. of the pump 2.

#### Feasible modifications of the Invention

**[0038]** The invention is not limited only to the embodiments described above and shown in the drawings, which primarily have an illustrative and exemplifying purpose. This patent application is intended to cover all adjustments and variants of the preferred embodiments described herein, thus the present invention is defined by the wording of the appended claims and thus, the equipment may be modified in all kinds of ways within the scope of the appended claims.

**[0039]** It shall also be pointed out that all information about/concerning terms such as above, under, upper, lower, etc., shall be interpreted/read having the equipment oriented according to the figures, having the drawings oriented such that the references can be properly read. Thus, such terms only indicates mutual relations in the shown embodiments, which relations may be changed if the inventive equipment is provided with another structure/design.

**[0040]** It shall also be pointed out that even thus it is not explicitly stated that features from a specific embodiment may be combined with features from another embodiment, the combination shall be considered obvious, if the combination is possible.

#### **Claims**

1. A submersible electric machine assembly (1) comprising:

- a submersible electric machine (2) having an integrated control unit (12) configured for monitoring and controlling the operation of the submersible electric machine (2),
- an electric power connector (3), and
- an electric power cable (4) interconnecting the electric power connector (3) and the submersible electric machine (2), and comprising at least one power wire (13) for supplying power from the electric power connector (3) to the control unit (12) of the submersible electric machine (2),

the submersible electric machine assembly being **characterized in that**

the electric power cable (4) comprises at least one communication wire (15) and the electric power connector (3) comprises an operating panel (16), wherein the operating panel (16) is connected to the control unit (12) of the submersible electric machine (2) via said at least one communication wire (15).

2. The submersible electric machine assembly according to claim 1, wherein the electric power connector (3) comprises a microcontroller unit (21) operatively arranged between the operating panel (16) and the at least one communication wire (15).
3. The submersible electric machine assembly according to claim 2, wherein the electric power connector (3) comprises a wireless communication unit (22) operatively connected to the microcontroller unit (21) and configured for wireless communication between the microcontroller unit (21) and a remote operator device.
4. The submersible electric machine assembly according to claim 2 or 3, wherein the electric power cable (4) comprises two communication wires (15).
5. The submersible electric machine assembly according to claim 4, wherein the control unit (12) of the submersible electric machine (2) comprises a master communication unit (23) and the microcontroller unit (21) of the electric power connector (3) comprises a slave communication unit (24), wherein said master communication unit (23) and said slave communication unit (24) are operatively connected to each other via the two communication wires (15).
6. The submersible electric machine assembly according to claim 5, wherein the slave communication unit (24) comprises a capacitor, the master communication unit (23) being configured to transfer DC-power charge pulses to said capacitor of the slave communication unit (24) via the two communication wires (15).
7. The submersible electric machine assembly accord-

ing to claim 4, wherein the microcontroller unit (21) of the electric power connector (3) comprises a master communication unit and the control unit (12) of the submersible electric machine (2) comprises a slave communication unit, wherein said master communication unit and said slave communication unit are operatively connected to each other via the two communication wires (15).

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8. The submersible electric machine assembly according to claim 7, wherein the master communication unit comprises a capacitor, the slave communication unit being configured to transfer DC-power charge pulses to said capacitor of the master communication unit via the two communication wires (15). 10  
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9. The submersible electric machine assembly according to claim 7, wherein the electric power connector (3) comprises a power supply unit operatively connected to the master communication unit. 20
10. The submersible electric machine assembly according to any of claims 5-9, wherein the master communication unit (23) and the slave communication unit (24) are configured for two-way data communication via the two communication wires (15). 25
11. The submersible electric machine assembly according to any preceding claim, wherein the operating panel (16) of the electric power connector (3) comprises a power supply switch (25) and at least one indicator (26) configured for indicating the condition of the submersible electric machine (2). 30
12. The submersible electric machine assembly according to any preceding claim, wherein the electric power cable (4) is hardwired to the electric power connector (3) and to the submersible electric machine (2). 35  
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13. The submersible electric machine assembly according to any preceding claim, wherein the control unit (12) of the submersible electric machine (2) comprises a Variable Frequency Drive (VFD). 45
14. The submersible electric machine assembly according to any preceding claim, wherein the submersible electric machine (2) is constituted by a submersible pump, preferably a submersible drainage pump. 50
15. The submersible electric machine assembly according to any preceding claim, wherein the submersible electric machine (2) comprises a drive unit having an electric motor (5) and a drive shaft (6) and comprises a hydraulic unit having an impeller (7) connected to said electric motor (5) via said drive shaft (6), the control unit (12) being operatively connected to the electric motor (5). 55

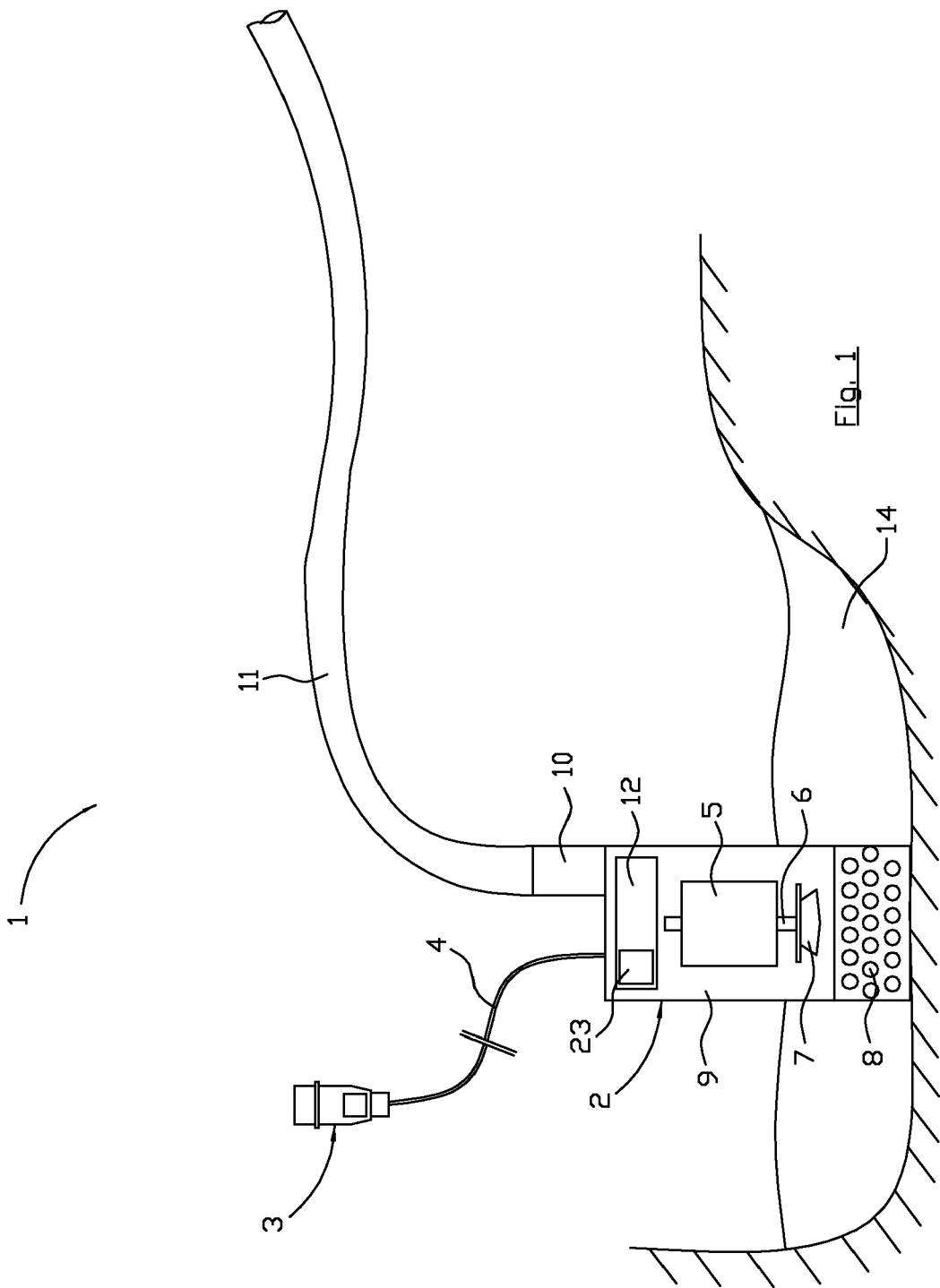
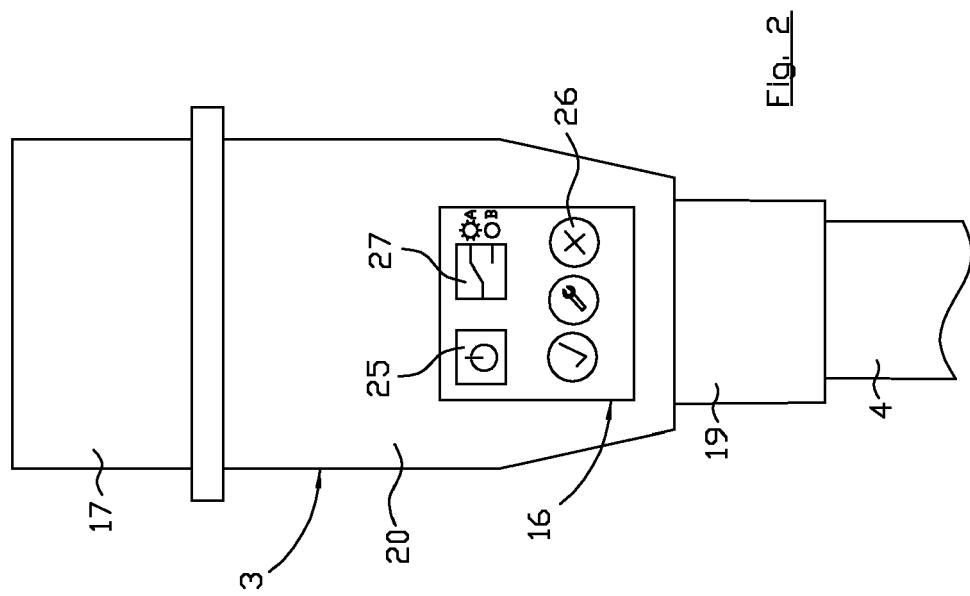
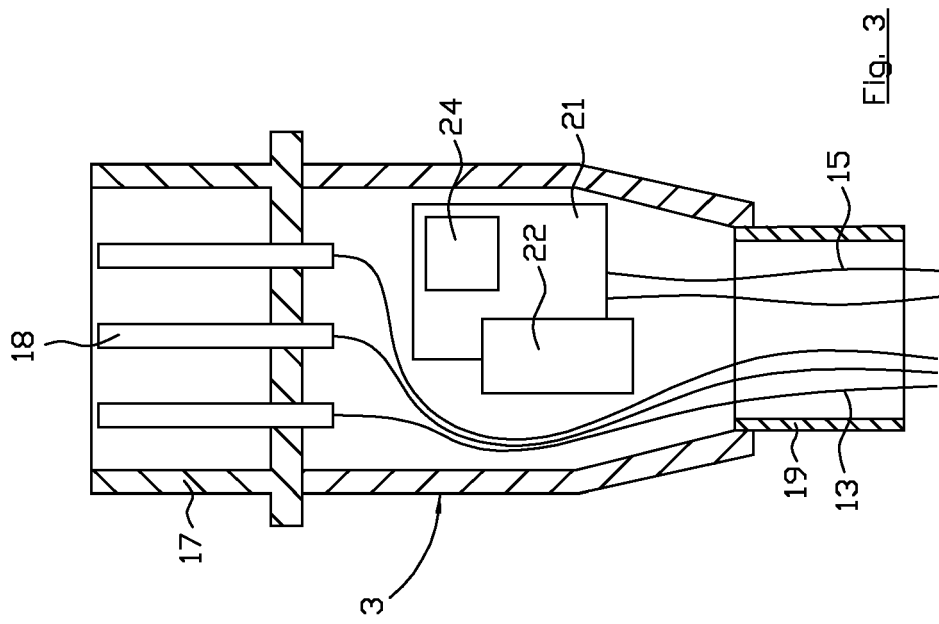


Fig. 1





## EUROPEAN SEARCH REPORT

Application Number  
EP 17 19 8309

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DOCUMENTS CONSIDERED TO BE RELEVANT			
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Place of search The Hague		Date of completion of the search 18 April 2018	Examiner de Verbigier, L
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EPO FORM 1503 03.82 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT  
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This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.  
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