United States Patent

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[54] **METHOD AND APPARATUS FOR MAKING EQUIPMENT CONNECTIONS AT REMOTE UNDERWATER LOCATIONS AND FOR PRODUCING FLUIDS FROM UNDERWATER WELLS**
14 Claims, 5 Drawing Figs.

[52] **U.S. Cl.** **166/.6,** 336/107, 336/192
[51] **Int. Cl.** **E21b 43/01**
[50] **Field of Search** ..... 166/.5, .6; 137/236; 61/72.3, 72.4; 336/48, 82, 107, 115, 192

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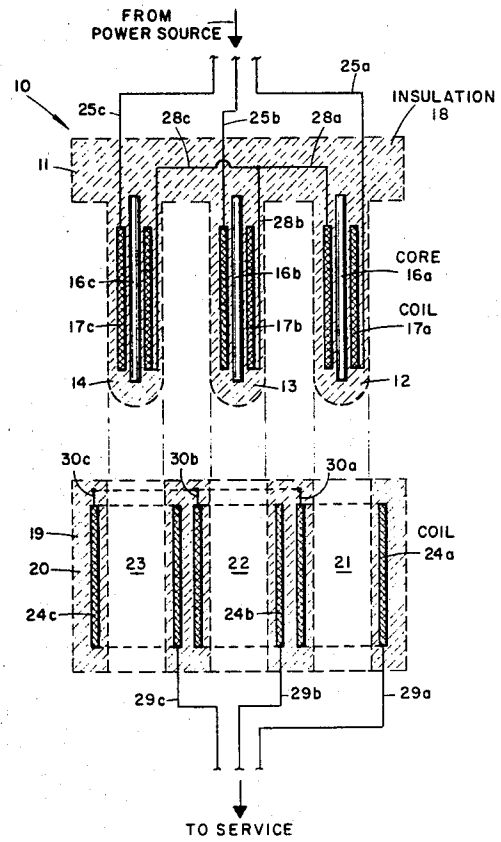
ABSTRACT: Method and apparatus for use in making electrical connections particularly at remote locations and/or under water. Also, method and apparatus for remotely processing fluids produced from subsea wells and for servicing such apparatus. A male section of an electrical connector contains at least two angularly spaced-apart prongs surrounded by electrically nonconductive material. Each prong comprises a coil arranged around a metallic (magnetic) core. A mating female section of the electrical connector engageable with the male section contains at least two angularly spaced-apart holes formed in an electrically nonconductive material. A coil imbedded in the nonconductive material is arranged around each hole. The coils of each section may be oriented linearly instead of angularly. One section is connected to a source of AC electrical power and the other section is connected to apparatus to be operated by electrical power. The other section is installed near such apparatus which may be at a remote underwater location. The one section connected to the source of AC is then engaged with the other section to thereby connect the source of electrical power and the equipment to be operated. The connection may be made underwater by hand, by divers, by mechanical means or hydraulically by pumping the one section connected to the AC power source through a conduit. The latter hydraulic technique may also be used in making surface electrical connections remotely for the conduit may be a surface pipeline. A fixed template is arranged on the sea floor and provided with pipe connections to at least one subsea well and to a surface terminal for produced fluids. A movable template, capable of being lowered to a submerged position on the fixed template and raised therefrom to the sea surface, is provided with sealed fluid-processing equipment having intake and discharge fluid conduits connected thereto. Guide means are provided for lowering and raising the movable template onto and from the fixed template. When so arranged, one of the pipe connections is connected to the inlet conduit of the processing equipment and the other pipe connection is connected to the discharge conduit thereof. One section of the electrical connector is arranged on the fixed template and the other section thereof is mounted on the movable template. When the movable template is arranged on the fixed template, the mating sections of the electrical connector are engaged for transmission of electrical power.



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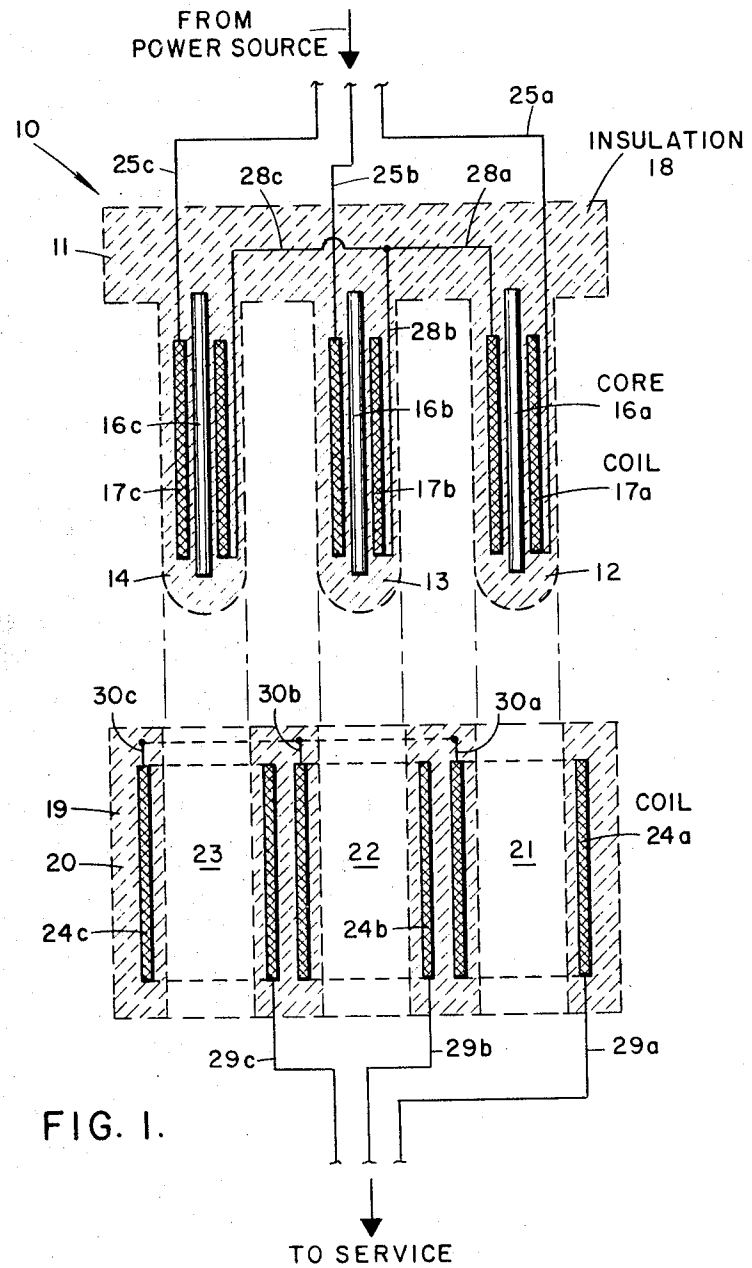

FIG. 1.

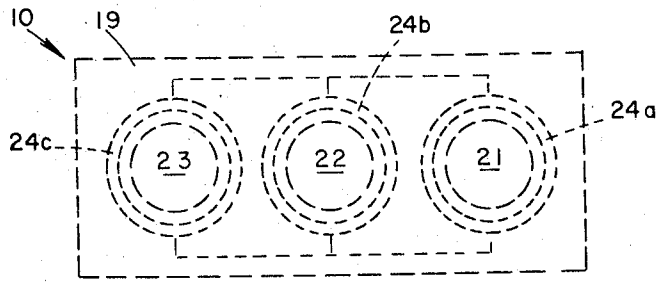

FIG. 2.

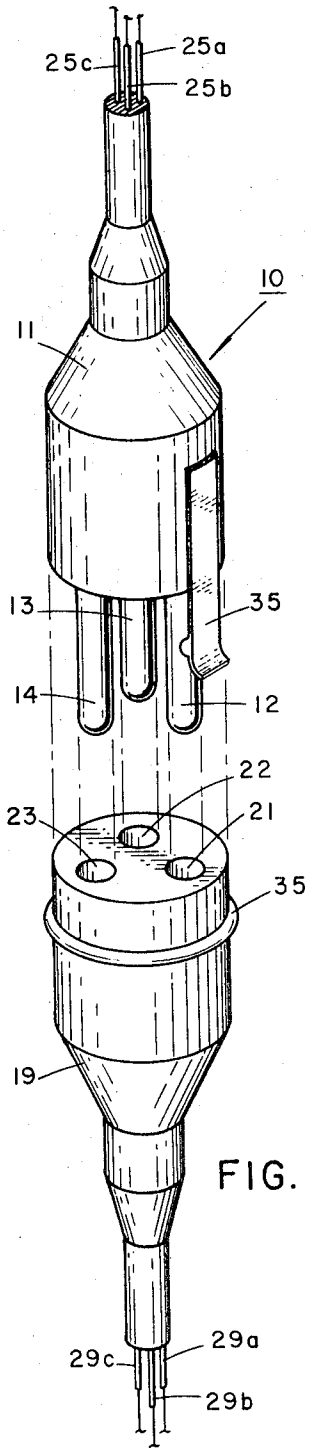

FIG. 3.

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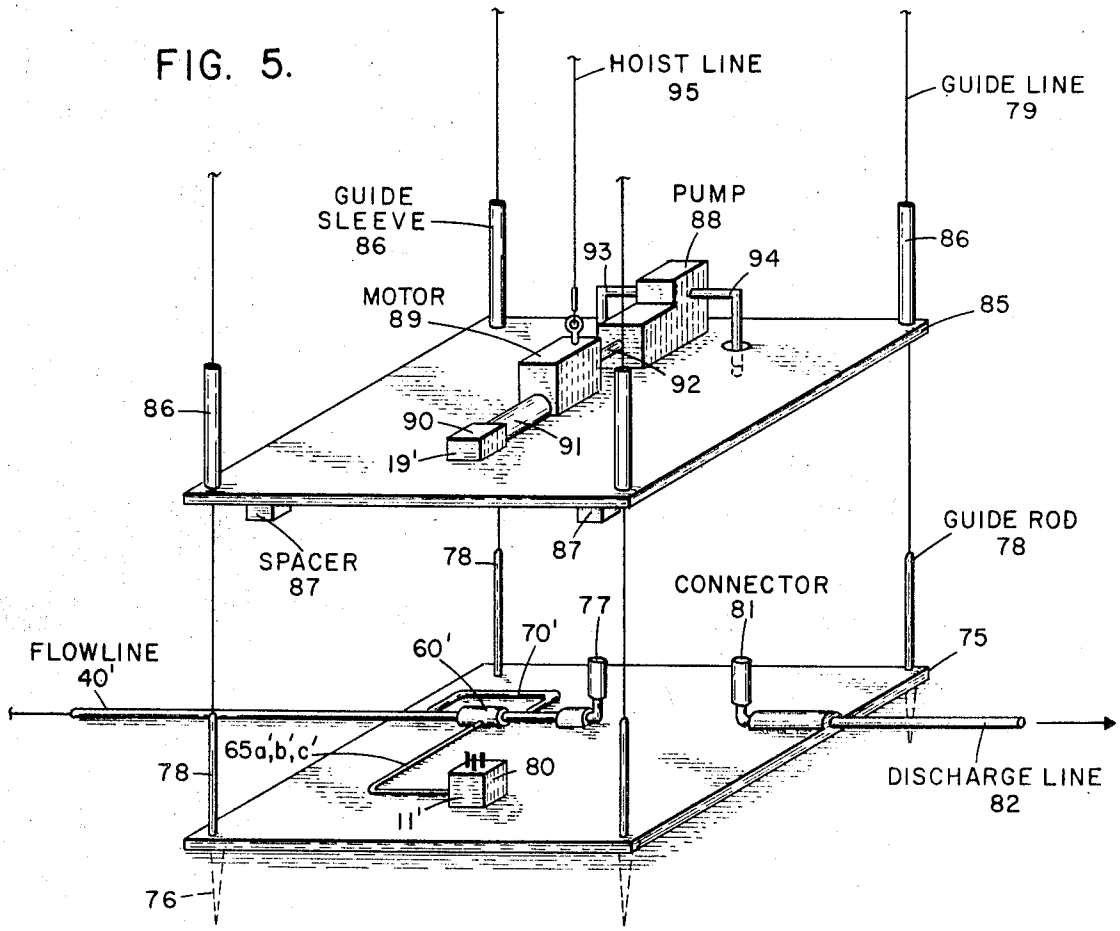
FIG. 5.



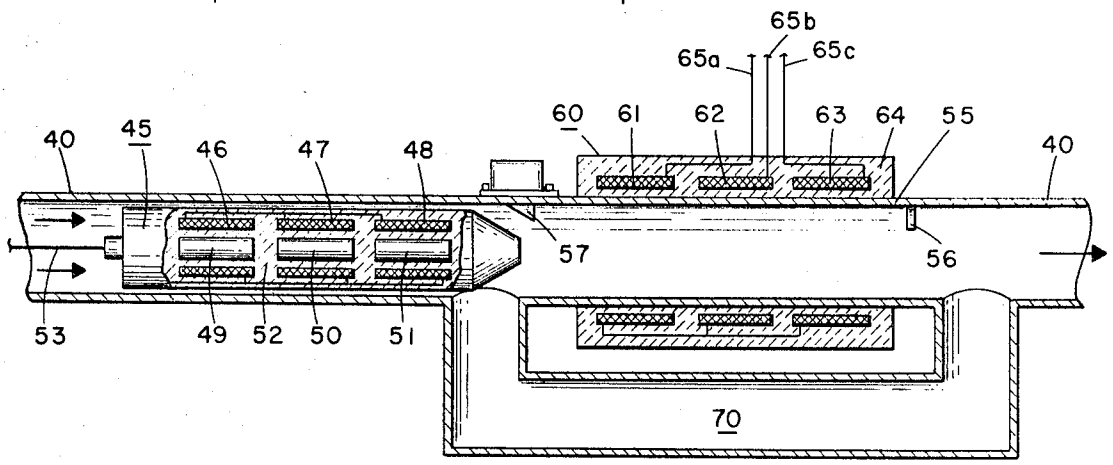


FIG. 4.

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METHOD AND APPARATUS FOR MAKING EQUIPMENT CONNECTIONS AT REMOTE UNDERWATER LOCATIONS AND FOR PRODUCING FLUIDS FROM UNDERWATER WELLS

FIELD OF THE INVENTION

The present invention generally concerns electrical connections, and more particularly, method and apparatus for making electrical connections at remote locations. The invention also concerns method and apparatus for making electrical connections underwater.

There are today many applications for making electrical connections at remote locations and particularly underwater remote electrical connections. Electrical connections that can be readily made underwater, and remotely, facilitate use of submerged equipment for producing wells, including electrically operated valves, pumps, lights, television, production control devices, etc. The present invention provides a simple solution for making remote electrical connections and for making electrical connections under water, and is particularly advantageous for use in offshore oil and gas exploration and drilling operations.

In addition, the present invention concerns operation and servicing of submerged fluid-processing equipment used in offshore oil and gas production operations.

SUMMARY OF THE INVENTION

In accordance with the teachings of the invention, one section of an electrical connector includes at least two spaced-apart magnetic cores, each surrounded by a coil of wire, adapted to engage with a sealed female section of the connector which includes at least two angularly spaced-apart holes formed in electrically nonconductive material, each of which is surrounded by inductance coils which are electrically sealed off by the nonconductive material. One of the sections is electrically connected to an AC current source and the other section is electrically connected to equipment to be supplied with electric power. The coils of the male and female sections are sealed in the nonconductive material so that the connection may be made without having to alter the conductive environment of underwater operations. When the connection is made underwater, it may be made by divers or robots or by lowering one section through the water to engage the other section by means of guidelines, or by pumping one section through a conduit to the other section which is remotely positioned in that conduit. Alternately, the coils of the mating sections may be oriented linearly instead of angularly. When the connection has been made between the sections either by moving the male section to the female section, or vice versa, and AC current is applied, current change in one of the circuits produces an induced e.m.f. in the other circuit through mutual inductance between the two sets of coils.

Also, in accordance with the teachings of the invention, a first member provided with a pipeline connection to at least one subsea well and a pipeline connection to a terminal for produced well fluids at the sea surface is fixed or arranged on the sea floor. A second member on which is arranged well fluid-processing equipment having intake and discharge fluid conduits connected thereto is removably arranged on the first member. Guide means are provided for positioning the second member onto the first member. When the first and second members are engaged, one of the pipe connections is connected to the intake fluid conduit and the other pipe connection is connected to the discharge fluid conduit. One section of a two-part electrical connector is mounted on the first member and the other mating section is mounted on the second member so that when the first and second members are engaged, the electrical connector parts are engaged and the electrical connection is made. The first and second members are preferably templates and the second template is removable for the purpose of removing processing equipment to the water surface for servicing of such equipment.

The objects and advantages of the invention will be apparent from a more detailed description thereof when taken with the drawings wherein:

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a schematic illustration of one embodiment of the electrical connector of the invention prior to makeup;

FIG. **2** is a top view of the female section of the electrical connector of FIG. **1**;

FIG. **3** is an isometric view of the electrical connector shown in FIGS. **1** and **2**;

FIG. **4** illustrates another embodiment of the invention in which the mating coils of the electrical connector are linearly arranged; and

FIG. **5** illustrates use of the electrical connectors illustrated in FIGS. **1** to **4** in the remote (underwater) processing of fluids produced from subsea wells.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to the drawings in greater detail, in FIGS. **1** to **3** is shown an electrical connector generally designated **10**. This connector includes a male section **11** containing three spaced-apart prongs **12**, **13** and **14**, each comprising a magnetic-metallic core **16***a*, *b*, *c*, about which is wound a coil of wire **17***a*, *b*, *c*. Each core and coil of wire is surrounded by insulating nonconductive material **18**, such as rubber, to electrically seal the male section. Connector **10** also includes a female section **19** comprising nonconductive material **20**, such as rubber, provided with three angularly spaced-apart holes or openings **21**, **22** and **23**, each surrounded by a coil of wire **24***a*, *b*, *c*. Nonconductive material **20** electrically seals these coils. Leads **25***a*, *b*, *c* connect one of the ends of coils **17***a*, *b*, *c* to an AC power source. The other ends of coils **17***a*, *b*, *c* are connected together by leads **28***a*, *b*, *c*. Leads **29***a*, *b*, *c* connect one of the ends of coils **24***a*, *b*, *c* to subsurface equipment to be supplied with electrical power. The other ends of coil **24***a*, *b*, *c* are connected together by leads **30***a*, *b*, *c*. Alternately, leads **29***a*, *b*, *c* could be connected to the AC power source and leads **25***a*, *b*, *c* could be connected to the subsurface equipment to be serviced with electrical power.

As shown in FIG. **3**, a latch mechanism **35** may be provided to latch sections **11** and **19** together once they have become engaged. When so engaged, the connection is equivalent to a three-phase power transformer. Any desired electrical circuitry, "Y," "Δ," "V," or "T" connections, may be used to achieve the desired output voltage and number of phases. The three-hole AC illustration in FIG. **3** shows the Y–Y electrical arrangement. It may be desired to make a remote electrical connection of this type for the purpose of transmitting electrical power to operate motors or for transmitting information signals across the electrical connection. Such information signals may be used, for example, to convey the status of the subsea equipment or to control operation of the subsea equipment.

In a typical underwater operation, one section (male or female) is positioned on or near the submerged equipment located on the ocean floor to which such section is electrically connected. The other section, wired to an AC source of power, is then brought into engagement with the one section previously located on the ocean floor and latched thereto by latch mechanism **35**. The electrical connection in accordance with the invention may be made by divers or robots or by lowering the other section through the water from the surface thereof on guide cables or by use of an acoustic or other signal-type guidance system.

The electrical connection may also be made by hydraulically transporting one section to the remotely positioned other section through a conduit. Such conduit may be a flowline connecting above-water installations to below-water well equipment or for surface operations may be a pipeline or other type conduit forming a closed passageway between two separated points. A technique for running such equipment

through a conduit is disclosed and claimed in application Ser. No. 746,097, entitled, "Method and Apparatus for Running a Line Through a Conduit," by Bielstein et al., filed July 19, 1968. Also, the coils of the connector sections may be arranged linearly instead of angularly. These modifications are illustrated in FIG. 4 where there is shown a pipeline **40** in which is arranged a male connector section **45** containing three linearly spaced-apart coils of wire **46, 47, 48**, each surrounding a magnetic core **49, 50, 51** arranged in nonconductive material **52**. Section **45** acts as a piston and is forced through pipeline **40** upon the application of fluid pressure behind it (in the direction indicated by the arrowed lines). Three leads indicated at **53** connect to the coils of wire **46, 47, 48** at one end thereof and at the other end thereof to a remote source of AC electrical power. Downstream of section **45**, pipeline **40** is formed of a nonconductive, nonmagnetic section **55** provided with stop **56** and spring-loaded latch members **57**. The female section **60** of the connector is arranged in the nonmagnetic section **55** of pipeline **40** and it includes three linearly spaced-apart coils **61, 62, 63** imbedded in electrically nonconductive material **64**. Three leads indicated at ***65a, b, c*** are connected at one end to coils **61, 62, 63**, respectively, and at the other end to equipment to be serviced by the electrical power induced in coils **61, 62, 63**. A bypass conduit **70** is connected to and communicates with pipeline **40** on either side of section **60**.

In the operation of this embodiment of the invention section **60** is installed in the portion **55** of pipeline **40**. Pipeline **40** may be a submerged flow line arranged on the floor of the ocean. When it is desired to make the electrical connection, section **45** is pumped through flow line **40** from the surface of the water until the forward end of section **45** engages stop **56**. In that position of section **45**, spring-loaded member **57** engages the rear of section **45** and locks the two sections of the electrical connection in place. Fluid flowing through pipeline **40** bypasses this connection through bypass conduit **70**.

Use of the electrical connection in the remote pumping of underwater wells is illustrated in FIG. **5**. There is shown in this FIG. a rectangular or square plate member **75** secured to the ocean floor by spikes or driven piling **76** connected to each corner of plate member **75**. The apparatus shown and described with respect to FIG. **4** is arranged on plate member **75**. This apparatus includes a pipeline or flow line **40'**, female section **60'**, bypass conduit **70'** and electrical leads ***65a', b', c'***. Flow line **40'** terminates in a pipe connector **77**. Each corner of plate member **75** is provided with a guide rod **78**, to each of which is connected a guideline **79**. Also arranged on plate member **75** is a male section **80** of an electrical connector **11'**, to which leads ***65a', b', c'*** are also connected. Male section **80** is the same as the male section **11** of FIGS. **1** and **2**. Also, another pipe connector **81** and a discharge flow line **82** are permanently affixed to plate member **75**. An upper plate member, preferably square or rectangular in shape, **85** has a guide sleeve **86** mounted on each corner thereof and a plurality of spacers **87** on its underside. Guidelines **79** extend through guide sleeves **86**. On plate member **85**, removable replaceable equipment including a pump **88** and motor **89** are mounted. A female section **90** of electrical connector **11'** is also mounted on plate member **85**. Its leads are connected to motor **89** within sealed housing **91**. Motor **89** drives pump **88** by means of shaft **92**. Pump **88** is provided with an intake conduit **93** which, when plate member **85** is in position on plate member **75**, sealingly engages pipe connector **77**. Similarly, a discharge line **94** from pump **88** sealingly engages pipe connector **81** when plate member **85** is in position on plate member **75**. Also, when plate member **85** is in that position, the prongs of male section **80** engage the holes in the female section **90** to complete the electrical connection. Remote pipe or flow line connectors such as **77** and **81** which permit pipe sections to be separated and then sealingly joined together again are known and may be of the type shown and described on page **1105** of the "Composite Catalog of Oil Field Equipment and Services," 1968, published by World Oil and in the "Cameron Marine Systems" brochure referenced therein.

Plate member **85** and the equipment associated therewith are raised and lowered on guidelines **79** by a hoist line **95** shown connected to the housing of motor **89**.

When it is desired to service pump **88** and/or motor **89** or to replace one or both of these units, plate member **85** is raised to the water surface by means of hoist line **95**. In that procedure, female section **90** of electrical connector **11'** is separated from the male section thereof and pipe connectors **77** and **81** are separated from the intake and discharge conduits, respectively, of pump **88**. After repairs or replacements have been made to pump **88** and/or motor **89**, plate member **85** is lowered on guidelines **79** by hoist line **95** until spacers **89** rest upon plate member **75**. In that position the prongs of male section **80** engage the holes of female section **90** and pipe connectors **77** and **81** sealingly connect with intake conduits **93** and **94**, respectively. If the male section of the other electrical connector is not in position within the female section **60'**, it is pumped through flow line **40'** to place it within the female section. The fluid flowing through flow line **40'** flows through bypass conduit **70'** and into intake conduit **93** of pump **88**. When it is desired to operate pump **88**, a source of AC electrical power, preferably from a 220 -Volt power source, is transmitted through leads **53** to the coils in female section **60'** to thereby induce a voltage in the coils of the male section. This voltage is transmitted to the connector **80** through leads ***65a', b', c'*** which in turn induces a voltage in the coils of the female section **90**, which power is then transmitted to the motor **89** to operate it and thence the pump **88** through shaft **92** to pump fluid through the intake conduit **93**, discharge line **94**, through the pipe connector **81** and to the discharge line **82**. Other fluid-processing equipment, such as flowmeters, separators, dehydration units (natural gas), etc., may be carried on removable plate member **85** in addition to or in substitution for pump **88**.

Changes and modifications may be made in the specific illustrative embodiments of the invention shown and described herein without departing from the scope of the invention as defined in the appended claims. Thus, instead of using three coils in each section, only two coils or more than three coils may be used in each section. Also, instead of using a 220-Volt power source, a 110-Volt power source might be used. The pump intake and discharge lines **93** and **94** may be reversed so as to permit pumping fluid from discharge line **82** into pipeline **40'**. Although only two flow lines and one pump are used for purposes of illustration, additional pumps and/or other fluid-processing equipment units and inlet and outlet flow lines attached thereto are contemplated by this invention. Further, means other than guidelines, such as an acoustic or other signal-type guidance system, may be used to position plate member **85** properly on plate member **75**.

I claim:

1. Apparatus for remotely processing fluids produced from subsea wells and connecting subsea equipment components comprising:

a first member fixed on the sea floor provided with a pipeline connection to at least one subsea well and another pipeline connection to a terminal for produced well fluids at the sea surface;

a second member provided with processing equipment for said produced well fluids having intake and discharge fluid conduits connected thereto;

guide means for positioning said second member onto said first member, in which position one of said pipelines connects to said intake fluid conduit and the other of said pipelines connects to said discharge fluid conduit; and

one section of an electrical connector mounted on said first member and a second section of said electrical connector mounted on said second member, said sections of said electrical connector being engageable with each other when said first and second members are engaged such that AC current applied to one section produces an induced e.m.f. in said other section, said one section being connected to a source of AC current and said other section being connected to at least one of said subsea equipment components for electrical operation thereof.

2. Apparatus as recited in claim 1 in which said first and second members are templates.

3. Apparatus as recited in claim 2 in which said equipment includes pumping means adapted to transmit well fluids from said subsea well to said terminal for produced well fluids through said pipelines.

4. Apparatus as recited in claim 2 in which said guide means includes guide lines, guide rods, guide sleeves and a hoist line.

5. Apparatus as recited in claim 2 in which said guide means is signal controlled.

6. Apparatus as recited in claim 1 in which one of said connector sections includes at least two spaced-apart magnetic cores, each surrounded by a first coil of wire, and both said cores and said first coils being surrounded by electrically nonconductive material to seal off said cores and coils electrically; and said other connector section including at least two spaced-apart second coils surrounded by electrically nonconductive material to seal off said second coils electrically.

7. Apparatus as recited in claim 6 in which one of said connector sections includes at least two angularly spaced-apart prongs, each prong comprising a magnetic core, a coil of wire surrounding each magnetic core and electrically nonconductive material surrounding said cores and said coils; said other connector section includes electrically nonconductive material containing at least two angularly spaced-apart holes about each of which a coil of wire is arranged; and said prongs being adapted to be inserted in said holes when said first and second connector sections are engaged.

8. Apparatus as recited in claim 7 in which one of said connector sections contains three spaced-apart prongs and said other connector section contains three holes for accommodation of said three prongs.

9. Apparatus as recited in claim 8 in which said connector sections are provided with latch means adapted to latch said connectors to each other.

10. Apparatus as recited in claim 1 in which said coils of said connector sections are linearly spaced-apart.

11. Apparatus as recited in claim 10 in which one of said connector sections contains three coils and said other connector section contains three coils.

12. Apparatus as recited in claim 10 in which one of said connector sections is pumpable through a pipeline.

13. A method for servicing apparatus used to process remotely fluids produced from said subsea wells and connecting subsea equipment components comprising the steps of:

arranging on the sea floor a first template containing a flow line connection to at least one subsea well and a flow line connection to a terminal for produced well fluids at the sea surface;

lowering and installing a removable second template on said first template, said second template containing well fluid-processing equipment and means adapted to connect said well fluid-processing equipment to said flow line connections;

retrieving said removable second template to the water surface for the purpose of servicing said well fluid processing equipment;

reinstalling said second template on said first template following servicing of said processing equipment; and

arranging on said first template one section of an electrical connector and arranging on said second template another section of said electrical connector, said connector sections, when engaged, comprising at least two sets of inductance coils arranged such that application of AC current to one set of coils induces an e.m.f. in the other set of coils, said connector sections being engaged when said second template is lowered and installed on said first template, said one section being connected to a source of AC current and said other section being connected to at least one of said subsea equipment components for electrical operation thereof.

14. A method for remotely connecting subsea equipment components comprising the steps of:

arranging on the sea floor a first template containing a flow line connection to at least one subsea well and a flow line connection to a terminal for produced well fluids at the sea surface;

lowering and installing a removable second template on said first template, said second template containing well fluid processing equipment and means adapted to connect said well fluid processing equipment to said flow line connections;

retrieving said removable second template to the water surface for the purpose of servicing said well fluid processing equipment;

arranging in a subsea conduit located on said first template one section of an electrical connector; and

pumping another section of said electrical connector to said conduit from a remote location until said connector sections engage, said connector sections, when engaged, comprising at least two sets of inductance coils arranged such that application of AC current to one set of coils induces an e.m.f. in the other set of coils, said other section being connected to a source of AC current and said one section being connected to at least one of said subsea equipment components for electrical operation thereof.