

PATENT SPECIFICATION

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- (21) Application No. 47752/77 / (22) Filed 16 Nov. 1977 / (19)
(31) Convention Application No. 743 586 (32) Filed 22 Nov. 1976 in
(33) United States of America (US)
(44) Complete Specification published 15 Oct. 1980
(51) INT. CL.³ E02D 29/00
(52) Index of acceptance
E1H 603 606 B
E1F 31E



(54) SUBSEA INSTALLATION

(71) We, SOCIETE NATIONALE ELF AQUITAINE (PRODUCTION), Tour Aquitaine — 92400 Courbevoie, France, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

Subsea stations and installations have been contemplated for use in water depths beyond convenient diver working depths. Such subsea stations have been installed, maintained and operated by automatic, remote systems. Such prior subsea installations have been designed for single and multiple well requirements.

In subsea installations below depths at which divers may readily operate, installation, maintenance and operation of such installations was accomplished by automatic, remote control means, remotely controlled robot devices, or by submarine devices. In many such prior subsea installations, connections of flowlines, power lines and various types of equipment usually required some relative horizontal movement of connector parts. Such relative horizontal movement of parts by remote control was often difficult because of the need for precise alignment, registration or orientation in a horizontal mode. Further, such prior subsea installations were inadequately protected from the hostile environment of the sea water, inadequately protected from subsea currents and movement of foreign matter by such currents. Maintenance and repair of a part of the installation often required shut-down of operating systems which were not directly associated with the part being repaired.

Solutions to some of the problems mentioned above are suggested by U.S. Patent No. 3,633,667 which shows a multiple well-head template provided with a wellhead unit and a production control unit, which were recoverable as units for maintenance and service. A subsea robot device movable about a wellhead on a rail is shown in U.S. Patent No. 3,099,316.

According to the present invention there is provided a subsea installation for assembly and use in virtually any depth of water, comprising in combination an elongate rigid base frame adapted to be permanently placed on the sea floor and including longitudinal members and transverse members defining with said side members a plurality of framed receptor openings, a conductor pipe centrally located in each opening and connected to said side and transverse members; a base guide unit receiveable in one of said receptor openings in coaxial alignment with said conductor pipe located in said one receptor opening; a removable unitary module assembly movable vertically into cooperation with said base guide unit for aligning and registering said module with said one receptor opening in said base frame; said module assembly having well operating means adapted for connection to well operating components by relative vertical movement; said side and transverse members at ends of said base frame having vertically disposed guide means for connection by relative vertical movement to well operating components; and control means for said module assembly adapted to be supported from said base frame and to be releasably interconnectable with said module assembly.

The invention also provides a method of assembling and installing such a subsea installation comprising the steps of lowering and placing on a seabed the base frame having the plurality of receptor openings; lowering the module assembly onto the base guide unit received in one of the receptor openings of said frame and releasably interconnecting said module assembly with said base guide unit; lowering and releasably connecting to said base frame two elongated side structures each extending along one side of the base frame to provide side structures on opposite sides of said module assembly; releasably interconnecting fluid conducting means on said side structures to said module assembly; interconnecting adjacent ends of said elongated side structures at one end of said base frame.

In addition the invention provides a method of assembling and installing a subsea installation according to the invention, comprising the steps of lowering and placing on a seabed the base frame having the plurality of receptor openings and spaced connector means for certain equipment to be lowered thereafter; lowering the base guide unit having a guide line to said base frame and releasably securing said unit thereto; lowering the module assembly pre-assembled at the surface onto the guide unit and releasably connecting said module assembly thereto; lowering and releasably connecting to said base frame two elongated side structures extending along either side of the base frame to provide side structures on opposite sides of said module assembly; releasably interconnecting fluid conducting means on said side structures to said module assembly; lowering and releasably interconnecting transversely disposed pipe loop means to cooperably associated connector means at one end of said base frame; and interconnecting said pipe loop means with said fluid conducting means.

A better understanding of the invention will be had from the following detailed description, given by way of example with reference to the accompanying drawings in which:—

Figure 1 is a perspective view of a sub-sea station or installation embodying this invention, the station and recoverable modules assembled therewith being drawn in detail.

Figure 2 is a schematic, transverse, sectional view taken in a vertical plane showing the arrangement of the rigid base means and a pair of side structures thereon.

Figure 3 is a perspective view of the rigid base assembly shown in Fig. 1.

Figure 4 is an enlarged, fragmentary, perspective view of one of the receptor openings within which is positioned a module base means.

Figure 5 is an enlarged, perspective view of an exemplary modular assembly shown in Fig. 1.

Figure 6 is a fragmentary, transverse, sectional view taken in a radial plane indicated by the line VI—VI of Fig. 5.

Figure 7 is a perspective view of a pair of side structures shown in Figs. 1 and 2.

Figure 8 is an enlarged, perspective view of a pipe loop means shown at one end of the station shown in Fig. 1.

Figure 9 is a top plan view schematically illustrating the connection of a seabed flowline to the pipe loop means on the subsea station shown in Fig. 1, the flowline being shown as extending beyond the subsea station and a remotely operated pipe connecting device being indicated in phantom lines.

Figure 10 is a fragmentary, schematic view of Fig. 9 showing the pipe cutting device and the seabed flowline after it has been cut at a selected point.

Figure 11 is a schematic view showing the pipe cutting device installing a pre-cut pipe length to connect the end of the seabed flowline and the free end of the pipe loop means.

Figure 12 is a schematic view showing the completed flowline-pipe loop connection.

Figure 13 is a top plan view of a drilling ship and a work boat carrying a rigid base template frame means thereon prior to lowering of the base frame means.

Figure 14 is a side elevational view illustrating the connection of drill pipe to the frame means on the work boat and winch means for lowering the frame means over the stern of the work boat.

Figure 15 is a view similar to Fig. 14 showing the rigid frame means tilted at an angle as it is moved over the stern of the work boat.

Figure 16 is a view similar to Figs. 14 and 15 showing the rigid frame means in vertical position off the stern of the work boat.

Figure 17 is a view similar to Figs. 14, 15 and 16 showing the rigid base means in a horizontal position and being lowered to the seabed.

Figure 18 is an enlarged, fragmentary view taken in the plane indicated by line XVIII—XVIII of Fig. 17 showing a means for controlling the angular orientation of the frame means.

Figure 19 is an end view of the drill ship with the rigid base means being lowered by drill pipe to the sea bottom.

In Fig. 1, a subsea station or installation embodying this invention is generally indicated at 20. Subsea installation 20, generally speaking, comprises a rigid template base means 21 having a plurality of frame receptor openings 22. In alignment and in registration with one or more of the receptor openings 22 are recoverable unitary module assemblies 23 and 24, which are releasably connected to base frame means 21 and which carry equipment particularly selected and adapted for the intended purpose and use of the subsea installation. The subsea installation is shown used for the production and handling of liquid hydrocarbons obtained from one or more subsea wells.

An elongated, recoverable, side structure 25 is releasably mounted on each longitudinal side of base means 21 and on opposite sides of the module assemblies 23, 24. The elongated side structure 25 carries suitable power lines and fluid conducting lines. Power and fluid conducting lines on each side structure 25 may be releasably

connected with associated lines on modular assemblies 23, 24 for operation thereof, as later described. At one end of base means 21, a transversely disposed pipe loop means 26 interconnects adjacent ends of the side structures 25 and may be releasably supported on the base means. At the opposite end of base means 21, a flowline connector means 27 is provided for connection with suitable fluid conducting lines on the associated side structure 25. At the same end of base means 21, an electrical power connecting means 28 is provided for supplying electrical power to the modular assemblies and to other power operated equipment on the installation 20. The power source may be remotely located on a ship, vessel platform or on shore. The power source may also be a nuclear or other self-contained power source adapted to be carried by the subsea station. The installation 20, generally described above, provides a complete operable installation intended to be permanent but includes unitary assemblies, each of which is recoverable, without interrupting operation of other units, for inspection and maintenance or for dismantling of the installation, except for the base means 21.

The rigid base means 21 (Fig. 3) comprises an elongated, rectangular, rigid structure of suitable length and width. In this example, base means 21 includes vertically spaced parallel side frame tubular members 30, the side members 30 along each side being interconnected by spaced vertical struts 31. Top members 30 are interconnected by transversely extending tubular members 32, which define with the top side members 30, the receptor openings 22. Each receptor opening 22 includes a conductor pipe 33 rigidly connected to the frame members 30 by transverse tubular elements 34 and rigidly connected to the transverse members 32 by central longitudinally extending members 35 connected to transverse members 32 by vertical struts 36. The base frame means 21 may also include longitudinally extending parallel tubular members 37 interconnecting transverse members 34, said members 37 being provided with longitudinally spaced cleats or eyelets 38, so arranged with respect to each receptor opening 22 as to provide means for connecting a plurality of guide lines depending from a support vessel. Also, the transverse members 34 and the longitudinally extending member 35 may be provided with support and securing pads 39 for attachment of equipment as later described.

Top side members 30 carry outboardly disposed longitudinally spaced removable guide posts 41 attached to members 30 in suitable manner and providing vertical guidance means for well operating components constituted by the side structures 25 as

hereafter described. At one end of the base means 21, vertically disposed guide posts 42 provide a guidance means for connection of another well operating component in the form of the pipe loop means 26. At the opposite end of the base means 21, vertical guide posts 43 are provided adjacent one corner for cooperable guidance of well operating components in the form of flowline connector means as later described. At the same end, vertical guide posts 44 may be provided for guidance of other well operating components in the form of an electrical connector means, as later described.

Along each side of base means 21 and mounted about a vertical pivotal axis at 46 are a plurality of spaced flowline support arms 45 of generally V-shape for supporting a flowline along side the base means 21. During installation, each support arm 45 may be pivoted about its pivotal axis 46 to lie generally within the plane of the top and bottom side tubular members 30. The arms 45 may be rotated through 90° to extend outboardly from the base means after the base means has been positioned on the seabed.

Other support pads, vertically disposed guide posts and eyelets or cleats may be secured to the base means to accommodate other equipment. The rigid base means 21 may be made of any suitable structural members, tubular members being preferred because of their strength, buoyancy characteristics, and their possible use as ballast means, if desired. The surfaces of the tubular members may be treated with corrosive resistant material and by sacrificial anodes.

Conductor pipes 33 centrally located with respect to the receptor openings 22 provide an upwardly and outwardly flaring seating surface, which may be used for centering and guiding of a modular unit in the opening, used for drilling a well hole there-through, and are so arranged to permit modular units or other equipment installed in the receptor opening to be vertically disposed in the event the sea bottom is at a slightly inclined angle.

For each opening 22, which is to receive a modular assembly such as 23, 24, there is provided a base guide means 50, Fig. 4. Each base guide means 50 includes a generally square or polygonal frame 51 formed of structural sections, such as I-section and having a centrally supported flanged cylindrical member 52 for coaxial alignment with conductor pipe 33. Cylindrical member 52 is supported by diagonal, structural elements 53. Depending from each frame member 51 are support plates 54 adapted for cooperable seating connection to securing pads 39 on base means 21. Support plates 54 may be welded to a back

plate 55 which includes a downwardly opening yoke 56 forming an opening for reception of tubular members 34 and 35.

5. Bahe guide means 50 also includes, at each corner, means forming a cylindrical thru bore means 58 having a vertically disposed through slot 59 facing diagonally outwardly from the base guide means. Bore 58 receives the lower end of a guide post 60 provided with a longitudinally extending slot 61 which is alignable with the slot 59 of the cylindrical bore means 58. The guide post 60 is adapted to receive therethru a guide line 62 which may be secured to a cleat 38 on tubular member 37. The guide line 62 may be retained within the guide post 60 by a top slot closure element 63 and by a suitable slot closing means 64 on the corner cylindrical bore means 58.
10. Thus, the base guide means 50 may be lowered along four guide lines into proper alignment and registration with the receptor opening and with the conductor pipe 33 therein. The guide lines may be released upon disconnection from the cleats on the tubular members, opening of the slot closure elements 63 on the guide posts and then moving the guide lines laterally through the vertical slots 69 and 61 to release the lines from the base guide means 50.

20. It will be understood that in some instances the base guide means 50 may be secured in the receptor opening before the base means 21 is lowered to its position on the sea floor. The construction of the base guide means 50, as described above, permits the lowering and connection of the base guide means to base means 21 in the event it is desired to occupy another receptor opening 22 with another type of modular assembly.

35. Modular assemblies 23 and 24 are pre-assembled and fabricated on shore to perform desired functions; in this example, modular assembly 23 (single module) includes the necessary equipment for a production control unit and modular assembly 24 (dual module) includes equipment for a well-head assembly. Since each modular assembly includes common structural elements and the well operating equipment associated with each assembly may be different because of the different uses and functions of the modulator assembly for brevity the structure of only one of the modular assemblies will be described in detail.

45. Modular assembly 24, Figs. 1, 5 and 6 may comprise a top circular wall means 70 having a depending peripheral flange 71 provided with a plurality of circumferentially spaced reinforcement ribs supporting a bottom annular horizontal flange 73. A downwardly facing recess 73a is provided by top wall 70 and depending flange 71 for

the collection of lighter than water pollutants, such pollutants collecting beneath the top wall 70 and being detected by suitable sensing means 73b. After detection of such pollutants, means may be actuated for removing the pollutants.

Below top wall 70 is provided a modular base 74. A plurality of peripherally spaced columns 75 are connected to the module base 74 and top wall means 70 by suitable connecting means. Columns 75 provide an open cage adapted to protect equipment within the cage from damage by debris or objects moving across the sea floor.

Module base 74, in this example, includes side tubular base members 76 and upwardly offset diagonal members 77 interconnected at vertical guide sleeves 82 and supporting a two part cylindrical housing 76 for axially positioning connector means 79 or other well operating equipment along the axis of the base guide means 50 and conductor pipe 33 on the base means 21. Extending between the top wall means 70 and the module base 74 and connected to the connector means 79 may be other suitable equipment arranged in axial alignment and providing a central structural core generally indicated at 81, rigidly supporting and interconnecting top wall 70 with base 74. A mandrel means 80 axially extends above top wall 70 for connection with well operating equipment which is lowered for association with the modular assembly 24 and is shown with protection closure means thereon.

Guidance means for the modular assembly 24 is provided by a vertically disposed cylindrical sleeve 82 provided at each end of base frame members 76 and dimensionally arranged to be guided over and to receive guide posts 60. A second part 74¹ carries safety mechanical tree equipment for association with the well and with production equipment thereabove on module part 74 which may be automatically or remotely controlled. Each sleeve 82 has a longitudinally extending slot 83 closed by suitable gate means 84 for facilitating insertion and removal of installing guide lines.

Modular part 74¹ comprises frame member 76¹ interconnected at their ends with diagonal offset members 77¹ and with vertical guide sleeves 82¹ which receive guide posts 60. Diagonal members 77¹ carry connecting means 79¹ forming part of the rigid core 81. Modular part 74¹ provides a connection to the module base means 50 and permits the upper module part 74 carrying automatic and remote control equipment to be recoverable as a separate module part.

Modular assembly 24 also includes guidance means for equipment being received vertically above the modular assembly. In this example, top wall means 70 is provided with triangular shaped upstanding angularly

spaced gusset walls 86 having downwardly and radially outwardly inclined edges 87 to provide conical guiding surfaces. Similarly, cylindrical top members 88 provided between certain of the gusset members 86 are provided with top edges lying in a transverse plane inclined downwardly and outwardly from the center of the top wall at approximately the same angle as the inclined edges of the plates 86. Thus, devices being lowered for assembly with the modular assembly 24 at the top wall means 70 and provided with a conical funnel corresponding to the cone indicated by inclined edges will be readily guided into coaxial alignment with the modular assembly.

Modular assembly 24 also includes on the top wall 70 a further guidance means, which includes a retractable vertically disposed guide post 91 which facilitates guidance of a device onto the modular assembly 24 by use of a single guideline as described and claimed in co-pending Patent Application No. 1465/78.

Initially, the modular assembly 24 is readily guided into position by four guidelines which are connected to the rigid base means 21 and which extend through the guide base means 50 and through the cylindrical guide members 82, 82¹ on the modular base means 74, 74¹. As seen in Fig. 1, the guidelines pass outside of the circumference of top wall means 70. The structure which forms the central post or core 81 of the modular assembly and the top wall means 70 provides means for supporting selected mechanical, hydraulic, electrical or other equipment within sealed housings supported beneath the top wall or associated with the central core member. The equipment assembly below top wall means 70 is arranged so that none of the equipment protrudes beyond the cylinder formed by the circular flange 71, nor beyond columns 75.

It will be understood that a modular assembly for use as a wellhead would be suitably equipped and may include a female drilling connector supported by the modular base 74¹ for cooperation with a male member carried by the base frame means 21, a plurality of housing for hydraulic, electrical and electronic units clustered beneath the top wall 70, a top cylindrical member 88 for reception of a sub-module, a plurality of accumulators for pressure fluid clustered around the core or central post member of the modular assembly, and various other tools and instruments adapted for mechanical automatic, or remote operation. A top cylindrical member 88¹ may receive a sub-module adapted to provide electrical and hydraulic control connections.

It should be noted that top wall means 70 includes an upwardly facing annular planar surface 90 outwardly of guide gusset

plates 86. Annular surface 90 is adapted to provide a seat for a subsea vehicle or capsule vertically guided onto the module assembly 24. Such a vehicle or capsule has an annular seal member for making a water-tight, air-tight seal with the surface 90. The capsule may include robot equipment to work in equipment carried by the module 24 through a cylindrical member 88. The capsule may be a pressurized vehicle enabling men to perform maintenance, inspection, and service on the module 24.

Another modular assembly is similarly equipped as a central control unit for one or more modular assemblies associated with the base frame means 21. Such a control modular assembly may receive electrical power from a remote source and be equipped to provide suitable power circuits of desired alternating current and direct current systems, a hydraulic power generating system with electrical power units, accumulators, reserve tanks, and distribution system, and devices for receiving control signals and transmitting such signals to the related equipment.

Elongate side structures 25, Fig. 7, are each a self-supporting, preassembled, removable unit which includes the necessary equipment for operably connecting with the module assemblies 23, 24; fluid conducting lines; power cables; a rail system for a subsea vehicle; and connecting means for the transverse pipe loop structure. Preferably, each elongate side structure is made of tubular members which may be provided with means for ballasting the tubular members, if desired.

Each side structure 25 includes a plurality of vertically spaced, parallel, inboard members 95, 96 and 97 and similarly arranged transversely spaced therefrom parallel, vertically spaced, outboard side members 98, 99 and 100. Outboard and inboard members are interconnected by a plurality of transversely extending members 101 and 102 and diagonal bracing members 103 where necessary. The top inboard and outboard members 97, 100 define with the transverse members 102, a longitudinally extending channel within which is received and supported and upwardly facing channel member 104. Channels 104 include along their inboard wall openings 106 in spaced relation and positioned opposite a receptor opening 22 to permit the bending of a conduit or electrical line towards a module or other equipment positioned in the receptor opening 22. In the example shown in Fig. 4, such an opening 106 may receive therethrough a transversely extending portion of a fluid control line 107 which may be equipped with suitable valve means 108 for connection to one of the module assemblies. The fluid line 197 is capable of being turned

about its longitudinal axis which lies parallel to the channel 104 to permit convenient positioning of the transverse or laterally extending portion 107 of the line. To further facilitate connection of the fluid conducting line 107 with a module assembly, the top inboard tubular member 97 may be provided with a plurality of aligned sections 97a at the ends of which are provided weight supporting plugs or bridging gates 109. Each gate may include a cylinder having steel end cores, the adjacent sections 97a and cylinders having "horizontal lap joints". Such gates may be removed so that the line 107 may be bent and passed therethrough as indicated at 110. It will be noted that each end of a section 97a is supported by vertical struts 111 and that the gate 109 provides access to the space between adjacent struts 111 of adjacent sections 97a.

Along the outboard members 98, 99 and 100 and in spaced, longitudinal relation may be provided vertical guide sockets 114 which cooperate with guide posts 41 provided on the base frame means 21. The side structure 25 has a suitable width such that when assembled with the base means 21 the outer side frame tubular members 98, 99 and 100 will extend beyond the side members 30 of base frame means 21. Thus, the side structures 25 provide protection for the rigid base frame means 21. Since the side structures 25 are removable from the rigid base means 21, in the event of severe damage to the side structures 25, they may be raised to the surface for repairs and then reassembled with the rigid base frame means 21.

At one end of each side structure 25, the outboard side tubular members 98 and 99 may be ended in spaced relation to stub sections of said members at the very end of the side structures to provide an opening 116. The topmost outboard side member 100 is provided with a section 117 above said opening, the section 117 being carried by a pair of spaced support arms 118 having a pivotally mounted connection at 119 to a central frame member of the side structure. The hinged arm support for the section 117 permits the section to be swung upwardly and away from the line of the external flowline 120, Fig. 1. The opening 116 and the hinging of the side member section 117 upwardly facilitates the making of a connection of a seabed flowline to the subsea installation as later described.

The side structures 25 may also be provided with securement means in the form of U-bolts 122 for securement of the end of side structure 25 to a transverse member 32 on the rigid base frame means 21.

At the end of the subsea installation at which the openings 116 are provided in the side structures 25, there may be provided a

pipe loop means 26 which extends laterally or transverse across one end of the rigid base frame means 21. The pipe loop means 26 provides a means for connecting fluid conducting lines on the side structures 25 to flowlines on the seabed through a three-dimensionally expandable and contractible pipe loop arrangement. In Fig. 8, loop means 26 comprises a support frame 125 including a pair of vertically spaced, parallel, transverse, tubular members 126, which carry at adjacent opposite ends a cylindrical socket 127 supported by brackets 128 and having a downwardly, outwardly flaring cone 129 for guidance reception of the upstanding vertical guide posts 42 on the rigid base means 21. The frame 125 also includes spaced upstanding channel members 130 connected at their bottom ends to a pair of vertically spaced longitudinally extending members 131, which define therebetween a longitudinally extending guide slot 132.

Pipe loop means 26 includes a fluid conducting pipe 135 adapted to be connected to a seabed flowline on one side of the rigid base frame means 21 and a pipe 136 adapted to be connected to a seabed flowline on the opposite side of the seabed installation. Pipe 136 is bent to provide a transversely extending portion 137 which lies in approximately the same plane as the end of pipe 135 at its connection to the flowline and which passes through the guide slots 132. At the opposite side of the seabed installation, the pipe portion 137 is bent upwardly in a vertical plane to provide a generally U portion 138, which may be connected by suitable coupling means 139 to a T fitting 140, which provides fluid communication through an automatic connector 141 to a fluid conducting line 142 on the side structure 25. At the other end of the T fitting 140, there may be provided a manually operable valve 142 which may be connected to a transversely extending pipe portion 143 which extends between the vertical members 130 and may be connected to a motor driven remotely actuated valve 144 at the opposite side of the pipe loop 26.

The pipe 136 follows a similar configuration in forming the pipe loop means 26. Pipe 136 may be bent to provide a transverse portion 146 which extends transversely through the guide slots 132 and then is bent upwardly to provide a U portion 147 lying in a vertical plane and which has a suitable connection 148 to a T fitting 149 to provide connection through an automatic connector 141 to a fluid conducting line 150, Fig. 1, carried by the side structure 25.

In the arrangement of the pipe loops 135, 137, 138 and 136, 146 and 147, it will be readily apparent that expansion and con-

traction of the pipe will be accommodated in a three-dimensional direction; that is, laterally, vertically and longitudinally relative to the end of the subsea installation. It will be understood that the fluid conducted in the pipes 135 and 136 may be of quite different characteristics. For example, fluid conduct in pipe 135 may be a hydrocarbon fluid being pumped under high pressure and at a certain temperature. Fluid conducted in pipe 13 may be a gas and may be of a quite different temperature. Thus, the pipe loop means 26 provides a unique, symmetrical construction for handling fluids of different characteristics and for providing three-dimensional yieldability to compensate for expansion and contraction of the pipe.

Pipe loop means 26 also provides desired flexibility and yieldability when making a connection to a subsea flowline which extends along the side of the rigid base means and partially beneath the side structure 25 for connecting the subsea installation to a remote station. When making such a connection between the pipe loop means 26 and such a flowline, the section 117 of the outboard top side member 100 may be moved by the hinge arms 118 to an upward position where opening 116 is open at the top for reception of a pipe connecting device schematically indicated at 152, Fig. 9. The connecting device 152 may be lowered and guided vertically through the opening 116 and over an extension of the seabed flowline. Connector 152 is equipped with a cutting member 153 which will then cut the flowline at a location near one end of opening 116. After cutting, the connector device 152 is adapted to lower a precut pipe section 154 which will span the distance between the cut end of the subsea flowline and the end of a pipe, such as 135 or 136, of the pipe loop 26. Upon lowering of the precut pipe into position; that is, coaxial alignment with the subsea flowline and pipe 136, the pipe connection device 152 couple the ends of the precut pipe to the cut flowline and to the pipe 136. It will be apparent that in the marking of such a pipe connection that the sea floor flowline will not be readily longitudinally or axially displaced because of its length and possible partial burial in the sea floor. The end of pipe 136 of the pipe loop 26 is readily laterally yieldable in the slot 132 and the 90 bending of pipe 136 between slot 132 and its free end, pipe 136 is readily and conveniently longitudinally axially displaced to couple pipe 136 to precut pipe section 154.

Means 27 for connecting a fluid conducting line to the subsea installation 20 is illustrated at the end of the installation opposite from the pipe loop means 26. Fluid connecting means 27 is described and claimed in a co-pending Patent Application No. 1472/78.

In general, fluid connecting means 27 comprises a longitudinally extending funnel-like connector 155 having its axis horizontal and provided with a suitable connection 156 to end transverse member 32 of the base frame means 21. In this example, funnel 155 carries on top of its cylindrical portion a pulley block 157 to assist in guiding the end of a fluid connector 158 into the funnel. Connector 158 may be secured in the funnel by suitable means.

A releasable connector unit 159 provided with spaced guide tubes 160 may be vertically lowered onto guide posts 43 provided on the rigid base means 21. Connector unit 159 may include and carry adjacent its bottom a means 161 for connecting to the connector 158. The connecting means is made in a vertical mode. The connector 158 and its attached line 162 may provide hydraulic pressure actuating fluid or other pressure fluid through unit 159 to suitable pipes or hoses located on the side structures 25 and the rigid base means 21 for fluid connection to equipment carried thereby and by modular assemblies 23 and 24 for operation of such equipment. It will be understood that the longitudinally extending side structures provide convenient means for distribution of such fluid conducting hoses and pipes.

Spaced from fluid connecting means 27 at the same end of the installation is an electrical power unit generally indicated at 28. As described above, rigid base means 21 includes a pair of upstanding guide posts 44 at said end, said guide posts 44 being adapted to receive a power unit or module 28 which is provided with guide sockets 166 for reception of posts 44 in a vertical mode. Connected to the electrical power unit 28 may be a suitable cable 165, which may extend to a remote power source. The electrical power unit 28 may comprise any desired electrical equipment for providing AC or DC current and for distribution of such electrical power to the modules 23 and 24 by cables along the side structures 21 or along the rigid base means 21.

The subsea station or installation 20 described above and its construction includes many advantages. The base means 21 provides a permanent structure or foundation upon which various modules and units of different types of construction can be readily supported by installation and guidance in a substantially vertical mode. The modular assemblies 23 and 24 and other modular assemblies to occupy the receptor openings 22 may be readily guided by one or more guide lines to their operating position on the base frame means 21. The elongated side structures 25 are assembled with the base means 21 in a vertical mode and such side structures are positioned on the base means

21 so that they overhang the sides of the base means in order to provide protection to the permanent base means 21. The side structures 25 are adapted to provide a longitudinally extending upwardly facing channel or recess in which may be laid pressure fluid lines and electrical power lines, fluid conducting lines and other means which may be used for operation and control of equipment carried by the modular assemblies 23 and 24. The side structures 25 are so constructed and arranged that the top inboard and outboard rails thereof are supported for use as a track for a subsea vehicle or capsule which may readily move from one modular assembly to another or to equipment thereon or remote manipulation and service of such equipment.

An important advantage of the installation is the provision of precisely located, fixed or controlled connection points for equipment with the base means and with the module assemblies and particularly the points of connection of fluid conducting lines and power lines. Such connecting points are predetermined, built into the assembly arrangement of the base means, side structures, pipe loop means, and in the relation of the module assemblies to equipment associated therewith. Thus, initial installation assembly, maintenance, or workover operations by operators or by remote control are facilitated and enhanced.

It should also be noted that the support of flowlines alongside the rigid base means provides a protected and a convenient means for connecting such flowlines to the pipe loop means 26 at one end of the installation. The pipe loop means 26 at one end of the installation. The pipe loop means 26 provides communication to either or both sides of the subsea installation and provides means for carrying manifold fluid from various modular assemblies on the installation. In this example, if one side structure is removed, the other side structure supports control means sufficient to operate the modular assemblies. The valving and automatic connector arrangement on the pipe loop means permits isolating and operating from one side structure while the other is removed. It will be understood that the power control means for operating the modules includes a main power system and a back-up power system which will permit continuance of operation of several module assemblies during shut down of one or more module assemblies.

In the above description, a single subsea installation or station is shown. The invention contemplates that a plurality of such subsea stations may be installed on the sea bottom in any selected arrangement as, for example, in a line whereby five and more receptor openings 22 may be located above

a linear arrangement of wells in several rows or columns, or by the arrangement of such stations in a polygonal arrangement having two, three or more stations arranged in any selected pattern depending upon the configuration and characteristics of the sea floor and the location and positioning of subsea wells.

In Figs. 13—19, there is shown a method of installing and lowering to the sea bottom a rigid base template means 21 as described above. In Fig. 13, a drilling ship 180 is shown with a smaller work boat 181 laying alongside the forward portion of the ship and with the stern of the work boat lying approximately opposite a drilling rig 182. In Figs. 14—17 are shown a sequence of steps for lowering the template 21 to the sea floor. In Fig. 14, template 21, at its forward end with respect to work boat 181, is provided with a connection 183 to a winch line 184. Winch line 184 extends aft from connection 183 to sheave block 185 adjacent the stern of work boat 181. Winch line 184 extends around the sheave block and then extends forwardly to a first winch means 186. The arrangement of the winch line 184, sheave block 185, winch means 186 is provided on each side of the template 21.

The drilling rig 182 carries a supply of drill pipe, one section of which is indicated at 188; and the end of such drill pipe may be provided with a connection 198 to flexible cable 190 connected at their other ends to the template to provide a sling for the template 21.

As the winch line 184 is drawn onto winch means 186, the winch line will pull the template 21 toward the stern of the work boat 181 and move the template 21 over the stern as shown in Fig. 15. It will be understood that the tubular construction of the template 21 permits suitable ballasting of the template, if required. For this purpose the tubular members of the template are provided with fluid intercommunication and suitable inlet and outlet valves for water and air.

As shown in Fig. 15, the winch means 186 pulls the template over the stern until it is partially in the water with the sling line 190 connected thereto. Such movement is controlled or restrained by second winch means 91 having a winch cable 192 connected to template 21 at 183.

In Fig. 16 the template is illustrated as hanging vertically in the water just beyond the stern of the work boat and with the sling lines connected thereto. In this vertical position of template 21, the second winch means may take all of the strain of the template load to permit the sheave lines 184 to be detached from template 21. From this vertical position of the template base means 21, the sling lines may be retracted

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so that the template 21 may lie horizontally below the surface of the water and below the opening in the drill ship through which the drill pipe and sling extend. While the template is fully supported from the drill pipe sling and drill ship, the restraint cable 192 may be released from its connection at 183 by suitable automatic means. In this position of the template below the drill pipe of the derrick, the drill pipe may be lowered and brought into engagement with and fixed to a keying member 194, which is received within an adaptor means 195 fixed to and carried by template 21 at the central conductor pipe 31. The adaptor means 195 includes vertically extending key slots 196 for reception of vertically extending key elements 197 on the keying member 194.

As the template 21 is lowered into the water, the drill pipe may be equipped with a suitable vertical slip joint means 199 to reduce and minimize motion transmitted from the drill ship to the template 21.

The template is then lowered to the sea bottom by the drill pipe and is held in horizontal position by the sling lines 190. As the template approaches the sea bottom, it is desirable that the longitudinal axis of the template be oriented in a certain position depending upon the configuration of the sea bottom and the direction from which the sea floor flowlines approach the subsea installation. The attitude or orientation of the template is sensed by an attitude control device 200 which transmits the position of the template to the drill ship. Angular or azimuth orientation of the base means may be controlled by the application of torque forces to the drill pipe through the rotary table on the drill ship in order to orient the template base means into a selected position on the seabed.

WHAT WE CLAIM IS:—

1. A subsea installation for assembly and use in virtually any depth of water, comprising in combination:

an elongate rigid base frame adapted to be permanently placed on the sea floor and including longitudinal side members and transverse members defining with said side members a plurality of framed receptor openings,

a conductor pipe centrally located in each opening and connected to said side and transverse members;

a base guide unit receivable in one of said receptor openings in coaxial alignment with said conductor pipe located in said one receptor opening;

a removable unitary module assembly movable vertically into cooperation with said base guide unit for aligning and registering said module assembly with said one

receptor opening in said base frame;

said module assembly having well operating means for connection to well operating components by relative vertical movement;

said side and transverse members at ends of said base frame having vertically disposed guide means for connection by relative vertical movement to well operating components;

and control means for said module assembly adapted to be supported from said base frame and to be releasably interconnectable with said module assembly.

2. An installation as claimed in claim 1 wherein said unitary module assembly includes a top wall spaced above said base guide unit, said top wall including means for entrapment of lighter than water pollutants, and means beneath the top wall for detecting the presence of said pollutants.

3. An installation according to claim 1 or 2, wherein said base guide unit includes a guide post, a longitudinal slot in the guide post, and means for releasably confining a guide line in the slot.

4. An installation as claimed in claim 1, 2, or 3 including an elongated removable side structure extending along and extending laterally beyond at least one side of said base frame and releasably connected thereto, said elongated side structure carrying one or more lines for conducting fluid; and means for connecting the fluid conducting lines on said elongated side structure to said module assembly.

5. An installation as claimed in claim 4 wherein at least one of said elongated side structures includes longitudinally extending outboard side rails having pivotally mounted side rail sections for movement to a depending position to facilitate maintenance and repair of flowlines alongside said base frame means.

6. An installation as claimed in claim 5, including means on said base frame means for supporting an end portion of a flowline laid on the sea bottom in a position adjacent said pivotally mounted side rail section for such maintenance and repair.

7. An installation as claimed in claim 4, 5 or 6, wherein said elongated removable side structure includes parallel inboard and outboard members adapted to serve as guide rails for a subsea capsule, said inboard member having releasable sections to provide openings for passage therethrough of a portion of a fluid line in a manner for vertical coupling of said fluid line to said module.

8. An installation as claimed in claim 1, 2 or 3 including an elongated side structure extending along each side of the rigid base frame and secured thereon, each elongated side structure having releasable connections to said module assembly for con-



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so that the template 21 may lie horizontally below the surface of the water and below the opening in the drill ship through which the drill pipe and sling extend. While the template is fully supported from the drill pipe sling and drill ship, the restraint cable 192 may be released from its connection at 183 by suitable automatic means. In this position of the template below the drill pipe of the derrick, the drill pipe may be lowered and brought into engagement with and fixed to a keying member 194, which is received within an adaptor means 195 fixed to and carried by template 21 at the central conductor pipe 31. The adaptor means 195 includes vertically extending key slots 196 for reception of vertically extending key elements 197 on the keying member 194.

As the template 21 is lowered into the water, the drill pipe may be equipped with a suitable vertical slip joint means 199 to reduce and minimize motion transmitted from the drill ship to the template 21.

The template is then lowered to the sea bottom by the drill pipe and is held in horizontal position by the sling lines 190. As the template approaches the sea bottom, it is desirable that the longitudinal axis of the template be oriented in a certain position depending upon the configuration of the sea bottom and the direction from which the sea floor flowlines approach the subsea installation. The attitude or orientation of the template is sensed by an attitude control device 200 which transmits the position of the template to the drill ship. Angular or azimuth orientation of the base means may be controlled by the application of torque forces to the drill pipe through the rotary table on the drill ship in order to orient the template base means into a selected position on the seabed.

WHAT WE CLAIM IS:—

1. A subsea installation for assembly and use in virtually any depth of water, comprising in combination:

an elongate rigid frame adapted to be permanently placed on the sea floor and including longitudinal side members and transverse members defining with said side members a plurality of framed receptor openings,

a conductor pipe centrally located in each opening and connected to said side and transverse members;

a base guide unit receivable in one of said receptor openings in coaxial alignment with said conductor pipe located in said one receptor opening;

a removable unitary module assembly movable vertically into cooperation with said base guide unit for aligning and registering said module assembly with said one

receptor opening in said base frame;

said module assembly having well operating means for connection to well operating components by relative vertical movement;

said side and transverse members at ends of said base frame having vertically disposed guide means for connection by relative vertical movement to well operating components;

and control means for said module assembly adapted to be supported from said base frame and to be releasably interconnectable with said module assembly.

2. An installation as claimed in claim 1 wherein said unitary module assembly includes a top wall spaced above said base guide unit, said top wall including means for entrapment of lighter than water pollutants, and means beneath the top wall for detecting the presence of said pollutants.

3. An installation according to claim 1 or 2, wherein said base guide unit includes a guide post, a longitudinal slot in the guide post, and means for releasably confining a guide line in the slot.

4. An installation as claimed in claim 1, 2, or 3 including an elongated removable side structure extending along and extending laterally beyond at least one side of said base frame and releasably connected thereto, said elongated side structure carrying one or more lines for conducting fluid; and means for connecting the fluid conducting lines on said elongated side structure to said module assembly.

5. An installation as claimed in claim 4 wherein at least one of said elongated side structures includes longitudinally extending outboard side rails having pivotally mounted side rail sections for movement to a depending position to facilitate maintenance and repair of flowlines alongside said base frame means.

6. An installation as claimed in claim 5, including means on said base frame means for supporting an end portion of a flowline laid on the sea bottom in a position adjacent said pivotally mounted side rail section for such maintenance and repair.

7. An installation as claimed in claim 4, 5 or 6, wherein said elongated removable side structure includes parallel inboard and outboard members adapted to serve as guide rails for a subsea capsule, said inboard member having releasable sections to provide openings for passage therethrough of a portion of a fluid line in a manner for vertical coupling of said fluid line to said module.

8. An installation as claimed in claim 1, 2 or 3 including an elongated side structure extending along each side of the rigid base frame and secured thereon, each elongated side structure having releasable connections to said module assembly for con-

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ducting fluid to and from said module assembly.

5 9. An installation as claimed in claim 8 wherein each of said elongated side structures includes fluid conducting lines; and transversely disposed pipe loop means releasably supported on said base frame means and having fluid interconnection with fluid lines on said elongated side structure and flowlines to stations remote therefrom.

10 10. An installation as claimed in claim 8 or 9, including means on said rigid base frame for supporting a flowline for connection to ends of said transversely disposed loop means.

15 11. An installation as claimed in any one of claims 1 to 10 wherein said unitary module assembly includes a module base cooperable with said base guide unit; a top circular wall; and a plurality of spaced, peripherally disposed columns interconnecting the module base and the module top wall adapted to protect equipment carried by said module assembly.

20 12. An installation as claimed in claim 11 including equipment means carried by said module beneath said top wall and within said columns whereby said equipment means is protected and shielded.

25 13. An installation as claimed in any one of claims 1 to 12 wherein said unitary module assembly includes a circular top wall spaced above said base frame means; and guidance means including edge means lying in the surface of a cone generated about the vertical axis of said module assembly for guiding a sea vehicle into aligned relationship with said module assembly.

30 14. An installation as claimed in claim 13 wherein said top wall includes a planar top circumferential surface for cooperation with a seal means on said sea vehicle.

35 15. A method of assembling and installing a subsea installation as claimed in claim 1 comprising the steps of:

lowering and placing on a seabed the base frame having the plurality of receptor openings;

50 lowering the module assembly onto the base guide unit received in one of the receptor openings of said frame and releasably interconnecting said module assembly with said base guide unit;

55 lowering and releasably connecting to said base frame two elongated side structures each extending along one side of the base frame to provide side structures on opposite sides of said module assembly;

60 releasably interconnecting fluid conducting means on said side structures to said module assembly;

65 interconnecting adjacent ends of said elongated side structures at one end of said base frame.

16. A method as claimed in claim 15, wherein the base guide unit is lowered into registration with said one receptor opening of the base frame placed on the sea bed and is secured to the base frame.

70 17. A method as claimed in claim 15 or 16, wherein said base frame is lowered from a work boat positioned alongside a drill ship with an end of said frame opposite a drilling derrick on the drill ship, the frame being lowered by connecting lines from said drill derrick to opposite ends of said frame means, the lines extending through an opening in the drill ship beneath the drilling derrick; providing first winch means on said work boat having winch lines connected to an adjacent end of said frame means through a sheave means carried by said work boat adjacent the opposite end of said base frame; providing a second winch means on said work boat having a winch line connected to the adjacent end of said frame for restraining said frame; operating the first winch means to move said frame over the stern of the work boat; lowering the frame vertically in the water until the derrick lines are drawn taut to position the base frame horizontally in the water; releasing the winch line from said second winch means from said frame; and lowering the base frame in horizontal position by drill pipe.

18. A method as claimed in claim 17, wherein the angular position of the frame means is controlled through said drill pipe during lowering of the frame.

19. A method as claimed in claim 17 or 18 including providing means on the drill pipe for sensing the angular orientation of the frame means.

20. A method of assembling, installing, maintaining and operating a subsea installation substantially as herein described with reference to the accompanying drawings.

21. A subsea installation substantially as herein described with reference to the accompanying drawings.

22. A method of assembling and installing a subsea installation as claimed in claim 1, comprising the steps of lowering and placing on a seabed the base frame having the plurality of receptor openings and spaced connector means for certain equipment to be lowered thereafter; lowering the base guide unit having a guide line to said base frame and releasably securing said unit thereto; lowering the module assembly pre-assembled at the surface onto said guide unit and releasably connecting said module assembly thereto; lowering and releasably connecting to said base frame two elongated side structure extending along either side of the base frame to provide side structures on opposite sides of said module assembly; releasably interconnecting fluid conducting means on said side structures to



said module assembly; lowering and releasably interconnecting transversely disposed pipe loop means to cooperably associated connector means at one end of said base frame; and interconnecting said pipe loop means with said fluid conducting means.

23. A method as claimed in claim 22, including the step of interconnecting sea flow lines to said pipe loop means.

24. A method as claimed in claim 22 or 23, including the step of lowering and interconnecting to the base frame at said other end pressure fluid supply means for equipment on said module assembly.

25. A method as claimed in claim 22, 23 or 24, including the step of lowering and interconnecting at said other end electrical power supply means for said module assembly.

26. A method as claimed in any one of claims 22 to 25, wherein the base frame is lowered and placed on the seabed by positioning said base frame alongside a drill ship and on a workboat; connecting

sling lines from said workboat to opposite ends of the base frame; lowering said base frame vertically in the water by winch lines until said sling lines are drawn taut to position said base frame horizontally in the water; releasing said winch lines from said base frame; and lowering said base means in horizontal position by drill pipe.

27. A method as claimed in claim 26, including the step of orienting the frame means with respect to a selected azimuth.

28. A method as claimed in any one of claims 22 to 27 wherein the module assembly, elongated side structures, fluid conducting means, pipe loop means, pressure fluid actuating means, and electrical actuating means, are assembled by relative vertical movement.

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