United States Patent

[11] 3,581,815

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[54] **UNDERWATER CONNECTOR WITH RETRIEVABLE SEALED ELECTRICAL ASSEMBLY**
21 Claims, 7 Drawing Figs.

[52] **U.S. Cl.** **166/.5,** 251/129, 335/260
[51] **Int. Cl.** **E21b 43/01**
[50] **Field of Search** ..... 166/.5, .6; 335/254, 260; 251/129, 131

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ABSTRACT: The disclosure concerns unusually advantageous method and apparatus for controlling a stack of underwater wellhead equipment, utilizing a sealed electrically energizable element lowered underwater into operative proximity to a fluid pressure control adapted to be actuated in response to energization of the element.

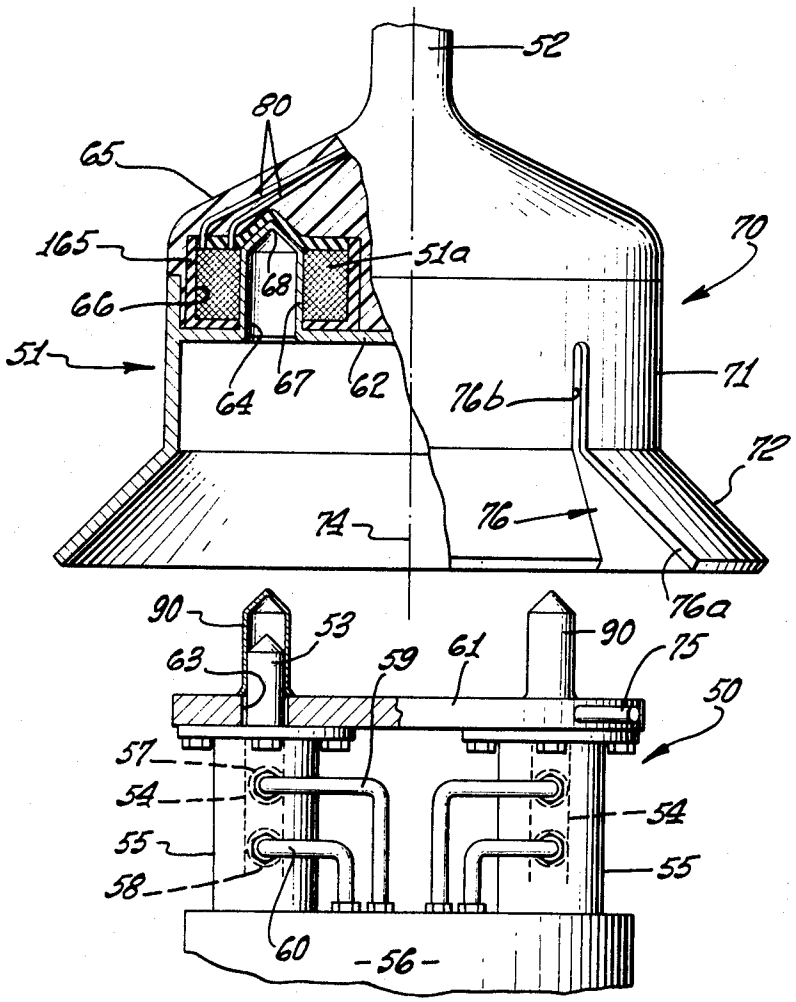

FIG. 1.

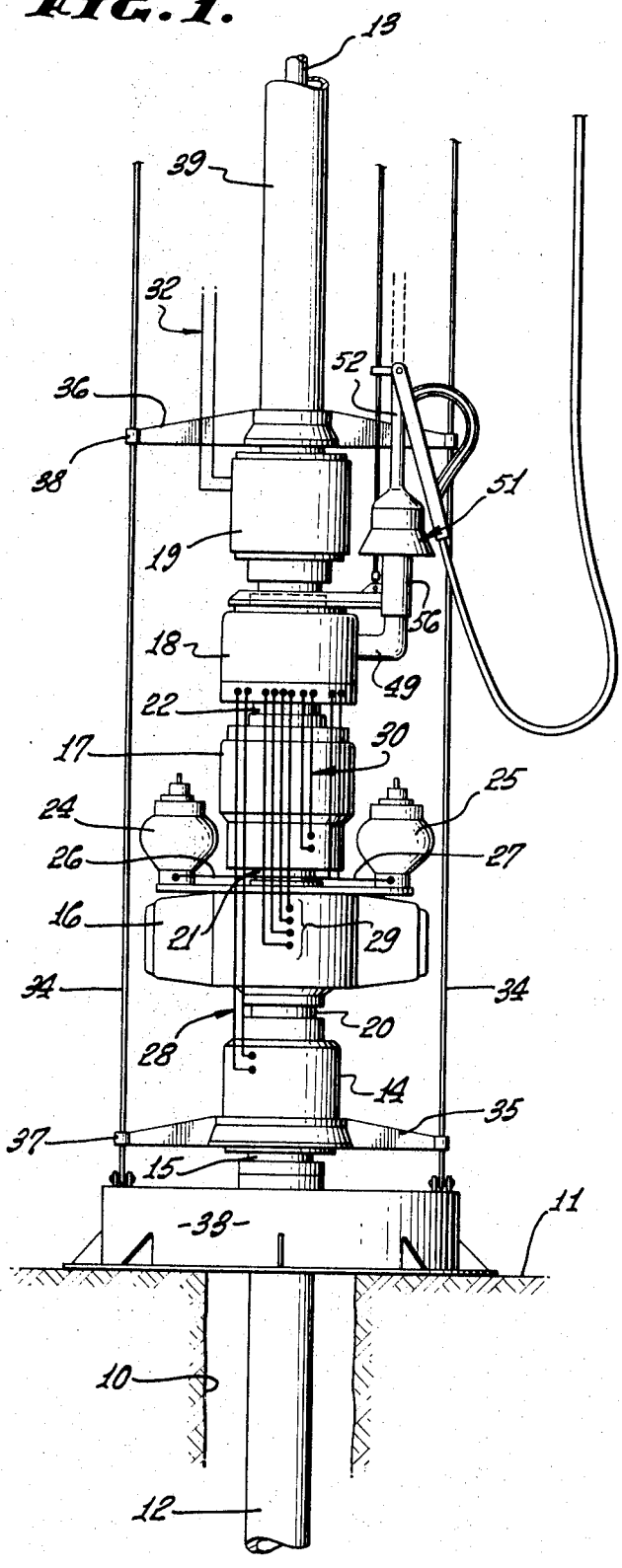

FIG. 4.

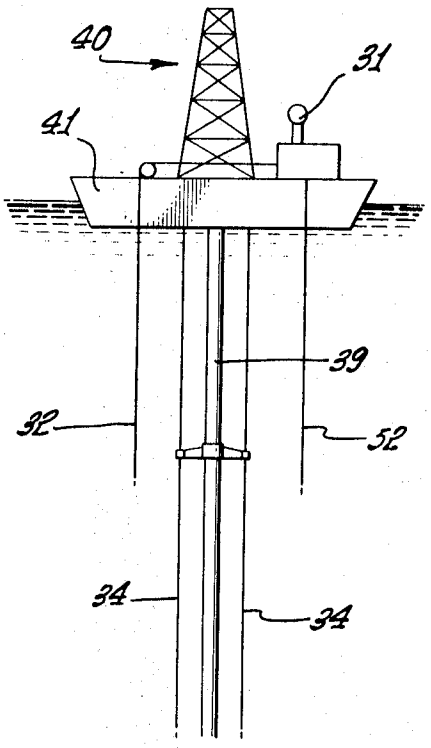

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FIG. 3.

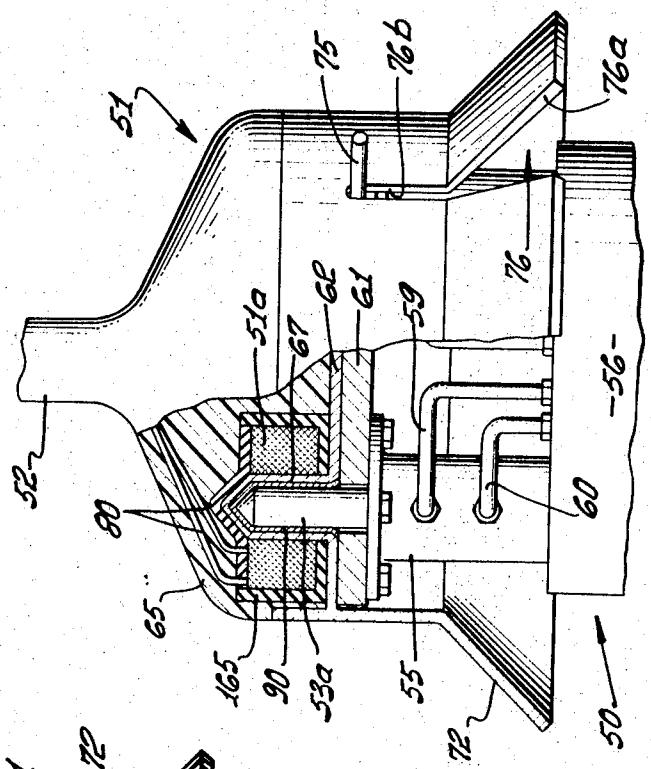

FIG. 2.

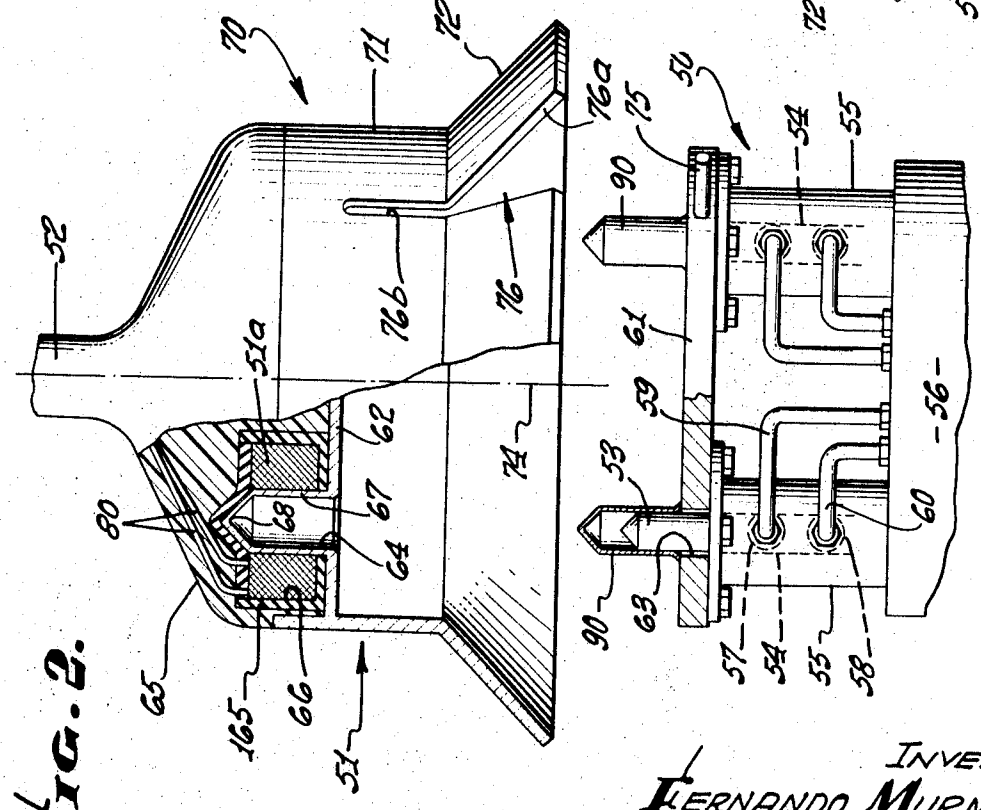

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FIG. 5.

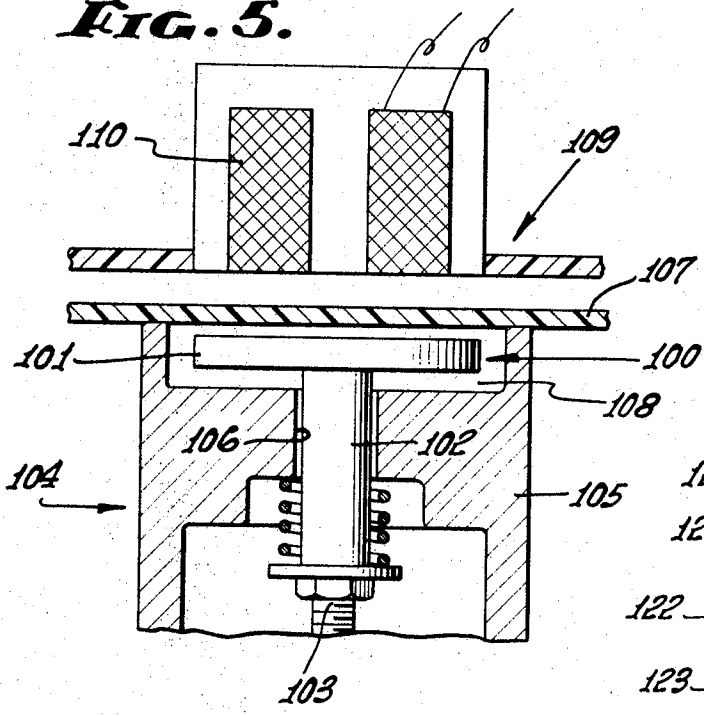


FIG. 7.

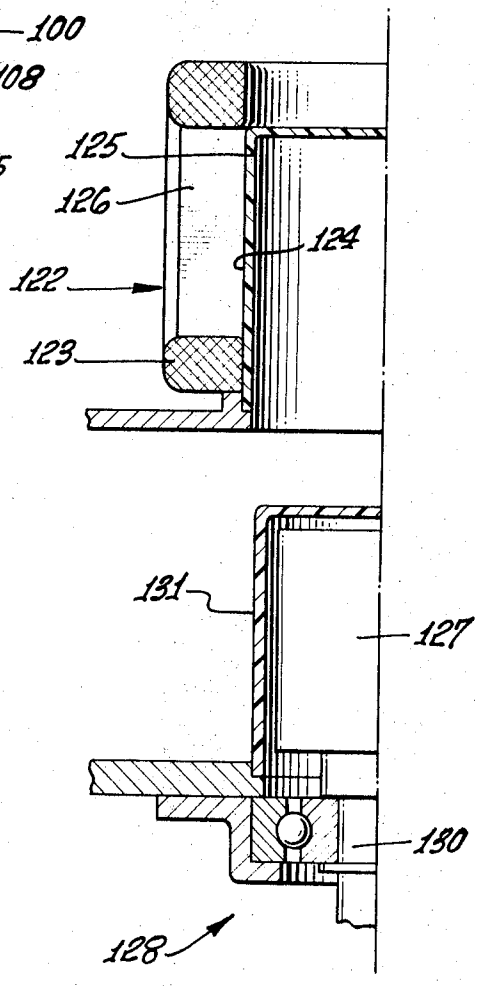
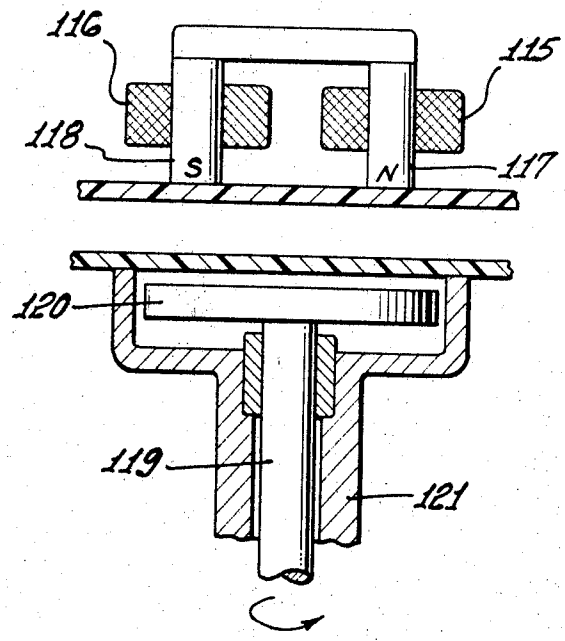


FIG. 6.



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UNDERWATER CONNECTOR WITH RETRIEVABLE SEALED ELECTRICAL ASSEMBLY

BACKGROUND OF THE INVENTION

This invention relates generally to the control of underwater wellhead equipment, and more particularly concerns methods and means for controlling such equipment in a stack, using electrical apparatus which is retrievable independently of the stack.

In certain underwater well-drilling or producing operations it is desirable to service the well as by means of a tool or a stack of tools connectable to a projecting well fitting, such as submarine stub casing terminating above the ocean floor. As an example, where well casing has already been sunk in the submarine hole with the free end of the casing projecting above the ocean floor, it is desirable to provide for the controlled operation of well blowout prevention equipment, safety valves, safety joints or connectors, as well as other auxiliary apparatus, typically mounted on a frame and in a stack attached to the projecting well casing, in order to serve the well. Commercial equipment of this nature is generally fluid pressure operated, and it has heretofore been considered necessary to provide a large bundle of separate pressure hoses, each extending from a surface location to a particular tool in the stack so that independent operation of such tools might be achieved as desired. However, where certain equipment in the stack is to be left at the underwater location for relatively long periods of time, say for example where the well is shut in, the continued dangling of the multiple hoses to great depths becomes impractical and a source of major difficulty. Thus, should the hoses deteriorate, or break, or become entangled with other equipment, the underwater tools may not remain operable with attendant risk of loss of the well including loss to the sea of great quantities of petroleum or gas.

Toward solving the above and other problems associated with servicing of underwater wells, it has been proposed that, after the stack has been lowered to the well head, electrical connection be made with electrical prime movers at the stack, such prime movers in turn operating the stack equipment, thereby obviating the need for such hoses. While this proposal has advantages, the problem of effectively connecting and disconnecting exposed electrical terminals under water remains, such terminals being subject to corrosion and deterioration.

BRIEF SUMMARY OF THE INVENTION

It is a major object of the present invention to provide method and apparatus which will further facilitate the operation of underwater wellhead equipment, eliminating the need for long dangling pressure hoses, and at the same time eliminating need to make and break exposed electrical terminals.

Basically, the method involves the steps of providing at the underwater stack a projecting valve-actuating element capable of being displaced in response to magnetic force application thereto, displacement of that element acting to control the valve for controlling pressure application to the valve; lowering to the actuating element a sealed element which is electrically energizable to cooperate magnetically with the actuating element; and transmitting electrical current to the electrically energizable element to energize it to effect displacement of the valve actuating element. As will be seen, the lowering step may include such mechanical intercoupling of the elements as obviates need for electrical terminal interconnection and the disadvantages of the latter at underwater locations. Thereafter, the electrically energizable element may be retrieved to the surface so as not to remain exposed to the sea water, whereby reliability and life of the equipment is substantially enhanced due to minimum exposure of the electrical unit to the sea water, that unit also being sealed for further reliability.

In its apparatus aspects, the invention basically comprises, in combination:

a. a fluid pressure control assembly adapted to be presented underwater and in such relation to the stack as to be actuated for altering fluid pressure application;

b. an operating assembly including a sealed electrically energizable element adapted to be lowered under water into operative proximity to the control assembly; and

c. at least one of the assemblies including structure adapted to be displaced in response to energization of the element for actuating the control assembly.

As will be seen, the electrically energizable element may comprise a solenoid coil, and the referred to structure may comprise part adapted to be magnetically displaced in response to coil energization. Further, the part is typically carried by the control assembly which also includes a valve element operated by the part. In one form of the invention, the part may comprise a plunger and in addition, there may be advantageously included a guide socket carried by the operating assembly and presented to receive relative penetration of the control assembly whereby the plunger may be guided into the coil.

These and other objects and advantages of the invention, as well as the details of an illustrative embodiment, will be more fully understood from the following description and drawings, in which:

DRAWING DESCRIPTION

FIG. 1 is an elevation showing a stack of well-servicing tools at a submarine well head location, together with apparatus permanently and detachably connected with the stack for controlling operation of the stack actuators;

FIG. 2 is an enlarged vertical section showing details of pressure control and operating assemblies embodying the invention, and in disconnected condition;

FIG. 3 is a view like FIG. 2, but showing the assemblies in connected condition;

FIG. 4 is a view of the surface equipment for lowering and elevating the stack and casing or tubing and the control assembly; and

FIGS. 5—7 show other forms of valve-actuating parts.

DESCRIPTION OF PREFERRED EMBODIMENTS

In FIG. 1 a drill hole 10 sunk beneath the ocean floor 11 contains a string of casing 12 cemented or otherwise fixed in position for further suitable drilling or producing operations. Drill pipe or tubing is shown at 13 extending downwardly through the casing string.

The submarine wellhead equipment includes a lower connector unit 14 releasably fastened onto the casing stub 15 projecting upwardly. In sequence above unit 14 are double master gate 16, blowout preventer 17, a pressure-distributing control unit 18, and another connector 19, intermediate tubular stubs or extensions being indicated at 20, 21, 22 and 23. The connectors 14 and 19 are releasably attached to stubs 15 and 23 respectively, and may be of the type disclosed in U.S. Pat. No. 2,962,096 to Knox; the unit 18 may comprise suitable manifolding; for distributing pressure to the various actuators; and the blowout preventer 17 may be of the type disclosed in U.S. Pat. No. 2,609,836 to Knox.

Fluid pressure is transmitted from an underwater supply source in the form of pressure vessels 24 and 25 to the unit 18 via lines 26 and 27; and pressure is controllably transmitted from unit 18 to the connector 14 via lines 28, to the master gate 16 via lines 29 and to the preventer 17 via lines 30. Fluid pressure is supplied from the surface source 31 seen in FIG. 4 via hoses 32 to the upper connector unit 19 in the stack, for operation independently of unit 18 or in combination therewith.

To complete the general description of FIG. 1, the numeral 33 designates the base of a frame for the wellhead equipment stack, the frame also including guide lines 34 attached to the base and transverse members 35 and 36 respectively attached to the lower connector 14 and the top of unit 19, said mem-

bers interconnecting the guide line at vertically spaced locations. The guide lines **34** extend to the surface, and the members **35** and **36** have slidable connection therewith at **37** and **38** for guiding the connectors downwardly into position as shown. If the connector **14** is released from the stub **15**, it and the equipment thereabove may be elevated to the surface as the casing **39** in the string or stack is run upwardly. Alternatively, if the connector **19** is released from the stub **23**, it and the casing **39** may be elevated as the casing **39** is run upwardly, leaving the equipment in the stack therebelow at the wellhead, as for example when the well is shut-in. The casing is run downwardly or upwardly by adding or subtracting casing lengths at the surface, by suitable means generally indicated at **40** in FIG. **4** and on platform or vessel **41**.

Extending the description to the remaining FIGS., mounted on the stack, as by elbow **49** in association with unit **18**, is a fluid pressure control assembly **50** presented underwater so as to be actuated for altering fluid pressure application, as via unit **18**, to the wellhead equipment (such as the preventer, gate, connector, etc.). Also shown is an operating assembly **51** including a sealed electrically energizable element (as for example solenoid coil annulus or annuli **51***a*) adapted to be lowered underwater (as by cable **52**) into operative proximity to the control assembly **50**.

At least one of these assemblies also includes structure adapted to be displaced in response to energization of the element **51***a* for actuating the control assembly. Such structure may for example comprise a part such as a plunger (or plungers) **53** which extends within the magnetic field the coil or coils **51***a* when the assemblies **50** and **51** extend in operative proximity as in FIG. **3**. As is clear from the drawings, plungers **53** are carried by assembly **50** to project upward for initial reception partly into the coils **51***a* in response to relative movement of the assemblies into operative proximity. Upon energization of coil **51***a* plunger **53** will be more fully drawn into the coil by magnetic pull, as seen at **53***a* in FIG. **3**.

The control assembly also includes a valve element or elements **54** having operative connection with the plunger or plungers so that the valve elements may be shifted in response to plunger displacement. Housings **55** contain the valve elements and are supported on base structure **56** mounted on the stack. Note the ports **57** and **58** in the valve housings through which pressure fluid flow is controlled, such flow passing via lines **59** and **60** from and to unit **18** for distribution to the wellhead equipment, the pressure originating at a vessel **24**. Plate structure **61** extends at the upper ends of the housings, and is connected to the housings, to seat the lower plate **62** of unit **51** in FIG. **3** position. Plungers **53** project upwardly through openings **63** in plate **61**, and through openings **64** in plate **62**. Note the provision of tubular protectors **90** closely receiving the plungers and mounted in plate **61** to prevent sea water access to the plungers. Coils **51***a* are sealed out of communication with the exterior, as by means of the resinous bodies **65** and **165** (forming recesses **66** receiving the coils) and the plate structure **62** capping the undersides of the bodies **165**. Note also the tubular metal sleeves **67** integral with plate **62** and received into the coils and sized for receiving the protectors **90**, the sleeves being closed at **68**.

A further feature of the invention has to do with the provision of guide structure presented to guide the plunger or plungers relatively into the coil or coils in response to underwater lowering of the operating assembly **51** into operative proximity to the control assembly. Such structure may typically include a socket **70** carried by the assembly **51** and presented to receive relative upward penetration of the control assembly. The socket is shown to include a tubular portion **71** and a flared portion **72** operable to guide the assembly **50** upwardly into tubular portion **71** wherein it is centered so that the plungers will align with the coils. Such alignment, about the vertical axis **74** becomes assured by virtue of the tongue and groove elements **75** and **76** on the assemblies and located to interfit during the relative penetration. Note for example the widened mouth **76***a* of the slot or groove **76** which loosely receives the tongue or rod **75** and acts to guide it into the guide extent **76***b* of the slot, for precise alignment. Slot **76***b* also serves as a water outlet on makeup.

The method of the invention involves the steps of providing at the stack a projecting valve-actuating element (as for example plunger **53**) capable of being displaced in response to magnetic force application thereto, displacement of that element acting to control the valve **54** for controlling pressure application to the apparatus; lowering to the element a sealed element (such as coil **51***a*) which is electrically energizable to couple and cooperate magnetically with the actuating element; and transmitting electrical current to the element **51***a* to energize it and effect displacement of the valve actuating element **53**. Such current transmission may be effected via lines or cables **80** running to the surface along the lowering cable **52** seen in FIG. **3**. Thereafter, the element **51***a* may be upwardly retrieved for removal from the sea during times when shifting of the positions of the underwater tools is not desired. In this regard, the various valves **54** (typically four-way) may be paired in association with the various underwater tools, in such manner that operation of one valve of a pair shifts a tool piston in one direction, and operation of another valve of a pair shifts the tool piston in the opposite direction. Surface retrieval equipment is indicated at **40** in FIG. **4**.

FIG. **5** illustrates a form of this invention wherein this valve-actuating part, which is magnetically displaced in response to coil energization, is carried for linear displacement while remaining out of penetrating relation with the coil. For example, part **100** comprises a plate **101** (as for example iron) on a central stem **102** connected at **103** to the valve (not shown). A housing **104** for that part **100** includes a body **105** in which the stem is guided at **106** for linear movement, and a nonmetallic panel **107** sealing the cavity **108** in which plate **101** is received. Operating assembly **109** including coil **110** is shown in operative proximity to the part **100** in the control assembly. Otherwise, the apparatus may be as shown in FIGS. **1—3**.

In FIG. **6**, the operating assembly includes solenoid coils **115** and **116** about pole pieces **117** and **118** which, for example may form north and south poles respectively, at a given instant. Spaced from the pole pieces is a valve-actuating part **119** including a plate **120** constructed to rotate when the coils are energized. A housing **121** carries the part **119** for rotation, as shown, and for protection against sea water contamination.

Finally, FIG. **7** shows an operating assembly **122** having a coil **123**, forming a bore **124** into which a protective sleeve **125** is received. Coil **123** may cooperate with suitable laminations and bars (identified at **126**) to define a motor stator providing a rotating magnetic field when the coil is energized with alternating current. The valve-actuating part here includes a motor rotor **127** in the fluid pressure control assembly **128**, the rotor being relatively receivable into the sleeve **125** when the assemblies **122** and **128** are brought into operating proximity. A connection to the rotor is shown at **130**, for suitably rotating the underwater valve (not shown). A protector **131** extends about the projecting rotor, to protect it from contamination by sea water.

I claim:

1. In apparatus of the character described, the combination comprising:

a fluid pressure control assembly to be presented underwater so as to be actuated for altering fluid pressure application,

a cable and an operating assembly including a sealed electrically energizable coil element supported by the cable to be lowered underwater into operative proximity to said control assembly,

at least one of said assemblies including structure adapted to be displaced in response to energization of said element for actuating said control assembly; said assemblies extending in operative proximity with one another and being relatively shiftable into and out of operative proximity in response to vertical displacement of the cable.

2. The combination of claim 1 wherein said structure comprises a part adapted to be magnetically displaced in response to electrical energization of said coil.

3. The combination of claim 2 wherein said part comprises a plunger which extends within said coil when said assemblies extend in operative proximity.

4. The combination of claim 3 wherein said plunger is carried by said control assembly to project for movement into said coil in response to coil energization, with said assemblies extending in operative proximity.

5. The combination of claim 2 wherein said control assembly includes a valve element having operative connection with said part.

6. The combination of claim 4 including guide structure presented to guide said part relatively into proximity with said coil in response to underwater lowering of said operating assembly into operative proximity to said control assembly.

7. The combination of claim 6 wherein said structure includes a socket carried by said operating assembly and presented to receive relative penetration of said control assembly.

8. The combination of claim 7 wherein said assemblies form tongue and groove elements one of which is on the socket, and located to interfit during said relative penetration.

9. The combination of claim 1 including an underwater wellhead assembly including a fluid responsive actuator operatively coupled to said fluid pressure control assembly.

10. The combination of claim 9 wherein said wellhead assembly supports said control assembly to be presented upwardly for downward seating of said operating assembly.

11. The combination of claim 2 wherein said part is carried for linear displacement in response to coil energization.

12. The combination of claim 2 wherein said part is carried for rotary displacement in response to coil energization.

13. The combination of claim 2 wherein said part is carried for said displacement while remaining out of coil-penetrating relation.

14. In apparatus of the character described, the combination comprising:

a fluid pressure control assembly adapted to be presented underwater so as to be actuated for altering fluid pressure application,

a cable and an operating assembly including at least two sealed solenoid coils supported by the cable to be lowered into operative proximity to said control assembly,

at least one of said assemblies including at least two parts, one adapted to be magnetically displaced in response to energization of one coil and the other adapted to be magnetically displaced in response to energization of the other coil, for actuating said control assembly, said assemblies extending in telescopically interfitting relation and being relative shiftable into and out said relation in response to vertical displacement of the cable.

15. The combination of claim 14 wherein said parts comprise plungers carried by said control assembly to project for reception into hollows formed in said coils.

16. The combination of claim 15 wherein said control assembly includes valve elements having operative connection with said plungers.

17. The combination of claim 15 including guide structure presented to guide said plungers relatively into said soils in response to underwater lowering of said operating assembly into operative proximity to said control assembly.

18. The combination of claim 15 including recessed protectors closely receiving the plungers to block sea water access thereto when said assemblies are spaced apart.

19. In the method of controlling, from the surface, pressure-operable apparatus installed in a stack of underwater wellhead equipment, the steps that include

providing at the stack a valve-actuating element capable of being displaced in response to magnetic force application thereto, displacement of said element acting to control the valve for controlling pressure application to said apparatus,

lowering to said actuating element a sealed coil element which is electrically energizable to cooperate magnetically with said actuating element,

bringing said elements into underwater alignment, and

transmitting electrical current to said electrically energizable element to energize same for effecting displacement of said valve actuating element.

20. The method of claim 19 including the further step of retrieving said electrically energizable element by elevating same in the sea relative to said valve-actuating element.

21. The method of claim 19 wherein said lowering step includes effecting intercoupling of said elements.