US 20010003288A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2001/0003288 A1**

CLAYTON et al. (43) **Pub. Date: Jun. 14, 2001**

(54) **VALVE ARRANGEMENT FOR CONTROLLING HYDRAULIC FLUID FLOW TO A SUBSEA SYSTEM**

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(*) Notice: This is a publication of a continued prosecution application (CPA) filed under 37 CFR 1.53(d).

(21) Appl. No.: **09/260,223**

(22) Filed: **Mar. 1, 1999**

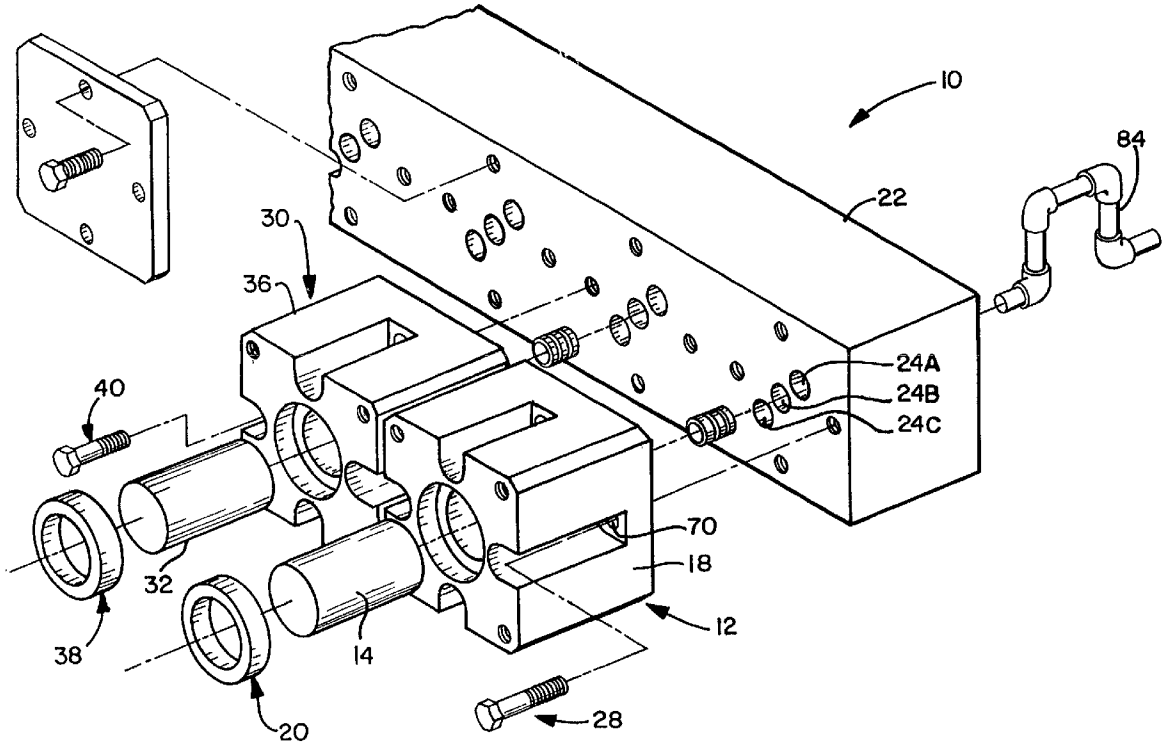
Publication Classification

(51) **Int. Cl.**[7] **F16K 11/10**

(52) **U.S. Cl.** **137/884**; 137/271

(57) **ABSTRACT**

A valve arrangement for controlling hydraulic fluid flow to a subsea system includes a plurality of docking modules each having a valve element for controlling the flow of a fluid and a docking module port for fluid flow between the valve element. The valve arrangement additionally includes a manifold having manifold ports of uniform cross section. The docking modules can be interchangeably mounted to the manifold ports as desired to tailor the valve arrangement for any selected valve operation. The valve arrangement also includes an adapter for alternately sealingly interconnecting a first docking module port which is different in shape or area than the cross section of the uniform size manifold port to any selected manifold port so as to permit sealed fluid flow between the first docking module port and the manifold port in one configuration of the valve arrangement and sealingly interconnecting a second docking module port of a different cross-sectional shape or area than the first docking module port to the same selected manifold port so as to permit sealed fluid flow between a second valve element and the first manifold port in another configuration of the valve arrangement.



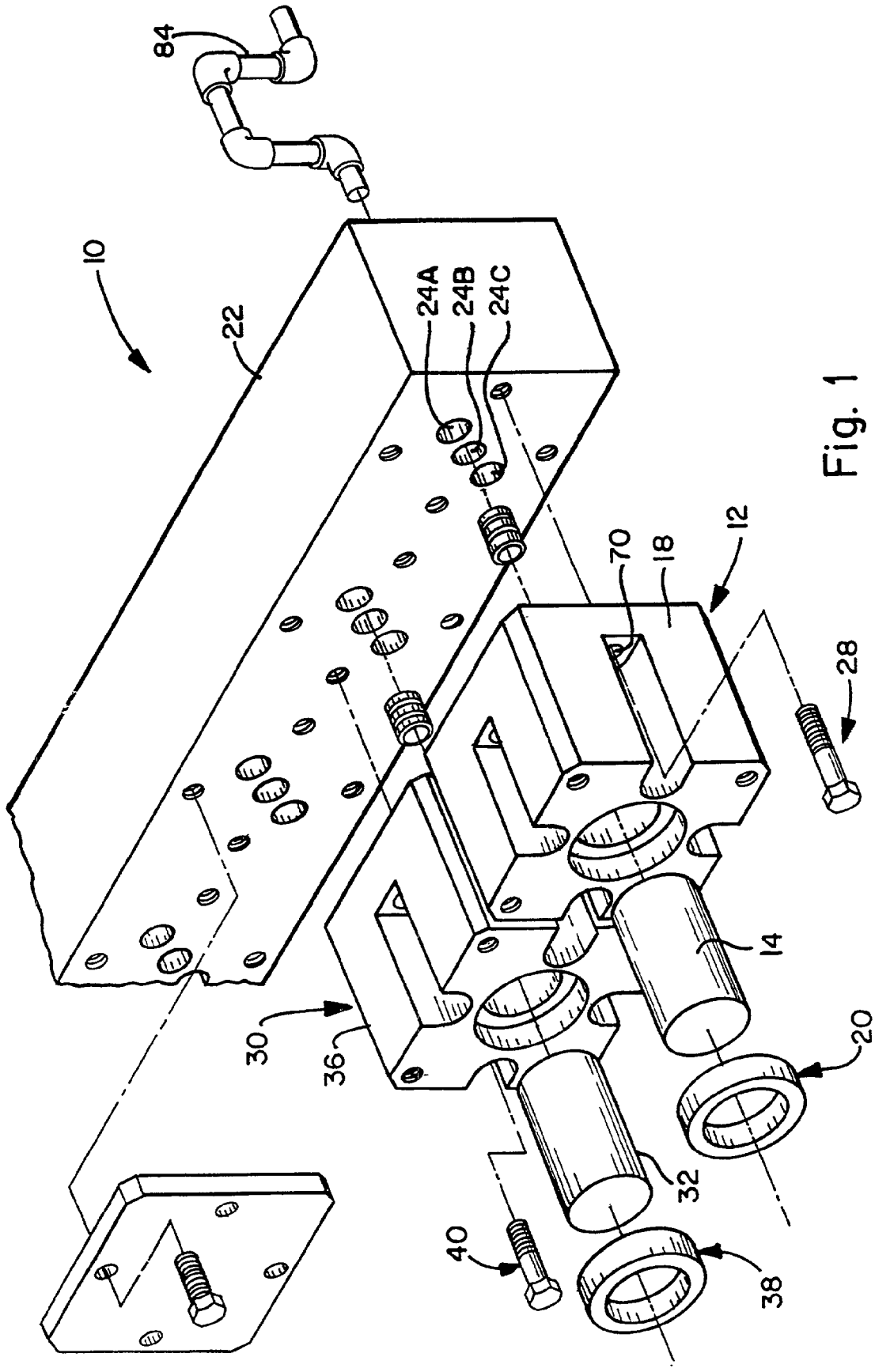


Fig. 1

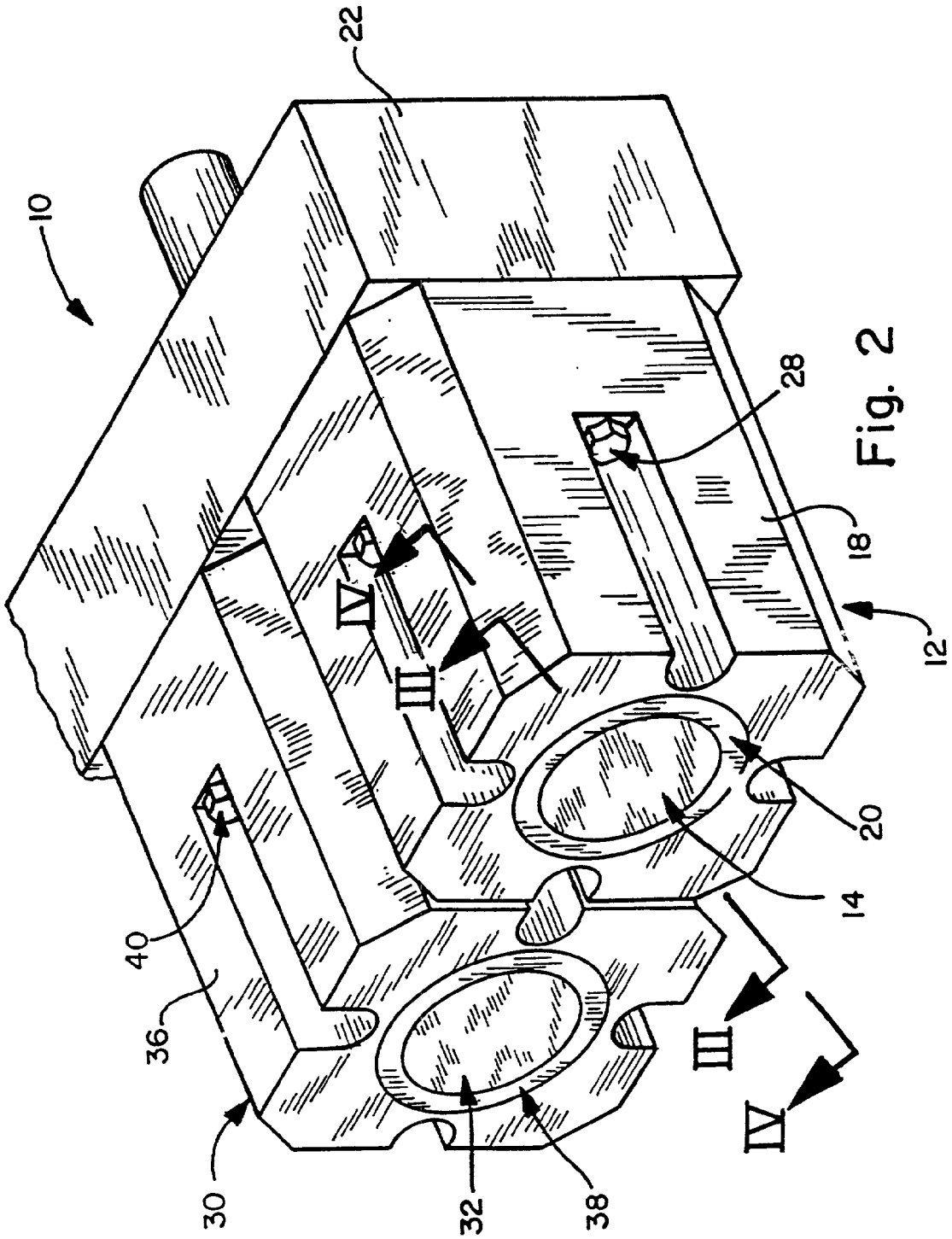


Fig. 2

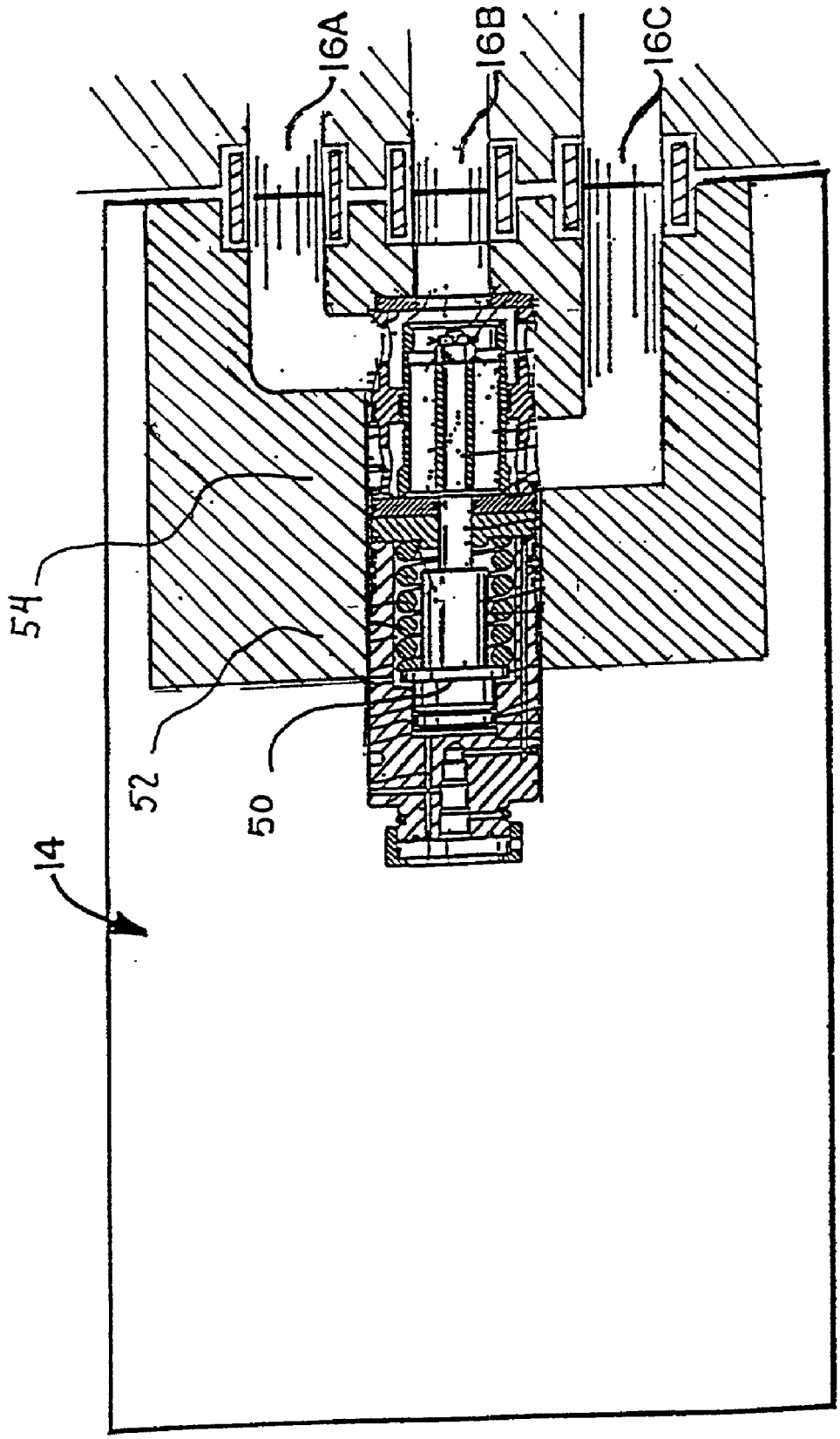


Fig. 3

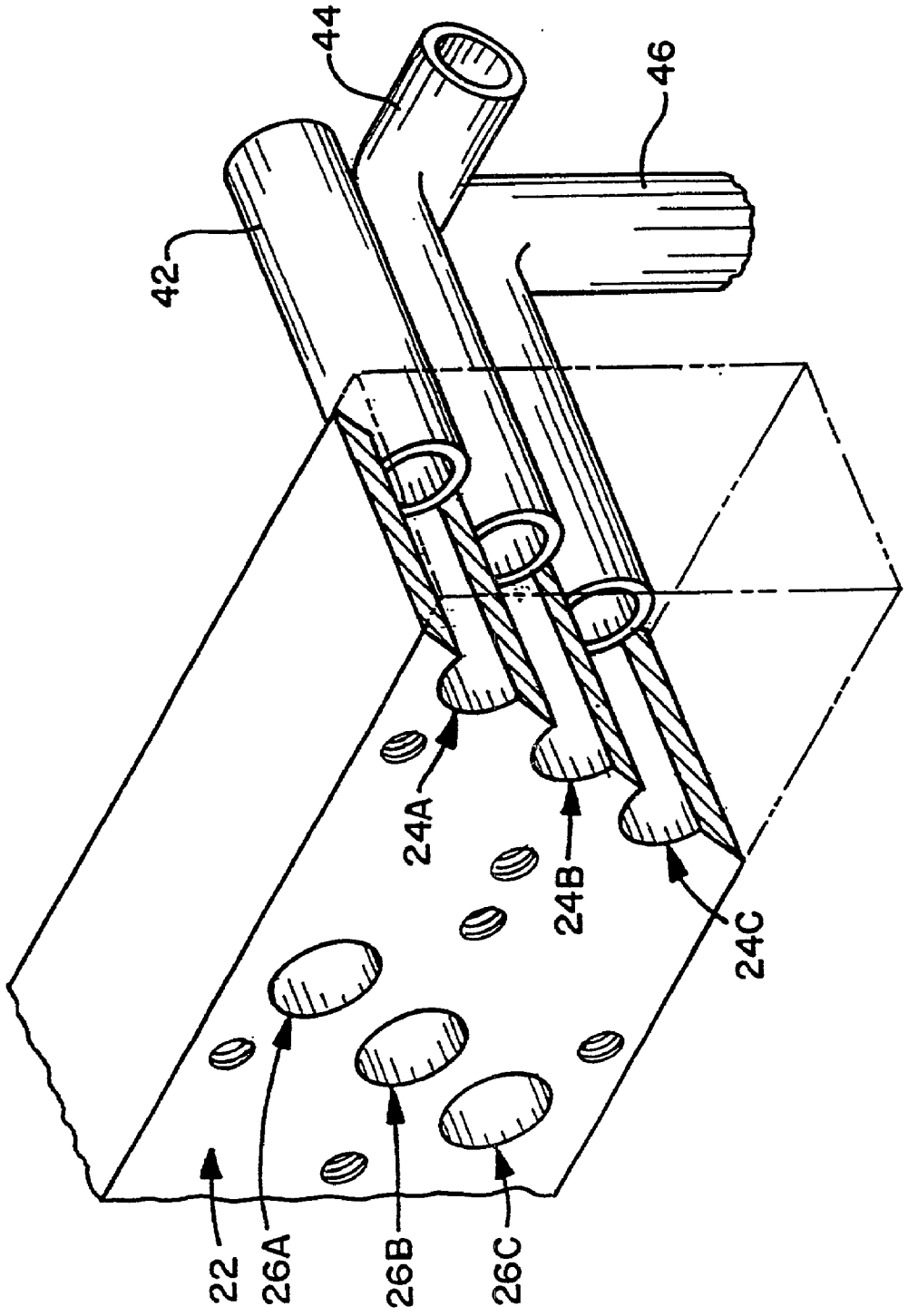


Fig. 4

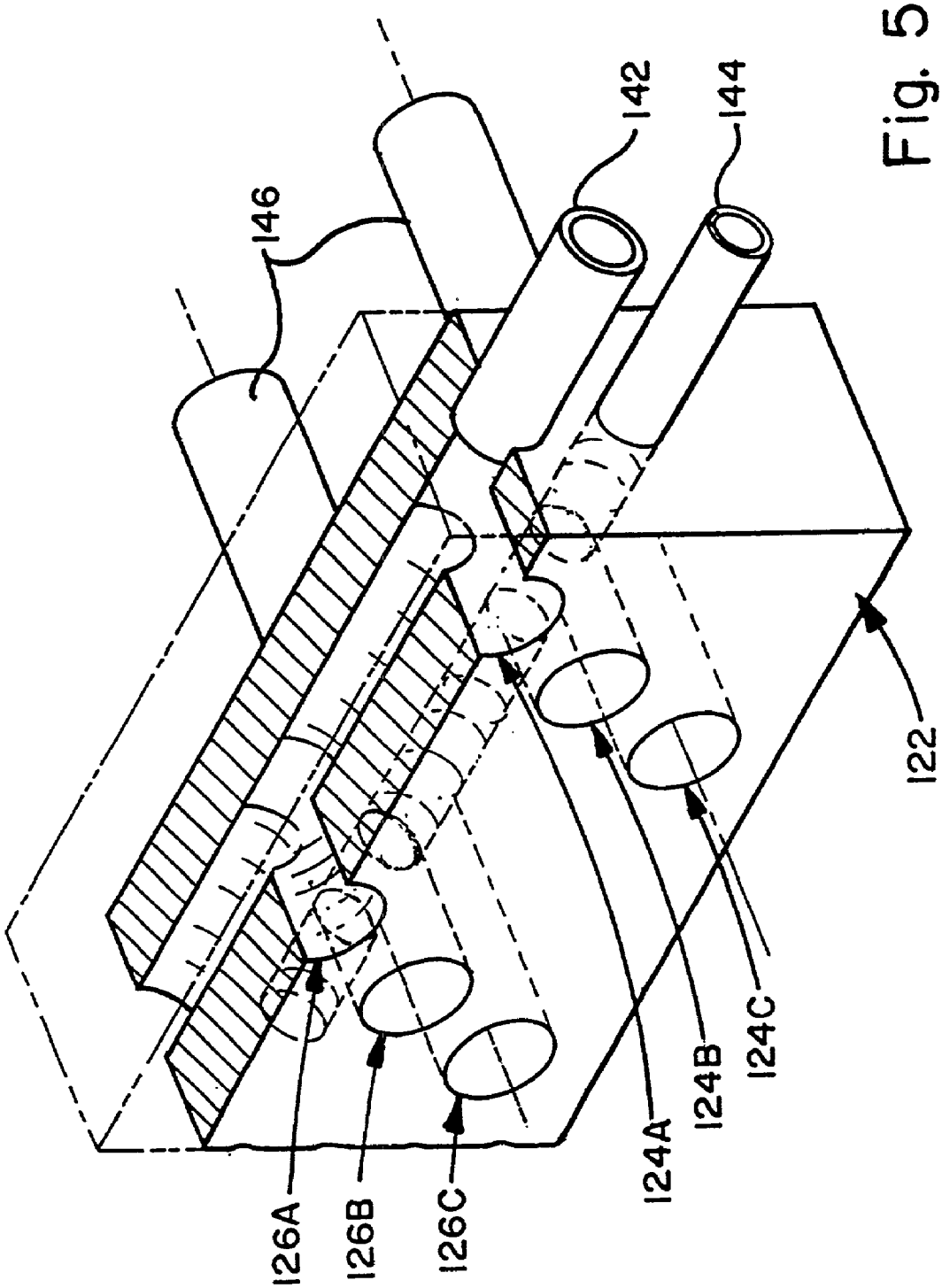


Fig. 5

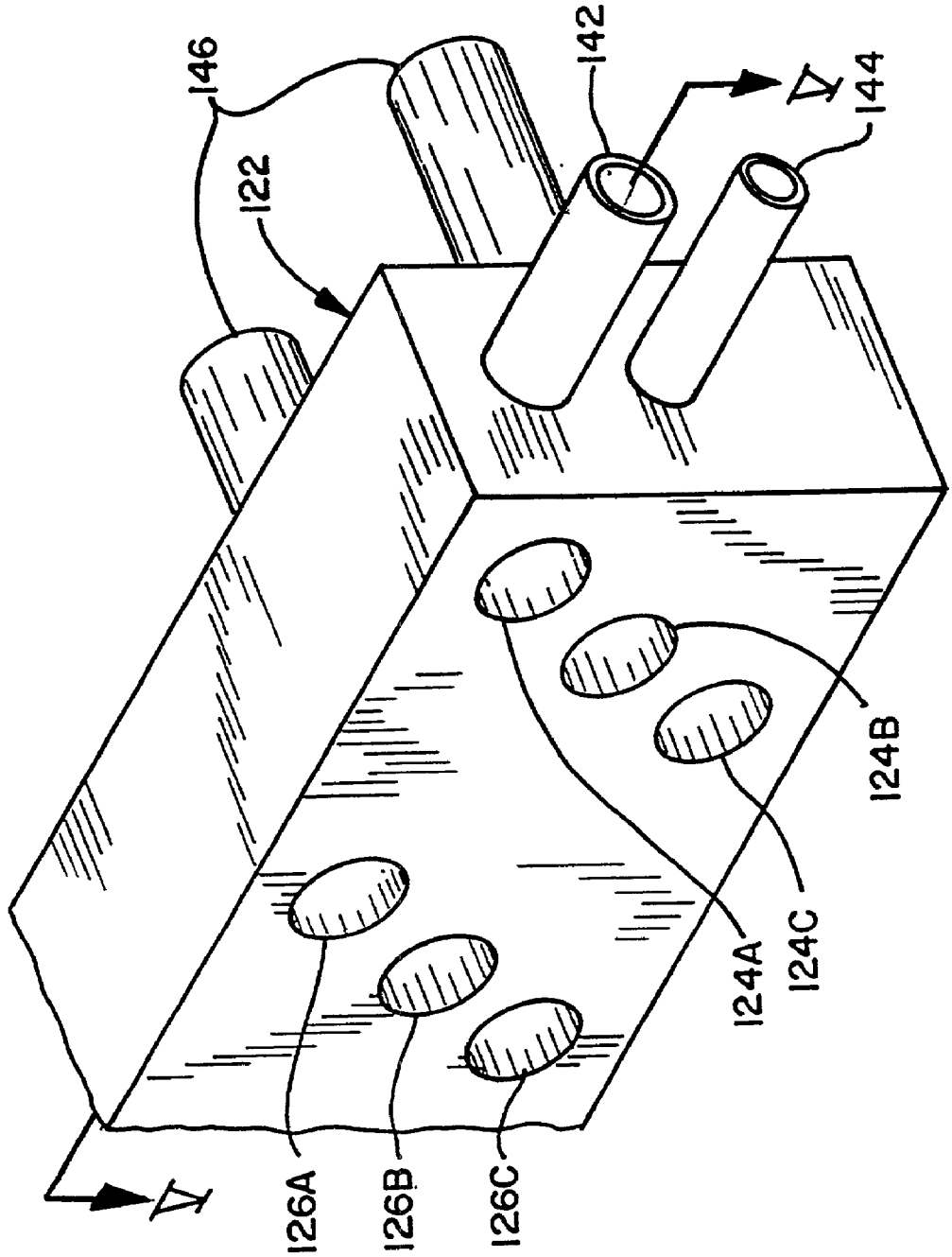


Fig. 6

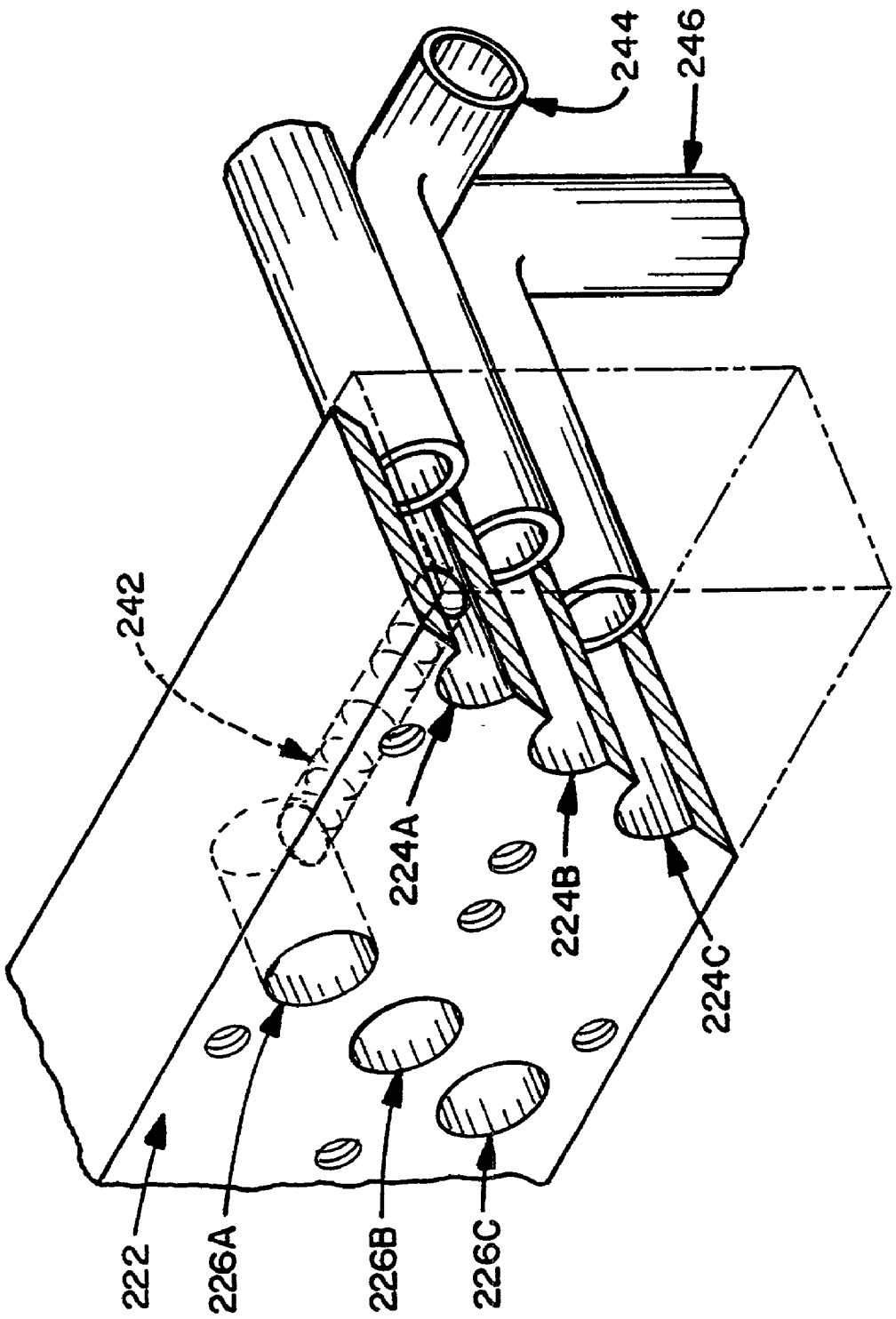


Fig. 7

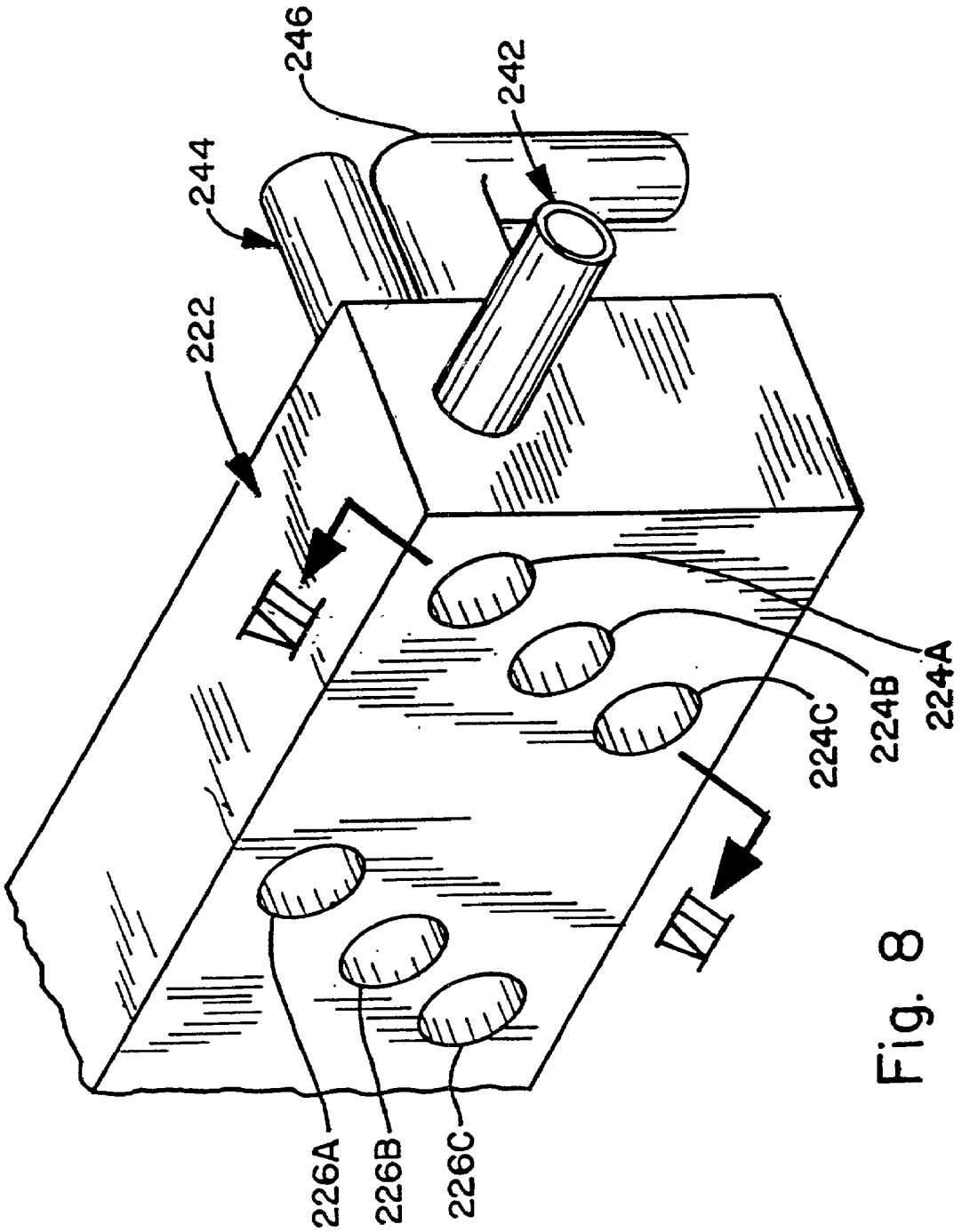


Fig. 8

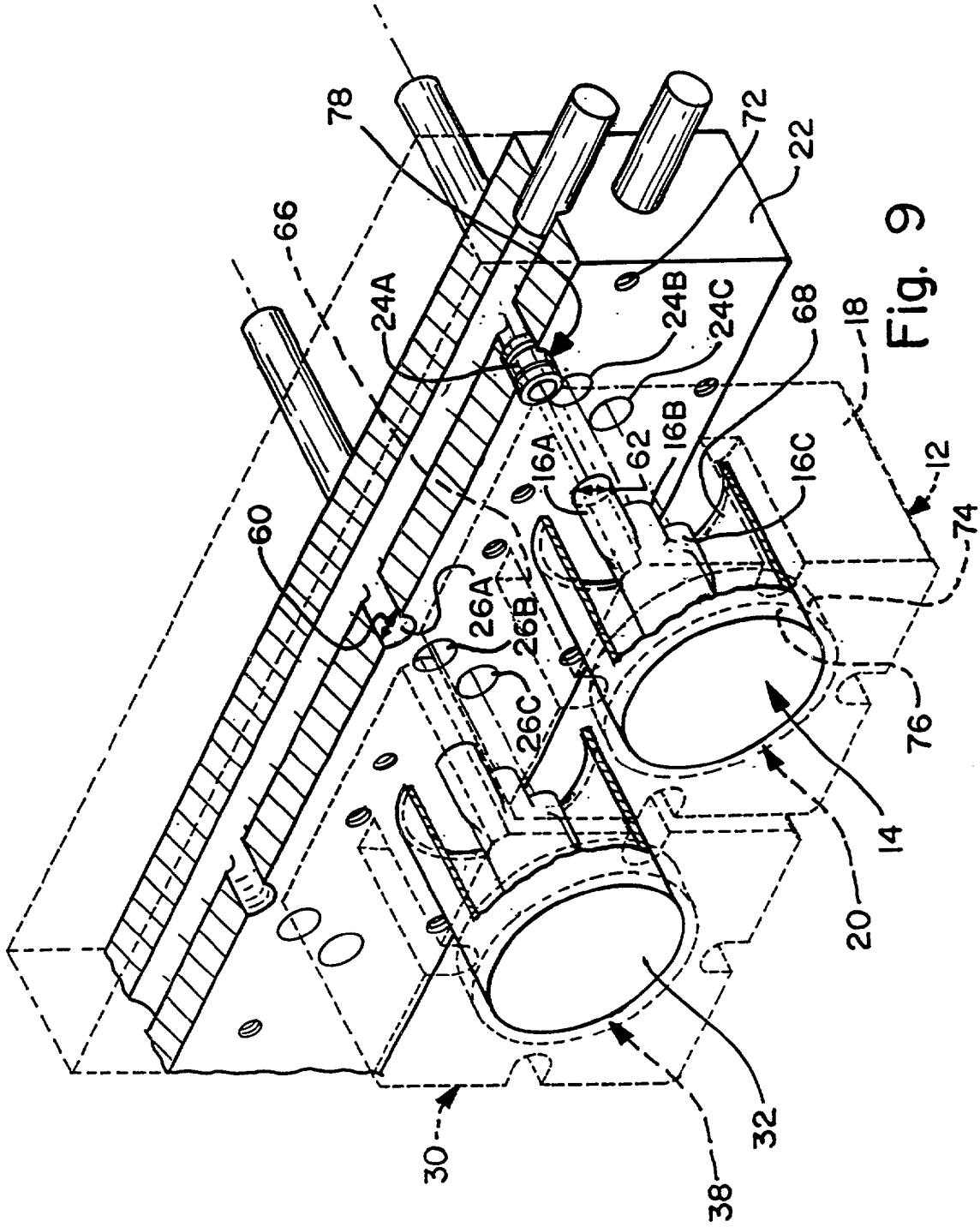

78
72
22
66
24A
24B
24C
68
18
16A
62
16B
16C
12
74
60
26A
26B
26C
76
14
20
30
32
38

Fig. 9

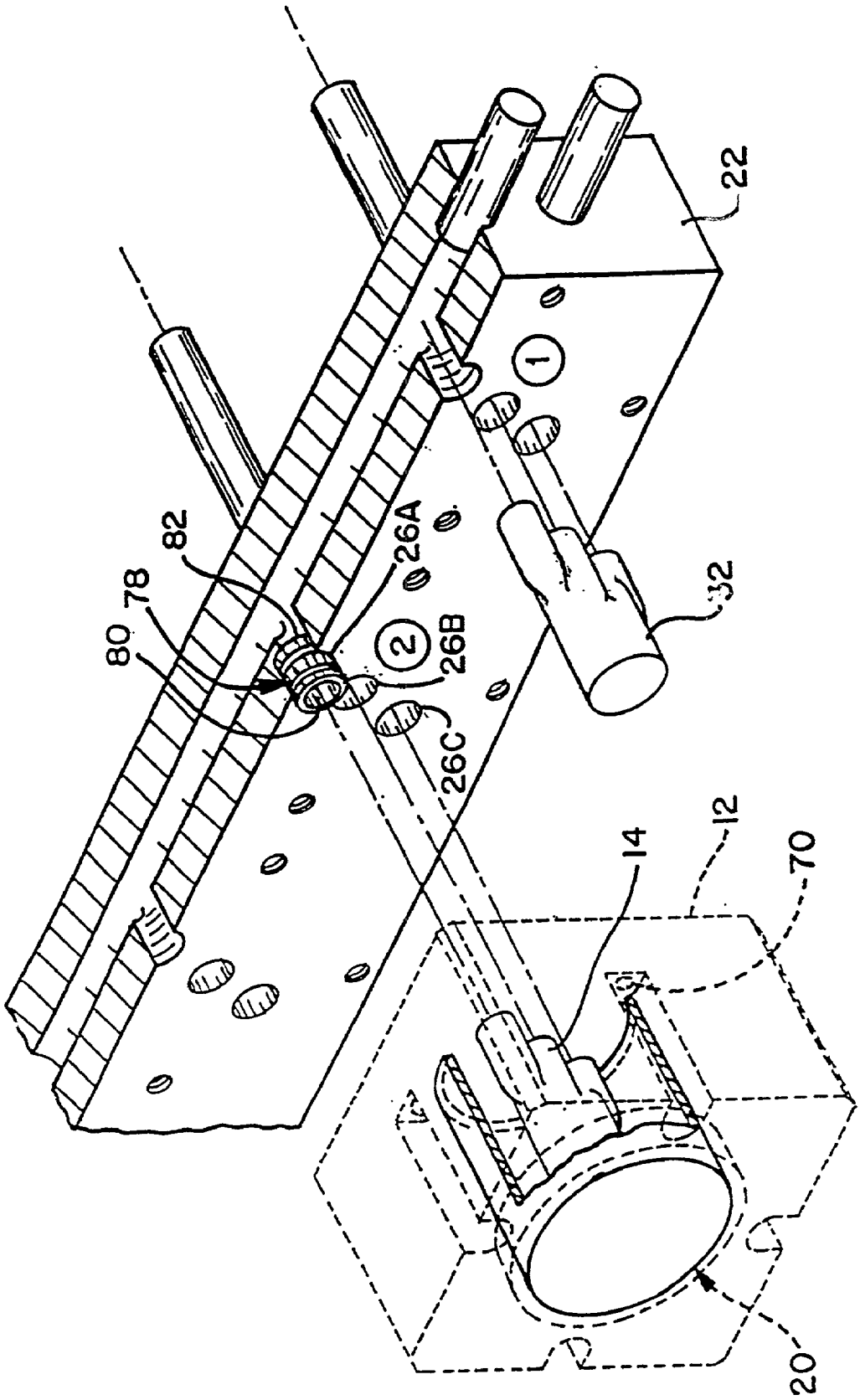


Fig. 10

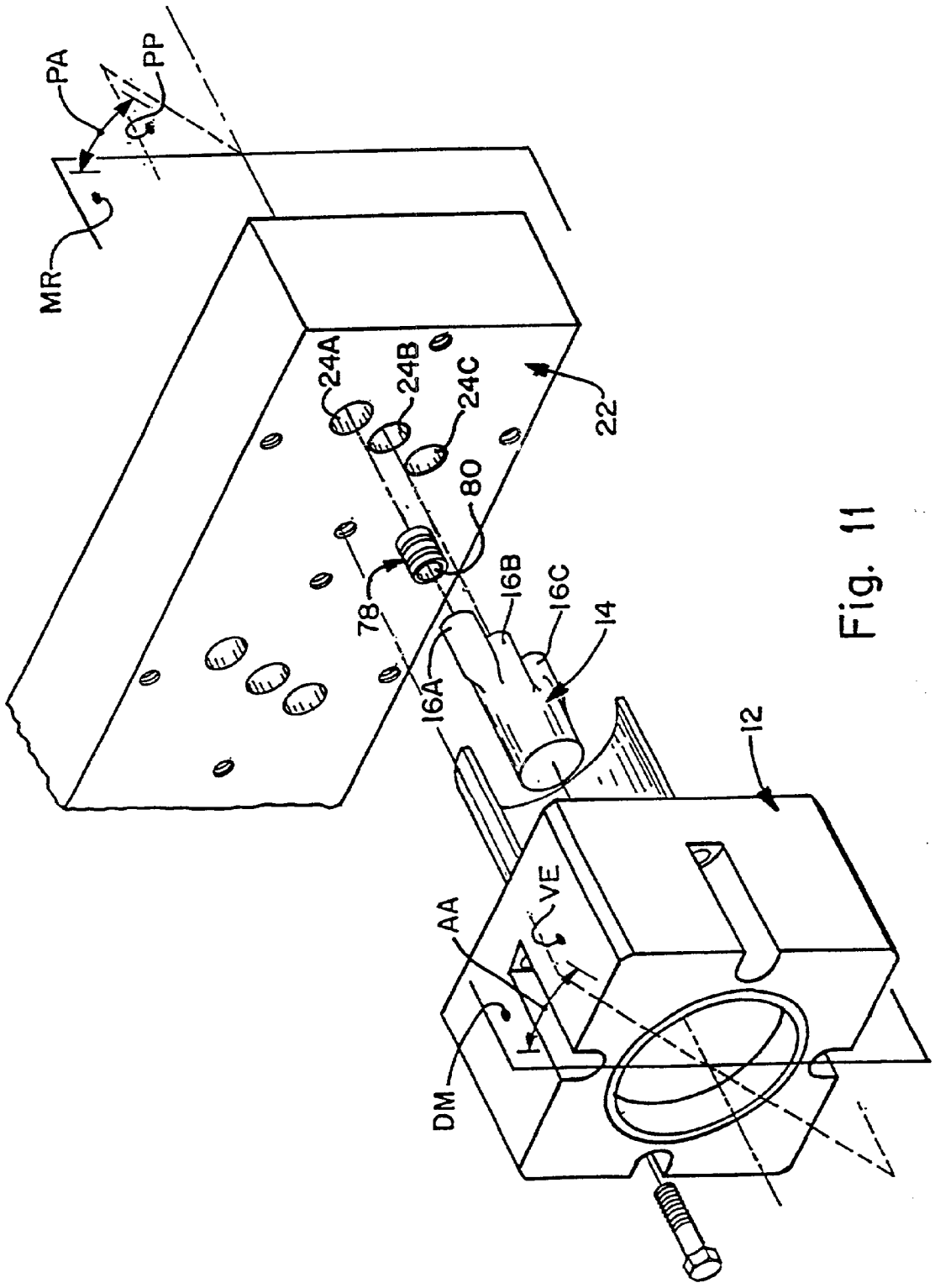


Fig. 11

VALVE ARRANGEMENT FOR CONTROLLING HYDRAULIC FLUID FLOW TO A SUBSEA SYSTEM

BACKGROUND OF THE INVENTION

[0001] The present invention relates to a valve arrangement and, more particularly, to a valve arrangement for a plurality of hydraulic control valves of the type commonly designated as sub-plate mounted (SPM) valves.

[0002] Hydraulic fluid supply systems supply hydraulic fluid to the hydraulic actuators of various mechanical devices for the actuation of the devices. Undersea wells are one source for the recovery of certain petroleum products such as oil and gas and the operation of such undersea wells presents considerable maintenance and installation challenges. In such subsea or underwater well environments, hydraulic fluid supply or control systems are commonly provided to control a blow out preventer. The blow out preventer typically includes a number of valves having specialized functions and these valves frequently are actuated by valve operators which are capable of being controlled from a remote location through energization by a controllable actuation system.

[0003] One type of controllable actuating system is comprised of hydraulic control valves arranged in a subsea structure which incorporates various hydraulic valves and regulators, hydraulic connector systems, solenoid operated pilot valves, and electronic packages. One type of hydraulic control valve which may be comprised in the hydraulic control arrangement for a subsea structure such as a blow out preventer is referred to as a sub-plate mounted (SPM) valve. This type of valve is typically a hydraulically piloted control valve which controls the flow of hydraulic fluid to and from a subsea operator such as, for example, blow-out preventer rams or choke and kill valves.

[0004] One conventional arrangement for accommodating a number of valves such as sub-plate mounted (SPM) valves comprises a relatively large valve block having valve pockets machined therein each for receiving a valve and drilled galleries for fluid communication with the valves. One drawback of this conventional arrangement is that the large valve block is typically customized for its particular installation and is thus configured to accommodate a selected group of valves which may be of differing sizes. Accordingly, should the fluid handling requirements change, modification or redesign of the valve block may be relatively complex or cost-prohibitive. If a single block of metal is machined or bored to create the valve pockets and galleries, another disadvantage arises in that the entire valve block may need to be discarded even if the damage is limited to only a portion of the block such as, for example, damage to the retaining threads of a valve pocket or the threads of a port.

SUMMARY OF THE INVENTION

[0005] It is one object of the present invention to provide a valve arrangement which facilitates its installation in its ultimate operational location and which facilitates the repair or replacement of key constituent elements thereof.

[0006] It is another object of the present invention to provide a valve arrangement which substantially promotes the installation and repair or replacement of constituent elements thereof in an operational location of the valve arrangement under adverse conditions such as might be found in surface or subsea hydraulic fluid control arrangements.

[0007] It is a further object of the present invention to provide a valve arrangement which offers a substantial range of flexibility in its configuration so that improvements, adaptations, and reconfiguration of the valve arrangement is facilitated.

[0008] According to one aspect of the present invention, a valve arrangement for controlling hydraulic fluid flow to a subsea system is provided. The valve arrangement includes a plurality of docking modules including a first docking module and a second docking module. The first docking module includes a first valve element for controlling the flow of a fluid and a first docking module port for fluid flow between the first valve element and an external source with the first docking module port having a cross section of a predetermined shape and area.

[0009] The second docking module includes a second valve element for controlling the flow of a fluid and a second docking module port for fluid flow between the second valve element and an external source with the second docking module port having a cross section which is different in at least one of shape and area than the cross section of the first docking module port. The valve arrangement additionally includes a manifold having a first manifold port and a second manifold port, the first and second manifold ports having generally the same cross-sectional shape and area which is different in at least one of shape and area than the cross section of the first docking module port.

[0010] The valve arrangement of the one aspect of the present invention also includes means for alternately sealingly interconnecting the first docking module port to the first manifold port so as to permit sealed fluid flow between the first valve element and the first manifold port in one configuration of the valve arrangement and sealingly interconnecting the second docking module port to the first manifold port so as to permit sealed fluid flow between the second valve element and the first manifold port in another configuration of the valve arrangement. Furthermore, the valve arrangement includes means for removably securing the first and second docking modules to the manifold for fluid flow between each docking module and the manifold.

[0011] In accordance with further details of the one aspect of the present invention, the means for alternately sealingly interconnecting includes an adapter means having a conduit of generally the same cross-sectional shape and area as the first module port and a seal interface surface. The adapter means may be a disposable element or, alternatively, an element which can be reused in successive securements of a docking module and the manifold. The adapter means is disposable relative to the manifold and the first docking module in a manner in which the seal interface surface of the adapter means is sealingly connected with the manifold and the first docking module and the conduit of the adapter means is aligned with the first docking module port and the first manifold port for fluid flow between the first docking module port and the first manifold port via the conduit of the adapter means.

[0012] According to another feature of the one aspect of the present invention, the valve arrangement further com-

prises a first mounting frame releasably securable with the first valve element to form the first docking module, means for releasably securing the first valve element to the first mounting frame, and the means for removably securing the first and second docking modules to the manifold includes means for detachably mounting the first mounting frame to the manifold. Preferably, the means for releasably securing the first valve element to the first mounting frame includes a frame mounted portion secured to the first valve element and a removable portion selectively movable between a retaining position in which it is secured to the frame mounted portion to thereby retain the first valve element and the first mounting frame in a secured together disposition and a non-retaining position in which the first valve element and the first mounting frame can be moved out of their secured together disposition with one another. Moreover, the frame mounted portion of the means for releasably securing the first valve element to the first mounting frame preferably includes a material having a hardness greater than the first mounting frame.

[0013] According to yet other details of the one aspect of the present invention, the first and second manifold ports have cylindrical cross sections of identical diameter and the first docking module port has a cylindrical cross section of smaller diameter than the individual diameter of one of the first and second manifold ports. Additionally, the second docking module port has a cylindrical cross of a diameter equal to the individual diameter of one of the first and second manifold ports.

[0014] Other optional features of the one aspect of the present invention include a common passageway formed in the manifold fluidly connected to the first and second manifold ports and a U-tube fluidly connected to the first manifold port.

[0015] According to another aspect of the present invention, a valve arrangement for controlling hydraulic fluid flow to a subsea system is provided and includes a first valve element for controlling the flow of a fluid and a second valve element for controlling the flow of a fluid. The valve arrangement of this another aspect of the present invention also includes a first docking module configured to interchangeably receive one of the first and second valve elements and having a first docking module port for fluid flow between the respective one of the first and second valve elements received by the first docking module and an external source, the first docking module port having a cross section of a predetermined shape and area.

[0016] Moreover, the valve arrangement includes a manifold having a first manifold port and a second manifold port, the first and second manifold ports having a substantially identical cross section which is different in at least one of shape and area than the cross section of the first docking module port.

[0017] In this another aspect of the present invention, the means for alternately sealingly interconnecting of the valve arrangement includes a conduit element having a conduit of generally the same cross-sectional shape and area as the first module port and having a connecting surface of generally the same cross-sectional shape and area as the substantially identical cross section of the first and second manifold ports. The conduit element is removably couplable with at least one of the first manifold port and the first docking module port in a manner in which the connecting surface is sealingly connected with the first manifold port and the conduit is aligned with the first docking module port for fluid flow between the first docking module port and the first manifold port via the conduit element. The valve arrangement also includes means for removably securing the first docking module to the manifold for fluid flow between the respective one of the first and second valve elements received in the first docking module and the manifold.

[0018] According to additional features of the another aspect of the present invention, the means for removably securing the first docking module to the manifold is operable to removably secure the first docking module in a selected predetermined relative orientation to the manifold and the first docking module includes means for alternately disposing the first valve element in a fluid flow disposition such that, upon securement of the first docking module in the one selected predetermined relative orientation to the manifold, the first valve element is sealingly communicated with the conduit of the conduit element via the first docking module port in the one configuration of the valve arrangement. Also, the first and second manifold ports preferably have cylindrical cross sections of uniform diameter, the first docking module port has a cylindrical cross section, and the cylindrical cross section of the first docking module port is of smaller diameter than the uniform individual diameter of the first and second manifold ports, and the conduit of the conduit element has a cylindrical cross section of the same diameter as the first docking module port.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] **FIG. 1** is an exploded perspective view of one embodiment of the valve arrangement of the present invention;

[0020] **FIG. 2** is an enlarged exploded perspective view of a portion of the one embodiment of the valve arrangement shown in **FIG. 1** and showing in greater detail the valve element and mounting frame of a docking module;

[0021] **FIG. 3** is an enlarged perspective view in partial vertical section of the valve element of the docking module shown in **FIG. 2**, taken along lines III-III thereof;

[0022] **FIG. 4** is an enlarged perspective view, in partial vertical section, of the one variation of the manifold shown in the one embodiment of the valve arrangement shown in **FIG. 1**, taken along lines IV-IV thereof;

[0023] **FIG. 5** is an enlarged perspective view, in partial horizontal section, of another variation of the manifold of the one embodiment of the valve arrangement and taken along lines V-V of **FIG. 6**;

[0024] **FIG. 6** is an enlarged perspective view of the another variation of the manifold of the one embodiment of the valve arrangement shown in **FIG. 5**;

[0025] **FIG. 7** is an enlarged perspective view, in partial vertical section, of a further variation of the manifold of the one embodiment of the valve arrangement and taken along lines VII-VII of **FIG. 8**;

[0026] **FIG. 8** is an enlarged perspective view of the further variation of the manifold of the one embodiment of the valve arrangement shown in **FIG. 7**;

[0027] **FIG. 9** is an enlarged perspective view, in partial horizontal section, of the another variation of the manifold shown in **FIGS. 5 and 6**, and showing, in exploded view, the first and second docking modules, in partial vertical section, mounted to the manifold via the adapter means in one configuration of the valve arrangement of the present invention;

[0028] **FIG. 10** is an enlarged perspective view of the another variation of the manifold shown in **FIGS. 5 and 6**, and showing, in exploded view, the first and second docking modules, in partial vertical section, mounted to the manifold via the adapter means in another configuration of the valve arrangement of the present invention; and

[0029] **FIG. 11** is an enlarged perspective exploded view of a portion of the valve arrangement shown in **FIG. 9** having the another variation of the manifold.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0030] As shown in FIGS. **1-4**, one embodiment of a valve arrangement for a subsea drilling control unit is illustrated. The valve arrangement, generally designated as **10**, is designed to control selected functions associated with the exploration or drilling of subsea wells for the extraction of hydrocarbons such as, for example, oil or gas. As will be described in more detail, the valve arrangement **10** is particularly suitable for controlling the operation of a blow-out preventer (BOP) stack and the ancillary function provided by Lower Marine Riser Packages (LMRP).

[0031] With particular reference now to **FIG. 2**, the valve arrangement **10** includes a first docking module **12** having a first valve element **14** for controlling the flow of a fluid, such as, for example, a hydraulic fluid, and a first series of docking module ports **16**A, **16**B, and **16**C for communicating the first valve element **14** with a manifold, to be described in more hereafter, for fluid flow between the first valve element **14** and the manifold when the first docking module **12** is mounted to the manifold. The first docking module **12** also includes a first mounting frame **18** releasably secured with the first valve element **14** by a means **20** for releasably securing the first valve element **14** to the first mounting frame **18**.

[0032] The valve arrangement **10** additionally includes a manifold to which the first docking module **12** is mountable. The manifold, generally designated as **22**, has a first series of manifold ports **24**A, **24**B, and **24**C, and a second series of manifold ports **26**A, **26**B, and **26**C. The first docking module **12** is removably securable to the manifold **22** by a means for removably securing the first docking module **12** to the manifold **22** is provided preferably in the form of a first module—manifold securing assembly **28**.

[0033] The valve arrangement **10** additionally includes a second docking module **30** having a second valve element **32** for controlling the flow of the fluid, a second series of docking module ports **34**A, **34**B, and **34**C, each for fluidly communicating between the second valve element **32** and the manifold **22**, and a second mounting frame **36**. The second mounting frame **36** is releasably securable with the second valve element **32** by operation of a second means **38** for releasably securing the second valve element **32** to the second mounting frame. The second docking module **30** is removably securable to the manifold **22** by operation of a means for removably securing the second docking module **30** to the manifold **26** preferably in the form of a second module—manifold fastening assembly **40**.

[0034] Reference is now made to **FIG. 4**, which is a partial vertical sectional view of the one variation of the manifold **22** of the one embodiment of the valve arrangement illustrated in FIGS. **1-3**, for a discussion in greater detail of the structure and operation of the manifold. As seen in **FIG. 4**, in the one variation of the manifold **22**, each of the first series of manifold ports **24**A, **24**B, and **24**C is independently fluidly communicated with an external source via a conduit **42**, **44**, **46**, respectively. Thus, none of the first series of manifold ports **24**A, **24**B, and **24**C is commonly communicated with a counterpart manifold port in the second series of manifold ports **26**A, **26**B, and **26**C. For example, the manifold port **24**A of the first series of manifold ports, which may be, for example, a port for handling fluid vented via the first docking module port **16**A, is not fluidly communicated with its counterpart manifold port **26**A of the second series of manifold ports, which itself is fluidly communicated with the second docking module port **34**A. Instead the first manifold port **24**A is independently communicated with the conduit **42** while the second manifold port **26**A is independently communicated with an external source via another conduit (not shown). In this variation of the manifold **22**, the manifold can be configured, for example, as a parallelepiped block of a homogenous material such as, for example, stainless steel and each of the first series of manifold ports **24**A, **24**B, and **24**C and the second series of manifold ports **26**A, **26**B, and **26**C is formed, for example, by machining or boring a cylindrical throughbore in the stainless steel block extending through the manifold **22** from one side thereof to an opposite side.

[0035] The manifold **22** can thus accommodate a plurality of docking modules, such as the first docking module **12** and the second docking module **30**, for selectively routing the flow of fluids to and from the respective valve elements comprised within each docking module such as, for example, the first valve element **14** and the second valve element **32** comprised in the first docking module **12** and the second docking module **30**, respectively. The valve elements of the docking modules may be selected to be identical—if, for example, the valve elements are SPM valves, then each valve element may be selected as a standard size SPM valve such as, for example, 0.75 inches, 1.0 inches, or 1.5 inches, it being understood that the standard size description is related to the valve's Cv, a standard measure of the volume of fluid that will pass through a valve at a given differential pressure. Alternately, the valve elements of the docking modules may be individually different from one another. For illustrative purposes in the following description, the first valve element **14** and the second valve element **32** are to be understood to be identical SPM valves, each having three ports—vent, inlet, and outlet ports—with the respective vent ports being designated with the "A" suffix (e.g., the ports **24**A, **26**A), the respective inlet ports being designated with the "B" suffix (e.g., the ports **24**B, **26**B), and the respective outlet ports being designated by the "C" suffix (e.g., the ports **24**C, **26**C). Moreover, the respective ports of the valve elements which perform the same vent, inlet, or outlet function will be referred to as counterpart ports.

[0036] With further reference now to the structure and operation of each of the valve elements of the first docking module **12** and the second docking module **30**, attention is drawn to **FIG. 3**, which is an enlarged perspective view, in longitudinal cross section of a portion of the first valve element **14**, it being understood that the second valve element **32** can, as desired, be identically configured as the first valve element **14** or may be comprised of a valve structured for a different type of valve operation. The first valve element **14** is representatively shown as a type of hydraulic control valve commonly referred to as a sub-plate mounted (SPM) valve which is configured to control the flow of hydraulic fluid to and from a subsea operator. Blow-out preventer (BOP) rams and choke and kill valves are two examples of the type of subsea operators to which the first valve element **14** may be operatively connected for controlling the flow of hydraulic fluid thereto. One exemplary configuration of a sub-plate mounted (SPM) valve which the first valve element **14** may comprise includes, as shown in **FIG. 3, a** valve configuration in which the first docking module port **16**A is a vent port, the first docking module port **16**B is an outlet or function port, and the first docking module port **16**C is an inlet or supply port. The first valve element **14** is operably controllable between a first flow disposition in which the first docking module port **16**B, in its function as an outlet port, is fluidly communicated with the first docking module port **16**C, in its function as an inlet port, and a second disposition in which the first docking module port **16**B, in its function as an outlet port, is fluidly communicated with the first docking module port **16**A, in its function as a vent port, while the first docking module port **16**C, in its function as an inlet port, is blocked. An SPM control valve having this configuration and controllable in this manner is disclosed in U.S. Pat. No. 5,771,931, which is herein incorporated by reference.

[0037] The first valve element **14** further includes a pilot pressure circuit passage **48** connectable to an external fluid source (not shown) for selectively introducing fluid into a piston chamber to thereby effect movement of a piston member **50**. The piston member **50** is moveable against the bias of a return spring **52** to dispose a flow passage **54** in a position for fluidly communicating the first docking module port **16**A [the inlet or supply port] and the first docking module **16**B [the outlet or function port] in the second disposition of the first valve element **14** while a seal sleeve isolates the first docking module **16***c* [the vent port] from the supplied fluid. The return spring **52** otherwise urges the piston member **50** to dispose the flow passage **54** in a position for fluidly communicating the first docking module port **16**B [the outlet or function port] and the first docking module **16**C [the vent port] in the first disposition of the first valve element **14**.

[0038] In **FIGS. 5 and 6**, another variation of the manifold of the valve arrangement of the present invention is illustrated. In this variation, the manifold, generally designated as **122**, includes a first series of manifold ports **124**A, **124**B, and **124**C for fluidly communicating the first docking module **12** with the manifold and a second series of ports **126**A, **126**B, and **126**C for fluidly communicating the manifold with the second docking module **30**. The counterpart manifold ports **124**A, **126**A, as well as other counterpart manifold ports (not shown), are commonly fluidly communicated with one another by a first common passageway **142** extending generally transverse to each of these respective counterpart manifold ports along the longitudinal extent of the manifold **122** and communicated at one axial end thereof with an external source (not shown). If, for example, each of the counterpart manifold ports **124**A, **126**A, are vent ports fluidly communicated with the respective vent ports of the first valve element **14** and the second valve element **32**, respectively, these manifold ports are operable to vent fluid to the common passageway **142** for flow of the vented fluid to the external source with which the common passageway **142** is communicated.

[0039] The manifold **122** further includes a second common passageway **144** fluidly communicating another plurality of counterpart manifold ports—namely, the counterpart manifold ports **124**B, **126**B, and other counterpart manifold ports (not shown). The second common passageway **144** is fluidly communicated with an external source for selective flow of fluid from the external source to the commonly communicated plurality of counterpart manifold ports or, alternatively, for fluid flow from the plurality of counterpart manifold ports to the external source. For example, the second common passageway **144** may be fluidly communicated with a hydraulic fluid supply source (HF) for common supply of hydraulic fluid to the first valve element **14**, the second valve element **32**, and any other valve elements secured to the manifold **122** and having a counterpart manifold port communicated with the second common passageway **144**. In the variation of the manifold **122** shown in **FIGS. 5 and 6**, the manifold port **124**C and the manifold port **126**C are each separately communicated with an external source (not shown) via a respective separate conduit **146** sealingly secured to the manifold **122**.

[0040] A further variation of the manifold of the valve arrangement of the present invention is illustrated in **FIGS. 7 and 8** and it can be seen that the manifold, which is generally designed as **222**, includes a first series of manifold ports **224**A, **224**B, and **224**C and a second series of manifold ports **226**A, **226**B, and **226**C. As seen in **FIG. 7**, which is a perspective view of the manifold **222** in partial section through the first series of manifold ports **224**A, **224**B, and **224**C, the counterpart manifold ports **224**A, **226**A are commonly fluidly communicated with a common passageway **242** for common fluid flow to or from an external source (not shown). The external source may be, for example, a hydraulic fluid collection location for collecting hydraulic fluid vented through the manifold ports **224**A, **226**A, or, alternatively, a hydraulic fluid supply source for supplying hydraulic fluid through these manifold ports.

[0041] The manifold ports **224**B, **226**B, which are counterpart manifold ports, are each separately communicated via a separate respective conduit **244** to an external source or sources (not shown). Likewise, the counterpart manifold ports **224**C, **226**C are each separately communicated with an external source or sources (not shown) via a separate respective conduit **246**. It can thus be appreciated that the manifold **222** is operable to selectively communicate two of the valve element fluid flow operations such as, for example, the vent and outlet operations, in an independent manner for each respective docking module mounted to the manifold while conducting fluid from the third valve element operation, such as, for example, the inlet operation, in a common or shared flow manner from a single external source (e.g., a

hydraulic fluid supply source) along the common passageway **242** to the plurality of docking modules mounted to the manifold.

[**0042**] Reference is now had to **FIGS. 9 and 10** to illustrate the flexibility and ease of installation offered by the valve arrangement **10**. In the illustrative configuration of the valve arrangement **10** shown in **FIGS. 9 and 10**, all of the manifold ports of the manifold **22** are of circular cross section and, further, all of the manifold ports have a circular cross section of the same diameter, generally designated as the diameter **60**. Additionally, each of the docking module ports **34**A, **34**B, and **34**C of the second docking module **30** has a circular cross section with a diameter equal to the diameter **60** of the manifold ports of the manifold **22** and, further, the circular cross sections of these docking module ports is identical. The docking module ports **16**A, **16**B, and **16**C of the first docking module **12** have identical circular cross sections of a diameter **62** less than the diameter **60**.

[**0043**] The first mounting frame **18** of the first docking module **12** is configured to interchangeably receive either the first valve element **14** or the second valve element **32**—specifically, the first docking module **12**. In the illustrative configuration shown in **FIG. 9**, for example, the respective received valve element received by the first docking module **12** is the first valve element **14** whereas, in the alternate configuration shown in **FIG. 10**, the respective received valve element received by the first docking module **12** is the second valve element **32**. In the configuration shown in **FIG. 9**, the first valve element **14** is adapted to be mounted to the manifold **22** such that each of the first docking module ports **16**A, **16**B, and **16**C is respectively linearly aligned with an associated one of the first manifold ports **24**A, **24**B, and **24**C when the first docking module **12** is mounted to the manifold **22**. The second docking module **30**, which includes the second valve element **32**, is configured in the illustrative configuration shown in **FIG. 9** such that each of the second docking module ports **34**A, **34**B, and **34**C is respectively linearly aligned with an associated one of the second manifold ports **26**A, **26**B, and **26**C, when the second docking module **30** is secured to the manifold **22**.

[**0044**] The first mounting frame **18** is specifically configured to interchangeably receive both the first valve element **14** and the second valve element **32** and includes a chamber **66**, preferably cylindrical, which is adapted to receive the complementary cylindrically shaped housing **68** of the respective first valve element **14** or second valve element **32**. The first mounting frame **18** also includes a plurality of throughbores **70**, each for supporting one of a plurality of securement bolts of the first module—manifold securing assembly **28**. The securement bolts are adapted to be threadingly secured in a respective threaded securement bore **72** formed in the manifold **22** to thereby secure the first docking module **12** to the manifold **22** in an orientation to be described in more detail hereafter.

[**0045**] The means **20** for releasably securing the respective received valve element (e.g., the first valve element **14**) to the first mounting frame **18** is preferably in the form of a threaded locking assembly having a frame mounted portion **74** secured to the first valve element **14** and a removable portion **76**. The frame mounted portion **74** includes threads formed in the first mounting frame **18** and the removable portion **76** is a cylindrical cap having external threads on its outer circumference adapted to be threadingly received in the threads of the frame mounted portion **74**. The cylindrical cap is selectively movable between a retaining position in which it is secured to the frame mounted portion **74** to thereby retain the first valve element **14** and the first mounting frame **18** in a secured together disposition and a non-retaining position in which the first valve element **14** and the first mounting frame **18** can be moved out of their secured together disposition with one another. The second means for releasably securing the second valve element **32** to the second mounting frame **36** is also preferably configured as a threaded locking assembly operable similarly to the threaded locking assembly of the means **20** for releasably securing the first valve element **14** to the first mounting frame **18**.

[**0046**] The removable portion **76** is preferably comprised of a material having a hardness greater than the first mounting frame **18**. For example, if the first mounting frame **18** is formed of a stainless steel such as, for example, 316 stainless steel, then the removable portion **76** may be formed of a material such as a steel sold under the designation "Monel" which has a hardness greater than that of 316 stainless steel.

[**0047**] It can be seen in the illustrative configuration of the valve arrangement **10** shown in **FIGS. 9 and 10** that the docking modules can accommodate docking module ports of varying geometries and dimensions. For example, the second valve element **32** has docking module ports at least one of which has a cross section different in at least its shape or its area than the respective docking module port of the first valve element **14**. Thus, the valve arrangement **10** of the present invention can accommodate the two different docking module port geometries and dimensions irrespective of which one of the particular docking modules—in this example, the first docking module **12** or the second docking module **30**—is mounted at the selected location on the manifold **22** for communication of its respective docking module ports with the associated manifold ports at the selected manifold location.

[**0048**] To further illustrate this operational flexibility, reference is made to **FIG. 9**, in which it can be seen that, in the one configuration of the valve arrangement **10** shown in **FIG. 9**, the first and second series of manifold ports **24**A, **24**B, and **24**C and **26**A, **26**B, and **26**C have, as noted, cylindrical cross sections of uniform diameter **60**, the first series of docking module ports **16**A, **16**B, and **16**C have identical cylindrical cross sections of diameter **62**, and the cylindrical cross section of the first docking module ports is of smaller diameter than the uniform individual diameter of the first and second manifold ports **24**A, **24**B, and **24**C and **26**A, **26**B, and **26**C. Accordingly, the first docking module ports **16**A, **16**B, and **16**C of the first docking module **12** must be sealingly interconnectable with the manifold ports of the manifold **22** in a manner which accommodates the cross sections of these docking module ports, on the one hand, and the different cross sections of the manifold ports, on the other hand, while still accommodating the second docking module ports **34**A, **34**B, and **34**C in the event that the respective received valve element received by the first docking module **12** is the second valve element **32**. The docking module ports **34**A, **34**B, and **34**C of the second docking module **30**, being of the identical cross-sectional size (circular) and area as any given series of manifold ports such as, for example, the series of manifold ports **26**A, **26**B,

and **26**C, can be readily sealingly interconnected to the manifold ports via a conventional seal or gasket arrangement customarily employed in sealingly interconnecting two conduit ends having identical cross-sectional sizes and areas. On the other hand, to effectuate the sealed fluid communication of the first docking module ports **16**A, **16**B, and **16**C with their respective associated manifold ports, the valve arrangement includes means for alternately sealingly interconnecting the first valve element **14** to one of the first series of manifold ports such as, for example, the first manifold port **24**A, via a first docking module port (i.e., the first docking module port **16**A) so as to permit sealed fluid flow between the first valve element **14** and the first manifold port **24**A in one configuration of the valve arrangement and, as seen in **FIG. 10**, sealingly interconnecting the second valve element **32** to the first manifold port **24**A via the same docking module port (in this example, the first docking module port **16**A) so as to permit sealed fluid flow between the second valve element **32** and the first manifold port **24**A in another configuration of the valve arrangement.

[**0049**] As seen in **FIG. 10**, the means for alternately sealingly interconnecting includes a conduit element **78** having a conduit **80** of generally the same cross-sectional shape and area as the first module port **24**A and having a connecting surface **82** of generally the same cross-sectional shape and area as the substantially identical cross section of the first and second manifold ports **24**A, **26**A. The conduit element **78** is removably couplable with at least one of the first manifold port **24**A and the first docking module port **16**A in a manner in which the connecting surface **82** is sealingly connected with the first manifold port **24**A and the conduit **80** is aligned with the first docking module port **16**A for fluid flow between the first docking module port **16**A and the first manifold port **24**A via the conduit element **78**. Also, the conduit **80** of the conduit element **78** has a cylindrical cross section of the same diameter as the diameter **62** of the first docking module port **16**A. If desired, appropriate countersunk bores can be provided in connection with each manifold port on the manifold **22** and each docking module port of the docking modules to accommodate therein the conduit elements **78**, which can include appropriate O-rings or other sealing elements to be sealingly accommodated within the countersunk bores.

[**0050**] Further in configuring the valve arrangement **10** to optimize its arrangement flexibility and ease of installation and repair, the means for removably securing the first docking module **12** to the manifold **22** is operable to removably secure the first docking module **12** in a selected predetermined relative orientation to the manifold **22**. As seen in **FIG. 11**, the cylindrical housing **68** of the first valve element **14** is secured within the corresponding cylindrical chamber **66** of the first mounting frame **18** at a predetermined relative orientation thereto such that the first docking module ports **16**A, **16**B, and **16**C are sealingly communicated with, and co-axial with, the respective conduit **80** of the conduit elements **78** which communicate the first docking module ports with their respective associated first manifold ports **24**A, **24**B, and **24**C upon mounting of the first docking module **12** to the manifold **22** in the one selected predetermined relative orientation of the first docking module **12** to the manifold **22**. Specifically, the cylindrical housing **66** of the first valve element **14**, as measured relative to a plane VE extending through the axial centerlines of the first docking module ports **16**A, **16**B, and **16**C, is disposed at an acute angle AA relative to an alignment plane DM of the first docking module **12**. The alignment plane DM of the first docking module **12** is an arbitrary reference plane which will be co-extensive with a manifold reference plane MR upon mounting of the first docking module **12** to the manifold **22**, thereby characterizing the one selected predetermined relative orientation between the first docking module **12** and the manifold **22**. The axial centerlines of the first manifold ports **24**A, **24**B, and **24**C are disposed on a manifold port plane PP which forms an angle PA with the manifold reference plane MR.

[**0051**] Thus, as a result of the predetermined angular orientation of the cylindrical housing **68** of the first valve element **14** relative to the corresponding cylindrical chamber **66** of the first mounting frame **18** in which it is received, the first docking module ports **16**A, **16**B, and **16**C are sealingly communicated with, and co-axial with, the respective conduit **80** of the conduit elements **78** which communicate the first docking module ports with their respective associated first manifold ports **24**A, **24**B, and **24**C upon mounting of the first docking module **12** to the manifold **22** in the one selected predetermined relative orientation. Since the second valve element **32** is also housed in a housing identical to the cylindrical housing **68** of the first valve element **14**, the second valve element **32** can be interchangeably received in the chamber **66** of the first mounting frame **18** at a predetermined relative angular orientation thereto such that the second docking module ports **34**A, **34**B, and **34**C are sealingly communicated with, and co-axial with, their respective associated first manifold ports **24**A, **24**B, and **24**C upon mounting of the first docking module **12** to the manifold **22** in the one selected predetermined relative orientation. Thus, it can be seen that the first docking module **12** includes means for alternately disposing the first valve element **14** in a fluid flow disposition such that, upon securement of the first docking module in the one selected predetermined relative orientation to the manifold, the first valve element **14** is sealingly communicated with the conduit **80** of the conduit element **78** via the first docking module port **16**A in the one configuration of the valve arrangement and the second valve element **32** in a fluid flow disposition such that, upon securement of the first docking module **12** in the one selected predetermined relative orientation to the manifold **22**, the second valve element **32** is sealingly communicated with the first manifold port **24**A via the first docking module port **16**A in the other configuration of the valve arrangement.

[**0052**] In some circumstances, the ease of interchangeably mounting the docking modules to the manifold **22** can be best optimized by configuring the docking module ports of each docking module such that each respective docking module port is linearly aligned—i.e., co-axial—with the respective associated manifold port on the manifold **22**. In other circumstances, however, it may be more preferred that the docking module ports of a docking module are not linearly aligned—i.e., not co-axial—with their respective associated manifold ports on the manifold **22**.

[**0053**] With reference again to **FIG. 1**, in the event that the valve arrangement **10** includes separate conduits for the entirety of the manifold ports or separate conduits for a sub-set of manifold ports such as, for example, all of the manifold ports associated with the vent ports of the valve elements secured to the manifold, it is preferred that the

valve arrangement include a U-shaped conduit tube **84** fluidly connected to each such manifold port. This arrangement permits ease of fault finding—i.e., leakage in any individual fluid passage can be readily ascertained.

[**0054**] While an embodiment and variations of the present invention have been shown, it will be appreciated that modifications thereof, some of which have been alluded to hereinabove, may still be readily made thereto by those skilled in the art. It is, therefore, intended that the appended claims shall cover the modifications alluded to herein as well as all the other modifications which fall within the true spirit and scope of the present invention.

We claim:

1. A valve arrangement for controlling hydraulic fluid flow to a subsea system comprising:

a first docking module having a first valve element for controlling the flow of a fluid and a first docking module port for fluid flow between the first valve element and an external source, the first docking module port having a cross section of a predetermined shape and area;

a second docking module having a second valve element for controlling the flow of a fluid and a second docking module port for fluid flow between the second valve element and an external source, the second docking module port having a cross section which is different in at least one of shape and area than the cross section of the first docking module port;

a manifold having a first manifold port and a second manifold port, the first and second manifold ports having generally the same cross-sectional shape and area which is different in at least one of shape and area than the cross section of the first docking module port;

means for alternately sealingly interconnecting the first docking module port to the first manifold port so as to permit sealed fluid flow between the first valve element and the first manifold port in one configuration of the valve arrangement and sealingly interconnecting the second docking module port to the first manifold port so as to permit sealed fluid flow between the second valve element and the first manifold port in another configuration of the valve arrangement; and

means for removably securing the first and second docking modules to the manifold for fluid flow between each docking module and the manifold.

2. A valve arrangement according to claim 1 wherein the means for alternately sealingly interconnecting includes an adapter means having a conduit of generally the same cross-sectional shape and area as the first module port and a seal interface surface, the adapter means being disposable relative to the manifold and the first docking module in a manner in which the seal interface surface of the adapter means is sealingly connected with the manifold and the first docking module and the conduit of the adapter means is aligned with the first docking module port and the first manifold port for fluid flow between the first docking module port and the first manifold port via the conduit of the adapter means.

3. A valve arrangement according to claim 1 and further comprising a first mounting frame releasably securable with the first valve element to form the first docking module, means for releasably securing the first valve element to the first mounting frame, and the means for removably securing the first and second docking modules to the manifold includes means for detachably mounting the first mounting frame to the manifold.

4. A valve arrangement according to claim 3 wherein the means for releasably securing the first valve element to the first mounting frame includes a frame mounted portion secured to the first valve element and a removable portion selectively movable between a retaining position in which it is secured to the frame mounted portion to thereby retain the first valve element and the first mounting frame in a secured together disposition and a non-retaining position in which the first valve element and the first mounting frame can be moved out of their secured together disposition with one another.

5. A valve arrangement according to claim 4 wherein the frame mounted portion of the means for releasably securing the first valve element to the first mounting frame includes a material having a hardness greater than the first mounting frame.

6. A valve arrangement according to claim 1 wherein the first and second manifold ports have cylindrical cross sections of identical diameter and the first docking module port has a cylindrical cross section of smaller diameter than the individual diameter of one of the first and second manifold ports.

7. A valve arrangement according to claim 6 wherein the second docking module port has a cylindrical cross of a diameter equal to the individual diameter of one of the first and second manifold ports.

8. A valve arrangement according to claim 1 wherein the manifold includes a common passageway fluidly connected to the first and second manifold ports.

9. A valve arrangement according to claim 1 and further comprising a U-tube fluidly connected to the first manifold port.

10. A valve arrangement for controlling hydraulic fluid flow to a subsea system comprising:

a first valve element for controlling the flow of a fluid;

a second valve element for controlling the flow of a fluid;

a first docking module configured to interchangeably receive one of the first and second valve elements and having a first docking module port for fluid flow between the respective one of the first and second valve elements received by the first docking module and an external source, the first docking module port having a cross section of a predetermined shape and area;

a manifold having a first manifold port and a second manifold port, the first and second manifold ports having a substantially identical cross section which is different in at least one of shape and area than the cross section of the first docking module port;

means for alternately sealingly interconnecting the first valve element to the first manifold port via the first docking module port so as to permit sealed fluid flow between the first valve element and the first manifold port in one configuration of the valve arrangement and sealingly interconnecting the second valve element to the first manifold port via the first docking module port so as to permit sealed fluid flow between the second valve element and the first manifold port in another

configuration of the valve arrangement, the means for alternately sealingly interconnecting including a conduit element having a conduit of generally the same cross-sectional shape and area as the first module port and having a connecting surface of generally the same cross-sectional shape and area as the substantially identical cross section of the first and second manifold ports, the conduit element being removably couplable with at least one of the first manifold port and the first docking module port in a manner in which the connecting surface is sealingly connected with the first manifold port and the conduit is aligned with the first docking module port for fluid flow between the first docking module port and the first manifold port via the conduit element; and

means for removably securing the first docking module to the manifold for fluid flow between the respective received valve element and the manifold.

11. A valve arrangement according to claim 10 wherein the means for alternately sealingly interconnecting is operable to removably secure the first docking module in a selected predetermined relative orientation to the manifold and the first docking module includes means for alternately disposing the first valve element in a fluid flow disposition such that, upon securement of the first docking module in the one selected predetermined relative orientation to the manifold, the first valve element is sealingly communicated with the conduit of the conduit element via the first docking module port in the one configuration of the valve arrangement and the second valve element in a fluid flow disposition such that, upon securement of the first docking module in the one selected predetermined relative orientation to the manifold, the second valve element is sealingly communicated with the first manifold port via the first docking module port in the other configuration of the valve arrangement.

12. A valve arrangement according to claim 11 wherein the first and second manifold ports have cylindrical cross sections of uniform diameter, the first docking module port has a cylindrical cross section, and the cylindrical cross section of the first docking module port is of smaller diameter than the uniform individual diameter of the first and second manifold ports, and the conduit of the conduit element has a cylindrical cross section of the same diameter as the first docking module port.

13. A valve arrangement according to claim 12 and further comprising a second docking module for interchangeably receiving one of the first and second valve elements and having a second docking module port for fluid flow between the respective received valve element and an external source, the second docking module port having a cross section which is different in at least one of shape and area than the cross section of the first docking module port, and means for removably securing the second docking module to the manifold for fluid flow between the respective received valve element and the manifold.

14. A valve arrangement according to claim 13 and further comprising a first mounting frame releasably securable with the respective received valve element received by the first docking module, means for releasably securing the respective received valve element to the first mounting frame, a second mounting frame releasably securable with the respective received valve element received by the second docking module, and means for releasably securing the respective received valve element to the second mounting frame.

15. A valve arrangement according to claim 14 wherein the means for releasably securing the respective received valve element to the first mounting frame includes a frame mounted portion secured to the respective received valve element and a removable portion selectively movable between a retaining position in which it is secured to the frame mounted portion to thereby retain the respective received valve element and the first mounting frame in a secured together disposition and a non-retaining position in which the respective received valve element and the first mounting frame can be moved out of their secured together disposition with one another.

16. A valve arrangement according to claim 15 wherein the removable portion of the means for releasably securing the respective received valve element to the first mounting frame includes a material having a hardness greater than the first mounting frame.

17. A valve arrangement according to claim 12 wherein the second docking module port has a cylindrical cross of a diameter equal to the individual diameter of one of the first and second manifold ports.

18. A valve arrangement according to claim 11 wherein the manifold includes a common passageway fluidly connected to the first and second manifold ports.

19. A valve arrangement according to claim 11 and further comprising a U-tube fluidly connected to the first manifold port.

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