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[54] **SATELLITE TREE MODULE AND FLOW LINE STRUCTURE FOR INTERCONNECTION OF A SATELLITE WELL TO A SUBSEA PRODUCTION SYSTEM**

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[52] **U.S. Cl.** **166/339;** 166/344; 166/349; 405/195.1; 405/224

[58] **Field of Search** 166/339, 351, 357, 344, 166/343, 350

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[57] **ABSTRACT**

A satellite tree module (STM) (**10**) for controlling flow between a satellite flow and a subsea production system includes at the bottom of the STM a connector (**12**) of an internal-latch, hydraulically operated type. A lower structure (**14**) consists of a central ring and projecting arms terminating in guide funnels. An upper structure (**18**) supports a reentry pole (**20**) integrated to the STM assembly (**10**) via an orientation key, a reentry mandrel (**22**) and a cap (**24**) for protection of the external profile of the reentry mandrel (**22**) and its receptacles. A flow system is arranged above the lower structure (**14**) and inside the upper structure (**18**). The flow system consists of a set of pipes and valves through which production-/injection, production testing and lift-gas fluids flow. A flow line terminal (**26**) and a control system responsible for the activation of the STM (**10**) components during the operational phase are amounted to one of the upper and lower structures.

15 Claims, 6 Drawing Sheets

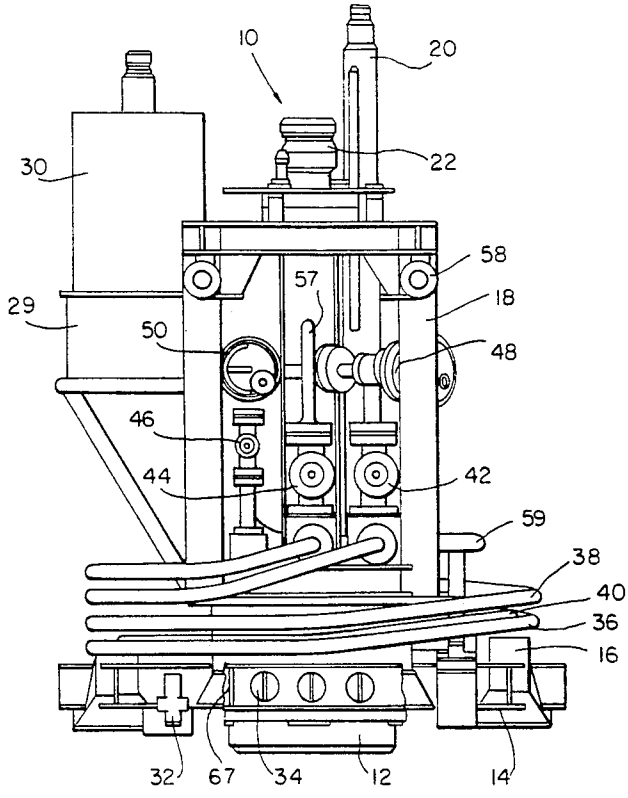


FIG. 1

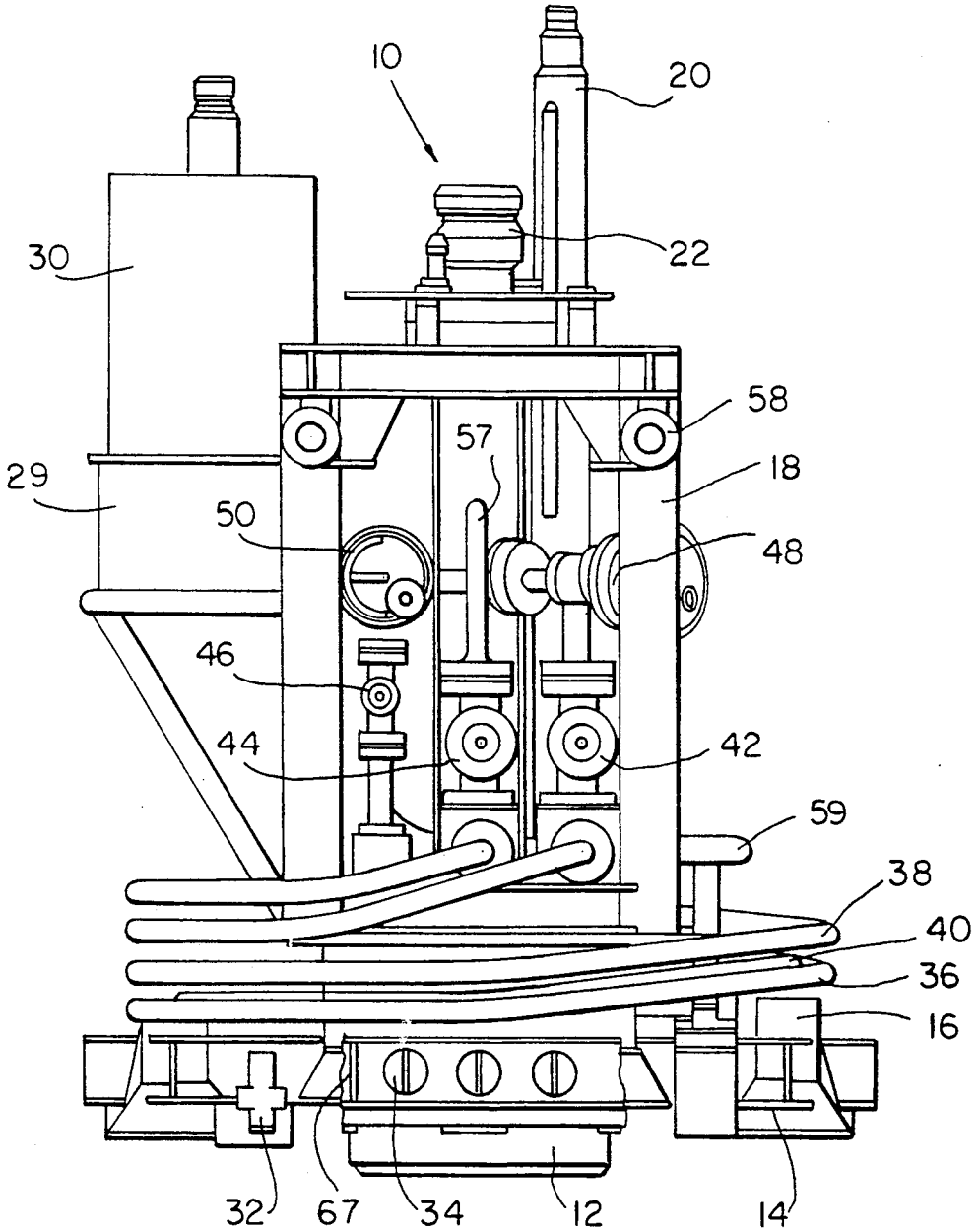
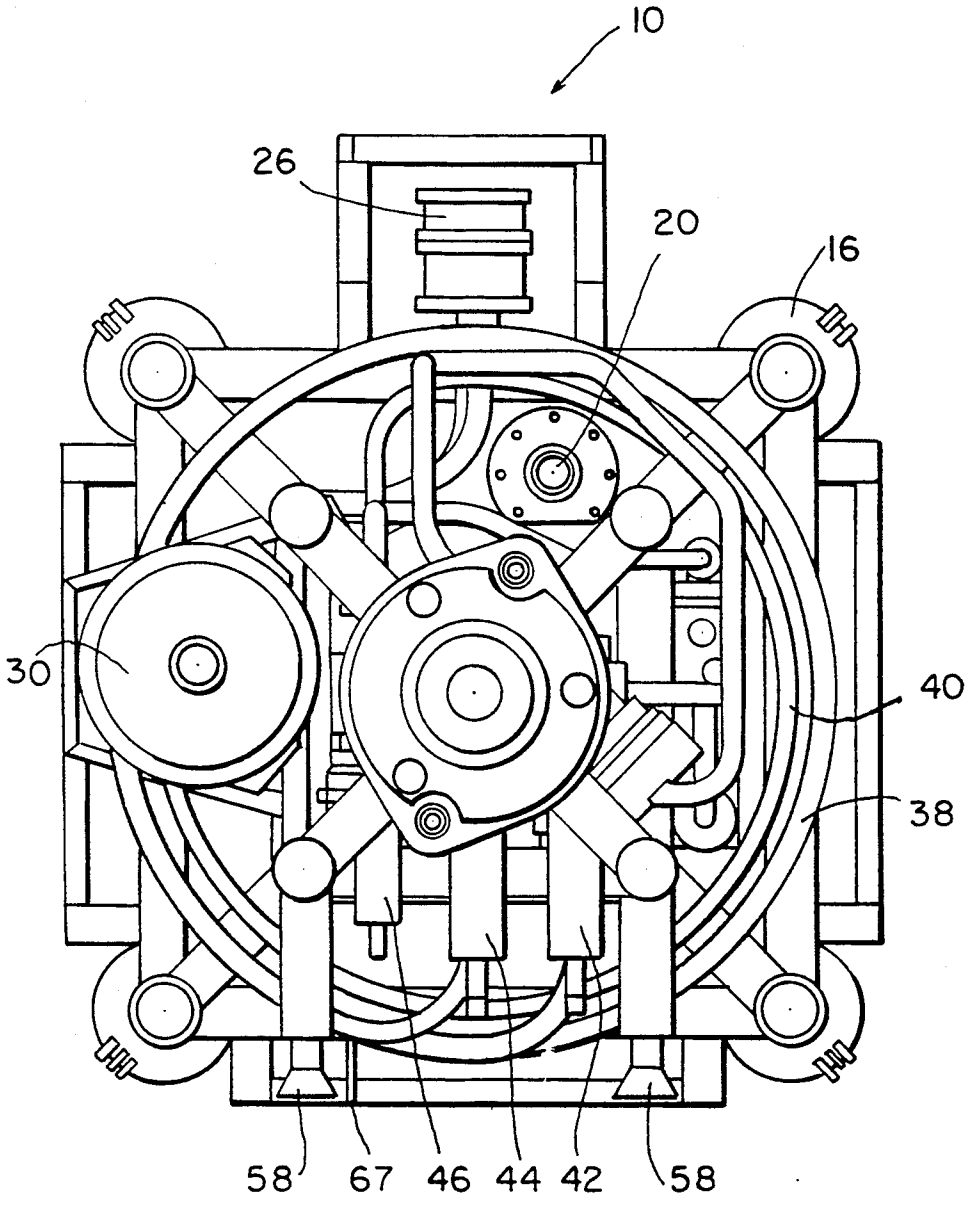


FIG. 2



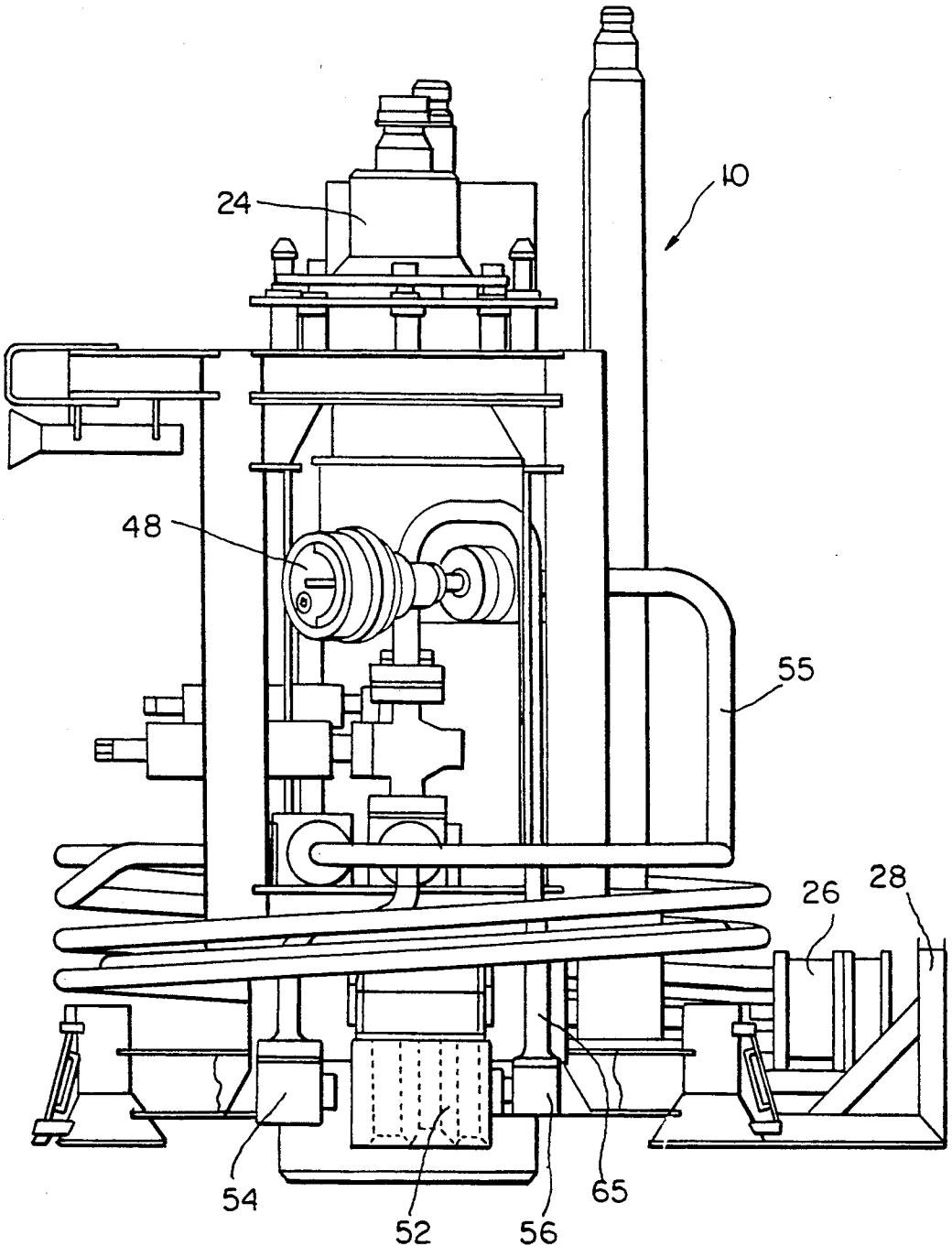


FIG. 3

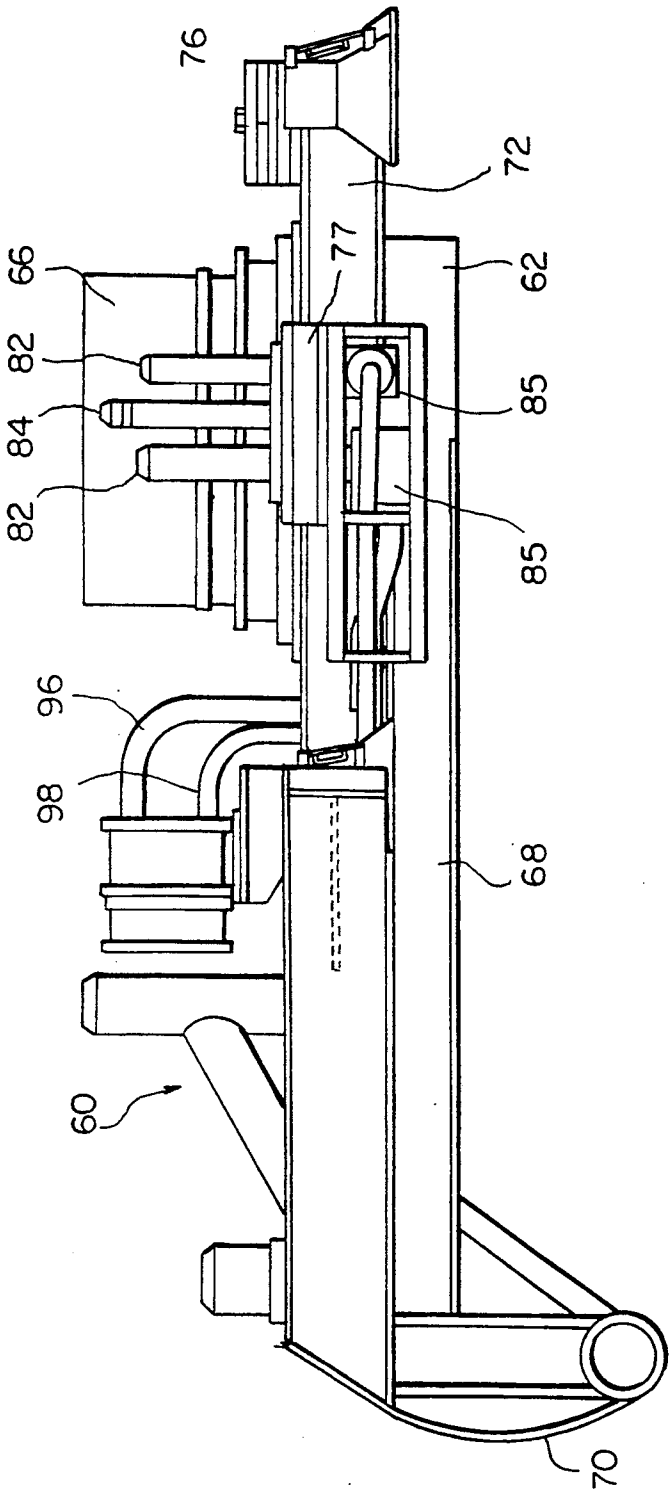


FIG. 4

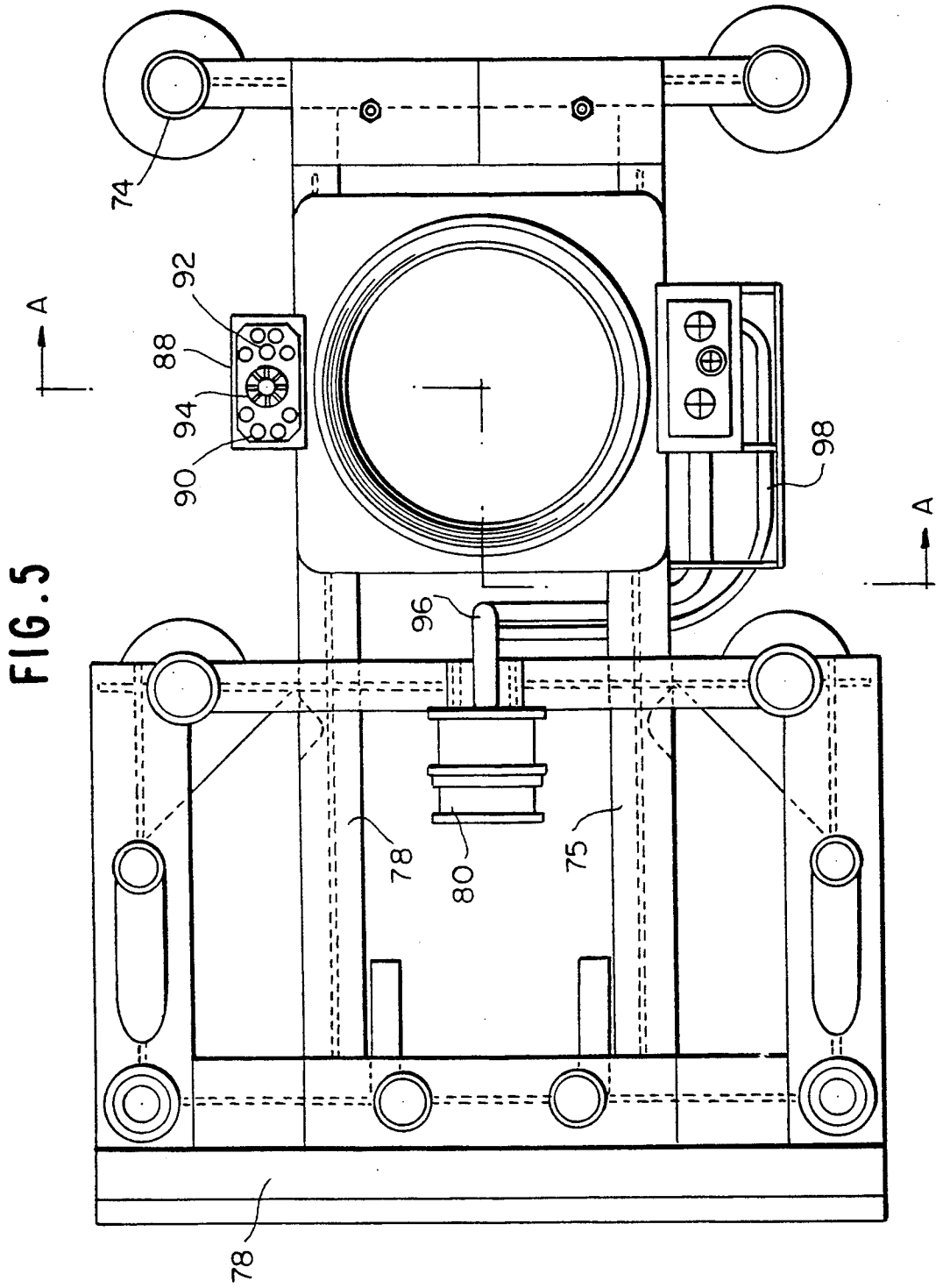


FIG. 5

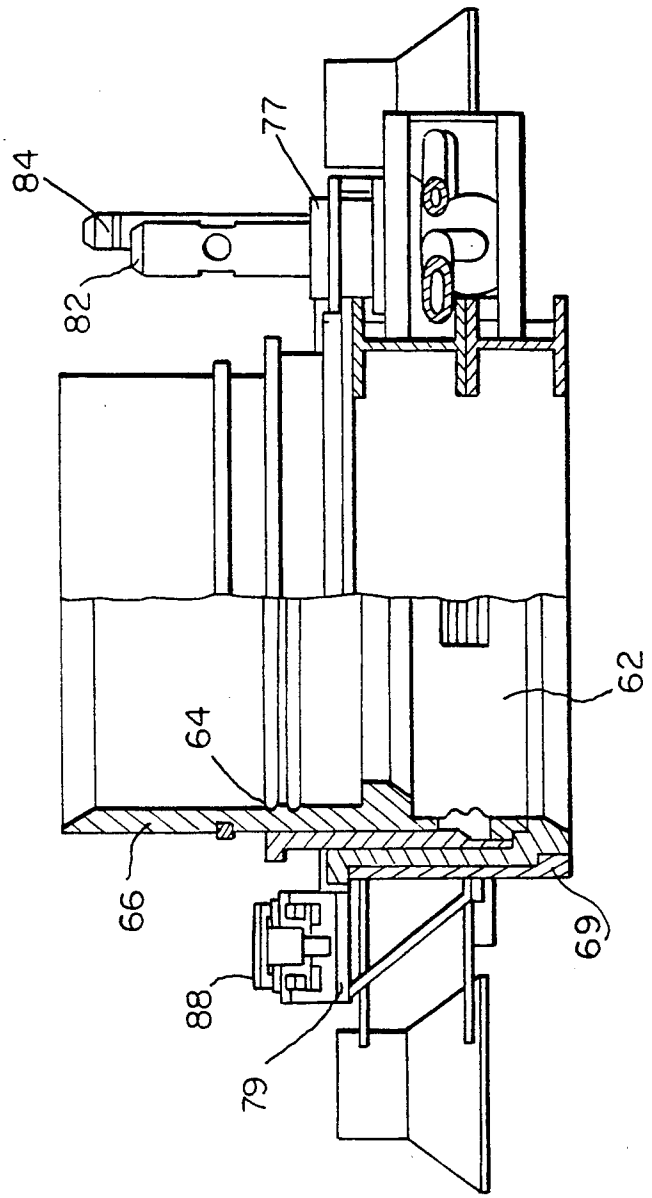


FIG. 6

SATELLITE TREE MODULE AND FLOW LINE STRUCTURE FOR INTERCONNECTION OF A SATELLITE WELL TO A SUBSEA PRODUCTION SYSTEM

FIELD OF THE INVENTION

This invention refers to a satellite tree module (STM) which effects flow control between a satellite well and a manifold of a subsea petroleum production system, as well as to a flow line structure (FLS) utilized for the interconnection of said satellite well to said petroleum production system. State of the Art

The subsea production systems for petroleum originating from wells located at large depths were developed for subsea completion, since such option is the most feasible, both technically and economically.

Among the subsea production systems is a template-manifold which includes, among other components, a template structure, a manifold, wet Christmas trees and satellite trees module. The subsea production systems known to date have, as their major characteristic, the provision, in the manifold, of active elements, such as chokes, maneuver valves and control modules. This leads to both an increased number of recoverable modules and a reduced system reliability.

OBJECT OF THE INVENTION

With the purpose of reducing the number of recoverable modules arranged in the manifold of a subsea production system, thus improving the reliability of the system, this invention is directed to satellite tree module providing flexibility to the connection of the flow lines to the manifold, presents valves and chokes oriented towards one single face and presents also a multiplexed control with hydraulic lines directly connected to the satellite wet Christmas tree.

Different from satellite tree modules known to date, the satellite tree module of this invention permits the advantegeous possibility of coupling the module selectively to one of plural mouths of a template-manifold, including an already installed wellhead; In addition, the satellite module presents flexibility for the connection of the flow lines to the manifold, while allowing alterations at the surface, in case of any difficulty.

This invention refers also to a structure of flow lines for interconnection of a satellite well to a subsea petroleum production system.

DESCRIPTION OF THE INVENTION

This invention refers to a satellite tree module (STM) for flow control between a satellite well and a manifold of a subsea petroleum production system of the type described in Brazilian application for privilege number PI 9005123 owned by a common assignee.

The satellite tree module (STM) of this invention includes:

in a lower part, an internal-latch type, hydraulically activated; connector;

a lower structure consisting of a central ring, and arms with guide-funnels;

an upper structure;

a reentry pole integrated to the STM via an orientation key;

a cap for protection of the external profile of said reentry mandrel and its receptacles;

a flow system consisting of a set of pipes and valves through which flow the fluids of the production/injection, production testing and gas-lift lines, with the system arranged over said lower structure and inside said upper structure;

a flow line terminal; and

a control system responsible for the activation of the functions of both the STM and a satellite Christmas tree associated with the STM during an operation phase.

DETAILED DESCRIPTION OF THE INVENTION

More specifically, the STM of this invention includes: at the bottom, a connector of internal-latch type, hydraulically activated; a lower structure consisting of a central ring and arms with guide-funnels; an upper structure consisting of tubular columns and beams; a reentry pole integrated to the STM assembly via an orientation key; a reentry mandrel allowing for STM installation with a wet Christmas tree (WCT) running tool; a cap for protection of said mandrel and its receptacles; a flow system, arranged above the lower structure and below the reentry mandrel. The system consisting of a set of pipes and valves through which flow the fluids of the production/injection, production testing and gas-lift lines. The system includes loops for the production, production testing and annulus lines, valves for the production and production testing lines, and one valve for the annulus line, chokes, one for the production/water-injection line and another choke installed in the annulus line, a vertical connection block and cross-pieces for handling the production and, production testing and annulus lines. A flow line terminal arranged on the lower structure to allow for the connection of the flow lines and of the hydraulic control lines between the STM and the manifold of the subsea production system; and a control system, which is the assembly responsible for the activation of the STM functions during the operation phase, and consists of a base for module formed of an electrohydraulic multiplexed control, hydraulic connector, pressure transducers, small-diameter valves and cables with electrical connectors.

This invention refers also to a flow line structure (FLS) for interconnection of a satellite well to a subsea production system, consisting of a connector for FLS locking to the drilling mouth of the template in the subsea production system with a mandrel with internal profile for STM locking. A main structure consists of beams with one extremity fastened to the connector and the other cantilevered. A cradle structure is compatible with the pulling and connection tools and is located at the cantilevered extremity of the main structure. A FLS terminal is located on the cradle structure. A vertical connection block is provided for the FLS flow lines. An electrohydraulic vertical connector and rigid pipes provide a flow conduction between the FLS terminal and the vertical connection block.

These objectives, characteristics and advantages of this invention shall become now more apparent through the following detailed description when taken together with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a front view of a satellite tree module (STM) forming a preferred embodiment of the invention;

FIG. 2 is a top plan view of the STM;

FIG. 3 is a side elevational view of the STM;

FIG. 4 is a lateral view of a flow line structure (FLS) thereof;

FIG. 5 is to top plan view of the FLS; and

FIG. 6 is a view partially in section thereof taken along AA of FIG. 5.

DETAILED DESCRIPTION OF THE FIGURES

This invention refers to a satellite tree module (STM), referred to in general by the numerical reference **10** in FIGS. **1** through **3**. It consists at the bottom of an internal-latch type, hydraulically activated connector **12** a lower structure **14** consisting of a central ring and arms with guide-funnels **16**; and an upper structure **18**. A reentry pole **20** is integrated to the assembly of the STM **10** via an orientation key. A reentry mandrel **22** and a cap **24**, FIG. **3**, for protection of the external profile of said reentry mandrel **22** and its receptacles are part of a flow system arranged above the lower structure **14** and inside the upper structure **18**. The flow system consists of a set of pipes and valves, through which flow the fluids of the production/injection, production testing and gas-lift lines. A flow line terminal **26** and a control system are responsible for the activation of the functions assigned to the STM **10** during the operation phase.

More specifically, this invention pertains to a satellite tree module (STM), referred to in general by the numerical reference **10** in FIGS. **1** through **3**, including at a bottom thereof, an internal-latch type, hydraulically activated connector **12**, with visual position indicator (locked/unlocked) easily seen from the rig TV or ROV/RCV, equipped with secondary mechanism unlocking for extension up to the top of the STM for purposes of activation by a tool to be run with a drill string. A lower structure **14** consists of a central ring and arms supporting guide-funnels **16** provided with portholes for the passage of the guide-cables. A upper structure **18** consists of tubular columns and beams. A reentry pole **20** is integrated to the assembly of the STM with an orientation key. A reentry mandrel **22** allows the STM installation with the WCT running tool, as is prepared at the top, to receive an STM running tool. A cap is provided to the STM, a tool for secondary unlocking of the connector and a handling tool, said reentry mandrel **22** is assembled on the upper structure **18** of the STM and presenting receptacles for connection of the hydraulic lines of the STM installation tool (connector locking and unlocking and testing of the gaskets in the vertical connection block) and of the STM cap. A cap **24** FIG. **3**, provides protection of the external profile of the reentry mandrel **22** and its receptacles. A flow system is arranged above the lower structure **14** and below the reentry mandrel **22**. The flow system consists of a set of pipes and valves, through which flow the fluids of the production/water-injection, production testing and gas-lift lines flow line terminal **26** is incorporated in the STM arrangement. The terminal is designed to effect the connection of the production, production testing and annulus flow lines and the hydraulic control lines between the STM and the manifold. The terminal consists basically of the terminal itself, a device for retraction of pipe loops and locking of the terminal, and a protection structure **28**. The protection structure **28** has the function of preventing terminal damages during the transportation and handling operations, and must be removed prior to running the STM. A control system constitutes the assembly responsible for the activation of the STM functions during the phase of operation with base **29**, FIG. **6** electrohydraulic multiplexed control module **30**. Hydraulic control lines, electrohydraulic connector **32**; pressure transducers installed directly at the crosspieces of the production and annulus lines. Small-diameter valves **34** effect isolation of the testing lines from the seals of the vertical connection block **52** and for the line of the backup system of the control **32**. Cables with electric connectors conduct a signal of the downhole pressure and temperature transmitter DPTT) and of the pressure transducers to the base **29** of the control module **30**.

The flow system includes two pipe loops **36, 38** of the production and production testing lines, and one loop **40** of the annulus line, with one loop extremity flanged an the other bevelled for purpose of welding at the terminal of connection **26** to the manifold. The loops **36, 38, 40** have a degree of flexibility compatible with the course required by the connection system. Two valves **42, 44** are provided for the production and production testing lines, respectively and one valve **46** for the annulus line. The valves **42, 44, 46** are gate type valves with normally closed hydraulic activators, usually closed; Two chokes **48, 50**, are provided one for the production/water-injection line and the other installed on the annulus line (for gas-lift control) hydraulically adjustable. The choke **48** has inlet and outlet flanges equidistant in relation to the choke centerlines of the body, to permit its installation in an inverted position to work in both production and injection mode. A vertical connection block **52** for three through holes for lodging in its orifices, the sealing gaskets for the sealing pins and having channels for the sealing testing lines of these seals and being attached to a cradle fastened to the lower structure **14**. A pipe **55** connects the choke **48** to the production loop **36**. A pipe **57** connects the production valve **42** to the production testing valve **44**. A pipe **59** connects the production valve **42** to the vertical connection block **52**; and a pipe **65** connects the choke **50** to the vertical connection block **52**. Also blocks (crosspieces) **54** are provided for the production and production testing line loops and a block (crosspiece) **56** is provided for the annulus line. The blocks **54, 56** fix one end of the lines to the lower structure **14**.

It must be pointed out that the lower structure **14** is designed to fasten the connector **12** to the upper structure **18**, and fastens the vertical connection block **51** and the vertical electrohydraulic connector **32** and guide the STM during its installation. The upper structure **18** receives, at the top, the reentry mandrel **22**, and fastens to the lower structure **14**. The upper structure **18** serves as a base for the control module **30**. The reentry pole **20** functions to guide and orient the tool for STM/STM-cap installation, the tool for secondary unlocking of the connector **12** and the tool for installation of the control module **30**.

The STM **10** and the STM cap **24** may preferably be installed with the same WCT running tool. The cap **24**, shown in FIG. **1**, acts as the structure for anchoring of the ROV **58**, which makes it easy to activate the override the mechanisms of the hydraulic activators of the flow valves, and the structure for anchoring of the ROV **67** for activation of the valves for testing and backup of the control system.

The valves of the STM **10** have their activators oriented towards an external face of the template-manifold which is equipped with an interface for secondary ROV operation. The STM is susceptible of conversion from

production to water injection through the mere inversion of the choke **48**.

In addition, as it may be seen in FIGS. **4** through **6**, a flow line structure (FLS) indicated generally at **60** is provided for interconnection of a satellite well to a subsea production system, externally locked to the time-plate guide-pipe. The FLS **60** includes a mechanical connector **62** activated by a specific tool to be locked to the external profile of the template guide-pipe, said mechanical connector **62** being provided at the top with a mandrel **66** with internal profile **64**, FIG. **6**, for locking to the STM A main structure **68** consisting of beams, has a central ring **69**, FIG. **6**, for attachment to the connector **62**. Beams **75**, FIG. **5** mount a cradle structure **78**, and supports **77**, **79** for attachment of the vertical connection block of the flow lines and of the electro-hydraulic plate and, respectively. A wall **70** to helps the approximation of the terminal of the lines originating from the satellite wet Christmas tree WCT during the pull. Arms **72** support guide-funnels **74** and counterweights **76** to balance the FLS during its running. The cradle structure **78** compatible with the pull and connection tools, is located at the cantilevered extremity of the main structure **68**. A hub **80**, FIG. **5**, of the FLS, located on the cradle structure **78**, functions to establish the connection of the lines originating from the satellite WCT with the FLS. A vertical connection block of the FLS flow lines, is an assembly formed by a block attached to the main structure **68** and further consisting of stabs **82** capable of compensating for minor deviations between same and the STM receptacles, an alignment pin **84** and blocks **85** (crosspieces) for attachment of the rigid piping of the flow lines, originating from the FLS. A plate **88** of hydraulic and electric connectors is installed on the main structure **68**, containing eight hydraulic line connectors **90** with a fast-coupling check valve, an electric connector **92** for signal transmission between FLS and STM and a central guide **94** with dogs or a spring ring for unlocking the STM plate from the FLS plate, and production piping **95** and annulus piping **98** for flow conduction between the FLS terminal **80** and the FLS vertical connection block.

The FLS **60** is installed with drill string through a moon-pool of a completion rig.

We claim:

1. A satellite tree module (STM) having a top and a bottom and comprising:

a lower structure, an upper structure;

an internal-latch type, hydraulically activated connector mounted to said lower structure and located at the bottom of the STM;

said lower structure comprising a central ring, said connector (**12**) passing through said ring and being coupled to a vertical connection block (**52**), and said lower structure further comprising a plurality of arms extending outwardly of said lower structure and terminating in guide-funnels (**16**);

a flow system contained inside said upper structure (**18**) at a level above said lower structure (**14**) and comprising pipes for production and production testing and valves coupled to said pipes for controlling the flow of production/injection, production testing and lift-gas fluids therethrough;

a control system mounted to one of said lower structure and said upper structure for controlling activation and deactivation of components of the satellite tree module during the operational phase;

said satellite tree module also including a re-entry pole (**20**) integrated to an assembly of said satellite tree module (**10**) by means of an orientation key; a re-entry mandrel (**22**) and a cap (**24**) mounted to said upper structure, said cap (**24**) protecting the external profile of said re-entry mandrel (**22**), and said satellite tree module further comprising a flow line terminal (**26**) connected to said set of pipes.

2. A satellite tree module, according to claim **1**, wherein said connector (**12**) comprises a secondary mechanical unlocking mechanism with extension up to the top of said STM (**10**) and being mounted to one of said lower structure and said upper structure for activation by means of a tool run with a drill string.

3. A satellite tree module, according to claim **1**, wherein said re-entry mandrel (**22**) comprises receptacles for connection of hydraulic lines of a STM (**10**) installation tool, of the STM cap (**24**) and of tools for the secondary connector (**12**) for unlocking and handling the STM (**10**).

4. A satellite tree module, according to claim **1**, wherein said flow system further includes:

loops (**36**, **38**) within said pipes for production and production testing and a loop (**40**) for an annulus line;

valves (**42**, **44**) for a production line and production testing line, respectively, and a valve (**46**) for the annulus line;

chokes (**48**, **50**) for the production/water injection line and for the annulus line; and wherein said pipes compromise

a first pipe connecting said choke (**48**) to said production line (**36**), a second pipe (**57**) connecting said production valve (**42**) to said production testing valve (**44**), a third pipe (**59**) connecting said production valve (**42**) to said vertical connection block (**52**), and a fourth pipe (**65**) connecting said annulus choke (**50**) to said vertical connection block; and said STM further comprises crosspieces (**54**) for said production and production testing lines and a crosspiece (**56**) for the annulus line.

5. A satellite tree module, according to claim **4**, wherein said valves (**42**, **44**, **46**) comprise normally closed gate valves having hydraulic activators.

6. A satellite tree module, according to claim **4**, wherein said chokes (**48**, **50**) are hydraulically adjustable, and one of said chokes (**48**) has inlet and outlet flanges equidistant in relation to a centerline of a choke body whereby, such that said one choke (**48**) may be installed in inverted position thereby working in both production and injection modes of the STM.

7. A satellite tree module, according to claim **1**, wherein said flow line terminal (**26**) includes a device for loop retraction and terminal locking, and said STM (**10**) further comprises a protection structure (**28**) at the bottom about said flow line terminal (**26**).

8. A satellite tree module, according to claim **4**, wherein said valves (**34**, **42**, **44**, **46**) have said activators oriented towards an external face of a template-manifold of said STM and said activators are equipped with an interface for remote control vehicle (ROV) operation.

9. A satellite tree module, according to claim **4**, wherein inversion of said choke (**48**) converts said STM (**10**) from production to water injection.

10. A satellite tree module, according to claim **1**, further comprising a satellite wet Christmas tree (WCT) and wherein, said STM comprises an electrohydraulic

multiplexed control and direct hydraulic outlets towards said satellite WCT.

11. A flow line structure (FLS) for interconnection of a satellite well to a subsea production system, said flow line structure (**60**) comprising means for externally locking said FLS to a guide-pipe of a template of a satellite tree module (STM) (**10**), a mechanical connector (**62**) with an internal profile (**64**) for locking to an upper part of said STM (**10**), a main structure (**68**) consisting of beams, a cradle structure (**78**) cantilever mounted to an extremity of said main structure (**68**), a terminal (**80**) located on said cradle structure (**78**) connecting lines originating from a satellite wet Christmas tree (WCT) to said FLS (**60**), a vertical flow line connection block, a plate (**88**) of hydraulic and electrical connectors, said plate (**88**) being fixably attached to said main structure (**68**), and production (**96**) and annulus (**98**) piping connecting said terminal (**80**) to said vertical connection block.

12. A flow line structure for interconnection of a satellite well to a subsea production system, according to claim **11**, wherein said mechanical connector (**62**) is connected to a mandrel (**66**) having an internal profile for locking and unlocking to said STM

13. A flow line structure for interconnection of a satellite well to a subsea production system, according to claim **11**, wherein said main structure (**68**) comprises a central ring (**69**) attached to said connector (**62**), beams (**75**) attached to said cradle structure (**78**), supports (**77**, **79**) fixing the vertical flow line connection block to said FLS and said supporting said electrohydraulic plate (**88**), a wall (**70**), arms (**72**) having guide-funnels (**74**) and counterweights (**76**).

14. A flow line structure for interconnection of a satellite well to a subsea production system, according to claim **11**, wherein said vertical flow line connection block includes an assembly formed by a block mounted to said main structure (**68**), stabs (**82**), alignment pin (**84**) and cross pieces (**85**) for attachment of rigid piping of said flow lines originating from said terminal (**80**).

15. A flow line structure for interconnection of a satellite well to a subsea production system, according to claim **11**, wherein said electrohydraulic plate (**88**) includes a plurality of hydraulic line connectors (**90**) having a fast-coupling check valve, an electrical connector (**92**) for effecting signal transmission between said FLS (**60**) and said STM (**10**), and a central guide (**94**) with one of dogs and a spring ring for locking and unlocking said plate (**88**) of said STM (**10**) to said plate of said FLS (**60**).

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