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(54) Title of the Invention: **Supplying water in subsea installations**
Abstract Title: **Subsea pressurised water supply to multiple consumer components**

(57) Pressurised water is supplied to a plurality of subsea water consumers by supplying pressurised water to a common shared header 12 that connects the consumers 26 and then supplying the pressurised water from the header 12 to the consumers 26 on demand, as required by the consumers 26. The common header 12 may be a looped header ring at the seabed and pressurised from a location outside the loop 14. Consumers 26 are supplied by a branch at a demand point 22. Each consumer branch can include means for boosting pressure or controlling flow rate such as a termination end 30, a valve and orifice 32, an operating valve 34, branches 36, or an ejector 38 (jet pump).
The consumers may be items of subsea hydrocarbon processing equipment, or more generally hydrocyclones, water injection systems, chemical injection systems, ejectors, hydraulic pumps, jetting systems, flushing circuits or pressure accumulators.
The header and the consumers may be supported together by a structure of a discrete subsea hydrocarbon processing unit that can be assembled on land and transported offshore for installation on the seabed.

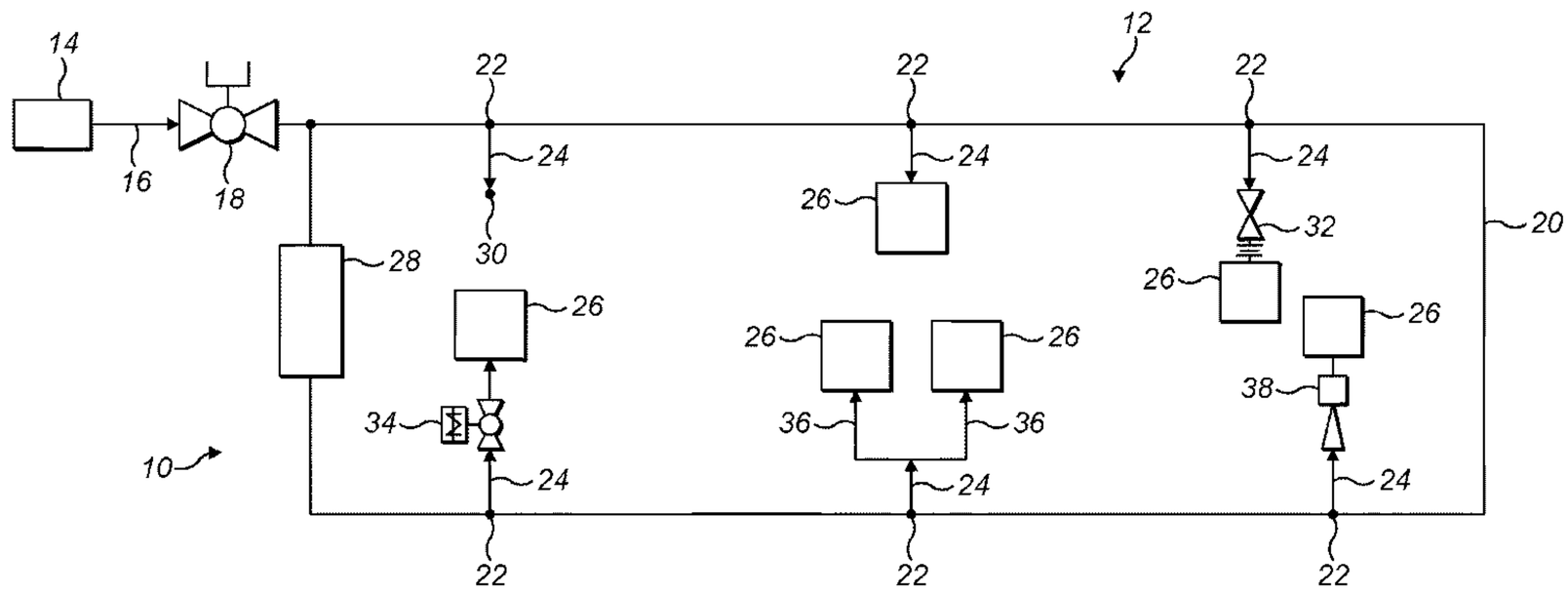

FIG. 1

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

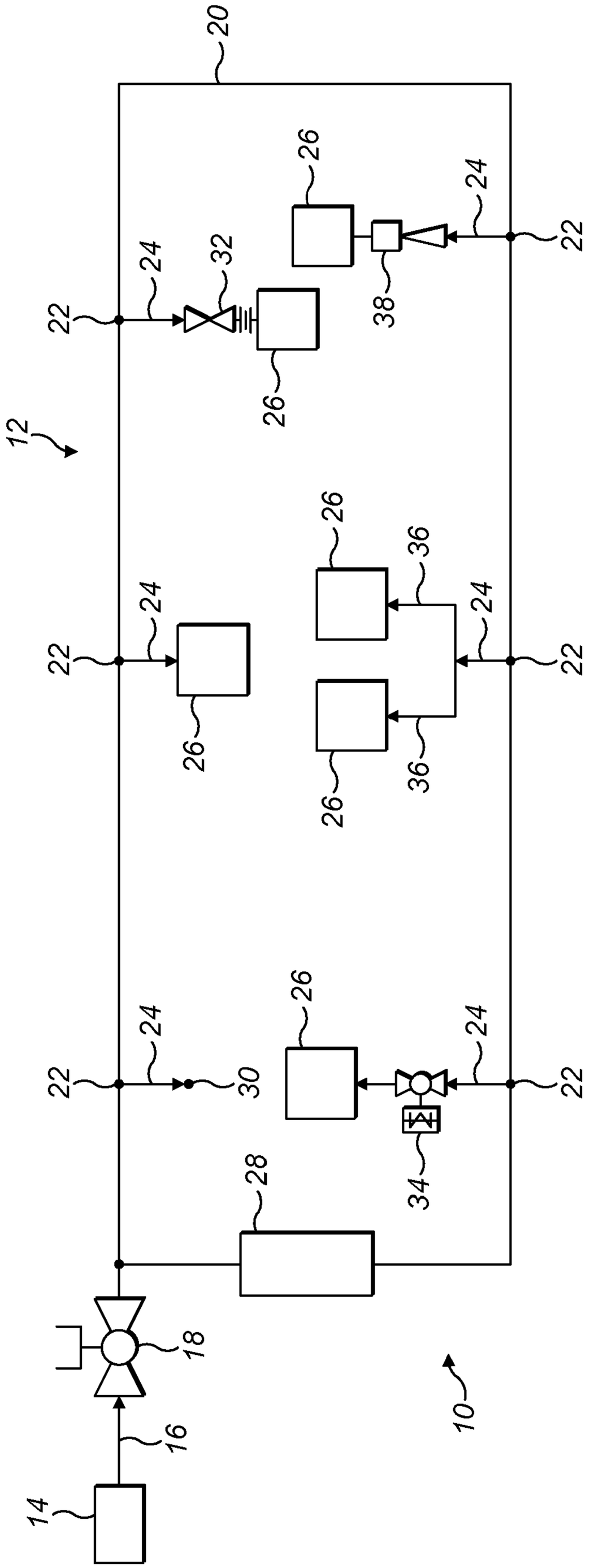

FIG. 1

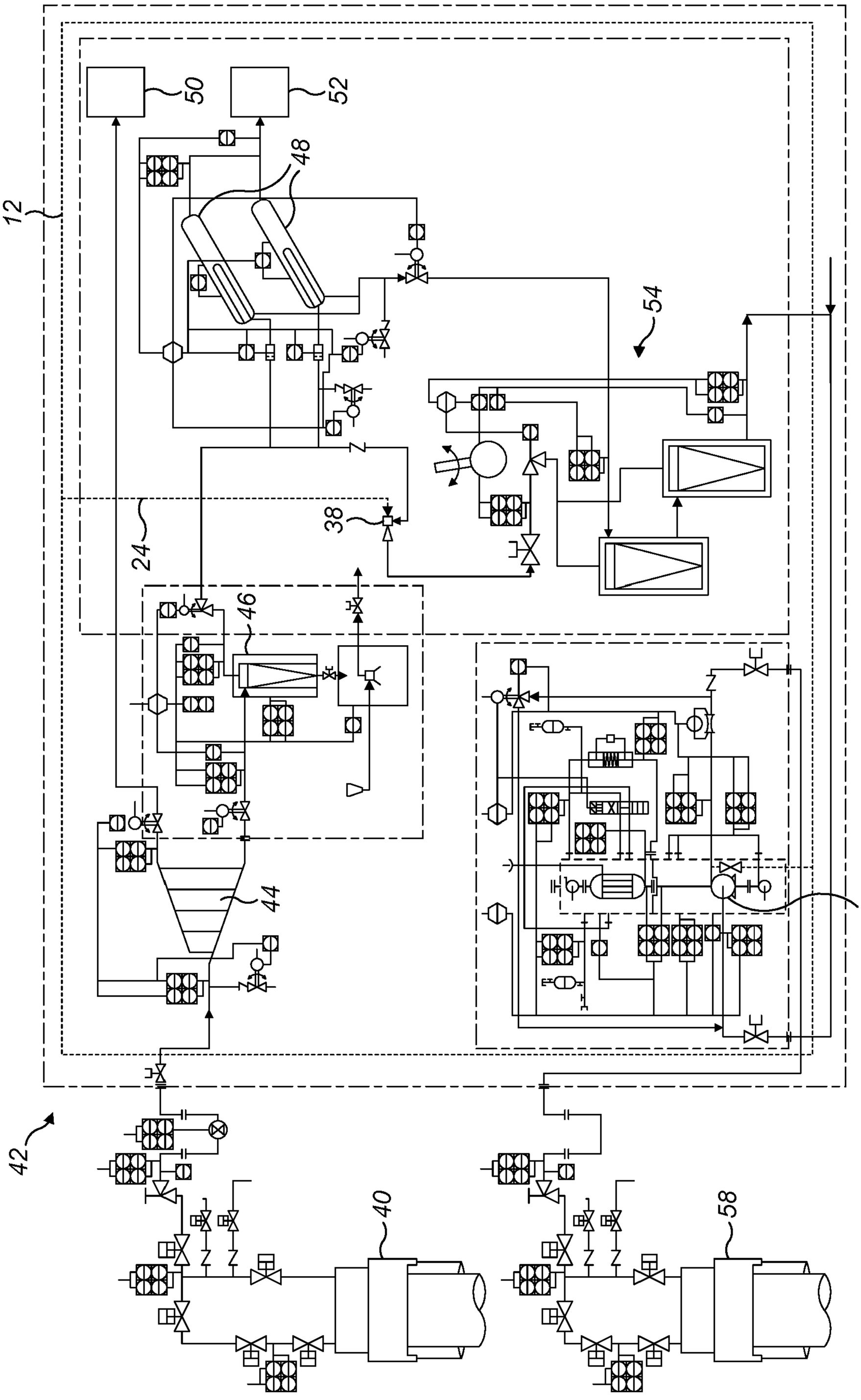

FIG. 2

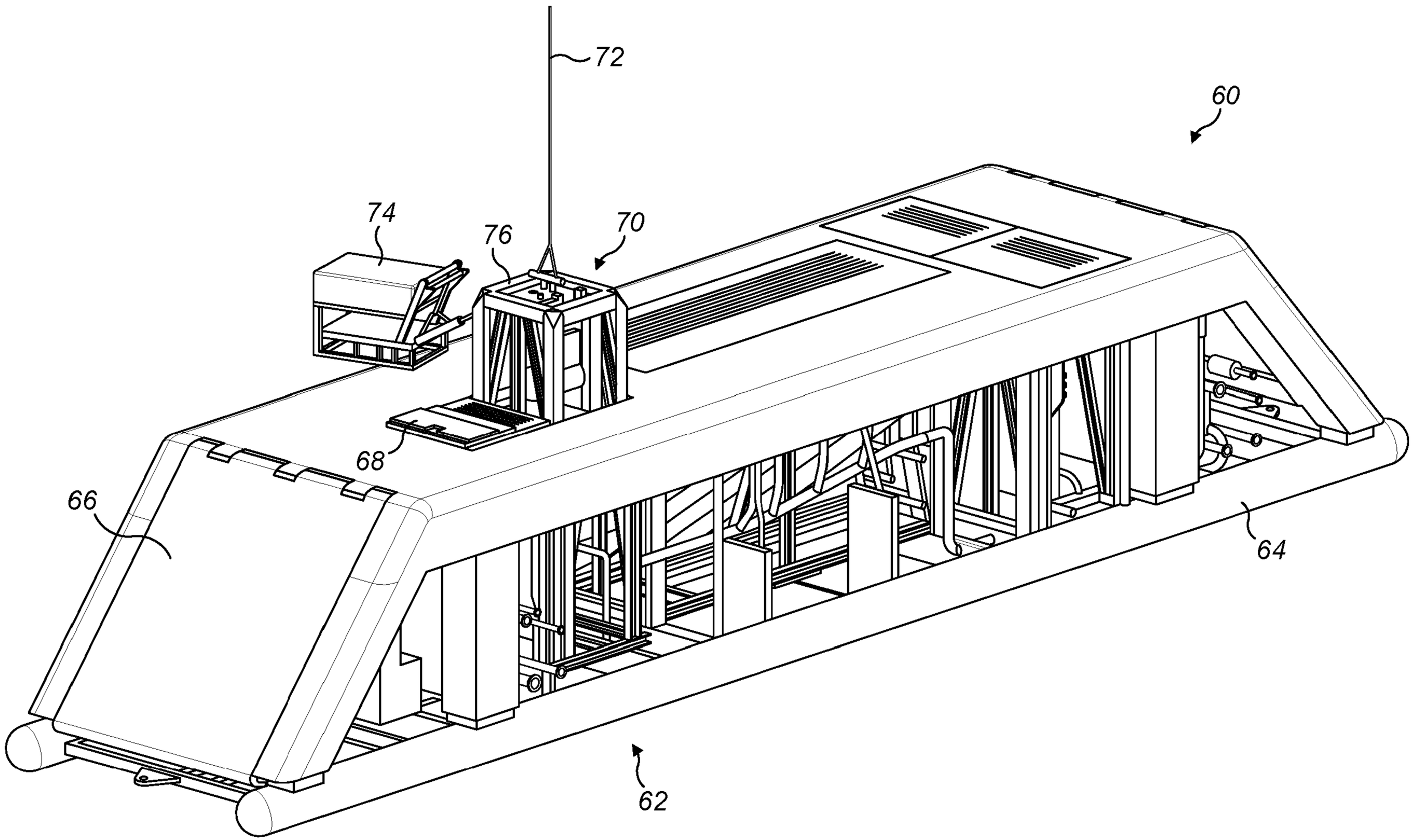

FIG. 3

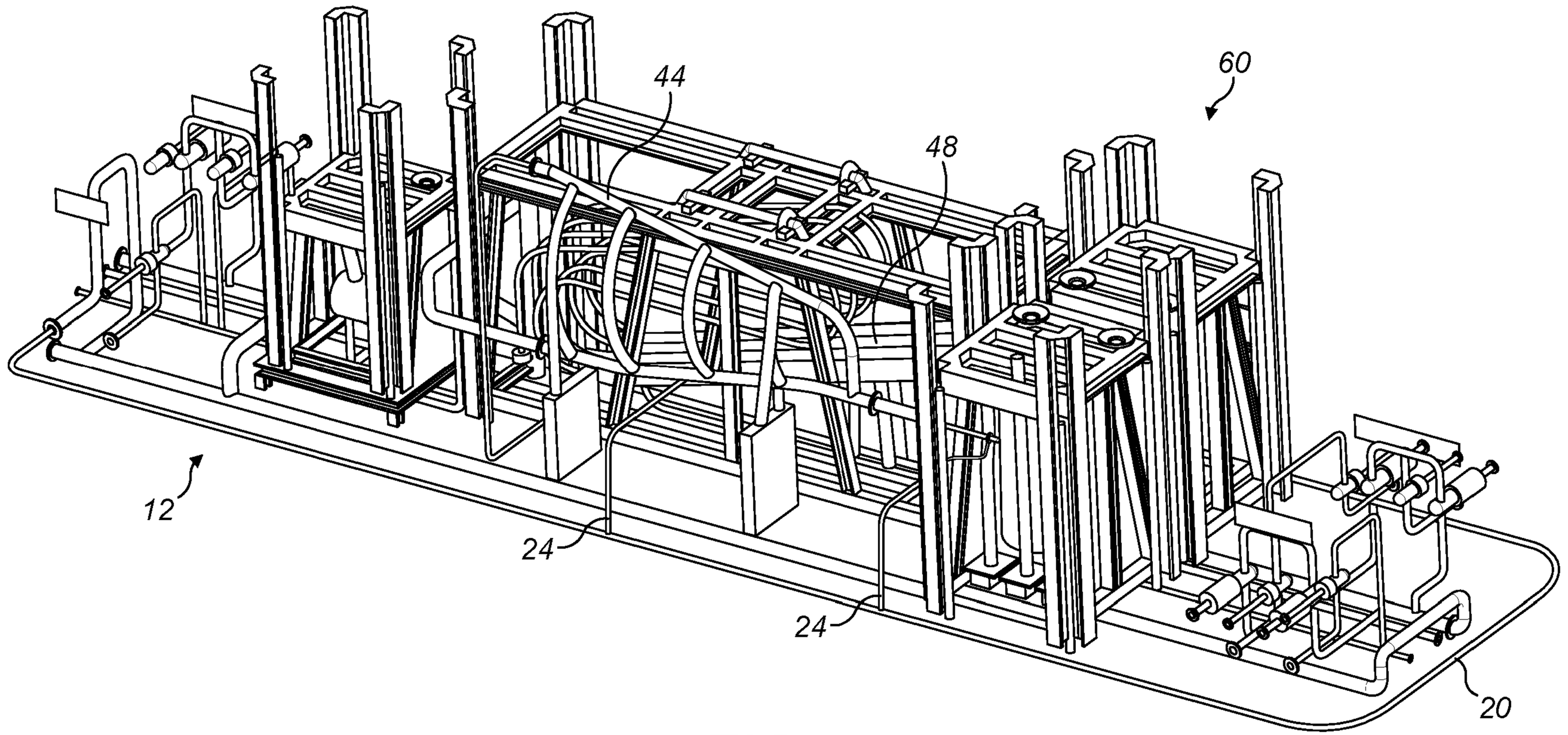

FIG. 4

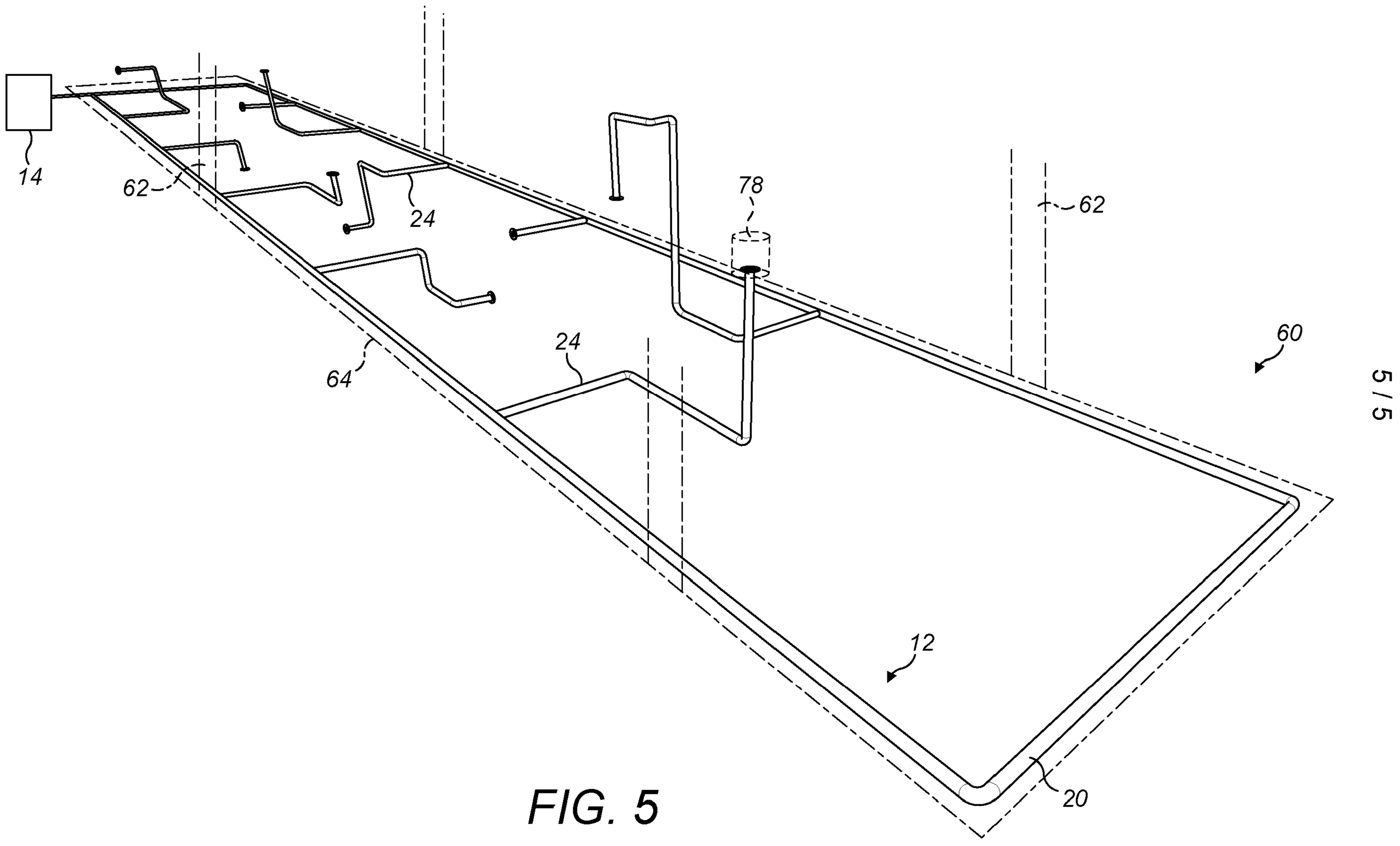

FIG. 5

Supplying water in subsea installations

This invention relates to the supply of water in subsea installations, particularly installations that are used for the production or processing of hydrocarbon fluids in the subsea oil and gas industry. The invention relates especially to the challenges of providing pressurised water to subsea systems on demand.

Pressurised water is often needed subsea, typically close to wellheads on the seabed. For example, water may be required for injection into hydrocarbon reservoirs. US 6171483 discloses an example of a water injection system. WO 2014/044976 teaches various ways of filtering or otherwise treating seawater before injection.

Other potential uses for pressurised water are: to provide clean water to a hydrocyclone that operates as a de-sander to separate sand from crude oil; to flush circuits for cleaning processing equipment or pig launching equipment; or to charge an accumulator.

GB 2450565 describes a subsea pressure boosting system based on a jet pump. WO 2015/036041 discloses a recirculation loop in a subsea separation system. The recirculation loop comprises a pump.

A typical subsea oil production system comprises production wells each with a wellhead, pipelines running on the seabed, structures to support valves and connectors, manifolds and risers to bring production fluids to the surface. At the surface, a topside installation that can be a platform or a vessel receives the production fluids before their onward transportation.

Crude oil is a multiphase fluid that generally contains sand, water and gas in addition to oil. These components of the wellstream interact in various ways that tend to decrease the flow rate in the production system, from the wellhead to export or storage. A critical failure mode in crude oil production is clogging or plugging of pipelines by solids because remediation of such blockages can be extremely expensive, especially in deep water.

When the temperature of a wellstream decreases below a certain threshold, at a given pressure, components of crude oil may react together or individually to coagulate or

precipitate as solid wax, asphaltenes or hydrates that could plug a pipeline. For example, wax will typically appear in oil at a temperature of around 30°C.

As crude oil is hot at the outlet of the wellhead, typically around 200°C, a common approach in subsea oil production is to maintain the oil temperature above the critical threshold until the oil has been delivered to a topside installation. There, the oil can be treated to allow the treated oil to be transported at ambient temperature in tankers or in pipelines. In this respect, conventional solutions to maintain oil temperature employ 'wet' thermal insulation, which involves covering the pipeline with thermally-insulating materials. The pipeline may also be heated by electrical heating or by heat transfer from hot fluids. However, as some pipelines can be very long, for example longer than 100km, such solutions can become extremely expensive.

Two main approaches are known in the art to reduce the cost of producing oil from marginal subsea fields. The first approach is to simplify subsea equipment as much as possible, for example by using a long, insulated pipeline extending from a wellhead and minimal additional equipment subsea. This presents a challenge that pipeline cost becomes a large element of development cost where fields are isolated or remote. The second approach therefore adopts an opposite tactic, namely to transfer at least some conventionally-topside processing functions to a subsea location. By displacing at least some oil processing steps from the topside to the seabed, the need for thermal insulation or heating can be reduced.

The present invention has particular benefits in relation to the second approach, which involves subsea processing of produced oil. In particular, there is a need to provide a convenient, compact and reliable supply of pressurised water to multiple items of subsea equipment that perform respective processing steps. In this respect, the teaching of the prior art is that each item of processing equipment has its own pump. This increases the complexity of a subsea processing system that comprises several such items of equipment.

Most conveniently, subsea processing may be performed by gathering items of processing equipment into a single unit that can be assembled and tested on land or at an inshore location and then can be transported and installed offshore in a single operation, for example by sub-surface towing. An example of such a unit is described in the paper *OTC-29002-MS Modular Integration Platform - Submerged Production Unit for Large Subsea Plants* presented at the 2018 Offshore Technology Conference

held in Houston, Texas. To reduce cost and to ease transportation and installation, it is necessary to keep the size and weight of the unit to a minimum. The presence of multiple pumps would militate against this.

Against this background, the invention resides in a method for providing pressurised water to a plurality of subsea water consumers. The method comprises: supplying pressurised water to a common header that connects the consumers; and supplying the pressurised water from the header to the consumers as required by the consumers. For example, valves may be opened between the header and the consumers to draw the pressurised water from the header as required by the consumers. The header may then be replenished with pressurised water through another valve in response to supplying pressurised water to the consumers.

Preferably, the header and the consumers are supported together by a structure of a subsea hydrocarbon processing unit. However, water may be pressurised at a location remote from the processing unit.

The pressurised water may be held in a looped header, in which case water may be pressurised at a location outside the looped header.

Some of the pressurised water in the header may be stored in a storage tank of the header that is in fluid communication with pipework of the header connecting the consumers. Pressure of the pressurised water may be boosted downstream of the header.

The method of the invention may comprise a preliminary step of coupling modules to the header subsea, the modules comprising the consumers. In that case, the modules may be lowered into a subsea position for fluid engagement with the header. Fluid couplings may be operated subsea to establish fluid communication between the modules and the header.

The consumers are apt to be items of subsea hydrocarbon processing equipment that use the pressurised water to process a wellstream or components of a wellstream.

Pressure of water in the header is preferably maintained above the ambient hydrostatic pressure of a surrounding body of water.

Correspondingly, the inventive concept embraces a subsea water distribution system that comprises: a common header connected to a plurality of subsea water consumers to supply pressurised water from the header to the consumers; and valves for controlling the supply of pressurised water from the header to the consumers in response to demand from the consumers.

The system may further comprise a pump for supplying pressurised water to the header, and a valve that is responsive to the demand from the consumers to replenish the header with pressurised water.

The consumers may be implemented in modules that can be coupled to the header subsea, in which case there may be subsea-operable fluid couplings arranged to effect fluid communication between the modules and the header.

Thus, the invention contemplates a central high-pressure distribution system that provides a sufficient supply of water under elevated pressure to various demand points at the pressure or pressures that they each require. Such demand points may, for example, be ejectors from the system or may perform subsea functions, like cyclonic separators. Providing a consistent high-pressure flow of water may improve the performance of such functions.

The central distribution system is driven and supplied with water by a water injection pump, a booster pump or another type of pump that is already available at a subsea station. This ensures the distribution and transportation of high fluid energy using produced water and/or seawater as a medium.

Highly-pressurised water enters a ring-looped piping system and various branches from the ring or loop lead to respective booster stations. Each of those booster stations may have further branches as required to convey the high-pressure water to the processes requiring it, such as on-demand jetting, flushing or pressure recharging. Automatic pressure valves, control valves or ejectors can be used, depending on the end termination of the demand point.

Conveniently, the ring loop system may extend along some or all sides of the frame or other supporting structure a subsea processing unit, with suitably long sections of piping.

Embodiments of the invention implement a method for supplying pressurised water to at least two subsea water consumers. The method comprises: providing a subsea structure comprising a water ring header making a closed loop; connecting the water consumers to the ring header; supplying pressurised water to the ring header; and opening valves as needed to supply water to the water consumers.

The pressure of water in the loop is preferably above the ambient hydrostatic pressure at the depth of the loop in a surrounding body of water.

The water may be supplied from the surface or from a subsea location. The water may be fresh water or treated seawater. In either case, the water may contain additives.

The water consumers may, for example, be hydrocyclones, water injection systems, chemical injection systems, ejectors, hydraulic pumps, jetting systems, flushing circuits or pressure accumulators. Conveniently, the water consumers may be connected to or mounted on the same subsea structure.

The water consumers may be replaceable modules of the subsea structure, which are connected to the ring header underwater by subsea-operable connectors.

The water may be pressurised by a pump. Preferably, however, the ring header does not itself comprise a pump. The ring header may however comprise piping, valves and/or sensors. The ring header may further comprise a storage buffer vessel.

Advantageously, the volume of the ring header is sufficient to compensate for transitory pressure drops. For example, the volume of the ring header may be sufficient to compensate for a transitory pressure drop caused by the operation of any one of the water consumers supplied by the ring header.

In summary, pressurised water is supplied to a plurality of subsea water consumers by supplying pressurised water to a common or shared header that connects the consumers and then supplying the pressurised water from the header to the consumers on demand, as required by the consumers. The consumers may be items of subsea hydrocarbon processing equipment, or more generally may be exemplified by hydrocyclones, water injection systems, chemical injection systems, ejectors, hydraulic pumps, jetting systems, flushing circuits or pressure accumulators.

The header and the consumers may be supported together by a structure of a discrete subsea hydrocarbon processing unit that can be assembled on land and transported offshore for installation on the seabed.

In order that the invention may be more readily understood, reference will now be made, by way of example, to the accompanying drawings in which:

Figure 1 is a schematic diagram of a high-pressure ring loop distribution system of the invention, comprising a water ring header and a selection of water consumers that may be supplied with pressurised water from the ring header;

Figure 2 is a detailed diagram of a subsea processing system comprising a water distribution system of the invention;

Figure 3 is a perspective view of a subsea processing unit that carries processing equipment necessary to implement a system like that of Figure 2;

Figure 4 is an internal perspective view of the equipment within the subsea processing unit of Figure 3, showing a water ring header of the invention; and

Figure 5 is a schematic perspective view of a water ring header comprising supply pipes for supplying pressurised water on demand to respective items of subsea equipment aboard a subsea processing unit like that shown in Figures 2 to 4.

In the ring loop distribution system 10 of Figure 1, a subsea water ring header 12 receives high-pressure water from an external water injection pump, booster pump or other available high-pressure pump 14 located externally to the ring header 12, on or near the seabed. In this example, the incoming water flows along a pipe 16 of eight-inch (203.2mm) diameter and its flow is controlled by a valve 18.

Downstream of the valve 18, the ring header 12 comprises an endless looped pipe 20 of, for example, six-inch (152.4mm) diameter. At various demand points 22 spaced along and around the ring header 12, the pipe 20 branches into narrower supply pipes 24 that may have a diameter of between say two inches (50.8mm) and four inches (101.6mm).

The supply pipes 24 effect fluid communication between the ring header 12 and respective water consumers 26, whereby the ring header 12 supplies high-pressure water to the consumers 26 as required whenever the consumers 26 are activated to draw water.

Conveniently, the looped pipe 20 and the supply pipes 24 of the ring header 12 have an aggregate volume that is sufficient to handle the transient pressure drop caused by the operation of any one of the consumers 26. However, if needs be, a storage tank 28 can be provided in fluid communication with the looped pipe 20 so as to add to the aggregate volume of the looped pipe 20 and the supply pipes 24.

In this simple example, there are six demand points 22 around the ring header 12, each comprising a respective booster station for boosting the pressure and/or flow rate of water supplied to the consumers 26 from the ring header 12 via the respective supply pipes 24. The booster stations may comprise or communicate with, variously: a termination end 30; a valve and orifice 32; an operating valve 34; branches 36; or an ejector 38, also known in the art as a jet pump.

Figure 2 shows a production Christmas tree 40 through which produced hydrocarbon fluids flow from a subsea well, in particular crude oil that entrains varying amounts of gas, sand and water. The produced fluids enter a subsea processing unit 42, first flowing through a gas harp 44 that separates most of the gas from the oil and then a de-sander 46 comprising at least one hydrocyclone that removes most of the sand from the oil. The oil then undergoes water separation in dual-pipe water/oil separators 48. Separated gas is pumped away or stored at 50 and separated oil is pumped away or stored at 52.

The oily water separated from the oil is treated in a water treatment unit 54. At least some of that treated water is conveyed to a water injection pump 56 that injects the water into the subsea well via an injection Christmas tree 58. The water injection pump 56 may also receive water from another source such as seawater, after treatment.

A ring header 12 receives pressurised treated water from the water injection pump and supplies that pressurised water to other equipment of the subsea processing system 42. For example, Figure 2 shows a jet pump or ejector 38 that receives pressurised

water from the ring header 12 via a supply pipe 24 and is in the water flow path from the water/oil separators 48 to the water treatment unit 54.

Moving on now to Figures 3 and 4 of the drawings, these show a subsea processing unit 60 in a practical embodiment of the invention. Like numerals are used for like features.

Figure 3 shows the unit 60 installed on the seabed, complete with an elongate supporting frame 62 that surrounds various functional or processing modules within the unit 60. Those modules implement the various sub-systems of the system 42 described above.

Figure 4 omits the frame 62 for ease of viewing the positional layout of the illustrated modules. The layout shown here may omits some of the modules required to implement the system 42 described above, which could be provided either onboard the unit 60 or outside and connected to the unit 60, for example on a neighbouring similarly-constructed unit installed on the seabed.

Specifically, the frame 62 of the subsea processing unit 60 shown in Figure 4 comprises a steel deck 64 that supports various processing modules and their connecting pipework. A GRP superstructure 66 is bolted together and connected to the deck 64 so that the deck 64 and the superstructure 66 together form a truss structure to carry the heavy payload of the processing plant during towing and installation. Conveniently, buoyancy required for towing the unit 60 to the production site may be pre-shaped and assembled into the superstructure 66.

As is conventional, the superstructure 66 has tapered ends to protect the unit 60 against over-trawling. Removable GRP cover panels 68 may be provided on the superstructure to minimise snagging risks and beneficially to reduce hydrodynamic flow of water within the unit as the unit moves through the water during installation.

Some cover panels 68, particularly on the sides of the superstructure, can be removed after installation to facilitate ROV access. Also, the upwardly-facing cover panels 68 on top of the superstructure 66 can be opened to provide apertures for access to the processing modules 70 supported in upwardly-opening silos on the steel deck 64 beneath.

The processing modules 70 are retrievable from their silos by being lifted through the apertures as shown in Figure 3, which shows a module 70 being lifted by a wire 72 hanging from a winch or crane of a surface vessel, not shown. A work-class ROV (WROV) 74 is shown performing and supervising the necessary subsea connection, guiding and monitoring operations.

More generally, subsea processing systems 42 of the invention can comprise a variety of processing modules 70 depending upon the type of processing needed for a particular field development. Standardised transport and installation frames 76 surrounding the required modules 70 can be installed into the subsea processing unit 60 in a plug-and-play fashion. Such frames 76 also help to reduce variations in terms of handling and installation procedures.

The WROV 74 guides the module 70 into an appropriate silo of the subsea processing unit 60 through the top of the unit 60. No guide wires are required. Upwardly-extending guide formations around the silo guide the transport and installation frame 76 into the correct position in the unit 60, while also aligning piping and electrical connectors between the unit 60 and the module 70.

Depending on the module 70, various connections will be necessary, for example electrical connections, hydraulic connections and piping. Normally, such connections will be vertically-oriented, coming up from main piping that runs at the level of the deck 64. Pipe connections may be made by standard clamp connectors actuated by the WROV 74.

Figure 4 shows some of the processing equipment within the subsea processing unit 60, such as the gas harp 44 and the dual-pipe water/oil separators 48. The looped pipe 20 and some of the supply pipes 24 of the ring header 12 are shown. The looped pipe 20 has a generally oblong shape in plan view to correspond to the shape of the frame 62 or deck 64 of the unit 60 that supports the processing equipment and the associated pipework, including the ring header 12.

Finally, Figure 5 shows how a practical ring header 12 may have a complex shape to effect the necessary fluid connections with the processing equipment of the unit 60. The generally oblong plan shape of the looped pipe 20 matching the plan shape of the frame 62 or deck 64 of the unit 60 can be appreciated here. The looped pipe 20 receives pressurised water from a pump 14 that is external to the unit 60.

The supply pipes 24 branch inwardly from the looped pipe 20 and then bend upwardly or downwardly as necessary to effect their fluid connections. A downwardly-engageable subsea-operable fluid connector 78 is shown schematically on one of the supply pipes 24.

Claims

1. A method for providing pressurised water to a plurality of subsea water consumers, the method comprising:

supplying pressurised water to a common header that connects the consumers; and

supplying the pressurised water from the header to the consumers as required by the consumers.

2. The method of Claim 1, comprising opening valves between the header and the consumers to draw the pressurised water from the header as required by the consumers.

3. The method of Claim 1 or Claim 2, wherein the header and the consumers are supported together by a structure of a subsea hydrocarbon processing unit.

4. The method of Claim 3, comprising pressurising the water at a location remote from the processing unit.

5. The method of any preceding claim, comprising holding the pressurised water in a looped header.

6. The method of Claim 5, comprising pressurising the water at a location outside the looped header.

7. The method of any preceding claim, comprising storing some of the pressurised water in the header in a storage tank of the header that is in fluid communication with pipework of the header connecting the consumers.

8. The method of any preceding claim, comprising boosting pressure of the pressurised water downstream of the header.

9. The method of any preceding claim, comprising a preliminary step of coupling modules to the header subsea, the modules comprising the consumers.

10. The method of Claim 9, comprising lowering the modules into a subsea position for fluid engagement with the header.

11. The method of Claim 8 or Claim 9, comprising operating fluid couplings subsea to establish fluid communication between the modules and the header.

12. The method of any preceding claim, wherein the consumers are items of subsea hydrocarbon processing equipment and use the pressurised water to process a wellstream or components of a wellstream.

13. The method of any preceding claim, comprising replenishing the header with pressurised water in response to supplying pressurised water from the header to the consumers.

14. The method of any preceding claim, comprising maintaining pressure of water in the header above the ambient hydrostatic pressure of a surrounding body of water.

15. The method of any preceding claim, comprising supplying the pressurised water to the header from a surface location.

16. The method of any preceding claim, comprising supplying the pressurised water to the header from a subsea location.

17. A subsea water distribution system, comprising:

a common header connected to a plurality of subsea water consumers to supply pressurised water from the header to the consumers; and

valves for controlling the supply of pressurised water from the header to the consumers in response to demand from the consumers.

18. The system of Claim 17, further comprising a pump for supplying pressurised water to the header.

19. The system of Claim 18, further comprising a valve responsive to the demand from the consumers to replenish the header with pressurised water.

20. The system of any of Claims 17 to 19, wherein the header and the consumers are supported together by a structure of a subsea hydrocarbon processing unit.

21. The system of any of Claims 17 to 20, wherein the header is a looped ring.

22. The system of any of Claims 17 to 21, wherein the header comprises a storage tank in fluid communication with pipework of the header that connects the consumers.

23. The system of any of Claims 17 to 22, further comprising booster systems downstream of the header and upstream of the consumers.

24. The system of any of Claims 17 to 23, wherein the consumers are implemented in modules that can be coupled to the header subsea.

25. The system of Claim 24, further comprising subsea-operable fluid couplings arranged to effect fluid communication between the modules and the header.

26. The system of any of Claims 17 to 25, wherein the consumers are items of subsea hydrocarbon processing equipment that use the pressurised water to process a wellstream or components of a wellstream.

27. The system of any of Claims 17 to 25, wherein the consumers are selected from: hydrocyclones; water injection systems; chemical injection systems; ejectors; hydraulic pumps; jetting systems; flushing circuits; and pressure accumulators.

Intellectual Property Office

Application No: GB1919099.0 **Examiner:** Contract Unit Examiner

Claims searched: 1-27 **Date of search:** 1 September 2020

Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

Category	Relevant to claims	Identity of document and passage or figure of particular relevance
X	1-4, 8-14, 16-20, 23-27	GB2561568 A (SUBSEA 7 NORWAY AS) page 20, line 15 - page 21, line 2; figure 1, page 22, lines 25-33
X	1-4, 8-14, 16-20, 23-27	WO02/33218 A1 (KVAERNER OILFIELD PROD AS; OLSEN GEIR INGE ET AL) page 9, paragraph 5, page 10, paragraph 5, page 11, paragraph 3, page 14, paragraphs 4,5 page 16, paragraph 2; figure 1c
A	-	WO01/71158 A1 (KVAERNER OILFIELD PROD AS; OLSEN GEIR INGE) figure 3
A	-	GB2279098 A (JP KENNY CALEDONIA LIMITED) figure 4

Categories:

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC^{X} :

Worldwide search of patent documents classified in the following areas of the IPC

E21B

The following online and other databases have been used in the preparation of this search report

Intellectual Property Office

International Classification:

Subclass	Subgroup	Valid From
E21B	0041/00	01/01/2006
E21B	0043/36	01/01/2006
E21B	0043/40	01/01/2006