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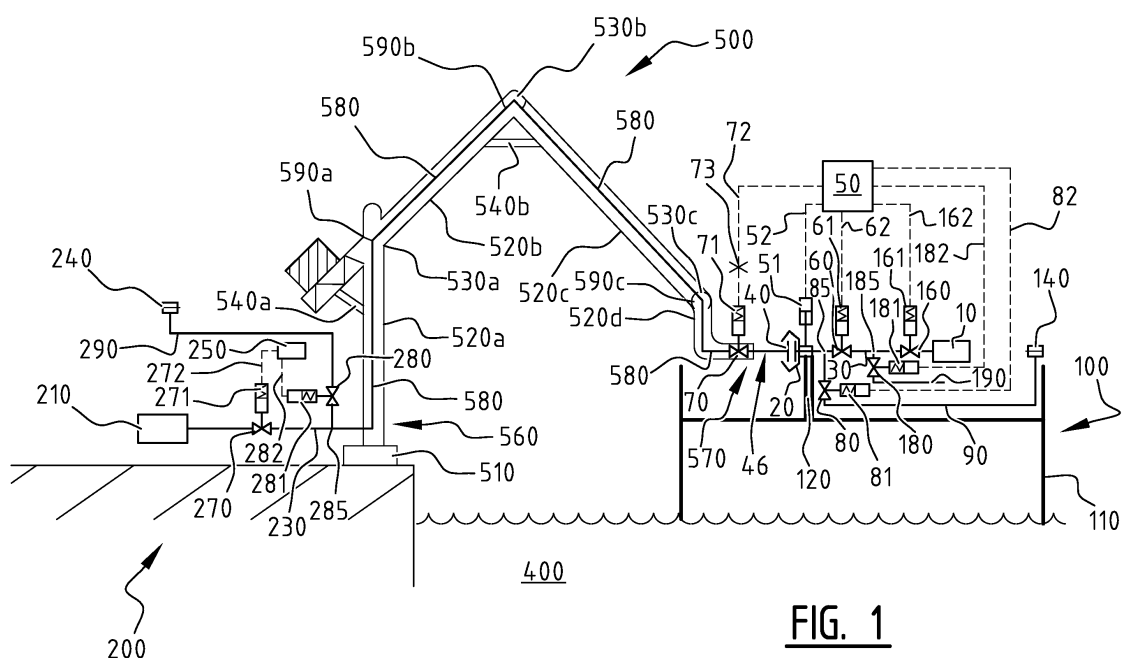
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(54) **Loading Assembly for conveying a pressurized Gas, and a floating Gas processing Unit**

(57) An improved loading assembly is presently proposed for conveying a pressurized gas between a floating gas processing unit and another structure. The loading assembly has an emergency disconnection coupler having a passive coupling part and an actuated coupling part, which actuated coupling part can be moved (actuated) from a locked position to an unlocked position. The pas-

sive coupling part is mechanically released from the actuated coupling part when the actuated coupling part is in the unlocked position, whereas the actuated coupling part is mounted on the floating gas processing unit regardless of whether the actuated coupling part is in its locked or unlocked position.

**FIG. 1****EP 2 808 293 A1**

Description

[0001] In a first aspect, the present invention relates to a loading assembly for conveying a pressurized gas between a floating gas processing unit and another structure located adjacent to the floating gas processing unit. In another aspect, the present invention relates to a floating gas processing unit.

[0002] A floating gas processing unit usually comprises a floating hull provided with equipment for receiving natural gas in a starting condition, processing the natural gas, and subsequently discharging the natural gas in a processed condition, whereby the processed condition is different from the starting condition.

[0003] An example of a floating gas processing unit is a floating gasification unit (FGU). An FGU receives liquefied natural gas (LNG), which is natural gas in a cryogenic liquefied condition, and vaporizes the liquefied natural gas by adding heat to it, thereby changing the condition to a vapour. The natural gas is discharged in the form of a revaporized natural gas in vapour phase. The revaporized natural gas is typically piped from the FGU to shore, where the natural gas may be used in various ways. For example it may be added to a natural gas distribution grid. Usually the liquefied natural gas is pressurized before being vaporized, in which case the revaporized natural gas is pressurized. A floating gasification unit often has cryogenic storage capacity for (temporarily) storing the LNG prior to it being vaporized. Such a floating gasification unit with cryogenic storage capacity is typically referred to as a floating storage and regasification unit (FSRU). A non-limiting example is described in US pre-grant patent application publication No. 2006/0156744.

[0004] Another example of a floating gas processing unit is a floating natural gas liquefaction unit (FLU). Specific examples include floating natural gas liquefaction and storage units (FLSU) such as described in for instance WO 2007/064209 and WO 2010/069910. Such an FLU can be arranged to receive pressurized the natural gas from the other structure and to cryogenically cool the natural gas whereby liquefying the natural gas to produce LNG. In case of an FLSU, the LNG may be stored in cryogenic storage tanks before being off-loaded to an LNG tanker.

[0005] Loading arms can be used to off-load (discharge) the revaporized gas from the FGU (or FSRU) or to load pressurized natural gas onto a floating gas processing unit such as the FLU (or FLSU), if the loading arms are adapted to convey pressurized gas. Or, stated more generally, loading arms can be used to transfer pressurized natural gas between a floating gas processing unit and another structure. They can be used to load natural gas to the floating gas processing unit and/or off-load processed natural gas from the floating gas processing unit. A number of companies, including FMC Technologies inc., and Emco Wheaton, and possibly others manufacture and sell such loading arms for transferring

pressurized gas.

[0006] Loading arms for pressurized natural gas should not be confused with loading arms such as described in e.g. US pre-grant patent application publication No. 2006/0156744, which are designed to transfer the cryogenic liquid LNG. Transfer of (cryogenic) liquids is usually done under low pressure (lower than 5 barg) and thus the rating of connectors is different than for pressurized gas.

[0007] It has recently been announced on Greenport.com ("Emco loading arms for Brazilian terminal" - 2 April 2013 - <http://www.greenport.com/news101>) that Emco Wheaton have supplied high-pressure loading arms for Bahia Regasification Terminal in Brazil. At this terminal LNG will be transferred from an LNG carrier to an FSRU which is permanently moored at the terminal. The loading arms will be used to transfer the LNG (in the form of compressed natural gas) from an FSRU to a shore based pipeline, once it has been vaporized onboard the FSRU. The loading arms can transfer high pressure natural gas to a pressure of 130 bar. The loading arms have a quick connect/disconnect coupler (QC/DC) with an integrated safety feature allowing rapid and automatic release of the loading arm from the FSRU in the event of an emergency. The loading arms consist of a number of articulated joints with swivels at the pivoting points for hard-pipe gas connections, supplemented with bundles of hydraulic lines (consisting of flexible tubes). The hydraulic lines are coupled to hydraulically actuated jaws, provided at the end of the loading arm, which form part of the QC/DC. These jaws are intended to clamp around a non-actuated spool part, which is mounted on the FSRU, to establish a high pressure natural gas connection between the regasification plant on the FSRU and the shore based pipe line.

[0008] Applicant presently proposes a number of improvements to the loading assembly as described above. Patent protection is sought for each of the proposed improvements individually and for any two or more of the proposed combined.

[0009] In accordance with the first aspect of the present invention, there is provided a loading assembly for conveying a pressurized gas between a floating gas processing unit and another structure that is located adjacent to the floating gas processing unit, the loading assembly comprising

- a base founded on the other structure;
- a loading arm mounted on the base, wherein the loading arm comprises a proximal end at the base and a distal end reaching out from the base;
- a gas conduit mounted on the loading arm to convey a pressurized gas stream between the distal end and the proximal end; and
- an emergency disconnection coupler for establishing a selectively disconnectable fluid connection between the floating gas processing unit and the other structure through the gas conduit, which emergency

disconnection coupler comprises a passive coupling part and an actuated coupling part configured to releasably lock against the passive coupling part whereby in a locked position of the actuated coupling part said fluid connection is established and whereby in an unlocked position of the actuated coupling part said fluid connection is interrupted whereby the passive coupling part is mechanically released from the actuated coupling part when the actuated coupling part is in the unlocked position, and wherein the actuated coupling part is mounted on the floating gas processing unit regardless of whether the actuated coupling part is in its locked or unlocked position.

[0010] In accordance with the second aspect of the invention, there is provided a floating gas processing unit, comprising a gas send out header, an actuated coupling part of an emergency disconnection coupler, and a spool part conduit mounted on the floating gas processing unit between the gas send out header and the actuated coupling part, wherein the actuated coupling part of the emergency disconnection coupler is arranged to cooperate with a loading arm via a passive coupling part, wherein said actuated coupling part is configured to releasably lock against the passive coupling part, whereby in a locked position of the actuated coupling part a fluid connection is established between a gas send out header and the passive coupling part via the spool part conduit and the actuated coupling part, and whereby in an unlocked position of the actuated coupling part said fluid connection is interrupted whereby the passive coupling part is mechanically released from the actuated coupling part when the actuated coupling part is in the unlocked position, and wherein the actuated coupling part is mounted on the floating gas processing unit regardless of whether the actuated coupling part is in its locked or unlocked position.

[0011] The invention will be further illustrated herein-after by way of example only, and with reference to the non-limiting drawing in which;

Fig. 1 schematically shows a loading assembly and floating gas processing unit according to embodiments of the invention;

Fig. 2 schematically shows an embodiment of a main power assembly functionally connected to loading arm drive cylinders;

Fig. 3 schematically shows an embodiment of a pressure gate arrangement that can be used in the loading assembly of Fig. 1;

Fig. 4 schematically shows a part of a floating gas processing unit according to another embodiment of the invention comprising an interface pipe piece provided with a breakaway weak link;

Fig. 5 schematically shows a part of an actuated coupling part comprising an integrated breakaway weak link that can be used;

Fig. 6 schematically shows a part of a floating gas

processing unit according to yet another embodiment of the invention comprising a mechanical link bar for actuating two isolation valves using a single valve actuator.

[0012] For the purpose of this description, a single reference number will be assigned to a line as well as a stream carried in that line. Same reference numbers refer to similar components. The person skilled in the art will readily understand that, while the invention is illustrated making reference to one or more a specific combinations of features and measures, many of those features and measures are functionally independent from other features and measures such that they can be equally or similarly applied independently in other embodiments or combinations.

[0013] An improved loading assembly is presently proposed for conveying a pressurized gas between a floating gas processing unit and another structure. One of the proposed improvements in the loading assembly concerns an emergency disconnection coupler comprised in the loading assembly and having a passive coupling part and an actuated coupling part, which actuated coupling part can be moved (actuated) from a locked position to an unlocked position. The passive coupling part is mechanically released from the actuated coupling part when the actuated coupling part is in the unlocked position, whereas the actuated coupling part is mounted on the floating gas processing unit regardless of whether the actuated coupling part is in its locked or unlocked position.

[0014] An advantage of this loading arm arrangement is that in an emergency release event the activated part is released from the loading arm so that the loading arm does not have to suspend the weight of the actuated coupling part of the emergency disconnection coupler. The actuated coupling part is normally heavier than the passive coupling part.

[0015] Another advantage is that the actuated coupling part can be powered with an emergency disconnect power assembly that is mounted on the floating gas processing unit. The power lines, usually a bundle of hydraulic lines, do not have to be guided along the loading arm, making the loading arm less complex and less vulnerable for malfunctions. Moreover, the power connection between the emergency disconnect power assembly and the emergency disconnection coupler does not have to be released in an emergency disconnect event.

[0016] Other improvements, which can be implemented regardless of whether the actuated coupling part is mounted on the floating gas processing unit or on the loading arm, include the following non-limiting examples:

- providing at least a spool-side isolation valve, and preferably also an arm-side isolation valve, in the form of a fail-close valve;
- providing a blow down arrangement with a blow down valve and a blow down vent stack all arranged

- on the floating gas processing unit;
- providing a blow down valve in the form of a fail-open valve;
- providing a separate emergency disconnect power assembly for powering the emergency disconnection coupler, which emergency disconnect power assembly is isolated from and operated independently from a main power assembly used for driving drive cylinders on the loading arm;
- interlocking the movement of the actuated coupling part from the locked position to the unlocked position to avoid that said movement is possible when the gas within the gas connection is pressurized at or above a predetermined threshold pressure;
- implementing a breakaway weak link in the loading arm arrangement to ensure the contained gas flow path breaks open at a preconceived location in case the mechanical load on the loading arm arrangement, caused by relative movement between the floating gas processing unit and the other structure, exceeds a predetermined limit.

[0017] In the drawings and description below, the flow direction of the gas is assumed to be from the floating gas processing unit to the other structure. Nonetheless, the invention is also intended to cover application of the loading arrangement for conveying pressurized gas from the other structure to the gas processing unit.

[0018] Figure 1 schematically shows a possible implementation of the loading assembly wherein a number of the proposed improvements are illustrated. Involved are a floating gas processing unit 100 and another structure 200 located adjacent to the floating gas processing unit 100, and a loading assembly for conveying a pressurized gas from the floating gas processing unit 100 to the other structure 200. The floating gas processing unit 100 comprises a floating hull 110 on which supports gas processing equipment to receive natural gas in a starting condition, to process the natural gas, and to discharge the natural gas in a processed condition. The processed condition is different from the starting condition. The floating gas processing unit 100 floats in a body of water 400.

[0019] The other structure 200 may also be a floating structure, or it may be a fixed structure such as a structure with a foundation on shore adjacent to the body of water, or a structure with a foundation in the body of water such as a platform or a jetty. In the description following below, the other structure 200 will be referred to as shore side 200 to facilitate ease of reading, but the invention applies to any type of other structure as indicated above.

[0020] The loading assembly comprises a loading arm 500 mounted on a base 510 located on the shore side 200. Numerous types of loading arms 500 are known in the art, and the invention is not limited to any particular type. The loading arm 500 shown in Figure 1 is an articulated loading arm having a plurality of articulates 520a, 520b, 520c, 520d which are pivotably connected one to another other by joints 530a, 530b, 530c. The pivoting

movement of the articulates may be controlled by loading arm drive cylinders 540a, 540b. These are coupled to the loading arm 500 to move parts of the loading arm 500, for instance the plurality of articulates 520a-d, relative to each other.

[0021] As schematically illustrated in Fig. 2, a main power assembly 550 may be provided on the shore side 200 and functionally coupled to the loading arm drive cylinders 540a, 540b. Preferably, the main power assembly 550 comprises a main arm hydraulic power system that is connected to the loading arm drive cylinders 540a, 540b via a plurality of arm hydraulic lines 541a, 541b.

[0022] Referring again to Fig. 1, the loading arm 500 comprises a proximal end 560 at the base 510 and a distal end 570 reaching out from the base 510. A gas conduit 580 is mounted on the loading arm 500. The gas conduit 580 is represented as a line in the figure. The gas conduit may be formed of hard pipe ends joined together via swivels 590a, 590b, 590c in the joints 530a, 530b, 530c. Other types of gas conduits may be employed instead, such as for instance flexible gas conduits or hard pipe parts joined together with flexible parts. The gas conduit 580 serves to convey a pressurized gas stream from the distal end 570 of the loading arm to the proximal end 560.

[0023] The floating gas processing unit 100 comprises a gas send out header 10, an actuated coupling part 20 of an emergency disconnection coupler, and a spool part conduit 30. All are mounted on the floating gas processing unit 100, as schematically illustrated by mounting stud 120. Multiple mounting studs may be used. The actuated coupling part comprises at least one coupling part actuator 51, which may be powered by any suitable means. For the remainder of this description it will be assumed that the coupling part actuator 51 is powered hydraulically employing hydraulic means.

[0024] The spool part conduit 30 extends between the gas send out header 10 and the actuated coupling part 20 whereby pressurized gas can flow from the gas send out header 10 through the spool part conduit 30 to the emergency disconnection coupler.

[0025] The actuated coupling part 20 of the emergency disconnection coupler is arranged to cooperate with the loading arm 500 via a passive coupling part 40. The actuated coupling part 20 is configured to releasably lock against the passive coupling part 40, whereby in a locked position of the actuated coupling part 20 a fluid connection is established between a gas send out header 10 and the passive coupling part 40 via the spool part conduit 30 and the actuated coupling part 20. In an unlocked position of the actuated coupling part 20, the fluid connection is interrupted. The actuated coupling part 20 may be of a known type having a plurality of jaws pivotally coupled to a body and distributed around a circumference of the body. The jaws can physically clamp to the passive coupling part 40 when the jaws are moved into an engaged position whereby the actuated coupling part 20 is in its locked position. A non-limiting example is dis-

closed in US Patent 6,843,511, the description of which is incorporated herein by reference.

[0026] The passive coupling part 40 is mechanically released from the actuated coupling part 20 when the actuated coupling part 20 is in the unlocked position. This may be done in an emergency disconnect event, for instance when the floating gas processing unit 100 is adrift, or routinely as part of a normal operations whereby the loading arm 500 is to be released from the floating gas processing unit 100 by free choice of the site operator. The passive coupling part 40 may be retained on the distal end 570 of the loading arm 500. The actuated coupling part 20, on the other hand, is mounted on the floating gas processing unit 100 regardless of whether the actuated coupling part 20 is in its locked or unlocked position. In other words, it stays mechanically connected to the spool part conduit 30.

[0027] The floating gas processing unit 100 may further comprise a spool-side isolation valve 60 that is arranged in the spool part conduit 30. The spool-side isolation valve 60 may be operated by means of a spool-side isolation valve actuator 61.

[0028] The passive coupling part 40 and the actuated coupling part 20 of the emergency disconnect coupler are both arranged downstream of the spool-side isolation valve 60.

[0029] An arm-side isolation valve 70 may be arranged in the gas conduit 580 that is mounted on the loading arm 500. The pressurized gas can thus flow from the gas send out header 10 through the spool-side isolation valve 60 and from there through the actuated and passive coupling parts of the emergency disconnect coupler to the arm-side isolation valve 70 and further into the gas conduit 580 on the loading arm 500. The arm-side isolation valve 70 may be operated by means of an arm-side isolation valve actuator 71.

[0030] A blow down valve 80 may be provided in fluid communication with the gas connection via a blow down junction 85 that is arranged in the gas connection, which is established in a section of the spool conduit 30 between the spool-side isolation valve 60 and the arm-side isolation valve 70. The blow down valve 80 may be operated by means of a blow down valve actuator 81.

[0031] Preferably the blow down junction 85 is configured between the spool-side isolation valve 60 and the actuated coupling part 20. The blow down valve 80 is suitably arranged in a blow down line 90 which is fed from the gas connection via the blow down junction 30. The blow down line 90 fluidly connects the gas connection to a first vent stack 140 that is provided on the floating gas processing unit 100. This provides the option for the gas connection between the spool-side isolation valve 60 and the arm-side isolation valve 70 to be selectively vented prior to selectively switching of the actuated coupling part 20 from the locked to the unlocked position. An advantage of the first vent stack 140 being available on the floating gas processing unit 100 is that no blow down line needs to be incorporated in the loading arm. Herewith,

not only can associated swivels be avoided, but also, by arranging the first vent stack 140 on the floating gas processing unit 100, the blow down line 90 to first vent stack 140 can be arranged less exposed to, and better protected from, external sources of damage than is possible on the loading arm and on the shore side 200. Suitably, the spool-side isolation valve 60 and the arm-side isolation valve 70 are both closed prior to opening the blow down valve 80 to vent the gas connection.

[0032] In addition to the spool-side isolation valve 60, an auxiliary spool-side isolation valve 160 may be configured in the spool part conduit 30. The auxiliary spool-side isolation valve 160 may be operated by means of an auxiliary spool-side isolation valve actuator 161. The auxiliary spool-side isolation valve 160 may be configured between the gas send out header 10 and the spool-side isolation valve 60. Similar to the blow down valve 80, an auxiliary blow down valve 180 may also be provided, which may be operated by means of an auxiliary blow down valve actuator 181. The auxiliary blow down valve 180, if provided, fluidly communicates with the spool part conduit 30 via an auxiliary blow down junction 185 arranged in the spool part conduit 30 between the auxiliary spool-side isolation valve 160 and the spool-side isolation valve 60. The auxiliary blow down valve 180 may be configured in an auxiliary blow down line 190, which may ultimately vent into the first vent stack 140 or another, a second, vent stack provided on the floating gas processing unit 100 (not shown).

[0033] Figure 1 further shows an emergency disconnect power assembly 50 that is mounted on the floating gas processing unit 100. The emergency disconnect power assembly 50 is operatively connected to the actuated coupling part 20 to power the actuated coupling part 20 to selectively switch the actuated coupling part 20 from the locked position to the unlocked position.

[0034] Optionally, the same emergency disconnect power assembly 50 can be employed to selectively switch the actuated coupling part 20 from the unlocked position to the locked position. In the latter case the emergency disconnection coupler can advantageously be used for coupling and decoupling the loading arm 500 to the gas send out header 10 of the floating gas processing unit 100 during normal (planned) operations while at the same time having the emergency functionality available.

[0035] The emergency disconnect power assembly 50 may be of any desired suitable type. In a preferred embodiment, it takes the form of a hydraulic system, which is operatively connected to the actuated coupling part 20 by means of at least one hydraulic line 52. Optionally, multiple hydraulic lines are connected to the emergency disconnect power assembly 50. For the purpose of maintaining clarity in the Figure, the hydraulic lines are represented by dashed lines by which they can easily be distinguished from other lines.

[0036] In one group of embodiments, the emergency disconnect power assembly 50 may be provided to exclusively power said selective switching, in which case a

separate valve power assembly could be provided to power at least the spool-side isolation valve 60 and the blow down valve 80, and optionally also the arm-side isolation valve 70.

This is illustrated in Fig. 1, wherein a spool-side isolation valve hydraulic line 62 is provided to power the spool-side isolation valve 60 and wherein a blow down valve hydraulic line 82 is provided to power the blow down valve 80 and wherein an arm-side isolation valve hydraulic line 72 is provided to power the arm-side isolation valve 70. A quick connection port 73 is preferably provided in the arm-side isolation valve hydraulic line 72, allowing to disconnect the hydraulic connection between the emergency disconnect power assembly 50 and the arm-side isolation valve 70, so that the loading arm 500 can safely disengage from the floating gas processing unit 100 and be moved away from the floating gas processing unit 100. It should be noted, however, that with the loading arrangement of the invention such quick connection ports are not necessary in the at least one hydraulic line to the actuated coupling part 20 as the actuated coupling part 20 can stay on the floating gas processing unit 100 in the case of a loading arm disconnect event.

[0037] Alternatively (not shown), at least the spool-side isolation valve 60 and the blow down valve 80, and optionally also the arm-side isolation valve 70, are operably connected to another power system available in addition to the emergency disconnect power assembly 50. This may be another hydraulic power system for hydraulically powering these valves, or, for instance, an instrument air system may be employed for pneumatically powering these valves. The instrument air system may be present on the floating gas processing unit 100 anyway, for pneumatically operating other instruments on the floating gas processing unit 100 that do not form part of the loading assembly.

[0038] The spool-side isolation valve 60 and the arm-side isolation valve 70 and the blow down valve 80 preferably all are fail-safe valves. Fail-safe valves are valves that are biased to move to or stay in a predetermined fail position (open or closed) in case power is lost.

For the spool-side isolation valve 60 and the arm-side isolation valve 70 the preferred fail position is closed (so-called fail-close valves), whereby the spool-side isolation valve 60 is biased to move (and/or stay) in closed position when the spool-side isolation valve 60 becomes unpowered and the arm-side isolation valve 70 is biased to move (and/or stay) in closed position when the arm-side isolation valve 70 becomes unpowered. The blow down valve preferably is a fail-open valve, which is biased to move (and/or stay) in open position when the blow down valve becomes unpowered.

[0039] Fail-safe valves may comprise actuators that are biased to inherently leave the valve in the predetermined fail position in case power to the actuator is lost. The actuators may for instance be spring-biased.

[0040] For instance, if in case the power supply is a hydraulic or a pneumatic one, the spool-side isolation

valve actuator 61 and the arm-side isolation valve actuator 71 may both be a spring biased piston actuator in which a spring mechanically interacts with a piston whereby spring action on the piston causes the valve concerned to close and whereby the valve is opened by hydraulically or pneumatically forcing the piston against the spring. In the embodiment of Fig. 1, the spool-side isolation valve actuator 61 is operably connected to the spool-side isolation valve hydraulic line 62, whereby the spool-side isolation valve 60 is opened by hydraulically forcing a spool-side isolation valve piston against a spool-side isolation valve biasing spring within the spool-side isolation valve actuator 61. Likewise, the arm-side isolation valve actuator 71 is operably connected to the arm-side isolation valve hydraulic line 72, whereby the arm-side isolation valve 70 is opened by hydraulically forcing an arm-side isolation valve piston against an arm-side isolation valve biasing spring within the arm-side isolation valve actuator 71. The blow down valve 80, which preferably is a fail-open valve, may be closable by hydraulically forcing a blow down valve piston against a blow down biasing spring within the blow down valve actuator 81. The blow down valve actuator 81 may be operably connected to the blow down valve hydraulic line 82.

[0041] Similarly, the optional auxiliary spool-side isolation valve 160 and optional auxiliary blow down valve 180 may be configured in the form of fail-safe valves, preferably whereby the optional auxiliary spool-side isolation valve 160 is of fail-close type and whereby the optional auxiliary blow down valve 180 is of fail-open type. In one example, as shown in Fig. 1, the auxiliary spool-side isolation valve actuator 161 is operably connected to an auxiliary spool-side isolation valve hydraulic line 162 and the auxiliary blow down valve actuator 181 is operably connected to an auxiliary blow down valve hydraulic line 182. In this case the auxiliary spool-side isolation valve 160 is opened by hydraulically forcing an auxiliary spool-side isolation valve piston against an auxiliary spool-side isolation valve biasing spring within the auxiliary spool-side isolation valve actuator 161; whereas the auxiliary blow down valve 180 is closed by hydraulically forcing an auxiliary blow down valve piston against an auxiliary blow down biasing spring within the auxiliary blow down valve actuator 181.

[0042] On the shore side 200, the loading assembly may further comprise a shore connection conduit 230 fluidly connected to the loading arm's gas conduit 580 at the proximal end 560 of the loading arm 500. The shore connection conduit 230 generally functions to fluidly connect the gas conduit 580 of the loading arm 500 to a shore gas distribution arrangement 210, which may comprise a gas distribution header connected to one or more gas pipelines and/or a gas grid.

[0043] An auxiliary arm-side isolation valve 270 may be configured in the shore connection conduit 230. Furthermore, a gas conduit blow down valve 280 may be fluidly connected to the shore connection conduit 230 via a gas conduit blow down junction 285 that is arranged

between the arm-side isolation valve 70 (usually positioned at the distal end 570 of the loading arm 500) and the auxiliary arm-side isolation valve 270. Preferably, the gas conduit blow down junction 285 is arranged in the shore connection conduit 230 between the proximal end 560 of the loading arm 500 and the auxiliary arm-side isolation valve 270. With this shore arrangement it is possible to selectively vent the entire gas conduit 580 on the loading arm 500 and at least part of the shore connection conduit 230. Preferably, the gas conduit blow down valve 280 is (only) opened when the arm-side isolation valve 70 and the auxiliary arm-side isolation valve 270 are both closed. The gas conduit blow down valve 280 is suitably arranged in a gas conduit blow down line 290, which is fed from the shore connection conduit 230 via the gas conduit blow down junction 285. The gas conduit blow down line 290 suitably connects the shore connection conduit 230 to an optional third vent stack 240 that is provided on the shore side 200.

[0044] The auxiliary arm-side isolation valve 270 may be operated by means of an auxiliary arm-side isolation valve actuator 271. The gas conduit blow down valve 280 may be operated by means of gas conduit blow down valve actuator 281. These actuators may be hydraulically driven actuators, preferably similar to those for the auxiliary spool-side isolation valve 160 and the auxiliary blow down valve 180. Particularly, the auxiliary arm-side isolation valve actuator 271 is connected to a shore power unit 250 via an auxiliary arm-side isolation valve hydraulic line 272, and the gas conduit blow down valve actuator 281 is connected to the shore power unit 250 via a gas conduit blow down valve hydraulic line 282. The shore power unit 250 may be configured in the form of a stand-alone hydraulic power unit. Alternatively, the main power assembly 550 (illustrated in Fig. 2) may fulfil the function of shore power unit 250 by powering the auxiliary arm-side isolation valve 270 and the gas conduit blow down valve 280 together with powering the loading arm drive cylinders 540a, 540b.

[0045] The movement of the actuated coupling part 20 from the locked position to the unlocked position is preferably interlocked to avoid that said movement is possible when the gas within the gas connection is pressurized at or above a predetermined threshold pressure. The interlocking is suitably pressure controlled, by the internal pressure inside the gas connection between the spool-side isolation valve 60 and the arm-side isolation valve 70. Herewith spurious opening of the emergency disconnection coupler during normal pressurized gas transferring operations, by mistake, can be avoided.

[0046] A pressure-controlled software interlock may for instance be provided, which overrides an emergency disconnection coupler opening signal as long as an internal pressure in the gas connection is below a predetermined override value. The internal pressure in the gas connection may be measured using one, or preferably multiple, pressure sensors. In one embodiment, two pressure sensors are provided and a two out of two voting

logic is applied to the two pressure sensors to decide whether the internal pressure is below the predetermined override value. If desired, other numbers of pressure sensors may be employed and/or other voting logic such as two out of three or three out of three, for example.

[0047] The predetermined override value may be set at 5 barg (bar gauge). Other override values may be employed if desired, whereby a balance should be considered between the time it takes to vent the gas connection before the emergency disconnection coupler can actually disengage, and the maximum amount of release of gas that that is tolerated. One can go as low as, for instance 1 barg for the override value, if desired to bring down the maximum amount of gas that can be released into the atmosphere.

[0048] Regardless of whether such a software interlock is provided, it is presently proposed in preferred embodiments of the invention to provide for a physical interlocking arrangement. Such physical interlocking may comprise a pressure gate that is driven by the gas pressure within the gas connection between the spool-side isolation valve 60 and the arm-side isolation valve 70. The intent of the pressure gate is to physically block movement of the actuated coupling part 20 from the locked position to the unlocked position by default, whereby this movement can only proceed when the internal gas pressure in the gas connection is below a preselected threshold value.

[0049] In one group of embodiments, the pressure gate in the physical interlocking arrangement may comprise a locking force system wherein the internal gas pressure exercises a variable biasing force on the actuated coupling part 20 in the locking direction, such that the at least one coupling part actuator 51, when it is powered to move to the open position, does not overcome the biasing force in the locking direction whenever the internal gas pressure in the gas connection is at or above the preselected threshold value.

[0050] In another group of embodiments the pressure gate of the physical interlocking arrangement may comprise a gate switch that is arranged in the power line that is powering the at least one coupling part actuator 51. The gate switch is of fail-open type, which is forced in a closed position (i.e. isolating the coupling part actuator 51 from power) by allowing the force of the internal gas pressure from the gas connection to act on the gate switch. If the internal gas pressure drops below the preselected threshold value, the force exercised by the internal gas pressure is insufficient to overcome the fail-open bias force in the gate switch and as a result the power connection to the coupling part actuator 51 is established.

[0051] One embodiment according to this latter group of embodiments is illustrated in Fig. 3. In the embodiment as shown, the at least one hydraulic line 52 comprises at least a first hydraulic line 52a and a second hydraulic line 52b. The emergency disconnect power assembly 50, which in this case is assumed to be a hydraulic unit, is connected to both the piston side and the shaft side of

the coupling part actuator 51: first hydraulic line 52a connects the emergency disconnect power assembly 50 to the shaft side and the second hydraulic line 52b connects the emergency disconnect power assembly 50 to the piston side. Pressurizing hydraulic line 52a while allowing the hydraulic fluid to be discharged from the piston side of the coupling part actuator 51 causes the actuated coupling part 20 to open. Vice versa, pressurizing hydraulic line 52b while allowing the hydraulic fluid to be discharged from the shaft side of the coupling part actuator 51 causes the actuated coupling part 20 to close. A solenoid valve may be arranged in the first and second hydraulic lines 52a, 52b to switch between connect, isolate, and cross connect positions. In the connect position the first hydraulic line 52a may be connected to the high-pressure discharge side of the emergency disconnect power assembly 50 and second hydraulic line 52b to the low-pressure return side of the emergency disconnect power assembly 50. In the cross connect position the second hydraulic line 52b may be connected to the high-pressure discharge side of the emergency disconnect power assembly 50 while the first hydraulic line 52a is connected to the low-pressure return side. In the isolate position one or both of the first and second hydraulic lines 52a, 52b may be fluidly isolated from the emergency disconnect power assembly 50.

[0052] Inside the emergency disconnect power assembly 50 the high-pressure discharge side may be fed from a pump (not shown) while the low-pressure return side may be led to a hydraulic fluid storage tank (not shown). The pump may be fed from the hydraulic fluid storage tank, thus closing a hydraulic power loop.

[0053] The gate switch may be embodied in the form of a spring-biased gate valve 53 arranged in any one of the hydraulic lines 52a, 52b. The gate valve 53 is operated by a gate valve actuator 55, which is in this case a spring-biased pneumatically operated actuator arranged to move the gate valve 53 in open position whenever the gate valve actuator 55 is powered by a force that is below the preselected threshold. The gate valve actuator 55 is fluidly connected to the gas connection between the spool-side isolation valve 60 and the arm-side isolation valve 70 via a gate line 56, so that it is powered by the force exerted by the internal gas pressure in the gas connection. When the internal gas pressure in the gas connection is at or above the preselected threshold, the gas pressure through the gate line 56 will force the gate valve 53 to close thereby hydraulically isolating the at least one coupling part actuator 51 from the emergency disconnect power assembly 50 so that the actuated coupling part 20 cannot be opened.

[0054] The gate valve 53 may be configured in the first hydraulic line 52a, the second hydraulic line 52b, or the gate valve 53 may be configured in the first hydraulic line 52a as illustrated in Figure 3 while a similar gate valve may be similarly arranged in second hydraulic line 52b to provide an additional layer of security.

[0055] As illustrated in Figure 3, the gate valve 53 may

optionally be embodied in the form of a three way valve. On one end the three way valve is fluidly connected to the emergency disconnect power assembly 50; on another end the three way valve is fluidly connected to the coupling part actuator 51, while on the third end the three way valve is fluidly connected to the low-pressure return side of the emergency disconnect power assembly 50 via a hydraulic return line 54. The purpose of this third end from the gate valve 53, and the hydraulic return line 54, is to return small amounts of hydraulic fluid that may inadvertently be let through when the gate valve 53 is retained in closed position.

[0056] The preselected threshold may be set independently from other override pressure values such as the override value of any optional software interlock if such is provided. The predetermined threshold may for instance be set at 5 barg. One can go as low as, for instance 1 barg for the predetermined threshold, but the consequence of a lower threshold is that the time it takes to depressurize (blow down) the gas connection becomes longer.

[0057] If a software interlock is applied in addition to the physical interlock, it is recommended that the preselected threshold for the physical interlock is the same or higher than the software override value.

[0058] As generally indicated in Fig. 1, a breakaway weak link 46 may optionally be provided in the gas connection, preferably between the spool-side isolation valve 60 and the arm-side isolation valve 70. Regardless of whether the actuated coupling part is mounted on the floating gas processing unit as per the description above, or on the loading arm as per the prior art arrangements, it may be recommended to implement such a breakaway weak link in the loading arm arrangement, which would be the mechanically weakest link in the contained gas flow path of the entire loading arm assembly counting from the gas send out header to the gas distribution arrangement on the other side of the arm. The breakaway link serves to ensure the contained gas flow path breaks open at a preconceived location in case the mechanical load on the loading arm arrangement exceeds a predetermined limit, a situation which may occur when for some reason the floating gas processing unit breaks away from the other structure.

[0059] Preferably, the breakaway weak link is provided in the gas connection between the spool-side isolation valve and the arm-side isolation valve, to ensure the contained gas flow path breaks open between these isolation valves thereby providing the maximum possible degree of isolation available in the arrangement by closing the available isolation valves once the contained gas flow path breaks open at the location dictated by the breakaway weak link. Preferably the closure of the isolation valves is triggered by an over-reach sensor which determines the distance the loading arm has to span between the floating gas processing unit and the other structure.

[0060] Preferably, the preconceived location of break-open is located in the gas connection between the

actuated coupling part of the emergency disconnection coupler and the arm-side isolation valve. Herewith it is achieved that the actuated coupling part does not have to be suspended on the loading arm in the event of a breakaway event.

[0061] In one embodiment, the breakaway weak link may comprise a rupture zone in one of the pipe pieces comprised in the gas connection. Such a rupture zone may take the form of a zone with a relatively thin pipe wall compared to the pipe wall thickness in the piping outside the zone. Alternatively, the rupture zone may take the form of a stress razor, which introduces a pre-conceived fatigue point in the piping comprised in the gas connection.

[0062] An example embodiment is illustrated in Fig. 4, which shows an embodiment of the gas connection between the spool-side isolation valve 60 and the arm-side isolation valve 70 that can be employed on a floating gas processing unit. The proximal end 570 of the loading arm including part of the gas conduit 580, and part of the spool part conduit 30 are also shown to provide reference. The breakaway weak link 46 is provided in the pipe piece comprised in the passive coupling part 40. In the embodiment shown in Figure 4, but this is not a requirement of the invention, the passive coupling part 40 of the emergency disconnection coupler forms part of an interface pipe piece 45 which may be connected to the gas conduit 580 of the loading arm via a flange connection 43. The rupture zone 48 is arranged on the interface pipe piece 45, as can be seen in the enlarged cross section of the breakaway weak link 46 shown in Fig. 4. The rupture zone 48 has been schematically represented as a zone having a smaller thickness in a first pipe wall 47 of the passive coupling part 40.

[0063] The interface pipe piece 45 is easily replaceable by decoupling the flange connection 43, for instance for inspection. A choice can be made in the procedure of operation about whether the flange connection 43 or the emergency disconnection coupler is used for engaging and disengaging the loading arm during normal operations. In the first option, the flange connection 43 is used to engage and disengage the loading arm to the floating gas processing unit 100 for normal operations while the emergency disconnection coupler is only used for disengaging the loading arm from the floating gas processing unit. In the second option, the flange connection 43 is pre-assembled on the loading arm prior to engaging, whereby the emergency disconnection coupler is used not only for disengaging the loading arm from the floating gas processing unit 100 in emergency situations but also for the engagement and disengagement operations in the course of normal, non-emergency, operations.

[0064] It is noted that an interface pipe piece as proposed above may also be employed without a rupture zone if this is considered beneficial to the operation of the loading arm and/or the emergency disconnection coupler.

[0065] Fig. 5 illustrates another embodiment of a

breakaway weak link that may be employed on any emergency disconnect coupler. The figure schematically shows, in cross section, a small part of the passive coupling part 40 and a small part of the actuated coupling part 20 including a coupling mechanism comprising a mechanical jaw 25 that forms part of the actuated coupling part 20. A plurality of such jaws are comprised in the emergency disconnection coupler, distributed along the circumference of the gas connection. The jaw serves to releasably clamp the actuated coupling part 20 against the passive coupling part 40 when in the locked position. The jaw may press a first coupling flange 49 of the passive coupling part 40 against the face of a second coupling flange 29 of the actuated coupling part 20, in a gas-tight manner, when the actuated coupling part 20 is in the lock position. The jaw 25 is moved away from the first and second flanges when the actuated coupling part 20 is moved to the unlocked position. The first coupling flange 49 may be provided on an open end of a first pipe wall 47 of the passive coupling part 40 and the second coupling flange 29 may be provided on an open end of a second pipe wall 27, belonging to the actuated coupling part 20.

[0066] It is presently proposed to integrate the breakaway weak link in the coupling mechanism, particularly in the jaws 25. As example there is shown an embodiment comprising a break zone 22 provided in the mechanical jaw. The break zone 22 suitably is provided in the form of a stress razor.

[0067] An advantage of combining the breakaway weak link with the coupling mechanism is that the absolute force and the dynamic straining in the coupling mechanism are both generally smaller than in the pipe piece between the coupler and the loading arm, as the jaws do not have to contain the internal gas pressure. Moreover, by providing the breakaway weak link in the actuated coupling part, it can never be inadvertently forgotten to install for instance by placing an incorrect interface pipe piece.

[0068] The elements in Fig. 5 are represented very schematically to illustrate that the breakaway weak link may be integrated with the actuated coupling part of an emergency disconnection coupler. The details of design are not limiting the invention. A variety of detailed designs of jaw-based actuated coupling parts are known in the art. Reference is made to US Pat. No. 6,843,511 as one example.

[0069] Regardless of the type of embodiment in which the breakaway weak link is employed, it is recommended that the entire loading arm arrangement is mechanically compliant with the breakaway weak link design forces to ensure the contained gas flow path breaks open at the preconceived location and not at an unintended other location.

[0070] In the embodiments so far described, the spool-side isolation valve 60 and the arm-side isolation valve 70 each are associated with their own spool-side isolation valve actuator 61 and arm-side isolation valve actuator

71. Fig. 6 shows an alternative embodiment that can be employed instead, whereby the spool-side isolation valve actuator 61 is employed for switching both the spool-side isolation valve 60 and the arm-side isolation valve 70. To this end, the spool-side isolation valve 60, which is mounted on the floating gas processing unit 100, comprises a mechanical link bar 65. The mechanical link bar 65 is functionally coupled, via a coupling mechanism 66, to the spool-side isolation valve 60 whereby any actuated movement of the spool-side isolation valve is transmitted to a related movement of the mechanical link bar 65. The related movement may be any suitable movement such as a rotary movement or a translation movement, selected according to suitable design principles. The mechanical link bar 65 is releasably connectable to a receiving arm coupling mechanism 76, which is functionally coupled to the arm-side isolation valve 70 whereby the related movement of the mechanical link bar 65 drives the arm-side isolation valve 70 to the same valve position as the spool-side isolation valve 60. This way, a single valve actuator can actuate two isolation valves.

[0071] An advantage of embodiments wherein a single valve actuator can actuate the two isolation valves is that the arm-side isolation valve actuator 71 can be omitted. As a result, the weight to be supported by the loading arm 500 can be lower. Moreover, the operational interaction between the emergency disconnect power assembly 50 and the arm-side isolation valve 70 takes place via the mechanical link bar 65, so that no quick connection port (such as quick connection port 73) is needed in any of the hydraulic lines of the entire loading arm arrangement. Herewith, inadvertent spillage of hydraulic fluid into the environment, such as into the water 400, can be avoided.

[0072] Control of at least the emergency disconnection coupler and the spool-side and arm-side isolation valves and the blow down valves is done from the floating gas processing unit. All input/output signals related to emergency disconnections are communicated directly from the floating gas processing plant without passing through the standard loading arm control package.

[0073] The internal gas pressure of the gas in the gas connection is generally envisaged to be within a range of from 40 barg to 130 barg under normal operating conditions wherein the processed gas is transferred between the floating gas processing unit and the other structure (e.g. the shore side).

[0074] The person skilled in the art will understand that invention and the specific embodiments disclosed herein may be applied in a wide variety of situations, particularly off-shore on ship-shaped structures. Examples include floating oil and/or gas processing facilities, including floating production storage and offloading (FPSO) structures, floating liquefied natural gas plants (FLNG) plants (which may or may not connect directly to sub-sea wells or which may be fed from other facilities), floating storage and regas units (FSRU) which comprise LNG storage and regasification equipment.

[0075] The person skilled in the art will understand that the present invention can be carried out in many various ways without departing from the scope of the appended claims.

Claims

1. A loading assembly for conveying a pressurized gas between a floating gas processing unit and another structure that is located adjacent to the floating gas processing unit, the loading assembly comprising
 - a base founded on the other structure;
 - a loading arm mounted on the base, wherein the loading arm comprises a proximal end at the base and a distal end reaching out from the base;
 - a gas conduit mounted on the loading arm to convey a pressurized gas stream between the distal end and the proximal end; and
 - an emergency disconnection coupler for establishing a selectively disconnectable fluid connection between the floating gas processing unit and the other structure through the gas conduit, which emergency disconnection coupler comprises a passive coupling part and an actuated coupling part configured to releasably lock against the passive coupling part whereby in a locked position of the actuated coupling part said fluid connection is established and whereby in an unlocked position of the actuated coupling part said fluid connection is interrupted whereby the passive coupling part is mechanically released from the actuated coupling part when the actuated coupling part is in the unlocked position, and wherein the actuated coupling part is mounted on the floating gas processing unit regardless of whether the actuated coupling part is in its locked or unlocked position.
2. The loading assembly of claim 1, further comprising an emergency disconnect power assembly mounted on the floating gas processing unit, wherein the emergency disconnect power assembly is operatively connected to the actuated coupling part to power the actuated coupling part to selectively switch the actuated coupling part from said locked position to said unlocked position and/or from said unlocked position to said locked position.
3. The loading assembly of claim 2, wherein said emergency disconnect power assembly is a hydraulic system, which is operatively connected to the actuated coupling part by means of one or more hydraulic lines.
4. The loading assembly of claim 2 or 3, further com-

- prising a plurality of loading arm drive cylinders coupled to the loading arm to move parts of the loading arm relative to each other, and a main power assembly in addition to said emergency disconnect power assembly, wherein said main power assembly is functionally coupled to said loading arm drive cylinders, and wherein the main power assembly is mounted on the other structure.
5. The loading assembly of any one of the preceding claims, further comprising:
 - a spool-side isolation valve arranged in a spool part conduit mounted on the floating gas processing unit;
 - an arm-side isolation valve arranged in the gas conduit;
 - a blow down valve;
 wherein the passive coupling part and the actuated coupling part are sandwiched between the spool-side isolation valve and the arm-side isolation valve whereby during operation a gas connection is established between the spool-side isolation valve and the arm-side isolation valve whereby the pressurized gas can flow from the spool-side isolation valve through the actuated and passive coupling parts to the arm-side isolation valve, and wherein the blow down valve fluidly communicates with the gas connection via a blow down junction arranged in the gas connection between the spool-side isolation valve and the actuated coupling part.
 6. The loading assembly of claim 5, wherein each of the spool-side isolation valve and the arm-side isolation valve and the blow down valve are biased valves whereby the blow down valve is moved in open position when the blow down valve is unpowered, and the spool-side isolation valve is moved in closed position when the spool-side isolation valve is unpowered and the arm-side isolation valve is moved in closed position when the arm-side isolation valve is unpowered.
 7. The loading assembly of claim 5 or 6, wherein movement of the actuated coupling part from said locked position to said unlocked position is interlocked with a pressure gate driven by the gas pressure within the gas connection between the spool-side isolation valve and the arm-side isolation valve, whereby said movement from said locked position to said unlocked position can only proceed when said gas pressure is below a preselected threshold value.
 8. The loading assembly of claim 7, wherein said movement of the actuated coupling part from said locked position to said unlocked position is physically interlocked by said pressure gate.
 9. The loading assembly of any one of claims 5 to 8, wherein the blow down valve is arranged in a blow down line that is fluidly connected with the gas connection via the blow down junction, wherein the blow down line fluidly connects the gas connection to a first vent stack arranged on the floating gas processing unit.
 10. The loading assembly of any one of claims 5 to 10, further comprising a shore connection conduit fluidly connected to the gas conduit at the proximal end of the loading arm, an auxiliary arm-side isolation valve configured in the shore connection conduit, and a gas conduit blow down valve fluidly connected to a gas conduit blow down junction arranged between the auxiliary arm-side isolation valve and the arm-side isolation valve, to selectively vent the gas conduit when the arm-side isolation valve and the auxiliary arm-side isolation valve are closed.
 11. A floating gas processing unit, comprising a gas send out header, an actuated coupling part of an emergency disconnection coupler, and a spool part conduit mounted on the floating gas processing unit between the gas send out header and the actuated coupling part, wherein the actuated coupling part of the emergency disconnection coupler is arranged to cooperate with a loading arm via a passive coupling part, wherein said actuated coupling part is configured to releasably lock against the passive coupling part, whereby in a locked position of the actuated coupling part a fluid connection is established between a gas send out header and the passive coupling part via the spool part conduit and the actuated coupling part, and whereby in an unlocked position of the actuated coupling part said fluid connection is interrupted whereby the passive coupling part is mechanically released from the actuated coupling part when the actuated coupling part is in the unlocked position, and wherein the actuated coupling part is mounted on the floating gas processing unit regardless of whether the actuated coupling part is in its locked or unlocked position.
 12. The floating gas processing unit of claim 11, further comprising an emergency disconnect power assembly, preferably in the form of a hydraulic system, mounted on the floating gas processing unit, wherein the emergency disconnect power assembly is operatively connected to the actuated coupling part to power the actuated coupling part to selectively switch the actuated coupling part from said locked position to said unlocked position and/or from said unlocked position to said locked position.
 13. The floating gas processing unit of claim 11 or 12, further comprising:

- a spool-side isolation valve arranged in the spool part conduit;
- a blow down valve;
- a first vent stack arranged on the floating gas processing unit;

wherein the passive coupling part and the actuated coupling part are arranged downstream of the spool-side isolation valve, and wherein during operation a gas connection is established between the spool-side isolation valve and an arm-side isolation valve arranged in a gas conduit that is mounted on the loading arm, whereby the pressurized gas can flow from the spool-side isolation valve through the actuated and passive coupling parts to the arm-side isolation valve, and wherein the blow down valve is arranged in a blow down line that is fluidly connected to said first vent stack, to selectively vent the gas connection.

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- 14.** The floating gas processing unit of any one of claims 11 to 13, further comprising an auxiliary spool-side isolation valve configured in the spool part conduit between the gas send out header and the spool-side isolation valve, and an auxiliary blow down valve that fluidly communicates with the spool part conduit via an auxiliary blow down junction arranged in the spool part conduit between the auxiliary spool-side isolation valve and the spool-side isolation valve.

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- 15.** The floating gas processing unit of any one of claims 11 to 14, wherein movement of the actuated coupling part from said locked position to said unlocked position is interlocked, preferably physically interlocked, with a pressure gate driven by the gas pressure within the gas connection between the spool-side isolation valve and the arm-side isolation valve, whereby said movement from said locked position to said unlocked position can only proceed when said gas pressure is below a preselected threshold value.

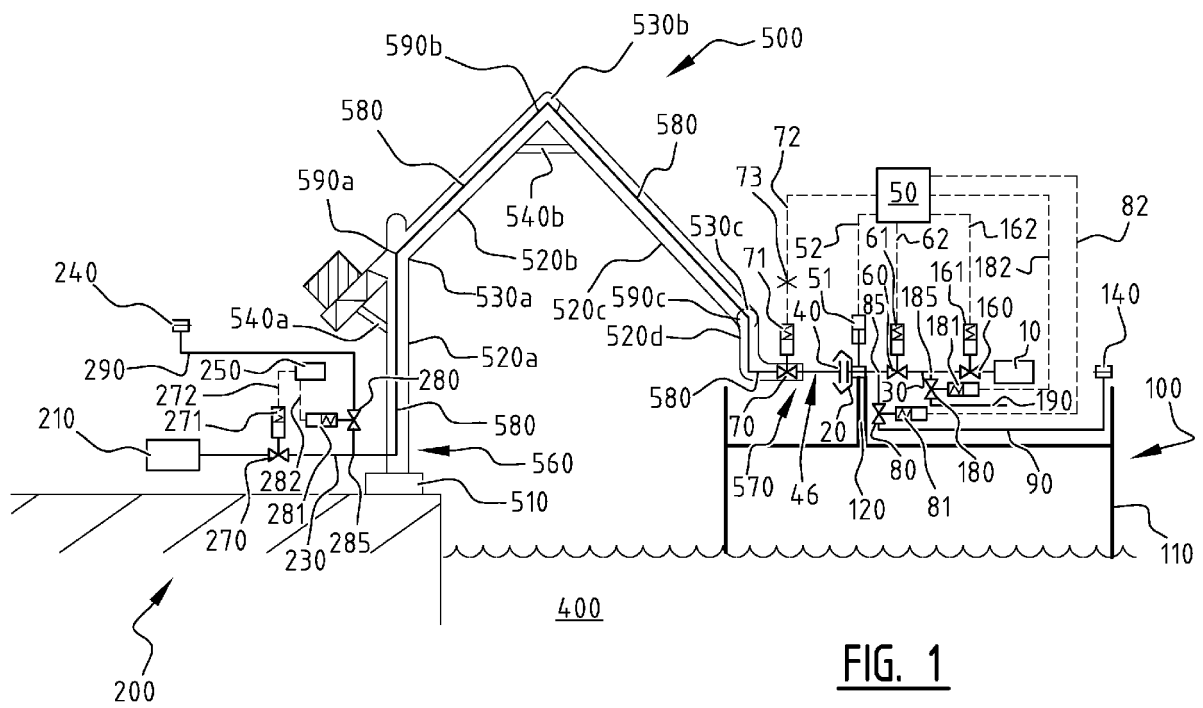
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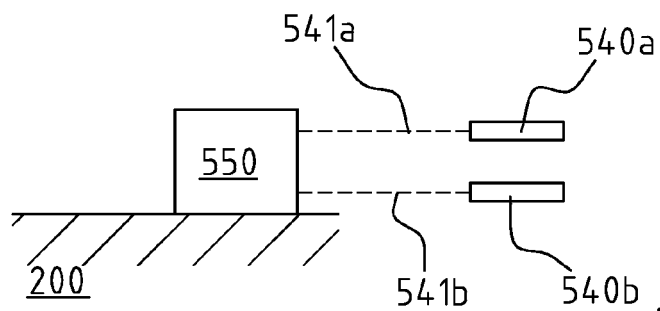


FIG. 2

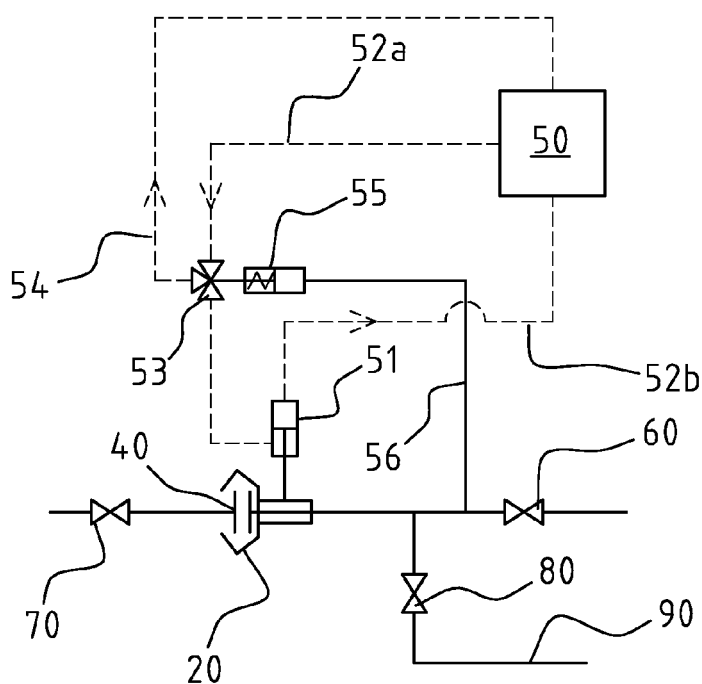


FIG. 3

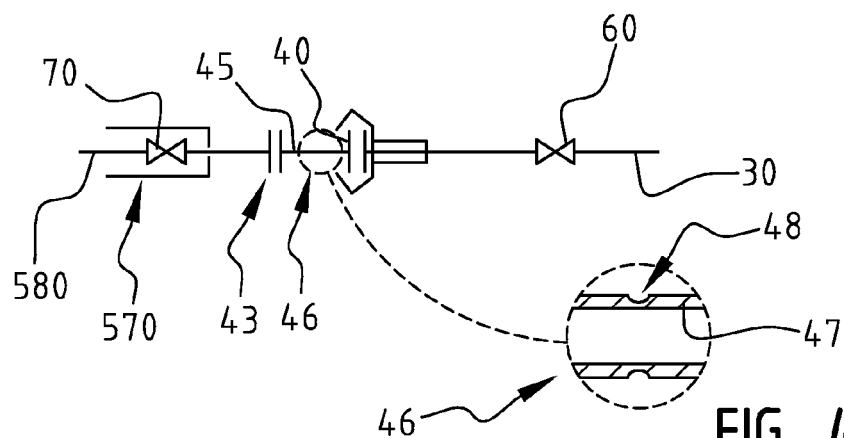
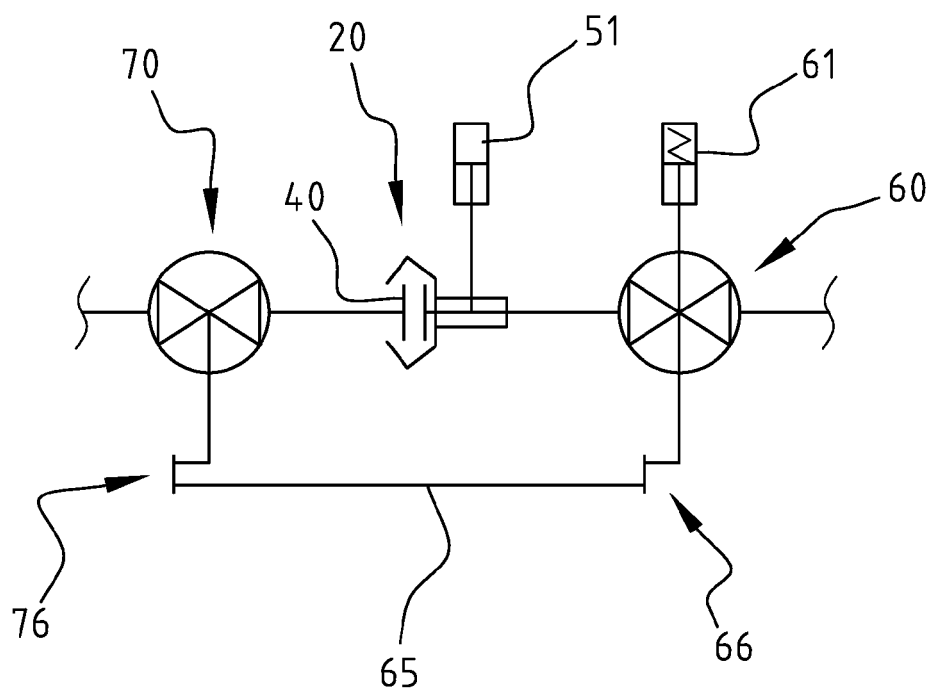
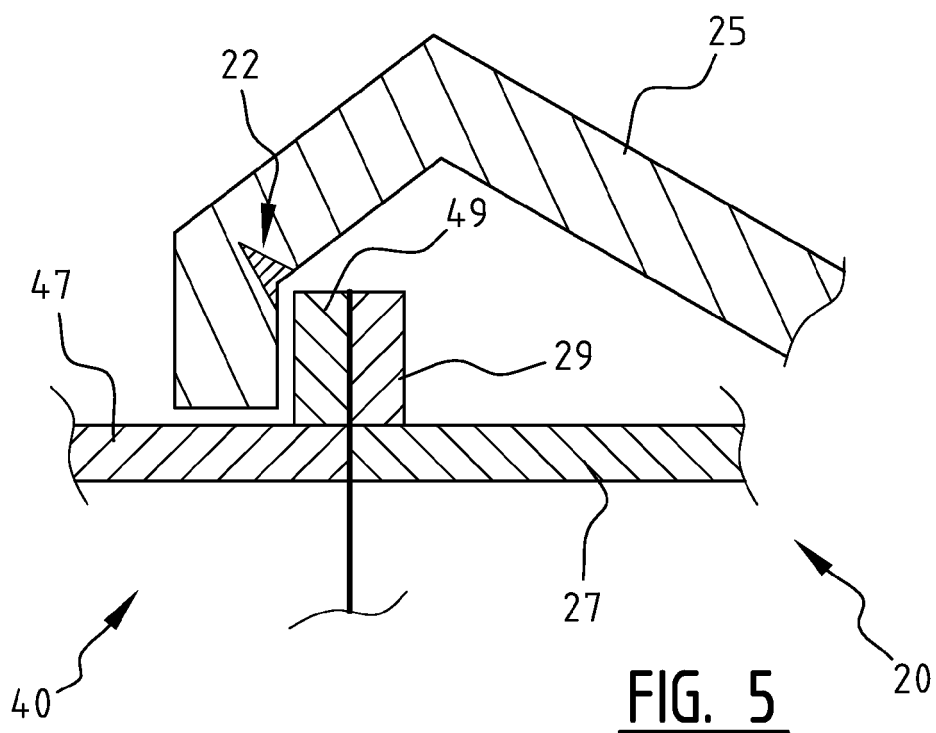


FIG. 4





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EUROPEAN SEARCH REPORT

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