US 20090183505A1

(19) **United States**
(12) **Patent Application Publication**
Madison
(10) **Pub. No.: US 2009/0183505 A1**
(43) **Pub. Date: Jul. 23, 2009**

(54) **PARALLEL FLOW CRYOGENIC LIQUIFIED GAS EXPANDERS**

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(21) Appl. No.: **12/356,830**

(22) Filed: **Jan. 21, 2009**

Related U.S. Application Data

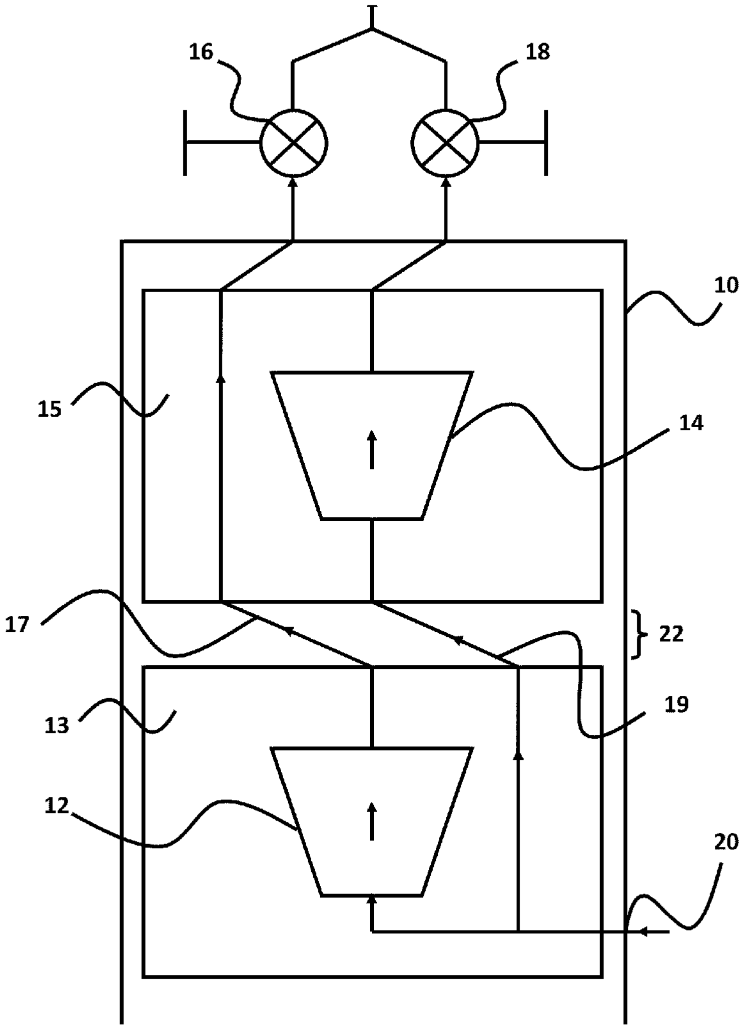
(60) Provisional application No. 61/011914, filed on Jan. 21, 2008.

Publication Classification

(51) **Int. Cl.**
F01D 13/02 (2006.01)
F01D 15/00 (2006.01)
(52) **U.S. Cl.** **60/420**; 290/52; 60/325; 60/421; 60/719

(57) **ABSTRACT**

One or more cryogenic liquefied gas expanders are configured within one or more containment vessels with parallel flow through the expanders, where cryogenic fluid enters through a common inlet and is split between a first expander and a second expander, while expanded cryogenic fluid is generated by both expanders and exits through a common outlet. Parallel flow between the liquefied gas expanders is further facilitated by a rotary control valve positioned either between vessels or between chambers within a vessel and between the two liquefied gas expanders.



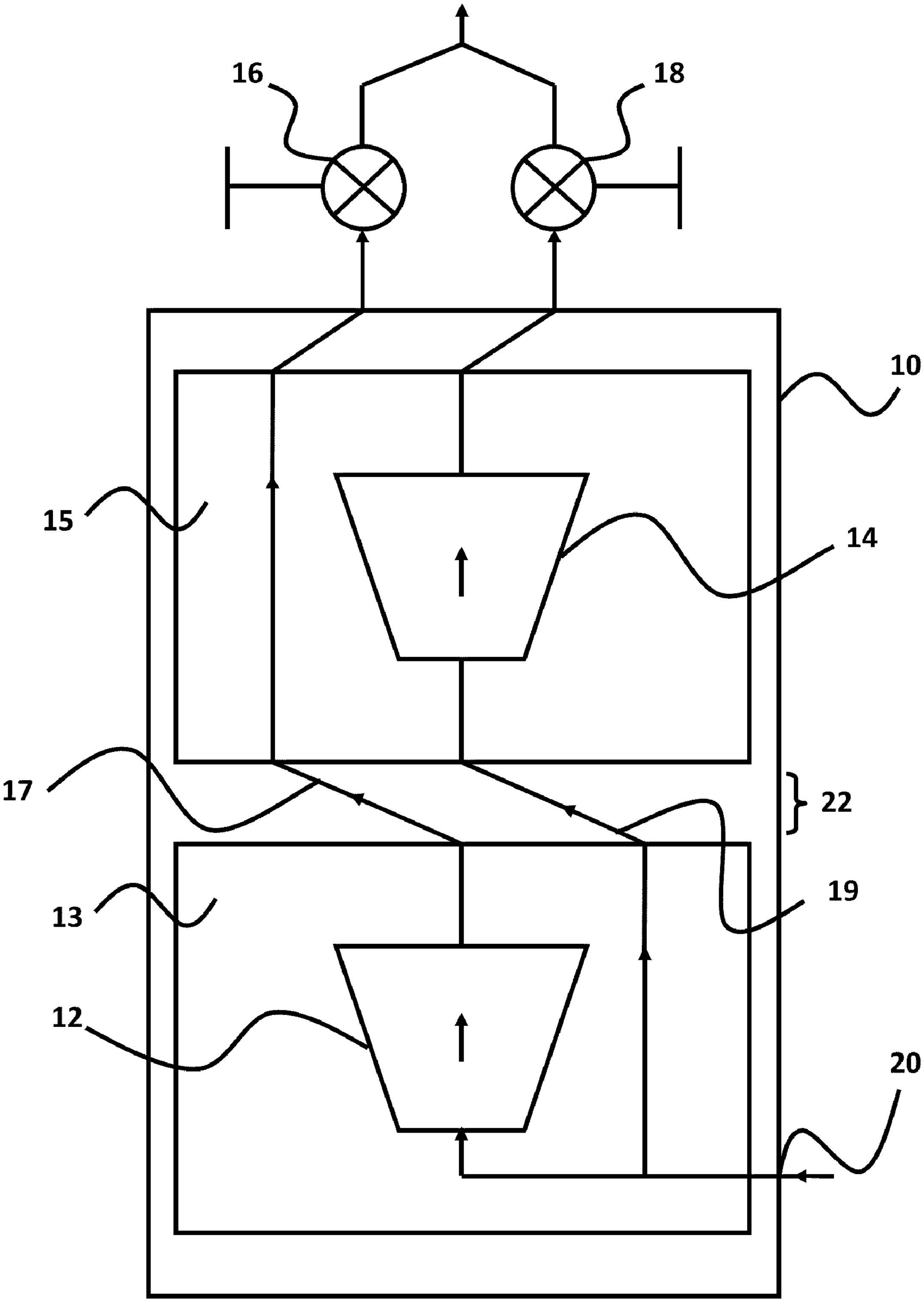


FIG. 1

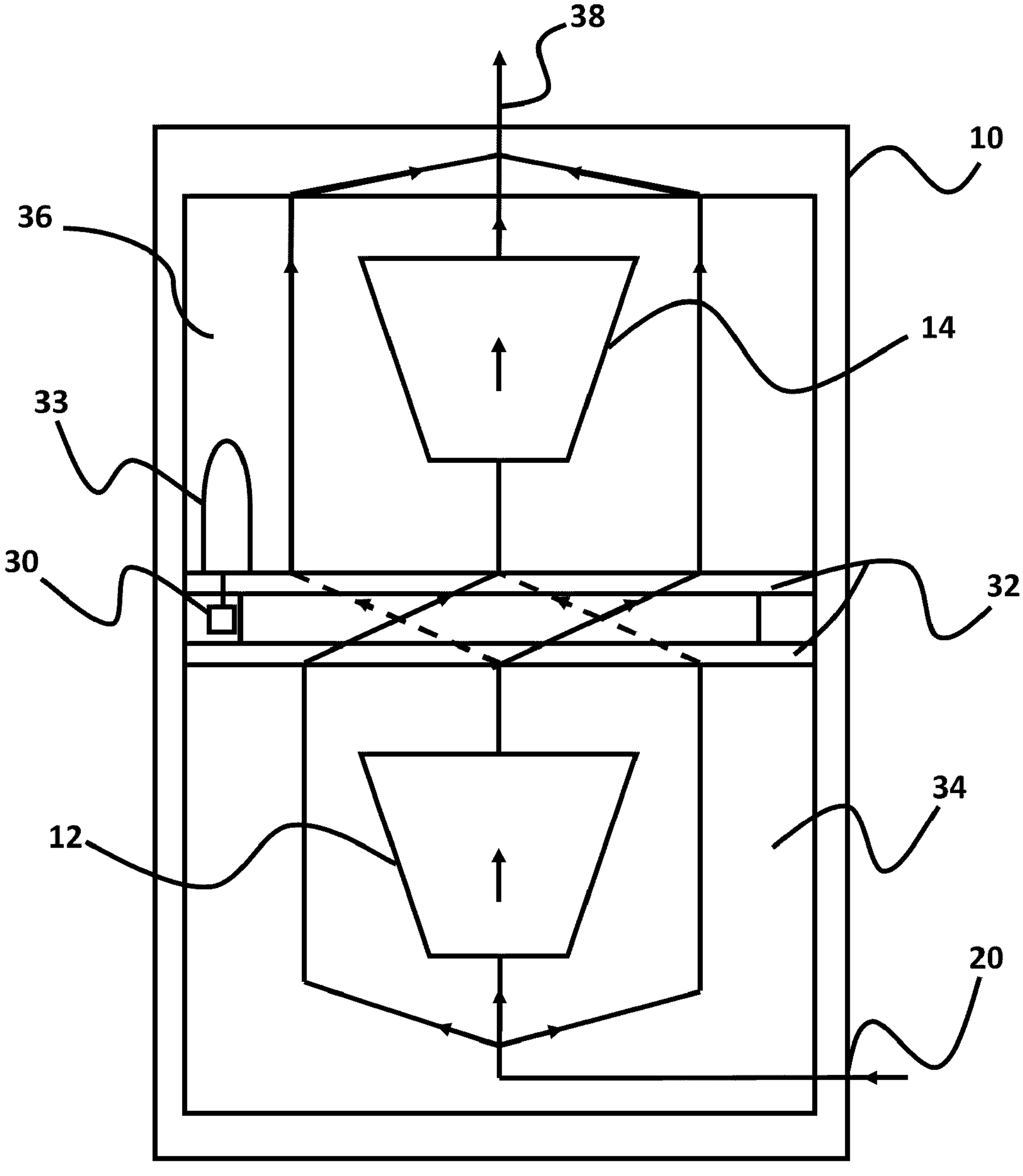


FIG. 2

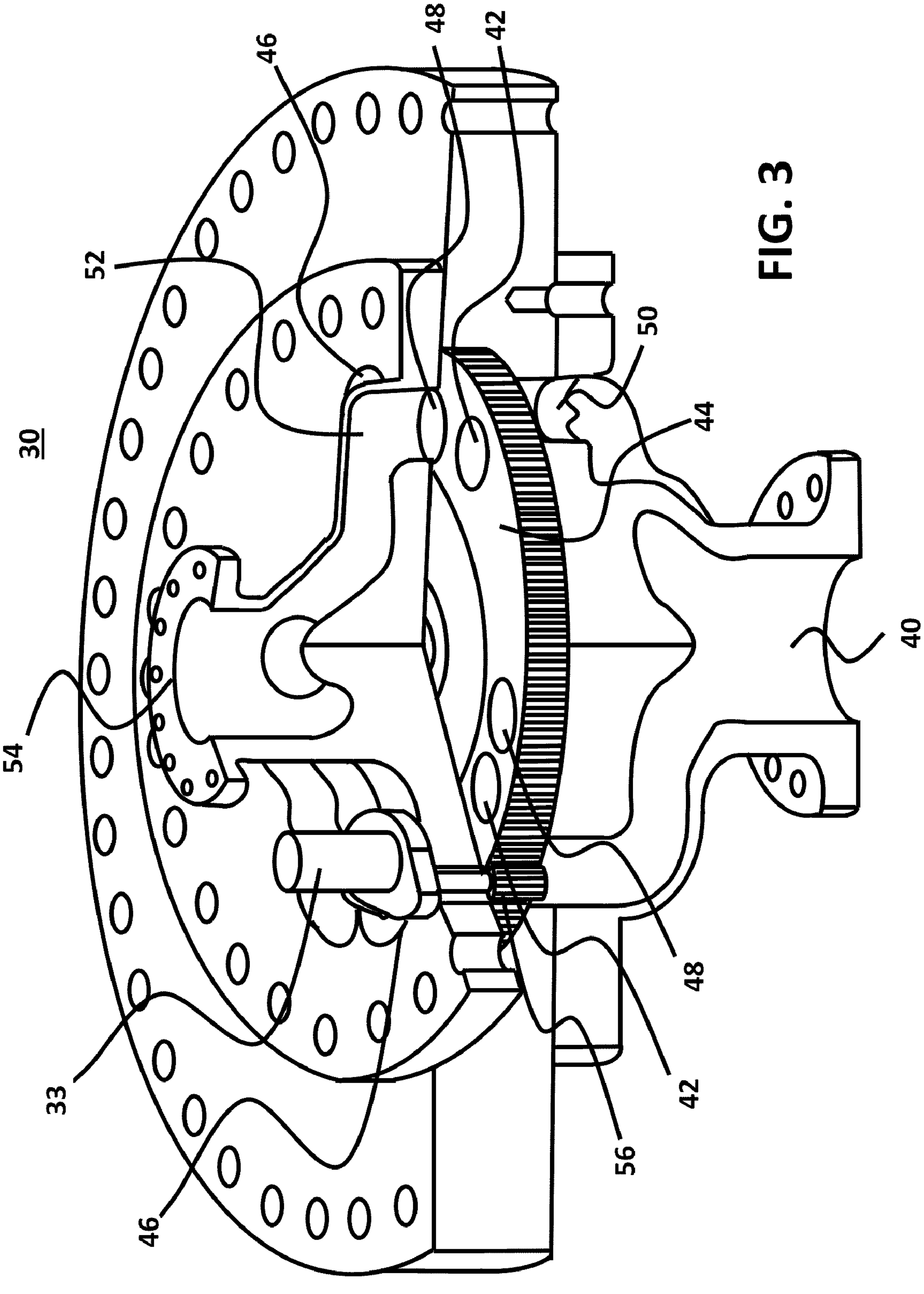


FIG. 3

PARALLEL FLOW CRYOGENIC LIQUIFIED GAS EXPANDERS

CROSS-REFERENCES TO RELATED APPLICATIONS

[0001] This is a utility patent application, taking priority from provisional patent application Ser. No. 61/011,914, filed Jan. 21, 2008, which application is incorporated herein by reference.

BRIEF DESCRIPTION OF THE INVENTION

[0002] The present invention is directed to cryogenic liquefied gas expanders configured within one or more containment vessels with parallel flow through the expanders, where cryogenic fluid enters through a common inlet and is split between a first expander and a second expander, while expanded cryogenic fluid is generated by both expanders and exits through a common outlet. Parallel flow between the liquefied gas expanders is further facilitated by a rotary control valve positioned either between the vessels or within a vessel and between the two liquefied gas expanders.

STATEMENT AS TO THE RIGHTS TO INVENTIONS MADE UNDER FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0003] Not Applicable.

REFERENCE TO A "SEQUENCE LISTING," A TABLE, OR A COMPUTER PROGRAM LISTING APPENDIX SUBMITTED ON A COMPACT DISK

[0004] Not Applicable.

BACKGROUND OF THE INVENTION

[0005] Cryogenic liquids are liquefied gases that are maintained in their liquid state at very low temperatures, typically below −150° C. or −238° F. Different cryogens become liquids under different conditions of temperature and pressure. Industrial facilities that produce, store, transport and utilize such gases make use of a variety of valves, pumps and expanders to move, control and process the liquids and gases. For example, Joule-Thomson (J-T) expansion valves are frequently used to reduce pressure within a system carrying liquefied natural gas (LNG). While J-T valves are important, they have limited value in comparison to certain types of liquefied gas expanders, which are able to reduce pressure while also reducing the enthalpy of the natural gas and generating work. For example, turbine expanders are able to reduce pressure and create rotational momentum that generates shaft torque (which reduces enthalpy). The shaft torque is then used by a generator to produce electrical power.

[0006] Hence, turbine expanders are frequently used to expand liquefied gas from a high pressure to a low pressure, while capturing energy generated by the expansion. In this manner, single-phase LNG expanders are used to enhance the performance of LNG liquefaction plants. Two-phase LNG expanders are further used to reduce liquefaction costs and increase production, which has the positive benefit of extending the lifetime of depleting gas fields by generating more usable liquid from the field.

[0007] When liquefied gas expanders are used in new plants, the new plant will require less power generation and smaller gas compressors, gas expanders and heat exchangers. When used in new or existing plants with pre-existing power generators, gas compressors, gas expanders and heat exchangers, the addition of liquefied gas expanders will increase LNG production. The value and importance of cryogenic liquefied gas expanders, and their various applications is disclosed in the presentation entitled "Comprehensive Applications for LNG Expanders," Joel V. Madison, Sixth World LNG Summit, Nov. 30, 2005, Rome, Italy, which is incorporated in its entirety herein by reference. International Publication Number WO/2007/148122 further discloses an LNG plant and the various manners in which expanders can be used therein, which is incorporated in its entirety herein by reference.

[0008] The publication and corresponding presentation entitled "Transient Characteristics of Two-Phase LNG Expanders," Finley et al., American Institute of Chemical Engineers (AIChE) Spring National Meeting 2007, 7th Topical Conference on Natural Gas Utilization, Apr. 22-26, 2007, Houston, Tex., which are incorporated in their entirety herein by reference, provide an explanation of how different types of liquefied gas expanders are used in LNG production. In particular, this publication and presentation discuss how the loss of power in one expander and certain transient characteristics and no-load conditions of expanders can be addressed through the use of a single-phase expander in series with a two-phase expander within a single vessel. United States Publication Number 2008/0122226, which is incorporated in its entirety herein by reference, also discloses the use of multiple expanders within a single vessel, but the expanders are used for distinctly different purposes and are neither in series nor in parallel.

[0009] The application of a single two-phase LNG expander in parallel with multiple Joule-Thomson (J-T) expansion valves within an overall LNG plant design is disclosed in the publication entitled "Two-Phase LNG Expanders," Kociemba et al., Gas Processors Association-GTL and LNG in Europe, Feb. 24-25, 2005, Amsterdam, The Netherlands, which is incorporated in its entirety herein by reference. The application demonstrated in this publication, however, is more reflective of the standard practice of placing a J-T valve in parallel with an expander to take the place of the expander should there be a need to shut the expander down temporarily.

[0010] When considering the modification of existing (in particular) LNG plant installations, the cost, size and construction impact of any modification, such as adding an expander, are major factors. Furthermore, while the addition of expanders may make it possible to increase flow capacity, increased flow capacity has historically required the size of the expanders to be increased and therefore the size of the vessels holding the expanders, as well as the passages and the diameter of the generators to be increased. In order to increase the diameter of current generators, the generator would have to be four pole, versus current two pole generators, which would significantly increase the size of the generators, while decreasing their efficiency, and significantly complicating the hydraulic component design, thereby further increasing costs.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

[0011] FIG. **1** is a diagrammatic view of a single vessel containing two expanders configured to operate in parallel flow through operation of two external valves;

[0012] FIG. **2** is a diagrammatic view of a single vessel containing two expanders configured to operate in parallel flow through operation of a rotary control valve;

[0013] FIG. **3** is a partial cross-sectional view of a rotary control valve in accordance with the present invention;

[0014] FIG. **4** further illustrates the rotary control valve of FIG. **3** when the passages to both the lower expander and the upper expander are open;

[0015] FIG. **5** further illustrates the rotary control valve of FIG. **3** when the passages to the lower expander are open and the passages to the upper expander are closed;

[0016] FIG. **6** further illustrates the rotary control valve of FIG. **3** when the passages to both the lower expander and the upper expander are closed;

[0017] FIG. **7** further illustrates the rotary control valve of FIG. **3** when the passages to the lower expander are closed and the passages to the upper expander are open; and

[0018] FIG. **8** is a cross-sectional view of the multiple expander vessel of FIG. **2** further illustrating operation of the rotary control valve of FIG. **3** and the interaction between the expanders within the vessel.

DETAILED DESCRIPTION OF THE INVENTION

[0019] The present invention is directed to cryogenic liquefied gas expanders, and more particularly to two liquefied gas expanders (herein referred to as "expanders") operating in parallel within one or more containment vessels with parallel flow through the expanders. As noted above, it is known to use single-phase or two-phase expanders (both a type of liquefied gas expander), by themselves or within a single vessel, to enhance the performance of cryogenic plants and facilities. Expanders are also used in series and in parallel, where the physical arrangement is in parallel (meaning the expanders are physically located next to one another) and the flow through the expanders is in parallel. While the use of multiple expanders has its benefits, additional or different benefits are possible if expanders are used in parallel in a more compact physical arrangement, such as within a single vessel or in a serial physical arrangement, with parallel flow between the expanders. In particular, a serial arrangement, parallel flow design allows for a higher flow capacity without increasing the size of the expanders, the size of the vessel(s), the size of the passages, or the diameter of the generators, thereby eliminating the need for a larger four pole generator. A serial arrangement, parallel flow design also reduces the cost of the expanders (overall), reduces space requirements and reduces disruption of the LNG plant for installation and maintenance.

[0020] In addition, the parallel flow design of the present invention increases operational flexibility. With two expanders operating in parallel within one or more vessels, and through utilization of the rotary control valve discussed below, the range of flow and head that the expanders can operate in is much larger than is possible with a single expander or multiple expanders, running in series or otherwise. For example, in a single or multi-expander design, to turn down flow by some percentage, the operating capacity of the expander(s) must be turned down by a corresponding percentage. Running such expanders at less than 100% or near full capacity, however, compromises the efficiency of the expanders and turning them down by as much as 50% renders the expander(s) inoperable. With the parallel flow design of the present invention, a fifty percent turndown is possible by simply not running one of the expanders and other percentage variations are possible through use of the control valves to selectively restrict flow through the expanders, as further described below.

[0021] As partially noted above, the serial arrangement, parallel flow design of the present invention is also much more compact than prior art designs with similar capacity. This is because the common inlet (for unexpanded cryogenic fluid) and outlet (for expanded cryogenic fluid) of the two expanders, as further illustrated below, reduces the amount of piping that is required and allows two expanders to operate within the space of approximately one expander. Since size, construction impact, and cost are all major factors in expander integration, this new design provides an attractive alternative to prior art designs that can be easily installed in both existing and new liquefaction plants. The novel rotary control valve of the present invention further enhances the compactness and operational flexibility of the design by eliminating the need for external control valves, as further explained below.

[0022] FIG. **1** provides a simplistic diagrammatic illustration of a single vessel **10** containing an expander **12** in a first chamber **13** and an expander **14** in a second chamber **15**, with the expanders **12** and **14** configured to operate in parallel flow through operation of two external valves **16** and **18** and passageways **17** and **19** between the first chamber **13** and the second chamber **15**. Cryogenic fluid entering the vessel **10** at point **20** would be split within the vessel **10**, with approximately half of the fluid being directed to expander **12** and half to expander **14**. The passageways **17** and **19** can either be formed by a natural divider **22** created between the two chambers **13** and **15** by the vessel **10**, as shown in FIG. **1**, or by positioning a plate or disk (not shown in FIG. **1**) between the two chambers **13** and **15**.

[0023] The plate or disk of the divider **22** would create the passageways **17** and **19** and could be bolted between the two chambers **13** and **15**, or welded, or both bolted and welded, so as to form a seal between the two chambers **13** and **15**. Technically, the two chambers **13** and **15** could be separate vessels that are joined together by the divider **22** to form a single vessel, so references to a single vessel, herein, are understood to include two vessels operating as a single vessel, and references to chambers are understood to include separate vessels joined together to effectively form a single vessel. The plate or disk between the chambers or vessels would be formed of stainless steel or some other similarly suitable material. The divider **22** and passageways **17** and **19** could be structured in such a way as to look very much like the plate **44** and accompanying passages of the rotary valve illustrated in FIG. **3** when positioned so as to enable flow between both chambers at the same time. Unlike the rotary valve, however, where plate **44** (shown in FIG. **3**) can be turned to create multiple different flow scenarios, as further described below, the divider **22** would be stationary at all times and only permit full flow between the two chambers **13** and **15**. The expanders utilized in any of the various configurations described herein could be single-phase liquefied gas expanders or two-phase liquid-vapor expanders that expand liquid or liquid and vapor, respectively, from high pressure to lower pressure, as well as fixed speed expanders or variable speed expanders, as further explained below.

[0024] To regulate the parallel flow between the two expanders **12** and **14**, external, independently operated valves **16** and **18** are utilized. When both valves **16** and **18** are open, fluid flows through expanders **12** and **14** along the illustrated paths. When valve **16** is open, but valve **18** is closed, fluid only flows through expander **12**. When valve **16** is closed and valve **18** is open, fluid only flows through expander **14**. The combination of valves and expander allows the careful control of the expanders **12** and **14** within the vessel **10**. Further flexibility is possible by partially opening/closing the valves **16** and **18** to control the flow through each expander. This aspect of the present invention makes it possible to control the flow through both variable speed and fixed speed expanders, without having to adjust the speed at which the expanders operate (something which, of course, was not possible with a fixed speed expander).

[0025] Although FIG. **1**, and FIG. **2** below, illustrate cryogenic fluid flowing through the vessels and expanders in a particular direction, known as upward flow, the direction of flow of the cryogenic fluid is not central to the present invention. Fluid could flow in the direction illustrated, or the opposite direction, referred to as downward flow, without departing from the intent of the present invention.

[0026] Further while the present invention is illustrated in the Figures of the drawing as a single vessel, multiple vessel configurations are possible as well. In such instances, one expander would be located within a first vessel and a second expander would be located within a second vessel, with passageways formed between the two vessels so that expanded fluid created by the first expander is routed to the second vessel and around the outside of the second expander and unexpanded fluid in the first vessel is routed to the second expander in the second vessel. To route the fluid appropriately between the two vessels, pipes could be utilized to route the unexpanded fluid and the expanded fluid as necessary, a plate or disk as described above could be positioned between the two vessels, or a rotary valve of the type described below could be positioned between the two vessels. The key is that all of the unexpanded fluid enters through the same vessel inlet with some of the unexpanded fluid in the first vessel being routed to the second vessel at the same time that expanded fluid from the first vessel is routed to the second vessel and out through a common vessel outlet, so that fluid flow between the two vessels is in parallel, regardless of the physical arrangement between the vessels or expanders. This enables vessels to be positioned in a serial arrangement while operating in parallel, versus being positioned in parallel and operating in parallel, which requires significantly more space and is not practical in many installations.

[0027] One drawback to the embodiment illustrated in FIG. **1** is the external nature of the valves **16** and **18**. Because cryogenic fluid will be running through the valves as soon as they are turned on, the valves must be kept at cryogenic temperatures so they are always ready for use, which adds expense and requires more space. The motor used to run such valves are also expensive and must be explosion rated to prevent any form of industrial accident. Likewise, any external equipment cannot leak to the environment given the nature and temperature of the fluids flowing through them. These issues could be mitigated if it were possible to internalize (within the same vessel(s) as the expander) the valves and motors required to operate the valves.

[0028] Accordingly, FIG. **2** discloses a structure similar to that of FIG. **1**, but in this preferred embodiment of the present invention, instead of two external valves being utilized, and additional passageways between the two chambers, a single rotary valve is used to direct fluid through one or both of the expanders, thereby further compacting the design, saving more space and cost, and reducing issues associated with externalized equipment. For example, utilization of a cryogenically submerged motor to operate a valve removes the requirement of making the motor explosion proof and makes motor or valve leakage inconsequential. As illustrated in FIG. **2**, the vessel **10** contains the two expanders **12** and **14** and a single rotary control valve **30** positioned in-between as a divider. As illustrated in FIG. **2**, two seals **32**, positioned on either side of the valve **30**, seal the valve **30** between the expanders **12** and **14** and create two sealed chambers **34** and **36** within the vessel **10**, but seals are not required and two vessels could be used in place of a single vessel with two chambers. A cryogenic submerged motor **33** is positioned within chamber **36** to operate the rotary control valve **30**, as further illustrated with respect to FIG. **3** below.

[0029] As noted above, in place of seals **32** between the valve **30** and the two chambers **34** and **36** (seals can pose issues at cryogenic temperatures anyway), it may be desirable to use the valve **30** as a form of divider and seal itself, especially since chamber **36** will be at a lower pressure than chamber **34**. Making a portion of the plate **44** (discussed below with respect to FIG. **3**) out of TEFLON like material (that is not affected by the temperatures within the vessel **10**) will also help to seal the two chambers **34** and **36**. While this may allow some leakage between the two chambers **34** and **36**, it would be small and therefore not a major issue, and the cryogenic fluid would still be retained within the vessel **10**. This is also the case with respect to the embodiment of FIG. **1**, where seals between the two chambers containing the expanders within the vessel **10** are not significant.

[0030] Returning to the embodiment illustrated in FIG. **2**, fluid entering the first chamber **34** of the vessel **10** at single point **20** is split within the vessel **10**, with approximately half of the fluid entering expander **12** and the other half going around the outside of expander **12**. Fluid exiting expander **12** is then directed by valve **30** to the portion of the second chamber **36** of the vessel **10** outside of expander **14**, while fluid flowing around the outside of expander **12** is directed by valve **30** to the input of the second expander **14**. Fluid exiting expander **14** and flowing around expander **14** come together at the single output **38** of the vessel **10**.

[0031] The rotary control valve **30** is further illustrated in FIG. **3**, which provides a partial cross-sectional view of the valve **30**. Intake assembly **40** to the valve **30** is bolted to the output assembly (not shown in FIG. **3**) of expander **12**. When a first set of passages **42**, formed in a plate **44** of the valve **30**, are aligned with the channels **45** (as shown in FIG. **4**) of the intake assembly **40**, the output fluid of expander **12** is directed to the outlet ports **46** so as to flow around the outside of expander **14**. When a second set of passages **48** formed in the plate **44** are aligned with the inlet ports **50**, vessel input fluid flowing around the outside of expander **12** is routed to the intake passages **52** of the intake assembly **54** of expander **14**. To control the flow of fluid through the expanders **12** and **14**, the motor **33** rotates a toothed gear **56** that engages the teeth of the plate **44** and rotates the plate **44** to the left or right. The plate **44** effectively operates like a sliding gate that opens or closes the flow passages or passageways at the crossing point between the seals of the two chambers **34** and **36**.

[**0032**] The operation of the rotary valve **30** is further illustrated with reference now to FIGS. **4**-**7**. In FIG. **4**, the plate **44** is positioned so that first set of passages **42** are aligned over the channels **45** of the intake assembly **40** so that fluid can flow out of the expander **12**. Likewise, the second set of passages **48** are aligned over the intake passages **52** of the intake assembly **54** so fluid can flow into expander **14**. In FIG. **5**, the plate **44** has been rotated to the left so that the second set of passages **48** are now aligned over the channels **45** of the intake assembly **40**, thereby leaving expander **12** open, and the first set of passages **42** are blocked, which also closes expander **14** by blocking the intake passages **52** (represented by the dotted circle). FIG. **6** illustrates the plate **44** further rotated to the left, so that the first set of passages **42** and the second set of passages **48** are both closed, thereby blocking the channels **45** and the intake passages **52**, and closing both expanders **12** and **14**. Rotating the plate **44** once more to the left, as illustrated in FIG. **7**, causes the first set of passages **42** to be aligned with the intake passages **52**, thereby opening expander **14**, with the second set of passages **48** and the channels **45** being blocked, thereby closing expander **12**. In addition, as previously noted, the plate **44** can also be partially rotated so as to only partially open/close the flow through the first set of passages **42**, the second set of passages **48**, or both sets of passages, thereby enabling significant operational flexibility.

[**0033**] The interaction between the expanders **12** and **14** and the rotary control valve **30** within the vessel **10** is further illustrated in FIG. **8**. Cryogenic fluid (either in the form of liquid or liquid/vapor) enters through the vessel intake point **20** and enters an interior of the first chamber **34**, where some of the fluid designated by the arrow **60** enters expander **12** (if the expander **12** is on and the valve **30** is open to expander **12**), while the remaining fluid flows around the outside of expander **12**, which is positioned within the first chamber **34**, as designated by the arrow **62** (if the valve **30** to expander **14** is open). The fluid entering the expander **12** is expanded and exits the expander **12**, passes through the valve **30** and enters the interior of the second chamber **36**, where it flows around the outside of expander **14**. The fluid flowing through the interior of the first chamber **34** and around the outside of expander **12** follows the path **62** into the valve **30** and into expander **14**, where it is expanded and exits expander **14** at outlet **30**. The cryogenic fluid output from the expander **12** merges with the cryogenic fluid output from the expander **14** near the common vessel outlet **38**.

[**0034**] While the present invention has been illustrated and described in terms of a preferred embodiment and several alternatives herein in association with the various drawing figures, it should not be limited to just the particular description contained in this specification. For example, the present invention could use a different type of gated valve positioned between the two chambers of the vessel **10**. Many other alternative or equivalent components and steps could be used to practice and be within the scope of the present invention.

What is claimed is:

1. A parallel flow system for expanding a cryogenic fluid, comprising:

a cryogenic vessel having a first chamber into which the cryogenic fluid flows through a vessel inlet, a second chamber from which an expanded cryogenic fluid flows through a vessel outlet, and a divider between the first chamber and the second chamber;

a first expander positioned within the first chamber for receiving a first portion of the cryogenic fluid and producing a first portion of the expanded cryogenic fluid while a second portion of the cryogenic fluid flows through an interior of the first chamber and around an outside of the first expander;

a second expander positioned within the second chamber for receiving the second portion of the cryogenic fluid and producing a second portion of the expanded cryogenic fluid while the first portion of the expanded cryogenic fluid flows through an interior of the second chamber and around an outside of the second expander;

a first passageway within the cryogenic vessel for routing the second portion of the cryogenic fluid from the interior of the first chamber to the second chamber; and

a second passageway within the cryogenic vessel for routing the first portion of the expanded cryogenic fluid from the first chamber to the interior of the second chamber.

2. The system as recited in claim 1, wherein the divider incorporates the first passageway and the second passageway.

3. The system as recited in claim 2, wherein the divider includes a rotary valve.

4. The system as recited in claim 3, wherein the rotary valve includes a rotating plate forming one or more openings therein, one or more passages for routing the first portion of the expanded cryogenic fluid from the first expander to the rotating plate, one or more passages for routing the first portion of the expanded cryogenic fluid from the rotating plate to the interior of the second chamber, one or more passages for routing the second portion of the cryogenic fluid from the first chamber to the rotating plate, one or more passages for routing the second portion of the cryogenic fluid from the rotating plate to the second expander, and a motor for turning the rotating plate, wherein a partial or complete alignment between the one or more openings, the one or more passages for routing the first portion of the expanded cryogenic fluid from the first expander to the rotating plate, and the one or more passages for routing the first portion of the expanded cryogenic fluid from the rotating plate to the interior of the second chamber creates the first passageway, and wherein a partial or complete alignment between the one or more openings, the one or more passages for routing the second portion of the cryogenic fluid from the first chamber to the rotating plate, and the one or more passages for routing the second portion of the cryogenic fluid from the rotating plate to the second expander creates the second passageway.

5. The system as recited in claim 1, further comprising one or more valves for regulating the cryogenic fluid flow and/or the expanded cryogenic fluid flow through the cryogenic vessel, wherein the one or more valves are located outside of the cryogenic vessel.

6. The system as recited in claim 1, wherein the first expander and the second expander are liquefied gas expanders.

7. The system as recited in claim 6, wherein the liquefied gas expanders include one phase expanders, two phase expanders, fixed speed expanders and variable speed expanders.

8. An internally controlled parallel flow system for expanding a cryogenic fluid within a cryogenic vessel, comprising:

the cryogenic vessel having a first chamber into which the cryogenic fluid flows through a vessel inlet and a second chamber from which an expanded cryogenic fluid flows through a vessel outlet;

a first expander positioned within the first chamber for receiving a first portion of the cryogenic fluid and producing a first portion of the expanded cryogenic fluid while a second portion of the cryogenic fluid flows through an interior of the first chamber and around an outside of the first expander;

a second expander positioned within the second chamber for receiving the second portion of the cryogenic fluid and producing a second portion of the expanded cryogenic fluid while the first portion of the expanded cryogenic fluid flows through an interior of the second chamber and around an outside of the second expander; and

a rotary valve positioned within the cryogenic vessel to create the first chamber and the second chamber and to route the second portion of the cryogenic fluid from the interior of the first chamber to the second expander and to route the first portion of the expanded cryogenic fluid from the first expander to the interior of the second chamber, whereby the first portion of the expanded cryogenic fluid and the second portion of the expanded cryogenic fluid merge at the vessel outlet to form the expanded cryogenic fluid.

9. The system as recited in claim 8, wherein the first expander and the second expander are liquefied gas expanders.

10. The system as recited in claim 9, wherein the liquefied gas expanders include one phase expanders, two phase expanders, fixed speed expanders and variable speed expanders.

11. The system as recited in claim 8, wherein the cryogenic vessel has a cryogenic fluid flow capacity, and wherein the cryogenic fluid flow capacity is regulated by fully opening, partially opening or closing the rotary valve.

12. The system as recited in claim 8, wherein the rotary valve includes a rotating plate forming one or more openings therein, one or more passages for routing the first portion of the expanded cryogenic fluid from the first expander to the rotating plate, one or more passages for routing the first portion of the expanded cryogenic fluid from the rotating plate to the interior of the second chamber, one or more passages for routing the second portion of the cryogenic fluid from the first chamber to the rotating plate, one or more passages for routing the second portion of the cryogenic fluid from the rotating plate to the second expander, and a motor for turning the rotating plate, wherein a partial or complete alignment between the one or more openings, the one or more passages for routing the first portion of the expanded cryogenic fluid from the first expander to the rotating plate, and the one or more passages for routing the first portion of the expanded cryogenic fluid from the rotating plate to the interior of the second chamber permits the expanded cryogenic fluid to flow between the first expander and the interior of the second chamber, and wherein a partial or complete alignment between the one or more openings, the one or more passages for routing the second portion of the cryogenic fluid from the first chamber to the rotating plate, and the one or more passages for routing the second portion of the cryogenic fluid from the rotating plate to the second expander permits the cryogenic fluid to flow between the interior of the first chamber and the second expander.

13. The system as recited in claim 12, wherein the rotary valve further includes a toothed gear driven by the motor, and wherein the rotating plate includes a series of teeth around a circumference for engaging with the toothed gear to turn the rotating plate.

14. The system as recited in claim 12, wherein the motor is a cryogenically submerged motor positioned within the cryogenic vessel.

15. The system as recited in claim 12, wherein at least a portion of the rotating plate is formed of a Teflon-like material.

16. The system as recited in claim 12, wherein the cryogenic vessel includes one or more seals between the first chamber and the second chamber.

17. A rotary valve for use within a cryogenic vessel for routing cryogenic fluid between a first chamber and a second chamber of the cryogenic vessel, comprising:

a rotating plate forming one or more openings therein;

a first set of one or more passages for routing cryogenic fluid from a first portion of the first chamber to a first portion of the second chamber;

a second set of one or more passages for routing cryogenic fluid from a second portion of the first chamber to a second portion of the second chamber;

a gear for engaging the rotating plate and turning the rotating plate in a desired direction; and

a motor for driving the gear and causing the one or more openings to fully or partially align with the first set of one or more passages and/or the second set of one or more passages to control a flow of the cryogenic fluid between the first chamber and the second chamber.

18. The rotary valve as recited in claim 17, wherein the one or more openings are fully or partially aligned with only the first set of one or more passages to route the cryogenic fluid between the first portion of the first chamber and the first portion of the second chamber, and wherein the one or more openings are not aligned with the second set of one or more passages to prevent the cryogenic fluid from being routed between the second portion of the first chamber and the second portion of the second chamber.

19. The rotary valve as recited in claim 17, wherein the one or more openings are fully or partially aligned with only the second set of one or more passages to route the cryogenic fluid between the second portion of the first chamber and the second portion of the second chamber, and wherein the one or more openings are not aligned with the first set of one or more passages to prevent the cryogenic fluid from being routed between the first portion of the first chamber and the first portion of the second chamber.

20. The rotary valve as recited in claim 17, wherein the one or more openings are fully or partially aligned with the first set of one or more passages to route the cryogenic fluid between the first portion of the first chamber and the first portion of the second chamber, and wherein the one or more openings are fully or partially aligned with the second set of one or more passages to route the cryogenic fluid from between the second portion of the first chamber and the second portion of the second chamber.

21. The rotary valve as recited in claim 17, wherein the gear includes a plurality of teeth around a circumference for engaging the rotating plate and wherein the rotating plate includes a series of teeth around a circumference for engaging the plurality of teeth of the gear.

22. The rotary valve as recited in claim 17, wherein the motor is a cryogenically submerged motor positioned within the cryogenic vessel.

23. The rotary valve as recited in claim 17, wherein at least a portion of the rotating plate is formed of a Teflon-like material.

24. The rotary valve as recited in claim 17, wherein the rotary valve is positioned between the first chamber and the second chamber and is surrounded by one or more seals between the first chamber and the second chamber.

25. A parallel flow system for expanding a cryogenic fluid, comprising:

a first cryogenic vessel into which the cryogenic fluid flows through a vessel inlet including a first expander for receiving a first portion of the cryogenic fluid and producing a first portion of the expanded cryogenic fluid while a second portion of the cryogenic fluid flows through an interior of the first cryogenic vessel and around an outside of the first expander;

a second cryogenic vessel from which an expanded cryogenic fluid flows through a vessel outlet including a second expander for receiving the second portion of the cryogenic fluid and producing a second portion of the expanded cryogenic fluid while the first portion of the expanded cryogenic fluid flows through an interior of the second cryogenic vessel and around an outside of the second expander;

a first passageway between the first cryogenic vessel and the second cryogenic vessel for routing the second portion of the cryogenic fluid from the interior of the first cryogenic vessel to the second expander; and

a second passageway between the first cryogenic vessel and the second cryogenic vessel for routing the first portion of the expanded cryogenic fluid from the first expander to the interior of the second cryogenic vessel.

26. The system as recited in claim 25, further comprising a rotary valve that incorporates the first passageway and the second passageway.

27. The system as recited in claim 26, wherein the rotary valve includes a rotating plate forming one or more openings therein, one or more passages for routing the first portion of the expanded cryogenic fluid from the first expander to the rotating plate, one or more passages for routing the first portion of the expanded cryogenic fluid from the rotating plate to the interior of the second cryogenic vessel, one or more passages for routing the second portion of the cryogenic fluid from the first cryogenic vessel to the rotating plate, one or more passages for routing the second portion of the cryogenic fluid from the rotating plate to the second expander, and a motor for turning the rotating plate, wherein a partial or complete alignment between the one or more openings, the one or more passages for routing the first portion of the expanded cryogenic fluid from the first expander to the rotating plate, and the one or more passages for routing the first portion of the expanded cryogenic fluid from the rotating plate to the interior of the second cryogenic vessel creates the first passageway, and wherein a partial or complete alignment between the one or more openings, the one or more passages for routing the second portion of the cryogenic fluid from the first cryogenic vessel to the rotating plate, and the one or more passages for routing the second portion of the cryogenic fluid from the rotating plate to the second expander creates the second passageway.

28. The system as recited in claim 25, further comprising one or more valves for regulating the cryogenic fluid flow and/or the expanded cryogenic fluid flow from the first cryogenic vessel to the second cryogenic vessel, wherein the one or more valves are located outside of either the first cryogenic vessel or the second cryogenic vessel.

29. The system as recited in claim 25, wherein the first expander and the second expander are liquefied gas expanders.

30. The system as recited in claim 29, wherein the liquefied gas expanders include one phase expanders, two phase expanders, fixed speed expanders and variable speed expanders.

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