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LIQUEFIED GAS CONVERTER

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2 Sheets-Sheet 1

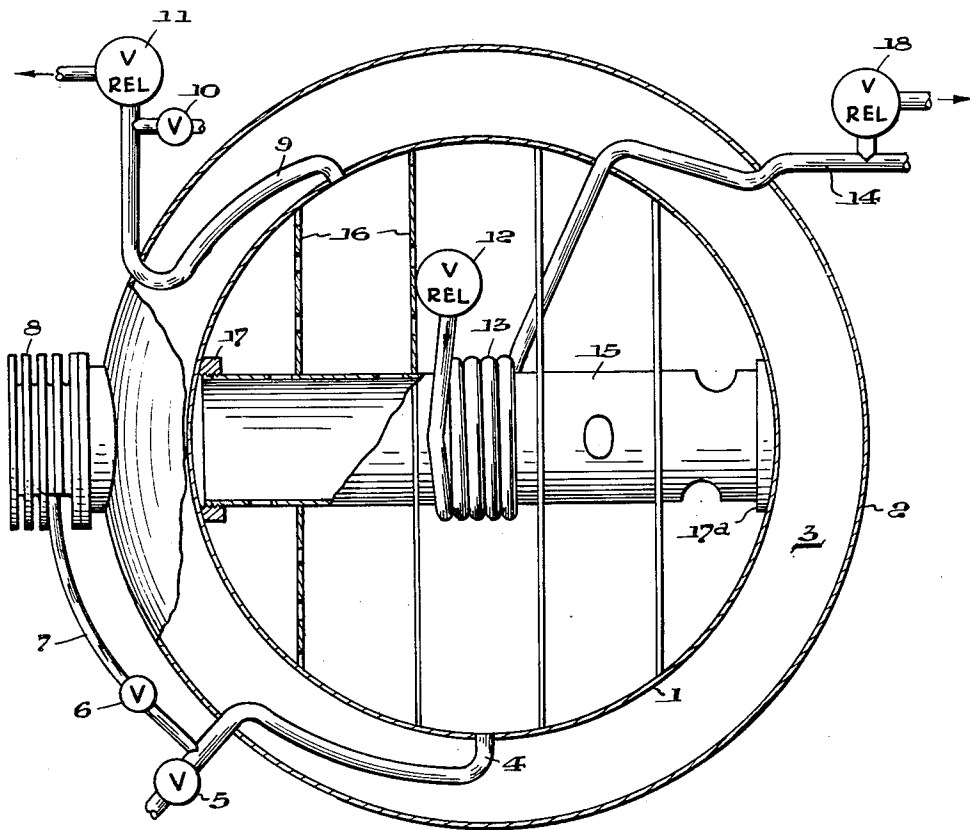


Fig. 1.

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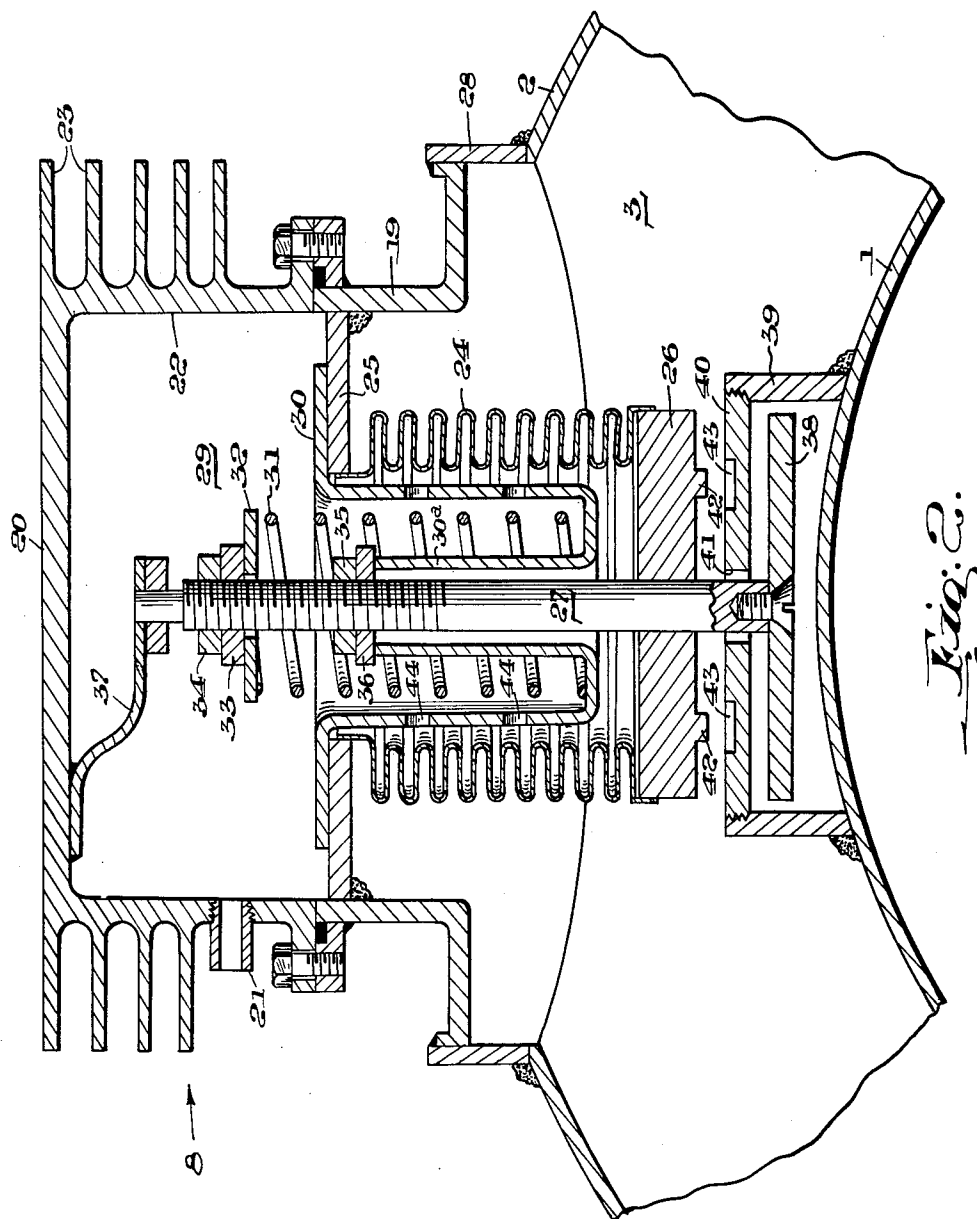
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LIQUEFIED GAS CONVERTER

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3 Claims. (Cl. 62—52)

This invention relates to liquefied gas converters for the storage and evaporation of liquefied gas to provide a fluid supply in the normal gaseous state, and more particularly to liquefied gas converters suitable for use in the substantial absence of gravity.

In order to conserve weight and space it is desirable to store and carry gases having a low critical temperature, such as oxygen and nitrogen, in the liquid phase at a temperature below the critical temperature and generally well below the critical temperature. Generally, the gases are used in the normal gaseous state, as for example, oxygen used for breathing purposes, and it is necessary to evaporate or convert the liquefied gas to the gaseous state for such use. Liquefied gas converters used heretofore have employed an insulated storage container and external heat exchangers to absorb the heat necessary for evaporation of the liquefied gas. These converters depend upon the gravitational separation of the heavier liquid phase from the lighter gas phase to minimize gas losses during storage and to provide a reliable delivery of gas when in operation.

Under storage conditions heat from the surrounding environment is transferred to the storage container and is absorbed causing evaporation of the liquefied gas thus increasing the pressure in the storage container; when the pressure reaches the maximum operating pressure it is necessary to vent the container to reduce the pressure. If only the gas phase is vented, the pressure is reduced with a minimum loss of fluid; if liquid phase is vented much more fluid is lost through venting, e.g. about 37 times as much with liquid oxygen at 120 p.s.i.g., thus severely reducing the effective capacity of the storage container. Under normal gravity conditions the lighter gas phase is always in the upper portion of the storage container, and gas phase only is discharged by simply venting at the top of the container. However, if the converter is subjected to random movements or abnormal gravity conditions such as the substantial absence of gravity, there is no stable location of gas and liquid phases or interfaces; therefore a vent cannot be located at any place on the storage container to discharge only the gas phase.

In operation of prior converters, a valve is opened permitting communication of the liquid and gas phases through an external pressurization heat exchanger connecting the top and bottom of the storage container. Liquid runs by gravity into the heat exchanger, absorbs heat, vaporizes, and thereby pressurizes the storage container. The storage container under pressure delivers liquefied gas from a discharge valve on the bottom of the storage container to a second heat exchanger where the liquefied gas is evaporated. Under conditions of random motion or in the substantial absence of gravity there is no assurance that liquefied gas will enter the pressurization heat exchanger to pressurize the system. Further, the discharge valve cannot be located to deliver only liquid phase to the evaporator heat exchanger. When gas rather than liquid is discharged evaporative cooling within the storage container will reduce the pressure so that the desired supply of gas cannot be maintained.

It is therefore an object of this invention to provide a liquefied gas converter that is suitable for use both under normal conditions and under unusual physical effects such as the substantial absence of gravitational ef-

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fects. A further object is to provide a method of supplying a controlled amount of heat to a liquefied gas converter. Another object is to provide a compact liquefied gas converter.

These and other objects are accomplished according to this invention by a liquefied gas converter in which the fluid held in an insulated storage vessel is discharged through a heat exchanger within the storage vessel, which heat exchanger is of sufficient size to evaporate any liquid entering the heat exchanger thereby discharging the fluid from the converter solely in the gas phase; and by supplying an automatically controlled sufficient amount of heat directly to the storage vessel to convert fluid from the liquid phase to the gas phase at the desired supply rate.

This invention will be described in detail hereinafter with reference to the accompanying drawings in which:

FIG. 1 is a view partly in section, partly in elevation, and partly diagrammatic, of a liquefied gas converter in accordance with this invention; and

FIG. 2 is a sectional view of a heat valve shown generally in FIG. 1.

Referring now to FIG. 1, an inner spherical vessel 1 is supported inside a second larger outer spherical vessel 2 by conventional low heat conductance supports (not shown) forming therebetween an evacuated space 3. The vessels are preferably made of metal, for example, stainless steel, and the inner vessel is adapted to hold a liquefied gas, under pressure. The vessels are spherical or any other convenient shape that is resistant to stresses, and are of suitable thickness to hold the desired pressure. The inner and outer vessels and all connections through or to them and throughout the converter are gas tight preventing leakage outside the desired flow paths indicated.

A conduit 4 leads from the inner vessel 1 to a valve 5 located without the outside vessel 2 and having connections suitable for filling purposes. Conduit 7 connecting conduit 4 and heat valve 8, which is described in detail hereinafter, is valved by on-off valve 6. A conduit 9, leads from the inner vessel, through the outer vessel to a suitable vent valve 10 and emergency pressure relief valve 11. The emergency pressure relief valve opens to discharge the contents of the converter in the event of an emergency pressure rise, as might occur for example with a loss of vacuum insulation caused by rupture of the outer vessel. In filling, valve 6 is closed to prevent liquefied gas from entering heat valve 8 and thereby overfilling the vessel, vent valve 10 is opened to permit filling at atmospheric pressure, and a liquefied gas supply tank is connected to valve 5, generally by a flexible hose having a suitable valve connector. Valve 5 is opened and the liquefied gas is transferred to the inner vessel by pressure transfer. When vent valve 10 begins to pass liquefied gas, valve 5 is closed, valve 10 is then closed and valve 6 is opened. The functions of valves 5, 6, and 10 are conveniently and automatically accomplished by use of a conventional fill valve.

An internal pressure relief valve 12 is located inside the inner vessel 1, and connects through and is supported by metal coil 13 and conduit 14 to a suitable gas receiver or manifold from which gas is withdrawn for use (not shown) and a pressure relief valve 18. The internal relief valve 12 and other relief valves shown, may be of conventional design and are preferably of all metal construction, suitably spring loaded ball relief valves. Relief valve 12 opens when the pressure in coil 13 is a predetermined amount lower than the pressure in inner vessel 1. The coil 13 is wrapped around a tubular metal element 15 having a plurality of annular metal heat transfer fins 16. The tubular element and fins have a plurality of openings to permit free movement of the fluid

through the element and fins within the inner vessel. The tubular element is secured to the inner vessel by collar 17 and ring 17a, both of which are permanently secured, as by welding, to the inner vessel 1. It is preferred to use metals having a high heat conductance, such as aluminum or copper, for the coil, fins, and other heat transfer elements.

The inner vessel is connected through conduits 4 and 7, and valve 6, which is maintained in an open position after filling, to a pressure actuated heat valve 8, which introduces heat to the inner vessel at pressures below a predetermined operating pressure. If it is desired to maintain storage in the converter below operating pressure, the pressure actuated heat valve may be kept in an open position by a separate pressure source. For example, valve 6 remains closed after filling, and the heat valve 8 is pressurized by a separately connected pressure source. The separate pressure source is closed off, and the heat valve remains open. By simply opening valve 6 the heat valve will then close and develop an operating pressure as next described.

After the inner vessel has been filled, the heat valve 8 transfers heat from the outside vessel, environment or other heat source to the inner vessel so long as the pressure in the inner vessel is below a predetermined operating pressure, thereby vaporizing liquefied gas increasing the pressure to the operating pressure within the inner vessel. The internal relief valve 12 maintains a predetermined pressure differential between the inner vessel and the coil 13, so that as the pressure within the inner vessel increases the internal relief valve opens passing fluid through coil 13 and conduit 14 to a gas receiver or manifold for use. Due to the transfer of heat to the coil from the inner vessel by conductance through tubular element 15, and from the bulk fluid in the inner vessel by conductance through fins 16 and tubular element 15, any liquefied gas passed by internal relief valve 12 is evaporated so that only gas phase fluid is discharged from coil 13.

When the inner vessel and thereby the gas supply system have reached the predetermined operating pressure, the heat valve 8 is automatically opened, stopping this supply of heat to the inner vessel. However, heat at a greatly reduced rate continues to pass by radiation and conduction through the supports and connections to the inner vessel. If no gas is withdrawn the pressure within the inner vessel, and thereby the pressure in coil 13 and supply conduit 14, increases slowly due to this residual heat transfer. When a predetermined pressure, higher than the operating pressure but lower than the maximum safe allowable pressure, is reached in conduit 14, pressure relief valve 18 opens to permit sufficient gas to escape to maintain the desired pressure. So long as the converter is in this stand-by condition and no gas is withdrawn, the pressure in the coil 13, conduit 14 and supply system will remain at the pressure set by relief valve 18, and the pressure within the inner vessel will be at a fixed higher pressure as set by internal relief valve 12.

When gas is withdrawn for use from conduit 14, the pressure in coil 13 is reduced; the internal relief valve 12 then opens to maintain the predetermined differential pressure between the inner vessel and the coil. This lowers the pressure in the inner vessel which actuates the heat valve 8; the heat valve is of such a size as to transfer sufficient heat to the inner vessel to maintain the operating pressure while supplying gas. If desired, a plurality of heat valves may be used.

In all phases of operation, that is, during pressure buildup, standby, or when supplying gas, all the fluid discharged from coil 13 is in the gas phase due to the heat transferred to the coil, regardless if liquid phase fluid is passed through internal relief valve 12 to the coil. The coil, or other internal heat exchanger preferably has sufficient heat transfer area to transfer heat

at least equal to the heat of vaporization of the entire designed supply rate. Thus, there is a minimum loss of fluid during standby or storage and the pressure in the inner vessel responds immediately to the removal of gas and thus immediately actuates the heat valve to supply the additional heat needed for converting liquefied gas to a gaseous supply.

A certain portion of heat is transferred to coil 13 by conduction from the inner vessel through tubular element 15, evaporating some liquid phase fully introduced to the coil. This net effect of this is the same as though gas phase fluid was passed by internal relief valve 12 to the coil. When liquid is passed into the coil, a portion of the liquid is evaporated due to the lower pressure in the coil. The latent heat of vaporization comes from the remaining liquid in the coil, thereby lowering its temperature to the new boiling point at the lower temperature. This liquid is then at a temperature lower than that of the bulk fluid in the inner vessel 1 and is evaporated by heat transferred from the warmer bulk fluid via fins 16 and tubular element 15 as well as directly to the coil. The net result of this heat removal from the bulk fluid is the condensation of vapors in the inner vessel, which lowers the pressure in the inner vessel and thereby actuates the heat valve. The heat valve supplies heat to the inner vessel which is transferred to the bulk fluid in the inner vessel primarily from the inner wall of the vessel and partly from the heat transfer fins thus evaporating more liquid and increasing the pressure to the desired operating pressure to satisfy further demand for gas supply. As is apparent to those skilled in the art, heat may be transferred to provide solely gas phase discharge by arrangements other than that described; for example, an extensive coil with sufficient area to transfer heat directly from the bulk fluid in the vessel to the coil may be used rather than the heat transfer fins.

A preferred method of supplying heat directly to the inner vessel is a heat valve which provides a heat conducting path from the outer vessel and the surrounding environment which is opened or closed in response to the pressure within the inner vessel.

Referring now to FIG. 2, the heat valve 8, shown in a pressure actuated open position for clarity, comprises a housing 20 consisting of a flanged metal collar 19, and a flanged metal cap 22, having a plurality of heat transfer fins 23 is removably secured to said collar 19. An annular support disc 25 is secured to the inside of collar 19. A bellows 24 is secured at one end to support disc 25 and at the other end to end plate 26. A metal valve stem 27 passes through and is secured to end plate 26. Metal ring 28 is secured to the outer vessel 2 and collar 19, thus totally sealing the insulating vacuum space 3 from the gas tight chamber 29 formed by the collar, cap, support disc, valve stem, and bellows members. Chamber 29 has a connection or fluid inlet 21 adapted to receive a conduit which connects into the inner vessel 1 as is shown in FIG. 1. A well member 30 supported by disc 25 provides a fixed support for spring 31 which is adjustably compressed between the well member and a compression washer 32, thereby applying a force to close the valve; the compression is adjusted by nut 33 and lock nut 34. The inner tube 30a of the well member is a stop for nut 36 and lock nut 35 which adjustably limits the travel of the valve stem to prevent contact with the inner vessel 1. A flexible metal heat conductor 37 is soldered or otherwise secured at one end to the outer end of valve stem 27, and at the other end to the valve cap 22. A valve head disc 38 is secured to the other or inner end of the valve stem. A threaded metal collar 39 is secured to inner vessel 1 and is adapted to receive a threaded metal valve seat formed as an annular disc 40 which has a central opening 41 of sufficient diameter to provide clearance for free passage of the valve stem,

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whereby no heat path is formed between the stem and the valve seat.

In the assembly of the heat valve, an assembly unit is made up of collar 19, support disc 25, bellows 24, bellows end plate 26, and valve stem 27. The valve stem is placed through the opening 41 in valve seat 40, and valve head 38 is secured to the end of the valve stem. A plurality of lugs 42 on the bellows end plate 26 engage a plurality of cavities 43 in contacting disc 40 when the assembly unit is displaced in position toward the inner vessel; the assembly unit can thus be used as a wrench to engage and tighten valve seat 40 to ring 39. When the contacting plate is secured, metal collar 19 is secured in proper position to ring 28 completing the assembly of parts within and sealing the insulating vacuum space 3.

When closed (shown open in FIG. 2), the heat valve provides a high heat conductance path from the ambient or external environment to the inner vessel via cap 22, flexible conductor 37, valve stem 27, valve head 38, valve seat 40, and ring 39. The cap 22 acts as a collector of heat from the ambient, as does the outer vessel itself. These parts are all preferably made of high conductance metals such as aluminum, copper, or the like, and all connections including screw connections are made in a manner to minimize resistance to heat flow, e.g. by soldering, welding or the like; the heat conductor 37 may be a metal strip or most conveniently a braided metal cable. The valve head and seat are preferably of silver and the contacting surfaces are polished optically flat to provide a minimum resistance to heat flow.

In operation, the spring 31 forces valve head 38 against valve seat 40, compressing bellows 24 and closing the heat transfer path. Heat is transferred to the inner vessel and thereby increasing the pressure therein; a conduit opening into the inner vessel and into chamber 29 through connection 21 equalizes the pressure in the inner vessel and chamber. The pressure in chamber 29 acts against the bellows end plate through a plurality of openings 44 in well member 30. When operating pressure is reached the force on the bellows end plate is sufficient to overcome the force of the spring; the spring is compressed, the bellows expanded, and valve head 38 is disengaged from seat 40, opening the heat transfer path.

Other methods of transferring heat to the bulk fluid in the inner vessel are contemplated by the invention, for example, a pressure actuated electrical heater heating the outside wall of the inner vessel, or a pressure actuated electrical heater within the inner vessel, directly heating the contained fluid.

According to the provisions of the patent statutes, I have explained the principle of my invention and have illustrated and described what I now consider to represent its best embodiments. However, I desire to have it understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically illustrated and described.

I claim:

1. A liquefied gas converter comprising an inner vessel adapted to contain fluid under pressure and spaced within an outer vessel, forming therebetween an evacuated insulating space, a pressure relief valve within said inner vessel, a coiled conduit within said inner vessel and in communication at one end with said pressure relief valve and at the other end with fluid conducting means extend-

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ing outside said outer vessel, said pressure relief valve being responsive to a pressure differential between the pressure in said inner vessel and a lower pressure in said coiled conduit, a perforated tube having perforated fins secured within and to said inner vessel and contacting said coiled conduit; a heat valve comprising a chamber connected to said outer vessel and hermetically sealed from said insulating space, said chamber being spaced from said inner vessel, fluid conduit means connecting said chamber with said inner vessel, a heat conducting valve seat connected to said inner vessel and spaced from said chamber and from said outer vessel, a reciprocally movable valve stem attached to said chamber and extending into said insulating space, a pressure responsive means connected to said chamber responsive to the pressure therein and connected to said valve stem for reciprocal actuation thereof, said valve stem being in heat conducting communication with said chamber, a valve head attached to said stem and engaged in heat conducting relationship with said seat, said pressure responsive means reciprocally moving said head to disengage said seat when the pressure in said chamber increases.

2. A liquefied gas converter comprising an inner vessel adapted to contain fluid under pressure and spaced within an outer vessel forming therebetween an insulating space, a pressure relief valve within said inner vessel, a conduit within said inner vessel and in communication at one end with said pressure relief valve and at the other end with fluid conducting means extending outside said outer vessel, said pressure relief valve being responsive to a pressure differential between the pressure in said inner vessel and a lower pressure in said conduit, a heat transfer surface entirely within said inner vessel and in direct heat conducting relationship with said inner vessel and said conduit, and a heating means connected to said inner vessel and responsive to the pressure therein, said heating means being operative to supply heat to said inner vessel and becoming inoperative when the pressure in said inner vessel increases.

3. A liquefied gas converter comprising an inner vessel adapted to contain fluid under pressure and spaced within an outer vessel forming therebetween an insulating space, a pressure relief valve within said inner vessel, a conduit within said inner vessel and in communication at one end with said pressure relief valve and at the other end with fluid conducting means extending outside said outer vessel, said pressure relief valve being responsive to a pressure differential between the pressure in said inner vessel and a lower pressure in said conduit, a perforated tube secured within said inner vessel and in heat conducting relationship with said inner vessel and said conduit, a plurality of perforated fins secured to and in heat conducting relationship with said tube, and a heating means connected to said inner vessel and responsive to the pressure therein, said heating means being operative to supply heat to said inner vessel and becoming inoperative when the pressure in said inner vessel increases.

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