

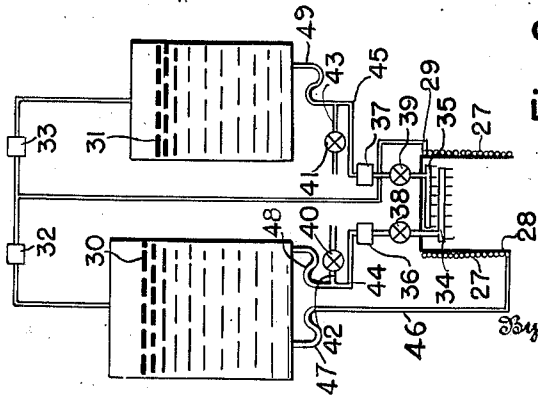
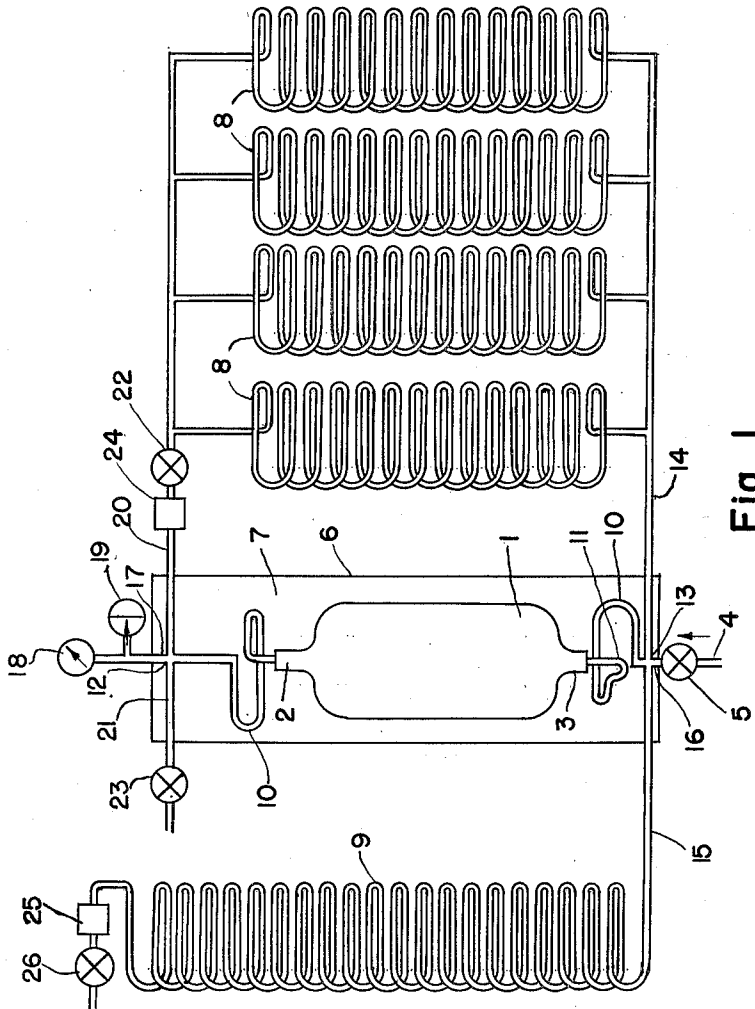
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HIGH-PRESSURE LIQUID OXYGEN CONVERTER

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HIGH-PRESSURE LIQUID OXYGEN
CONVERTER

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This invention relates to liquid oxygen converters and more especially to apparatus for charging high-pressure oxygen cylinders from a source of liquid oxygen.

The object of the present invention is to devise apparatus whereby to charge high-pressure oxygen cylinders from a liquid oxygen source in a most expeditious and efficient manner.

Another object is to devise apparatus whereby liquid oxygen and other liquid fuel can be delivered at high pressures to evaporators or combustion chambers in jet motors, rockets and the like.

Another object is to include in an apparatus for charging high-pressure oxygen cylinders, a container, a conduit with a control valve between the bottom of said container and the source of liquid oxygen, a pressure build-up coil connected between the top and bottom of said container and a warming coil connected to the bottom of said container for delivery of gaseous oxygen at high pressure to one or more oxygen cylinders, said coils being exposed to the atmosphere and of suitable length and capacity to permit sufficient absorption of heat at the desired rate to permit rapid and efficient operation.

Another object is to construct a self-contained liquid oxygen converter apparatus, comprising an insulated container tapped at the top and bottom, a pressure build-up coil between said taps, a pressure-closing valve in said coil, an evaporator coil connected to the lower tap, said coils being spiralled about and suitably spaced from each other and from the container for maximum absorption of atmospheric heat, and a flow control means at the end of said evaporator coil.

Another object in this construction is to devise a liquid oxygen converter which will take liquid oxygen and start charging high-pressure oxygen cylinders at 1800 pounds per square inch within a few minutes after filling the converter, and in which the charging may be interrupted at any time and the apparatus allowed to sit idle for several hours before any loss occurs from relief of excess pressure.

These objects are accomplished by making use of non-equilibrium conditions of density in a pressure build-up circuit, wherein the gravitational or accelerational pressure due to liquid in the descending part of the circuit forces gas formed by evaporation of the liquid in an evaporator to rise in the ascending part of the circuit and to be compressed in a space above the liquid thus increasing the pressure throughout the entire system. Advantage is taken of the relative

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ease of maintaining temperature gradients in liquid oxygen, due to its rapid change of density with temperature, to obtain very high pressures quickly without warming the mass of liquid to be delivered. The gas compressed over the liquid by reason of gravitational circulation in the pressure build-up circuit partially condenses on the surface of the liquid forming a hot layer with a surface temperature corresponding to a vapor pressure approximately equal to the actual pressure in the system.

This mode of operation is the same as described in my copending applications Serial No. 647,411, filed February 13, 1946, on Liquid Oxygen Converters and Serial Number 645,692, filed February 5, 1946 on Liquid Oxygen Converters.

Other and more specific objects will appear in the following detailed description of one form of the apparatus which was built in accordance with this invention, having reference to the accompanying drawings in which:

Fig. 1 illustrates diagrammatically the combination of parts of the present embodiment of the apparatus exemplifying one preferred form of the invention; and

Fig. 2 shows one specific application of the present invention used in connection with rockets or the like.

Referring to Fig. 1, the container is shown at 1, and has upper and lower taps 2 and 3 respectively, the lower tap being connected to a supply conduit 4 having a shut-off valve 5 of suitable design therein for purposes of filling the container preparatory to charging the oxygen cylinders (not shown).

The container 1 used in one form of this converter was adapted from one of the wire wound aircraft oxygen cylinders used in naval aircraft, having a capacity of about 500 cu. in., mounted in a ½ in. plywood box 6 about 14" x 14" x 30" with opacified silica aerogel insulation packing 7.

With the pressure build-up coils 8 and the evaporator coil 9 spacedly wound around this box, the overall diameter of the entire apparatus was about 23½ in. and the overall height about 44 in. The total weight was about 111 lbs.

The cylinder was modified by removing the valve and welding in a plug which was tapped for ⅛-inch pipe at 2, and by welding in a ⅛-inch pipe nipple at the opposite end at 3. This container 1 was suspended in a box as shown in Fig. 1 and had a stainless steel tube 10 about 30 inches long of ¼-inch inner diameter (0.009 inch wall of thickness) at each end leading to

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the outside of the box. The tubes were coiled inside the box, and in addition the bottom tube was bent so that a liquid trap was formed at 11 close to the container. The box was closed tightly and the space between box and container was filled with silica aerogel 7 for insulation.

Outside the box the tubes 10 from the container terminated in pipe-crosses 12 and 13 to which were soldered flanges for fastening them to the box. One of the outlets 14 of the lower pipe-cross 13 was connected to the set of pressure build-up coils 8, one 15 to the evaporator coil 9, and one 16 to the filler connection 4. One outlet 17 of the upper pipe-cross 12 was connected to a pressure gage 18 and a safety blow-out plug 19, while two outlets 20 and 21 were connected to manually operated high pressure line valves 22 and 23, one of which 22 was in series with the pressure build-up coils 8 and a pressure closing valve 24, while the other 23 was for relieving to the atmosphere the gas which is internally developed during filling of the container i.

In some models, it may be preferable to use a vacuum space for insulation instead of the aerogel packing 7. No difficulty should be encountered in fabricating such a vessel, since it will entail only the addition of a relatively light container surrounding the pressure tank. The surfaces of both containers next to the vacuum will require polishing or plating to give high reflectance for insulating efficiency.

The evaporative capacity of the pressure build-up circuit, consisting of four parallel branches each of 36 feet length and made of $\frac{1}{8}$ inch copper tubing, was about 300 liters per minute (standard temperature and pressure) as determined by the flow that could be drawn off the gas phase while the pressure was maintained at 1800 pounds per square inch. The temperature of the gas delivered at the top of the pressure build-up circuit was as low as -50°C. , however.

The time required to build the pressure up to 1800 pounds per square inch when the container is full is about one minute. This represents evaporation of sufficient gas to fill the tubes (40% of the volume of the whole apparatus), as well as any void in the internal container left by the evaporation of that gas, to a pressure of 1800 pounds per square inch.

The pressure closing valve 24 was made by enlarging the valve port of an ordinary single stage high-pressure pressure reducer and installing it in series with the pressure build-up coils and the manual valve 22. Its operation is such that the valve remains open, allowing circulation, until a certain pressure (depending upon the adjustable spring pressure on the diaphragm of the pressure reducer) is reached, when it closes, stopping the circulation. Since this rate of flow should be large and the driving force is only the differential pressure due to differing density of gas and liquid columns, the resistance to flow in the pressure build-up circuit must be held to a minimum. In designing or selecting the pressure closing valve, these requirements should therefore be kept in mind.

The evaporation coil 9 was composed of about 200 feet of $\frac{1}{8}$ " O. D. copper tubing (0.035 inch wall) coiled around the box 6 starting at the lower pipe-cross 13, spiralling upward to the top, and then back down in a larger diameter spiral. The space between the two spirals was maintained at about one inch by wooden spacers at

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the four corners of the box. The coil had in series with it at its terminus the flow controller 25 and a manually controlled valve 26.

When constructed, the length was limited by the amount of tubing available. No limitation is placed on the length by the general design, however, and twice as much evaporative capacity would be desirable. A coil, of the dimension cited, will evaporate and warm 200 liters per meter of gas normal temperature and pressure to within 20° of ambient temperature, 300 liters per minute to within about 30° , or 400 liters per minute to within 60° .

Both the pressure build-up coil and the main delivery coil can equally well be replaced by other types of heat exchangers, for atmospheric heating, or by other types of heaters, such as electric or flame. Particularly in the case of jet motors of rockets, flame heating of the pressure build-up evaporator which may be a coil, a jacket or manifold of tubes in or surrounding the combustion chamber, is desirable to increase the rate of delivery.

The diagrammatic showing in Fig. 2 is illustrative of one adaptation of the invention in which flame heating is used, in connection with a jet motor. The evaporator coil 27 corresponding to coils 8 of Fig. 1 may be in contact with or incorporated as a jacket in the wall of the combustion chamber 28 of the jet motor and has inlet connection to the oxygen container through conduit 46 and trap 47. The outlet 29 from this coil is connected to the upper portions of the oxygen and fuel containers 30 and 31 through pressure closing valves 32 and 33 respectively, thus providing the necessary high pressure for supplying the liquid oxygen and fuel to their respective high pressure burner jets 34 and 35 through the pressure opening valves 36 and 37 and controllers 38 and 39 respectively. The oxygen and fuel are withdrawn from the bottoms of their containers by conduits 44 and 45 which are provided with container filler connections 42 and 43 having cut-off valves 40 and 41 therein respectively. Traps 48 and 49 are also provided as indicated. For jet use a warming delivery coil corresponding to 9 of Fig. 1 is unnecessary, the discharge being directly into the combustion chamber 28 of the motor.

The flow controller 25 was devised to regulate the delivery flow, and to limit it to a value within the evaporating capacity of the coil 9. The flow controller 25 was constructed by placing a restriction upstream to and in series with a line valve of the diaphragm type, wherein the packing is replaced by a diaphragm which flexes against the valve rod to close the valve. The line valve was connected so that direction of flow was such that the fluid would enter the valve into the space directly beneath the diaphragm, that is, opposite to the normal direction. The upper valve stem was removed from the valve and a tube, connected to the delivery line upstream of the restriction, was connected to the opening left by the upper valve stem, so that the upstream pressure would act to depress the diaphragm and close the valve. The valve spring and the downstream pressure both tend to hold the valve open, so that the net pressure differential across the restriction operating on the diaphragm will close the valve when it becomes great enough to overcome the spring action. The pressure in the valve below the diaphragm is thus maintained at a constant differential below that in the supply line, thereby maintaining the

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same differential across the restriction. The flow through the device is then that which will pass the restriction on the set differential determined by the diaphragm and spring characteristics. The flow, while not constant at varying pressure because of the corresponding variation in density, is quite constant for a fixed delivery pressure.

Inasmuch as one of the main applications of a flow controller is to prevent delivery of too cold a gas, or of liquid, a thermally responsive valve can be used. For constant rate of delivery the controlled pressure acting across a fixed restriction in the liquid delivery line is the simplest arrangement.

Operation

During operation, the outlet of the converter beyond valve 26 is connected with a bank of cylinders to be filled. The charging pressure, at the cylinder manifold, is indicated by a large gage suitably placed. The converter pressure is indicated by the small gage 18 mounted near the top of the converter.

In filling, the liquid supply is connected to the filler connection 4, the pressure build-up control valve 22 closed, the relief valve 23 opened, and the liquid is forced in under pressure. When full (determined by weighing or, more simply, by the issuance of liquid from the relief valve exit) the relief valve is closed and the filler disconnected.

Opening of the manual valve 22 in the pressure build-up circuit then allows circulation to proceed in the pressure build-up coils 8. Liquid flows out the bottom tap and vaporizes in the coils by absorbing atmospheric heat, the resulting gas going back into the container through the top tap 2. Because of the active evaporation in coils 8, the level of the liquid in these coils is lower than the liquid level in container 1, so that a hydrostatic pressure differential is available to maintain the circulation. Some of the evaporated gas goes to developing pressure over the liquid and some recondenses in the liquid to form a warmer layer at the surface. This process continues until sufficient pressure is developed to close the pressure closing valve 24, or until the manual valve 22 is closed.

With pressure in the container 1, and the delivery valve 26 open, liquid is forced out into the evaporator coil 9 where it vaporizes by atmospheric heat.

Modifications and improvements in design may be made without departing from the spirit and scope of this invention, as defined in the appended claims.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

What is claimed is:

1. A high pressure liquid oxygen converter comprising an insulated container having upper and lower connections including a liquid trap in said lower connection, one or more pressure build-up coils exposed to the atmosphere, connected in parallel between said upper and lower connections, and having a pressure closing valve and a control valve in series near the upper connection, said coils extending downwardly to a level below the bottom of said container, and a warming delivery coil exposed to the atmosphere connected to the lower connection and having a pressure responsive flow control valve and a

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manual shut-off valve in series at its outer end for delivery of high pressure oxygen.

2. A high pressure liquid oxygen converter comprising an insulated container having upper and lower connections including a liquid trap in said lower connection, one or more pressure build-up coils exposed to the atmosphere, connected in parallel between said upper and lower connections, and having a pressure closing valve and a control valve in series near the upper connection, said coils extending downwardly to a level below the bottom of said container, and a warming delivery coil exposed at the atmosphere open to the liquid phase in said container, and having a pressure responsive flow control valve and a manual shut-off valve in series at its outer end for delivery of high pressure oxygen.

3. A high pressure liquid oxygen converter comprising an insulated container having upper and lower connections including a liquid trap in said lower connection, one or more pressure build-up coils exposed to the atmosphere, connected in parallel between said upper and lower connections, and having a pressure closing valve and a control valve in series near the upper connection, said coils extending downwardly to a level below the bottom of said container, a warming delivery coil exposed to the atmosphere connected to the lower connection and having an automatic flow control valve and a manual shut-off valve in series at its outer end for delivery of high pressure oxygen.

4. A high pressure liquid oxygen converter comprising an insulated container having upper and lower connections including a liquid trap in said lower connection, one or more pressure build-up coils exposed to the atmosphere, connected in parallel between said upper and lower connections, and having a pressure closing valve and a control valve in series near the upper connection, said coils extending downwardly to a level below the bottom of said container, a warming delivery coil exposed to the atmosphere open to the liquid phase in said container, and having an automatic flow control valve and a manual shut-off valve in series at its outer end for delivery of high pressure oxygen.

5. A liquid oxygen container having upper and lower connections including a liquid trap in said lower connection, atmospheric heat absorption means connected between said upper and lower connections located at least partially below the level of the bottom of said container for vaporizing a portion of the contents and causing a circulation therethrough automatically, a pressure closing valve near the upper connection for stopping said circulation when a predetermined pressure is reached, and delivery means exposed to the atmosphere open to the liquid phase in said container for delivering said oxygen at said predetermined pressure, said delivery means being provided with an automatic control valve and a manual control valve.

6. A liquid oxygen container having upper and lower connections including a liquid trap in said lower connection, atmospheric heat absorption means connected between said upper and lower connections located at least partially below the level of the bottom of said container for vaporizing a portion of the contents and causing a circulation therethrough automatically, a pressure closing valve near the upper connection for stopping said circulation when a predetermined pressure is reached, and delivery means exposed to the atmosphere connected to the lower end of

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said container for delivering said oxygen at said predetermined pressure, said delivery means being provided with an automatic control valve and a manual control valve.

7. A main liquid container having upper and lower connections, a liquid trap in said lower connection, heat absorption means connected between said upper and lower connections located at least partially below the level of the bottom of said container for vaporizing a portion of the contents thereof and causing a circulation there-through automatically, a pressure closing valve for stopping said circulation when a predetermined pressure is reached, and delivery means open to the liquid phase in said container for delivering said liquid at said predetermined pressure, said delivery means including an automatic control valve.

8. The apparatus of claim 7 with at least one additional container for holding a liquid, a conduit between the gas phase region of said additional container and the upper connection of said main container, a second pressure closing valve in said conduit, and delivery means open to the liquid phase in said additional container for delivery of liquid therein at a predetermined pressure as fixed by said second pressure closing valve.

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9. The apparatus as defined in claim 8 including additionally a mixing chamber for combining the output of said container delivery means.

10. The apparatus as defined in claim 8, including additionally an automatic pressure control valve in each of said delivery means.

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