

March 24, 1953

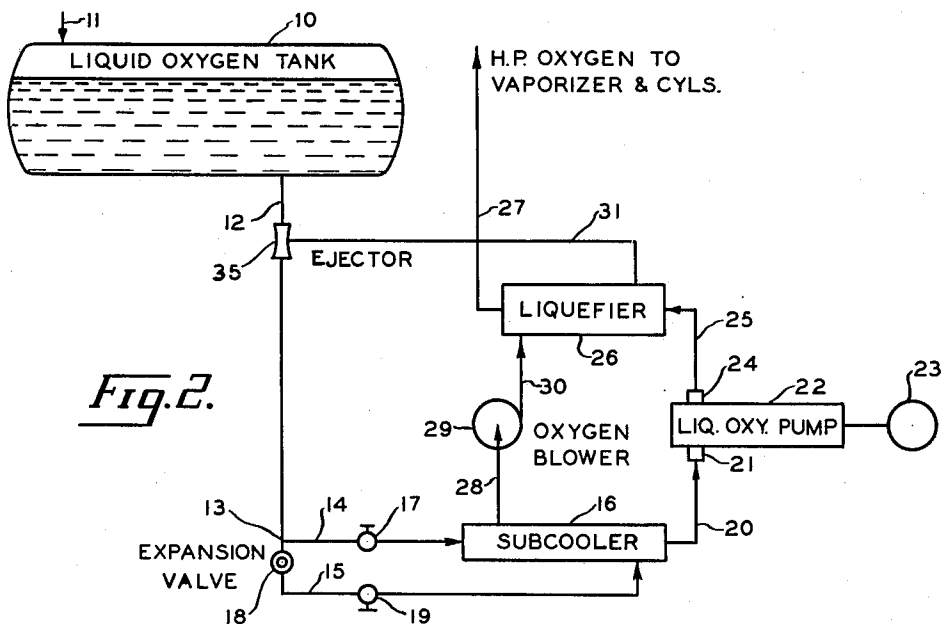
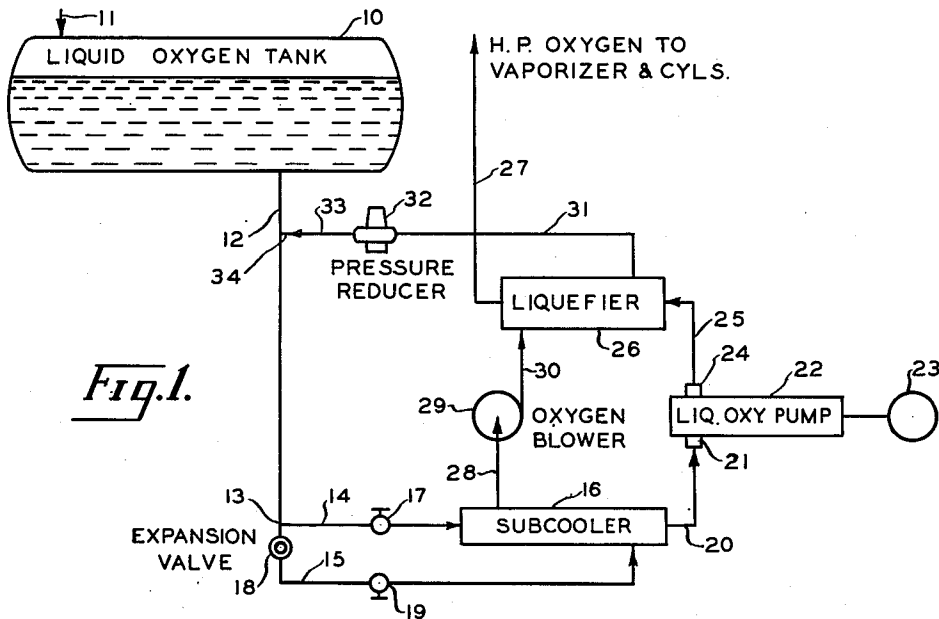
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2,632,302

VOLATILE LIQUID PUMPING

Filed June 29, 1949

2 SHEETS—SHEET 1



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2 SHEETS—SHEET 2

Fig. 4.

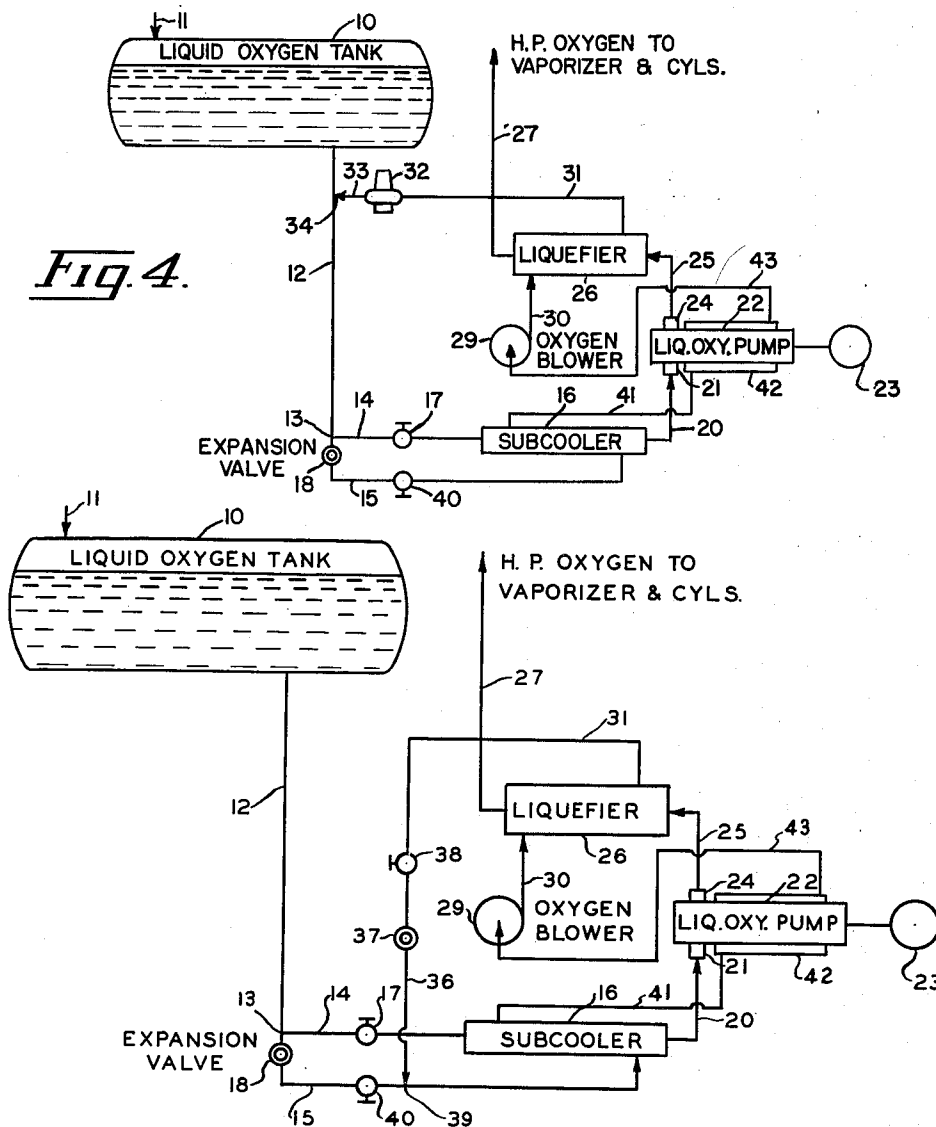


Fig. 3.

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VOLATILE LIQUID PUMPING

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This invention relates to the pumping of liquefied gases or volatile liquids, as for example liquid oxygen, liquid nitrogen, liquefied petroleum gases, natural gasoline, or any like normally gaseous product in the liquid condition or any liquid volatile under the pumping conditions.

In the production, storage and use of certain liquids having low boiling points at atmospheric pressure, it is often highly economical and desirable to transfer them from one point to another in the liquid rather than in the gaseous condition.

For example, it is now common practice to store liquefied petroleum gases in large quantities, at or near atmospheric pressure, in heavily insulated tanks. Such liquefied gases have, on occasion, to be transferred at a controlled rate to a vaporizer wherein they are vaporized and superheated, under pressure, to a temperature suitable for delivery into a distribution system. The use of the present invention is a simple and convenient means for effecting such transfer.

It is also common practice to store oxygen, nitrogen and other so-called permanent gases in the liquefied form, to transport the liquid through pipe lines, and to bring it back to the gaseous condition at the point at which it is to be used or placed in pressure cylinders for final distribution. In such cases, the stored liquefied gas is usually at slightly above atmospheric pressure while the conditions of gas phase storage or distribution may require that the gasified liquid be at a relatively high pressure, often up to or over 2500 pounds per square inch. In such service, it is extremely desirable to apply the finally required pressure to the liquid rather than to a gaseous stream, as both the cost of power and the weight of apparatus required in the former case are small fractions of the corresponding figures in the latter.

In pumping liquids which at normal atmospheric pressure boil at temperatures ranging from zero degrees to 190° below centigrade zero, great difficulty is experienced in keeping a pump in operation. At the lower temperatures, the heat head between the atmosphere and the liquid stream is so great that even the best of insulation becomes relatively ineffective. In consequence, some atmospheric heat leaks into the liquid on the suction side of the pump and, as the liquid is usually just at its boiling point, any input of heat causes the evolution of gas, which has its usual effect of reducing the effective stroke length and finally of locking the pump.

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Even with the higher boiling liquids in this class, when pumping against considerable back pressure, the liquid is heated somewhat by the very act of increasing its pressure, and any such liquid leaking back past the discharge valve into the pump cylinder may partially vaporize under intake stroke conditions, contributing to vapor lock.

In all cases the actuating end of the pump, the end to which power is applied, is almost necessarily in contact with the atmosphere and at a temperature much higher than that of the liquefied gas, the metallic structure of the pump thus transmitting atmospheric heat to the stream being pumped. Additionally, because of the impossibility of lubricating the plunger packing adequately, more or less heat is produced by rod friction and added to the atmospheric heat tending to raise the temperature of the stream at the suction end of the pump.

One remedy for these difficulties is found in subcooling the liquid stream going to the pump to a temperature below its boiling point at the pressure existing in the pump cylinder during the suction stroke, as described and claimed in copending applications Serial No. 488,650, filed May 27, 1943, now Patent No. 2,480,093, August 23, 1949, and Serial No. 605,407, filed July 16, 1945, now Patent No. 2,480,094, August 23, 1949, of Carl R. Anderson.

This invention has as an important object the provision of an improved combination of steps and apparatus whereby a highly volatile liquid may be economically pumped to a pressure of several hundred atmospheres without gas locking the pump.

A further important object of the present invention is the provision of method and apparatus for subcooling a stream of volatile liquid to be pumped by heat exchange with a portion of the stream which has been previously expanded, together with economical recovery of the expanded portion.

A still further important object of the present invention is to provide means for recovering the expanded portion and returning it to the system in liquid form.

These and other objects which will appear hereinafter are accomplished by the present invention which provides method and apparatus by subcooling a volatile liquid by diverting a small portion of such liquid, expanding the portion and passing the expanded liquid into heat exchange relation with the remainder of the stream, thereafter compressing the small portion and lique-

fying the same by passing it in heat exchange relation with the subcooled liquid stream which has been pumped to a high pressure, and finally returning the thus liquefied small portion to the system.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

Figure 1 is a diagrammatic view of the invention wherein the reliquefied portion is reduced in pressure before it is recycled to the storage tank withdrawal conduit.

Figure 2 is a diagrammatic view of a modification of the invention wherein the reliquefied portion may be injected directly into the storage tank withdrawal conduit.

Figure 3 is a diagrammatic view of a further modification wherein the diverted stream is maintained as a separate cycle.

Figure 4 is a diagrammatic view of a further modification including pump cooling.

As shown in Figure 1, the volatile liquid to be pumped is stored in a storage vessel 10. The storage vessel is provided with an inlet conduit 11 and a withdrawal conduit 12. At point 13 in the withdrawal conduit, it is divided into two conduits 14 and 15, each leading to separate passageways in a two-passageway interchanger or subcooler 16. Conduit 14 is provided with a control valve 17. Conduit 15 is provided with an expansion valve 18 and a control valve 19. The liquid flowing through conduit 14 leaves the subcooler 16 at its opposite end through conduit 20 which leads to the intake valve 21 of a pump 22. The motor which actuates the pump plunger is shown at 23. The pump may be a single acting plunger pump similar to that described in Patent No. 2,439,957 to Carl R. Anderson, dated April 20, 1948, and operates in a similar manner. The pump is provided with a discharge valve 24 connected to conduit 25 leading to one passageway through a liquefier 26 which is connected at the opposite end to a conduit 27. Conduit 27 may, if desired, be connected to a vaporizer and to storage cylinders for storing the high pressure gas at atmospheric pressure.

A second passageway through the subcooler 16 is connected at its entrance end to conduit 15 and at its exit end to conduit 28 leading to a gas blower 29. Conduit 30 connects the exhaust of the blower 29 with the entrance end of a second passageway through the liquefier 26, conduit 31 being connected to the exit end of this second passageway. Conduit 31 leads to a conventional diaphragm controlled pressure reducer 32 and thence to conduit 33 which joins with the liquid withdrawal conduit 12 at point 34.

The operation of the system will now be described for pumping liquid oxygen as an example, although it should be noted that the invention is not limited to oxygen but is applicable to any liquefied gas or volatile liquid. In the preferred manner of operation, the liquid oxygen is stored in the container 10 at a temperature of about 95.5° K. and a pressure of approximately 1.7 atmospheres. The liquid is withdrawn from the container through the withdrawal conduit 12 and thence through conduit 14 and valve 17 to the subcooler 16. A small portion of the liquid stream ranging from 3 to 10% of the total stream withdrawn is diverted at 13 to conduit 15 where it is expanded in expansion valve 18 to substantially atmospheric pressure and is thereby cooled to a

temperature of approximately 90° K. This small stream is then passed through the subcooler 16 where it is vaporized while passing in heat exchange with the main stream of warmer liquid. The main stream is thus subcooled to a temperature of approximately 91° K., at which temperature it is pumped in the liquid oxygen pump 22 to the desired pressure. The stream leaves the pump discharge valve at a temperature of about 93° K. Since the liquid is pumped while at a temperature below the equilibrium boiling point temperature of the liquid for that pressure, the liquid as a result may be pumped continuously without vaporization of the liquid within the pump or the pump becoming gas bound.

After passing through the subcooler and the pump jacket, if desired, the gaseous portion of the oxygen passes to the blower 29 where the pressure of the gaseous oxygen is raised to about 5 atmospheres at an approximate temperature of 155° K. By heat exchanging this stream of gas with the high pressure liquid oxygen from the pump in liquefier 26, the stream of gas is reliquefied. The reliquefied stream passes from the liquefier to the pressure reducing means 32 at a temperature of 94° K. and 5 atmospheres pressure. The pressure is reduced to approximately 1.7 atmospheres in the pressure reducer and the stream is merged at 34 with the withdrawn stream leaving the container 10.

The apparatus and operation of the system shown in Fig. 2 is similar to that previously described and like reference numerals indicate like parts in both figures. In Fig. 2, the necessity for a pressure reducing means 32 has been removed by having the reliquefied stream passing through conduit 31 conducted to an ejector device 35 by which the liquid under pressure is ejected directly into the liquid withdrawal conduit 12. By means of ejector 35, the pressure on the liquid passing to pump 22 is raised which has the same effect as subcooling the liquid. In other words, the liquid is no longer at its equilibrium temperature at the higher pressure and thus may be heated several degrees before it will vaporize.

The modification of the invention shown in Fig. 3 provides for maintaining the cooling stream in a separate cycle from the liquid being pumped. The conduit 31 leads to conduit 36, expansion valve 37, control valve 38 and joins with conduit 15 at 39. A check valve 40 is provided in conduit 15 upstream from point 39.

A conduit 41 is shown leading from the subcooler 16 to a cooling jacket 42 surrounding the pump 22. Conduit 43 connects the exit from the cooling jacket 42 with the blower 29.

In operation, the system is started by diverting a small stream of the oxygen to be pumped through conduit 15 and expansion valve 18 to the subcooler 16 and thence to the pump cooling jacket 42. This small stream—now gaseous—passes to the blower 29 wherein its pressure is raised to about 5 atmospheres and it then passes through the liquefier 26 where it is liquefied by heat exchange with the cold high pressure stream of oxygen from the pump 22. The reliquefied stream of oxygen is expanded in expansion valve 37 to atmospheric pressure and is recycled to the subcooler 16. This small stream of oxygen is thus continuously recycled in its closed system, undergoing the steps of being vaporized during the subcooling, compressed in the blower, reliquefied in the liquefier and expanded in the expansion valve. If needed, additional oxygen may be added to the recycled stream by divert-

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ing at 13 some of the stream flowing to the sub-cooler.

The modification shown in Figure 4 includes the pump cooling feature of Figure 3, but the pump cooling stream after compression and condensing is returned to the system in the same manner as that of the modification of Figure 1. Similar parts in Figure 4 to those of Figure 3 and Figure 1 are identified by the same reference numeral.

In normal operation of all four illustrated systems, the subcooler 16, and when used, the pump jacket also, is maintained with the parts to be cooled submerged in boiling liquid oxygen, the vapors passing off from the boiling liquid going to the blower 29 for compression and reliquefaction in the liquefier. The level of the boiling liquid is maintained in the subcooler, or in the pump jacket when used, by control of the amount of fluid passing through expansion valve 12. The diagrammatic showing in the drawings would necessitate manual control, but obviously any suitable automatic control of this valve could be used, a float control being the simplest example.

In the claims appended hereto, the term, sub-cooling of the main stream, is meant to include either the subcooling in the subcooler or the sub-cooling accomplished by the pump cooling jacket, or both.

Having described my invention, what I claim as new and desire to secure by Letters Patent is:

1. The method of pumping a highly volatile liquid and preventing the evolution of vapor therefrom during pumping which comprises, diverting a small portion of a stream of liquid to be pumped, expanding the small portion to produce a refrigerating effect, passing the cold expanded portion in heat exchange with the larger stream to subcool the larger stream while vaporizing the small portion, pumping the subcooled stream to a higher pressure, compressing the vaporized portion to a pressure appreciably higher than the pressure of the stream to be pumped, reliquefying the vaporized portion by heat exchange with the high pressure stream, reducing the pressure of the reliquefied portion and returning the portion to the stream of liquid to be pumped.

2. A system for pumping a highly volatile liquid and preventing the evolution of vapor therefrom during pumping comprising, a source of supply for the liquid to be pumped, a conduit for conducting a main stream of liquid from the source of supply, a conduit for conducting a small portion of liquid from the source of supply, means for expanding the small portion to produce a refrigerating effect, a heat exchanger having passageways therethrough in heat exchange relationship, a first passageway of which is connected to the conduit for the main stream and a second passageway of which is connected to the means for expanding the small portion for subcooling the main stream and vaporizing the cold expanded portion therein, a pump connected to the first passageway of the heat exchanger for pumping the subcooled stream to a higher pressure, compressor means connected to the second passageway of the heat exchanger for compressing the vaporized portion to a pressure appreciably higher than that of the source, a second heat exchanger having passageways therethrough in heat exchange relationship, a first passageway of which is connected to the pump discharge and a second passageway of which is connected to the compressor outlet for reliquefying the va-

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porized compressed portion, and pressure reducing means for returning the reliquefied portion to the system on the high pressure side of the expansion means.

3. A system for pumping a highly volatile liquid and preventing the evolution of vapor therefrom during pumping comprising, a source of supply for the liquid to be pumped, a conduit for conducting a main stream of liquid from the source of supply, a conduit for conducting a small portion of liquid from the source of supply, means for expanding the small portion to produce a refrigerating effect, a heat exchanger having passageways therethrough in heat exchange relationship, a first passageway of which is connected to the conduit for the main stream and a second passageway of which is connected to the means for expanding the small portion for subcooling the main stream and vaporizing at least a portion of the cold expanded stream therein, a pump connected to the first passageway of the heat exchanger for pumping the subcooled stream to a higher pressure, a cooling jacket surrounding the pump connected to the second passageway of the heat exchanger for cooling the pump while vaporizing the balance of the cold expanded portion, compressor means for compressing the vapor leaving the cooling jacket to a pressure appreciably higher than that of the source, a second heat exchanger having passageways in a heat exchange relationship, a first passageway of which is connected to the pump discharge and a second passageway of which is connected to the compressor outlet for reliquefying the vaporized compressed portion, and pressure reducing means for returning the reliquefied portion to the system on the high pressure side of the expansion means.

4. Apparatus for pumping a highly volatile liquid and preventing the evolution of vapor therefrom during pumping comprising, a source of supply for the liquid to be pumped, a conduit for conducting a main stream of liquid from the source of supply, a conduit for conducting a small portion of liquid from the source of supply, means for expanding the small portion to produce a refrigerating effect, a heat exchanger having passageways therethrough in heat exchange relationship, a first passageway of which is connected to the conduit for the main stream and a second passageway of which is connected to the means for expanding the small portion for subcooling the main stream and vaporizing the cold expanded portion therein, a pump connected to the first passageway of the heat exchanger for pumping the subcooled stream to a higher pressure, compressor means connected to the second passageway of the heat exchanger for compressing the vaporized portion to a pressure appreciably higher than that of the source, a second heat exchanger having passageways therethrough in heat exchange relationship, a first passageway of which is connected to the pump discharge and a second passageway of which is connected to the compressor outlet for reliquefying the vaporized compressed portion, means for reducing the pressure of the reliquefied portion, and conduit means for returning the portion to the main stream of liquid to be pumped.

5. Apparatus for pumping a highly volatile liquid and preventing the evolution of vapor therefrom during pumping comprising, a source of supply for the liquid to be pumped, a conduit for conducting a main stream of liquid from the source of supply, a conduit for conducting a

small portion of liquid from the source of supply, means for expanding the small portion to produce a refrigerating effect, a heat exchanger having passageways therethrough in heat exchange relationship, a first passageway of which is connected to the conduit for the main stream and a second passageway of which is connected to the means for expanding the small portion for subcooling the main stream and vaporizing at least a portion of the cold expanded stream therein, a pump connected to the first passageway of the heat exchanger for pumping the subcooled stream to a higher pressure, a cooling jacket surrounding the pump connected to the second passageway of the heat exchanger for cooling the pump while vaporizing the balance of the cold expanded portion, compressor means for compressing the vapor leaving the cooling jacket to a pressure appreciably higher than that of the source, a second heat exchanger having passageways therethrough in heat exchange relationship, a first passageway of which is connected to the pump discharge and a second passageway of which is connected to the compressor outlet for reliquefying the vaporized compressed portion, means for reducing the pressure of the reliquefied portion, and conduit means for returning the portion to the main stream of liquid to be pumped.

6. Apparatus for pumping a highly volatile liquid and preventing the evolution of vapor therefrom during pumping comprising, a storage container for the liquid, a heat interchanger having two passageways therethrough for subcooling the liquid to be pumped, conduit means connecting the storage container and one passageway of the interchanger, second conduit means connecting the storage container and the second passageway of the interchanger, an expansion valve in the second conduit means, a pump including an inlet and a discharge, means connecting the first passageway of the heat interchanger and the inlet to the pump, a second heat interchanger having two passageways therethrough for reliquefying the fluid used for subcooling, means connecting the discharge from the pump and one passageway of the second heat interchanger, a compressing means including an inlet and a discharge, means connecting the second passageway of the first heat interchanger and the inlet to the compressing means, means connecting the discharge from the compressing means and the second passageway of the second heat interchanger, a pressure reducing means, means connecting the second passageway of the second heat interchanger and the pressure reducing means, and means for connecting the pressure reducing means to the first mentioned conduit connecting the storage container and the one passageway of the first interchanger.

means connecting the second passageway of the second heat interchanger and the pressure reducing means, and means for connecting the pressure reducing means to the first mentioned conduit connecting the storage container and the one passageway of the first interchanger.

7. Apparatus for pumping a highly volatile liquid and preventing the evolution of vapor therefrom during pumping comprising, a storage container for the liquid, a heat interchanger having two passageways therethrough for subcooling the liquid to be pumped, conduit means connecting the storage container and one passageway of the interchanger, second conduit means connecting the storage container and the second passageway of the interchanger, an expansion valve in the second conduit means, a pump including an inlet and a discharge, a cooling jacket surrounding the pump containing an inlet and a discharge thereto, means connecting the first passageway of the heat interchanger and the inlet to the pump, a second heat interchanger having two passageways therethrough for reliquefying the fluid used for subcooling, means connecting the discharge from the pump and one passageway of the second heat interchanger, a compressing means including an inlet and a discharge, means connecting the second passageway of the first heat interchanger and the inlet to the cooling jacket, means connecting the discharge from the cooling jacket and the inlet to the compressing means, means connecting the discharge from the compressing means and the second passageway of the second heat interchanger, a pressure reducing means, means connecting the second passageway of the second heat interchanger and the pressure reducing means, and means for connecting the pressure reducing means to the first mentioned conduit connecting the storage container and the one passageway of the first interchanger.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,292,375	Hansen	Aug. 11, 1942

FOREIGN PATENTS

Number	Country	Date
668,512	France	July 15, 1929