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METHOD AND APPARATUS FOR PUMPING VOLATILE LIQUIDS AND RECOVERING VAPORS IN CONNECTION WITH THE PUMPING OPERATION

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Fig. 1.

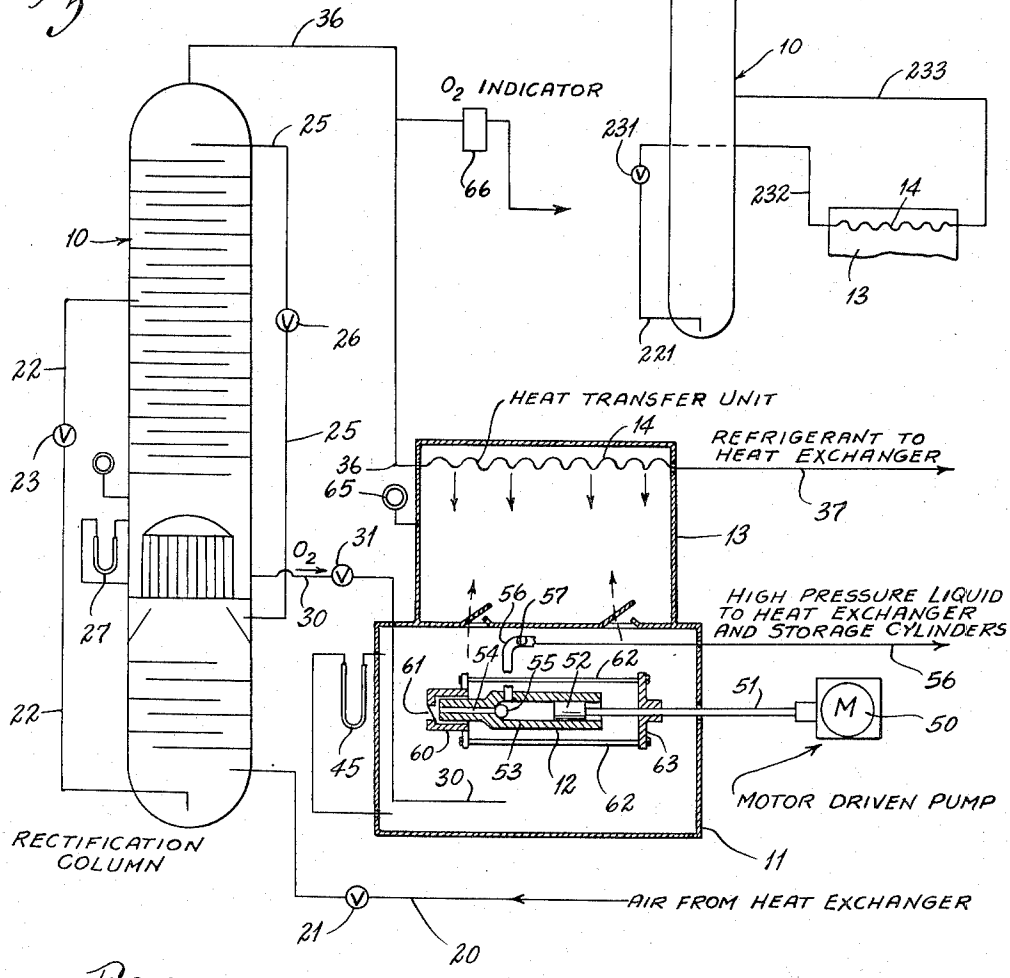
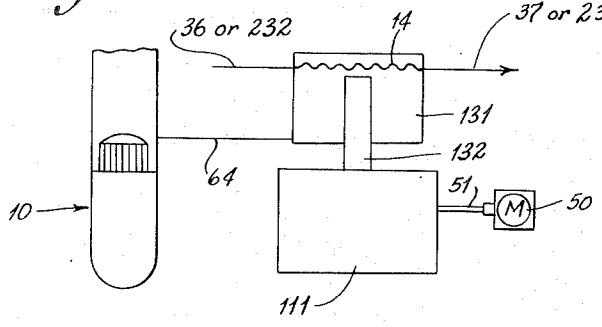


Fig. 2.

Fig. 3.



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METHOD AND APPARATUS FOR PUMPING VOLATILE LIQUIDS AND RECOVERING VAPORS IN CONNECTION WITH THE PUMPING OPERATION

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The present invention relates to an apparatus and a method useful in connection with pumping volatile liquids, and particularly highly volatile liquids. Representative liquids are air and its components, and particularly liquid oxygen, although it will be understood that other such liquids can be handled to advantage by the invention.

In pumping liquid oxygen, and especially delivering liquid oxygen to storage vessels by means of a liquid pump, there is always the problem of vaporization of some of the liquid, which vaporization occurs in the process of pumping, or in the other steps of handling the liquids that are associated with the pumping operation.

Heretofore the approaches to solution of this problem have taken the form of extensive sub-cooling of the oxygen, but this is relatively expensive because it necessitates sub-cooling of at least a major part of the liquid being treated, whereas only a small part actually vaporizes. Another approach to the problem has been to return vapors arising at the pumping operation back to the rectification column; but this is very unsatisfactory because it upsets the normal operation of the column and raises the oxygen content of the nitrogen, thus reducing the yield of the oxygen.

In the present system, the foregoing disadvantages are avoided. In very general language, the invention consists of confining vapors that may be formed during the pumping operation in a container separate from the rectification column and recondensing them by heat transfer with a source of cold, and particularly with a source of cold that is derived from the column itself.

Additional objects of the invention include preventing or minimizing the loss of yield of oxygen occurring in present conventional methods of drawing liquid oxygen from a rectification column by means of a liquid pump, which loss occurs through vaporization of the oxygen in the pumping operation. Another object is to reduce the amount of refrigeration required for a given yield of oxygen by eliminating the losses previously mentioned and by minimizing the amount of energy required to overcome such losses. Another object is to maintain the high purity of the oxygen by maintaining the high yields mentioned.

Other objects will appear from the description to follow.

In the drawings:

Figure 1 is a schematic diagram of the invention associated with a rectification column;

Figure 2 is a view of a modification of parts of the invention, wherein an oxygen component is used as a refrigerant; and

Figure 3 is a modification of parts of the invention, wherein recondensed vapors are returned to the column.

Referring to Figure 1, the rectification column 10 is shown as piped to a container 11 in which a pump 12 is located. Another container 13 is associated with the container 11 and is provided with a heat transfer unit 14. This latter unit, as will appear, is supplied with a cold refrigerant. While the containers 11 and 13 are illustrated as separated by a divider, it is to be understood that the division is not essential. Consequently the term "container means" is used to include both the so-called "containers" 11 and 13, whether they be separate or undivided.

The rectification column 10 is illustrated only sufficiently to demonstrate the application of the present invention. It is shown as supplied with air from a heat exchanger by way of a pipe 20, passing through a valve 21, and entering the lower end of the column. A mixture of oxygen and nitrogen is delivered from the lower part of the column by way of a pipe 22 through an expansion valve 23, to the upper part of the column. Liquid nitrogen is delivered from the lower part of the column by a pipe 25 passing through an expansion valve 26 into the upper part of the column. Liquid oxygen accumulates in the bottom of the upper part of the column as a result of the rectification process, as is known in the art. A liquid level indicator 27 indicates the amount of liquid oxygen in the column. This liquid oxygen may be drawn off by way of a pipe 30 controlled by a valve 31.

Vapor nitrogen can be drawn off the top of the column by way of a pipe 36 that leads to the heat transfer unit 14, and thence by way of a pipe 37 to a heat exchange unit of the system.

As noted, the pipe 30 opens into the bottom of the container 11, and a liquid level of liquid oxygen, as indicated by a liquid level gauge 45, is provided so that the pump 12 is immersed therein. The pump may be one of the types employed for the pumping of liquid oxygen or other volatile liquids. A particularly appropriate pump is that shown in United States Letters Patent No. 2,630,757, issued March 10, 1953, in the name of L. R. Cartier. Such a pump has a pump motor 50 driving a piston rod 51 that has a piston 52 in a cylinder 53. This pump has an inlet passage 54 controlled by a check valve 55, and it has an outlet 56 controlled by a check valve 57. The outlet 56, as shown diagrammatically, leads off to a suitable discharge point such as a heat exchanger or storage cylinder.

A loader cup 60 is provided, it having a check valve 61. This loader cup is connected by connecting rod 62 to a crosshead 63 attached to the piston rod 51. The operation of this pump is described fully in the other application. Suffice it to say that the cup 60 is charged on the compression stroke of the pump. On such compression stroke the liquid in the cylinder is driven out the discharge line past the valve 57. Then, on the suction stroke of the piston 52, the loader cup 60 loads the pressure cylinder under pressure to prevent flashing.

In spite of all precautions, there is a certain amount of vaporization in the pumping of liquid oxygen, owing to the generation of heat in the pumps themselves and to the pressure reductions that normally take place in the pumps. In the present invention, such vapors rise through the liquid and, being warm, pass upwardly into the container 13. When they reach the upper part of this container, they come in contact with the heat transfer unit 14. This heat transfer unit is kept cold, as will appear, so that the liquid oxygen striking the heat transfer unit while in vapor form is recondensed and falls down, so that it may join with the body of liquid oxygen in the container 11, or may be separately collected in the container 13.

The cooling medium in the heat transfer unit 14 may be a gas such as the nitrogen that leaves the upper part of the column by way of the pipe 36.

A pressure gauge 65 is employed to indicate pressure within the tank 13, and an oxygen indicator 66 is employed to indicate the oxygen content in the nitrogen leaving the top of the column 10. Preferably, this latter is a continuous automatic analyzer.

A description of the use and operation of the invention need involve only certain phases of the rectification. It also must be mentioned that the invention is not limited to use with the rectification column. However, it has particular application thereto because of the availability in the column of a colder medium than that being pumped. This is notably true in the case of the separation of oxygen as a liquid from the air by means of the rectification column, since there vapor nitrogen at a temperature below the boiling point of oxygen is available, as also is the nitrogen-oxygen mixture that also is colder than the boiling point of pure oxygen.

When liquid of volatile character is being pumped, and, because of the generation of heat or reduction of pressure, is to some degree being vaporized, such vapors are trapped within the container system that includes the pump and the heat exchanger 14. In the preferred construction, these vapors are passed from the immediate chamber 11 into the chamber 13, where they may be to some degree separately identified and handled particularly after their recondensation.

When these vapors rise, owing to being warmer, into the upper part of the chamber 13 or to wherever the heat transfer unit 14 is disposed, they strike the cold surfaces of the heat transfer unit and are thereby recondensed, so that they fall as a liquid to the bottom of the container 13. Where it is desired, they may be caused to move directly back into the liquid in the container 11, or they may be conducted from the lower part of the container 13 back into the liquid column, as will later be described.

Figure 2 illustrates the use of a cold oxygen product for the heat transfer unit 14. The pipe 221 conducts a mixture rich in oxygen from the lower part of the column 10 to the expansion valve 231. Thence, instead of being conducted to the upper column directly, it is transmitted by the pipe 232 to the heat transfer unit 14 within the container 13. From the unit 14, the oxygen is conducted by the pipe 233 back to the upper part of the column, for further treatment in conventional manner. In this arrangement, the nitrogen outlet 361 leads off the top of the column and also connects into the indicator 661. Otherwise, the apparatus is like that of Figure 1 or 3. The operation is the same, except that the refrigerant for the unit 14 is the oxygen product.

Figure 3 illustrates a separate pump chamber 111 and recondensing chamber 131. A pipe 132 leads from the top of container 111 to the top of the inside of the container 131 adjacent the unit 14. Vapors from the pumping container 111 rise through the pipe 132, and become condensed in container 131, falling to the bottom thereof, whence they may flow back to the column 10 by gravity through the pipe 64, preferably reentering the column at the point indicated.

In this process and apparatus, there is thus the separation out of the vapors arising from the pump and a recondensation before they are returned to the system. Heretofore attempts have been made to return these vapors from the pump to the column for treatment therein, without recondensation outside the column. It has been found, however, that this is a very unsatisfactory procedure resulting in upsetting the normal operation of the column and raising the oxygen content of the nitrogen so that the yield of oxygen is correspondingly reduced.

The present invention is an improvement over subcooling of the liquid being pumped. If the liquid to be pumped is sub-cooled sufficiently to overcome all tendencies at vaporization in the pumping operation, all of the liquid being pumped must be so sub-cooled. With the present invention, the recondensation is limited to the relatively small proportion of liquid that vaporizes in the pumping operation. The amount of energy required to recondense this relatively small portion of vaporized liquid is less than the amount of energy required to sub-

cool the whole mass being pumped, so that the present system is more enonomical. Not only that, it has been found that it is impractical or impossible to eliminate all vaporization in the pumping operation by sub-cooling. As a matter of fact, even with sub-cooling the present invention can be valuable to recondense those vapors that inescapably are formed in the pumping operation.

What is claimed is:

1. In an apparatus for pumping volatile liquids: a pump for the liquid; a container means having a lower portion to receive the volatile liquid to be pumped and for surrounding and enclosing the pump, and having an upper portion open to the lower portion, the upper portion being adapted for receiving and confining vapors of the liquid vaporized by the operation of the pump and escaping upwardly during the pumping operation; and a refrigerated heat transfer unit in the upper portion of the container means to be contacted by the vapors so that they are recondensed and descend as a liquid within the container, and a rectification column for separating the liquid that is to be pumped from another fluid product of lower boiling point, including means to lower the temperature of the fluid to below the boiling point of the first-named liquid; and connections for conducting the product of lower boiling point to the heat transfer unit to condense the vapors as stated.

2. The apparatus of claim 1, and means for conducting the recondensed liquid back to the column.

3. A method of handling a volatile liquid from a rectification column wherein the liquid is separated by refrigeration from another fluid of lower boiling point, comprising conducting the first liquid away from the column to a receptacle containing a pump; pumping the liquid; vaporizing some of the liquid at the pump, separating the vapors thus produced from the liquid in the receptacle, and confining the same; withdrawing a fluid from the column at a temperature below the boiling point of the vapors; providing heat transfer between such fluid and the vapors thus separated while the vapors remain confined as aforesaid; and recondensing the confined vapors.

4. The method of claim 3, wherein the liquid from the recondensed vapors is returned to the column.

5. The method of claim 4, wherein the volatile liquid is essentially oxygen and the other fluid from which it is separated is essentially nitrogen, and the fluid for recondensing the oxygen vapors by heat transfer is a nitrogen-containing fluid from the column.

6. In a system for handling a liquid fraction of the kind described, comprising: a rectification column for producing a cold, volatile liquid and a colder fluid fraction; a pipe from the column for conducting the liquid therefrom; a container means into which the pipe discharges; a liquid pump in the container means to apply pressure to the liquid, and to vaporize some of the liquid and release the vapor in the vapor-receiving portion of the container means, the container means including a portion to receive the vapor; a heat exchanger in the container means, and connected to the column to receive the colder fraction from the column, the heat exchanger being adapted to be in contact with the vapor from the pump to recondense the same, but being separate from the liquid in the container.

7. The combination of claim 6, with also a conductor pipe connected between the column and the container to return the liquid recondensed from the vapors, back into the column.

8. The combination of claim 6, wherein the container has two chambers with the pump in one and the heat exchanger in the other, and a one-way connection between them to conduct the vapors from the pump chamber to the recondensing chamber, and a liquid pipe leading from the recondensing chamber.

9. The combination of claim 8, wherein the last-named pipe is connected back into the column.

10. In an apparatus for pumping volatile liquids: a liquid container means, a source of volatile liquid connected to the liquid container means, the liquid container being separate from the source and having a lower portion for receiving from the source the liquid to be pumped, and an upper portion to receive vaporized liquid that rises from the lower portion; and to contain the same separate from the source of volatile liquid; a pump having its inlet within the lower portion of the liquid container means, to withdraw liquid therefrom and to deliver it under pressure to a suitable pump outlet; a source external to the liquid container of refrigerant capable of liquefying vapor arising from the liquid, and a refrigerated heat-transfer unit in the upper part of the liquid container means connected to the source of refrigerant to receive refrigerant therefrom to recondense vapors from the liquid.

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