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LIQUEFACTION OF LOW-BOILING GASES

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2 Sheets-Sheet 1

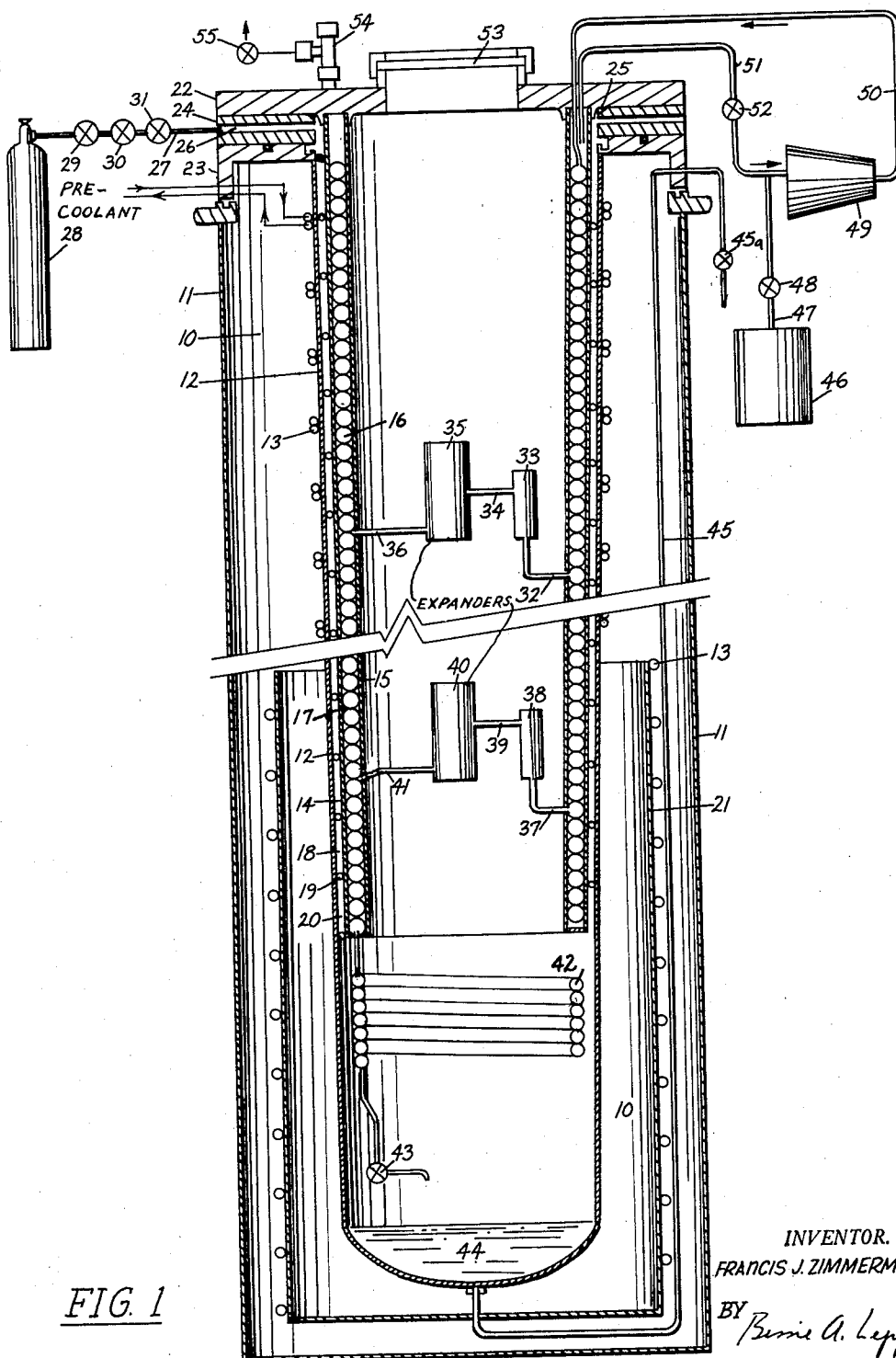


FIG. 1

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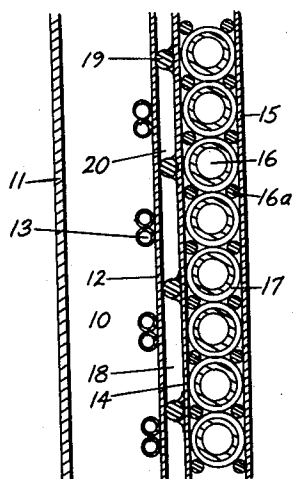


FIG. 2

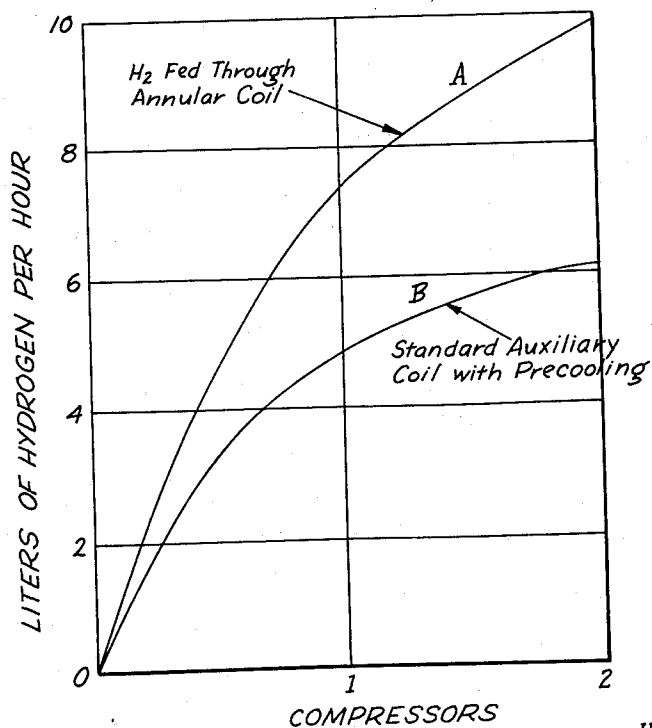


FIG. 3

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LIQUEFACTION OF LOW-BOILING GASES

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5 Claims. (Cl. 62—8)

This invention relates to a refrigeration system for the production of low temperatures and particularly to the liquefaction of gases.

In United States Patent 2,458,894 issued January 11, 1949, to Samuel C. Collins, there is disclosed a cycle for liquefying gases, particularly helium which has the lowest known boiling point, i.e., 4.2° K. or -268.9° C. In a low temperature refrigeration system, such as that of the Collins process it is desirable to have sufficient flexibility of operation which permits the rapid and efficient liquefaction of other gases while taking advantage of the helium refrigeration in the system. Rapid liquefaction and high thermodynamic efficiency means a considerable saving in helium, an important factor in areas or countries where helium is expensive.

The Collins process and apparatus is frequently used to liquefy hydrogen or other gases with higher boiling points, but the amount so liquefied is relatively limited. However, I have found that by the use of a different type of heat exchange system the hourly rate of liquid hydrogen can be approximately doubled.

It is therefore an object of this invention to provide a highly efficient refrigeration system for the liquefaction of gases, particularly hydrogen. It is another object to provide, in a system designed primarily for liquefying helium, sufficient flexibility of operation which permits the use of helium refrigeration to liquefy other gases with boiling points above the boiling point of helium. It is a further object to provide a system for liquefying gases which embodies the use of helium, and which is thermodynamically efficient and hence economical to run even though helium may be expensive to procure. It is yet a further object of this invention to so modify the Collins low-temperature refrigeration cycle as to practically double the rate at which hydrogen may be liquefied. These and other objects of this invention will be apparent in the following description.

The improvements in the liquefaction rate of hydrogen, or other gas, are achieved in this invention by the use of a heat exchanger which makes use of the outer case of the Collins-type cryostat heat exchanger and the inner Dewar wall. The gas to be liquefied is thereby put into very efficient heat exchange relationship with cooled helium and nitrogen precooling gas if used. This invention is discussed below in detail and with reference to the accompanying drawings, in which

Fig. 1 is in part a cross-sectional view of a Collins-type cryostat showing the connections between the heat exchange system, and the auxiliary liquefying system making up the improvements in such a cryostat embodied in this invention;

Fig. 2 is a cross-sectional view of a small section of the heat exchange system to show the relationship of the elements of the system; and

Fig. 3 illustrates production rates for liquid hydrogen by the process of this invention compared with the previous method used.

The process of this invention will be described below

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in terms of the liquefaction of hydrogen. However, it is obvious that the same process may also be used for all gases having boiling points above hydrogen, which means in effect all the known gases except helium itself.

Fig. 1 shows a cross-sectional view of the heat exchange system of a Collins cryostat embodying the improvements of this invention, along with a diagrammatical representation of auxiliary equipment. The entire heat exchange system is surrounded by an evacuated area 10 which is enclosed by outer jacket 11 and inside wall 12 which make up a Dewar-type flask, i.e., a double-walled container with the space between the walls evacuated. In this evacuated area precooling coils 13 for carrying liquid nitrogen or liquid air are wound about inside wall 12 in the upper portion of the heat exchange system and around radiation shield 21 in the lower portion. A double-walled flask hereinafter called the heat exchanger with walls 14 and 15 contains helically wound finned tubing 16 through which high-pressure helium is passed. The passage 17 surrounding this helically wound tubing serves as a pathway for cold, low pressure helium which is returned through the heat exchanger to precool the incoming helium. In passage 17 cord packing 16a (Fig. 2) is also wound in such a manner as to touch the fins of finned tubing 16 and walls 14 and 15. This cord packing 16a serves to hold the finned tubing 16 firmly in place and to better direct the passing of gas through passage 17. Between wall 14 of the heat exchanger and wall 12 of the Dewar-type flask, channel 18 is formed by helically wound wire 19 which serves as a channel spacer and to create a passageway 20 within channel 18. To form channel 18, flange 22 of the heat exchanger is separated from flange 23 of the Dewar-type flask by spacer flange 24 and sealed with an O ring seal 25. At one point space flange 24 has an inlet line 26 drilled in to permit introduction through lead line 27 of the gas to be liquefied. In the line leading from gas source 28 (usually a pressure flask) there may be placed one or more reducing valves, such as 29 and 30, if desired, and flow meter 31.

Part way down the heat exchanger a draw-off line 32 connects finned tubing 16 with charcoal trap 33 which in turn is connected by line 34 to a first expansion engine 35. The exhaust line 36 of expansion engine 35 leads to passage 17. Similarly, line 37 leads from finned tubing 16 to charcoal trap 38 and line 39 to a second expansion engine 40, the exhaust line 41 of which is connected with passage 17. A Joule-Thomson heat exchanger 42 and Joule-Thomson valve 43 are provided as part of the helium liquefying cycle. A draw-off line 45, controlled by valve 45a, is provided for removing the liquefied gas from the Dewar.

Helium source 46 is connected by line 47, controlled by valve 48, to compressor 49 which in turn is connected by line 50 to the tubing 16 of the helium heat exchanger. Passage 17 surrounding finned tubing 16 is in turn connected to compressor 49 by means of line 51 controlled by valve 52.

Flange 22 of the heat exchanger may contain auxiliary equipment such as sight glass 53, thermocouple connections 54 and relief valve 55.

The helium refrigeration cycle may be described briefly first before describing the liquefaction cycle. To begin, pure helium from source 46 is compressed by compressor system 49 and the warm, high-pressure helium is introduced into helical tubing 16 at the top of the main heat exchanger. After passing part way through tubing 16 a portion of this high-pressure helium is drawn off by line 32, passed through charcoal pot 33 and then, by way of line 34, led into the first expansion engine 35. There it is expanded and cooled to about 80° K. and returned to passage 17 to cool the incoming

high-pressure helium in finned tubing 16 by out-of-contact heat transfer. A second portion of the high-pressure helium from finned tubing 16 is similarly expanded in the second expansion engine 40 and reduced to a temperature of about 12° K. and returned to passage 17. The Joule-Thomson heat exchanger 42 and Joule-Thomson valve 43 are closed to prevent helium from liquefying and entering the lowest portion of the Dewar flask. The recirculated low-pressure helium passing up through passage 17 flows by way of line 51 into the compressor system 49 to be compressed and recycled through the system as described.

The liquefaction cycle may now be described using hydrogen as an example. Hydrogen is taken as a gas to illustrate this invention since it has the lowest boiling point (20.4° K.) of any gas except helium itself. It follows then that any gas having a boiling point above that of helium may be liquefied in the manner described.

Hydrogen from source 28, after passing through suitable pressure regulating valves 29 and 30 and flow meter 31, if desired, is introduced by line 27 into heat-exchanger inlet 26. This inlet 26 leads to channel 18 and then to passageway 20 formed by spacing wire 19. As the hydrogen is forced, under pressure, spirally downward in channel 18 it is cooled by out-of-contact heat exchange by means of the cold helium in passage 17. Inasmuch as the helium from the second expansion engine 40 is about 12° K. liquefaction of hydrogen probably begins in the region where the helium from this expansion engine is returned to passage 17. By the time the hydrogen passes the cold end of the helium heat exchanger it is completely liquefied and it drops to the bottom of the Dewar flask to collect as liquid hydrogen 44. The liquefied hydrogen may then be drawn off as desired by means of draw-off line 45.

As in the case where helium is to be liquefied, the rate of liquefaction may be increased with the use of liquid nitrogen precooling. The liquid nitrogen is circulated in tubing 13 in the top portion of the Dewar around wall 12 and in the bottom portion around radiation shield 21.

Although the helical path of channel 18 may be constructed by other suitable means, it is conveniently formed by winding a wire about the double-walled flask, using the wire as a divider between it and the vacuum jacket and also to form the helical path itself. The wire is preferably one that is relatively flexible and easily soldered. The width and/or thickness of channel 18 may be easily varied to suit each gas to be liquefied by varying the wire diameter and/or the pitch of the wire 19.

The marked improvement in liquefaction rates may be seen in Fig. 3 in which are plotted the liters of liquid hydrogen which can be obtained by using one and two helium compressors with a cryostat such as illustrated in Fig. 1. Such a cryostat has a normal capacity for liquefying 4 and 8 liters of helium, using one and two compressors, respectively. Curve A represents the rate achieved by the process of this invention, curve B the rate for the system without the modification embodied in this invention. It can be seen from Fig. 3 that the liquefaction rate is almost doubled.

The performance figures shown in Fig. 3 were obtained when a 0.031-inch silver solder wire spaced about 1½ inches apart was wound and soldered about the heat exchanger. This lifted the main heat exchanger out of the Dewar-type flask about one inch, requiring a spacer flange 24 of this height.

Thus, by the process of this invention, helium refrigeration is used in an efficient manner, making it possible to achieve marked improvement in liquefaction rates for hydrogen and all other gases having boiling points about helium.

I claim:

1. In an apparatus for liquefying a gas having a boiling point higher than that of helium, comprising helium refrigeration means, a double-walled container with the space between the walls evacuated surrounding said helium refrigeration means, channel means separating said helium refrigeration means from said container, said helium refrigeration means comprising finned tubing means for carrying high pressure helium to a first and a second expansion engine and means for conducting the resulting low temperature, low pressure helium around said finned tubing means in a counter-current direction in which said high-pressure helium moves through said finned tubing means, said channel means forming a helical path to lead the gas to be liquefied in the direction of flow of said high-pressure helium in said finned tubing means of said helium refrigeration means.

2. In an apparatus for liquefying gas having a boiling point higher than that of helium, heat exchange means for circulating low-pressure, low-temperature helium in out-of-contact heat exchange with high-pressure helium, a double-walled container with the space between the walls evacuated surrounding said heat exchange means and channel means separating said heat exchange means from said double-walled evacuated container, said channel means being in out-of-contact heat exchange relation with said low-pressure, low-temperature helium and having a helical passageway arranged to direct said gas in the same direction of flow as said high-pressure helium.

3. An apparatus in accordance with claim 2 wherein precooling means are located within the evacuated area of said double walled container with the space between the walls evacuated and are in out-of-contact heat-exchange relation with said channel means.

4. Apparatus in accordance with claim 2 wherein said helical path of said channel means is formed by wrapping wire helically around said heat exchange means, the diameter of said wire and the width of said channel being equal.

5. In an apparatus for liquefying gas having a boiling point higher than that of helium, means for supplying said gas, channel means for conducting said gas in a helical path in out-of-contact heat exchange with low-temperature, low-pressure helium gas to a liquid collection area, double-walled container with the space between the walls evacuated and helium refrigeration means located within said double-walled container and forming therewith said channel means, said helium refrigeration means comprising a source for said helium, a compressor, tubing means for carrying high-pressure helium to a first and second expansion engine, and means for conducting the resulting low-temperature, low-pressure helium around said tubing means in a counter-current direction in which said high-pressure helium moves through said tubing means, and means for drawing off said liquefied gas from said collecting area.

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