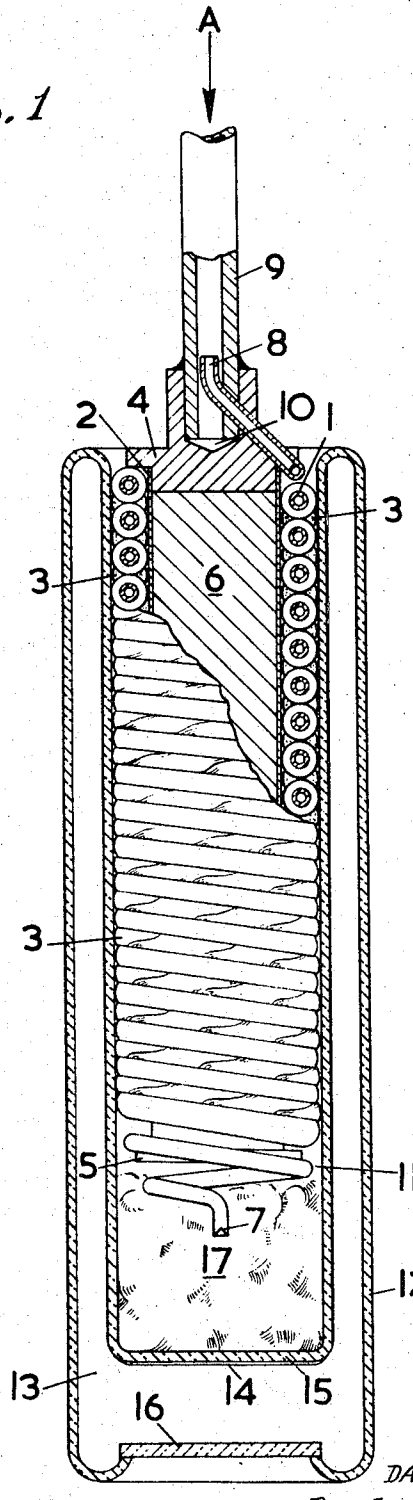
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APPARATUS FOR THE COOLING AND LIQUEFACTION OF GASES

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Fig. 1



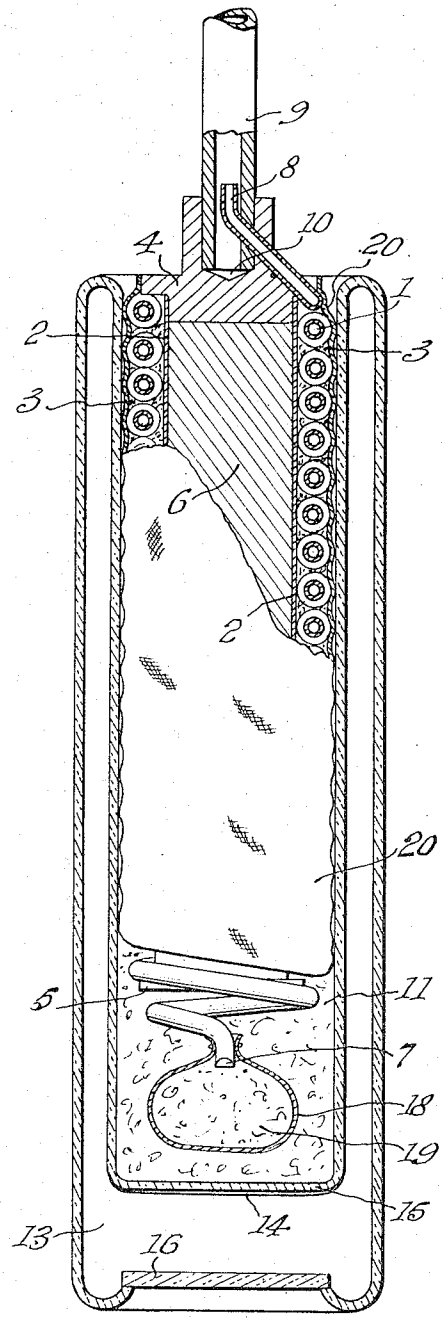
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Fig.2.



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APPARATUS FOR THE COOLING AND LIQUEFACTION OF GASES

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9 Claims. (Cl. 252—238)

This invention relates to the cooling and liquefaction of gases and apparatus therefor.

A gas below its inversion temperature may be cooled and consequently liquified by an apparatus of the Linde type generally known as a Linde liquifier. Such a liquifier in its simplest form comprises a heat exchanger coil through which a gas is pumped, and then expanded on emerging from the coil, the expanded gas passing to exhaust along or over the outside of the heat exchanger coil. The whole apparatus is thermally insulated, generally by means of a vacuum jacket.

One of the requirements for the heat exchanger of a Linde apparatus is that it should be extensive enough to give a reasonable efficiency of transference of heat between the incoming gas and the cooled exhaust gas to obtain an adequate cooling effect: and for some applications a short running up time is desirable.

For instance, in the infra-red detection field it is most desirable that cooled detection cells should be used and for certain applications a very convenient way of cooling such cells would be by means of a gas cooler or liquifier fed from a source of compressed gas. A typical detection cell is that described by A. S. Young in Journal of Scientific Instruments, April 1955; a cooler for a very small detection cell must be of very small dimensions say 2–3 cm. long and 0.75–1 cm. in diameter.

It has been determined that such a small apparatus can be constructed and used provided that provision is made for the input gas to be at very high pressure, e.g., air at 4000 lbs. per sq. in. and for the exhaust gas to be as near atmospheric pressure as practicable.

Accordingly, the invention contemplates a heat exchanger for use in an apparatus of the Linde type in which the ratio of input gas pressure to exhaust gas pressure is high; this is in contrast to conditions in the more usual Linde apparatus where the ratio of gas input pressure to gas exhaust pressure is relatively lower.

Another object of the invention is to provide a heat exchanger which can be easily fitted into a detection cell it is required to cool.

Yet another object of the invention is to provide a heat exchanger having means restricting the flow of liquified gas over its cooling area when the apparatus in which it is used is inverted.

A further object of the invention is to provide a heat exchanger having means restricting the spreading of liquified gas by fluid issuing from its expansion valve.

According to the invention a heat exchanger comprises a tube having fins helically wound thereon and itself wound about a cylindrical mounting of low thermal capacity, a pressure head for feeding one end of the tube, an expansion nozzle terminating the other end of the tube, and resilient worming wound with the tube to define in conjunction with the internal wall of a cylindrical container into which the heat exchanger is inserted in operation a passage through the tube fins and extending concentrically with the axis of the cylindrical mounting for gas expanded by the expansion nozzle.

The worming, by virtue of its resilience, enables the heat exchanger to fit snugly in the cooling space of a typical detection cell for example. An additional refinement consists of a resilient tubular sheath resting over the finned and wormed helically wound tube.

An additional requirement for an apparatus according to the invention is that it should be able to function irrespective of its attitude. To this end the cylindrical mounting of the heat exchanger is arranged to reduce convection within the mounting.

A further refinement is an arrangement of an absorbent material adjacent the exhaust of the expansion valve whereby any liquid which is formed is absorbed by the material to reduce its mobility. A permeable bag can be arranged to enclose the expansion valve.

A method of operating an apparatus of the Linde type in which the rate of cooling is simply adjustable, consists in feeding the gas input with a gas containing a second relatively easily liquified gas as an impurity. In such a method of operation the gas is liquified and the second gas being more easily liquified, liquifies and eventually solidifies in the heat exchanger itself; this blocks the passage of further gas.

The apparatus thereupon ceases to cool and commences to warm up. After it has warmed sufficiently to melt the frozen second gas the flow of gas can again commence and cooling recommences.

When cooling commences the blocking action is initiated and the flow of gas eventually ceases again. This cycle of events can continue indefinitely. It will be appreciated that the amount of second gas impurity which is present in the gas input to the apparatus can be adjusted to vary the rate of cooling which the apparatus can achieve.

The invention will be understood more readily from the accompanying drawings, in which:

FIG. 1 illustrates an apparatus for cooling and liquifying a gas in a detection cell for infra-red radiations, the view being a vertical longitudinal section through the cell with parts further broken away to show structural details more completely; and

FIG. 2 is a view similar to FIG. 1, but showing a somewhat modified structure.

A single heat exchanger coil **1** is wound upon a copper-nickel cylinder **2** and wormed with cotton packing threads **3**. The coil **1** which is shown in cross section is a tube of copper nickel alloy and is of 0.3 mm. bore; it is finned throughout its length and secured between brass end caps **4** and **5** by soft solder. A low thermal capacity material known as Brillite powder is packed in a space **6** between the end caps **4** and **5**. One end **7** of the coil **1** is pinched to form an expansion valve. The other, high pressure end **8** is led into a gas input manifold or pressure head formed by a tube **9** which is hard-soldered into a socket **10** in the end cap **4**.

In use the coil **1** is inserted into a cooling space **11** of a detection cell **12**. In the figure the cell is of the type due to Young and Lawson in which a double-walled Dewar flask **13** carries a photo-sensitive layer **14** on an internal face **15**, the photo-sensitive layer **14** receiving radiations through a sapphire window **16**. The sapphire window is preferably sealed into the cell by the method described and claimed in British Patent No. 647,616 due to J. L. Craston which also issued as United States Letters Patent No. 2,584,427.

The coil **1** fits snugly into the cooling space **11** of the cell **12** by virtue of the cotton packing threads **3** which effectively cushion the coil **1** against the glass sides of the cell **12**. A part **17** of the cooling space **11** of the cell **12** is filled with cotton wool. In a typical example the overall length of the coil **1** was 2.5 cm. and the diameter of the cylinder **2** was 5 mm.

To facilitate the fitting of the coil **1** into a space such as

the cooling space 11 a resilient, tubular sheath is fitted over the outside of the tube 1 and the packing threads 3. The material of the sheath is conveniently a metal but it is possible that suitable plastic materials could be used. This tubular sheath is shown in FIG. 2 as 20. FIG. 2 additionally shows a permeable bag 18. Preferably, the bag 18 contains an absorptive material 19 such as cotton wool.

The operation of the cell is as follows:

High pressure air at 4,000 lbs. per sq. inch enters the tube 9, in the direction shown by the arrow A, from a convenient source, for example an air bottle. The air passes down the coil 1, expands through the pinched end 7 and passes back round the outside of the coil 1, being guided into intimate contact with the finned surface of the coil 1 by the cotton wormings 3, after which it exhausts to the atmosphere. In a typical example approximately 120 cc. of air pass through the coil 1 each second and liquid air forms in the space 17 after a period of the order of 24 seconds. The absorptive material in the space 17 absorbs the liquid air and enables the apparatus to be used without undue difficulty in attitudes other than the upright one shown in the drawing.

One way of controlling the cooling produced by the apparatus which may be convenient in practice is to arrange that the input air contains about 0.5 percent of carbon dioxide. This causes the fins of the coil 1 to become blocked some time after liquefaction has commenced. The flow of air ceases and the apparatus absorbs heat from its surroundings until the solid carbon dioxide which is blocking the coil 1 melts; whereupon the flow of air can recommence, and the coil 1 again become blocked; the cell will then absorb heat from the surroundings to become unblocked and so on.

Although the apparatus has been described as used with air it will be appreciated that depending upon the properties of a gas other gases may in practice be used. For instance nitrogen or oxygen is suitable.

In constructing heat exchangers as described in the apparatus above the tube which forms the coil 1 is typically 0.5 mm. outside diameter and 0.3 mm. inside diameter; it must be very smooth internally in order to promote satisfactory flow of the high pressure gas. The finning on the coil 1 is of copper which has been tinned and wound as a continuous spiral with a pitch of three turns per mm. In the typical example given the fins were 0.1 mm. thick and 0.3 mm. wide.

Although the low thermal capacity filling of the space 6 is specified as Brillite powder it will be appreciated that any convenient material of low thermal capacity can be used. The object of such a material is two-fold, on one hand a low thermal capacity is produced, and on the other hand a low convection region is produced within the cylinder on which the heat exchanger coil is wound. Low convection enables the heat exchanger to function irrespective of its attitude by reducing adverse heat flows with the cylinder.

To prevent liquified gas from swirling onto the heat exchanger coil especially when the exchanger is inverted a permeable bag can be used to enclose the expansion valve and cut down the velocity of emergent gas; preferably the bag contains an absorptive material such as cotton wool.

An important feature in the actual manufacture of the heat exchanger is to arrange for the correct packing and positioning of the cotton threads. The object of the cotton packing is to make the exhaust gases pass correctly through the fins of the tubing as shown. Gas must not be allowed to leak between the walls and the packing which should be twisted tightly to give a uniform thickness and a good tight fit with the inner and outer tubes. Ideally the fins of the exchanger should also just touch the inner and outer walls of the exchanger but in practice a reasonable working tolerance has to be left. It should be noted that the bulk flow of the return gas passing through the long channels of a section the same as that between adjacent

fins may in fact be non-turbulent. A severe escape of gas past the cotton packing may increase the time required to make liquid by 5 to 6 times and in the steady liquefying state frosting will occur at the top of the cell. In the calculation of the efficiency of the liquefier this loss of efficiency with loose packing can be taken care of by reducing the effective "wetted surface" per unit length of the exchanger on the low pressure side. It is however exceedingly difficult to make any estimate of the loss of efficiency due to loose packing and it is better to measure the performance of the liquefier directly to check any alteration in the method of packing.

In order to achieve a high quality in the packing of the exchanger strict tolerances have to be put on the inner and outer tubes, the O.D. of the fins themselves and on the packing. Using the inside of a glass cell as the outer of the exchanger imposes a close tolerance on the glassware, which, although it can be met may be objectionable. An alternative referred to above, is to provide a thin metal or thin plastic sheath which can then seal to the top of the cell. The plastic material of a plastic sheath must be chosen bearing in mind that many materials tend to split as they are cooled, presumably owing to their relatively high expansion coefficients.

I claim:

1. A heat exchanger comprising a cylindrical mounting of low thermal capacity, said mounting comprising a hollow metal cylinder containing a distributed filling of low thermal capacity adapted to restrict convection flow within the cylinder, a tube helically wound about said mounting, a pressure head for feeding one end of said tube, an expansion nozzle terminating the other end of said tube, fins helically wound about said tube, a cylindrical container, the said tube inserted in said container, and resilient worming wound with the tube to define in conjunction with the internal wall of said container a passage through the helically wound fins and extending concentrically with the axis of the cylindrical mounting for gas expanded by the expansion nozzle, whereby the gas flows at right angles to the axis of the said tube, dividing about each coil to flow circumferentially around opposing sides of the said tube.

2. A heat exchanger as claimed in claim 1, wherein a resilient, tubular sheath is fitted over the finned and wormed helically wound tube, whereby an external surface is obtained to the heat exchanger which can be matched with the internal surface of the cylindrical container.

3. A heat exchanger as claimed in claim 1, wherein a bag of fluid permeable material encloses the expansion nozzle.

4. A heat exchanger as claimed in claim 1, wherein an absorbent packing is positioned adjacent the expansion valve.

5. The combination in a single unitary fitting comprising a glass detection cell including a double-walled Dewar flask carrying a photo-sensitive layer on an internal face, a heat exchanger fitted within the said flask, said exchanger comprising a cylindrical mounting of low thermal capacity, a tube helically wound about such mounting, fins helically wound about said tube, a pressure head for feeding one end of said tube, an expansion nozzle terminating the other end of said tube, and resilient worming wound with the tube to define in conjunction with the internal wall of said flask a passage through the tube fins and extending concentrically with the axis of the cylindrical mounting for gas expanded by the expansion nozzle.

6. In the combination as claimed in claim 5, a resilient tubular sheath extending over the finned and wormed helically wound tube of the heat exchanger, whereby an external surface is obtained to the heat exchanger which can be matched with the internal surface of the flask.

7. In the combination as claimed in claim 5, wherein an absorbent packing is positioned adjacent the expansion valve of said heat exchanger.

8. In the combination as claimed in claim 5, wherein a bag of fluid permeable material encloses the expansion nozzle of said heat exchanger.

9. In the combination as claimed in claim 8, wherein the bag contains an absorbent packing.

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