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GAS-EXPANSION REFRIGERATOR

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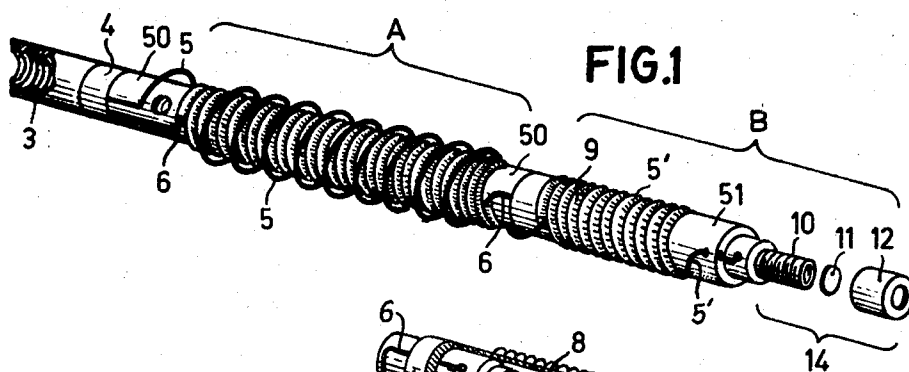


FIG. 1a

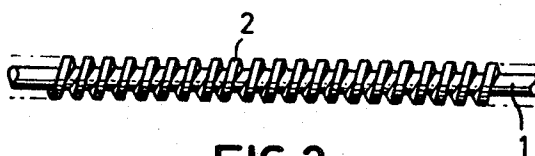


FIG. 2

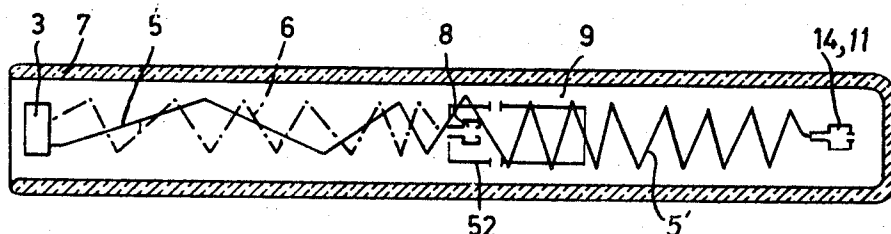


FIG. 3

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GAS-EXPANSION REFRIGERATOR

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7 Claims

ABSTRACT OF THE DISCLOSURE

A gas-expansion refrigerator for use with pressurized gas has a thermally-insulated housing containing first and second tubes through which pressurized gas flows and is discharged through their respective first and second expansion valves. Gas discharged from one tube counterflows in heat-exchange relationship with both tubes pre-cooling the gas therein, and gas discharged from the second tube counterflows in heat-exchange relationship with the second tube cooling the gas therein, such that the gas expands to a lower temperature from the second valve than from the first valve.

The invention relates to a small-size gas-expansion refrigerator.

There are already known single-expansion refrigerators of the Joule-Thompson type comprising a heat exchanger formed by a thin tube provided with ribs helically wound around a cylindrical mandril, which heat exchanger terminates in an expansion opening, the assembly being mounted in intimate frictional contact inside a tube thermally insulated by vacuum. The gas cooled by the expansion rises inside the thermally insulated tube in a counter-flow along the thin tube, which cools the gas not yet expanded, which process is cumulative and permits of liquefying the gas after a given period of time.

There are also known large liquefying or cooling systems for scientific purposes or large-scale industrial purposes, in which a cooling effect is obtained in two cooling stages, the first stage forming a pre-cooling stage for the second stage.

These systems are expensive, bulky and suitable only for special purposes.

The invention relates to a device of the first-mentioned kind, that is to say to a gas-expansion refrigerator and to a counterflow heat-exchanger mounted in a tube of a high thermal insulation capacity, based on a two-stage cooling effect. The invention has for its object to provide a simple, efficacious, fairly cheap and small-size device.

The device according to the invention is mainly characterized in that it comprises in one tube of high thermal insulation capacity two elements, each of which comprises a heat exchanger followed by an expander to which the gas to be cooled is fed in parallel, whilst said elements are arranged side by side in thermal contact in said tube so that the first element operates as a preliminary cooler for the second element, arranged at the end of the tube. It is found that the efficiency of the device is considerably higher than that of two elements mounted thermally in parallel.

The invention will be explained more fully with reference to the accompanying drawing, in which:

FIG. 1 shows partly in an exploded view the arrangement of the various elements of the tube. FIG. 1a shows a fragmentary and partial-sectional view of the tube.

FIG. 2 shows the form of the tube for the heat exchanger.

FIG. 3 shows the system of the connections and the

circulation of the gas in the device according to the invention.

As stated above the device according to the invention comprises the parallel combination of two cooling elements A and B, mounted in the same double-walled tube or housing 7, the vacuum being maintained in the intermediate space as in the Dewar vessel. This tube is shown only diagrammatically in FIG. 3, since it is not essential for this invention. For the sake of clarity the diameter of the tube is shown on a greatly enlarged scale, and the walls of the tube define first and second adjacent interior chambers A' and B'. The heat exchanger of each of these elements operating on a counter-flow, is formed by a nickel tube 1 (shown on an enlarged scale in FIG. 2) around which a square-section silver wire 2 is wound, which serves as the ribs. The tube thus obtained is wound itself on a mandril formed by a thermal insulator, for example, of nylon, formed by two consecutive portions 50 (element A) and 51 (element B), interconnected by a silver sleeve 52. The gas to be liquefied (nitrogen or argon) enters under a high pressure (150 to 200 bars) through an end piece 3, shown in a sectional view in FIG. 1 and comprising a porous copper filter 4. Two tubes 5 and 6 project from this end piece. The tube 6 is connected with the expander 8, formed by a chamber communicating with the ambience through an orifice of a few tenths of a mm. in diameter, which may be varied in accordance with the desired results. The gas escapes through two small apertures 9 of the sleeve 52, whilst being cooled, and returns along the tubes 5 and 6 in first and second passages defined between tubes (6 and 5) and (5') and the walls of chambers A' and B' respectively. The expander 8 thus produces the pre-cooling effect. At this place liquefied nitrogen is accumulated in the sleeve 52. The tube 5 of nickel, not provided with ribs, is wound also around the tube 6 and the sleeve 52 and it feeds the second element B. The latter is formed substantially in the same manner as the former and comprises an exchanger with a wound wire 5 to form ribs 5' like the wire 6 of the element A and an expander 14, shown in FIG. 1 dismounted in three parts, that is to say an end piece 10 with screwthread, the end of which is provided with the disc 11 with the expansion opening and a socket 12, screwed onto the end piece 10 for mounting the assembly. The exchanger tube 5 opens out in the end piece 10 and the gas expands through the opening of the disc 11. Then the gas returns past the tube 5' (element B), and then the tubes 5 and 6 (element A). The liquefied nitrogen accumulates on the bottom of the tube 7, to which may advantageously be connected the cooling ring (not shown) of a tube of a mosaic infrared analyser, the junctions of which have to be cooled to very low temperatures. This application is, of course, not excluding other possibilities. A device according to the invention may be employed in any case where the problems of size, manoeuvrability and low cost price are to be observed in particular.

The gases mentioned above are not the only gases that may be used; the tube 6 might be fed by nitrogen and the tube 5 by hydrogen for liquefying the latter.

The particular importance of the invention stands out in the small size, if it is considered that on this principle liquefying systems of 5 mms. in diameter and about 10 cms. in length can be constructed. The dimensions of the apparatus depend, of course, upon the cooling power and with the values mentioned above a power of 5 to 10 w. has to be envisaged.

The device according to the invention has a great adaptability in use. The expanders 8 and 14 are constructed in the same manner, so that the diameter of the openings of the discs such as 11 can be readily changed according to the gases employed and the desired powers: it is sufficient to remove the socket 12 and to replace the disc by

another having the appropriate opening. With the expander 8 this requires to remove the portion of the mandril 50 from the sleeve 52, which can be readily done, since the spring formed by the turns of the wire 5 around this sleeve provides sufficient elasticity.

What is claimed is:

1. A method of refrigerating a gas comprising the steps: (a) flowing a first gas through a first conduit disposed in a first passage, (b) expanding the first gas through a first valve, (c) counterflowing the expanded gas in pre-cooling heat exchange relationship with said first conduit and gas therein, (d) flowing a second gas through a second conduit disposed partly within said first passage and also within a second passage, (e) expanding gas in said second conduit through a second valve to a temperature lower than that in the first, (f) counterflowing said second expanded gas in precooling heat exchange relationship with said second conduit and gas therein, (g) whereby some of the gas in said second conduit having been pre-cooled by said first and second expanded gas, is liquefied upon the discharging and expansion thereof.

2. A gas-expansion refrigerator for use with pressurized gas from a source, comprising:

- (a) a thermally-insulated housing having walls defining first and second separate parts of an interior chamber;
- (b) a first tube disposed in the first part of the chamber, and a second tube disposed in both parts, first and second passages being defined in the first and second parts respectively, between said tubes and said chamber walls,

(c) each tube having an inlet for receiving said gas, the first tube having a first expansion valve at its outlet end for discharging expanded gas at a first temperature to counterflow in said first passage in pre-cooling heat exchange relationship with both tubes and gas within the tubes, the second tube having a second expansion valve at its outlet end for discharging expanded gas at a temperature lower than that at said first valve to counterflow in said second passage in further precooling heat exchange relationship with said second tube.

3. Apparatus as defined in claim 2 wherein said chamber defines a longitudinal axis disposed generally vertically when the apparatus is operated with the second

chamber part being below the first and having a closed bottom end, whereby liquefied gas accumulates in said closed end.

4. Apparatus as defined in claim 2 further comprising:

- (a) first and second elongated mandrils disposed in end-to-end relationship, with the first and second tubes coiled around the first and second mandrils respectively,

- (b) a sleeve joining the adjacent ends of the mandrils and containing said first expansion valve therein; and

- (c) a fitting carried by the remote end of the second mandril for containing the second expansion valve, which is thus situated adjacent said bottom end.

5. Apparatus as defined in claim 2 wherein the second expansion valve comprises (a) a hollow end piece into which pressurized gas from the second tube is introduced, (b) a closure member having a small aperture therein for sealing the remote end of the end piece, the aperture functioning as the expansion valve, and (c) means for securing the closure member to the end piece.

6. Apparatus as defined in claim 2 wherein the entering gas is under a pressure of about 150 to 200 bars (millibars).

7. Apparatus as defined in claim 2 wherein at least one of said tubes comprises:

- (a) a nickel conduit, and
- (b) silver wire wound helically around the tube and secured thereto, the tube then formed into a helical coil with the silver wire extending therefrom as heat-exchange elements.

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