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3,391,546

REFRIGERATING APPARATUS

Filed Aug. 3, 1966

2 Sheets-Sheet 1

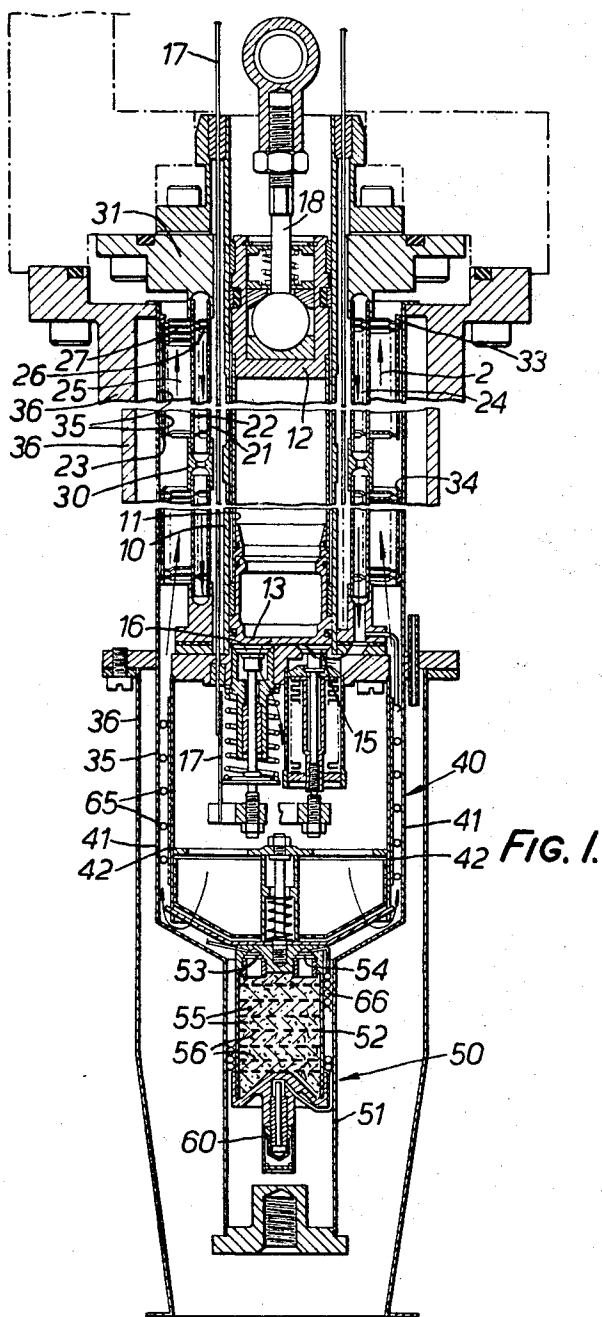


FIG. 1.

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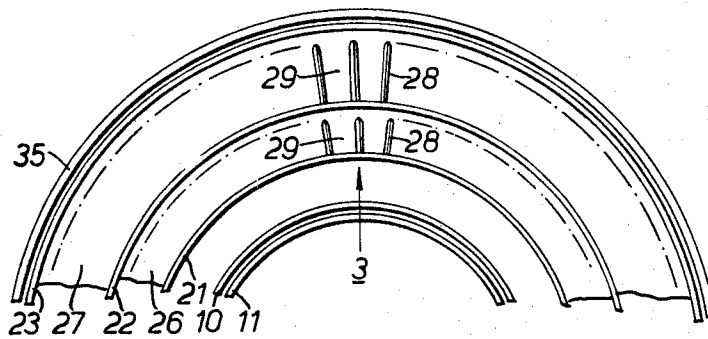


FIG. 2.

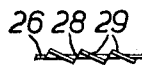


FIG. 3.

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3,391,546

REFRIGERATING APPARATUS

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Filed Aug. 3, 1966, Ser. No. 570,006

Claims priority, application Great Britain, Aug. 6, 1965,

33,770/65

2 Claims. (Cl. 62-45)

ABSTRACT OF THE DISCLOSURE

A cryogenic unit includes an absorbent cleaner for cleaning refrigerant fluid, comprises a metal vessel closed at its cold end and having at its opposite warm end a fluid inlet and a fluid outlet spaced apart from one another, a number of parallel spaced partitions of a material of good thermal conductivity such as copper gauge extending transversely to a line leading from the cold end to the warm end of the vessel, and an absorbent material occupying the spaces between the partitions, so that as the refrigerant travels in generally U-shaped paths it is cooled by the partitions as it flows from the warm end to the cool end and cools them as it flows back from the cool end to the warm end.

This invention relates to refrigerating apparatus, in particular cryogenic apparatus, and is concerned with a cleaner for cleaning a refrigerant fluid intended for mounting in proximity to the cold end of a cryogenic apparatus.

It is customary to provide an absorber unit for cleaning the refrigerant in a completely separate vessel so as to remove any contaminants from the gas before it enters the cryogenic apparatus, and also to provide absorber units at specific low temperature levels between stages.

The present invention employs an absorber which is physically located within and forming part of the second stage of a cryogenic cooler and through which the gases pass after having been cooled by the first stage. The term absorbent is used herein to include adsorbent or like cleaning materials.

Thus in accordance with the invention the cleaner includes a metal vessel to contain an absorbent material in the spaces between a series of foraminous partitions of a material of good thermal conductivity extending in directions transverse to a direction leading to the cold end of the apparatus.

Thus in one form of the invention the cleaner is mounted within, but spaced from, an outer vessel, whilst a heat exchanger comprising a helically coiled pipe surrounds the vessel within the outer vessel, and an expansion nozzle is carried by the cold end of the inner vessel between it and the outer vessel, gas inlets and outlets being provided opening from the absorber vessel adjacent its warm end, of which the outlet communicates through one path of the heat exchanger with the expansion nozzle, while the other path of the heat exchanger connects the space between the nozzle and the outer vessel to an exhaust outlet.

The invention lends itself particularly to applications in which saving of space is particularly important, in which case a cold absorbent bed of adequate capacity may not be readily feasible. In addition where the first and second stages are connected in parallel in the gas circuit, it may be unnecessary to remove contaminants from the gas passing through the first stage to the same extent as from the gas passing through the second stage. Thus the first stage may comprise an expansion machine working on the Claude cycle whilst the second stage comprises an expansion nozzle relying on the Joule Thomson effect of

cooling by isenthalpic expansion below the inversion temperature, in which case the removal of contaminants is particularly important from any gas which is to pass through the expansion nozzle. In general, contaminants are most efficiently removed by absorption at a temperature near to their liquefying points, and therefore it is desirable to have absorbent at a temperature as near as possible to the lowest temperature of the system, in this case 28° K.

With the absorber situated between the gas at the temperature prevailing between the stages and the gas or liquid at the temperature to which it is finally cooled, it is important to prevent the gas in the absorber from carrying heat from the warmer to the colder end. This is done in the arrangement in accordance with the invention by providing the partitions of foraminous material of good thermal conductivity such as copper which extend transversely across the absorber. Thus any warm gas flowing down on one side of the absorber will be progressively cooled by the foraminous partitions and correspondingly any gas flowing up on the other side will take up heat from those partitions and cool them.

The invention may be put into practice in various ways but one specific embodiment will be described by way of example with reference to the accompanying drawings, in which:

FIGURE 1 is a longitudinal section through a cryogenic apparatus which includes an absorber in accordance with the present invention and also includes a heat exchanger in accordance with the present applicants' co-pending U.S. patent application Ser. No. 570,062, filed Aug. 3, 1966,

FIGURE 2 is an enlarged view of part of one of the louvred washers looking in the direction of the arrow 2 of FIGURE 1, and

FIGURE 3 is a detail view of the louvres seen from the ends of the twisted teeth in the direction of the arrow 3 of FIGURE 2. In some cases dimensions are shown considerably exaggerated for the sake of clarity.

The apparatus employs neon as working fluid and comprises two stages. The first stage employs an expansion engine working on the Claude cycle to produce an outlet temperature of some 50° K. from an initial supply of gas at a temperature of about 75° C. The second stage employs the Joule Thomson effect, namely relying on isenthalpic expansion of the gas below its inversion temperature through an expansion nozzle. In this case the second stage cools the neon down to its liquefaction temperature, namely 28° K.

The apparatus is of elongated form and for purposes of description it will be assumed that it is placed vertically with its cold end at the bottom.

The heat exchanger embodying the companion invention surrounds the cylinder 10 of the first stage which contains an elongated piston, comprising a tube 11 having plugs 12 and 13 at its ends, extending for the majority of the height of the unit. At its lower end the cylinder is provided with an inlet valve 15 and an exhaust valve 16 operated by wires 17 extending up through the annular space between the cylinder and the heat exchanger. The piston is provided with a connecting rod 18 at its upper end for actuating it in suitable timed sequence with the valves.

The heat exchanger comprises three coaxial tubes 21, 22 and 23 of which the inner tube 21 and middle tube 22 are of thin metal, such as stainless steel, whilst the outer tube 23 is of a plastics material. The space between the inner and middle tubes forms a passage 24 for the descending high pressure gas whilst the space between the middle and outer tubes forms a passage 25 for the ascending low pressure gas.

Each passage is occupied by a large number of louvred copper washers 26 or 27 forming fins. The louvres may be formed by punching radial slots 28 extending from the inner periphery of the washer to a point just short of its outer periphery and then twisting the tongues 29 so formed about radial axes so as to lie at an angle to the plane of the washer, for example 18° or 20° as indicated in FIGURE 3. Conveniently the heat exchanger is made in two portions each constituting part of its length and the two portions of the inner and middle tubes are connected by a connecting ring 30.

In assembling the heat exchanger the inner tube 21 is silver plated and the washers 26 of the inner passage 24 are threaded on to it using removable spacers made of mica, and are vacuum brazed to it. The mica spacers are then removed and the middle tube 22 also silver plated is fitted over the washers. The washers 27 of the outer passage 25 are then assembled round the middle tube 22 with mica spacers and assembled in a jig with end flange 31 or 32 and the connecting ring 30. The assembly is then vacuum brazed and the spacers removed. Finally the plastics outer tube 23 is shrunk over the outer washers to seal their outer edges. Each section of the plastics outer tube has at its upper end an annular rib 33 or 34 to form a seal with the inner wall 35 of a vacuum flask 36 within which the apparatus is contained.

The lower end of the apparatus comprises a valve casing 40 having double walls 41 and 42, and, at the lower end of the valve casing, the second stage expansion unit 50. The latter comprises an outer casing 51, being the lower part of the inner wall 35 of the surrounding vacuum flask, having within it and spaced from it a cylindrical absorber vessel 52 forming the subject of the present invention.

At its upper end the absorber vessel has an inlet opening 53 and an outlet opening 54 provided with plugs and filters. The absorber vessel is occupied in the main by a suitable granular absorbent 55, such as Linde Molecular Sieve 13X which is primarily a calcium aluminium silicate material which serves to clean the refrigerant fluid by removing from it any contaminants, for example air, before it passes through the final expansion nozzle. In order to prevent the gas circulating in the absorber vessel from carrying heat from the hot end to the cold end a number of copper gauze discs 56 are embedded in the material so as to lie in horizontal planes, to effect a lateral exchange of heat between the incoming and outgoing streams of gas without facilitating axial conduction of heat.

At its lower end the absorber vessel 52 carries the expansion nozzle 60 which may be of known construction.

The connections for the flow of gas are as follows: High pressure gas is admitted to the upper end of the inner high pressure passage 24 of the heat exchanger and flows down in helical paths through the louvred washers 26 in that passage. At its lower end the gas stream divides into two, of which the major part flows to the inlet valve 15 of the expansion engine. The smaller portion flows out laterally and passes down through a finned helical tube 65 in the annular space between the walls 41 and 42 of the valve casing to the inlet 53 of the absorber. From the outlet 54 of the absorber this gas flows through

a further finned helical tube 66 in the annular space between the absorber vessel 52 and the outer casing 51 to the expansion nozzle 60. The low pressure gas issuing from the expansion nozzle flows up past the fins of the finned tube 66 in the space between the absorber vessel and the outer casing 51 and past the fins of the finned tube 65 between the double walls of the valve casing to join the gas from the exhaust valve of the expansion engine and flow up through the louvred washers 27 in the outer low-pressure passage 25 to the top of the heat exchanger where it is exhausted for recompression.

The fact that the heat exchanger is made in two portions on the one hand facilitates the production of tubes of sufficient accuracy, and on the other hand provides in effect a gas baffle to prevent any leakage of gas from the piston seal reaching the warm end of the space between the cylinder and the heat exchanger. In a modified arrangement (not shown) at least the inner tube is in one piece and the connecting ring is omitted.

The arrangement described provides a very compact cryogenic cooler with the main first stage heat exchanger nested around the piston and cylinder of the first stage, and the absorber interposed between the first and second stages and nested within the second stage heat exchanger.

What I claim as my invention and desire to secure by Letters Patent is:

1. A cleaner for cleaning a refrigerant fluid intended for mounting in proximity to the cold end of a cryogenic apparatus, including an absorber vessel closed at one end, which will be termed the cold end, and having at its opposite warm end a fluid inlet and a fluid outlet spaced apart from one another, the fluid in both said inlet and said outlet being at substantially the same temperature, a plurality of spaced foraminous partitions of a material of good thermal conductivity extending in directions transverse to a line leading from the cold end to the warm end of the vessel, and an absorbent material occupying the spaces between the partitions.

2. A cryogenic unit including a cleaner as claimed in claim 1 mounted within, but spaced from, an outer vessel, a heat exchanger comprising a helically coiled pipe surrounding the vessel within the outer vessel, and an expansion nozzle carried by the cold end of the inner vessel between it and the outer vessel, the fluid inlets and outlets opening from the absorber vessel adjacent its warm end of which the fluid outlet communicates through one path of the heat exchanger with the expansion nozzle, while the other path of the heat exchanger connects the space between the nozzle and the outer vessel to an exhaust outlet.

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