June 6, 1961 H. O. McMAHON 2,986,891

LOW-TEMPERATURE VESSELS

Filed Feb 10, 1958 2 Sheets-Sheet 1

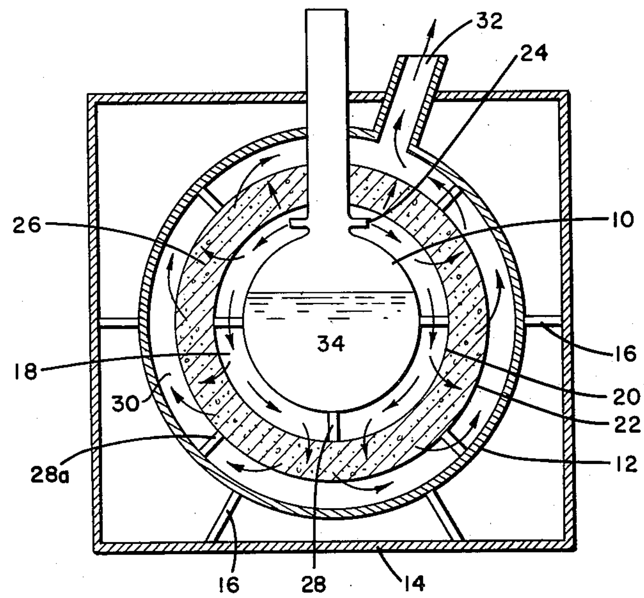

Fig. 1

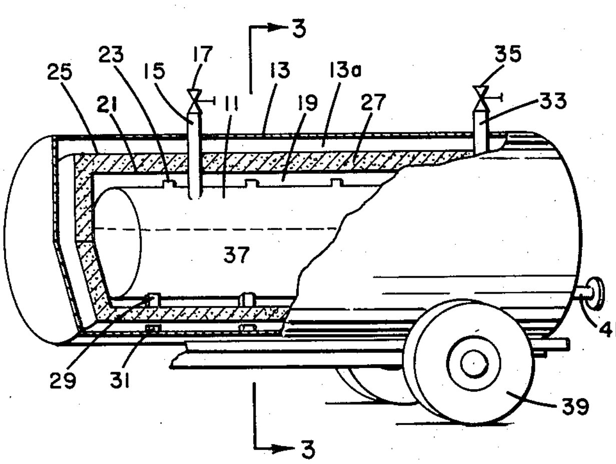

Fig. 2

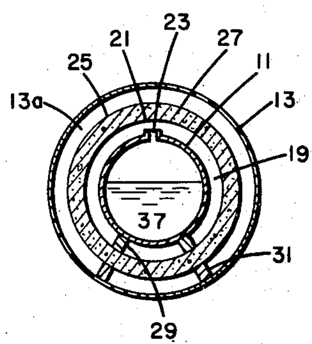

Fig. 3

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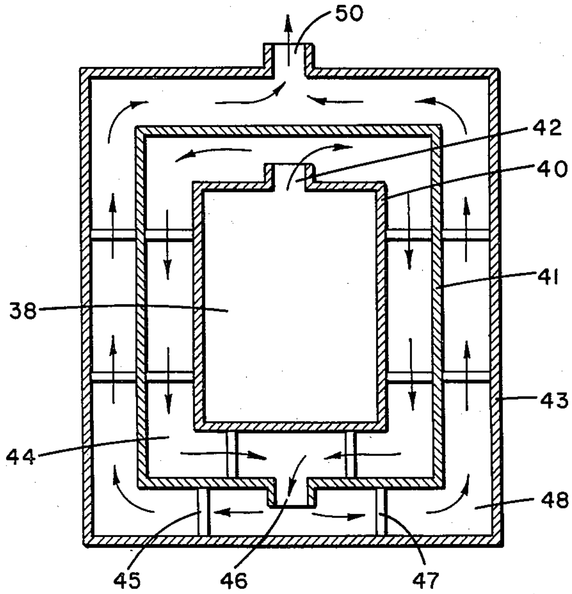

Fig. 4

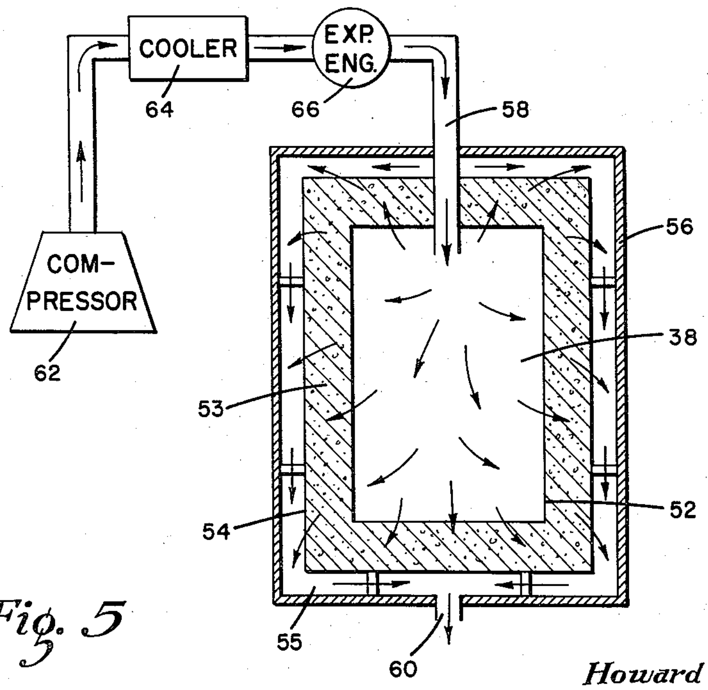

Fig. 5

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LOW-TEMPERATURE VESSELS

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Filed Feb. 10, 1958, Ser. No. 714,122
5 Claims. (Cl. 62—45)

This invention relates to maintaining an enclosed space at a low temperature and more particularly to minimizing possible heat transfer from the surrounding atmosphere into the enclosed space.

It is desirable to be able to maintain enclosed spaces, either large or small, at temperatures below those of the atmosphere surrounding the enclosed space. Thus for example, it is necessary to maintain large spaces such as cold storage houses, refrigeration plants, and domestic refrigerators at temperatures around 0° C.; while it is necessary to maintain the interior of storage vessels, tank cars, and dewar-type containers at temperatures as low as —269° C. to be able to handle, transport, and store liquefied gases. Although these enclosed areas vary in size, design and performance characteristics required of them, they are all subject to heat losses by reason of heat transferred from their surroundings into the enclosed space which must be kept at a low temperature.

Many complicated systems having been devised to minimize these heat leaks from the surroundings, and they include evacuating a space surrounding the area to be cooled and using various insulations, some being evacuated. The necessity of evacuating an annular space about the enclosed area introduces complications in manufacture and of course is not practical for large enclosed spaces such as refrigerators and cold storage units.

It would therefore be desirable to provide a refrigeration system which is simple in construction and which, at the same time, is more effective in preventing the inflow of heat from the surrounding atmosphere.

It is therefore an object of this invention to provide a system wherein the heat leak from the surrounding atmosphere into an enclosed space maintained at a low temperature is minimized. It is another object to provide containers for liquefied gases in which the loss of liquid due to boil-off is maintained at a minimum. Another object is to provide a refrigerating system which employs simple auxiliary equipment, has no internal coil system, and maintains a consistent temperature throughout the cold space while at the same time does not dehumidify items stored therein.

Briefly, this invention involves economically and efficiently maintaining an enclosed space at a low temperature by venting cold gas from the enclosed space into a passage surrounding substantially all of the enclosed space, and in a direction countercurrent to the flow of heat from the surroundings. The gas which is vented from the enclosed space may be supplied through boil-off of liquefied gas stored therein or it may be supplied from external sources. The passage may in turn be surrounded with porous insulation or may contain porous insulation.

This invention will be described in detail with reference to the accompanying drawings in which

FIG. 1 represents a cross-sectional view of a flask suitable for storing liquefied gases according to the process of this invention;

FIG. 2 represents a tankcar, partly in cross-section, partly in plan view, designed in accordance with this invention;

FIG. 3 is a cross-sectional view of the tankcar of FIG. 2 taken along lines 3—3 of FIG. 2;

FIG. 4 represents a cross-section view of an enclosed space maintained at a low temperature and using the process of this invention without insulation; and

FIG. 5 is a cross-sectional view of an enclosed space such as a cold storage room maintained at a low temperature in accordance with the practice of this invention, in which cold gas is supplied from an external source.

In order to achieve the improved performance in the storage of cold liquids, or in the maintaining of low temperatures in relatively large areas, in accordance with the practice of this invention, it is necessary that a fluid, normally a gas, at a temperature below that of the surrounding atmosphere be vented or released from the enclosed space into a passage extending around substantially all of the enclosed space or directly from the enclosed space radially outward and in a direction countercurrent to the direction of normal heat influx from the surrounds. The passage may or may not be surrounded with porous insulation, or the insulation may serve also as the passage. It is preferable that the vented gas reach a temperature approximating the temperature of the atmosphere at the point where it is finally drawn off.

This invention may be further illustrated with reference to FIGS. 1 through 5 in which three different arrangements are shown.

FIG. 1 represents a cross-sectional view of a flask or container suitable for storing liquefied gases according to the teaching of this invention. In FIG. 1 container **10** is placed within an outside protective vessel **12** which may in turn be surrounded by any convenient configuration such as box **14** for additional protection. Vessel **12** is held in place by any suitable supporting means such as supports **16**. Surrounding substantially all of flask **10** and in concentric relationship therewith is passage **18** which is defined by the outside wall of flask **10** and by a permeable wall **20** (such as screening) which also substantially surrounds flask **10** and is in concentric relationship therewith. Concentric with permeable wall **20** is another permeable wall **22** and these define an annular space between them, said space containing insulation **26**. Ports **24** lead out from the neck of flask **10** into space **18**. These ports are placed above the normal line of liquid **34** stored in flask **10**. The spacing **18** between flask **10** and permeable wall **20** is maintained by any suitable way such as supports **28** and the spacing between permeable wall **22** and protective wall **12** is also maintained by any suitable means such as supports **28**_a_. A lead-off line **32** is connected with space **30** to permit gas to pass out of the storage system either into the atmosphere or into a suitable recovery system not shown.

The arrangement shown in FIG. 1 is particularly well suited to the storing, handling, and transporting liquefied gases at very low temperatures. It will be seen that it combines the use of an annular passage surrounding the storage vessel **10** and insulation **26**. When a portion of the liquid **34** in flask **10** boils off to form cold gas, the gas passes through ports **24** into annular space **18** and then in a radial direction (as indicated by the arrows) through permeable wall **20**, insulation **26** and finally through permeable wall **22** into space **30**. It will be seen from this arrangement that the cold gas vented from flask **10** is continually passing in a direction countercurrent to the direction of incoming heat from the surroundings. This heat from the surroundings is flowing inwardly through box **14** and thence through the protective vessel **12**. By this system of heat exchange it is possible to make use of the entire refrigerating content of the vented gas if it is directed in this manner to sweep out the incoming heat. By the time the gas leaves the system through lead-off line **32**, it has preferably been raised to the temperature of the surrounding atmosphere.

Inasmuch as the incoming heat is responsible for the boil-off of the liquefied gas, the practice of this invention makes possible the reduction of liquid loss to a minimum. If ideal conditions were obtained, there should not of course be any liquid boil-off. However, this is not entirely practical; but I have found that under nearly ideal conditions, with the gas diffusing evenly through the insulation 26 and leaving the system at ambient temperature, that liquid hydrogen boil-off, for example, will be only 27% of the boil-off rate of a conventionally vented system in which the gas would leave the storage vessel at a temperature only slightly above that of the liquid hydrogen.

FIG. 2 shows essentially the same arrangement as that illustrated in FIG. 1 except that FIG. 2 applies the arrangement to a tankcar suitable for transporting liquefied gases. Thus in FIG. 2 the inside tank 11 is surrounded first by annular space 19 and then by insulation 27 which is contained in permeable walls 21 and 25. Outside tank wall 13 and permeable wall 25 provide an annular space 13*a* for drawing off the gases comparable to space 30 of FIG. 1. Ports 23 are provided to vent the boil-off gas into annular space 19. Line 15, including valve 17, is provided to introduce liquefied gas 37 into the tankcar while vent 33, including valve 35, is provided to release the warmed gas from the system. Suitable supports to maintain the various elements in their proper position such as 29 and 31 are supplied. Such a tankcar would of course be equipped with wheels 39 and coupling 41. Inasmuch as FIGS. 1 and 2 illustrate vessels for storing liquefied gases, the cold gas necessary to the practice of this invention is supplied from an internal source; i.e., the liquefied gas itself.

In FIG. 4 it is shown how an enclosed space 38 may be maintained at a low temperature by the use of concentric containers 40, 41 and 43 having ports 42, 46 and 50, respectively, at alternating and opposite ends of the containers. Such concentric containers form in this arrangement annular passages 44 and 48 which achieve the effect of countercurrent heat flow of the vented gas with respect to the direction of heat flowing in from the surroundings. Thus cold gas leaving port 42 flows completely around container 40 as indicated by the arrows, leaves by way of port 46 and flows in an opposite direction through space 48 to be vented to the atmosphere or to any other sytsem (not shown). Suitable supports such as 45 and 47 may be placed at different points to maintain the necessary spacing between the containers. In the arrangement of FIG. 4 the cold gas to be vented may be supplied from an internal source if it is used to store liquefied gases or from an external source if it is used as a cold storage unit or the like.

FIG. 5 illustrates how the practice of this invention may be adapted to a refrigerator or to a cold storage unit. In this arrangement the cold gas is supplied from a source external to the space to be cooled as contrasted with the arrangement in FIGS. 1 and 2 in which the cold gas is supplied from an internal source.

In FIG. 5 the space 38 to be maintained at a cold temperature is defined by a permeable structure 52. Surrounding permeable structure 52 is an outside permeable structure 54 which defines therewith space 53. Structure 52 and 54 may be permeable walls in which case they would contain within the passage defined therewith insulation 53. However, it is also possible that structures 52 and 54 and insulation 53 may be an integral unit such as a rigid insulation material which needs no additional walls to contain it. For example, this integral unit may be a fairly thick glass fiber mat, bonded if necessary with a suitable binding agent. Structure 54 and outside wall 56 in turn define an annular passage 55 which leads to port 60. An incoming line 58 connects with space 38 and also with a source of cold gas which may include compressor 62, cooler 64 and expansion engine 66. Gas which is to serve as the coolant may be compressed in compressor 62, passed through cooler 64 in which condensibles such as water and CO_2 are removed and then into expansion engine 66 for expanding and further cooling. The then cooled gas is introduced by line 58 into space 38 where it circulates and from which it passes radially through porous structures 52–54 into annular spaces 55 and out through port 60. The temperature and flow rate of the incoming gas may be so controlled that the outgoing gas at port 60 is at approximately the same temperature as the surrounding atmosphere. Again as in the case of the arrangements discussed above, it will be noted that by directing the flow of cooled gas in the manner described, i.e., counter-current to the influx of heat from the surroundings, the maximum amount of refrigeration is obtained from the cold gas. Furthermore, in the practice of this invention as it may be applied to refrigerators and cold storage units, it should be noted that several other advantages are obtained over the usual arrangement wherein coolants are introduced and passed through coils contained in the space to be cooled. First of all, the temperature throughout the space is constant, and the air itself is the coldest element within the space, not the usually employed coils. Since the water and other condensibles have been removed and no coils are used, there can be no frost formed and hence there is no defrosting problem. Moreover, there is no tendency in this system to dehydrate the materials stored within the space, a problem which is always present in conventional refrigeration.

From the above descriptions of this invention it will be seen that a method and apparatus are provided which make possible the maintaining of an enclosed space at a low temperature while minimizing the heat leak in from the surroundings and minimizing the heat loss from within, thus achieving improved refrigeration.

The wide use of liquefied gases in industrial and military application requires that such liquefied gases be handled and stored with a minimum loss.

I claim:

1. Method of maintaining an enclosed space at a low temperature with a minimum amount of heat leak from surroundings into said enclosed space, comprising the steps of introducing cold gas at one point in said space into a first passage enveloping said space, directing the cold gas thereby to envelop said enclosed space substantially completely, simultaneously forcing said gas radially outward through a gas-permeable barrier from substantially all of said first passage into a second passage enveloping said first passage and said enclosed space and concentric therewith, and withdrawing said gas from said second passage, the directions of gas flow in said first passage and in said second passage being essentially countercurrent.

2. Method in accordance with claim 1 wherein the step of introducing said cold gas into said first passage comprises venting said gas from said enclosed space.

3. Method in accordance with claim 1 wherein the step of introducing said cold gas into said first passage comprises bringing cold gas from an external source into said first passage.

4. Container adapted to maintain a body of liquefied gas at subambient temperature, comprising an inner gas-tight vessel, an outer gas-tight vessel surrounding said inner vessel and spaced therefrom, a gas permeable barrier between said vessels and spaced from each of them to define inner and outer spaces substantially concentric with said inner vessel, first gas outlet means in said inner vessel adapted to vent gas from a point in the wall thereof, and second gas outlet means in said outer vessel adapted to vent gas entering said spaces from said first gas outlet means, said gas-permeable barrier being adapted to cause said gas to pass throughout said inner space and thence through said barrier into said outer space.

5. Container capable of being maintained at a low temperature, comprising inner vessel means, first and second passage means substantially enveloping said inner vessel means, gas outlet means associated with said vessel means and adapted to vent gas therefrom into said first passage means, gas-permeable barrier means located between said

first and second passage means and concentric therewith, gas outlet means adapted to remove gas from said second passage means, and supporting means to maintain said vessel, said first and second passage and said gas-permeable barrier means in spaced relationship.

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