

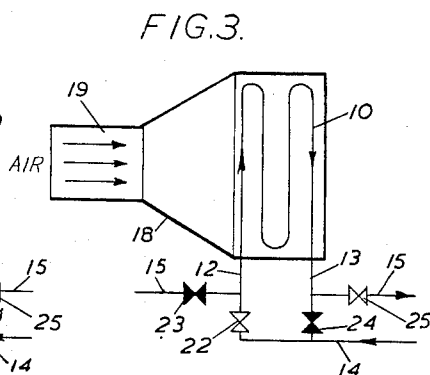
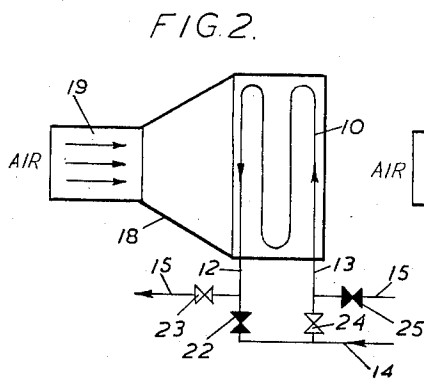
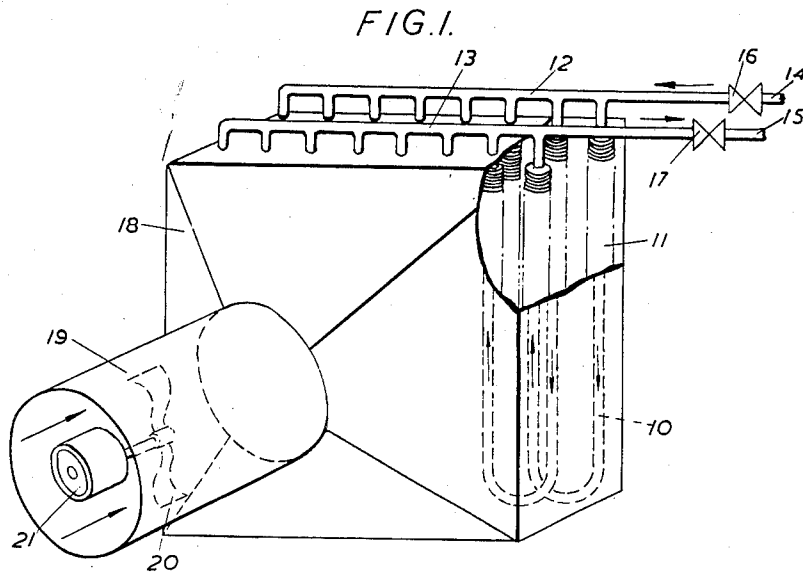
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VAPORISATION OF LIQUEFIED GASES

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VAPORISATION OF LIQUEFIED GASES

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This invention relates to the vaporisation of liquefied gases of low boiling point, and more particularly to the vaporisation of liquid oxygen and liquid nitrogen at temperatures below -50°C .

At the present time, liquid oxygen and liquid nitrogen are usually vaporised by passing them through an evaporating device, such as a system of tubes, heated by direct contact with steam or by a bath of water heated by steam or by electricity. The apparatus required for this purpose is usually complicated and expensive, particularly when the oxygen is at a high pressure. Moreover, the steam or electrical energy necessary to provide the heat required for evaporation is considerable and imposes a considerable cost upon the operation.

In order to avoid the necessity for providing such expensive heating means, it has previously been proposed to make use of atmospheric air as the heating medium. In this case the only energy consumed is that necessary to pass a current of air across the surface of the evaporator. The methods heretofore proposed, however, have been limited in their application by the formation of frost deposits by the condensation of water from the atmosphere on the surface of the evaporator containing the evaporating liquefied gas. The accumulation of such deposits impairs the flow of heat to the evaporating liquid and makes the apparatus both inefficient and unsuitable for prolonged operation.

It is an object of the present invention to provide a method for vaporising liquefied gases and in particular liquid oxygen or liquid nitrogen by means of atmospheric air without substantial deposition of frost. The term "vaporisation" is intended to cover not only the conversion of condensed gas to vapour at constant temperature but also the heating of the vapour as formed above the temperature of evaporation but not above the ambient temperature.

According to the present invention, a process for the vaporisation of a liquefied gas comprises passing the liquefied gas through an evaporator in indirect heat exchange with a stream of atmospheric air passing externally of the evaporator the vaporisation conditions being such that the temperature of the outer surface of the evaporator does not fall substantially below the freezing point of water at atmospheric pressure.

In order to ensure that the temperature of the outer surface of the evaporator does not fall below this value, it is necessary to maintain a rapid flow of heat from the air to the evaporator surface, and to achieve this it is necessary both to control the rate of flow of the air and to provide an evaporator having a high surface area on the air side relative to the area on the side of the evaporating liquid.

In its passage over the surface of the evaporator, the temperature of the air stream will fall by virtue of the heat exchange between the air and the evaporator surface; the magnitude of this temperature drop will be directly related to the rate of heat transfer, which is dependent upon the velocity of the air, and will be inversely

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related to the mass flow rate of the air. The flow of heat from the air to the evaporator surface necessary to maintain the temperature of the latter at or above the freezing point of water may be maintained by regulating the mass flow of the air and its velocity so as to obtain a high rate of heat transfer accompanied by only a small fall in temperature of the air in its passage past the evaporator. The permissible fall in temperature will depend upon the initial temperature and state of humidity of the air but in general the temperature of the air should not be allowed to fall below 5°C .

Occasionally, under winter conditions, the temperature of the air may be initially below 0°C ., in which case any water vapour which is condensed must inevitably appear as frost. Under these conditions, however, the water content of saturated air is relatively slight, and if the air is not fully saturated initially it is still possible to avoid all condensation by regulating the air flow so that the air is not cooled below its condensation temperature. Even if this limit is slightly exceeded the effect will not be serious, as the quantity of frost deposited will be small.

In order to ensure a high rate of heat flow between the air stream and the surface of the evaporator, it is necessary that the evaporator should have a high surface area on the air side, relative to that on the side of the evaporating liquid. Preferably the ratio between these surface areas should be at least 10:1. For example, if the evaporator is of tubular construction, the tubes may be furnished with gills or fins in intimate contact with the outer wall or formed integrally with it. These gills promote the flow of heat not only by increasing the effective surface area of the tubes but also by inducing a high degree of turbulence in the air stream flowing over them, which is known to be an effective aid to heat transfer. In the case of tubular evaporators it has been found that the necessary conditions are satisfied by gill-bearing tubes of which the total effective external surface area is not less than ten times the external surface area of tubes without gills but otherwise of the same dimensions. When the gills are arranged perpendicular to the axis of the tubes the longitudinal distance between the gills should not exceed $\frac{1}{4}$ inch.

A preferred form of evaporator for use in accordance with the invention comprises a plurality of finned tubes connected by tubular manifolds arranged so as to constrain the oxygen stream to pass twice through the evaporator, the first time in a general direction parallel to the direction of flow of the air, and the second time counter-current to it. This arrangement ensures that the cold liquid oxygen entering the evaporator first comes into contact with the warm air to reduce frosting at this end, and that the gaseous oxygen leaving the evaporator again comes into contact with the warm air, so as to leave the evaporator at its maximum temperature.

Where a tubular evaporator is used both the vaporisation of the liquid oxygen and for the subsequent heating of the vapour to the ambient temperature, it is found that the tendency for frost to be deposited extends only to those tubes in which the liquid oxygen is vaporised and not to those in which the superheating of the vapour occurs. In such cases, an additional protection against the deposition of small amounts of frost may be provided by periodically reversing the direction of flow of the liquid oxygen through the evaporator so that the tubes at either end of the evaporator are used alternatively for vaporisation and superheating. By this means any small deposit of frost which may have been formed on the vaporising section of the evaporator during one period of operation will be melted and removed during the subsequent period when the direction of flow of the liquid is reversed.

This invention will now be more particularly described with reference to the accompanying drawings in which

Figure 1 shows diagrammatically and partly in section a perspective view of an apparatus according to the invention; and

Figures 2 and 3 illustrate diagrammatically the feature of reversing the flow of the stream of liquefied gas.

Referring to Figure 1, the apparatus consists essentially of an evaporator and a fan. The evaporator comprises a series of U-shaped tubes 10, each provided with a series of gills 11, the size and number of such gills being sufficient to ensure that the ratio of the outer surface to the inner surface of the tubes 10 is at least 10:1. The ends of the tubes 10 are connected to two manifolds, 12 and 13, connected respectively to the inlet and outlet lines 14, 15 for the gas to be vaporised through valves 16, 17.

The vaporiser tubes are surrounded by an outer casing 18, the ends of the tubes 10 protruding through the casing so that the manifolds 12, 13 are located outside the casing. An air inlet 19 is located in one side of the casing, a fan blade 20 mounted on a rotatable shaft 21 being mounted within the air inlet 19. The air inlet 19 is mounted perpendicularly to the arms of the tubes 10 through which the liquefied gas first passes.

In operation, rotation of the fan blade 20 by the shaft 21 causes a stream of air to be driven through the inlet 19 to the interior of the evaporator casing 18. This stream of air passes externally of the tubes 10, meeting first the arms of the tubes through which the liquefied gas first passes and causes the liquefied gas to vaporise, the vaporised gas passing off through the manifold 13 and the outlet line 15. The speed of rotation of the fan 20 is so arranged that the velocity of the air stream is sufficiently high to prevent the outer surface of the tubes 10 from falling substantially below the freezing point of water at atmospheric pressure. Under these circumstances, there is little or no deposition of frost on the outer surface of the tubes 10.

Figures 2 and 3 illustrate diagrammatically a modified form of the apparatus of Figure 1 adapted both to vaporise the liquefied gas and subsequently to heat the vapour to the ambient temperature. The tubes 10 are formed with an extended path in the form of a double-U and the manifolds 12 and 13 are each connected to both the inlet and outlet lines 14, 15 through valves 22, 23 and 24, 25 respectively.

In operation, whilst the direction of flow of air through the evaporator remains constant, the flow of liquid there-through may be reversed at will. As shown in Figure 2, by opening valves 23 and 24 and closing valves 22 and 25, the liquid is constrained to flow through the tubes 10 in such a manner that, while the flow of liquid in each straight section of the tubes is cross-current to the direction of air flow, the overall direction of flow of the liquid from inlet to outlet is counter-current to the flow of air. Similarly, as shown in Figure 3, by closing valves 23 and 24 and opening valves 22 and 25, the liquid is constrained

to flow in an overall direction from inlet to outlet co-current with the flow of air.

We claim:

1. Process for the vaporisation of liquefied oxygen or nitrogen with subsequent heating of the vapor formed to a temperature not above the ambient temperature, which comprises passing a stream of the liquefied gas through an evaporator, passing a stream of atmospheric air externally of the evaporator in indirect heat exchange with the liquefied gas passing internally therethrough at a velocity such that the fall in temperature of the air in its passage past the evaporator is maintained at a value sufficiently small to prevent the outer surface of the evaporator from falling below the freezing point of water at atmospheric pressure, and periodically reversing the direction of flow of the liquefied gas through the evaporator while maintaining constant the direction of flow of the stream of atmospheric air externally of the evaporator.

2. Process according to claim 1 wherein the ratio of the surface area of the evaporator exposed to the stream of atmospheric air to the surface area of the evaporator exposed to the evaporating liquefied gas is at least 10:1.

3. Process for the vaporisation of liquefied oxygen or nitrogen which comprises passing the liquefied gas through an evaporator, passing a stream of atmospheric air externally of the evaporator in indirect heat exchange with the liquefied gas passing internally therethrough, maintaining the air contact surface of the evaporator at a temperature above the freezing point of water at atmospheric pressure by regulating both the mass flow and velocity of the air to such volume and rate that the temperature of the air contact surface of the evaporator is held thereby above the freezing point of water at atmospheric pressure, and periodically reversing the direction of flow of the liquefied gas through the evaporator while maintaining constant the direction of flow of the stream of atmospheric air externally of the evaporator.

References Cited in the file of this patent

UNITED STATES PATENTS

505,588	Behn et al.	Sept. 26, 1893
1,521,385	Messer	Dec. 30, 1924
1,787,444	French	Jan. 6, 1931
2,000,112	Wheller	May 7, 1935
2,040,118	Young	May 12, 1936
2,200,502	Johnson	May 14, 1940
2,273,257	Gardner	Feb. 17, 1942
2,336,077	Eberhart	Dec. 7, 1943
2,359,219	Jones	Sept. 26, 1944
2,446,498	Underwood	Aug. 3, 1948
2,479,866	Rosebaugh	Aug. 23, 1949

FOREIGN PATENTS

4,694	Great Britain	Mar. 31, 1904
11,901	Australia	Mar. 24, 1933