

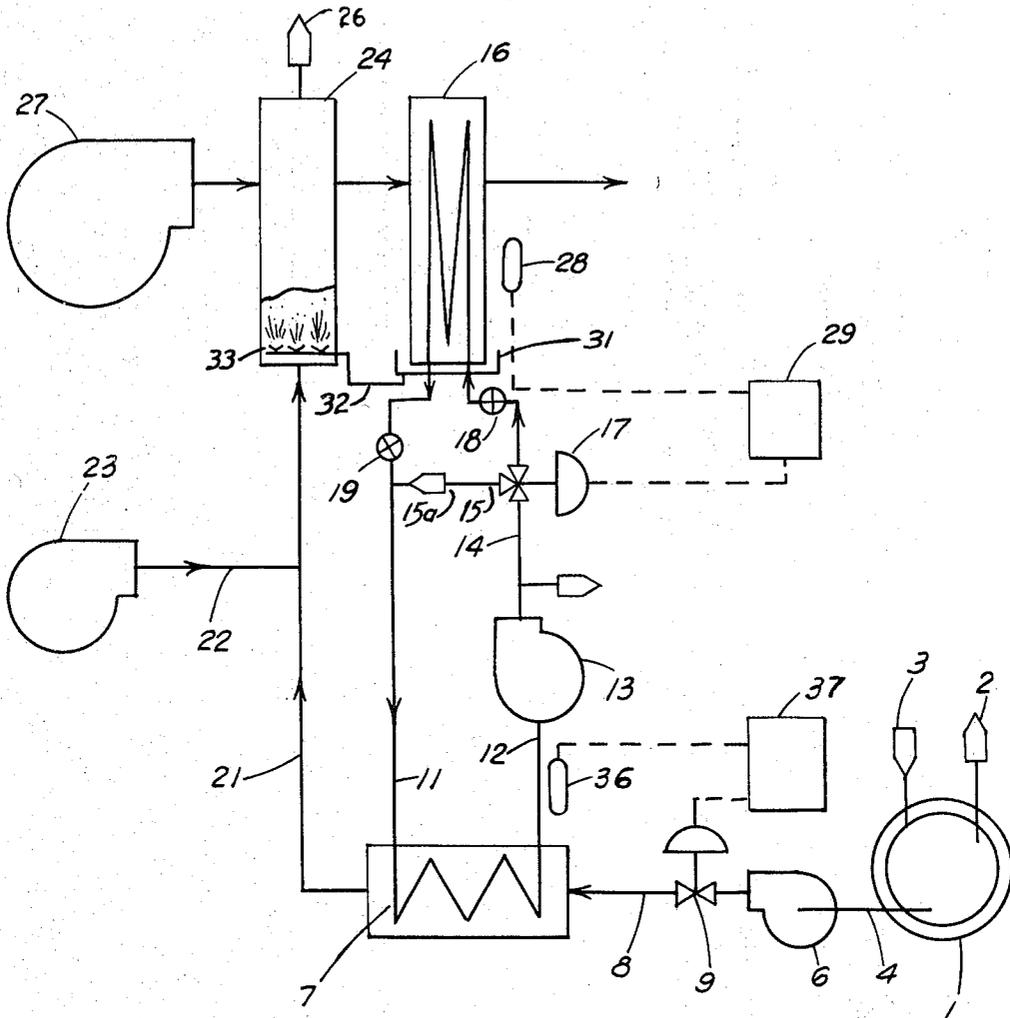
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J. E. PEAVLER

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FLUID COOLING ARRANGEMENT EMPLOYING LIQUIFIED GAS

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INVENTOR.

James E. Peavler

BY *Edward M. Steuterman*

ATTORNEY

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**FLUID COOLING ARRANGEMENT EMPLOYING LIQUIFIED GAS**

James E. Peavler, Maryland Heights, Mo., assignor to American Air Filters Company, Inc., Louisville, Ky., a corporation of Delaware

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**ABSTRACT OF THE DISCLOSURE**

A high capacity cooling system where first and second vaporizable-condensable fluids are used to cool a selected fluid without adversely exposing the selected fluid to extremely low temperature. The first vaporizable-condensable fluid is passed through a heat exchange device in heat exchange relation with the second, vaporizable-condensable fluid whereby the first fluid is vaporized and the second fluid is cooled. The second fluid is then expanded and passed through a heat exchange device in heat exchange relation with the selected fluid to cool the selected fluid and the vaporized first fluid emitted from the first heat exchange device is then passed to a heat exchange device to precool the selected fluid before heat exchange with the second fluid.

**BACKGROUND OF THE INVENTION**

In certain applications, for example ground equipment for cooling aircraft equipment and occupants during periods of ground operation for preflight checkout and maintenance, it is desirable to provide a highly reliable cooling system to periodically provide a cooling effect for a relatively short period of time. Usually, a substantial cooling capacity is required during such periodic operation so that any mechanical refrigeration installation capable of furnishing the requisite cooling capacity would be very large but would only be operated intermittently. Such intermittent operation is obviously inefficient and the cost of such equipment makes such system prohibitive for most situations. Additionally, such installations require a substantial source of power, for example heavy electrical service, which likewise is used only periodically for indefinite periods.

Cooling systems utilizing a vaporizing cryogenic fluid have been used in some such applications but such cryogenic fluids vaporize at very low temperatures and in most cases the temperature is too low to provide satisfactory direct heat transfer for cooling most fluids, for example ambient air having a significant moisture content, because vapors carried by the fluids freeze on the heat exchanger device thereby closing the air flow passage and adversely affecting the heat transfer efficiency. For this and other reasons, such systems have not been widely used in intermittent air conditioning applications.

**SUMMARY OF THE INVENTION**

The present invention provides a straightforward arrangement and method for providing a periodic cooling effect using a cryogenic fluid-secondary working fluid system where only a nominal power supply is required for operation of the apparatus.

Moreover, it is recognized that the present invention provides a straightforward and efficient cooling arrangement so, for a given cooling capacity, the amount of cryogen used in the system is advantageously minimized.

Furthermore, apparatus provided by the present invention requires very few working parts so maintenance cost is reduced accordingly.

Moreover, it is recognized that the present invention provides a cooling method and apparatus which can in-

clude two heat exchange devices where a change of state of working fluid occurs in each heat exchange device to minimize the size and cost of the heat exchange devices.

Various other features of the present invention will become obvious to those skilled in the art upon reading the disclosure set forth hereinafter.

More particularly, the present invention provides a method for cooling a selected fluid comprising: passing first vaporizable-condensable fluid through a first heat exchange device so a portion of the first fluid is vaporized; passing a second condensable-vaporizable fluid through the first heat exchange device in heat exchange relation with the first fluid to cool the second fluid; passing the vaporized first fluid through a second heat exchange device; passing the selected fluid to be cooled through the second heat exchange device so heat is transferred from the selected fluid to the first fluid; reducing the pressure of the cooled second fluid emitted from the first heat exchange device; passing the reduced pressure second fluid through a third heat exchange means whereby a portion of the second fluid is vaporized; and, passing the selected fluid emitted from the second heat exchange means through the third heat exchange device in heat exchange relation with the second fluid whereby heat is transferred from the selected fluid to the second fluid.

It is to be understood that the example of the present invention given hereinafter is not by way of limitation and that various changes can be made in the arrangement, form, or configuration of the apparatus and method disclosed without departing from the scope or spirit of the present invention.

The drawing discloses a schematic arrangement of elements employed to cool 2 selected fluid.

Referring to the figure, a cryogenic fluid, for example liquid nitrogen, is stored in a container, for example an insulated tank 1 having a high pressure relief 2 and a vacuum breaker 3. Container 1 has an outlet conduit 4 which communicates with nitrogen pump 6, driven by a motor (not shown). Nitrogen is emitted from pump 6 through a conduit 8 to a first heat exchanger 7 as shown, and a flow valve 9 is provided in conduit 8 to modulate flow of nitrogen supplied to heat exchanger 7 where the nitrogen is vaporized so the temperature is decreased.

A second vaporizable-condensable working fluid, for example a refrigerant such as Freon<sup>1</sup>-22, is circulated through heat exchanger 7 in heat exchange relation with the nitrogen supplied to the heat exchanger so the refrigerant is cooled and the nitrogen flowing through heat exchanger 7 is vaporized by the heat received from the refrigerant.

A refrigerant pump 13, driven by a motor (not shown), communicates with the outlet from heat exchanger 7 by means of a conduit 12 and with a heat exchanger 16 by means of a conduit 14. In the example shown in the figure, heat exchanger 16 is used as a refrigerant evaporator. A flow control valve 17 is provided in conduit 14 to control the supply of refrigerant to heat exchanger 16 and an expansion valve 18 is provided between flow control valve 17 and the inlet to the evaporator 16 to selectively reduce the pressure of refrigerant admitted to heat exchanger 16. An evaporator pressure controller 19 can be provided in conduit 11, between heat exchanger 16 and heat exchanger 7 to regulate the refrigerant pressure within evaporator 16.

A refrigerant bypass 15 is provided to connect valve 17 with conduit 21 to bypass refrigerant around heat exchanger 16 under certain conditions. Bypass 15 includes a pressure relief valve 15a which can be set at a selected pressure to permit refrigerant to flow directly from valve 17 to conduit 21 at the selected pressure to avoid high

<sup>1</sup> Trademark—E. I. du Pont Company.

pressure at the outlet from pump 13 during operation when very little cooling is required and very little refrigerant is supplied to heat exchanger 16 to maintain the temperature of the selected air stream.

A conduit 21 is provided to receive nitrogen exhausted from heat exchanger 7, a conduit 22 can be provided to communicate with conduit 21 to supply a third fluid, for example air, which can be admitted to conduit 21 and mixed with the nitrogen emitted from heat exchanger 7. A blower 23 can be provided to control the quantity of air to be mixed with the nitrogen carried by conduit 21.

The selected fluid to be cooled, for example air, can be supplied by a blower 27 and flows through precooler heat exchanger 24 in heat exchange relation with the mixed nitrogen and air stream supplied to heat exchanger 24 by conduit 21.

A selected air temperature control arrangement can be provided and in the example of the figure the arrangement includes a temperature sensitive element 28 disposed in the selected air stream on the outlet side of heat exchanger 16 to sense the final temperature of the air stream emitted therefrom. Temperature element 28 communicates with a controller 29, which operates refrigerant flow control valve 17 as shown, to control the supply of refrigerant to the heat exchanger 16 to thereby control the available cooling capacity of the heat exchanger.

Likewise, a temperature sensing element 36 is provided to sense the temperature of refrigerant emitted from heat exchanger 7 through conduit 12 and communicates with a controller 37 which modulates flow through nitrogen flow valve 9 to control the supply of nitrogen to heat exchanger 16 and the cooling capacity of heat exchanger 16.

A pan 31 can be provided beneath heat exchanger 16 to receive moisture removed from the selected air stream and, as shown, in the apparatus shown in the figure, an outlet conduit 32 can be provided from pan 31 so condensate flows from pan 31 to heat exchanger 24 to be mixed with the combined gas stream from conduit 21. Sprays 33 can be provided to distribute the condensate into the combined nitrogen-air stream admitted to heat exchanger 24.

In operation, nitrogen pump 6 draws liquid nitrogen from container 1, increases the pressure of the liquid nitrogen and supplies the nitrogen to throttling valve 9 which controls the rate at which nitrogen is supplied to heat exchanger 7, where the nitrogen is vaporized. Valve 9 is operated by a controller 37 in response to the temperature of the second fluid emitted from heat exchanger 7 through conduit 12 where the temperature is determined by a thermal element 36.

The pressure in the space above the liquid in tank 1 is dependent on heat gain by the tank which causes vaporization of liquid nitrogen until temperature-pressure equilibrium is established. In some cases, particularly on long storage, increasing temperature within the tank causes undesirably high pressure in the tank so a vent 2 is provided to relieve the pressure so more nitrogen vaporizes and reduces the temperature within the tank. In other instances, during operation, nitrogen may be withdrawn from the container at a rate greater than the rate of vaporization so a vacuum breaker 3 is provided to admit air to the tank to avoid a vacuum.

Refrigerant is circulated by pump 13 through the circuit including heat exchangers 16 and 7 to transfer a cooling effect from the vaporizing cryogenic fluid, nitrogen, to the selected air stream. The refrigerant is cooled in heat exchanger 7 by vaporization of the nitrogen admitted to the exchanger. Pump 13 is provided to increase the pressure of the cooled refrigerant and a cooperative expansion valve 18 is provided to reduce the pressure of the refrigerant to permit vaporization and provide a cooling effect in heat exchanger 16. It will be noted that, in accordance with one feature of the present invention, the refrigerant is condensed before the pressure is increased so that only a nominal amount of auxiliary power is re-

quired to provide the pressure prior to expansion in valve 18 which provides the cooling effect in heat exchanger 16. Refrigerant flow control valve 18 is provided to control the flow rate of refrigerant in accordance with the temperature of the air stream. For example, as the temperature of the air stream increases, the valve opens to allow more refrigerant to flow through expansion valve 18 to heat exchanger 16 to provide additional cooling capacity. It will be noted that coordinated operation of valves 9 and 17 regulates the flow and temperature of refrigerant to expansion valve 18 and that such coordinated operation provides stable system operation.

Evaporator pressure regulator 19 is provided to control the refrigerant pressure in evaporator 16 and since there is equilibrium between the temperature and pressure of the vaporizing refrigerant, and pressure regulator 19 can be used to limit the minimum temperature to which the selected fluid is exposed.

Vaporized refrigerant emitted from heat exchanger 16 is then returned to heat exchanger 7 to be cooled by nitrogen vaporized in heat exchanger 7 as hereinbefore described.

Nitrogen is emitted from heat exchanger 7 through conduit 21 and an auxiliary air stream, supplied by a blower 23 and conduit 22, is mixed with the vaporized nitrogen. The combined air stream is then supplied to precooler heat exchanger 24 and emitted through outlet 26, as hereinbefore described.

Condensate formed by moisture separated from the air stream passing through heat exchanger 16 is received in pan 31. In accordance with one feature of the present invention, the condensate is transferred to sprays 33 through a conduit 32 as hereinbefore described. In the example shown, a selected positive air pressure can be maintained in heat exchanger 16 by regulating flow of the selected air stream through heat exchanger 16 so the condensate flows through conduit 32 and is emitted through sprays 33 into the nitrogen-air stream flowing through heat exchanger 24.

It has been recognized that because of the excess dry nitrogen present in the mixed gas stream admitted to heat exchanger 24, the humidity of the stream is quite low so the condensate supplied from pan 31 will vaporize rapidly to lower the temperature of the gas stream from conduit 21 to provide additional cooling effect in pre-cooling heat exchanger 24.

The invention claimed is:

1. A method for cooling a selected fluid comprising: passing a first vaporizable-condensible fluid through a first heat exchange device so a portion of said first fluid is vaporized; passing a second vaporizable-condensible fluid through said first heat exchange device in heat exchange relation with said first fluid to cool said second fluid; passing said first fluid emitted from said first heat exchange device through a second heat exchange device; passing a third fluid to be cooled through said second heat exchange device where heat is transferred from said third fluid to said first fluid; reducing the pressure of said cooled second fluid; passing said reduced pressure second fluid through a third heat exchange device where a portion of said second fluid is vaporized; passing said third fluid emitted from said second heat exchange device through said third heat exchange device in heat exchange relation with said second fluid whereby heat is transferred from said third fluid to said second fluid; and, returning a portion of said second fluid from said third heat exchange device to said first heat exchange device.

2. The method of claim 1 including removing moisture from said third fluid by condensation in said third heat exchange device and vaporizing the resulting condensate into said first fluid supplied to said second heat exchange device.

3. The method of claim 1 including mixing a selected quantity of a fourth fluid with said vaporized first fluid

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emitted from said first heat exchange device and supplying said mixed first and third fluids to said second heat exchange device.

4. The method of claim 3 wherein said first fluid is liquid nitrogen and wherein said fourth fluid combined with said first fluid emitted from said first heat exchange device is ambient air.

5. Apparatus for cooling a selected fluid comprising: a source of a first vaporizable-condensable fluid; a source of second vaporizable-condensable fluid; first heat exchange means having first fluid inlet means communicating with said source of first vaporizable-condensable fluid, a first fluid outlet, and inlet and outlet means for said second fluid; second heat exchange means communicating with the first fluid outlet from said first heat exchange means so first fluid emitted from said first heat exchange means passes through said second heat exchange means; a third heat exchange means communicating with said second fluid inlet and outlet means of said first heat exchange means so said second vaporizable-condensable fluid is circulated through said first heat exchange means and said second heat exchange means wherein said second fluid passes through said first heat exchange means in heat exchange relation with said first vaporizable fluid; means to reduce the pressure of said second fluid prior to admission of said second fluid to said third heat exchange means; and, means to provide a third fluid to be cooled through said second heat exchange means in heat exchange relation with said first fluid to precool said selected fluid and to pass said precooled selected fluid emitted from said second heat exchange device through said third heat exchange device in heat transfer relation with said second vaporizable-condensable fluid so heat is transferred from said selected fluid to said second vaporizable-condensable fluid.

6. The apparatus of claim 5 including means to mix a selected quantity of a fourth fluid with first fluid emitted from said first heat exchange means and to supply said combined first and fourth fluids to said second heat exchange means.

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7. The apparatus of claim 5 including second fluid control means disposed between the conduits connecting said first heat exchange means and said third heat exchange means to regulate the flow of said second fluid to said third heat exchange device in accordance with the temperature of the third air stream emitted from said third heat exchange means.

8. The apparatus of claim 5 including conduit means communicating with said first heat exchange means and said third heat exchange means to return second fluid from said third heat exchange means to said first heat exchange means; and, pressure regulator means disposed in said conduit connecting said third heat exchange means with said first heat exchange means to regulate the pressure of refrigerant in said third heat exchange means.

9. The apparatus of claim 5 including condensate receiving means disposed to receive liquid condensed from said third fluid in said third heat exchange means; and, means to transfer said moisture received in said moisture receiving means to said second heat exchange means to mix said liquid with said first fluid passing through said second heat exchange means.

10. The apparatus of claim 5 including flow control means in said conduit connecting said source of first vaporizable-condensable fluid with said first heat exchange means to control the rate of flow of first fluid through said conduit in response to temperature of said second fluid emitted from said first heat exchange means.

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