United States Patent [19]

Westling

[11] **3,756,040**

[45] **Sept. 4, 1973**

[54] **CRYOGENIC REFRIGERANT EVAPORATOR-DIFFUSER**

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[22] Filed: **Apr. 12, 1972**

[21] Appl. No.: **243,160**

[52] **U.S. Cl.** **62/314,** 62/514, 165/133, 239/602

[51] **Int. Cl.** **F25b 19/00**

[58] **Field of Search** 62/514, 511, 315; 165/174, 133; 239/34, 145, 602

[56] **References Cited**

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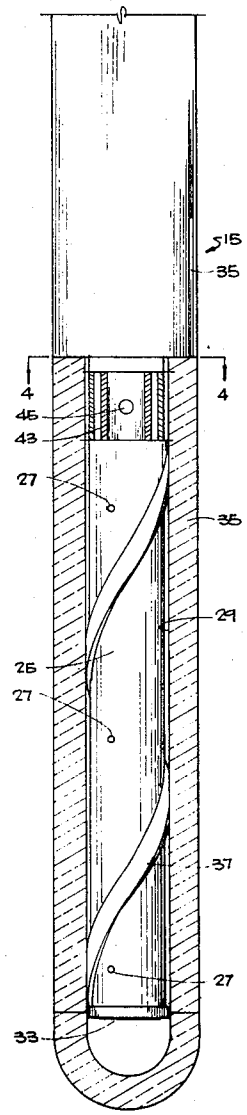
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Primary Examiner—Meyer Perlin
Attorney—Bruce & McCory

[57] **ABSTRACT**

A cryogenic refrigerant evaporator-diffuser system comprising an elongated conduit into which a cryogenic liquid refrigerant is injected. A plurality of orifices are provided at predetermined intervals along the length of the conduit to allow the injected liquid refrigerant to vent into channels formed around the outer surface of the conduit. A continuous outer jacket of rigid, highly porous material surrounds the channels whereby the liquid refrigerant injected into the channels is uniformly exuded at negligible velocities through the pores of the jacket for its full length to substantially uniformly distribute the refrigerating effect to the surrounding space.

1 Claim, 4 Drawing Figures



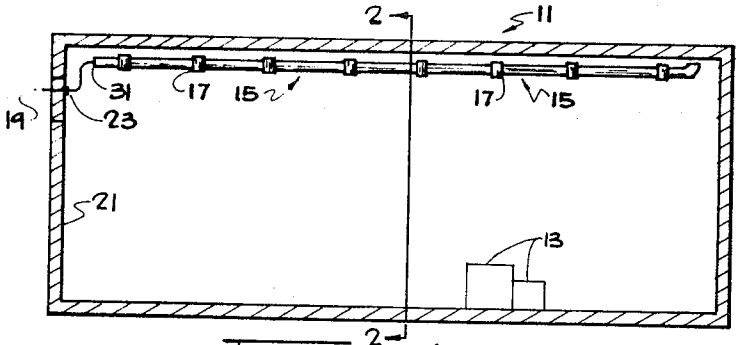


Fig - 1

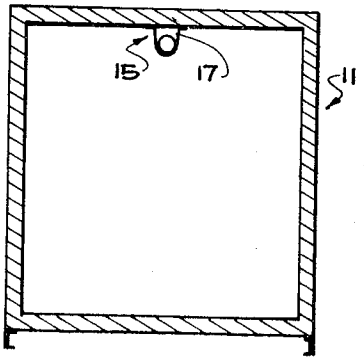


Fig - 2

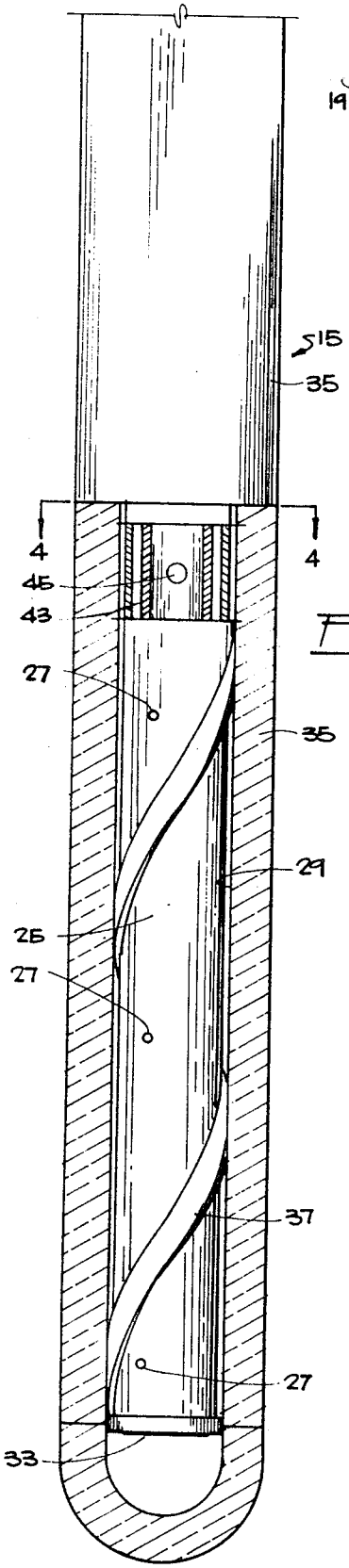


Fig - 3

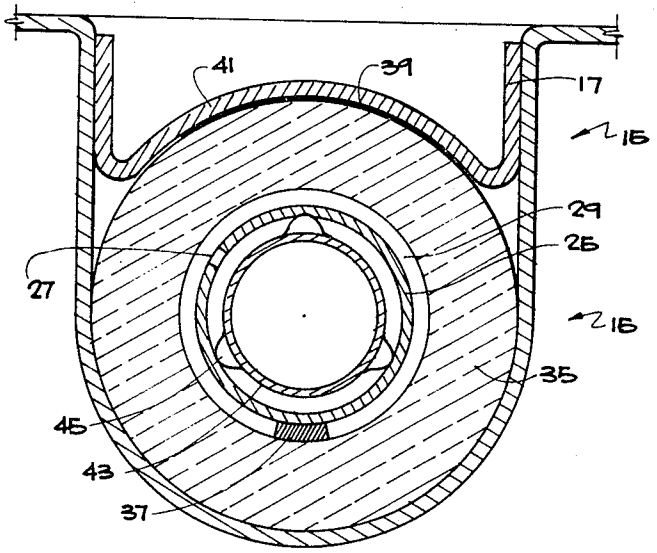


Fig - 4

CRYOGENIC REFRIGERANT EVAPORATOR-DIFFUSER

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention related generally to refrigeration means and, more particularly, to the refrigeration of enclosures by the heat absorbing capabilities of an expendable liquid cryogenic refrigerant.

2. Description of the Prior Art

Presently employed cryogenic systems for refrigerating enclosures, such as rail cars, trucks, or intermodal containers normally release the refrigerant into the enclosure from a supply source by thermostatically controlled devices sensing the temperature of the enclosed space. Pressurized liquid refrigerant is normally used, and injected into one end of a distributing conduit known as a "spray header." The spray header is usually arranged against the ceiling of the enclosure and extends for substantially the entire length thereof. The conduit is uninsulated and provided with a number of perforations or orifices at intervals along its length to permit the escape or spray of the pressurized refrigerant over the top of the material or products held within the enclosure. This spray absorbs heat contained within the compartment.

In general, the heat sources in a compartment derive from the sensible and latent heats of the following: any products contained therein; heat transmitted through the boundaries or walls of the compartment; heat of respiration of fresh products, such as vegetables, fruits or the like; and the converted heat of fans when such are utilized to augment circulation within the compartment.

With the conventional spray header described above, the expanding liquid escaping through the perforations produces a concentration of the refrigerating effect in the space immediately adjacent the inlet end of the header and the perforations. The gas produced when the liquid expands displaces the natural air of the compartment which can, incidently, provide a beneficial environment for certain respiring products. There are also other inherent faults with the presently employed system.

In particular, liquid nitrogen is widely used as a refrigerant. This liquid has a state temperature of −320° F at atmospheric pressure and expands rapidly with heat gain which produces similar temperatures in the immediate environment thereof. Extreme temperature differentials are set up between the jet streams of emerging liquid refrigerant and the products in the immediate environment, dangerously exposing the same to physiologic hazards. In particular, unfrozen perishables may be severely damaged by freezing, and certain sensitive fruits and vegetables may be injured by organoleptic impairment of maturation known as "chill damage."

In addition, with the existing cryogenic systems, ranges of interspacial and product temperatures considered as wide by technologic standards are very common. These differing product temperatures adversely and variously affect the quality, maturation rates, ultimate shelf-life and appearance of products, to a degree varying with the departure from established optimums. The initial conditions of products loaded into the system are thus disturbed during transit, resulting in non-uniform products delivered to their destinations.

The arrangement of the spray header described above is such that when a steady state condition has been reached in the compartment and by the cargo contained therein, only small quantities of refrigerant are intermittently injected in an attempt to retain the specified environmental temperature. The presence of but small quantities of liquid refrigerant results in intervals wherein the spray header is not completely filled whereby the principal refrigerating effect will be at the inlet end of the header and progressively less refrigerating effect along the length of the header.

This above-mentioned condition produces a non-uniform removal of heat within the compartment, which in turn results in non-uniform interspacial temperatures. In addition, because of these non-uniform conditions, the automatically operated thermostatic control devices of the present systems causes the quantity of liquid refrigerant injected into the header to be in excess of immediate demands. This injected quantity is beyond control and must irrepressibly expand to produce control device hunting or cycling of temperature. The excess liquid refrigerant is wasted and shortens the operational radius and time interval of a given charge of supply refrigerant. These temperature variations are, in particular, deleterious to frozen foods which require constant temperatures to conserve their high quality life.

The principal factors affecting successful transportation of unfrozen products are criterial temperatures and the stabilization of the product's moisture content. It is a scientific fact that moisture-vapor within an enclosure will migrate independently of the movement of the atmosphere within that space. The vapor moves positively through undisturbed atmosphere from zones of higher vapor pressure such as within the warmer product, towards zones of lower vapor pressure such as in the spray header jet streams where the vapor pressure is nil. It is therefore obvious that when the liquid refrigerant is jetted from a spray header of the existing systems, any moisture within the enclosure will merge with the expanding spray to form localized fog or appear as entrained micro-crystals of frost in the jet stream. Either phenomenon is performed at the obvious expense of the moisture-bearing product. The dehydrating transfer of the product's moisture is irreversible and the effect is accelerated and dimensionally extended by the high velocities of spray jets as employed in existing cryogenic systems.

Spray headers have also been used in numerous other applications, notably for the precooling of tanks used in transporting or storing liquid cryogenic refrigerants at extremely low state temperatures and low pressures. In these applications contacts of the cryogenic liquid with the tank boundaries through accidental or careless flooding of a spray header are fraught with catastrophic consequences. The focalized point of contact with the metal suffers local embrittlement and lines of excessive fiber stress. This can result in fracture or rupture of tank boundaries. Attendant distrust of feeding control devices associated with the spray header of existing systems causes apprehensions and great time consuming precautions in precooling tanks to receive cryogenic fluid cargoes. The problem is particularly serious with the new generation of liquid petroleum gas tankships. Many ships have large integrally structured tanks with flat walls normally subject to hydraulic static pressures only, and which are subject to high ambient tempera-

tures. These walls are particularly susceptible to failure if in shock contact with cryogenic liquids.

The present invention provides a cryogenic system for overcoming the problems and hazards set forth above. The cryogenic evaporator-diffuser of the present invention provides a means for uniformly refrigerating a transport enclosure carrying cryogenic liquid cargo, frozen foods, or perishable products in established criterial manner. The exuding function of the evaporator-diffuser in introducing precooling gases into a transporting or storage tank assures a safe and rapid operation in all services.

In the system of the present invention, the center conduit of the evaporator-diffuser is placed downstream from a thermostatically controlled feeding device. This conduit is such that the volume of liquid refrigerant it holds is a comparative small fraction of the volume impounded in an existing system's spray header. In consequence, the refrigerating effect coincident with the irrepressable evaporation of the residual quantity of the liquid is proportionately very small, whereby product temperature variation is nil and refrigerant wastage is negligible.

In addition, the infinitely greater area of the cryogenic evaporator-diffuser of this invention, together with the negligible velocity of entry, allows an absorptive merging of the expanded gas and the compartment medium to sustain highly desirable humidities approaching saturation point of the medium. Dehydration of products within the compartment is thus comparitively suppressed.

SUMMARY OF THE INVENTION

The present invention is a cryogenic refrigerant evaporator-diffuser for refrigerating an enclosure comprising an elongated central conduit having an inlet and a plurality of outlets spaced at predetermined intervals along the entire length thereof mounted within the enclosure. A porous jacket is mounted on and completely surrounds the elongated conduit. At least one channel is formed between the jacket and the conduit whereby liquid refrigerant injected into the conduit will pass through the conduit and be vented from the outlets into the channel. The refrigerant will be substantially uniformly distributed longitudinally in the channel and over the inner surface of the jacket for passage of the liquid refrigerant through the pores of the jacket to the outer surface of the jacket to thereby provide diffusion of the refrigerant into the atmosphere of the enclosure to absorb heat.

OBJECTS OF THE INVENTION

It is therefore an important object of the present invention to provide an improved cryogenic refrigerating system adaptable to be used for storing and transport of fresh or frozen foods or for precooling tanks for carriage or storage of cryogenic liquids.

It is another object of the invention to provide a refrigerating system to more effectively and more efficiently utilize the heat absorbing capabilities of expendable cryogenic refrigerants, to conserve attachable supplies of the refrigerant and thus extend the radius of transport operations by a unit quantity of a cryogenic refrigerant.

It is a further object of the invention to so distribute and diffuse a cryogenic refrigerant that the refrigerating effect is of constant and uniform magnitude throughout a compartment of permissably unlimited length.

It is still another object of the invention to provide a means of minimizing wasteful and irrepressible expenditure of a cryogenic refrigerant residual in the system isolated by closed control devices to prevent excessive variations of refrigerating effect with consequent undesirable fluctutations of spacial and product temperatures.

It is still a further object of the invention to provide a means of expanding and diffusing a cryogenic refrigerant into a compartment by low velocity exudation over extensive surfaces to prevent deleterious impingement of the refrigerant upon the surfaces of the products being transported or stored.

It is yet another object of the invention to provide a refrigerating system adaptable to the storage of unfrozen or frozen foods, the sustained high quality of which is dependent upon the constancy of their temperature.

It is yet a further object of the invention to provide a system which uniformly diffuses refrigerant within the atmosphere of an enclosure to maintain uniform optimum temperatures of products and to suppress migration of product moisture to the refrigerant.

It is a still further object of the present invention to provide a cryogenic refrigeration means capable of removing unwanted heat from an enclosure without danger of freezing or causing chill damage to sensitive perishables contained in the enclosure.

It is still another object of the present invention to provide a refrigerant distributing system which when the injected charge of refrigerant is partially expended, or, when less than full charges are thermostatically demanded, or, when the partially filled inner conduit of the system is in a slanted or tilted position the distribution and function of the system will provide the same uniformity of refrigerating effect for the full length of the compartment that is provided by a fully charged system.

It is still a further object of the invention to provide a system for the controlled and safe introduction of a precooling gas or refrigerant into a tank used for the transport or storage of cryogenic gases in their liquid state.

And it is still another object of the present invention to provide a precooling of ship's tanks safeguarded against the inadvertant flooding and spillage of cryogenic cooling liquid therein which could endanger the integrity of the tank boundaries.

DESCRIPTION OF THE DRAWINGS

FIG. 1 is a longitudinal side elevation in cross section showing an insulated compartment or enclosure having a cryogenic diffuser system of the present invention secured to the ceiling thereof;

FIG. 2 is a cross section taken along line 2—2 of FIG. 1;

FIG. 3 is a longitudinal top plan view, partially in cross section, showing the cryogenic diffuser system of the present invention; and

FIG. 4 is an enlarged cross sectional view taken along line 4—4 of FIG. 3.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawings, there shown in FIG. 1 is an insulated compartment or enclosure 11, such as

a cargo container, a railroad car, a tank for containing liquids, or a truck body in which cargo **13** is kept in a refrigerated or cooled state. The container or enclosure is fitted with a cryogenic evaporator-diffuser refrigerating system **15** disposed centrally of the ceiling and extending substantially the entire length of the enclosure. The system suspended from the ceiling by a plurality of spaced brackets **17.**

Liquid refrigerant, such as liquid nitrogen, is injected into the system **15** from a supply (not shown) often disposed externally of the enclosure via a controlled feed line **19** extending through one insulated wall **21** of the enclosure. The feed line **19** is connected to the system **15** by any conventional means and can include a quick disconnect coupling **23.**

FIG. **3** shows a cross sectional longitudinal view of the evaporator-diffuser system **15** of the present invention. The system includes an inner conduit **25** into which the cryogenic refrigerant is injected from the feed line **19.** Thermostatically controlled means (not shown) control the injection of the refrigerant in response to changes in the internal temperature of the enclosure. Conduit **25** can be made from any desired material and can be of any diameter depending on the structural need of an installation.

A plurality of output openings or orifices **27** are provided in the conduit at predetermined intervals and, preferably on the upper portion thereof, along the length of the conduit. These orifices allow the cryogenic refrigerant which has been injected into the conduit by the thermostatic control means to be vented into a channel **29** formed externally of the conduit. The conduit is anchored, in any convenient manner, at the injection end thereof to accommodate expansive movement during the extreme temperature differentials to which it is subjected.

Conduit **25** includes an injection fitting **31,** to which the quick-connecting coupling **23** is releasably engaged, and an end cap **33.** An outer jacket, preferrably made from a rigid unsheathed, highly porous material such as a chemically and physically inert molecular sieve, surrounds or jackets the tube **25.** Molecular sieve of this type is produced by the Linde division of UNION CARBIDE and are synthetic crystalline alumino-silicates, honeycombed with cavities which are interconnected with pores varying from about **3** to about **10** angstrom units in diameter.

A spacer **37,** preferably spirally wound and preformed from one or more pieces, made from any resilient material, is provided between the interior surface of the jacket and the outer surface of the conduit to form the substantially annular longitudinal channel **29.** The orifices of the conduit are shown communicating with this channel whereby liquid refrigerant can be injected directly into the channel.

The channel **29** allows injected quantities of cryogenic refrigerant to be substantially evenly dispersed therein. Because of the conformation of the channel, the refrigerant will move circumferentionally and substantially longitudinally through the channel and be confined between the injection fitting **31** and by the diametrically extended portion of cap **33,** sealingly engaged with the inner wall of the jacket.

The refrigerant will therefore be substantially evenly distributed over the entire inner surface of porous jacket **35** to pass through and exude as a liquid, a gas, or a mixture of both, at a substantially negligible velocity. The refrigerant passing through the jacket, will reach the exterior surface thereof where it is free to diffuse with the atmosphere within the enclosure and to uniformly absorb heat from the same.

If desired, other means, such as rifled passages, straight channels, or the like (not shown), may be provided on the inner face of the jacket **35** or the outside surface of tube **25.** These passages or channels would then eliminate the need of the spiral spacer strip **37.**

with the evaporator-diffuser system suspended from the ceiling of the compartment by the brackets **17,** the refrigerant effluent from the jacket will be substantially evenly diffused with in the interior of the entire compartment **11.** Conventional outlets (not shown) to the atmosphere prevent pressurizing of the compartment.

FIG. **4,** shows the orifices **27** of the evaporator-diffuser conduit placed above the horizontal transverse centerline of the tube **25.** Therefore, when less than flooded conditions pertain, residual amounts of the liquid will expand into the spiral channel **29** upon demand. For all conditions, the top sector of the jacket **35** may be masked by tape or other material **39,** as shown, to prevent direct contact of the exuding refrigerant with the ceiling or bridging portions **41** of the brackets **17.** In this manner, any structural heat bridges will be precluded.

The inner conduit **25** is fitted with a space-consuming core or reducing element **43** to provide predetermined volumes of residual liquid refrigerant. This core is provided by embossing, with a plurality of welted lugs **45** for centering, the core within the conduit. In this manner, the quantity of injected refrigerant may be more closely metered to reduce the surplus amount of refrigerant that will be irrepressibly expended subsequent to the closing of the thermostatically operated feeding device (not shown). This in turn minimizes the overabsorption of heat beyond the needed capacities of the operating system, and avoids the production of excessive compartment and product temperature oscillations.

At full capacity, the entire outer surface of the porous jacket would be substantially wetted by the effluent and provide the desirable low velocity diffucion into the atmosphere of the compartment. The low velocity diffusion of the gaseous refrigerant into the enclosure would provide a thermally uniform environment for the perishable products.

In usual operations, cargo contained within an enclosure would have been precooled or prefrozen to a specified carrying temperature. This cargo would have gained heat only from ambient exposures during loading or transfer.

After sealing the cargo in the compartment, the injected quantities of liquid refrigerant would move successively through the feed line, the quick-connecting coupling, and to the interior of the center conduit. The liquid would then be vented through the orifices of the conduit into the spiral channel formed around the conduit. The liquid would then expand in or through the pores of the jacket to effuse from the surface thereof for diffusion into the atmosphere of the enclosure.

In addition, the moderate insulating value of the porous jacket acts as a retardant against too rapid heat gain by the liquid refrigerant to prevent premature evaporation within the conduit. This promotes the progressive delivery of the liquid refrigerant within the full length of the evaporator-diffuser, and establishes one

of the unique characteristics of the present invention in that there are no functional or technological limitations to the length of the compartment or the refrigeration distributing means.

While the invention has been described in considerable detail, it is not to be limited to such details as have been set forth except as may be necessitated by the appended claims.

I claim:

1. A cryogenic refrigeration evaporator-diffuser comprising

an elongated central conduit having a reduced inlet opening and a plurality of outlets spaced at predetermined levels on the top portion of the conduit along the entire length thereof,

a rigid, porous jacket formed from a molecular sieve completely surrounding said elongated conduit, and

a resilient spacer held between said jacket and said conduit and spirally wrapped around the entire length of said conduit to form a spiral channel between adjacent portions of the spacer, said outlet openings being fluidly connected to said spiral channel whereby, refrigerant injected into said conduit will be vented into said spiral channel for substantially even distribution within said channel and over the inner surface of said jacket whereby, said refrigerant will pass through the pores of the jacket to be exuded into the atmosphere of said portable enclosure at a substantially negligible velocity.

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