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— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

[Continued on next page]

(54) Title: SYSTEM AND METHOD FOR DELIVERING CRYOGENIC FLUID TO A SPRAY HEAD USED TO COOL AN ENCLOSED SPACE

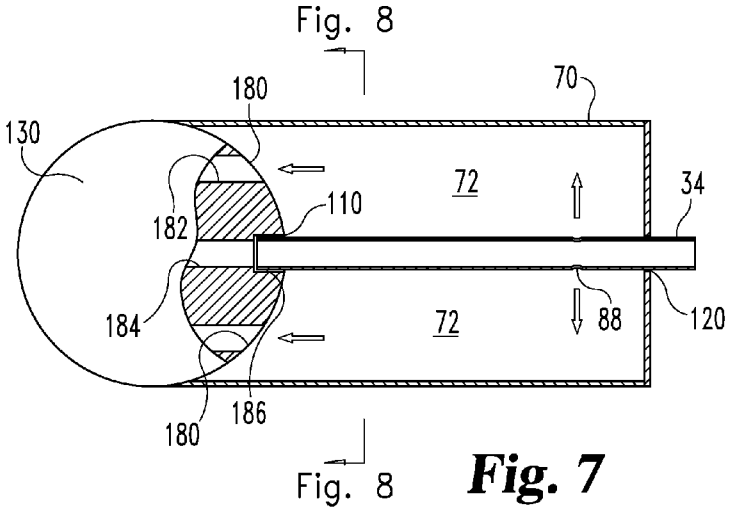


Fig. 7

(57) Abstract: A system for delivery of a cryogenic fluid to a spray head for use in cooling an enclosed space includes a supply tank (26) for the cryogenic fluid, a spray head (130) having a liquid supply inlet (186) and a vapor supply inlet (180), and a cryogenic liquid supply conduit (34) communicating from the supply tank to the liquid supply inlet (186) of the spray head. A vapor supply conduit (70) surrounds the spray head (130) and a portion of the liquid supply conduit (34). One or more holes (88) are provided in the liquid supply conduit (34) to allow cryogenic liquid to escape into the vapor supply conduit (70) for delivery to the vapor supply inlet (180) of the spray head. In addition, a gap (110) is provided between the liquid supply conduit (34) and the liquid supply inlet (186) of the spray head (130) such that cryogenic liquid can escape from the gap (110) into the vapor supply conduit for delivery to the vapor supply inlet of the spray head. The gap (110) between the liquid supply conduit (34) and the liquid supply inlet (186) of the spray head (130) allows for movement therebetween to accommodate thermal expansion and contraction of the components relative to one another.

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SYSTEM AND METHOD FOR DELIVERING CRYOGENIC FLUID TO A SPRAY HEAD USED TO COOL AN ENCLOSED SPACE

RELATED APPLICATION DATA

This application claims the benefit of US Provisional Application Ser. No. 61/321,119 filed April 5, 2010, and US Application Ser. No. 12/939,542 filed November 4, 2010, which are hereby incorporated by reference.

BACKGROUND

The present disclosure relates to the refrigeration of enclosed spaces, such as the refrigeration space of a food transport vehicle, wherein the refrigeration is accomplished at least in part by spraying a cryogenic fluid into the space. More particularly, but not exclusively, it relates to a system and method for distributing the cryogenic fluid to the inlet ports of a cryogenic fluid spray head which sprays the cryogenic fluid into the enclosed space to be cooled.

Within the transportation industry, it is well know that certain items need to be transported in refrigerated spaces. For example, perishable food is typically transported to grocery stores by refrigerated trucks which carry enough food to supply a plurality of stores. Thus, such a truck stops repeatedly at successive stores, whereupon workers at each store enter the truck and unload selected amounts of food.

SUMMARY

The present invention provides systems and techniques for cooling an enclosed space, such as the enclosed space of a food transport vehicle, by spraying a cryogen into the enclosed space. While the actual nature of the invention covered herein can only be determined with reference to the claims appended hereto, certain aspects of the invention that are characteristic of the embodiments disclosed herein are described briefly as follows.

According to one aspect, cryogen is provided to a spray head having a liquid inlet, a vapor inlet, and a plurality of ejection ports. A vapor supply conduit is configured to supply vaporized cryogen to the vapor inlet of the spray head, and a liquid cryogen supply conduit is configured to supply liquid cryogen to the liquid inlet of the spray head. The liquid cryogen supply conduit is non-hermetically engaged with the liquid inlet of the spray head at a junction location, and the vapor supply conduit surrounds the junction location so as to capture the liquid cryogen that escapes from the junction location and provide it to the vapor inlet of the spray head.

These and other aspects are discussed below.

BRIEF DESCRIPTION OF THE FIGURES

Although the characteristic features of this invention will be particularly pointed out in the claims, the invention itself, and the manner in which it may be made and used, may be better understood by referring to the following description taken in connection with the accompanying figures forming a part thereof.

FIG. 1 is a top perspective view of a refrigeration vehicle cooled with liquid nitrogen with portions of the side and top walls thereof broken away as described more fully in US Patent No. 6,345,509, which is hereby incorporated by reference in its entirety.

FIG. 2 is a side view of the sprayer head as shown in US 6,345,509.

FIG. 3 is a side view of an existing sprayer head assembly.

FIG. 4 is an underside view of the FIG. 3 sprayer head assembly in partial section along the line indicated in FIG. 3.

FIG. 5 is a sectional view of the FIG. 3 sprayer head assembly along the line indicated in FIG. 4.

FIG. 6 is a side view of a sprayer head assembly of the new design.

FIG. 7 is an underside view of the FIG. 6 sprayer head assembly in partial section along the line indicated in FIG. 6.

FIG. 8 is a sectional view of the sprayer head assembly of FIGS. 6 and 7 along the line indicated in FIG. 7.

FIG. 9 is an underside, cross-sectional view of an alternate embodiment of the present invention.

FIG. 10 is an end, cross-sectional view of the embodiment of FIG. 9 along the line indicated in FIG. 9.

DETAILED DESCRIPTION

For the purposes of promoting an understanding of the principles of the invention, reference will now be made to the embodiments illustrated in the drawings and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the invention is hereby intended. Alterations and further modifications in the illustrated devices, and such further applications of the principles of the invention as illustrated herein are contemplated as would normally occur to one skilled in the art to which the invention relates.

According to one aspect, the present invention involves a refrigeration system of the type wherein the cooling effect is achieved by releasing a cryogenic fluid into the space to be cooled. As used herein, a "cryogenic fluid" means a fluid having a boiling point less than -73°C (200°K) at 1atm pressure. Typically, the boiling point of cryogenic fluid used herein will be below about -150°C (123°K) or below about -180°C (93°K) at 1 atm pressure. A "cryogenic liquid" means a cryogenic fluid in liquid phase and a "cryogenic vapor" or "vaporized cryogen" means a cryogen fluid in vapor phase. Typically, the liquid cryogen will be a liquid nitrogen, which has a boiling point of -196°C (77°K).

Depicted in FIG. 1 is a refrigeration truck 10 for the transporting of perishable food. The truck comprises a body or shell formed by a front wall 12, a rear wall 14, a top wall 16, a floor 18, and side walls 20, 22, some or all of the walls preferably being thermally insulated. A door 24 is provided in the rear wall 14 to afford access to the refrigeration space of the truck body for the loading and unloading of food. As illustrated, the refrigeration space is divided into separate compartments by one or more divider(s) 63.

Mounted beneath the floor 18 is a tank 26 containing liquid nitrogen or any other suitable liquid cryogen, such as liquid CO_2. Alternatively, the tank could be built into the walls of the truck body. Situated within the refrigeration space is a plurality of spray heads 30. The spray heads 30 are mounted beneath the top wall 16 and are fluidly connected to the tank 26 by a main conduit 32 and respective sub-conduits 34. A remotely controllable valve 36 is disposed in each sub-conduit 34 for controlling the supply of liquid nitrogen to the spray heads 30.

Each spray head 30 comprises a plurality of spray nozzles 31 connected to a manifold (FIG. 2). The nozzles 31 are preferably arranged in a fan-like array to spray in all horizontal directions. The spray heads are positioned throughout the refrigeration space such that during use, the spray heads 30 can be used to provide cooling to the refrigeration space by themselves or in connection with additional means of cooling the space. As illustrated, four spray heads 30 are horizontally spaced from one another and from all vertical walls 12, 14, 20, 24 and are arranged along a longitudinal center line adjacent the top of the refrigeration space. The number and position of the spray heads 30 may vary depending upon the length of the space and whether the space is divided into compartments, as will be later discussed.

Also shown disposed at the top of the space is an optional evaporator panel 40 connected to the tank 26 by a conduit 46. The panel 40 can be of conventional construction, i.e., comprised of a pipeline or a pipe coil in thermal contact with an extended heat exchange surface (not shown) and used to provide supplemental cooling to the refrigeration space. Alternatively, the evaporator panel 40 may be omitted entirely.

When present, the panel 40 may be fixed beneath the top wall 16 with a measurable gap situated therebetween to ensure an adequate heat exchange with the atmosphere inside the space. To make the heat exchange surface of the panel perform even more effectively, the surface can be perforated and/or corrugated, furnished with special coatings or with conventionally used hardware to avoid freezing. A valve 41, remotely controllable, controls the flow of liquid nitrogen through the evaporator.

Disposed in the front wall 12 is a portal 42 for communicating the refrigeration space with ambient air. The portal 42 is provided with a louver arrangement or a sliding or hinged door (not shown) such that the portal 42 can be selectively opened and closed. As illustrated, portal 42 is disposed in the upper portion of the front wall 12, but portal 42 could have different shapes or sizes, such as extending substantially from the floor to ceiling (i.e. from bottom 18 to top 16 walls) or be located in the side walls 20, 22 or roof/top wall 16. Shown extending across the portal 42 is an optional heat exchanger 44 which may be used as a

supplemental manner of cooling. Alternatively, the heat exchanger 44 may be omitted from the portal 42.

When present in the portal 42, the heat exchanger 44 may be of conventional construction, e.g., it comprises coils through which liquid nitrogen can flow. The heat exchanger 44 is connected to the tank 26 via the conduit 46, and a remotely controllable valve 48 controls the supply of liquid nitrogen to the heat exchanger 44.

A ventilator, such as a rotary fan 50, is disposed at the portal 42 for forcing ambient air through the portal 42 and through the heat exchanger 44 (if present). If a louver arrangement is employed for closing the portal 42, the louvers could be motor driven, or spring-biased closed and then forced open by the air flow. Alternatively, the portal 42 could be opened and closed by way of a sliding or hinged door, which may be remotely operable.

Regardless of whether the heat exchanger 44 is present in portal 42, by operating the fan 50 while the louver arrangement is open, the refrigeration space of the truck can be purged of gaseous nitrogen by in-flow of ambient air to create a breathable atmosphere in the truck. As explained more fully in US Patent No. 6,345,509, including the heat exchanger 44 and operating the fan 50 while liquid nitrogen is being conducted through the heat exchanger 44 provides a mechanism to chill the ambient air as it is being drawn through the portal 42.

Sensors 62 are provided in the interior space for monitoring temperature and the oxygen content of respective regions of the space, and this information may be displayed in appropriate locations, such as inside the vehicle or at the rear door.

A main controller 60 is provided which is connected to the sensors 62 and the valves 36, 41, 48 for controlling the flow of liquid nitrogen selectively to the spray heads 30, the evaporator panel 40, and the heat exchanger 44, respectively. The controller 60 is also connected to motors for controlling the fan 50 and the louver arrangement (if motor-driven) such that the portal 42 is kept closed when the fan 50 is de-energized and the valve 48 is closed. It is desired that the portal 42 be kept closed when the refrigeration space is in a cooled state, to minimize the amount of liquid nitrogen needed to cool the space.

A switch (not shown) may be provided which senses when the rear door 24 is open/closed. When the door is open, the valves 36 would automatically be held

closed, for safety reasons. As an additional safety measure, warning lights (not shown) may be used to indicate when the oxygen level inside the vehicle is safe enough for humans to work inside.

In operation, the tank 26 is filled with liquid nitrogen at, for example, about -196°C. Prior to loading the truck with food, the refrigeration space of the truck may be pre-cooled by opening the valves 36 to the spray heads 30 to cause liquid nitrogen to be sprayed within the refrigeration space. The liquid nitrogen evaporates and pre-cools the refrigeration space, the walls of the body and all internal elements, to a desired temperature. This can be done while the truck is in transit to, or awaits loading at, a loading site. The valves 36 are completely or partially closed when the desired interior temperature is reached, as detected by the temperature sensors 62.

During this operation, an atmosphere of almost pure gaseous nitrogen, which does not support safe breathing, is created inside the refrigeration space. Because of this, the refrigeration space must be purged with air prior to the loading operation. That purging operation is performed by opening the louver device and the door 24 (or through a separate vent), and actuating the fan 50. If heat exchanger 44 is present, the valve 48 is opened to admit liquid nitrogen to the heat exchanger 44 to cool the ambient air as it is being introduced.

Thus, ambient air is forced into the refrigeration space to displace gaseous nitrogen through the open door 24. When equipped with heat exchanger 44, that ambient air can itself be cooled to help maintain a desired temperature. During this operation, the temperature of the space may be monitored by the sensors 62 to enable the controller 60 to adjust the valve 48 and thereby control the extent to which the incoming air is cooled, to keep the interior space from becoming too cold. Alternatively, the ambient air is not cooled and the temperature of the space is simply monitored to assure that it stays within a proper temperature range.

The purging procedure can be performed prior to arrival of the truck at the loading site, in order to save time.

Once the refrigeration space has been filled with air and a suitable atmosphere has been created, a food-loading operation is performed. At that time, the valve 48 is closed, the fan 50 is stopped, and the valve 41 may be opened to supply liquid nitrogen to the evaporator 40 (if present) which cools the inside air as

that air contacts heat exchange surfaces of the evaporator. During the loading operation, the interior temperature is monitored by sensors 62, and the controller opens/closes the valve 41 as necessary to maintain the desired interior temperature.

Once the food has been loaded, the door 24 is closed, and the truck is transported to its first destination. During transport, the cooling function is switched back to the spray heads 30 by closing the valve 41 and opening the valves 36. If the truck is subjected to a heavy thermal loading, i.e., if the ambient air is very warm, the spray cooling can be augmented with evaporator cooling by fully or partially opening the valve 41 to supply liquid nitrogen to the evaporator 40.

When the truck reaches its first destination, it is necessary to purge gaseous nitrogen from the refrigeration space. Hence, the purging operation described above is repeated, i.e., the valves 36 and 41 (if present) are kept closed, and the valve 48 is opened to direct liquid nitrogen through the heat exchanger 44 (if present).

The louver device is opened, and the fan 50 is actuated. This procedure can be initiated before the truck reaches the first destination, so that the truck is ready for unloading when it arrives. During unloading, the temperature within the refrigeration space can be maintained by actuating the evaporator 40.

The above operations are repeated, to enable the truck to travel to numerous unloading sites, while ensuring that the food is always kept at an appropriate temperature.

It will be appreciated that liquid nitrogen flowing through the heat exchanger 44 or the evaporator 40 will be converted into inert gaseous nitrogen, and can be exhausted into the ambient air (e.g., via vent 46A) without a pollution risk.

The fan 50 may be reversible, i.e. capable of being operated to exhaust air from the refrigeration space of the truck. In that event, when food is to be on-loaded from an air conditioned storehouse, the pre-cooling of the refrigeration space of the truck prior to the on-loading of food is performed by backing the truck to the storehouse so that upon opening the door 24, the refrigeration space communicates with an air-conditioned (chilled) interior of the storehouse. Then, the fan 50 is driven in the reverse mode to draw-in cold air from the storehouse and circulate it through the refrigeration space. In that way, the temperature of the refrigeration space is reduced without the need to expend any nitrogen. That is, the valves 48 and 41 are

"off" during this phase of operation. When the refrigeration space reaches a desired temperature, food is on-loaded while the fan continues to be operated in reverse to maintain the cold temperature. Hence, the liquid nitrogen will be conserved.

The tank 26 can be of any suitable conventional type. For example, the tank can be pre-fabricated as a group of small diameter vessels integrated into a complete functional unit. Each vessel could include coaxial interior and exterior walls spaced apart by screen-vacuum thermal insulation. Pressurization of liquid nitrogen in the tank can be affected in any suitable manner, e.g., through the use of a pump, or a small electric heater immersed in the liquid nitrogen.

As noted earlier, the refrigeration space can be divided into a plurality of separate chambers by suitable partitions 63. The partitions 63 can be mounted in any suitable fashion, e.g. they could be hinged to the top wall 16 so as to be swingable to an upper inactive position when not needed. When a partition is provided, the spray heads 30 disposed in each chamber would be separately connected to the tank 26, and the evaporator would be divided into separate sections disposed in respective chambers and provided with respective valves 41. Hence, the chambers could be kept at different temperatures, e.g., to store foods having different thermal requirements. The controller would respond to the respective temperature sensors to maintain proper temperature conditions in each chamber.

Instead of being hinged, the partitions could be mounted in any suitable way, including being adjustable forwardly and rearwardly, whereby the sizes of respective compartments can be adjusted.

Turning now to FIGS. 3-5, more particular aspects of how the cryogenic fluid has conventionally been delivered to the spray head 30 are shown. The spray head 30 is of the type which receives the cryogenic fluid via multiple inlet ports 80, 86 and distributes the cryogenic fluid via multiple ejection ports 31. The liquid supply conduit 32 from the storage tank 26, more specifically, the sub-conduit 34 downstream from the control valve 36, is secured to the liquid inlet port 86 of spray head 30 in a fluid tight manner so as to provide liquid nitrogen directly to liquid flow path 84 within spray head 30. Holes 88 are provided in an upstream portion of the liquid supply conduit 34, and these holes 88 allow a portion of the liquid nitrogen to escape and be vaporized. The vaporized stream is contained in the

chamber 72 within housing 70, which is secured to conduit 32 at 90 and to spray head 30 so as to form a vapor manifold which contains the vapor and directs it into vapor inlet ports 80 to vapor channels 82 within spray head 82. Within spray head 30, vapor channels 82 are combined with liquid flow channel 84 to produce the output spray from ejection ports 31. Insulation 92 has been provided around the portion of the conduit 34 adjacent the spray head 30.

One drawback to the vapor and liquid distribution system of FIGS. 3-5 is that temperature strains can lead to failure.

FIGS. 6-8 depict an improved arrangement for distributing the cryogenic fluid to the inlet ports of the spray head. Spray head 130 is designed to receive cryogenic liquid via inlet port 186 and vaporized cryogen via inlet ports 180, and the spray head is designed to combine the input streams so as to expel the cryogenic fluid into the refrigeration space by way of the multiplicity of ejection ports 131. The cryogenic liquid is supplied via the liquid supply conduit 34 and a vapor manifold 170 is secured to the conduit at 120 and to the head 130 such that liquid which escapes from holes 188 in conduit 34 is vaporized into vapor space 172 and directed into vapor inlet ports 180 by manifold 170.

However, rather than being secured to the head 130 in a fluid tight connection, conduit 32 is engaged with the liquid conduit 184 in a non-fluid tight manner. More specifically, the end of conduit 34 is received within inlet port 186 with an allowance or gap 110 between the outer diameter of the conduit and the inner diameter of port 186. The gap allows relative translation between the conduit 34 and the head 130 due to thermal cycling. In addition, any liquid that escapes from the non-fluid tight junction would be contained in the vapor space 172 of housing 170 and, together with the vapor which is formed by the fluid which escapes from the upstream holes 188 in conduit 34, is supplied to the vapor inlets 180.

FIGS. 9 and 10 illustrate an alternative configuration in which the vapor inlets and the liquid inlets are on opposite sides of the spray head. As shown in FIG. 9 in cross-sectional view (looking from the bottom), the vaporizer 270 has a rectangular shape with two cut outs 210 and 212 formed between the outer portion of housing 276 and the walls 274. Similar to the previous embodiment, the conduit 134 is connected with the vaporizer housing 276 at the location 278. The end 280 of

conduit 134 is received within and spaced from the inlet port 286 of liquid conduit 284 in head 230 to allow for relative movement therebetween. Holes 288 are provided in conduit 134 and cryogen escaping through said holes will vaporize and move through passageways 272 into vapor inlet ports 280. In this manner, a more circuitous path is provided for cryogen escaping from the holes 288, and any cryogen leaking from the gap between conduit 134 and inlet port 286, to enter the vapor inlet ports 280.

While the invention has been illustrated and described in detail in the drawings and foregoing description, the same is to be considered as illustrative and not restrictive in character. Only certain embodiments have been shown and described, and all changes, equivalents, and modifications that come within the spirit of the invention described herein are desired to be protected. Thus, the specifics of this description and the attached drawings should not be interpreted to limit the scope of this invention to the specifics thereof. Rather, the scope of this invention should be evaluated with reference to the claims appended hereto.

What is claimed is:

1. A system for providing cryogenic fluid to a spray head for use in cooling an enclosed space, the spray head having a first inlet for receiving a cryogenic liquid, a second inlet for receiving a cryogenic vapor, and a multiplicity of ejection ports for spraying cryogenic fluid into the enclosed space, the system comprising:

a supply tank for containing a cryogenic liquid;

a cryogenic liquid supply conduit configured to supply the cryogenic liquid from the supply tank to the first inlet of the spray head; and

a cryogenic vapor supply conduit configured to supply cryogenic vapor to the second inlet of the spray head;

wherein the cryogenic liquid supply conduit is non-hermetically engaged with the first inlet of the spray head at a junction location, and wherein the vapor supply conduit surrounds the junction location such that, during use, cryogenic fluid which escapes from the junction location is captured in the vapor supply conduit and provided to the second inlet of the spray head.

2. The system of claim 1 wherein the supply tank contains liquid nitrogen.

3. The system of claim 1 incorporated into a food transport vehicle.

4. The system of claim 1 wherein the cryogenic liquid supply conduit is received within the first inlet to the spray head.

5. The system of claim 1 wherein the first liquid inlet to the spray head is received within the cryogenic liquid supply conduit.

6. The system of claim 1 wherein the cryogenic vapor supply conduit also surrounds an upstream portion of the cryogenic liquid supply conduit having at least one hole formed therein such that, during use, cryogenic fluid which escapes

from the at least one hole in the liquid supply conduit is captured in the vapor supply conduit and provided to the second inlet of the spray head.

7. The system of claim 6 wherein the vapor supply conduit also surrounds the portion of the cryogenic liquid supply conduit between the at least one hole in the upstream portion and the junction location.

8. The system of claim 7 wherein a substantial portion of the liquid cryogenic liquid supply conduit between the at least one hole and the junction location is in thermal communication with the surrounding vapor supply conduit.

9. The system of claim 1 wherein the first and second inlets are on the same side of the spray head such that the fluid flow directions defined by the first and second inlets are less than 90° apart.

10. The system of claim 1 wherein the first and second inlets are on opposite sides of the spray head such that the fluid flow directions defined by the first and second inlets are greater than 90° apart.

11. A method for providing cryogenic fluid to a spray head for use in cooling an enclosed space, the spray head having a first inlet for receiving a cryogenic liquid, a second inlet for receiving a cryogenic vapor, and a multiplicity of ejection ports for spraying cryogenic fluid into the enclosed space, the method comprising:

delivering cryogenic liquid to the first inlet of the spray head via a cryogenic liquid supply conduit which is non-hermetically engaged with the first inlet;

capturing cryogenic fluid which escapes from the junction between the cryogenic liquid supply conduit and the first inlet of the spray head with a cryogenic vapor supply conduit; and

delivering cryogenic vapor and the escaped cryogenic fluid to the second inlet of the spray head via the cryogenic vapor supply conduit.

12. The method of claim 11 further comprising capturing cryogenic fluid which escapes from one or more upstream holes in the cryogenic liquid supply conduit with the cryogenic vapor supply conduit.

13. The method of claim 11 wherein the spray head is used to cool the refrigeration space of a food transport vehicle.

14. The method of claim 11 wherein the cryogenic liquid is liquid nitrogen.

15. The method of claim 11 wherein the first and second inlets are on the same side of the spray head such that the cryogenic liquid and the cryogenic fluid are delivered into the spray head in flow directions that are less than 90° apart.

16. The system of claim 1 wherein the first and second inlets are on opposite sides of the spray head such that the cryogenic liquid and the cryogenic fluid are delivered into the spray head in flow directions that are greater than 90° apart.

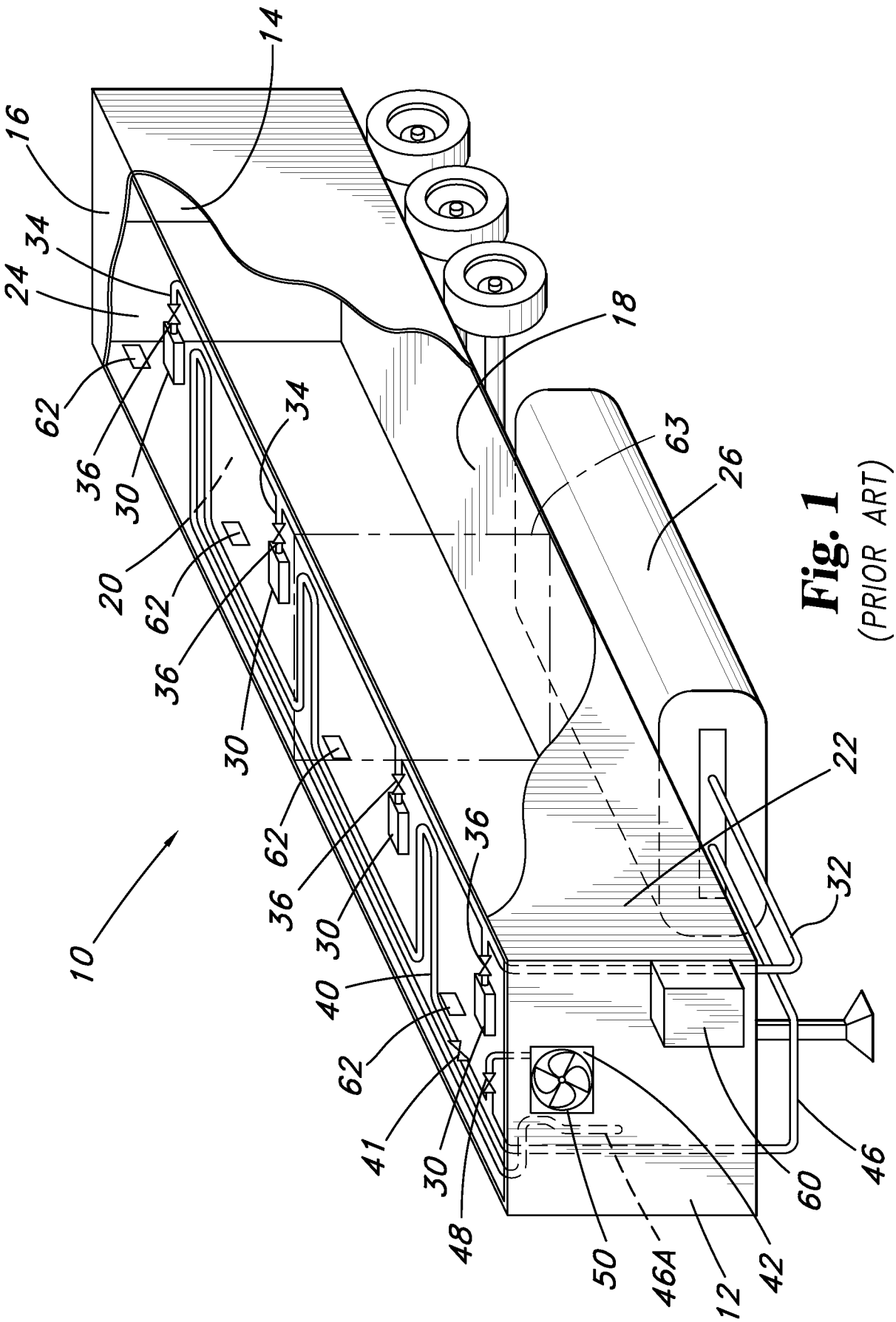


Fig. 1
(PRIOR ART)

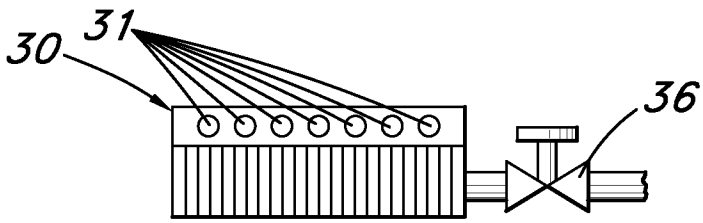


Fig. 2
(PRIOR ART)

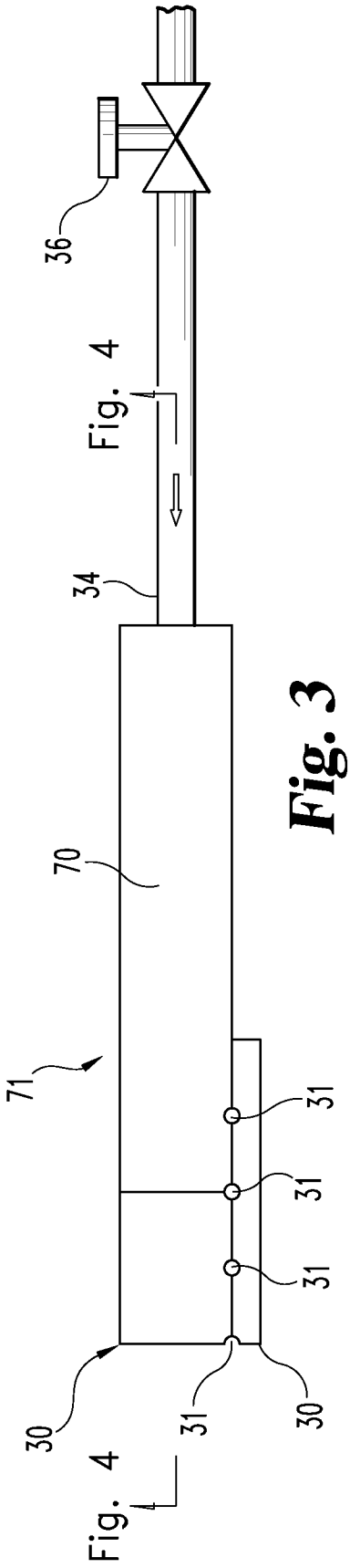


Fig. 3
(PRIOR ART)

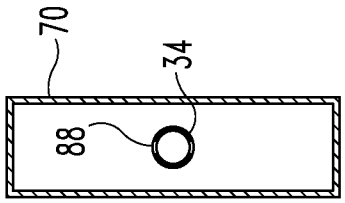


Fig. 5
(PRIOR ART)

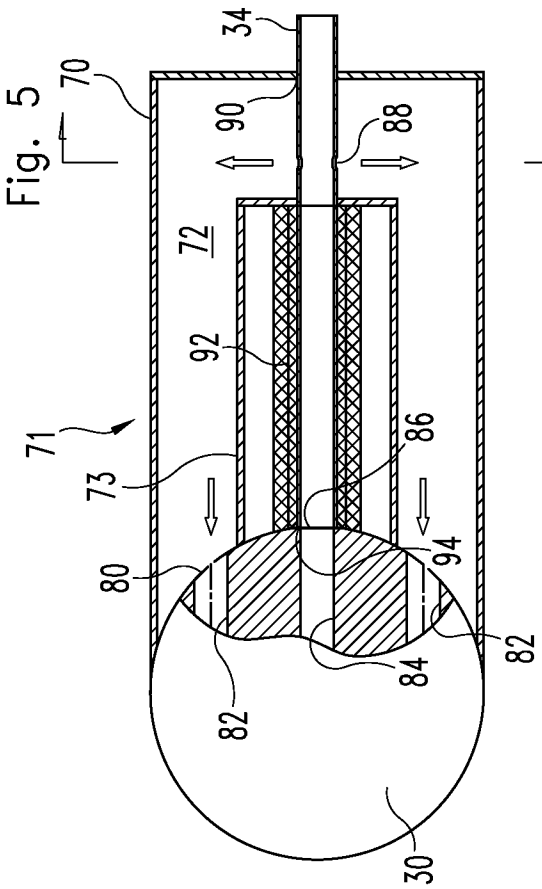


Fig. 4
(PRIOR ART)

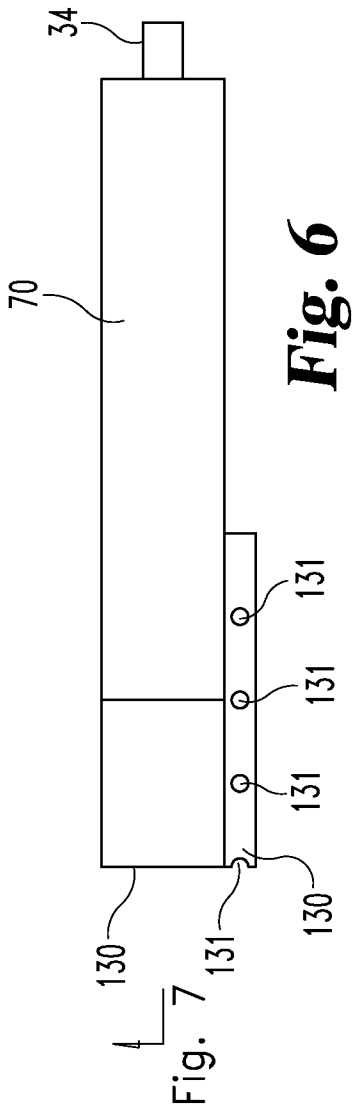


Fig. 6

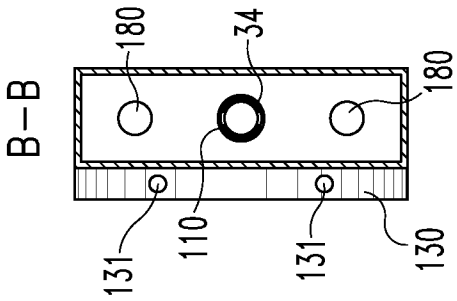


Fig. 8

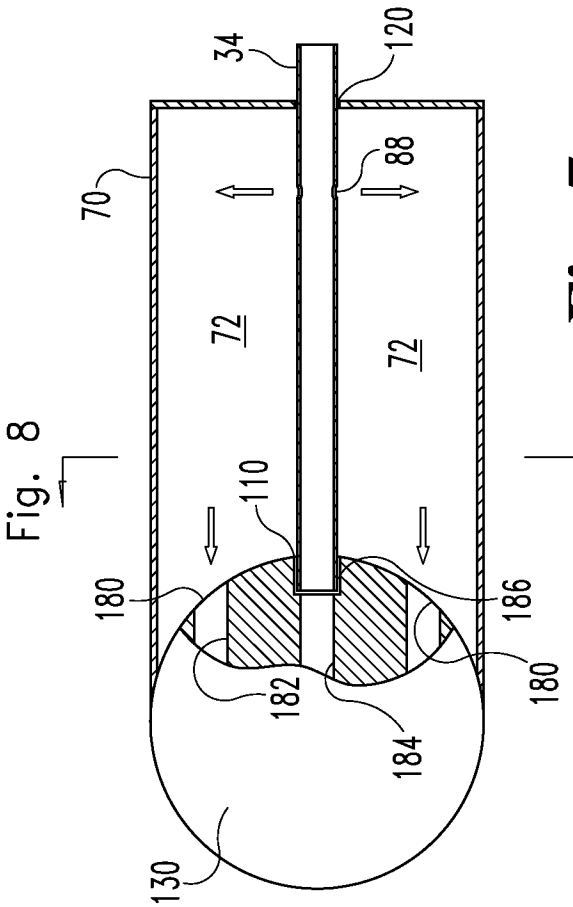


Fig. 7

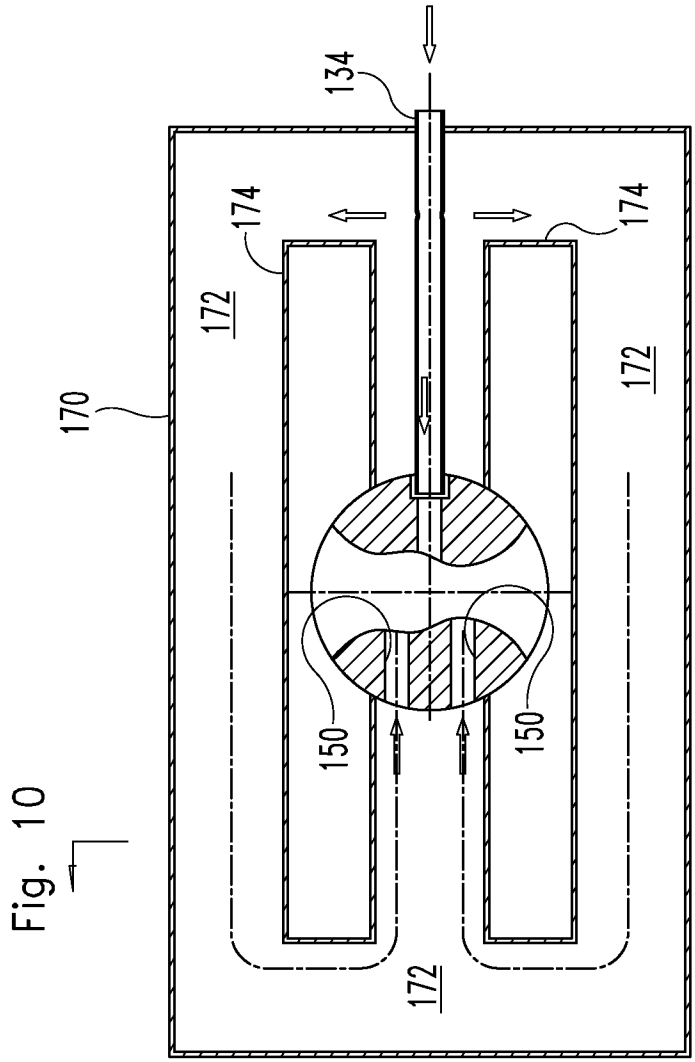


Fig. 9

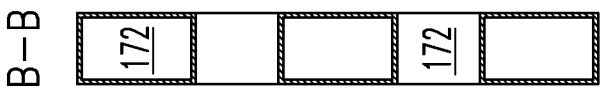


Fig. 10