



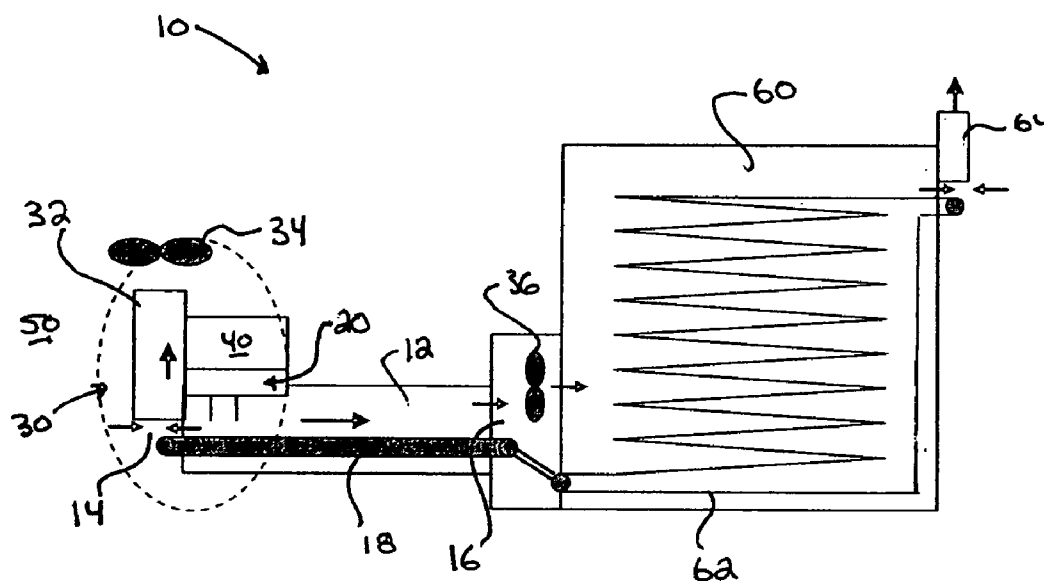
US 20090019869A1

(19) **United States**(12) **Patent Application Publication**  
**Girard et al.**(10) **Pub. No.: US 2009/0019869 A1**(43) **Pub. Date: Jan. 22, 2009**(54) **SYSTEM AND METHOD FOR VAPOR  
CONTROL IN CRYOGENIC FREEZERS****Publication Classification**(51) **Int. Cl.**  
**F25D 3/11** (2006.01)(52) **U.S. Cl.** ..... 62/168; 62/465(57) **ABSTRACT**

A cryogenic freezer with cryogenic vapor control is disclosed. The cryogenic freezer is characterized in that the vapor control system is adapted to control the speed of the transition fan which moves some of the cryogen from a first cryogenic freezer to a second freezer in response to differences between the temperature of the process room, operating temperature of the cryogenic freezer, and a temperature of the exhaust. By adjusting the transition fan speed in response to such temperature differences the vapor control system operates to limit the flow of air from the process room into the freezer and also limits cryogen vapor flow from the freezer to the process room.

(76) Inventors: **John M. Girard**, Downers Grove,  
IL (US); **Glenn T. Sameshima**, Oak  
Park, IL (US)

Correspondence Address:  
**PRAXAIR, INC.**  
**LAW DEPARTMENT - M1 557**  
**39 OLD RIDGEBURY ROAD**  
**DANBURY, CT 06810-5113 (US)**

(21) Appl. No.: **11/879,894**(22) Filed: **Jul. 19, 2007**

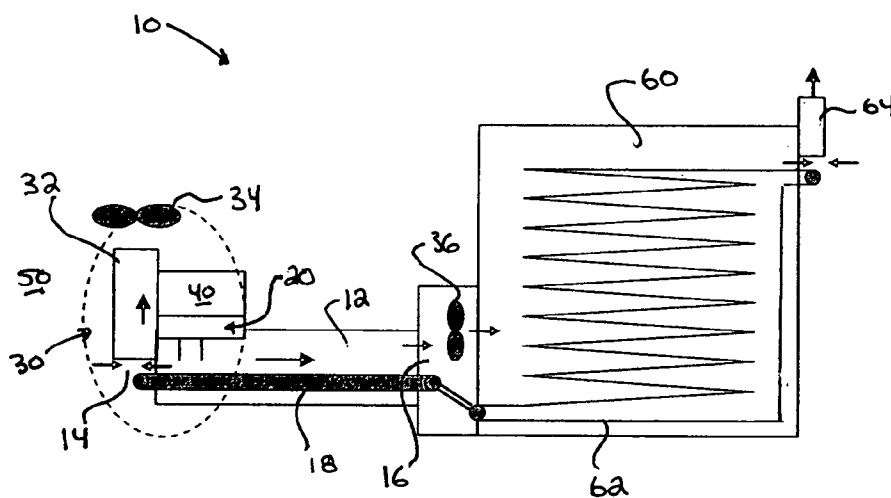


Fig. 1

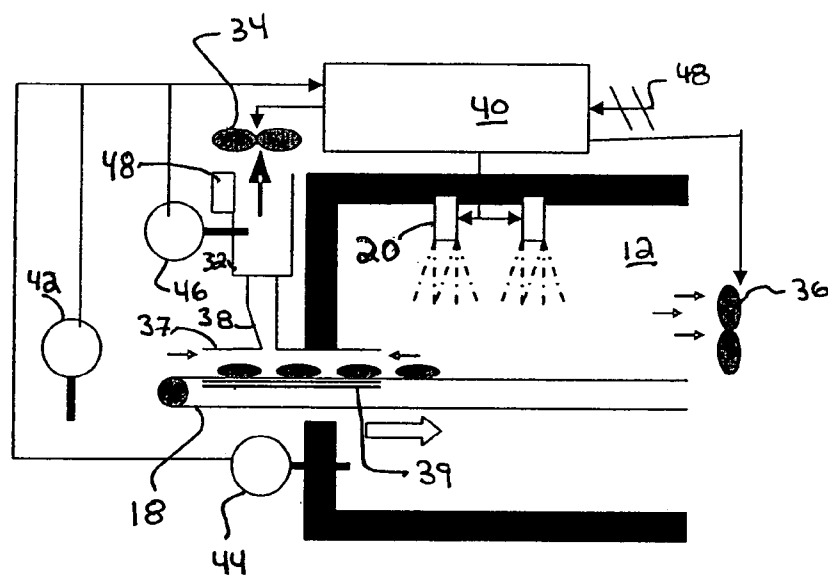


Fig. 2

## SYSTEM AND METHOD FOR VAPOR CONTROL IN CRYOGENIC FREEZERS

### FIELD OF THE INVENTION

**[0001]** The present invention relates to cryogenic refrigeration and freezing systems, and more particularly to a system and method for the control of freezer vapors within the cryogenic refrigeration and freezing systems.

### BACKGROUND OF THE INVENTION

**[0002]** In many conventional cryogenic refrigeration or freezing systems, the system typically run the exhaust fans and transition fans at the same speed and usually at a speed that can handle peak cryogen usage. Running the exhaust fans and transition fans at the same speed may result in the exhaust system forcing cryogen vapors out of the refrigeration equipment before some of the refrigeration energy can be extracted. In addition, running the exhaust fans and transition fans at the same speed may also result in pulling excess fresh air into the freezer that needs to be refrigerated which, in turn may cause deposition of water vapor from the excess room air inside the freezer. Both of these problems, namely inefficient cryogen usage as well as excess room air tend to increase costs of operating the cryogenic refrigeration system.

**[0003]** Prior art attempts to solve these problems of system inefficiency involved the use of variable speed fans where the speed of the fan was correlated directly to the cryogen injection rate. Alternatively, the speed of the variable speed fan would be controlled or adjusted based on the vapor temperature at the exhaust or product exit. While the use of variable speed fans generally increased the efficiency of such cryogenic refrigeration or freezing systems, there were still shortcomings in the system design. For example, if the food-process room temperature were to vary, such process room temperature change would likely affect the exhaust temperature causing erroneous adjustments in fan speed leading to inefficiencies in freezer operation.

**[0004]** What is needed therefore, is a freezer vapor control system that further improves the operational efficiency of cryogenic based refrigeration or freezer system by precisely controlling fan speeds to extract more of the refrigeration capacity from the cryogen and limit the volume of makeup air infiltrating into the freezer or refrigeration system. By extracting more of the refrigeration capacity from the cryogen, less cryogen will be used to achieve the desired product temperature. Similarly, by limiting or reducing the volume of makeup air infiltrating into the freezer the cryogen use will be further reduce and the associated problems with water ice build up in the freezer should be minimized or eliminated.

### SUMMARY OF THE INVENTION

**[0005]** The present invention may be characterized as a cryogenic freezer system comprising: a freezer compartment having an entrance, an exit and a conveyor disposed therein for treating a food product; a cryogen supply subsystem adapted to provide a cryogen to treat the food product within the freezer compartment; an exhaust subsystem, including an exhaust fan disposed proximate the entrance of the freezer compartment; a transition fan disposed proximate the exit of the freezer compartment; a control subsystem operatively coupled to the cryogen supply subsystem and adapted to control the cryogen introduced into the freezer compartment and the transition fan in response to selected inputs; and a

plurality of temperature sensors coupled as inputs to the control subsystem, said temperature sensors adapted to ascertain a temperature of the process room, an operating temperature of the freezer compartment; and a temperature of the exhaust. The control subsystem is adapted to govern the transition fan in response to a temperature difference between the temperature of the process room and the temperature of the exhaust.

**[0006]** In another aspect, the present invention may be characterized as a method of controlling a cryogenic freezer system comprising the steps of: (a) injecting a cryogen into a freezer compartment, the freezer compartment having an entrance, an exit and a conveyor disposed therein for treating a food product; (b) directing a portion of the cryogen vapors in said freezer compartment via an exhaust fan to an exhaust disposed proximate the entrance to the freezer compartment and directing the remainder of the cryogen vapors in said freezer compartment to a second freezer compartment via a transition fan; (c) monitoring the operating temperatures associated with the cryogenic freezer system including a temperature of the process room, an operating temperature of the freezer compartment, and a temperature of the exhaust; (d) controlling the injection of cryogen into the freezer compartment in response to a temperature difference between the temperature of the freezer compartment and the temperature of the exhaust; and (e) controlling the operation of the transition fan in response to a temperature difference between the temperature of the process room and the temperature of the exhaust.

### BRIEF DESCRIPTION OF THE DRAWINGS

**[0007]** While the specification concludes with claim distinctly pointing out the subject matter that applicants regard as their invention, it is believed that the invention will be better understood when taken in connection with accompanying drawings in which:

**[0008]** FIG. 1 is a schematic view of the present cryogenic freezer system in accordance with an embodiment of the invention; and

**[0009]** FIG. 2 is a partial view of the entrance area of the cryogenic freezer system in accordance with an embodiment of the invention.

### DETAILED DESCRIPTION

**[0010]** The following description sets forth the best mode presently contemplated for practicing the present cryogenic freezer system with vapor control. It is not to be taken in a limiting sense, but rather should be read in conjunction with the appended claims.

**[0011]** With reference to FIG. 1 and FIG. 2, there is shown an embodiment of the present cryogenic freezer system **10** with vapor control. As seen therein, the cryogenic freezer system **10** includes a first freezer compartment **12** having an entrance **14**, an exit **16**, and a conveyor **18** disposed therein for treating a food product. The freezer system **10** further includes a cryogen injection or supply subsystem **20** adapted to introduce a cryogen into the first freezer compartment **12** to treat the food product as well as an exhaust subsystem **30** and a vapor control subsystem **40**. In the illustrated embodiment, the exhaust subsystem **30** preferably includes an exhaust duct **32** disposed proximate the entrance **14** of the first freezer compartment **12** in flow communication with an exhaust fan **34**. The exhaust subsystem **30** is adapted to prevent much of the cryogenic vapors used in the cryogenic freezer system **10**

from filling the process area 50 surrounding the first freezer compartment 12. Due to the proximity of the exhaust duct 32 to the entrance 14 of the first freezer compartment 12, the exhaust subsystem 30 tends to pull some ambient process room air into the exhaust duct 32 where it mixes with the exhausted cryogenic vapors.

[0012] The illustrated first freezer compartment 12 is shown juxtaposed to a second freezer compartment 60 wherein the food product conveyed through the first freezer compartment 12 is transported in a continuous manner to a second conveyor 62 within the second freezer compartment 60 for further treatment. The illustrated embodiment depicts the first freezer compartment 12 as a cryogenic tunnel freezer and the second freezer compartment 60 as a spiral freezer, although other freezer configurations are equally suitable for use with the present system. Preferably, the cryogenic freezer can be a straight, flighted or immersion freezer disposed upstream of a second freezer that is mechanical or cryogenic based freezer. A variable speed transition fan 36 is disposed proximate the exit 16 of the first freezer compartment 12 and is adapted to forcibly direct some of the cryogenic vapors from the first freezer compartment 12 to the second freezer compartment 60. A secondary exhaust duct 64 may be associated with the second freezer compartment 60 to prevent any cryogenic vapors present in the second freezer compartment 60 from filling the process room.

[0013] The vapor control subsystem 40 is adapted to control the cryogen supply subsystem 20, the exhaust fan 34 and the transition fan 36 in response to selected inputs. These inputs to the vapor control subsystem 40 typically include a plurality of temperature sensors 42, 44, 46 as well as various user inputs 48. In the illustrated embodiment, first temperature sensor 42 is adapted to ascertain a temperature of the process room, second temperature sensor 44 is adapted to sense the operating temperature within the first freezer compartment 12; and third temperature sensor 46 is adapted to sense the temperature of the exhaust. The vapor control subsystem 40 is adapted to govern the injection or supply of the cryogen into the freezer compartment 12 and the speed of the transition fan 36 in response to the various inputs. By varying the speed of the transition fan 36, the flow of the cryogenic vapors from the first freezer compartment 12 to the second freezer compartment 60 is precisely controlled which in turn, controls the flow of cryogen vapors from the first freezer compartment 12 to the exhaust duct 32.

[0014] In order to maximize the use of the refrigeration capacity of the cryogen vapor, or cryogen efficiency, the flow of cryogen vapors exiting the first freezer compartment 12 near the entrance 14 is preferably controlled in a precise manner. Too much cryogen vapor flow exiting the first freezer compartment 12 via the exhaust duct results in excessive amounts of refrigeration BTUs to be lost to the exhaust. Too little flow of cryogen vapor from the first freezer compartment 12 at the entrance 14 allows excess room air to enter the first freezer compartment 12 increasing cryogen demands within the first freezer compartment 12. Excess room air also tends to create freezer operational problems due to ice build up attributable to water vapor condensing inside the first freezer compartment 12 and exhaust duct 32.

[0015] In the present embodiment, the exhaust fan 34 operates at a fixed fan speed and pulls a mixture of cryogen vapors from the first freezer compartment 12 and process room air from the surrounding area proximate the entrance 14. The exhaust flow of cryogenic vapor from the first freezer com-

partment 12 via the exhaust duct 32 is dependent not only on the speed of the exhaust fan 34, but also on the speed of the transition fan 36, which is preferably a variable speed fan. The speed of the transition fan 36 is preferably set by the vapor control subsystem 40 in response to three ascertained temperatures, namely the process room temperature; the vapor exhaust temperature in the exhaust duct; and the temperature in the first freezer compartment 12. By adjusting or varying the speed of the transition fan 36, the flow of cryogen vapors directed from the first freezer compartment 12 to the second freezer compartment 60 is controlled which, in turn, also controls the flow of cryogen vapors from the first freezer compartment 12 to the exhaust duct 32.

[0016] Turning to FIG. 2, there is shown a more detailed schematic view of the entrance area to the cryogenic freezer system 10. The entrance 14 to the tunnel freezer or first freezer compartment 12 and the exhaust duct 32 in particular, must be designed to focus and properly mix the various gas flows. As depicted in FIG. 2, the exhaust subsystem 30 includes, a main exhaust duct 32, an exhaust duct pickup 37 a vapor focusing tunnel 38, and a baffle or plate 39.

[0017] The baffle or plate 39 is disposed under the conveyor 18 proximate the entrance 14 of the first freezer compartment 12 to limit cryogen vapor flow from within the first freezer compartment 12 to the exhaust duct pickup 37. The plate 39 directs the cryogen vapor from inside the first freezer compartment 12 to flow along the conveyor 18, across the food product, and up into the exhaust duct pickup 37. Similarly, the baffle or plate 39 directs any process room air flowing into first freezer compartment 12 toward the exhaust duct pickup 37.

[0018] The vapor focusing tunnel 38 is a diverging channel that directs the cryogen vapor and process room air from the exhaust duct pickup 37 to the exhaust duct 32. The design and orientation of the exhaust duct pickup 37 together with the vapor focusing tunnel 38 operate to limit any process room air infiltration into the first freezer compartment 12 or cryogen vapor flow from the first freezer compartment 12 to the process room. The pull of the exhaust fan 34 provides the forces needed to direct any cryogen vapor or process room air via the exhaust duct pickup 37 into the vapor focusing tunnel 38 where the gas streams are mixed, and further direct the mixed gas stream to the exhaust duct 32.

[0019] The present embodiment of the cryogenic freezer system 10 maintains a regulated flow of cryogen vapors out of the entrance 14 of the first freezer compartment 12 while directing a variable flow of the cryogen vapors from the first freezer compartment 12 into the second freezer compartment 60. Such adjustment of the cryogen flow from the first freezer compartment 12 to the second freezer compartment 60 based on variations in processing room temperatures and other system temperatures also operates to adjust the flow out of the first freezer compartment 12 via the exhaust duct 32. Controlling the flow of cryogen vapors out of the first freezer compartment 12 via the exhaust duct 32 allows the user to maintain a desired minimum temperature in the exhaust system.

[0020] The present system represents an improvement on conventional control systems for cryogenic freezers by monitoring the active temperature at three locations relative to the process. Temperature element 46 monitors the temperature of the exhaust gas stream. Temperature element 42 monitors the temperature of the process room while Temperature element 44 monitors the operating temperature inside the first freezer

compartment. In addition, a gas analyzer and/or flow sensing device 48 monitors the gas concentrations and/or flow of various gases in the exhaust system. The present control scheme monitors the above-identified temperatures, associated temperature differences and exhaust system flows to provide corrective action to the transition fan and other elements of the present freezer system.

**[0021]** By comparing the temperature difference between the exhaust stream and freezer compartment as well as the temperature difference between the exhaust stream and the process room, the control system can optimize the operation of the system, and in particular, the operation of the transition and exhaust fans. The underlying principle of the present control scheme is to maintain an even energy exchange between the cryogenic vapor in the freezer compartment and exhaust gas stream on the one hand, and the exhaust gas stream and the process room air stream on the other hand.

**[0022]** As more cryogen is introduced into the first freezer compartment, some portion of the cryogen vapor leaves the entrance to first freezer where it is mixed with and presumably cools the exhaust gas stream. As a result, the temperature difference between the exhaust gas stream temperature and the process room temperature increases as more cryogen is added. At the same time, the temperature difference between the exhaust gas stream temperature and freezer compartment temperature narrows as more cryogen is added.

**[0023]** By doing an energy balance based on: (1) the temperature differences between the process room air stream and the exhaust gas stream; and (2) the temperature differences between exhaust gas stream and the freezer compartment, one can determine whether excess cryogen cooling capacity is being lost in the exhaust gas stream and/or whether excess process room air is infiltrating the freezer compartment and adversely impacting performance of the freezer. Adjusting the transition fan speed in response to the energy balance assessment, the system performance can be optimized. Adjustment of the transition fan speed upward or higher will tend to direct more of the cryogen vapors from the first freezer compartment to the second freezer compartment and therefore less cryogen vapors leave the first freezer compartment via the entrance or exhaust allowing the temperature of the exhaust stream to increase, which in turn, likely cause a change to the temperature differences used in the present control scheme. Conversely, adjustment of the transition fan speed downward or lower allows more of the cryogen vapors to remain in the first freezer compartment and/or leave the first freezer compartment via the entrance or exhaust. Generally, lowering the transition fan speed translates to a decrease or lowering in the temperature of the exhaust gas stream and, of course, a change to the temperature differences used in the present control scheme.

**[0024]** Although the present control scheme is primarily concerned with controlling the speed of the transition fan, it is also contemplated that the present control scheme can be employed to concurrently control the speeds of both the transition fan as well as the exhaust fan. Still further, adjustments to the cryogen injection could also be operatively coupled to the present vapor control system.

**[0025]** The present control scheme also ensures that the exhaust gas stream temperature remains above the freezing point of water. This lower limit of the exhaust gas stream temperature makes sure that water vapor entrained in the exhaust gas stream does not form ice in the exhaust system and the exhaust system remains operational. When the con-

trol scheme senses that the exhaust gas stream temperature is below, at, or near the freezing point of water, adjustments to the transition fan speed to direct more cryogen vapor to the second freezer compartment or a reduction in the cryogen injection to the first freezer compartment are initiated in an effort to allow the temperature of the exhaust gas stream to remain above the selected threshold point. Such a feature of the control system would reduce the frequency of running a thawing cycle for the freezer.

**[0026]** Similarly, in an effort to avoid problems associated with water condensation and ice formation, the present control scheme also should ensure that there is an actual flow within the exhaust system. To that end, a flow sensing device is preferably incorporated into the exhaust system and operatively coupled to the control system. The flow sensing device provides a positive indication there is an active exhaust flow and, if capable of monitoring the concentrations of cryogen vapor (nitrogen or carbon dioxide) in the exhaust gas stream, is useful as a safety feature that would prevent personnel from entering or accessing the freezer compartment until the cryogen vapor is at a safe and/or acceptable level.

**[0027]** Control of the transition fan and exhaust fan is also responsive to the level of cryogen injection into the first compartment freezer. In the present embodiment, the fan speeds are initially set based on the cryogen injection into the first compartment freezer and subsequently refined using the present energy balance control scheme. The present control scheme is an iterative process that continually assesses the three temperatures and the above-identified temperature differences and makes adjustments to the fan speeds as required.

**[0028]** Although not shown, the present cryogenic freezer system could be implemented with a single freezer compartment configuration. In such single compartment embodiment, the transition fan is employed to bias the cryogen vapor flow inside the freezer compartment, as needed, to balance the energy transfers as described above. Another single freezer compartment arrangement, such as a cryogenic tunnel freezer using nitrogen, might also utilize the transition fans to perform two distinct functions. First, the transition fan is used to drive the nitrogen vapor within the freezer toward the product exit end or the product entrance end in response to the three measured temperatures and the temperature differences therebetween. The second function is to utilize the transition fans to act like a second exhaust blower and drive cryogen vapor out.

#### INDUSTRIAL APPLICABILITY

**[0029]** As described herein, the present system and method for controlling vapors within a cryogenic freezer system operates to reduce the cost to operate and maintain a cryogenic freezer in several ways. First, the disclosed system and method improves the efficiency and utilization of the injected cryogen in that by extracting more of the refrigeration capacity from the cryogen, the freezer consumes less cryogen to achieve the same or similar performance. In addition, the disclosed system and method reduces the volume of makeup air infiltrating into the freezer compartments. This reduction in makeup air further reduces the cryogen needed to achieve the desired refrigeration performance as well as eliminates the associated problems with water and ice build up in the freezer compartments and exhaust ducts attributable to the incoming makeup air.

**[0030]** One of the many advantages the present embodiment has over prior art control systems for cryogenic freezers

is its ability to accommodate changes in process room temperature relative to the exhaust gas temperature. Another advantage is realized by coupling the control of the transition fan speed not solely to cryogen injection levels, but rather to both cryogen injection levels and operating temperature differences to minimize any lag times in the control scheme. Yet another advantage is the ability to minimize the need for running thawing cycles, as the temperature in the exhaust system is continuously monitored and kept above 0 degrees Centigrade.

**[0031]** While the present invention has been described with reference to a preferred embodiment, numerous changes, additions and omissions may be made without departing from the spirit and scope of the present invention, as defined by the appended claims.

1. A cryogenic freezer system comprising:
  - a freezer compartment having an entrance, an exit and a conveyor disposed therein for treating a food product;
  - a cryogen supply subsystem adapted to provide a cryogen to treat the food product within the freezer compartment;
  - an exhaust subsystem, including an exhaust fan disposed proximate the entrance of the freezer compartment;
  - a transition fan disposed proximate the exit of the freezer compartment;
  - a control subsystem operatively coupled to the cryogen supply subsystem and adapted to control the cryogen introduced into the freezer compartment and the transition fan in response to selected inputs; and
  - a plurality of temperature sensors coupled as inputs to the control subsystem, said temperature sensors adapted to ascertain a temperature of the process room, an operating temperature of the freezer compartment; and a temperature of the exhaust;
 wherein the control subsystem is adapted to govern the transition fan in response to a temperature difference between the temperature of the process room and the temperature of the exhaust.
2. The system of claim 1 wherein the control subsystem is further adapted to govern the transition fan in response to the temperature difference between the operating temperature of the freezer compartment and the temperature of the exhaust.
3. The system of claim 1 wherein the control subsystem is further adapted to govern the transition fan to maintain the exhaust temperature above 0 degrees Centigrade.
4. The system of claim 1 wherein the exhaust subsystem further comprises a plate disposed beneath the conveyor belt proximate the entrance and wherein the plate directs a portion of the cryogen vapor flow within the freezer to the exhaust fan.
5. The system of claim 1 wherein the exhaust subsystem further comprises an exhaust pickup and a vapor focusing tunnel disposed proximate the entrance of the freezer wherein the exhaust pickup and vapor focusing tunnel limit the flow of air from a process room into the freezer compartment and further limits cryogen vapor flow from the freezer compartment to the process room.
6. The system of claim 1 wherein the exhaust subsystem further comprises an exhaust duct and a flow sensing device disposed in the exhaust duct, said flow sensing device adapted to provide an input to the control subsystem.

7. The system of claim 1 further comprising a second freezer compartment adjacent the exit of the freezer compartment and wherein the transition fan is adapted to direct cryogen flow from within the freezer compartment to the second freezer compartment.

8. The system of claim 7 wherein the second freezer compartment is a mechanical freezer and the cryogen flow to the second freezer provides a supplemental cryogen refrigeration capacity to the mechanical freezer.

9. The system of claim 7 wherein the freezer compartment is a cryogenic tunnel freezer and the second freezer compartment is a spiral freezer.

10. The system of claim 1 further comprising a second freezer compartment adjacent the exit of the freezer compartment and wherein the transition fan is adapted to direct cryogen flow from within the freezer compartment to the second freezer compartment or evacuate the cryogen vapor from the cryogenic freezer system in response to commands from the control subsystem.

11. A method of controlling a cryogenic freezer system comprising the steps of:

- injecting a cryogen into a freezer compartment, said freezer compartment having an entrance, an exit and a conveyor disposed therein for treating a food product;
- directing a portion of the cryogen vapors in said freezer compartment via an exhaust fan to an exhaust disposed proximate the entrance to the freezer compartment and directing the remainder of the cryogen vapors in said freezer compartment to a second freezer compartment via a transition fan;
- monitoring the operating temperatures associated with the cryogenic freezer system including a temperature of the process room, an operating temperature of the freezer compartment, and a temperature of the exhaust;
- controlling the injection of cryogen into the freezer compartment in response to a temperature difference between the temperature of the freezer compartment and the temperature of the exhaust; and
- controlling the operation of the transition fan in response to a temperature difference between the temperature of the process room and the temperature of the exhaust.

12. The method of claim 11 further comprising the step of controlling the operation of the transition fan in response to a temperature difference between the operating temperature of the freezer and the temperature of the exhaust.

13. The method of claim 11 wherein the step of controlling the operation of the transition fan further comprises controlling the transition fan to maintain the exhaust temperature above a prescribed threshold.

14. The method of claim 11 wherein the step of directing a portion of the cryogen vapors in said freezer compartment to an exhaust disposed proximate the entrance further comprises directing the cryogen vapors from the freezer compartment to an exhaust pickup and concurrently directing any infiltrating process room air to the exhaust pickup thereby limiting the flow of air into the freezer compartment and limiting cryogen vapor flow from the freezer compartment to the process room.

\* \* \* \* \*