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Barrett

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[54] **DIRECT CONTACT FOOD FREEZER**

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[21] Appl. No.: **48,912**

Related U.S. Application Data

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[52] **U.S. Cl.** **62/60,** 62/64, 62/85, 62/266, 62/374

[51] **Int. Cl.** **F25d 3/10,** F25b 43/00

[58] **Field of Search** 62/64, 63, 266, 60, 62/374

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[57] **ABSTRACT**

This invention provides a direct contact freezing device using a low boiling point, inert refrigerant in a stream having portions at different velocities for the direct contact freezing of comestibles without clumping of the particles or icing of the freezer.

12 Claims, 9 Drawing Figures

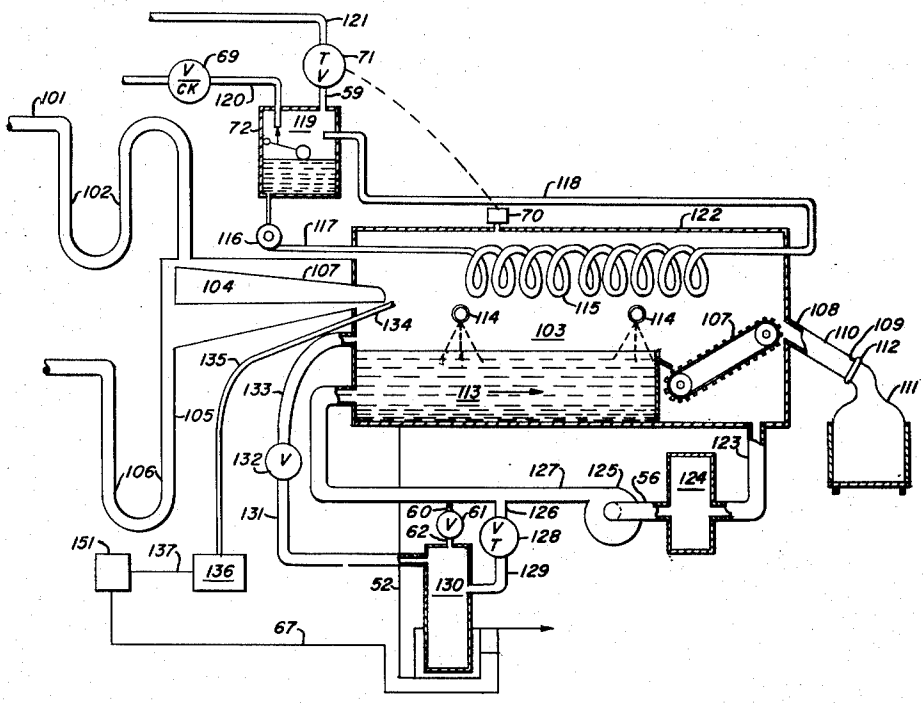
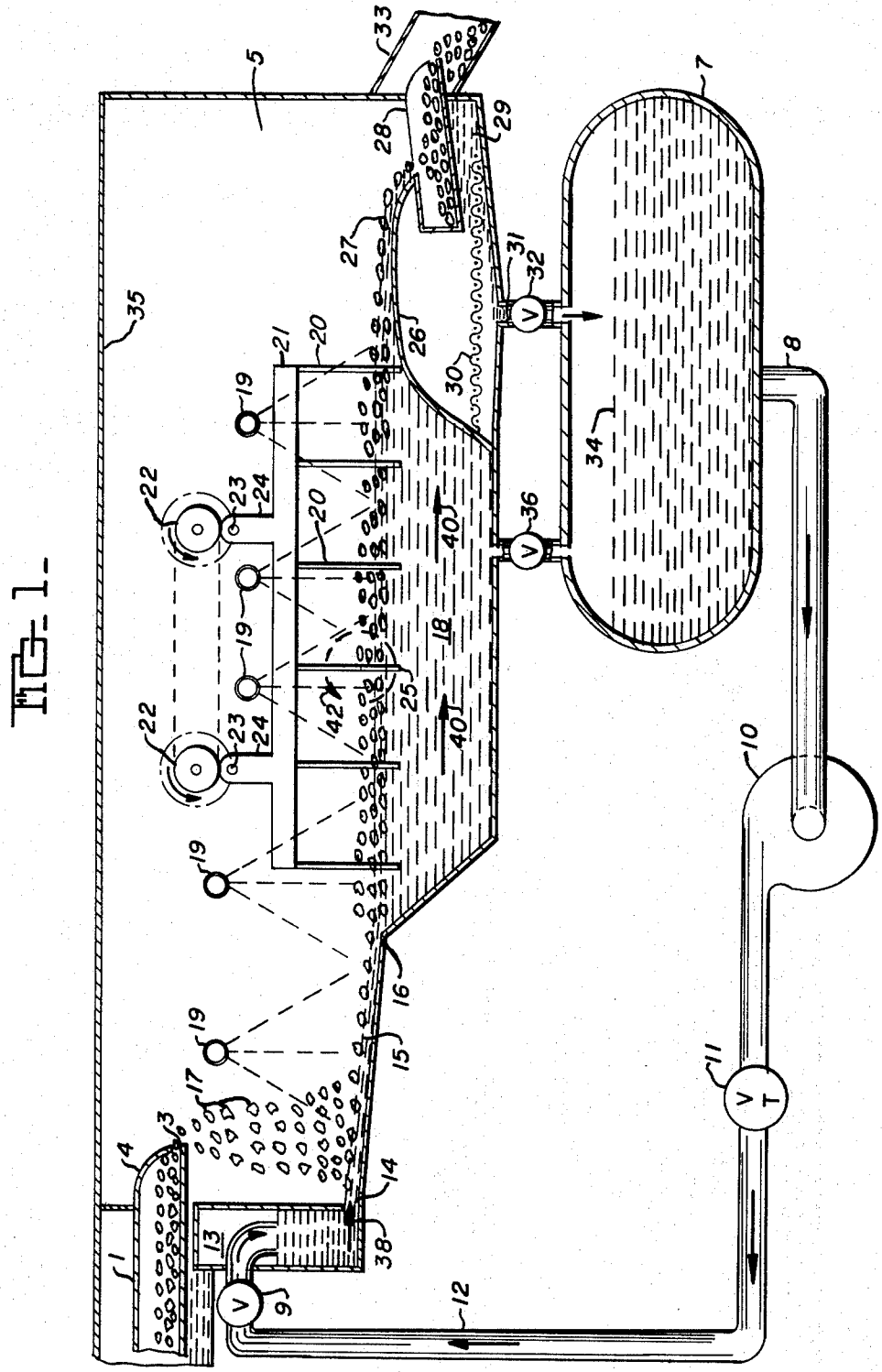


FIG. 1.



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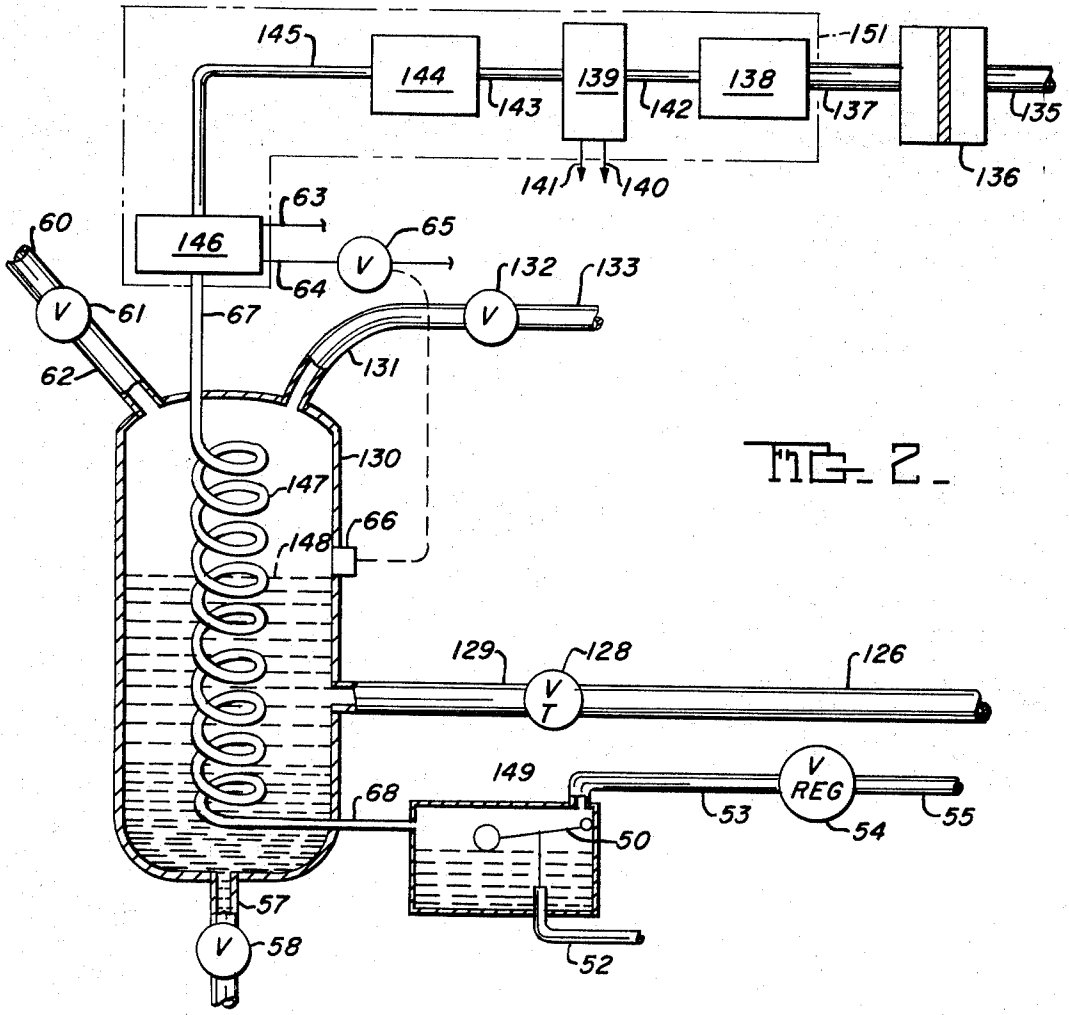
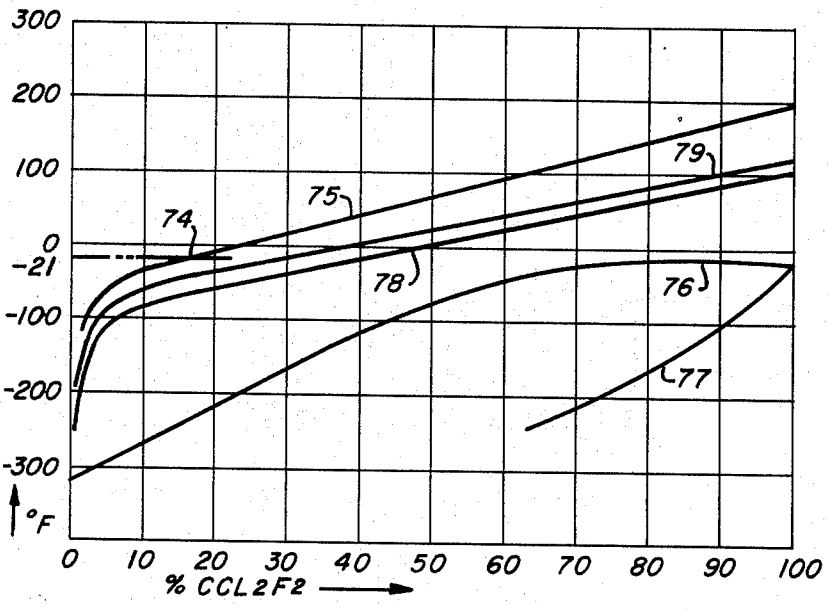


FIG. 2

FIG. 3



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FIG. 8.

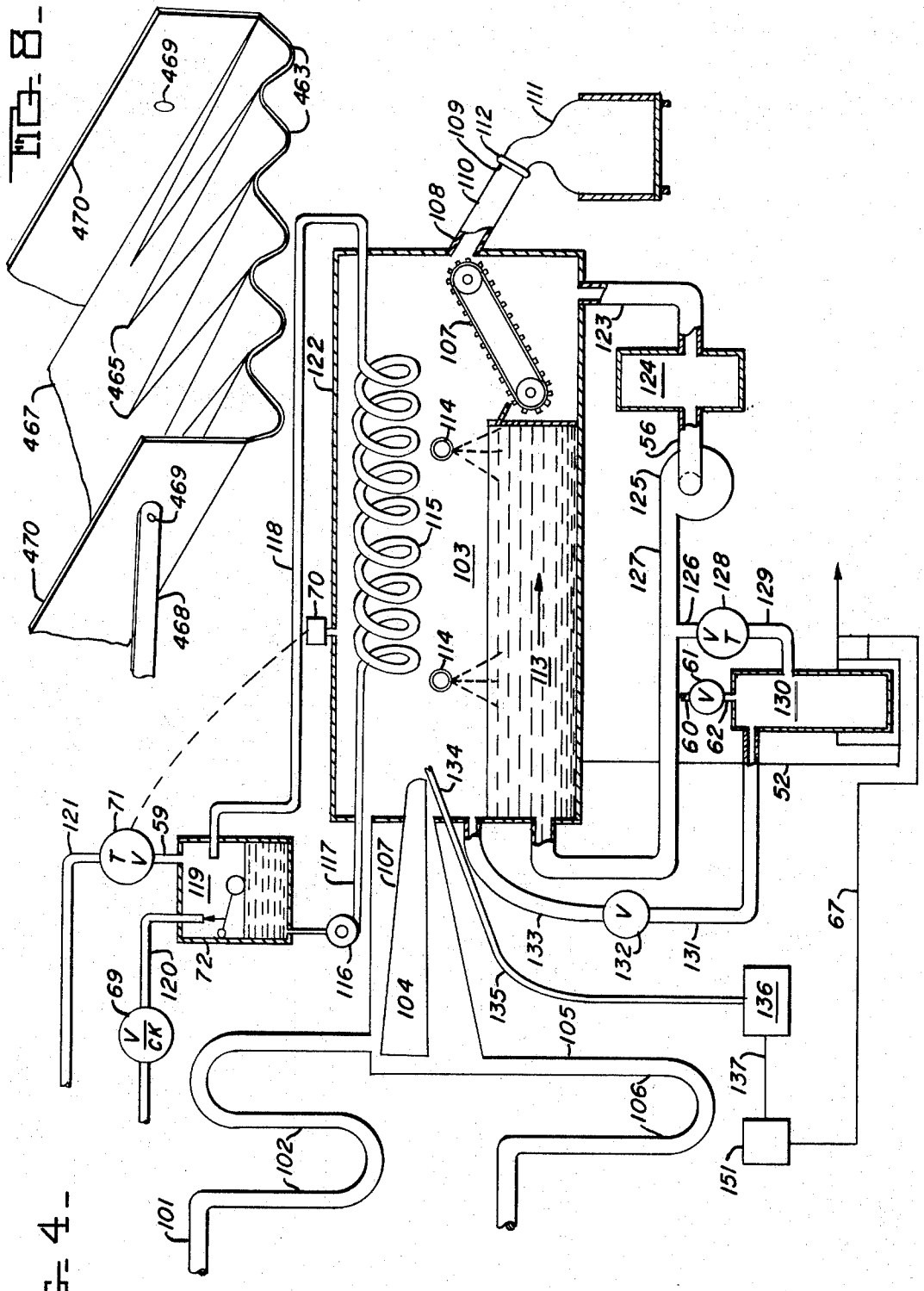


FIG. 4.

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FIG. 6

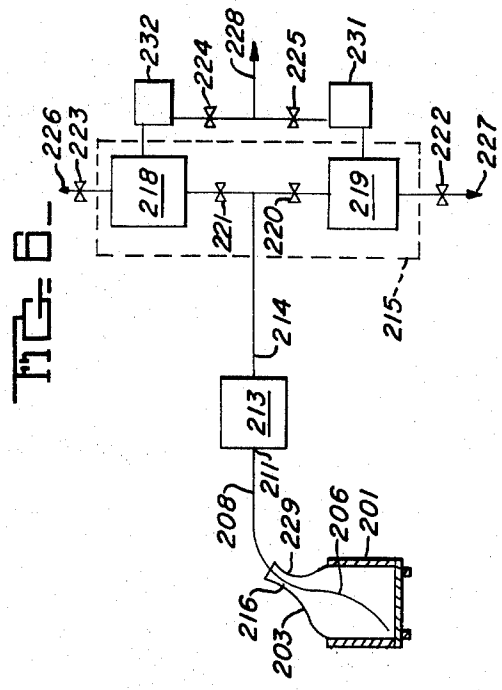
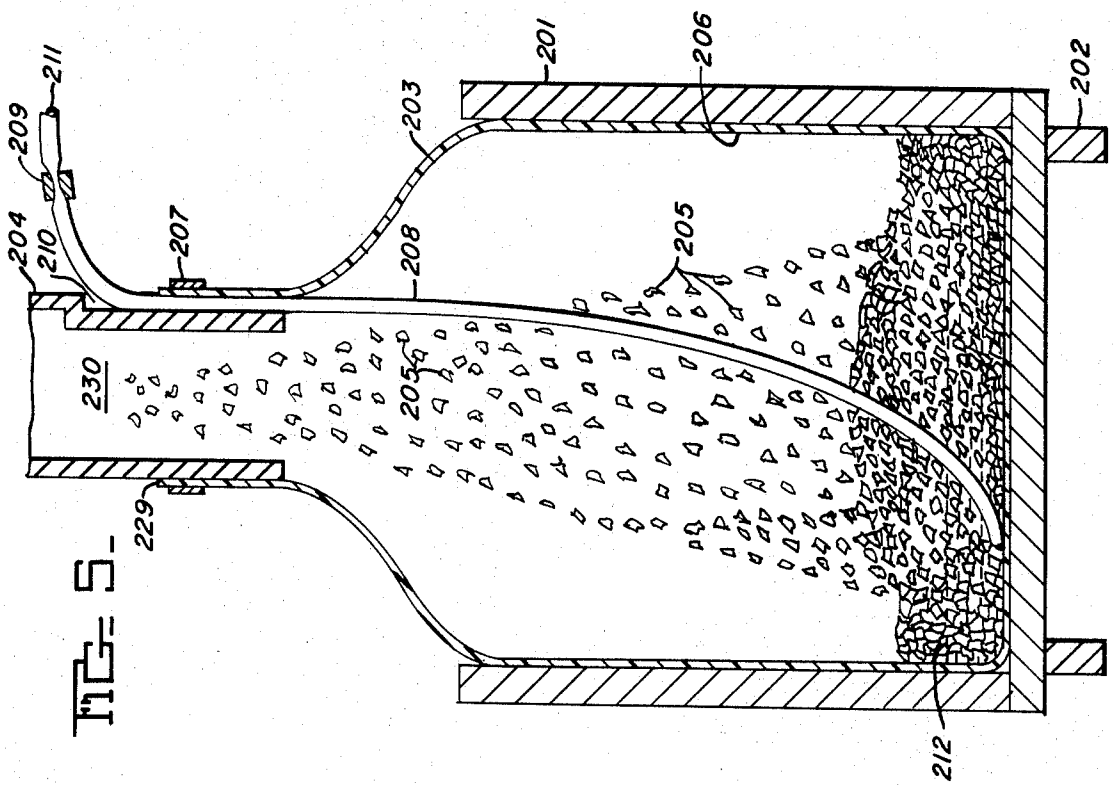


FIG. 5



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FIG. 7

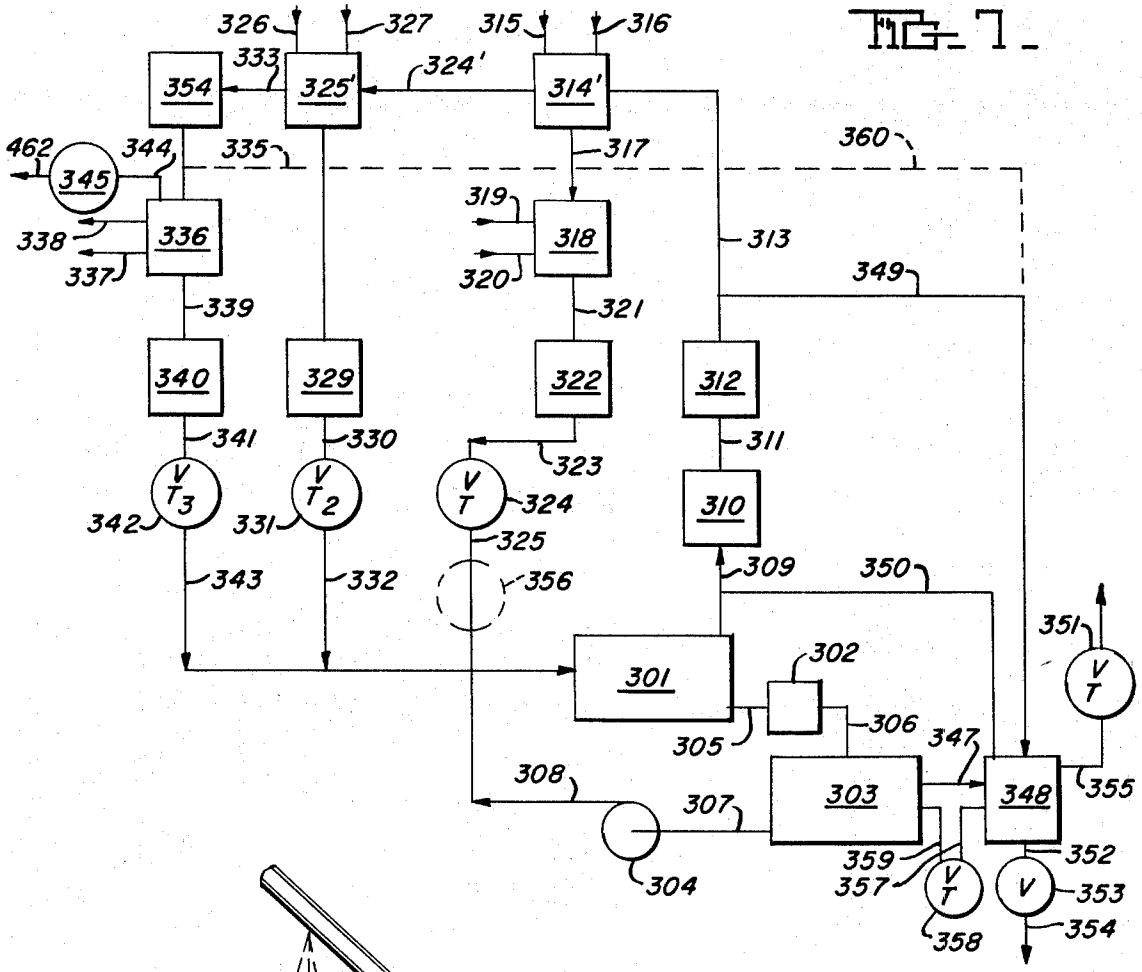
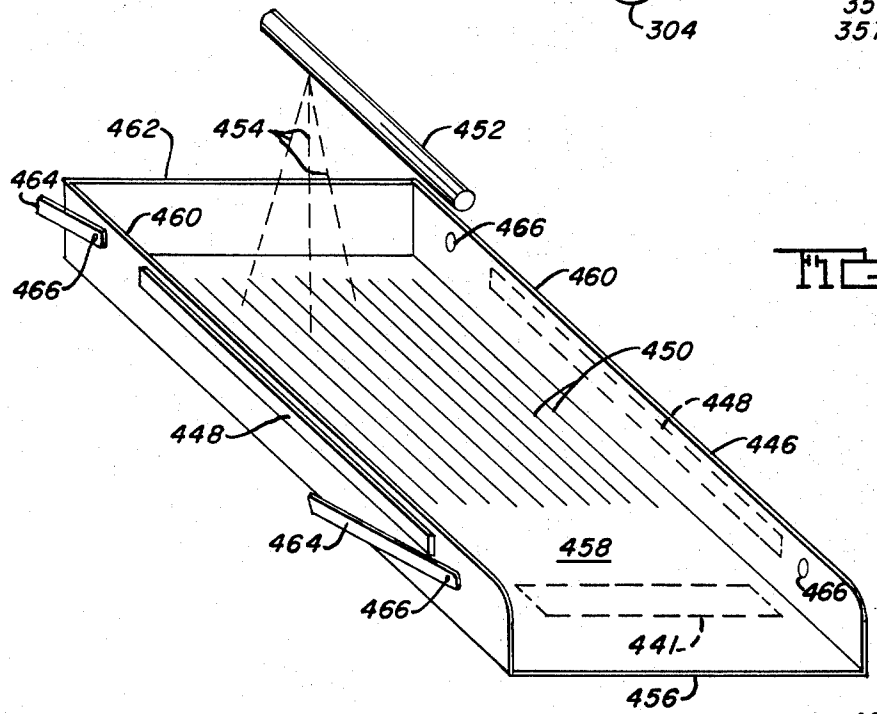


FIG. 9



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DIRECT CONTACT FOOD FREEZER

This application is a continuation of Ser. No. 48,912, now abandoned.

This direct contact freezing device provides for the introduction of surface wetted comestibles from a dewatering conveyor which controls the amount of water introduced into the system, and which is sealed with respect to the surrounding atmosphere, into a relatively high velocity stream of liquid refrigerant traveling at a rate which will provide for separation between the particles while an initial shell of ice is formed around each particle. There may also be overhead sprays in this initial zone which will enhance the quick surface freezing of the particles. Following this zone the comestibles enter a more slowly flowing body of fluid through which they travel at a greatly, reduced speed, and at a considerably increased depth for a time duration sufficient to provide complete freezing of the particles. In this zone also liquid refrigerant may be sprayed over the unconsolidated bed of comestibles to enhance the freezing rate. Motion in this low velocity zone is created by the low velocity flow of the refrigerant stream supporting the bed, but may be enhanced by mechanical devices arranged to provide direction movement of the comestible particles through the freezing zone. At the exit of the main freezing portion of the freezer, the stream depth is reduced; its velocity is increased, and the comestibles are carried to a refrigerant draining conveyor; thence through an exit leading to a sealed packaging zone. The liquid refrigerant from the drain conveyor is returned through a screen, or filter, and a valve to a storage container sufficient to contain all of the refrigerant in the system. Liquid refrigerant is removed from the storage container through another valve; thence to a circulating pump and a flow control valve to the zone of the freezer at which the comestibles are initially introduced. Valves associated with the storage container provide for removal and storage of all refrigerant so that the system may be repaired or cleansed. The storage container is formed of pressure containing material, such that the refrigerant is contained at ambient temperature without leakage. There is thus provided a circulatory direct contact refrigeration system adequate to freeze comestible particles without clumping as well as transportation of the comestibles through the freezer at a controlled rate. Condensation and purification of the refrigerant liquid and gas for this system will be provided as hereinafter described.

FIG. 1 is a schematic representation of the freezing system of this invention; FIG. 2 is a schematic representation of a liquid purifier and air separator constructed according to the principles of this invention;

FIG. 3 is a phase equilibrium chart for CCl_2F_2 and air;

FIG. 4 is an overall schematic layout of a second embodiment of this invention;

FIG. 5 is a schematic representation of plastic lined structural container constructed according to the principles of this invention;

FIG. 6 is a schematic layout of a refrigerant recovery system embodying the container of FIG. 5;

FIG. 7 is schematic representation of a refrigerant circulation, purification and recondensation system for a direct contact food freezer constructed as a fourth embodiment of the principles of this invention;

FIG. 8 is a fragmentary three dimensional view of a channeling food delivery means constructed according to the principles of this invention; and

FIG. 9 is a schematic representation of a food glazing means constructed according to the principles of this invention.

In FIG. 1 there is shown a draining transporting conveyor 1 preferably of the shaking type into which the comestibles such as particles or portions 17 have been deposited by a sealed conveyor system (not shown). Excess water is drained from the comestibles being shaken and transported in this conveyor into a water catch portion 2 through openings in the bottom of the shaking conveyor zone in a well known manner. Water is returned by sealed conventional means from catch portion 2 to the primary conveyor system. The comestibles travel along the shaking conveyor 1 to a discharge point 3 through a relatively sealed opening 4 in an insulated shell 35 surrounding a main freezer body 5. This sealing portion 4 is provided to minimize the entry of water vapor from the conveyor area into the main body of the freezer 5. It is desirable to minimize the entry of water vapor into the freezing compartment since any that enters will later have to be removed in the purifying system. For the same reason, the fall distance 6 from the conveyor to the refrigerant liquid stream 15 is made a practical minimum.

Refrigerant liquid from a storage tank 7 located below the level of the main body 5 flows out through a pipe 8, a pump 10, a control valve 11, an inlet pipe 12 and sealing valve 9 to a flow equalizing chamber 13. At the bottom of the equalizing chamber 13, there is an adjustable horizontal orifice 14 which allows a relatively shallow stream of rapidly flowing refrigerant 15 as shown by arrows 38 to enter the main freezing compartment 5. The equalizing chamber 13 provides an increasing outflow stream velocity through orifice 14 as the level of the fluid in the equalizing chamber increases; thus with an increased fluid flow through the system the level in the chamber increases and a higher velocity stream exists. The outlet orifice 14 may be adjusted in the case of greater changes in flow volume to provide the proper velocity of exiting stream 15. This stream 15 flows down a sloping bottom portion 16 and its velocity can be maintained by inclination of the slope portion 16 with respect to the horizontal high velocity stream 15 across the width of the main freezing body 5 and provides an area into which the comestible particles or portions 17 may fall without touching the sides of the main freezing body 5 or the bottom of the stream channel 16 or each other. In this area 15 liquid refrigerant is sprayed on the particles from a spray manifold 19 to insure complete contact of refrigerant with all of the surface of each particle. This method of treatment and introduction of the comestible particles insures that each particle will be glazed or encased in a protective layer of ice created by the high heat transfer rate between the boiling liquid refrigerant and the wetted particles before they touch anything except the boiling liquid refrigerant. Thus the formation of ice on any portion of the freezer by direct contact is eliminated as is clumping of particles caused by freezing together of a number of particles. After the particles have traveled the length of the sloping high velocity stream 15, they enter the low velocity portion 18 of the main freezer body 5. In this portion the comestibles will travel at a much slower rate and will accumulate to a

height of several inches as they travel across low velocity zone **18** as shown by the arrows **40** in this zone.

Liquid refrigerant spray is introduced through several spray manifolds **19** to provide adequate boiling refrigerant to all of the particles through all portions of the main freezer body **5.** Since the particles **17** were encased by a shell of very cold ice almost from the moment of their introduction there is no clumping of the particles as they proceed through the low velocity zone **18.**

The jets emitted from manifolds **19** may also be located and set directionally to stir the particles or food portions and to provide conveying action as the particles proceed with the flowing refrigerant through any or all portions of the freezer.

To enhance the motion of awkwardly shaped comestible particles such as broccoli, cauliflower or spinach a mechanical conveyor preferably of adjustable speed and any conventional type may be provided. Shown in FIG. **1** is a useful form of such a conveyor. Rake-like elements **20** are attached to a frame **21** which is driven in a circular path by suitably powered, synchronized rotating elements **22** having a pin portion **23** attached to rotating elements **22** associated with bearing portion **24** connected to frame **21,** all portions of the frame and rake assembly travel in an orbital path similar to that traveled by pin **23.** This is illustrated by a bottom point **25** on one of the rakes **20.** The orbit as shown by the arrow **42** for this point has a horizontal component of motion in its bottom portion of travel in the direction in which the comestibles travel through zone **18.** While in the upper portion of its orbit where it is not engaged with the comestibles its horizontal component of motion is in the opposite direction to the flow of comestibles in flow zone **18.** All points on all rakes have a similar orbit. Thus the comestibles can be gently urged through flow zone **18** by a conveyor as well as by the flow of the liquid refrigerant. It is obvious that other conveyor forms can be used.

At the exit from the main low velocity freezing zone **18** the bottom of the freezer is sloped upwardly as shown at **26** to increase the velocity of the outflowing refrigerant stream **27** in order that a thin high velocity flow of comestibles may exit from the main freezer portion **18** to the refrigerant drainage conveyor **28.** This is to provide certainty of comestible outflow. Drainage conveyor **28** has an upward sloped perforated bottom portion so that exit refrigerant will flow out at **29** and the drained comestibles will flow out into a sealed discharge chute **33.** The liquid refrigerant flows through a screen or filter portion **30** into a pipe **31,** through a storage tank sealing valve **32** into the storage tank **7.** Level of the refrigerant liquid as shown at **34** of the storage tank is variable depending on the amount of refrigerant contained in the system and supplies a reservoir from which losses in the system may be made up. At all times however a storage capacity above the level **34** is maintained such that all of the refrigerant in the system may be returned and sealed in the storage container **7** by valves **9, 36** and **32;** thus the system may be emptied for cleaning or maintenance without loss of refrigerant. The gaseous refrigerant formed by a boil off during the freezing process is compressed, condensed, separated from entrained air and other impurities and returned to the circulating system by means hereinafter described and illustrated. It will also be necessary to purify the circulated liquid refrigerant to remove oils and other impurities gathered.

The main body of the freezer **5** is encased in a continuous sealed housing **35** preferably made of metal so that air or water vapor may not enter into the main freezer body **5.**

It is to be understood that while this is a preferred embodiment of this invention and principles proposed by this invention may be equally well practiced in other forms and with other elements.

In the operation of this direct contact food freezer the freezing compartment as a whole is enclosed in housing **35** which is sealed from the outside environment to prevent the loss of refrigerant and the entrance of water or air. The system is preferably operated at one atmosphere of pressure to minimize sealing problems but could be operated at any desired pressure with proper seals. Not shown in FIG. **1** are the seals associated with the inlet of the comestibles fed to shaking conveyor **1** or the outlet sealing arrangements associated with outlet food chute **33.** A refrigerant preferably CCL_2F_2 (R–12) is circulated from storage tank **7** through pipe **8,** pump **10** and pipe **12** to equalizer chamber **13,** out of equalizer chamber **13** through orifice **14** along sloped high velocity flow path **16** into low velocity chamber **18** past upward sloping bottom **26** to high velocity exit stream **27** through the perforated bottom of exit conveyor **28** through filter **30** and pipe **31** back to storage chamber **7.** This refrigerant in flowing through the various velocity portions of the freezer provides the function of a boiling heat transfer source to extract heat from the freezer comestibles, provides a high velocity particle isolating conveying medium for the entering comestible particles at **15,** provides a low velocity transport means in the main freezing area **18** and a high velocity transport means at **27** for the comestibles as they exit the freezer.

The comestibles are dropped a short distance from conveyor **4** into high velocity liquid zone **15.** Conveyor **4** is arranged near the lateral center of the flow path formed by high velocity flow portion **15** so that the comestible particles drop from the conveyor into the liquid without touching the sides of the freezer body **35** or the bottom of the flow path **16.** They are subjected to a continuous spray of refrigerant liquid from manifold **19** in this flow phase so that each particle becomes completely encrusted with a shell of very cold ice near −21° F. in the case of R–12 which boils at −21° F. at 1 atmosphere. While the thickness of the shell is small, nevertheless, it provides a non-sticking surface for each of the particles so that when they leave the high velocity liquid zone **15** and enter the main freezing section, low velocity zone **18,** the particles may be accumulated to a thickness of several inches, in fact, to any practical thickness desired without a tendency for them to clump together as freezing continues.

Since comestible particles are, without exception, lighter than R–12, the particles will float on the surface of the bath in zone **18** with approximately one-third of the bed submerged in refrigerant and two-thirds of the bed supported above the liquid level. Refrigerant is supplied for the elevated portion of the bed by sprays from the manifolds **19;** thus each particle is continuously covered by a layer of boiling refrigerant and the freezing of the particles progresses at a rapid rate.

Directional sprays from manifolds **19** are useful in providing agitation in the high velocity portion of the

channel 5 and aimed sprays in the low velocity zone 18 are useful through the kenetic energy of the sprayed liquid to provide conveying action to the floating particles in the direction of flow in zone 18.

The flow rate in this zone 18 is controlled by adjustment of a regulating valve 11 in the circulating system so that the comestibles will be completely frozen at the time they have reached sloping portion 26 where the stream velocity increases to carry particles out of the freezer to exit conveyor 28. Exit conveyor 28 has a perforated bottom portion which slopes upward toward its discharge end and drains refrigerant from the comestibles for return to the storage chamber 7.

The flow rate through freezer portion 18 has been adjusted in the case of R–12 refrigerant at 1 atmosphere to discharge the comestibles at a temperature below the freezing point of the comestibles but above the boiling point of the refrigerant and there is available heat in the comestible particles with respect to the refrigerant as they reach conveyor 28. This retained heat is sufficient to boil off any refrigerant remaining on the comestibles as surface wetness after draining in conveyor 28; thus the comestible particles when flow rates and temperatures have been adjusted as described exit into discharge chute 33 completely free of liquid refrigerant and at a temperature above that of the boiling refrigerant.

When it is desired to clean or repair the freezing chamber 35 pump 10 is stopped, a drain valve 36, communicating between zone 18 and the storage tank 7, is opened and the fluid refrigerant will drain into tank 7, pipe 12, pump body 10 and pipe 8. At this time valves 9, 36, and 32 are closed. Preferably pump 10 is a hermetically sealed unit as normally used in refrigeration systems with the motor inside the enclosure. Under these circumstances with valves 9, 32 and 36 closed a gas and liquid tight storage system is provided for the refrigerant which may be constructed of materials adequately strong to resist the pressure generated by the refrigerant at ambient temperatures. Thus no auxiliary refrigeration is required to assure long time storage of the refrigerant. With the refrigerant drained from chamber 35 the chamber may be warmed up as desired and opened for maintenance or cleaning without the loss of significant quantities of refrigerant.

Conveyor 21 can be provided if desired to move irregular shaped comestible particles such as broccoli through the zone 18 if because of their interlocking nature they do not move freely as the result of liquid refrigerant flow.

A second embodiment of this invention provides a direct contact food freezer using a low boiling point inert refrigerant condensed by heat transfer to another refrigerant (see FIGS. 2, 3 and 4).

This direct contact freezing device provides for the introduction of surface wetted comestibles from a dewatering conveyor which controls the amount of water thereon and which is sealed with respect to the surrounding atmosphere, into a body of a first refrigerant in which the comestibles are frozen, removal of the comestibles from the body of the first refrigerant by means of a conveyor device which provides drainage of the excess first refrigerant from the comestibles, delivery of the comestibles to a sealable outlet device from which they travel to a sealed container. In the process of freezing the comestibles the first refrigerant is boiled off and is recondensed in a heat exchanger communicating with the condensable first refrigerant gas in the freezing compartment. The first liquid refrigerant condensed by the heat exchanger is returned to the main body of first liquid refrigerant associated with the freezer. A second refrigerant used in the inside of the condenser is preferably a boiling refrigerant and the system is operated as a flooded system with an excess amount of refrigeration available in the heat exchanger from the second refrigerant so that the pressure in the direct contact freezer body may be retained at approximately 1 atmosphere through any variation of comestible throughput that may occur.

The comestibles entering the feeder conveyor are carried in suspension in water through a barometric seal and this water on leaving after the comestibles have been removed also exits through a barometric seal. Comestibles leaving the main body of the freezer are discharged to a chute which leads to a storage container made of an impervious material preferably a plastic bag contained in a transportation compartment such as a wooden box. In order to provide effective sealing the mouth of the plastic bag is attached in gas tight relationship to the discharge chute. The discharge chute is fashioned with a valve near its outlet end which when closed seals the chute and provides a short time storage pocket for comestibles above it so that when the valve is closed, the system remains sealed for the time period during which a filled plastic bag is detached from the discharge chute and an empty one is installed in its place.

The freezing system includes a filter which separates solid materials from the returning circulating refrigerant, a pump to induce circulation of the refrigerant through the freezer, a purifier to remove from the liquid refrigerant dissolved oils and other materials, a gas purifying system to remove from the boiled off refrigerant gas entrained air and other gaseous components.

FIG. 4 shows the inlet flow pipe 101 containing comestible particles or portions in suspension in a stream of water. This suspension passes through a barometric seal shown at 102 disposed vertically a distance adequate to provide a water pressure barrier to either outflow or inflow of gases from the main body 103 of the refrigerator. The flow of water and suspended comestibles is carried through pipe 101 and is discharged on conveyor 104, in a closed compartment 107 the bottom of which has an upward slope to the main body 103 of the refrigerator. The conveyor 104 is preferably of the shaking type; it effectively separates the comestible portions from the carrying water, and conveys the comestibles into the main body of the freezer 103. The water separated from the comestibles by conveyor 104 is discharged through pipe 105 and a barometric seal 106. Barometric seal 106 is effective to prohibit passage of gas into or out of freezer body 103 through the water return system. Compartment 107 is constructed to completely enclose conveyor 104 and seal the area except for the entering stream of water and comestibles, the discharge stream of water and the channel connecting the conveyor 104 with the freezer body 103. The main body of the freezer 103 contains a bath 113 of boiling liquid refrigerant preferably CCL_2F_2 (refrigerant R–12, the assigned name of the refrigeration industry). While this freezer is shown using a pump circulated conveying fluid, the freezer might also be constructed with a moving link belt and sprays for delivering refrigerant liquid to the comestibles.

A discharge conveyor **157** delivers the frozen comestibles to an outlet chute **108.** The outlet chute **108** is constructed with a sealing valve **109** so placed that there is a pocket formed in the chute at **110** when the valve is closed. The valve is closed, when it is desired to remove a filled plastic container **111** and replace it with an empty comestible container. The top of the plastic container is clamped or tied around the chute at **112** to effect a gas seal between the plastic container and the discharge chute; thus no gaseous R–12 may escape during the process of filling the plastic container or bag **111** with the frozen comestibles, nor can outside air or other contaminates leak into the chute **108** to reach the main body of the freezer **103.** During the changing period, the comestibles accumulate in pocket **110,** after the bags are changed, valve **109** is opened allowing the stored comestibles in pocket **110** as well as those being steadily delivered from conveyor **157** to chute **108,** to flow into bag **111,** the system remaining at all times in a sealed condition.

As the comestibles are frozen in liquid bath **113** or by the sprayed refrigerant emitting from manifolds **114,** heat is given up to the direct contact refrigeration fluid which boils vigorously. This refrigerant gas is recondensed on the outside of heat exchanger or cooling coils **115** which are preferably cooled by the circulation of a second lower boiling point refrigerant such as ammonia in the interior of the coil or heat exchanger. This heat exchanger is operated as a flooded system preferably with a circulating pump **116,** pumping excess quantities of liquid ammonia through pipe **117,** heat exchanger **115** and pipe **118** back to level control chamber **119** in which the ammonia level may be controlled by a level control device. Liquid ammonia is supplied to the level control chamber by pipe **120** and evaporated ammonia gas is discharged through pipe **121.** Heat exchanger **115** has a heat transfer capacity greater than that required to refrigerate the maximum amount of comestibles to be delivered in any time period. This available heat transfer capacity together with a continuous supply of liquid ammonia refrigerant pumped from level control chamber **119** insures that the boiled off R–12 from bath **113** and/or sprays **114** can always be condensed and that no excess pressure will build up in the main body of the freezer **103** which might cause leakage through the containing walls **122,** through the barometric seals **102** and **106,** through the plastic container clamping seal **112,** or through the plastic container **111** by reason of rupture.

Pressure control in freezer body **103** may be accomplished by a number of means all correlated to sensed pressure in freezer body **103.**

1. By controlling the flow of R–12 from chamber **103** to heat exchanger **115** by an adjustable opening or resistance in the flow passage between them.

2. By controlling the mass inflow rate of the entering comestibles.

3. By controlling the rate of flow of NH_3 to heat exchanger **115.**

4. By adjusting the pressure of the NH_3 in the heat exchanger **115** and thus the boiling temperature of the NH_3 in the heat exchanger.

A preferred means of controlling pressure in freezer body **103** is to provide a check valve **69** in the inflow ammonia line **120** to prevent outflow of gas or liquid from ammonia level control chamber **119.** A flow control valve **71** is installed in ammonia gas outflow line **59** from chamber **119.** Flow control valve **71** is responsive to pressure sensing means sensing the pressure in freezer body **103.** With a pressure decrease in freezer body **103,** sensor **70** effects a closure of valve **71** at a rate responsive to the rate of and/or the pressure decrease in freezer body **103.** Closure of valve **71** results in an increase in pressure in the ammonia in exchanger **115** at which it boils, quickly increasing the temperature of the boiling liquid NH_3 and reducing the condensation of R–12 thus holding the pressure in freezer body **103** at or near ambient pressure.

In a direct contact freezer for comestibles there will be contamination of the liquid refrigerant. Certain comestibles such as French fried potatoes will carry oil which is miscible with R–12, vegetables such as lima beans will have surface waxes which will be soluable in R–12, other products will contribute other contaminants to the refrigerant R–12 to a degree that the refrigerant must be purified in order to maintain high flavor standards and minimum sedimentation or deposition in the freezer. To effect purification, refrigerant is removed from the body of the refrigerator **103** through exit pipe **123** to filter **124** where solid entrained particles are removed. The refrigerant continues through pipe **56** to pump **125** and pipe **127** back to the body of the refrigerator **103** and also to spray manifolds **114.** A controlled side stream to be further purified is removed from pipe **127** through pipe **126,** through throttling valve **128** and pipe **129** to liquid purifier body **130,** see FIG. **2.** In purifier body **130** this stream of fluid is in heat exchange with a condensing flow of gas inside heat exchanger **147.** The flow of liquid through the throttling valve **128** is adjusted so that all of the fluid entering purifier **130** can be vaporized. The boiled off gas passes out of purifier **130** through pipe **131,** valve **132** and pipe **133** to the main body of the refrigerator **103.** Condensibles remain in the body of purifier **130** and from time to time as required valve **128** is closed and contained R–12 fluid in the main body of purifier **130** is boiled off, valve **132** is then closed and the remaining condensibles in purifier body **130** are drained out through pipe **57,** valve **58** to waste. Cleaning solutions may be introduced through pipe **60** normally closed valve **61** and pipe **62** to flush out remaining contaminants and sediments from the body of purifier **130.**

There will be some contamination by air and water vapor of the gas at the top of the body of the freezer **103,** FIG. **4.** These gases will be principally concentrated in the areas above the R-12 liquifying coils **115** and are best withdrawn at a point located as at **134** above or remote from the freezer **103** with respect to heat exhanger **115.** These gases are conducted through pipe **135** to filter **136** of FIG. **2** where solid foreign materials as well as water crystals are removed. The gas then proceeds through a pipe **137** to the first stage **138** of oil free compressor **151,** pipe **142** to the interstage cooler **139** of compressor **151** where it is cooled in heat exchange with a stream of water entering at **140** and exiting at **141.** The gas leaves the intercooler through pipe **143** entering the oil free compressor stages **144** exiting through pipe **145** to aftercooler **146.** In aftercooler **146** the mixture of R–12 and contaminants, principally air, having been compressed to approximately 400 PSIA by the last stage of compressor **144** is cooled in heat exchange with a stream of water entering through pipe **63** and exiting through pipe **64** and flow control valve **65.** Flow control valve **65** is gov-

erned by level sensor **66** associated with the level **148** of the boiling liquid in purifier **130.** The partially cooled gas from aftercooler **146** exits through pipe **67** and enters the inside of heat exchanger portion **147** located in the body of purifier **130.** In this heat exchanger the condensible gas is liquified and flows out through pipe **68** to separating chamber **149** along with gas that has not been condensed. Liquid direct contact refrigerant is removed from separation chamber **149** in a controlled manner by level control valve **50** and enters pipe **52** for return to the main body of refrigerant in pipe **127** or in refrigerator body **103.** Non-condensible gas is vented from the separating chamber through pipe **53** constant pressure regulator **54** and pipe **55** to atmosphere. The non-condensible gases will consist primarily of air and water. As is seen in FIG. **3** when a mixture of R–12 (CCL_2F_2) and air at **400** PSIA is cooled to approximately −30° F. as would be the case with the mixture of R–12 and air existing in this system and boiling at 1 atmosphere in purifier body **130** as proposed in this freezer the gas remaining at this temperature and pressure would have a content of 13 percent R–12 by weight and 87 percent air by weight. If constant inlet pressure valve **54** is set at 400 PSIA gas can only reach this pressure and exit through valve **54** given adequate heat exchange in heat exchanger **147** at −30° f. when the mixture of air and R–12 is at a concentration of 87 percent air by weight or greater, see 400 PSIA phase equilibrium curve FIG. **3.** The air will carry a small amount of water vapor with it as the air is exited through regulating valve **54** to waste.

In this manner the boiling refrigerant contained in the freezer is purified by filter **124,** by condensing the condensibles in purifier **130** and separating the R–12 from air in the heat exchanger **147** of purifier **130.** Heat transfer in purifier **130** is balanced by control of the fluid level **148** in purifier **130** through appropriate linkage of level control **66** and valve **65** controlling the cooling water flow through aftercooler **146** and control of refrigeration liquid inlet flow by adjustable throttle valve **128.**

In the operation of the direct contact freezer shown in FIGS. **2** and **4** the direct contact refrigerant R–12 (CCL_2F_2) is condensed either in the same chamber as the comestibles of the R–12 or in a chamber directly associated with the freezing chamber. There are a number of simultaneous requirements in direct contact freezing necessary to successful operation of the freezer. As a primary objective the refrigerant bath **113** in freezer body **103** in FIG. **4** must be sealed from the surrounding atmosphere otherwise a substantial loss of refrigerant will be sustained. The refrigerant must be maintained in a pure state in both the gaseous and liquid phases thus the refrigerant must be refined to maintain it in a pure state. The proper temperature must be maintained in the recondensing coils **115** otherwise pressures either above or below ambient pressure will exist in the body of the freezer **103.** In the operation of this invention comestibles are delivered in pipe **101** through barometric seal **102,** which effectively seals the inflow circuit, to conveyor **104** where the major portion of water is removed through the perforated bottom and returned through pipe **105** and barometric seal **106** to the primary comestible conveyor system. Barometric seal **106** operates as an effective seal between chamber and outside ambient conditions. The comestibles are delivered relatively dewatered from conveyor **104** and compartment **107** through relatively restricted opening **73** into the main body of the freezer **103** where they are sprayed with refrigerant from manifolds **114** and/or put in contact with a main body of liquid refrigerant **113** for freezing. After removal from the main body of refrigerant **113** the comestibles are delivered by dewatering conveyor **157** here shown as an uphill vibrating or other mechanical conveyor to chute **108** for exit from the system. Conveyor **157** might also be a stationary gravity conveyor made of longitudinal wires or slates to provide a porous bottom and effect the removal of refrigerant as the comestibles travel on their way to chute **108.** Chute **108** is effectively sealed to a delivery container **111** preferably an impervious plastic bag tieing the plastic bag around chute **108** or clamping it around chute **108.** As a part of chute **108** a sealed valve **109** is provided which may be closed at the time a full container **111** would be removed and replaced by an empty container **111.** When valve **109** is closed a pocket **110** is formed in chute **108** such that the outflowing comestibles from conveyor **109** may be contained at this point for the container changing period. When the new container **111** has been placed and sealed to chute **108,** valve **109** is opened and the comestibles in pocket **110** as well as those in regular process through freezer body **103** are delivered to container **111.** Chute **108,** valve **109,** seal **112** and container **111** thus effectively seal the outlet of the main freezer body **103** with respect to the surrounding air. All systems associated with circulation of liquid refrigerant **113,** purification, recondensation and removal of the air from the vaporized liquid **113** are closed systems within themselves and thus act as effective seals between the main body of the freezer **103** and the outside ambient air.

Overflow refrigerant removed by conveyor **157** is returned through pipe **123** to filter **124** where particles of ice, comestibles of foreign material is removed before the liquid progresses through pipe **56** to sealed pump **125** which delivers the main portion of circulating refrigerant through pipe **127** to the main body of refrigerant **113** in the freezer **103.** A side stream is removed from pipe **127** through pipe **126** of FIG. **2** passing through throttling valve **128,** which controls the amount of refrigerant flowing in the side stream, into the boiler portion of the boiler condenser **130.** Here the side stream is vaporized by warm condensing gas flowing in heat exchanger **147** in such quantity that when the gas is fully condensed all of the refrigerant liquid entering in pipe **129** will have been fully evaporated, contaminants remaining. The boiled off gases pass out through valve **132** and pipe **133** to the main body of the freezer **103** in FIG. **4.** A stream of gas is removed from the main body **103** through intake **134** located remotely from the main body **103** with respect to heat exchanger **115** which continuously reliquifies boiled off refrigerant from liquid body **113** for return to liquid body **113.** At this remote point most of the air and any other non-condensibles which may have leaked into the main body of freezer **103** will be concentrated. This mixture principally air and refrigerant gas is withdrawn through pipe **135** (FIG. **2**) through filter **136,** to remove solids such as ice crystals or comestibles, passes on through **137** to the lower stage **138** of oil free compressor system **151,** pipe **142** and intercooler **139** if required for cooling through pipe **143** to the higher pressure stages **144** of the compressor **151** through pipe

145 to an aftercooler 146 where the compressed gas is put in heat exchange with water or other cooling medium entering through pipe 63 and exiting through pipe 64 and control valve 65. Control valve 65 operates in cooperation with liquid level sensing device 66 to control the flow of coolant to aftercooler 146 so that gas passing from the aftercooler 146 through pipe 67 to heat exchanger 147 will be liquified in heat exchanger 147 of boiler condenser 130 to refrigerant air equilibrium at a temperature approximately that of the boiling liquid refrigerant being maintained at liquid level 148 by this control action. Thus, a mixture, principally remaining air and refrigerant, will be delivered through pipe 68 to separating compartment 149 where purified liquid refrigerant is withdrawn through pipe 52 by control device 50 to provide constant liquid level 51 in the control compartment 149. The remaining gas principally air is discharged through inlet pressure control valve 54 to atmosphere. Regulating valve 54 is set at a pressure level such that the discharged air will contain a minimal amount of refrigerant.

The relationship between the quantities of air and refrigerant in an air refrigerant mixture is shown in the curve of FIG. 3. Curve 75 on this graph shows the relationship of a mixture of air and R–12 gas at a pressure of 400 PSIA (pounds per square inch absolute) and stabilized conditions above a corresponding mixture of air and R–12 liquid. Curve 75 shows the gas side of what is usually shown as a pair of curves. The area above curve 75 consists completely of a gaseous mixture. If a temperature line of 100° F is followed horizontally across the sheet to the intersection with curve 75 it is seen that the per cent by weight of R–12 (CCL_2F_2) in the gas mixture about 60 percent the remaining 40 percent being air. This means that if a mixture of air and gas is present at 100° F and 400 PSIA the mixture at the dew point will be about 60 percent R–12, and 40 percent air. Conversely any vapor boiled off from a liquid mixture of air and R–12 which boils at 100° F and 400 PSIA will be about 60% R-12 and 40% air. For illustration presume that the pressure maintained in heat exchanger 147 by regulating valve 54 working in conjunction with compressor low and high states 138 and 144 respectively is 400 pounds per square inch absolute. The equilibrium point on the 400 PSIA curve at −21° F is point 74 corresponding to mixture of 15 percent R–12 and 85 percent air. If the high stage of the compressor 144 delivers at least 400 PSIA of a mixture of R–12 and air containing more than 14 ½percent R–12, if valve 65 actuated by control device 66 provides proper temperature control of gas entering heat exchanger 147 through pipe 145, if exchanger 147 has enough heat transfer surface, and if the temperature in the liquid inside boiler condenser 130 is −21° F the condition of the gas exiting through pressure regulating valve 54 will be shown at point 74 FIG. 3. Another combination of pressure and temperature would provide equilibrium at another point on a similar curve showing the relationship at the dew point between a refrigerant and air mixture. Curves 76, 78 and 79 respectively show this relationship at 14.7 PSIA, 140 PSIA and 200 PSIA.

A similar control system could be achieved by generally controlling the gas exiting from 146 in FIG. 2 through 67 to heat exchanger 147 in pressure and temperature. Under these conditions given adequate surface area in heat exchanger 147 an interrelation of controls between the meter valve 128 and level control valve 66 would insure that gas exiting through constant pressure regulating valve 54 would fall on or above a chosen point on a curve such as shown in FIG. 3.

In conjunction with the above described process, refrigeration for heat exchanger 147 is furnished by the bath of refrigerant retained in boiler condenser 140 entering through control valve 128. Liquid entering boiler condenser 130 through pipe 129 is continuously vaporized or distilled in boiler condenser 130 and exited through valve 132 to pipe 133 to the main body of the freezer 103, FIG. 4. This process of distillation purifies the refrigerant entering at 129 and results in high boiling point constituents being retained in boiler condenser 130.

From time to time it is necessary to remove the contaminants accumulating in boiler condenser 130. Preferably this is done by closing throttling valves 128 and 65 (FIG. 3). At this time though not essential the exit pipe 55 from pressure regulator valve 54 would best be connected to the body of main freezer 103, FIG. 4, since no separation of air from refrigerant is occurring in 147. With warm gas flowing into 147 through pipe 67 the residual refrigerant in boiler condenser 130 is evaporated, the refrigerant passing as usual through valve 132 to pipe 133 and to the main body of the freezer 103 (FIG. 1). When a desired concentration of impurities has been reached in the body of boiler condenser 130 (FIG. 2), they may be withdrawn to waste through pipe 57 and valve 58. Flushing may be provided if desired through inlet pipe 60, valve 61 and pipe 62. After purging boiler condenser 130, valves 58 and 61 are closed, valves 128 and 65 are reopened and when boiler condenser 130 has again been filled to the level 148 the process will continue as previously described.

The flow of comestibles to the freezer through pipe 101 (FIG. 4) and conveyor 104 under normal conditions is unlikely to be constant and it is desirable to deliver the frozen comestibles into container 111 at a constant temperature. In order to meet this requirement it is necessary to control the refrigeration being delivered by heat exchanger 115. This is particularly desirable since without close control of the refrigeration delivered by heat exchanger 115 there will be a variation in the pressure existing in the main body of freezer 103. A liquid boiling at a given temperature has a fixed vapor pressure over the liquid and an increase in heat introduced to liquid bath 113, by an increased comestible flow, results without a corresponding increase in refrigeration furnished by heat exchanger 115 in increased pressure in the main body of freezer 103. In the case of a decreased flow of comestibles there would be a corresponding requirement for decreased refrigeration in heat exchanger 115 if an under pressure is to be avoided in the main body of freezer 103. Either condition is undesirable as at some point a barometric or other sealing means could be overcome with a resulting flow of air into the main body of the freezer 103 or a flow of refrigerant from the main body of the freezer to outside air. Either case results in loss of refrigerant either directly or through the refrigerant recovery system.

To avoid this undesirable condition a preferred control means is shown in FIG. 4 the refrigerant is supplied in this instance by ammonia entering through check valve 69 and pipe 120 to a constant level reservoir 119.

The refrigerant being circulated from this reservoir through pump **116**, pipe **117**, heat exchanger **115** and pipe **118** back to the reservoir. Evaporated ammonia refrigerant would exit through pipe **118** along with the liquid to reservoir **119** returning to the primary refrigeration system through pipe **59**, throttling valve **71** and pipe **121**. A pressure sensing valve **70** extends through the walls of the main freezer body **122** and communicates to throttling valve **71** and change in the pressure inside freezer body **103**. The control mechanism between **70** and **71** may be any of a number of well-known sensor valve control valve mechanisms. By means of this control system valve **71** is moved toward a closed position when a decrease of pressure is sensed at **70**. As the boiling ammonia gas in heat exchanger **115** has no other means of escape the pressure and the temperature of the boiling liquid in the circulating ammonia system rises and the refrigeration supplied to the main body of freezer **103** by heat exchanger **115** is reduced. Other means of reducing the heat transfer of heat exchanger **115** might be reduction of refrigerant flow through the heat exchanger or restriction of the flow from the main body of the freezer **103** to heat exchanger **115**.

This process has been described in respect to direct contact refrigerant R–12 and primary refrigerant ammonia. It is to be understood that the process will work equally well with other refrigerants. Particular arrangement of details and devices have been described but it is understood that other similar arrangements of equipment are also contemplated.

A third embodiment of this invention provides a means to remove refrigerant from the interstices of comestibles frozen in a direct contact food freezer and stored in a receiving container (see FIGS. **5** and **6**).

This refrigerant removal device, as shown in FIGS. **5** and **6**, provides for the removal of trapped refrigerant in the interstices of comestibles or the like which have been frozen in a direct contact food freezer and deposited in a sealed container for transportation or storage. It is generally true that the volume accounted for by the interstices between comestibles in a container is greater than the volume of comestibles in the container. When comestibles are frozen in a sealed direct contact freezer system, the interstices are completely filed with refrigerant normally in a gaseous form. A typical refrigerant such as CCL_2F_2 (R–12) at a temperature of 0° F has a weight of 0.375 pounds per cubic foot. It is thus advantageous for economic reasons to recover a high proportion of the refrigerant. In this invention a preferred arrangement includes a plastic impervious storage liner inside a structurally competent storage container, the storage liner being adapted for sealing to a discharge chute for a direct contact food freezer. Prior to filling, a tubular member is inserted to the bottom of the plastic storage container and sealed near its exit end and supported above the eventual level of the comestibles in the storage container. Subsequent to the filling of the storage container with comestibles the tube is attached to an evacuating means which removes the dense refrigerant gas from the bottom of the storage container through the tube. Air or other gas less dense than the refrigerant is admitted to the top of the container to replace the refrigerant being removed from the interstices between the comestibles. The refrigerant withdrawn by the evacuating device is delivered for purification and/or recondensation.

Referring to FIG. **5**, **201** is structurally adequate transportation or a storage container having supporting elements **202** adapted to receive the fork means of a motorized lift truck (not shown). Storage container **201** is preferably lined with a plastic bag **203** which is sealed in generally gas tight relationship to a discharge duct **204** forming a gas tight flow path through which comestibles **205** are delivered into the main body of container **206**. Sealing of plastic container **203** to duct **204** is effected by clamping device **207** which might be a rubber band or spring. Prior to attaching plastic bag **205** to discharge **204** flexible tubular means **208** is inserted to the bottom of plastic bag **203** contained in container **201**. The exit portion of tubular member **208** is sealed or clamped by element **209**. Tubular element **208** may be recessed into a cavity **210** of discharge duct **204** such that the end **211** of tubular member **208** projects outside of the plastic container. It would also be practical to support tubular member **208** by an attachment inside duct **204** so that it would be held above the final filling level **212** of the comestibles in the main body of container **203**.

Referring now to FIG. **6** the plastic container **203** has been removed from discharge duct **204**, the end **211** of tubular member **208** has been attached to an evacuating device **213** which could appropriately be a fan. Evacuating device **213** is connected to duct **214** which can deliver gas evacuated by device **213** either directly to the main body of a direct contact freezer **113** (see FIG. **4**) or to a purifying device **215** in which the refrigerant may be separated from the gases delivered by evacuating device **213** through duct **214**. As shown in FIG. **6** when plastic bag **203** is connected to the evacuation device **213**, a relatively small opening **216** is left between the neck of the plastic bag and the tubular member **208** so that when the evacuating device **213** is operated a flow of gas (arrow **217**) may enter the main body of the container **206**.

Purifying device **215** is preferably an activated charcoal purifier having chambers **218** and **219** adapted to alternately receive unpurified refrigerant through duct **214**. Valves **220**, **221**, **222**, **223**, **224** and **225** are adapted to control the flow of refrigerant through the chambers **218** and **219** of purifier **215** alternately in a manner to provide continuous purification of refrigerant flowing in through duct **214** to one chamber of the purifier while the refrigerant is being recovered from the other chamber for return to the direct contact freezer. As an example, refrigerant entering through duct **214** may pass through open valve **221** to chamber **218** for refrigerant collection. Valves **220** and **224** being closed. The contaminating gases of the refrigerant flowing in duct **214** being discharged through valve **223** to exit **226**. Upon reversal of the cycle gases from duct **214** enter chamber **219** through valve **220**, valves **221** and **225** being closed with gases separated from the refrigerant stream being exited through valve **222** to exit **227**. At alternate periods refrigerant retained in chamber **218** after application of appropriate recovery means are discharged through valve **224** to exit **228** for return to the direct contact freezer system. Valves **221**, **223** and **225** being closed. Alternately refrigerant recovered in chamber **219** is returned through valve **225** and exit **228** to the direct contact freezer system; valves **220**, **222** and **224** being closed.

In the operation of this invention plastic container **203** in FIG. **5** is inserted in a collapsed minimal internal

volume condition into structural container **201** and attached to duct **204** by clamping device **207.** Tubular member **208** having been previously inserted into plastic container **203** with discharge end **211** emerging from the opening **229** in plastic container **203.** The collapsed state of plastic bag **203** provides a minimal amount of air in the main body **206** of plastic bag **203** which air passes through opening **230** in discharge duct **204** to the main body of the freezer to which duct **204** is attached in sealing relationship. If an open non-collapsed container **203** is attached to duct **204** a considerable quantity of air will be contained in container **203** which on filling of container **203** will be displaced into duct **204** and thence to the body of the direct contact freezer. The presence of this pollutant air in the direct contact freezer results in either excess purification equipment, loss of refrigerant, or both. Tubular member **208** is retained by clamping inside duct **204** or by passing between duct **204** and plastic bag **203** which is attached in sealing relationship to duct **204** by clamping device **207.** It is necessary that tubular member **208** be thus retained in an accessible position with respect to the opening **229** in plastic bag **203** so that opening **211** of tubular member **203** may be attached to evacuating device **213** as shown in FIG. **6** when it is desired to recover the refrigerant from the interstices between the comestibles. Tubular member **208** is sealed by an appropriate clamping or sealing device **209** so that refrigerant gas entering with the comestibles through duct **230** cannot escape through tubular member **208.** Tubular member **208** when located between plastic bag **203** and discharge duct **204** is preferably recessed into a cavity **210** in duct **204** in order to provide adequate sealing of plastic bag **203** to duct **204** by sealing member **207.**

When plastic bag **203** supported in container **201** is filled to an appropriate level **212,** sealing element **207** is loosened or removed and plastic bag **203** is detached from discharge chute **204.** The end **211** of tubular member **208** is retained on the outside of neck **229** of plastic bag **203.** As shown in FIG. **6** the neck or opening **229** of plastic bag **203** is held in position in proximity to tubular element **208** by an appropriate means. Tube **208** is connected at its end **211** to an evacuation device **213.** Sealing or clamping device **209** is removed from tubular member **208** and when evacuation device **213** is activated a flow of dense refrigerant preferably R–12 is withdrawn from the main body **206** of container **203.** Air or other less dense gas enters opening **229** of the plastic bag **203** in stream indicated by arrow **217** in relatively restricted flow channel **216.** The relatively restricted flow channel **216** and the relatively great difference in density prevents ready defusion of refrigerant to the air being admitted into the main body of the container **206** or between the air and the heavy body of refrigerant gas filling the interstices of the comestibles in the bottom portion of the container and being withdrawn by evacuation device **213.** In normal practice evacuation is continued until the greater portion of refrigerant in main body **206** is withdrawn by evacuation device **213.** The period of operation of evacuation device **213** may be controlled by timing means or by means of an instrument sensing the percentage of refrigerant present and being withdrawn through tubular member **208,** stopping the process of evacuation at a predetermined preferable low percentage of refrigerant versus air or other gas introduced in stream **217.**

The refrigrant collected from the main body **206** of container **203** is discharged through duct **214** either directly to the direct contact freezer refrigerant system or to a purifying device **215.** Purifying device **215** would preferably be a dual chamber activated carbon type. Gas from duct **214** on one half of the cycle entering through valve **220** to activated carbon chamber **219** in which chamber the refrigerant is retained by the activated carbon while the air or other gas present in the mixture entering through duct **214** would be discharged through valve **222** to exit **227.** Valves **221** and **225** being closed at this time. At an appropriate time when the activated carbon in container **219** has approached its capacity with respect to the collection of refrigerant from the stream entering through duct **214;** valves **220** and **222** are closed and valves **221** and **223** are opened so that the stream of entering refrigerant and other gas from duct **214** passes through valve **221** into purifying chamber **218** the refrigerant as before being retained by the activated carbon and the air or gas passing out through valve **223** to discharge **226.** During the period when gases in duct **214** are purified in chamber **218,** the activated carbon in chamber **219** is being reactivated preferably by introducing stream into chamber **218** thereby raising the temperature of the activated carbon in chamber **219,** recondensing the steam to water in condenser **231** while passing the separated refrigerant out through valve **225** and exit **228** to the direct contact freezer refrigeration system; valves **220** and **222** being closed during this process. For increased performance each purifier chamber **218** or **219** may be preconditioned for improved purification action, after it has been purged of refrigerant, by cooling the active contents of the chamber below ambient temperature, preferably to approximately the temperature of the boiling refrigerant in the main body of the direct contact food freezer, with a refrigerating medium such as circulating refrigerated air. When the cycle is again reversed the purging process described for purifier chamber **219** is repeated in purifier chamber **218;** valves **221, 223** and **225** being closed and valve **224** open. Steam condensation occurring in condenser **232.** It is to be understood that other forms of purifiers may be used in place of the activated carbon purifier described.

The refrigerant air mixture in duct **214** will be essentially pure refrigerant at the beginning of the operation of evacuation device **213** and after some period of operation of evacuation device **213,** a decrease in refrigeration purity will be experienced due to mixing of air entering through flow channel **216** with the remaining refrigerant in main body **206** of container **203.** If it is desired, duct **228** may be connected directly with the refrigeration system of the direct contact food freezer during the first portion of this evacuation cycle or during the total portion of the evacuation cycle in which case purification of the evacuated refrigerant air mixture will be performed by the purification apparatus associated with the direct contact freezer.

In this preferred embodiment one form of container, evacuator system, and purifier have been described, it is understood that the intent of this invention may be practiced with variations in the form of container, evacuator, or purification system.

A fourth embodiment of this invention provides a food freezing device (see FIG. 7) using a low boiling point, inert refrigerant for the direct contact freezing of comestibles.

This direct contact food freezing device provides for the introduction of comestibles through an entrance which is sealed with respect to the surrounding atmosphere into a body of refrigerant in which the comestibles are frozen, removal of the comestibles from the body of the refrigerant and delivering them through a gas tight flow channel to a storage container. Refrigeration for freezing the comestibles is provided by a direct contact refrigerant such as CCL_2F_2 (R–12). This refrigerant is purified as a liquid to remove soluble oils and other impurities from the refrigerant and it is purified as a gas to remove gaseous contaminants principally air from the refrigerant. As the refrigerant is evaporated in the sealed direct contact freezer compartment, it is evacuated by a compressor through an intake filter and compressed. The compressed refrigerant gas is circulated to a water cooled condenser where a major portion of the refrigerant is condensed. This condensed portion of refrigerant may be further cooled as a liquid to cause solidification of crystals of dissolved liquid components principally water. The liquid is then returned through a reducing valve to the liquid circulating system of the food freezer. A noncondensed stream of gas from the first cooler or condenser is passed through a further cooler in heat exchange with refrigerant R–12 boiling near atmospheric pressure or below where an additional quantity of refrigerant is condensed, filtered and returned through a reducing valve to the circulating system of the direct contact freezer. A stream of noncondensed gas from the refrigerant cooled condenser is further compressed and subsequently cooled in a heat exchanger cooled by R–12 at near or below atmospheric pressures to provide a final condensation of refrigerant. Unwanted gaseous contaminants principally air are discharged into a throttling valve and the refrigerant is returned through a filter and reducing valve to the refrigerant circulating system of the direct contact food freezer. The refrigerant used to freeze the food in the direct contact freezer is thus purged of its impurities and reliquified for continued use as a food freezant.

In FIG. 7 reference numeral **301** indicates the body of the freezer in which comestibles are frozen by direct contact with the refrigerant preferably CCL_2F_2 (R–12). Liquid is circulated through this freezer being withdrawn through pipe **305** to filter **302**, through pipe **306**, to a storage compartment **303** through pipe **307** to pump **304** which returns the refrigerant through pipe **308** to the main body of the food freezer **301**. The evaporated gaseous refrigerant being produced as a result of freezing comestibles in freezer **301** exits through pipe **309**, through filter **310** and pipe **311** to oil free compressor **312**. After compression in ocmpressor **312** to a desired level, the refrigerant progresses through pipe **313** to water or air cooled heat exchanger **314**. Water entering said heat exchanger through pipe **315** and exiting through pipe **316**. A major portion of the refrigerant is condensed in this heat exchanger and returns through pipes **317** to heat exchanger **318** where it may be supercooled in heat exchange with a refrigerant such as R–12 boiling near or below atmospheric pressure whereby the condensed liquid is cooled to a temperature approximately equal to or less than the temperature of the liquid refrigerant in food freezer **301**. Liquid refrigerant enters heat exchanger **318** through pipe **319** and exits through pipe **329**. The supercooled liquid then flows through pipe **321** to filter **322** where crystalized foreign materials principally water are removed before the refrigerant flows into pipe **323** to pressure reducing valve or valves **324**. In usual refrigeration systems a pressure reducing valve such as **324** reduces the temperature and pressure directly from that at the discharge of heat exchanger **314** to that in the body of the food freezer **301**. This reduction in temperature may result in crystalization of water in the reducing valve causing erratic operation. The above described supercooling arrangements for the refrigerant liquid before pressure reduction eliminates this possibility. After pressure reduction in throttling valve **324**, liquid refrigerant flows through pipes **325** and **308** to main body of freezer **301**.

A stream of noncondensed gases is passed from heat exchanger **314** through pipe **324'** to heat exchanger **325'**. In heat exchanger **325'** the noncondensed gas is placed in heat exchange with R–12 entering through pipe **326** and exiting through **327** at a pressure near or below atmosphere such that the noncondensed gases entering at **324** are stripped of condensibles to a temperature equal to or below that of the liquid refrigerant in the main body of the food freezer **301**. The condensed liquids primarily R–12 pass through pipe **328** to filter **329** where crystalized or solidified materials such as water are removed thence through pipe **330** to expansion valve **331** where the pressure of the liquid is reduced, the liquid being returned through pipe **332** and pipe **308** to the main body of the freezer **301**.

An uncondensed flow of gas including refrigerant and contaminants principally air exits from heat exchanger **325** through pipe **333** to oil free compressor **334** where the gas is compressed to a considerably higher pressure. After compression the gas passes through pipe **335** to heat exchanger **336** where the contaminated high pressure gas is placed in heat exchange with R–12 entering through pipe **337** and exiting through pipe **338** at approximately atmospheric pressure or below which cools the uncondensed gases to a temperature approximately equal that of the liquid refrigerant in the main body of freezer **301** or below. R–12 is liquified in heat exchanger **336**, exits through pipe **339** to filter **340** through pipe **341**, through pressure reducing valve **342**, to pipe **343** and pipe **308** to the main body of the freezer **301**. A stream of noncondensed gas principally air is exited from the top of heat exchanger **336** through pipe **344** to inlet pressure control valve **345** to exit pipe **346** either to atmosphere or to an additional purification device for removal of the small amount of R–12 still contained in this exit gas.

A stream of liquid refrigerant is removed from storage reservoir **303** through pipe **347** to boiler condenser **348** where it is placed in heat exchange with a stream of gaseous refrigerant flowing through pipe **313** and pipe **349**. In the boiler condenser **348** the liquid is evaporated for purification and returned to the main refrigeration system through pipe **350**, the impurities being retained in the boiler and eventually being discharged through pipe **352**, valve **353** to exit **354**. The gaseous refrigerant entering through pipe **349** is condensed in boiler condenser **348**; noncondensibles exiting through pipe **350** and control valve **351**. Condensed gaseous refrigerant entering boiler condenser **348** through **349** is

returned through pipe **357**, throttling valve **358** and pipe **359** to refrigerant storage container **303**.

A preferred embodiment of this invention has been described, but it is understood that other similar arrangements can be used for purifying and recondensing the refrigerant. One alternate system includes the elimination of heat exchanger **318** and providing an additional refrigerant throttling valve **356** in line **325**. This provides two levels of temperature and pressure in the refrigerant since it is not supercooled by heat exchanger **318**, a quantity of liquid refrigerant will flash in each of the throttling valves to provide the refrigeration necessary to cool the discharged liquid to a temperature corresponding to the pressure existing at the discharge of the throttling valve. The flash gas present between the expansion valves **324** and **356** might be returned interstage to compressor **312** thereby reducing somewhat the work required for compression.

In the operation of this invention unfrozen comestibles are introduced through a sealing means to the main body of the sealed freezer **301** in which it is frozen and exited to storage. Freezing is effected in the main body of the freezer by direct contact with a stream and/or sprays of liquid refrigerant. The comestibles are frozen and an amount of heat is transferred from the comestibles to the refrigerant causing evaporation of the refrigerant. In addition certain substances such as surface oils or cooking oils are dissolved by the liquid refrigerant and circulated with it. The gaseous refrigerant in the freezer becomes contaminated primarily by air which leaks past the seals, is carried by the incoming product or leaks in through inadvertent openings in the casing of the food freezer **301**. To provide a satisfactory continuous operation of such a freezer, these contaminants must be removed and the gasified refrigerant must be reliquified for return to the circulating main body of refrigerant in freezer **301**. The evaporated gas removed from the main body of the freezer **301** exits through pipe **309** and carries with it a small amount of food material as well as some ice crystals formed as a result of the entrance of water vapor into the body **301** of the freezer, associated with the entering comestibles or the air inadvertently leaking into the freezer. These food particles and ice crystals are removed in filter **310**. The gas remaining passes through pipe **311** to oil free compressor **312** where it is compressed, passing through pipe **312** to heat exchanger **314** which is cooled by water on the opposite side of the heat exchanger surface with respect to the gas stream. A major portion of the refrigerant is condensed in this heat exchanger and returns through pipe **317** to heat exchanger **318** where it is cooled to a temperature approximately that of or below the temperature of the liquid refrigerant in the food freezer **301**. When the condensed liquid refrigerant is supercooled with respect to its existing pressure and temperature, dissolved water insoluble at that temperature is converted to particles of ice which pass through pipe **321** to filter **322** where they are removed along with any other solid particles which might be contained in the liquid at that point. The filter liquid refrigerant passes through pipe **323**, pressure reducing valve **324** where it is reduced in pressure, but not in temperature, to at least the pressure and temperature of liquid in freezer **301**. By this process there is no formation of ice cyrstals in the throttling valve **324** thus it is not plugged or affected by a deposit of ice which would occur if the pressure reduced liquid were not supercooled prior to the valve. A noncondensed stream of gas containing refrigerant and air exits from heat exchanger **314** through pipe **324** to an additional heat exchanger **325** where it is cooled in a heat exchange with R–12 refrigerant at approximately or below atmospheric pressure. This reduces the temperature of the gas entering through pipe **324** and an additional quantity of refrigerant is condensed exiting through pipe **328** in a supercooled condition with respect to its pressure. It is filtered in filter **329** to remove crystalized particles of water or other solids, exited through pipe **330** to pressure reducing valve **331** for return to the freezer **301** through pipes **332** and **308**. As before the supercooling of the liquid refrigerant in heat exchanger **325** and the filtering of the liquid refrigerant in filter **325** prevents the formation of solids in control valve **331** thus insuring reliable operation. A stream of gas containing considerable R–12 is uncondensible at the pressure and temperature of heat exchanger **325** and passes out through pipe **333** to oil free compressor **354** where it is additionally compressed. Exiting through pipe **335** it is cooled in heat exchanger **336** approximately to or below the temperature of the liquid refrigerant in the body of freezer **301**. The liquid refrigerant exiting through pipe **339** is supercooled with respect to its pressure and may contain particles or other solid material which is filtered out by filter **340**. The fluid being passed through pipe **341** to pressure control valve **342** is exited through pipe **343** to freezer body **301**. A stream of gas noncondensible at the pressure and temperature in heat exchanger **336** is removed from the top portion of the heat exchanger **336** through pipe **344** and discharged through inlet pressure controlling valve **345** and exit **346** either to atmosphere or to a purification device where additional R–12 may be removed for return to freezer **301**.

In order to purify the liquid refrigerant in freezer which may have picked up oils or the like a stream removed through pipe **305** filtered through filter **302** passes through pipe **306** to storage container **303** and is removed through pipe **347** to a boiler condenser **348** where it is evaporated in heat exchange with a stream of warm gas entering through pipe **349** which is condensed while evaporating the liquid entering through pipe **347**. The non-evaporated liquid impurities entering through pipe **347** are withdrawn from time to time through pipe **352** and valve **353** to exit **354** while any non-condensed gases entering boiler condenser **348** through pipe **349** are exited through pipe **355** and pressure control valve **351**. Liquids condensed in boiler condenser **348** from entering gas stream **349** are returned through pipe **357**, throttling valve **358** and pipe **359** to the refrigerant storage tank **303**.

An alternate arrangement is to pass the gases exiting from compressor **334** through dot and dash line circuit **360** to pipe **349** instead of having gases from pipe **349** picked up from pipe **313**. In this case the boiler condenser combination **348** would provide the function of heat exchanger **336**, throttling valve **342** and pressure control valve **345**.

In FIG. **8** is shown a conveyor **461** adapted to carry liquids or a flowable mixture of liquids and solids. The conveyor formed by bottom portion **467** and side portions **470** has formed in the bottom channelizing paths **463** beginning in the relatively smooth portion **467** at points **465**. The conveyor may be operated as a stationary device, or to enhance the formation of discrete

food portions the conveyor may be pulsated or vibrated as by arms **468** attached to the conveyor **461** by pins **469.** Arms **468** may be driven in a pulsating manner by conventional mechanical, hydraulic or magnetic vibrating means.

Referring to FIG. **8** conveyor **461** is adapted to carry solid foods associated with liquid such as fruits in syrup, solid foods in their own juices or liquid foods such as soups or juices such foods herein described as flowable foods. All of these foods may be frozen in individual separate pieces by discharging them in relatively small streams into contact with flow R–12 or by spraying them with R–12 refrigerant as they fall from a channelizing element such as shown in FIG. **8.** Various other configurations or channelizing such as dividing a single pipe into mulitple pipes may also be used; the essential point being that the flowable foods must be delivered in relatively small streams such that surface tension will break up the streams into discrete portions. The flowable foods introduced into the bottom of conveyor **461** are broken up in this manner by channels **463** beginning at the points **465** in the bottom **467** of the food conveying duct **461.** The duct or conveyor may be open or closed at the top and may have an inclination suitable for forming the flowable food materials into discrete streams; a steep slope may be required for more viscous fluid conglomerates.

In order to promote the formation of discrete liquid portions of flowable foods it is desirable to create a pulsing flow. In FIG. **8** conveyor **460** may be pulsed through arms through arms **468** acting through pins **469.** Other methods of pulsating may also be used including flow interrupting means in conveyor **460** and flow variation means in the channel feeding liquid to the conveyor **460.**

FIG. **9** is a schematic drawing of a direct contact food glazing system. Conveyor **446** is formed by bottom portions **458** and side Portions **460** and **462.** Frozen food pieces from the earlier described direct contact freezer are fed through chute **33** of FIG. **1** into conveyor **446,** FIG. **9,** where they are transported to discharge edge **456** by oscillations supplied through support oscillating arms **464** connected to the conveyor through pins **466.** Longitudinal slots **450** are formed in the conveyor bottom **458** of a width to retain passing food pieces but to pass glazing water sprayed from manifold **452** to contact food carried by conveyor **446.** Heating element **447** and **448** are energized by electrical means (not shown) or by flowing warm fluids and are adpated to maintainer conveyor **446** at just over 32° F so that no ice will be formed on the conveyor **446.** Water sprayed from manifold **452** also is maintained at a temperature just over 32° F. In order that no excess heat may be transferred to the food pieces normally arriving at the conveyor at a temperature of 0° F, and forms an ice layer on the food pieces as a result of the heat extracted from the 32° F water by the lower temperature 0° F food pieces.

In operation of the apparatus of FIG. **9** frozen food pieces are retained inside the conveyor **446** by bottom portions **458,** side portions **460** and back portions **462.** Frozen food pieces delivered to this conveyor, resting above the slots **450,** are sprayed by water **454** being projected from spray manifold **452.** The water sprayed over the food from manifold **452** is maintained at a temperature very close to but just above **32°F** so that it will transfer a minimum amount of heat to the frozen food pieces being carried by conveyor **446.** The food pieces delivered to **446** would normally be at a temperature of approximately 0° F; consequently, when they contact water at about 32° F, a film of ice is formed on the exterior of the food pieces. This is highly desirable in cases where a water seal preventing dehydration and deterioration of food pieces is desired or in cases where the liquid surrounding a food piece contains a solution of liquids and solvents such as a sugar syrup or in fruit juice containing sugars and other material in solution with water. In such cases differential freezing occurs, the first frozen crystals being essentially pure water and the final ice formed carrying a higher content of sugar or other materials in solution in the water. The resulting outside ice formed freezes at a much lower temperature than water and in some instances may retain a sticky characteristic which would cause the food pieces to agglomerate when stored. By encasing the final frozen pieces in a shell of ice, as hereinabove set forth a non-sticking surface can be created which will provide for good storage characteristics with no adhesion or freezing between food pieces during storage at the normal storage temperatures of around 0° F. In order to prevent ice buildup on the conveyor **446,** side heating elements **448** and bottom heating elements **447** make contact with the conveyor. These heating elements may be electric resistance devices or they may be circulated fluid devices connected to a source of heated liquid of appropriate flexible tubing (not shown). Conveyor **446** is carried and oscillated by arms **464** attached to conveyor **446** by pins **466.** These arms are activated by conventional pneumatic, hydraulic electrical or mechanical vibrating devices to provide a constant vigorous motion of conveyor **446.** This motion providing a vigorous agitiation of food pieces being carried by conveyor **446** such that the food pieces are only momentarily in contact with each other, thus preventing the food pieces from freezing together. Excess water flows out of conveyor **446** through longitudinal slots **450** in the conveyor bottom **458.** These slots are sufficiently narrow to retain the food, but allow the excess water delivered from spray manifold **452** to be drained away from the conveyor for recirculation.

What is claimed is:

1. A method of freezing food portions in a direct contact food freezer comprising the steps of introducing said food portions into a freezing compartment, contacting said food portions with a boiling liquid refrigerant, having a boiling point at 1 atmosphere higher than −50° F. to freeze said food portions, discharging said food portions from said freezer, receiving said food portions in a substantially impervious container and recovering the gaseous refrigerant from said container to said food freezer, said container being in releasable sealed relationship with said food freezer.

2. The method of direct contact food freezing as specified in claim **1** in which the said receiving container is a substantially impervious pliable container.

3. The method of direct contact food freezing as specified in claim **1** in which the said container has a smaller internal volume when containing no food portions than when at least partially filled with food portions.

4. The method as specified in claim **1** including the additional step of returning said recovered gaseous refrigerant to said freezer.

5. The method as sepcified in claim 1 including the additional step of purifying said recovered gaseous refrigerant subsequent to said recovering.

6. The method as specified in claim 1 wherein said recovering of said gaseous refrigerant is by withdrawing the gaseous refrigerant from said container at a location below the horizontal centerline of said container.

7. The method as specified in claim 6 including the additional step of admitting to said container at a location above said horizontal centerline a gas having a lesser density than said gaseous refrigeration, while simultaneously withdrawing said gaseous refrigerant.

8. The method as specified in claim 11 wherein said discharging is into a substantially impervious sealed food storage zone and including the additional step of recovering excess gaseous refrigerant from said storage zone.

9. The method as specified in claim 8 wherein said recovering of said excess gaseous refrigerant is by withdrawing said excess gaseous refrigerant from said storage zone al a location below the horizontal centerline of said container while simultaneously admitting to said storage zone at a location above said horizontal centerline a gas having a lesser density than said excess gaseous refrigerant.

10. The method as specified in claim 8 including the additional step of purifying the excess gaseous refrigerant subsequent to said recovering.

11. A method of freezing food in a direct contact food freezer comprising the steps off: introducing said food into a freezing compartment by hydraulic sealing means including a liquid barometric seal; subsequent to said introducing contacting said food with a liquid refrigerant having a boiling point at one atmosphere higher than −50° F to freeze said food; simultaneously with said introducing and said contacting maintaining a separation between said liquid refrigerant and said hydraulic sealing means; and discharging said food from said freezing compartment through an exit adapted to seal at least a major portion of the gasified refrigerant within said food freezer.

12. A method of freezing food in a direct contact food freezer specified in claim 11 in which the said food includes food portions in liquid; the said hydraulic sealing means includes a conveying liquid in an enclosed flow path and including the additional step of removing said conveying liquid from said direct contact food freezer through a second barometric seal.

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