United States Patent [19]

Harrison

[11] **3,866,432**

[45] **Feb. 18, 1975**

[54] **HELICAL CONVEYOR HEAT EXCHANGE SYSTEM**

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[73] Assignee: **Cryo-Chem, Inc.**, Gardena, Calif.

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[21] Appl. No.: **345,990**

[52] **U.S. Cl.** **62/208**, 62/375, 62/381

[51] **Int. Cl.** **F25b 41/00**

[58] **Field of Search** 62/381, 374, 375, 376, 62/380, 63, 208

[56] **References Cited**

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3,412,573	11/1968	Pauliukonis	62/374
3,609,987	10/1971	Waldin	62/63
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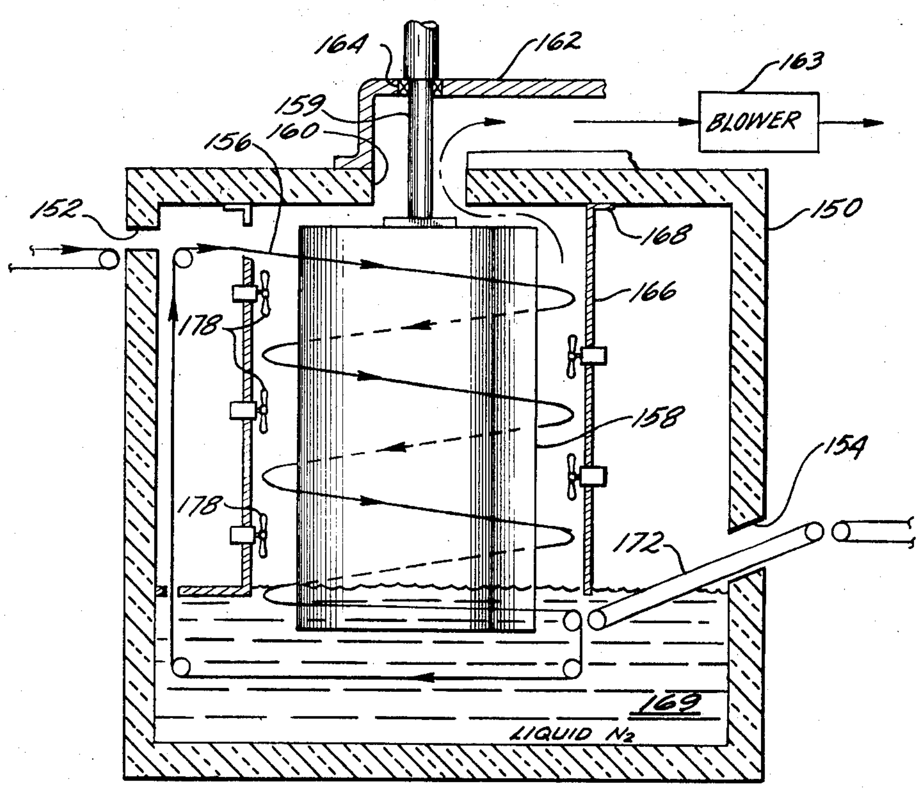
Assistant Examiner—Ronald C. Capossela
Attorney, Agent, or Firm—Christie, Parker & Hale

[57] **ABSTRACT**

Food is frozen in a high temperature gradient environment by moving the food along a helical conveyor countercurrently to a fan-driven stream of cold nitrogen gas produced by contacting liquid nitrogen with the food near the discharge end of the conveyor. The food at the discharge end of the conveyor is subjected to about −320° F, the boiling point of nitrogen at atmospheric pressure. Before leaving the freezer, the nitrogen gas is warmed substantially above that temperature by contact with the food on the helical conveyor.

10 Claims, 4 Drawing Figures



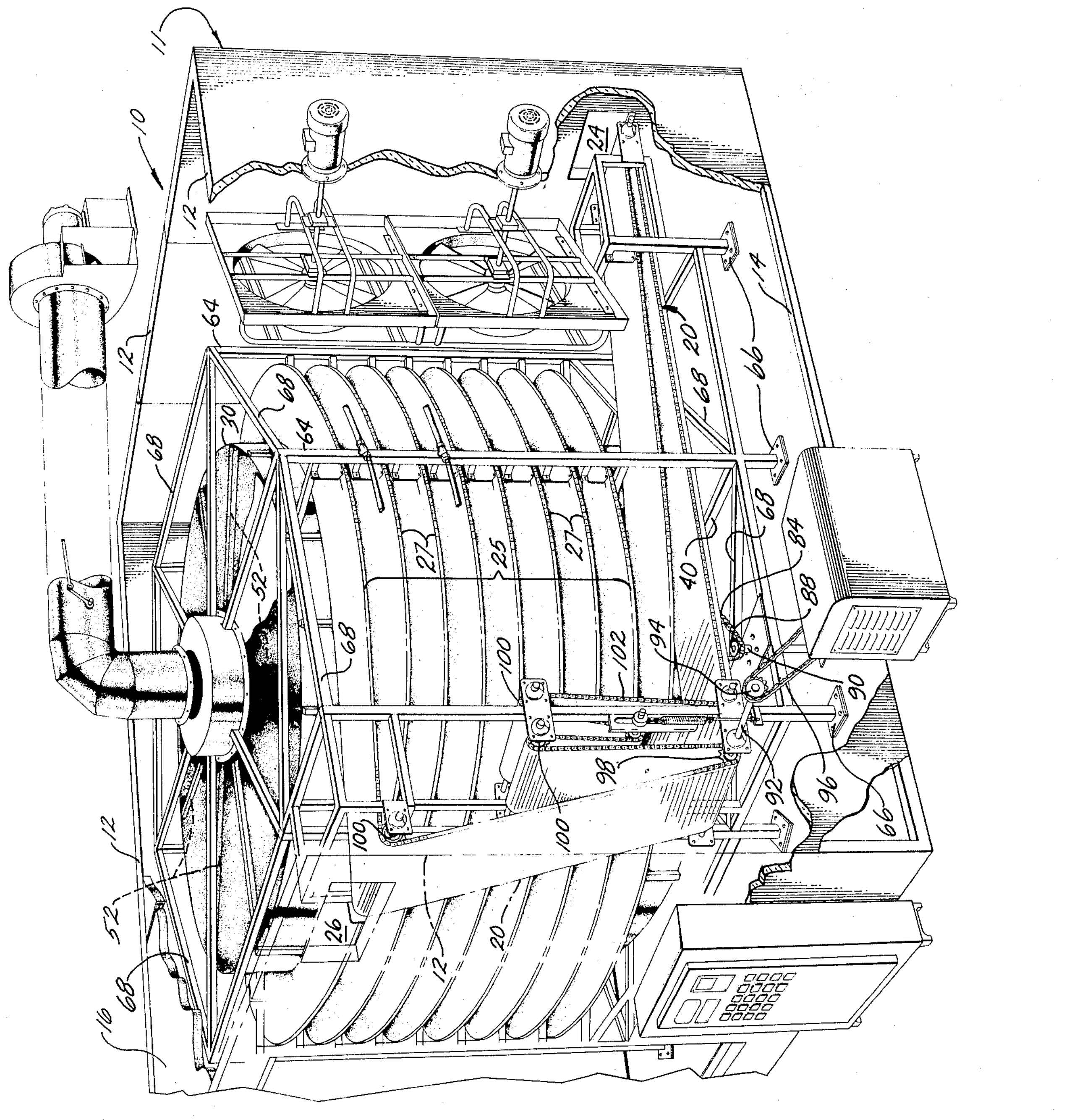

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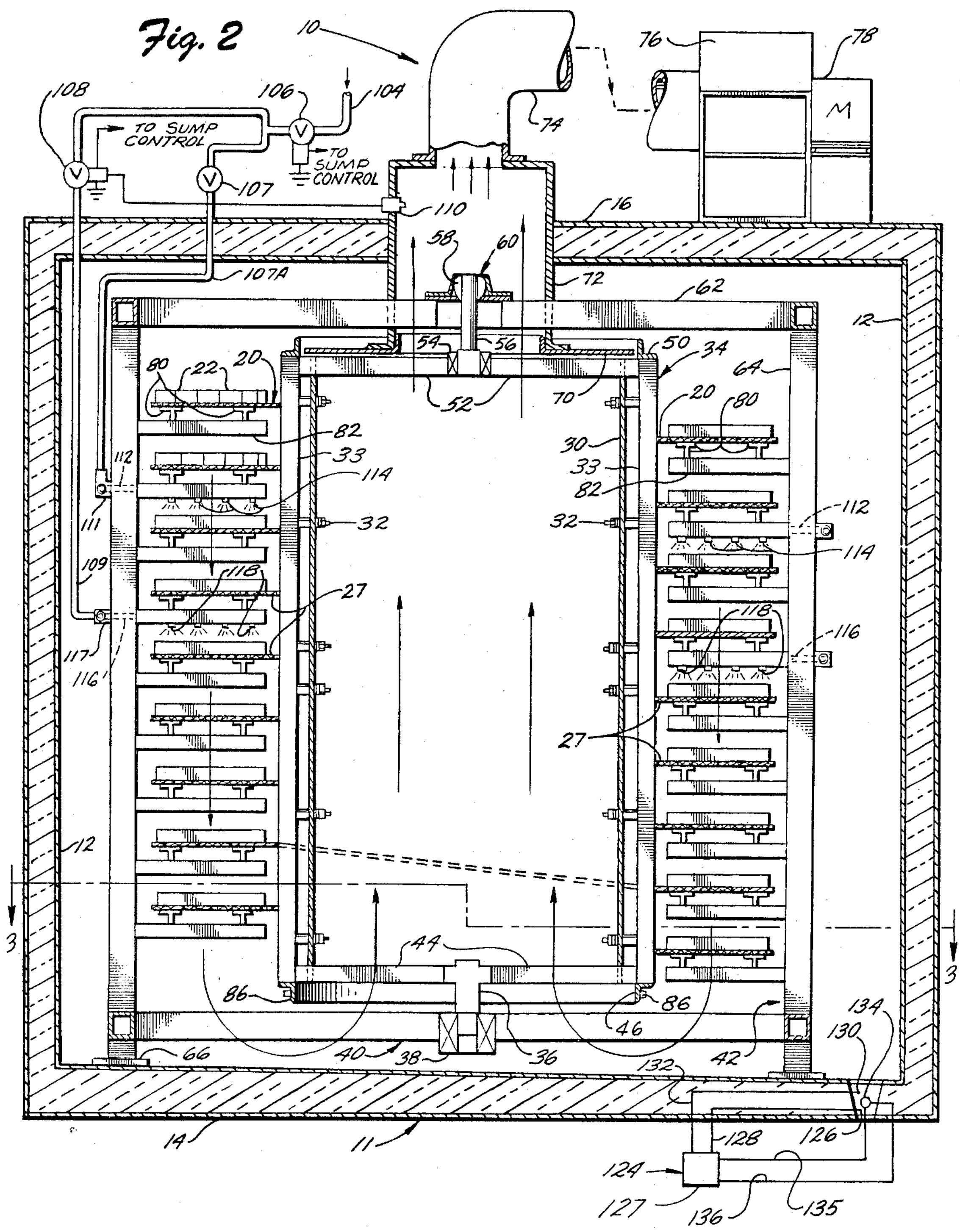
Fig. 1

Fig. 2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TO SUMP CONTROL
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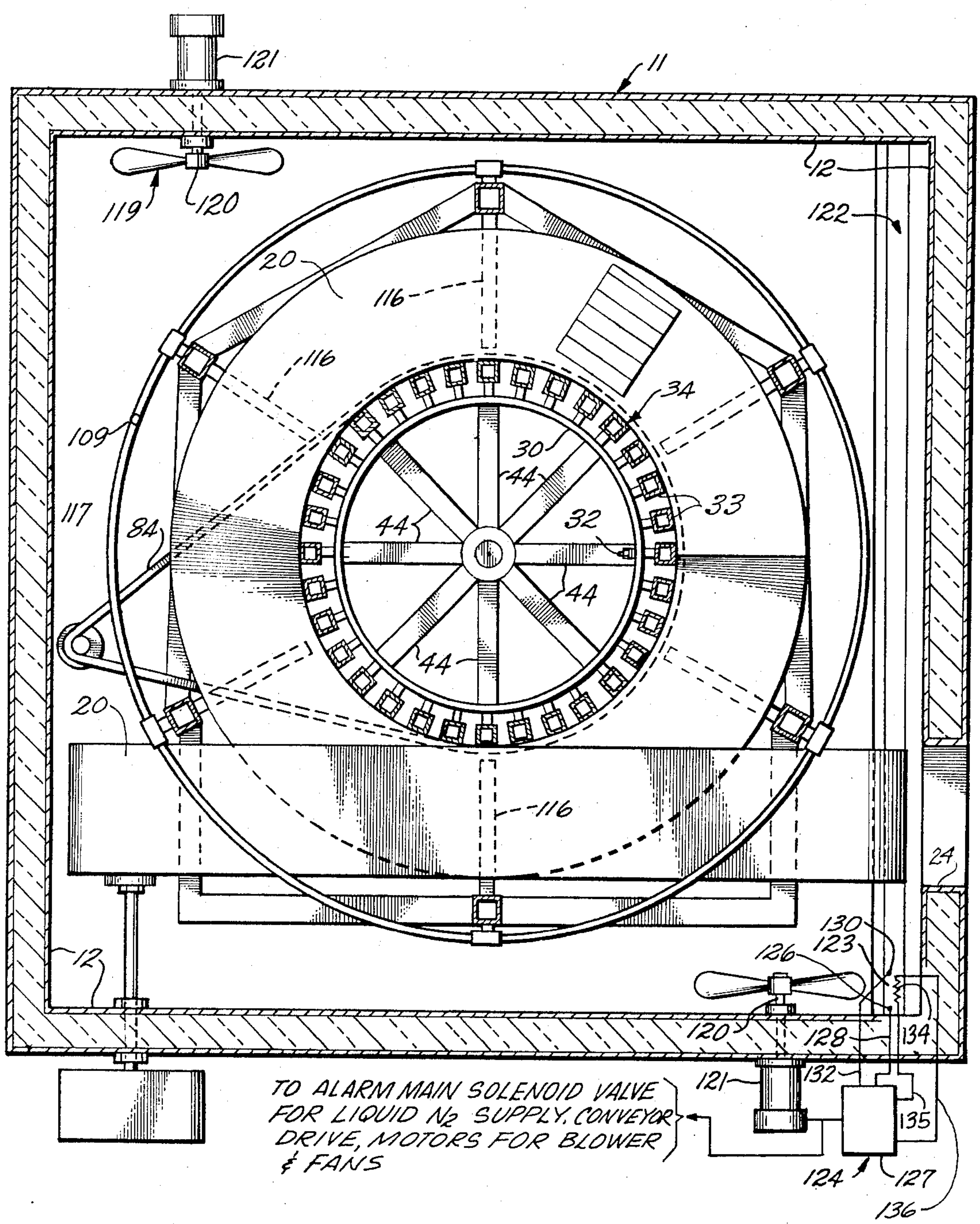
Fig. 3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117
84
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116
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130
123
126
12
120
128
134
121
132
135
TO ALARM MAIN SOLENOID VALVE FOR LIQUID N_2 SUPPLY, CONVEYOR DRIVE, MOTORS FOR BLOWER & FANS
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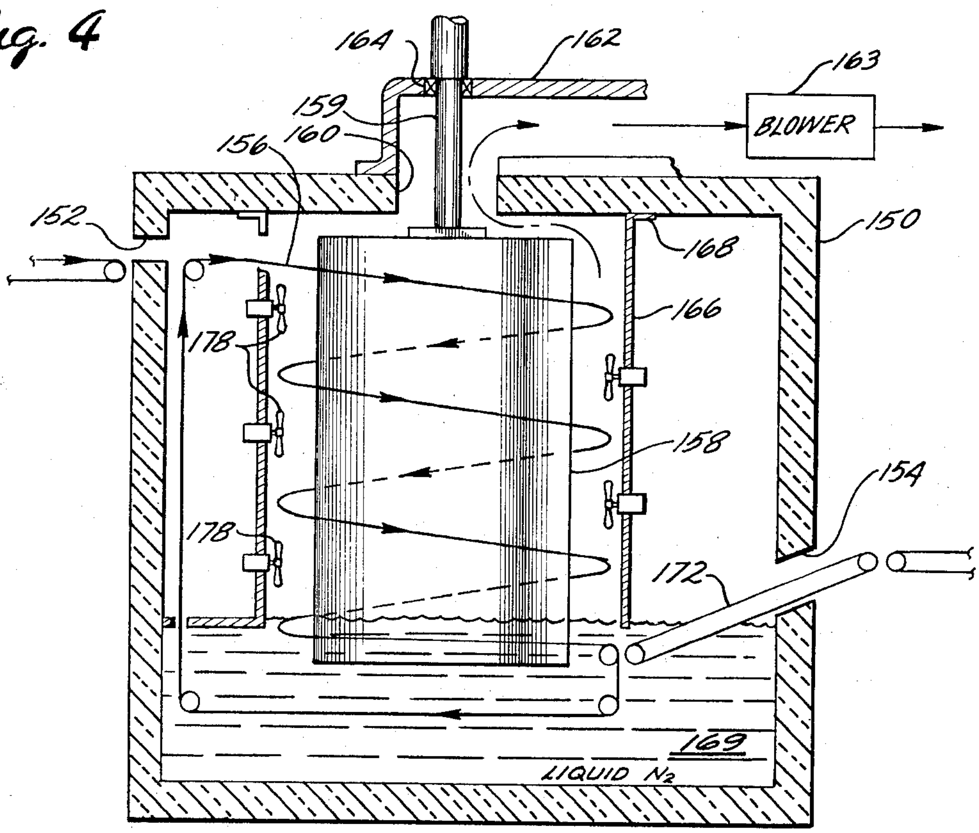
127
136

Fig. 4


16A
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BLOWER
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152
150
168
166
178
158
15A
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172
169
LIQUID N2

HELICAL CONVEYOR HEAT EXCHANGE SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an endless helical conveyor belt heat exchanger system, and more particularly to such systems using a cooling fluid in two phases, e.g., liquid and gaseous nitrogen.

2. State of the Prior Art

The use of a helical conveyor system in food freezing applications is a well established practice as shown in U.S. Pat. No. 3,348,659. The use of liquid nitrogen in a helical conveyor system is shown in U.S. Pat. No. 3,412,573.

It is apparent that the lower the temperature of the cooling medium within a freezer, the higher the rate of heat transfer from the product, the shorter the transit time through the freezer to achieve the required cooling, and the higher the productivity of the equipment, as expressed in pounds per hour of product throughput. It is also apparent that to maintain the pressure within the freezer at essentially atmospheric, which is presently required for practical commercial operation, the cooling medium must be removed from the enclosure at the same rate it is introduced. At the present time, there are three principal refrigeration systems used in commercial freezers. They are:

1. "Air blast" freezer system, using closed cycle mechanical refrigeration;
2. Carbon dioxide open cycle refrigeration; and
3. Liquid nitrogen open cycle refrigeration.

In an air blast freezer, the refrigerant, which is chilled by conventional closed-cycle mechanical equipment, is circulated through an evaporative coil located within the insulated enclosure or freezer box. Air is drawn through ducts and directed by fans across the evaporator coils, and chilled to the desired temperature, usually about −40° F. The cold air is then circulated past the food product, and then exhausted by a blower and recycled past the evaporator coil. In this system the interior of the insulated chamber is kept essentially at a constant temperature throughout. The atmosphere of the chamber is constantly recirculated, so only sufficient refrigeration is added to the air to balance the heat load of the product throughput. This system is economical in terms of refrigeration energy, but the relatively high temperature freezing environment of only −40° F. requires much longer transit times and slower speeds for a given amount heat transfer than is required by the other two refrigerant systems.

The carbon dioxide open cycle refrigeration system injects pressurized liquid at 300 psig and 0° F. through nozzles directly into the enclosure. This flow is usually directed into a suction plenum behind circulation fans. The liquid carbon dioxide, in passing through the nozzles to atmospheric pressure, expands to a mixture of 55 percent gas and 45 percent solid carbon dioxide, which is in the form of very small particles. Both the gas and the solid material are exhausted from the nozzles at about −109° F. The light solid particles are entrained in the gas flow and circulate more or less evenly throughout the compartment, subliming to gas as latent heat is added from the product moving through the interior of the enclosure. The gas-solid mixture is essentially homogeneous, and the entire enclosure volume is kept at a relatively constant temperature of −100° F. CO_2 gas is constantly exhausted from the enclosure at −100° F.

In the carbon dioxide system, the refrigeration effect is obtained almost totally from the latent heat of sublimation contained in the 45 percent of the injected carbon dioxide which has expanded to the solid particle state. Since the amount of refrigeration available in the gas from −109° to 0° F. is 20 BTU's per pound, carbon dioxide gas exhausted at −100° f. results in a substantial loss of refrigeration. For example, uniform temperature operation in the enclosure results in a loss of 15 percent of the available refrigeration effect of the liquid carbon dioxide. In large systems this loss is prohibitive, and carbon dioxide recoverey and reliquification systems are required to make the operation economical. However, the advantage of this system is that the ambient temperature of −100° F. in the freezer results in faster transit time than can be employed with the air blast system.

The use of liquid nitrogen as a refrigerant creates substantially lower ambient temperatures in the freezer, which result in even faster transit time for the product. Despite the reduced freezing times and increased productivity obtained in a helical convey freezer using liquid nitrogen as a refrigerant, its use has been severely limited by the inefficient utilization of the refrigeration effect available in the liquid nitrogen, with resulting uneconomic operating costs. When operating the freezer with a substantially constant temperature throughout the enclosure, as in U.S. Pat. No. 3,412,573, the thermodynamic characteristics of nitrogen result in a large waste of refrigeration. This is due to the fact that the liquid nitrogen, which enters the chamber at a temperaturue of −320° V., has a latent heat of vaporization of 86 BTU's per pound. The resulting gas at −320° F. has a refrigeration capacity of 80 BTU's per pound between −320° and 0° F. Therefore, if the chamber is operated at a constant low temperature, −200° F. for example, the liquid nitrogen being added to mix with the gas to maintain that temperature, exhaust gas is constantly discharged at a temperature of −200° F. This results in a loss of 50 BUT's per pound of refrigerant as compared to an exhaust temperature of 0° F. The following table shows the percent loss of refrigerant at various internal operating temperatures as compared to a gas exhaust temperature of 0° F.

Internal Ambient Temp.°F.	Latent Ht.of Vaporization BTU/LB	Refrig. of Gas BTU/LB	Total Refrig. Used BTU/LB	Total Refrig. Available BTU/LB	% Utilized	% Lost
−320	86	0	86.0	166	48.0	52.0
−250	86	17.5	103.5	166	62.3	37.7
−200	86	30.0	116.0	166	69.9	30.1
−150	86	42.5	128.5	166	77.4	22.6
−100	86	55.0	141.0	166	84.9	15.1

The preceding table shows that the production rate advantage which can be obtained from the use of liquid nitrogen by operating at low internal temperatures is offset by the economic loss involved in non-utilization of available refrigeration capacity in the exhaust gas.

SUMMARY OF THE INVENTION

This invention provides novel apparatus and method to introduce, control, and circulate nitrogen refrigerant so as to utilize the maximum refrigeration capability and enable economical refrigeration use, while at the same time providing the benefit of improved quality and increased productivity obtainable from a low temperature environment in a freezere using a helical conveyor.

Briefly, the apparatus includes a thermally insulated enclosure with an inlet and outlet for material to be cooled or frozen. A helical conveyor in the enclosure carries the material from the inlet toward the outlet. Means are provided for introducing a liquid coolant, say, nitrogen, into the enclosure to contact the material on the conveyor adjacent the enclosure outlet so the liquid coolant absorbs sufficient heat to vaporize. Fan means in the enclosure blow the vaporized coolant around the helical conveyor in the direction opposite to that in which material is moved on the conveyor to effect countercurrent cooling of material with the vaporized coolant. Means are also provided for removing vaporized coolant from the enclosure after a substantial amount of the heat has been absorbed by the vaporized coolant from the product.

Preferably, an annular upright baffle adjacent the helical conveyor forces the vaporized coolant to flow in a helical path countercurrent to the product carried by the conveyor. The liquid coolant is preferably injected through two manifold systems, one of which is on continuously, and the other of which is cycled on and off in response to the temperature of the vaporized coolant leaving the enclosure.

In the presently preferred embodiment of the apparatus, the helical conveyor moves around an upright axis and carries the product from a lower to an upper portion of the enclosure. Nozzles mounted over the upper end of the conveyor spray liquid nitrogen onto the product near the discharge end of the helical conveyor. The liquid nitrogen is vaporized or else spills down onto the product carried by lower loops of the conveyor and is vaporized there. The cylindrical baffle is preferably within the helical conveyor, and is open at its bottom and closed at its top except for an exhaust duct connected to a blower, which exhausts vaporized nitrogen gas from the inside of the baffle. One of more fans in the enclosure, and outside the baffle, impart a tangential component to theh vaporized nitrogen gas and cause it to swirl around the baffle and helical conveyor in a direction opposite to the movement of the product on the conveyor. In an alternate embodiment, the baffle is on the outside of the helical conveyor, and the fans are inside the baffle. A core in the center of the heelical conveyor confines the gas to a helical path countercurrent to the movement of the product.

A sump in the floor of the enclosure collects any liquid nitrogen which may not be vaporized, and a liquid nitrogen level sensor in the sump generates an alarm signal and stops the injection of liquid nitrogen into the enclosure if the level of liquid nitrogen in the sump rises above a desired level.

In terms of method for effecting rapid heat transfer, the invention includes the steps of moving material to be cooled on a conveyor in a freezer from an inlet to an outlet for the material. A portion of a coolant liquid, say, liquid nitrogen, is introduced into the enclosure at a first location near the is introduced into the enclosure at a first location near the outlet for the material, and a second portion of the cooling liquid is introduced into the enclosure at a second location spaced farther from the inlet than the first location. The liquid coolant is supplied to the enclosure to contact the material to be cooled at a rate which causes the liquid coolant to be vaporized into gaseous form. The gas is then forced by fans to flow through the enclosure countercurrently to the movement of the material on the conveyor.

Preferably, the temperature of the gasified coolant is sensed as it is removed from the enclosure, and the injection of the cooling liquid into the enclosure at the second location is varied in response to the temperature of the gas leaving the enclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be more fully understood from the following detailed description and the accompanying drawings, in which:

FIG. 1 is a fragmentary perspective view, partially broken away, of the heat exchanger system using liquid nitrogen as a coolant;

FIG. 2 is a sectional elevation of the system of FIG. 1;

FIG. 3 is a view taken on staggered line **3—3** of FIG. 2; and

FIG. 4 is a diagrammatic sectional elevation of an alternate embodiment of the invention in which the product to be cooled is passed down a helical conveyor into a pool of liquid coolant.

Referring to FIGS. 1–3, a freezer **10** includes a boxlike enclosure **11** with four insulated side walls **12,** a bottom wall **14,** and a top wall **16.** An endless conveyor **20** in the enclosure carries food packages **22** (FIG. 2) from an inlet **24** in the lower corner of one of the side walls of the enclosure, around an ascending helical path **25** in the central portion of the enclosure, and to an outlet **26** in the upper corner of a side wall opposite from that which includes the inlet.

The helical conveyor is of the type described in U.S. Pat. No. 3,348,659. Its helical portion includes nine loops **27** disposed around an upright cylindrical and hollow baffle **30** secured by bolts **32** (FIG. 2) to the inside surfaces of equally spaced vertical ribs **33** in an upright rotatable drum **34,** which includes at its lower end a downwardly extending stub shaft **36** mounted to revolve in a thrust bearing **38** supported by the bottom **40** of a cage **42,** which surrounds the helical portion of the conveyor.

The bottom of the drum includes eight radially extending and horizontally drum spokes **44** secured at their respective inner ends in the center of the drum to the upper end of the stub shaft **36,** and at their respective outer ends to a lower horizontal drum hoop **46.**

The vertical drum ribs **33** are secured at their lower ends to the lower drum hoop **46** and at their upper ends to an upper horizontal drum hoop **50.**

Eight horizontal and radially extending top drum spokes **52** are secured at equally spaced intervals at their respective outer ends to the upper hoop, and at their respective inner ends to a stabilizing bearing **54**, which receives the lower end of a stub shaft **56** secured in a socket **58** of a hub **60** secured to the inner ends of six horizontal and radially extending cage spokes **62**, which are each secured at their respective outer ends to a respective downwardly extending cage rib **64**. The lower ends of the cage ribs are secured to pads **66** on the floor of the enclosure. The upper and lower ends of the cage ribs are braced by horizontal struts **68**.

The upper end of the baffle is covered by an outwardly extending flange or baffle cover **70** secured to the lower end of an exhaust stack **72**, which extends up through the center of the enclosure top wall. The exhaust stack is connected by a duct **74** to a blower **76** driven by an electric motor **78**.

The helical portion of the conveyor slides on a pair of laterally-spaced, helical tracks **80** mounted on top of a helical shalf **82** secured at its outer periphery to the inner portions of the cage ribs. The inner edges of the loops in the helical portion of the conveyor belt are frictionally engaged by the vertical drum ribs, which maintain proper tension in the conveyor (as described in U.S. Pat. No. 3,348,659), when the drum is rotated by a chain **84** secured around a sprocket **86** mounted on the periphery of the lower end of the drum. Chain **84** also extends around a drive sprocket **88** mounted on the upper end of a vertical shaft **90**, which is driven through a conventional gear train (not shown) in synchronization with a horizontal conveyor drive shaft **92**, the outer end of which extends through a side wall of the enclosure and carries a drive sprocket **94** driven by conventional chain drive **96**. The inner end of horizontal shaft **92** carries a drive sprocket **98**, which engages the conveyor to apply the proper tension to cause the belt to move over a system of idler sprockets **100** in a tension take-up mechanism **102** (FIG. **1**), which forms no part of the present invention, and therefore is not described in detail.

Liquid nitrogen is supplied to the enclosure from a cryogenic storage tank (not shown) through a supply line **104**, which is connected through a main control solenoid-operated valve **106** and a first manifold valve **107** to a first or upper manifold line **107**A, and through a second manifold valve **108**, which is solenoid operated, to a second or lower manifold valve **108**, which is solenoid operated, to a second or lower manifold line **109**. The solenoid operated valve **108** is controlled by a temperature sensor **110** mounted in the exhaust stack.

The first liquid nitrogen manifold line extends down through the top wall of the enclosure, and is connected to an upper circular distributor pipe **111** disposed around the outside of the cage just below the second loop from the top of the helical portion of the conveyor. A first set of six separate horizontal and radially extending spray nozzle lines **112** are connected at their respective outer ends to the circular distributor at equally spaced intervals. Each spray nozzle line extends inwardly through a respective cage rib, and terminates at its inner end just short of the drum. Four radially spaced and downwardly directed nozzles **114** in each nozzle line spray liquid nitrogen onto the food product supported by the third loop from the top of the helical portion of the conveyor. A second set of six horizontal and radially extending spray nozzle lines **116** (FIGS. **1** and **2**) are located at equally spaced intervals around the space between the cage and the drum just below the fourth loop from the top of the helical portion of the conveyor. The outer end of each of the second set of spray lines extends through a respective cage rib and is connected to a lower circular distributor pipe **117** secured around the outside of the cage and connected to the lower end of the second manifold line which extends down through the top of the enclosure. A set of fourth nozzles **118** is secured to the underside of each of the spray lines in the second set to direct a stream of liquid nitrogen onto the food product carried by the fifth loop in the helical conveyor.

As shown in FIGS. **1** and **3**, a separate pair of vertically spaced fans **119** are mounted in diametrically opposed corners of the enclosure to rotate on respective horizontal shafts **120** extending to the exterior of the enclosure where each shaft is connected to and driven by an electric motor **121**. The fans blow nitrogen gas around the helical portion of the conveyor in a counterclockwise (as viewed in FIG. **3**) direction, which is opposite to the direction of the travel of the helical portion of the conveyor.

The insulated floor of the enclosure slopes down from left to right (as viewed in FIG. **2**) to an elongated gutter **122** in the floor of the enclosure along the lowest edge in the enclosure. The gutter slopes downwardly, in the direction perpendicular to the floor slope, from one end to another so that any excess liquid nitrogen which might each the enclosure floor is collected in a sump **123** at the lower end of the gutter. A liquid nitrogen level control system **24** is mounted in the lower portion of the sump to prevent the accumulation of an excessive amount of liquild nitrogen. The control system includes a lower thermocouple contact **126** mounted in the bottom of the sump and connected to a control box **127** by a lead **128**. An upper thermocouple contact **130** is mounted in the sump above the first contact and connected to the control box through a lead **132**. An electrical heating element **134** is connected by leads **135, 136** to the control box, which is supplied power from a conventional source (not shown). If sufficient liquid nitrogen collects in the sump to rise to the level of the lower contact **126**, a conventional control circuit in the control box energizes the electrical heating element until the liquid nitrogen is evaporated to the level below that of the lower thermocouple contact sensor. If the capacity of the heater is insufficient to evaporate the liquid nitrogen as fast as it accumulates, the level of the liquid nitrogen rises to the upper contact **130**, which causes the control circuit to generate an alarm signal, closes the main valve in the liquid nitrogen supply line to shut off the supply of liquid nitrogen to the enclosure, and turns off the motors for the conveyor, fans and blower.

In using the equipment shown in FIGS. **1–3**, the product to be cooled or frozen enters at the bottom of the enclosure on the conveyor, moves in an ascending helical path around the rotatable drum, and exits at the top of the enclosure through the outlet. The drum and conveyor are driven synchronously through a conventional gear train (not shown) by power supplied to the horizontal shaft **92** (FIG. **1**). Liquid nitrogen is sprayed onto the ascending product through both manifolds, and is vaporized into gaseous nitrogen, which is blown in a counterclockwise direction (as viewed in FIG. **3**) by the fans around the helical portion of the conveyor. The blower connected to the exhaust duct creates a reduced pressure inside the rotating drum so the gaseous nitrogen is drawn down and into the open lower end of the drum and is discharged from the drum through the exhaust stack and blower. The upper end of the cylindrical baffle makes a close sliding fit against the stationary baffle cover, so there is negligible leakage of nitrogen gas between the cover and the baffle.

When the temperature of the nitrogen gas leaving through the exhaust stack reaches a desired value, −5° F. for example, indicating that sufficient liquid nitrogen has been supplied to the enclosure for the rate of product being conveyed through the enclosure, the temperature sensor in the exhaust stack actuates solenoid valve **108** to close it, thus interrupting the supply of liquid nitrogen to the lower set of spray nozzles. Valve **107** stays open so the upper nozzles continue to spray liquid nitrogen in an amount which supplies about 75 percent of the required cooling. Valve **108** stays closed until the temperature of the nitrogen gas in the exhaust stack exceeds a desired value, +5° F. for example, indicating that insufficient nitrogen is being introduced into the system. The temperature controller then opens solenoid valve **108**, permitting liquid nitrogen to flow through the nozzles in the lower manifold, which supplies about 50 percent of the required cooling.

As the liquid nitrogen is discharged from the nozzles, part of it comes in direct contact withi the product on the conveyor. Heat is transferred from the product, which is at a substantially higher temperature than the liquid nitrogen, and the liquid nitogen is vaporized to nitrogen gas as it absorbs the latent heat of vaporization. Liquid nitrogen which is not vaporized at the level where it is injected flows over the product and drips through the conveyor onto warmer product below, so the liquid nitrogen is vaporized at lower levels as it absorbs latent heat. The gas generated by the vaporizing of the liquid nitrogen is circulated in a tangential direction by the fans in the enclosure. They provide a substantial horizontal velocity vector to the gas flow. The negative pressure induced in the cylindrical baffle by the exhaust blower causes the nitrogen gas to have a downward velocity component from the manifold spray nozzles to the bottom of the enclosure, then a horizontal radial inward component into the bottom opening of the cylindrical baffle. The gas circulation past the product on the conveyor thus has a horizontal tangential component imparted by the circulation fans, and a vertically downward component due to the exhaust suction. This results in a substantially helical flow path of the circulating gas in a direction countercurrent to the direction of the product moving on the helical portion of the conveyor.

Thus, the nitrogen gas which is generated from the liquid nitrogen at a temperature of −320° F., is warmed as it transfers heat from the product by convection. As indicated above, when the exhaust gas temperature exceeds a pre-set value, indicating that insufficient liquid nitrogen is being introduced into the system, the temperature controller causes the opening of the solenoid valve for the lower liquid nitrogen manifold, permitting additional liquid nitrogen to flow through the orifice nozzles in the manifolds. The spray manifolds are located on different levels to disperse the liquid nitrogen for more complete vaporization. All of the nozzles are located at an elevation above the middle loop of the helical portion of the conveyor to permit sufficient length of travel of the resultant vaporized nitrogen gas to absorb a substantial amount of sensible heat from the product to the gas.

The lower set of nozzles being sized to permit a total liquid nitrogen flow about 25 percent greater than that required by the product heat load insures proper on-off cycling of the solenoid valve in the lower manifold to maintain control of the exhaust temperature within close limits. Even closer control is obtained by using a conventional proportional control valve in the supply line to the lower manifold. The valve position is controlled by the temperature sensor monitoring the exhaust gas temperature. In such a system the proportional control valve controls flow, even with changing input product load, to maintain within very close limits the required temperature of the output gas.

Although substantially all of the liquid nitrogen introduced through the manifolds is vaporized, either by direct contact with the product, or by convection from the circulating gas, some small quantity of nitrogen may remain in the liquid state as it falls to the sloped floor of the enclosure. If so, it drains into the gutter and then into the sump where it is vaporized by the electrical heating element. If the equipment should malfunction and supply an excess amount of liquid nitrogen to the enclosure, causing the level of liquid nitrogen to rise in the sump above the desired value, the liquid level control in the sump shuts off all liquid nitrogen supplied to the enclosure, and stops the motors for the conveyor belt, blower, and fans.

An alternate embodiment of the invention is shown in FIG. **4.** An enclosure **150** has an inlet opening **152** at its upper portion, and a discharge opening **154** in its lower portion on the side of the enclosure opposite from the inlet. An endless conveyor **156** carries a product (not shown) to be frozen in a descending helical path in a counterclockwise direction (as viewed from above) around an upright imperforate drum **158**, which is suspended above the floor of the enclosure by a vertical shaft **159** secured to the upper end of the drum and extending up through an exhaust opening **160** covered by an exhaust duct **162** connected to a blower **163.** The upper end of the shaft **159** is supported in a thrust bearing **164** mounted in the exhaust duct.

A cylindrical baffle **166**, secured by flanges **168** to the roof of the enclosure, surrounds the helical portion of the conveyor, and hangs down so that its open lower end terminates just below a pool of liquid nitrogen **169** in the bottom of the enclosure. A plurality of fans **170** are mounted within the baffle to direct a circular flow of gas in the annular space between the baffle and the drum in a clockwise direction (as viewed from above) so the gas flows countercurrently to the product moving down the helical portion of the conveyor.

The liquid nitrogen in the bottom of the enclosure is vaporized as it is contacted by the product carried by the lower portion of the helical conveyor. This causes nitrogen to be vaporized and rise in the annular space between the cylindrical baffle and the imperforate drum. The nitrogen gas is given an upward velocity component by the blower reducing the pressure within the exhaust duct, and the fans cause the nitrogen gas to siwrl in a clockwise direction in the annular space while the product moves in a counterclockwise direction. The product is removed from the liquid nitrogen by an endless transfer belt **172** and carried out through the enclosure discharging opening.

The level of the liquid nitrogen in the enclosure, and the temperature of the exhaust gas, is controlled as described with the embodiment shown in FIGS. 1–3.

From the foregoing description, it will be apparent that this invention provides an improved cooling or freezing apparatus which substantially increases the product throughput because of the large temperature gradient imposed by liquid nitrogen at −320° F., and which obtains high efficiency by using a substantial portion of the sensible heat in the vaporized nitrogen gas before it leaves the cooling enclosure.

I claim:

1. Cooling apparatus comprising a thermally insulated enclosure with an inlet and an outlet for material to be cooled, the inlet being below the outlet, a helical conveyor having upper and lower ends disposed in the enclosure about an upright axis to carry the material upwardly from the inlet to the outlet of the enclosure, an upright annular and imperforate baffle disposed within the helical convevyor, means for introducing liquid nitrogen into the enclosure to contact the material on the conveyor at a point nearer the enclosure outlet than the inlet so the liquid nitrogen absorbs sufficient heat to vaporize to nitrogen gas, fan means in the enclosure arranged to impart a horizontal velocity vector component to the nitrogen gas thus blowing it around the helical conveyor in the direction opposite to that in which the material is moved on the conveyor, means for creating a lower pressure at the lower end of the helical conveyor than at the upper end so that a vertical velocity vector component is imparted to the gas so that substantially all the nitrogen gas flows down the helical conveyor, the net flow of the gas being to spiral downwardly around the helix to effect countercurrent cooling of material with the nitrogen gas, and means for removing nitrogen gas from the enclosure.

2. Apparatus according to claim **1** which includes a first manifold for spraying a portion of the liquid nitrogen on the product on the conveyor at the point nearer the enclosure outlet than the inlet, and a second manifold for spraying the balance of the liquid nitrogen onto the product at another point farther from the enclosure outlet than where the first manifold is located, but closer to the enclosure outlet than the inlet.

3. Apparatus according to claim **2** which includes means for varying the amount of liquid nitrogen supplied through the second manifold while maintaining substantially constant flow of liquid nitrogen through the first manifold.

4. Apparatus according to claim **3** which includes means responsive to the temperature of the vaporized nitrogen removed from the enclosure for controlling the amount of liquid nitrogen flowing through the second manifold.

5. Apparatus according to claim **1** which includes a sump in the floor of the enclosure for collecting excess liquid nitrogen, and vaporizing means in the sump for vaporizing liquid collected there.

6. Apparatus according to claim **5** which includes a sensor in the sump for detecting the presence of liquid nitrogen, and means responsive to the sensor for shutting off the flow of liquid nitrogen into the enclosure.

7. Apparatus according to claim **5** which includes means responsive to the sensor for stopping the conveyor.

8. Apparatus according to claim **5** which includes a sensor in the sump for detecting the present of liquid nitrogen, and means responsive to the sensor for energizing the vaporizing means.

9. Apparatus according to claim **8** which includes a first sensor at one level in the sump for developing a signal when liquid accumulates in the sump, means responsive to the signal from the first sensor for energizing the vaporizer, a second sensor disposed about the first sensor for detecting the presence of liquid in the sump at a level above that of the first sensor, and means responsive to the signal from the first sensor for stopping the flow of liquid nitrogen into the enclosure.

10. Apparatus according to claim **9** which includes means responsive to the sensor for stopping the conveyor.

* * * * *

PO-1050
(5/69)

UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,866,432 Dated February 18, 1975

Inventor(s) Donald I. Harrison

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 2, line 20 - "-100°f." should be -- -100°F--;
Col. 2, line 25 - "recoverey" should be --recovery--;
Col. 2, line 45 - "-320°V" should be -- -320°F.--;
Col. 2, line 53 - "BUT's" should be --BTU's--;
Col. 3, line 16 - "freezere" should be --freezer--;
Col. 3, line 54 - "of" (second occurrence) should be --or--;
Col. 3, line 56 - "theh" should be --the--;
Col. 3, line 62 - "heelical" should be --helical--;
Col. 4, lines 8 and 9 - "is introduced into the enclosure at a first location near the" should be deleted (repetition);
Col. 4, line 60 - "horizontally" should be --horizontal--;
Col. 5, lines 46 and 47 - "valve 108, which is solenoid operated, to a second or lower manifold" should be deleted (repetition);
Col. 6, line 29 - "each" should be --reach--;
Col. 6, line 31 - "24" should be --124--;
Col. 6, line 46 - "electrical" should be --electric--;
Col. 7, line 27 - "withi" should be --with--;
Col. 8, line 63 - "siwrl" should be --swirl--;
Col. 8, line 68 - "discharging" should be --discharge--;
Col. 10, line 26 - "present" should be --presence--;
Col. 10, line 39 - before "sensor" insert --signal from the second--.

Signed and sealed this 13th day of May 1975.

(SEAL)
Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks