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REFRIGERATION AIR DRYER

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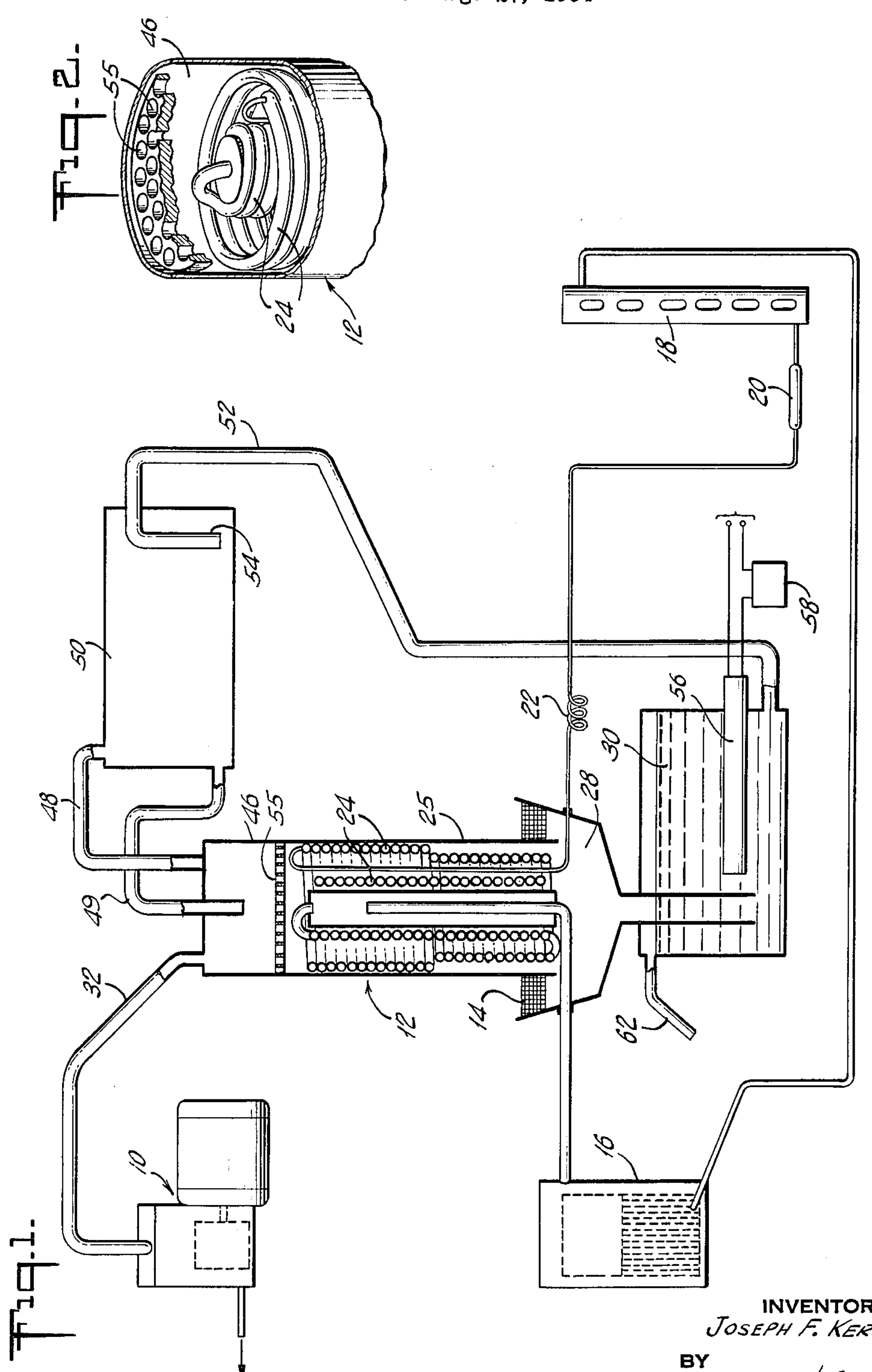

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REFRIGERATION AIR DRYER

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This invention relates to refrigeration air dryers for dehumidifying moist air by cooling it to subzero temperatures, thereby precipitating water vapor out of the air in the form of ice, frost and condensed water. The invention is an improvement in prior art refrigeration air dryers, such as exemplified by British Patent No. 893,773, which was issued on April 11, 1962, to the Puregas Equipment Corporation of Copiague, New York.

The above noted British patent discloses a refrigeration air dryer containing an air compressor, a refrigeration heat exchanger, a desiccant tower, and an automatic defrost circuit. The air compressor blows moist air through the heat exchanger and then through the desiccant tower, both of which are operable to remove water vapor from the air. In normal operation, the water vapor is removed by the refrigerated heat exchanger in the form of ice, frost, and condensed water. The condensed water drains out the bottom of the heat exchanger through a float drain trap, but the ice and frost accumulate until they eventually begin to obstruct the flow of air through the heat exchanger. When this occurs, the automatic defrost circuit activates an electric heater to melt the ice and clear the obstruction. During the defrost period, the air compressor continues to blow air through the heat exchanger and through the desiccant tower, but the moisture is removed by the desiccant tower rather than by the heat exchanger.

After the ice and frost have been melted, the defrost heater is deactivated, and the heat exchanger begins to remove the moisture from the air again. The desiccant tower, however, has become partially charged with moisture during the defrost period, so it begins to release moisture to the dry air entering therein from the heat exchanger, until it has given up sufficient moisture to reach equilibrium. In other words, in normal operation, moisture is removed from the air in the heat exchanger and added to the air in the desiccant tower, but at such a slow rate that the moisture content of the output air is not appreciably increased. In the defrost period, the situation is reversed; moisture is added to the air in the heat exchanger and removed from the air in the desiccant tower. Needless to say, the desiccant tower's capacity for removing moisture is selected to exceed the total moisture content of the air passed therethrough during the defrost period. Also, the system is designed so that the air passing through the desiccant tower during the normal, non defrost period is sufficient in volume and dryness to completely reactivate the desiccant tower without exceeding the desired degree of dryness in the output air.

The above described prior art device was a major advance in refrigeration air dryers. It eliminated the need for interrupting the dehumidification process to defrost the heat exchanger or to remove moisture from the desiccant tower, thereby eliminating the need for duplicate, alternately operating dehumidification devices such as previously required for continuous dehumidification.

Although it was a great advance over previously known air dryers, this prior art device still contained room for improvement in terms of cost, simplicity of structure, efficiency, and reliability, particularly in the structure of the heat exchanger and the automatic defrost circuit. The principal object of this invention is to provide such improvements.

The improvements provided by this invention stem from a rather simple rearrangement of the basic air dryer components. In the above described prior art device, the heat exchanger was coupled to the high pressure side of the air compressor. This was done to gain a reduction in the dew point of the output air by cooling the input air under pressure. When an air-water vapor mixture is cooled under pressure, and then expanded back to atmospheric pressure, the dew point drops below the actual temperature to which the mixture is cooled. Since a reduced dew point is indicative of a reduced percentage of moisture, the output air will be significantly dryer if the input air is cooled under pressure. Accordingly, it has been the practice to couple the heat exchanger to the high pressure side of the air compressor to utilize this natural advantage of cooling the input air under pressure.

In accordance with this invention, however, it has been found that significant, unexpected advantages can be obtained by coupling the heat exchanger to the low pressure side of the air compressor and cooling the air at atmospheric pressure. It has been found that these unexpected advantages far outweigh the lower dew point obtained by cooling under pressure. For example, cooling at atmospheric pressure makes it possible to replace the prior art electric defroster circuit with a novel defroster system which is simpler, faster, and more reliable in operation. The novel defroster system comprises means for flushing a stream of hot water over the ice-encrusted interior of the heat exchanger. This type of defroster system would obviously be precluded in a pressurized heat exchanger. In addition, cooling at atmospheric pressure eliminates the need for a pressurized heat exchanger and for a float-drain trap to remove condensed water from the heat exchanger without loss of air pressure. Since the pressurized heat exchanger and float-drain trap are relatively complex and expensive, this results in a significant structural simplification. Furthermore, it increases the reliability of operation by eliminating the possibility of drain trap stoppages.

In addition to the foregoing advantages, cooling at atmospheric pressure also increases the efficiency of the air compressor and eliminates the need for reheating the cooled air to prevent condensation on the outside of the air conduits. The cold, dry air input to the air compressor raises the compressor's efficiency, and the compression process automatically reheats the cooled air back to room temperature. The foregoing advantages far outweigh the lower dew point obtained in the prior art devices by cooling the air under pressure.

Although the above noted rearrangement of the heat exchanger and air compressor is basic to this invention, it does not comprise the entire invention. This invention also includes a novel automatic defrosting system, novel suction pump means, and a novel defroster control system.

The novel defrosting system of this invention provides a significant increase in defrosting speed without any sacrifice of efficiency. In the prior art, an electric defrost heater was used to melt the frost, and a relatively long time period was required for the heat to permeate the heat exchanger to the extent of melting the bond between the frost and the heat exchanger surfaces. In accordance with this invention, however, it has been found that the frost can be melted free of the heat exchanger surfaces much faster by flushing hot water through the interior of the heat exchanger. This shortens the defrosting time period from 10 minutes to 2 minutes in a typical unit. Since the heat exchanger releases moisture to the air during the defrosting period, or fails to remove moisture due to the fact that it has not returned to the freezing temperatures of water vapor, it will be appreciated that defrosting speed is an important consideration in refrigeration air dryers.

The defrosting system of this invention includes a nonpressurized heat exchanger which is coupled to the low pressure side of the heat exchanger and which is adapted to receive a stream of hot water through the interior thereof.

The defrosting system also includes a novel suction pump which utilizes the existing air compressor as the power source for flushing hot water through the heat exchanger during the defrost period. As the frost obstruction begins to form in the heat exchanger, the air pressure between the heat exchanger and the air compressor drops below atmospheric pressure. This occurs because the air compressor begins to act as a suction pump when its air inlet is constricted by the formation of frost. In this invention, the suction is used to raise hot water from a tank under the heat exchanger to a tank above the heat exchanger. When the upper tank is filled to a desired level with hot water, its entire contents are automatically flushed through the interior of the heat exchanger by a siphon system. The hot water melts and loosens the frost, which falls into a pan beneath the heat exchanger. The hot water and melted ice water then return to the lower tank, where they are reheated for the next defrosting operation.

The combination of the above described suction pump and automatic siphon system comprises a novel defroster control system which replaces the differential pressure switch previously used. Since water pipes are cheaper than differential pressure switches, and more reliable this novel control system provides a significant reduction in cost and a significant increase in reliability.

Accordingly, an object of this invention is to provide an improved refrigeration air dryer.

Another object is to provide a refrigeration air dryer which is simpler in structure and more reliable in operation than those heretofore known in the art.

An additional advantage of the invention is to provide an improved automatic defrosting system for use in connection with refrigeration heat exchangers.

Another object is to provide novel suction pump means for use in connection with the automatic defrosting system of this invention.

Another object is to provide an improved defroster control system for use in connection with the novel automatic defrosting system.

Another object is to provide an improved automatic defrosting system, novel suction pump means, and an improved defroster control system for use in refrigeration air dryers or the like.

A further object of this invention is to provide a refrigeration air dryer in which moist air is cooled at atmospheric pressure.

Other objects and advantages of this invention will become apparent to those skilled in the art from the following description of one specific embodiment thereof, as illustrated in the attached drawings, in which:

FIG. 1 is a block diagram of one embodiment of the invention; and

FIG. 2 is a cut-away prospective view of the heat exchanger of FIG. 1.

Referring to FIG. 1, an air compressor **10** draws moist air into heat exchanger **12** through an air filter **14**.

The air is cooled to a sub-zero temperature in heat exchanger **12** by means of a refrigerator system including refrigeration compressor **16**, condenser **18**, strainer **20**, capillary **22**, and refrigerant coils **24**, which are wound in several concentric spiral layers inside the heat exchanger casing **25**. The coils are positional with respect to each other and to casing **25** to produce turbulence, thereby bringing the air into repeated contact with the refrigerated surfaces, and promoting the exchange of heat between the air and the refrigerant. The cooling process precipitates moisture out of the air in the form of ice, frost and condensed water. The ice and frost accumulate on refrigerant coils **24** and on the heat exchanger casing **25**, but the condensed water drops into a funnel pan **28** below heat exchanger **12**, from whence it drains into a hot water tank **30** below the heat exchanger. Pan **28** and hot water tank **30** are parts of an automatic defrost system which will be described later.

The cold dry air is drawn through the heat exchanger into air compressor **10** via air conduit **32**. Compressor **10** compresses the air and raises its temperature back to normal. From compressor **10** the dry air at approximately room temperature may be directed through a desiccant tower, as described in the aforementioned British patent.

In time, the ice and frost accumulating within heat exchanger **12** begin to obstruct the flow of air therethrough. When this occurs, the pressure within the top part **46** of the heat exchanger begins to drop below atmospheric, thereby developing a suction in conduits **48** and **49**, between top part **46** and hot water tank **50** positioned above heat exchanger **12**. This suction draws water from lower tank **30** to upper tank **50** via a water conduit **52**, which enters upper tank **50** through an input siphon pipe **54**. Siphon pipe **54** acts automatically to siphon the water from upper tank **50** back to lower tank **30** when the system is shut off.

The water in lower tank **30** is preferably maintained at approximately 140° F., for example, by an electric heater **56** and thermostat switch **58**. As the frost obstruction within heat exchanger **12** increases, this hot water is drawn into upper tank **50** at a rate proportioned to the amount of frost obstruction. When upper tank **50** is filled, the hot water begins to flow through output conduit **49**, which is bent to constitute an output siphon. When the flow through siphon pipe **49** commences, all of the water in upper tank **50** is quickly flushed through heat exchanger **12** due to the siphon action. A perforated diffuser plate **55** at the top of the heat exchanger serves to spread the hot water over the entire interior. The hot water melts the accumulated ice and frost, breaks the sheets of frost free from the heat exchanger surfaces, then returns to lower tank **30** via pan **28**. The unmelted pieces of ice and frost drop into funnel **28**, where they quickly melt and drain into tank **30**. The cold water in tank **30** is then reheated by heater **56**. After the defrosting operation, the water level in tank **30** rises, due to the water added by the frost. When the water level rises too far, however, the excess water is drained away through a drainage tube **62** coupled to the top of tank **30**.

During the above described defrosting operation, the air compressor continues to draw air through the heat exchanger, but the moisture may be removed by the desiccant tower (not shown).

It should now be apparent that the foregoing defrosting system operates automatically when a predetermined degree of frost obstruction is reached, regardless of the time required for the frost to build up.

The structure of the heat exchanger is shown in greater detail in FIG. 2. In this particular embodiment of the invention, the top part **46** is an integral part of casing member 25, but it could be made removable if desired. Conduits 32, 48 and 49 can be secured to the top of casing member 46 by any suitable air-tight joints.

From the foregoing description it will be apparent that this invention provides a novel improved refrigeration air dryer, a novel automatic defrosting system, novel suction pump means, and a novel defroster control system. It should be understood, however, that this invention is by no means limited to the specific embodiments disclosed herein, since many modifications can be made in the disclosed structure without departing from the basic teaching of this patent application. For example, the novel heat exchanger and defrost system are not restricted to refrigeration air dryers; they can be used in many other applications as well. Also, in some embodiments of the defrosting system it may be desirable to use an electric pump to raise the hot water from the lower tank to the upper tank, instead of relying on the suction generated by the air compressor. In other embodiments, it may be desirable to use the refrigerant condenser coils as a source of heat for the hot water tanks.

While the foregoing description sets forth the principles of the invention in connection with specific apparatus, it is to be understood that the description is made only by way of example and not as a limitation of the scope of the invention as set forth in the objects thereof and in the accompanying claims.

What is claimed is:

1. A refrigeration air dryer comprising:

an air compressor having an air inlet and an air outlet;

a heat exchanger including an air inlet end and an air outlet end coupled to the inlet of the air compressor;

refrigeration means coupled to the heat exchanger for cooling the air entering therein;

and hot water defrosting means coupled to said heat exchanger to remove the frost from the interior thereof, said defrosting means comprising:

- a water tank mounted below one axial end of said heat exchanger;
- a first fluid conduit means coupling said water tank to one end of said heat exchanger to receive water therefrom;
- second fluid conduit means coupled to the opposite end of said heat exchanger and including a second water tank mounted above said heat exchanger;
- means for pumping water from said first tank to said second tank;
- means for discharging water from said second tank into said heat exchanger;
- and means for returning the water to said first water tank via said first fluid conduit means.

2. The combination defined in claim **1** wherein said second tank is coupled to the air outlet end of said heat exchanger and said pump means comprises said air compressor, the air compressor acting to create a suction at the air outlet end of the heat exchanger when frost obstructs the flow of air through said heat exchanger, and the suction drawing water from said first tank to said second tank.

3. The combination defined in claim **2** wherein said discharging means comprises a siphon output conduit coupled between said second water tank and the air outlet end of said heat exchanger, said siphon output conduit being operable to discharge the contents of said second tank into the air outlet end of said heat exchanger when the water in said second tank reaches a predetermined level.

4. The combination defined in claim **3** and also including a siphon input conduit coupled between said first and second water tanks, said input siphon conduit being operable to conduct water from said first tank to said second tank under the influence of said suction and being operable to siphon said water back to said first tank if said suction terminates before the water level in said second tank reaches said predetermined level.

5. The combination defined in claim **4** and also including a pan mounted below the air inlet end of said heat exchanger, said pan collecting water and frost which fall through the interior of said heat exchanger, and means piping said water in said first water tank.

6. In an air cooling system containing a refrigeration heat exchanger having an air inlet end and an air outlet end, a defroster system comprising (1) a water tank, (2) first fluid conduit means coupling said water tank to one end of said heat exchanger to receive water therefrom, (3) means for heating the water in said water tank, (4) second fluid conduit means coupling said water tank to the other end of said heat exchanger to deliver hot water thereto, and (5) means responsive to the formation of ice and frost for flushing said hot water through the interior of said heat exchanger via said second fluid conduit means and returning the water to said tank via said first fluid conduit means.

7. The combination defined in claim **6** wherein said second fluid conduit means includes a second water tank mounted above said first water tank, and further comprising means for pumping water from said first tank to said second tank, and means for discharging water from said second tank into said heat exchanger.

8. The combination defined in claim **7** and also including an air compressor coupled to the air outlet end of said heat exchanger to draw air therethrough, said second tank being coupled to said air outlet end of the heat exchanger, and wherein said pump means comprises said air compressor, the air compressor creating a suction at the air outlet end of the heat exchanger when frost obstructs the flow of air through said heat exchanger, and the suction acting, as a portion of said ice and frost-responsive means to draw water from said first tank to said second tank.

9. The combination defined in claim **8** wherein said discharging means comprises a siphon output conduit coupled between said second water tank and the air outlet end of said heat exchanger, said siphon output conduit being operable to discharge the contents of said second tank into the air outlet end of said heat exchanger when the water in said second tank reaches a predetermined level.

10. The combination defined in claim **9** and also including a siphon input conduit coupled between said first and second water tanks, said input siphon conduit being operable to conduct water from said first tank to said second tank under the influence of said suction and being operable to siphon said water back to said first tank if said suction terminates before the water level in said second tank reaches said predetermined level.

11. A refrigeration air dryer comprising: an air compressor having an air inlet and an air outlet; a heat exchanger having an air inlet and an air outlet, the air outlet thereof being coupled to the air inlet of said air compressor; refrigeration means coupled to said heat exchanger for cooling the air entering therein; water defrosting means coupled to said heat exchanger for removing frost from the interior thereof; and means responsive to the formation of ice and frost in said heat exchanger for initiating said defrosting means.

12. The refrigeration air dryer claimed in claim **11** wherein said means for initiating said defrosting means is responsive to a decreased pressure in said heat exchanger.

13. The refrigeration air dryer claimed in claim **12** in which said defrosting means includes a water reservoir having an outlet into said heat exchanger.

14. The method of dehumidifying air comprising the steps of: cooling the air in a heat exchanger to precipitate the moisture therefrom; collecting the precipitated moisture in a water reservoir; heating the water reservoir; and cycling the water from said reservoir through said heat exchanger in response to a decreased pressure initiated by frost and ice therein.

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