This invention relates to refrigeration apparatus, and is particularly concerned with refrigerators which include a high humidity compartment especially adapted to preserve foodstuffs without dehydration thereof. The invention has especial reference to such refrigerators, in which the compartment air is forcibly circulated in heat exchange relation with an evaporator.

More specifically, the present invention has reference to refrigerators of the multiple temperature type in which the temperature of the air in the main food storage compartment is maintained above that existing in other portions of the box, and the relative humidity in said compartment is at a high value.

In such apparatus, it has proven difficult to insure the desired degree of humidity throughout all seasons of the year, while preventing the humidity from reaching undesirably high values at certain times, and particularly in damp climates. Proper humidity control is particularly important, in view of the fact that cooling of the "moist-cold" compartment is customarily accomplished by effecting the necessary heat transfer through the walls of said compartment. This method of heat transfer has certain evident advantages, such as, for example, as affording a food compartment which is clear and unobstructed, but these advantages need not be considered in detail here. Effecting the cooling in the above mentioned manner results in maintenance of the temperature of the compartment walls at a value well below the dew point temperature of the air in said compartment at the high relative humidity customarily existing in the latter. As a consequence, excessively high humidity produces undesirable condensation upon the walls.

By the present invention, the difficulties and objections previously encountered are eliminated and, to this end, it is a primary object of this invention to provide a refrigerator having novel means for controlling the humidity conditions therein, and for decreasing the average temperature differential between the air within the compartment and the walls thereof.

More particularly, it is an object of the present invention to provide a refrigeration apparatus having novel means for removing moisture from the cabinet air, as and when required, and for lowering the temperature of said air with respect to that of the wall structure.

To this end, the invention contemplates the provision of humidity-responsive means for withdrawing air from the food compartment, passing it in heat exchange relation with a cold zone and re-injecting it into the compartment after its temperature has been reduced and after the desired degree of moisture has been removed therefrom.

A further object of the invention resides in the provision of a refrigeration apparatus, in which circulating air provides heat transfer capacity additional to that effected through the walls of the food storage compartment. It is also an object of the invention to provide a refrigerator in which undesired moisture is removed from the cabinet air without causing the accumulation of frost in any portion of the refrigerating system.

Broadly, the present invention provides a refrigerator having a plurality of zones maintained at "moist-cold," sharp-freeze and intermediate temperatures respectively, in accordance with the requirements of various foodstuffs to be preserved therein; while a more specific object of the invention resides in the provision of such refrigeration apparatus, having a moisture-removing evaporator portion which affords heat transfer capacity in addition to that supplied by the evaporator arranged to cool the walls of the main food storage compartment.

These and other objects and advantages of the invention may be more clearly understood by reference to the following description and to the accompanying drawings in which:

Fig. 1 is an elevational and partial sectional view of a refrigerator embodying the invention, the refrigerator being shown with the main food compartment door removed therefrom;

Fig. 2 is a sectional view taken on the line 2—2 of Fig. 1, and with the main door included in the assembly;

Fig. 3 is an enlarged perspective view from the rear of the refrigerator inner tank structure, certain portions being broken away for the sake of clarity in illustration;

Fig. 4 is an enlarged sectional view taken on the line 4—4 of Fig. 1;

Fig. 5 is an enlarged sectional view taken on the line 5—5 of Fig. 2; and

Fig. 6 is an enlarged sectional illustration of a detail of the construction.

In Figs. 1 and 2 of the drawings, there is illustrated a domestic refrigerator of the mechanical type which includes an outer shell, an inner metal shell or liner member providing the main food storage space, indicated generally at 5. This space 5 is fitted with a plurality of shelves, of any desired type. Vertical and horizontal breaker strips 7 and 8, respectively, of low thermal conductivity, are fitted around the forward marginal edge of the cabinet opening, while thermal insulation, portions of which are indicated at 9, completely surrounds the inner liner member 4 as well as the outside surfaces of the cooling means presently to be described. The cabinet is provided with a door 16, said door being adapted to seat thereagainst in the plane...
of the breaker strips 7 and 8, as illustrated in Fig. 2.

A machinery compartment 11 is located in the lower portion of the cabinet structure, which compartment houses the compressor unit indicated generally at f2. The main, sharp-freezing evaporator storage section is shown at 13 and includes, generally, a relatively large well-type storage section 14, in which access may be had through a door 15, and a smaller ice-freezing space indicated at 16. This evaporator may be supported within the refrigerator in any convenient manner, as for example, by welding its outer vertical walls to an inturned flange formed about the lower edges of the inner liner 4. Certain features of the particular evaporator illustrated, are disclosed and claimed in the pending application of Donald E. Dailey, Serial No. 515,950, filed December 28, 1943, and as such features, per se, form no part of the present invention, detailed description thereof is not deemed necessary.

In the embodiment illustrated, and as best seen in Figs. 2 and 4, a double-thickness insulating partition 17 provides the floor for the main storage compartment 13, a partition being interposed between the main evaporator sections and the storage compartment 8, in order to make it possible to operate said compartment at relatively high temperatures as compared with the temperature of the evaporator sections 14 and 16, and to prevent the undesired frosting-out of moisture present in said compartment 8. As clearly appears in Fig. 4, gasket members 18 surround the partition 17, said gaskets being interposed between the partition members and the adjacent wall portions of the inner liner 4.

Referring to Fig. 3, it will be seen that the main food storage section 8 is cooled, primarily, by means of tubing 18 secured in convoluted arrangement about the exterior surface of the inner liner, and constituting the evaporator portion of a secondary refrigerant circuit of known type. Condensation of the secondary liquid is effected by means of heat exchange association between the secondary tubing and a small evaporator 28, which constitutes a series-connected portion of the primary circuit utilized to effect refrigeration of the sharp-freezing compartments 14 and 16. A detailed description of this portion of the apparatus is not necessary herein, since the invention is not concerned therewith.

Another form of primary refrigerant circuit may be employed, there has been illustrated an arrangement in which (referring to Figs. 1 to 3) the liquid refrigerant formed in the condenser 21 is delivered to a central shelf 22, in the ice freezing compartment, said delivery being effected through a capillary tube 23 arranged in heat exchange relation with the suction line 24. From the entry point 23a, the volatile refrigerant is delivered to passages 26 arranged about evaporator storage section 13, after which it flows through a lower pass of tubing 28 (see Fig. 4) and is delivered to the small auxiliary evaporator element 20 by means of an upwardly extending conduit 27. After being passed in heat exchange relation with the refrigerant of the evaporator, the refrigerant may be returned to the compressor unit through the downwardly extending suction conduit shown at 24 in Figs. 1 and 3. It should be observed that the lower pass of tubing 28, referred to above, is arranged in close proximity to an airflow passage 29, to be described in greater detail hereinafter.

It is assumed, of course, that the primary circuit will have a capacity which is more than sufficient to meet the maximum heat load condition which may be encountered in practice, during the different cycles of operation presently to be described.

It should be borne in mind that the invention is particularly concerned with an arrangement in which the major portion of the cooling of the main food storage compartment 8 is accomplished through the medium of the secondary tubing 18; while additional heat transfer capacity is provided and the elimination of undesired humidity from said compartment is accomplished by effecting periodic circulation of compartment air through the several ducts appearing in Fig. 3, and thence into the passage 28 arranged in heat exchange relation with the primary evaporator tubing 25. At this point, there is a transfer of latent heat from the moisture-laden air to the low temperature tubing 28 and, consequently, some of the moisture is condensed upon the surrounding surfaces. Following this, the air whose absolute humidity has now been substantially decreased, is re-injected into the food storage compartment, and, combining with the primary refrigerant, further induces a cooling and drying effect on the moisture until the desired equilibrium condition is reached to lower the overall relative humidity therein. This circulation is effected, as and when required, by means of a motor 30 and associated fan 31 operable periodically in response to the humidity conditions existing in the compartment 8.

In the embodiment illustrated, this controlled circulation is initiated by a humidostat 32 (see Figs. 1 and 2) which may be of any desired type. Since the invention is not concerned with the particular humidostat employed, a description of the details thereof is not necessary herein. However, it will be understood that the humidostat is adapted to initiate operation of the motor 30 when the relative humidity in compartment 8 has risen to a point just above a predetermined value. Further, while humidostat control is preferably employed, it will be evident that it would be possible to effect refrigeration control by means of the air circulation fan by other means. For example, the motor 30 could be energized at periodic, timed intervals, in accordance with the humidity conditions found in practice in any particular locality. With such an embodiment, the device 32 should be understood to include an automatic timing device of any desired known form. While such operation would not result in as high a degree of control of the relative humidity as can be obtained by the use of a humidostat, it would be possible to prevent the existence of undesirably high humidity conditions without causing the humidity in the refrigerator to drop below a desired minimum. This will be apparent from the fact that if, for example, the passage 28 is maintained at a mean temperature of 33° F., (which will create a condition of 100-per cent relative humidity at 33°, if condensation is occurring) the air would be re-injected into the compartment at approximately 22° relative humidity, at the 40° F. temperature preferably maintained in said compartment. It might, under certain circumstances be desirable to circulate the primary refrigerant, even if the conditions were not such that condensation would occur in the passage 28, and such circulation is also contemplated by the present invention.

Referring now with more particularity to the construction and operation of the air circulation apparatus, it will appear that the duct work, see for example the passage 29, preferably comprises
half-round tubing secured to the rear face of liner 4, by means of flanges 33, which may be bonded to said wall in any convenient manner. A horizontal air-withdrawal duct 36 extends across a substantial portion of the width of liner 4, in section 33, as appears clearly in Figs. 1 and 2. An aperture 38 is provided in the liner wall in registry with duct portion 34. A similar air injection duct 38 extends across the back of the upper portion of the liner member; the liner wall being apertured at 37 to permit penetration of air from said duct 38 into the food compartment 8.

Extending downwardly from the lower conduit 34, is a short connection duct 39 which, as may be seen from a comparison of Figs. 3 and 6, is in communication with a generally L-shaped saddle structure 42 secured in air-tight arrangement with section 16 of the primary evaporator, as by means of the flanges shown at 42a. As appears most clearly in Fig. 3, this saddle structure which defines the passage 16 is divided into inflow and outflow sections 18 and 19, respectively, by means of a partition member shown at 41. Reference to Figs. 3, 4 and 5 will show that the fan 31 is in communication with outflow section 49, while the downwardly extending duct 38 is in free communication with the inflow section 36.

The air flow is designated by arrows appearing in the drawings, from which it will be apparent that the air withdrawn from the compartment through duct 34, passes downwardly into the inflow section 36 of saddle structure 42, thence forwardly through said saddle structure, around the forward end of partition 41 (as before seen in Fig. 4) and thence through outflow portion 49 and the blower unit 31. From this point, the air is directed upwardly through the vertical passage 29, from whence it is delivered to duct 38 for re-injection into the main food storage compartment. As appears in Fig. 5, a plurality of fins 43 depend from the supporting plate 44, said fins serving to promote heat transfer between the passing air and the evaporator tubing 25.

When the fan is in operation, in response to a condition of excessive humidity in the compartment 5, the invention contemplates the maintenance of the temperature of air passing through the inflow and outflow channels at a temperature above the freezing point. This is desirable in order that the moisture condensed at this point will not be frozen and thereby restrict the passage area, and to this end, a sheet of insulating material 45 is preferably interposed between the tubing 25 and said inflow and outflow passages. As will now be evident, the moving air gives up a portion of its heat to the tubing 25, thereby reducing the temperature of said air below the dew point, and the resulting condensate flows to a sump or trap 46 formed in the rear portion of outflow section 49. From this sump the liquid is delivered through pipe 47 into a receptacle (not shown) associated with the compressor unit 12, in order that the condensate may be evaporated by the heat of said unit, and in addition, may provide cooling for the unit.

Under normal conditions of operation, i.e., when the relative humidity in compartment 5 is below a desired predetermined maximum, the fan 31 is not in operation and the storage compartment is cooled solely by the secondary tubing 19 arranged about the liner walls. Since sufficient tubing is used to present a large heat exchange surface, it is possible to maintain compartment 8 at relatively low temperatures, for example in the neighborhood of 38–40°F, without creating any frosting zones within the refrigerator. Dehydration of the foods within the compartment is, therefore, prevented.

However, should the humidity rise to an undesirably high value, which may occur very frequently in certain climates, the humidostat 32 will respond thereto and initiate operation of the motor 30 and its associated blower. The compartment air is then caused to circulate in heat exchange relation with the primary evaporator tubing 25 and is re-injected into the refrigerator; in the manner previously described, and shown by the air flow indications on the drawings.

This air circulation is continued until sufficient moisture has been removed in the passages of the saddle-like structure 42, to restore the desired percentage of relative humidity in compartment 5, at which time the humidostat will disconnect the motor circuit.

From the foregoing description, it will be understood that the invention provides a refrigerator having a novel and advantageous humidity control means.

It is particularly to be noted that the circulating air is cooled during the circulating process by an evaporator having heat transfer capacity additional to that tubing which is refrigerating the compartment through the walls thereof; thereby not only further cooling the compartment as a whole, but also reducing the air temperature with respect to that of the walls. This latter effect, as will now be understood, minimizes the tendency of the free moisture to deposit upon said walls.

Further, this humidity control is effected without attendant undesirable frosting, and by an arrangement which lends itself well to the usage of a plurality of zones maintained at temperatures varying in accordance with the demands of the various foodstuffs to be refrigerated.

I claim:

1. In a refrigerator having a walled portion defining a high humidity food storage compartment, first cooling means in heat exchange relation with walls of the compartment and adapted to maintain said compartment at non-frosting temperatures, second cooling means providing heat transfer capacity in addition to that provided by said first cooling means, and means responsive to humidity condition within said compartment for effecting intermittent forced circulation of the compartment air in heat exchange relation with said second cooling means to condense moisture from said air and to cause the temperature of the air in said compartment to approach that of the walls thereof.

2. In a refrigerator having a walled portion defining a high humidity food storage compartment, first cooling means in heat exchange relation with walls of the compartment and comprising a volatile refrigerant system adapted to maintain said compartment at non-frosting temperatures, second cooling means comprising a volatile refrigerant system providing heat transfer capacity in addition to that provided by said first cooling means, and means for effecting controlled forced circulation of the compartment air in heat exchange relation with said second cooling means.

3. In a refrigerator having a walled portion defining a high humidity food storage compart-
a secondary refrigeration system including an evaporator in heat exchange relation with walls of the compartment and adapted to maintain said compartment at non-frosting temperatures, a primary refrigeration system having a portion thereof arranged in heat exchange relation with a portion of said secondary system, said primary system including an evaporator having an airflow passage in heat exchange relation therewith, and means responsive to humidity condition within said compartment for effecting intermittent forced circulation of the compartment air through said passage in heat exchange relation with said primary evaporator to condense moisture from said air and to cause the temperature of the air in said compartment to approach that of the walls thereof.

4. A construction in accordance with claim 3, wherein said last means is responsive to an increase in relative humidity above a predetermined value and is adapted to maintain said circulation until the relative humidity is reduced to said predetermined value.

5. In a refrigerator having a walled portion defining a high humidity food storage compartment, a secondary refrigeration system including an evaporator in heat exchange relation with walls of the compartment and adapted to maintain said compartment at non-frosting temperatures, a primary refrigeration system having a portion thereof arranged in heat exchange relation with a portion of said secondary system, said primary system including an evaporator having an airflow passage in heat exchange relation therewith, means responsive to humidity condition within said compartment for effecting intermittent forced circulation of the compartment air through said passage in heat exchange relation with said primary evaporator to condense moisture from said air and to cause the temperature of the air in said compartment to approach that of the walls thereof, and means limiting the temperature reduction effected in said passage to a value above the freezing point of water.

6. In a refrigerator having a walled portion defining a high humidity food storage compartment, first cooling means in heat exchange relation with walls of the compartment and comprising a volatile refrigerant system adapted to maintain said compartment at non-frosting temperatures, second cooling means comprising a volatile refrigerant system including an evaporator adapted to operate at temperatures below those prevailing in said compartment and having an airflow passage in heat exchange relation therewith, means responsive to humidity condition within said compartment for effecting intermittent forced circulation of the compartment air through said passage in heat exchange relation with said evaporator to condense moisture from said air and to cause the temperature of the air in said compartment to approach that of the walls thereof, and means limiting the temperature reduction effected in said passage to a value above the freezing point of water.

7. In a refrigerator having a walled portion defining a high humidity food storage compartment, first cooling means in heat exchange relation with walls of the compartment and comprising a volatile refrigerant system adapted to maintain said compartment at non-frosting temperatures, second cooling means comprising a volatile refrigerant system including an evaporator adapted to operate at temperatures below those prevailing in said compartment and having an airflow passage in heat exchange relation therewith, means responsive to humidity condition within said compartment for effecting intermittent forced circulation of the compartment air through said passage in heat exchange relation with said evaporator to condense moisture from said air and to cause the temperature of the air in said compartment to approach that of the walls thereof, and means limiting the temperature reduction effected in said passage to a value above the freezing point of water.

8. A refrigerator comprising a plurality of refrigerated zones, one of which is adapted to be maintained at a condition of high relative humidity, cooling means comprising a volatile refrigerant evaporator adapted to maintain said one zone at a non-frosting temperature and creating within the zone an area maintained at a temperature below that of the air in said zone, cooling means comprising a volatile refrigerant evaporator adapted to operate at a temperature below that prevailing at any location in said one zone, and arranged to cool another of said zones, means for effecting forced circulation of air from said one zone in heat exchange relation with said second-mentioned cooling means, and means for controlling the operation of said air circulating means said last means being adapted to initiate operation of said air circulating means upon the relative humidity in said one zone exceeding a predetermined value.

9. A construction in accordance with claim 8, in which said second-mentioned cooling means is adapted to operate at a sub-freezing temperature and in which construction there is included an airflow passage in heat exchange relation with said second-mentioned cooling means through which the circulating air is passed, the arrangement of said air evaporator characterized in that the heat exchange relation between said passage and said cooling means is such as to limit reduction of the air temperature to a value above the freezing point of water.

MALCOLM G. SHOEMAKER.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

<table>
<thead>
<tr>
<th>Number</th>
<th>Name</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,188,526</td>
<td>Bur Jen</td>
<td>Jan. 30, 1940</td>
</tr>
<tr>
<td>2,244,900</td>
<td>Starr</td>
<td>June 14, 1941</td>
</tr>
<tr>
<td>2,187,442</td>
<td>Alsing</td>
<td>July 25, 1939</td>
</tr>
<tr>
<td>2,068,606</td>
<td>Horlacher</td>
<td>Aug. 30, 1938</td>
</tr>
<tr>
<td>2,182,850</td>
<td>Philipp</td>
<td>Aug. 30, 1938</td>
</tr>
<tr>
<td>2,236,190</td>
<td>Wolfert</td>
<td>Mar. 5, 1940</td>
</tr>
<tr>
<td>2,132,865</td>
<td>McCloy</td>
<td>Oct. 25, 1938</td>
</tr>
<tr>
<td>2,068,435</td>
<td>Rutishauser</td>
<td>Jan. 19, 1937</td>
</tr>
<tr>
<td>1,979,142</td>
<td>Cowan</td>
<td>Dec. 29, 1934</td>
</tr>
<tr>
<td>2,068,604</td>
<td>Miller</td>
<td>Oct. 30, 1934</td>
</tr>
<tr>
<td>2,363,447</td>
<td>Siedle</td>
<td>Nov. 21, 1944</td>
</tr>
<tr>
<td>2,319,522</td>
<td>Schweller</td>
<td>May 18, 1943</td>
</tr>
</tbody>
</table>