

[54] **APPARATUS FOR DRYING MATERIALS**

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[51] Int. Cl. **F26b 21/06**

[58] Field of Search **34/40, 73, 92, 175, 34/177; 165/163; 62/331, 169, 170, 268, 270**

[56] **References Cited**

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Primary Examiner—Kenneth W. Sprague

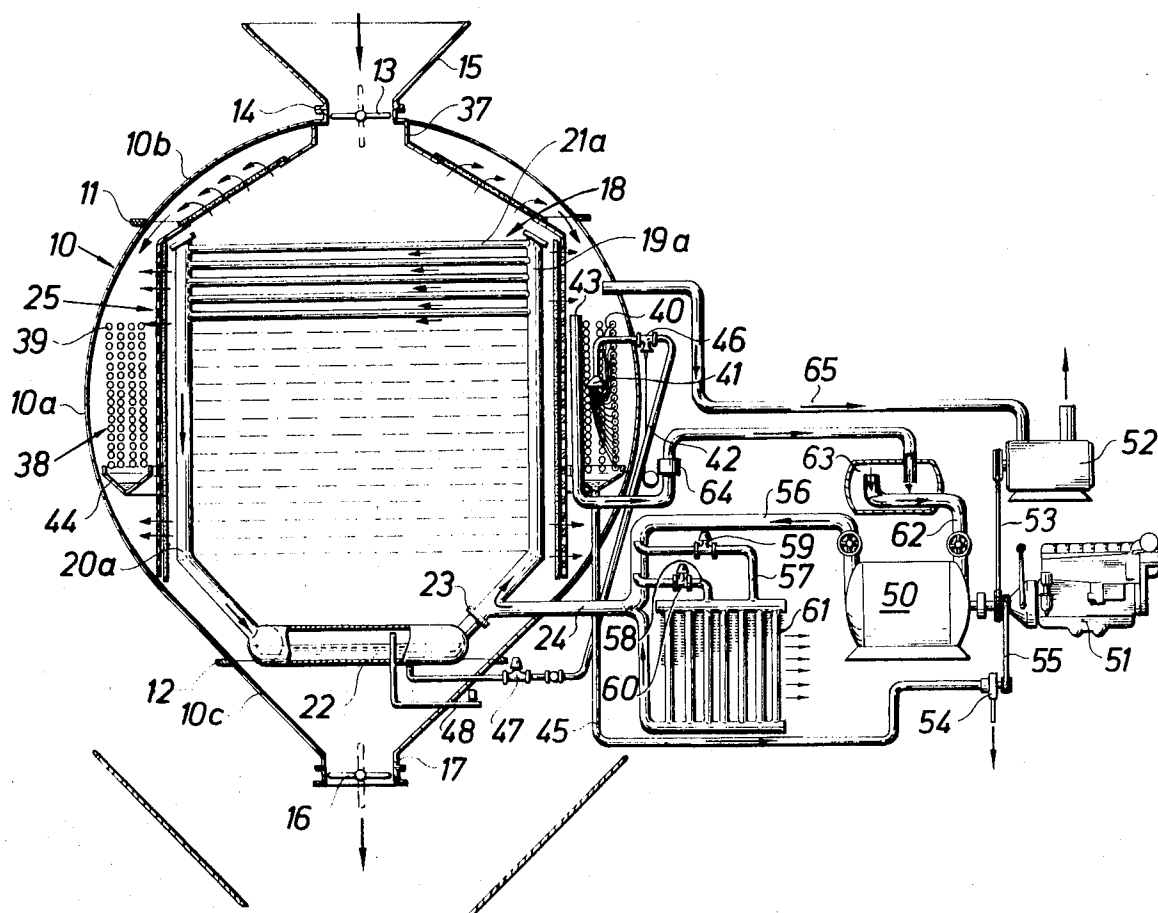
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[57] **ABSTRACT**

A drying apparatus comprising a sealable container is provided with a refrigerant circulating system having a condenser and an evaporator for the refrigerant which are both arranged in the container but are separated from each other by a gas permeable wall defining a space for the material to be dried the condenser being disposed in said space.

14 Claims, 4 Drawing Figures



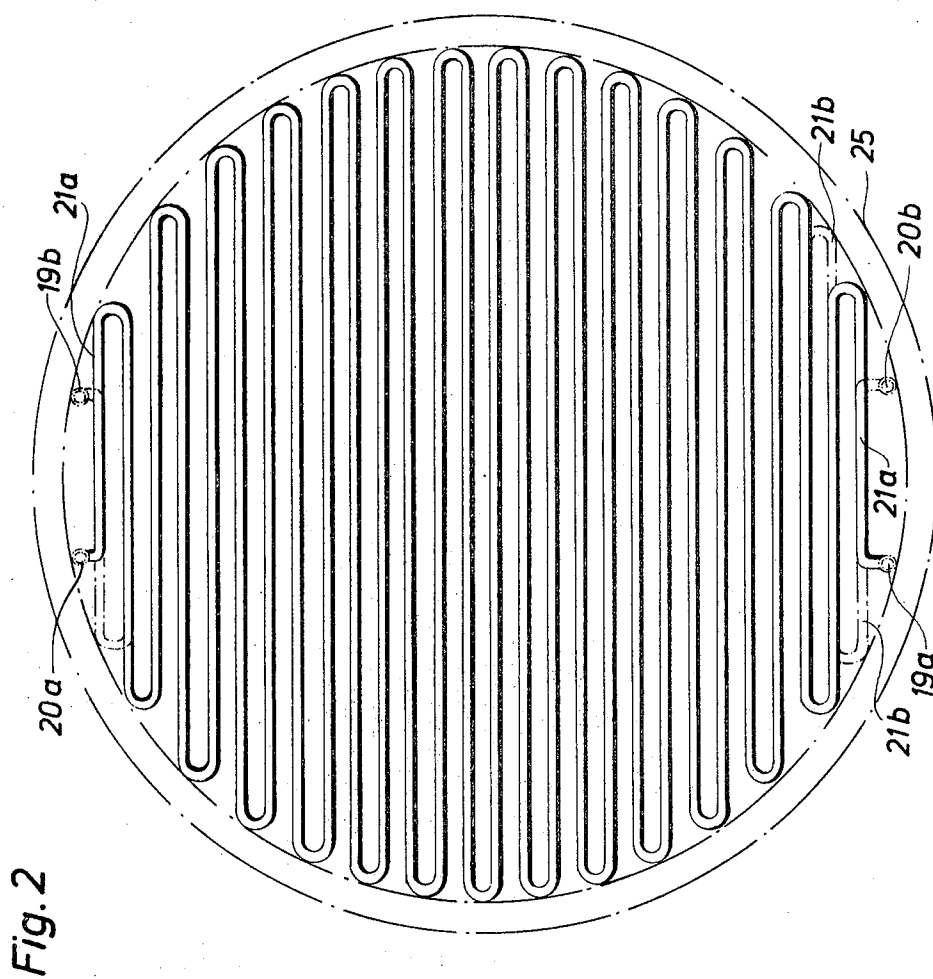


Fig. 3

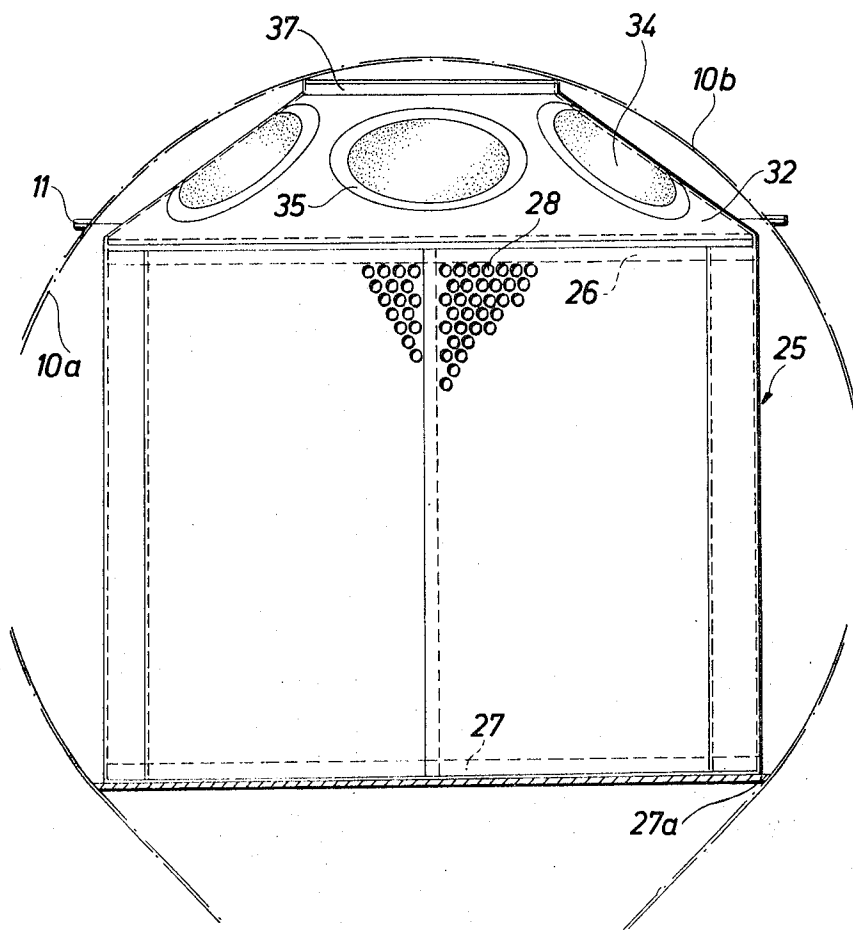
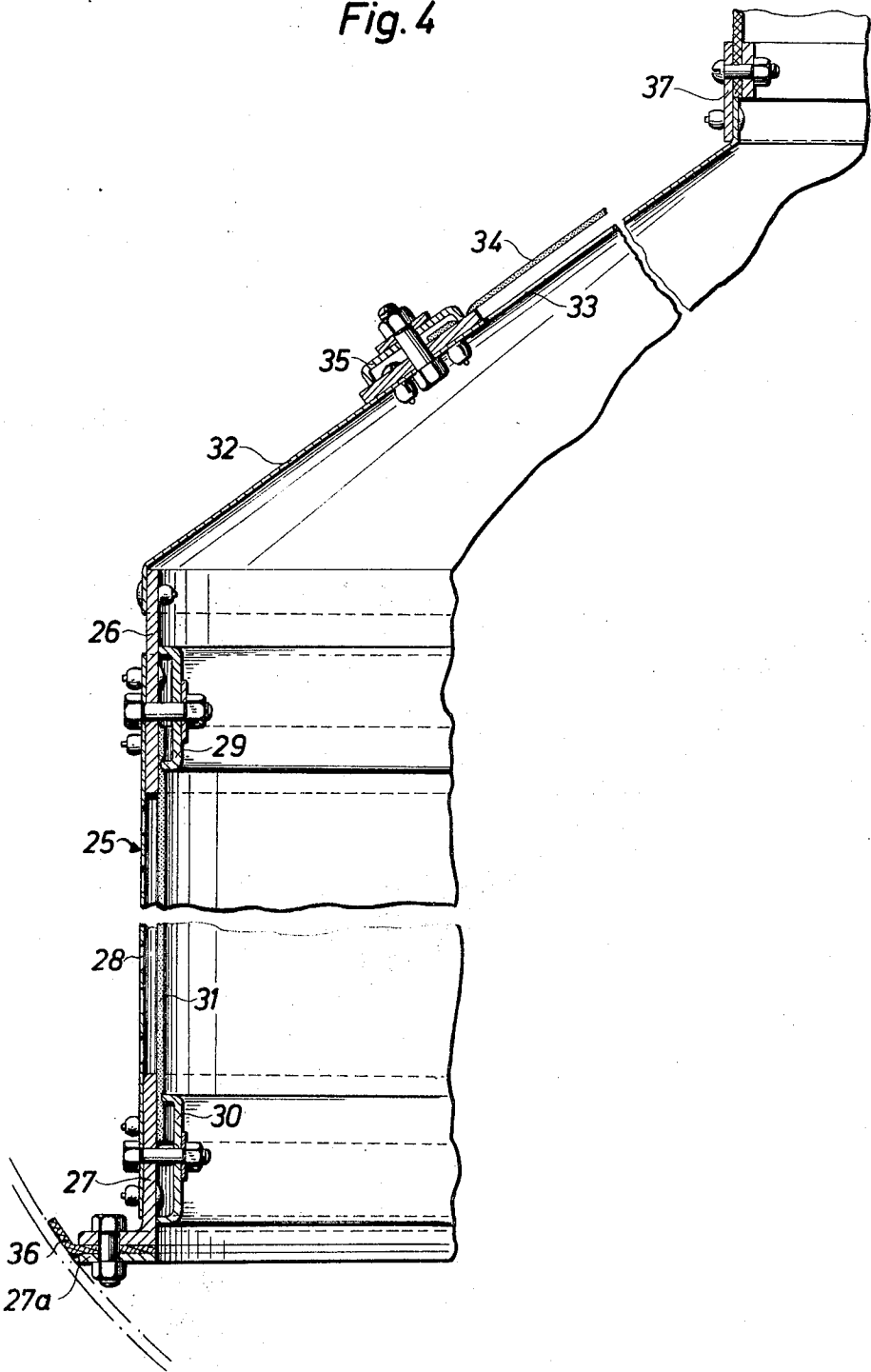


Fig. 4



APPARATUS FOR DRYING MATERIALS

The present invention relates to an apparatus for drying materials such as vegetables, berries, seeds, and corn or grain.

A prior art drying apparatus of this kind comprises a sealable container for the material to be dried, means for exhausting air from the container, and a closed system including a compressor for pumping a refrigerant through said system, a condenser disposed in said container and operating as a heater for the refrigerant in said system, and an evaporator operating as cooler for moisture boiled off from the material being dried.

In the drying apparatus previously known the evaporator operating as a cooler for moisture boiled off from the material is disposed in a conduit connecting the container for the material to be dried with an exhauster. In this case the steam boiled off from the material during the heating thereof will pass through said conduit to the cooler in which the steam is transferred to the liquid phase by condensation, the liquid thus formed then being removed by the exhauster. Since the steam quantities boiled off from the material to be dried are very large — the steam flow from for instance five tons of corn or grain may be of the order of 35.3×10^4 cubic feet per hour (10,000 m³ per hour) when the evaporation heat is supplied at a temperature of the material to be dried of 68°F (20°C) — the arrangement in the drying apparatus previously known involves substantial flow losses between the container for the material to be dried and the cooler for boiled off moisture that is detrimental to the capacity of the drying apparatus.

An object of the invention is to provide a drying apparatus of the kind referred to above facilitating a greater efficiency of the drying process and at the same time providing an apparatus of a more compact form than that of the prior art, such a compact form involving considerable structural advantages as well as an easy installation of the apparatus.

According to the invention this object and others are achieved in a drying apparatus of the kind referred to characterized in that said evaporator for the refrigerant is disposed in said container separated from the condenser also disposed therein by a gas permeable wall arranged in the container and defining the space for the material to be dried.

An embodiment of the drying apparatus according to the invention now will be described in greater detail by way of example with reference to the accompanying drawings.

In the drawings

FIG. 1 is a diagrammatic view of the drying apparatus according to the invention showing the container for the material to be dried in a vertical sectional view as well as components connected therewith and forming part of the refrigerating system;

FIG. 2 is a cross-sectional view of the container for the material to be dried;

FIG. 3 is a side view of a casing arranged in the container for the material to be dried and enclosing the space for such material; and

FIG. 4 is an enlarged fragmentary vertical sectional view of said casing.

The drying apparatus disclosed in the drawings comprises a metal sheet container 10 of substantially spherical form composed by an intermediate part 10a, an

upper cap 10b connected with said intermediate part 10a at a flange connection 11, and a conical bottom part 10c connected with the intermediate part 10a at a flange connection 12. Container 10 has at the top thereof an inlet socket 14 controlled by a valve 13, a supply hopper 15 being connected with such inlet socket. The conical bottom part 10c is provided with an outlet socket 17 controlled by a valve 16. In container 10 there is provided a pipe system 18 including two ascending pipes 19a and 20a and a number of looped pipes 21a connected at their ends to said ascending pipes and arranged in horizontal planes one over the other to form a number of pipe levels. Pipe system 18 comprises two further ascending pipes 19b and 20b as will be seen in FIG. 2, and looped pipes 21b arranged between such ascending pipes said looped pipes being indicated by dash and dot lines in FIG. 2. Looped pipes 21b alternate with looped pipes 21a. However, they have been omitted from FIG. 1 in order not to make this Figure obscure. Ascending pipes 19a and 20b are disposed at the diametrically opposite side of the container in relation to ascending pipes 19b and 20a as will be seen in FIG. 2. All ascending pipes are connected at the lower end thereof to a recipient 22 but there is provided communication between ascending pipes 20a, 20b and the interior of recipient 22, only, the communication between ascending pipes 19a, 19b and the interior of recipient 22 being interrupted as will be seen at 23 in FIG. 1 as far as ascending pipe 19a is concerned. At their lower ends ascending pipes 19a and 19b communicate with a supply pipe 24 extended from container 10 said pipe being connected with the refrigerant circulation system provided in the apparatus as will be described later.

Pipe system 18 thus provided is enclosed in a casing 25 which is introduced as a pre-fabricated unit into container 10 through the opening provided by removing cap 10b from the intermediate part 10a. The construction of the casing 25 is shown in greater detail in FIGS. 3 and 4. It comprises a cylindrical wall 28 of perforated metal sheet having stiffening or rigidifying rings 26 and 27, respectively, at top and bottom. The perforations of the cylindrical wall 28 are covered on the inner side thereof by a filter cloth 31 of needle felt, preferably of a synthetic textile material such as polyester fibre, said cloth being attached to rings 26 and 27 by clamping means 29 and 30. At the top thereof the cylindrical wall 28 is connected to a frusto-conical wall 32 providing a number of large openings 33 covered by filter cloth 34 of the same kind as filter cloth 31, filter cloth 34 being attached to wall 32 on the outer side thereof by clamping means of the same construction as clamping means 29 and 30 as is shown at 35. The cylindrical wall 28 rests at the lower end thereof against the inner surface of the intermediate part 10a by means of an outwardly projecting flange 27a formed on ring 27, a sealing element 36 of flexible sealing material attached to said flange sealingly engaging the inner surface of the wall of the container. At the top the cylindrical wall 28 connects to inlet socket 14 by means of a socket 37. Thus, it will be seen that casing 25 defines a space in container 10 adapted to receive the material to be dried and connecting to inlet socket 14 and outlet socket 17. Pipe system 18 is provided in this space looped pipes 21a, 21b extending at several levels through the space.

A second pipe system 38 is provided in the space between the outside of casing 25 and the inside of the intermediate part 10a, and this pipe system comprises a number of coiled pipes 39 arranged at different levels and each connected at one end thereof by a small capillary tube 40 to a distributor 41 provided on a pipe 42 the other end of said coiled pipes being connected to a common manifold 43. Below pipe system 38 there is provided an annular collecting bowl 44 having a drain pipe 45. Pipe 42 connects distributor 41 with recipient 22 and communicates with the recipient at the bottom thereof. In pipe 42 there is provided an expansion valve 46 as well as a solenoid valve 47. Recipient 22 is provided with an overflow pipe 48 extended from container 10.

To the elements provided in the container for the material to be dried there is connected said system for circulating a refrigerant. Such refrigerant may comprise R22 or other conventional refrigerant. The system comprises as a main component thereof a cooling compressor 50 of a known type having automatic capacity control included therein, and this compressor is connected directly to a drive motor 51 shown as an internal combustion engine such as a diesel engine although such drive motor may comprise any suitable power source. To drive motor 51 there is connected also an exhauster 52 which is driven by the motor over a V-belt transmission 53, and a water pump 54 which is driven over a V-belt transmission 55. The pressure pipe 56 of the compressor is connected to supply pipe 24. However, from pipe 24 are branched two pipes 57 and 58 each having a solenoid valve 59 and 60, respectively. Pipes 57 and 58 connect with the inlet of a heat exchanger 61, the outlet thereof being connected to supply pipe 24. When both solenoid valves are closed the total flow of refrigerant passes through pipe 56 directly to supply pipe 24. However, more or less of the refrigerant flow may be passed through heat exchanger 61 to supply pipe 24 by opening one or both of valves 59 and 60. Heat exchanger 61 may be of the type having a number of parallel flanged pipes for heat exchange between the refrigerant passing through the heat exchanger and the surrounding air; if necessary air may be forced through the heat exchanger by means of a fan. The suction pipe 62 of compressor 50 is connected to manifold 43 through a liquid trap 63 said manifold having a sensing body 64 operatively connected with expansion valve 46 to control such valve in dependence of the temperature of the refrigerant flowing through manifold 43.

Exhauster 52 is connected to the interior of container 10 by a pipe 65 to exhaust initially air from the container and to maintain therein a predetermined underpressure in relation to the surrounding atmosphere. If container 10 could be made absolutely gas proof which, however, is not possible in connection with an economic manufacture in a commercial scale, exhauster 52 could be stopped when the predetermined underpressure has been reached in the container.

In the circulation system thus described the refrigerant is compressed in the vapor phase by compressor 50 and delivered through pipe 56 to supply pipe 24 a major or minor part of the refrigerant passing through heat exchanger 61. From supply pipe 24 the compressed refrigerant will be supplied to ascending pipes 19a and 19b to be distributed therefrom to looped pipes 21a and 21b arranged at different levels.

Thereby, the refrigerant heated by the compression will heat the material to be dried which has been introduced into container 10 in the space surrounded by casing 25, uniform heating of such material will be obtained due to the fact that the refrigerant is supplied to looped pipes 21a and 21b, respectively, from diametrically opposite sides. Said loops should have a diameter sufficiently large to allow the liquid condensed therein during the heat exchange with the material to be dried, to occupy a relatively small part of the cross-sectional area of such pipes, and excellent heat exchange between the refrigerant and the material thereby being obtained. The refrigerant passes from the looped pipes through ascending pipes 20a and 20b, respectively, as a condensate which collects in recipient 22. This condensate leaves the recipient through solenoid valve 47 in pipe 42 said solenoid valve being open when the apparatus is operated, and arrives at expansion valve 46 to be distributed to the coiled pipes 39 by means of distributor 41 and capillary tubes 40. The condensed refrigerant expanding in pipes 39 takes up the evaporation heat and will change to the vapor phase, the evaporated refrigerant then being sucked up by compressor 50 through manifold 43, liquid trap 63, and suction pipe 62 to be recompressed and resupplied to pipe system 18. Since expansion valve 46 is thermostatically controlled in dependence of the temperature of the refrigerant in the vapor phase, passing to suction pipe 62 of the compressor liquid shock in the circulation system will be prevented.

Thus, it will be seen that pipe system 18 operates as a condenser in the refrigerant circulation system, pipe system 38 operating as an evaporator. When heat is supplied to the material to be dried by means of the hot refrigerant circulating through the condenser, moisture is boiled off from such material as steam and this steam passes out of casing 25 through filter cloth 31 and perforated metal sheet 28 and through openings 33 and filter cloth 34 to be received directly by the space in the container defined between the container wall and casing 25. In this space the steam is condensed on the evaporator formed by pipe system 38 which is held at a low temperature by the evaporation of the refrigerant in this pipe system the refrigerant thereby taking up the evaporation heat. The condensed water is collected in bowl 44, and water pump 54 is connected to said bowl by means of pipe 45 to remove continuously the condensed water from the bowl. This pump is of the "sealed" type for instance an impeller pump which is able to operate against the underpressure in container 10.

When the refrigerant is compressed, energy is supplied thereto as frictional heat and the object of heat exchanger 61 is to remove from the refrigerant the energy thus supplied before the refrigerant is delivered to the condenser. In this manner there may be maintained during the drying process a balance between the steam condensing energy and the evaporation heat supplied and, thereby, it is possible to limit the heat transfer through the refrigerant circulation system to the heat quantity necessary for the evaporation of the moisture in the material to be dried without raising the temperature of such material. A temperature rise could be detrimental for the quality of the material. Thus, the moisture contained in the material to be dried is removed by causing such moisture to boil at an underpressure at which the boiling temperature of water is substantially

lower than the boiling temperature of water at atmospheric pressure and has a value which does not involve a detrimental raise of the temperature of the material to be dried.

What I claim is:

1. Apparatus for drying materials comprising:
a sealable container for the material to be dried;
means for reducing the pressure in said container by exhausting air therefrom;
a closed pipe system including a heat pump having a compressor for pumping a refrigerant through said system, a condenser for the refrigerant arranged as a heating element in said container and connected with said system, and an evaporator arranged in the container as a cooler for moisture boiled off from the material being dried; and
a gas permeable wall defining first and second spaces in the container, the material to be dried being located in one of said spaces in the container and said evaporator being disposed in the other of said spaces.
2. Apparatus as claimed in claim 1 in which said condenser for the refrigerant is surrounded by said evaporator.
3. Apparatus as claimed in claim 1 in which said condenser for the refrigerant comprises two ascending pipes and a number of loops connected therewith at different levels, each loop having one end connected with one of said ascending pipes the other end being connected with the other ascending pipe.
4. Apparatus as claimed in claim 3 in which two further ascending pipes are provided together with loops connected therewith, the loops connected with one pair of ascending pipes alternating with loops connected with the other pair of ascending pipes.
5. Apparatus as claimed in claim 3 in which one of the two ascending pipes is connected with an inlet for refrigerant the other one being connected with a recipient for condensed refrigerant, the recipient being arranged below said loops.
6. Apparatus as claimed in claim 4 in which one pipe of each pair of ascending pipes is connected with an inlet for refrigerant, and the other pipe of each pair being connected with a recipient for condensed refrigerant, the recipient being arranged below said loops.
7. Apparatus as claimed in claim 1 in which the gas

permeable wall is arranged as a casing surrounding said condenser for the refrigerant.

8. Apparatus as claimed in claim 7 in which said gas permeable wall comprises a perforated metal sheet wall, the perforations of which are covered by filter cloth.

9. Apparatus as claimed in claim 7 in which said container is substantially spherical and is arranged to be separated in a horizontal plane above the horizontal diametrical plane, and in which said casing has a smaller outer dimension than the opening provided by separating said container in said horizontal plane.

10. Apparatus as claimed in claim 9 in which said casing has a cylindrical part, and a frusto-conical part connected to an inlet for said material to be dried.

11. Apparatus as claimed in claim 1 in which there is provided between said compressor and said condenser for the refrigerant a heat exchanger arranged outside the container.

12. Apparatus as claimed in claim 11 in which there are provided means for supplying only part of the refrigerant flow to the heat exchanger.

13. Apparatus as claimed in claim 1 in which in connection with the evaporator forming a cooler for the removed moisture, there is provided a collecting vessel for the condensate formed, and in which said vessel is connected to a drain pipe with a pump therein for removing said condensate from the container.

14. Apparatus for drying materials comprising:
a sealable container for the material to be dried;
means for reducing the pressure in said container by exhausting air therefrom;
a closed pipe system including a heat pump having a compressor for pumping a refrigerant through the system, a condenser for the refrigerant arranged as a heating element in the container and connected with the system, and a heat exchanger cooled by the evaporation of the refrigerant arranged in the container as a cooler for condensing moisture boiled off from the material being dried; and
a gas permeable wall defining first and second spaces in the container, the material to be dried being located in one of said spaces in the container and the heat exchanger being disposed in the other of said spaces.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,762,065 Dated October 2, 1973

Inventor(s) LARS OSTEN WAHLGREN

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

Column 6, line 43, after "cated" delete "is" and substitute therefor --in--.

Signed and sealed this 25th day of December 1973.

(SEAL)
Attest:

EDWARD M. FLETCHER, JR.
Attesting Officer

RENE D. TEGTMEYER
Acting Commissioner of Patents