Feb. 15, 1966 W. NERGE 3,234,661

CONTROLLED MULTIPRESSURE DRYING APPARATUS

Filed Jan. 19, 1962 2 Sheets-Sheet 1

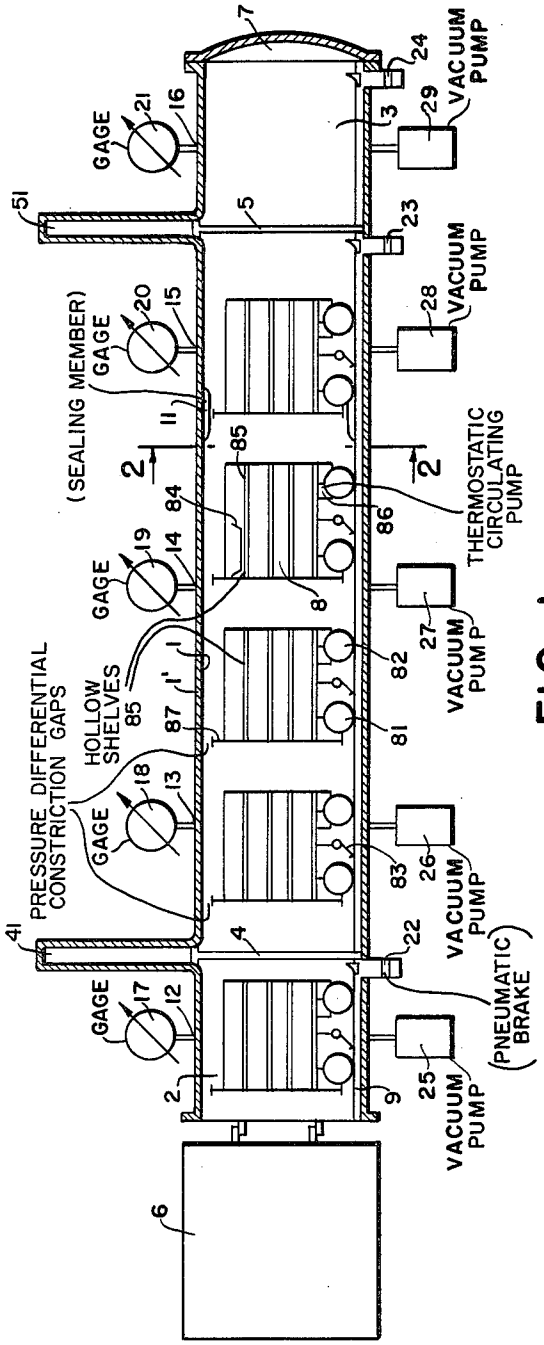


FIG. 1.

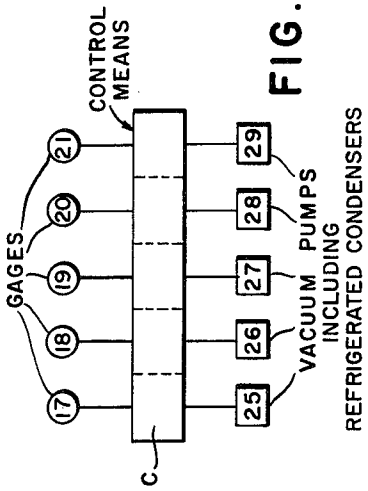


FIG. 5.

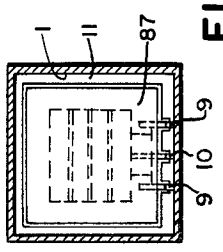


FIG. 2.

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CONTROLLED MULTIPRESSURE DRYING APPARATUS

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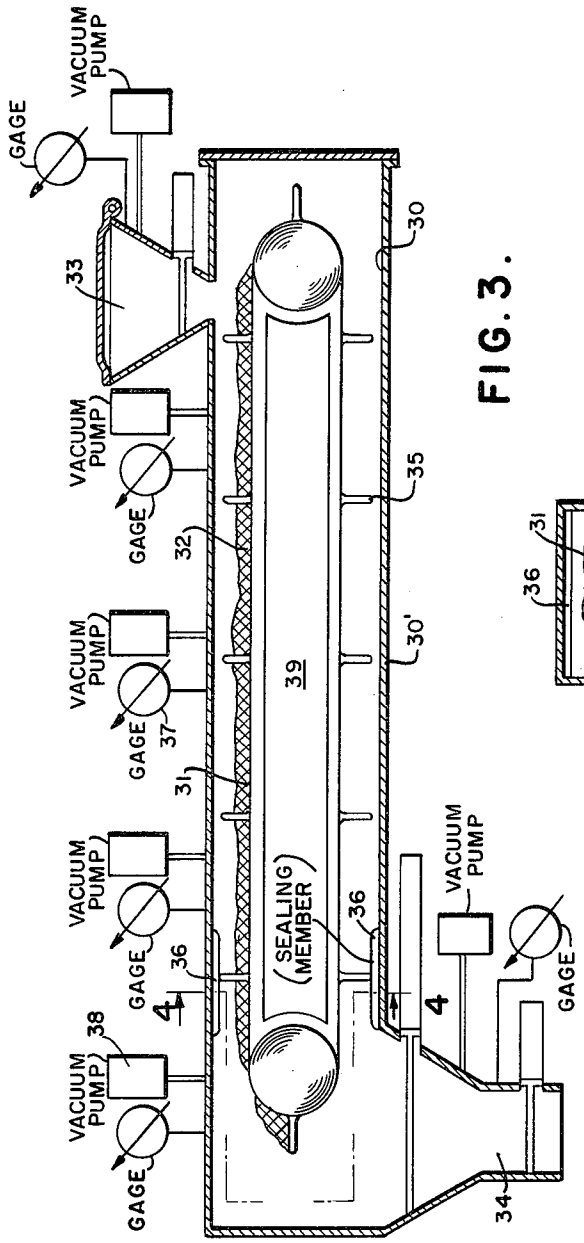


FIG. 3.

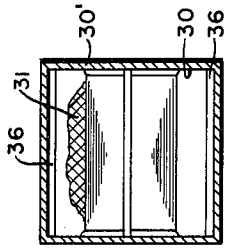


FIG. 4.

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CONTROLLED MULTIPRESSURE DRYING APPARATUS

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5 Claims. (Cl. 34—48)

The present invention relates generally to vacuum freeze drying, and, more particularly, to the continuous vacuum freeze drying of substances which pass through a tubular vacuum freeze drying chamber having at least two compartments which are at least partially sealed or sealable with respect to each other.

Process controls for such processes are already known for following or surveying the progressive drying of the goods. This is accomplished by keeping the course or progress of the vacuum freeze drying process under surveillance by periodically, and for fixed periods of time, completely sealing the vacuum freeze drying chamber from the evacuating means and ascertaining the pressure increase which is obtained at the end of the period during which sealing has taken place. By using this method, an accurate picture of the drying state of all of the goods in the apparatus may be obtained according to an integral value, and thus substantial progress has been achieved as compared to prior measuring processes wherein the state of only one or several representative samples is checked, for example, by using thermocouples.

When an attempt is made to carry out continuous vacuum freeze drying processes on a large industrial scale, considerable difficulties are encountered in adapting for this purpose the above-described advantageous integral method for determining the drying state of the goods. These difficulties are mostly due to the required arrangement and control of the sealing members which must bring about a momentary complete sealing of the vacuum drying chamber, or of an appropriately sealable compartment formed by a portion of the entire vacuum drying chamber.

With these defects of the prior art in mind, it is a main object of the present invention to provide an improved device for continuous vacuum freeze drying which obviates the problems encountered by prior apparatus.

Another object of this invention is to provide apparatus of the type described wherein a simple arrangement of the sealing means which are necessary is provided, and thus the difficulties which were previously present in using continuous vacuum freeze drying processes are eliminated.

A further object of this invention is to provide freeze drying apparatus wherein the known method for determining the drying state of the goods in the apparatus from the pressure increase, may be used even under the unique conditions imposed by large scale industrial applications thereof.

These objects and others ancillary thereto are accomplished according to preferred embodiments of the invention, wherein a tubular vacuum drying chamber is provided in apparatus which may be used in a process for continuous vacuum freeze drying of substances, which substances are passed through this chamber. The chamber is provided with at least two partial chambers or compartments which may be substantially or at least partially sealed from one another. The goods are preferably placed in transporting means. The continuous vacuum freeze drying process is carried out under continuous program control wherein the velocity of the goods being transported through any compartment is such that

at predetermined measuring points of these compartments, predetermined pressure or temperature values are maintained by the evacuating means and heat exchange means.

In this process, instead of the previously required sealing time of the vacuum drying chamber, there is a residence time or time which the goods inserted in the apparatus must remain in the individual compartments. This period of time is dependent upon the velocity of the goods which are conveyed through the chamber. If at least a substantial amount of, or partial, sealing is achieved, then the pressure increase at a definite measuring point within the compartment represents an indication of the progress of the drying of the goods. By making appropriate tests, pressure values may be obtained or ascertained which are coordinated with the desired orderly procedure of the vacuum freeze drying process at measuring points along the vacuum drying chamber.

Thus, in the practical application of this process, there is only need for maintaining these previously ascertained pressure values constant. This may be accomplished by appropriate control of the evacuating means or heat exchange means, respectively, which communicate with each compartment. This invention provides a substantial simplification of the previously required apparatus and reduces the expense thereof, in particular eliminating the expensive sealing means as well as the switching device for the periodic actuation of these sealing means which was previously necessary.

As the containers which receive the goods inserted into the apparatus take up substantially the entire cross section of the vacuum drying chamber, there is thus a partial or substantial sealing effect between the individual compartments, without additional sealing means being necessary, which makes possible the formation of a pressure gradient from one compartment to the next. This may be enhanced by providing special sealing means in addition to those which are provided by the containers.

Additional objects and advantages of the present invention will become apparent upon consideration of the following description when taken in conjunction with the accompanying drawings in which:

FIGURE 1 is a diagrammatic longitudinal sectional view of one embodiment of the freeze drying apparatus according to the present invention.

FIGURE 2 is a lateral cross section of the apparatus of FIGURE 1 taken substantially along the plane defined by reference line 2—2 of FIGURE 1 and illustrating the sealing arrangement.

FIGURE 3 is a diagrammatic longitudinal sectional view of another embodiment of the invention.

FIGURE 4 is a cross section of the apparatus of FIGURE 3 illustrating the sealing arrangement, taken along line 4—4.

FIGURE 5 is a diagrammatic view illustrating one type of control arrangement which may be used.

In the present invention, there are conveying means for conveying the goods to be dried through the tubular vacuum freeze drying chamber. The conveying means include transport elements which take up a substantial amount of the cross section of the tubular chamber and thus provide a partial sealing between individual compartments which are formed thereby, which permits the formation of a pressure gradient between chambers. Thus, the process may be performed in a vacuum drying chamber which is not subdivided and one which is of considerable longitudinal length. Appropriately fixed pressure and/or temperature values are to be maintained at several measuring points which are distributed along the length of the drying chamber. However, it may be useful to increase the sealing effect of the cross section of the conveying means which include the transport elements

which may be designed as transfer cars or sections of a conveyor belt, by additional sealing means provided on the wall of the vacuum drying chamber or on the transport elements.

It has proven to be particularly advantageous to increase the cross section of the transfer cars, or at least some of them, with respect to the chamber by providing screen-like elements which are preferably arranged at a uniform distance. By this means, there is appropriate subdivision of the vacuum drying chamber into at least partially sealed compartments defined by the screen-like elements, between which and the interior chamber wall a number of constriction gaps are formed. Thus, pressure differences may be formed in the individual partial chambers or compartments by using suitably adjusted evacuating means, which pressure differences may be kept under constant surveillance by appropriately arranged measuring instruments.

With more particular reference to the drawings, the embodiment of FIGURES 1 and 2 illustrates a tubular vacuum drying housing **1'** defining an internal chamber **1**. Inlet and outlet locks **2** and **3** are connected to the entrance and exit of the vacuum drying chamber **1**, respectively, and may be sealed from the chamber **1** by means of gate valves **4** and **5**. These valves are controlled by pneumatic cylinders **41** and **51**. The locks may be sealed from the atmosphere by entrance and exit gates **6** and **7**, respectively.

A plurality of transfer cars **8** are located interiorly of the vacuum drying chamber and are constructed with pairs of wheels **81** and **82** which are arranged to run along rails **9**, built into the chamber **1**. The wheel pair **81** is driven electrically and receives the necessary energy from a contact rail **10** from which the electric energy is derived by a current collector **83** and fed to a motor (not shown). Pneumatically operated brakes **22**, **23**, and **24** are disposed before the gate valves and the gates to safeguard the cars and prevent them from running into the gates.

The goods which are to be vacuum freeze dried are deposited into containers or receiving vessels **84** which are placed upon a plurality of carrier plates **85** on the cars **8**. These plates are disposed one above the other, and the vessels are disposed on the plates and in good heat conducting relationship therewith. The carrier plates **85** are formed as hollow chambers so that a heat transfer medium for heating or cooling purposes may be pumped therethrough by means of a thermostat control pump **86** which can be controlled to different temperatures. The thermostat means **86** are arranged on the car **8** and also receive energy necessary for their operation and for emitting the necessary control pulses by means of current collector **83**.

Construction disks **87** are provided on the cars **8** and conform to the cross section of the drying chamber and closely apporach the surface of the inner wall of vacuum chamber **1**, thereby to define constriction gaps between this wall and disks **87**. Sealing members **11** are arranged at least at one point on the surface of the wall to reduce the width of the constriction gap. When the constriction disks **87** of the cars **8** pass this point, the entire cross section is substantially sealed from one side of the car to the other.

Suitable pressure sensing elements **17**, **18**, **19**, **20** and **21** of known design are arranged along the vacuum chamber **1** and the locks **2** and **3** at measuring locations or points **12**, **13**, **14**, **15**, and **16**, respectively. These measuring or sensing elements may also be members comprising a portion of an electric control device which automatically controls and coordinates the evacuating means or heat exchange means in accordance with the measured values, to maintain the pressure values and/or the temperature values at a predetermined value according to a previously selected program. Such evacuating means suitable for removing water vapor and other gases are provided and are indicated at **25**, **26**, **27**, **28**, and **29** in FIGURE 1.

They may be designed, for example, in the form of condensers cooled to a low temperature and rotary vacuum pumps.

Another embodiment is illustrated in FIGURES 3 and 4. This embodiment differs in the means for conveying or transporting the goods which are to be subjected to the drying operation. The goods **31** which are to be dried are transported by means of a conveyor belt **32** which extends through a vacuum chamber **30** of a vacuum chamber housing **30'**. In this embodiment, also, inlet and outlet locks **33** and **34**, respectively, are provided. Constriction partitions **35** extend from conveyor belt **32** at longitudinally spaced locations therealong. These partitions perform the same function as the constriction disks **87** in the embodiment of FIGURE 1.

In this second embodiment, also, additional sealing means are provided in the form of a sealing member **36** arranged on the inner surface of the wall of chamber **30**, which substantially completely seals this section of the chamber from one side of the sealing means to the other. Measuring or sensing elements **37** and evacuating means **38** are also provided. In the section defining chamber **39** within the conveyor assembly, heating means are arranged for supplying the heat energy which is necessary for sublimation of the water vapor, i.e., sublimation of the ice into the water vapor state.

The operation of the freeze drying plant according to the present invention will now be described, particularly in connection with the embodiment of FIGURE 1, it being understood, however, that the embodiment of FIGURE 3 will operate in a similar manner.

The goods which are to be dried are usually frozen outside of the apparatus and are placed into the receiving vessels **84** on the cars **8**. If lumpy type goods are being processed where there is no fear of foaming, the freezing process may take place after the goods have been placed into the first sealable compartment or partial chamber section, for example, in chamber or lock **2**. The freezing will then be carried out by a sudden or rapid lowering of the pressure.

In a practical embodiment according to FIGURE 1, orange juice was dried by filling vessels **84** with juice, and freezing exteriorly of the chamber. This juice had a bulk density of about 0.6 kg. per liter. In this manner it was possible to accommodate about 40 kg. of goods to be dried on a car. There was room for 4×4 or 16 vessels **84** on a single car. In the particular example being considered the drying time amounted to 12.5 hours and the length of the chamber between the gate valves **4** and **5** was about 5 meters. The velocity of the goods to be dried was 0.4 meter per hour with the motion of the conveying means in the apparatus according to FIGURE 1 taking place in stepwise manner, while in the apparatus according to FIGURE 3 a continuous motion thereof is possible.

The pressure in the chamber at the measuring points **12** through **16** will depend upon the nature of the goods to be dried. In the case of orange juice the operation was carried out with the following pressures:

Measuring point:	Pressure, mm. Hg
13	$4 \cdot 10^{-1}$
14	$2 \cdot 10^{-1}$
15	$8 \cdot 10^{-2}$

The pressures in the inlet and outlet locks **2** and **3** are maintained at $1 \cdot 10^{-1}$ mm. Hg and $8 \cdot 10^{-2}$ mm. Hg, respectively. The relatively small pressure drop from point **13** to point **14** is necessary in order to allow for the diffusion coefficient which is increased through the already dried layer. The low pressure at point **15** is caused by the later drying and gradation of pressure is accomplished by use of sealing means on the wall.

It is possible to retain the pressure differences in the vacuum chamber **1** solely by the sealing effect of the cars and by the additional sealing means provided so that the

particular advantage of the present process is that further complicated valve devices and sealing structures within the chamber are not needed. According to the pressure values noted above, control of the evacuating means and/or of the heating means is accomplished and performed with the object of retaining the pressure and/or temperature values constant in the program, the temperature and pressure being interrelated by a well-known principle, the interrelation being readily obtainable by reference to appropriate steam tables.

When the desired degree of drying has been attained, the transfer cars **8** will finally leave the vacuum chamber **1** through outlet lock **3** and will be emptied and readied for renewed filling in the process which is a cyclic process.

The constriction gap depends on the pumping speed of the vacuum pumps and therefore it depends on the correctly dimensioned intake connection of such pumps. For the system in FIGURE 1 i.e. showing small vacuum pumps communicating with the vacuum chamber at spaced intervals therealong (**26**, **27**, **28**), it would be sufficient the constriction gap amounts to 10–20% of the intake port section.

If, however, the vacuum pumps **26** and **27** in FIGURE 1 are omitted and instead pump **28** is increased the section of the constriction gap should in relation to the intake section of the vacuum pump be larger (up to 100% and larger) so as to allow evacuation of the front portions of the vacuum chamber between vacuum pump **28** through the series connected constriction gaps.

The sealing members **11** and **36** on the interior walls of chambers **1** and **30**, respectively, may, for example, be constructed of soft feedthrough material such as rubber or plastic. The disks **87** and partitions **35** may be constructed of metal: such as steel, stainless steel (nirosta) or aluminum.

As indicated in FIGURE 5, the process is continually surveyed and under constant surveillance due to the measuring or sensing means which may be temperature or pressure responsive. These means are elements **17** through **21** which are connected with and feed information to the control means C which, in turn, controls the evacuating means **25** to **29**. However, if the sensing means is temperature sensitive, then the control means will, of course, control the temperatures in these various partial chambers.

In the embodiment of FIGURES 3 and 4, the control may be such that the speed of the conveying means is controlled, thereby to control the progress of the drying operation. In this manner, the drying process may be under constant surveillance.

Pressures and temperatures should be adapted to the nature of the substance to be dried. The pressure amounts four mm. Hg maximum when the material is fed in through the air lock and is reduced down to 20 microns until extraction, depending on the nature of the substance and the desired residual moisture. The temperature of the heater plates can be varied from 20 to 150 degrees centigrade.

The cars **8** of the embodiment of FIGURES 1 and 2 provide for heating or cooling in the following manner:

The cars **8** are equipped with heater plates **85** as mentioned in column 3. These heater plates can be designed in such a way f.i. that below a top metal plate pipe coils are welded or brazed through which the heat exchange agent flows. The plates will then also be connected in parallel to the thermostat.

It will be understood that the above description of the present invention is susceptible to various modifications, changes, and adaptations, and the same are intended to be comprehended within the meaning and range of equivalents of the appended claims.

What is claimed is:

1. Apparatus for continuous vacuum freeze drying, comprising, in combination:

(a) a vacuum drying chamber comprising a tubular housing having at opposite ends demountable inlet and outlet gates adapted to seal said vacuum drying chamber from atmosphere when in a closed position and to provide access into said vacuum drying chamber when in an open position;

(b) a plurality of evacuating means each including a refrigerated condenser and arranged at predetermined distances along said chamber for creating different pressures therein; and

(c) a conveyor belt for conveying goods to be dried through said chamber and including a plurality of belt sections separated from one another by partitions which define constriction gaps between the inner wall of said chamber and said conveyor belt and wherein said constriction gaps are small enough to allow the maintenance of different pressures on opposite sides thereof and large enough to allow the free movement of said conveyor belt within said tubular housing.

2. Apparatus as defined in claim **1**, comprising a plurality of means for sensing the pressure at several places along said chamber, said sensing means being spaced apart a distance greater than that between two successive partitions.

3. Apparatus as defined in claim **1** comprising heating means along said chamber.

4. Apparatus as defined in claim **3**, comprising additional sealing means arranged on the wall of said chamber for momentarily cooperating with said partitions to provide a smaller constriction gap between adjacent compartments.

5. Apparatus for continuous vacuum freeze drying, comprising, in combination:

(a) a vacuum drying chamber comprising a tubular housing having inlet and outlet gates connected to opposite ends thereof, said inlet and outlet gates adapted to seal said vacuum-drying chamber from atmosphere when in a closed position and to provide access into said vacuum-drying chamber when in an open position;

(b) evacuation means including refrigerated condensers and heating means arranged at predetermined distances along said chamber for providing different temperatures;

(c) a conveyor means for conveying goods to be dried through said chamber, and including constriction elements which reduce the free cross section of the chamber with one of said elements being disposed between two of said evacuation and heating means at any one instant, said constriction elements providing a clearance gap between the inner wall of said tubular housing and said conveyor means, and wherein said clearance gap is small enough to allow the maintenance of different pressures on opposite sides thereof and large enough to allow the free movement of the conveyor means through said tubular housing;

(d) means for sensing the temperature at several places along said chamber, said sensing means being spaced apart a distance greater than that between two successive elements; and

(e) means connected for receiving information from said temperature sensing means and for controlling said heating means to thus control the progress of the drying operation.

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