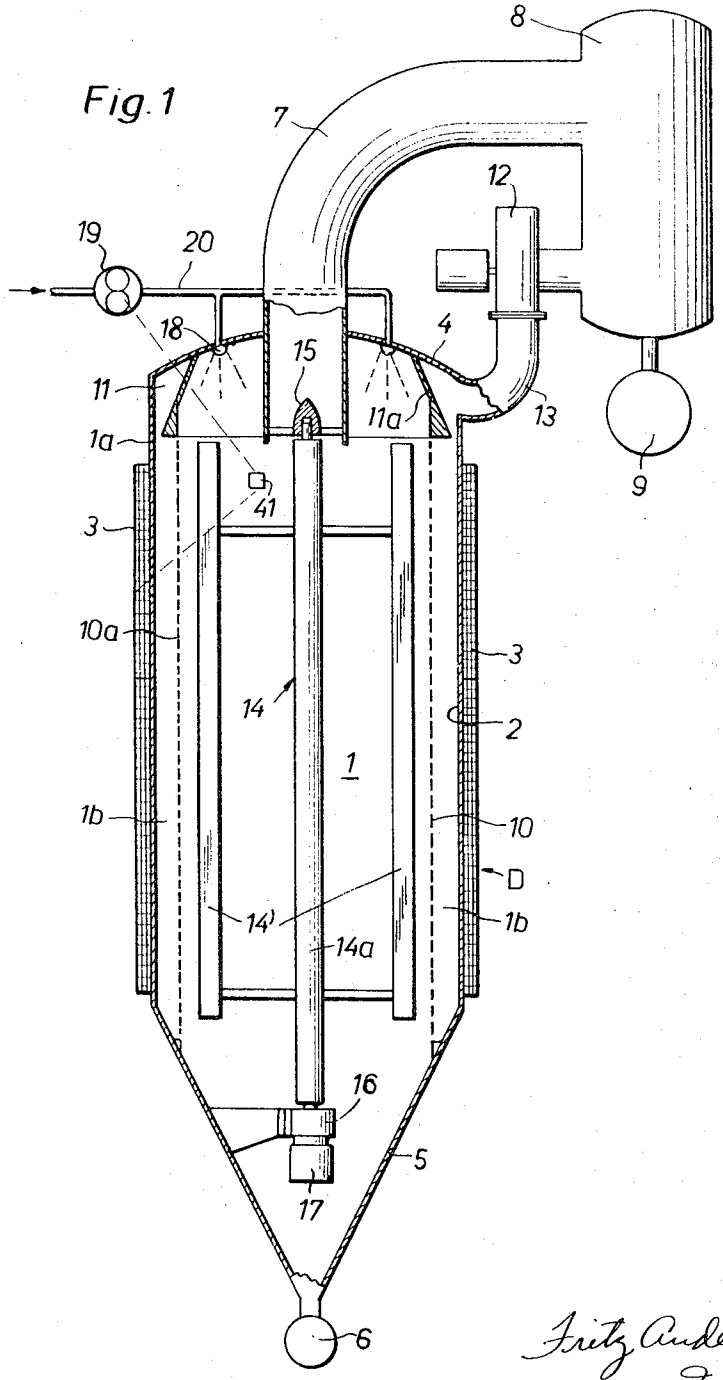
Jan. 31, 1967 F. ANDERWERT 3,300,868

PROCESS FOR DRYING HEAT-SENSITIVE MATERIALS AS WELL AS DRYING APPARATUS FOR THE PERFORMANCE OF THE AFORE-MENTIONED PROCESS

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Fig. 1

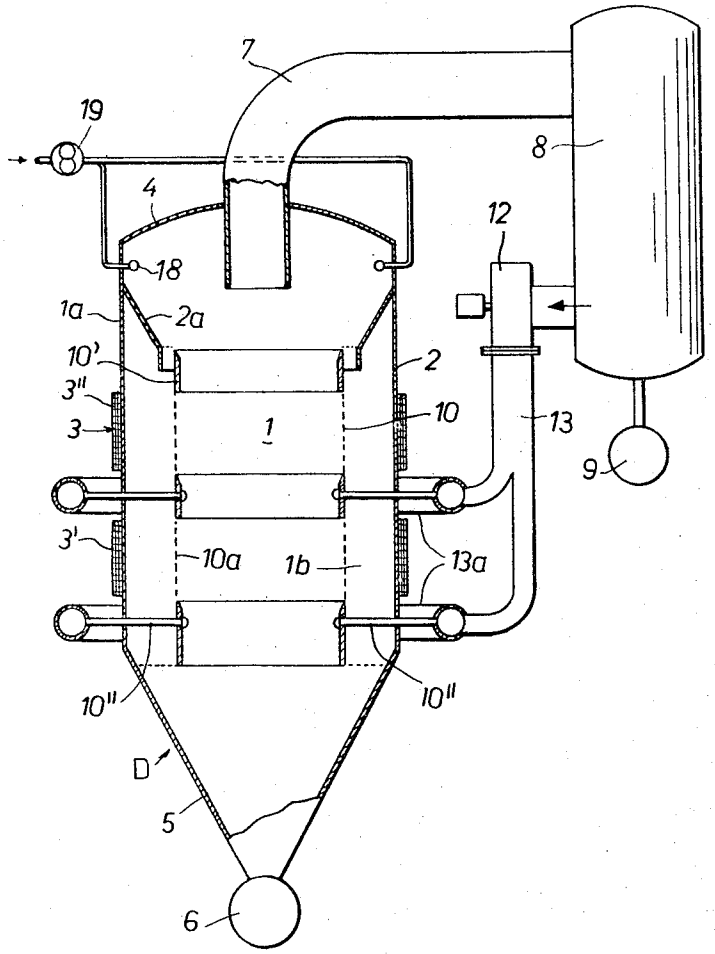


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Fig. 2



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Fig. 3

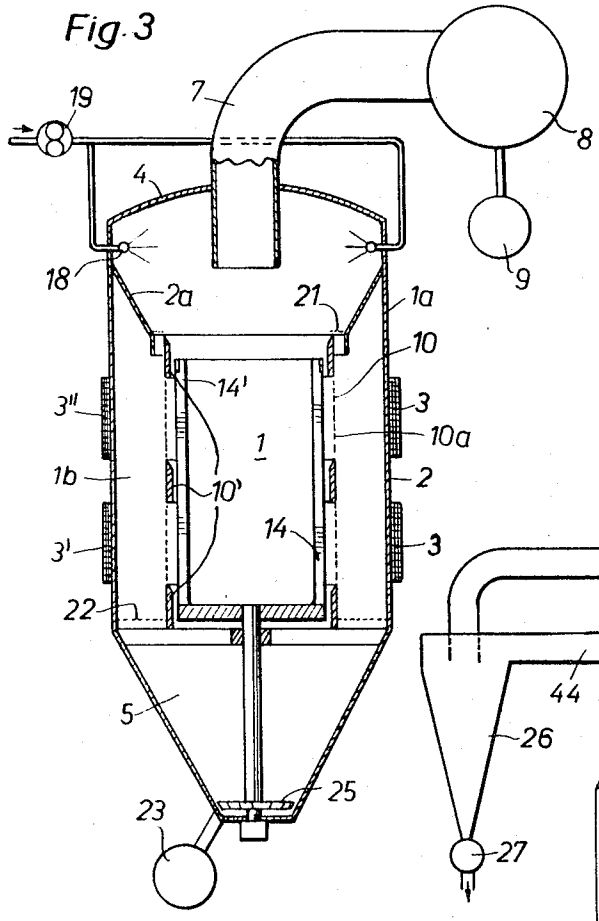


Fig. 4

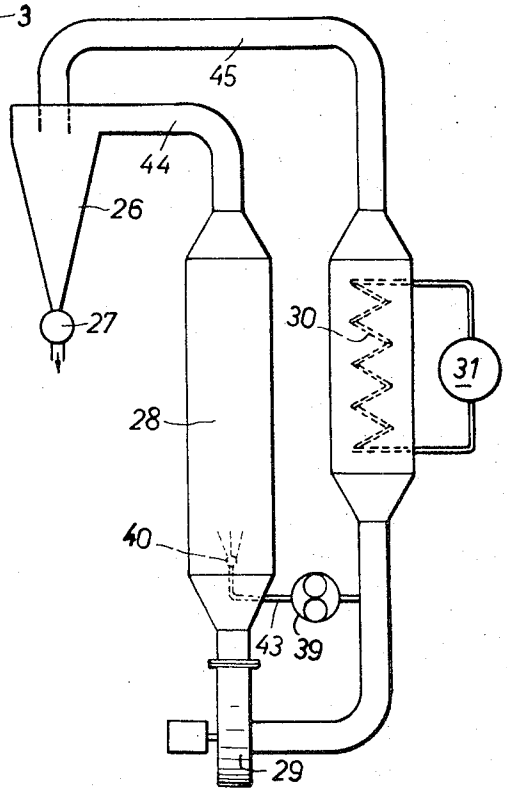
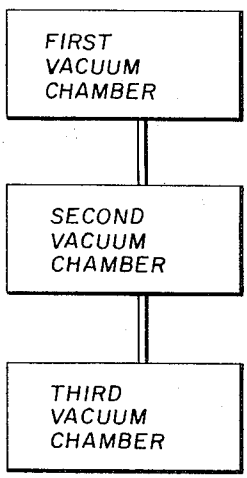


Fig. 5



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3,300,868

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Claims priority, application Switzerland, Apr. 24, 1964, 5,347/64
18 Claims. (Cl. 34—5)

The present invention has reference to an improved process which is particularly suitable for drying heat-sensitive atomizable materials, for instance milk, fruit juices, aroma-rich extracts and the like, as well as relating to an improved drying apparatus for the performance of the aforesaid process.

When drying, particularly when drying heat-sensitive materials, it is of importance to quickly introduce the quantity of heat necessary for vaporisation as well as to give the vapors which are evaporating sufficient opportunity to rapidly diffuse out of the material to be dried, and to be removed from the drying apparatus or installation. These requirements are considerably fulfilled during drying of solutions with atomizing or spraying dryers for instance. In this case, the solution to be evaporated is atomized and moves in counterflow or in the same direction of flow as the hot gases, whereby instantaneous vaporization takes place and the product for the most part falls to the floor as dried powder. However, this process which of necessity works with hot gases, generally with hot air, does not afford the protective conditions necessary for products of the previously mentioned type.

Therefore, it is advantageous to subject such products to vacuum freeze drying wherein removal of water from the material to be dried takes place by vaporisation or sublimation in vacuum and condensation of the water at low temperatures. In addition to the prevention of high temperatures a further advantage of the last-mentioned process resides in the considerable exclusion of air. Vacuum freeze drying is already known in numerous variations which permit treating of lumpy materials, powders, as well as also liquid concentrates. For example, an apparatus for the continuous drying of liquid materials is disclosed in United States Patent 2,471,035. Such apparatus contemplates spraying the material to be dried into a vacuum chamber, the temperature and pressure conditions being such that there occurs almost instantaneous solidification of the individual particles. Then, the particles travel through a drying zone which, if desired, can be heated, there are completely dried and discharged as powder.

However, as has been discovered, operation of such type apparatus in actual practise results in different difficulties which are advantageously overcome by the inventive process as well as the new and improved drying apparatus provided for carrying out the inventive process.

Accordingly, it is a primary object of the present invention to provide an improved process for effectively drying heat-sensitive materials, particularly safeguarding against contact of the material which is processed from contact with heat-furnishing surfaces, and further, to substantially prevent entrainment of the dried product by the escaping vapor stream.

A further very important object of this invention concerns the provision of an improved physical structure of apparatus for carrying out the inventive process and which incorporates means for preventing contact between heat-sensitive materials in particle form and radiation surfaces of the apparatus, and means for generating a vortex to

prevent entrainment of the dried particles together with the resulting vapors out of a drying compartment.

Still another considerable object of this invention has reference to an improved construction of apparatus for producing pulverulent charge for apparatus for drying heat-sensitive materials.

According to the inventive process, heat-sensitive material, particularly in the form of aqueous liquids or concentrates such as milk, fruit juices, coffee extracts and the like, and in the form of atomized particles are dried during their fall through a vacuum compartment or chamber. The process of the invention is particularly characterized by the features that the heat effecting vaporization or sublimation is delivered by radiation whereas contact of the emitting or radiation surfaces by the particles to be dried is prevented, and furthermore, separation of the dried particles from the vapors is enhanced by vortex formation or turbulence in the vacuum compartment or chamber.

The inventive apparatus for the execution of the previously mentioned process embodies a housing provided with an evacuated drying chamber or compartment partially bounded by emitting or radiation surfaces and through which travels the falling material. According to an important aspect of the invention there is provided means for preventing contact between the atomized particles and the radiation surfaces, and means for generating a vortex in order to prevent carrying out of the particles together with the resultant vapors from the drying compartment.

It should be understood that the inventive process renders possible an exceptionally protective drying operation. Furthermore, it permits exact maintenance in the drying chamber of a boundary or threshold value of the temperature determined by the properties of the product by controlling the vapor temperature. Namely, it has been found that the vapor temperature in an evacuated system is approximately equal to the temperature prevailing in the drying compartment. Thus, if the vapor temperature exceeds the mentioned boundary limit, then regulation is carried out either by (a) increasing the infeed velocity of the material to be dried, or (b) reducing the delivered radiation energy, or (c) a combination of both. The pressures prevailing in the drying compartment are preferably below 3 torr; they can however, even be higher, e.g. when solid particles are fed to the drying chamber.

By atomizing the liquid which is to be dried at the upper end of the drying chamber droplets of different size are produced.

It has been found that although small particles dry considerably quicker than large particles, there does not occur any overheating of the small particles, rather there takes place heat transmission to the surrounding medium. This, in turn, gives additional heat to the relatively large particles which can take up considerably less heat by radiation than the small particles.

It is possible to limit the particle temperature to a selective upper value in that the temperature of the emiting or radiation surfaces and/or the quantity of material is regulated in accordance with the vapor temperature. The emitting surfaces can be subdivided into a plurality of zones and the temperature of the zones accommodated to the course of drying. Thus, the inventive drying process can take place in a plurality of successively arranged zones possessing different temperatures, such temperatures being adjusted to the progressive drying operation.

With atomization or spraying under pressure of a solution to be dried the particles possess considerable velocity which reduces as a function of the undertaken displacement path. Preferably, the particles first then arrive in the actual drying zone when they approximately

reach a fall velocity corresponding to their mass. It is possible to prevent a high velocity of the particles in the drying zone by tangentially spraying the material above the drying zone and braking at an impact surface.

Other features, objects and advantages of the invention will become apparent by reference to the following detailed description and drawings wherein like reference characters have been used for substantially the same or analogous elements throughout the various embodiments, and in which:

FIGURE 1 schematically illustrates an exemplary embodiment of inventive drying apparatus;

FIGURE 2 schematically illustrates a second embodiment of drying apparatus;

FIGURE 3 schematically illustrates still a further embodiment of drying apparatus;

FIGURE 4 shows an apparatus for producing a pulverulent charge for a drying chamber; and

FIGURE 5 is a diagrammatic view of a plurality of vacuum chambers connected in series.

Prior to beginning a detailed discussion of the physical structure of the different exemplary embodiments disclosed, it is here pointed out that the term "vaporisation" as employed hereinafter including the claims is used in its broader sense as also encompassing sublimation, and in the first instance sublimation is the type of transition process generally involved with the present invention.

Describing now the drawings, the illustrated drying apparatus D of FIGURE 1 incorporates an evacuated housing **1***a* providing therein a drying compartment or chamber **1**. The housing **1***a* includes a substantially cylindrical external wall **2** which is surrounded by a heating jacket **3**. Drying compartment **1** additionally exhibits a cover or ceiling member **4** and a funnel-shaped floor or base **5** which is closed by a bucket wheel **6** or equivalent expedient capable of removing the dried product while maintaining vacuum conditions in the compartment **1**. A vapor conduit **7** is axially connected to the roof or ceiling **4** and conducts the vapors to a condenser **8** from which the vacuum pump **9** draws off non-condensable gas and vapors. Vacuum pump **9** advantageously also serves to evacuate the housing **1***a*. A cylinder **10** formed of wire mesh or sieve netting **10***a* is coaxially arranged in the drying compartment **1** and separates its central region from the heated external wall **2**. The annular or ring-shaped compartment **1***b* formed between the wire cylinder **10** and the outer or external wall **2** merges via member **11***a* providing a constriction into an upper ring-shaped or annular compartment **11**, whereby a blower **12** sucks gas out of the condenser **8** and blows such through the agency of the conduit **13** into the annular compartment **11**. Moreover, agitation or mixer means **14** provided with two vanes **14'** and having its shaft **14***a* mounted for rotation in bearings **15**, **16** and driven by drive means **17** is arranged axially within the drying chamber or compartment **1**. The cylinder **10** formed of wire mesh **10***a* already prevents or inhibits to a certain extent passage of the particles from drying compartment **1** to the ring-shaped compartment **1***b*.

The material to be dried is delivered from a non-illustrated container to atomizer or sprayer means **18** arranged at the ceiling **4**, by means of a pump **19** and a delivery conduit **20** and is atomized in the evacuated drying compartment or chamber **1**. As schematically indicated in FIGURE 1, a temperature feeler **41** arranged in the drying compartment **1** serves to control the delivery pump **19** and/or heating means **3** as a function of the temperature of the vapor stream. As shown in FIGURE 1 schematically the temperature feeler **21** is connected to the control mechanism **41***a*. Such control mechanism controls by the line **41***c* the heating means **3** and by the line **41***b* the pump **19**. The control **41***a* can control the heating means **3** or the pump **19** independently or both at the same time. It will be understood that a similar arrangement can also be provided for the embodiments of FIGURES 2 and 3.

In a short time the material to be dried and introduced in particle form into the drying compartment **1** freezes due to the low pressure prevailing in this compartment, whereby the frozen particles slowly float downwardly and drop to the operating region or zone of the heated wall **2**, taking up radiant heat from such wall and are thus dried. Generally, the particles leave the atomizer means **18** with considerable velocity; however, during their downward movement are braked and then subjected to the law of gravity. Exposure to radiation preferably takes place at that location where the particles freely fall.

The vapors resulting from drying are set into rotation by the mixer or agitator **14** and thus move towards the axis of the vortex or eddy and flow via the vapor conduit or draft **7** to the condenser **8**. The dry particles fall into the funnel-shaped floor **5** of the housing **1***a* and are carried away by the bucket wheel **6**. The blower **12** brings about a circulation in that gases are sucked-out of the condenser **8** and are delivered via the compartment **11** to the annular compartment **1***b* between the heated chamber wall **2** and the cylinder **10** preferably formed of strong reflecting material, and finally blown through the wire mesh **10***a* thereof into the drying compartment **1**. In this manner, there is further prevented that the particles contact or pass through the wire mesh or sieve netting **10***a*. This netting **10***a* which becomes raised in temperature due to taking up radiant heat is maintained at a moderate temperature by the circulating vapors. If desired, the cylinder **10** may be supported by cooled rings, such as are shown at **10'** in the embodiment of FIGURE 2.

The mixer or agitator means **14** rotating about the axis of the drying compartment **1** places into rotation the vapor-gas mixture located in the aforesaid compartment **1**, whereby the particles by centrifugal forces are transported to the outer areas, whereas the vapors escape through the conduit **7**.

The speed of rotation of the mixer means **14** is to be accommodated to the smallest particles and must be chosen to be sufficiently large to prevent these particles from arriving at the center or nucleus of the vortex and from becoming entrained upwardly due to the ascending vapors.

FIGURE 2 illustrates a drying apparatus D wherein spraying-in or atomization of the solution to be dried is undertaken substantially horizontally at the upper end of the drying compartment **1** and vortex formation takes place by laterally or tangentially blowing in vapors. More specifically, it will be appreciated that like reference characters have here been employed for the same or analogous elements as disclosed in conjunction with the previous embodiment, so that it will be immediately recognized that the apparatus of FIGURE 2 once again discloses a drying compartment **1** with cylindrical external wall **2** and heating means or device **3**, a cover or ceiling **4** and a funnel-shaped floor **5** closed by a bucket wheel **6** or equivalent structure. It will be seen that the heating means **3** are shown to incorporate a lower heating section **3'** and an upper heating section **3''**, so that the heating surfaces are divided into different temperature zones which can be controlled in accordance with the course of drying. The vapor conduit or tube **7** conducts the vapors to a condenser **8** provided with a vacuum pump **9** and from where a portion of non-condensed vapors are introduced and distributed throughout the entire length of the drying compartment **1** by means of the blower **12** and the distributor conduit **13**. It will be seen that distributor conduit **13** incorporates branch pipes **13***a* which lead to the annular compartment **1***b* formed between outer wall **2** and cylinder **10**. The spray nozzles **18** in this instance are not mounted at the ceiling **4** of the drying compartment **1**, rather are located at the

upper end of the cylindrical outer wall **2**. It will also be recognized that the cylinder **10** formed of wire mesh or sieve netting **10***a* is provided over its entire height with a number of distributed cooling rings **10'** each carried at a support mounting **10''**. Thus, in this embodiment the vapors which are introduced tangentially into the ring-shaped chamber **1***b* not only serve to prevent the particles for the most part from passing from the drying compartment **1** through the cylinder **10**, but also serve to form the vortex, so that no mixer means is here employed.

FIGURE 3 schematically illustrates a sublimation apparatus capable of carrying out the inventive process, the evacuated housing **1***a* of which provides a drying compartment **1** which is also effective as a cyclone separator. The cylindrical outer wall **2** here again exhibits heating means **3** having two heating zones defined by the lower and upper heating sections **3'** and **3''** respectively, and a cylinder **10** is arranged concentric to the axis of the cylindrical wall **2**. Cylinder **10** is formed of sieve netting or wire mesh **10***a*. Furthermore, there is provided an agitator or mixer **14** the axis of rotation of which is substantially coincident with the axis of the cylinder **10**. The cylinder **10** formed of sieve netting **10***a*, the rings **10'** for securing the sieve netting and the mixer vanes or blades **14'** possess external surfaces which strongly reflect radiation, so that they absorb little radiant heat. The rings **10'** which are formed of hollow sections can be cooled, possibly also the mixer blades **14'**. The sieve netting **10***a* formed of thin wires or filaments is very effectively cooled by the flowing vapors as well as the vortex. The temperature of the sieve netting **10***a* is only slightly above the temperature of the vapors.

The cylinder **10** formed of wire mesh or sieve netting **10***a* confines the vapor vortex so that it does not have any effect upon the annular compartment **1***b* behind the sieve netting **10***a*. Annular or ring-shaped compartment **1***b* remains as a dead chamber. The flow resistance of thin threads or filaments is also relatively high in vacuum and a sieve netting therefore functions in vacuum similar to a filter gauze or mesh at atmospheric pressure.

The top of the annular compartment **1***b* is bounded by a sieve netting cover **21** and at the bottom by a sieve netting floor **22**. The particles which fall into the annular or ring-shaped compartment **1***b* through the sieve netting cover **21** are subjected to radiation, the ice crystals sublimate, the vapors generate an over-pressure in this annular compartment and stream through the sieve netting into the interior of the drying compartment **1** and entrain particles therewith.

In the last illustrated embodiment as well as in the embodiment of FIGURE 2, liquid material is sprayed tangentially from above into the drying compartment **1** such that the particles after having moved through a larger brake path first then impact at the cylinder wall **2** and internal baffle wall **2***a*. The kinetic energy imparted to the particles due to the spraying-in operation and the vapors resulting from expansion help in forming a vortex which is driven by the mixer **14** of FIGURE 3. A centrifugal force towards the outside acts upon the particles rotating with the vortex and this is opposite the flow resistance of the vapors streaming towards the vortex axis.

The circulation or rotational speed of the vortex is selected so large that the small and light particles do not arrive at the nucleus or core of the vortex, that is their centrifugal force is larger than the flow resistance. With this speed of circulation there is imparted to the larger and heavier particles a relatively radial velocity towards the outside. These particles stream through the sieve netting **10***a* into the annular compartment **1***b*. There, they are braked by the flow resistance. The dimensioning of the annular compartment **1***b* is selected so large that the particles come to rest before contacting the radiation surfaces or walls **2**.

The vapors ascend towards the top in the vortex nucleus and flow through the draft or immersion tube **7** into the condenser **8**. A vacuum pump **9** ensures for evacuation and maintenance of a vacuum. The dry product falls into the floor portion or funnel **5** and is delivered by a suitable removal device **25** to a discharge apparatus **23**, and from this location can be sterilely packed under vacuum or a protective gas.

FIGURE 4 depicts an apparatus which renders it possible to deliver material in the form of solid particles to a drying compartment. This apparatus possesses a freezing or refrigeration tunnel **28**, a ventilator **29**, a gas cooler **30**, a refrigerating machine **31**, a cyclone separator **26**, a delivery conduit **43** terminating in a nozzle **40** having a pump **39**, and a feed device **27** e.g. bucket wheel through the agency of which the illustrated system is operably connected with the drying compartment. At a desired location of the system it must be possible to apply a vacuum in any convenient manner. It can be assumed for instance, that the drying compartment is of the type depicted in FIGURE 1.

The liquid material flows out of a non-illustrated container and via the pump **39** to the atomizer means **40** arranged in the freezing tunnel **28**. Freezing takes place in the tunnel **28** in a cold gas stream withdrawn from the gas cooler **30** by the ventilator **29**. In so doing, the fluid particles are entrained and cooled by the gas stream so that they are brought in frozen condition via conduit **44** into the cyclone **26**. The frozen particles are separated in the cyclone **26** and arrive via the bucket wheel **27** at the upper end of the drying compartment, whereby the gas from the cyclone **26** is returned to the gas cooler **30** by the conduit **45**.

In FIGURE 5 a plurality of vacuum chambers is shown connected in series and in such vacuum chambers different temperatures may be provided to control the temperatures in accordance with the progression in drying of the material.

It will be clearly understood that the herein described drying apparatuses are only given as illustrative examples for purposes of explaining the inventive concepts, and are not in any way to be considered as limited to the illustrated arrangements. Thus, for example, the blower **12** of FIGURE 1 could withdraw and circulate vapors out of the vapor conduit **7** instead of gas out of the condenser **8**. Furthermore, the condenser could be arranged internally of the drying compartment.

While there is shown and described present preferred embodiments of the invention it is to be distinctly understood that the invention is not limited thereto but may be otherwise variously embodied and practised within the scope of the following claims.

What is claimed is:

1. Process for drying heat-sensitive materials in particle form in a vacuum chamber during fall of the particles through the aforesaid vacuum chamber, comprising the steps of: furnishing radiant energy as the heat of drying effecting vaporisation, preventing contact of the particles to be dried with radiation surfaces furnishing the radiant energy used for drying, and forming a vortex in the vacuum chamber for facilitating separation of the dried particles and the vapors.

2. Process for drying heat-sensitive materials as defined in claim **1** further including the step of controlling at least the quantity of furnished radiant energy as a function of the temperature of the vapors.

3. Process for drying heat-sensitive materials as defined in claim **1** further including the step of controlling at least the speed of delivery of the material to be dried as a function of the temperature of the vapors.

4. Process for drying heat-sensitive materials as defined in claim **1** further including the step of controlling the quantity of radiant energy as well as the speed of delivery of the material to be dried as a function of the temperature of the vapors.

5. Process for drying heat-sensitive materials as defined in claim 1 including the step of effecting drying of the material in a number of successive zones at different temperatures, and controlling the temperature of such zones in accordance with the progression in drying of the material.

6. Process for drying heat-sensitive materials in particle form in a vacuum chamber during fall of the particles through the aforesaid vacuum chamber, comprising the steps of: furnishing radiant heat as the heat of drying effecting vaporisation of liquid contained in the particles, controlling the movement of the particles to prevent contact of such particles to be dried with radiation surfaces furnishing the radiant heat used for drying, and forming a vortex in the vacuum chamber for facilitating separation of the dried particles and the vapors.

7. Apparatus for drying heat-sensitive materials comprising means defining an evacuated drying compartment at least partially bounded by radiation surfaces, the material to be dried being in particle form and falling through said evacuated drying compartment, means for preventing contact between the particles and the radiation surfaces, and means for generating a vortex to prevent removal of the particles together with the vapors resulting from drying of the particles from the drying compartment.

8. Apparatus for drying heat-sensitive materials as defined in claim 7 wherein said means defining an evacuated drying compartment at least partially bounded by radiation surfaces incorporates an evacuated housing, heating means for heating said radiation surfaces, a radiation permeable hollow member coaxially arranged in said evacuated housing and possessing a smaller diameter than the diameter of said housing, and means arranged internally of said hollow member for generating a vortex rotating about the lengthwise axis of said hollow member.

9. Apparatus for drying heat-sensitive materials as defined in claim 8, said hollow member being formed of wire netting and is of substantially cylindrical configuration.

10. Apparatus for drying heat-sensitive materials as defined in claim 9 further including outlet means arranged above the zone of the vortex and coaxially with respect to said hollow member.

11. Apparatus for drying heat-sensitive materials as defined in claim 7 further including means for preparing and introducing the material to be dried in pulverulent form into said evacuated drying compartment.

12. Apparatus for drying heat-sensitive materials as defined in claim 11 wherein said preparing and introducing means comprises a freezing tunnel, means for delivering liquid material into said freezing tunnel, a gas cooler, a refrigeration machine cooperating with said gas cooler, means for delivering a cold gas stream from said gas cooler to said freezing tunnel for freezing said liquid material to form frozen particles, separator means for receiving the frozen particles from said freezing tunnel, and means for discharging the frozen particles from said separator means into said drying compartment.

13. Apparatus for drying heat-sensitive materials as defined in claim 8 wherein said hollow member is spaced from said radiation surfaces to provide therebetween a ring-shaped compartment, said means for preventing contact between the particles and the radiation surfaces incorporating means for directing a gas stream into said ring-shaped compartment to prevent movement of particles contained within said hollow member into said ring-shaped compartment.

14. Apparatus for drying heat-sensitive materials as defined in claim 13 wherein said means for generating a vortex comprises rotatable agitator means arranged within said hollow member.

15. Apparatus for drying heat-sensitive materials as defined in claim 13 wherein said vortex generating means incorporates means for directing a gas stream tangentially into said ring-shaped compartment.

16. Apparatus for drying heat-sensitive materials as defined in claim 8 wherein said hollow member is spaced from said radiation surfaces to provide therebetween a ring-shaped compartment, said means for preventing contact between the particles and the radiation surfaces incorporating means enabling movement of particles from above into said ring-shaped compartment so that said particles vaporize therein and create an overpressure which prevents movement of particles contained within said hollow member into said ring-shaped compartment.

17. Apparatus for drying heat-sensitive materials as defined in claim 16 wherein said ring-shaped compartment is of sufficient size to prevent the particles located therein from reaching the radiation surfaces due to a braking action exerted thereon by the flow resistance of the resultant vapors appearing within the ring-shaped compartment.

18. Apparatus for preparing materials for introduction in pulverulent form into a drying compartment comprising a freezing tunnel, means for delivering liquid material into said freezing tunnel, a gas cooler, a refrigeration machine cooperating with said gas cooler, means for delivering a cold gas stream from said gas cooler to said freezing tunnel for freezing said liquid material to form frozen particles, and separator means incorporating a cyclone for receiving the frozen particles from said freezing tunnel.

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