

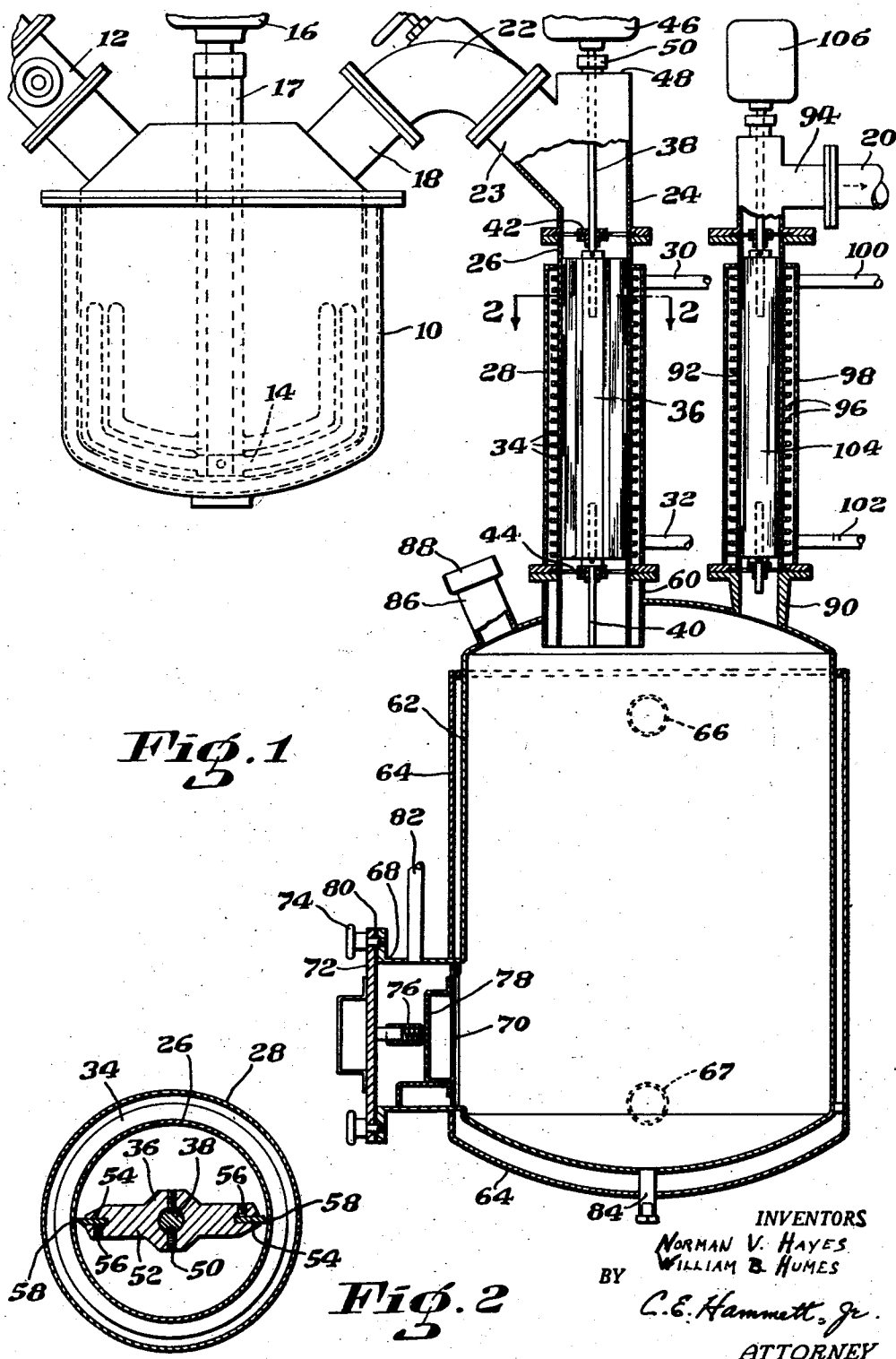
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DESICCATION METHOD AND APPARATUS

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DESICCATION METHOD AND APPARATUS

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This invention relates to methods and apparatus for desiccating substances such as foods, chemicals, plasma and the like, and more particularly to such methods and apparatus in which the desiccation is performed at low temperature and under low pressure.

Desiccation at atmospheric pressures requires subjecting the substance to elevated temperatures for long periods of time in order to evaporate the moisture. In the case of substances such as those previously mentioned, the consequence of such exposure to elevated temperatures is a serious deterioration of the product. Vitamins in foods are destroyed and taste is impaired. Vital components of many chemicals and plasmas are impaired or destroyed by such treatment.

By reducing the free air pressure on the substance, the temperature at which the moisture content of the substance will evaporate is also reduced. Thus if the pressure is reduced to a sufficiently low value, the moisture will evaporate at a temperature low enough so that desiccation may be effected without impairment of the qualities of the substance. For most substances of the character above mentioned, that temperature is 0° C. or lower, that is, at or below the freezing point of the moisture of the substance. To produce effective desiccation by evaporation or sublimation at such low temperatures usually calls for the maintenance on the substance of a total pressure below 3 mm. Hg.

When a substance undergoes desiccation in a closed system, the vapor pressure of the evaporating moisture tends to increase the pressure in the system. In order to maintain a low total pressure during desiccation, therefore, it is necessary to remove or pump the vapors substantially as fast as they form. Mechanical pumps, which can be utilized to provide the initial low free air pressure in the system, do not have the pumping speed necessary to remove evaporating vapors with sufficient rapidity to maintain the desired low pressure after desiccation starts.

In application of Richard S. Morse, Serial No. 483,274, filed April 16, 1943, there are disclosed a method and apparatus for vacuum desiccation in which the evaporating vapors are rapidly and effectively pumped by freezing them on a refrigerated condenser within the system, the efficiency of the condenser being maintained through continual removal of the ice of condensed vapors from its surface. In this way it is possible to maintain during desiccation of a large volume of a substance a low pressure on the substance, considerably below 3 mm. Hg., produced initially in

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the system by ordinary mechanical pumping means.

It is the object of this invention to provide improvements upon the method and apparatus of the aforesaid application by means of which substantially all of the vapors of evaporation may be effectively eliminated from the system in advance of the mechanical pump so that the amount of vapor pumping required of the mechanical pump is reduced to zero or a negligible value and the efficiency of the system is considerably improved.

We have found that if ice removed from the condenser in the aforesaid apparatus is permitted to resublime in the system, the efficiency of the apparatus is reduced and that this undesirable condition can be substantially completely eliminated by a controlled refrigeration of that part of the system, between the condenser and the mechanical pump, which receives the ice removed from the surface of the condenser.

This refrigeration may be effected by circulating a refrigerating substance over the walls of that part of the pumping passage in which ice from the condenser is received to maintain a controlled low temperature in those walls. Curiously, however, if that temperature is appreciably lower than the temperature of the condenser, the vapors emanating from the substance undergoing desiccation will pass through the condenser without condensing and then freeze preferentially upon the colder surface of the walls of the passage succeeding the condenser. Under the conditions involved, the vapors evidently seek out the coldest condensing surface exposed to their path, regardless of relative distance from their source. Such preferential freezing of the vapors upon the pumping passage walls beyond the condenser is, of course, undesirable.

We have found that this last mentioned difficulty can be overcome by carefully controlling the refrigeration of those walls to maintain their temperature at or above the temperature of the condenser. However, to effectively accomplish our purpose of preventing resublimation of the ice in this part of the passage, we have found that the temperature of the passage walls should not greatly exceed that of the condenser and preferably is not more than 10° C. above the temperature of the condenser.

As an alternative or supplementary procedure to that just described, preferably supplemental, we may prevent vapors of resubliming ice from reaching the mechanical pump by refreezing them. To this end we provide a second or auxiliary con-

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denser between the first condenser and the mechanical pump, this second condenser being kept at a temperature equal to or slightly above that of the first condenser to avoid preferential, initial condensation thereon of vapors from the desiccating substance. As in the case of the first condenser, the ice of condensed vapors is scraped or otherwise removed from the surface of this second condenser, and this ice is returned to the part of the pumping passage between the two condensers where the ice removed from the first condenser is collected for withdrawal.

The invention will be further described with reference to the accompanying drawing wherein Fig. 1 is a view partly in section, partly in side elevation, of a preferred form of apparatus of the invention, and Fig. 2 is a transverse section view on the line 2—2 of Fig. 1.

Referring to Fig. 1 of the drawing, an hermetically sealable vessel 10 receives the substance to be desiccated which may be fed thereto through a valved inlet duct 12. The vessel 10 is shown as provided in its interior with an agitator device 14 operated by an external motor 16 to agitate and increase the surface exposure of the substance, the operating shaft extending through a gland 17 which forms a pressure tight seal around the shaft. The substance in the vessel may be heated in any suitable manner to prevent excessive lowering of its temperature by rapid evaporation of moisture therefrom. Vessel 10 is provided with a port 18 which is connected by intermediate connections hereinafter described with the pumping port 20 of a mechanical vacuum pump (not shown) which may be of usual construction. Ports 18 and 20 and intermediate connections form a pumping passage through which air may be exhausted from the vessel 10 by the mechanical pump.

Port 18 is connected by a valved curved duct section 22 with a branch 23 of a conduit section 24 which communicates with the upper end of a vertically disposed conduit section 26. Section 26 forms the main vapor condenser of the apparatus and to that end is provided with a jacket 28 which is supplied with a suitable refrigerant, such as carbon dioxide gas, through pipes 30, 32 connected thereto and to a suitable source of such refrigerant. The outer surface of section 26 is also provided with projecting metal fins 34 over which the refrigerant circulates within jacket 28 and which aid effective heat transmission from the cylindrical inner surface of the section 26, which constitutes the condensing surface, to the refrigerant.

Mechanism is provided for continually removing ice from the condenser surface of section 26. As in the apparatus disclosed in application Serial No. 483,274 previously mentioned, this mechanism is in the form of a continuously operating scraper but its form differs from, and it is an improvement upon, that of the aforesaid application. As shown in Figs. 1 and 2, this mechanism comprises a rotor 36 extending longitudinally centrally through the section 26 and rotatably mounted therein by a pair of shafts 38 and 40 fastened, respectively, in suitable sockets in the upper and lower ends of the rotor, these shafts in turn being rotatably mounted in thrust bearings in the hubs of a pair of spiders 42, 44 which are respectively fastened between the upper end of section 26 and the preceding portion 24 of the pumping passage, and between the lower end of section 26 and the next succeeding portion of the passage. The upper end of shaft 38 extends

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through the upper end of duct section 24 where it is operatively connected with a motor 46, the upper end of section 24 being hermetically sealed about the shaft 36 by means of a cover 48 provided with a gland 50 through which the shaft passes. A pair of blade receiving arms 52 extend oppositely from rotor 36 to adjacent the condenser surface, each provided with a longitudinal slot in which the inner end of a flat scraper blade 54 is received and fastened by set screws 56. The outer edge of each blade 54 has a beveled scraping edge 58 which extends as close as is practicable to the condenser surface, about $\frac{1}{64}$ inch clearance being sufficient. The blades and their support extend the full length of the condenser surface of section 26.

The lower end of condenser section 26 is connected to a port 60 in the top of an hermetically sealable ice receptacle 62. The sides and base of the receptacle are provided with a jacket 64 within which there may be circulated a refrigerating fluid by means of pipes 66, 67 connected to a suitable source of the refrigerant. Near the base of the receptacle is a port 68 extending through the receptacle and jacket and outwardly thereof, through which ice may be periodically removed from the interior of the receptacle. The inner end of port 68 is closed by a removable door 70 and its outer end is closed by a cover 72 removably fastened to the port by screws 74. Cover 72 is provided on its inner surface with a spring pressed piston 76 which bears against a lug 78 on the outer face of door 70, pressing the door into position with respect to an inner rim of the port. A gasket 80 provides a pressure tight seal between cover 72 and port 68. Door 70 may be effectively insulated from external heat by evacuating the space within port 68 between the door and cover 72 through a pipe 82 which may be connected to the mechanical pump.

Receptacle 62 is provided in its base with a drain plug 84 and at its top with a port 86 sealed by a cover 88 containing a sight glass through which the condition of ice within the receptacle may be viewed.

A third port 90 in the top of the receptacle is connected with the pumping port 20 of the mechanical pump by means of a vertical conduit section 92 fastened to port 90 and a T-shaped conduit section 94 fastened to the top of section 92 and with its lateral branch connected to port 20. Ports 90 and 20 and sections 92 and 94 which form the outlet pumping passage from receptacle 62 are all of substantially the same inner diameter which is considerably smaller than that of the inlet passage to the receptacle. Section 92 forms a second or auxiliary condenser and to this end is provided on its outer surface with fins 96 and is surrounded with a jacket 98 through which a refrigerant may be circulated by means of pipes 100, 102. Within condenser section 92 is mounted a scraper blade unit 104 operated by a motor 106. Inasmuch as this assembly, its mounting and operating connections are, as shown, identical except for smaller size to those of the main scraper unit previously described, a detailed description thereof is unnecessary.

It will be understood that the various sections making up the pumping passage are sealed together in pressure tight relation and that pressure tight seals such as glands are provided around operating parts extending into the passage.

In operation, the kettle 10 is charged with a quantity of substance to be desiccated and the

system from the inlet to the kettle to the inlet to the mechanical pump is hermetically sealed. The mechanical pump is started, reducing the free air pressure in the system to a point below the vapor pressure of the moisture of the substance to be desiccated. This causes a rapid evaporation of moisture from the substance producing a low temperature of the substance which may fall below the freezing point of the substance. The rate of evaporation may be increased by operating the agitator 14 and the temperature of the substance may be controlled by the application of heat to the kettle.

Refrigerant is circulated through pipes 30 and 32 to maintain the inner surface of condenser section 26 at a desired low temperature which is less than 0° C. and below the vapor pressure of the evaporating moisture, preferably from -40° C. to -70° C. The evaporating vapors flow from outlet port 18 of the kettle through conduit portions 22, 23 and 24 and between the spokes of spider 42 into the condenser section 26 where they condense and freeze to solid form on the inner surface of the condenser. Rotor 36 is continuously operated by motor 46 causing blades 58 to scrape the condenser surface to remove the solidified vapors or ice, the ice particles falling through the section 26, spider 44 and port 60 into container 62.

The operation as so far described is essentially the same as that of the apparatus of application Ser. No. 483,274 previously referred to. However, we have found that the vertical arrangement of the condenser cylinder herein is an improvement over the inclined cylinder shown in the aforesaid application. In the latter, the rotary movement of the helical blades is relied on to remove the bulk of the ice particles scraped from the condenser surface from the lower end of the condenser. This increases the load on the scraper and reduces its efficiency. The present arrangement permits the ice particles to drop directly out of the condenser into the ice receptacle, thus reducing the load on the scraper. Also, we have found that the straight scraper blades and their supporting rotor herein described form a stronger, more efficient scraper unit than the helical blade assembly disclosed in the said application.

The walls of the ice receptacle are kept at a carefully controlled low temperature by circulation of a refrigerant within the jacket 64. To avoid preferential condensation of vapors on the receptacle walls, that temperature should be no lower, and is preferably kept slightly higher, than the temperature of the preceding condenser. On the other hand, the purpose of refrigerating the receptacle is to prevent as far as possible resublimation of vapors from the ice passing to the receptacle from the preceding condenser and to attain this purpose we have found that the temperature of the receptacle should be no more than 10° C. higher than that of the preceding condenser. Our preferred practice is therefore to keep the ice receptacle at a temperature equal to or not more than 10° C. above the temperature of the condenser 26.

Any vapors which do exist in the receptacle are prevented from escaping with the free air to the mechanical pump by the auxiliary condenser 92, in the outlet to the pump, which freezes and traps them. Scraper unit 104 is continually operated to remove the frozen vapors from the surface of the auxiliary condenser from which, as solid particles, they fall back into the

receptacle. The auxiliary condenser is kept at substantially the same low temperature as the main condenser, but here again care is taken that the temperature does not drop below that of the main condenser to prevent the vapors bypassing the main condenser and freezing preferentially in the auxiliary condenser.

While the system is in operation, door 70 and cover 72 are locked in position and the space between them is evacuated to effectively insulate the outer surface of door 70. When it is desired to remove the ice from the receptacle, pipe 82 is closed and cover 72 and door 70 are removed. The accumulated ice may then be withdrawn from the system through port 68. To prevent loss of vacuum in the entire system on such occasions, suitable valves may be provided in the inlet and outlet ports to the receptacle so that it may be temporarily closed off from the rest of the system.

Having described a preferred form of the process and apparatus of our invention, what we desire to claim and secure by Letters Patent is:

1. In a process for the rapid desiccation of substances such as food products, chemical products, plasma and the like under sub-atmospheric free air pressure in an hermetically sealed duct system connected to a free air pressure reducing means, the steps which comprise condensing and freezing to solid form the vapor emanating from the substance upon a cold surface within said system maintained at a temperature below 0° C. and substantially below the temperature of the substance, removing solidified vapors in solid form from said surface, and subjecting the walls of said system in proximity to said removed solidified vapors within the system to controlled refrigeration such as to maintain their inner surface at a temperature within the range from a temperature 10° C. above to a temperature equal to the temperature of the condenser surface.

2. In a process for the rapid desiccation of substances such as food products, chemical products, plasma and the like under sub-atmospheric free air pressure in an hermetically sealed duct system connected to a free air pressure reducing means, the steps which comprise condensing and freezing to solid form the vapor emanating from the substance upon a pair of cold surfaces spaced longitudinally of the system between the substance being desiccated therein and said pressure reducing means, said surfaces being maintained at a temperature below 0° C. and substantially below the temperature of the substance and the one of said surfaces nearest said substance being at least as cold as the other one of said surfaces, removing solidified vapors in solid form from each of said surfaces, and subjecting the walls of said system in proximity to said removed solidified vapors within the system to controlled refrigeration such as to maintain their inner surface at a temperature within the range from a temperature 10° C. above to a temperature equal to the temperature of the one of said condenser surfaces nearest the substance being desiccated.

3. In a process for the rapid desiccation of substances such as food products, chemical products, plasma and the like under sub-atmospheric free air pressure in an hermetically sealed duct system connected to a free air pressure reducing means, the steps which comprise condensing and freezing to solid form the vapor emanating from the substance upon a cold surface within said system maintained at a temperature below 0° C. and substantially below the temperature of the sub-

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stance, removing solidified vapors in solid form from said surface while maintaining the surface at condensing temperature, passing the ice so removed to a receptacle in said system, and maintaining said solidified vapors in said receptacle at a controlled temperature low enough to prevent substantial sublimation thereof at the pressure maintained in the system by circulating a fluid refrigerant in indirect contact, through a heat conducting wall, with the interior of said receptacle.

4. In a process for the rapid desiccation of substances such as food products, chemical products, plasma and the like under sub-atmospheric free air pressure in an hermetically sealed duct system connected to a free air pressure reducing means, the steps which comprise condensing and freezing to solid form the vapor emanating from the substance upon a cold surface within said system maintained at a temperature below 0° C. and substantially below the temperature of the substance, removing solidified vapors in solid form from said surface while maintaining sub-atmospheric pressure in the system and maintaining the surface at vapor-condensing temperature, passing the solidified vapors so removed to a receptacle in said system, and maintaining said solidified vapors in said receptacle at a controlled temperature low enough to prevent substantial sublimation thereof at the pressure maintained in the system by circulating a fluid refrigerant in indirect contact, through a heat conducting wall, with the interior of said receptacle.

5. In apparatus for the desiccation of substances under sustained low pressures which includes a free air pressure reducing means and an hermetically sealable duct system connected to said means including a container for a said substance, the combination of a vapor condenser connected in said system between said container and said pressure reducing means and having a condensing surface exposed to vapors emanating

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from a said substance in said container, means for refrigerating said surface to a temperature low enough to cause vapors to condense and freeze to substantially solid form thereon at the pressure maintained in the system, a receptacle in said system adjacent said condenser, means for removing solidified vapors in solid form from said condenser surface to said receptacle, means for operating said removing means while said system is hermetically sealed and a low free air pressure is maintained therein by said pressure reducing means, and means for circulating a fluid refrigerant in indirect contact, through a heat-conducting wall, with the interior of said receptacle to maintain the solidified vapor therein at a temperature low enough to prevent substantial sublimation thereof at the low pressure maintained in the system.

6. Apparatus as claimed in claim 5 wherein said condenser comprises a substantially cylindrical and vertically disposed conduit connected to and disposed above the receptacle, the inner surface of said conduit forming the condensing surface of said condenser, and the solidified vapor removing means comprises a rotary support within said conduit carrying a substantially straight scraper blade extending longitudinally of the conduit and having its outer edge in close proximity to the inner surface of the conduit.

7. Apparatus as claimed in claim 5 wherein the receptacle is provided with a port through which accumulated ice may be removed, said port being provided at its inner and outer ends with movable closure means adapted when in port closing position to form therebetween a sealed chamber in said port, said chamber having means for connection with said pressure reducing means to form therein a vacuum insulating said inner closure means from said outer closure means.

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