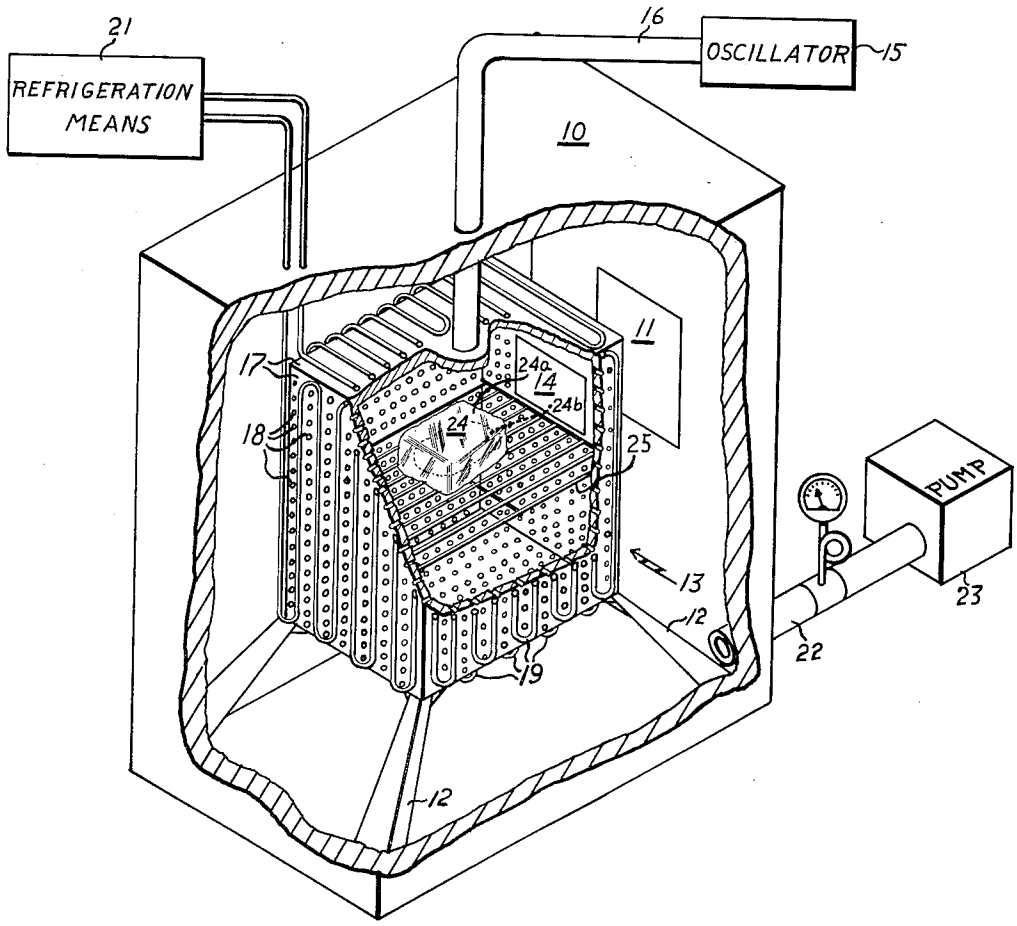
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FREEZE-DRYING APPARATUS

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FREEZE-DRYING APPARATUS

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This invention relates to the use of microwave energy for the freeze-drying of material such as foods.

Drying by sublimation of such materials as foods, tissues and cultures of organisms that have first been frozen has proved to be a useful preservation process particularly for heat labile substances. However, many materials are not amenable to this treatment because of their dimensions or structures. For example, as beefsteak or bone tissue is freeze-dried, the highest surface at which sublimation occurs steadily recedes behind a dried portion of the substance that acts as a poor conductor for heat. As the process goes on, more and more heat is dissipated in the dried portion of the material before reaching the vaporizing surface to cause sublimation.

An improved technique over the application of heating utilizes the fact that many materials in the dry state absorb little electromagnetic energy at radio or microwave frequencies compared to the energy absorbed by the same material in a moist frozen state. The result is that microwave energy applied to moist frozen material is absorbed almost entirely by the moist frozen portion of the material. By this process, little or no energy is lost in transmission through the dried material, making the drying process far more efficient. In fact, a given sized piece of beefsteak can be dried by microwave energy in about one-third of the time required to dry it in other forms of heating under the same conditions.

It is important that the sublimed water be removed from the place where the heat of sublimation is applied. Heretofore it has been considered necessary to physically separate the place of sublimation from a place of desublimation where refrigeration is provided so that the condensate will not flow back to the place of sublimation and to pump the moisture in vapor form from the place of sublimation to the place of desublimation where the moisture is collected thereby effecting dehydration of the material being processed. However, the expansion of water in its sublimation from ice is several orders of magnitude, i.e., one pound of water at 1 mm. pressure occupies a volume of about 14,300 cu. ft. This substantial increase in volume has heretofore required the use of high capacity motors and pumps and suction pipe lines of large dimensions even when moderate quantities of water are to be removed. Further the efficiency of freeze-drying systems depends to a large extent, particularly during the initial drying phase, on the unimpeded flow of vapor from the region of sublimation or high vapor pressure to the region of low vapor pressure or the desublimator. As pointed out heretofore the place where the heat of sublimation is applied was separated from the desublimator where refrigeration occurs, so that the condensate will not flow back into the system.

The present invention contemplates a single vacuum chamber enclosing an RF still constructed in the form of an RF choke and comprised of screen material opaque to radio and microwave frequency energy while providing a large number of passages in combination with coils or the like containing a refrigerant surrounding and enclosing the RF still. Conventional means are provided to supply microwave energy to the interior of the still, lower the temperature of the condenser coils to about —30° to —40° C. and evacuate the vacuum chamber to about 0.5–1 mm. pressure. Upon reduction of the temperature of the coils and the pressure in the chamber to the

desired operating temperature and pressure, and provision of microwave energy to the still or container containing the frozen material to be treated, water in the frozen material is sublimated and collected on the coils and non-condensable gases are eliminated by the vacuum pump. Due to the location of the condenser coils in close proximity to the frozen material being dried, the large area of cold surface provided by the condenser coils and the large number of passages in the radio frequency screen, there is provided at all times a highly efficient and very short and substantially unimpeded vapor path from the region of high vapor pressure in the still to the low vapor pressure at the condenser coils thereby greatly increasing the efficiency of freeze-drying systems and simplifying their construction and manufacture.

Other and further features and advantages of the invention will become apparent from the following description taken in connection with the accompanying drawing illustrating the invention which shows a perspective view with parts broken away of an apparatus for carrying out the invention.

In the drawing the reference numeral **10** designates a sealed container or evacuation chamber having a sealable access door **11**. Supported within the container as by legs **12** is a second conductive container or heating chamber **13** containing an access door **14**. The heating chamber **13** forms a cavity to which propagated electromagnetic radio frequency energy is applied from an oscillator **15** through a transmission line **16** of the wave guide type such as shown, for example, in Patent No. 2,540,036 issued January 30, 1951 to P. L. Spencer. Frequencies which are especially significant for this purpose are those in the microwave range, which may be considered as those lying between 300 megacycles per second and 30,000 megacycles per second. The two most practical frequencies in this range are in the region of 2450 megacycles per second and 915 megacycles per second. In accordance with the invention the heating chamber **13** is adapted to prevent the propagation of electromagnetic energy from its interior to the container **10** while permitting atmospheric communication therebetween. This may be achieved by forming the walls **17** of the heating chamber **13** with openings **18** of a diameter small with respect to the wave length of the radio frequency energy to prevent the propagation of the radio frequency energy from the interior of chamber **13** while permitting atmospheric communication. Disposed in close proximity to and substantially enclosing the walls **17** of the heating chamber **13** are condenser coils **19**. Condenser coils **19** are connected to suitable refrigeration means **21** adapted to lower the temperature of the condenser coils **19** to about —30° to —40° C. A pipe **22** provides communication between the interior of container **10** and a pump **23**. Material **24** in the frozen state to be dried is supported on a centrally located platform **25** of dielectric material formed with suitable openings or slots to permit the free passage of the vapor. The access door **14** is of course closed to prevent leakage of radio frequency energy. As radio frequency energy penetrates the frozen material **24**, the ice or other component to be vaporized evaporates without first becoming a liquid, that is it sublimates due to the absorption of the radio frequency energy-producing heat. This sublimation produces a region of dried material, represented by the section **24***a*, and leaves a core of frozen undried material, represented by the section **24***b*. The dried material **24***a* offers no appreciable impedance thus permitting the sublimation of the moist material to continue at a substantially uniform rate. The only precaution that need be taken is to keep the radio frequency energy from being applied fast enough to raise the temperature of any portion of the material above the melting point of the vaporizable portion of the

material. Should this be permitted to happen, the liquid, particularly if water, would offer considerably greater impedance to the radio frequency energy and hot spots might develop, which in the case of food, would cause changes affecting the flavor. However, known methods for maintaining the voltage supplied to the oscillator at a predetermined value will accomplish this objective.

The present invention may be used to evaporate out from any material any component that may be evaporated from the solid state. Upon closure of door **11** the evacuation of chamber **10** by pump **23** serves to reduce the partial pressure of the component to be evaporated in the atmosphere of the heating chamber **13**. The heating of the material **24** provides a high vapor pressure at the material **24** and the cooling of the condenser coils **19** provide a large low temperature region in close proximity to the material **24**. This, in combination with the heating chamber **13** having walls **17** effectively comprising microwave energy chokes, provides at all times a substantially more efficient, very short and unimpeded vapor path from the region of high vapor pressure or material **24** to the low vapor pressure region or condenser coils **19** which rapidly condense and collect in frozen form the vapor sublimated from the material **24** in the heating chamber **13**.

Vapor condensed on the coils **19** may be removed during off cycles of the still by raising the temperature of the coils **19** to a point above freezing and removing the vapor as it forms with the pump or other suitable means. This process may be accelerated if the refrigeration means **21** is reversible, i.e., the coils can be heated.

This invention is not limited to the particular details of construction and materials described, as many equivalents will suggest themselves to those skilled in the art. It is accordingly desired that the appended claims be given a broad interpretation commensurate with the scope of the invention within the art.

What is claimed is:

1. Apparatus for removing a vaporizable component by sublimation from material including a solid and said vaporizable component in the solid state comprising: first container means for providing an atmosphere at a pressure substantially lower than atmospheric pressure; pump means communicating with said first container means for maintaining said lower pressure; second container means disposed in said first container means enclosing said material to be treated, a substantial portion of said second container means containing a plurality of passages forming a microwave energy choke for preventing the propagation of microwave energy from the interior of said second container means to the interior of said first container means while permitting substantial atmospheric communication therebetween; a microwave electrical energy generator; a propagated electromagnetic wave-guiding structure coupled to said generator and communicating with said second container means for

applying propagated electromagnetic microwave energy to said material to supply the heat of sublimation to sublimate a substantial portion of said component; condenser means having a substantial area substantially enclosing and adjacent said portion of said second container means forming a microwave energy choke for at least assisting in causing said sublimed component to pass outwardly through said choke portion and thereafter to condense on said condenser means; and means for maintaining said condenser means at a temperature substantially lower than freezing whereby there is provided a short substantially unimpeded vapor path between said material and said condenser means and said sublimed component is efficiently condensed on said condenser means.

2. In combination, means for generating electromagnetic energy having a frequency in the microwave region of the spectrum, a chamber for receiving a frozen aqueous material, waveguide means connected between said generating means and said chamber for coupling said electromagnetic energy to said chamber to sublimate a substantial portion of the water in said material, a sealed container for enclosing said chamber, means for maintaining the pressure within said sealed container at a value substantially lower than atmospheric pressure, a plurality of apertures in a portion of the walls of said chamber for preventing the propagation of said electromagnetic energy from said chamber to said sealed container and for providing atmospheric communication therebetween, and means for condensing water sublimated from said material.

3. In combination, means for generating electromagnetic energy having a frequency in the microwave region of the spectrum, a chamber for receiving a frozen aqueous material, waveguide means connected between said generating means and said chamber for coupling said electromagnetic energy to said chamber to sublimate a substantial portion of the water in said material, a sealed container for enclosing said chamber, means for maintaining the pressure within said sealed container at a value substantially lower than atmospheric pressure, a plurality of apertures in a portion of the walls of said chamber for preventing the propagation of said electromagnetic energy from said chamber to said sealed container and for providing atmospheric communication therebetween, condenser means having a substantial area adjacent to and enclosing a substantial portion of said chamber for condensing in frozen form water sublimated from said material, and means for maintaining said condenser means at a low temperature.

References Cited in the file of this patent

UNITED STATES PATENTS

2,345,204	Lodwig	Mar. 28, 1944
2,513,991	Bradbury	July 4, 1950
2,585,825	Nyrop	Feb. 12, 1952
2,859,534	Copson	Nov. 11, 1958