

[54] **METHOD AND APPARATUS FOR DEEP-FREEZING**

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[58] Field of Search: 62/71, 346; 165/91, 165/89

[56] **References Cited**

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[57] **ABSTRACT**

An improved method and apparatus for the transformation of a liquid product into flakes by freezing, said method utilizing a cylinder rotating about its own axis and having its outer face passing in succession in front of a station at which a thin layer of said liquid is deposited on said outer face, and a station adapted to scrape-off said thin layer in the frozen state, the cooling being effected inside said cylinder by a refrigerant fluid injected into the interior of said cylinder and adapted to circulate in heat-exchange relation with said cylinder, in which method substantially all the internal volume of said cylinder is caused to participate in the heat-exchange process by injecting a cryogenic liquid as the refrigerant fluid in circulation in a plurality of conduits in heat-exchange with a thermal filling medium occupying substantially all the interstitial space between said conduits and the outer face of said freezing cylinder, the vaporization of said cryogenic liquid and the heating of the vapours being effected in said conduits. The cryogenic liquid may be for example liquid nitrogen.

7 Claims, 2 Drawing Figures

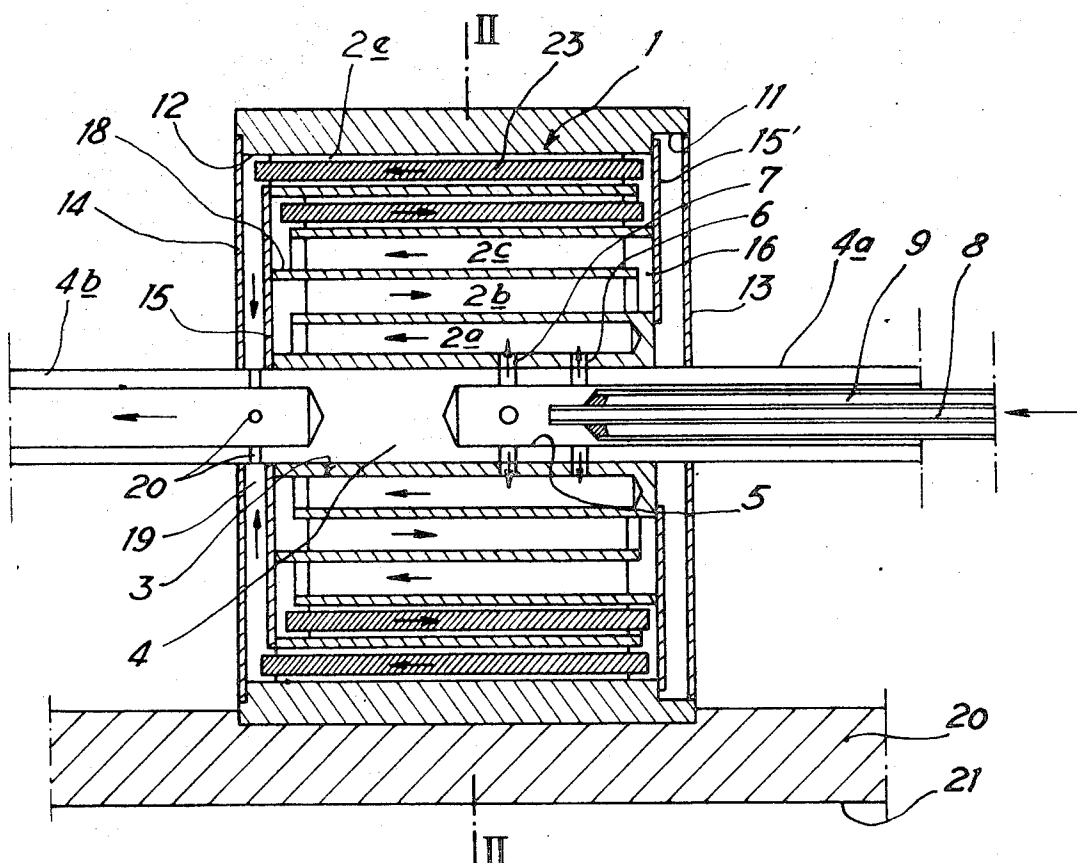


Fig. 1

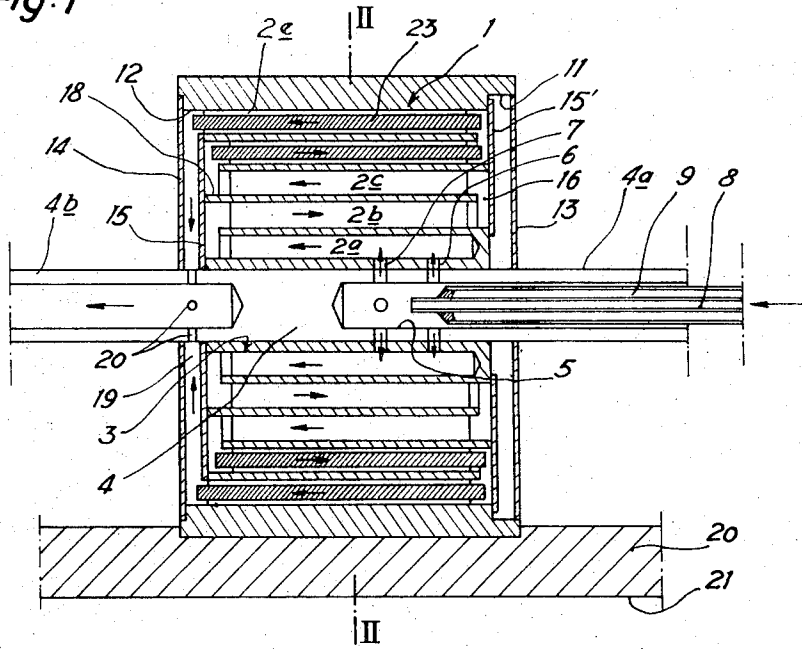
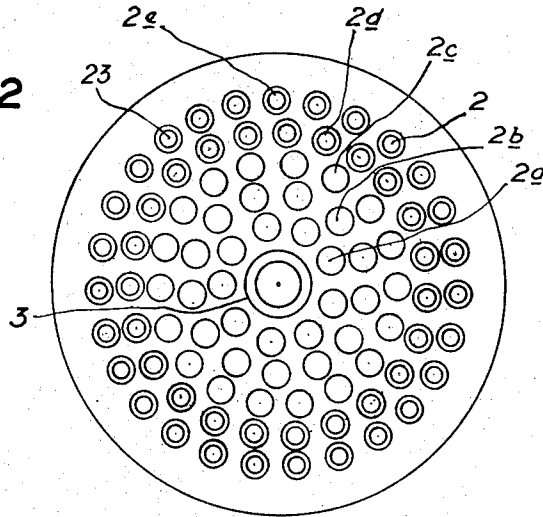


Fig. 2



METHOD AND APPARATUS FOR DEEP-FREEZING

The present invention relates to a method of deep-freezing of a product initially in the liquid form, and more particularly to the preparation of flakes of frozen products, utilizing a cylinder rotating about its own axis and having its outer face presented successively in front of a station at which a thin layer of the said liquid is deposited on the said face, and in front of a station for scraping-off the said thin layer in the frozen state.

In this kind of operation, it has been proposed to effect the cooling of the freezing cylinder in numerous ways. In operation, a cooling fluid is continuously injected into the cylinder in which it circulates in conduits in heat exchange with a cylindrical wall, the outer face of which forms the freezing face. Up to the present time, efforts have been made to cause the frigorific energy to be evolved in the immediate vicinity of the freezing wall, and to this end, conduits have been prepared for the flow of the cooling fluid which are practically underlying the freezing wall. As it is necessary to have simultaneously a relatively high speed of flow and a relatively long period of contact of the cooling fluid with the contact wall, a great variety of combinations of flow circuits has been proposed by putting in series and/or in parallel conduit elements which are all placed in an underlying layer of the freezing wall.

Arrangements of this kind permit the use of moderately cold cooling fluids, at most at a few degrees or a few multiples of 10° below zero, but already at these temperatures they frequently have the drawback of failing to ensure a satisfactory distribution of the temperature over the freezing surface, while in addition they necessitate expensive auxiliary cooling devices for the cooling fluid, for example by means of thermostatically controlled chambers supplied with cooling fluid at a very much lower temperature, for example that of liquid nitrogen. Furthermore, it is necessary to provide circulation means for the cooling fluid between the cooling station and the freezing cylinder.

A device for freezing a liquid product such as water has also been proposed, utilizing a rotating cylinder in which the internal space participates in the heat exchange of a refrigerant fluid injected with a sealed heat-transfer liquid filling medium which extracts the heat from the product to be frozen, for example a brine.

However, this heat-transfer filling medium is essentially comprised in a very small annular space between the outer active face of the cylinder and an internal casing, with the addition of a few conduits and means permitting the operation of a circulation in closed circuit of the heat-transfer liquid, by periodically plunging the said conduits in a renewed bath of refrigerant which occupies the lower space of the cylinder.

For this reason, this heat-transfer medium occupies a small fraction of the internal volume of the cylinder, so that the result is a low heat efficiency of the frigories inside the cylinder, causing an increase in the heat evacuation time, since only a part of the conduits is immersed in the refrigerant during the rotation of the cylinder.

It is clear that it would be more economical to feed the freezing cylinder directly with a very cold liquid, but in that case the drawbacks referred to above concerning lack of uniformity of temperature at the point of freezing, already considerable with a moderately cold fluid, become so great that it is not possible to op-

erate in this manner with the methods and apparatus as at present employed.

An object of the present invention concerns a method of freezing permitting direct injection of a very cold liquid, for example liquid nitrogen, into a freezing cylinder. Another object of the invention is furthermore to ensure practically complete uniformity of temperature at the place of cooling. Still a further object of the invention is to achieve all these objects with a good thermal efficiency. Still a further object of the invention is a thermal device which can be used as a freezing device and in this case utilizing the above method, or as an evaporator.

In the method according to the invention, substantially the whole of the internal volume of the said cylinder is caused to participate in the heat exchange by injecting a cryogenic liquid as the refrigerant fluid in circulation in a plurality of heat exchange conduits with a thermal filling medium occupying substantially all the interstitial space between the said conduits and the outer face of the freezing cylinder, while the vaporization of the said cryogenic liquid and the heating of the vapours is effected in the said conduits. There is thus obtained an efficient heat exchange by conduction in a good heat conducting medium.

Another characteristic feature of the invention is that the vapours of the cryogenic liquid are gradually heated up to a temperature at the outlet of the vapours, which is only slightly less than the temperature of the heat-transfer medium in the vicinity of the periphery of the cylinder.

In fact, the whole volume of the cylinder is utilized to the maximum extent for the heat exchange and it is thus possible to form freezing devices which develop a high freezing power per unit volume.

The invention has also for its object a thermal device which can be employed for freezing, of the kind comprising a cylinder rotating about an axial shaft, when so desired a station for depositing a liquid in a thin layer, angularly downstream of the said freezing station, a station for scraping-off the product in the frozen state, means for cooling inside the said cylinder, said cooling means incorporating conduits for the circulation of a cryogenic fluid injected into the interior of the cylinder, characterized in that substantially all the internal volume comprised between the outer surface of the said cylinder and the said conduits for the circulation of the heat-exchange fluid is constituted by a heat-transfer filling medium.

The characteristic features and advantages of the invention will further be brought out in the description which follows below by way of example, reference being made to the accompanying drawings, in which:

FIG. 1 is a view in axial cross-section of a freezing cylinder according to the invention;

FIG. 2 is a view in cross-section, taken along the line II—II of FIG. 1.

Referring to FIGS. 1 and 2, a freezing cylinder is essentially composed of a metal core 1, of aluminum, copper or iron for example, chromium plated on its lateral face, pierced with a large number of longitudinal passages 2, for example forming five rings 2a, 2b, 2c, 2d, 2e, these passages being uniformly distributed in the metallic mass 1. This metallic mass 1 has on the one hand an axial perforation 3 to permit the introduction of a shaft 4 formed by a portion 4a with an axial clearance forming a supply conduit for a cryogenic liquid,

while a second portion 4b constitutes the evacuation conduit for the vapours of this cryogenic liquid. The supply conduit 4a is essentially composed of a bore 5 formed in the shaft 4, with a plurality of radial conduits such as 6 and 7, each opening into one of the conduits 2a of the first ring of conduits 2a which is the closest to the axis. In order to permit the introduction of the cryogenic liquid into the body of the cylinder, a conduit 8, insulated at 9, is engaged in the bore 5 up to the level of the radial passages 6 and 7.

On the other hand, the metallic mass 1 of the freezing cylinder is provided, opposite each front face, with recesses 11 and 12 serving as housings for the end shields 13 and 14 and with masks 15, 15' permitting the passage of the cryogenic fluid from a conduit 2a to a conduit 2b of the next outer ring of conduits and from thence to a conduit 2c of the ring 2c, etc, the whole being preferably arranged so that all the conduits 2a, 2b are fed radially in series in the central zone, while some are fed in series and some in parallel in the peripheral zone, where the transverse passages are more numerous. In order to permit these changes from one conduit to the other, it is observed that clearances such as 16 are provided on the front faces of the cylinder 1 in such manner that the adjacent conduits such as 2b, 2c, 2d, are connected in series.

The annular end-plate 14 with its mask 15 forms an annular radial passage 19 which is fed at the periphery by the peripheral conduits 2e, and which communicates by radial perforations 20 with the interior through the evacuation conduit 4b.

This freezing device ensures the introduction into the conduit 4a of the cryogenic liquid, for example liquid nitrogen, which flows through passages 6 and 7 and from thence into each of the longitudinal conduits 2a, then into the conduits 2b, and so on into the conduits 2c, 2d, 2e. In the first conduits, the cryogenic liquid is vaporized while giving up to the metallic mass of the cylinder 1 the frigorific energy due to the heat of vaporization, while in the peripheral conduits 2d and 2e, the vapours of cryogenic liquid are gradually heated, so that the outlet temperature of the cryogenic liquid vapours is only slightly less than the temperature of the metallic mass of the cylinder 1 in the vicinity of its periphery.

In the usual manner, this cylinder 1 is arranged to dip at its lower portion into a mass of liquid 20 to be frozen, placed in a tank 21, while in a downstream portion with respect to the direction of rotation is arranged a scraper device which detaches and breaks-up the frozen products into flakes in a manner known per se. It is preferable that the flow of the vapours of the cryogenic liquid in the peripheral channels is of the turbulent type. To this end, the section of passage of the said channels is reduced, for example by cores 23 engaged in these latter.

The means for driving in rotation (not shown in the drawings) are of course arranged on the shaft 4 of the freezing cylinder. These means have not been described since they are well known per se. This method of freezing is especially applicable to a first phase of lyophilization of products.

What we claim is:

1. In a method of freezing a product which is initially in liquid phase, by rotating a cylinder about a horizontal axis with a portion of the periphery of the cylinder immersed in the product and removing frozen liquid

from another portion of the periphery of the cylinder while passing a refrigerant fluid through the cylinder; the improvement in which the refrigerant fluid is a cryogenic liquid and passes in a plurality of conduits in heat exchange with a thermal filling medium which is a solid metallic heat transfer mass and that occupies substantially all of the interstitial space between the conduits and the outer face of the cylinder, the refrigerant fluid being introduced into the cylinder adjacent the axis of the cylinder and moving from adjacent the axis of the cylinder to adjacent the periphery of the cylinder through a progressively increasing number of said conduits thereby to accommodate the expanding volume of the refrigerant fluid as it warms.

2. In a method of freezing a product which is initially in liquid phase, by rotating a cylinder about a horizontal axis with a portion of the periphery of the cylinder immersed in the product and removing frozen liquid from another portion of the periphery of the cylinder while passing a refrigerant fluid through the cylinder; the improvement in which the refrigerant fluid is a cryogenic liquid and passes in a plurality of conduits in heat exchange with a thermal filling medium which is a solid metallic heat transfer mass and that occupies substantially all of the interstitial space between the conduits and the outer face of the cylinder, the refrigerant fluid flowing in a zig-zag path including a plurality of said conduits that extend parallel to said axis with the fluid moving in opposite directions through adjacent conduits that are spaced progressively farther from said axis.

3. In a method of freezing a product which is initially in liquid phase, by rotating a cylinder about a horizontal axis with a portion of the periphery of the cylinder immersed in the product and removing frozen liquid from another portion of the periphery of the cylinder while passing a refrigerant fluid through the cylinder; the improvement in which the refrigerant fluid is a cryogenic liquid and passes in a plurality of conduits in heat exchange with a thermal filling medium which is a solid metallic heat transfer mass and that occupies substantially all of the interstitial space between the conduits and the outer face of the cylinder, the refrigerant fluid being introduced along the axis of the cylinder and vaporizing by the time it reaches the periphery of the cylinder.

4. In apparatus for freezing an initially liquid product, comprising a cylinder, means mounting the cylinder for rotation about a horizontal axis whereby the cylinder dips into the liquid product and the liquid product freezes on the surface of the cylinder and the frozen liquid product is removed from the surface of the cylinder, and means for introducing a refrigerant fluid into the cylinder to cool the cylinder; the improvement in which the cylinder is a metallic body having passageways therethrough parallel to the axis of the cylinder, the space between the passageways and the periphery of the cylinder being occupied by solid metal, said passageways being relatively small in number adjacent the axis of the cylinder and relatively great in number adjacent the periphery of the cylinder, means for introducing a refrigerant fluid comprising a cryogenic liquid into the cylinder adjacent the axis of the cylinder, and means for removing vaporized cryogenic liquid from adjacent the periphery of the cylinder.

5. Apparatus as claimed in claim 4, and means for directing said refrigerant fluid through said passageways

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in series in a progressively radially outward direction.

6. Apparatus as claimed in claim 5, and means for directing said fluid through said passageways in zig-zag relationship with the fluid passing in opposite directions parallel to the axis of the cylinder through radially adjacent passageways.

7. Apparatus as claimed in claim 6, said directing

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means comprising end plates on said cylinder, said end plates cooperating with the ends of said passageways whereby some of said passageways communicate only with radially inward passageways at one end and only with radially outward passageways at the other end.

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