APPARATUS AND METHOD FOR CHILLING OR FREEZING OBJECTS UTILIZING A ROTARY DRUM HAVING PROMINENCES FORMED ON AN INNER SURFACE THEREOF

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ABSTRACT

In an apparatus and method for chilling or freezing objects, an interior surface of a rotating drum includes recesses formed between prominences extending inwardly from the interior surface. One or more liquid CO₂ nozzles inject solid CO₂ towards the interior surface. The injected snow replenishes a depth of solid CO₂ in empty or partially empty recesses and/or provides a fresh layer of solid CO₂ on top of the objects. Because the interior surface is made of polyethylene and the depth of solid CO₂ is replenished in empty or partially empty recesses, the product/drum sticking problem experienced by conventional apparatuses and methods is reduced or avoided. Optionally, the CO₂ snow is injected into empty or partially empty recesses by at least one first liquid CO₂ nozzle and is deposited on top of the objects by at least one second liquid CO₂ nozzle so that each opposing surface of the object is in direct contact with solid CO₂.
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BACKGROUND

[0001] Many food products must be chilled below 40°F prior to shipment. Sometimes this is achieved by mixing the product with solid CO₂ (either dry ice “snow” or dry ice pellets) in a stainless steel drum. However, the interior surface of the stainless steel drum becomes too cold that moist products can stick to the surface, resulting in damaged product, un-recovered product, and disruption of the flow of product through the drum.

[0002] To solve this problem, many prior art references utilize a small amount of water that forms an ice layer on the stainless steel surface. See, e.g., U.S. Pat. No. 5,220,812 to Palbiński et al. and U.S. Pat. No. 5,603,567 to Peach. Others position the CO₂ nozzles so that CO₂ snow is only administered on the pieces of food being cooled. See, e.g., U.S. Pat. No. 6,497,106 to Lang et al. Either method fails to provide effective two-sided exposure of the object to CO₂ snow and thereby extends the amount of time it takes to chill the product.

[0003] Thus, there is a need in the art for a method of cooling food with solid CO₂ in a rotating drum without incurring too much product sticking.

SUMMARY

[0004] There is provided an apparatus for chilling or freezing objects, the apparatus comprising a rotatable drum defining an enclosure having an interior surface, an inlet at one end of the drum, an outlet at an opposing end of the drum, and at least two CO₂ nozzles located within the enclosure, at least one CO₂ nozzle positioned horizontally and at least one CO₂ nozzle positioned vertically, the interior surface being polyethylene having prominences thereon, wherein the prominences are not directional vanes.

[0005] There is also provided a method for chilling or freezing objects, the method comprising the following steps. The above-provided apparatus is provided. CO₂ snow is ejected from the at least one CO₂ nozzle positioned horizontally to produce a blanket of CO₂ snow on the interior surface between the prominences. The object to be chilled or frozen is introduced into the inlet of the drum. The drum is rotated. CO₂ snow is ejected from the at least one CO₂ nozzle positioned vertically to produce a blanket of CO₂ snow on the object. The object is removed from the outlet of the drum.

[0006] There is also provided another apparatus for chilling or freezing objects, the apparatus comprising a rotatable drum defining an enclosure having an interior surface, an inlet at one end of the drum, an outlet at an opposing end of the drum, one or more liquid CO₂ nozzles disposed in an interior of the drum each one of which is adapted to inject a stream of solid CO₂ into the enclosure towards the interior surface. The interior surface of the drum is comprised of polyethylene having prominences molded into the polyethylene. Portions of the interior surface in between prominences form recesses relative to the prominences that are adapted and configured to retain a depth of solid CO₂. The prominences are not directional vanes.

[0007] There is also provided another method for chilling or freezing objects, comprising the following steps. The above apparatus is provided. The drum is rotated. The objects are introduced into the interior the drum. A stream of solid CO₂ is injected into the enclosure towards the interior surface from one or more liquid CO₂ nozzles, wherein the solid CO₂ is deposited in the recesses and/or on top of the objects. The objects are removed from the outlet of the drum.

[0008] The apparatus or method may include any one or more of the following aspects:

[0009] the apparatus or method further comprises directional vanes on the interior surface.

[0010] the prominences extend approximately 0.25 to 1 inches from the interior surface.

[0011] the apparatus further comprises directional vanes on the interior surface.

[0012] said at least two liquid CO₂ nozzles comprise at least one first liquid CO₂ nozzle and at least one second liquid CO₂, each of said at least one first liquid CO₂ nozzle being disposed in an interior of the drum and being adapted, configured, and oriented to provide a first stream of solid CO₂ towards a first angular position on the interior surface, each of said at least one second liquid CO₂ nozzle being disposed in the drum interior and being adapted, configured, and oriented to provide a second stream of solid CO₂ towards a second angular position on the interior surface, and the first angular position is between 70-110° and/or 250-290° with respect to vertical and the second angular position is between 160-200° with respect to vertical.

[0013] the apparatus further comprises directional vanes on the interior surface.

[0014] the prominences extend approximately 0.25 to 1 inches from the interior surface.

[0015] the apparatus further comprises directional vanes on the interior surface.

[0016] said at least two liquid CO₂ nozzles comprise at least one first liquid CO₂ nozzle and at least one second liquid CO₂, each of said at least one first liquid CO₂ nozzle being disposed in an interior of the drum and injects a first stream of solid CO₂ towards a first angular position on the interior surface, each of said at least one second liquid CO₂ nozzle being disposed in the drum interior and injects a second stream of solid CO₂ towards a second angular position on the interior surface, and the first angular position is between 70-110° and/or 250-290° with respect to vertical and the second angular position is between 160-200° with respect to vertical.

[0017] the first stream(s) deposits a fresh layer of solid CO₂ in the recesses and the second stream(s) deposits solid CO₂ on top of the objects tumbling at or adjacent to a bottom of the drum.

[0018] the objects are food products.

[0019] the food products are meat products.

BRIEF DESCRIPTION OF THE DRAWINGS

[0020] For a further understanding of the nature and objects of the present invention, reference should be made to the following detailed description, taken in conjunction with the accompanying drawings, in which like elements are given the same or analogous reference numbers and wherein:

[0021] FIG. 1 is a cross-sectional, front (inlet) view of an embodiment of the disclosed chilling or freezing apparatus taken along an axis of the rotating drum that illustrates alternative positions and orientations for the CO₂ snow nozzles.
FIG. 2 is a side, elevation view of another embodiment of the disclosed chilling or freezing apparatus that includes directional vanes but which omits the prominences for the sake of clarity;

FIG. 3 is an isometric, schematic view of the rotating drum of the disclosed chilling or freezing apparatus;

FIG. 4 is an elevation side view of one embodiment of the interior surface of the rotating drum;

FIG. 5 is an elevation side view of a second embodiment of the interior surface of the rotating drum; and

FIG. 6 is an elevation side view of a third embodiment of the interior surface of the rotating drum.

DESCRIPTION OF PREFERRED EMBODIMENTS

Disclosed is an apparatus and method for chilling or freezing objects. While the preferred embodiments are disclosed with respect to food products, and preferably with respect to meat products, such as chicken, beef, and turkey parts, the disclosed apparatus and method may also be utilized with any object that requires chilling or freezing, such as seafood, produce, golf ball centers and insulated wire scrap.

In the inventive apparatus and method, an interior surface of a rotating drum (forming an enclosure) includes recesses formed between prominences that extend inwardly from the interior surface. The recesses are adapted and configured to be filled or partially filled with solid CO₂ from one or more liquid CO₂ nozzles disposed within the enclosure that inject solid CO₂ towards the interior surface. In the event that solid CO₂ is sublimated or tumbles out of recesses in portions of the drum rotating overhead, a depth of solid CO₂ is replenished by injection of the solid CO₂ from the nozzle(s). Typically, the solid CO₂ is deposited into the empty or partially empty recesses prior to that portion of the inner surface passage under the objects tumbling inside the rotating drum. In this way, the depth of solid CO₂ in empty or partially empty recesses is replenished and the objects to be cooled or frozen at most only touch the innermost portions of the prominences. Thus, the problem of product/drum sticking that is experienced by conventional apparatuses and methods is reduced or avoided.

Alternatively, or in addition to the above-described solid CO₂ depth replenishment or partial replenishment, the nozzle(s) may deposit a fresh layer of solid CO₂ on top of the objects tumbling at or adjacent to a bottom of the rotating drum. When combined with the above-described CO₂ depth replenishment or partial replenishment, each of the opposing surfaces of the objects are in direct contact with solid CO₂ so that the efficiency of the cryogenic cooling is enhanced in comparison to conventional apparatuses and methods.

The solid CO₂ that is deposited into empty or partially empty recesses is injected by at least one first liquid CO₂ nozzle and the solid CO₂ that is deposited on top of the objects is injected by at least one second liquid CO₂ nozzle. Each of the at least one first liquid CO₂ nozzle is adapted, configured and oriented to inject a first stream of solid CO₂ towards a first angular position on the interior surface while each of the at least one second liquid CO₂ nozzle is adapted, configured and oriented to inject a first stream of solid CO₂ towards a second angular position on the interior surface. The first angular position is generally around a one quarter revolution of the drum from a top of the drum while the second angular position is generally around a half revolution of the drum from a top of the drum. Typically, the first angular position is between 50-130° or 230-310° (or in the case of two first liquid CO₂ nozzles at same axial position of the drum, between 50-130° and between 230-310°) with respect to vertical. Typically, the second angular position is between 140-220° with respect to vertical. More typically, the first angular position is between 80-120° with respect to vertical and the second angular position is between 160-200° with respect to vertical.

Solid CO₂ has a significant latent heat of vaporization. When heat is transferred from the object (to be cooled or frozen) to the solid CO₂, an amount of the solid CO₂ is sublimated. Solid CO₂ at atmospheric pressure is at a temperature of around −78.5°C. When the objects to be cooled or frozen are food products, the liquid CO₂ injected from the nozzle(s) is typically food-grade CO₂.

The rotatable drum may have any shape that permits rotation, including but not limited to cylindrical, a hexagonal prism (e.g., elongated hexagon), or an octagonal prism (e.g., elongated octagon). Typically, it is cylindrical. The axis of the rotatable drum is generally positioned more horizontal than vertical. Typically, the drum axis is declined from the outlet towards the inlet in order to move the objects from the inlet to the outlet by the force of gravity. The interior surface of the rotatable drum is polyethylene, typically food-grade polyethylene. Polyethylene exhibits much less sticking between it and the objects to be cooled in comparison to conventional drum materials such as stainless steel.

The drum has prominences extending inwardly from the inner surface. Recesses are formed between the prominences. Solid CO₂ injected by the nozzle(s) fills or partially fills these recesses with CO₂ snow. In this manner, a portion of the surface of the object adjacent the inner surface of the drum is in contact with solid CO₂ (filling or partially filling a recess) instead of with the inner surface of the drum. In this manner, at most only a portion of each object to be chilled or frozen is in direct contact with one or more prominences. Thus, the problem of sticking exhibited by conventional apparatuses and methods is reduced or avoided. It should be noted that the inner surface of the drum is continuous and not perforated, so that the solid CO₂ may not pass through the drum in the radial direction.

The particular shape of the prominences is not essential to the invention so long as the prominences are sized and spaced to form valleys that can be filled with CO₂ snow to cool or freeze objects extending across them or suspended on the prominences. The desired shape of the prominences is typically driven by the ease with which the shapes may be manufactured, such as by molding, and/or is driven by the shape and size of the object to be cooled or frozen. While the shapes of each of the prominences need not be uniform, typically they are. Similarly, while the spaces in between the prominences need not be uniform, typically they are.

By way of a non-limiting example, in the case of meat products to be chilled or frozen, the heights of the prominences typically extend approximately 0.25 inches to approximately 1 inch from the interior surface of the drum. However, one of ordinary skill in the art will recognize that for larger or smaller objects, the heights of the prominences may respectively extend a longer or shorter distance from the interior surface. One of ordinary skill in the art will of course recognize that the depth of a particular recess will equal the height of an adjacent prominence. Thus, for prominences having heights of 0.25 inches or 1 inch, the corresponding recesses have depths of 0.25 inches or 1 inch, respectively.
Consequently, the solid CO\textsubscript{2} filling the recess in the foregoing example will have a fill depth of 0.25 inches to 1 inch.

[0036] The prominenices may be cylindrically shaped so that each portion of a planar, circular top surface of the prominence extends a same height from the interior surface of the drum. Alternatively, the prominence may be hemispherically shaped so that the height of the prominence is at a minimum at its outer circumference and is at a maximum in the center of the prominence. While an outer edge of each cylindrical or hemispherical projection is typically located approximately 0.25 inches to 2.00 inches from the outer edges of adjacent cylindrical or hemispherical prominence, this prominence-to-prominence spacing distance may be greater or smaller depending upon the size of the object to be chilled or cooled.

[0037] The cross-sectional shape of the prominence (taken along a height of the prominence) may take include: crescent moons, semicircles, ovals, rectangles, parallelograms, trapezoids, crosses, triangles, squares, pentagons, hexagons, heptagons, octagons, and the like. Combinations of these shapes may also be used.

[0038] The prominence may also be shaped as parallel ridges. The heights of the ridges and the spacing in between adjacent ridges are not limited and may be varied upon the size and shape of the object to be cooled or frozen. The parallel ridges may be oriented parallel to the axis of the drum, perpendicular to the axis of the drum, or angled to the axis of the drum. Alternatively, the parallel ridges may be oriented such that they form spirals with an axis of the spiral being the axis of the drum. In this way, the spiral-oriented parallel ridges form "rifling" that helps move the object (to be chilled or frozen) along the axis of the drum from the inlet to the outlet.

[0039] The prominenices are not directional vanes, but instead are positioned to suspend the object away from the interior surface. Directional vanes are commonly used in rotatable drums to direct the object from the inlet to the outlet during rotation. Directional vanes can further be distinguished from the prominence of the invention by the fact that directional vanes have a height dimension (in the radial direction extending inward towards the axis of the drum) that is at least three times greater than its width dimension, while the prominence of the invention do not. Because the directional vanes have such a high aspect ratio (height to width), they are very poorly suited to contain a depth of solid CO\textsubscript{2} in between the vanes. In other words, the relatively high height of the vanes results in a relatively great depth of solid CO\textsubscript{2} that may tend to accumulate in between the vanes. The relatively greater depth and corresponding mass of solid CO\textsubscript{2} will greatly increase the energy needed to rotate the drum. Additionally, the high aspect ratio and corresponding greater surface area will increase the extent to which there is direct contact between a chilled vane and a substantial portion of a surface of the object to be cooled or chilled. One of ordinary skill in the art will recognize that these disadvantages of directional vanes do not solve the problem of product/drum sticking exhibited by conventional apparatuses and methods. Nevertheless, the disclosed apparatus may include some amount of directional vanes in addition to the prominences.

[0040] As best illustrated in FIG. 1, the objects 11 to be cooled or chilled are introduced into the inlet of the drum 12 and the drum 12 is rotated.

[0041] Solid CO\textsubscript{2} may be injected towards the inner surface 9 of the drum 12 from one or more first liquid CO\textsubscript{2} nozzle 34, 34" to produce a blanket of solid CO\textsubscript{2} snow 21 on the inner surface 9 between the prominences 38. The liquid CO\textsubscript{2} is introduced to the nozzle 34, 34" via a header 13. In FIG. 1, the first liquid CO\textsubscript{2} nozzle 34" may be oriented to inject a stream of solid CO\textsubscript{2} at a first angular position of the drum 12, generally between 50-130° or the first liquid CO\textsubscript{2} nozzle 34" may be oriented to inject a stream of solid CO\textsubscript{2} at a converse first angular position of the drum 12 between 230-310° with respect to vertical. Alternatively, each of the first liquid CO\textsubscript{2} nozzles 34, 34" may be utilized, one of which injects a stream of solid CO\textsubscript{2} to a first angular position between 50-130° with respect to vertical and the other of which injects a stream of solid CO\textsubscript{2} to a converse angular position between 230-310° with respect to vertical.

[0042] As the drum 12 rotates (assuming for the sake of argument, in the clockwise direction), the gravity causes the objects 11 to tumble downwardly from the prominences 37 and solid CO\textsubscript{2} 21 in the recesses formed between the prominences 37 from the "left" side of the drum (for example, just short of 270°) towards the bottom of the drum 12 (for example, at around 180°) as that side is rotated upwardly towards a top (for example, at around 0°) of the drum 12. The drum 12 may be rotated in either clockwise or counter-clockwise direction and one of ordinary skill in the art will recognize that the angular positions described herein may be adjusted to account for any change in rotational direction. After the object 11 has tumbled away from that side of the drum 11, solid CO\textsubscript{2} 21 is freshly deposited in the recesses of a portion (for example, at around 270°) of the drum 12 that is being rotated upwardly from a bottom of the drum 12 to a top of the drum 12. Alternatively (or in addition to the deposition of snow at around 270°), the solid CO\textsubscript{2} 21 is freshly deposited in the recesses of a portion (for example, at around 90°) of the drum 12 that is being rotated downwardly from a top of the drum to a bottom of the drum 12. In this manner, solid CO\textsubscript{2} that is diminished through sublimation or which is jarred loose by bumping of the objects or which falls out of recesses by the force of gravity may be replenished or partially replenished in the recesses that are empty or partially empty. As a result, a substantial area of the inner surface 9 of the drum 12 is separated from the objects 11 by a layer of solid CO\textsubscript{2} 21.

[0043] A stream 38 of solid CO\textsubscript{2} may also be injected by a second liquid CO\textsubscript{2} nozzle 36 to produce a blanket of solid CO\textsubscript{2} (not shown) on top of the object 11. The second liquid CO\textsubscript{2} nozzle 36 may also be used in conjunction with one or both of the first liquid CO\textsubscript{2} nozzles 34, 34". This allows each opposing layer of the object 11 to be cooled or frozen by contact with solid CO\textsubscript{2} 21. In other words, the object 11 is sandwiched between the solid CO\textsubscript{2} 21 in the recesses and the layer of solid CO\textsubscript{2} (not shown) on top of the object 11. The combination of the two nozzle orientations and the prominences 37 allow both sides of the object to contact the solid CO\textsubscript{2}, resulting in more efficient cooling.

[0044] One of ordinary skill in the art will recognize that the schematic illustration of FIG. 1 depicts a cross-section of the invention at an axial position of the drum 12. Typically, there are multiple first liquid CO\textsubscript{2} nozzles 34 or 34" each one of which is oriented to inject a first stream of solid CO\textsubscript{2} 35 or 35° at more or less a same first angular position. Thus, there are typically multiple first streams 35 or 35° of solid CO\textsubscript{2} that are parallel to, and spaced from one another in the axial direction of the drum 12. Similarly, there are typically multiple second liquid CO\textsubscript{2} nozzles 36 each one of which is oriented to inject a second stream 38 of solid CO\textsubscript{2} at more or less a same second
angular position. Thus, there are typically multiple second streams 38 of solid CO₂ that are parallel to, and spaced from one another in the axial direction of the drum 12.

[0045] The objects 11 can traverse the drum 12 from an inlet to an outlet of the drum 12 by force of gravity caused by a declination of the drum 12 from the inlet to the outlet. The objects 11 can also traverse the drum 12 through the use of direction vanes (not shown in FIG. 1 that urge the objects 11 from the inlet to the outlet as the drum 12 is rotated. The objects 11 are then removed from the outlet of the drum 12.

[0046] As best shown in FIG. 2, the object 11 is introduced into the inlet 22 of the drum 12 by a conveyor 10. One of ordinary skill in the art will recognize that alternate methods of introduction may also be used without departing from the teachings herein.

[0047] In the embodiment depicted in FIG. 2, the drum 12 is rotated by drive motor 15 and drive wheels 16. One of ordinary skill in the art will recognize that alternate mechanisms may be utilized to rotate drum 12 without departing from the teachings herein. During rotation of the drum 12, directional vanes 14 move the object 11 from the inlet 22 to the outlet 23.

[0048] In the embodiment depicted in FIG. 2, the chilled or frozen object 11 exits the outlet 23 of the drum 12 via buckets 17 (in a way well known to those skilled in the art of material handling) and discharge slide 18. One of ordinary skill in the art will recognize that alternate outlet mechanisms may be utilized without departing from the teachings herein.

[0049] In the embodiment depicted in FIG. 2, liquid CO₂ 20 is introduced via liquid CO₂ injection header assembly 13 and nozzles 22a and 22b. The liquid CO₂ 20 is expanded to solid CO₂ 20 at nozzles 22a and 22b. Exhaust ducts 19 prevent the CO₂ gas from the escaping from drum 12 into the atmosphere.

[0050] As best illustrated in FIG. 3, the object 11 (not shown in FIG. 3) is introduced into the inlet 22 of the rotating drum 12 and removed from the outlet 23. Cutaway portion 24 of rotating drum 12 provides further detail in FIGS. 4-6 of the interior surface 25 of the rotating drum. FIGS. 4-6 are not drawn to scale.

[0051] As best shown in FIG. 4, one embodiment of the interior surface 25 of rotating drum 12 includes prominences 37 having a cylindrical configuration. The cylindrical prominences 37 extend approximately 0.5 inches from the interior surface 25 as shown by line z₁ to z₂ (height). Without limiting the scope of the invention, the diameter of the cylindrical prominence 37 can be approximately 1 inch as shown by line x₁ to x₂.

[0052] As best illustrated in FIG. 5, the prominences 26 are hemispherical. The hemispherical prominences 37 extend approximately 0.5 inches from the interior surface 25 to its apex as shown by line z₁ to z₂ (height). The diameter of the hemispherical prominence 26 at its base is approximately 1 inch as shown by line x₁ to x₂. The distance between hemispherical prominences is approximately 1 inch as shown by line x₁ to x₂.

[0053] As best shown in FIG. 6, the prominences 37 have a ridge configuration. The ridged prominences 37 extend approximately 0.5 inches from the interior surface 25 to its apex as shown by line z₁ to z₂ (height). The distance between ridged prominences is approximately 2 inches as shown by line x₁ to x₂. The ridged prominences 26 are approximately 0.5 inches wide as shown by line x₁ to x₂. The length of the ridged prominences 37 can vary from as much as one full revolution of the inner surface of the drum 12 to any fraction of one full revolution. The ridged prominences 37 may extend around the inner surface at a same axial distance along an axis of the drum 12. Alternatively, they may be formed as a single helix or as parallel helices. One of ordinary skill in the art will recognize that, depending upon the orientation of the ridged prominences 37, the length (y₁-y₂) may equal or exceed the circumference of the rotating drum 12.

[0054] One of ordinary skill in the art will recognize that other shapes and/or greater or smaller diameters or widths (x₁-x₂) or lengths (y₁-y₂) or heights (z₁-z₂) of the prominences 37 or distances (x₁-x₂) between the prominences 37 may be used without departing from the scope of this invention. As discussed above, the diameter and/or height of the prominences 37 is typically driven by the ease with which they may be manufactured or by the shape and size of the object 11 to be cooled or frozen. Furthermore, one of ordinary skill in the art will recognize that uniformity amongst the prominences is not required to practice the teachings of the disclosed method and apparatus and that variation of shape, width, length, height, and distance may occur within one drum 12.

[0055] It will be understood that many additional changes in the details, materials, steps, and arrangement of parts, which have been herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claims. Thus, the present invention is not intended to be limited to the specific embodiments in the examples given above and/or the attached drawings.

What is claimed is:

1. An apparatus for chilling or freezing objects, the apparatus comprising a rotatable drum defining an enclosure having an inner surface, an inlet at one end of the drum, an outlet at an opposing end of the drum, one or more liquid CO₂ nozzles disposed in an interior of the drum each one of which is adapted to inject a stream of solid CO₂ into the enclosure towards the interior surface, wherein:

- the interior surface of the drum is comprised of polyethylene having prominences molded into the polyethylene;
- portions of the interior surface in between prominences form recedes relative to the prominences that are adapted and configured to retain a depth of solid CO₂;
- and the prominences are not directional vanes.

2. The apparatus of claim 1, wherein:

- said at least two liquid CO₂ nozzles comprise at least one first liquid CO₂ nozzle and at least one second liquid CO₂;
- each of said at least one first liquid CO₂ nozzle being disposed in an interior of the drum and being adapted, configured, and oriented to provide a first stream of solid CO₂ towards a first angular position on the inner surface;
- each of said at least one second liquid CO₂ nozzle being disposed in the drum interior and being adapted, configured, and oriented to provide a second stream of solid CO₂ towards a second angular position on the inner surface; and
- the first angular position is between 70-110° and/or 250-290° with respect to vertical and the second angular position is between 160-200° with respect to vertical.

3. The apparatus of claim 1, further comprising directional vanes on the interior surface.
4. The apparatus of claim 1, wherein the prominences extend approximately 0.25 to 1 inches from the interior surface.

5. The apparatus of claim 4, further comprising directional vanes on the interior surface.

6. A method for chilling or freezing objects, comprising the steps of:
   providing the apparatus of claim 1;
   rotating the drum;
   introducing the objects into the interior the drum; and
   injecting a stream of solid CO₂ into the enclosure towards the interior surface from one or more liquid CO₂ nozzles, wherein the solid CO₂ is deposited in the recesses and/or on top of the objects; and
   removing the objects from the outlet of the drum.

7. The method of claim 6, wherein:
   said at least two liquid CO₂ nozzles comprise at least one first liquid CO₂ nozzle and at least one second liquid CO₂;
   each of said at least one first liquid CO₂ nozzle being disposed in an interior of the drum and injects a first stream of solid CO₂ towards a first angular position on the inner surface;
   each of said at least one second liquid CO₂ nozzle being disposed in the drum interior and injects a second stream of solid CO₂ towards a second angular position on the inner surface; and
   the first angular position is between 70-110° and/or 250-290° with respect to vertical and the second angular position is between 160-200° with respect to vertical.

8. The method of claim 7, wherein in the first stream(s) deposits a fresh layer of solid CO₂ in the recesses and the second stream(s) deposits solid CO₂ on top of the objects tumbling at or adjacent to a bottom of the drum.

9. The method of claim 6, wherein the objects are food products.

10. The method of claim 9, wherein the food products are meat products.

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