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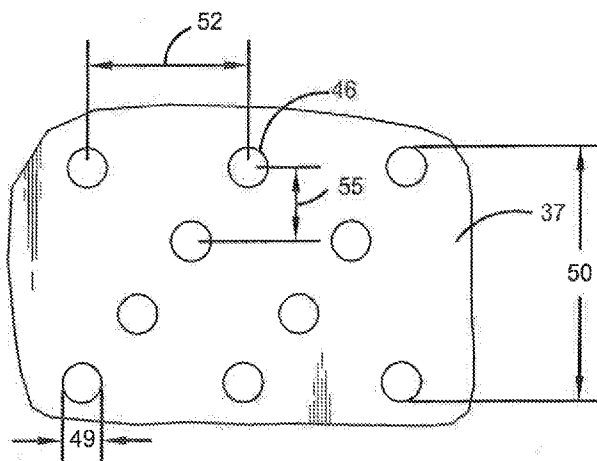


FIG. 2

(57) Abstract: An impinger for cooling or freezing products includes an impingement plate containing openings for directing impingement jets of a mixture of gas and solid or liquid cryogen toward the products transported on a conveyor, wherein the openings in aggregate have an open area of about 7% to about 12% of the total surface area of the impingement plate, the impingement plate providing a back pressure restriction of about 220 to about 475 Pa. A process for cooling or freezing products within a housing chamber includes transporting the products, particularly IQF food products, on a moving substrate within the chamber, mixing a gas with solid or liquid cryogen to form a mixture, directing the mixture to the aforementioned impinger; and selectively directing the pressurized impingement jets of the mixture from the impingement plate toward the products transported on the substrate.



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## SPECIFICATION

METHOD AND APPARATUS FOR IMPINGEMENT FREEZING OF IRREGULARLY  
SHAPED PRODUCTS

## BACKGROUND

[0001] The present embodiments relate to a method and apparatus for the impingement freezing of irregularly shaped products. Typical products include Individually Quick Frozen (IQF) food items.

[0002] Commercial freezers typically rely on the transfer of heat from a product that is to be chilled or frozen by one of two methods: convection from gaseous, liquid or solid coolants, such as cryogen, fed through a system of axial tubes or nozzles and fans, or high pressure impingement of the coolant or cryogen. High pressure impingement is very useful for transferring heat through the boundary layer around thin, flat products with a high surface area to weight ratio.

[0003] In certain embodiments, the coolant or cryogen may comprise nitrogen or carbon dioxide. The term “cryogen” is used herein similarly to the term “coolant”, and is not intended to necessarily be limited to materials which have a purely cryogenic effect, although that meaning is intended to be included in the use of “cryogen”. The term “coolant” as used herein means any material which provides a cooling effect to a product.

[0004] The total heat transfer rates are dependent on local heat transfer coefficients. That is, the amount of heat transferred from the products to the cryogen is dependent on the rate of heat transfer locally between the cryogen and the product.

[0005] The heat transfer resulting in the cooling or freezing of the products results generally from the impingement of a stream of cryogenic vapor or liquid on the product. Additional heat transfer may also be achieved by spraying or mixing liquid or solid cryogen into the impingement streams of cryogen.

[0006] Many commercial freezers rely on the transfer of heat from a product that is to be chilled or frozen by using an axial fan or blower. Typically, the fan or blower is situated near a

conveyor belt upon which the product is being carried. The product entering the freezer has a boundary layer of gas surrounding it which insulates the product from the surrounding atmosphere. Traditional freezers have employed blowers that generate currents of cooling vapor in many directions. However, a significant portion of the cooling vapor does not contact the product in a perpendicular direction. Under these conditions, the cooling vapor which does contact the product often does not possess sufficient energy to substantially reduce the thickness of the boundary layer around the surface of the food product.

[0007] When axial tubes or nozzles and fans are used, the process suffers from a low heat transfer coefficient between the product and cryogen. Further, due to the poor heat transfer, more and colder cryogen must be blown across the product, potentially leading to the buildup of condensation in the form of snow or ice in the tubes or nozzles. And, an unnecessary increase in cryogen use without increased benefit will reduce the cost-effectiveness of the known process.

[0008] Increasing the velocity of the stream of cooling vapor (or cryogen) which impinges the food item will increase the average heat transfer coefficient in a linear manner. At a certain point, however, unless the impingement stream of cooling vapor is carefully controlled, the velocity may also damage the product, or carry the product off the conveyor and into undesirable locations elsewhere in the freezer.

[0009] In other freezers, products are frozen or cooled within a housing chamber having a cryogen supply, and a conveyor extending into the chamber for transporting the food products on the conveyor; the chamber containing at least one impingement hood disposed above the conveyor; and the impingement hood including a shell supporting an impinger containing openings. Gas and solid or liquid cryogen are mixed within the impingement hood, the mixture of gas and cryogen are directed to the impinger, and impingement jets of the mixture are directed through the impingement plate toward the products transported on the conveyor.

[0010] The transfer of heat from products, such as a food product, to a cryogen may be accomplished with the use of an impingement hood by which solid or liquid cryogen is sprayed into gas (such as carbon dioxide or nitrogen) circulated at the item or food product while using an impinger, such as an impingement plate, to create a stream of cryogen. The design of the device increases the heat transferred from the product to the cryogen. The cryogen, for example

solid carbon dioxide snow or liquid nitrogen, is introduced into an impinging flow of gas, wherein heat transfer occurs with respect to the gas and the product, to cool the product during impingement.

[0011] The use of the impingement hood provides consistent cooling and/or freezing of the product items across the width of the conveyor upon which the product travels through the freezer. The impingement hood provides for an increased coolant pressure at the area of the conveyor along which the products travel for freezing or cooling. The impingement hood may further result in the reduction of dehydration of the product, which is accomplished through the immediate freezing of the exterior of the product upon entry into the apparatus.

[0012] Alternatively, the transfer of heat from a product, such as a food product, to a cryogen may be accomplished with the use of sequential modules. Modularity enables an arrangement to meet specific freezing requirements for various products. An entrance module has liquid cryogen piping and sprayer(s) which enable a stream of liquid cryogen to be sprayed into the jet of gaseous cryogen circulating within the module and toward the conveyor and product. The conveyor may be an open mesh or have open links to provide access to the product from below. Each module contains at least one impinger which enables jets of cryogenic gas to impinge the upper and/or lower surfaces of the food items. The impinger may be an impingement plate having a specific configuration of stamped or chamfered holes. The sprayer(s) may comprise a plurality of full cone low flow rate spray nozzles. The use of this configuration enables a rapid heat transfer from the exterior of the product resulting in rapid cooling and/or crust freezing of product upon entering the series of modules and decreases any dehydration of the product.

[0013] A series of intermediate modules may be in array with the entrance module before reaching the exit module. Intermediate and exit modules may comprise a similar system of piping, impinger, sprayer, and nozzle, but enable a certain length of freezing time depending on the conveyor speed or throughput of product required and the amount of time such product needs to be in the cryogenic environment to reach a desired goal. The modularity of the freezer provides for any variation in these parameters.

[0014] While high pressure impingement is very useful for thin, flat products with a high surface area to weight ratio, its advantage in the ability to transfer heat through the boundary layer

around such a product is less useful for irregularly shaped products. Further, when high pressure impingement is used for irregularly shaped products, such as Individually Quick Frozen (IQF) food products, the velocity of cryogen may be sufficient to damage the product and/or carry the product off of the conveyor within the impingement freezer and into undesirable locations within the freezer. IQF food products are smaller, more irregular solid pieces of food such as, without limitation, peas, shrimp, cut beans, cauliflower pieces, poultry portions, or meat chunks, typically from about 0.25 inches to 0.75 inches in cross sectional area, and in chunks or cubes.

[0015] What is needed, therefore, is a method and apparatus for impingement freezing, which will provide more efficient heat transfer than the use of axial tubes or nozzles and fans, and which will not damage irregularly shaped products or displace the products from processing lines as may occur with the use of high pressure impingement chilling methods.

#### SUMMARY

[0016] Provided is an impinger for cooling or freezing products in which the product is transported or conveyed on a conveyor, such as a belt or other moving substrate, comprising an impingement plate containing openings for directing impingement jets of a mixture of gas and solid or liquid cryogen toward the products transported on a conveyor, wherein the openings comprise an open area of about 7 percent to about 12 percent of the total surface area of the impingement plate, and wherein the impingement plate provides a back pressure restriction in a circulation path of the mixture of about 220 to about 475 Pa (about 0.9 to about 1.9 inches of water column).

[0017] Also provided is a process for cooling or freezing products within a housing chamber comprising: transporting the products on a moving substrate within the chamber; mixing a gas with solid or liquid cryogen to form a mixture; directing the mixture of gas and solid or liquid cryogen to an impinger, the impinger comprising an impingement plate containing openings for providing pressurized impingement jets of the mixture, wherein the openings comprise an open area of about 7 percent to about 12 percent of the total surface area of the impingement plate and wherein the impingement plate provides a back pressure restriction in a circulation path of the mixture of about 220 to about 475 Pa (about 0.9 to 1.9 inches of water column); and selectively

directing the pressurized impingement jets of the mixture from the impingement plate toward the products transported on the substrate.

#### BRIEF DESCRIPTION OF THE DRAWINGS

[0018] The accompanying drawings are included to provide a further understanding of the apparatus and process provided herein and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments of the apparatus and process provided herein and, together with the description, serve to explain the principles described herein but are not intended to limit the specification or any of the claims.

[0019] FIG. 1 is an elevational, lateral, cross sectional view of an impinger in an impingement hood freezer embodiment.

[0020] FIG. 2 is a top, plan view of an impingement plate for use in the impinger of FIG. 1.

[0021] FIG. 3 is a side, cross sectional view of a chamfered opening in the plate of FIG. 2.

[0022] FIG. 4 is an elevational, partially cross sectional view of a sequence of modules in a modular-type freezer embodiment.

[0023] FIG. 5 is an elevational, cross sectional end view of a single module in the freezer of FIG. 4, having an impinger.

[0024] FIG. 6 is an elevational, cross sectional cutaway view of a portion of a single intermediate module, having an impinger above and below the conveyor.

#### DESCRIPTION

[0025] The present embodiments are directed to an impinger for cooling and/or freezing products, particularly irregularly shaped products, in which the product is conveyed on a conveyor, such as a belt, mesh, screen, or other moving substrate, the impinger comprising an impingement plate with openings for directing impingement jets of a mixture of gas and solid or liquid cryogen toward and/or onto the product transported on the conveyor, wherein the openings are about 7 percent to about 12 percent of the surface area of the impingement plate. The

impingement plate provides a back pressure restriction in a circulation path of the mixture of gas and cryogen of about 220 to about 475 Pa (about 0.9 to about 1.9 inches of water column).

[0026] As the openings comprise a larger percentage of the surface area of the impingement plate as compared to conventional impingers, the velocity of gas/cryogen mixture decreases, but the area coverage of the mixture is greater. The decrease in velocity of mixture prevents the impinger from displacing (by blowing for example) product off of the conveyor, and also results in better, more uniform distribution of flow over a product, resulting in improved heat transfer.

[0027] The open area and size of the holes or apertures the impingement plate may range from about 2.8 cm<sup>2</sup> to about 20.5 cm<sup>2</sup> (about 0.44 in<sup>2</sup> to about 3.15 in<sup>2</sup>). In certain embodiments, all holes in the impingement plate may be of uniform size; in other embodiments, sizes may vary within the stated range. Such holes or apertures result in the impingement plate providing a back pressure restriction in a circulation path of the mixture of gas and solid or liquid cryogen of about 220 to about 475 Pa (about 0.9 to about 1.9 inches of water column). In some embodiments, the back pressure restriction in a circulation path of the mixture of gas and solid or liquid cryogen may be from about 270 to about 475 Pa (about 1.1 to about 1.9 inches of water column). This results in an impingement velocity of the mixture of gas and solid or liquid cryogen through the openings of about 13.7 to about 17.8 meters per second (about 2700 to about 3500 feet per minute), or in some embodiments, from about 16.2 to about 17.8 meters per second (about 3200 to about 3500 feet per minute).

[0028] The openings (the holes or apertures) may be, without limitation, of a substantially circular shape. Alternatively, the holes or apertures may be polygonal, hexagonal, octagonal, regular, or irregular in shape, such as necessary to provide the desired jet velocity and therefore, heat transfer without damage to the product. The openings may be, without limitation, stamped into the impingement plates or chamfered. A stamped or less substantially circular opening generally results in more turbulent flow of the mixture than that of a chamfered and/or more substantially circular opening, which decreases efficiency of the heat transfer for larger products, but increases the uniformity of heat transfer for smaller products, such as, without limitation, about 0.25 inch to about 0.75 inch (about 0.6 to about 2 cm) sized chunks or cubes.

[0029] The distance between the impingement plate and product on the conveyor may be from about 1 inch to about 5 inches (about 2.5 to about 12.7 cm), and in some embodiments, from about 3 inches to about 4 inches (about 7.6 to about 10.2 cm). The distance from the bottom of the impinger to the food product, and the arrangement of the hole pattern on the impingement plate is designed to increase the total heat transfer rate.

[0030] The mixture of gas and cryogen may be recirculated after initial impingement in order to more efficiently transfer heat from the product relative to the amount of mixture used, with any means for recirculation known in the art.

[0031] The impingement plate may also be provided with a vibrator or another “deicing” device. The vibrator may be of the electrical variety, however, in one embodiment the vibrator may be a ball valve pneumatically actuated by compressed nitrogen or carbon dioxide gas supplied through conduits at about 414 kPa (60 psi). The vibrations provided by the vibrator prevent snow and ice from building-up or accumulating on the impingement plate. Furthermore, the frequency and time intervals of the vibrations provided by the vibrator may vary depending on the process conditions including the moisture content of the food product, the humidity of the ambient air in and outside the freezer and the temperature of the freezer.

[0032] The present embodiments are further directed to a process for cooling or freezing products within a chamber including transporting the products on a moving substrate within the chamber, mixing a gas with solid or liquid cryogen to form a mixture, and directing the mixture of gas and solid or liquid cryogen to an impinger, wherein the impinger comprises an impingement plate with openings for providing pressurized impingement jets of the mixture toward the product. The openings of the impingement plate are about 7% to about 12% of the total surface area of the plate, and the plate provides a back pressure restriction in a circulation path of about 220 to about 475 Pa (about 0.9 to about 1.9 inches of water column). The products may be, without limitation, individually quick frozen (IQF) food products, described above.

[0033] The method of transferring heat from a product, such as a food product, to a cryogen may be accomplished with the use of an impingement hood by which solid or liquid cryogen is sprayed into gas (such as carbon dioxide or nitrogen) circulated to contact the item or food product while using an impinger, such as an impingement plate, to create a stream of cryogen.

The design and configuration of the impingement plate as described herein increases the heat transferred from the product to the cryogen. The cryogen, for example solid carbon dioxide snow or liquid nitrogen, is introduced into an impinging flow of gas, wherein heat transfer occurs with respect to the gas, cryogen, and the product, to cool the product during impingement. The hood may comprise a shell supporting the impinger, the shell optionally being adapted to accommodate a gas circulation device for directing the mixture of gas and solid or liquid cryogen to the impinger.

[0034] In particular and referring to FIG. 1, there is shown a freezer embodiment including an impingement hood 25, and which may include a conveyor 13, impinger 16 including an impingement plate 37, shell 19, impeller 22, and at least a partial enclosure 28 or housing. The embodiment may include a motor 31 that drives the impeller 22 in order to direct a cryogen mixture 34 through the impinger 16 toward and/or onto products 40 being transported on the conveyor 13. The impeller 22 also collects the mixture 34 for recirculation, in order to ensure efficient use of the mixture 34.

[0035] Alternatively, as shown in FIGS. 4 and 5, the transfer of heat from products, such as food products, to a cryogen may be accomplished with the use of sequential modules. Modularity enables an arrangement to meet specific freezing requirements for various products. An entrance module 70 has liquid cryogen piping 64 and sprayer 67 which enable a stream of liquid cryogen to be sprayed into the jet of gaseous cryogen circulating within the module and toward and/or onto the conveyor 13 and its carried product. Each module may contain an impinger 16 which enables jets of cryogenic gas to impinge the upper and/or lower surfaces of the food items. The impinger 16 may be a plate having a specific configuration of rounded or chamfered holes. A sprayer 67 is provided in one or more modules in order to entrain droplets of liquid cryogen in the jets of cryogenic gas. FIGS. 4 and 5 show lengthwise (FIG. 4) and side (FIG. 5) views of an embodiment having a modular configuration. FIG. 4 shows the embodiment wherein multiple modules are in sequence. This modular embodiment comprises a conveyor 13, impinger 16 comprising an impingement plate 37 (shown in more detail in FIG. 2), and an impeller 22. A motor 31 drives the impeller 22 to force the cryogen mixture 34 through the impinger 16 comprising the impingement plate 37, toward product on the conveyor 13.

[0036] Impeller 22 of entrance module 70 is in fluid communication with intake cone 76 and low pressure plenum 90 and generates a flow of cryogen out of the exit 86 to be circulated as a flow of cryogenic vapor around the interior of the module in accordance with the flow patterns of the mixture 34 represented by arrows in FIG. 5. The cryogenic vapor flows from exit 86 past sprayer 67 entraining liquid cryogen into the stream and through impinger 16, thereby impinging cryogen on items on conveyor 13. A high pressure flow of the cryogen and gas mixture enters high pressure plenum 88 and the impinger 16 (which comprises the top of high pressure plenum 88 below the conveyor) and flows under and through the impinger 16 which provides impingement jets on the underside of the open structure conveyor 13 and product on the conveyor. The warmed gas flows to the low pressure plenum, separated in part by baffle 47 from high pressure plenum 88, and is taken up by impeller 22 through the intake cone 76.

[0037] In certain embodiments, a series of intermediate modules may be in array or nested together with the entrance module 70 before reaching an exit module 21. Still referring to FIG. 4, the intermediate 20 and exit 21 modules may comprise a similar system of piping, sprayer, and impinger 16, and enable a certain length of freezing time depending on the conveyor 13 speed or throughput of product required and the amount of time such product needs to be in the cryogenic environment to reach a desired temperature. The modularity of the freezer provides for any variation in these parameters. Further, modularity allows for local recirculation by allowing recirculation of cryogen to a low pressure area of an individual module for uptake by the impeller 22 through the intake cone 76.

[0038] FIG. 6 is an elevational, cross sectional cutaway view of the intermediate module 20 taken through line A-A of FIG. 4. An impeller 22 powered by motor 31, mounted on top plate 8 as shown in FIG. 5, circulates the cryogen mixture 34 according to the arrows shown in FIG. 6. Impingers comprising impingement plates 37, positioned above and below conveyor 13, increase the velocity of the gas to generate impingement jets of the cryogen mixture toward product on the conveyor 13, as the mixture passes from the high pressure plenum 88 to the low pressure plenum 90 within the module.

[0039] Referring back to FIGS. 2 and 3, FIG. 2 is a top view of the impingement plate 37. The impingement plate 37 comprises openings 46, each opening having a diameter 49. Openings 46 are spaced apart by radial pitch 52, axial pitch 55, and may have a pattern repeat 50. The open area and size of the openings 46 (holes or apertures) on the impingement plate 37 may range from about 2.8 cm<sup>2</sup> to about 20.5 cm<sup>2</sup> (about 0.44 in<sup>2</sup> to about 3.15 in<sup>2</sup>). Such holes or apertures result in the method providing the mixture 34 of gas and solid or liquid cryogen for heat transfer at a velocity of about 13.7 to about 17.8 meters per second (about 2700 to about 3500 feet per minute), or in some embodiments, from about 16.2 to about 17.8 meters per second (about 3200 to about 3500 feet per minute). According to this method, the impingement plate 37 provides a back pressure restriction or pressure drop of about 220 to about 475 Pa (about 0.9 to about 1.9 inches of water column), or in some embodiments, the back pressure restriction in a circulation path of the mixture 34 of gas and solid or liquid cryogen may be from about 270 to about 475 Pa (about 1.1 to about 1.9 inches of water column). FIG. 3 is a view of a chamfered opening 46. Opening 46 has a diameter 49. The chamfer comprises an outer diameter 58 and longitudinal length 61. The chamfer increases flow efficiency, which in some embodiments may not be desired, as it may focus the flow of cryogen onto the surface of the product. Embodiments without chamfer are also useful as the non-chamfered openings tend to diffuse cryogen flow.

[0040] In certain embodiments, the mixture of gas and cryogen may be recirculated after initial impingement in order to more efficiently transfer heat from the product relative to the amount of mixture, using any means for recirculation known in the art, such as the impeller shown in FIGS. 1, 4, and 5.

[0041] The following examples are set forth merely to further illustrate the subject of a method and apparatus for impingement freezing of irregularly shaped products. The illustrative examples should not be construed as limiting the subject matter in any manner.

## EXAMPLE 1

[0042] An embodiment was tested wherein the radial pitch 52 of the holes 46 in a 22 gauge stainless steel impingement plate 37 was about 4 inches (about 10.1 cm), the axial pitch 55 was about 4.4 inches (about 11.2 cm), the diameter 49 of each hole 46 was about 1.5 inches (about 3.8 cm), and the impingement plate comprised approximately 10% open area from the aggregate of the holes 46. Cryogen mixture was applied to IQF food products through the impingement plate at a pressure drop across the plate of about 270 Pa (about 1.1 inches water column), which resulted in impingement jet velocities of about 16.3 meters per second (about 3200 feet per minute). The lower than conventional velocity distributed across a larger diameter hole created less impact force on the product and increased the convective heat transfer coefficient by 1.9 times over that of axial flow fans.

## EXAMPLE 2

[0043] An embodiment was tested wherein the radial pitch 52 of the holes 46 in a 22 gauge stainless steel impingement plate 37 was about 3.1 inches (about 7.9 cm), the axial pitch 55 was about 3.5 inches (about 8.9 cm), the diameter of each hole was about 1 inch (about 2.54 cm), and the impingement plate comprised approximately 7.5% open area from the aggregate of the holes 46. Cryogen mixture was applied to IQF food products through the impingement plate at a pressure drop across the plate of about 475 Pa (about 1.9 inches water column), which resulted in impingement jet velocities of about 17.8 meters per second (about 3500 feet per minute). The lower than conventional velocity distributed across a larger diameter hole created less impact force on the product and increased the convective heat transfer coefficient by 2.3 times over that of axial flow fans.

## EXAMPLE 3

Table 1

| Freezing Application               | Convective Heat Transfer Mechanism<br>W/m <sup>2</sup> * K (Btu/ft <sup>2</sup> *h*F) |                          |                 |
|------------------------------------|---------------------------------------------------------------------------------------|--------------------------|-----------------|
|                                    | Axial Fans                                                                            | Conventional Impingement | IQF Impingement |
| IQF<br>(Individually Quick Frozen) | 45.43<br>(8)                                                                          | Ineffective              | 102.21 (18)     |
| Flat Products                      | 34.7 (6)                                                                              | 102.21 (18)              | 51.1 (9)        |

[0044] Table 1 displays the results of testing heat transfer to both flat and IQF products using axial fans, high velocity impingement conventionally used in the industry, and the lower velocity impingement resulting from the presently claimed impinger embodiment. Testing was conducted at minus 100° F (minus 73C). The axial fan arrangement used 36 inch diameter axial fans operating at 1750 revolutions per minute with 4 inch blades at a 26 degree pitch. The openings in the impingement plate of the conventional impinger were of approximately 1.5 cm (approximately 0.625 inches) in diameter, and the impingement plate comprised approximately 5.5% open area. These conventional plates typically provide impingement velocities of about 20 or more meters per second (about 4000 feet per minute). The operating pressure was about 622 Pa (2.5 inches water column). By increasing the diameter of the openings in the subject impingement plates to about 3.8 cm (about 1.5 inches) and thereby decreasing the operating pressure to about 300 Pa (1.2 inches water column), impingement velocity was reduced and heat transfer to the irregularly shaped IQF products was increased as indicated in Table 1. Heat transfer of conventional impingement could not be measured (“Ineffective”) on IQF food products due to the volume of product blown off of the conveyor. Further, heat transfer to irregularly shaped products increased using the subject impingement plates, as there was a better distribution of flow. When the diameters of openings increased to above 7.5 cm (about 3 inches), heat transfer to product was less than that of an axial fan configuration. As shown in Table 1, using the impinger of the claimed embodiments, the convective heat transfer

coefficients can be obtained for IQF food products that are realized in conventional impingement freezers for flat products.

[0045] Testing was further conducted under similar conditions, except that the impingers comprised impingement plates with openings of about 7.6 cm (3 inches) in diameter. Under these conditions, the gas/cryogen mixture blew IQF product off of the conveyor.

[0046] Impingement plates according to the present embodiments can be installed or retrofitted in existing impingement freezers to provide more efficient convective heat transfer for irregularly shaped products, such as IQF food products.

[0047] The impinger apparatus and process of the present embodiments are thus demonstrated as increasing the overall production rate and efficiency of IQF freezing systems. This results in better overall operating efficiency for impingement freezers, allowing potential reduction in equipment size and floor space, and potential reduction in equipment cost.

[0048] In a first embodiment, there is provided an impinger for cooling or freezing products which may comprise an impingement plate containing openings for directing impingement jets of a mixture of gas and solid or liquid cryogen toward the products transported on a conveyor; wherein the openings comprise in aggregate an open area of about 7% to about 12% of the total surface area of the impingement plate; wherein the impingement plate provides a back pressure restriction in a circulation path of the mixture of about 220 to about 475 Pa (about 0.9 to about 1.9 inches of water column).

[0049] The impinger of the first embodiment may include an impingement plate that provides a back pressure restriction in a circulation path of the mixture of about 270 to about 475 Pa (about 1.1 to about 9 inches of water column).

[0050] The impinger of either the first or subsequent embodiment may further include that the impingement velocity of the mixture through the openings is about 13.7 meters per second to about 17.8 meters per second (about 2700 to about 3500 feet per minute).

[0051] The impinger of any of the first or subsequent embodiments may further include that the impingement velocity of the mixture through the openings is about 16.2 meters per second at to about 17.8 meters per second (about 3200 to about 3500 feet per minute).

[0052] The impinger of any of the first or subsequent embodiments may further include that the cross-sectional area of the openings are within the range of about 2.8 cm<sup>2</sup> to about 20.5 cm<sup>2</sup> (about 0.44 in<sup>2</sup> to about 3.15 in<sup>2</sup>).

[0053] The impinger of any of the first or subsequent embodiments may further include that the openings are substantially circular holes, each having a diameter in the range of about 1.9 cm to about 5.1 cm (about 0.75 to about 2 inches).

[0054] The impinger of any of the first or subsequent embodiments may further include that the openings are substantially circular holes, each having a diameter in the range of about 2.5 to about 3.8 centimeters (about 1 to about 1.5 inches).

[0055] The impinger of any of the first or subsequent embodiments may further include that the openings are punched holes or chamfered holes.

[0056] The impinger of any of the first or subsequent embodiments may further comprise a vibrator mounted for co-action with the impingement plate.

[0057] In a second embodiment, there is provided a process for cooling or freezing products within a housing chamber comprising: transporting product on a moving substrate within the chamber; mixing a gas with solid or liquid cryogen to form a mixture; directing the mixture of gas and solid or liquid cryogen to an impinger, the impinger comprising an impingement plate containing openings for providing pressurized impingement jets of the mixture, wherein the openings comprise in aggregate an open area of about 7% to about 12% of the total surface area of the impingement plate and wherein the impingement plate provides a back pressure restriction in a circulation path of the mixture of about 220 Pa to about 475 Pa; and selectively directing the pressurized impingement jets of the mixture from the impingement plate toward the products transported on the substrate.

[0058] In the process of the second embodiment, the products may comprise individually quick frozen (IQF) food products.

[0059] In the process of either the second or a subsequent embodiment, the impingement jet velocity of the mixture through the openings may be about 13.7 meters per second to about 17.8 meters per second.

[0060] The process of any of the second or subsequent embodiments may further include that the impingement velocity of the mixture through the openings is about 16.2 meters per second to about 17.8 meters per second.

[0061] The process of any of the second or subsequent embodiments may further include that the cross-sectional area of the openings are within the range of about 2.8 cm<sup>2</sup> to about 20.5 cm<sup>2</sup> (about 0.44 in<sup>2</sup> to about 3.15 in<sup>2</sup>).

[0062] The process of any of the second or subsequent embodiments may further include that the openings are substantially circular holes, each having a diameter in the range of about 1.9 cm to about 5.1 cm (about 0.75 to about 2 inches).

[0063] The process of any of the second or subsequent embodiments may further include that said mixing of the gas with solid or liquid cryogen occurs at least partially within an at least partially enclosed impingement hood above the substrate, the impingement hood comprising a shell supporting the impinger, the shell being adapted to accommodate a gas circulation device for directing the mixture of gas and solid or liquid cryogen to the impinger.

[0064] The process of any of the second or subsequent embodiments may further include that the housing chamber comprises a plurality of attached modular enclosures; the process including spraying liquid cryogen in at least one enclosure near the products to form the mixture; circulating the mixture from a low pressure area to create a high pressure area above and below the substrate in each enclosure; directing the mixture through the impinger impingement plate to generate the impingement jets in each enclosure; impinging the products with the impingement jets in each enclosure; and recirculating the mixture to the low pressure area in each enclosure.

[0065] The process of any of the second or subsequent embodiments may further include re-circulating the mixture of gas and the cryogen after impingement onto the products into the impinger.

[0066] In a third embodiment, a method is provided for increasing heat transfer to IQF products in an impingement freezer, including installing or retrofitting the impinger of the first or subsequent impinger embodiments as at least one impinger in the freezer.

[0067] It will be understood that the embodiments described herein are merely exemplary, and that one skilled in the art may make variations and modifications without departing from the spirit and scope of the invention. All such variations and modifications are intended to be included within the scope of the invention as described and claimed herein. Further, all embodiments disclosed are not necessarily in the alternative, as various embodiments of the invention may be combined to provide the desired result.

## CLAIMS

What is claimed is:

1. An impinger for cooling or freezing products, comprising:  
an impingement plate containing openings for directing impingement jets of a mixture of gas and solid or liquid cryogen toward the products transported on a conveyor,  
  
wherein the openings comprise an open area in aggregate of about 7 percent to about 12 percent of the total surface area of the impingement plate, and  
  
wherein the impingement plate provides a back pressure restriction in a circulation path of the mixture of about 220 to about 475 Pa.
2. The impinger of claim 1, wherein the impingement plate provides a back pressure restriction in a circulation path of the mixture of about 270 to about 475 Pa.
3. The impinger of claim 1, wherein an impingement velocity of the mixture through the openings is about 13.7 meters per second to about 17.8 meters per second.
4. The impinger of claim 1, wherein an impingement velocity of the mixture through the openings is about 16.2 meters per second to about 17.8 meters per second.
5. The impinger of claim 1, wherein a cross-sectional area of the openings is within a range of about 2.8 cm<sup>2</sup> to about 20.5 cm<sup>2</sup>.
6. The impinger of claim 1, wherein each of the openings is a substantially circular hole having a diameter in a range of about 1.9 to about 5.1 centimeters.

7. The impinger of claim 1, wherein each of the openings is a substantially circular hole having diameters in a range of about 2.5 to about 3.8 centimeters.
8. The impinger of claim 1, wherein the openings are punched holes or chamfered holes.
9. The impinger of claim 1, further comprising a vibrator mounted for co-action with the impingement plate.
10. A process for cooling or freezing products within a housing chamber, comprising:  
transporting the products on a moving substrate within the chamber;  
  
mixing a gas with solid or liquid cryogen to form a mixture;  
  
directing the mixture of gas and solid or liquid cryogen to an impinger, the impinger comprising an impingement plate containing openings for providing pressurized impingement jets of the mixture, wherein the openings comprise in aggregate an open area of about 7 percent to about 12 percent of the total surface area of the impingement plate, and wherein the impingement plate provides a back pressure restriction in a circulation path of the mixture of about 220 to about 475 Pa; and  
  
selectively directing the pressurized impingement jets of the mixture from the impingement plate toward the products transported on the substrate.
11. The process of claim 10, wherein the products comprise individually quick frozen (IQF) products.
12. The process of claim 10, wherein an impingement jet velocity of the mixture through the openings is about 13.7 meters per second to about 17.8 meters per second.
13. The process of claim 10, wherein an impingement velocity of the mixture through the openings is about 16.2 meters per second to about 17.8 meters per second.

14. The process of claim 10, wherein a cross-sectional area of the openings is within a range of about 2.8 cm<sup>2</sup> to about 20.5 cm<sup>2</sup>.

15. The process of claim 10, wherein each of the openings is a substantially circular hole having a diameter in a range of about 1.9 to about 5.1 centimeters.

16. The process of claim 10, wherein said mixing of the gas with solid or liquid cryogen occurs at least partially within an at least partially enclosed impingement hood above the substrate, the impingement hood comprising a shell supporting the impinger, the shell being adapted to accommodate a gas circulation device for directing the mixture of gas and solid or liquid cryogen to the impinger.

17. The process of claim 10, wherein the housing chamber comprises a plurality of attached modular enclosures; the process including spraying liquid cryogen in at least one enclosure near the products to form the mixture; circulating the mixture from a low pressure area to create a high pressure area above and below the substrate in each enclosure; directing the mixture through the impinger impingement plate to generate the impingement jets in each enclosure; impinging the products with the impingement jets in each enclosure; and recirculating the mixture to the low pressure area in each enclosure.

18. The process of claim 10, further comprising re-circulating the mixture of gas and the cryogen into the impinger after impingement onto the products.

19. A method for increasing heat transfer to individually quick frozen (IQF) products in an impingement freezer, comprising at least one of installing and retrofitting the impinger of claim 1 as at least one impinger in the freezer.

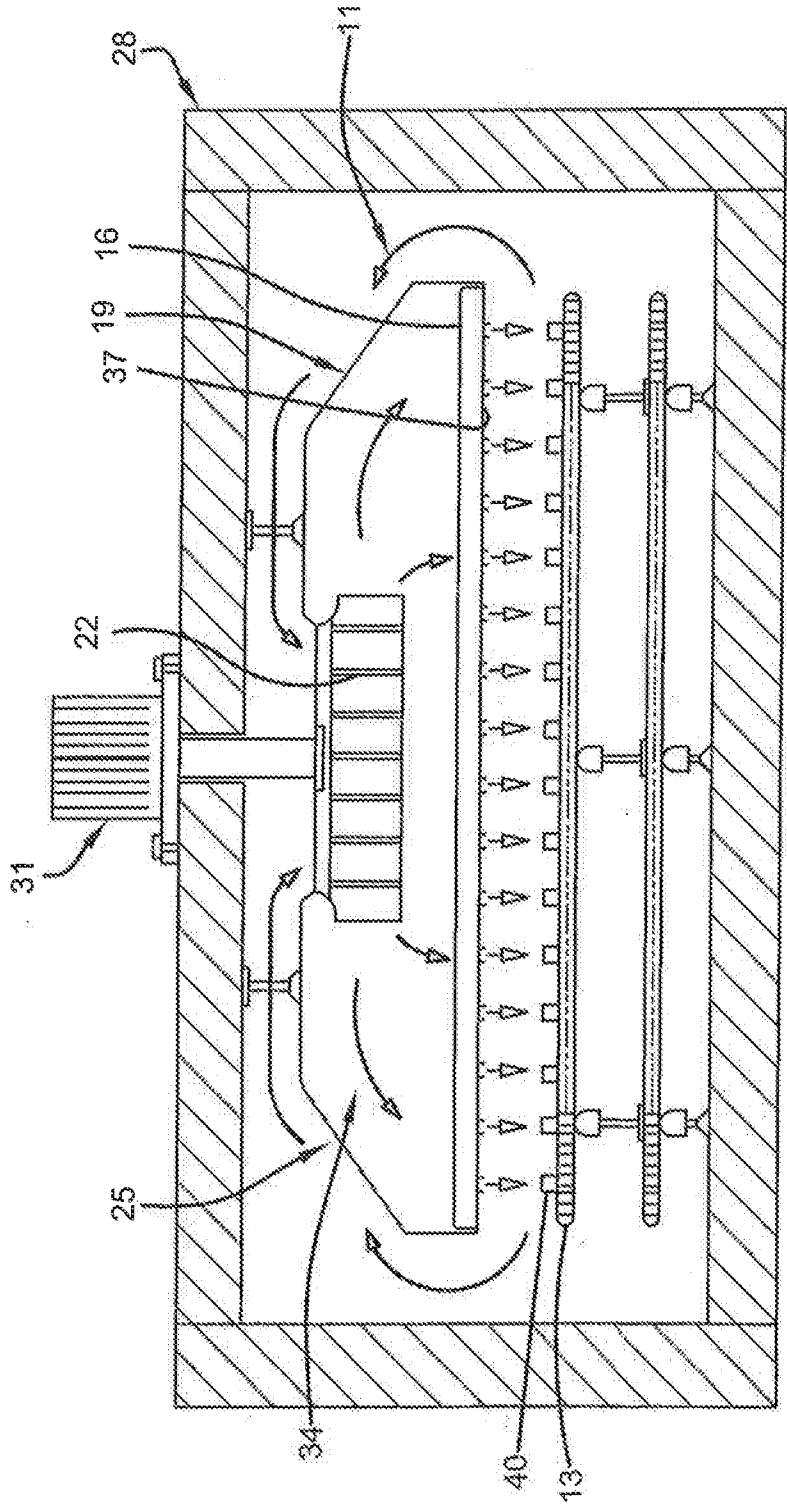


FIG. 1

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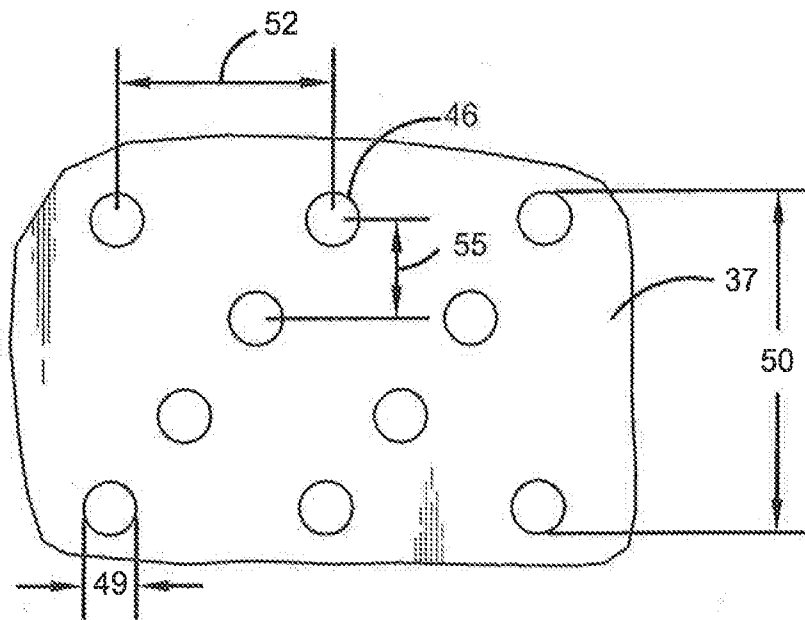


FIG. 2

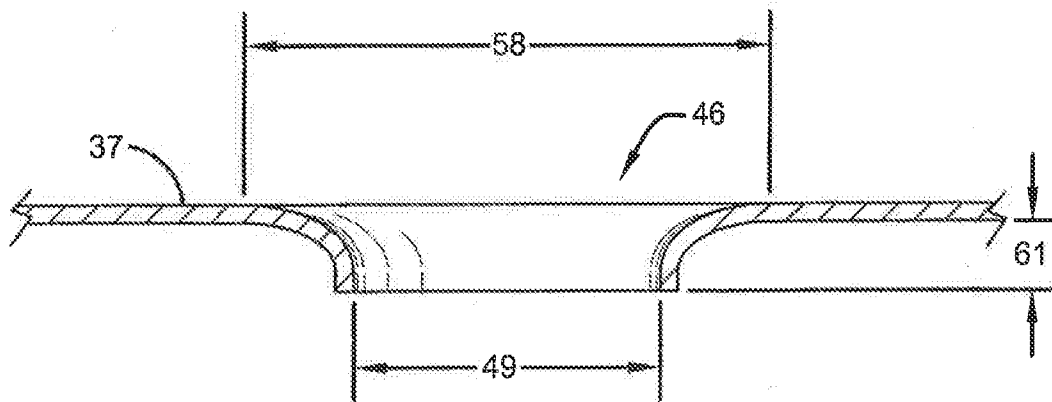
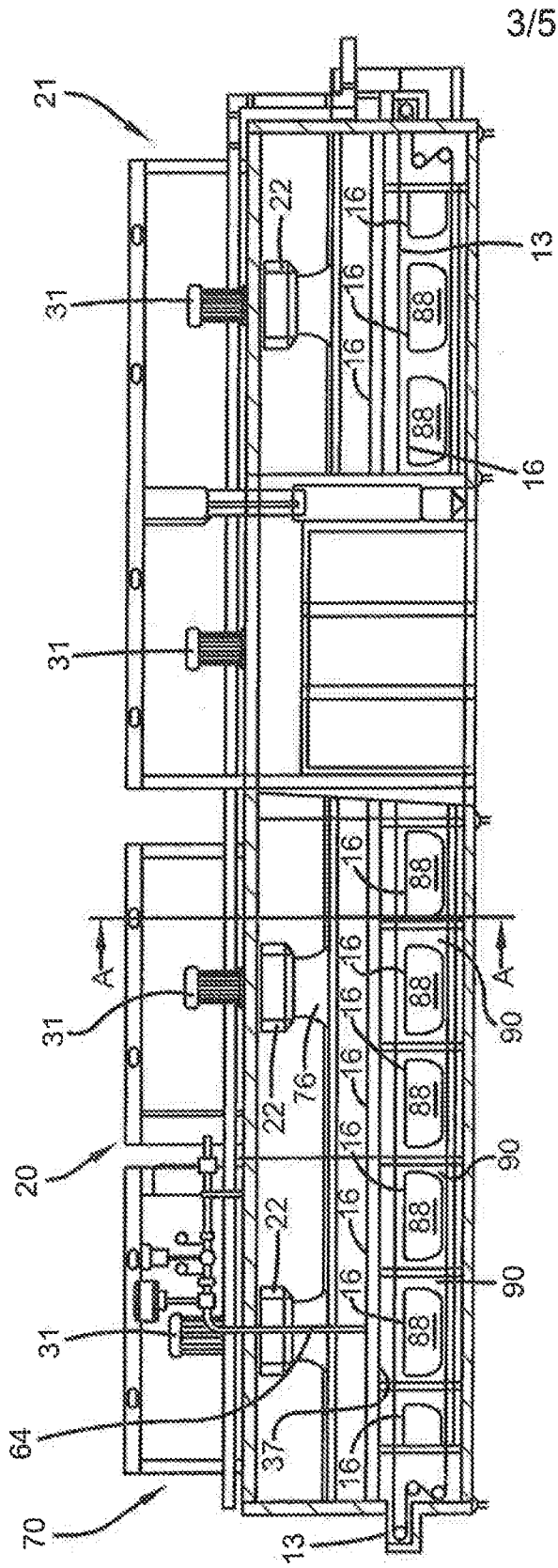


FIG. 3



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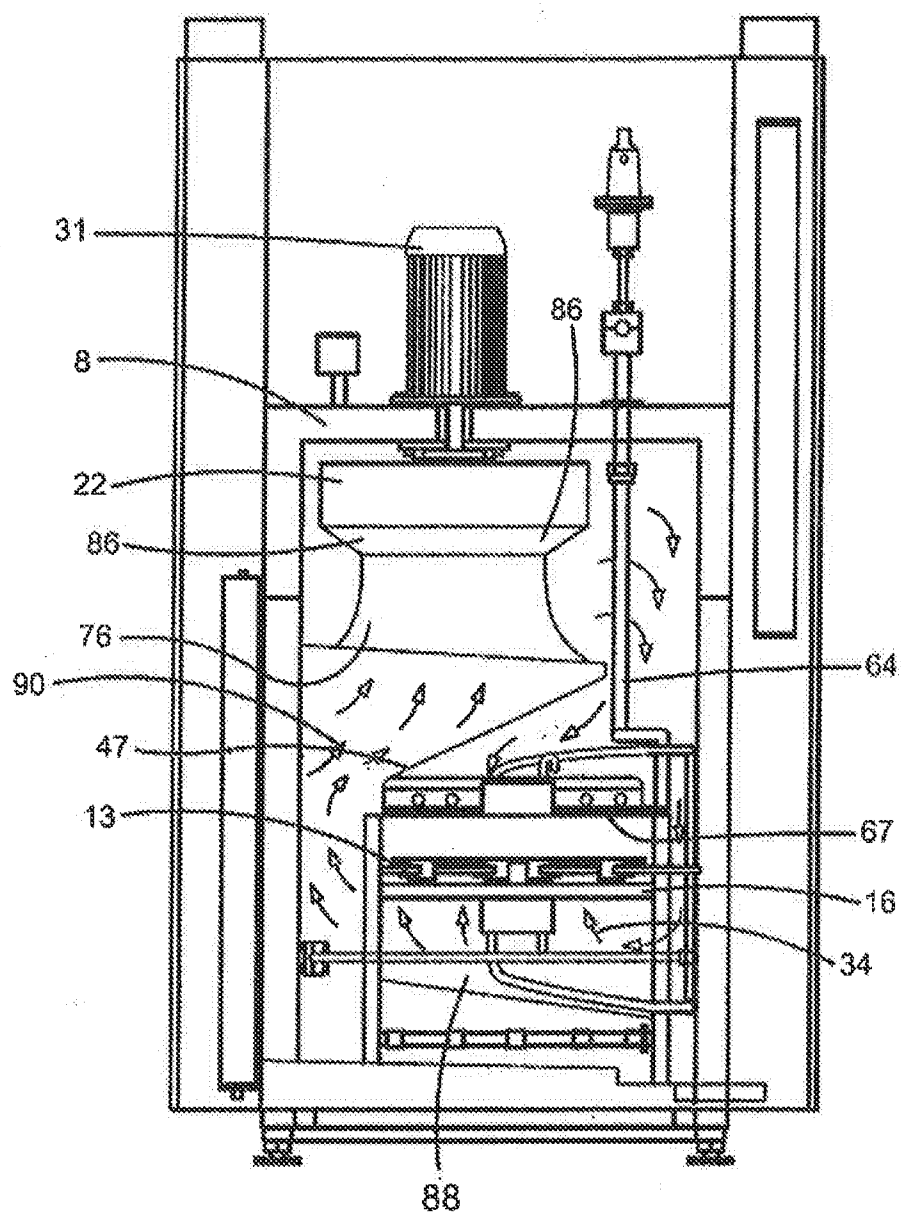


FIG. 5

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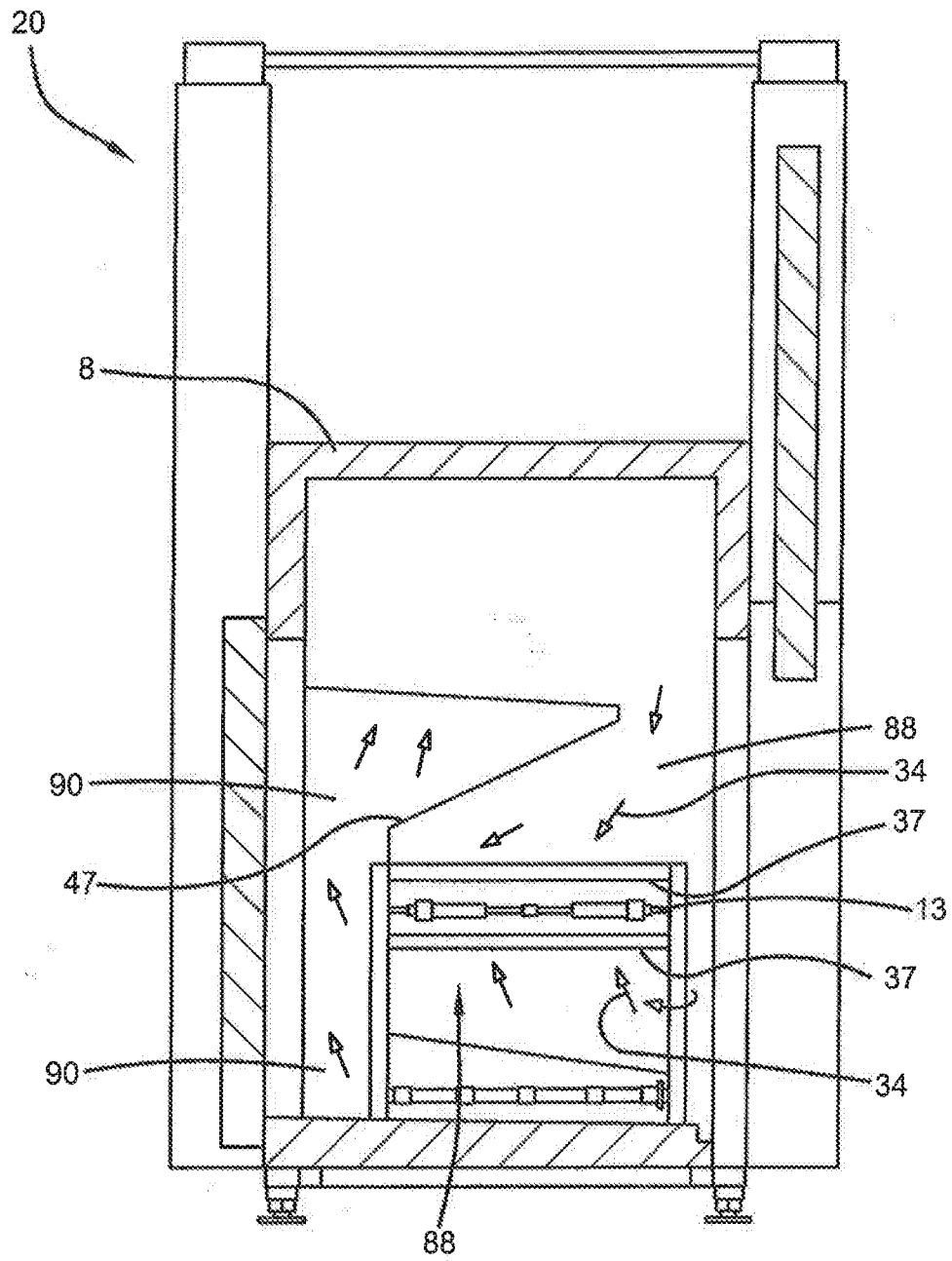


FIG. 6

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 17/42486

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - F25D 13/06 (2017.01)

CPC - F25D 13/06, F25D 13/067

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History Document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

See Search History Document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History Document

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category*     | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                 | Relevant to claim No.          |
|---------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------|
| X<br>---<br>Y | US 6,434,950 B2 (NEWMAN et al.) 20 August 2002 (20.08.2002), entire document, especially Fig 1-2, 4-8; col 3, ln 38-51, 66-67; col 4, ln 1-14, 21-26, 41-45, 52-61; col 5, ln 29-36, 37-39, 48-57) | 1-10, 12-18<br>-----<br>11, 19 |
| Y             | US 2013/0125576 A1 (NEWMAN et al.) 23 May 2013 (23.05.2013), entire document, especially para [0007]-[0008], [0010]                                                                                | 11, 19                         |
| A             | US 2014/0298851 A1 (MILLER et al.) 09 October 2014 (09.10.2014), entire document                                                                                                                   | 1-19                           |
| A             | US 2012/0318884 A1 (MCCORMICK et al.) 20 December 2012 (20.12.2012), entire document                                                                                                               | 1-19                           |
| A             | US 2007/0214679 A1 (BRANDT, JR.) 20 September 2007 (20.09.2007), entire document                                                                                                                   | 1-19                           |
| A             | US 4,171,625 A (MORGAN et al.) 23 October 1979 (23.10.1979), entire document                                                                                                                       | 1-19                           |

☐ Further documents are listed in the continuation of Box C.☐ See patent family annex.

|                                                                                                                                                                         |                                                                                                                                                                                                                                                  |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
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Date of the actual completion of the international search  
06 September 2017

Date of mailing of the international search report

28 SEP 2017

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