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(54) **Title:** CRYOGENIC SPIRAL FREEZER

(57) **Abstract:** An upwardly helical flow path of cryogen-rich air inside a cryogenic spiral freezer may be used to chill or freeze products.

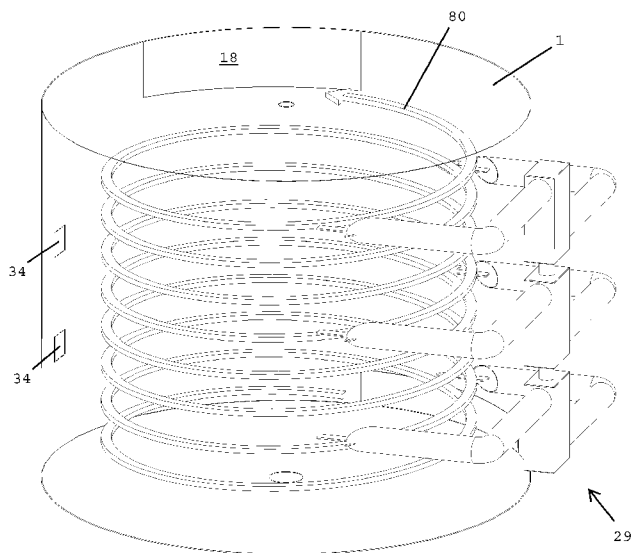


FIG 9



TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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CRYOGENIC SPIRAL FREEZER

Cross-Reference to Related Applications

None.

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Background

Typically, cryogenic spiral freezers (spirals) have fans placed in two and a half corners of the often-square-shaped spiral enclosure. A conveyor belt feeds into the spiral via an opening (the inlet) in the housing located at one of the corners (the starting corner). The starting corner typically has room for a fan or fans only at positions well above the inlet. An adjacent corner constitutes the exit portion. The exit portion includes an opening in the housing (the outlet) from which the conveyor belt emerges for unloading of chilled products. The exit portion also includes a device (take-up tower) for providing tension to the portion of conveyor belting returning to the front of the spiral. Typically, there is no room near the take-up tower for fans. Thus, the remaining two corners are often the only areas that have sufficient room to mount fans directing air to all levels of the spiral. As a result of this fan placement, as the spiral belting revolves, a direct and aggressive airflow is directed across the belt only two, and sometimes three, times per revolution of the belt as the product to be chilled passes directly in front of a fan. Since a spiral freezer relies on aggressive airflow to achieve maximum heat transfer between the flowing cold vapor and the relatively warm product, this means that for a significant percentage of each revolution of the belt, the product does not receive the full advantage provided by exposure to an aggressive airflow.

Thus, there is a need in the art to provide spiral freezers that allow a greater number of exposures of products to an aggressive airflow per belt revolution.

Typically, the corner fans in a spiral direct airflow across the width of the belt. In other words, the above-mentioned aggressive airflow is in a direction perpendicular to the travel direction of the belt. Due to turbulence caused by impingement of the airflow onto the belting support member, the belting, and the product, the velocity of the airflow diminishes as the airflow travels from the outer

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portion of the belt and across the product to the inner portion of the belt. As a result, product placed on an outer side of the conveyor belting is exposed to a higher airflow velocity than product placed on an inner side of the conveyor belting. Thus, a temperature gradient is created where more heat is removed from the outermost product than the innermost product. This temperature gradient across the belt can impact the quality of freezing that the products on the inside receive, or cause the operator to over-freeze the outside product in order to achieve satisfactory results on the inside.

Thus, there is a need in the art to provide spiral freezers that allow a greater uniformity of freezing for products across the width of the conveyor belt.

Cryogenic spiral conveyors are normally enclosed within a large rectangular, insulated structure. Because of the nature of the cryogenic vapor (whether CO₂ or N₂), the coldest, densest gas falls to the floor of the spiral. Typically, the conveyor belting entrance to the spiral is located at floor level. Thus, it is the natural tendency of the cold vapor to escape out that opening (the path of least resistance). As the coldest vapor leaves the spiral, it causes a "siphon effect" such that warm air is sucked into the enclosure through the exit opening for the spiral conveyor belting. This "warm air infiltration" causes a reduction in the heat transfer rate of the freezer, and is countered by injecting larger amounts of cryogen just to maintain the temperatures necessary to freeze the product. Warm air infiltration also introduces room air and higher moisture levels in the spiral enclosure, leading to a buildup of highly undesirable water ice on all the cold surfaces within the spiral as well as the product. Warm air infiltration increases the cryogenic freezing cost and reduces productivity.

Thus, there is a need in the art to provide spiral freezers that avoid or reduce undesired buildup of water ice on product and cold surfaces and increased cryogenic freezing costs.

Cryogenic spiral conveyors are normally enclosed within a large rectangular, insulated structure. The enclosure is normally longer on the side that contains the take-up tower. The spiral belting is driven by a combination of a center drum, normally made up of a cage design, and a take-up drive located in the take-up tower system. On many smaller to medium spiral freezers, there are no access doors to

the freezer enclosure on the narrow ends of the rectangle. This means that there is very limited space for maintenance on the narrow ends of the enclosure, and sanitation can only be achieved through a high pressure spray. Also, the inside of the drum is virtually inaccessible. Limited access means that in worst cases, a partial
5 disassembly of the spiral is necessary (for drum cage wear strip maintenance), and the inside portions of the belting and support structure are outside of arm's reach on the narrow ends of the rectangular enclosure for purposes of maintenance or sanitation. Limited access means inadequate sanitation, excessive volumes of hot water and energy for sanitation, and excessive maintenance time and cost.

10 Thus, there is a need for spiral freezers that provide increased ease of access to freezer interiors, increased sanitation, increased ease of sanitation, lower hot water and energy usage, and decreased maintenance time and cost.

Summary

There is provided a cryogenic spiral freezer, comprising: a rotatable drum; a
15 conveyor belt support spiraling up and around the drum to form a spiral ramp, each full revolution of the conveyor belt support around the drum constituting a tier, the conveyor belt support not being connected to the rotatable drum; an endless conveyor belt disposed on top of the conveyor belt support along a helical path; a cryogen injection apparatus comprising a feed line leading to at least one manifold
20 extending in between adjacent tiers of the conveyor belt support, each of said at least one manifold including at least one nozzle positioned and configured to inject cryogen downwardly towards the conveyor belt; a cylindrical freezing chamber housing enclosing the drum, and conveyor belt support; and a blower apparatus
25 comprising at least one blower each one of which is associated with a corresponding blower inlet and a corresponding blower outlet. Each of said at least one blowers is adapted and configured to draw in cryogen-rich air from the corresponding inlet and blow cryogen-rich air out of the corresponding outlet to induce a helical flow path of cryogen-rich air above and parallel to the helical path of the conveyor belt.

There is also provided a method of chilling or freezing products in a spiral
30 freezer. The method comprises the following steps. A plurality of items are introduced onto a conveyor belt that moves in a helical path within a spiral freezer. Cryogen is injected into a flow of chilled air in the spiral freezer to provide cryogen-

rich air. The cryogen-rich air flows along a helical flow path above and parallel to the helical path of the conveyor belt within the spiral freezer.

The cryogenic spiral freezer or method may include one or more of the following aspects:

- 5 - the helical flow of the cryogen-rich air is above and parallel to the helical path of the conveyor belt along the entire helical path of the conveyor belt.
- the helical flow path of the cryogen-rich air is upward and in a same direction as travel of the conveyor belt along the helical conveyor belt path.
- the conveyor belt travels its helical path while supported by an upwardly
10 spiraling conveyor belt support; and the helical flow of the cryogen-rich air is constrained above and below by adjacent tiers of the conveyor belt support.
- the conveyor belt rotates around and up a cylindrical drum disposed in a center of the spiral freezer along the helical path; the drum has a continuous outer surface that prevents a flow of gas into an interior of the drum; the spiral
15 freezer comprises a cylindrical freezing chamber housing that encloses the the conveyor belt along its helical path; and the helical flow of the cryogen-rich air is constrained on one side by the continuous outer surface of the drum and constrained on an opposite side by the freezing chamber housing.
- the conveyor belt travels its helical path while supported by an upwardly
20 spiraling conveyor belt support; a blower apparatus comprises at least first and second blowers each one of which includes a blower inlet and a blower outlet; the inlet of the first blower receives cryogen-rich air from a first portion of the spiral freezer in between adjacent tiers of the conveyor belt support and blows it from the outlet of the first blower into a second portion of the spiral
25 freezer in between adjacent tiers of the conveyor belt support; and the inlet of the second blower receives cryogen-rich air from a third portion of the spiral freezer in between adjacent tiers of the conveyor belt support and blows it from the outlet of the second blower into a fourth portion of the spiral freezer in between adjacent tiers of the conveyor belt support.

- the cryogen-rich air blown from the outlet of the first blower outlet flows along an axis that, when said axis crosses a midpoint of the helical path, said axis is parallel to the tangent line of the helical path.
- the cryogen-rich air blown from the blower outlets is blown in a direction that is never perpendicular to a direction of travel of the portion of the conveyor belt traveling directly underneath the blown cryogen-rich air.
- the conveyor belt has a middle portion in between inner and outer edges; the conveyor belt rotates around and up a cylindrical drum disposed in a center of the spiral freezer along the helical path through frictional engagement between the inner edge of the conveyor belt and an outer circumferential surface of the cylindrical drum; the conveyor belt is supported by an upwardly spiraling conveyor belt support forming a ramp underneath the helical path; and the inner edge and the middle portion of the conveyor belt are continuously supported by the conveyor belt support from a bottom of the helical path to a top of the helical path.
- the cryogen is liquid nitrogen.
- the cryogen is liquid carbon dioxide.
- via a freezing chamber housing outlet, the conveyor belt exits the freezing chamber housing enclosing the helical path and the helical flow path and enters into an interior of a take-up tower housing; the conveyor belt travels over, under, and/or around a plurality of rollers in a tensioning apparatus inside the take-up tower housing; via a freezing chamber housing inlet, the conveyor belt exits the take-up tower housing and enters the freezing chamber housing; and a gaseous atmosphere inside the interior of the freezing chamber housing is isolated from a gaseous atmosphere inside the interior of the take-up tower housing by a wall of the freezing chamber housing except for flow communication via the freezing chamber housing inlet and freezing chamber housing outlet.
- via the freezing chamber housing outlet, allowing a portion of the cryogen-rich air exiting the interior of the freezing chamber housing to enter into the interior of the take-up tower housing; and re-circulating a portion of the cryogen-rich air exiting the freezing chamber outlet back to an interior of the freezing

chamber housing via a recirculation passageway and a recirculation blower disposed outside the freezing chamber housing adjacent to the freezing chamber housing outlet.

- the drum has a continuous outer surface that prevents a flow of gas into an interior of the drum.

- the conveyor belt has a width W , and the freezing chamber housing is spaced from an outer edge of the conveyor belt by no more than $0.1W$.

- the conveyor belt support has a continuous surface that supports at least all portions of the conveyor belt in between inner and outer edges of the conveyor belt and prevents a flow of gas through the conveyor belt support.

- the cryogenic spiral freezer further comprises:

- a take-up tower housing;

- plurality of rollers disposed within an interior of the take-up tower housing that support travel of the conveyor belt through the take-up tower housing interior, wherein:

- the freezing chamber housing has an inlet and outlet allow travel of the conveyor belt into and out of the freezing chamber, respectively;

- the freezing chamber inlet and outlet are in communication with the take-up tower housing interior; and

- the interior of the freezing chamber housing is isolated from the interior of the take-up tower housing by a wall of the freezing chamber housing except for the freezing chamber housing inlet and outlet.

- the cryogenic spiral freezer further comprises a pair of parallel conveyor belt support rails supporting inner and outer edges of the conveyor belt as it travels through the interior of the take-up tower housing, the conveyor belt support rails connecting with a top of the conveyor rail support to support travel of the conveyor belt out of the freezing chamber housing and into the take-up tower housing interior.

- the take-up tower housing has a first opening communicating with an exterior of the take-up tower housing to form a product exit and a second opening

communication with the exterior of the take-up tower housing to form a product entry where chilled or frozen product may be unloaded from the conveyor belt;

- said spiral freezer further comprises a rear-most roller receives that travel of the conveyor belt therearound at a position located adjacent the product exit and a front-most roller that receives travel of the conveyor belt therearound at a position located adjacent the product entry where product to be chilled or frozen may be loaded onto the conveyor belt.
- the cryogenic spiral freezer further comprises a recirculation blower disposed adjacent the freezing chamber outlet and a recirculation passageway defined by an outer surface of the freezing chamber housing and an outer surface of a concave portion of the take-up tower housing, the recirculation passageway providing a gas flow passage communicating between the freezing chamber outlet and one or more air return openings formed in the freezing chamber housing, the recirculation blower oriented to draw in a portion of cryogen-rich air exiting the freezing chamber outlet and blow the drawn-in portion into the recirculation passageway.
- said blower assembly comprises a plurality of blowers each one of which being associated with a blower inlet and a blower outlet, and said blower inlets are vertically aligned at one radial position with respect to an axis of the freezing chamber housing and said blower outlets are vertically aligned at another radial position with respect to the axis of the freezing chamber housing.
- each of said blowers is driven by a common blower motor drive shaft which in turn is driven by a single blower motor.
- each of said at least one blower is disposed outside the freezer chamber housing.
- the conveyor belt support has a dimpled surface.
- the conveyor belt has a midline equidistant from inner and outer edges of the conveyor belt;

- each of said at least one blower outlets is oriented along a corresponding axis; and
- each of said at least one axes extends over the midline of the helical path parallel to a line tangent to the midline.
- 5 - the induced helical flow of the cryogen-rich air is above and parallel to the helical path of the conveyor belt along the entire helical path of the conveyor belt.
- the conveyor belt has a midline equidistant between inner and outer edges of the conveyor belt;
- 10 - the conveyor belt rotates around and up a cylindrical drum disposed in a center of the spiral freezer along the helical path through frictional engagement between the inner edge of the conveyor belt and an outer circumferential surface of the cylindrical drum; and
- the midline of the conveyor belt is continuously supported by the conveyor
15 belt support from a bottom of the helical path to a top of the helical path.

Brief Description of the Drawings

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
20 analogous reference numbers and wherein:

Figure 1A is an isometric view of an embodiment of the inventive spiral freezer taken from a point of view to the right side of and behind a product exit.

Figure 1B is an isometric view of the freezer of Figure 1A taken from a point of view to the right side of and in front of a product entry.

25 Figure 2 is an isometric view of an assembly including the drum, drive shaft, drive motor, and support structure of the freezer of Figure 1A.

Figure 3 is an isometric view of the assembly of Figure 2 that also includes a conveyor belt support configured as a spiral ramp.

30 Figure 4 is an isometric view of the conveyor belt and rollers of the freezer of Figure 1A.

Figure 5A is an isometric view of the assembly of Figure 3 that also includes the conveyor belt and rollers of Figure 4 and the blower assembly and cryogen injection assembly of Figure 1A.

5 Figure 5B is an isometric view of the assembly of Figure 5A taken from a point of view to the right side of and in front of the product entry.

Figure 6 is an isometric view of the blower assembly of Figure 5A.

Figure 7 is a rear elevation view of the assembly of Figure 3 that also includes the blower assembly of Figure 6.

10 Figure 8A is an isometric view of the freezer of Figure 1A with the take-up tower housing and exhaust vents removed.

Figure 8B is an isometric view of the freezer of Figure 8A taken from a point of view to the right side of and in front of the product entry.

15 Figure 9 is an isometric view of the freezing chamber housing and blower apparatus of Figure 1A revealing interior features and the helical flow path of cryogen-rich air that is taken from a point of view to the left side of and in front of a product entry.

Figure 10 is an isometric view of the freezer of Figure 8A with the conveyor belt and rollers removed.

20 Figure 11 is an isometric view of the take-up tower housing of the freezer of Figure 1A revealing interior features that is taken from a point of view to the left side of and in front of the product entry.

25 Figure 12 is an isometric view of the freezer of Figure 1A revealing interior features that does not include the blower apparatus, support legs and arms, cryogen injection apparatus, conveyor belt, rollers, or exhausts that is taken from a point of view to the right side of and behind a product exit.

Detailed Description

30 The inventive freezer allows products to be chilled or frozen by subjecting them to a flow of cold cryogen-rich air inside a spiral freezer. The flow of cryogen-rich air follows the same helical path as the conveyor belt and thus is co-current to the travel direction of the conveyor belt. The helical flow path of the cryogen-rich air

is produced by a plurality of blowers each one of which separately receives cryogen-rich air from in between adjacent tiers of the conveyor belt from one portion of the freezer and blows it into a different portion of the freezer in between adjacent tiers of the conveyor belt. The flow of the cryogen-rich air blown by the blowers follows a
5 flow path that is tangent to the travel direction of the conveyor belt. The spiral enhanced or maintained by restricting its ability to flow through the conveyor belt, by restricting its ability to flow through the drum, and by restricting its ability to flow out of an area in between adjacent tiers of the conveyor belt travel.

The inventive freezer may be used to chill or freeze a wide variety of products,
10 including foodstuffs and other industrial products. The foodstuffs include but are not limited to meat, poultry, seafood, produce, sauces, ready-to-eat meals, and ready-to-cook meals.

As best illustrated in **FIG 1A** and **1B**, an embodiment of the inventive spiral freezer includes a freezing chamber housing **1** that is connected to a take-up tower
15 housing **5** containing a conveyor belt tensioning apparatus. Inner surfaces of the freezing chamber housing **1** define a freezing chamber. While the freezing chamber and take-up tower housings **1**, **5** may be constructed of any material used for such purposes in the field of spiral freezers, typically they are constructed of molded insulated fiberglass for ease of manufacture and lowered material costs.

A conveyor belt **9** receives product to be chilled or frozen at a position
20 adjacent to a product entry **13** and yields chilled or frozen product at a product exit **17**. A take-up tower exhaust **21** and an inlet exhaust **25** are used to exhaust cryogen-rich air to vent. A blower assembly **29** induces a spiral flow path for cryogen-rich air inside the freezing chamber. A recirculation blower (not illustrated) is
25 disposed at an upper portion of a recirculation passageway **33** that re-circulates cryogen-rich air from an upper portion of the take-up tower housing to the interior of the freezing chamber via a plurality of openings in the freezing chamber housing **1**. The cryogen-rich air is produced by injecting cryogen into the freezing chamber via a cryogen injection apparatus **37**.

30 The cryogen may be liquid nitrogen. As the cryogen is injected from the cryogen injection apparatus **37** into the gaseous atmosphere of the freezing chamber, the substantial latent heat of vaporization of the nitrogen cools the

atmosphere inside the freezing chamber. Also, nitrogen still in liquid form may impinge surfaces of the product to be chilled or cooled. The latent heat of vaporization of the impinging nitrogen cools the product. Moreover, the significant sensible heat remaining in the vaporized nitrogen helps to cool both the product and the atmosphere through heat exchange.

Alternatively, the cryogen may be liquid carbon dioxide. In this case, the liquid carbon dioxide exits the cryogen injection apparatus **37** in the form of low-temperature CO₂ snow and low-temperature CO₂ vapor. The substantial heat of sublimation of the solid CO₂ snow cools the atmosphere inside the freezing chamber. Any solid CO₂ snow that impinges upon the surfaces of product also cools the product by the same mechanism. Similar to the use of nitrogen as the cryogen, the significant sensible heat remaining in the sublimated carbon dioxide helps to cool both the product and the atmosphere through heat exchange.

When the inventive freezer is used for chilling or freezing foodstuffs, the liquid nitrogen or liquid carbon dioxide are food-grade liquid nitrogen or food-grade liquid carbon dioxide.

A drum motor **41** rotates a drum (hidden) contained within the freezing chamber housing via a spindle **45**. The drum is supported by receiving a top portion of the spindle in an upper bearing **49** and a lower bearing (hidden). The upper bearing **49** is in turn supported by a plurality of support arms **53** that lead to a corresponding plurality of support legs **57** that are connected to a blower motor **65**. The support legs **57** and the lower bearing are secured to a base **69**. While **FIGS 1A** and **1B** illustrated three support arms **53** and legs **57**, one of ordinary skill in the art will recognize that more or fewer may be utilized.

As best shown in **FIG 2**, a cylindrical drum **42** is rotated by the spindle **45** which is secured to and extending through an axis of the drum **42**. The spindle **45** is driven by the drum motor **41** and extends between the upper and lower bearings **49**, **73**. As best illustrated in **FIG 3**, conveyor belt support **77** extends in a spiral path around the drum **42** to form a spiral ramp. The conveyor belt support **77** is not connected to the drum **42** so that the conveyor belt support **77** remains stationary during rotation of the drum **42**. Each revolution of the conveyor belt support **77** constitutes one tier. Thus, in **FIG 3**, ten tiers are illustrated. As best shown in **FIG 4**,

the conveyor belt 9 is guided via a plurality of rollers 10 where one or more of the rollers 10 is rotated with a drive motor (not illustrated) to urge travel of the conveyor belt around, over, or under the rollers 10 in a belt travel direction. While the conveyor belt 9 may be constructed of any material used for conveyor belts in the field of spiral freezers, including a metal such as stainless steel, typically it is constructed of polyethylene, such as UHMW, or other polymer material having similar physical properties.

As best illustrated in **FIGS 5A** and **5B**, a suitable amount of tension is applied to the conveyor belt 9 by maintaining an appropriate amount of space in between at least one pair of adjacent rollers 10. The tension applied to the conveyor belt 9 causes an inner edge of it to frictionally engage a circumferential surface of the drum 42 so that, as the drum 42 is rotated by the drum motor 41 via the spindle 45, the conveyor belt 9 is driven in a spiral path on top of the conveyor belt support 77 around and up the drum 42. The conveyor belt 9 completes several revolutions around the drum 42, each one of which constitutes a tier. While **FIGS 5A** and **5B** illustrate nine tiers, one of ordinary skill in the art will recognize that more or less tiers may be utilized based upon the residence time desired within the freezing chamber. The conveyor belt support 77 may be constructed of any material used in the field of spiral freezers, including a metal such as stainless steel or a polyethylene (such as UHMW) or other polymer material having similar physical properties. Typically, when the conveyor belt 9 is made of a polymer material, the conveyor belt support 77 is made of stainless steel and when the conveyor belt 9 is made of stainless steel, the conveyor belt support 77 is made of a polymer material.

As best shown in **FIGS 5A, 5B, 6, and 7**, the freezer includes a blower assembly 29 includes the blower motor 65 that drives a plurality of blowers 66A, 66B, 66C via a common drive shaft 71. The blowers 66A, 66B, 66C may be of any type in the field of gas handling. Typically, they are of the impeller type that receives an axial flow of air and ejects it with a radial flow. Each blower 66A, 66B, 66C includes a blower inlet 68A, 68B, 68C that receives cryogen-rich air from in between adjacent tiers from one portion of the freezing chamber and a blower outlet 67A, 67B, 67C that blows the cryogen-rich air over the conveyor belt 9 in between adjacent tiers from a different portion of the freezing chamber in a direction parallel to the travel direction of the conveyor belt 9. Except for the portions of the blower

inlets 68A, 68B, 68C and blower outlets **67A, 67B, 67C** disposed inside the freezing chamber in between adjacent tiers of the conveyor belt support **77**, the remainder of the blower assembly **29** is typically located outside the freezing chamber in order to avoid contamination of the interior of the freezing chamber with motor oil from the blower motor **65**. It is also typically done to allow operation of the mechanical portions of the blowers **66A, 66B, 66C** at temperatures higher than that of the interior of the freezing chamber.

While **FIGS 5A, 5B, 6, and 7** illustrate three blowers **66A, 66B, 66C**, one of ordinary skill in the art will recognize that more or fewer may be utilized depending upon the strength of the spiral gas flow path desired. Also, while **FIGS 5A, 5B, 6, and 7** illustrate that the inlets **68A, 68B, 68C** and outlets **67A, 67B, 67C** of each of the blowers **66A, 66B, 66C** are arranged in parallel and are designed to receive and blow cryogen-rich air from portions of the freezer spaced 180° from one another, one of ordinary skill in the art will recognize that they need not be spaced 180° apart. Rather, any angular spacing less than or greater than 180° is possible so long as the size of the blower **66A, 66B, 66C** allows such a configuration. However, they are typically spaced from one another by 180°. Moreover, while **FIGS 5A, 5B, 6, and 7** illustrate that each one of the blower inlets **68A, 68B, 68C** of a particular blower **66A, 66B, 66C** is higher than the associated one of the blower outlets **67A, 67B, 67C** by two tiers of the conveyor belt support **77** (more precisely the vertical distance separated by 1.5 revolutions of the conveyor belt support **77**), one of ordinary skill in the art will recognize they need not be separated by more than tier and that, alternatively, they may be separated by more than two tiers. Furthermore, while **FIGS 5A, 5B, 6, and 7** illustrate a single set of vertically aligned blowers **66A, 66B, 66C**, one of ordinary skill in the art will recognize that one more than one set of vertically aligned blowers **66A, 66B, 66C** may be utilized and that the blowers **66A, 66B, 66C** in general need not be vertically aligned. Typically, the blowers **66A, 66B, 66C** are vertically aligned so that they may be driven by a common draft shaft **71**.

As best illustrated in **FIGS 5A, 5B, and 7** the freezer also includes a cryogen injection apparatus **37** that includes a vertical feed line **38** that leads to plurality of horizontal manifolds **39**. It should be noted that, in an effort to achieve clarity in the **FIGS**, the conveyor belt **9** is not illustrated in **FIG 7**. Each of the manifolds **39** includes one or more injection nozzles (not illustrated) that are adapted and

configured to inject cryogen downwardly toward the product on the conveyor belt **9**. Typically, there are several injection nozzles that are equally spaced along each of the manifolds **39** across the width of the conveyor belt **9** in order to achieve uniform chilling or freezing across the width of the conveyor belt and avoid the chilling or freezing gradient problem experienced by many conventional cryogen spirals. While the **FIGS** illustrate four manifolds **39**, one of ordinary skill in the art will recognize that fewer (as few as one, two or three) or more may be utilized. Such a one will also recognize that each of the manifolds **39** need not be vertically aligned and more than one set of vertically aligned manifolds **39** may be utilized. Typically, the manifolds are either vertically aligned or radially spaced around the conveyor belt support **77**.

As best shown in **FIGS 8A** and **8B**, the conveyor belt **9** is supported by a plurality of rollers **10**. Product (not illustrated) to be chilled or frozen is deposited upon the conveyor belt **9** at a point in between the forward-most roller **10** and an inlet **14** in the freezing chamber housing **1**. Inside the freezing chamber housing **1**, the conveyor belt **9** with the product is wound around the drum **42** (hidden in **FIGS 8A, 8B**) in a spiral path on top of the conveyor belt support **77** (hidden in **FIGS 8A, 8B**). The travel direction of the conveyor belt **9** is upwardly counter-clockwise, but one of ordinary skill in the art will recognize that an upwardly clockwise travel direction can instead be utilized with the appropriate arrangement of the conveyor belt support **77** and other related features.

After reaching the top tier of the spiraled conveyor belt support **77**, the conveyor belt **9** exits the freezing chamber housing through an outlet **18** and enters the interior of the take-up tower **5** enclosed by the take-up tower housing **5**. The conveyor belt **9** then travels out of the product exit **17** (not shown in **FIGS 8A, 8B**) where chilled or frozen product is removed from the conveyor belt **9** and around the rear-most roller **10**. The conveyor belt returns through the product exit **17** and into an interior of the take-up tower housing **5**. After travel through the series of rollers **10** providing the suitable tension, the conveyor belt **9** travels out of the product entry **13** (not shown in **FIGS 8A, 8B**) and around a forward-most roller **10** where it is once again loaded with product to be chilled or frozen.

One of ordinary skill will recognize that conveyor belts in spiral freezers actually follow a cylindrical helix path. The cryogen-rich air inside the freezing

chamber of the inventive freezer follows that same helical conveyor belt path in between adjacent tiers of the conveyor belt support. As best illustrated by **FIG 9** where the freezing chamber housing **1** is depicted as transparent, the cryogen-rich air follows an upwardly helical flow path **80** inside the housing **1**. When viewed alongside **FIGS 3, 5A, 5B, and 7**, it is evident that the upwardly helical flow path **80** of the cryogen-rich air is above and parallel to the helical path that the conveyor belt **9** takes over the conveyor belt support **77**. Thus, the flow path **80** of the cryogen-rich air is co-current with a travel direction of the conveyor belt **9**. This novel helical flow path **80** for the chilled air provides three main advantages.

First, the product is effectively cooled by the inventive freezer than with conventional spiral freezers for a given level of heat to be removed from the product. Because the flow of cryogen-rich air is now a continuous helical flow co-current to the direction of the product travel, exposure of the product to an aggressive airflow is significantly increased. As a result, the effectiveness of the heat transfer is increased. Stated another way, for a given amount of injected cryogen, the inventive freezer has a higher chilling or freezing capacity. This allows a processor to increase production. Stated yet another way, for a given amount of product, the almost continuous exposure of the product to an aggressive airflow allows less cryogen to be consumed for a given amount of heat for lower processing costs.

Second, the product receives higher quality freezing from the inventive freezer than with conventional spiral freezers for a given level of heat to be removed from the product. Because the flow of cryogen-rich air is not perpendicular to the direction of travel of the conveyor belt, the problem of over-chilling of product placed near an outer edge of the belt and under-chilling of products placed near an inner edge of the belt is avoided. Thus, there is greater uniformity of product freezing from belt edge to belt edge. In the context of the chilling of food products, uniformity of chilling is important for achievement of a desired appearance and texture in the chilled or frozen product.

Third, the inventive freezer tends to reduce the siphon effect experienced by many conventional cryogenic spiral freezers. Because the inlet of the conveyor belt into the spiral freezer is located at floor level, the cold, denser gas wants to escape out that opening. As the coldest gas leaves the spiral freezer, warm air is sucked into

the outlet of the spiral freezer by a siphoning effect. The warm air infiltration causes a reduction in the refrigeration capacity of the cryogen thereby necessitating the injection of additional amounts of cryogen for purposes other than chilling the product. The inventive freezer works against this problem (that is otherwise experienced by conventional cryogenic spiral freezers) by creating a flow of chilled air in the direction opposite that of the siphon. Because warm air infiltration also introduces moisture into the freezing chamber, the inventive freezer tends to avoid the degree of highly undesirable water ice buildup on all the cold surfaces that is experienced by conventional cryogenic spiral freezers.

The helical flow of cryogen-rich air is created by a pull-push effect of the blower apparatus **29**. At a location in between adjacent tiers at one side of the freezing chamber, the cryogen-rich air is drawn inside the inlet **68A, 68B, 68C** of one of the blowers **66A, 66B, 66C** and redirected to a location in between adjacent tiers on another side of the freezing chamber from the associated outlet **67A, 67B, 67C** at a position lower than where the cryogen-rich air was drawn in. This pull-push effect of the blower assembly **29** induces the helical flow path **80** of the cryogen-rich air in between adjacent tiers of the conveyor belt support **77** from the bottom-most tier to the top-most tier.

The helical flow path **80** of the cryogen-rich air is maintained or enhanced by enclosing it in between the outer circumferential surface of the drum **42** and the inner surface of the cylindrical freezing chamber housing **1**. In contrast to conventional spiral freezers having drums with porous circumferential surfaces to allow chilled air to pass through the drum **42**, the drum **42** of the inventive freezer is for the most part sealed and its outer circumferential surface is continuous. Thus, the momentum of the helical flow of cryogen-rich air is not decreased by flow of the cryogen-rich air into the interior of the drum **42** and a restricted channel in between the drum **42** and freezing chamber housing **1** is provided. Utilization of a drum **42** with a continuous outer surface avoids the sanitation issues experienced by conventional cryogenic spiral freezers having porous drums. As discussed in the Background, the inside of a conventional spiral freezer drum is virtually inaccessible. Limited access means that, for the worst cleanup situations, a partial disassembly of the conveyor support rail structure is necessary for conventional cryogenic spiral freezers. The helical flow path **80** of the cryogen-rich air is further enhanced by only allowing a relatively small

gap in between an outer edge of the conveyor belt **9** and an inner surface of the freezing chamber housing **1**. Typically, for a conveyor belt **9** having a width W , an inner surface of the freezing chamber housing **1** is spaced from an outer edge of the conveyor belt **9** by no more than a gap of $0.1 W$.

5 The helical flow path **80** of the cryogen-rich air is also maintained or enhanced by enclosing it in between adjacent tiers of the conveyor belt support **77**. In contrast to conventional spiral freezers having a pair of parallel conveyor support rails supporting only the inner and outer edges of the conveyor belt, the conveyor belt support **77** of the inventive spiral freezer substantially supports the entire width of the
10 conveyor belt **9**.

Substantially supporting the entire width of the conveyor belt **9** means that most of the surface of the conveyor belt **9** (including its middle portion and portions in between its middle and its inner and outer edges) is supported by the conveyor belt support **77** and that the flow of cryogen-rich air through the conveyor belt **9** is
15 inhibited. Typically, the conveyor belt support has a continuous upper surface from an inner edge to an outer edge of the conveyor belt **9**. The conveyor belt support may optionally have a discontinuous surface whereby an otherwise continuous surface includes a uniform distribution of openings so that, while the surface of the conveyor belt support **77** is not perfectly continuous, it does support the middle of the
20 conveyor belt **9** (as well as portions of the conveyor belt **9** in between the middle and the edges) and also inhibits a flow of the cryogen-rich air through the conveyor belt **9**.

Additionally, one of ordinary skill in the art will recognize that the inner and outer edges of the conveyor belt **9** may project somewhat inwardly and outwardly,
25 respectively, from the conveyor belt support **77** without departing from the invention or impeding the creation of the helical flow path **80** of cryogen-rich air. Thus, there may be a limited gap in between the drum and an inner edge of the conveyor belt support **77** and/or the outer edge of the conveyor belt **9** may be unsupported.

The conveyor belt support **77** may optionally have a dimpled surface so that
30 wear of the conveyor belt support **77** and conveyor belt **9** is minimized. If that feature is desired, the conveyor belt **9** contacts only the top surfaces of the dimpled portions of the conveyor belt support **77**.

Although the conveyor belt support **77** is illustrated as providing continuous support to the conveyor belt in the travel direction of the belt **9** as it travels from the bottom of the drum **42** to the top of the drum **42**, one of ordinary skill in the art will recognize that the inventive spiral freezer may utilize individual tiers of conveyor belt supports **7** that sandwich and connect one or more tiers of conventional conveyor belt support rails (a parallel pair of rails that only support the inner and outer edges of the conveyor belt **9**). For example, the conveyor belt **9** may be supported across substantially its entire width for one revolution the conveyor belt support **77** immediately upon entry into the freezing chamber. At the termination of this first revolution, the conveyor belt support **77** may connect with a pair of conventional conveyor belt support rails for one or even two or more revolutions around the drum so that the conveyor belt **9** travels upon rails instead of the conveyor belt support **77**. At the termination of that revolution or those revolutions, the conveyor belt **9** can once again be supported across substantially its entire width by the conveyor belt support **77**. This sequence of conveyor belt support **77** and pair of parallel conveyor belt support rails can be repeated up to the top of the spiral freezer.

As best illustrated in **FIGS 1A, 1B, 10, 11, and 12**, a portion of the flow of cryogen-rich air exiting the freezing chamber outlet **18** is directed downwardly into the re-circulation passageway **33** by the recirculation blower **36**. The re-circulation passageway **33** is formed by an outer surface of the freezing chamber housing **1** and an inner surface **32** of a concave, wedge-shaped portion of the take-up tower housing **5**. The cryogen-rich air in the re-circulation passageway **33** is returned to the freezing chamber via a plurality of return air inlets **34** formed in the freezing chamber housing **1**.

As best shown in **FIGS 11 and 12**, the take-up tower housing **5** is adapted and configured to fit together with the freezing chamber housing **1** in complementary fashion. Edges **6** of walls of the take-up tower housing **5** define a front opening **8** that opens into an interior of the take-up tower housing **5**. The outer surface of the freezing chamber housing **1** nestles inside the front opening **8** and against the edges **6** to prevent air from infiltrating in between the edges **6** and outer surfaces of the freezing chamber housing **1**.

With reference to each of the **FIGS**, in operation, the conveyor belt **9** travels up and around the forward-most roller **10** after which product to be chilled or frozen is loaded upon it. The loaded conveyor belt **9** with product enters product entry **13** which is an opening in a front face of the take-up tower housing **5**. After traversing a short distance, the loaded conveyor belt **9** then enters the inlet **14** of the freezing chamber housing **1**.

The product on the conveyor belt **9** is immediately subjected to an injection of cryogen from nozzles (not illustrated) formed in the bottom-most manifold **39** of cryogen injection apparatus **37**. After traveling one revolution around the drum **42** (hence, traveling one tier), the conveyor belt **9** passes underneath the outlet **67A** of the bottom-most blower **66A**. The flow of cryogen-rich air blown from the outlet **67A** is centered upon an axis that is tangent to travel direction of the conveyor belt **9**. The conveyor belt **9** then travels one more revolution around the drum **42** where it is again subjected to an injection of cryogen from the nozzles of the manifold **39**. The conveyor belt **9** then travels one-half a revolution around the drum **42** where it passes underneath the inlet **68A** of the bottom-most blower **66A**. The conveyor belt **9** then 1.5 more revolutions around the drum **42** where it passes underneath the outlet **67B** of the middle blower **66B** and is again subjected to an injection of cryogen from the nozzles of the manifold **39**. The conveyor belt **9** then travels 1.5 more revolutions around the drum **42** where it passes underneath the inlet **68B** of the middle blower **66B**. The conveyor belt **9** then travels one-half a revolution around the drum **42** where it is again subjected to an injection of cryogen from manifold **39**. The conveyor belt **9** then travels one more revolution around the drum **42** where it passes underneath the outlet **67C** of the top-most blower **66C**. The conveyor belt **9** then travels one more revolution around the drum **42** where it is again subjected to an injection of cryogen from manifold **39**. The conveyor belt then travels one-half a revolution more around the drum **42** and passes underneath the inlet **68C** of the top-most blower **66C**. After traveling one-half a revolution more around the drum **42**, the conveyor belt **9** has reached the top tier of the conveyor belt support **77** and exits the outlet **18** of the freezing chamber housing **1**.

One of ordinary skill in the art will recognize that, while the conveyor belt **9** is traveling up and around the drum **42** it is subjected to a flow of cryogen-rich air

flowing in a helical flow path **80** co-current to the travel direction of the conveyor belt **9**.

After exiting the outlet **18**, the conveyor belt **9** immediately emerges into the interior of the take-up tower housing **5**. Upon leaving the outlet **18**, the conveyor belt **9** is no longer supported by the conveyor belt support **77** but is instead supported by conventional conveyor belt support rails (not illustrated). Because the conveyor belt **9** is no longer supported by the conveyor belt support, a portion of the cryogen-rich air at the top of the spiral freezer (which tends to be colder than the atmosphere inside the take-up tower housing **5**) exits the freezing chamber at the freezing chamber outlet **18** and spills down through the conveyor belt **9** to the bottom portion of the interior of the take-up tower housing **5**.

By isolating the freezing chamber from the interior of the take-up tower housing **5**, the inventive spiral freezer exhibits a lower degree of cryogen consumption for the same degree of chilling of the items in the freezing chamber. It also tends to inhibit the accumulation of ice on surfaces inside the freezing chamber that eventually need to be removed, thereby necessitating shutting down the chilling or freezing process. The mechanisms responsible for these advantages are two-fold.

First, because the interior of the freezing chamber is relatively isolated from the interior of the take-up tower housing **5**, there is much lower turbulent air flow in between the two spaces. Thus, the relatively warmer air infiltrating from the ambient atmosphere outside the product exit **17** has a greater tendency to remain trapped at an upper portion of the interior of the take-up tower housing **5** due to its lower density while the relatively colder air spilling from the outlet **18** collects at the lower portion of the interior of the take-up tower housing **5**.

Second, because the gaseous atmosphere inside the take-up tower housing **5** does not fully participate in the flow of cryogen-rich air inside the freezing chamber, the relatively moist air infiltrating into the product exit **17** does not get mixed with the colder cryogen-rich air to the same degree as in conventional cryogenic spiral freezers. Because there is less water vapor to condense and freeze inside the freezing chamber (in comparison to conventional cryogenic freezers), less of the cryogen is consumed in condensing and freezing that water vapor.

These two mechanisms result in significant advantages for the inventive freezer. When ice accumulates on surfaces in the inventive freezer, it tends to accumulate more in the interior of the take-up tower housing 5 and less inside the freezing chamber. As a result, the inventive freezer is significantly easier to defrost because there are fewer surfaces to defrost inside the take-up tower housing 5 in comparison to the freezing chamber.

The conveyor belt 9 then emerges from product exit 17 which is an opening in a rear face of the take-up tower housing 5. Product is removed from the conveyor belt 9 after which time the conveyor belt 9 travels down and around the rear-most roller 10. The unloaded conveyor belt 9 then emerges back into the take-up tower housing 5 via the product exit 17. The conveyor belt 9 then travels through the series of rollers 10 providing sufficient tension. Next, the conveyor belt 9 travels out the product entry 13 at the open front face of the take-up tower housing 5 and up and around the front-most roller to complete the cycle.

Apart from the sanitary advantages provided by isolating the freezing chamber from the interior of the take-up tower housing 5, the inventive freezer is easier to clean/sanitize for other reasons. Because the drum 42 is for the most part sealed, it is very difficult for food product to get inside the drum 42 from the sides, the top or the bottom. As a result, it is ordinarily not necessary to take the spiral conveyor belt support 77 off of the drum 42 or to take apart the drum 42 for removal of food particles. Also, a conveyor belt support 77 that extends across the side and middle portions of the conveyor belt 9 from the bottom to the top of the drum 42 reduces the amount of food that falls from the conveyor belt 9 and onto a floor of the freezing chamber. As discussed in the Background, many conventional cryogenic spiral conveyors have no access doors on narrow ends of the rectangle shape enclosing the freezing chamber and take-up tower. Because these conventional cryogenic spiral freezers have very limited space for maintenance on the narrow ends of the enclosure, sanitation can only be achieved through a high pressure spray.

Because the cylindrical freezing chamber housing 1 is made up mostly of curved doors, all areas of the freezing chamber floor can easily be flushed with minimal water and all areas of the conveyor belt 9 and conveyor belt support 77 are within

easy arm reach. As a result, there is no need for an operator to wholly enter the interior of the freezing chamber housing 1 - an action that is typically otherwise required in sanitizing conventional cryogenic spiral freezers. Additionally, all belt repairs and maintenance can be completed by an operator while standing outside the freezing chamber housing 1. Thus, the inventive freezer avoids the problems experienced by conventional cryogenic spiral freezers of inadequate sanitation, excessive volumes of hot water and energy for sanitation, and excessive maintenance time and cost.

Parts List

1	freezing chamber housing
5	take-up tower housing
6	edges (of walls of the take-up tower housing)
8	front opening (opens into an interior of the take-up tower housing)
9	conveyor belt
10	rollers
13	product entry
14	inlet (of freezing chamber housing)
17	product exit
18	outlet (from freezing chamber housing)
21	take-up tower exhaust
25	inlet exhaust
29	blower assembly
32	inner surface (of concave, wedge-shaped portion of take-up tower housing)
34	return air inlets
38	vertical conduit (I need to add to specification -oops) for cryogen

39	manifold
33	recirculation passageway
37	cryogen injection apparatus
41	drum motor
42	a cylindrical drum
45	spindle
49	upper bearing
53	support arms
57	support legs
65	blower motor
69	base
66A, 66B, 66C	blowers
67A, 67B, 67C	blower outlets
68A, 68B, 68C	blower inlets
71	common drive shaft
73	lower bearing
77	conveyor belt support

Preferred processes and apparatus for practicing the present invention have been described. It will be understood and readily apparent to the skilled artisan that many changes and modifications may be made to the above-described embodiments without departing from the spirit and the scope of the present

invention. The foregoing is illustrative only and that other embodiments of the integrated processes and apparatus may be employed without departing from the true scope of the invention defined in the following claims.

What is claimed is:

1. A cryogenic spiral freezer, comprising:

a rotatable drum;

5 a conveyor belt support spiraling up and around the drum to form a spiral ramp, each full revolution of the conveyor belt support around the drum constituting a tier, the conveyor belt support not being connected to the rotatable drum;

an endless conveyor belt disposed on top of the conveyor belt support along a helical path;

10 a cryogen injection apparatus comprising a feed line leading to at least one manifold extending in between adjacent tiers of the conveyor belt support, each of said at least one manifold including at least one nozzle positioned and configured to inject cryogen downwardly towards the conveyor belt;

15 a cylindrical freezing chamber housing enclosing the drum, and conveyor belt support; and

a blower apparatus comprising at least one blower each one of which is associated with a corresponding blower inlet and a corresponding blower outlet, wherein each of said at least one blowers is adapted and configured to draw in cryogen-rich air from the corresponding inlet and blow cryogen-rich air out of the corresponding outlet to induce a helical flow path of cryogen-rich air above and parallel to the helical path of the conveyor belt.

2. The cryogenic spiral freezer of claim 1, wherein the drum has a continuous outer surface that prevents a flow of gas into an interior of the drum.

25 3. The cryogenic spiral freezer of claim 1, wherein the conveyor belt has a width W , and the freezing chamber housing is spaced from an outer edge of the conveyor belt by no more than $0.1W$.

30 4. The cryogenic spiral freezer of claim 1, wherein the conveyor belt support has a continuous surface that supports at least all portions of the conveyor belt in between inner and outer edges of the conveyor belt and prevents a flow of gas through the conveyor belt support.

5. The cryogenic spiral freezer of claim 1, further comprising:

a take-up tower housing;

plurality of rollers disposed within an interior of the take-up tower housing that
5 support travel of the conveyor belt through the take-up tower housing interior,
wherein:

the freezing chamber housing has an inlet and outlet allow travel of the
conveyor belt into and out of the freezing chamber, respectively;

the freezing chamber inlet and outlet are in communication with the
10 take-up tower housing interior; and

the interior of the freezing chamber housing is isolated from the interior
of the take-up tower housing by a wall of the freezing chamber housing except
for the freezing chamber housing inlet and outlet.

6. The cryogenic spiral freezer of claim 5, further comprising a pair of
15 parallel conveyor belt support rails supporting inner and outer edges of the conveyor
belt as it travels through the interior of the take-up tower housing, the conveyor belt
support rails connecting with a top of the conveyor rail support to support travel of
the conveyor belt out of the freezing chamber housing and into the take-up tower
20 housing interior.

7. The cryogenic spiral freezer of claim 5, wherein:

the take-up tower housing has a first opening communicating with an exterior
of the take-up tower housing to form a product exit and a second opening
25 communication with the exterior of the take-up tower housing to form a product entry
where chilled or frozen product may be unloaded from the conveyor belt;

said spiral freezer further comprises a rear-most roller receives that travel of
the conveyor belt therearound at a position located adjacent the product exit and a
front-most roller that receives travel of the conveyor belt therearound at a position
30 located adjacent the product entry where product to be chilled or frozen may be
loaded onto the conveyor belt.

8. The cryogenic spiral freezer of claim 5, further comprising a recirculation blower disposed adjacent the freezing chamber outlet and a recirculation passageway defined by an outer surface of the freezing chamber housing and an outer surface of a concave portion of the take-up tower housing, the recirculation passageway providing a gas flow passage communicating between the freezing chamber outlet and one or more air return openings formed in the freezing chamber housing, the recirculation blower oriented to draw in a portion of cryogen-rich air exiting the freezing chamber outlet and blow the drawn-in portion into the recirculation passageway.

9. The cryogenic spiral freezer of claim 1, wherein said blower assembly comprises a plurality of blowers each one of which being associated with a blower inlet and a blower outlet, and said blower inlets are vertically aligned at one radial position with respect to an axis of the freezing chamber housing and said blower outlets are vertically aligned at another radial position with respect to the axis of the freezing chamber housing.

10. The cryogenic spiral freezer of claim 9, wherein each of said blowers is driven by a common blower motor drive shaft which in turn is driven by a single blower motor.

11. The cryogenic spiral freezer of claim 1, wherein each of said at least one blower is disposed outside the freezer chamber housing.

12. The cryogenic spiral freezer of claim 1, wherein the conveyor belt support has a dimpled surface.

13. The cryogenic spiral freezer of claim 1, wherein:
the conveyor belt has a midline equidistant from inner and outer edges of the conveyor belt;
each of said at least one blower outlets is oriented along a corresponding axis; and

each of said at least one axes extends over the midline of the helical path parallel to a line tangent to the midline.

14. The cryogenic spiral freezer of claim 1, wherein the induced helical flow
5 of the cryogen-rich air is above and parallel to the helical path of the conveyor belt along the entire helical path of the conveyor belt.

15. The cryogenic spiral freezer of claim 1, wherein:
the conveyor belt has a midline equidistant between inner and outer edges of
10 the conveyor belt;

the conveyor belt rotates around and up a cylindrical drum disposed in a center of the spiral freezer along the helical path through frictional engagement between the inner edge of the conveyor belt and an outer circumferential surface of the cylindrical drum; and

15 the midline of the conveyor belt is continuously supported by the conveyor belt support from a bottom of the helical path to a top of the helical path.

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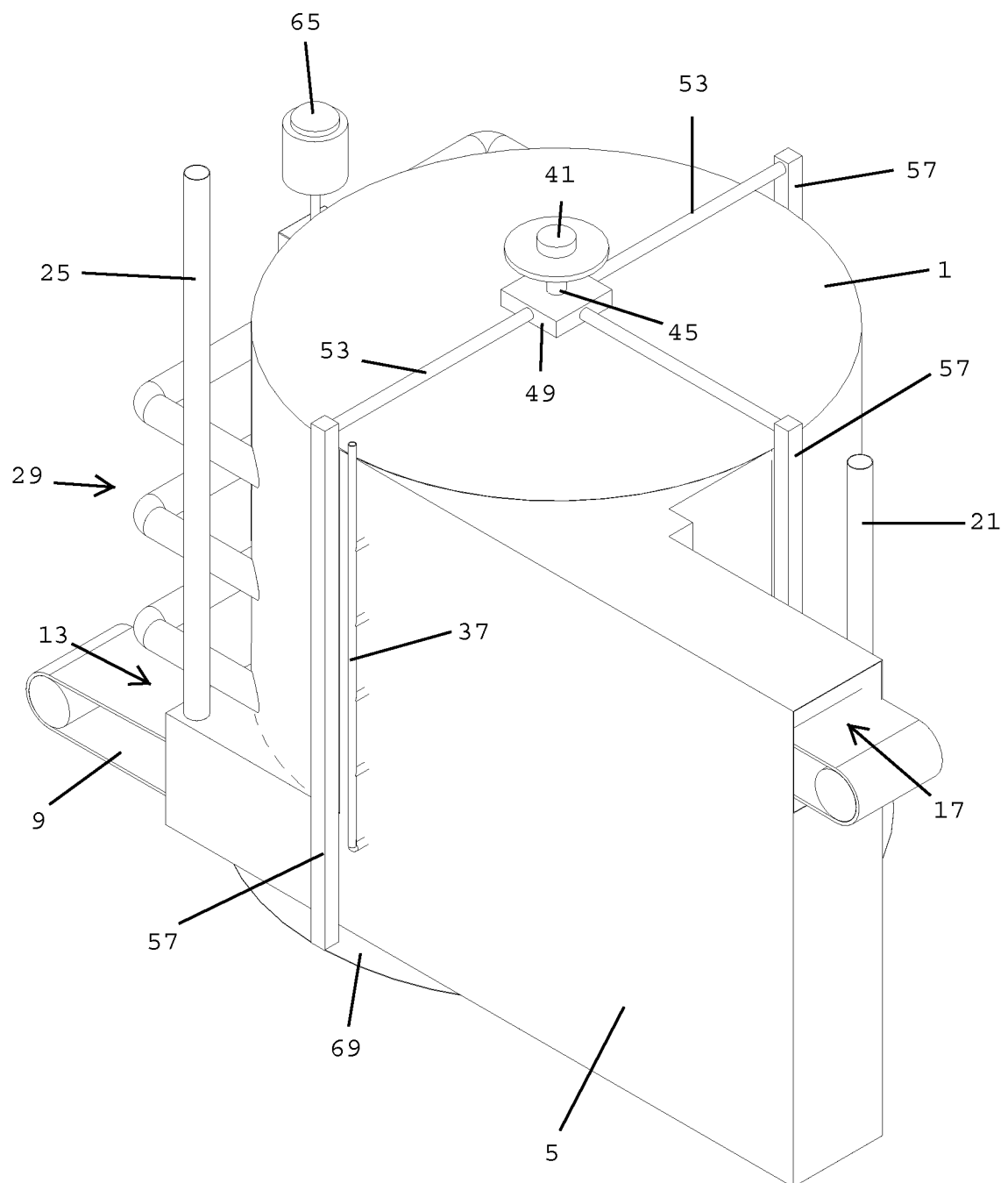


FIG 1A

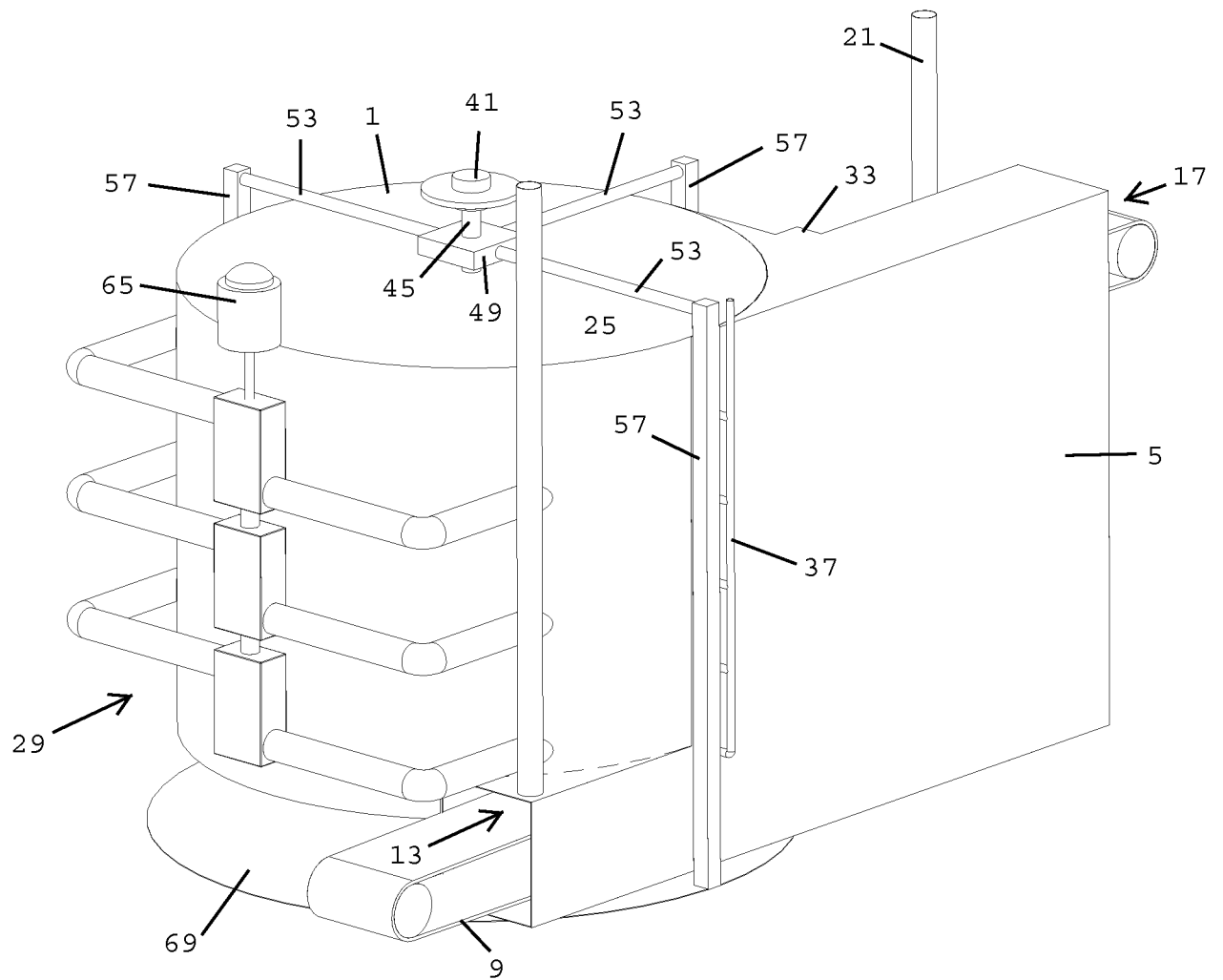


FIG 1B

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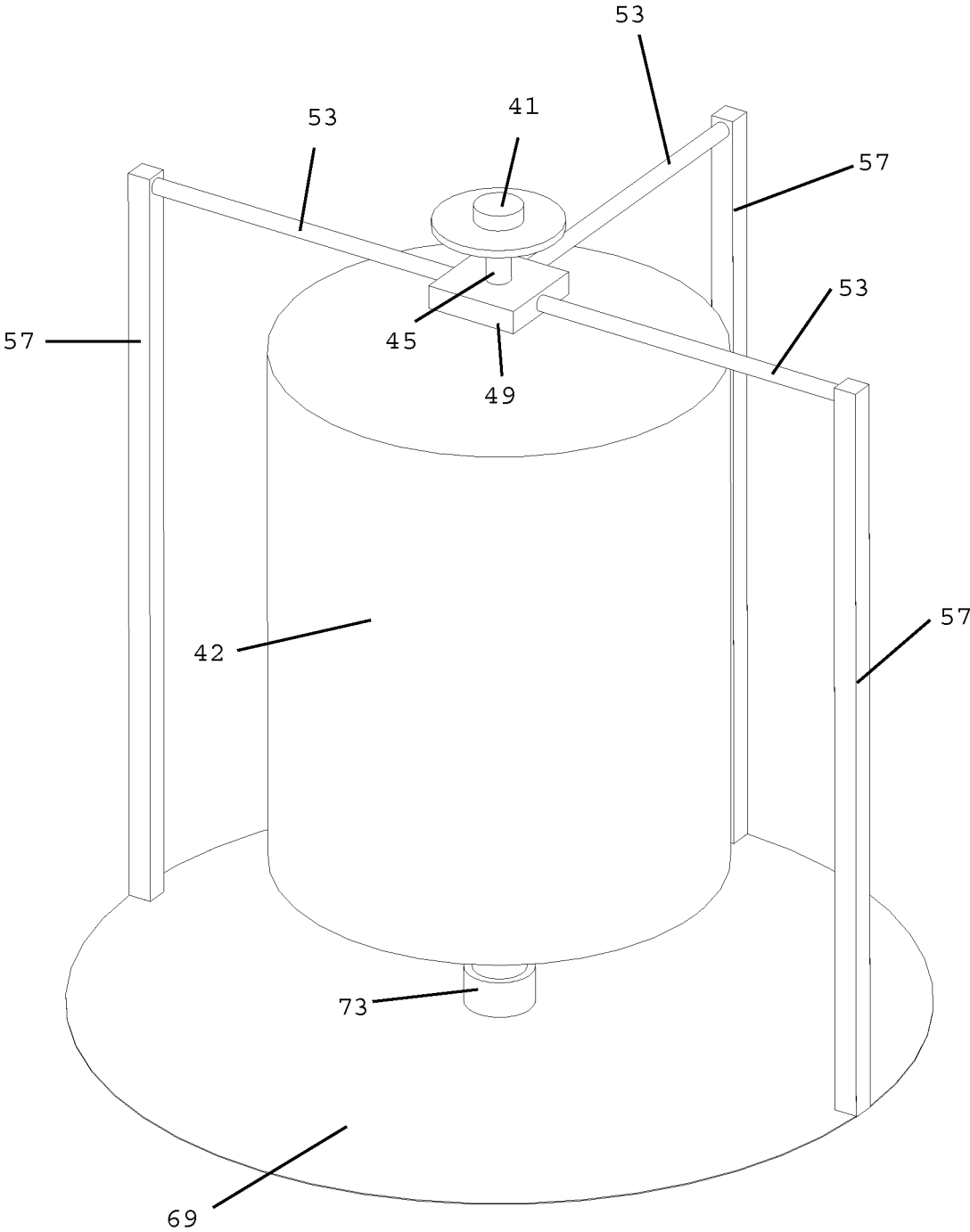


FIG 2

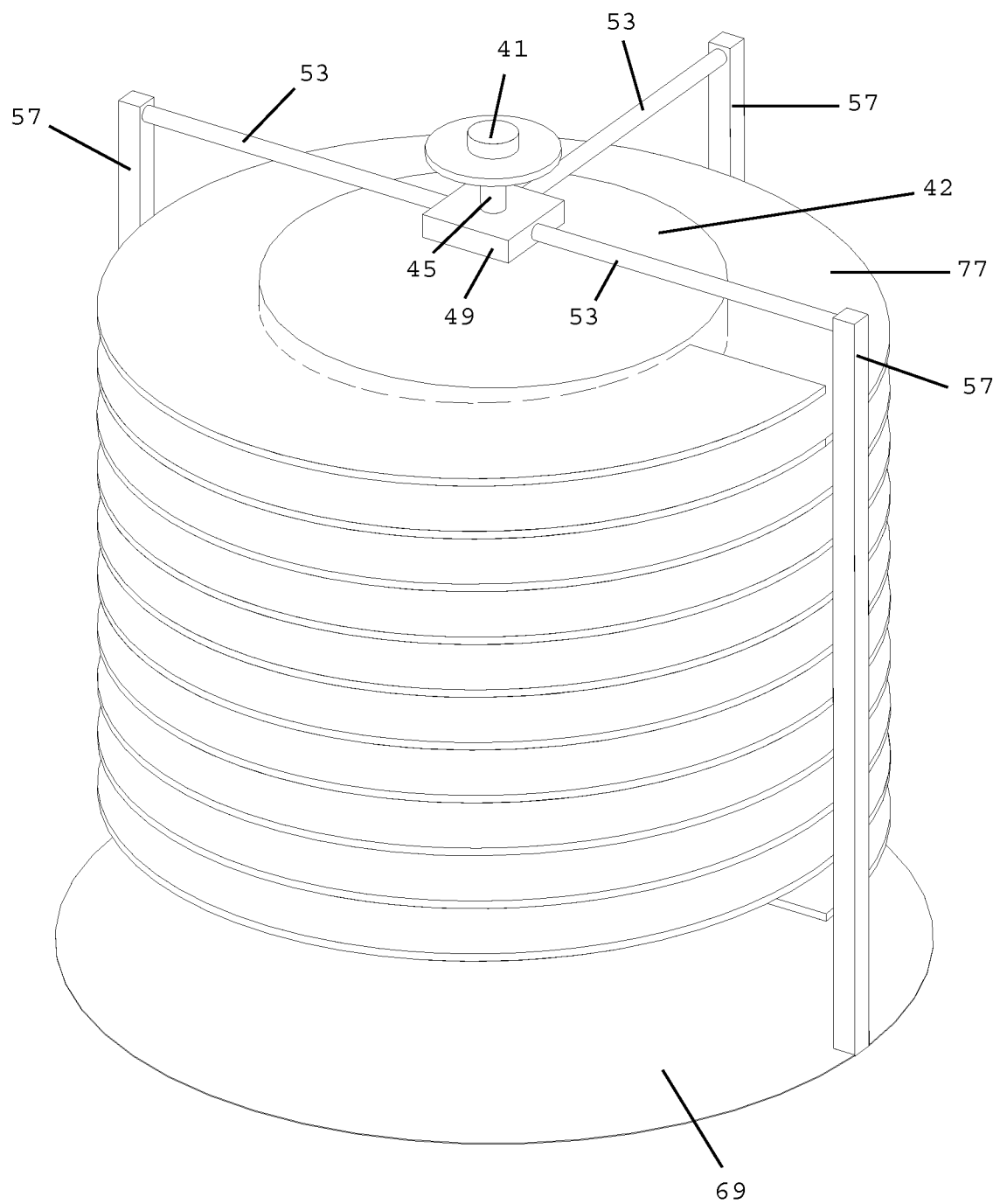


FIG 3

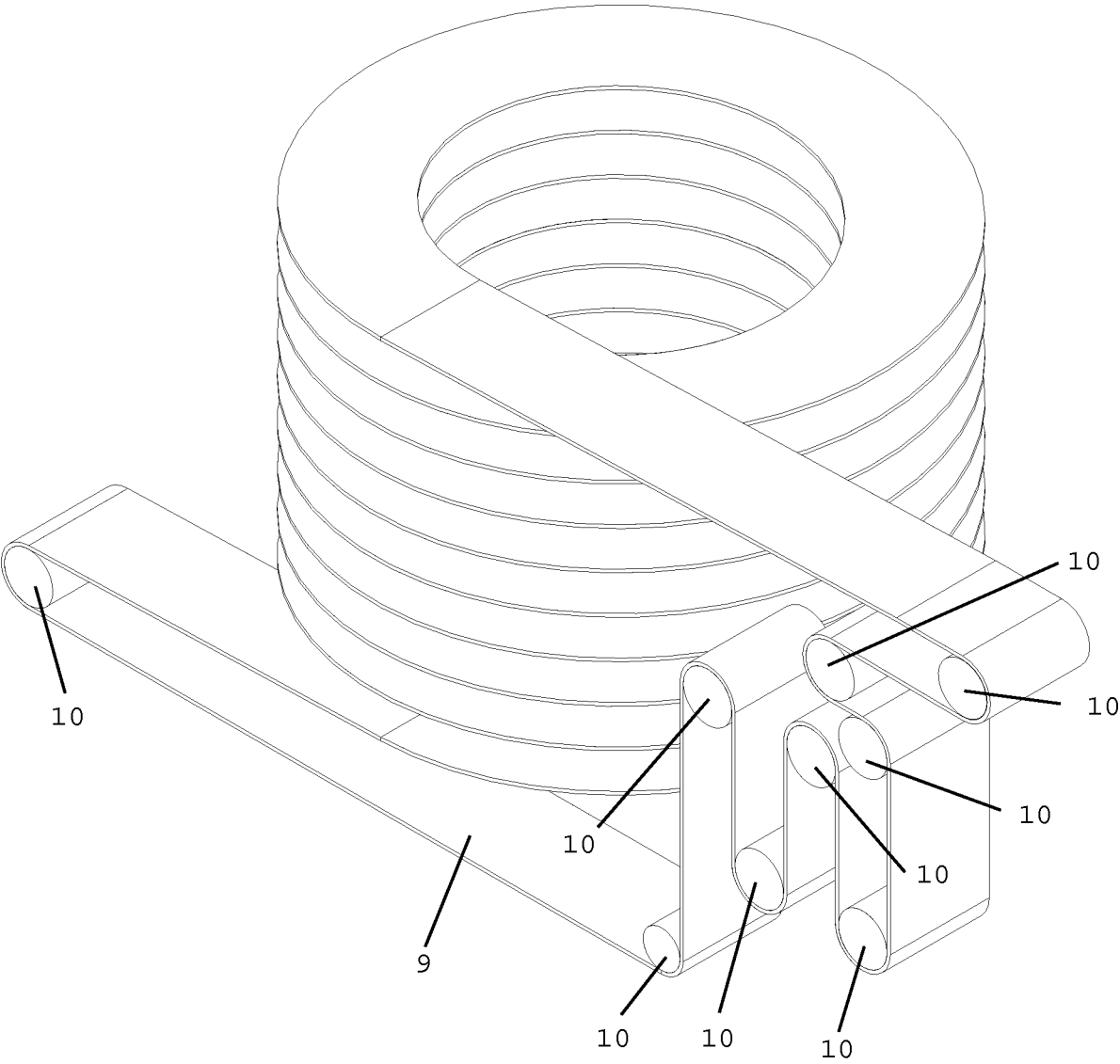


FIG 4

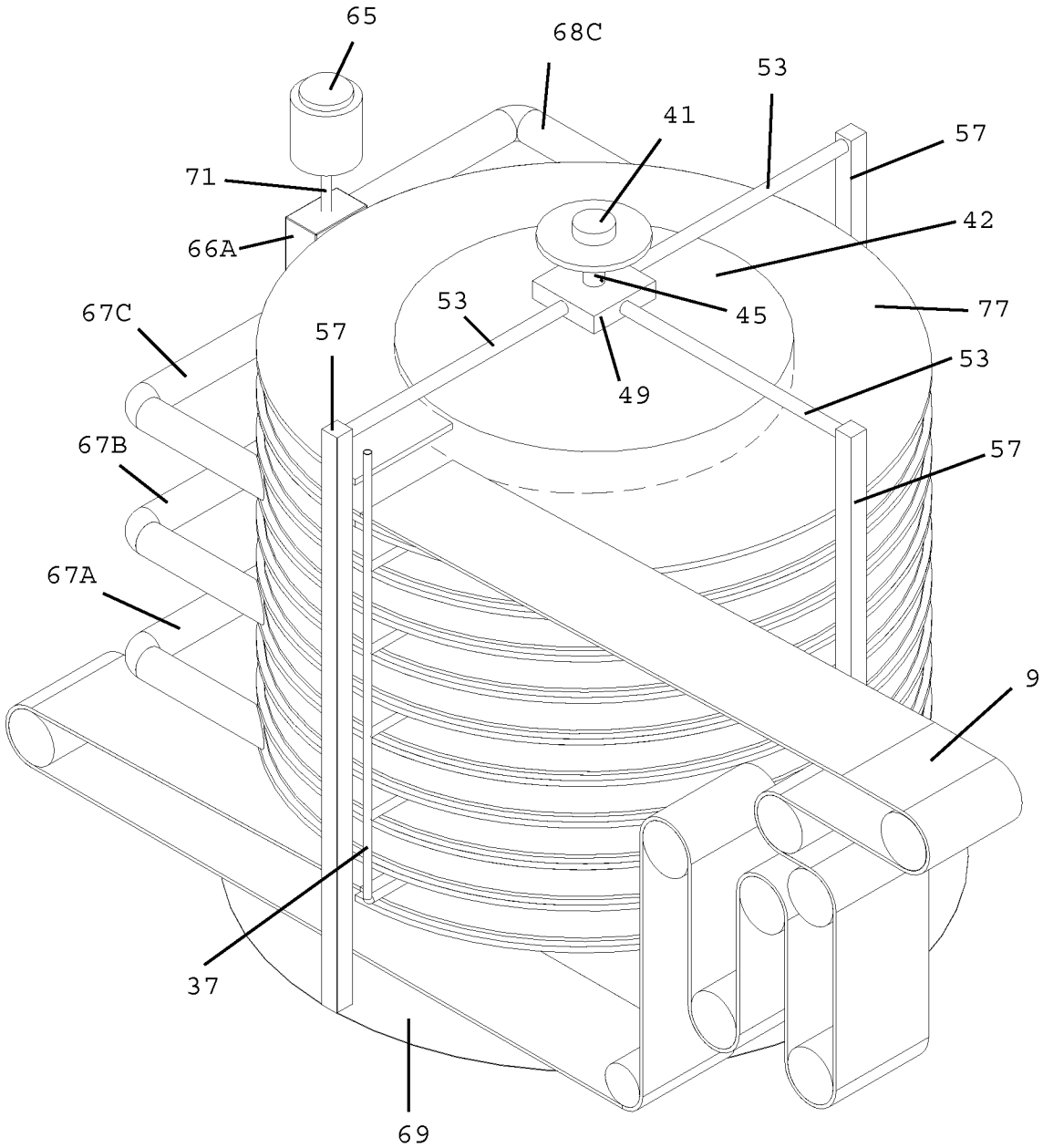


FIG 5A

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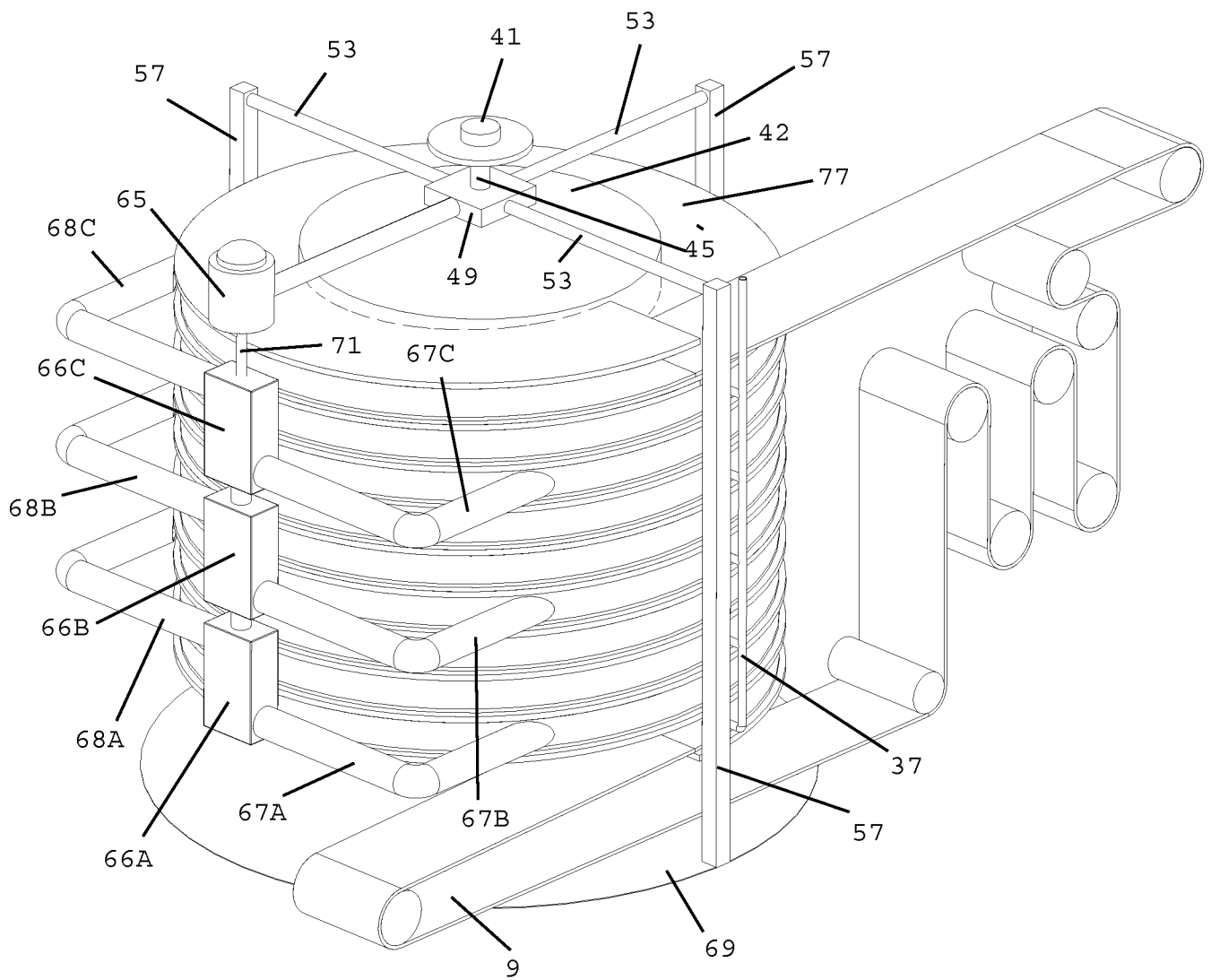


FIG 5B

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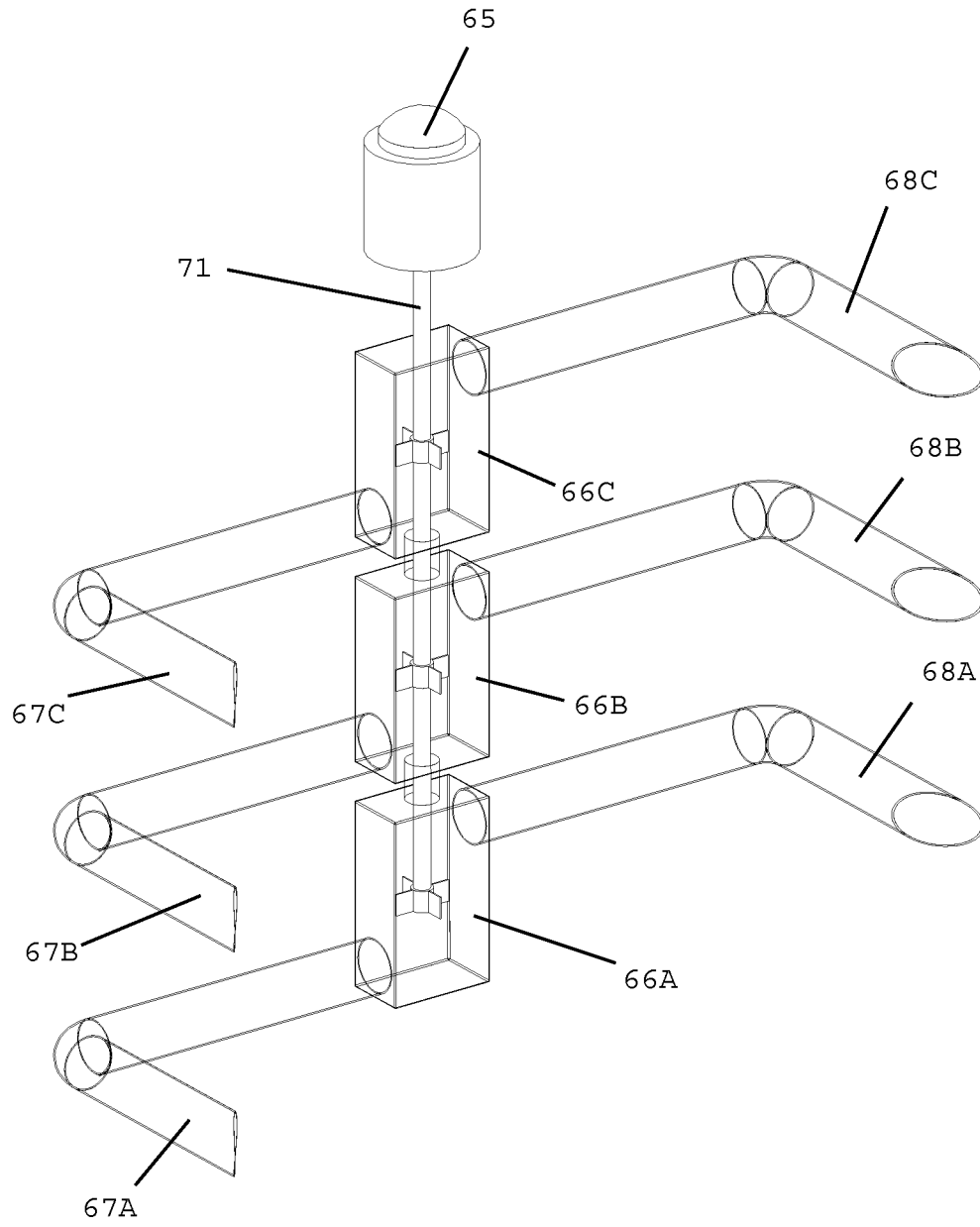


FIG 6

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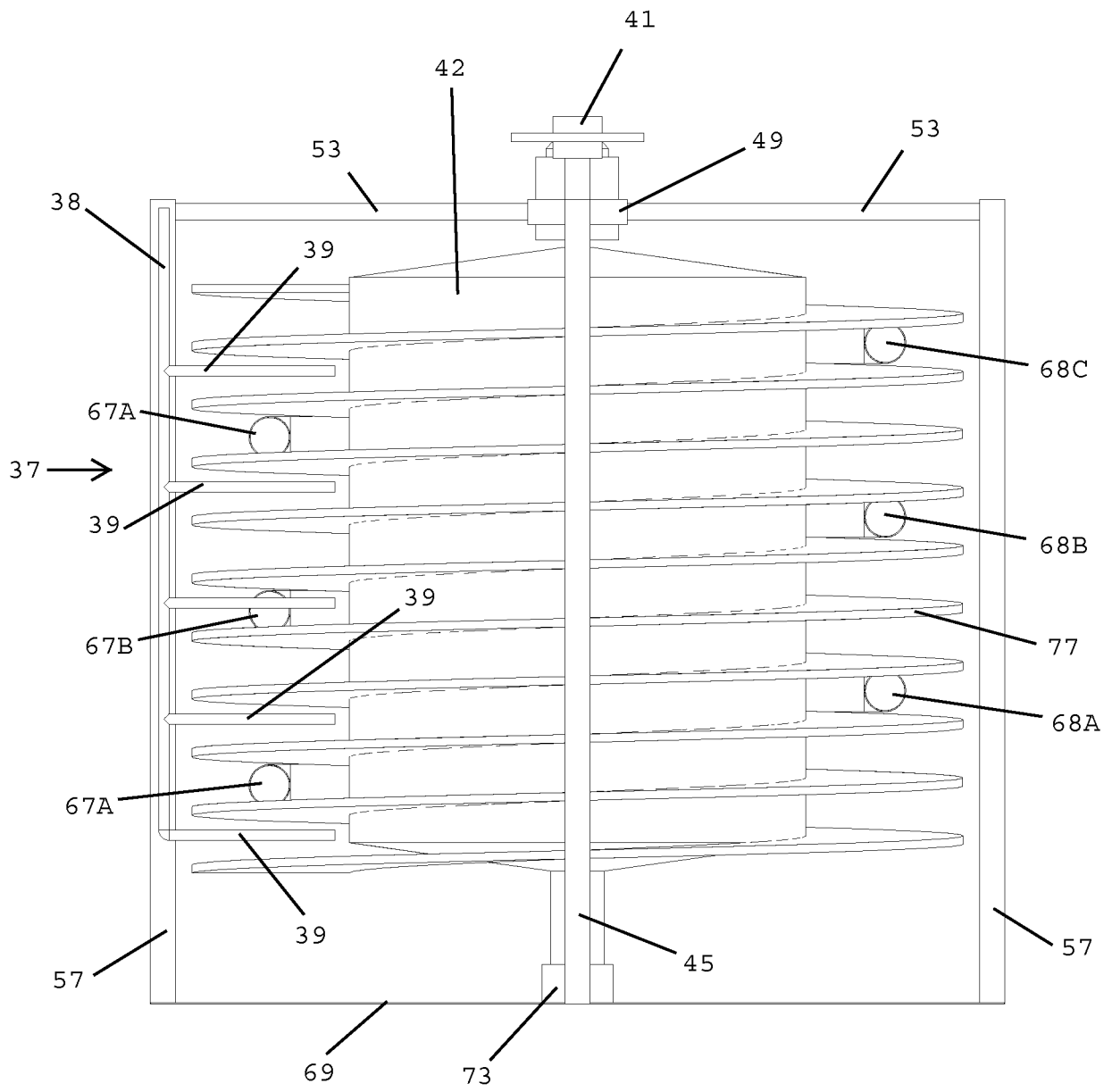


FIG 7

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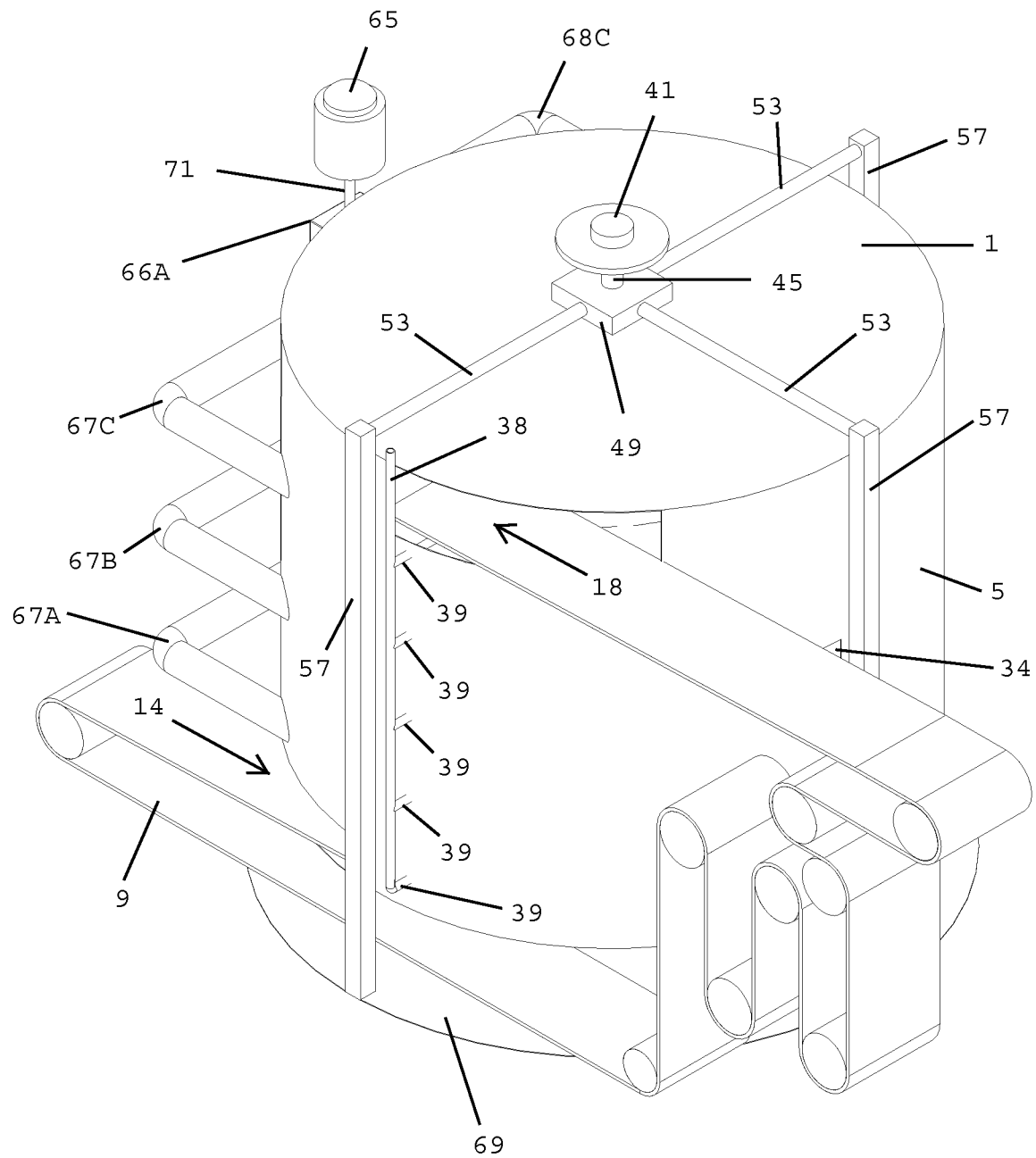


FIG 8A

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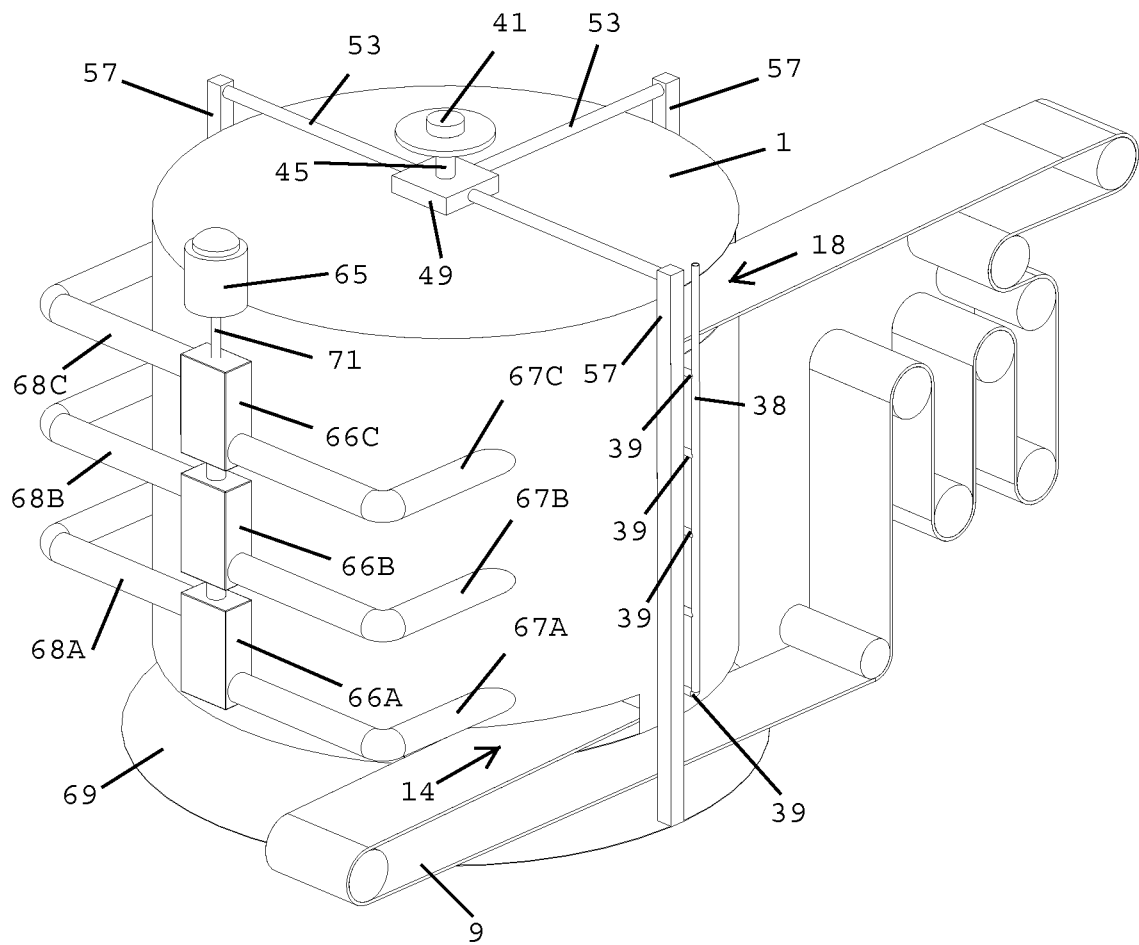


FIG 8B

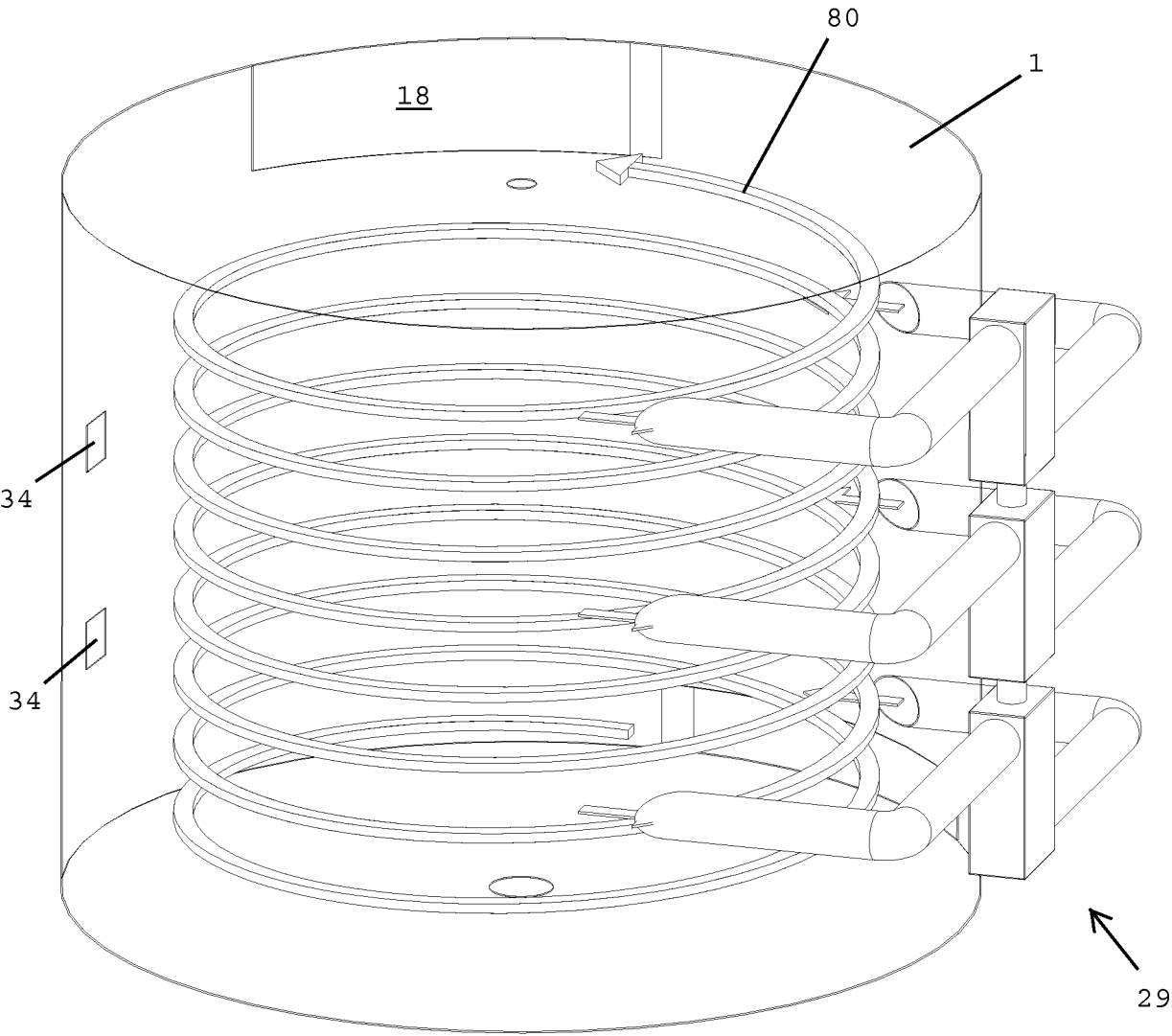


FIG 9

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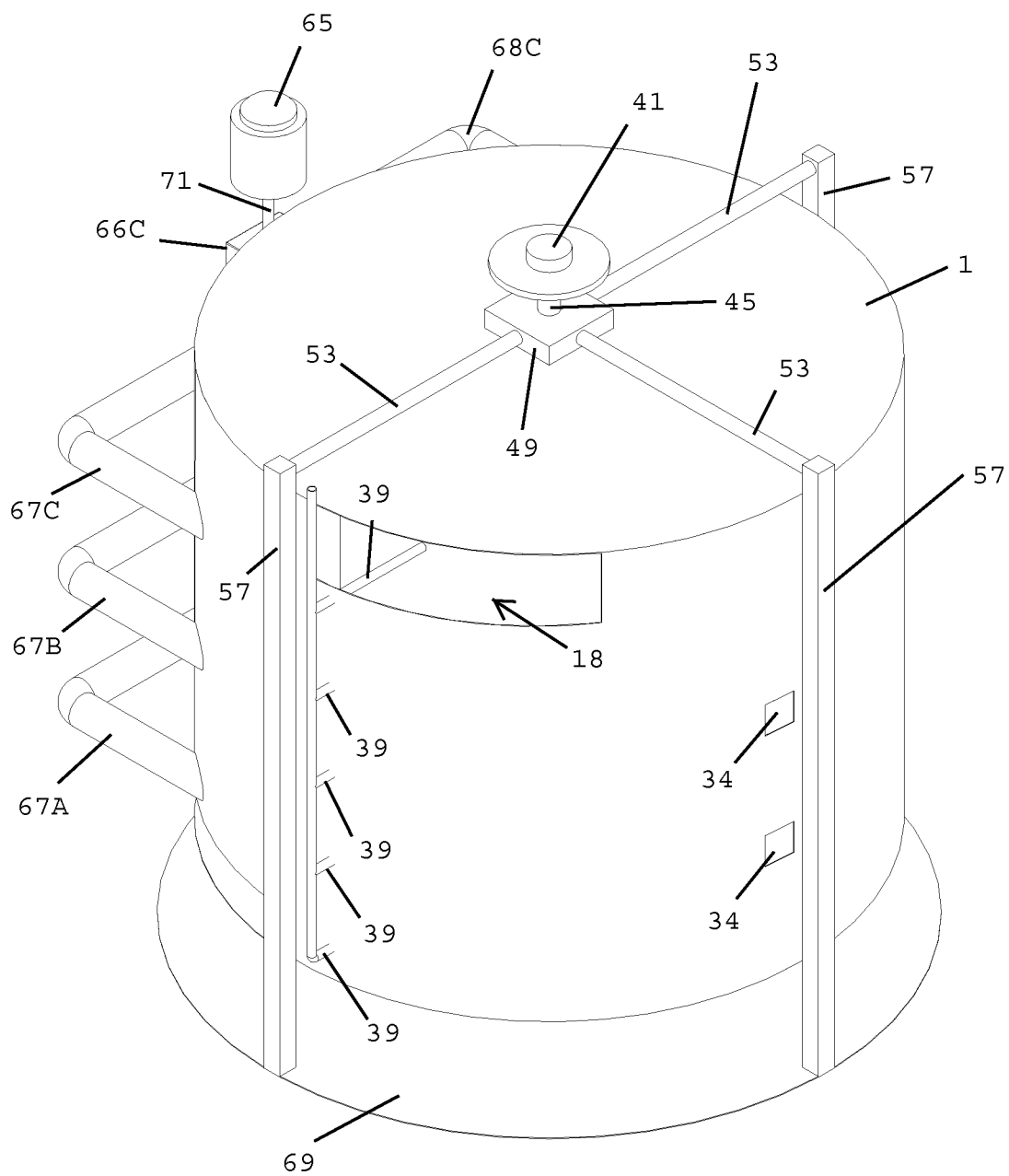


FIG 10

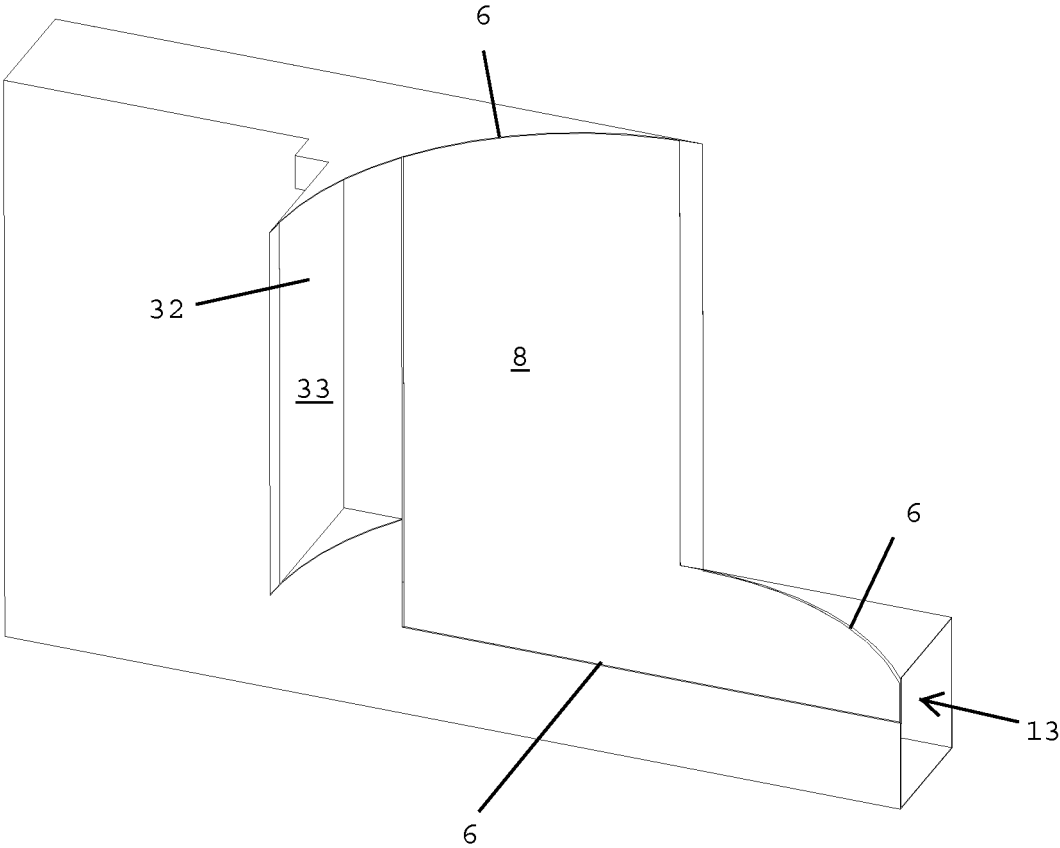


FIG 11

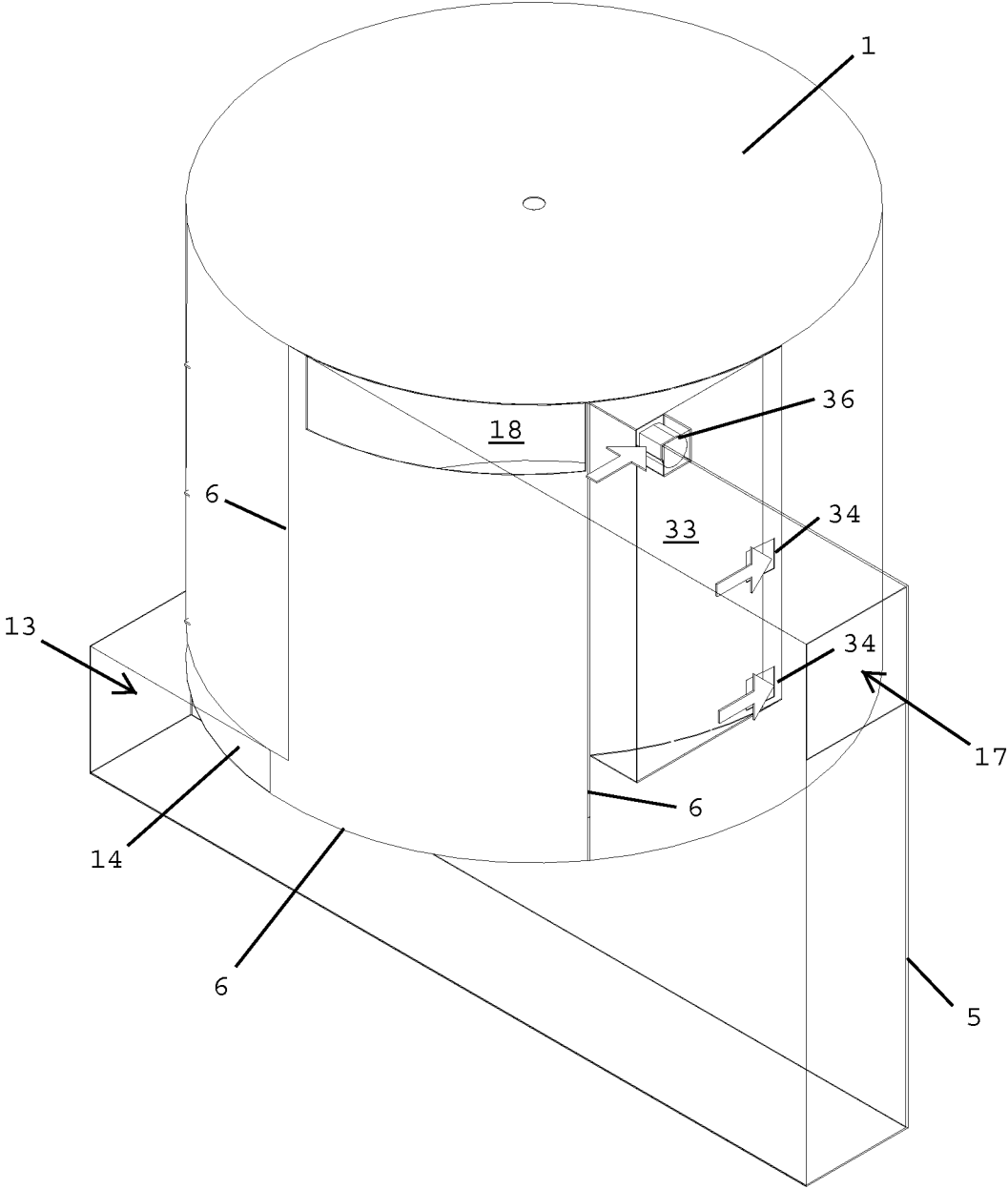


FIG 12