(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 2 684 004 B1

(12) EUROPEAN PATENT SPECIFICATION

(45) Date of publication and mention of the grant of the patent:
14.09.2016 Bulletin 2016/37

(21) Application number: **12758301.1**

(22) Date of filing: **12.03.2012**

(51) Int Cl.:
B01F 15/06 *(2006.01)* ***F28F 19/00*** *(2006.01)*
F28G 3/10 *(2006.01)* ***F28D 1/06*** *(2006.01)*
F28D 7/12 *(2006.01)* ***F28G 3/12*** *(2006.01)*
F28D 7/10 *(2006.01)* ***B01F 7/24*** *(2006.01)*
B08B 9/04 *(2006.01)*

(86) International application number:
PCT/US2012/028820

(87) International publication number:
WO 2012/125586 (20.09.2012 Gazette 2012/38)

(54) MULTI-SURFACE HEAT EXCHANGE WITH VACUUM CAPABILITY AND MAGNETIC SCRAPERS

MEHRFLÄCHIGER WÄRMEAUSTAUSCH MIT VAKUUMKAPAZITÄT UND MAGNETISCHEN ABSTREIFERN

ÉCHANGE DE CHALEUR À SURFACES MULTIPLES DOTÉ D'UNE CAPACITÉ DE MISE SOUS VIDE ET DE RACLOIRS MAGNÉTIQUES

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **11.03.2011 US 201161464952 P**

(43) Date of publication of application:
15.01.2014 Bulletin 2014/03

(73) Proprietor: **Blentech Corporation**
Rohnert Park, CA 94927 (US)

(72) Inventors:
- **ZAKIS, Janis**
  Rohnert Park
  CA 94927 (US)
- **VOIT, Daniel, Clay**
  Rohnert Park
  CA 94927 (US)
- **CORUM, Gerald, Lou**
  Rohnert Park
  CA 94927 (US)

(74) Representative: **Boult Wade Tennant**
Verulam Gardens
70 Gray's Inn Road
London WC1X 8BT (GB)

(56) References cited:

DE-A1- 3 131 770	JP-A- S6 475 891
US-A- 3 354 136	US-A- 3 354 136
US-A- 3 424 234	US-A- 3 621 506
US-A- 3 621 506	US-A- 3 770 252
US-A- 3 770 252	US-A- 4 105 066
US-A- 4 105 066	US-A- 4 176 969
US-A- 4 640 345	US-A1- 2003 042 007
US-A1- 2003 042 007	US-A1- 2007 159 919
US-A1- 2007 280 045	US-A1- 2010 064 717

EP 2 684 004 B1

Description

BACKGROUND OF THE INVENTION

Technical Field

[0001] The present invention relates generally to commercial heat exchange systems, and more particularly to a scraped surface heat exchanger for continuous or batch heating or cooling of liquids or slurries by heat exchange across surfaces.

Background Art

[0002] At present there are numerous kinds of scraped surface heat exchangers commercially available and in use, particularly in the food, biotechnology, chemical, and pharmaceutical industries. They share many limiting design features. Generally, a scraped surface heat exchanger consists of heated or cooled surface surrounding a pipe or body having a rotating pipe/agitator inside. Commonly, high viscosity slurry products are pumped through the vessel either to heat or to cool the product, and the amount of time that the material remains within the heat exchanger is dependent upon the flow rate generated by the pump. Within the interior space, where a slurry is pumped, a shaft with rigid or flexible scrapers is rotated. The action of the scrapers pulls heated or cooled product away from the vessel heat exchange surfaces.

[0003] Batch Single Surface Scraped Heat Exchangers: In batch systems, materials, including slurries and products in other forms, are loaded into metal vessels, such as stainless steel vessels, for heating or cooling. A jacketed surface encloses an interior trough. With the product loaded, the device can be used to heat or cool the product by circulating a heat transfer medium through the jacket walls. A mixer, or one or more agitator arms with attached scrapers, is installed either longitudinally or vertically. These devises are simple and commonly available, but they have limitations:

[0004] First, they are designed for batch production, which often makes high volume production prohibitive.

[0005] Second, as the size of the vessel increases, the amount of time a heating or cooling process takes increases significantly. This is because the amount of heat transfer area relative to the product volume decreases as a vessel size increases.

[0006] Third, the kinds of scrapers generally used are pushed against the heat transfer surfaces by the force applied by the product as the agitator is turning. Although uncommon, scraper designs have been devised to apply augmented force to the scrapers against the walls by using metal springs. This can have the advantage of the applying a more uniform and higher spring force. Additionally, it allows the scrapers to float along inconsistencies within a trough. However, the addition of a spring at least potentially compromises sanitation. This is of particular concern for food, pharmaceutical and biotechnology applications. Coil springs can be used, but they are extremely difficult to clean; and as such, they commonly require complete disassembly after processing is completed. Leaf springs by contrast, require a rigid fixation, which is often achieved by the use of bolts. Similar to coil springs, leaf springs create a potentially unsanitary surface in the product area.

[0007] Single Surface Heat Exchanger: Continuing with the consideration of prior art devices, the most simple and common form of continuous scraped surface heat exchangers are single surface heat exchangers. They consist of a jacketed pipe section with an agitator arm installed axially within the pipe. Either water, steam, or another kind of heat transfer medium flows through the jacketed section while product is continuously pumped through the pipe. The agitator arm has plastic or metal scrapers installed that scrape product off of the heat transfer surface. As compared to un-scraped surfaces, this scraping action increases the rate of heat transfer from the product to the heat transfer medium. The advantage is more evident for products with high viscosity or non-Newtonian characteristics. This is nearly always the case with foods, and is frequently the case with cosmetics.

[0008] These devices, however, have several disadvantages. First, they have a low ratio of heat transfer surface area to product, such that to achieve large amounts of heat transfer, the process usually requires ganging multiple, very large, identical machines. This approach, while functional, requires an owner/operator to maintain many machines. Considered in very concrete terms: single surface heat exchangers include a motor bearing and seal at each end, which can wear very rapidly. Maintenance is constant. For commercial production, the cost of ownership can therefore be very high.

[0009] A second disadvantage is that the scrapers are forced against the machine end wall by the combination of the product viscosity and centrifugal force from mixer rotation. This means that the force of scraping varies according to the product being processed and can only be adjusted slightly by increasing agitator speed. Unfortunately, increasing agitator speed to increase scraping force also increases the amount of shear applied to the product. Thus, increasing the scraping force has the detrimental, unintended consequence of damaging particulates and breaking down product viscosity. This is a notable disadvantage for food and pharmaceutical production.

[0010] Third, single surface continuous scraped heat exchanger machines are designed to pump completely through the vessel. While they can be adapted for vacuum operation, it is extremely difficult to maintain a head space critical to a controlled vacuum cooling or cooking processes. Furthermore, product pumped into the machine is intermixed with product throughout the chamber. This makes it impossible to maintain first-in/first-out flow control, a feature vital to vacuum cooking and cooling processes. The inability to effectively work with a vacuum is a significant limiting feature in the existing art.

[0011] A fourth disadvantage of the presently known single surface scraped heat exchanger designs is that long, relatively small diameter pipes are used for product introduction and discharge. While this reduces manufacturing costs, it also means that high pressure drops are required to induce flow for high viscosity products. For shear thickening products, this problem is prohibitive. To obtain flow with high pressure drops, large and numerous pumps must be employed, and this damages many products through excessive pump shear. Compounded, high energy inputs are required to perform the same process, driving up the cost of operation considerably.

[0012] Two surfaces scraped surface heat exchangers: Another design of scraped surface heat exchanger has been recently introduced to the market: the two surfaces scraped surface heat exchanger. This device consists of a two concentric pipes with an agitator arm turning in the cylindrical space. The device can be mounted in either a generally horizontal or generally vertical orientation. The two surfaces design has several advantages over the single surface scraped surface heat exchanger. First, it generally includes a large diameter pipe with a concentric inner pipe also used for heat exchange. This means that there is a larger ratio of heat transfer surface to product volume. The pipes, typically having diameters of one inch and above, can be used to process products with large particulates and they require lower pressure drops to induce flow. Fewer pumps are thus required for flow, providing a benefit for food production. Another notable advantage, when compared with a single surface heat exchanger, is that the agitator is often installed through only a single side. This reduces the number of bearings and seals involved in the machinery. When comparing a single surface heat exchanger with a two surface exchanger, based on the ratio of heat transfer surface to product volume, the number of bearings and seals is generally reduced by a factor of five or more.

[0013] However, extant two surfaces scraped surface heat exchanger designs are not without disadvantages. First, both surfaces make contact with the same product flow. Therefore, although the temperatures of the different surfaces could be independently controlled, at least in theory, operation at different temperatures for each surface is not advantageous because of the fundamental design of the exchanger, causing intermixture of newly introduced and earlier introduced product.

[0014] Second, the jacket sections are generally welded permanently into the body. Because the machines experience significant thermal stress and cycling, damage to the heat exchange surfaces is common. Such damage can be repaired, but even the most skilled welders cannot return the surfaces to their original fabricated state because concentricity and smoothness is lost. For food applications, this can make the difference between a sanitary machine acceptable for use and a machine that requires wholesale body replacement. Furthermore, after repairs, scraping efficiency is diminished by the changed surface conditions, thereby lowering the overall effectiveness of the machine. As with the single surface heat exchanger, this can mean that the machine can no longer be used, even if it has only a small crack. Again, this problem is particularly true for food, pharmaceutical, or biotechnology concerns, where hygiene is the most critical factor. The problem of cracks or jacket failures is perhaps the most notable, unresolved problem in the two surfaces heat exchangers, because they are inherently exposed to a high degree of thermal stress and cycling; failures are certain within a given span of time.

[0015] Further, existing designs do not control the movement of product in the headspace of the vessel. When product enters the vessel it will often intermix with product that has been in the vessel for some time, and the flow out will therefore consist of a mixture of product that recently entered the machine and product that entered long before. In short, any product pumped into the vessel will readily mix throughout. The lack of portioning is a disadvantage for continuous vacuum cooking or cooling operations. Because the product is completely mixed, lower rates of concentration or cooling are achieved. Two surface designs must be significantly modified if headspace control is to be achieved.

[0016] The two surfaces designs also suffer from the same scraper disadvantage as the single surface designs. The scrapers are mounted in such a way that they are urged against the vessel wall via the force applied by the product. This is not an easily controllable force. Springs could, in theory, be added to these scrapers, but they would suffer from the same sanitary problems as the scrapers on batch scraped surface heat exchangers. And because sanitary design is a critical feature for food, pharmaceutical, and biotechnology applications, any improvement to this element would be a valuable achievement.

[0017] Lastly, although these simple scrapers can sweep product back from the heat transfer surface, they do not effectively blend products, particularly those that have high yield stress. This is because the scrapers do not incite turbulence and folding action and are unidirectional. A scraper that could control the force against the heat transfer wall and mix products with high viscosity and or high yield stresses would be also be a valuable improvement. By designing scrapers that can operate in either direction, the agitation device can then be reversed to break up laminar flow currents that easily form for high viscosity products.

[0018] Other Multi-Surface Heat Exchangers: The inventors know of one commercially available three-surface heat exchanger. This heat exchanger includes three concentric pipes, each having a heat transfer jacket. An agitator turns between the jacket sections, driven from a single end. The device operates in a horizontal orientation, and it offers advantages over two- and single-surface designs; notably, it has a much higher heat transfer surface to product volume ratio, resulting in production increases using a single machine. However, the design suffers from some of the same design shortcomings as the two- and one-surface machines. First, when operated in a horizontal orientation, the product level and flow cannot be sufficiently controlled and contained. This makes vacuum cooking and cooling processes unachievable. Product flow entering the outer chambers cascades unpredictably to the lower sections. The units also include the kinds of scrapers urged to the heat exchange surfaces by product, thus they do not apply an even force nor do they allow for the independent adjustment of scraping force and agitator RPM. Lastly, such units manufactured as a single body suffer from thermal fatigue, and require frequent, costly repair or replacement. When a failure occurs, complete body replacement is required.

[0019] The foregoing patents reflect the current state of the art of which the present inventor is aware. Reference to, and discussion of, these patents is intended to aid in discharging Applicant's acknowledged duty of candor in disclosing information that may be relevant to the examination of claims to the present invention. However, it is respectfully submitted that none of the above-indicated patents disclose, teach, suggest, show, or otherwise render obvious, either singly or when considered in combination, the invention described and claimed herein.

[0020] In United States Patent 4,105,066 there is described a heat exchanger with a scraping cooling arrangement for fluid matter which tends to adhere to the heat exchanging surface.

[0021] In United States Patent 3,354,136 there is described a material-treatment apparatus comprising a container with a head through which a drive shaft passes and an opening at the bottom for entry or exit of process materials. The container includes a jacket and an annular space for heating or cooling fluid.

[0022] In United States Patent 3,770,252, there is described an apparatus for subjecting viscous material to a mixing and heat exchange treatment.

Disclosure of Invention

[0023] In accordance with the present invention, there is provided a multi-surface heat exchanger for processing food in accordance with the appended claims.

[0024] The present invention solves the above-described shortcomings of the single-and two-surface heat exchangers by providing an improved continuous flow or batch multi- surface scraped surface heat exchanger for heating or cooling of liquids or slurries that includes a unique geometry. The inventive heat exchanger includes as a series of three or more concentric tubes operated in a vertical orientation, offering more heat transfer surface than the surfaces traditionally presented with only one or two heat exchange surfaces.

[0025] The present invention includes four or more heat transfer surfaces, three of which are independently temperature and flow controllable. The vessel is mounted vertically so that product flow and product level can be controlled. Slurry products are cooled or heated across all of the surfaces in line or in parallel. The unique geometry and design permits simultaneous vacuum processing for vacuum cooking or cooling.

[0026] In addition to increased heat transfer surfaces, the inventive apparatus incorporates magnetically or spring-tensioned scrapers for high viscosity products, removable and interchangeable jacket sections allowing for ease of maintenance and repair, and vacuum construction for combination vacuum cooling or cooking. This combination is not possible with the existing technology.

[0027] The foregoing summary broadly sets out only the more important features of the present invention so that the detailed description that follows may be better understood, and so that the present contributions to the art may be better appreciated. However, there are additional features of the invention that will be described in the detailed description of the preferred embodiments of the invention which will form the subject matter of the claims appended hereto.

Brief Description of the Drawings

[0028] The invention will be better understood and objects other than those set forth above will become apparent when consideration is given to the following detailed description thereof. Such description makes reference to the annexed drawings wherein:

FIG. 1A is an upper right front perspective view of the continuous multi-surface heat exchange with vacuum capability and magnetically-tensioned scrapers of the present invention;

FIG. 1B is a lower left rear perspective view thereof;

FIG. 2 is a an upper left view showing the heat exchange vessel and portions of the rotor assembly in cross-section;

FIG. 3 is a cross-sectional right side view in elevation showing the heat exchange vessel geometry and construction, as well as product flow path (the rotor assembly other than the drive axle has been removed for clarity);

FIG. 4 is an upper perspective view of the rotor and scraper assembly of the present invention;

FIG. 5 is a perspective view of a rotor arm with scrapers deployed along its length;

FIG. 5A is a detailed perspective view taken along section line 5A of FIG. 5, showing placement of a scraper magnet in relation to a pivotally attached scraper blade;

FIG. 6 is a top plan view showing the rotor assembly position within the heat exchange vessel;

FIG. 7 is a bottom view of the inventive apparatus showing the motor mounted below the vessel platform and coupled to the rotor assembly drive shaft;

FIG. 8 is a bottom view of the vessel showing a possible configuration for a product inlet and outlet as well as heat exchange fluid inlets and outlets for each jacket section;

FIG. 9A is an upper front perspective view showing an alternative embodiment of the magnetically-tensioned scraper of the present invention mounted on a scraper bar;

FIG. 9B is an upper rear perspective view thereof;

FIG. 10A is a front view in elevation thereof;

FIG. 10B is a side view in elevation thereof;

FIG. 10C is an end view in elevation thereof;

FIG. 11 is a front view in elevation showing two scraper assemblies in a side-by-side relationship with the scraper blades positioned with a staggered geometry so that the swept area is continuous from top to bottom of the heat exchanger surfaces;

FIG. 12A is an upper front perspective view of a single scraper blade;

FIG. 12B is an upper rear perspective view thereof;

FIG. 13A is a side view in elevation thereof;

FIG. 13B is a bottom view thereof as seen along view lines 13B-13B of FIG. 13A;

FIG. 13C is a rear view thereof as seen along view lines 13C-13C of FIG. 13A; and

FIG. 13D top plan view thereof as seen along view lines 13D-13D of FIG. 13A.

Best Mode for Carrying Out the Invention

[0029] Referring to FIGS. 1A through 13D, wherein like reference numerals refer to like components in the various views, there is illustrated therein a new and improved continuous multi-surface heat exchange with vacuum capability and a magnetic scraper assembly, generally denominated **10** herein.

[0030] Referring first to FIGS. 1-8, it is seen that in a preferred embodiment, the apparatus comprises a vertically oriented heat exchange vessel **12** mounted atop a platform **14** in a generally vertical orientation. A right angle motor **16** or standard motor with a gear box and gearing to deliver rotation in a vertical axis is mounted on the underside of the platform.

[0031] The vessel includes a series of three cylindrical jacket sections, including an outer jacket section **18**, a middle jacket section **20**, and an inner jacket section **22**. As will be appreciated, the outer jacket section functions as the vessel's outer shell, the middle jacket section is coaxially disposed within the outer jacket section, and the inner jacket section is coaxially disposed within both the outer and middle jacket sections.

[0032] The outer jacket section includes an upper rim **24** with an annular sealing ring **26** on which to seat a lid **28**, which is pivotally attached to the vessel shell on or below the upper rim and preferably driven by pneumatic or hydraulic actuators **30** or other mechanical means. The lid may include one or more openings **32** for any of a number of functional elements, including a product discharge port, a viewing port, a vacuum hose connection, and so forth. The lid is a preferably sealable with clamps for vessel operation under pressure.

[0033] The vessel base **34** includes outer, middle, and inner concentric channels, **36**, **38**, **40**, respectively, which accept the lower edges **42**, **44**, **46**, of the respective outer, middle, and inner jacket sections **18**, **20**, **22**. Each jacket section - outer, middle, and inner - is divided into inner portions and outer portions **48/50**, **52/54**, **56/58**, respectively, by a partition **60**, **62**, **64** sealed at its lower edge **66**, **68**, **70** to its respective jacket section floor **72**, **74**, **76**. The outer, middle, and inner jacket sections each include at least two couplings **78/80**, **82/84**, **86/88** disposed in its floor, each of said couplings having a fluid inlet and fluid outlet for the introduction of heating and/or cooling fluid. Connection of the jacket sections to the vessel base is preferably, though not necessarily accomplished using bolts. The bolts can be passed through the vessel base into threaded apertures in the jacket section floor. The outer jacket fluid inlets **90**, **92**, middle jacket fluid inlets **94**, **96**, and inner jacket fluid inlets **98**, **100**, are disposed under the inner portion of their respective jacket section; while the outer jacket fluid outlets **102**, **104**, middle jacket fluid outlets **106**, **108**, and inner jacket fluid outlets **110**, **112**, are each disposed under the outer portion of their respective jacket section.

[0034] The outer jacket section is capped with the upper rim **24**, and the upper edge **110** of its partition **60** terminates slightly below the inner and outer upper edges **112**, **114** of this jacket section. Likewise, the inner and outer upper edges **116/118**, **120/122**, of each of the middle and inner jacket sections **20**, **22**, are each capped with a ring **124**, **126**, in such a way that several openings or gaps are created over a substantial portion of the upper edge of their respective partitions. The upper edge of the partitions in each jacket section is gapped or spaced apart from the cap so that it functions as a weir for fluid flowing from the inner to the outer portion. As known in the art, barreling is preferably disposed on each side of each partition induces turbulent and swirling fluid flow to maximize heat transfer (not shown).

[0035] As will be appreciated from the foregoing, the vessel construction provides four distinct heat exchange surfaces **128**, **130**, **132**, **134**, considered in order of the inner surface of the outer jacket section, the outer and inner surfaces of the middle jacket section, and the outer surface of the inner jacket section, respectively.

[0036] Operatively coupled to motor **16** is a reversibly rotatable rotor assembly drive shaft **136** coaxially centered in the cylindrical space **138** defined by the inner jacket section **22**. The drive shaft includes a collar **140** at its upper end with a dome-shaped cap **144** threadably inserted into the collar, or otherwise removably connected to the collar. The collar includes an expanded ring portion **146** that is stabilized and centered on and within one or more bearing sets **148**, **150** disposed in a cup **152** atop the inner jacket section. A dynamic seal (not shown but well known in the art) prevents product infiltration into the inner jacket section interior.

[0037] A spider bracket **154** is captured between the dome-shaped cap **144** and the expanded ring portion

146. [See esp. FIGS. 4 and 6.] The spider bracket includes at least two radially extending long arms **156** and at least two radially extending short arms **158**, each of which have an elongate scraper bar mounting column attached and cantilevered downwardly. Attachment of the scraper bar mounting column can be accomplished through integral manufacture, welding, or affixation using fastening apparatus, all as well known in the art. Accordingly, the system includes first and second outer scraper bar mounting columns **160**, **162**, and first and second inner scraper bar mounting columns **164**, **166**, When magnetically-tensioned scrapers are employed, each scraper bar mounting column may be hollow so that magnets can be inserted in the scraper bar mounting column in various places along the length of the column. Each scraper bar mounting column preferably includes an inner edge inserted into a longitudinally disposed slot **168** cut along the length of a generally cylindrical scraper bar. Thus, the system also includes first and second outer scraper bars **170**, **172**, and first and second inner scraper bars **174**, **176**. All or a substantial portion of the length of each scraper bar is cylindrical in cross section.

[0038] Scrapers **178** are disposed in a stacked relationship along the length of each scraper bar. The scrapers include a blade portion **180** with a beveled edge **182** and a stem **184** that includes some curvature along its length or on an undersurface portion **186** that wraps partially around the scraper bar. Opposing curved fingers **188** integral with the stem grip the bar and allow pivotal movement of the scraper about the cylindrically shaped portions of the scraper bar. Scrapers are removed from the scraper bar simply by sliding them upwardly and off the upper end of the scraper bar. A retaining clip may be provided at the end of the bar to prevent upward movement of the scrapers during use. The vessel lid also functions in this manner.

[0039] In a preferred embodiment, powerful rare earth magnets **190** (such as neodymium or samarium-cobalt magnets) are positioned in the scraper bar mounting column and in the scraper stem with their adjacent sides of the same polarity so as to repel each other strongly. [See FIGS. 5 and 5A.] Thus, the scraper stem is urged to rotate so as to force the scraper blade edge to engage the surface of the thermal exchange surface with which is it associated. As will be appreciated, the magnets may be embedded in the scraper and mounting column structures or mounted on the structures without affecting the essential function or operability of the magnets, and both configurations are thus contemplated. The magnetic fields provided by magnets in the inventive system are preferably arranged in such a way to provide an axial retaining force on the shaft.

[0040] Referring now particularly to FIGS. 2, 3, and 8, it will be seen that the vessel base 34 includes fluid inlet ports and pipes for both heating/cooling fluids and product. Specifically, product is introduced into the vessel through product inlet pipe 192 and is discharged from the vessel through product outlet pipe **194**. Heat exchange fluid is pumped into the outer jacket section through outer jacket inlet pipes **196** and is discharged through outer jacket outlet pipes **198**. It is pumped into the middle jacket section through middle jacket inlet pipes **200** and is discharged through middle jacket outlet pipes **202**. And it is pumped into the inner jacket section through inner jacket inlet pipe **204** and is discharged through inner jacket outlet pipe **206**. The flow from middle jacket outlet pipes **202** and inner jacket outlet pipe **206** may be combined in an outlet manifold **208** and discharged through a single pipe **210**. Because each jacket section is supplied with heat exchange fluid through separate sources, the temperature of the fluid provided to each jacket section can be varied, slightly or even dramatically. Further, the temperature of the heat exchange fluid supplied to any one or more of the jacket sections can be changed quickly or slowly during processing. This ensures that each of the heat exchange surfaces can be finely tailored to produce the optimal product output. As will be appreciated by those with skill in the art, any of a number of suitable heat transfer fluids can be employed in the jacket sections, including water, glycol, thermal oil, ammonia, carbon dioxide, and the like.

[0041] From the foregoing and by reference to the drawings, it will be appreciated that the products to be processed are pumped from below and through the vessel base and are also discharged through the vessel base. However, the design does not prohibit operation in a horizontal orientation or flow from bottom to top or top to bottom. Several different configurations for flow profiles are possible. The product inlet and outlet positions can be varied in any of a number of ways with top and bottom, central and outer relative positions in essentially any combination. Additionally, pumps can be provided at both the product inlet and product outlet, and the product level over the weir can be finely controlled by varying the speed of the two pumps.

[0042] In still another alternative embodiment, fluid material from spray manifolds may be applied to the product in the presence of a vacuum. This adaptation allows the machine to operate as a vacuum concentration or vacuum cooling system. It can also be used as a scraped surface ice accumulator in large freeze drying systems, which would vastly reduce the time needed to maintain and clean the traditional pipe ice accumulators.

[0043] Advantageously, the vessel lid may be opened or entirely removed to allow easy cleaning and inspection of the heat transfer surfaces as well as the removal and inspection of the scrapers. The force applied by the magnetically tensioned scrapers ensure even and effective scraping regardless of agitator RPM. Furthermore, the scrapers may be configured such that adjacent scrapers on the scraper bars are stacked in an opposing orientation, and the scrapers on the companion bar in the vessel section at the same level are also oriented in an opposing relationship. Thus, as the rotor assembly turns, product along the entire heat exchange surface is scraped at least once every rotation of the assembly, and the rotor assembly direction of rotation may be reversed without affecting the amount of blade edge engaging the heat exchange surfaces. The opposing (bidirectional) scrapers boost folding and mixing, which greatly increases the rate of heat transfer over traditional scraping. The scraper edges are also subjected to a constant sharpening process as it engages the stainless steel surfaces of the heat exchange jacket section.

[0044] When magnets are employed for scraper tensioning, the magnets are arranged to apply an opposing force toward one another. When burn or product build-up occurs, the countering scraper lifts, amplifying the scraping force on the leading scraper. With a simple alteration in geometry, the scrapers can be modified so that the magnets are positioned to attract as well, and the assembly achieves the same goal. The scrapers can also be arranged for unidirectional scraper by attaching the attracting or repulsing magnet to a fixed bar.

[0045] In alternative embodiments, magnets may be placed in the scraper stem and put into a repulsion relationship with magnets disposed in the scraper bar mounting column, within the jacket section itself, or even on the rotor assembly.

[0046] In yet another embodiment, an electromagnet may be employed within the scraper box or shell with complementary magnets in the jacket system. In such a case, the magnetic force applied to the scraper would be an attractive rather than repelling force, with the electromagnet pulling the scraper blade edge into a tighter relationship to the heat exchange surface. Such a configuration has the advantage that the scraping force can be adjusted by varying the strength of the electromagnet. This allows the operator to vary the degree of scraping without the need to alter the mixer RPM. Separation of these variables means highly sensitive products can be operated with maximum scraping but minimum shear.

[0047] Referring next to FIGS. 9A through 13D, there is shown an alternative preferred embodiment of the inventive scrapers, in this instance a contoured scraper **300**. These are configured to dramatically enhance product folding and mixing in a system using a reversible scraper assembly, often necessary in horizontally oriented batch processors, though they are also suitable for vertically oriented processors, as well. The scrapers importantly induce cross-flow mixing currents in the product being processed. The scrapers are mounted on a scraper shaft assembly **302**, which is, in turn, mounted on a scraper drive or rotor assembly, much as the rotor assembly shown in FIG. 4. Either the scraper shaft assembly or the rotor assembly includes mounting means to clamp or otherwise affix the scraper shaft assembly to the scraper drive.

[0048] Each contoured scraper includes a front side **304**, a back side **306**, a top flange **308**, an edge **310**, and one or two offset bosses **312**, through which shaft holes **314** are drilled or machined. The front side includes surface features designed to facilitate mixing and folding of the processed product. In a preferred embodiment, a primary channel **316** and a secondary channel **318** generally parallel with the primary channel, are disposed on the front side, each having a right- or left-hand slant according to the processor product flow directions desired. The top flange **308** may be drilled with one or more cylindrical magnet receptacles **320** into each of which a rare earth magnet is disposed. Alternative contour features include plates, vanes, baffles, flow diverters, and other surface features that would appropriately control the movement of a product slurry over the scraper surface.

[0049] The shaft assembly includes a central portion **322** and first and second coaxially disposed and longitudinally extending shaft portions **324**, **326**, which are inserted through the shaft holes. Clips **328**, **330** may be provided at each end to retain the scrapers on the respective shafts.

[0050] The bosses are offset in such a way that scrapers can be mounted with top flange portions in an opposing orientation, such as is shown in all of FIGS. 9A through 11. When the polarity of the magnets is oriented identically in the receptacles, they repel one another and urge the flange portions apart, thereby driving the scraper blades downwardly and toward the processor heat exchange surfaces or vessel surfaces **332**. As shown in FIG. 11, the scraper assemblies can be configured with a staggered orientation so that the surface area covered by the scraper movement is essentially continuous and unbroken in the longitudinal dimension **334**. Some degree of overlap may also be provided, as desired.

[0051] As may be appreciated from the foregoing, the angled contours are designs to shift and fold product as it is processed. The action replicates the scrape-and-flip action of a spatula. This improves mixing, reduces burn on, and increases heat transfer. Traditional scraping systems tend merely to momentarily lift product off the heat exchange surface, and for materials with a high yield stress, the material is quickly returned right back to the heat exchange surface. Burn on is thus not so much prevented as delayed and only slightly decreased.

[0052] Spring-tensioned scrapers may also be employed. Where repelling magnets have been described above, springs could also be used to impart the force urging the blade edges to the vessel walls, and when selected for use, helical compression springs are the preferred kind. Such springs may be of a number of kinds, including helical compression, coil, leaf, or rubber springs integrated or vulcanized into the scraper assembly. They may be disposed along the length of the scraper bar mounting column under the scraper stem, as in the first embodiment described above, or in an opposing relationship in the top flange portions of scrapers mounted on the shaft assembly.

[0053] In yet another alternative, springs and magnets may be used in combination to provide the tensioning force for the scrapers.

[0054] However, a hitherto unappreciated advantage in using magnets to tension the scrapers in food processing has to do with how rare earth magnets attract ferrous metals. In food products, ferrous metals are considered contaminates. Processors of slurry products are generally expected to install inline magnets or metal detectors to remove any potential metal contaminates. The use of magnets in the scrapers of the present invention fully or partially eliminates the need for inline magnets elsewhere in the process stream, because these potential contaminates will be attracted to the magnet surfaces without interfering with their effectiveness.

[0055] The jacket sections are designed as individual vessels. They are fastened and sealed in place. They may be bolted onto the vessel base or secured with any of a number of fastening means. When in place, the jacket section mates with a header section for distribution of the heat transfer medium. The removable jacket section design means that if a single jacket section fails or is damaged in any way, as is often the case with machines that experience a high degree of thermal cycling, the section can be quickly and easily removed and replaced with a modular section. The jacket sections can be connected to a common header or individually. When operated individually they have the advantage (not obtainable in traditional scraped surface heat exchangers) that the surfaces can be operated in series or at different temperatures. In so doing, the differential temperature can be maximized, improving the performance and efficiency of the vessel. It will be appreciated that the jackets need not be removable to achieve many of the other advantages of the present invention, and a welded connection or other permanent attachment of the jacket sections to the vessel base is possible.

[0056] The design of the jacket internal sections is prepared using either a spiral or directional flow barrier for liquids or remains open for steam vessels. For steam vessels, new live steam is piped directly to the top section of the jacket, and condensate is collected and extracted (for return to the boiler) from the base of the header. For liquid heat transfer media, the jacket section can also be designed with turbulence inducing flow barriers or "gun barreling."

[0057] The design of the middle jacket section has another distinct and important advantage. This device acts a "weir." When processing for cooling or concentration, mixing is restricted to two distinctly controllable isolated chambers: one between the outer and middle jacket sections; and another between the middle and inner jacket sections. The weir acts to ensure first-in, first-out flow, which improves the performance for vacuum cooking and cooling applications. This ensures that maximum processing is accomplished within the chamber. The advantage is obtained when processing simply for chilling or heating. The flow rate from one chamber to the next can be controlled using load cells or a level sensor to control the feed pump and the rate of flow depth over the process weir. The agitator design assists with control of flow between the weirs. For concentration applications, the feed pump can also be controlled by use of an inline refractometer or density analyzer.

[0058] With a simple modification of the vessel cover, product can also be added or extracted from the top. This configuration has advantages for vacuum cooking and cooling so that the unit can be used as a combination spray drier/scraped surface evaporator. By using the vessels in this manner, the heated vapor extracted by the vacuum can be used to string together several stage processes to enhance energy utilization.

[0059] Because the heat exchange surfaces are separated and can be operated at different temperatures, burn on is better controlled. For cooking applications, increasing the surface temperatures of the heat transfer surfaces closest to the outlet provides this benefit. Operating with center-out product flow also means that the area to which product is exposed is highest when the differential temperature is reduced, further increasing heat transfer. As an example, a protein dense product is prone to burn on when the surface temperature is much hotter than the product. Burn on can be reduced by slowly increasing the differential temperature of the surface relative to the product volume as the product is heated. This can be achieved in a batch machine by increasing the heat transfer media temperature as the product temperature increase. For inline heat exchangers this can only be achieved by using multiple systems operating in parallel. In the present invention, however, the final jacket section can be operated at a slightly higher steam pressure or water temperature. This increases the overall heat transfer slightly higher without creating burn on conditions. Conversely, for product cooling, although burn on is not a factor, the rate of heat flux is determined largely by the difference in temperature between the product and the surface. Therefore, a colder surface cools more quickly. The heat transfer surfaces closest to the outlet can be operated at a cooler temperature, speeding the overall process. The center surface is designed such that the heat transfer media flows to maintain the highest average differential temperature for the process. The flow barrier dividing this surface acts as an insulator. Those with skill may appreciate that the benefits of "center out" heat transfer mode may be most profound for cooling. This is because the heat transfer slows when the differential temperature decreases closer to the product outlet as a result of having more heat transfer area at the outer shell.

[0060] Under different process conditions, the ability to control each jacket at different temperatures has benefits. When chilling a product it is not possible to lower the chilling liquid to a temperature too far below the freezing point of the product without causing the product to freeze to the heat exchange surfaces. By controlling the temperature differential between the chilling liquid and the product, it is possible to chill the product faster without causing an accretion of frozen product on the heat exchange surfaces. To do this the temperature differential is varied as the product progresses through the heat exchanger, which is only possible if the jackets can be maintained at different temperatures, a feature provided in the present invention.

[0061] Several other benefits are achieved with this design. For instance, inlets and outlets can be located at the same end of the heat exchangers so that pipe connections between multiple chilling stages are shorter. For food applications this decreases surfaces that must be cleaned. Also, in the present invention, added heat transfer surfaces can achieved by flowing heat transfer media through the scraper/mixer assembly.

[0062] Vacuum capability can be provided in a manner well known in the art. A pump is connected to the vessel through a pipe in fluid communication with the vessel interior. A separator, in the form of a wider diameter pipe, may be disposed in line with the pump pipe. If vacuum cooking or cooling is employed, a heat exchanger or condenser would also be placed in line.

[0063] The present invention may also be employed as a thin film evaporator. In such an application, a plurality of spray nozzles are disposed at approximately the height if the inner jacket section upper edge (the weir) and are adapted to spray compositions such as fruit juice onto the cooking or cooling surfaces. The scrapers scrape material off as it is evaporated or cooled, thereby creating a thickened slurry. This is advantageous for such fruit industry applications in which multi-effect evaporators currently employed are not very effective, such as when making orange juice concentrate, apple concentrate, or tomato pasta sauce. End products include such things as fruit fillings for snack bars. Natural fillings with this machine where current products have to have added sugar.

[0064] A slurry chilling system that truly solves the problems set out in the background discussion must have the following characteristics: (1) Low shear with good mixing for viscous sensitive products; (2) maximum surface area with minimum floor space; (3) independently controllable heat exchange surface temperatures; (4) vacuum operation capability for combination vacuum/jacket cooling or vacuum/jacket cooking; (5) interchangeable/removable jacket sections for simplified maintenance; (6) true agitation of product, i.e., the product must be agitated or tumbled as it moves through the chiller to ensure that no hot spots are allowed to persist as the product is chilled; (7) effective heat exchange surface scraping; (8) scrapers that induce mixing in slurry products; (9) control of the chilled product so that different temperatures of chilled liquid are not mixed together in the process; (10) a large cylindrical space in each processing zone so that large particulates (e.g., up to 2 inches or so) can be processed. The scraped surface heat exchanger of the present invention achieves all of these advantages.

[0065] The above disclosure is sufficient to enable one of ordinary skill in the art to practice the invention, and provides the best mode of practicing the invention presently contemplated by the inventor. While there is provided herein a full and complete disclosure of the preferred embodiments of this invention, it is not desired to limit the invention to the exact construction, dimensional relationships, and operation shown and described. Various modifications, alternative constructions, changes and equivalents will readily occur to those skilled in the art and may be employed, as suitable, without departing from the true spirit and scope of the invention. Such changes might involve alternative materials, components, structural arrangements, sizes, shapes, forms, functions, operational features or the like.

[0066] Therefore, the above description and illustrations should not be construed as limiting the scope of the invention, which is defined by the appended claims.

Claims

1. A multi-surface scraped heat exchanger (10) for processing food, comprising:

a heat exchange vessel (12) having a base (34), a lid (28), and at least two cylindrical heat exchange surfaces (128, 130, 132, 134),
a rotor assembly motor (16);
a rotor assembly (136 - 188) mounted in said heat exchange vessel and operatively coupled to said rotor assembly motor, said rotor assembly including scraper mounting apparatus (154, 160, 162, 164, 166) and a drive shaft (136) extending through the base of the heat exchange vessel;
a plurality of scrapers (178) mounted on said scraper mounting apparatus so as to allow pivotal movement of said scrapers, each of said scrapers having a blade portion (180) that engages a heat exchange surface of said heat exchange vessel;
tensioning apparatus (190) to urge said blade portion of said plurality of scrapers toward said heat exchange surface, **characterized in that** the base includes an inlet and an outlet for heat exchange fluid.

2. The heat exchanger of claim 1, wherein said heat exchanger vessel includes a cylindrical outer jacket section (18) having one heat exchange surface (128), a cylindrical middle jacket section (20) coaxially disposed within said outer jacket section and having two heat exchange surfaces (130, 132), and a cylindrical inner jacket section (22) coaxially disposed within said middle jacket section and having one heat exchange surface (134), said jacket sections defining an inner processing zone between said inner jacket section and said middle jacket section, and an outer processing zone between said middle jacket section and said outer jacket section.

3. The heat exchanger of claim 2, wherein each of said jacket sections includes a floor (72, 74, 76) disposed on a lower end, a heat exchange fluid inlet (90, 92, 94, 96, 98, 100) and a heat exchange fluid outlet (102, 104, 106, 108, 110, 112) disposed in said floor, a partition (60, 62, 64) dividing said jacket section into inner and outer fluid flow sections, and a cap disposed on an upper end, wherein said partition is spaced apart from said cap (24, 124, 126) so as to function as a weir (116, 118) for fluid flowing from one of said inner or outer fluid flow sections to the other of said fluid flow sections.

4. The heat exchanger of claim 2, wherein said middle jacket section is a weir over which product flows from said inner processing zone to said outer processing zone.

5. The heat exchanger of claim 4, wherein at least one of said outer, middle, and inner jacket sections are removably attached to said vessel base.

6. The heat exchanger of any preceding claim, wherein the tensioning apparatus comprises at least one of a spring and a magnet to provide a tensioning force to the at least one scraper.

7. The heat exchanger of claim 4, wherein at least one of said outer jacket section, middle jacket section, and inner jacket section, has a heat exchange fluid supply (196, 200, 204) that is independent of a heat exchange fluid supply for one or more of the other of said jacket sections, such that at least one jacket section is independently temperature controlled in relation to the other of said jacket sections.

Patentansprüche

1. Mehrflächiger Schabewärmetauscher (10) zur Verarbeitung von Lebensmitteln, der Folgendes aufweist:

   einen Wärmeaustauschbehälter (12), der eine Basis (34), einen Deckel (28) und wenigstens zwei zylindrische Wärmeaustauschflächen (128, 130, 132, 134) aufweist;
   einen Rotoranordnungsmotor (16);
   eine Rotoranordnung (136 - 188), die in dem Wärmeaustauschbehälter angebracht ist und mit dem Rotoranordnungsmotor wirkverbunden ist, wobei die Rotoranordnung eine Schaberbefestigungsvorrichtung (154, 160, 162, 164, 166) und eine Antriebswelle (136) einschließt, die sich durch die Basis des Wärmeaustauschbehälters erstreckt;
   eine Mehrzahl von Schabern (178), die an der Schaberbefestigungsvorrichtung angebracht sind, so dass eine Drehbewegung der Schaber ermöglicht wird, wobei jeder der Schaber einen Schaufelabschnitt (180) aufweist, der eine Wärmeaustauschfläche des Wärmeaustauschbehälters in Eingriff nimmt;
   eine Spannvorrichtung (190), um den Schaufelabschnitt der Mehrzahl von Schabern in Richtung der Wärmeaustauschfläche zu drücken, **dadurch gekennzeichnet, dass** die Basis einen Einlass und einen Auslass für Wärmeaustauschfluid einschließt.

2. Wärmetauscher nach Anspruch 1, wobei der Wärmeaustauschbehälter einen zylindrischen äußeren Mantelabschnitt (18), der eine Wärmeaustauschfläche (128) aufweist, einen zylindrischen mittleren Mantelabschnitt (20), der koaxial innerhalb des äußeren Mantelabschnitts angeordnet ist und zwei Wärmeaustauschflächen (130, 132) aufweist, und einen zylindrischen inneren Mantelabschnitt (22) einschließt, der koaxial innerhalb des mittleren Mantelabschnitts angeordnet ist und eine Wärmeaustauschfläche (134) aufweist, wobei die Mantelabschnitte eine innere Verarbeitungszone zwischen dem inneren Mantelabschnitt und dem mittleren Mantelabschnitt und eine äußere Verarbeitungszone zwischen dem mittleren Mantelabschnitt und dem äußeren Mantelabschnitt definieren.

3. Wärmetauscher nach Anspruch 2, wobei jeder der Mantelabschnitte einen Boden (72, 74, 76), der an einem unteren Ende angeordnet ist, einen Wärmeaustauschfluideinlass (90, 92, 94, 96, 98, 100) und einen Wärmeaustauschfluidauslass (102, 104, 106, 108, 110, 112), die in dem Boden angeordnet sind, eine Trennwand (60, 62, 64), die den Mantelabschnitt in innere und äußere Fluidflussabschnitte unterteilt, und eine Kappe einschließt, die an einem oberen Ende angeordnet ist, wobei die Trennwand von der Kappe (24, 124, 126) beabstandet ist, so dass sie als Überlauf (116, 118) für Fluid dient, das von entweder dem inneren oder dem äußeren Fluidflussabschnitt zu dem anderen der Fluidflussabschnitte fließt.

4. Wärmetauscher nach Anspruch 2, wobei der mittlere Mantelabschnitt ein Überlauf ist, über welchen ein Produkt von der inneren Verarbeitungszone zu der äußeren Verarbeitungszone fließt.

5. Wärmetauscher nach Anspruch 4, wobei wenigstens ein Mantelabschnitt des äußeren, mittleren und inneren Mantelabschnitts abnehmbar an der Behälterbasis befestigt ist.

6. Wärmetauscher nach einem der vorhergehenden Ansprüche, wobei die Spannvorrichtung wenigstens entweder eine Feder oder einen Magneten aufweist, um eine Spannkraft für den wenigstens einen Scha-

ber bereitzustellen.

7. Wärmetauscher nach Anspruch 4, wobei wenigstens entweder der äußere Mantelabschnitt, der mittlere Mantelabschnitt oder der innere Mantelabschnitt eine Wärmeaustauschfluidversorgung (196, 200, 204) aufweist, die unabhängig von einer Wärmeaustauschfluidversorgung für einen oder mehrere der anderen Mantelabschnitte ist, so dass wenigstens ein Mantelabschnitt unabhängig temperaturgesteuert in Bezug auf die anderen der Mantelabschnitte ist.

Revendications

1. Échangeur de chaleur (10) à surfaces raclées pour le traitement d'aliments, comprenant :

un récipient (12) d'échange de chaleur ayant une base (34), un couvercle (28), et au moins deux surfaces cylindriques d'échange de chaleur (128, 130, 132, 134),
un moteur d'ensemble rotor (16) ;
un ensemble rotor (136 - 188) monté dans ledit récipient d'échange de chaleur et couplé de manière fonctionnelle audit moteur d'ensemble rotor, ledit ensemble rotor comportant un appareil de montage de racloir (154, 160, 162, 164, 166) et un arbre d'entraînement (136) s'étendant à travers la base du récipient d'échange de chaleur ;
une pluralité de racloirs (178) montés sur ledit appareil de montage de racloir de manière à permettre un mouvement de pivotement desdits racloirs, chacun desdits racloirs ayant une partie de lame (180) qui s'engage avec une surface d'échange de chaleur dudit récipient d'échange de chaleur ;
un appareil de tension (190) destiné à solliciter ladite partie de lame de ladite pluralité de racloirs vers ladite surface d'échange de chaleur, **caractérisé en ce que** la base comporte une entrée et une sortie pour un fluide d'échange de chaleur ;

2. Échangeur de chaleur de la revendication 1, dans lequel ledit récipient d'échangeur de chaleur comporte une section de chemise extérieure cylindrique (18) ayant une surface d'échange de chaleur (128), un section de chemise intermédiaire cylindrique (20) disposée de manière coaxiale à l'intérieur de ladite section de chemise extérieure et ayant deux surfaces d'échange de chaleur (130, 132), et une section de chemise intérieure cylindrique (22) disposée de manière coaxiale à l'intérieur de ladite section de chemise intermédiaire et ayant une surface d'échange de chaleur (134), lesdites sections de chemise délimitant une zone intérieure de traitement entre ladite section de chemise intérieure et ladite section de chemise intermédiaire, et une zone extérieure de traitement entre ladite section de chemise intermédiaire et ladite section de chemise extérieure.

3. Échangeur de chaleur de la revendication 2, dans lequel chacune desdites sections de chemise comporte un fond (72, 74, 76) disposé sur une extrémité inférieure, une entrée de fluide d'échange de chaleur (90, 92, 94, 96, 98, 100) et une sortie de fluide d'échange de chaleur (102, 104, 106, 108, 110, 112) disposées dans ledit fond, une cloison (60, 62, 64) divisant ladite section de chemise en sections d'écoulement de fluide intérieure et extérieure, et un capuchon disposé sur une extrémité supérieure, où ladite cloison est espacée dudit capuchon (24, 124, 126), de manière à fonctionner en tant que déversoir (116, 118) pour un fluide s'écoulant depuis l'une desdites sections d'écoulement de fluide intérieure ou extérieure vers l'autre desdites sections d'écoulement de fluide.

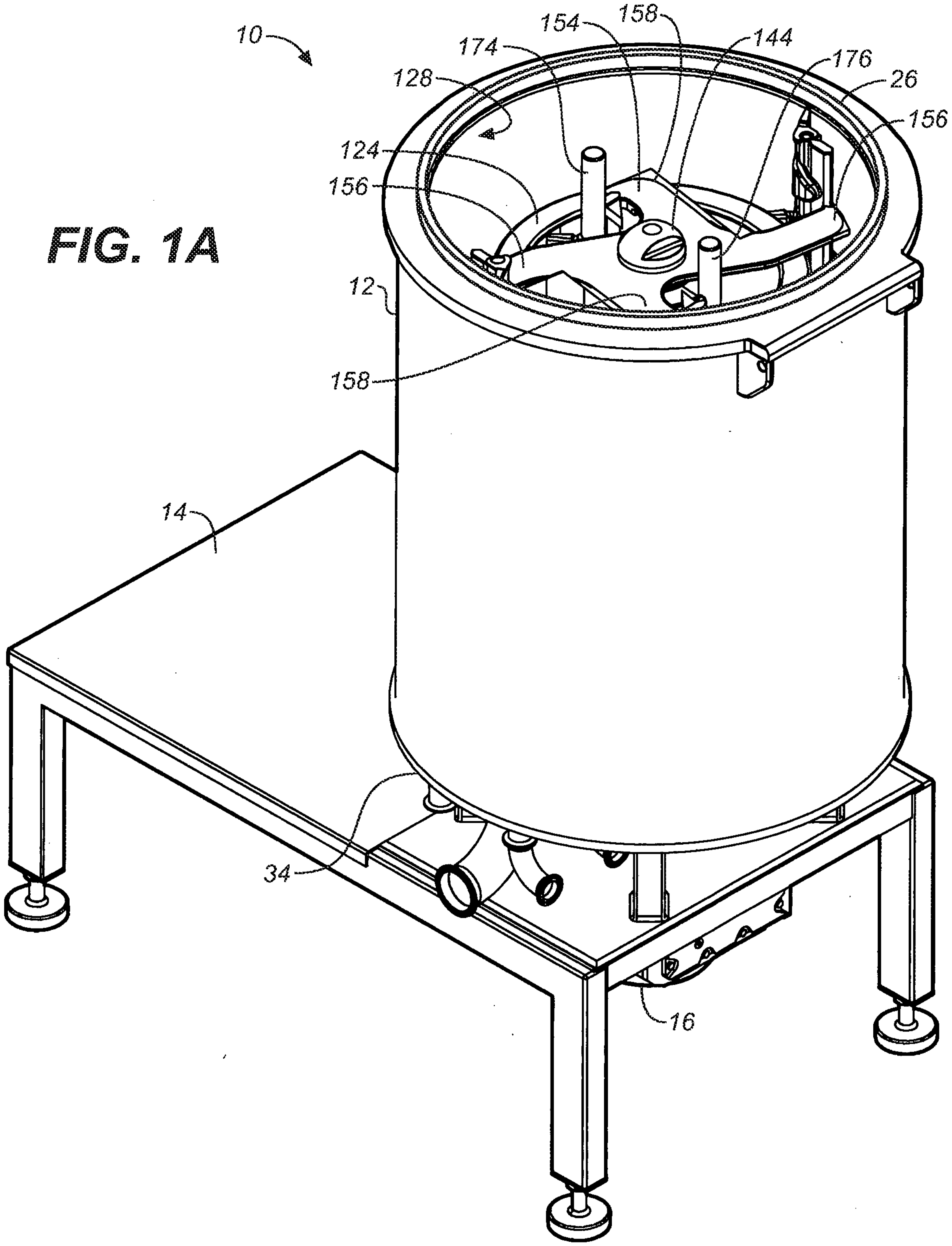
4. Échangeur de chaleur de la revendication 2, dans lequel ladite section de chemise intermédiaire est un déversoir sur lequel s'écoule un produit depuis ladite zone intérieure de traitement vers ladite zone extérieure de traitement.

5. Échangeur de chaleur de la revendication 4, dans lequel au moins l'une desdites sections de chemise extérieure, intermédiaire et intérieure est fixée de manière amovible à ladite base de récipient.

6. Échangeur de chaleur de l'une des revendications précédentes, dans lequel l'appareil de tension comprend au moins l'un parmi un ressort et un aimant pour fournir une force de tension pour l'au moins un racloir.

7. Échangeur de chaleur de la revendication 4, dans lequel au moins l'une desdites section de chemise extérieure, section de chemise intermédiaire et section de chemise intérieure, a un élément d'alimentation en fluide d'échange de chaleur (196, 200, 204) qui est indépendant d'un élément d'alimentation en fluide d'échange de chaleur pour l'une ou plusieurs des autres desdites sections de chemise, de sorte qu'au moins une section de chemise ait une température indépendamment régulée par rapport à l'autre desdites sections de chemise.

FIG. 1A



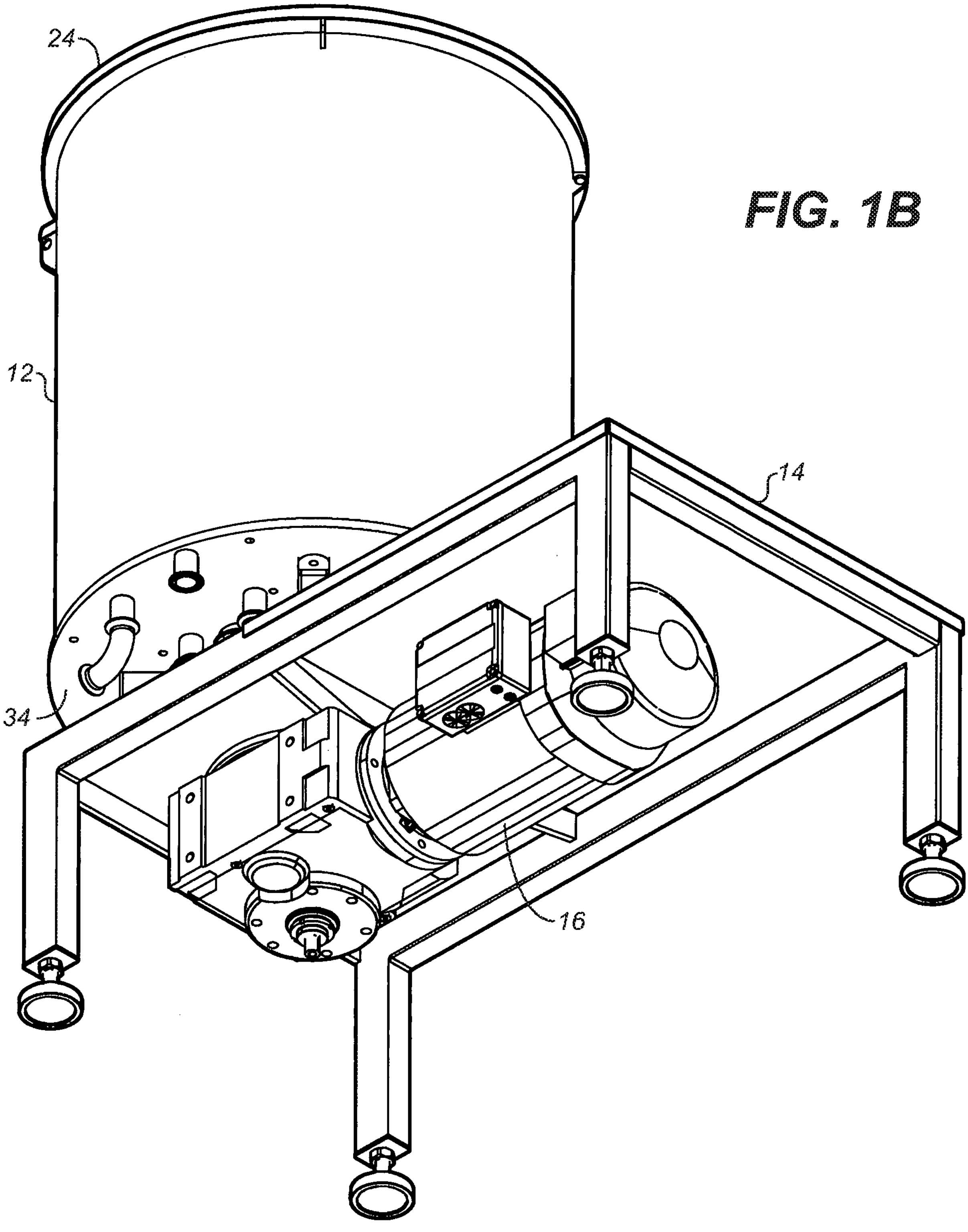


FIG. 1B

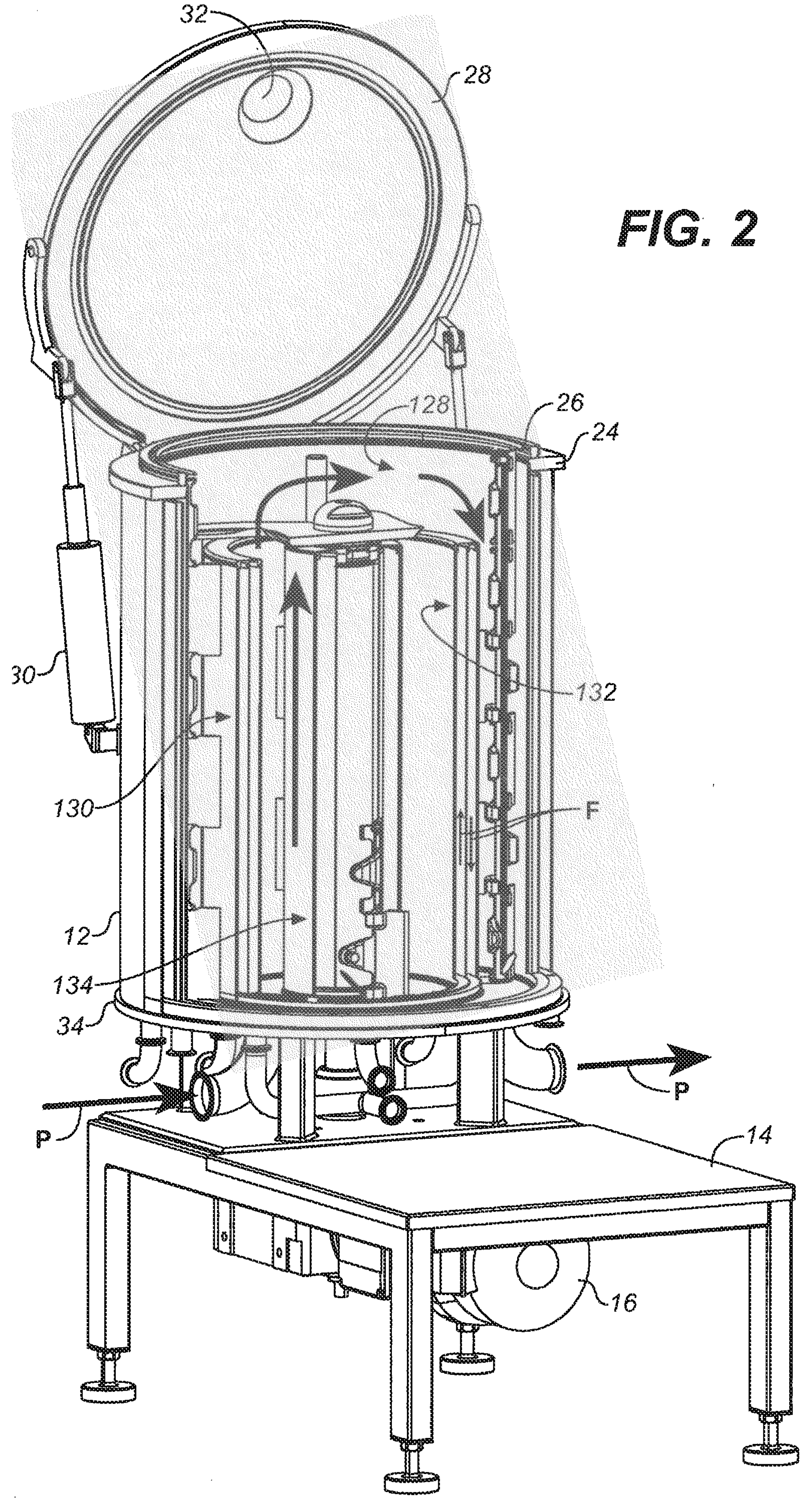


FIG. 2

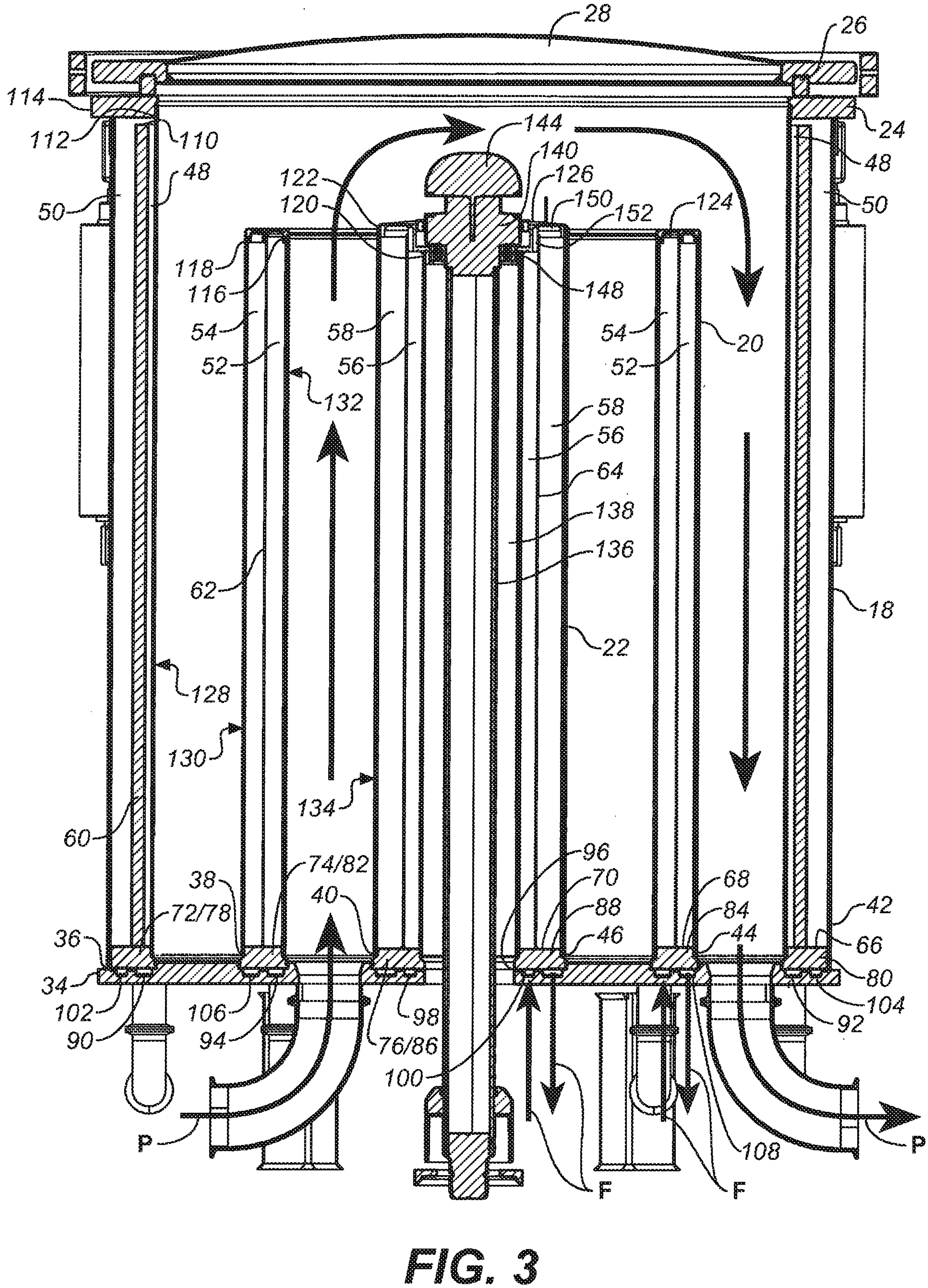

28
26
114
112
110
24
144
140
48
122
126
150
120
152
124
50
118
116
148
54
58
54
20
52
56
52
132
58
56
64
138
136
62
18
22
128
130
134
60
96
74/82
38
70
68
40
88
84
42
72/78
46
44
66
36
80
34
102
106
98
104
90
94
76/86
92
100
108
P
P
F
F

FIG. 3

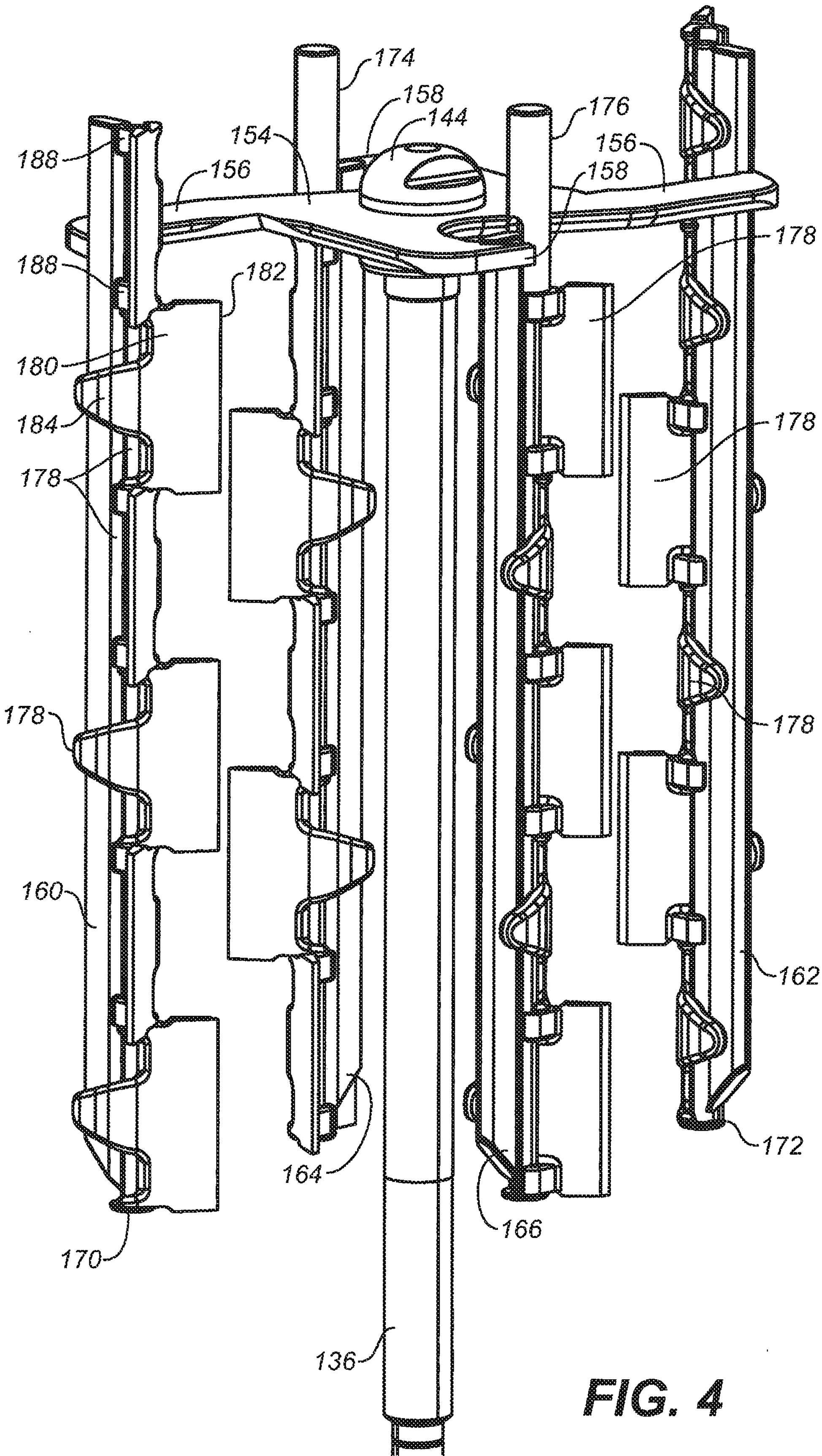

174
158
144
176
154
156
156
158
188
188
182
178
180
184
178
178
178
178
160
162
164
172
166
170
136

FIG. 4

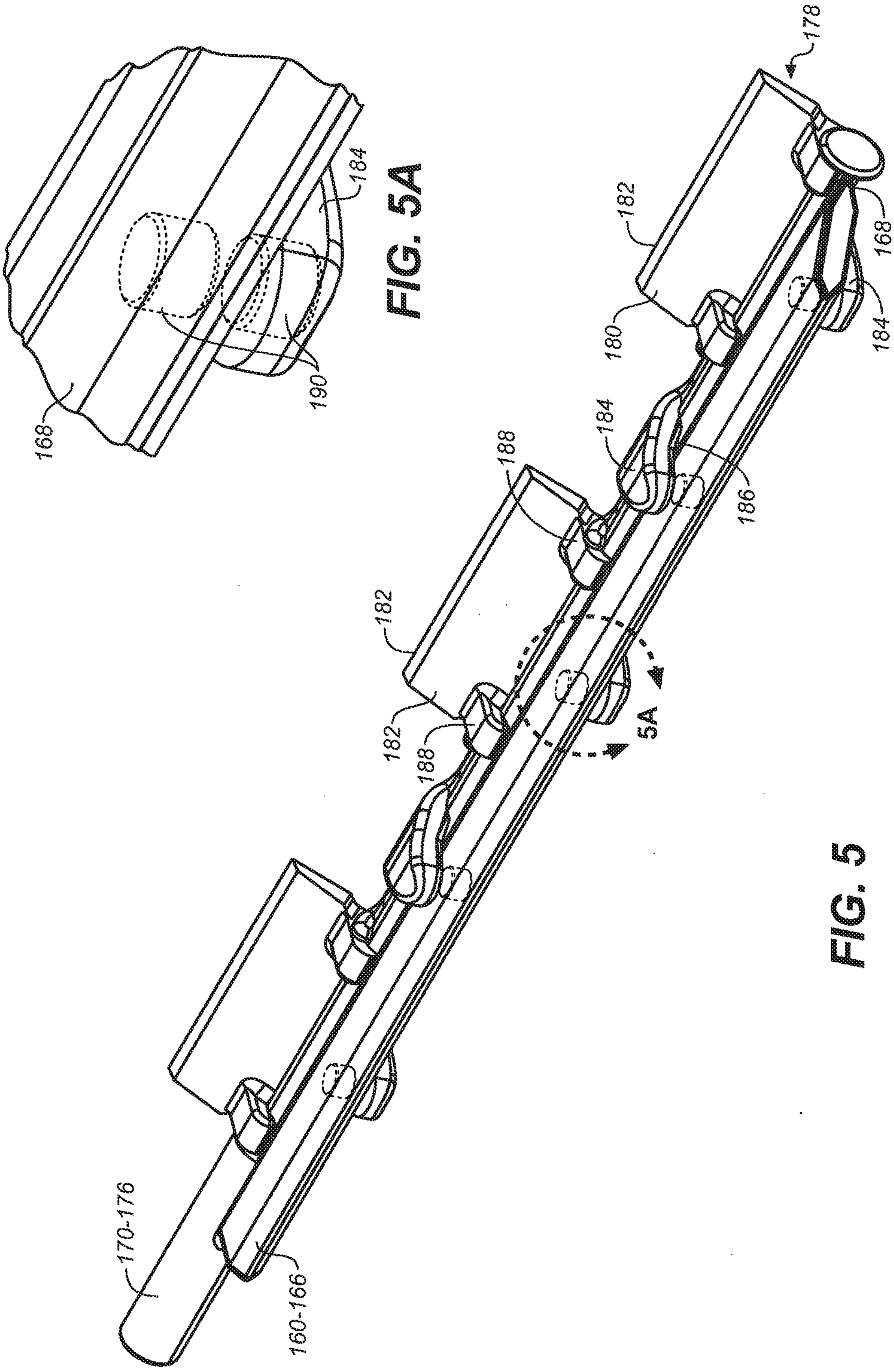

168
184
190
178
182
168
180
184
188
186
182
182
188
5A
170-176
160-166

FIG. 5A

FIG. 5

FIG. 6

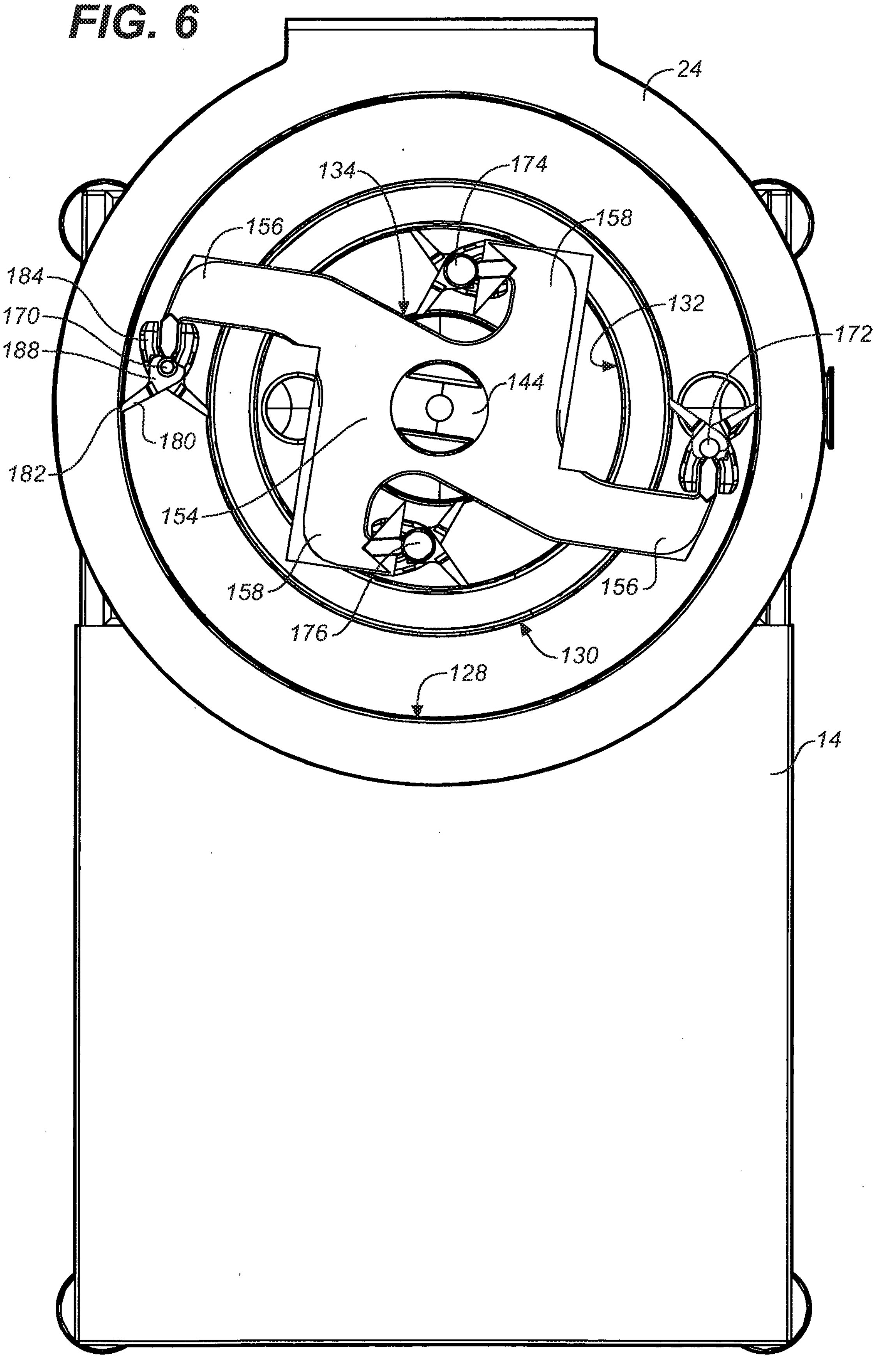
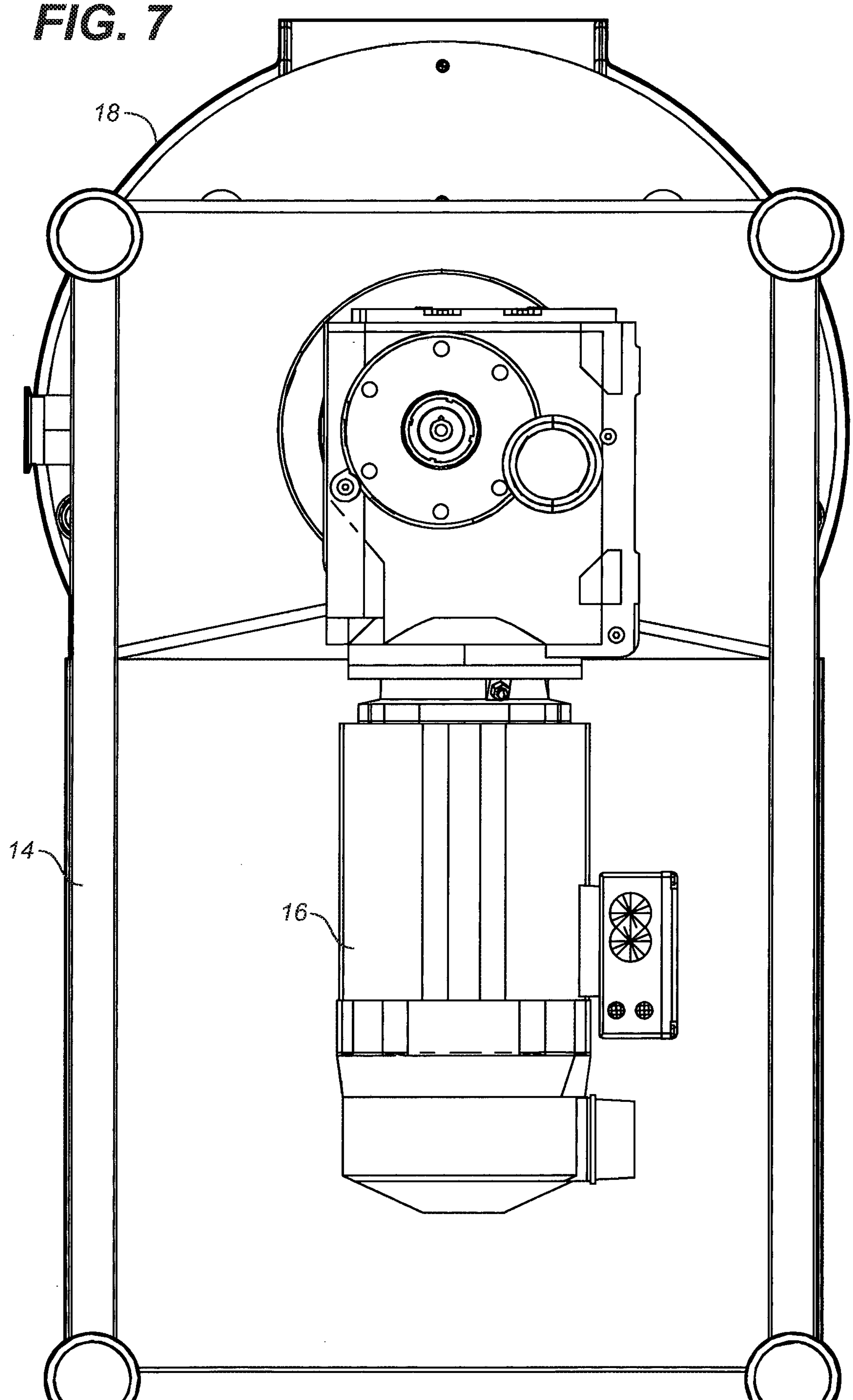

24
134
174
156
158
184
170
188
132
172
144
180
182
154
158
176
156
130
128
14

FIG. 7



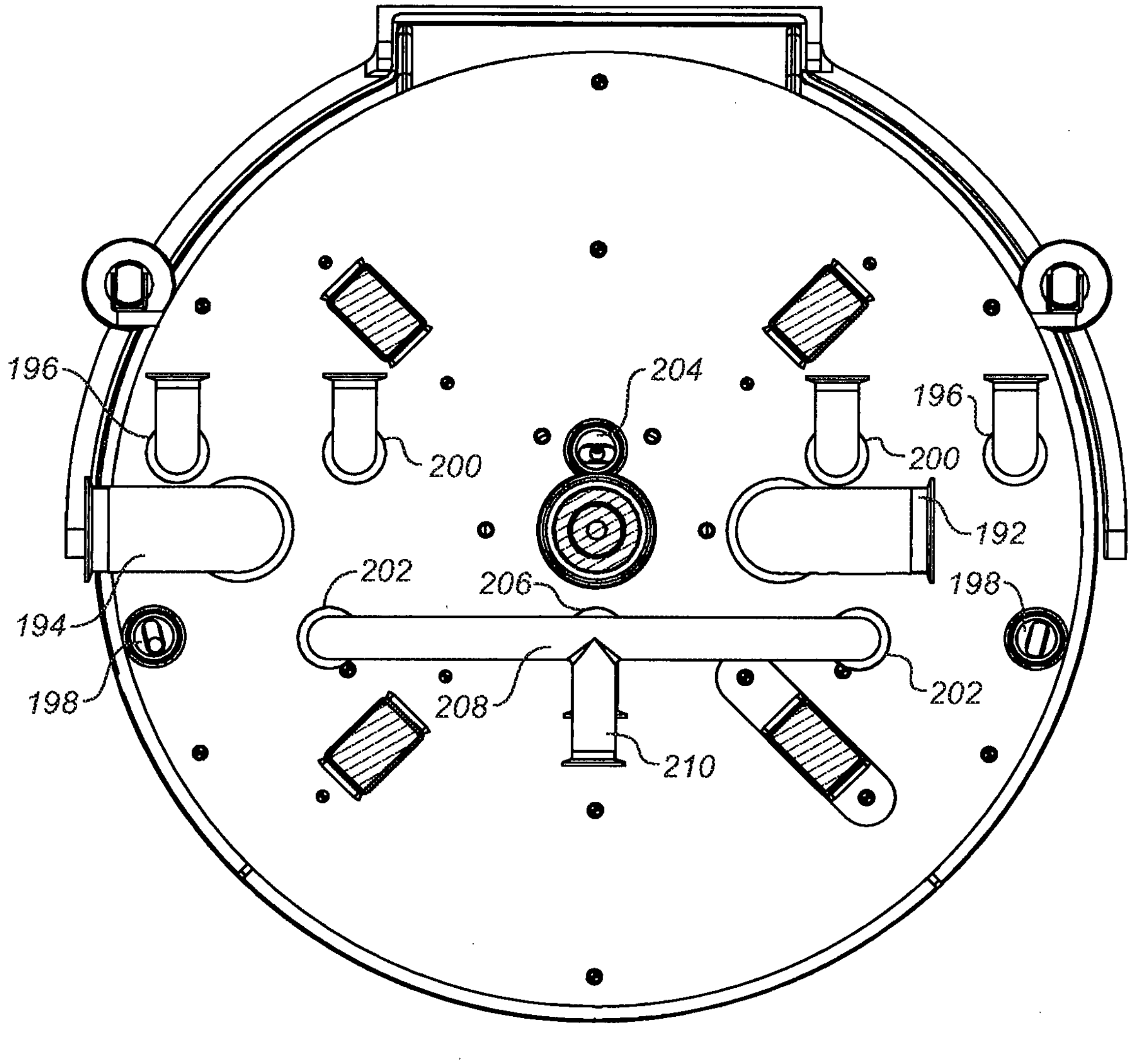


FIG. 8

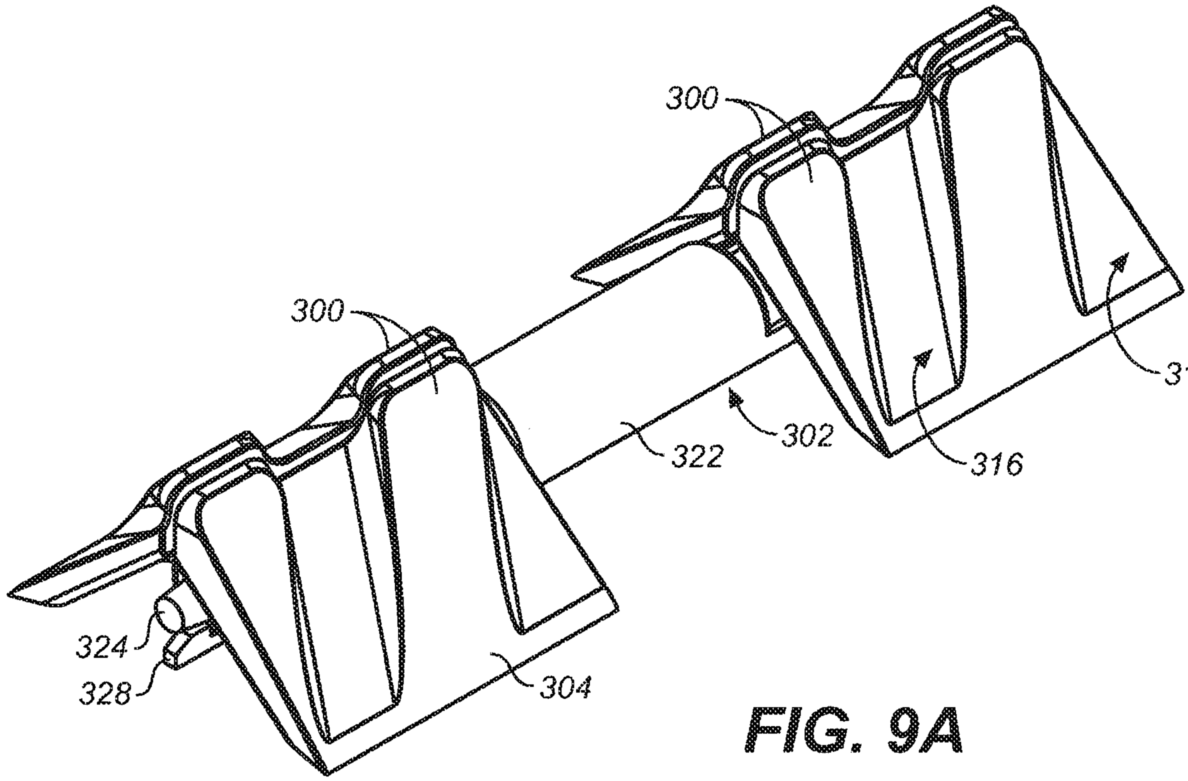

300
300
302
322
304
316
318
324
328

FIG. 9A

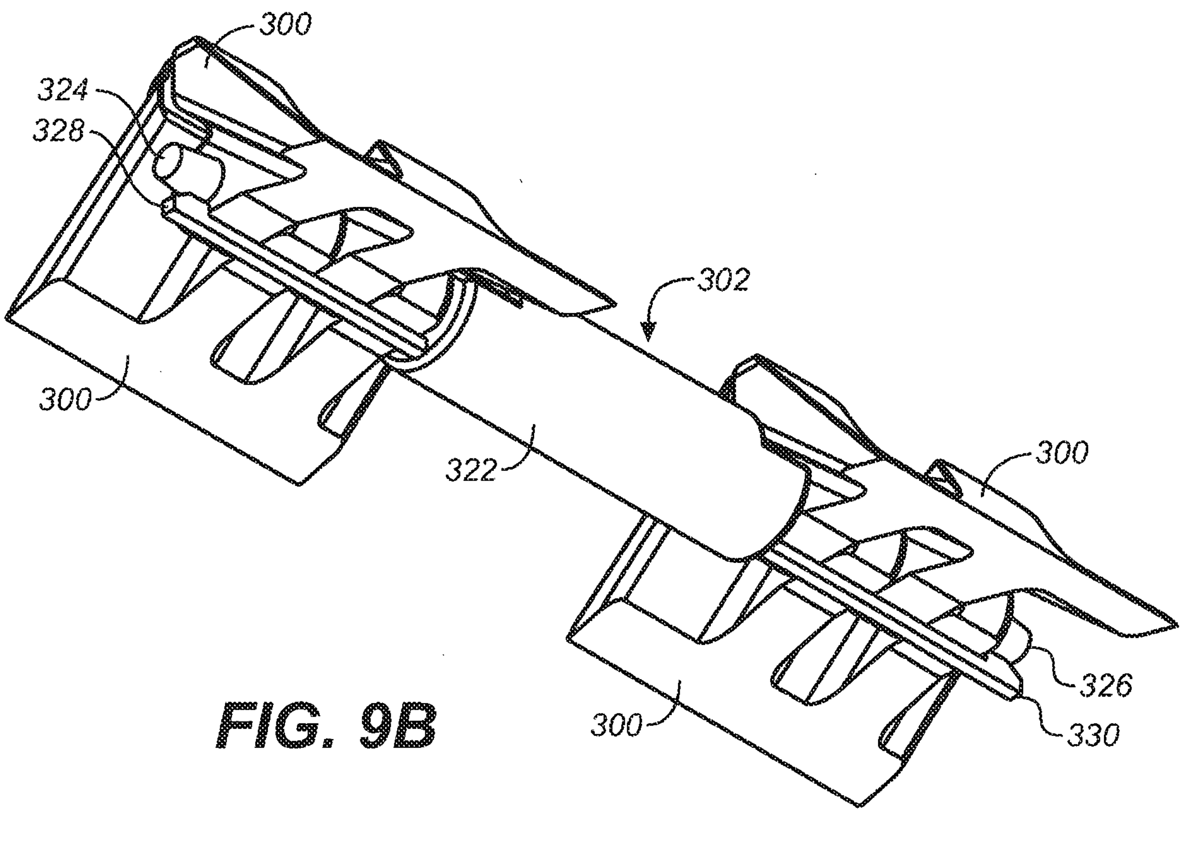

300
324
328
302
300
322
300
326
330
300

FIG. 9B

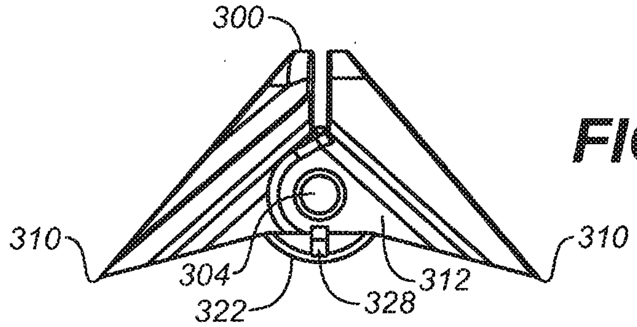


FIG. 10C

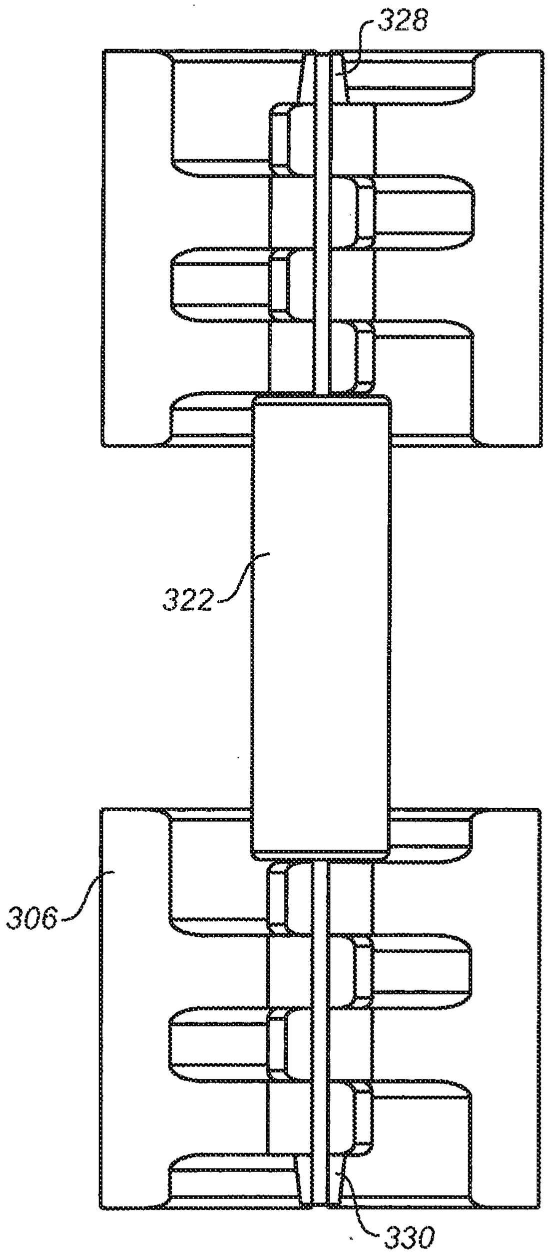


FIG. 10A

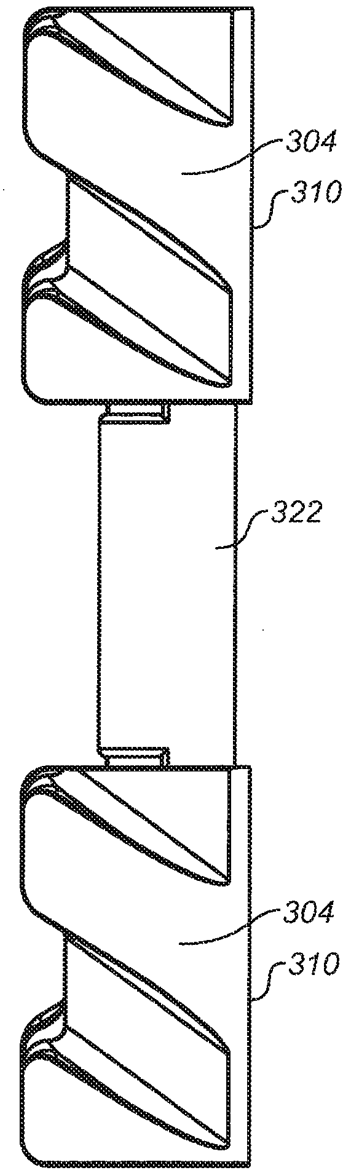


FIG. 10B

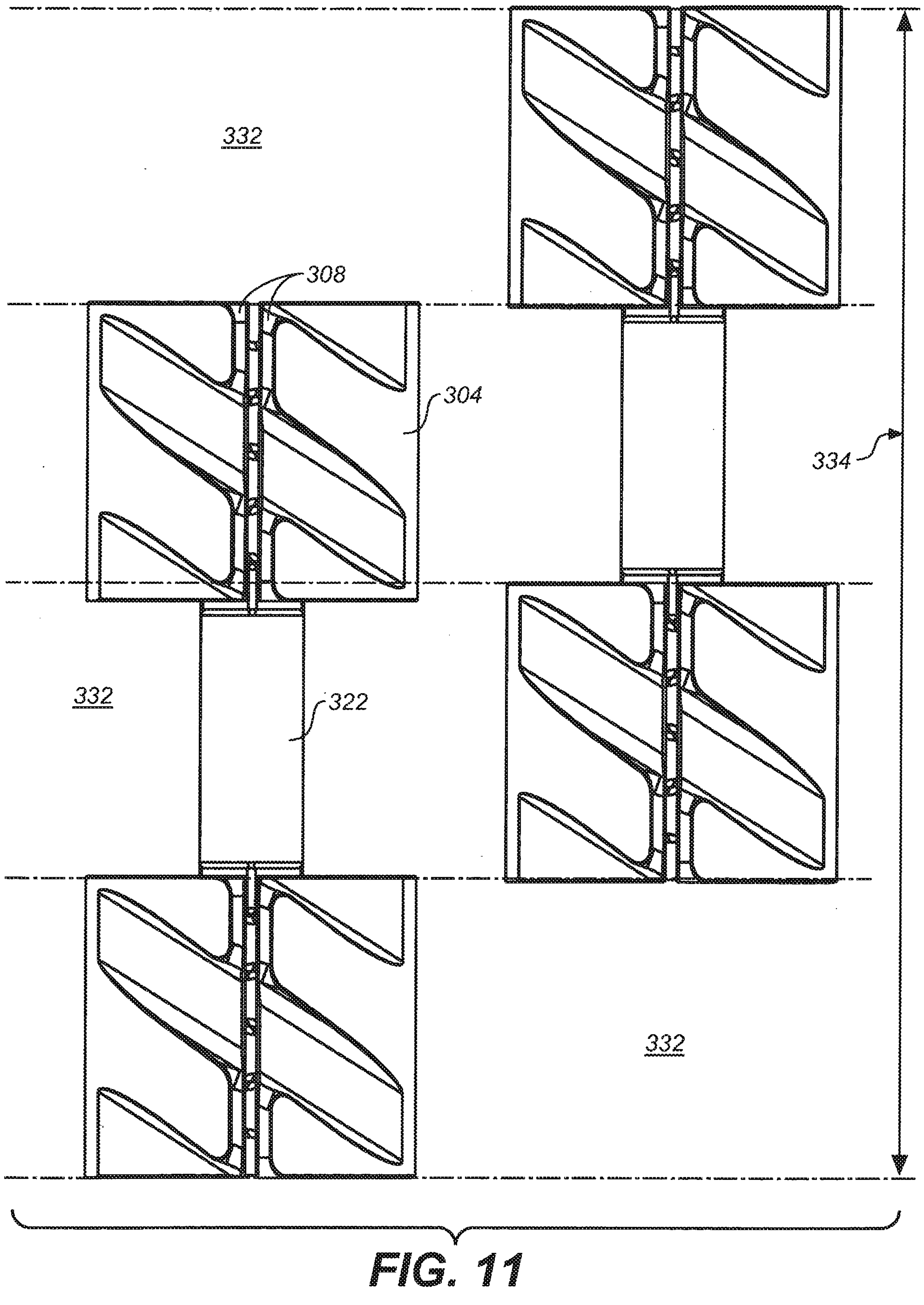


FIG. 11

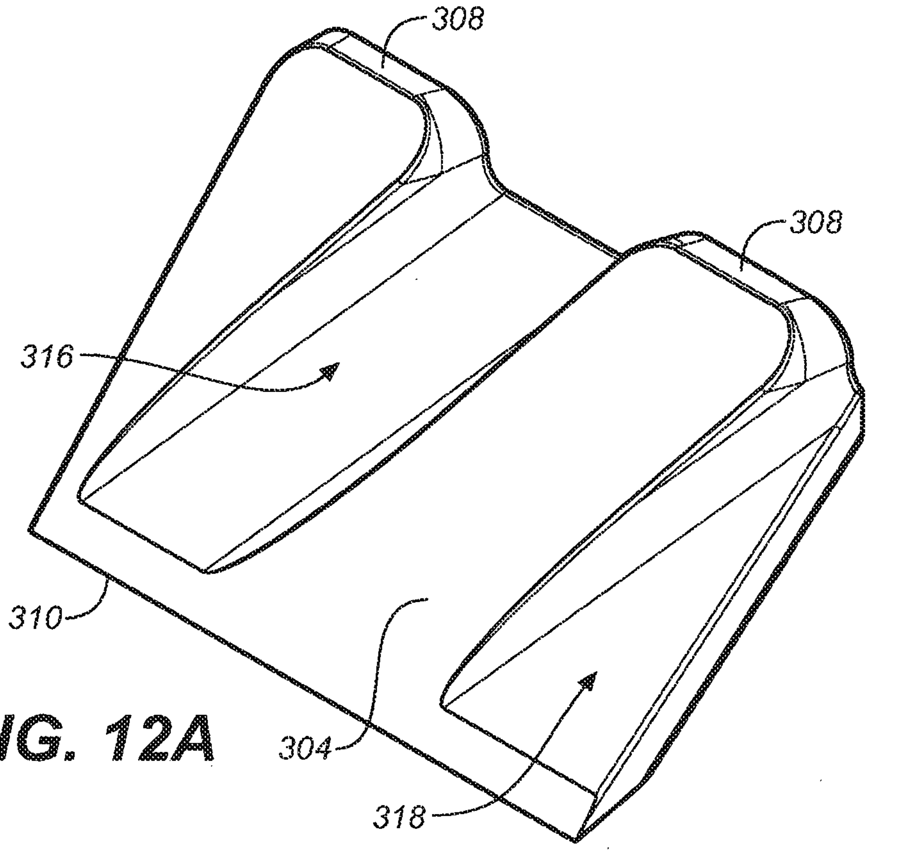


FIG. 12A

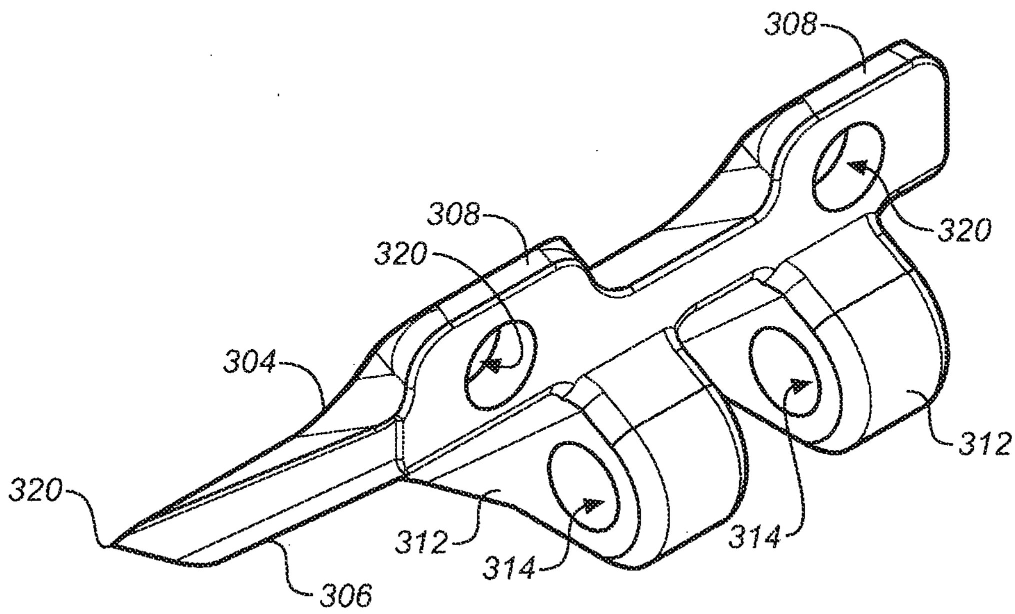


FIG. 12B

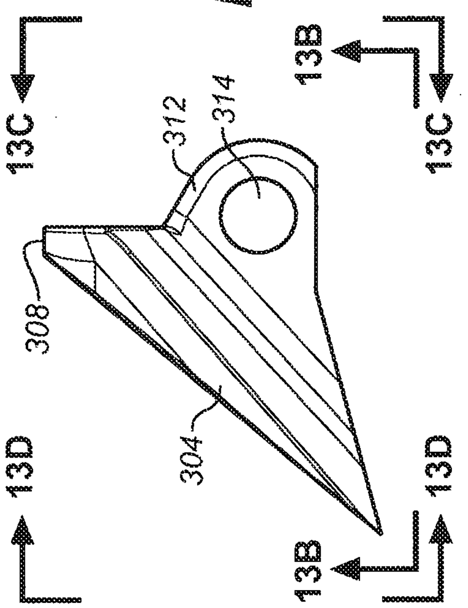


FIG. 13A

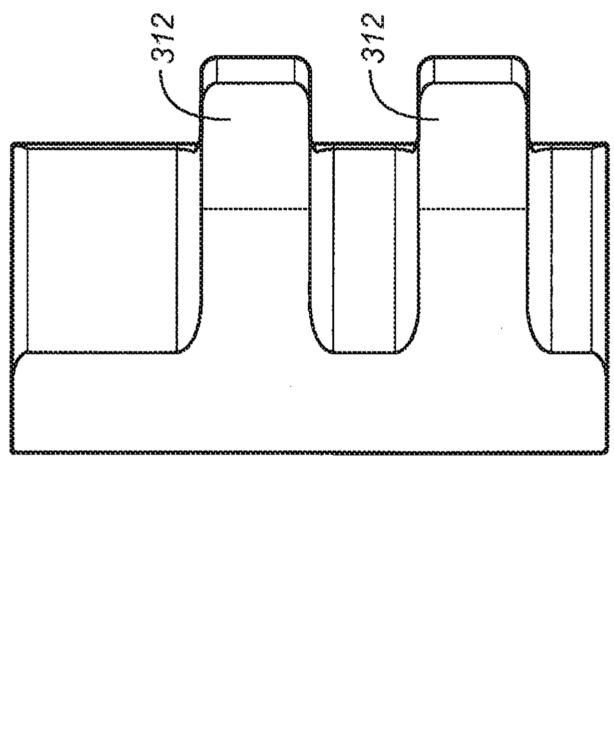


FIG. 13B

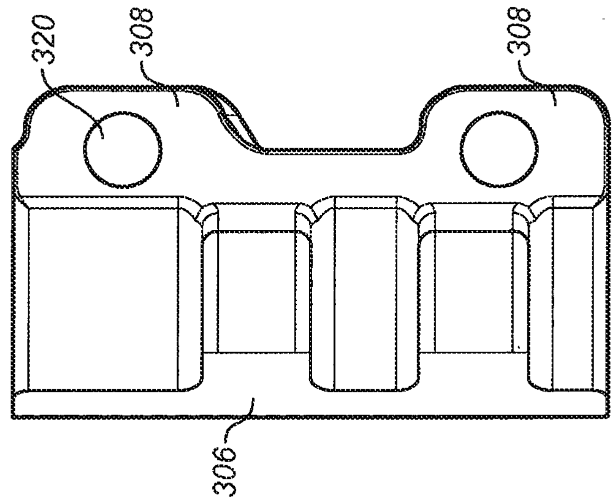


FIG. 13C

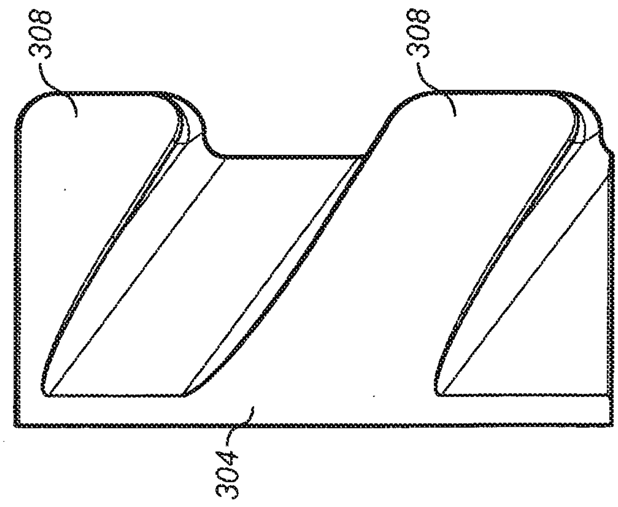


FIG. 13D

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 4105066 A **[0020]**
- US 3354136 A **[0021]**
- US 3770252 A **[0022]**