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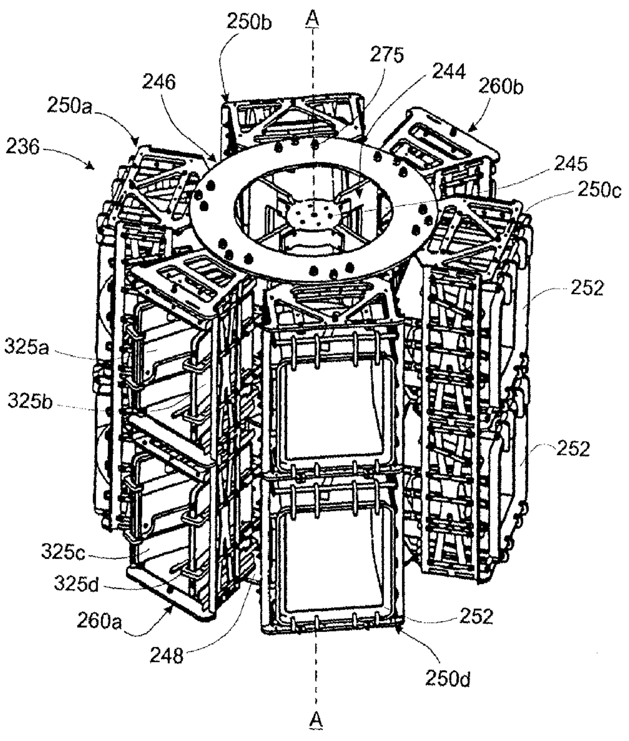
(54) Title: METHOD AND APPARATUS FOR CLEANING SEMICONDUCTOR WAFERS AND OTHER FLAT MEDIA



(57) Abstract: A machine (10) for cleaning containers (52) such as flat media carriers (52) or boxes (52) has inside and outside arrays of nozzels (R1-R8) arranged to spray a cleaning solution onto containers (52) supported on a spinning rotor (70) in a chamber (24). The cleaning solution, a mixture of water and a detergent or surfactant is prepared by drawing out surfactant directly from a surfactant storage vessel (35) by means of a metering pump (48, 49). The flow rate of the water is measured by a flow meter (116, 118) and in combination with the metering pump (48, 49), a proper surfactant is injected into the water line (140) to produce a mixture with a desired surfactant concentration for removing contaminants. Box holder assemblies (250a-250d) on the rotor (70) include upper and lower hooks (322, 324) for securing boxes (52) to the rotor (70). A box door holder assembly (206a, 206b) is also provided on the rotor (70). The box door holder assembly (206a, 206b) preferably has a plurality of box door holding positions. Each box door holding position advantageously has a door guide (344) and door hooks (322, 324) for holding a door. The box door holder assembly allows both the boxes (52) and their doors to be cleaned with the centrifugal cleaner (10), avoiding the need for separate cleaning of the doors. In one configuration, the rotor (70) is provided an even number of box holder assemblies (206a, 206b) symmetrically spaced about the rotor (70) and an even number of door holder assemblies (206a, 206b) symmetrically spaced about the rotor (70).

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DESCRIPTION

Method And Apparatus For Cleaning Semiconductor Wafers And Other Flat Media

Field of the Invention

The field of the present invention relates to cleaning apparatus for rinsing and drying containers and carriers used to hold and process semiconductor wafers, substrates, flat panel displays and other flat media.

Background Of The Invention

Flat media, such as silicon or other semiconductor wafers, substrates, photomasks, flat panel displays, data disks, and similar articles require extremely low contamination levels. Even minute contaminants can cause defects. Accordingly, it is necessary to maintain a high level of cleanliness during all or nearly all stages of production of these types of flat media. The flat media described may be referred to below as "wafers", although it will be understood that "wafers" means any form of flat media.

Wafers are typically processed in batches. For example, in manufacturing semiconductor chips, for use in computers, telephones, televisions, and other electronic products, silicon wafers will undergo many batch processing steps, such as oxidation, photolithography, diffusion, chemical vapor deposition, metallization and etching. Batch handling may occur throughout the entire production process, or for one or more processing steps or related handling operations. Batch processing of this type almost always utilizes some type of carrier or container to hold the wafers being processed.

A wafer carrier, box, cassette, boat or container holds a group of wafers. At certain stages in the manufacturing process, the wafer carriers must be cleaned. Cleaning them is difficult because they typically have features which include slots, grooves or apertures, and inside corners which can trap contaminants. The difficulty in cleaning is enhanced by the extremely low contamination levels which are required for processing the wafers.

Accordingly, cleaning of wafer carriers remains a difficult, time consuming and relatively costly procedure. Sticky-back labels, fingerprints, dust, metal particles, photoresist and organic chemicals may also contaminate the wafer carriers.

Various machines have been made and used for cleaning wafer carriers. In these machines, the carriers are mounted on a rotor and spin within a chamber, while cleaning solutions are sprayed onto the carriers. The spinning movement minimizes process time and also helps in drying the carriers. In certain applications, a detergent or surfactant is introduced and mixed with de-ionized water. Used in this way, a surfactant acts as a wetting agent which helps to remove loosely adhered particles, while a detergent chemically reacts with contaminants to clean them away. Typically the surfactant is used only once and then discarded as waste. Detergent, if concentrated, may be recycled.

The surfactant or detergent is typically held in a vessel or tank. Since the surfactant or detergent stream is applied in a small flow volume, to produce the desired concentration level, it may be difficult to control volume flow of the surfactant or detergent into the carriers. In the past, surfactant has been pumped from the bulk storage vessel into a holding tank where it is diluted to a desired level. The diluted surfactant solution is then drawn out of the holding tank by a venturi into the water stream where it is mixed or aspirated with the water. The water and surfactant mixture is then directed to the rinsing manifold ready for injection into the wafer carrier.

Accordingly, it is an object of the invention to provide an improved machine for cleaning carriers and containers for flat media.

Ease of loading and unloading carriers or boxes, and their doors, into and out of the rotor, and maintaining the rotor in balance under various conditions, remain as engineering challenges. Accordingly, it is also an object of the invention to provide an improved rotor.

Brief Statement Of The Invention

The present invention is directed to an apparatus for cleaning flat media carriers includes a rotor rotatably mounted within a chamber. Nozzles within the chamber are arranged to spray a washing mixture of water and a detergent or surfactant onto carriers supported on the rotor. The washing mixture is prepared by drawing out surfactant directly from a surfactant bulk storage vessel using a metering pump. The flow rate of the water is measured by a flow meter and in combination with the metering pump, a proper amount of surfactant is injected into the water line to produce a mixture with a desired surfactant concentration for removing contaminants.

In a second aspect of the invention, the surfactant or detergent solution is injected into the water line at or upstream of an inline mixing control valve to ensure that the water and surfactant are thoroughly mixed before being injected into the wafer carrier.

In a third aspect of the invention, where the wafer carrier is provided with multiple rinse manifolds for spraying the carrier, a flow meter is provided in the water inlet line for each manifold and a separate metering pump is provided for injecting surfactant into each water line to ensure that a proper amount of surfactant is injected into each water line to produce a mixture with a desired surfactant concentration.

In a fourth aspect, a system for cleaning carriers used for handling wafers includes a box cleaner having a rotor within an enclosure. Box holder assemblies on the rotor include upper and lower hooks for securing boxes to the rotor. A box door holder assembly is also provided on the rotor. The box door holder assembly preferably has a plurality of box door holding positions. Each box door holding position advantageously has a door guide and door hooks for holding a door. The box door holder assembly allows both the boxes and their doors to be cleaned with the centrifugal cleaner, avoiding the need for separate cleaning of the doors.

In a fifth and separate aspect, the rotor is provided with an even number of box holder assemblies symmetrically spaced about the rotor and an even number of door holder assemblies symmetrically spaced about the rotor. This helps to allow the rotor to avoid out of balance conditions

In a sixth aspect spray manifolds have straight spray nozzles and angled spray nozzles. The straight spray nozzles provide a spray towards the center of the rotor and directly into the box. The angled spray nozzles, oriented towards and/or away from the spin direction, are better positioned to spray leading and/or trailing surfaces, corners, and features of the box. This results in improved cleaning.

The spray manifolds may also have angle spray nozzles directed at up and/or down angles.

Other and further objects, inventive features, and advantages, will appear hereinafter. The invention resides as well in subcombinations of the features described.

Brief Description Of The Drawings

In the drawings, wherein the same reference numbers denote the same elements throughout the several views:

Fig. 1 is a front, top and right side perspective view of the present cleaning apparatus.

Fig. 2 is a back, top and left side perspective view thereof.

Fig. 3 is a front, top and right side perspective view of the apparatus shown in Figs. 1 and 2, with the covers removed.

Fig. 4 is a back, top and left side view thereof.

Fig. 5 is a back, top and left side perspective view with various components removed for purposes of illustration.

Fig. 6 is a front, top and right side perspective view of certain major components of the apparatus shown in Figs. 1-5.

Fig. 7 is a perspective view of the rotor removed from the chamber.

Fig. 8 is a plan view thereof.

Fig. 9 is a section perspective view illustrating air movement through the apparatus.

Fig. 10 is a schematic diagram showing fluid flow and interconnections in the present machine.

Fig. 11 is a left front side perspective view of a preferred configuration for the pumping and control valve system of Fig. 10.

Fig. 12 is a rear right side perspective view of the configuration of Fig. 11.

Fig. 13 is a schematically illustrated top view showing orientations of spray manifolds and nozzles.

Fig. 14 is a perspective view of an alternative rotor within the cleaning system shown in Fig. 1.

Fig. 15 is a top view of the rotor shown in Fig. 15.

Fig. 16 is a top left side perspective view of a door holder assembly of the rotor of Figs. 14 and 15.

Fig. 17 is a right side elevation view thereof.

Fig. 18 is an exploded perspective view of the top compartment of the door holder assembly of Fig. 17.

Fig. 19 is a perspective view of the bottom tray of the compartment of Fig. 18.

Fig. 20 is a perspective view of the enclosure, rotor and spray manifolds of the system shown in Fig. 1.

Figs. 21-26 are diagrams of spray patterns, nozzle orientation, and container/rotor movement, within the system shown in Fig. 20.

Fig. 27 is a perspective view of an angle spray nozzle used in the system shown in Fig. 20.

Fig. 28 is an enlarged section view of the nozzle shown in Fig. 27.

Fig. 29 is a perspective view of a section of a left or right spray manifold.

Fig. 30 is a perspective view of a section of an up or down spray manifold.

Detailed Description Of The Drawings

Turning now in detail to the drawings, Figs. 1 and 2 illustrate a carrier cleaning machine 10 having a frame 12 and housing panels 14 forming an enclosure. A back door 16 and front door 16A are provided on the front and back surfaces of the machine 10. The machine 10 is generally installed in a clean room, of the type used in manufacturing semiconductors. An air filter enclosure 18 is located above the front door 16A, and contains a filter which filters clean room air. An exhaust duct 26 extends out of the top of the machine 10, at the back right corner, and is ordinarily connected to a facility or building exhaust duct.

Referring to Figs. 3, 6 and 9, a cylindrical chamber 24 is supported within the frame 12. The chamber 24 has cylindrical side walls 25 and is closed off on the top and bottom by a top plate 36 and a bottom plate 38. The top plate 36, has a central opening 37 so that air passing through the filter box 18 can flow into and downwardly through the chamber 24. An exhaust plenum 50 at the lower back and right side of the chamber 24 connects to the exhaust duct 26, for moving air out of the chamber 24. A drain opening 39 at a low point of the chamber 24, in the exhaust plenum 50 drains fluids out of the chamber.

Referring to Figs. 5, 9 and 13, outer rinse manifolds 28 (R1-R4), each having e.g., 12 spray nozzles, are positioned around the outside circumference of the chamber 24, on the chamber cylindrical side walls 25. The outer rinse manifolds 28 may be located on the outside of the cylindrical side walls 25, as shown in Figs. 4-6 and 10, or may be on the inside surface of the cylindrical side walls 25, so long as the rinse spray nozzles 30 on the outer rinse manifolds 28 are appropriately positioned to spray the work pieces, i.e., the wafer carriers.

Inner rinse manifolds 29 are positioned near the center of the chamber 24, with each inner rinse manifold (R5-R8) having a plurality of rinse spray nozzles 30 oriented to spray outwardly onto the work pieces (i.e., wafer carriers, containers or lids).

Similarly, outer dry manifolds 64 (D5-D8), each having a plurality of dry spray nozzles 66, are spaced apart around the circumference of the chamber 24, on the chamber cylindrical side walls 25. Inner dry manifolds 65 (D1-D4), each also having a plurality of dry spray nozzles 66 are positioned near the center of the chamber 24. A preferred orientation of the dry manifolds (D1-D8) and the rinse manifolds (R1-R8) is shown in Fig. 13.

Referring momentarily to Fig. 10, the outer dry manifolds 64 are connected via a distribution manifold 61 and then by fluid lines 63 to a supply 120 of pressurized gas such as air or nitrogen via control valve 63a. Similarly, the inner dry manifolds 65 are connected via a distribution manifold 68 and then by fluid lines 67 to a pressurized gas supply 130 via control valve 67a. The outer rinse manifolds 28 are connected via a distribution manifold 141 then by fluid lines 140 to a control valve 170 and a source 110 of de-ionized (DI) water. The inner rinse manifolds 29 are connected via a distribution manifold 151and then by fluid lines 150 to a control valve 180 and the DI-water source 110. Pressurized gas lines are also connected to the spray manifolds, for purging, via the control valves 170, 180. A boost pump 46 increases the water pressure of the DI-water from the external source 110 to the rinse manifolds 28 and 29.

The control valves 170, 180 are preferably mixing control valves which ensure that the surfactant is thoroughly mixed with the DI-water.

Referring to Figs. 3-6, and 10-12, a surfactant tank or bottle 35 is connected to surfactant metering pumps 48 and 49 via a fluid line 190. The surfactant metering pump 48 is connected to the mixing control valve 170 via fluid lines 192. Pump 48 pumps surfactant from the tank or bottle 35 into the control valve 170 where it is mixed with the DI water for injection into the outer rinse manifolds 28 via fluid lines 140. The surfactant metering pump 49 is connected to the control valve 180 via fluid lines 194. Pump 49 pumps surfactant from the tank or bottle 35 into the control mixing valve 180 where it is mixed with the DI water for injection into the inner rinse manifolds 29 via fluid lines 150.

The drain opening 39 at the bottom of the chamber 24 leads to a diverter 90 which connects the drain opening 39 to either a reclaim tank 42 or to a facility waste drain 92.

On the surfactant side, a return line 142 from fluid line 192 proximate the mixing control valve 170 provides for priming of surfactant (under the control of control valve 145) back to vessel 35; and a return line 152 from fluid line 194 proximate the mixing control valve 180 provides for priming of surfactant (under the control of control valve 155) back to vessel 35. On the DI-water side, a recirculation line 147 from fluid line 115 proximate the mixing control valve 170 provides for recirculation of DI-water; and a recirculation line 157 from fluid line 117 proximate the mixing control valve 180 provides for recirculation of DI-water. The recirculation lines 147 and 157 provide a flow of water through the tool even when the tool is idle to prevent bacteria formation in lines and valves.

Referring momentarily to Fig. 9, air heaters 58 are provided within an air inlet plenum 56 behind the air filter box 18 and over the center or inlet opening 37 leading into the top of the chamber 24. Blanket heaters 55 are also provided around the top of the chamber 24. A computer/controller 112 is linked to and controls the various pumps, valves, heaters, and flow sensors.

Referring to Figs. 6-9, a rotor 70 is rotatably supported within the chamber 24 on a base 104. The rotor has a top ring 72 and a bottom ring 74 connected by a frame work 75. Ladders 76 are pivotally supported on upper and lower ladder supports 82 extending radially outwardly from the top ring 72 and the bottom ring 74. Each ladder 76 has a plurality of compartments 78 for holding containers or carriers 85, or container lids 87, as shown in Fig. 9. The configuration of the ladders 76 and the design of the compartments 78 on the ladders 76 are adapted for the specific sizes and types of carriers, containers, and lids to be cleaned. The entire rotor 70 is rotatably supported on a center column 100 and a rotor axle 106 within the center column 100. A rotor drive motor 102 spins the rotor 70. The detailed design features of the rotor 70, center column 100 and rotor axle 106 are well known, and are described in U.S. patent No. 5,224,503. Alternately, the tool may be constructed with non-rotating ladders.

In use, the machine 10 is typically installed in a silicon wafer or other flat media manufacturing facility. As the wafers are moved through various processing steps, the carriers 85 become contaminated, and must be cleaned before wafers are replaced into the carriers. The door 16 or 16A of the machine 10 is opened. The rotor 70 is turned or indexed until a ladder 76 is aligned with the door. The ladder 76 is then turned 180° so that the empty compartments 78 can be accessed through the door 16. The carriers 85 are loaded into the compartments 78 and the ladder is turned back to its original position, so that the compartments 78 are facing to the inside of the chamber 24. The ladders 76 are preferably provided with a latch or detent to lock the ladders into the closed or operating position, with the compartments 78 facing the inside of the chamber 24. The next ladder 76 is then brought into alignment with the door, for loading, by turning the rotor 70 (by hand or via control of the rotor drive motor 102). Loading continues until all of the ladders 76 are filled.

A facilities panel 40 on the machine 10, as shown in Fig. 6, has connections to input de-ionized water and gas, e.g., nitrogen or air into the machine 10, and a connection for the waste drain 92, as well as gauges and valves for measuring and controlling fluid/gas flow.

The surfactant tank 35 is supplied with a detergent or surfactant, for example, Valtron DP 94001 (a high pH alkaline detergent) a preferred surfactant for removing photoresist. The term "surfactant" as used in this application means a surfactant or a detergent. The controller 112, via appropriate control of valves and pumps, delivers DI-water and surfactant into the mixing control valves 170, 180 to make a desired DI-water/surfactant mixture for injection into each of the rinse manifolds 28, 29. The DI-water boost pump 46 boosts the water pressure in the supply line 114 to deliver DI-water to both mixing control valve 170 and mixing control valve 180. A flow meter 116 is disposed in the fluid line upstream of the outer rinse mixing control valve 170 to measure the flow of DI-water being supplied thereto. Similarly, a flow meter 118 is disposed in the fluid line upstream of the inner rinse mixing control valve 180 to measure the flow of DI-water being supplied thereto.

The system is initially calibrated by using information from the flow meter 116 in combination with controls on the metering pump 48 to set a reasonably precise surfactant concentration for the DI-water/surfactant mixture for injection into the outer rinse manifolds 28. Similarly, the system is calibrated by using information from the flow meter 118 in combination controls on the metering pump 49 to set a reasonably precise surfactant concentration for the DI-water/surfactant mixture for injection into the inner rinse manifolds 29. Preferably, the solution is 1:10000 surfactant, with the balance being DI-water, for each of the manifolds, but having separate flow control/metering, the surfactant concentration levels may be individually set.

The metering pumps 48, 49 are preferably a type of positive displacement pump, such as a diaphragm pump. The flow rate of such a diaphragm pump may be adjusted my adjusting the pump stroke (which sets the pumping volume per stroke) and/or the pump speed (strokes per minute). The pumps are preferably set at a relatively high speed so that surfactant is delivered into the system at a less pulsed/intermittent manner.

The system operator may adjust the surfactant/DI-water concentration by adjusting the pump stroke (which sets the pumping volume per stroke) and/or the pump speed (strokes per minute).

Though the system may be operated by having a preset pumping rate for the metering pumps 48, 49 and surfactant/DI-water concentration, an electronic control system may be implemented, using inputs from flow meters 116, 118 and electronic control of the pumping rates of the metering pumps.

A low-level sensor 35a may be provided on the surfactant vessel 35 for alerting that the fluid level in the vessel is low and needs replacement. The sensor 35a may either be a liquid sensor inside the vessel, or capacitive sensor located outside the vessel, or some other suitable device. The sensor may just determine when the level has reached a particular (low) level, indicating time for surfactant replacement, or certain types of sensors may provide a signal corresponding to surfactant level. For example, the tray 35b (see Fig. 11) in which the vessel 35 is inserted may comprise a load cell supporting the surfactant vessel 35 to provide the weight of the vessel 35 with the change in weight of the vessel as determined by the load cell providing an indication of fluid level.

The controller 112 controls the rotor drive motor 102, causing the rotor 70 to spin in a first direction, at a low speed, e.g., 1-50 rpm. Via control of the pumps 46, 48, 49 and valves 170, 180, the DI-water/surfactant solution is sprayed onto the carriers 85 on the spinning rotor.

After a sufficient duration e.g., 3-10 minutes, the rotor 70 reverses direction while the surfactant solution spraying continues, for improved spray coverage. The inner rinse manifolds 29, located inside of the rotor 70, spray radially outwardly from the center of the chamber 24. The outer rinse manifolds 28, located around the chamber cylindrical side walls 25 spray radially inwardly toward the chamber center. This dual spray action, combined with bi-directional rotation of the rotor 70, provides virtually complete coverage of all surfaces of the containers 85.

After completion of application of the surfactant solution, the manifolds are purged by gas or nitrogen flowing through check valves 143, 153 and the control valves 170, 180 as shown in Fig. 10.

During the surfactant wash cycle, the diverter valve 90 is positioned to direct fluid to the facility waste drain 92. Typically, as the machine 10 begins the rinse cycle, the diverter 90 remains in position to connect the drain opening 39 to the facility waste drain 92. DI-water is sprayed onto the carriers 85 from all of the rinse manifolds (R1-R8), with the rotor 70 spinning in a first direction, and then reversing and spinning in the opposite direction, e.g., at from 1-50 rpm, preferably about 6 rpm. The heaters 58 are then turned on, and the rotor accelerated up to e.g., 300 rpm, so that water droplets on the containers 85 are centrifugally flung off of the containers, and the containers are dried. The blanket heaters 55 are located on the outside of the top of the chamber 24 and are on continuously, for warming the top of the chamber. The DI rinse water goes out the waste drain 92.

If desired, for example in a water circulation mode where DI-water (without surfactant) is circulated through the chamber, the diverter valve 90 may be switched to a position

While the machine 10 is useful for cleaning various contaminants, the specific cleaning parameters, such as duration of surfactant, rinse water, and air/gas spray, rotation speeds and sequences, heater operation, surfactant concentration, etc., may be varied somewhat to achieve optimum results, with different containers and contaminants, as would be apparent to one skilled in the art from the descriptions herein.

Surfactants are generally not flammable or explosive, and do not have the same environmental disadvantages associated with solvents. On the other hand, surfactants can be very expensive. Using the metering pumps to produce a precise and consistent concentration of surfactant for the DI-water/surfactant mixture, the system conserves surfactant.

Turning now to the design shown in Figs. 14 and 15, the rotor assembly 236 has an even number of box holder assemblies 250a, 250b, 250c, and 250d symmetrically arranged on a rotor frame 244. Similarly, an even number door holder assemblies 260a and 260b also symmetrically arranged on rotor frame 244.

Each box holder assembly 250a-250d has the same design and is positioned radially opposite another box holder assembly. Specifically, box holder assembly 250a is positioned radially opposite box holder assembly 250c; and box holder assembly 250b is positioned radially opposite box holder assembly 250d. Similarly, door holder assemblies 260a and 260b are positioned radially opposite each other. Thus the rotor assembly 236 has box holder and door holder assemblies arranged in a symmetrical and rotationally balanced configuration.

The box holder assemblies 250a-250d and door holder assemblies 260a and 260b are attached to the rotor frame 244 and form the rotor assembly 236. The rotor frame 244 includes a top ring plate 246 and a bottom ring plate 248 attached to a core structure 245. The box holder assemblies 250a-250d are rigidly attached to the top and bottom ring plates 246 and 248, preferably via bolts 275.

Referring to Fig. 16, each door holder assembly 260a and 260b has a top plate 272, a bottom plate 276, a middle plate 274, side plates 278, 280, and arms 292 attached to the side plates. Each door holder assembly 260 is rigidly attached to the top and bottom ring plates 246 and 48 of the rotor frame 244, preferably via bolts 275 extending through the top plate 272 and bottom plate 276 of the door holder assembly.

Each door holder assembly 260a and 260b has an upper compartment 306 and a lower compartment 308, generally separated by the middle plate 274. Referring still to Fig. 16, each of the compartments 306 and 308 has two door holding positions, the top compartment 306 illustrated as holding doors 325a and 325b and the lower compartment illustrated as holding doors 325c and 325d. The door holding positions are preferably mirror images of each other.

Referring also now to Figs. 18 and 19, each compartment 306 and 308 has a bottom surface or tray 335, a pair of left side hooks 322, a pair of right side hooks 324, and a top plate 340. Fig. 18 illustrates details of the compartment elements. Fig. 19 illustrates details of the bottom tray 335. Door slots 336 and 337 are provided in the bottom tray 335, to receive the bottom edges of the doors. The slots 336, 337 are arranged in a radial direction relative to the spin axis AA of the rotor. The slots 336, 337 each include a rear ramp 338 and 339 at the radially inward or back end thereof. Each of the hooks 322 and 324 has a leg 325 and a foot 327 attached to the leg 325. The hooks 322 and 324 are preferably mirror images of each other. The legs 325 extend circumferentially (i.e., in a direction generally tangent to the rotor path of rotation). The feet 327 extend radially inwardly towards the axis of rotation AA of the rotor. The doors are held in the door holders so that they approximately align or are parallel with a radius R of the rotor. The plane P of the broad flat sides of the door is preferably within ± 30, 20, or 10 degrees of the radius R, as shown in Fig. 16.

In use, to load doors into the door holder assembly 260, the enclosure door 16 (shown in Fig. 1) is opened and the rotor assembly is indexed or rotated until the door holder assembly 260a or 260b moves into alignment with the enclosure door 16. The doors 325a-d are then loaded into the door holder assembly 260a or 260b by hand.

When a door (for example door 325a) is installed into the compartment, the bottom of the door 325a fits within the door slot 336. The door slot helps to laterally support the door (e.g., to hold the door against side to side movement).

The door (for example door 325a) is installed into the door holder by inserting the door vertically through the opening in the compartment past the slot 336 and past the side hooks 322. The door is then moved laterally into position over the slot 336. The bottom of the door engages the ramp 338 which guides the bottom of the door downwardly and radially outwardly into the slot 336. The radially outward edge of the door also comes into contact with the side hooks 322. Once in the slot 336, the door is moved back radially outwardly until it is engaged by the side hooks 322. The door 325a is then securely positioned and held in place by the hooks, against movement by centrifugal forces exerted by the spinning rotor. Each of the other doors is loaded in the same way. A center guide 344 on the bottom tray 335 helps to guide the inner or back end of the door into the door slot. The doors 325 are unloaded from the door holder assembly 260 using the reverse of the sequence of steps described above.

When loaded into a door holding position, the door is in a vertical position, i.e., one edge of the door is facing the rotor axis A-A and the opposite door edge is facing radially outwardly from the rotor, (and is engaged by the hooks). The plane or face of the door is vertical and perpendicular to the path of movement of the rotor. The plane of one door faces the plane of the adjacent door in the same compartment 306 or 308. The doors are held at the sides of the compartment 306 or 308. The central area of the compartment is empty, to allow space for loading and unloading. The door holder assemblies 260a, 260b are narrower, and occupy a smaller sector of the rotor assembly, than the box holder assemblies.

Using the sequence described above, the door holder assembly 260a, 260b is loaded with doors 325a-d, typically with two doors in the upper compartment 306, and two doors in the lower compartment 308.

The two door holder assemblies 260a, 260b each carry four doors, for a total of eight doors. The rotor assembly 236 has four box holder assemblies 250a-d, each assembly holding two boxes, for a total of eight boxes. As a result, eight boxes and box doors can be cleaned in a single cycle of the cleaning system. The rotor assembly 236 is balanced because the loading is symmetrical about the spin axis AA.

While the rotor is described here with four box holder assemblies, and two door holder assemblies, each having two compartments (upper and lower) other members and configurations made also be used.

Referring to Fig. 20, in an improved centrifugal box cleaner embodiment 400, outer spray manifolds 402, 404, 406, 408, and 410 spray fluid radially inwardly onto and into the boxes or containers 85. Inner liquid spray manifolds 412 spray liquid radially outwardly, onto the back surfaces of the boxes. The inner liquid spray manifolds 412 are positioned radially within the spinning rotor 403. The outer spray manifolds 402, 404, 406, 408, and 410, are positioned either within the enclosure 401, as shown in Fig. 20, or are positioned outside of the enclosure 401, with nozzles on the manifolds extending through openings in the enclosure.

The inner and outer liquid spray manifolds may also be set up within the box cleaner 400 to spray a gas, such as clean dry air, during a drying cycle. Alternatively, separate inner and/or outer gas spray manifolds may be provided.

Referring to Figs. 21 and 22, the first outer liquid spray manifold 402 has a plurality of preferably evenly spaced apart spray nozzles 430 and 432. The nozzles 430 are straight spray nozzles which spray out directly towards the spin axis and center C of the rotor 36. The straight spray nozzles 430 may be cone nozzles, which spray out in a cone pattern, encompassing a solid angle of e.g., 10-60° or 15-45°, and preferably about 30°. Alternatively, the straight spray nozzles 430 may be fan type nozzles providing a flatter spray pattern. For better effect in cleaning boxes, the nozzles 432 also included on the first manifold 402 are angle spray nozzles. Preferably, the first manifold 402 will have 2 or 4 angle spray nozzles 432, separated by at least one, and preferably several, straight spray nozzles 430.

Referring to Fig. 22, the angle spray nozzles 432 on the first outer liquid spray manifold 402 are configured to spray at an angle θ away from an approaching FOUP box or container, or angled in the direction of rotor rotation A. The straight spray nozzles 430 on the first manifold 402 spray directly towards the center C of the rotor assembly. The straight spray nozzles 430 on the first manifold 402 clean various surfaces of the box, as with existing spray techniques. The angle spray nozzles 432 on the first manifold 402, however, are better configured for cleaning interior corners of the boxes, as shown in Fig. 16. If desired, all of the nozzles on the first manifold 402 may be angle spray nozzles 432, oriented to spray at the angle θ shown in Fig. 22. Alternatively, all of the nozzles may be angle spray nozzles 432, but may have different spray angles. However, preferably, the first manifold 402 has 2 or 4 angle spray nozzles 432 with both oriented to spray at angle θ, and with the remaining nozzles being straight spray nozzles 430. Preferably, the first manifold 402 will therefore have 2 or 4 angle spray nozzles 432, and 5 or 7 straight spray nozzles 430, and with all nozzles preferably equally spaced apart. Of course, other numbers and configurations may be used.

Referring to Figs. 21 and 22, the second outer spray manifold 404 is preferably oriented at about 90° to the first manifold 402, on or in the enclosure. The second manifold 404 has straight spray nozzles 430, which preferably spray out in a direction generally perpendicular to the spray from the straight spray nozzles 430 on the first manifold 402. The second manifold 404 also has at least one, and preferably from 2-4 angle spray nozzles 432 oriented to spray radially inwardly towards the center C, but at a downward angle θ (angled towards the bottom of the rotor or box cleaner 400).

The third outer liquid spray manifold 406 is preferably designed substantially as a mirror image of the first outer liquid spray manifold 402. That is, the third outer liquid spray manifold 406 has straight spray nozzles that spray towards the center C, and also has angle spray nozzles 432 oriented at angle θ toward the approaching box, and opposite to the direction of rotation A.

The fourth outer liquid spray manifold 408 has straight spray nozzles 430 which spray towards the center C, and at least one angle spray nozzle 432 (and preferably 2-4) oriented to spray upwardly at an angle θ (towards the top of the box cleaner 400).

To avoid interfering with adjacent spray nozzles, the downwardly oriented angle spray nozzles 432 on the second outer spray manifold 404, and the upwardly oriented angle spray nozzles 432 on the fourth outer spray manifold 408, are advantageously spaced apart from the next adjacent lower and upper (respectively) straight spray nozzle 430 by a distance sufficient to avoid extensively colliding spray patterns. Consequently, the spacing between the straight spray nozzles 430 and angle spray nozzles 432 on the second and fourth outer spray manifolds 404 and 408 preferably are not equal. In contrast, the spacing between the angle spray nozzles 432 on the first 402 and the third 406 outer spray manifolds, may be, and preferably is, approximately uniform.

The up and down angles of the spray angle nozzles 432 on the fourth 408 and second 404 outer spray manifolds are not necessarily equal to each other or to the angle θ of the angle spray nozzles 432 on the first 402 and the third 406 outer spray manifolds. The angles may be varied with different applications, but preferably all of the angles (right on manifold 402, down on manifold 404, left on manifold 406, and up on manifold 408) are between 10-80, 20-70, 30-50, and more preferably 40-50°. In the embodiment shown, all of the angle spray nozzles are designed to spray at an angle θ of 45°.

The manifolds 402, 404, 406, and 408 are advantageously equally spaced apart at 90° intervals around the perimeter of the inside walls of the chamber. Preferably, between each of the manifolds 402, 404, 406 and 408 having angle spray nozzles, is at least one straight spray manifold 410, preferably having only straight spray nozzles 430, as shown in Fig. 22.

The inner spray manifolds 412 preferably all have only straight spray nozzles 430, primarily for cleaning the back surfaces of the boxes. However, the inner spray manifolds 412 may also have angle spray nozzles 432, similar to the outer spray manifolds.

In the embodiment shown, there is a total of 8 outer spray manifolds, 402, 404, 406, 408 and the 4 outer straight spray manifolds 410. There are also preferably 8 inner liquid spray manifolds, which may be aligned with the outer spray manifolds, as shown in Fig. 22, or which may be offset or staggered vertically. They may also be offset angularly, so that the spray from the inner liquid spray manifolds 412 is aimed at a point in between 2 outer spray manifolds. If desired, the vertical positions of the nozzles 430 and 432 on the outer spray manifolds may be offset or staggered, to provide a wider range of spray coverage.

As shown in Figs. 27 and 28, the angle spray nozzles 432 include a guide surface 434 extending over the nozzle outlet 436, to create a conical spray pattern oriented at angle θ to the axis end of the nozzle body 438. When installed, the axis N generally intersects with the center of rotation of the rotor C, while the guide surface 434 causes the spray pattern to extend at the angle θ relative to the axis N.

Figs. 21-26 show operation of the box cleaner 400, as the rotor turns in direction A carrying a box. Cleaning fluid is supplied to all of the manifolds 402, 404, 406, 408, 410 and 412, such that liquid preferably simultaneously sprays out of all nozzles 430 and 432 on all of the manifolds. In Fig. 21, a straight spray from the straight spray nozzles 430 of the manifold 410 reaches and cleans certain side and back interior surfaces of the box. As the rotor moves the box into the position shown in Fig. 16, the straight spray nozzles 430 on the manifold 402 preferably spray onto and into the box, with a similar pattern and geometry as the straight spray from manifold 410 in Fig. 21. However, the angle spray nozzles 432 on the manifold 402 spray at an angle θ, so that the trailing exterior side surfaces 452 and the leading interior corners 454 and interior side wall 456 are more directly sprayed and cleaned.

Turning to Fig. 23, when the box 52 rotates into the range of the manifold 404, the straight nozzles 430 on the manifold 404 spray into and onto the box in a way similar to the straight nozzles 430 on the manifolds 410 and 402. However, the angle spray nozzles 432 on the manifold 404 spray down at an angle, thereby better cleaning the up-facing surfaces 450 of the box.

Turning to Figs. 24, with the rotor spinning, the box moves into the range of the manifold 406. The straight spray nozzles 430 of the manifold 406 spray into and onto the box, as described above with respect to the straight spray nozzles 430 on the manifolds 412, 402 and 404. The angle spray nozzles 432 on the manifold 406 spray at an angle minus θ, to better cover and clean the leading exterior side walls and the trailing interior corners of the box.

Referring to Fig. 25, as the box 52 moves into the range of the manifold 408, the straight spray nozzles 430 on the manifold 408 spray into and onto the box, as described above. The angle spray nozzles 432 on the manifold 408 spray up, thereby better cleaning the downwardly facing surfaces of the box. The rotor typically spins at 200-500 rpm. Generally, after spinning in direction A, the spin direction is reversed. As a result, the leading/trailing relationship of the angle nozzles on manifolds 402 and 406 is also reversed.

For manufacturing efficiency, the manifolds 402-410 may be identical, with the nozzles 420 and 432 then subsequently installed in the left, right, up, or down directions, as described. Consequently, only a single manifold design, and only 2 nozzle designs, are needed, to manufacture all of the manifolds 402, 404, 406, 408 and 410. In this case, the manifold 404 having downwardly spraying nozzles 432, and the manifold 408 having upwardly spraying nozzles 432 can have nozzle holes closed off with a plug 460, to avoid having the up or down angled spray pattern interfere with an adjacent straight spray pattern.

The straight spray nozzles 430 preferably spray out in a solid conical angle of from 15-45°, and preferably about 30°. Preferably, all of the outer spray manifolds have more straight spray nozzles than angle spray nozzles. This provides for cleaning of the rotor itself, as well as the boxes. Using all angle spray nozzles on a manifold tends to diminish the cleaning of the rotor. For rotors having ladders such as ladders 50 which have two box positions, 2, 3, or 4 angle nozzles are preferred on the manifolds 402-408. For ladders having more box positions, more angle nozzles are preferred.

Consequently, by having a spray nozzle on a manifold oriented at an angle toward or away from the direction of rotation, or up or down, improved cleaning is achieved. Of course, straight spray nozzles may be equivalently attached to a manifold, with an angle or offset, or the manifold itself may be angled, so that the nozzles spray out at an angle, to achieve the advantageous results described. The angle spray patterns may also be used in a box cleaner having a rotor which also holds box or FOUP doors. A manifold 402-408 may also have at least one angle spray nozzle spraying in a plus θ direction, as well as at least one angle spray nozzle spraying in a minus θ direction (on the same manifold).

Claims

1. A method for removing contaminants from flat media carriers, comprising the steps of:

loading the carriers onto a rotor within a flat media carrier cleaning machine;

spinning the rotor;

spraying a water/surfactant mixture onto the carriers via an inlet line by the steps of:

injecting water into the inlet line,

measuring the flow of water entering the inlet line,

pumping surfactant directly from a storage vessel into the inlet line using a flow metering pump,

mixing the surfactant and water to obtain a surfactant/water mixture,

setting flow rate of the flow metering pump to achieve a desired concentration of surfactant for the surfactant/water mixture.

2. A method according to Claim 1 further comprising the steps of

discontinuing pumping surfactant;

rinsing the carriers by spraying the carriers only with water.

3. A method according to Claim 2 further comprising the steps of

discontinuing injecting of water into the inlet line;

drying the carriers by spraying the carriers with a dry gas.

4. A method according to Claim 4 wherein the dry gas is selected from the group consisting of: nitrogen and compressed air.

5. A method according to Claim 1 wherein the water comprises de-ionized water.

6. A method according to Claim 1 further comprising the step of spinning the rotor at from 1-50 rpm while spraying the mixture toward the carriers.

7. A method according to Claim 1 further comprising the step of adjusting flow rate of surfactant being pumped into the inlet line by adjusting operation of the metering pump.

8. A method according to Claim 1 wherein the surfactant and water are injected into the inlet line via and under the control of a mixing control valve.

9. An apparatus for cleaning flat media carriers, comprising:

a rotor rotatably mounted within a chamber;

a first inside array of nozzles and a first outside array of nozzles arranged to spray fluid onto a media carrier on the rotor;

a first control valve connected by a first fluid line to the first inside array of nozzles;

a first water inlet line for providing water to the first control valve;

a first flow meter for measuring water flow through the first water inlet line;

a second control valve connected by a second fluid line to the first outside array of nozzles;

a second water inlet line for providing water to the second control valve;

a second flow meter for measuring water flow through the second water inlet line;

a surfactant storage vessel;

a first surfactant injection line connecting the surfactant storage vessel to the first control valve;

a first metering pump in the first surfactant injection line for pumping surfactant directly from the surfactant storage vessel to the first control valve at a controllable pumping rate;

a second surfactant injection line connecting the surfactant storage vessel to the second control valve;

a second metering pump in the second surfactant injection line for pumping surfactant directly from the surfactant storage vessel to the second control valve at a controllable pumping rate;

a pressurized water source connectable to the first and second inlet water lines.

10. An apparatus according to Claim 9 further comprising a housing around the chamber.

11. An apparatus according to Claim 9 further comprising a boost pump connected to the water source for providing a desired inlet water pressure to the first and second water inlet lines.

12. An apparatus according to Claim 9 wherein the flow rates of each of the first and second metering pumps is separately controllable for providing a desired surfactant concentration in the surfactant/water mixture for each of the first and second fluid lines.

13. An apparatus according to Claim 9 further comprising a surfactant return line connected between the first surfactant injection line proximate the first control valve and the surfactant storage vessel for providing a return path for surfactant back to the surfactant storage vessel.

14. An apparatus according to Claim 9 further comprising a recirculation line connected between the first water inlet line proximate the first control valve and the water source for providing a recirculation path for water back to the water source.

15. An apparatus according to Claim 9 wherein the first control valve comprises a mixing control valve for mixing the water and surfactant.

16. An apparatus for cleaning media carriers, comprising:

a rotor rotatably mounted within a chamber;

a plurality of media carriers insertable into the chamber onto the rotor;

an inner array of nozzles disposed in the chamber and arranged to spray fluid onto the media carriers on the rotor;

an outer array of nozzles disposed in the chamber and arranged to spray fluid onto the media carriers on the rotor;

a first control valve connected by a first fluid line to the inner array of nozzles;

a first water inlet line for providing water to the first control valve;

a second control valve connected by a second fluid line to the outer array of nozzles;

a second water inlet line for providing water to the second control valve;

a surfactant storage vessel;

a first surfactant injection line connecting the surfactant storage vessel to the first control valve;

a first metering pump in the first surfactant injection line for pumping surfactant from the surfactant storage vessel to the first control valve at a controllable pumping rate;

a second surfactant injection line connecting the surfactant storage vessel to the second control valve;

a second metering pump in the second surfactant injection line for pumping surfactant from the surfactant storage vessel to the second control valve at a controllable pumping rate;

a water source connected to the first and second control valves;

means for controlling pumping rate of each of the first and second metering pumps to produce a desired surfactant concentration in the surfactant/water mixtures being provided in the first and second fluid lines to each of the inner and outer arrays of nozzles.

17. An apparatus according to Claim 16 further comprising

a first flow meter disposed in the first water inlet line for measuring flow rate of water being provided to the first control valve;

a second flow meter disposed in the second water inlet line for measuring flow rate of water being provided to the first control valve.

18. An apparatus according to Claim 16 wherein the first control valve comprises a mixing control valve for mixing the surfactant and the water.

19. An apparatus according to Claim 16 further comprising a surfactant return line connected between the first surfactant injection line proximate the first control valve and the surfactant storage vessel for providing a return path for surfactant back to the surfactant storage vessel.

20. An apparatus according to Claim 16 further comprising a recirculation line connected between the first water inlet line proximate the first control valve and the water source for providing a recirculation path for water back to the water source.

21. An apparatus according to Claim 16 further comprising

a first distribution manifold disposed in the first fluid line;

a plurality of inner nozzle manifolds connected to the first distribution manifold, each inner nozzle manifold having a plurality of inner nozzles connected thereto, wherein the first distribution manifold distributing surfactant/water mixture to the inner nozzle manifolds;

a second distribution manifold disposed in the second fluid line;

a plurality of outer nozzle manifolds connected to the second distribution manifold, each outer nozzle manifold having a plurality of outer nozzles connected thereto, wherein the second distribution manifold distributing surfactant/water mixture to the outer nozzle manifolds.

22. An apparatus according to Claim 16 wherein said first metering pump comprises a positive displacement diaphragm pump, and wherein said means for controlling pumping rate of the first metering pump comprises means for adjusting pumping speed.

23. An apparatus according to Claim 21 wherein said means for controlling pumping rate of the first metering pump further comprises means for adjusting pump stroke length.

24. A system for cleaning boxes used for holding flat media substrates, with each box each having a door, comprising:

a rotor;

first and second box holder assemblies positioned symmetrically on opposite sides of the rotor, each box holder assembly having at least one box holding position; and

first and second box door holder assemblies positioned symmetrically on opposite sides of the rotor, with each door holder assembly having at least one door holding position.

25. The system of claim 24 with the first box door holder assembly comprising a first pair of hooks at a first side of the box door holder assembly, and a second pair of hooks at a second side of the box door holder assembly.

26. The system of claim 25 wherein each of the hooks comprises a leg and a foot attached to the leg.

27. The system of claim 26 wherein the legs of each pair of hooks extend towards each other.

28. The system of claim 27 wherein the foot of each pair of hooks extends radially inwardly towards an axis of rotation of the rotor.

29. The system of claim 24 where the first box door holding assembly has first and second spaced apart box door holding positions, for holding box doors in a vertical position.

30. The system of claim 24 with at least one of the first and second door holder assemblies further comprising a centrally located guide on a bottom surface of the door holder assembly.

31. The system of claim 24 wherein the first door holder assembly holds a door with an upper and a lower edge of the door aligned on a radius of the rotor.

32. The system of Claim 24 wherein each box holder assembly includes two positions for holding boxes.

33. The system of Claim 24 wherein each door holder assembly includes four positions for holding box doors.

34. The system of Claim 24 wherein each box door position includes an upper door hook, a lower door hook, and a bottom slot for accepting a bottom edge of a box door.

35. The system of Claim 34 wherein the slot includes a ramp at one end thereof.

36. The system of Claim 24 wherein the door holder assembly comprises a left side plate and a right side plate attached to a top plate, a middle plate and a bottom plate,

forming a upper compartment and a lower compartment, and wherein each compartment having a plurality of sets of upper and lower door hooks and a plurality of bottom slots.

37. The system of Claim 36 wherein a left upper and a left lower door hook is attached to the left side plate, and a right upper and right lower door hook is attached to the right side plate.

38. The system of Claim 36 wherein when positioned in a bottom slot, a box door is arranged in a vertical plane parallel to a radius of the rotor.

39. The system of Claim 37, wherein the box door is restrained against movement via centrifugal force holding an outer edge of the door with at least one door hook.

40. The system of claim 24 further comprising an enclosure, with the rotor rotatably mounted within the enclosure, and with a plurality of spray nozzles within the enclosure positioned to spray a fluid towards the rotor.

41. A system for cleaning boxes used for holding flat media substrates and doors of the boxes, comprising:

a rotor;

a door holder assembly on the rotor, with the door holder including:

upper and lower left side hooks and upper and lower right side hooks horizontally spaced apart from the upper and lower left side hooks;

with each of the hooks having a leg extending towards a central area of the door holder assembly, and with each of the hooks having a foot attached to the leg and extending inwardly towards an axis of rotation of the rotor.

42. A system for cleaning boxes used for holding flat media substrates, with each box each having a door, comprising:

a rotor;

first and second box holding means positioned symmetrically on opposite sides of the rotor, for holding boxes; and

first and second door holding means positioned symmetrically on opposite sides of the rotor, for holding doors of the boxes.

43. A cleaning system for cleaning boxes used for moving and storing semiconductor wafers, comprising:

an enclosure;

a rotor rotatably supported within the enclosure, with the rotor having box positions for holding a box;

a plurality of spray manifolds positioned to spray a cleaning or rinsing fluid towards the rotor, with at least one of the spray manifolds having a plurality of straight spray nozzles, and also having at least one angle spray nozzle.

44. The method of claim 1 wherein at least some of the water mixture is sprayed at an angle θ relative to the spinning rotor.

45. The apparatus of claim 9 wherein at least one of the nozzles in the first outside array is directed at an angle relative to the other nozzles in first outside array.

46. The system of claim 40 wherein at least one of the spray nozzles is an angled spray nozzle.

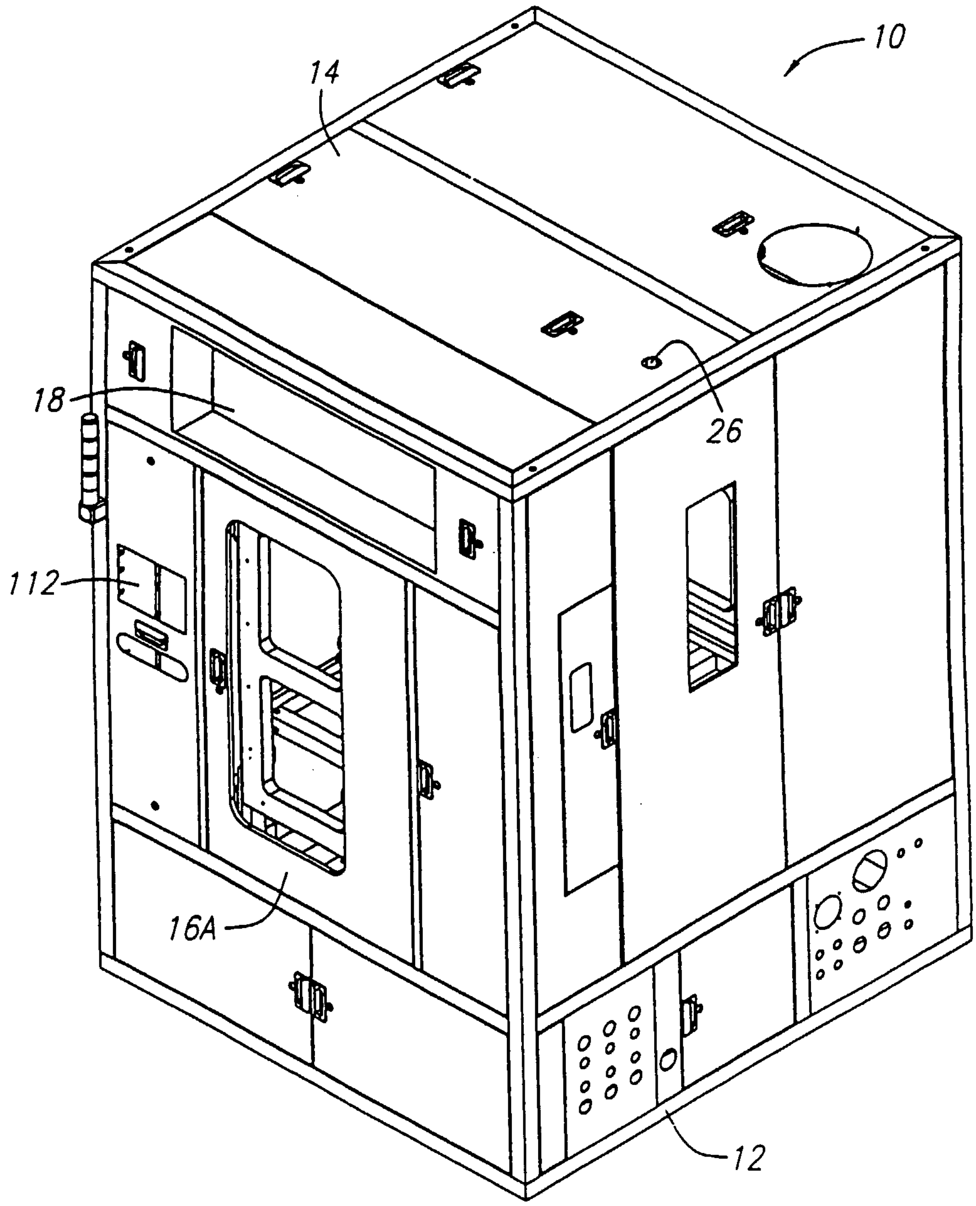


Fig. 1

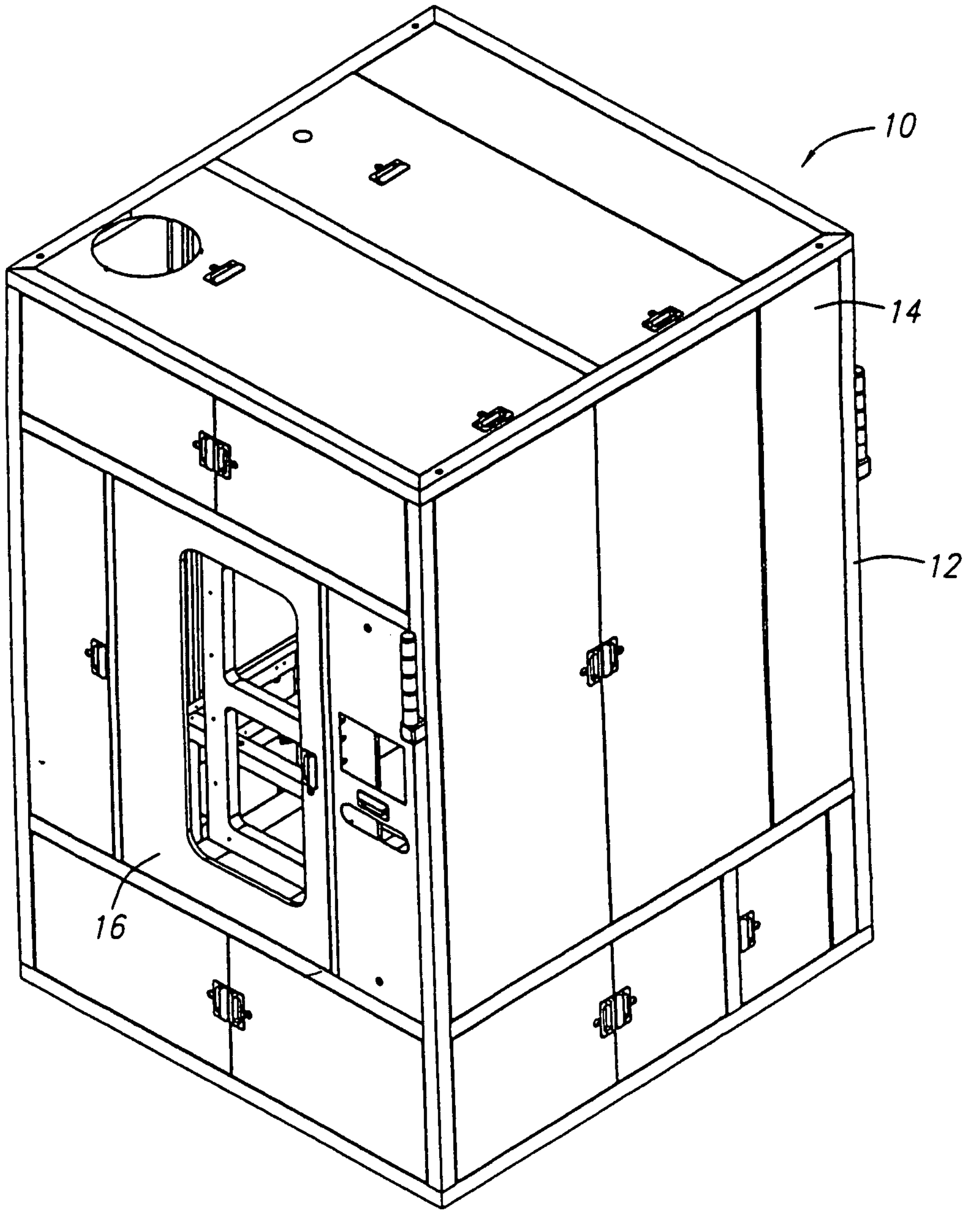


Fig. 2

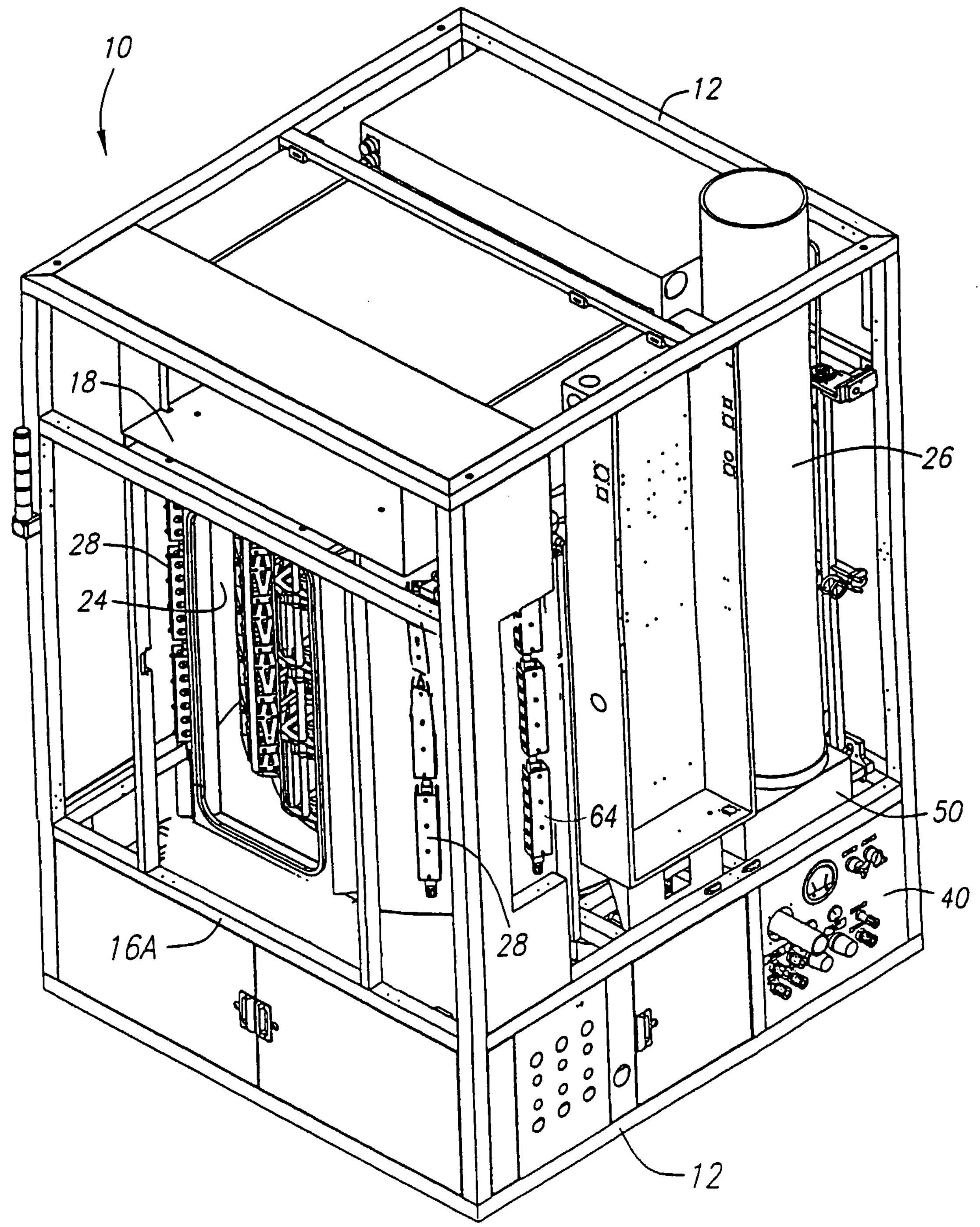


Fig. 3

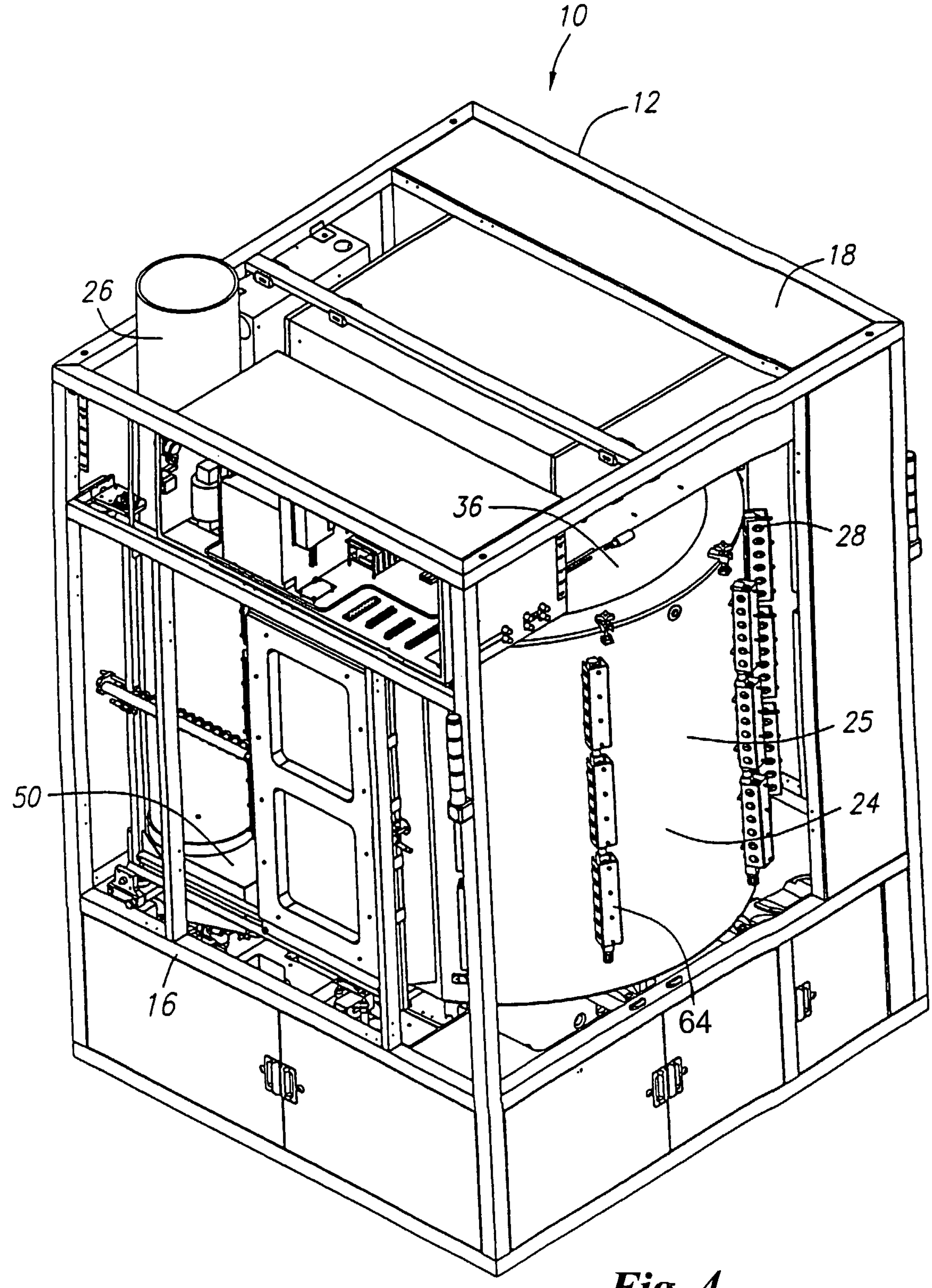


Fig. 4

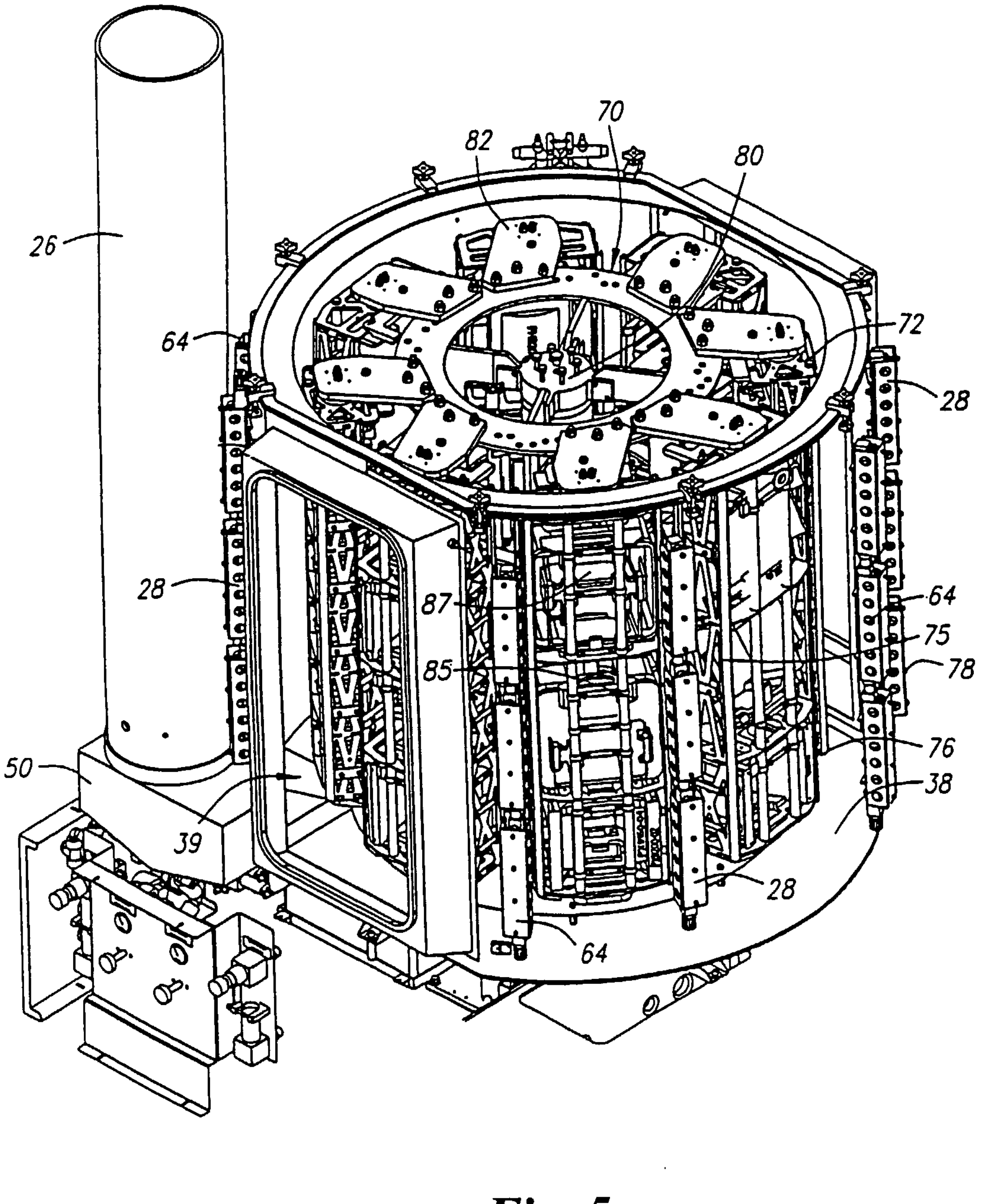


Fig. 5

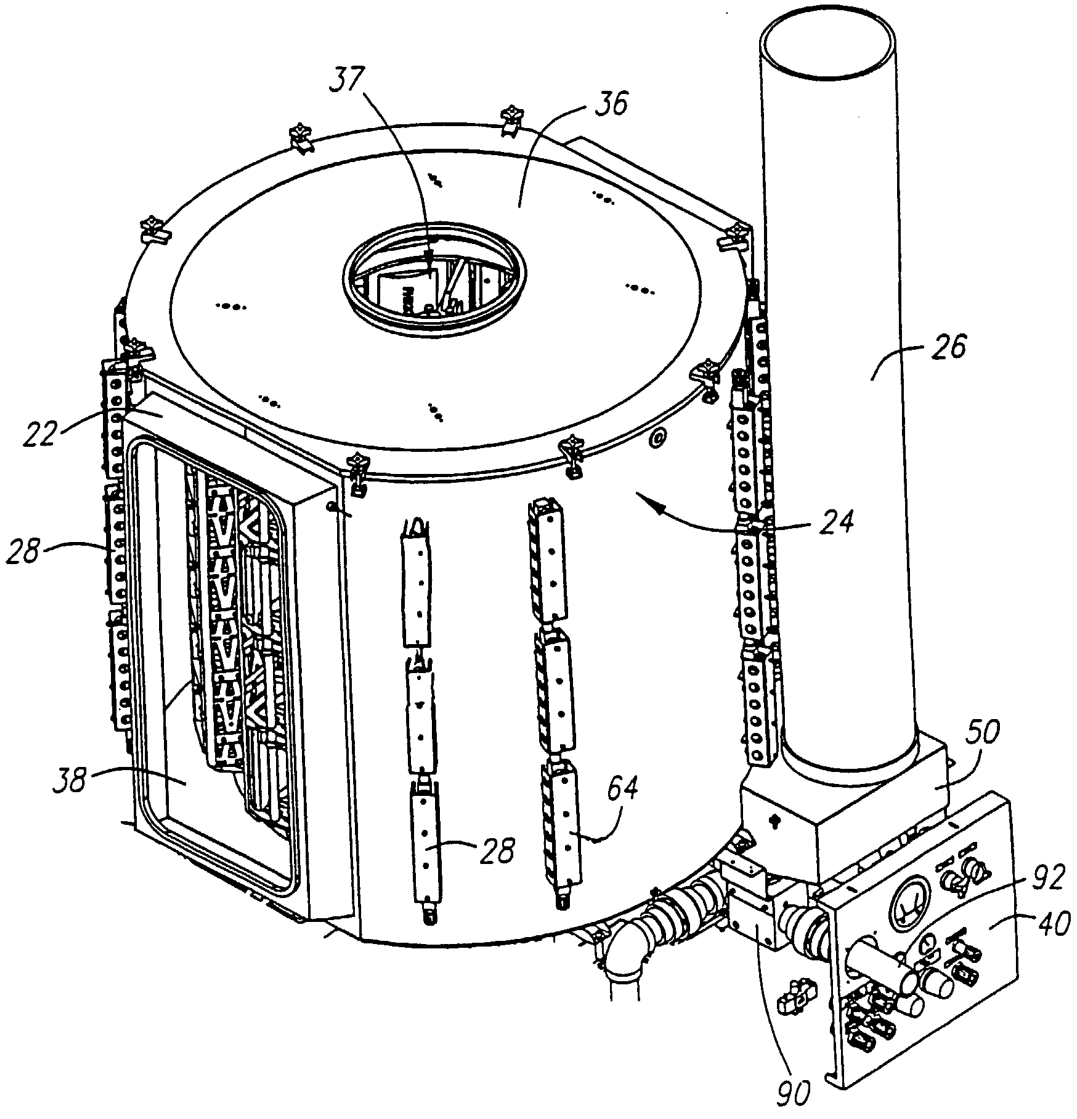


Fig. 6

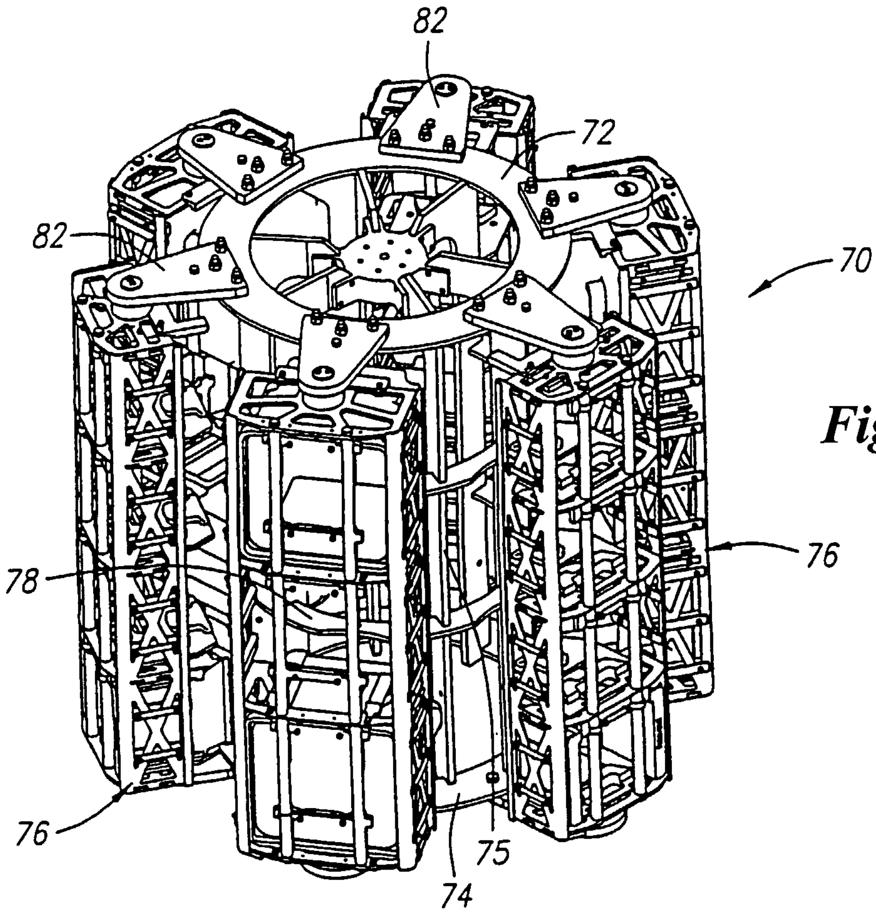


Fig. 7

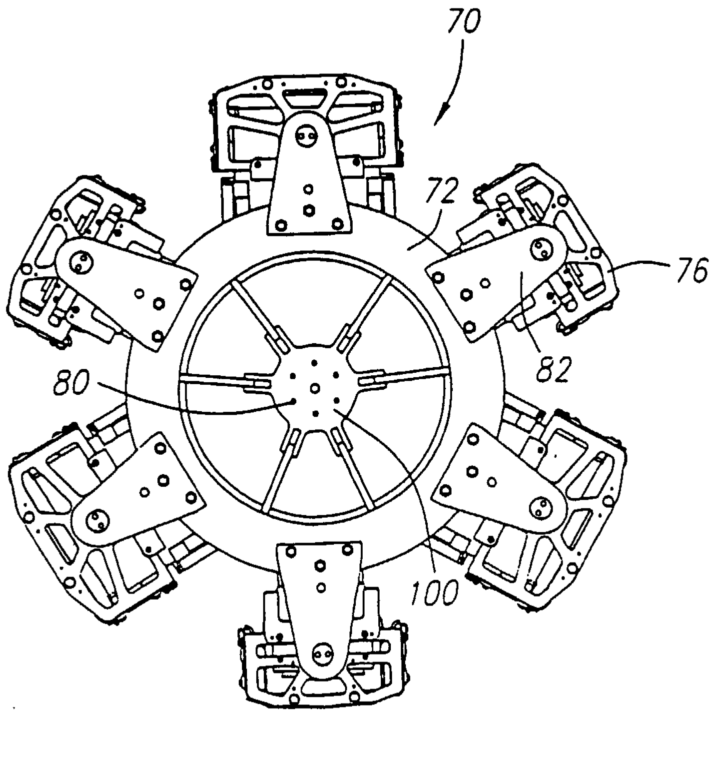
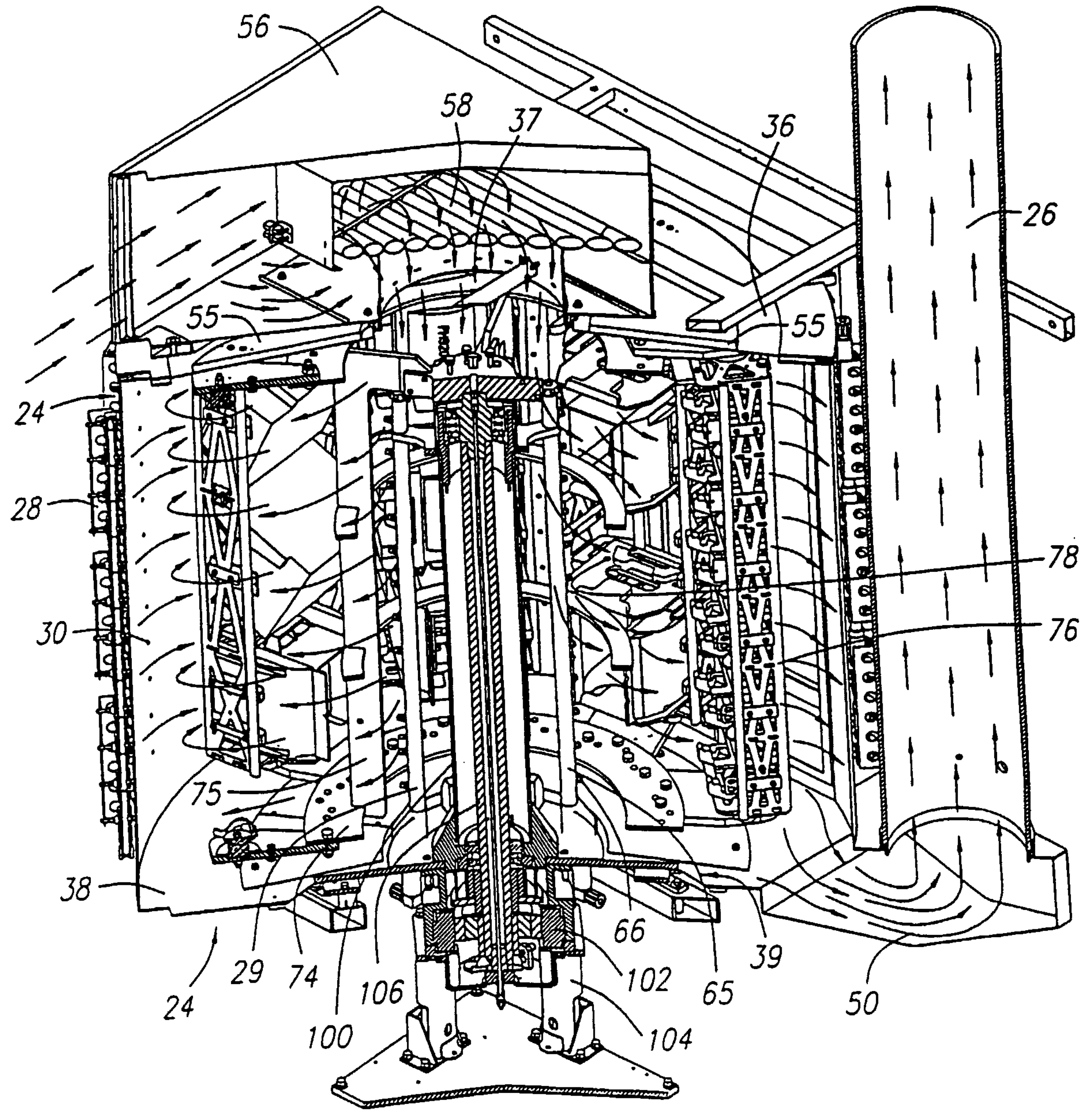


Fig. 8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24
28
78
30
76
75
38
29
74
106
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66
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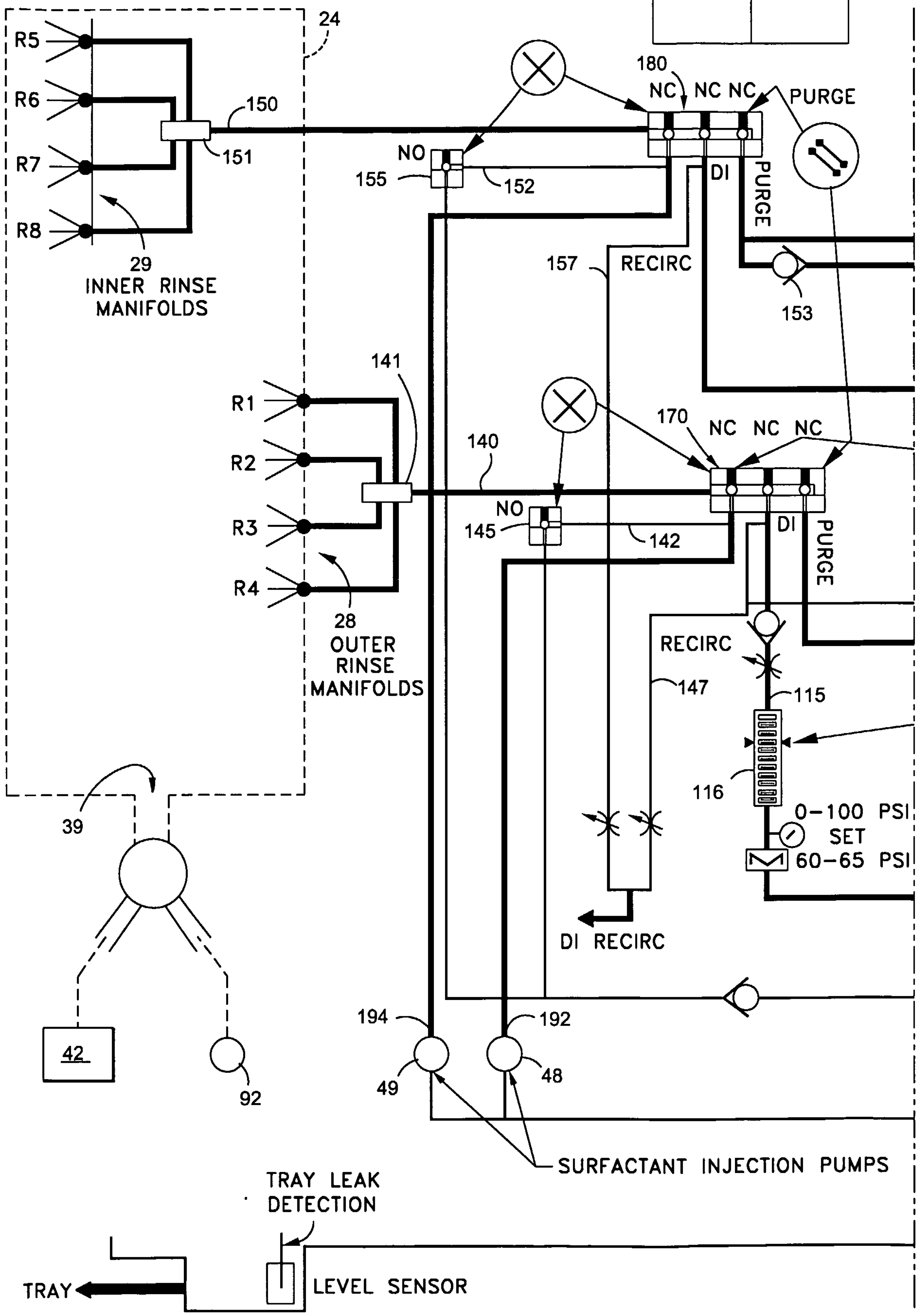
39
50
24
100
104

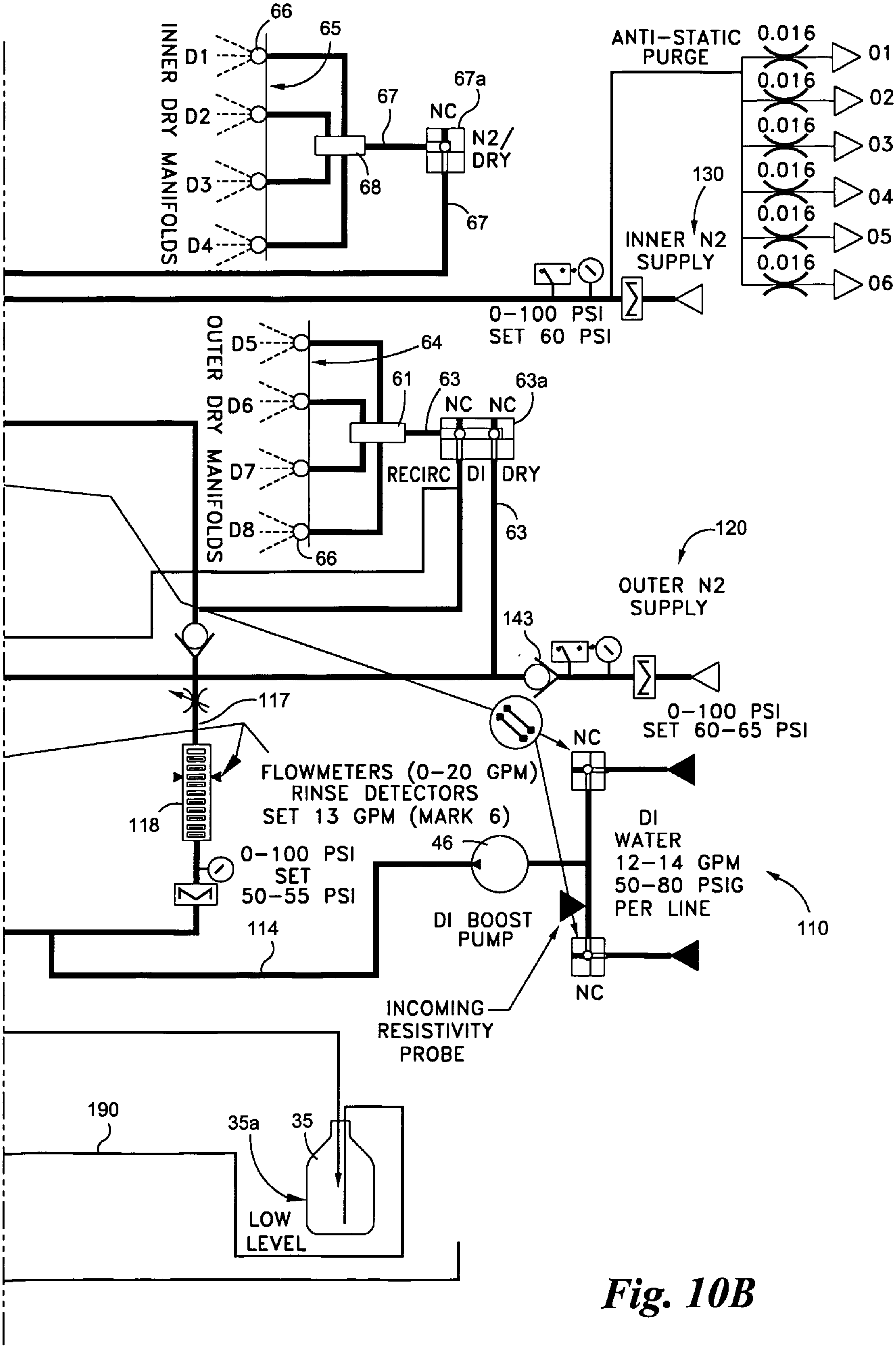
Fig. 9

Fig. 10A

Fig. 10

Fig. 10A	Fig. 10B





INNER DRY MANIFOLDS
D1
D2
D3
D4
66
65
67
67a
NC
N2/
DRY
68
67
ANTI-STATIC
PURGE
0.016
01
02
03
04
05
06
130
INNER N2
SUPPLY
0-100 PSI
SET 60 PSI
OUTER DRY MANIFOLDS
D5
D6
D7
D8
64
61
63
63a
NC NC
RECIRC
DI
DRY
63
66
120
OUTER N2
SUPPLY
143
0-100 PSI
SET 60-65 PSI
117
NC
FLOWMETERS (0-20 GPM)
RINSE DETECTORS
SET 13 GPM (MARK 6)
118
0-100 PSI
SET
50-55 PSI
46
DI BOOST
PUMP
DI
WATER
12-14 GPM
50-80 PSIG
PER LINE
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114
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INCOMING
RESISTIVITY
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35a
35
LOW
LEVEL

Fig. 10B

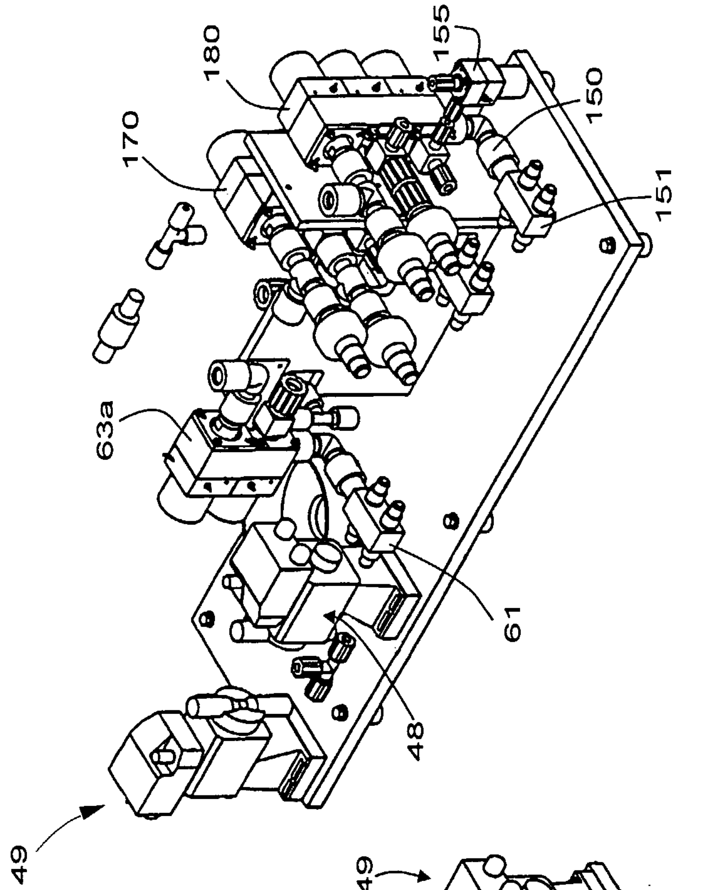
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Fig. 12

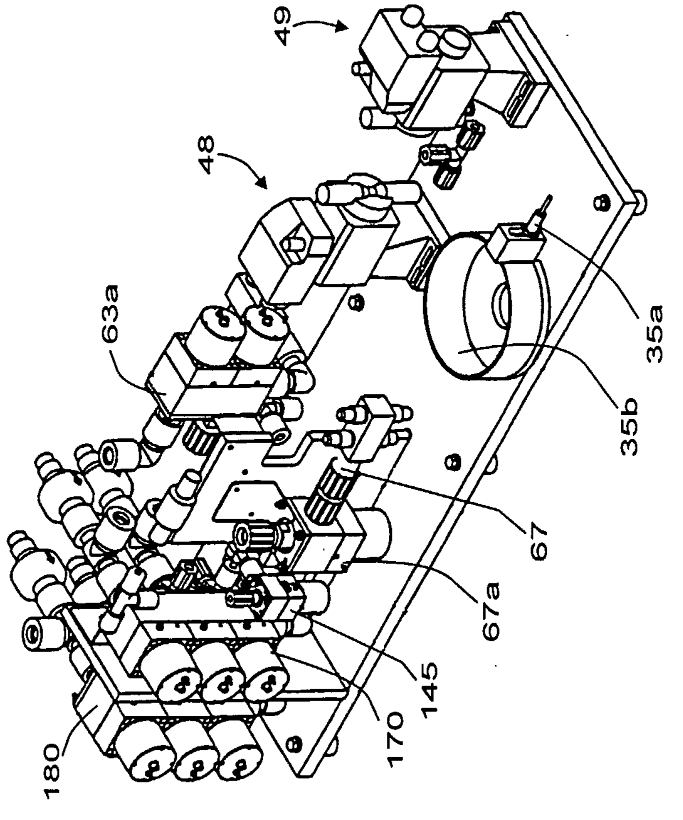
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Fig. 11

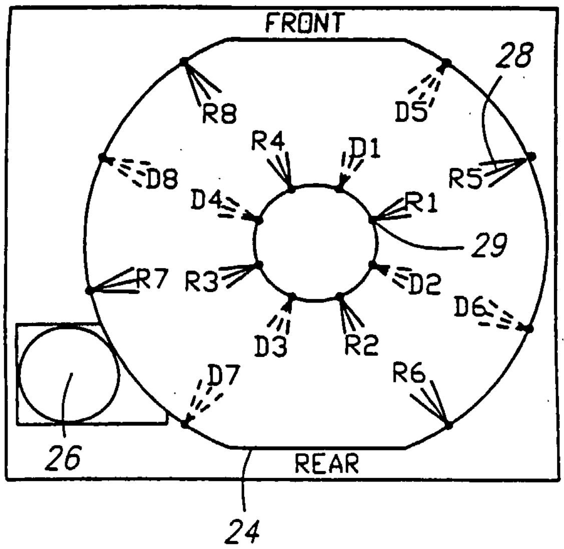
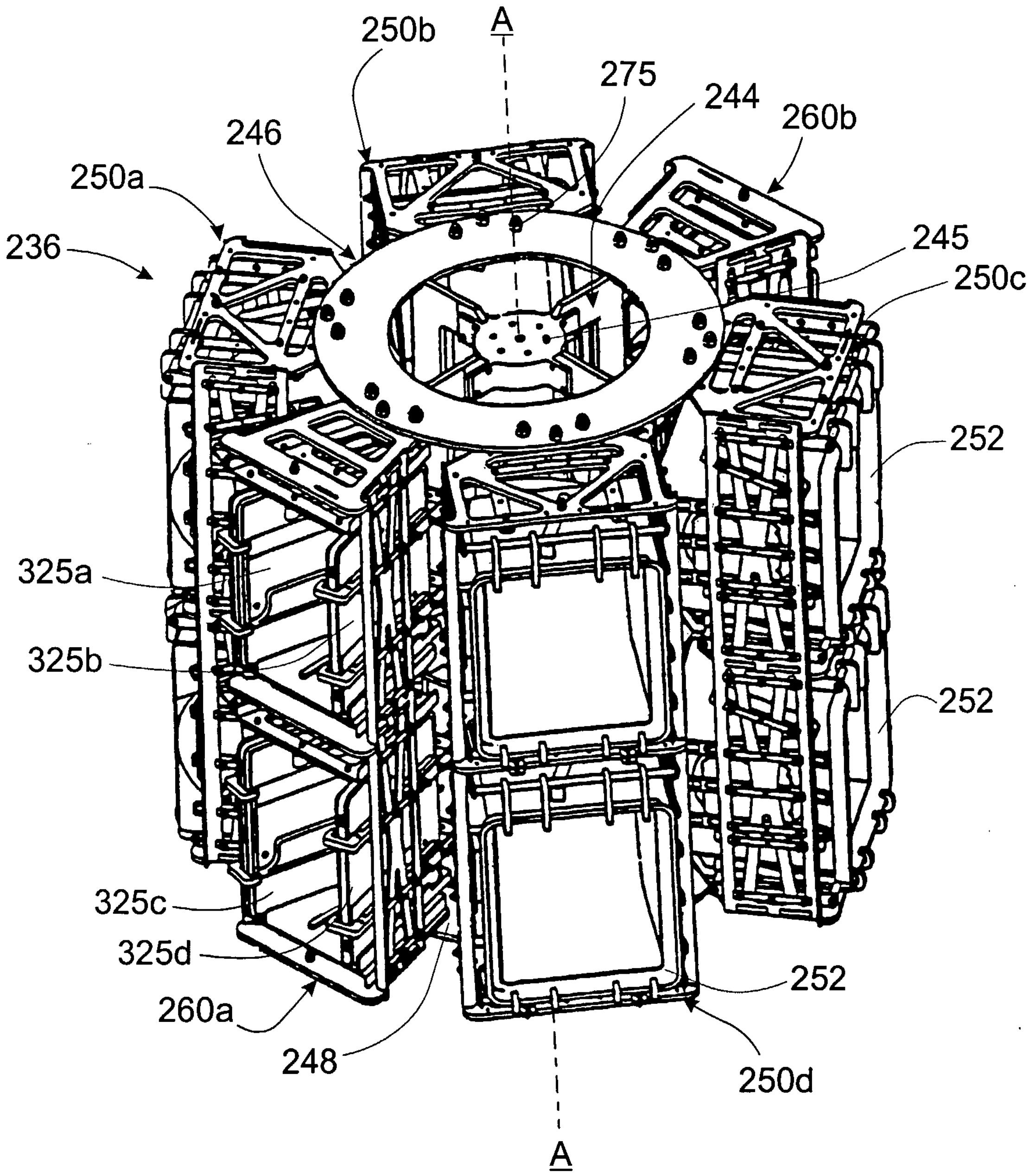


Fig. 13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250d
A

Fig. 14

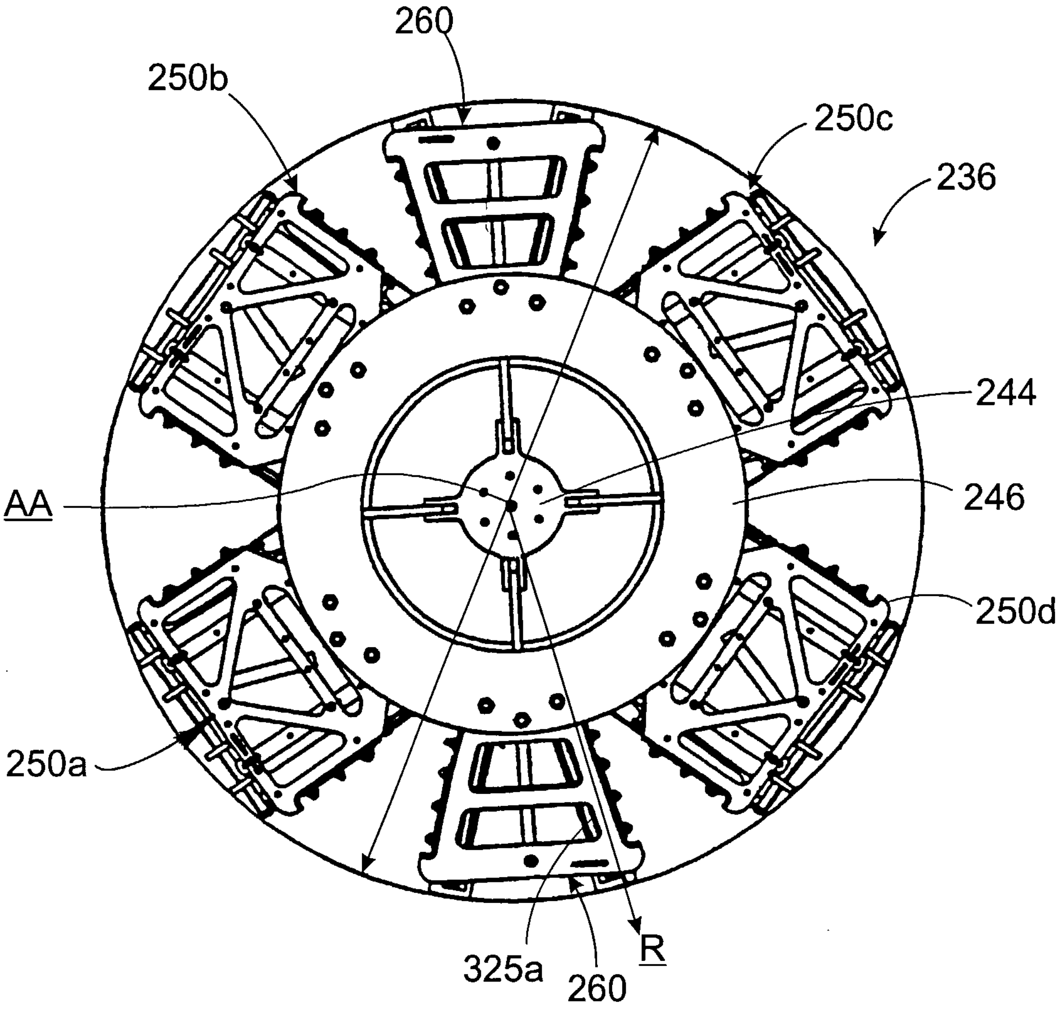

Fig. 15

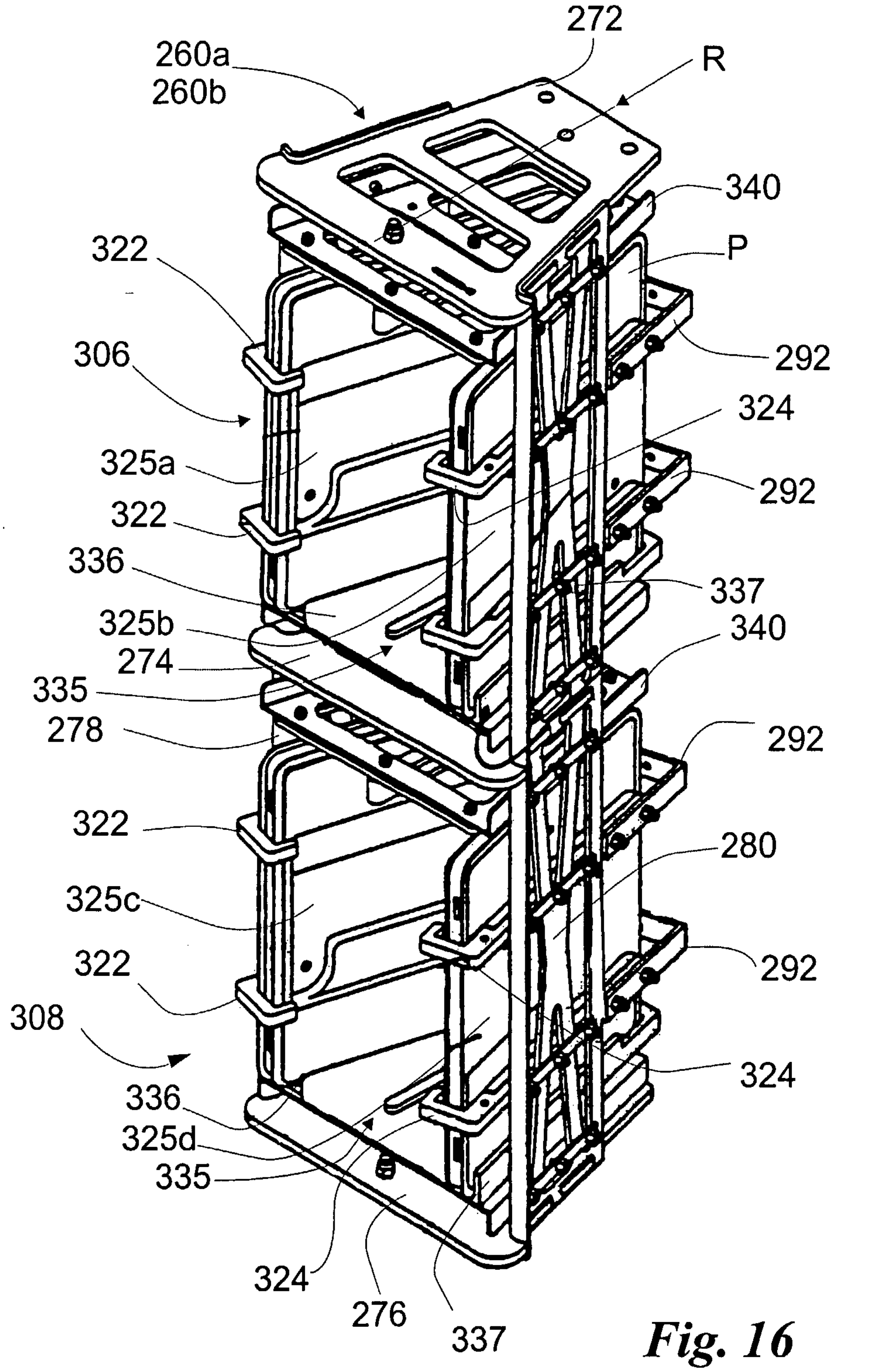
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Fig. 16

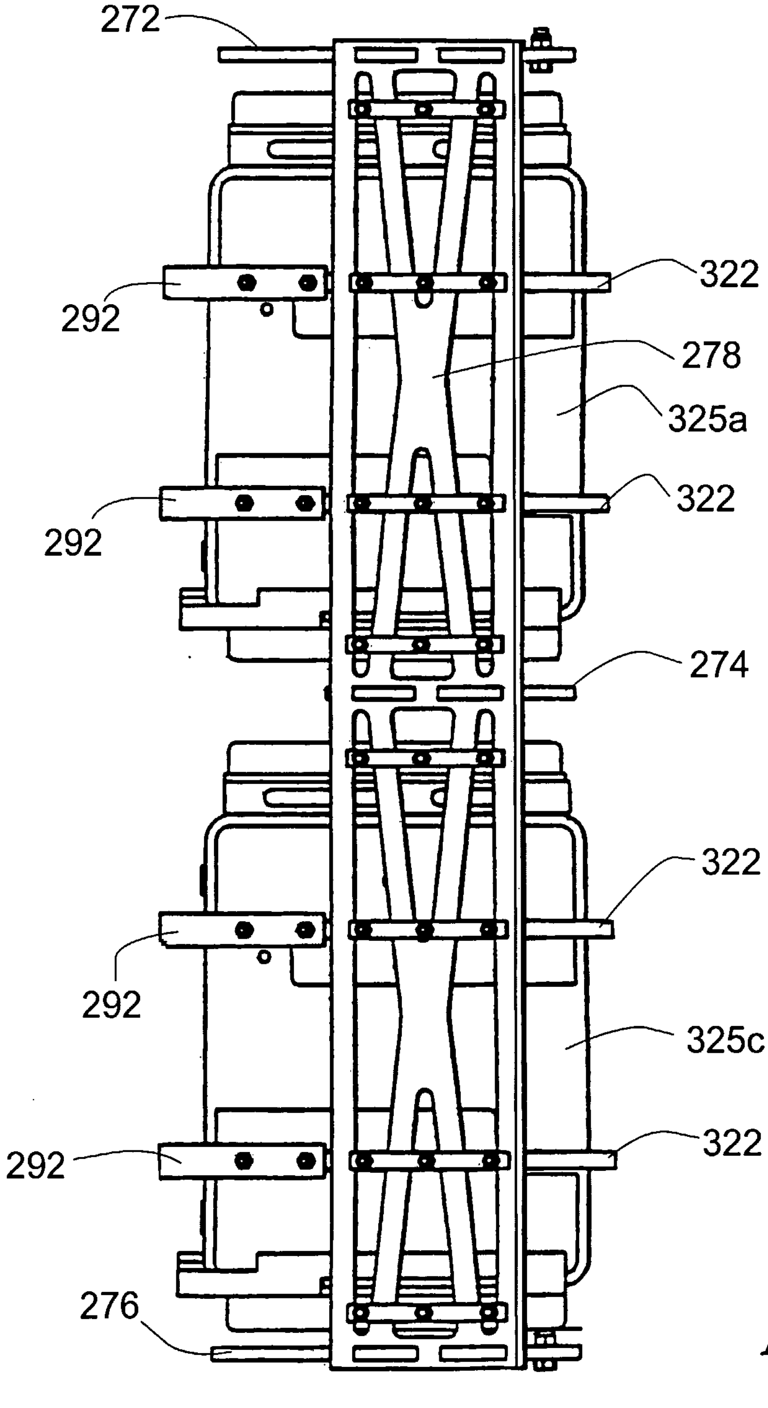

Fig. 17

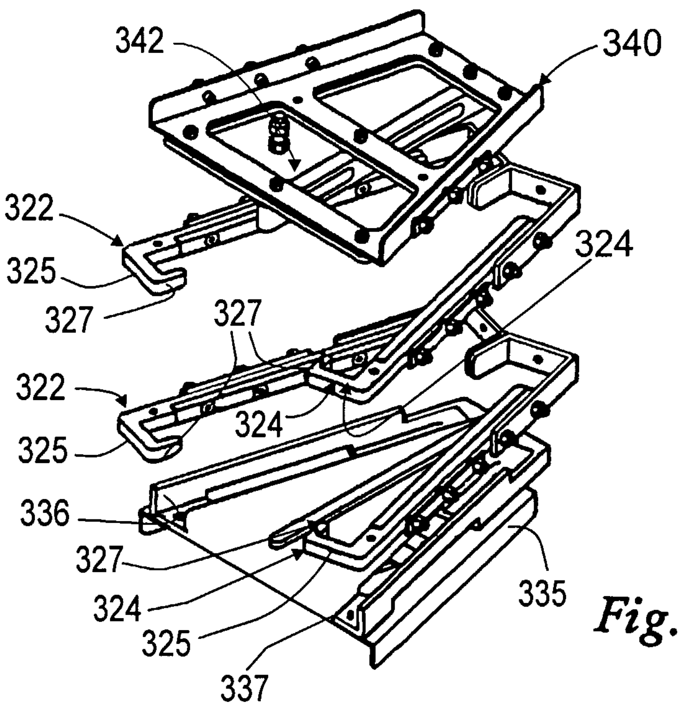
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Fig. 18

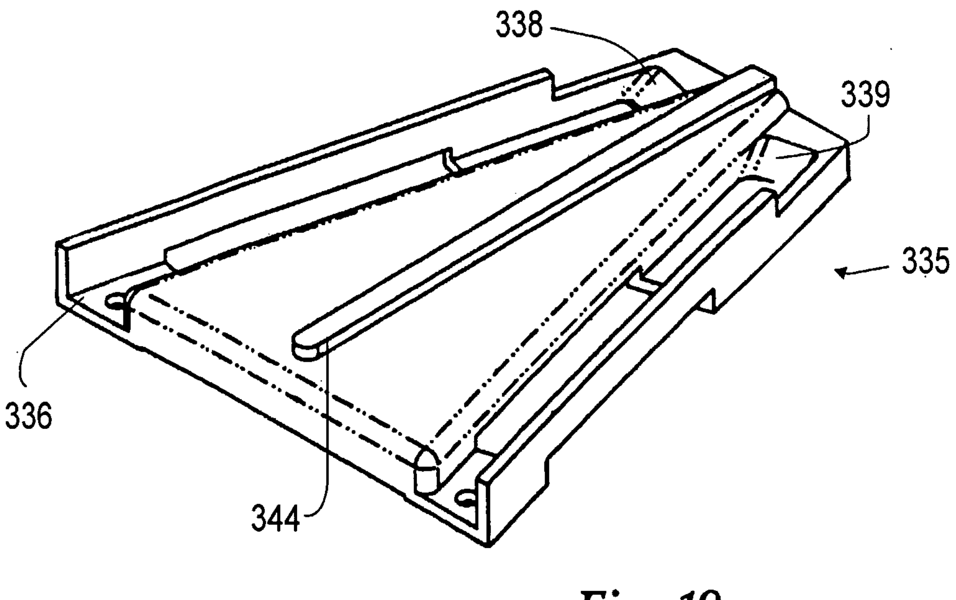
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Fig. 19

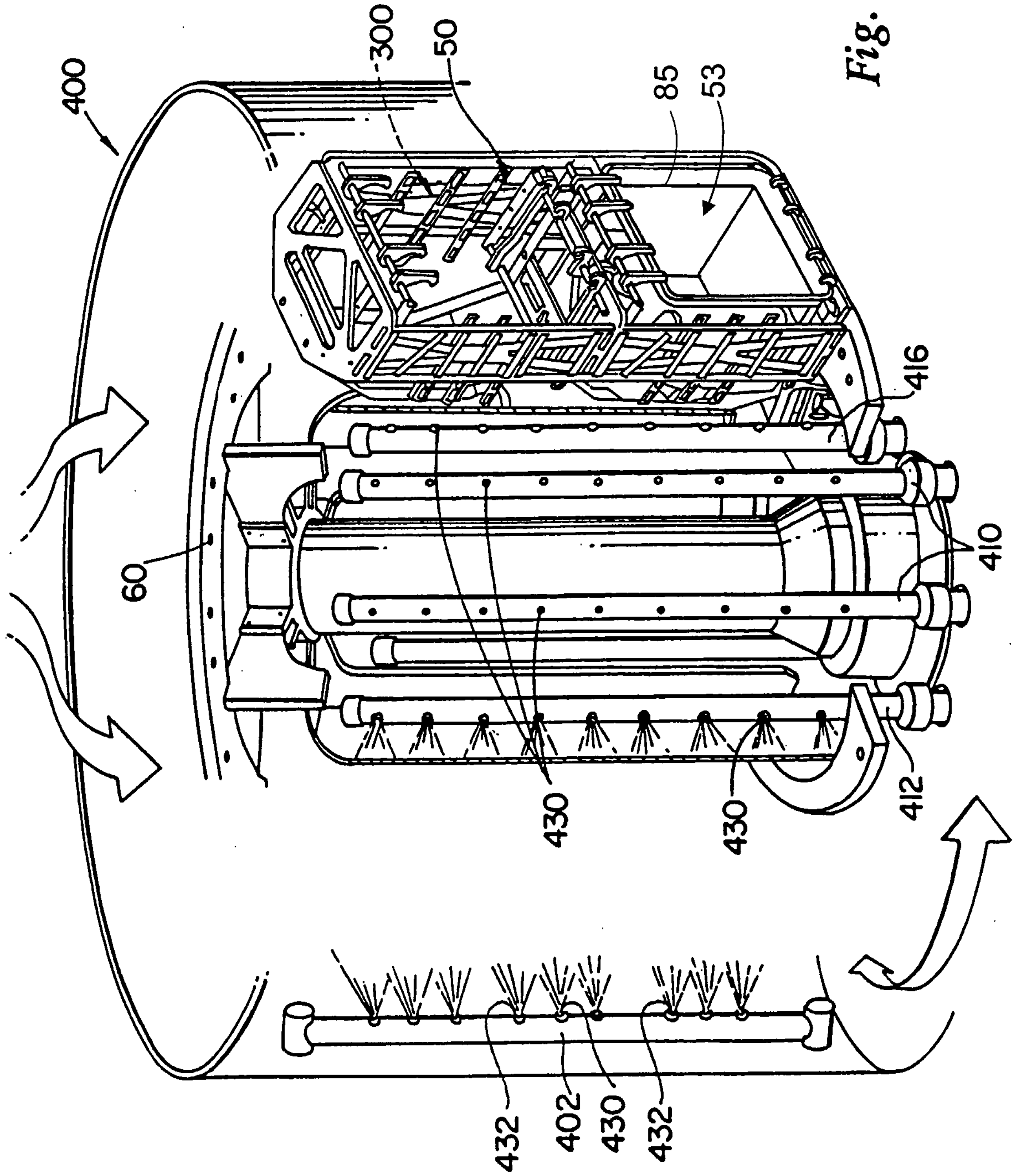


Fig. 20

Fig. 21

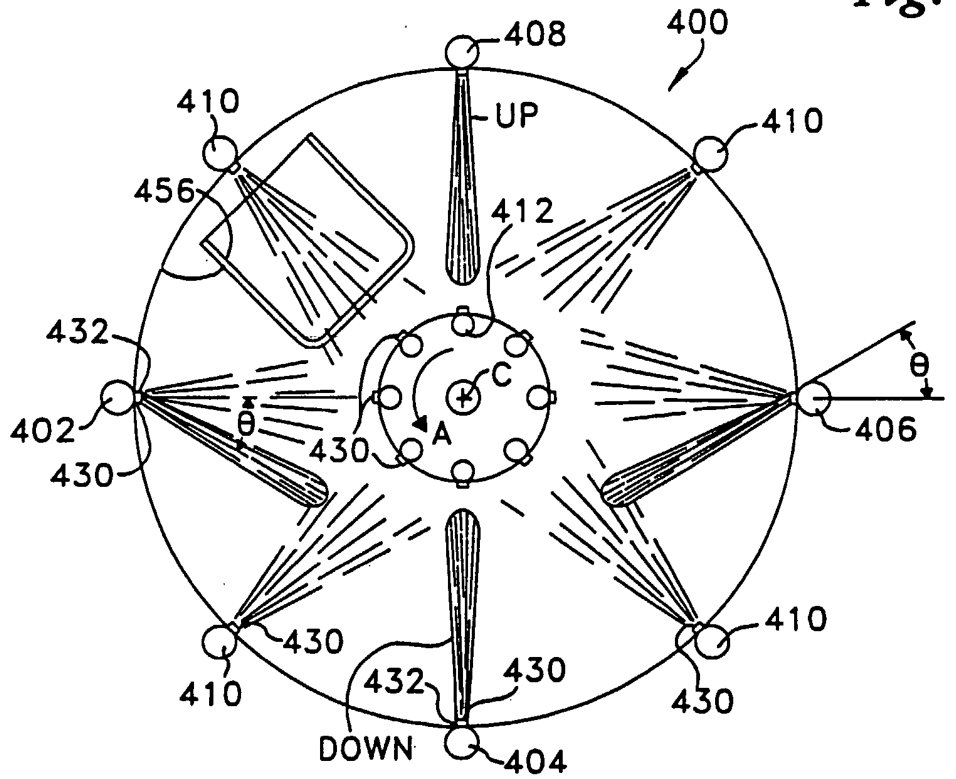
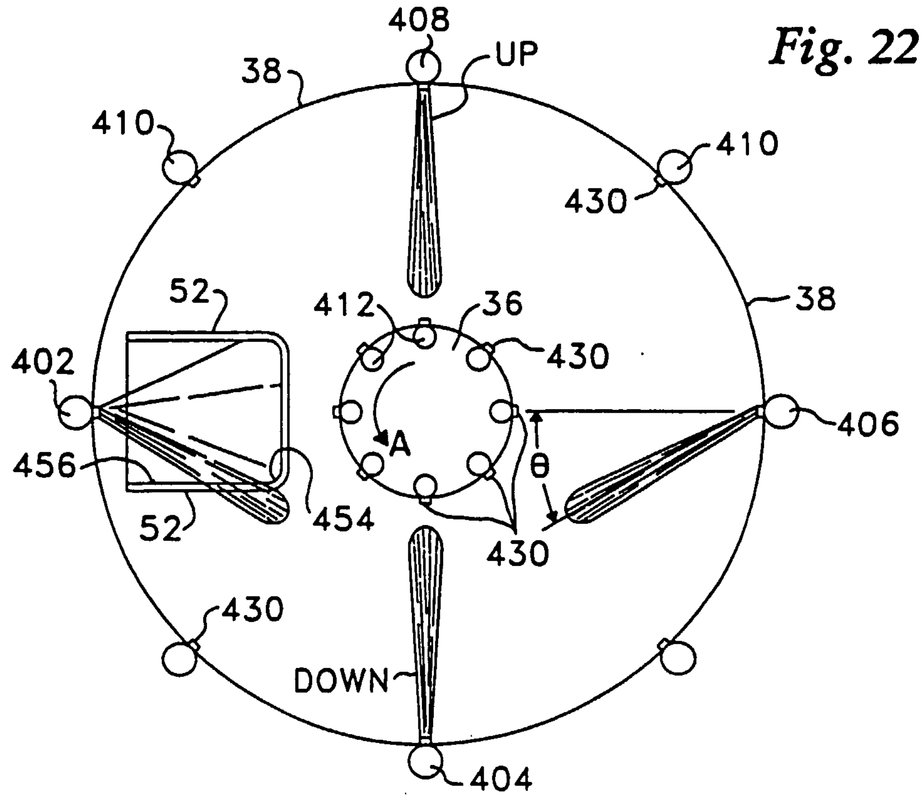

400
408
UP
410
410
456
412
432
θ
C
402
A
406
θ
430
430
430
410
430
410
430
432
DOWN
404

Fig. 22


408
UP
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410
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430
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θ
456
454
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430
430
DOWN
404

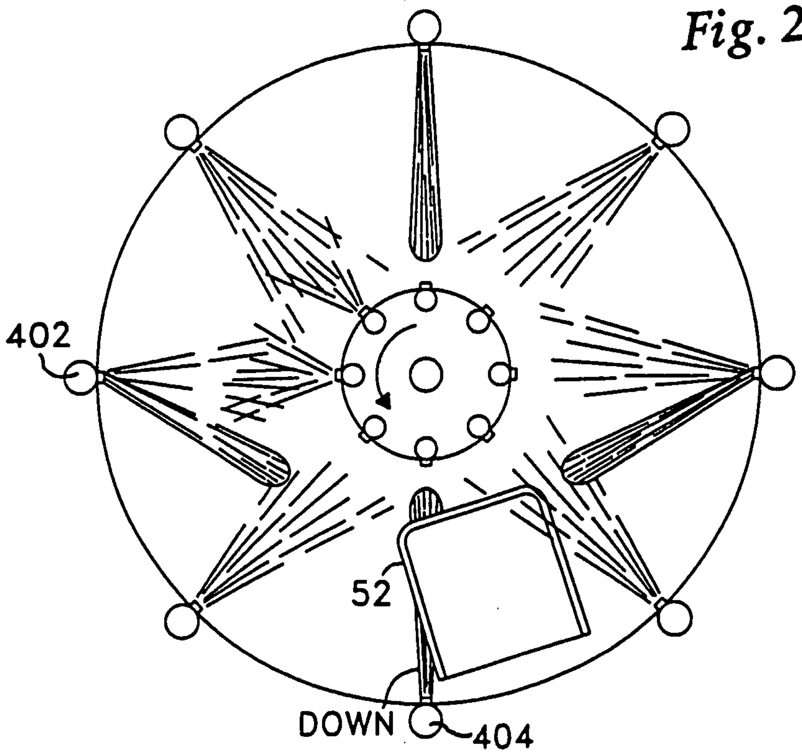


Fig. 23

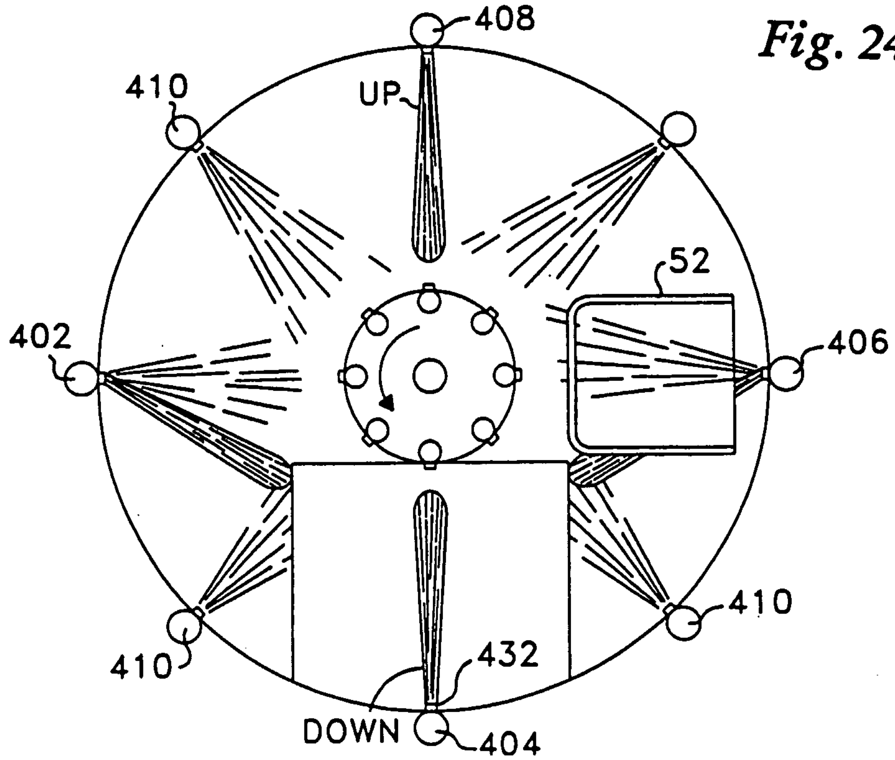


Fig. 24

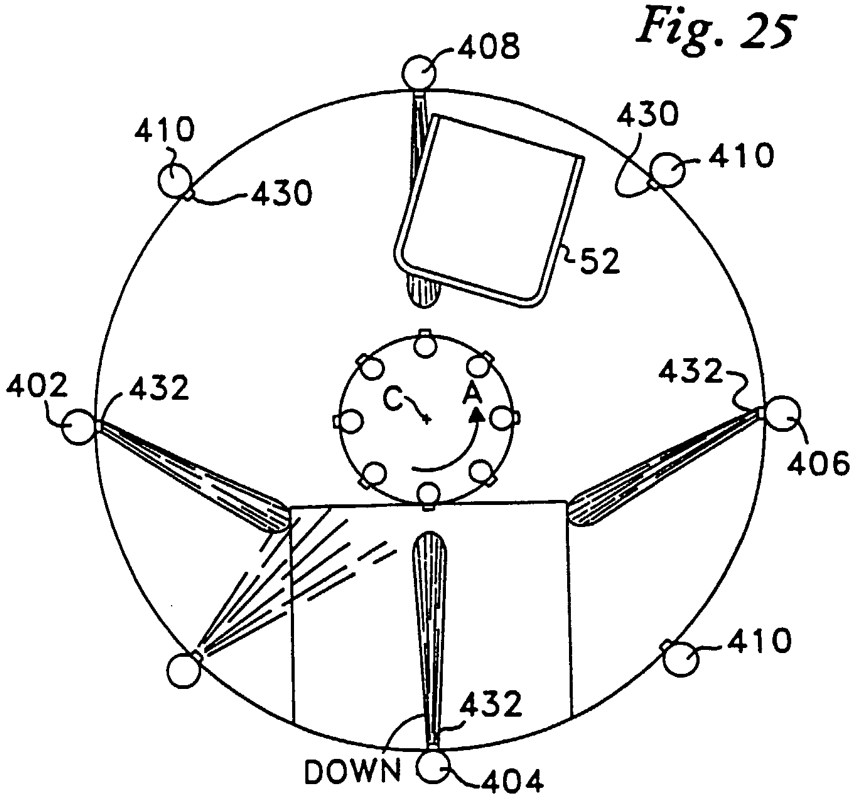
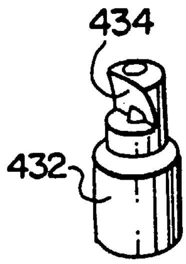


Fig. 25

Fig. 27



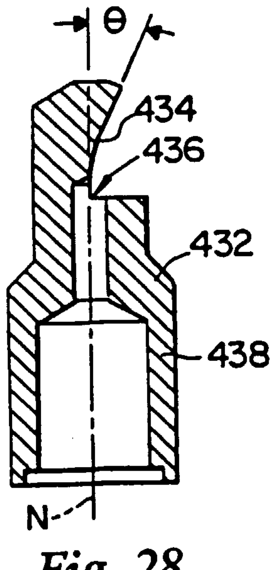


Fig. 28

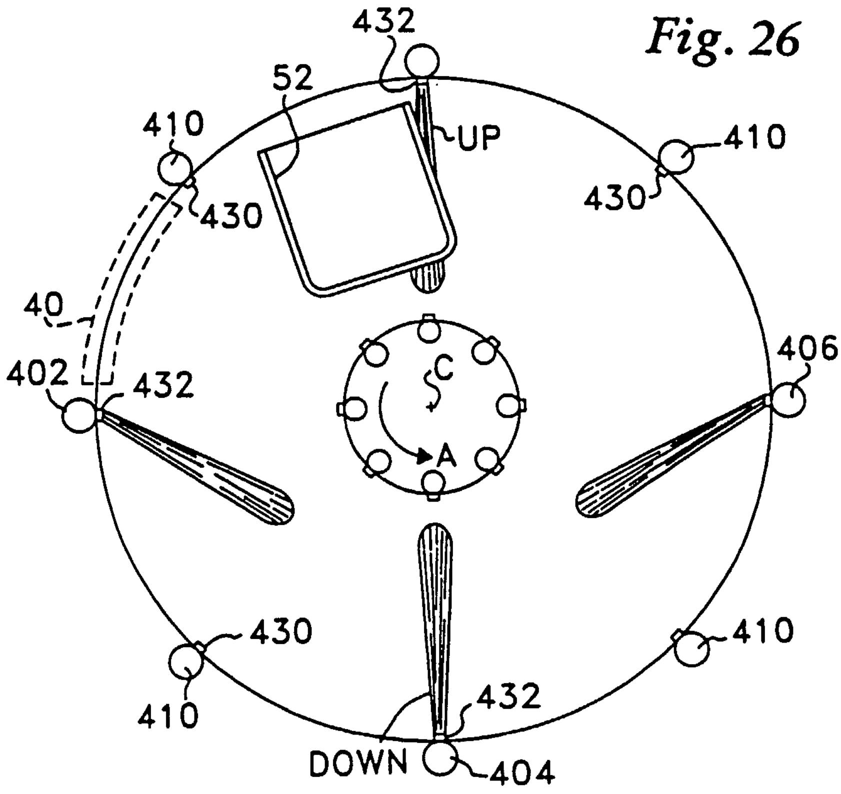


Fig. 26

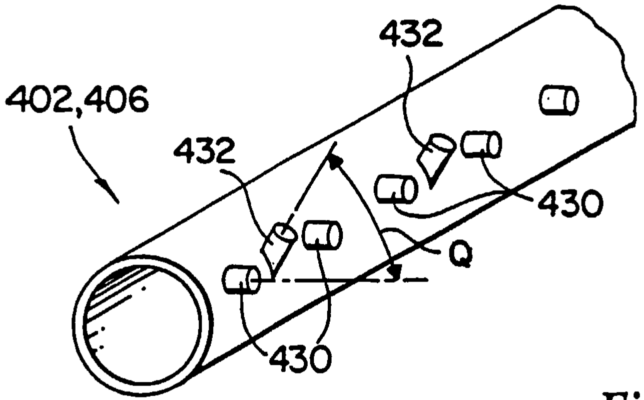


Fig. 29

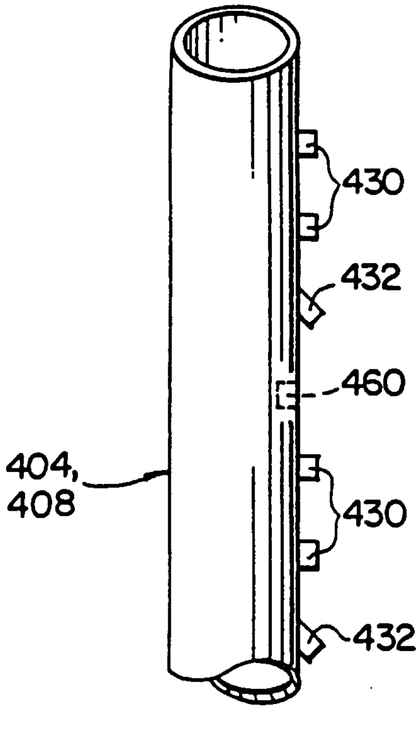


Fig. 30