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(71) Applicant: SEMITOOL, INC. [US/US]; 655 West Reserve Drive, Kalispell, MT 59901 (US).

(72) Inventors: DAVIS, Jeffry, A.; 3040 Highway 2 East, Kalispell, MT 59901 (US). DOLECHEK, Kert, L.; 2142 Mission Trail, Kalispell, MT 59901 (US). CURTIS, Gary, L.; 655 Hoffman Draw, Kila, MT 59920 (US).

(74) Agents: OHRINER, Kenneth, H. et al.; Lyon & Lyon LLP, Suite 4700, 633 West Fifth Street, Los Angeles, CA 90071-2066 (US).

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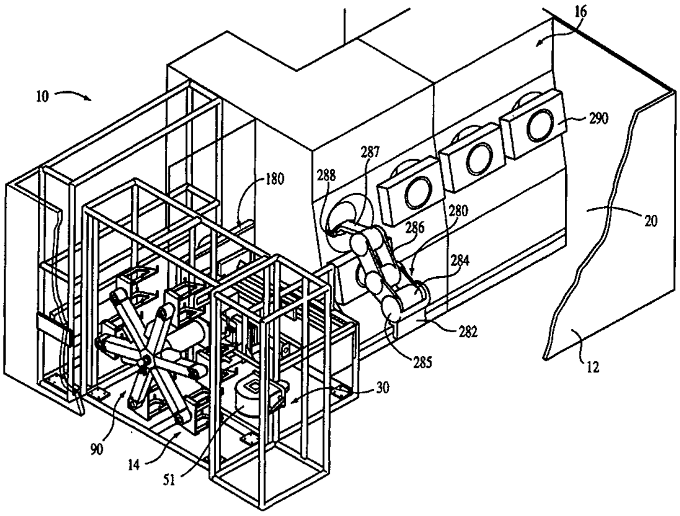

(57) Abstract

A processor (10) for processing articles, such as semiconductor wafers (50) includes an enclosure (12) defining a substantially enclosed clean processing chamber (20) and at least one processing station disposed in the processing chamber. An interface section (14) is disposed adjacent an interface end of the enclosure. The interface section includes at least one interface port through which a pod (51) containing articles for processing are loaded or unloaded to or from the processor. The interface section is hygienically separated from the processing chamber since the interface section is generally not as clean as the highly hygienic processing chamber. An article extraction mechanism adapted to seal with the pod is employed. The mechanism is disposed to allow extraction of the articles contained within the pod into the processing chamber without exposing the articles to ambient atmospheric conditions in the interface section. The article processor also preferably includes an article insertion mechanism that is adapted to seal with a pod disposed in the interface section.

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DESCRIPTION

SEMICONDUCTOR WAFER INPUT/OUTPUT HANDLING SYSTEM

Cross-Reference To Related Applications

The present application is a continuation-in-part of co-pending U.S.S.N. 08/851,480 (Attorney Docket No. SE 10-0121) which is a continuation of U.S.S.N. 680,463, filed July 15, 1996, now U.S. Patent No. 5,664,337, which is a continuation-in-part of U.S.S.N. 622,349, filed March 26, 1996 which are hereby incorporated by reference.

Statement Regarding Federally Sponsored Research Or Development

Not Applicable.

Background Of The Invention

The present invention relates to an automated semiconductor wafer processing apparatus that is used, for example, to execute liquid and gaseous processing of wafers. Such an apparatus can be used to process semiconductor wafers, data disks, semiconductor substrates and similar articles requiring very low contaminant levels. More particularly, the present invention relates to such an apparatus having an improved input/output wafer handling system.

The processing of semiconductor wafers and the like has become of great economic significance due to the large volume of integrated circuits, data disks, and similar articles being produced. In recent years, the features used in integrated circuits and data disks have decreased significantly in size, thus providing greater integration and greater capacity. In addition, the diameters of semiconductor wafers have increased over time, providing greater economies of scale with respect to each processed wafer.

While the apparatus and methods utilized heretofore for processing semiconductor wafers have operated with varying degrees of success, they have also sometimes suffered problems with regard to contamination or particle additions which can occur during processing. As the features and geometries of the discrete components formed on the semiconductor devices have become smaller and more densely packed, and as the diameters of the semiconductor wafers have increased, the need for more stringent control over contamination and breakage has become more acute.

A constant challenge in the production of semiconductors is the culmination of particle contamination. With respect to all types of semiconductor processors, preventing contaminant particles from entering into the processor enclosure is of paramount importance. Such particles can affect the photographic processes used to transfer the integrated circuit layouts onto the wafers being processed by causing deterioration of the image being transferred onto the wafer. Contaminant particles may also result in the altering of the characteristics of the device that is being manufactured.

One of the greatest sources of contaminating particles is the presence of environmental dust carried in the air surrounding the semiconductor processors. To reduce the amount of environmental contamination, semiconductor integrated circuit manufacturers have taken extreme measures to provide working areas with relatively low amounts of environmental dust. These areas are called "clean rooms". Such working areas are expensive to build and operate. It is therefore preferable to limit the number and size of the clean rooms used to manufacture a particular device.

Another problem associated with traditional semiconductor processors relates to the fact that toxic and corrosive processing fluids, such as acids, caustics, solvents and other processing fluids are used in the manufacturing process. Such processing fluids must be maintained within controlled processing chambers to avoid corrosion and other harmful effects to personnel and materials outside of the semiconductor processor enclosure. Of concern are both liquid and gaseous forms of processing fluids, both of which should be prevented from exiting the processor chamber and contacting machine parts susceptible to corrosion. Thus, there exists a need to provide semiconductor processing equipment that adequately seals processing fluids inside the processing chamber during manufacturing and prevents them from escaping and causing damage.

The present inventors have recognized the foregoing problems and have addressed solutions for them in the apparatus described herein. The apparatus provides an improved system for batch wafer handling in automated semiconductor process equipment. Further, the apparatus provides a processing system which permits use of standard wafer containers or pods. Still further, the apparatus provides a processing system for multiple wafer container loading wherein air infiltration during the loading operation is minimized while also allowing continuous automated processing of the wafers.

In accordance with a further feature of the present apparatus, the apparatus is provided with an improved door actuating and sealing assembly that provides a fluid tight seal which prevents contaminant particles from entering a processing chamber and prevents processing fluids and vapors from escaping from the chamber.

Brief Summary Of The Invention

A processor for processing articles, such as semiconductor wafers, in a substantially clean atmosphere is set forth. The processor includes an enclosure defining a substantially enclosed clean processing chamber and at least one processing station disposed in the processing chamber. An interface section is disposed adjacent an interface end of the enclosure. The interface section includes at least one interface port through which a pod containing articles for processing are loaded or unloaded to or from the processor. The interface section is hygienically separated from the processing chamber since the interface section is generally not as clean as the highly hygienic processing chamber. An article extraction mechanism adapted to seal with the pod is employed. The mechanism is disposed to allow extraction of the articles contained within the pod into the processing chamber without exposing the articles to ambient atmospheric conditions in the interface section. The article processor also preferably includes an article insertion mechanism that is adapted to seal with a pod disposed in the interface section. The article insertion mechanism is disposed to allow insertion of the articles into the pod after processing by the at least one processing station. The article insertion mechanism allows the insertion of the articles without exposing the articles to ambient atmospheric conditions in the interface section.

Brief Description Of The Several Views Of The Drawings

FIG. 1A is a perspective view of a semiconductor processing system in accordance with one embodiment of the invention showing the various stations of the input/output section and the general components of the processing section.

FIG. IB is a front perspective view of a semiconductor processing system according to the present invention with portions broken away to better illustrate some of the principal components thereof.

FIG. 1C is a top view of the semiconductor processing system of FIG. 1A illustrating flow of semiconductor wafers therethrough.

FIG. 2 is a rear perspective view of the semiconductor processing system with some portions removed to better illustrate certain components.

FIG. 3 is a perspective view of an input/output subassembly of the processing system illustrated in FIG. 1.

FIG. 4 is a perspective view of a load plate used in the input/output subassembly.

FIG. 5a is a perspective view of a wafer container in conjunction with the load plate and the elevator plate of the input/output subassembly.

FIG. 5b is a top view illustrating the transfer of a wafer container from the elevator plate to the load plate.

FIG. 6 is a perspective view of a preferred semiconductor inventory subassembly forming part of the processing system illustrated in FIG. 1.

FIG. 7 is a perspective view of a container transfer forming part of the docking assembly of the processing system illustrated in FIG. 1.

FIG. 8 is a perspective view of a hatch interface forming part of the docking subassembly of the processing system illustrated in FIG. 1.

FIG. 9a is a front perspective view of a wafer transfer comb forming part of the transfer subassembly of the processing system illustrated in FIG. 1.

FIG. 9b is a rear perspective view of the wafer transfer comb illustrated in FIG. 9a.

FIG. 10 is a perspective view of the conveyor for the wafer comb illustrated in FIGS. 9a and b.

FIG. 11A is a perspective view of a wafer bunching comb forming part of the processing system illustrated in FIG. 1.

FIG. 11B is a cross-sectional view illustrating a groove of the comb of FIG. 11 A.

FIG. 12 is a perspective view of a semiconductor processor forming a part of the processing system illustrated in FIG. 1 and employing a novel door actuation and sealing mechanism.

FIG. 13 is a perspective view of the processor door actuation assembly.

FIG. 14 is a cross-sectional side view of the processor door in an open position.

FIG. 15 is a cross-sectional side view of the processor door in a closed position.

Detailed Description Of The Invention

FIGS. 1A, 1B, and 2 generally illustrate a processing system 10 which includes a basic frame 12 defining the walls of the processing system 10. Generally stated, the processing system 10 is divided into two principal sections -- an interface section 14 for receiving and inventorying semiconductor articles, and a processing section 16, which contains one or more processing stations 3 for processing the semiconductor articles using, for example, liquid and/or gaseous processing procedures.

As illustrated, the interface section 14 is preferably divided into a plurality of stations. In the disclosed embodiment, the interface section 14 is comprised of a container access station 5, an inventory station 6, a container docking station 7, and a wafer transfer station 8. In operation, wafer containers 51 are inserted into the processing system 10 through a door 32 at container access station 5. Each container 51 is then stored at the inventory station 6 until such time as the container is accessed by the components of the container docking station 7. A wall 11 effectively separates the stations 5, 6, and 7, from the wafer transfer station 8. To this end, wall 11 is provided with one or more doors against which each container 51 may seal and allow direct access of the wafers contained in the container 51 without contamination by the exterior surfaces of container 51. As such, the wafers in any given container 51 may be inserted into the processing section 16 of the processing system 10 without exposure to potentially contaminating environments.

With reference to FIGs. 1A and 1B, the frame 12 is constructed to form an enclosure that substantially encloses the processing system components and defines a working space 20. The semiconductor articles, such as semiconductor wafers, are held and maneuvered within the working space 20 in relative protection from dust and contamination. The working space 20 can be supplied with purge gas and/or operated at either slightly elevated pressures relative to ambient atmospheric pressure.

The upper portions of processing system 10 are sealed with respect to the ambient environment and may be provided with an interface filter above the interface section 14 and a processing filter above the processing section 16 to provide the requisite filtering of ambient air before it enters the processing area 20. These filter sections preferably employ HEPA type ultrafiltration filters. Air moving equipment, such as fans or the like forces air through the filters and downwardly into the working space 20.

The processing system 10 also has a process station maintenance section and an instrumentation and control section that are separated from the work space 20 by portions of the frame 12. Since these sections potentially have higher contamination levels due to the presence and operation of various equipment components associated with the processing stations, it is preferable to separate these sections from work space 20. The processing system 10 is preferably mounted in a wafer fabrication facility with clean room access to the front of the processor 15 and with gray room access to the maintenance section and the instrumentation and control section rearward of the work space 20. Such gray rooms require fewer precautions against contamination than clean rooms and, as such, they are less costly to build and maintain. The foregoing configuration thus reduces plant costs while allowing ready access to portions of the process system 10 more typically needing maintenance.

A front control panel 22 is disposed proximate the interface section 14 and allows operator control. The control panel 22 is preferably a touch screen cathode ray tube control display allowing finger contact to the display screen to effect various control functions. A secondary control panel may be included in the control section and accessed from the gray room so that operation can be effected from either front or back of the machine. All user programmable control functions and options are preferably displayed upon the control panel to effect operation and set up of the processing system 10 by a user.

Semiconductor wafers 50 are supplied to and removed from the enclosed work space 20 of processing system 10 through interface section 14. The wafers are supplied to the interface section in industry standard wafer containers or pods 51. The wafer containers are available from various manufacturers such as Empak, which sells a wafer container under the trademark CAPSIL.

As best illustrated in FIGS. 5a and 5b, the wafer container 51 has a cover 52 which, when removed, allows semiconductor wafers to be inserted into and removed from the wafer container. Typically, the cover 52 is translucent to allow visual detection and optical scanning of the wafers within the container 51. The wafer container 51 also includes a window 54 to permit viewing and optical scanning of the wafers. On the side opposite the window 54, the wafer container 51 is provided with features to facilitate handling of the wafer container 51 by automated equipment. These features include a set of inner circular slots 55, and a set of outer circular slots 56. The manner in which the disclosed embodiment of the processing system 10 interacts with these features will be explained in further detail hereafter. The wafer containers 51 are sealed and can be supplied with purge gas. The number of wafers positioned within the container 51 can vary, but at this time, the industry standard wafer containers typically have a capacity for 13 to 25 wafers having a diameter of 300 mm.

In the disclosed embodiment, the interface section 14 functions as both an input subassembly for receiving wafers to be processed, and an output subassembly for withdrawing processed wafers. Additionally, the interface section 14 can provide a holding or inventorying capability for both unprocessed and processed wafers. The interface section 14 includes an input/output subassembly, generally indicated by the numeral 30, which allows the wafer containers to be loaded into and removed from the processing system 10. The subassembly 30 is disposed in station 5 of the disclosed embodiment of the system 10.

The input/output subassembly includes an entry port, which is controllably opened and closed by the entry port door 32. The entry port door 32 may be pneumatically powered by an air cylinder 33 or the like to slide upwardly and downwardly on a guide track 34 to open and close the port. The components within the input/output subassembly 30 are preferably operated so that they will not move until the entry port door 32 is closed, thus enabling the port door to function as a safety mechanism for the operator.

When the entry port door 32 is opened, one or more wafer containers 51 may be loaded onto a loading elevator 40 within container access station 5. The loading elevator includes a container lift plate 42 which is adapted to receive a wafer container 51. In the disclosed embodiment, the container lift plate 42 is provided with coupling pins 44, which are mounted on the lift plate so that they are aligned and can be received within the respective inner slots 55 (Fig. 5b) provided on the industry standard wafer containers 51. As shown, the portion of the lift plate 42 between the coupling pins 24 is cut out, forming an almost pie-shaped cut-out 45. This cut-out portion 45 permits the wafer container 51 to be transferred to a loading plate 60, as will be described in further detail below. To assist with the positioning of the wafer container inner slots 55 onto the coupling pins 44 of the lift plate 42, the upper edge of the lift plate 42 is provided with at least one guide block 46. The lift plate 42 is carried on a guide track 47, and is raised to an overhead position and lowered to a loading/unloading position adjacent the entry port door 32 by operation of a pneumatic cylinder 48.

The loading elevator 40 allows the wafer containers to be loaded into the processing system in different ways. When the lift plate 42 is in its lower position adjacent the entry port door 32, the wafer container 51 can be loaded laterally onto the lift plate either via human loading or automated robot loading. When the lift plate 42 is raised to its overhead position, loading can be accomplished vertically through an access door disposed through the top of station 5 through use of an overhead transport system.

With the container lift plate 42 in its overhead position, a wafer container 51 can be loaded onto the loading plate 60 in the input/output subassembly. As show in FIG. 4, the loading plate 60 is provided with coupling pins 62, similar to the coupling pins 44 of the lift plate 42, except that the coupling pins 62 on the loading plate are aligned with and adapted to be received by the outer slots 56 (Fig. 5b) on the wafer container. The loading plate 42 also includes at least one mounting block 64 to assist in the positioning of the wafer container onto the loading plate. At its leading edge 65, the loading plate has a pie-shaped projection 66 that is slightly smaller than and complementary to the cut out portion 45 of the lifting plate. As best shown in FIG. 5b, the cut-out portion 45 allows the loading plate 60 to translate through the lift plate 42 to transfer a wafer container from the lift plate to the load plate, or vice versa, as described in further detail below.

The loading plate 60 is mounted on a guide track 70 for transverse horizontal movement in the direction of arrows 71 relative to the entry port door 32. The horizontal drive mechanism is preferably comprised of a motor drive and belt assembly 72, although other drive arrangements may be utilized. A second mounting and drive arrangement 75 mounts the loading plate 60 and includes various mounting arrangements and drive arrangements for moving the loading plate both vertically and rotationally about a vertical axis. The mounting and drive arrangement 75 include a drive arm 78 which is coupled via a mounting plate arrangement to the loading plate 60. The drive arm 78 is preferably driven vertically by a motor and lead screw drive arrangement 80 to raise and lower the loading plate 60. A motor and harmonic drive assembly 82 is coupled to the loading plate 60 to provide the rotational drive about a vertical axis 83. The motor and harmonic drive assembly 82 rotates the loading plate 90°, from a position in which the leading edge 65 of the loading plate is facing the entry port door 32, to a position in which the leading edge 65 is facing the container inventory subassembly 90 (see FIG. 1B). Each of the drive mechanisms preferably includes an incremental encoder to control the positioning of the loading plate 60 and an absolute encoder to determine the relative horizontal, vertical, and rotational position of the loading plate 60. The drive mechanisms operate in combination to position the loading plate 60 at the container inventory subassembly 90 (illustrated in FIG. IB) to permit the wafer containers 51 to be transferred to and from the container inventory subassembly 90.

The loading plate 60 can either receive a wafer container 51 from an operator through the entry port, or can receive a wafer container that has been placed and temporarily stored on the lift plate 42 to facilitate both input and output operation of the container access station 5. In order to transfer the wafer container from the lift plate 42 to the loading plate 60, the lift plate 42 is lowered to its load/unload position, and the loading plate 60 is rotated so that its leading edge 65 is facing the entry port door 32. In this position, the loading plate 60 is below the lifting plate 42. The loading plate 60 may then be raised so that the pie-shaped projection 66 of the loading plate translates through the cut-out portion 45 of the lifting plate 42. As best shown in FIG. 5b, during this action, the coupling pins 62 on the loading plate engage the outer slots 56 on the wafer container 51, while the coupling pins 44 on the lifting plate are removed from the inner slots 55 on the wafer container, thus accomplishing a complete transfer of the wafer container 51 to the loading plate 60. The loading plate 60 can then be rotated 90° to transfer the wafer container 51 to the inventory subassembly 90.

Referring to FIG. 6, the inventory subassembly 90 includes a central horizontal hub 92 with a plurality of arms 94 radially extending therefrom. In the present embodiment, the number of arms is six, although other numbers of arms can be employed. Mounted on the end of each arm is a container carrier 96 having an upper and a lower shelf 97, 98, respectively. A bearing and timing shaft arrangement 99 mounts each container carrier 96 to an arm 94. The bearing and timing shaft arrangement 99 may be coupled with a timing belt to insure that the upper and lower shelves 97, 98 of each container carrier 96 always remain horizontal regardless of the relative position of the arms about the central hub 92. Mounted on each arm 94 is a tension pivot assembly 106 which functions to reduce any play in the timing system. The upper and lower shelves 97, 98 of each container carrier 96 include coupling pins 102 which are positioned on each shelf so that they are aligned with the inner slots 55 on the standard wafer container 51.

A drive arrangement in the form of an indexer 104 with twelve preset index positions rotates the arms 94 with their container carriers 96 around the axis of the hub 92 from a preset loading position adjacent the input/output subassembly to a preset container transfer position 180° opposite the loading position. An absolute encoder 108 is mounted on the central hub 92 to detect the relative positions of the arms 94.

In normal operation, each of the shelves will have a wafer container mounted thereon (twelve altogether) to facilitate the continuous processing of a full complement of wafers without interruption. The inventory subassembly 90 can, however, handle fewer than twelve wafer containers 51 depending on the batch processing requirements of the system user.

Detectors, such as, for example, optical sensors, can be mounted in fixed relationship with the frame 12 and positioned to optically scan the semiconductors wafers within the wafer containers as the containers are rotated about the central hub 92. Preferably, such detectors are placed at a location adjacent the interface between the input/output subassembly 30 and the container inventory subassembly 90, and at a location adjacent the interface between the container inventory subassembly 90 and a container docking subassembly 110. Such optical scanning allows the processing system 10 to keep track of all wafers as they are processed through the system.

In operation, the indexer 104 rotates the arms 94 until a shelf on one of the container carriers 96 reaches a preset loading position adjacent the input/output subassembly 30. A wafer container 51 may then be transferred from the loading plate 60 to the respective container shelf by moving the loading plate 60 until it is positioned above the shelf, rotating the loading plate until the inner slots 55 on the wafer container 51 are aligned with the coupling pins 102 on the shelf, and lowering the loading plate 60 so that the inner slots 55 are received by the coupling pins 102. The loading plate 60 may then be rotated slightly to clear it from the shelf and then withdrawn. To unload the wafer container 51 from the inventory subassembly 90 for processing, the arm and the container shelf holding the wafer container 51 can be rotated 180° about the hub so that the wafer container can be accessed by the container docking subassembly 110 disposed in the container docking station 6.

As best illustrated in FIG. 2, the container docking subassembly 110 includes a robotic conveyor 111 comprising a robotic arm 112 mounted on a carriage 114 for linear movement along a guided track 115. The robotic arm 112 of the disclosed embodiment has three jointed segments - a lower or first segment 116 mounted to the carriage 114, a middle or second segment 117 linked to the first segment via a timing belt arrangement or the like, and an upper or third segment 118 linked to the second segment. This robotic arm construction enables the arm to move up, down and back and forth while occupying a minimum amount of space. The third segment 118 has a horseshoe shaped appearance and permits the robotic arm to lift and separate the wafer container 51 from a container shelf within the container inventory subassembly 90. Coupling pins 122 positioned on the third segment are adapted so that they may contact and be received within the outer set of slots 56 on the wafer container 51 to complete the transfer to the robotic arm 112.

The carriage 114, together with the robotic arm 112, slide along the guided track 115 to a position adjacent to a container transfer subassembly, generally indicated at numeral 150. As illustrated in FIG. 7, the container transfer subassembly includes a docking plate 152 mounted on a linear slide 154 for movement in the direction of arrows 151. Coupling pins 156 are positioned on the docking plate 152 so as to align with the inner slots 55 on the wafer container 51. The docking plate 152 also includes an aperture 158 for receiving a latch hook 160 which is sized and adapted to latch into a groove or the like located on the door of the wafer container 51. The latch hook 160 may be mounted on a pneumatic slide which permits the latch hook to move towards and away from the wafer container 51 to latch and unlatch the wafer container 51. Roller guides 164 are provided on the latch hook 160 to facilitate contact and engagement of the latch hook with the wafer container. An overhead frame 166, mounted to the docking plate 152, houses sensors for detecting the presence of wafers within the wafer container. Another sensor, such as a fiber optic cable, may be used to detect the presence of a wafer container on the docking plate.

The linear slide arrangement 154 slides the docking plate 152 into a position adjacent a hatch interface, generally indicated by numeral 180 in FIGs. 1B, 8A and 8B. The hatch interface 180 is disposed in the wafer transfer station 8. Referring now to FIGs. 8A and 8B, the hatch interface 180 includes a hatch cover 182 which supports an interface plate 184 that is sized and adapted for sealing engagement with the door of the wafer container 51. The interface plate supports a perimeter seal 186 which seals the interface plate 184 with the wafer container door.

Vacuum cups 188 fit through apertures 190 in the interface plate to make vacuum sealing contact with the wafer container door and secure the door to the interface plate. T-shaped locking keys also extend through apertures in the interface plate and insert into receptors in the wafer container door. A rotary actuator 194 turns the locking keys to lock the wafer container door into sealing engagement with the interface plate. In the event of a loss of vacuum through the vacuum cups 188, the T-shaped keys help to retain the container door against the interface plate 184. The hatch cover 182 and interface plate 184 are mounted to a pneumatic cylinder assembly 196, comprised of cylinder assemblies 196a and 196b, which allow the hatch cover and interface plate to slide forward and backward, and up and down, relative to the wafer container.

In operation, vacuum is applied to the vacuum cups 188 so that the container door is held in vacuum sealing relationship with the interface plate 184. The vacuum seal traps any contaminants that might be on the container door and prevents them from entering into the processing section. The actuator 194 turns the keys to lock the container door to the interface plate. The pneumatic cylinder assembly 196a slides the interface plate 184 and hatch cover 182 backwards (i.e. away from the container), causing the container door to move with the interface plate. This opens the container and exposes the interior of the container to the clean environment of the processing section. The pneumatic cylinder assemblies 196a and 196b then cooperate together to slide the interface plate 184 and the hatch cover 182, together with the container door, downward, and then forward (i.e. toward the container) to move the door out of the way for handling and processing of the wafers.

In a preferred embodiment, the processing system is provided with two container transfer subassemblies 150, and two hatch interfaces 180, as generally illustrated in FIG. 2, that are disposed within and proximate to the container docking station 7. This allows one container transfer subassembly 150 to handle wafer containers 51 holding unprocessed wafers, while the other subassembly 150 handles containers 51 holding processed wafers, thus permitting efficient handling of the wafers.

The wafers are removed from the container 51 by a wafer transfer subassembly 200 disposed in the wafer transfer station 9. The wafer transfer subassembly 200 includes a wafer comb 202 (see FIGs. 9a and 9b) mounted on a carriage assembly 230 (see FIG. 10). Referring now to FIGs. 9a and 9b, the wafer comb 202 comprises an outer comb frame 204 having outwardly extending engagement arms 208, each of which carries a set of teeth 210 at the outer end thereof. The middle portion of the outer comb frame also carries a middle set of teeth 212. A complementary-shaped inner comb frame 214 has an outer set of teeth 220 mounted on the outer ends of each of its engagement arms 218 and a middle set of teeth 222 mounted on the middle portion of the frame. The inner comb frame is positioned adjacent the outer comb frame such that the middle set of teeth 212 on the outer comb frame extend through an opening 224 in the inner comb frame, and the outer and middle sets of teeth 220, 222, respectively on the inner comb frame are adjacent the corresponding sets of teeth on the outer comb frame.

The outer comb frame 204 is slideable vertically with respect to the inner comb frame 214. The inner comb frame 214 is in fixed positional alignment with the carriage assembly 230. When the outer comb frame is in its lowest position, the teeth on the outer comb frame are aligned with the teeth on the inner comb frame in an "open" wafer comb position. In this position, the wafer comb 202 can be inserted into the open wafer container until the teeth of the wafer comb are interleaved with the wafers in the container. The wafers are held within the wafer comb by slightly lifting the outer comb frame 204 to the "closed" wafer comb position illustrated in FIGS. 9a and 9b. Various mechanisms, such as a lead screw driven by a stepper motor, can be used to actuate lifting of the outer comb frame 204. In this closed position, the teeth on the outer comb frame are offset with respect to the teeth on the inner comb frame, causing the wafers to be cantilevered on the outer comb frame teeth. The wafer comb is designed such that the individual teeth are canted down at a slight angle from horizontal, such as a 10 mm pitch, to insure that the wafers remain positioned within the wafer comb.

To insure proper positioning of the wafers within the wafer comb, it may be desirable to provide the wafer comb with sensors. In one embodiment, sensors 226 are provided at each tooth of the middle set of teeth 212 on the outer comb frame 204.

The carriage assembly 230 which mounts the wafer comb 202 is itself mounted on a guide track 232 for linear movement toward and away from the open wafer container 51. The carriage assembly 230 includes a rotary drive mechanism 234, such as a rotary motor 236 and harmonic drive 238, for rotating the wafer comb 90° about a horizontal axis, from a horizontal position, to a vertical position, best shown in FIG. 2. The carriage assembly 230 also includes a vertical drive mechanism 240 for lifting the wafer comb so that the wafer comb can deposit the wafers onto a wafer support in the form of a wafer bunching comb 250 (see FIG. 2).

Referring to FIGs. 11A and B, the wafer bunching comb 250 has an upper surface 252 on which is provided a series of wafer-receiving grooves 254. Each of the grooves has downwardly converging receiver sides 256 which adjoin a relatively narrow slot section 258. The slot section has substantially parallel side walls and is sized to provide a width about 0-10% greater than the thickness of the wafers being received therein. The receiver sides help to insure proper insertion of the wafers within the grooves while minimizing contact with the wafer surface. The upper surface 252 and the slot sections therein are dimensioned to form an arc that generally corresponds to a segment of the diameter of the wafer. The particular number of grooves in the wafer bunching comb may vary. Typically there will be 26 to 50 grooves in order to correspond with the capacity of two of the associated wafer containers being used, so that the wafers from two wafer containers can be processed at once. Sensors 260 are provided on the upper surface 252 to detect the proper positioning of the wafers within the grooves.

The wafer bunching comb 250 has a longitudinal slot 262 that is sized to permit the vertical drive assembly 240 (see FIG. 10) of the wafer comb to pass therethrough. The vertical drive assembly 240 can lift the wafer comb until it is slightly higher than the wafer bunching comb 250, and the horizontal drive assembly can linearly move the wafer comb until the vertical drive assembly is positioned within the longitudinal slot and the wafers are aligned with the grooves in the wafer bunching comb 250. The wafers can then be lowered in a controlled fashion into the grooves in the wafer bunching comb.

Once the wafers are in place in the wafer bunching comb 250, the docking assembly steps can be reversed so that the container door can be replaced onto the wafer container, the wafer container can then be retracted from the interface plate, and placed back onto a wafer container shelf of the inventory subassembly. The entire docking and wafer transfer processes can then be repeated so that the wafers from two wafer containers are positioned on the wafer bunching comb 250.

FIGS. 1B, 1C, and 2 show a robotic conveyor, generally indicated by the numeral 280, for conveying the wafers within the processing system, specifically between, to and from the bunching comb 250 and one or more processing stations, such as processing stations 290. The robotic conveyor 280 includes a mounting beam or rail 282 upon which a movable conveyor robot subassembly 284 is mounted and moves relative to the rail.

The robotic device can be of various designs. In one design, the robotic conveyor comprises an articulated arm having an upper arm portion 285, a lower arm portion 286, and a hand portion 287. Mounted to the hand portion is an engagement tool 288 for engaging the semiconductor wafers and delivering them to various individual or plural work stations. Further details of suitable conveyor devices and other aspects of the processing system are described in U.S. Patent No. 5,544,421, issued August 13, 1996; U.S. Patent No. 5,660,517 issued August 26, 1997; and U.S. Patent No. 5,664,337, issued September 9, 1997, each of which is herein incorporated by reference.

FIG. 1C illustrates flow of semiconductor wafers as they are processed by the processor 10. As illustrated, the pods 51 are first place in the insertion station 5. The components of the insertion station 5 rotate the pod 51 and place it on the inventory subassembly 90 of the inventory station 6 where they remain until such time as the wafers contained therein are to be processed. When the wafers of a pod 51 are to be processed, the respective pod 51 is removed from the inventory subassembly 90 by one of the docking subassemblies 150. The docking subassembly 150 transports the pod to the hatch interface where the wafers are removed from the pod without being exposed to the ambient atmospheric conditions of the interface section. Rather, the wafers are only exposed to the clean environment of the workspace area 20. After extraction, the wafers are presented to the wafer conveying system 280 which transports them for processing in the appropriate processing station(s) 290. After removal from the processing station(s), the wafers are returned to the same or different pod and the pod is sealed without exposing the wafers to the ambient atmospheric conditions of the interface section. The respective docking subassembly 150 then returns the pod containing the processed wafers to the inventory subassembly 90 where the pod is stored until such a time as the wafers therein are to undergo further processing within the work space 20 or until they are removed through station 5 by an operator as directed, for example, through control panel 22.

The processing section of the processing system includes at least one and preferably a plurality of individual processing stations 290 which can be of various construction. Further details with respect to suitable processions stations, and more specific explanation about the loading (installing) and unloading of the wafers into the processing stations are described in U.S. Patent No. 5,664,337, issued September 9, 1997, which is herein incorporated by reference.

Referring to FIGS. 12 through 15, each processing station 290 includes a processing vessel 292 which partially encloses a processing bowl. The processing vessel also mates with a movable door 512 which can be moved between the closed position shown in FIG. 12, and a retracted position shown in phantom outline. The disclosed embodiment of the processing system 10 includes an improved door assembly 500 for the processing vessel.

Referring to FIGS. 12 and 13, the door assembly 500 is in fixed positional alignment with a front wall 502 of a processing vessel. The front wall 502 is provided with an access opening, defined here by a circular opening 506 of the front wall (best illustrated in FIG. 15). When the front wall 502 is mounted to the remaining portions of the processor, the opening periphery 506 is positioned to be in alignment with an access opening 507 (See FIG. 15) formed in the front wall of the processor bowl 294.

The door assembly 500 further includes a door support plate 510 which mounts a door 512 and a door extension and retraction operator 514. The door 512 includes a stiffening plate 504 and a viewing window 508 that permits visual inspection of the processing chamber defined by the bowl 294. The door extension and retraction operator 514 of the disclosed embodiment includes a stationary outer cylinder 516 coupled to the door support plate 510, and an operative extension part 518. The operative extension part 518 is concentrically positioned inside of the outer cylinder 516 for controllable extension and retraction relative to the outer cylinder. Additional features and the operation of the door extension and retraction operator 514 are discussed in greater detail below.

The door support plate 510 includes a viewing aperture 520 for providing visibility through the window 506 into the processing chamber contained within the bowl 294 of the processor. The door support plate 510 is coupled on each side to slideable guide brackets 522 using, for example, conventional fasteners. Each slideable guide bracket 522 is slideably mounted to a respective pneumatic band cylinder 524. The band cylinders 524 are connected to the front wall 502 of the processing vessel via mounting plates 528. The combination of the guide brackets 522, the band cylinders 524, and the mounting plates 528 provides a simplified and rigid door mounting construction that needs no additional guides or support blocks. The guide brackets 522 are mounted for substantially vertical movement so that the door assembly can be moved between an open or fully displaced position to allow access into the bowl of the processor, and a closed position wherein the door assembly is in substantially concentric alignment with the access opening. In the closed position, the door can be extended into the access opening and sealed against the bowl of the processor.

Referring to FIGS. 14 and 15, which show sectional views of the door assembly 500, the movement of the extension part 518 relative to the outer cylinder 516 is explained in greater detail. To this end, an annular inner stationary cylinder 530 has an annular flange portion 532 and an axially extending ring portion 534. The annular flange portion 532 is securely mounted on its outer side upon the door support plate 510. At the point of mounting, the annular flange portion is bounded on its opposite side by the outer cylinder 516. A plurality of fasteners secure the outer cylinder 516 and the annular flange portion 532 to the mounting plate 510.

The extension part 518 is concentrically positioned between the inner cylinder ring 530 and the outer cylinder 516, and includes a U-shaped portion 519 that defines an annular guide receptacle 520. As illustrated in FIG. 14, the axially extending ring portion 534 fits within the annular guide receptacle 520. The extension part 518 also includes an annular piston portion 540. The annular piston portion 540 rides within an annular piston operation chamber

542 defined by the ring portion 534 and the outer cylinder 516.

The piston 540 bifurcates the piston operation chamber 542 into two operative compartments: a retraction chamber compartment 543 and an extension chamber compartment 544. Each piston chamber compartment is adapted to hold pneumatic or hydraulic fluid. Multiple annular seals 550 are positioned about the piston 540 and the extension part 518 to seal separate fluid within the chambers 543 and 544.

Separate fluid supply conduits are preferably provided to the retraction chamber 543 and the extension chamber 544 to increase or decrease fluid pressure within the respective chambers and effectuate movement of the piston. As shown in FIG. 15, when hydraulic fluid is supplied under an increased pressure to the extension chamber 544, a pressure differential is created on the piston 540 which will cause the extension part 518 to extend away from the door support plate. Movement of the extension part 518 and the integral piston 540 into the extended position shown in FIG. 15 moves the door into sealing engagement with the access opening 506 formed in the front wall 502 of the processor bowl, thereby closing the semiconductor processor. Mounted on the periphery of the door 512 is an annular door seal 551. Preferably, the door seal is formed of Teflon using known machining techniques. The door seal includes an axially extending shroud portion 552 and an annular tongue portion 554. When the door is in the closed position shown in FIG. 15, the shroud portion 552 of the door seal lies in a plane that is within the front wall of the processor, and the tongue portion presses in sealing engagement against the outside rim of the processor bowl, thereby effectuating a seal between the door and the processor bowl. The door seal also preferably includes a flange portion 555 which acts as a stop for the door seal.

The combination of the piston 540 and the door seal 550 provides a highly reliable and effective door closing and sealing mechanism. Movement of the piston allows the extension part to move the door outwardly from the support plate equidistantly at all times without the need for peripheral adjustments to ensure equidistant movement. By seating against the outside rim of the processor bowl, the tongue portion provides an effective fluid tight seal and automatically compensates for any misalignment between the door and the processor.

Numerous modifications may be made to the foregoing system without departing from the basic teachings thereof. Although the present invention has been described in substantial detail with reference to one or more specific embodiments, those of skill in the art will recognize that changes may be made thereto without departing from the scope and spirit of the invention as set forth in the appended claims.

Claims

1. A processor for processing articles in a substantially clean atmosphere, the processor comprising:

an enclosure defining a substantially enclosed clean processing chamber;

at least one processing station disposed in the processing chamber;

an interface section disposed adjacent an interface end of the enclosure, the interface section including at least one interface port through which a pod containing articles for processing are loaded or unloaded to or from the processor, the interface section being hygienically separated from the processing chamber;

an article extraction mechanism adapted to seal with the pod and disposed to allow extraction of the articles contained within the pod into the processing chamber without exposing the articles to ambient atmospheric conditions in the interface section.

2. An article processor as claimed in claim 1 and further comprising an article insertion mechanism adapted to seal with a pod disposed in the interface section, the article insertion mechanism being disposed to allow insertion of the articles into the pod after processing by the at least one processing station, the article insertion mechanism allowing the insertion of the articles without exposing the articles to ambient atmospheric conditions in the interface section.

3. An article processor as claimed in claim 1 wherein the article extraction mechanism automatically seals with the pod and automatically extracts the articles contain therein.

4. An article processor as claimed in claim 1 wherein the article insertion mechanism automatically seals with the pod and automatically inserts the articles therein.

5. An article processor as claimed in claim 1 and further comprising at least one conveyor for conveying the articles to the at least one processing station from the article extraction mechanism.

6. An article processor as claimed in claim 2 and further comprising at least one conveyor for conveying the articles from the at least one processing station to the article insertion mechanism.

7. An article processor as claimed in claim 1 wherein the interface section further comprises an inventory station disposed along a pod transfer path between the interface port and the article extraction mechanism.

8. An article processor as claimed in claim 1 wherein the article extraction mechanism comprises an automatic hatch mechanism for sealing with and removing an opening cover of the pod.

9. An article processor as claimed in claim 8 wherein the article extraction mechanism further comprises an article carriage assembly for engaging and removing the articles through an opening left by the removal of the opening cover of the pod.

10. An article processor as claimed in claim 2 wherein the article insertion mechanism comprises an automatic hatch mechanism for sealing with and placing an opening cover on the pod.

11. An article processor as claimed in claim 10 wherein the article extraction mechanism further comprises an article carriage assembly for engaging and inserting the articles through an opening present before placement of the opening cover of the pod.

12. An article processor as claimed in claim 1 wherein the articles are semiconductor wafers.

13. An article processor as claimed in claim 12 wherein the at least one processing station executes a processing operation on the semiconductor wafers using a liquid or gaseous process.

14. A processor for processing articles comprising:

an enclosure for providing a substantially enclosed workspace therewithin;

an interface section located adjacent an interface end of the enclosure, the interface section including at least one interface port through which sealed article containers contain articles are loaded or unloaded to or from the processor;

an article inventory subassembly disposed within the interface section for holding a plurality of sealed article containers;

a container docking subassembly receiving sealed article containers from the article inventory subassembly for opening and closing the containers without exposing the articles to ambient atmospheric conditions within the interface section;

an article transfer subassembly cooperating with the article containers through an open end thereof exposed by the container docking subassembly for extracting the articles from the article containers;

at least one processing station, the processing station having an access opening which opens to the work space to allow installation and removal of articles relative to the at least one processing station;

at least one conveyor for conveying the articles to and from the at least one processing station and the article transfer subassembly.

15. A semiconductor processor according to claim 14 wherein the processor includes an input/output subassembly within the interface section and adjacent to the at least one interface port.

16. A semiconductor processor according to claim 15 wherein the input/output subassembly includes an elevator for receiving a sealed article container.

17. A semiconductor processor according to claim 16 wherein the elevator comprises a vertical guide track and an elevator lift plate slideably engaged on the guide track.

18. A semiconductor processor according to claim 15 wherein the input/output subassembly includes a loading plate for receiving a sealed article container.

19. A semiconductor processor according to claim 16 wherein the input/output subassembly includes a loading plate for receiving a sealed article container, and the loading plate and the elevator lift plate are provided with cooperating features that permit the loading plate to translate through the elevator lift plate.

20. A semiconductor processor according to claim 18 wherein the loading plate is rotatable about a vertical axis.

21. A semiconductor processor according to claim 14 wherein the article inventory subassembly includes a

plurality of container shelves adapted for receiving the sealed wafer containers.

22. A semiconductor processor according to claim 21 wherein the container shelves are mounted on arms that radially extend from a central horizontal hub.

23. A semiconductor processor according to claim 14 wherein the article inventory subassembly comprises:

a plurality of arms radially extending from a central horizontal hub;

a container carrier mounted on each arm opposite the central horizontal hub;

at least one container shelf disposed on each container carrier and adapted to receive a sealed wafer container.

24. A semiconductor processor according to claim 22 wherein the arms are rotatable about the central horizontal hub.

25. A semiconductor processor according to claim 23 wherein the arms are rotatable about the central horizontal hub.

26. A semiconductor processor according to claim 14 wherein the container docking subassembly includes a robotic conveyor for receiving the sealed article containers from the article inventory subassembly.

27. A semiconductor processor according to claim 26 wherein the robotic conveyor includes a carriage moveably mounted upon a track.

28. A semiconductor processor according to claim 27 wherein the robotic conveyor includes a robotic arm mounted to the carriage.

29. A semiconductor processor according to claim 28 wherein the robotic arm comprises:

a first segment mounted on the carriage;

a second segment connected to the first segment for pivotal motion at an elbow joint; and

a third segment connected to the second segment and adapted to engage a sealed wafer container.

30. A semiconductor processor according to claim 26 wherein the container docking subassembly includes a hatch interface which forms a vacuum lock when the sealed article container is in an engaged position therewith.

31. A semiconductor processor according to claim 30 wherein the hatch interface is mounted to a carriage for slideable movement therewith.

32. A semiconductor processor according to claim 30 wherein the container docking subasembly includes a container transfer which operatively transfers the sealed article container between the robotic conveyor and the hatch interface.

33. A semiconductor processor according to claim 32 wherein the container transfer includes a container docking plate adapted to engage the sealed article container.

34. A semiconductor processor according to claim 33 wherein the container docking plate is mounted to a carriage for slideable movement between the robotic conveyor and the hatch interface.

35. A semiconductor processor according to claim 14 wherein the article transfer subassembly includes engagement arms having engagement arm article supports thereon which directly engage and simultaneously move a plurality of semiconductor articles from and to the article container.

36. A semiconductor processor according to claim 15 wherein the engagement arms are mounted to a carriage for rotation about a horizontal axis.

37. A semiconductor processor according to claim 35 wherein the article transfer subassembly includes an article support having a plurality of slots which directly receive the plurality of semiconductor articles from the engagement arms.

38. A semiconductor processor according to claim 14 wherein the at least one processing station comprises:

a processing enclosure for receiving one or more articles for processing, the enclosure having an access opening through which the semiconductor articles are installed into and removed from the enclosure, the access opening being at least partially defined by an opening periphery;

a door guide mounted to the processing enclosure;

a door assembly mounted upon said guide;

the door assembly including an outer cylinder and an extension part concentrically aligned with the outer cylinder; the extension part being axially movable relative to the outer cylinder for controllable extension or retraction relative thereto;

an actuator for actuating the extension part into extended and retracted positions; and

a seal for sealing between the door assembly and the opening periphery of the access opening.

39. A semiconductor processor for processing semiconductor articles comprising:

a processing enclosure for receiving one or more articles for processing, the enclosure having an access opening which is at least partially defined by an access opening peripheral lip;

a door support frame mounted to the processing enclosure;

a door assembly mounted upon the door support frame, the door assembly including a fixed portion and an extension portion, the extension portion being movable relative to the fixed portion for controllable extension or retraction relative thereto;

an extension part actuator for actuating the extension part into extended and retracted positions;

a seal for sealing between the door assembly and the peripheral lip of the access opening.

40. A semiconductor processor according to claim 39 wherein the seal has an annular sealing surface which seals against the peripheral lip of the access opening.

41. A semiconductor processor according to claim 39 wherein the extension part actuator includes a piston.

42. A semiconductor processor according to claim 41 wherein the piston is annularly shaped and extends integrally from the extension part and is received within an annular chamber.

43. A semiconductor processor according to claim 39 wherein the door support frame is constructed to allow translational movement of the door assembly relative to the access opening.

44. A semiconductor processing according to claim 39 wherein the door support frame is constructed to allow translational movement of the door assembly relative to the access opening, the door support frame comprising at least one door guide.

45. A door assembly adapted for use in a semiconductor processor for processing semiconductor articles comprising:

at least one guide adapted to be connected to a processing enclosure having an access opening which is at least partially defined by a peripheral lip;

a door assembly mounted upon the guide, the door assembly including a fixed member and an extension member, the extension member being positioned in concentric alignment with the fixed member and being axially movable relative thereto between extended and retracted positions;

an actuator operatively coupled to the door assembly for actuating the extension member between the extended and retracted positions; and

a seal mounted on the door assembly for sealing between the door assembly and the peripheral lip when the extension member is in the extended position.

46. A door assembly according to claim 45 wherein the actuator is a piston.

47. A door assembly according to claim 46 wherein the piston extends integrally from the extension member, the piston being received within an annular chamber.

48. A door assembly according to claim 45 wherein the door assembly is movable along the guide between an aligned position, in which the door assembly is aligned with the access opening, and a displaced position.

49. A door assembly according to claim 45 wherein the seal has an annular sealing surface which seals against the peripheral lip of the access opening.

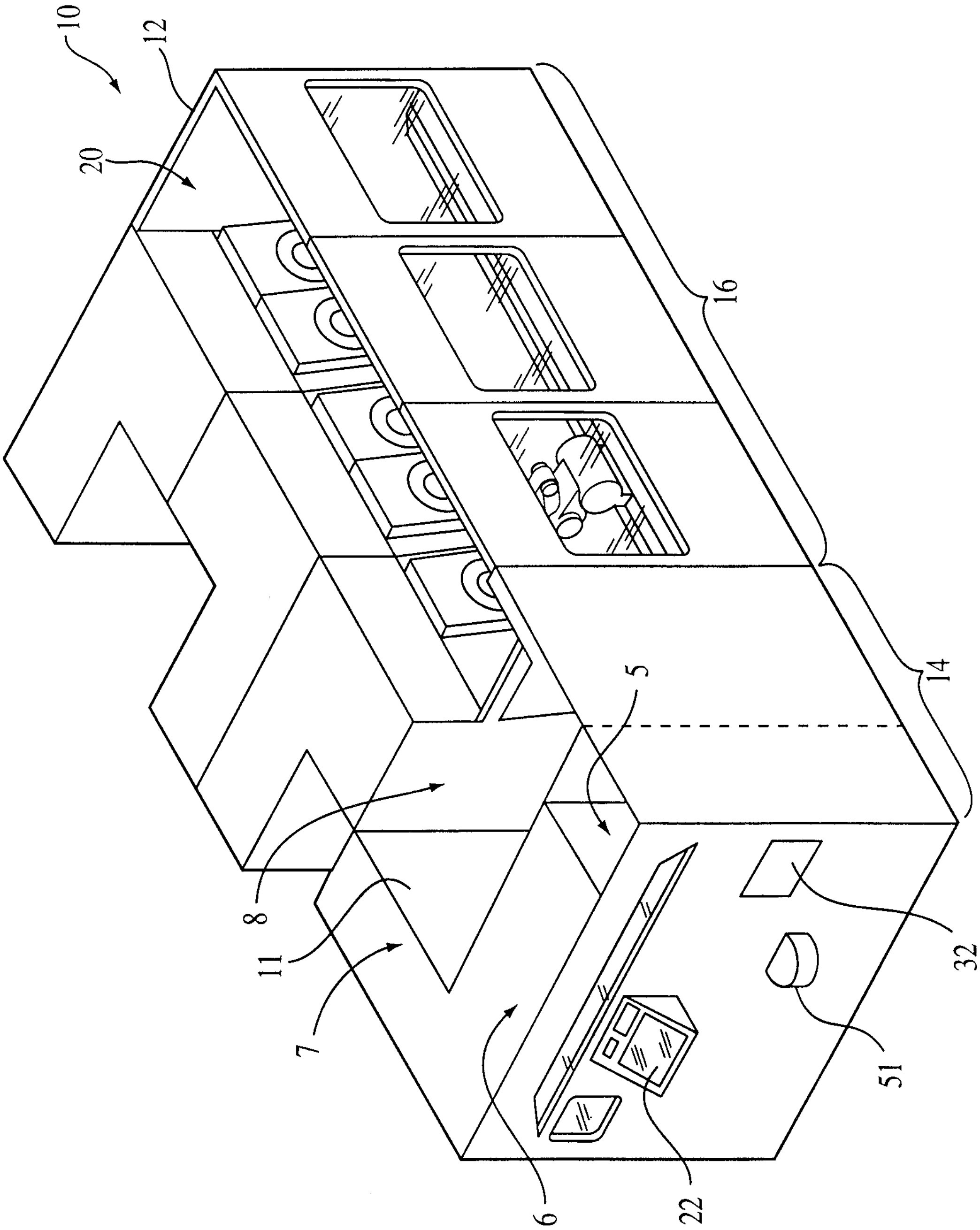

FIG. 1A

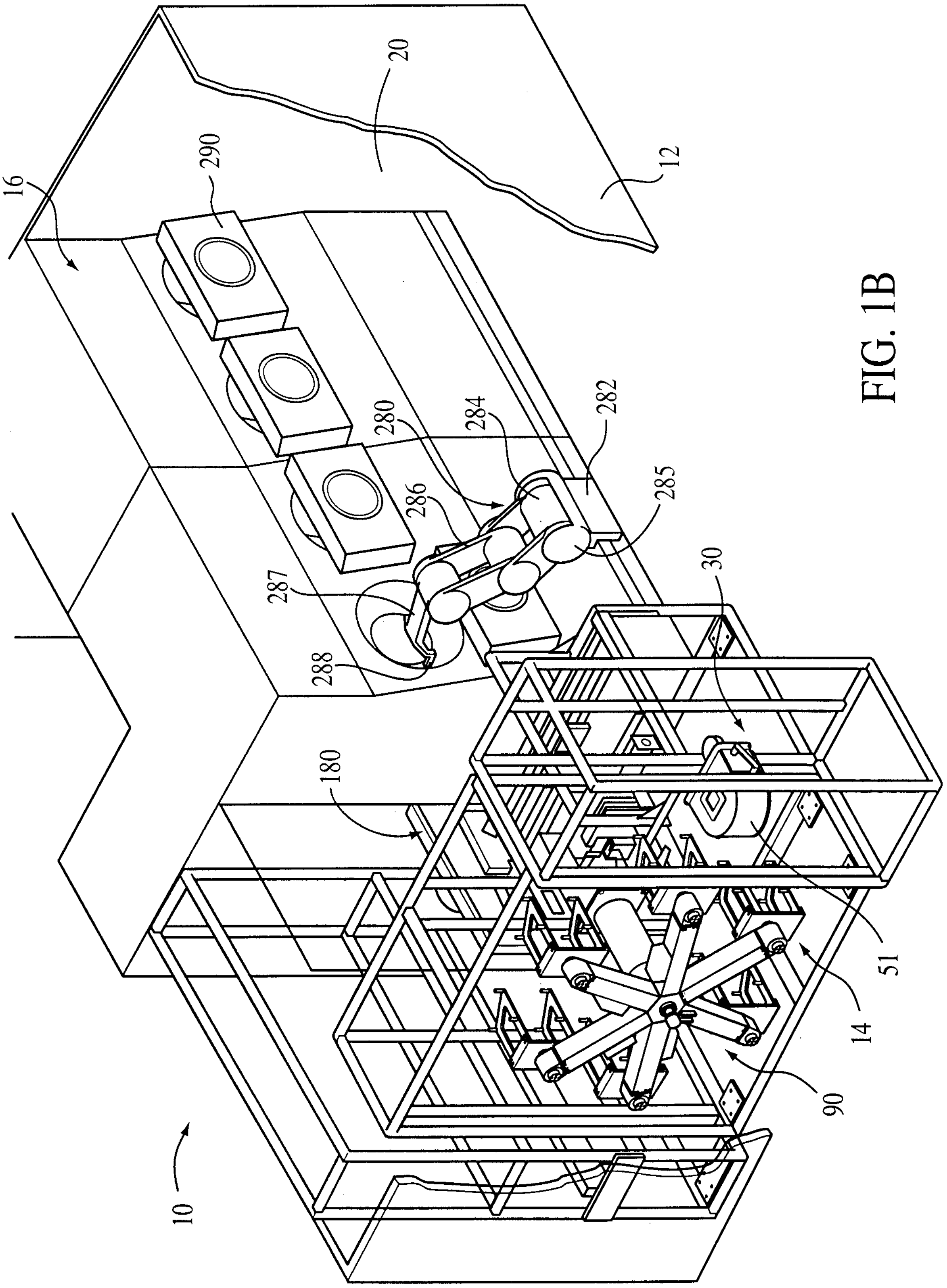

FIG. 1B

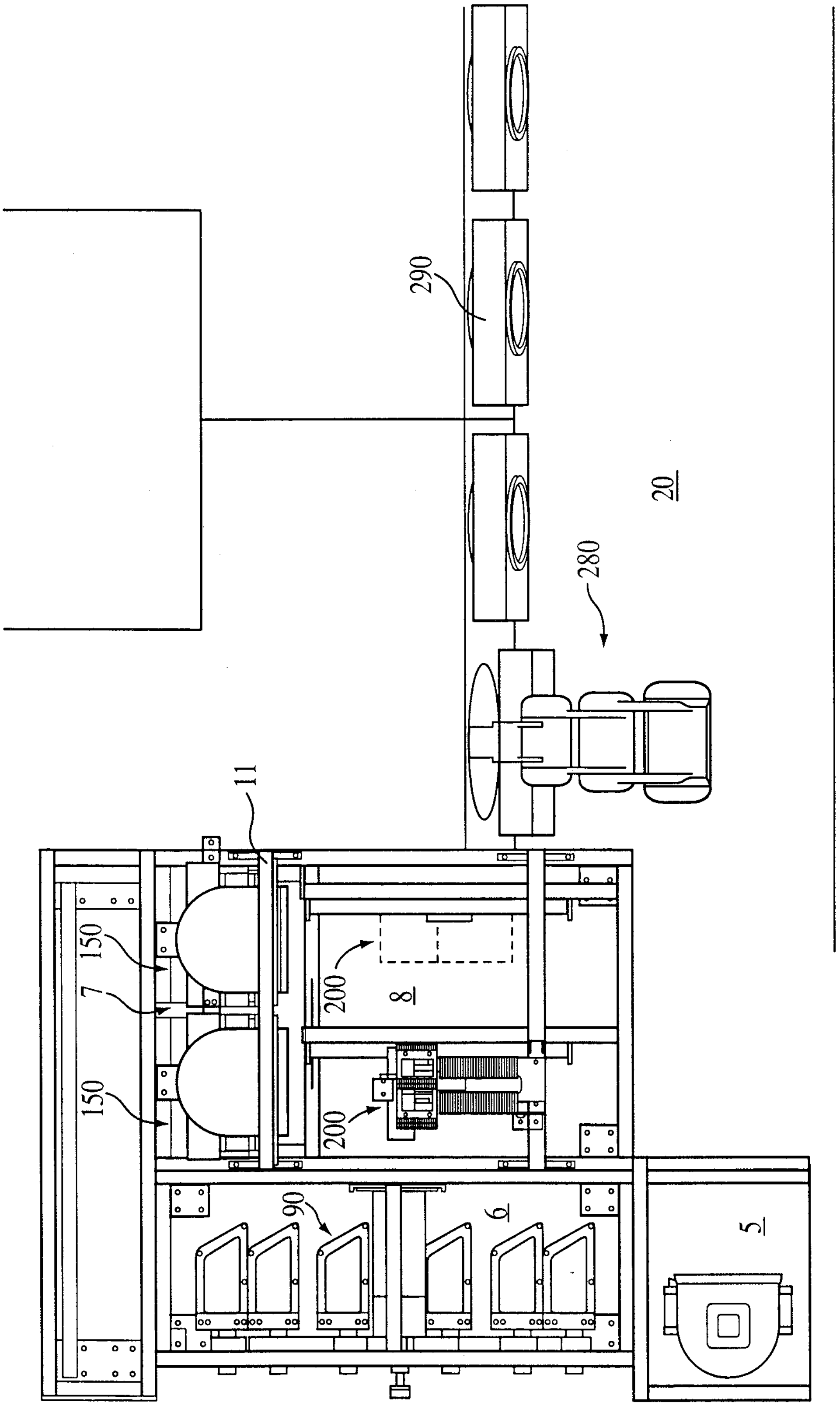

FIG. 1C

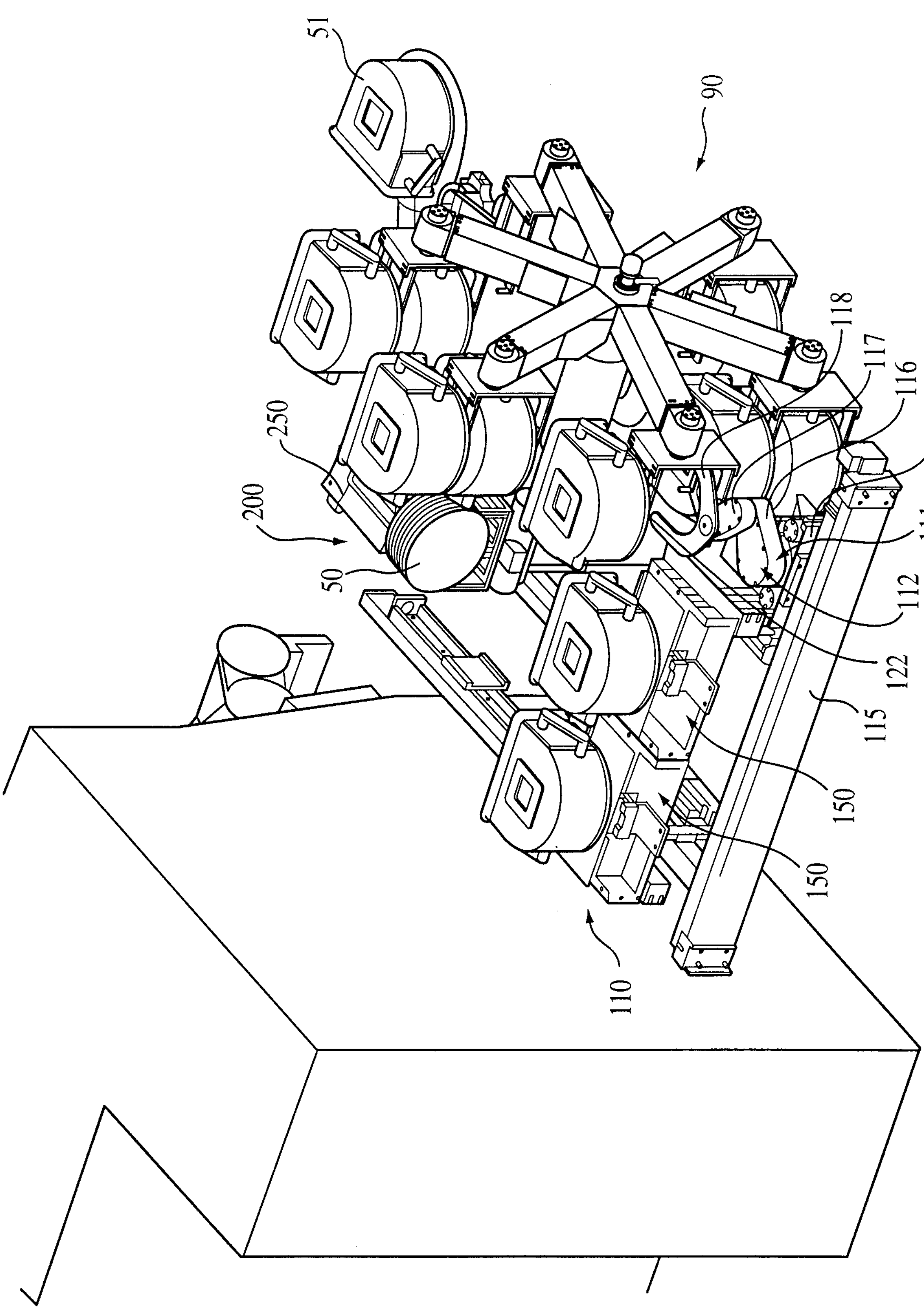

FIG. 2

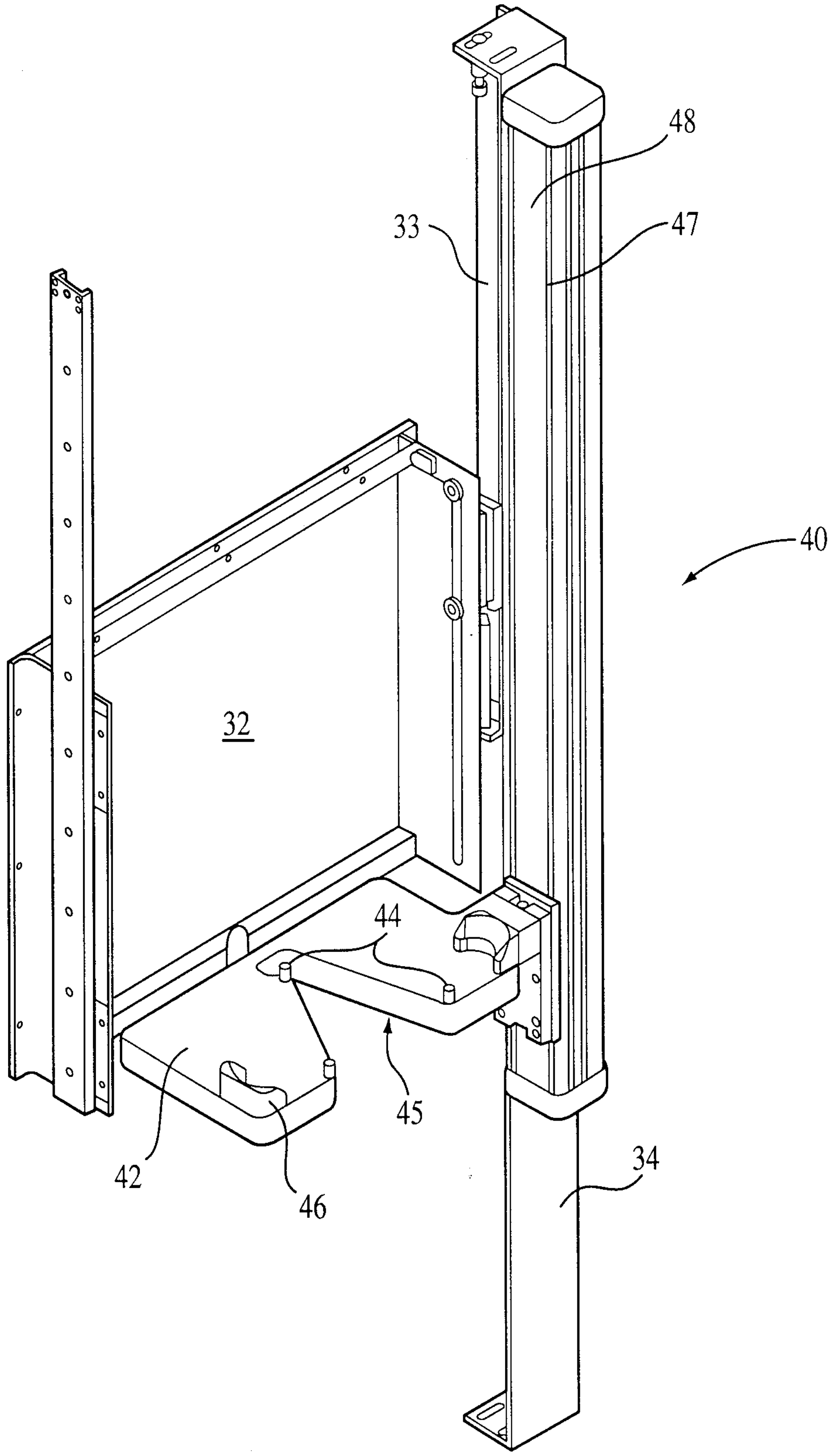

FIG. 3

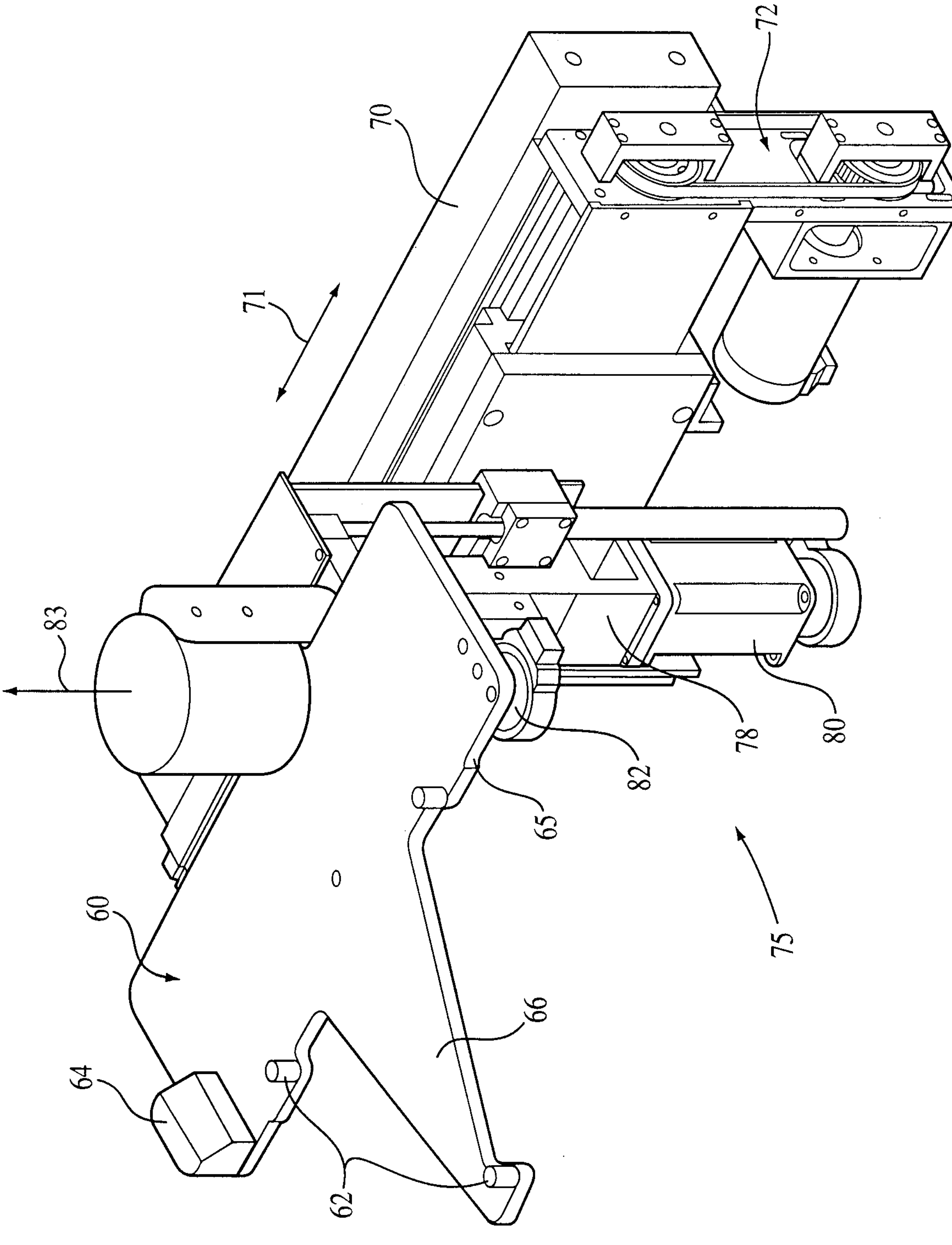

FIG. 4

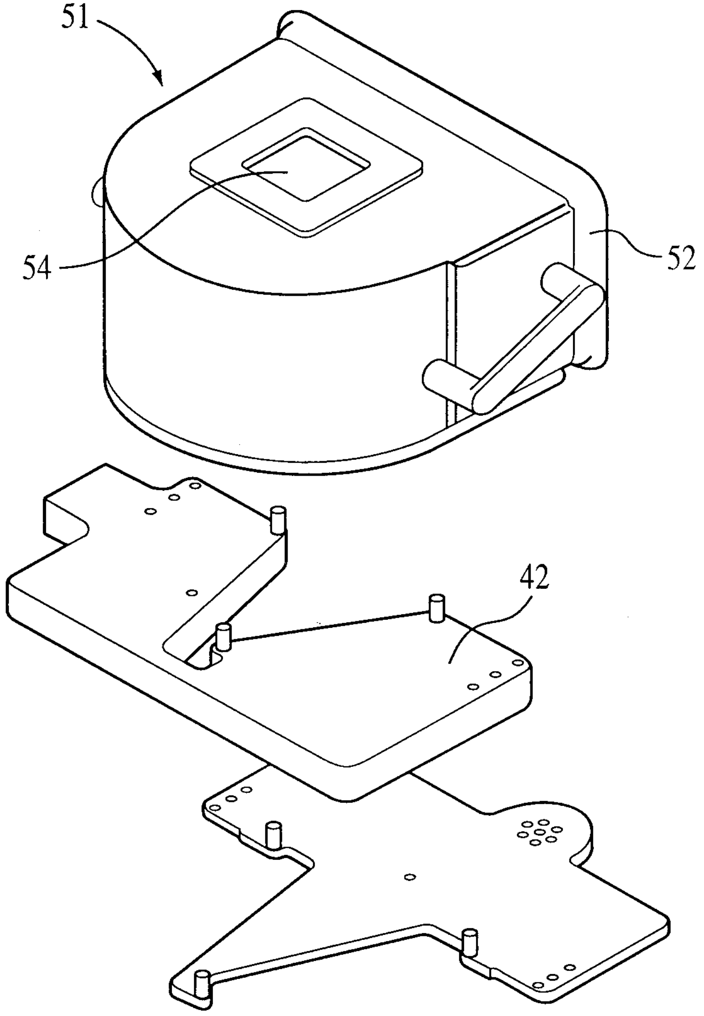

FIG. 5A

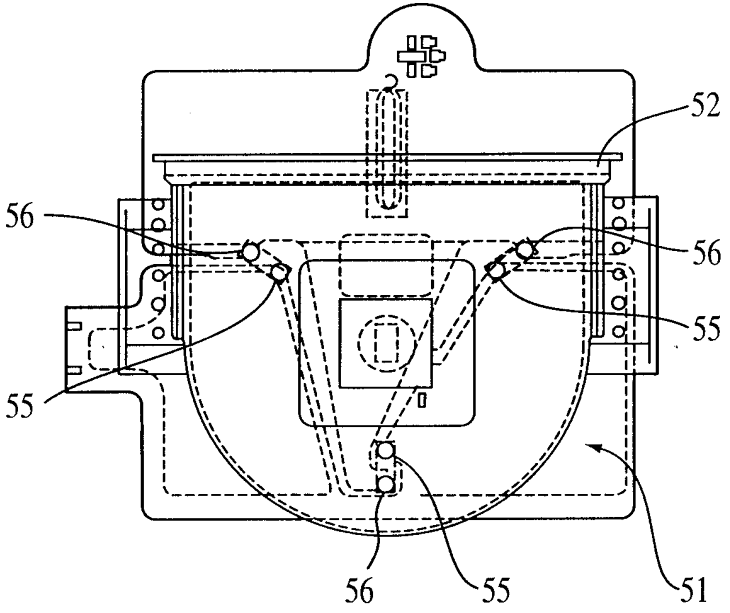

FIG. 5B

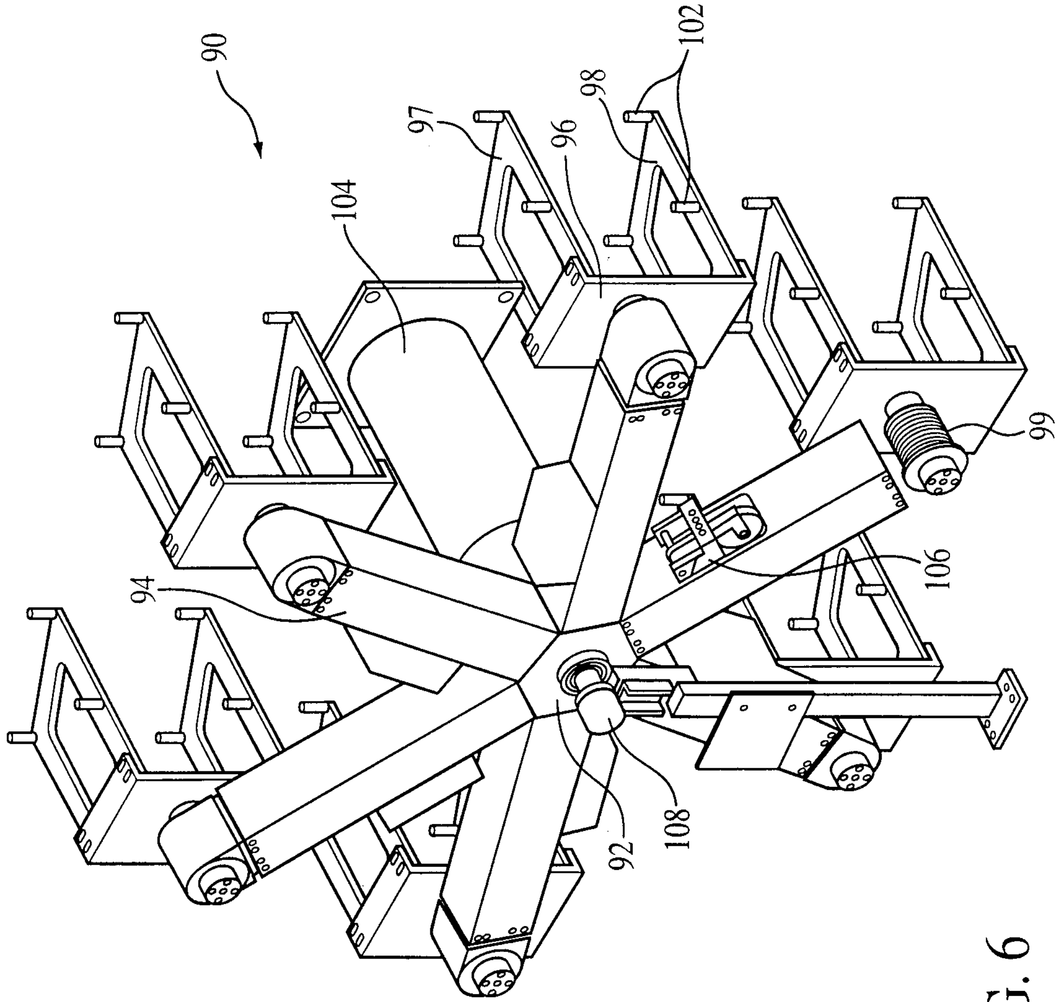

FIG. 6

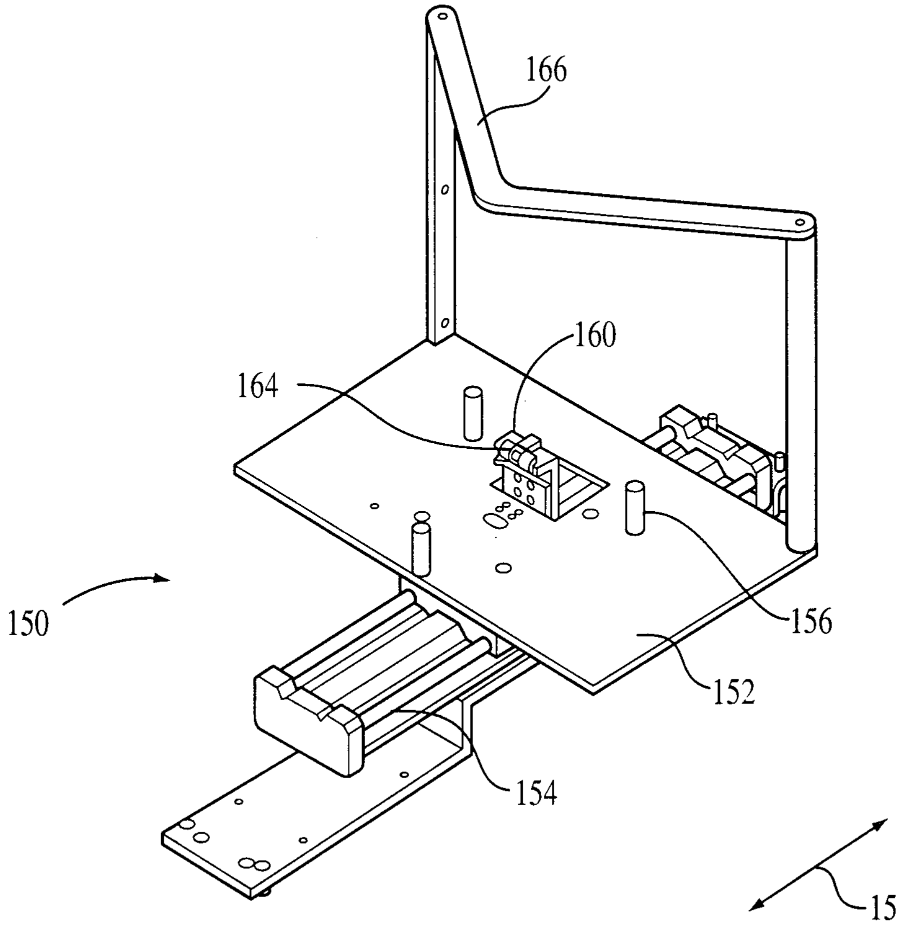

FIG. 7

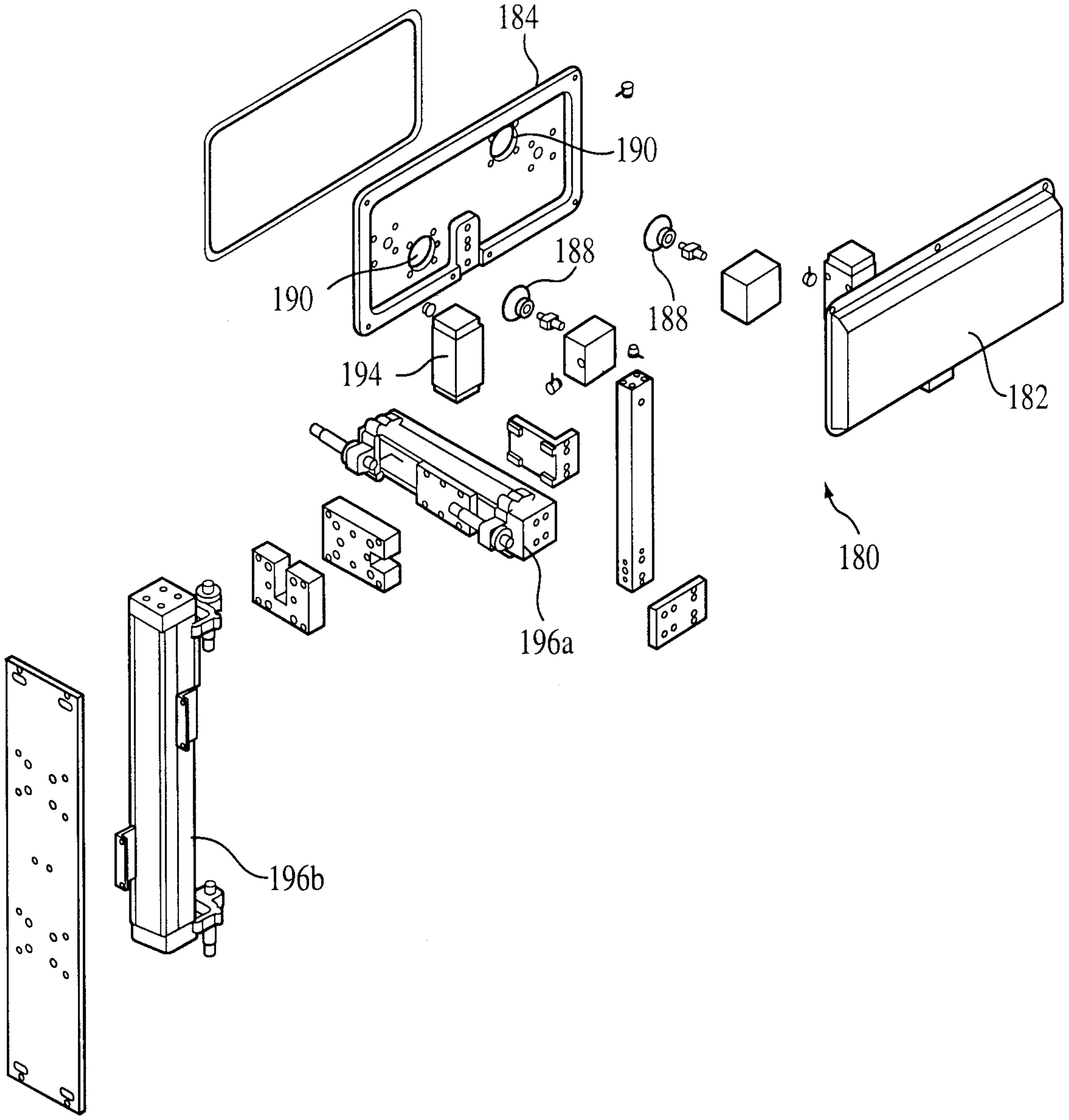

FIG. 8A

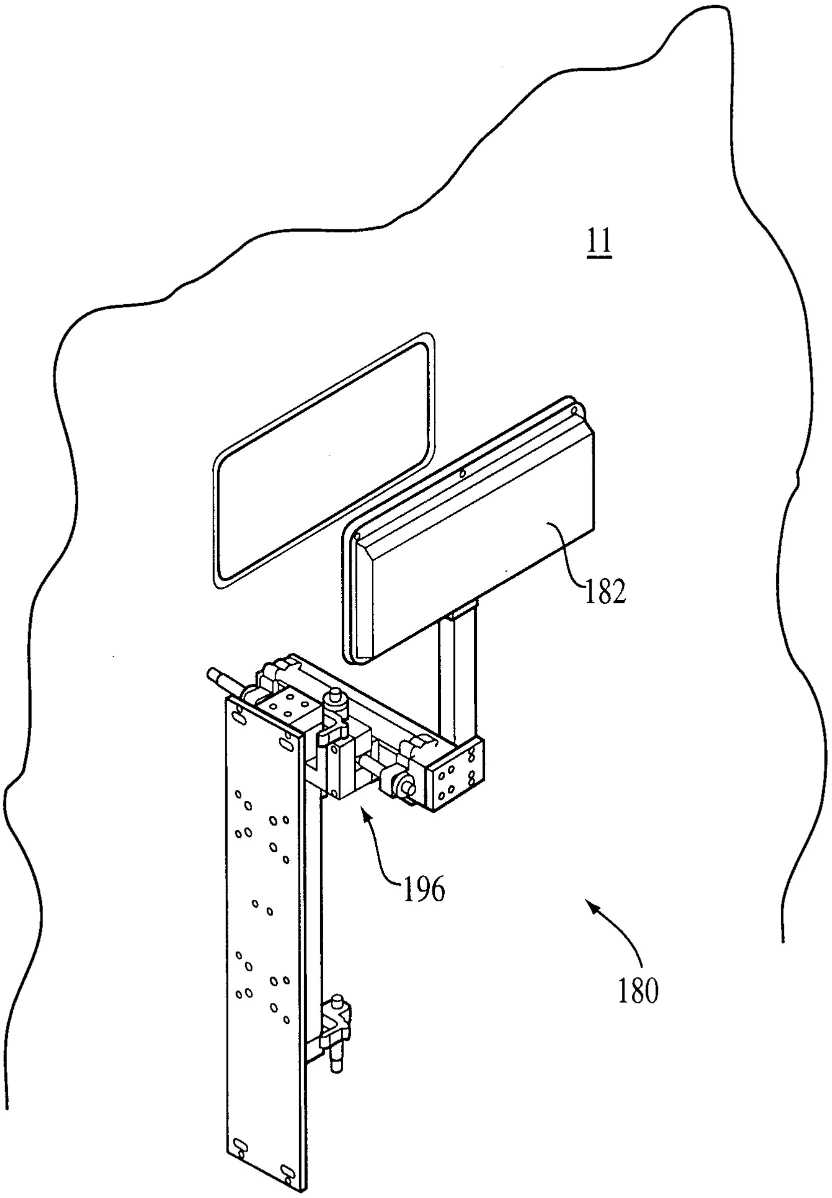

FIG. 8B

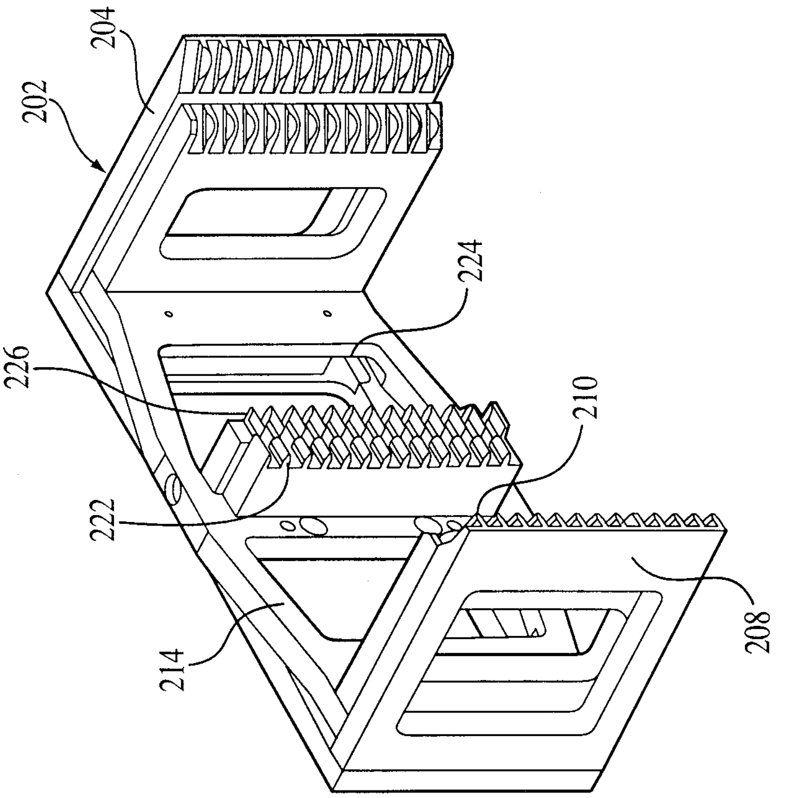

FIG. 9B

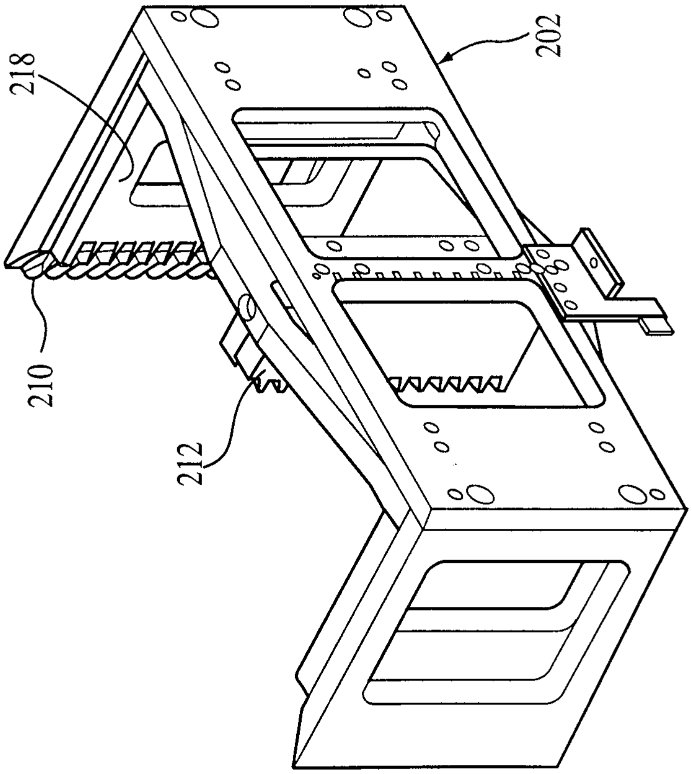

FIG. 9A

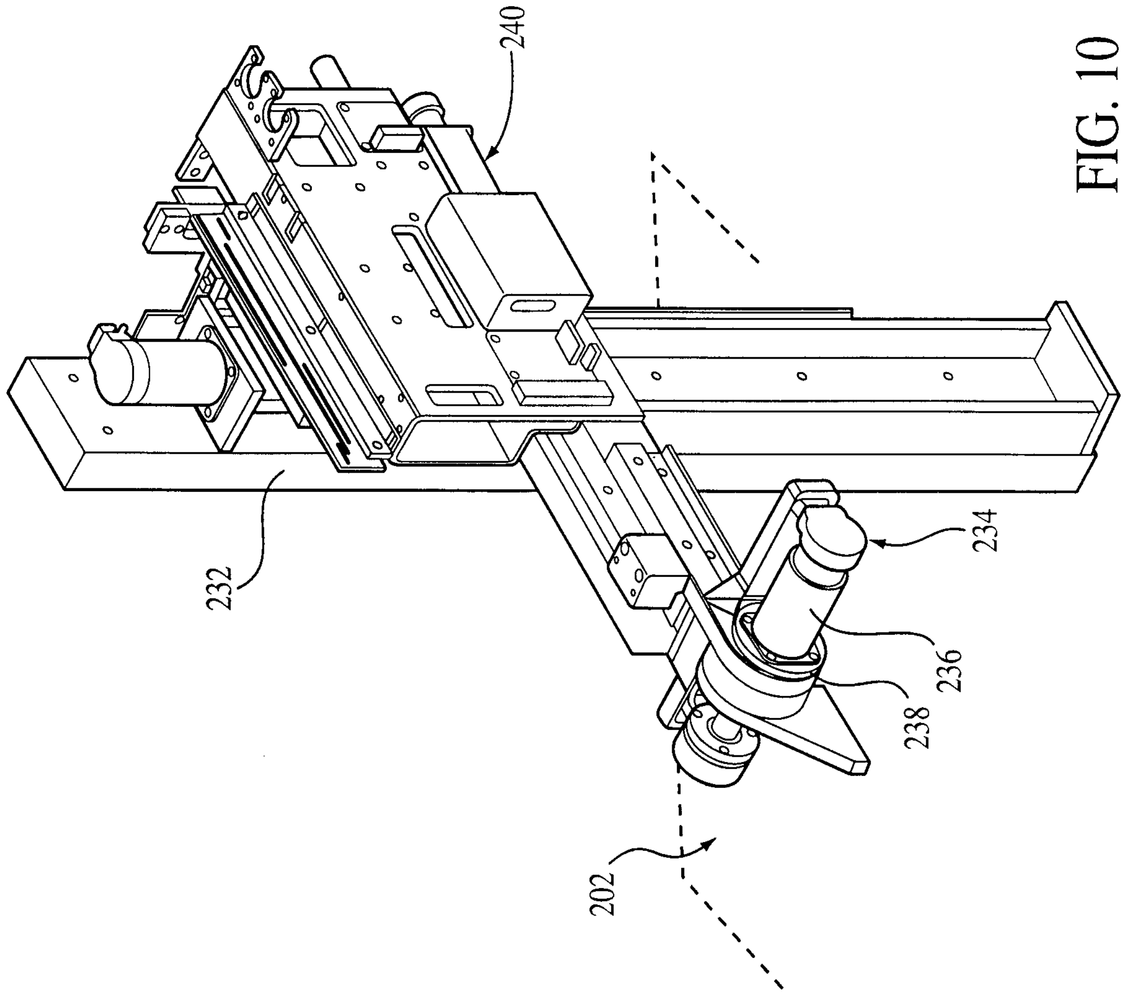

FIG. 10

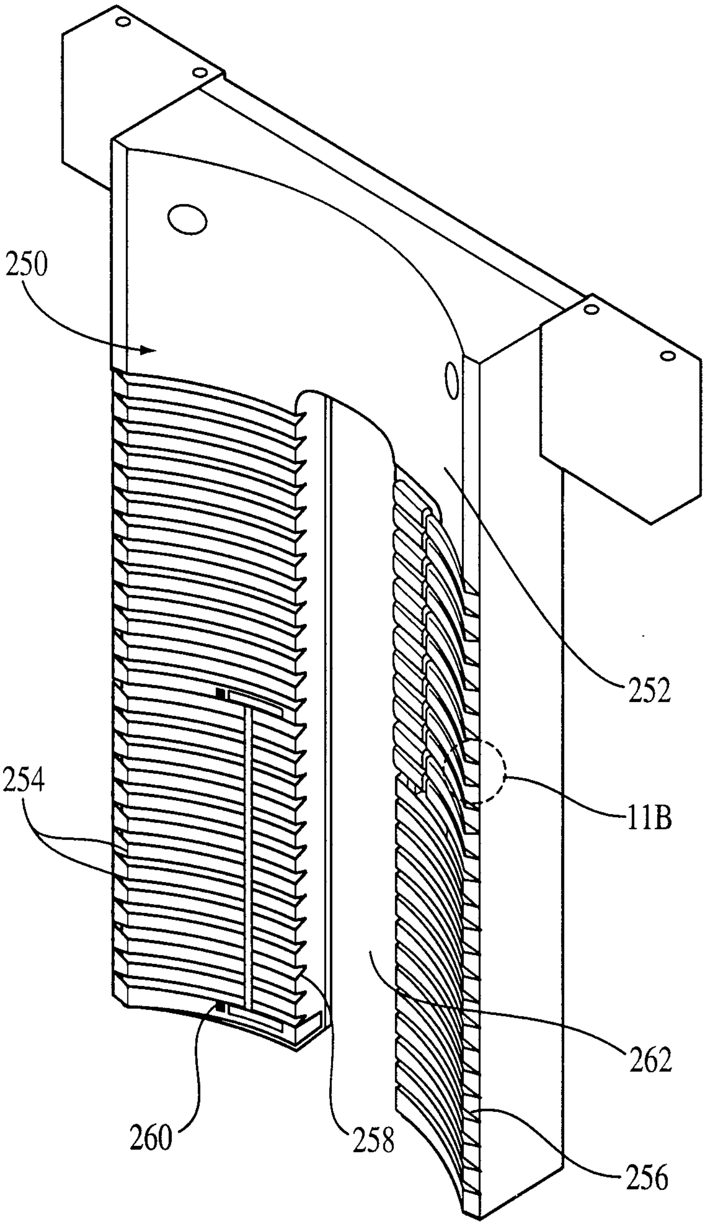

FIG. 11A

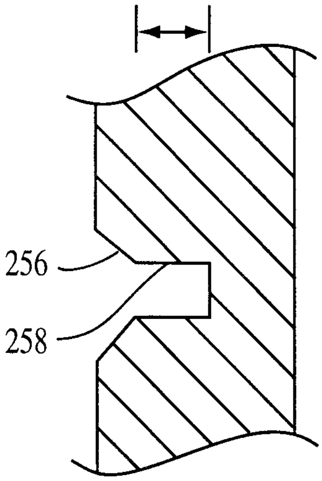

FIG. 11B

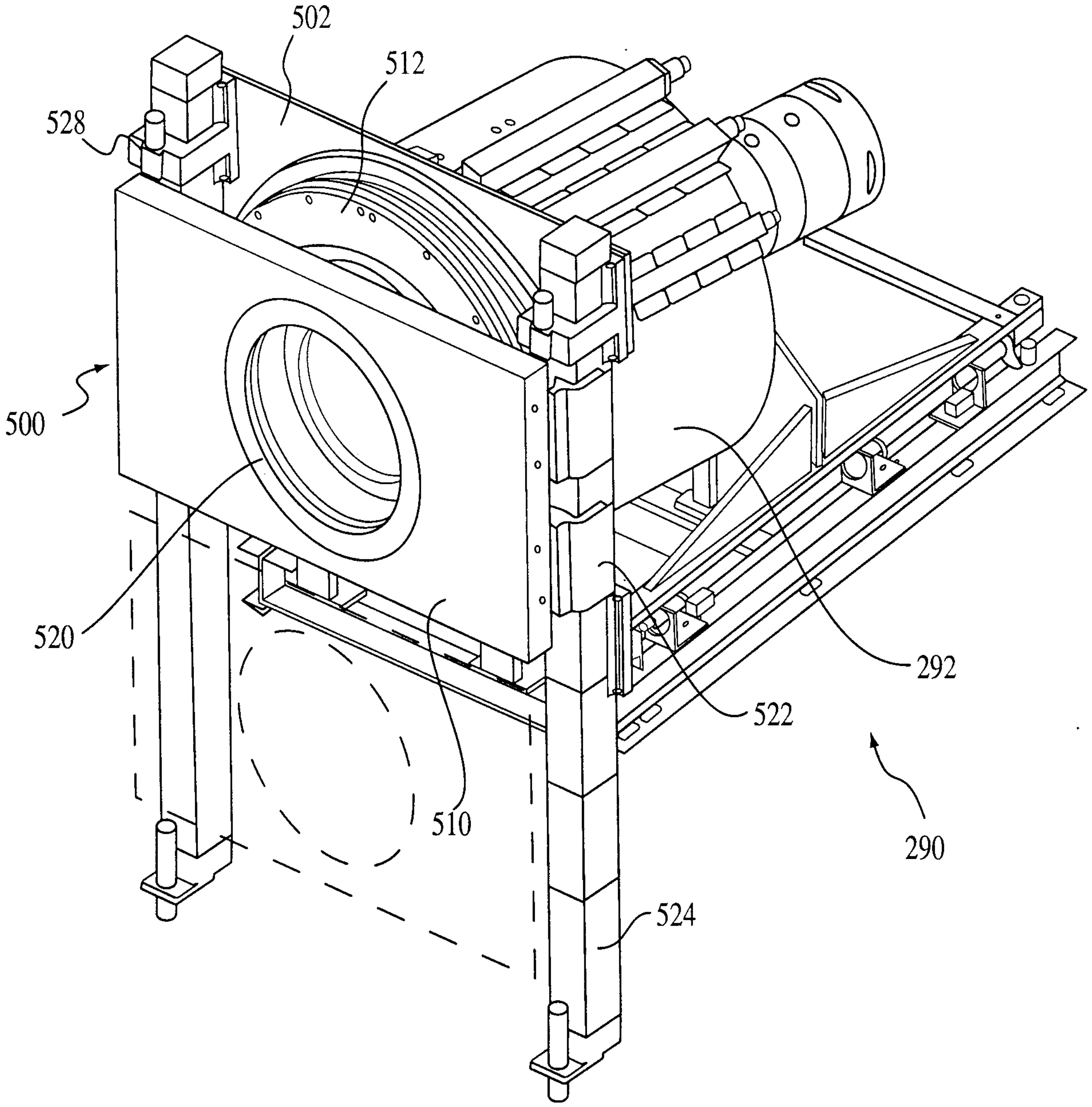

FIG. 12

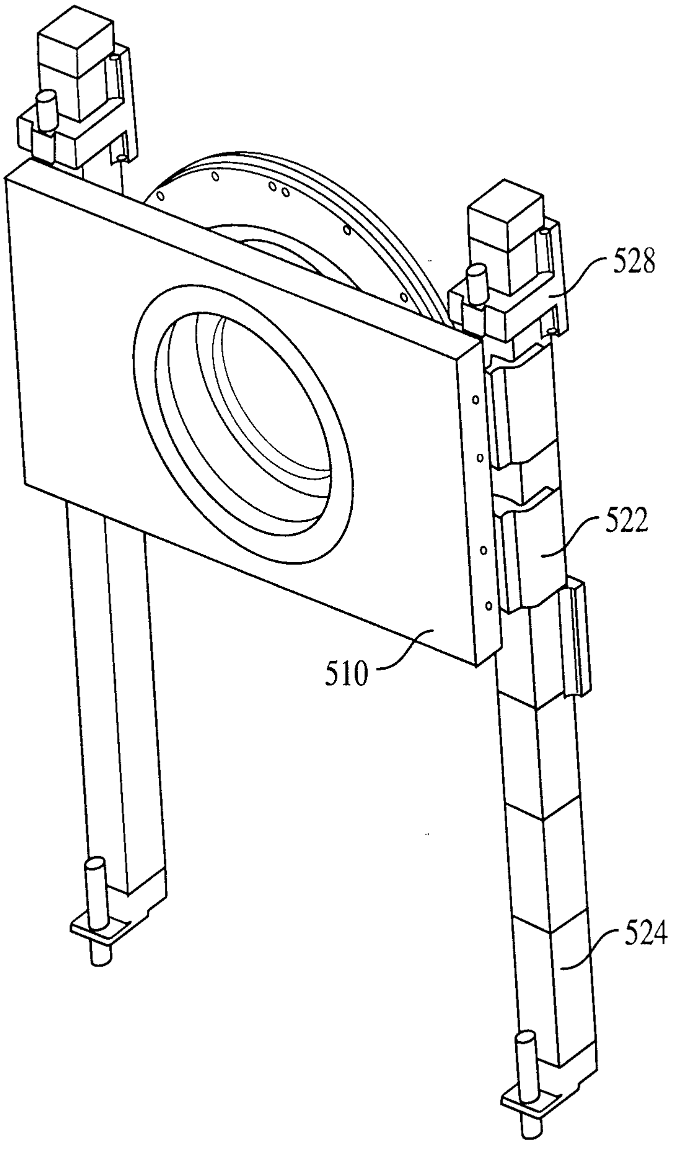

FIG. 13

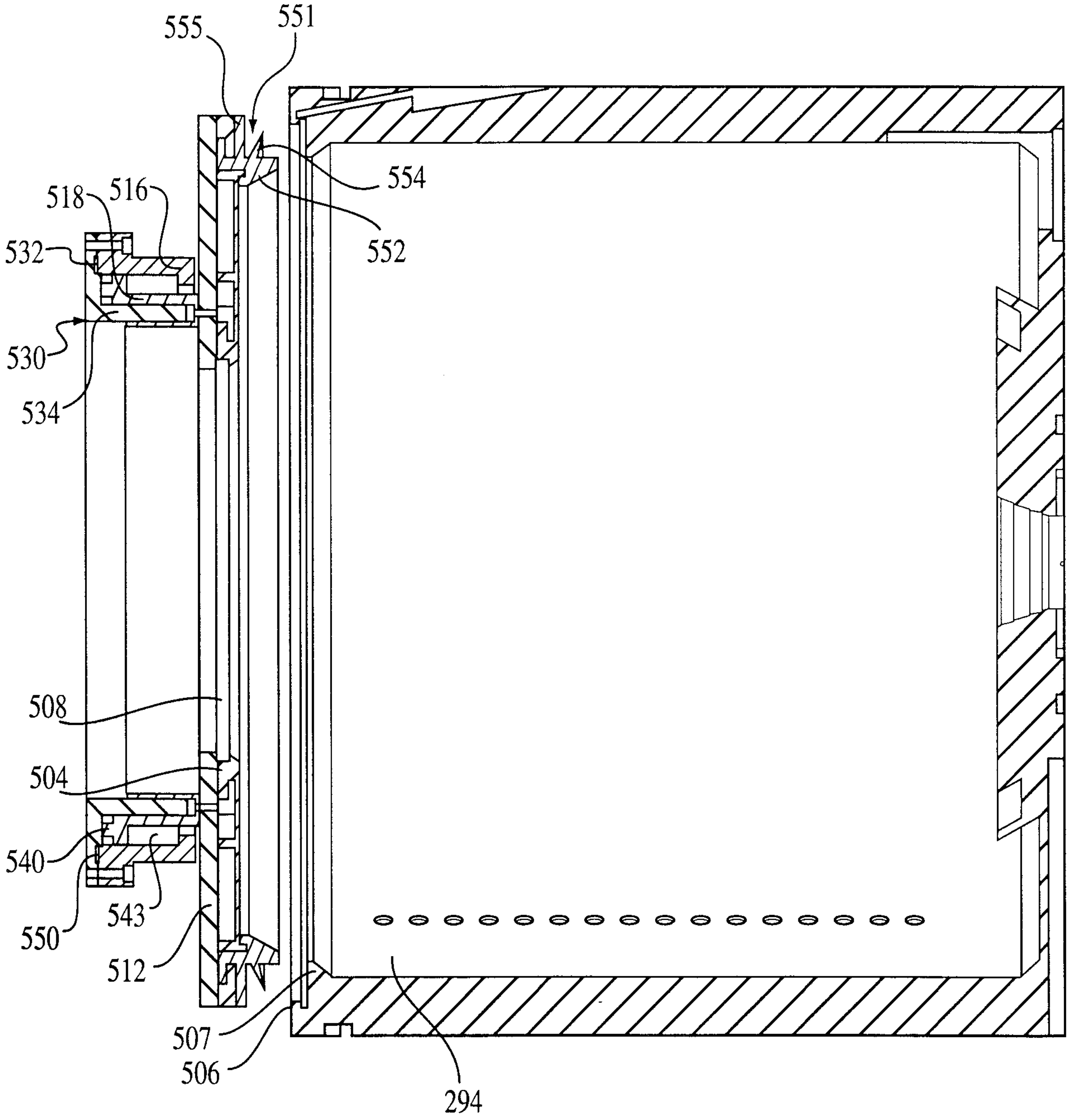
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FIG. 14

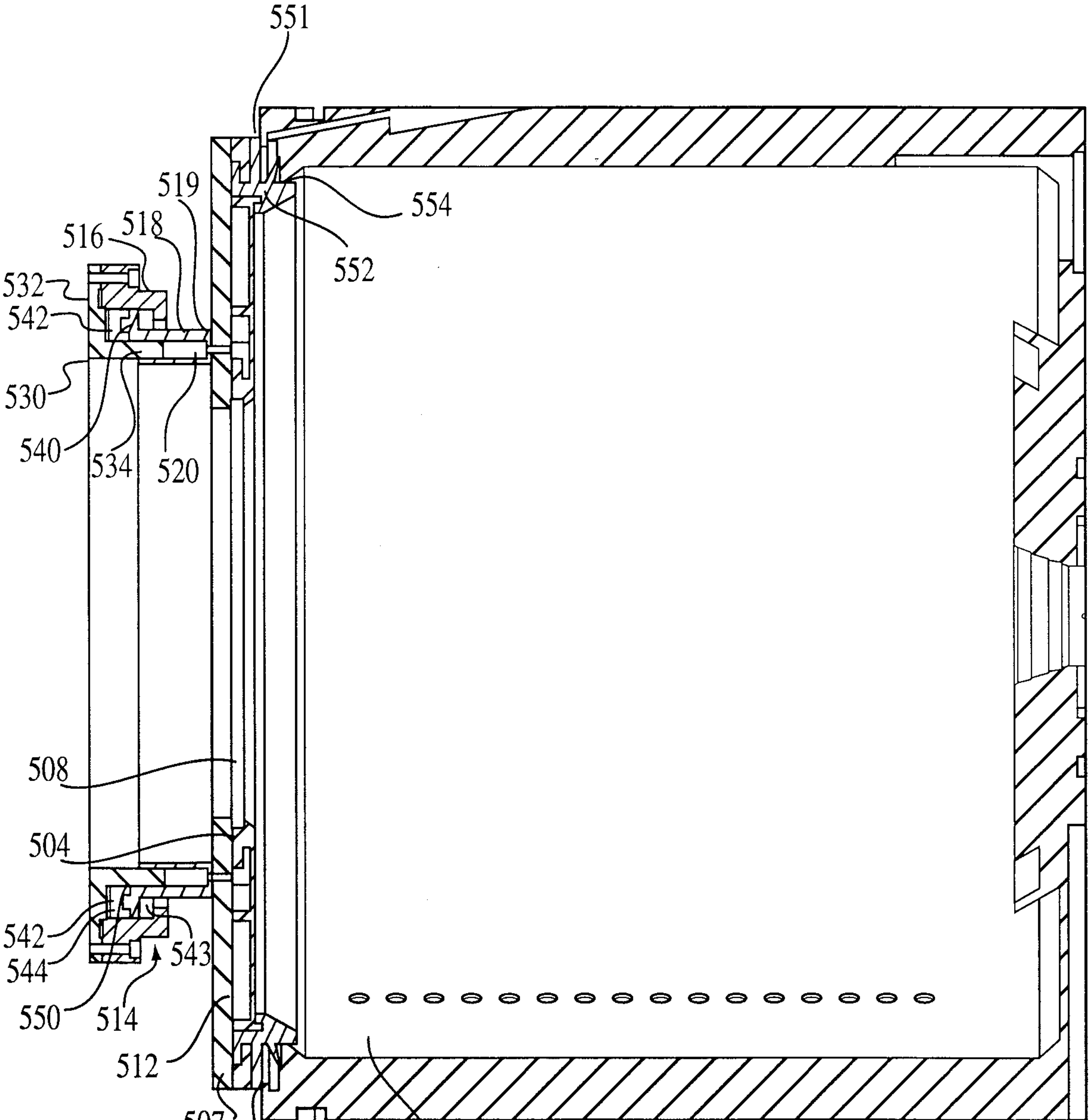
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FIG. 15

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/26685

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B65G 47/ 90
US CL :414/217,416,739,940,222; 118/719; 49/475.1,404.349
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 414/217,416,417,403,935,937,939,940,941,222,225; 118/719; 49/475.1,404,349

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

none

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

none

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,674,039 A (WALKER ET AL) 07 OCTOBER 1997 (07.10.97) (SEE ENTIRE DOCUMENT)	NONE
A	US 5,613,821 A (MUKA ET AL) 25 MARCH 1997 (25.02.97) (SEE ENTIRE DOCUMENT)	NONE
A	US 5,364,219 A (TAKAHASHI ET AL) 15 NOVEMBER 1994 (15.11.94) (SEE ENTIRE DOCUMENT)	NONE
A	US 5,215,420 A (HUGHES ET AL) 01 JUNE 1993 (01.06.93) (SEE ENTIRE DOCUMENT)	NONE
A,P	US 5,772,386 A (MAGES ET AL) 30 JUNE 1998 (30.06.98) (SEE ENTIRE DOCUMENT)	NONE

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

*	Special categories of cited documents:	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A"	document defining the general state of the art which is not considered to be of particular relevance		
"E"	earlier document published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means		
"P"	document published prior to the international filing date but later than the priority date claimed	"&"	document member of the same patent family

Date of the actual completion of the international search

03 MARCH 1999

Date of mailing of the international search report

17 MAR 1999

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Facsimile No. (703) 305-3230

Authorized officer
Frank E. Werner

Telephone No. (703) 308-1113