

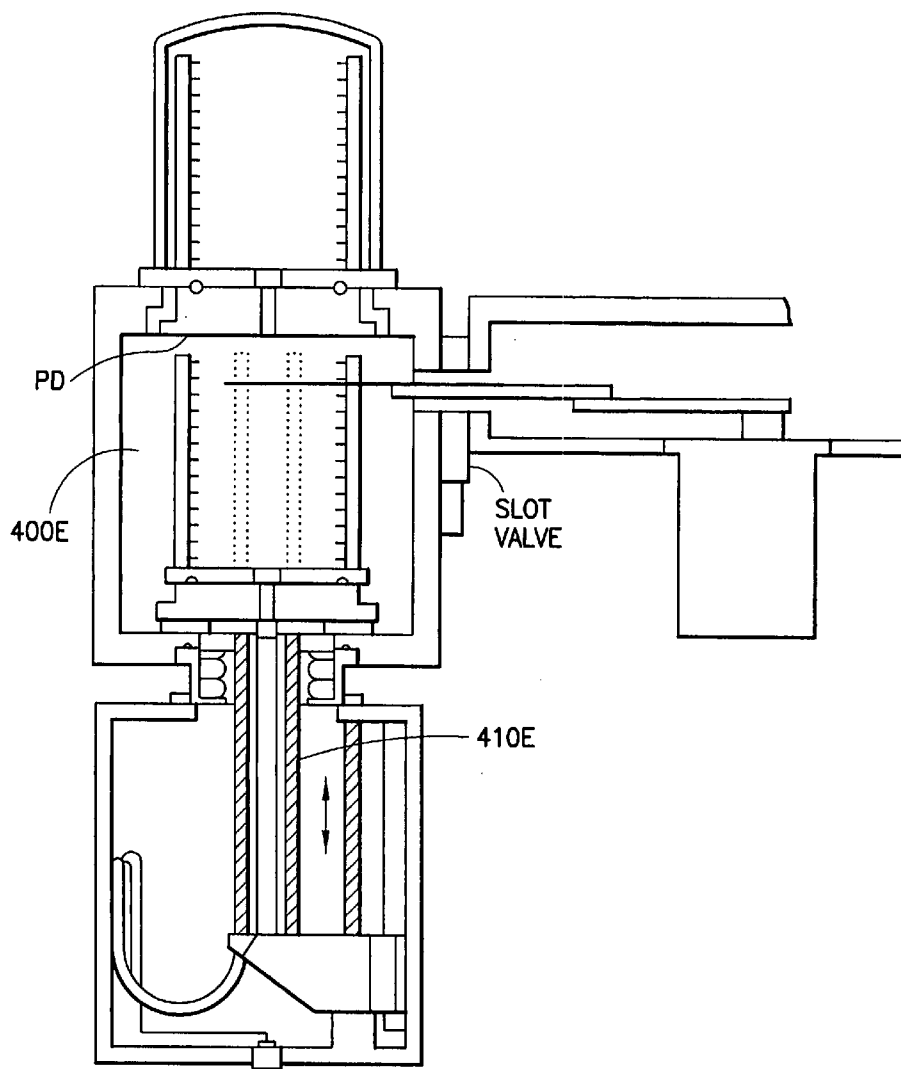


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(19) **United States**(12) **Patent Application Publication**
Bufano et al.(10) **Pub. No.: US 2007/0201967 A1**(43) **Pub. Date: Aug. 30, 2007**(54) **REDUCED CAPACITY CARRIER,
TRANSPORT, LOAD PORT, BUFFER
SYSTEM****Related U.S. Application Data**(60) Provisional application No. 60/733,813, filed on Nov.
7, 2005.(76) Inventors: **Michael L. Bufano**, Belmont, MA
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Austin, TX (US)**Publication Classification**(51) **Int. Cl.**
B65H 1/00 (2006.01)(52) **U.S. Cl.** **414/222.01; 414/935**(57) **ABSTRACT**

A semiconductor workpiece processing system having at least one processing apparatus for processing workpieces, a primary transport system, a secondary transport system and one or more interfaces between first transport system and second transport system. The primary and secondary transport systems each have one or more sections of substantially constant velocity and in queue sections communicating with the constant velocity sections.

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425 POST ROAD
FAIRFIELD, CT 06824 (US)(21) Appl. No.: **11/556,584**(22) Filed: **Nov. 3, 2006**

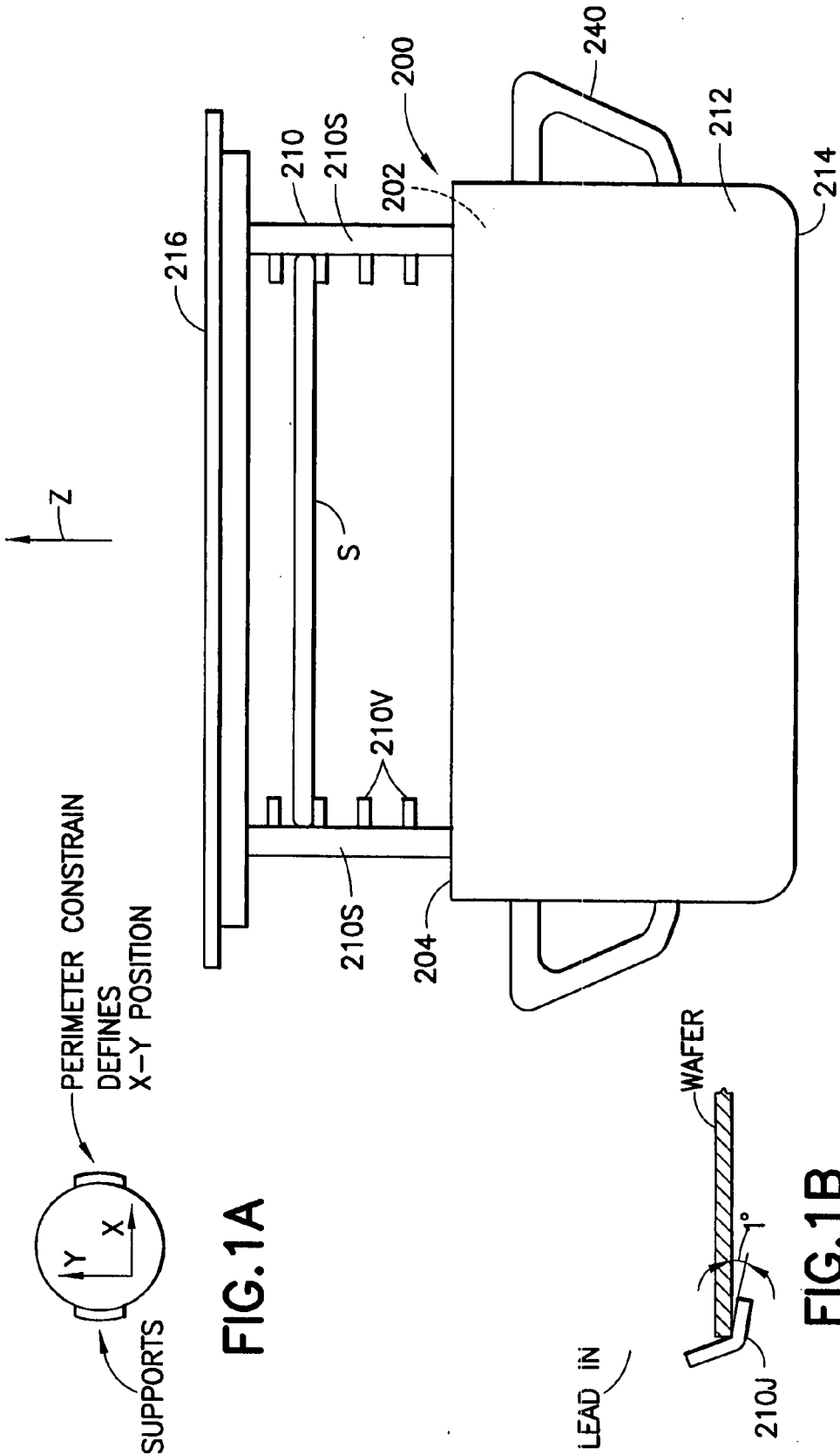


FIG. 1

FIG. 1B

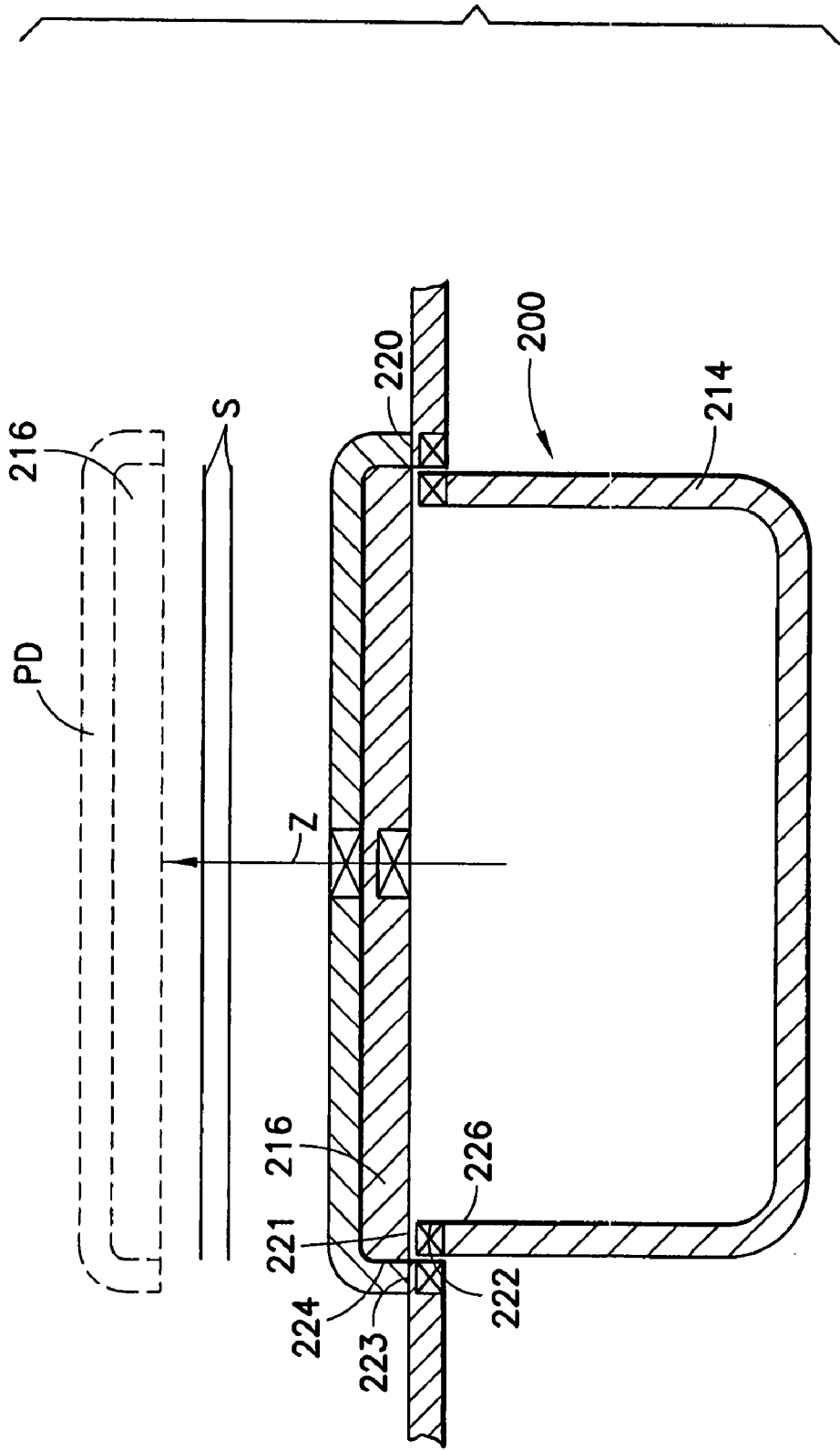
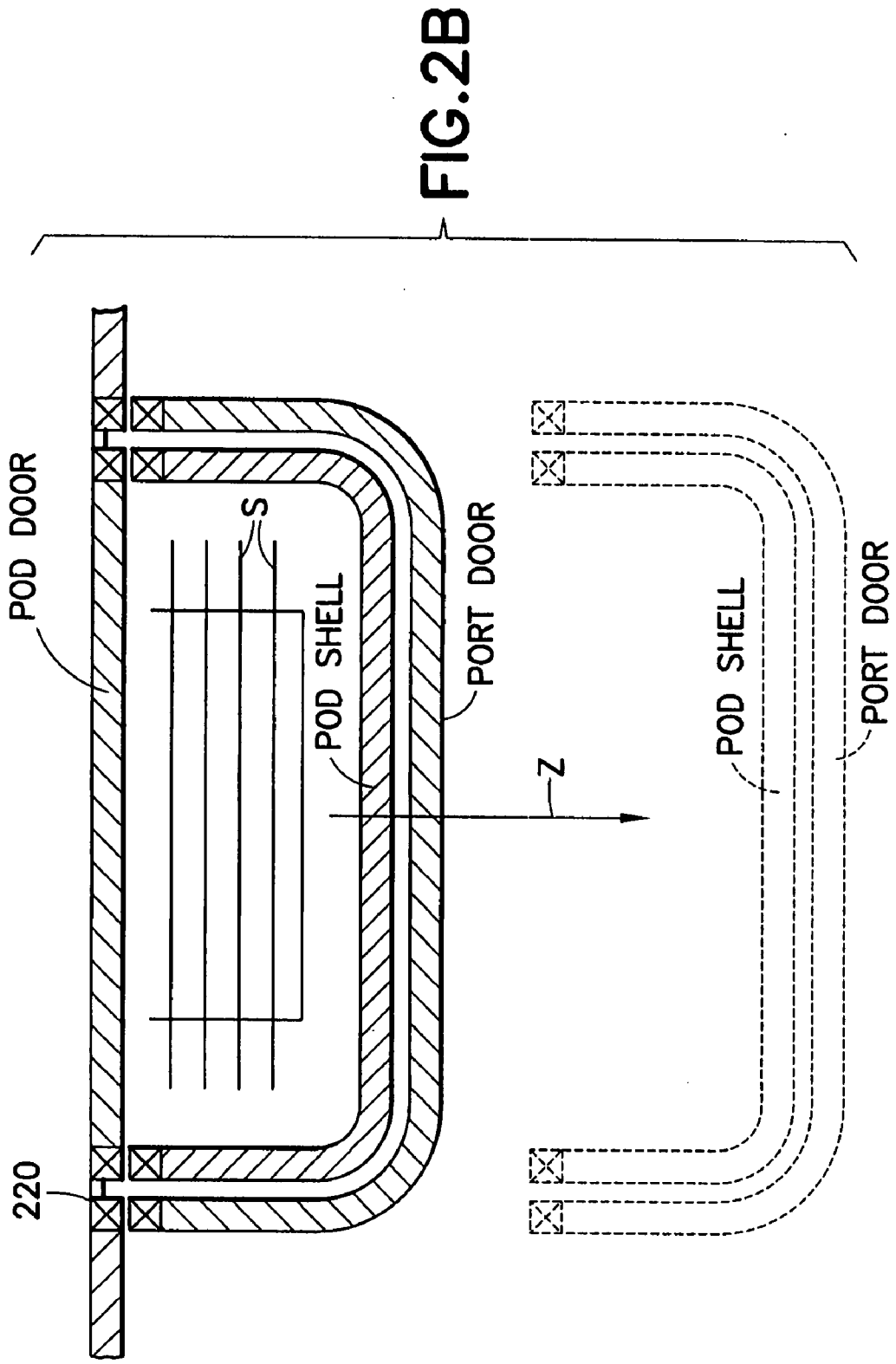


FIG. 2A



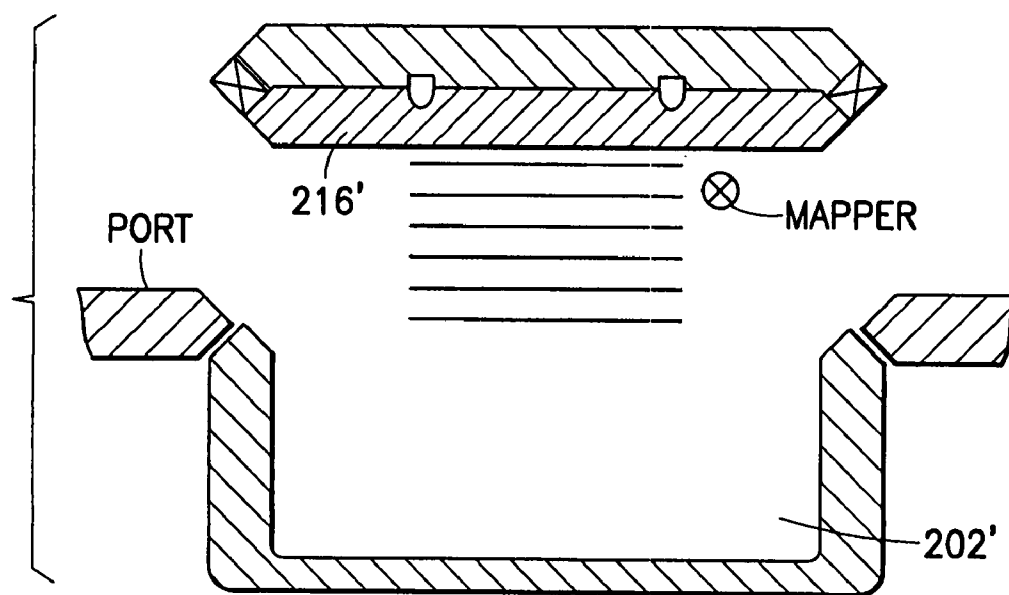


FIG.3A

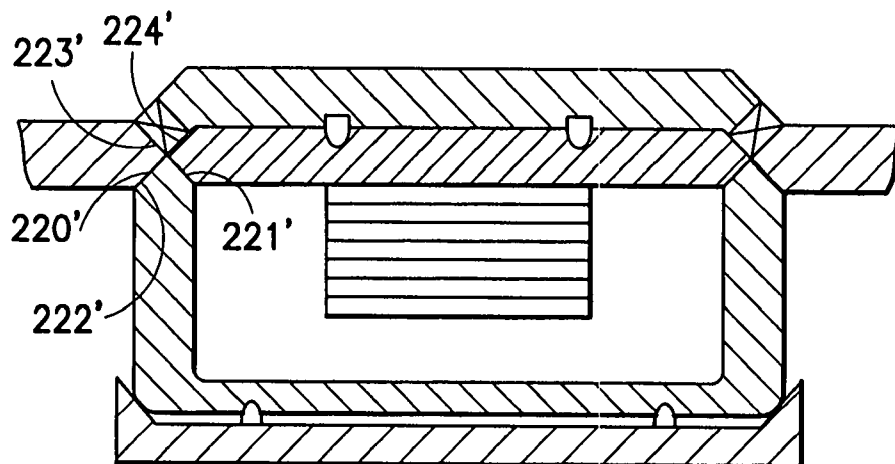


FIG.3B

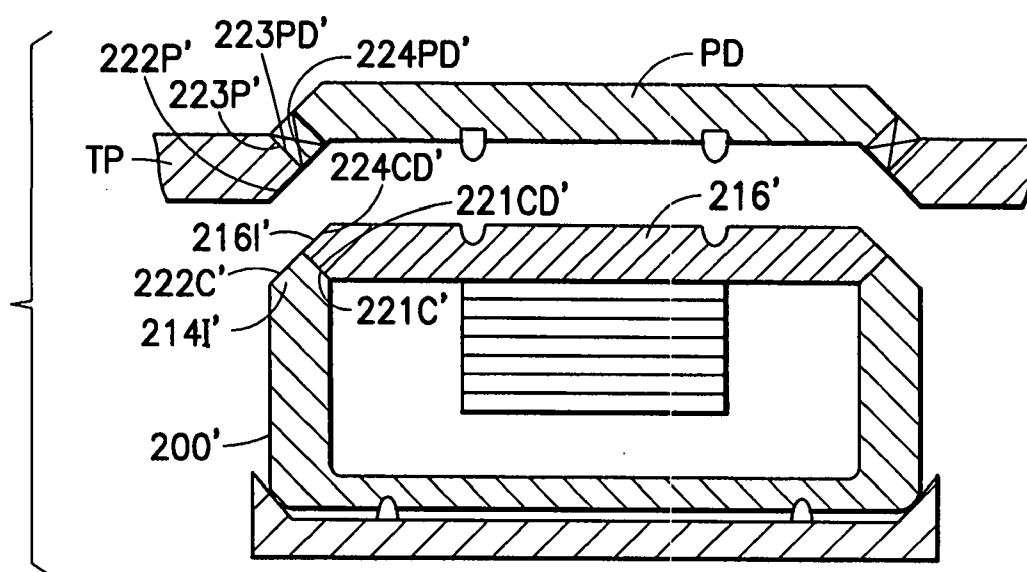


FIG.3C

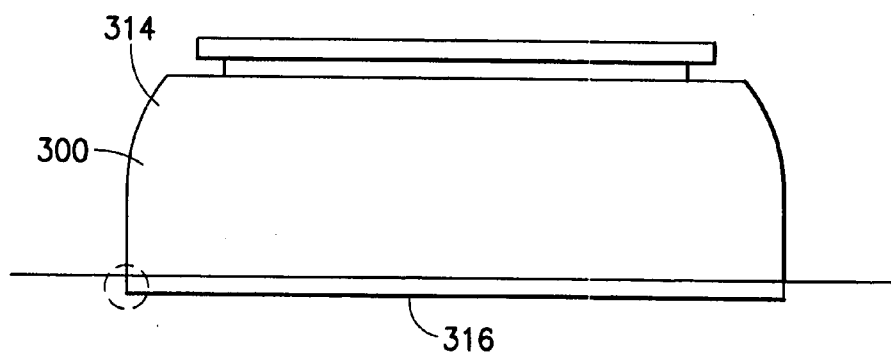


FIG. 4

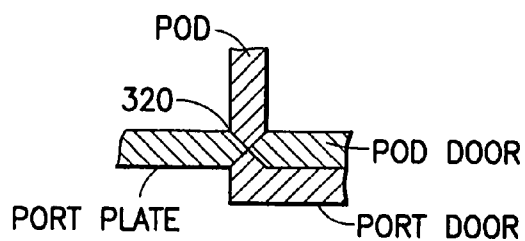


FIG. 4A

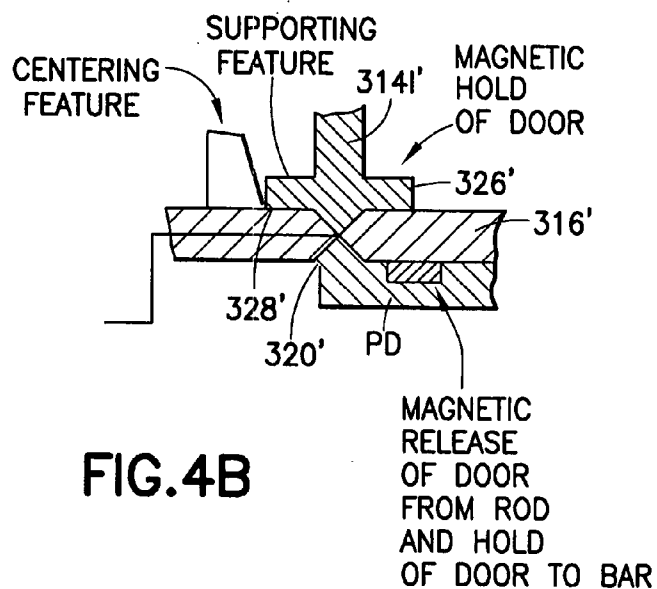


FIG. 4B

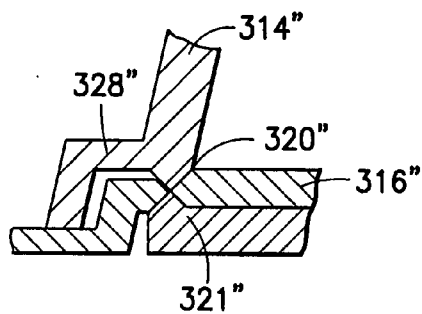
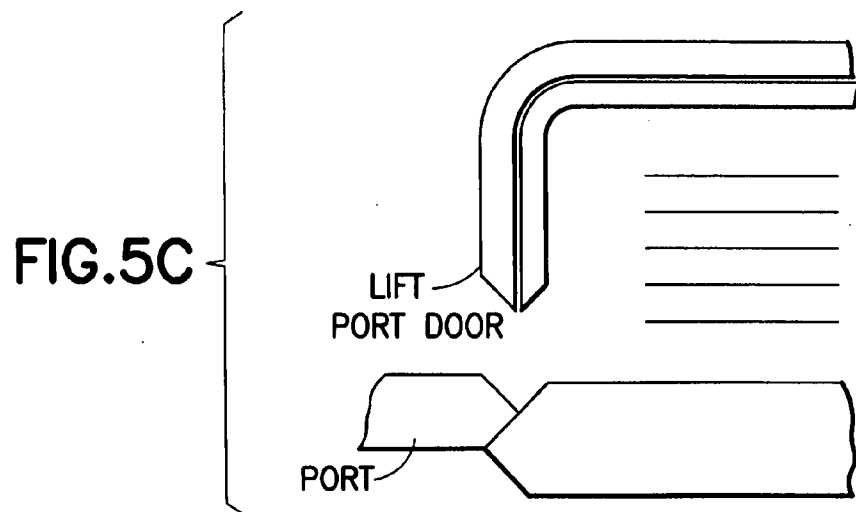
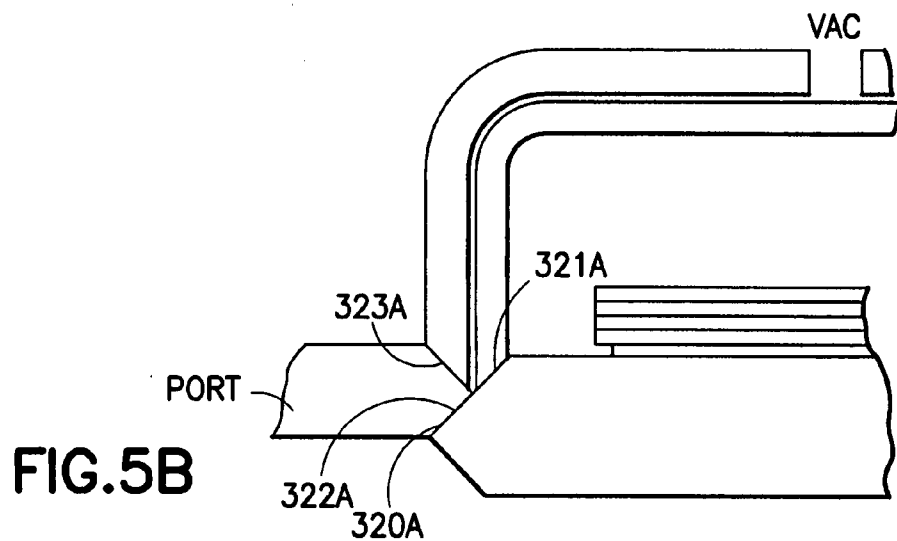
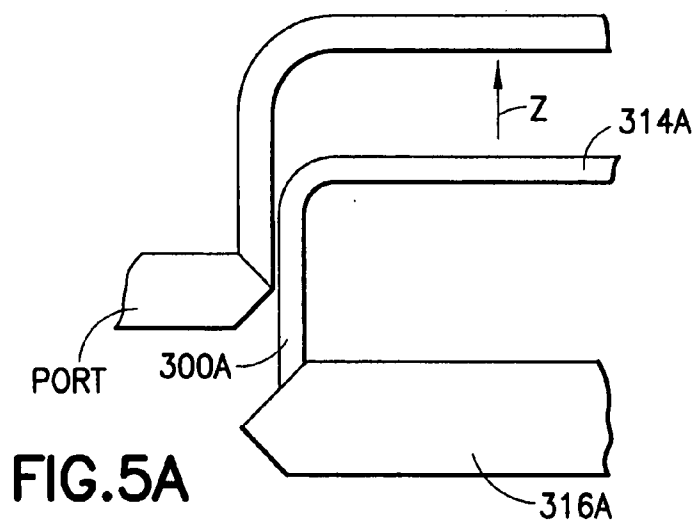


FIG. 4C



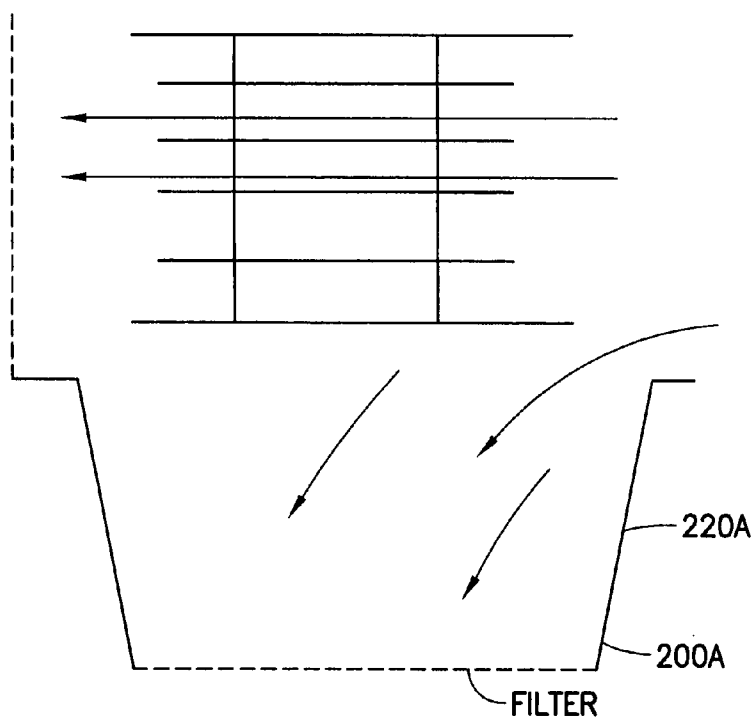


FIG. 6A

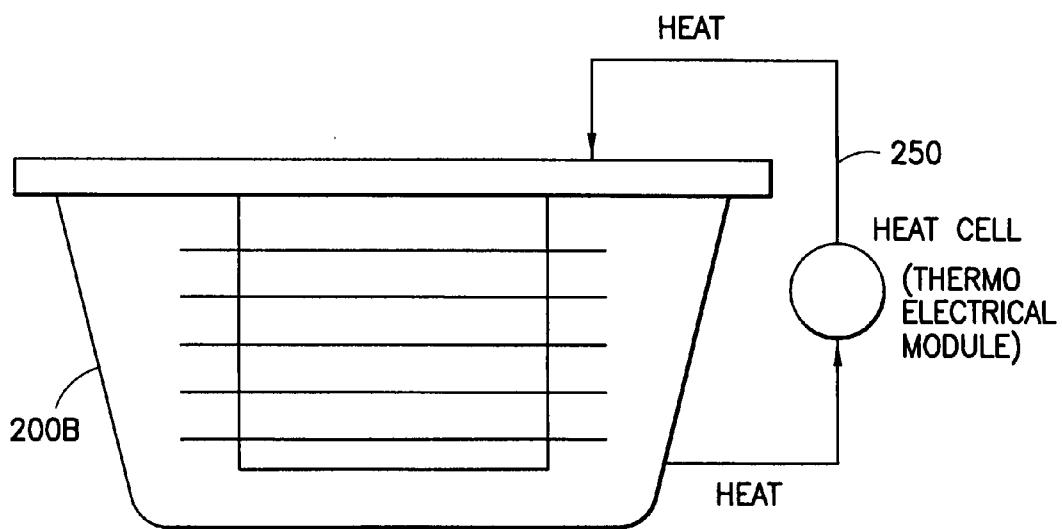


FIG. 6B

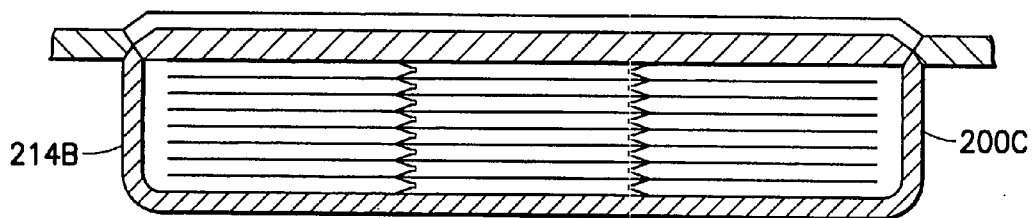


FIG. 7A

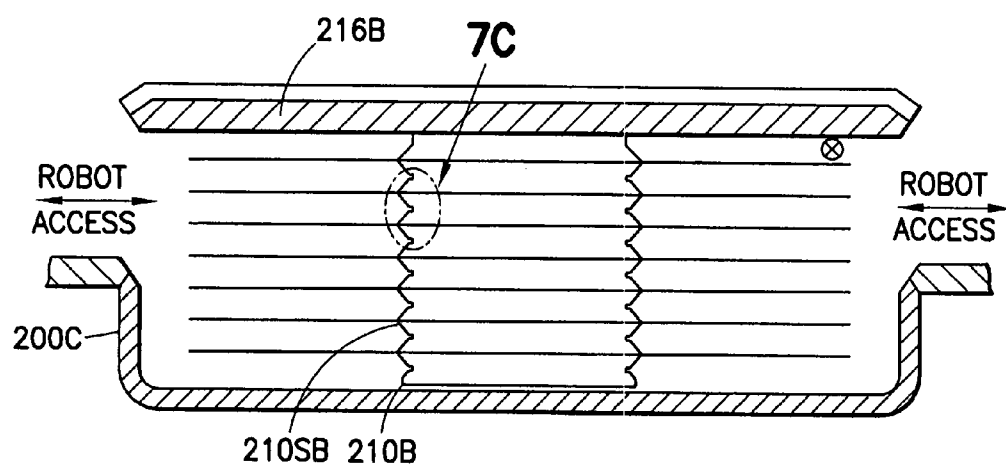


FIG. 7B

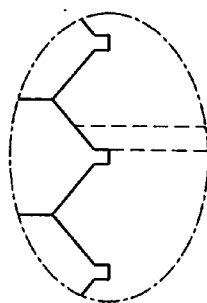
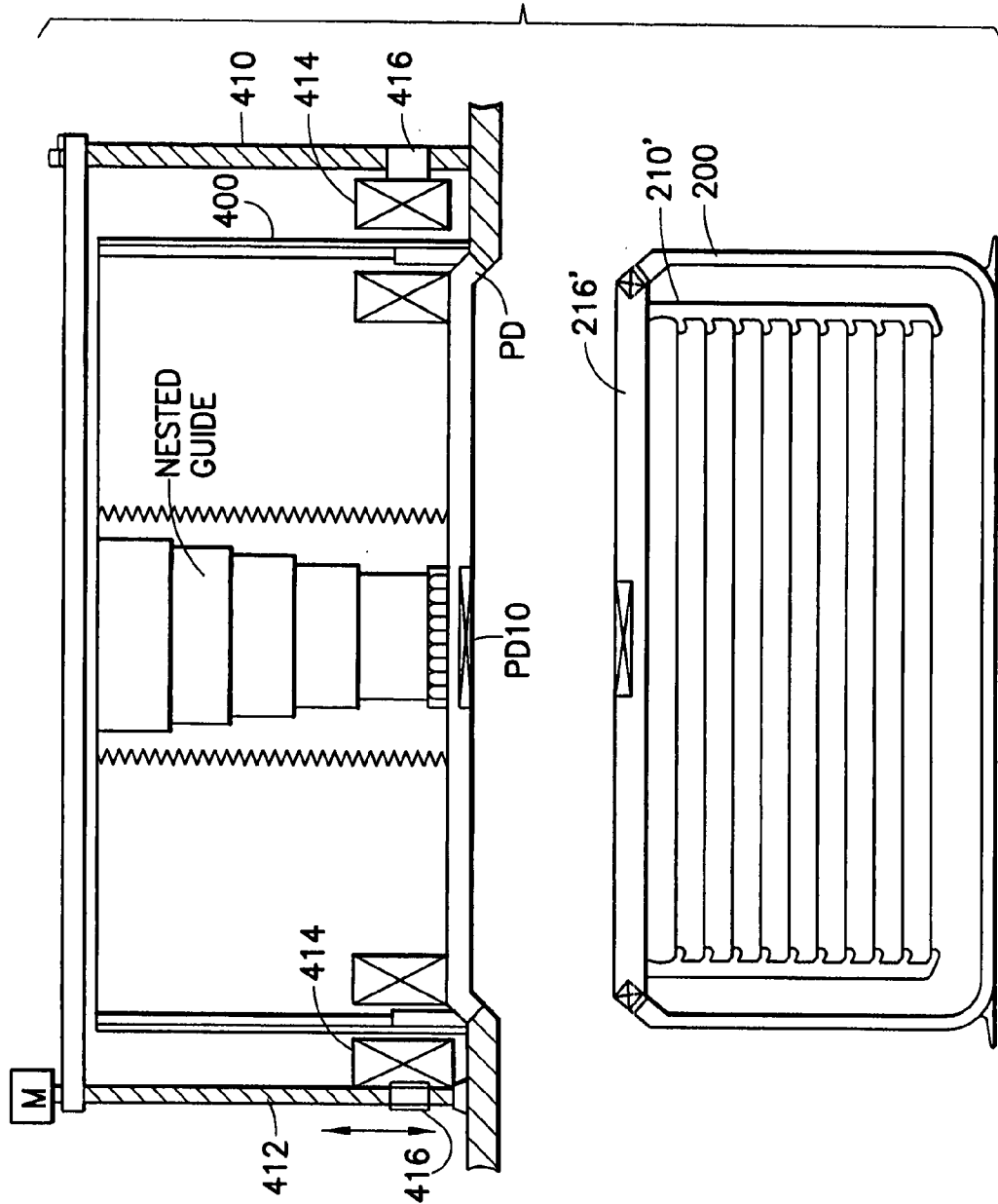
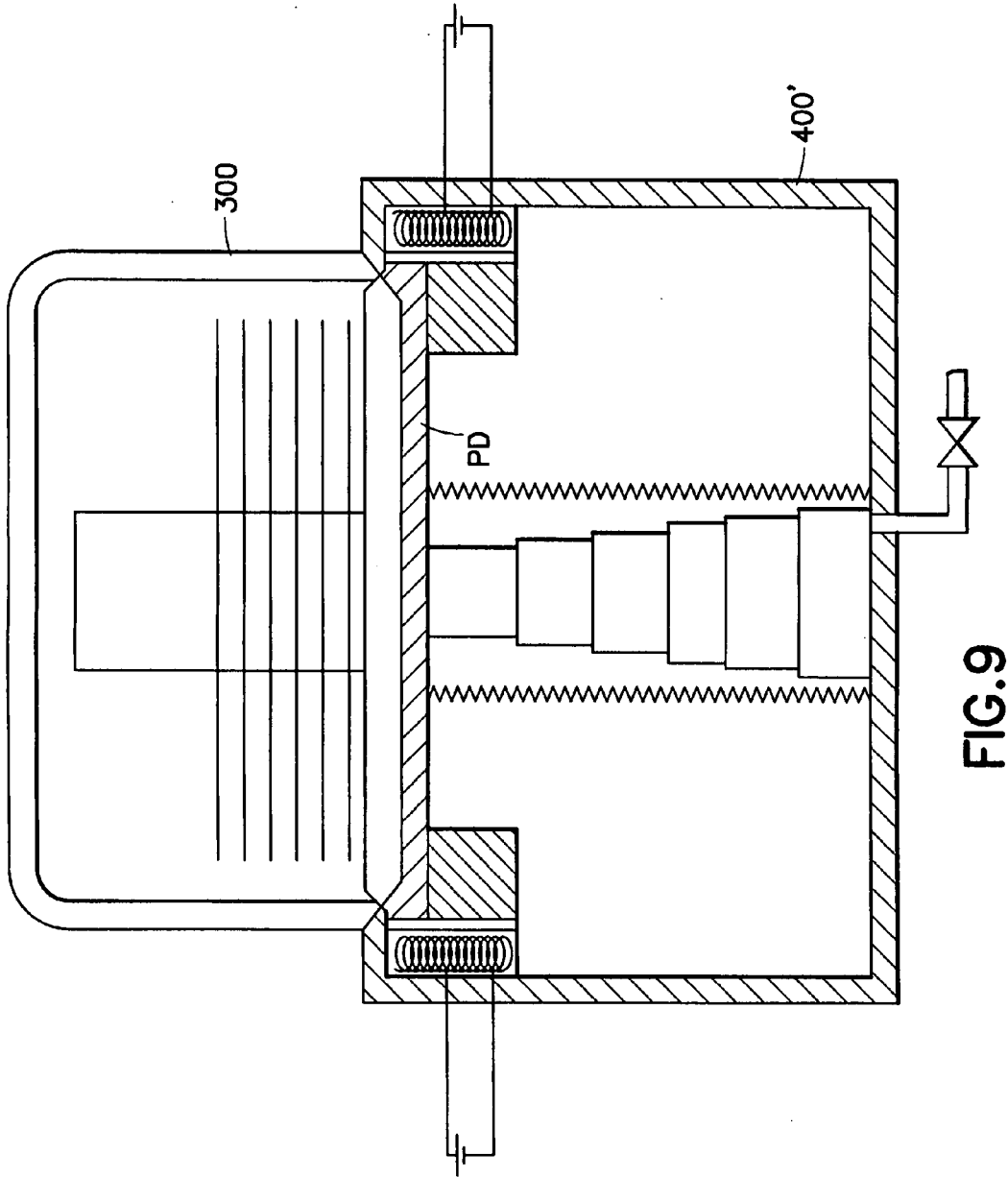


FIG. 7C

FIG. 8.





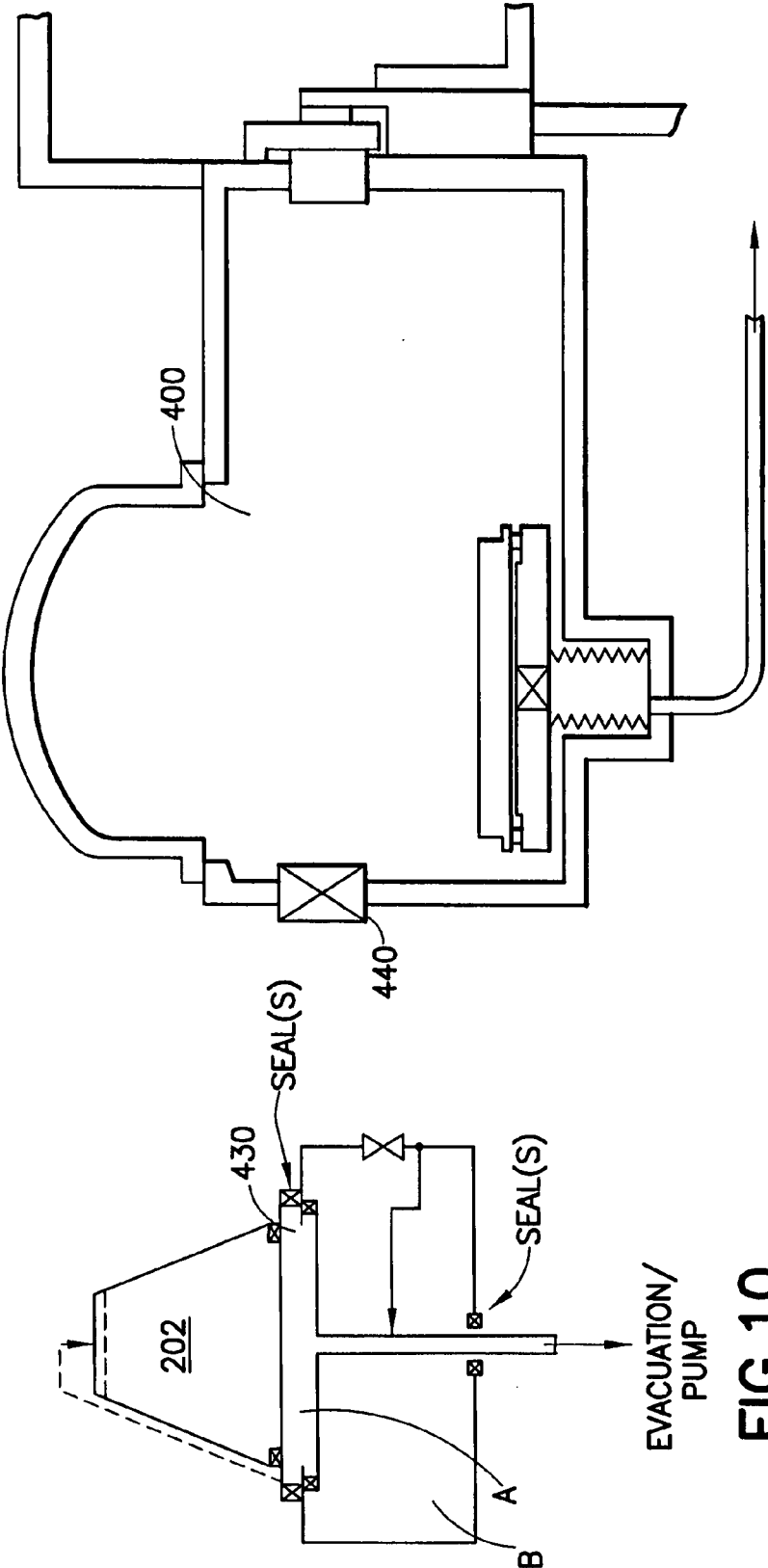


FIG.10A

FIG.10

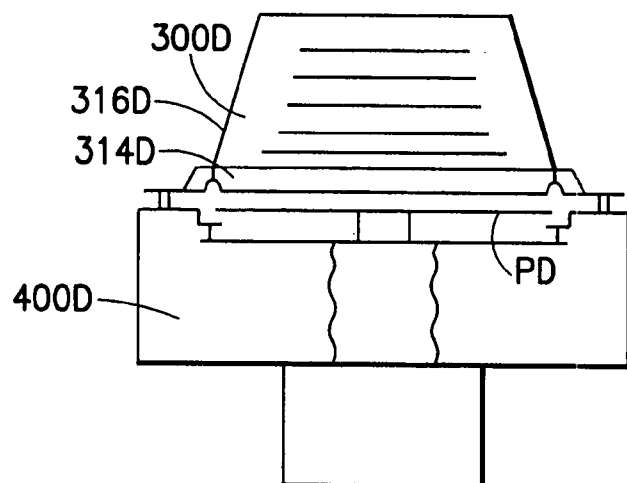


FIG. 11

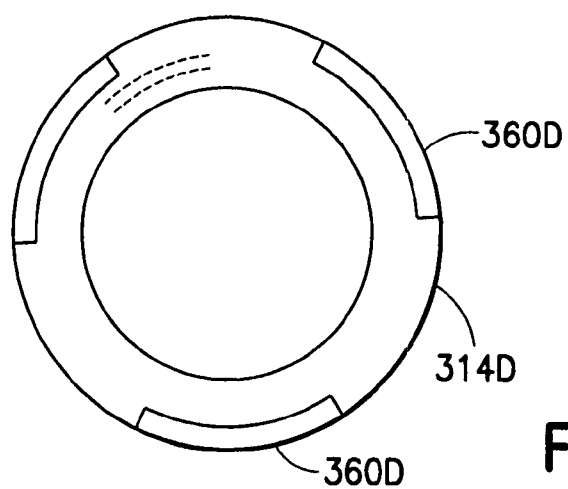


FIG. 12A

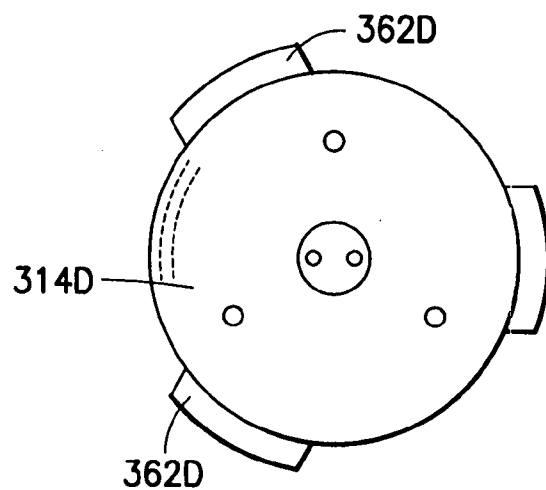


FIG. 12B

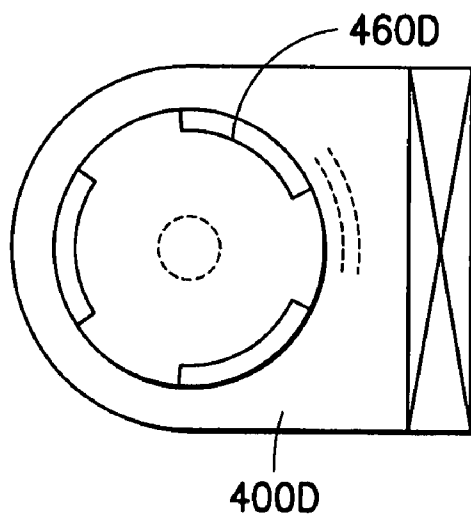


FIG. 13A

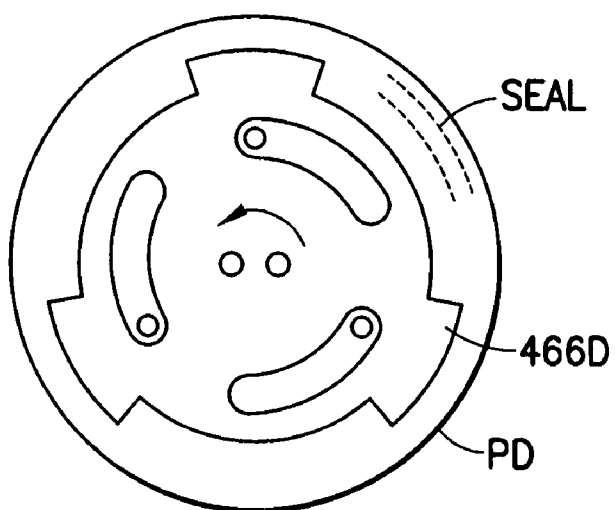


FIG. 13B

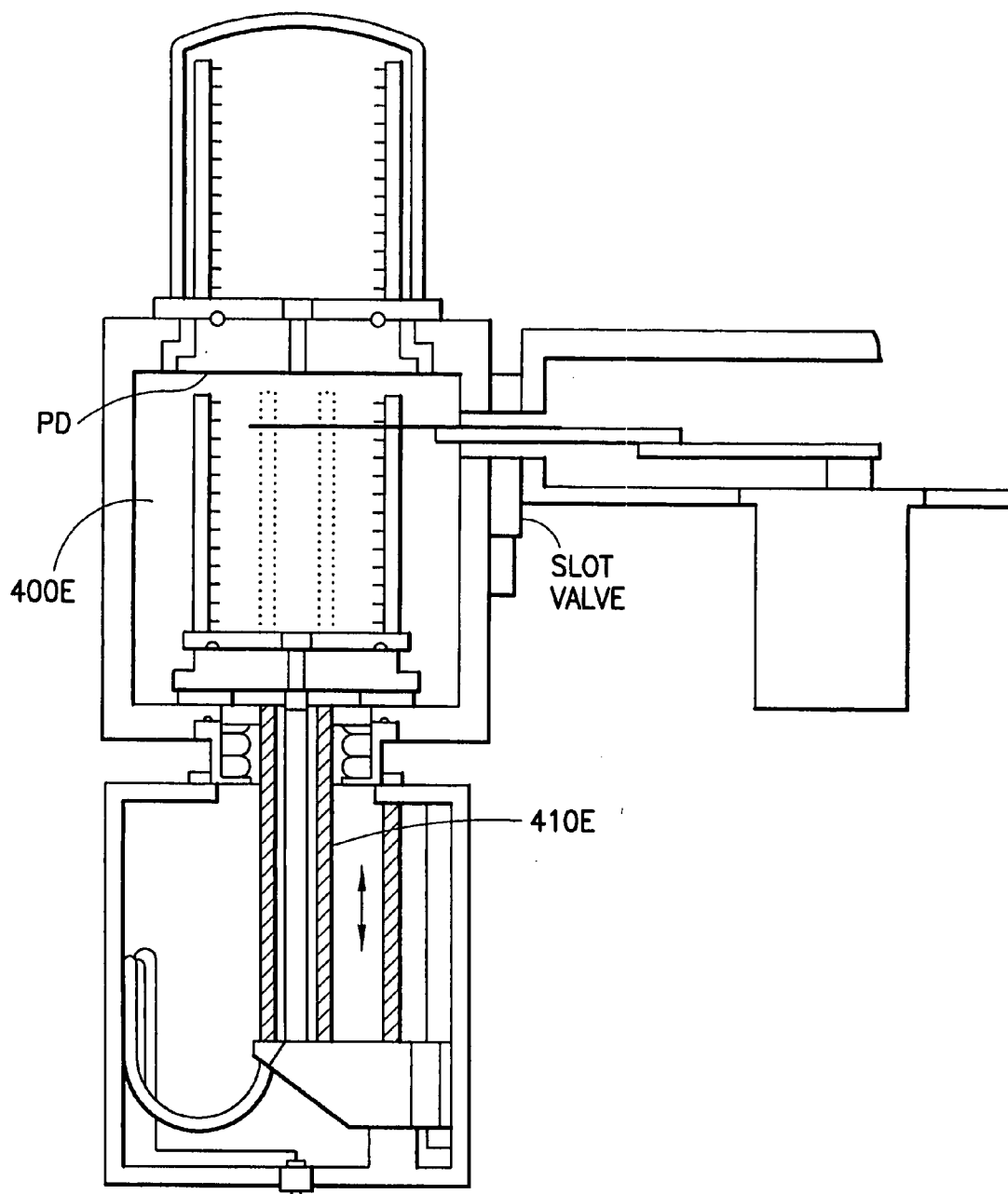


FIG.14

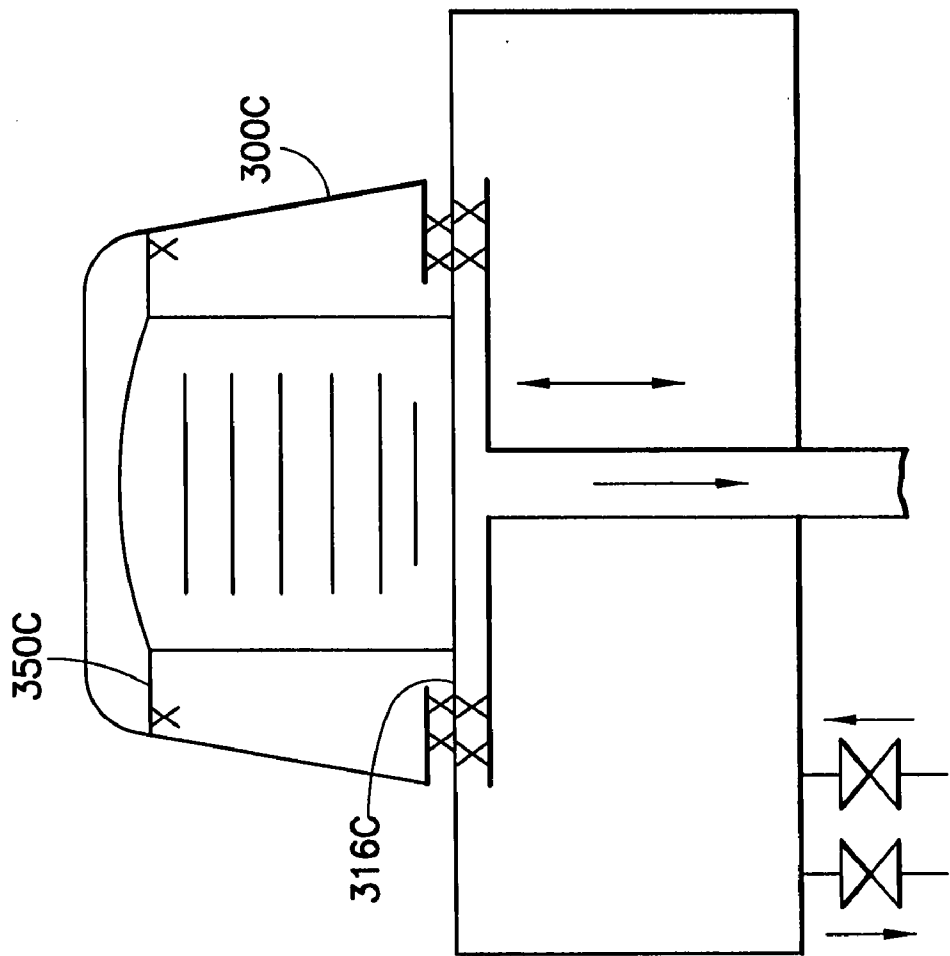


FIG.15

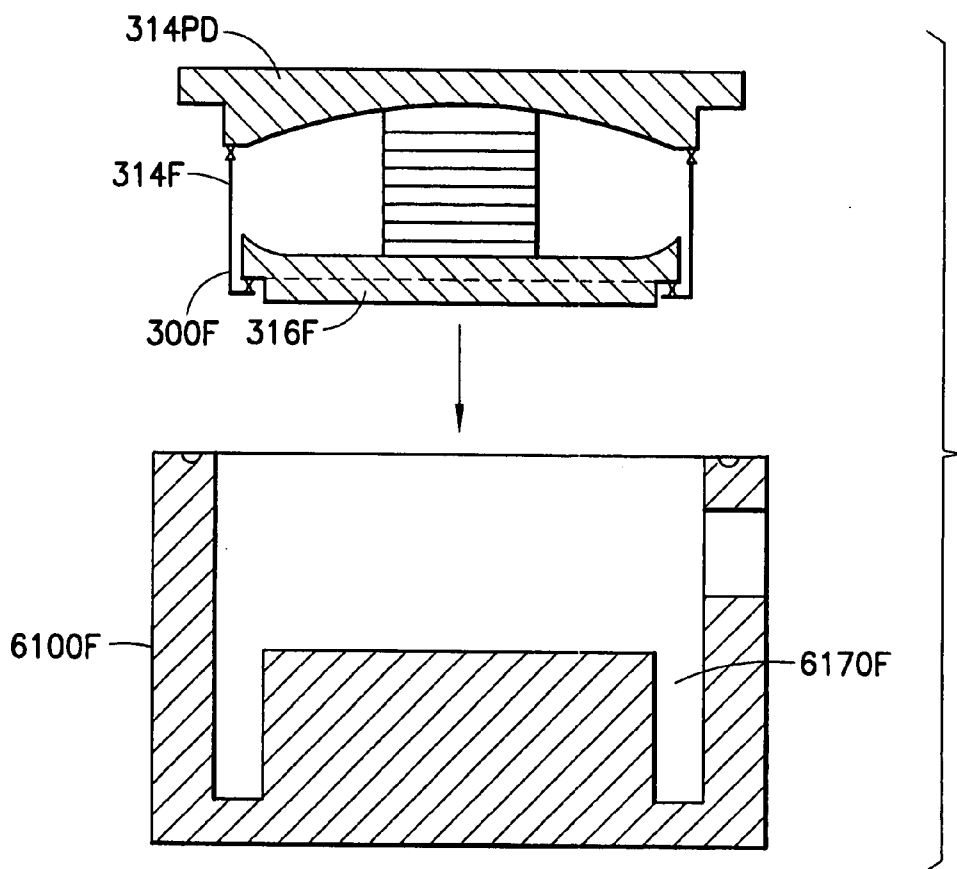


FIG. 16A

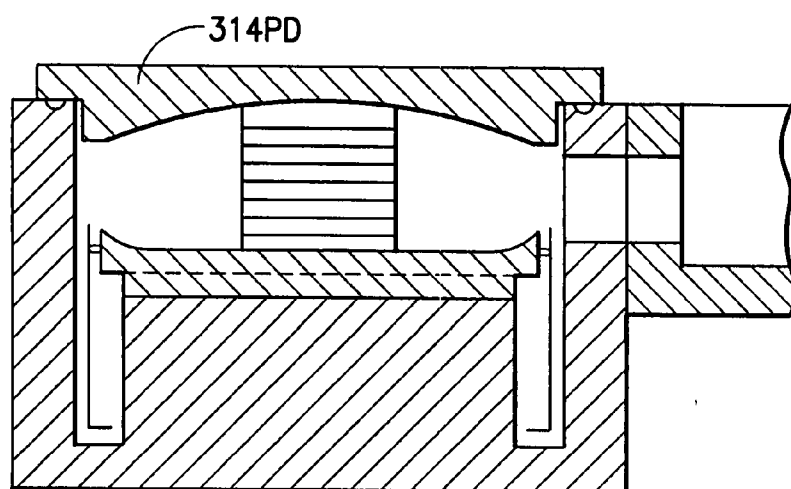


FIG. 16B

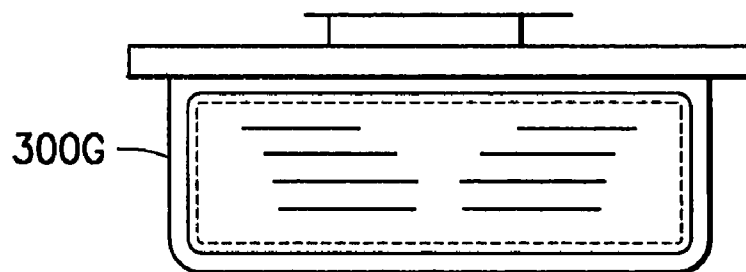


FIG. 17

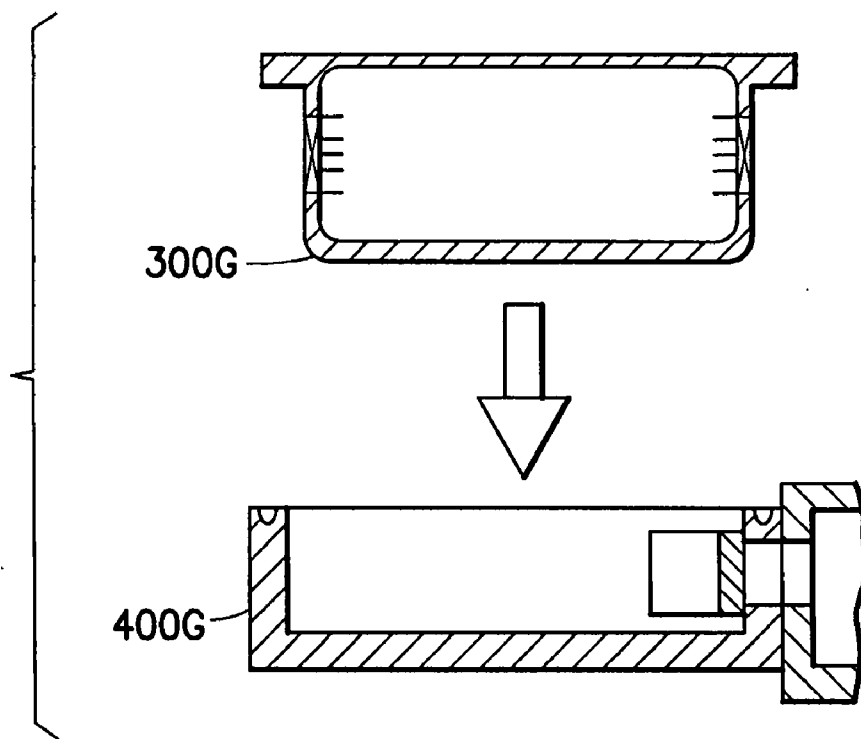


FIG. 17A

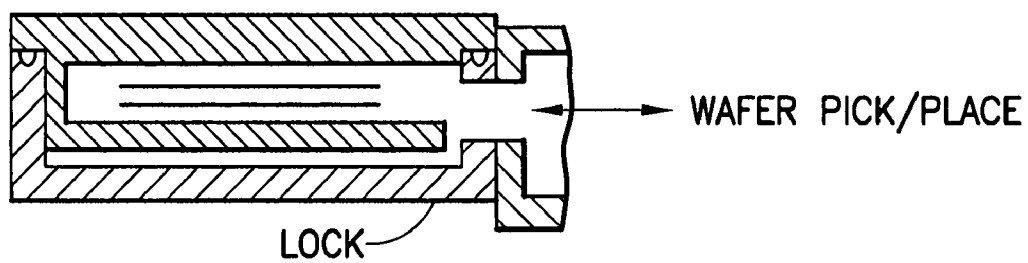


FIG.17B

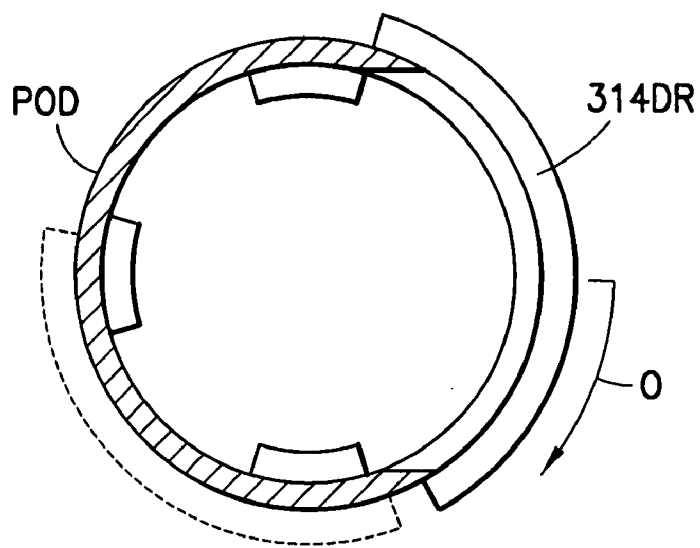


FIG.17C

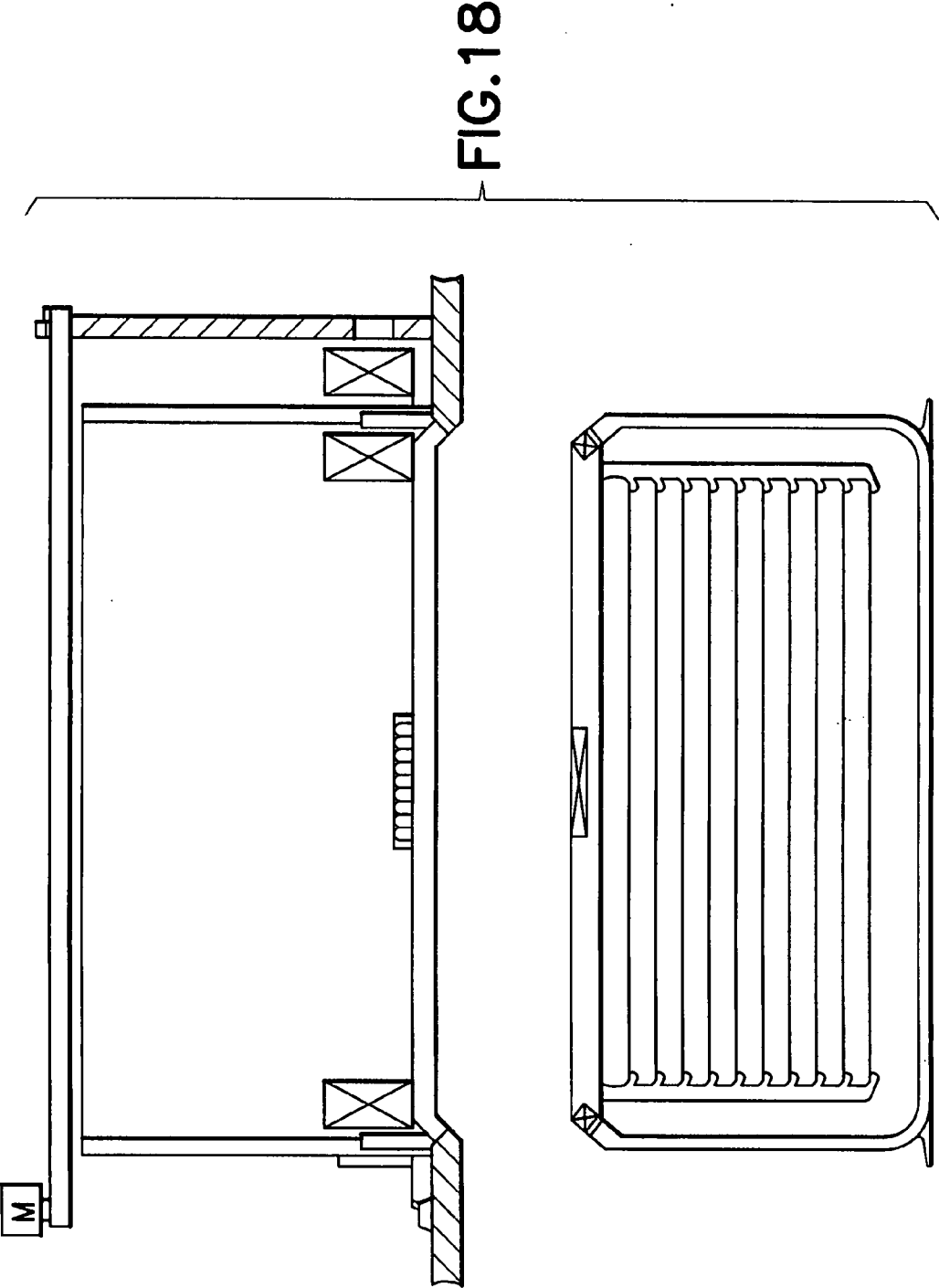
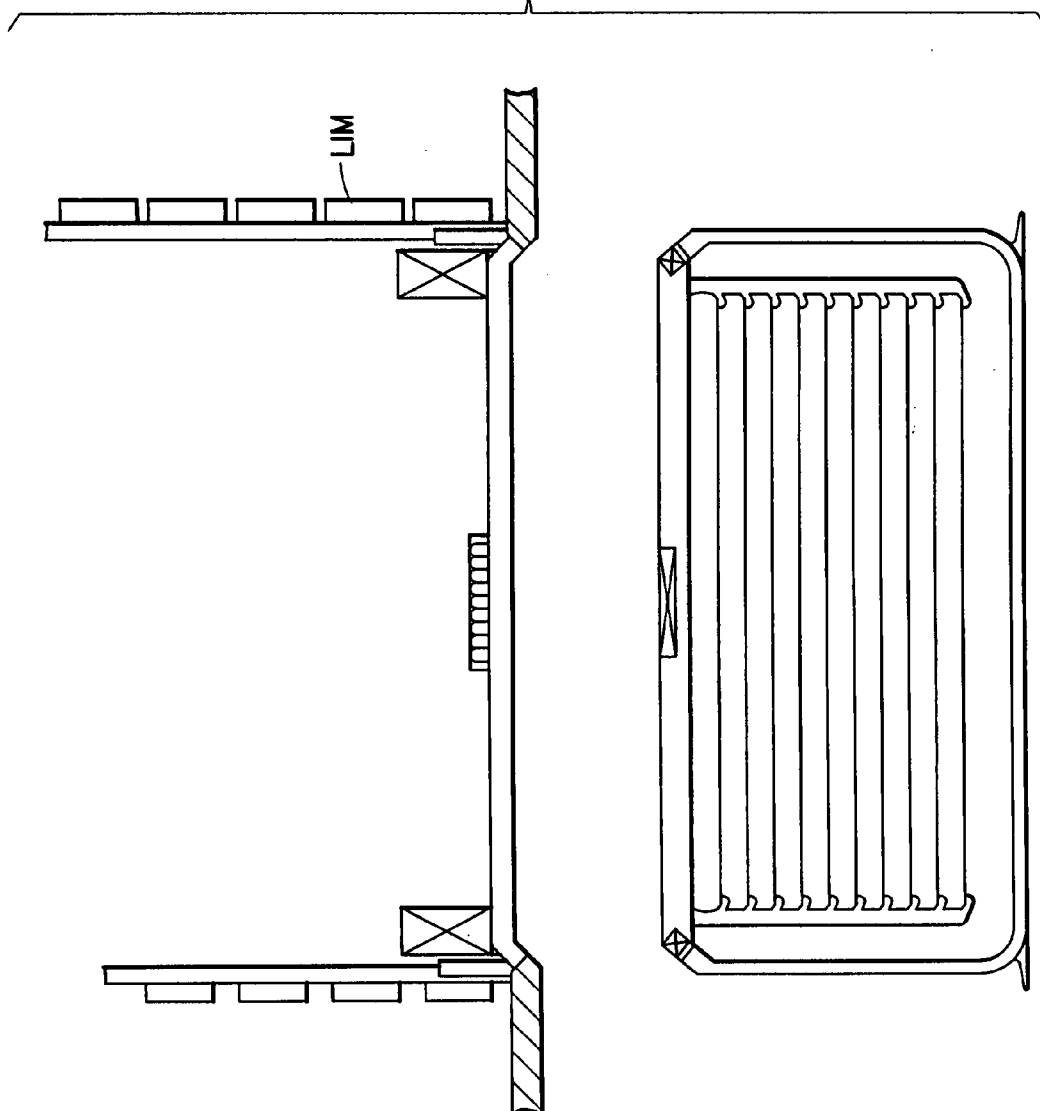


FIG. 19



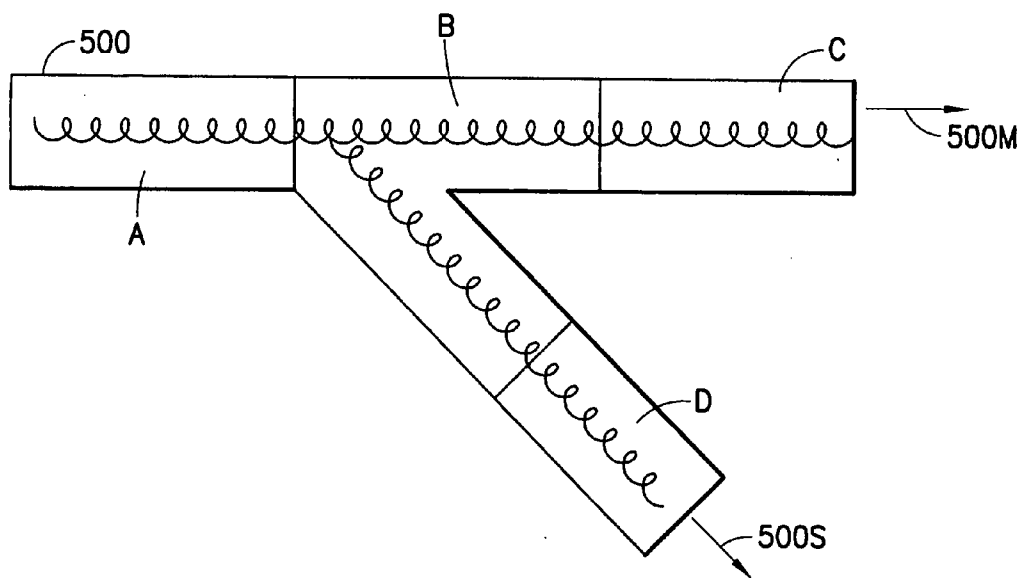


FIG. 20

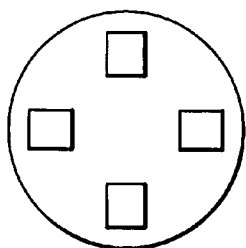


FIG. 20C

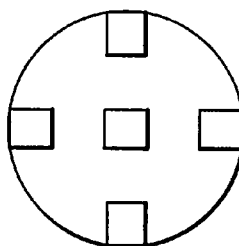


FIG. 20D

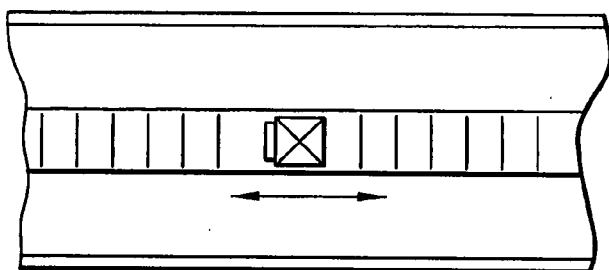


FIG. 20A

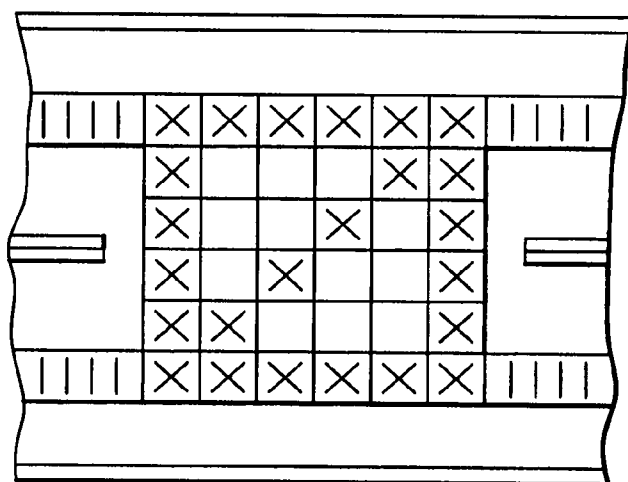


FIG. 20B

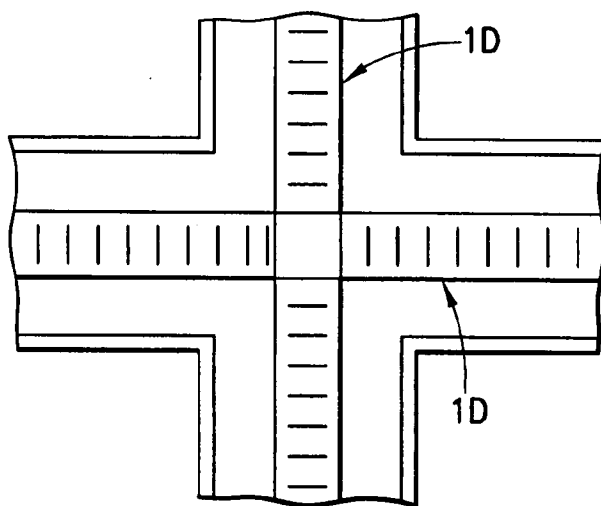


FIG. 21

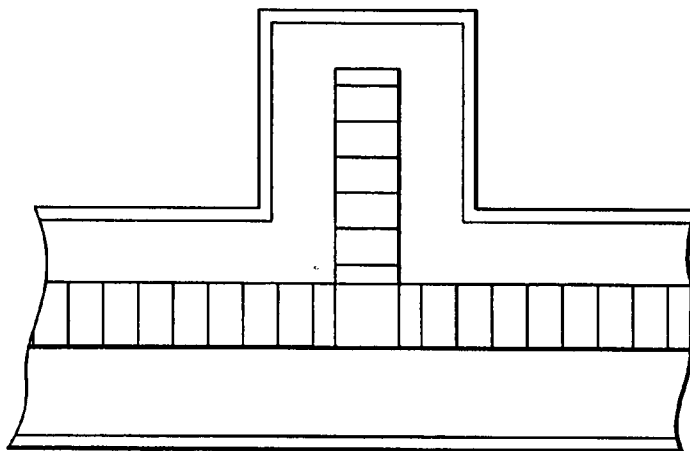


FIG. 22

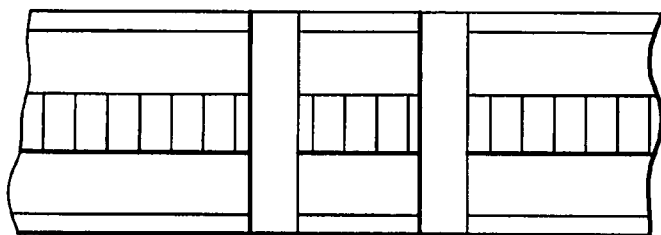


FIG. 23

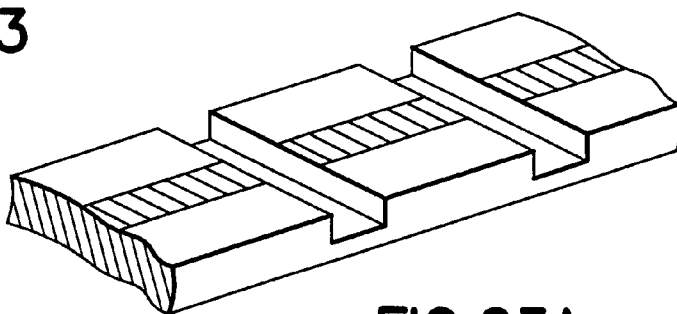


FIG. 23A

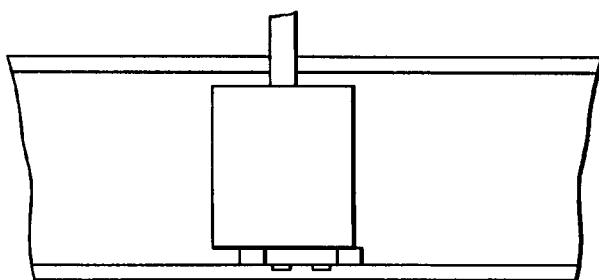


FIG. 24

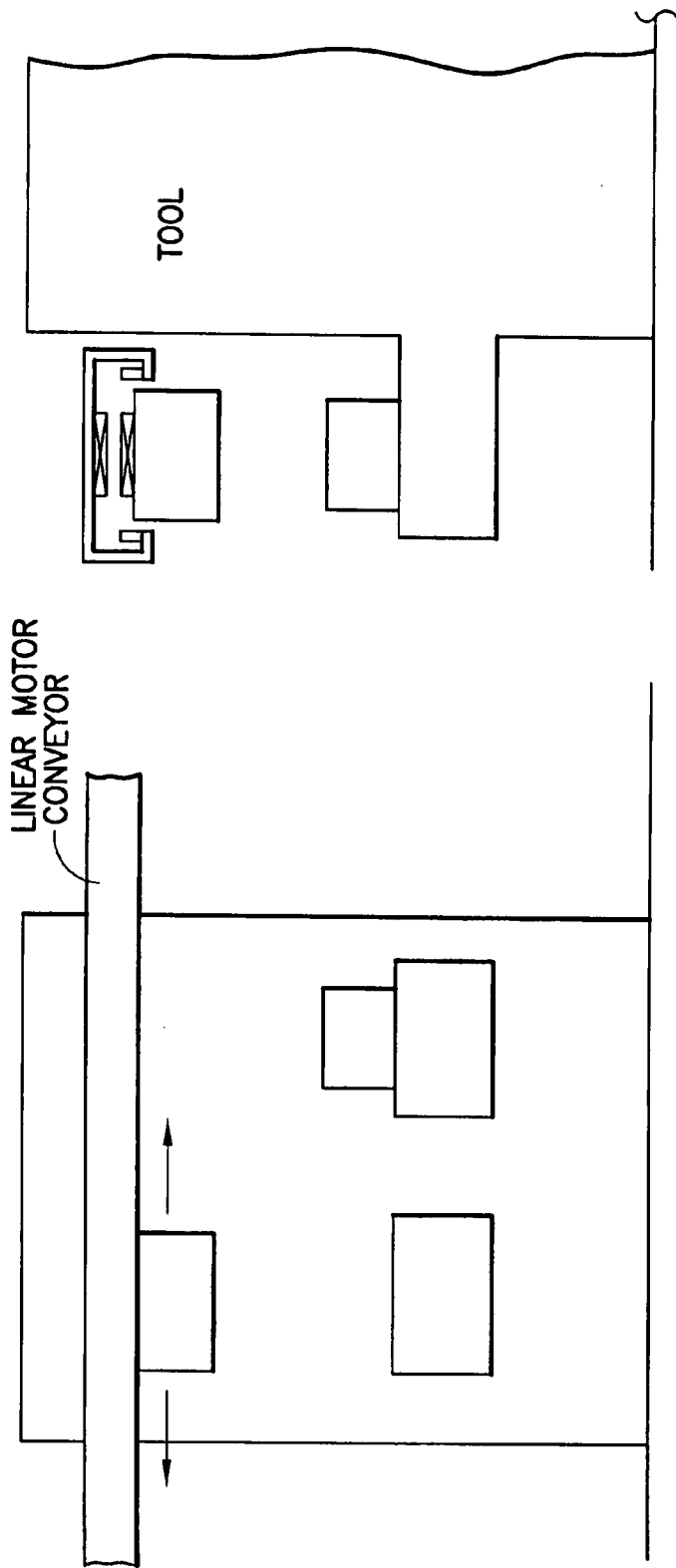


FIG. 25B

FIG. 25A

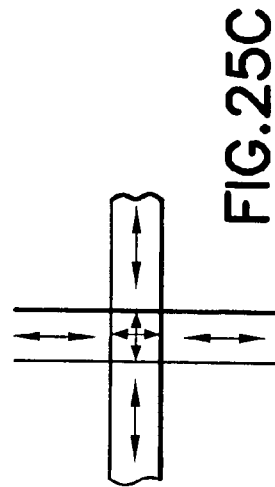


FIG. 25C

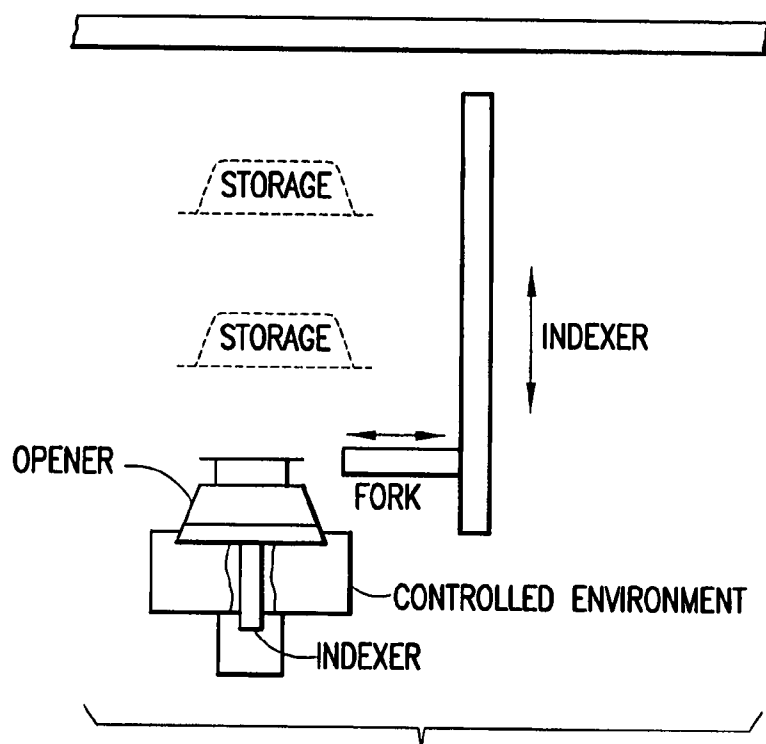


FIG. 26A

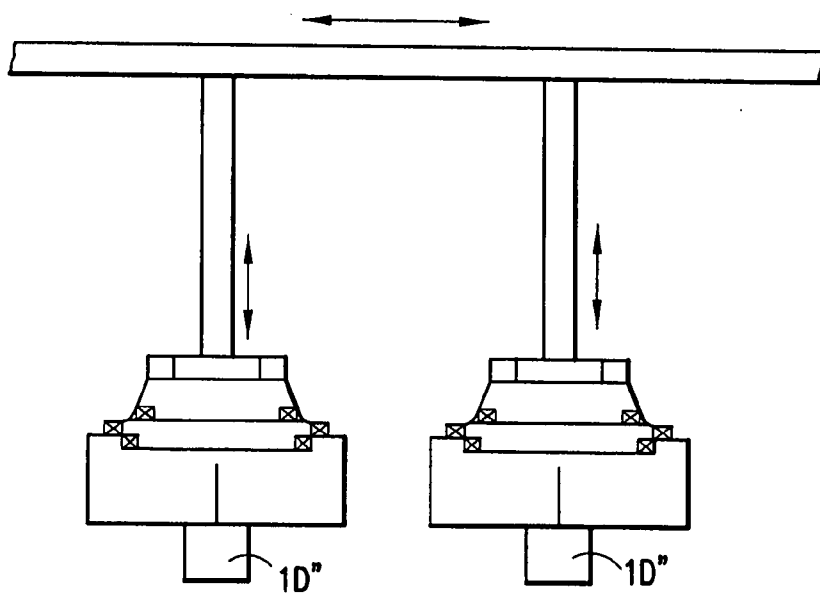


FIG. 26B

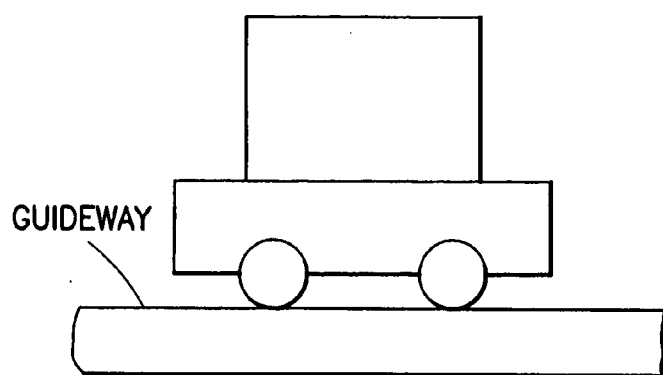


FIG. 27

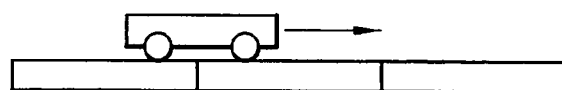


FIG. 27A

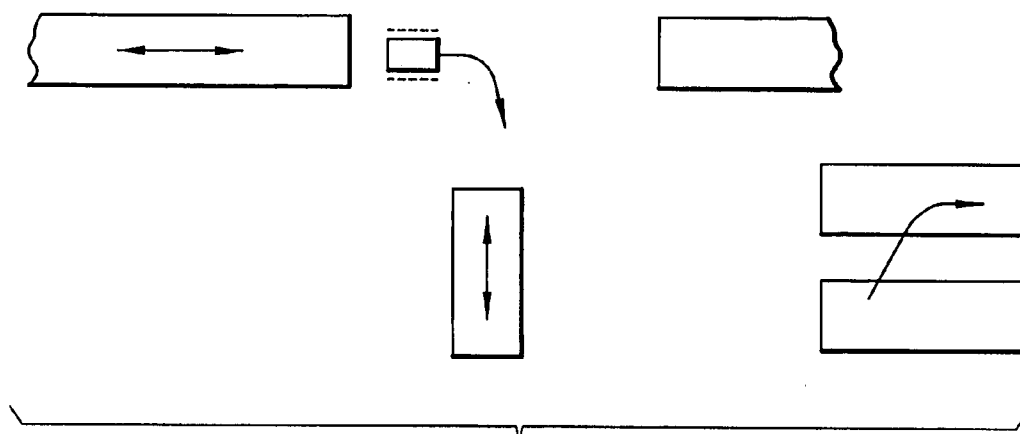


FIG. 27B

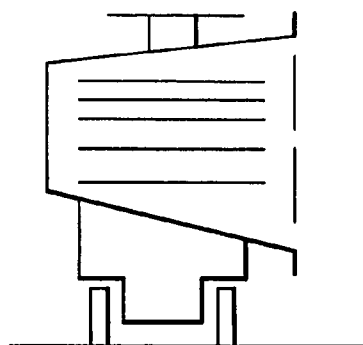


FIG. 28

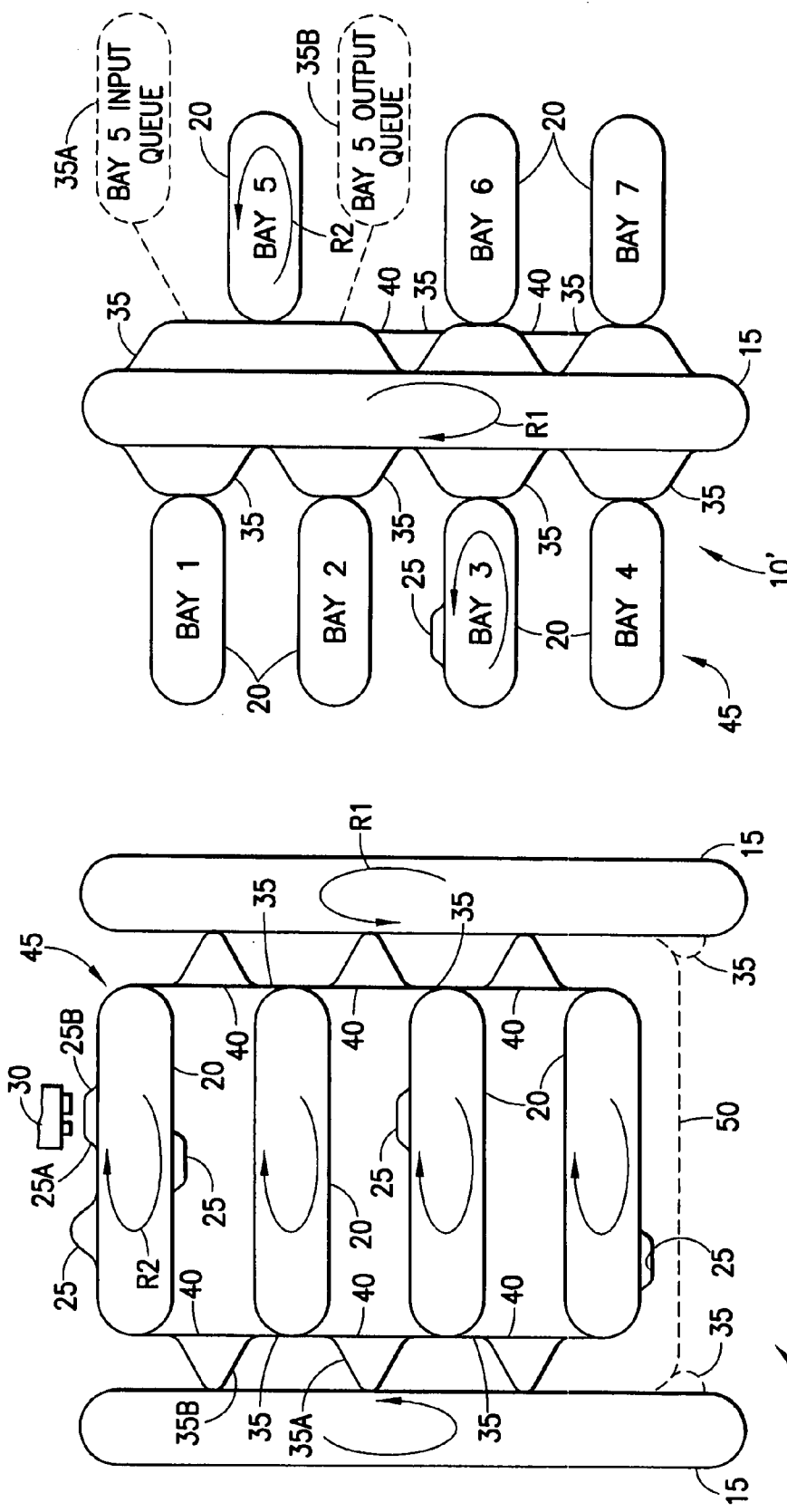


FIG.29B

FIG.29A

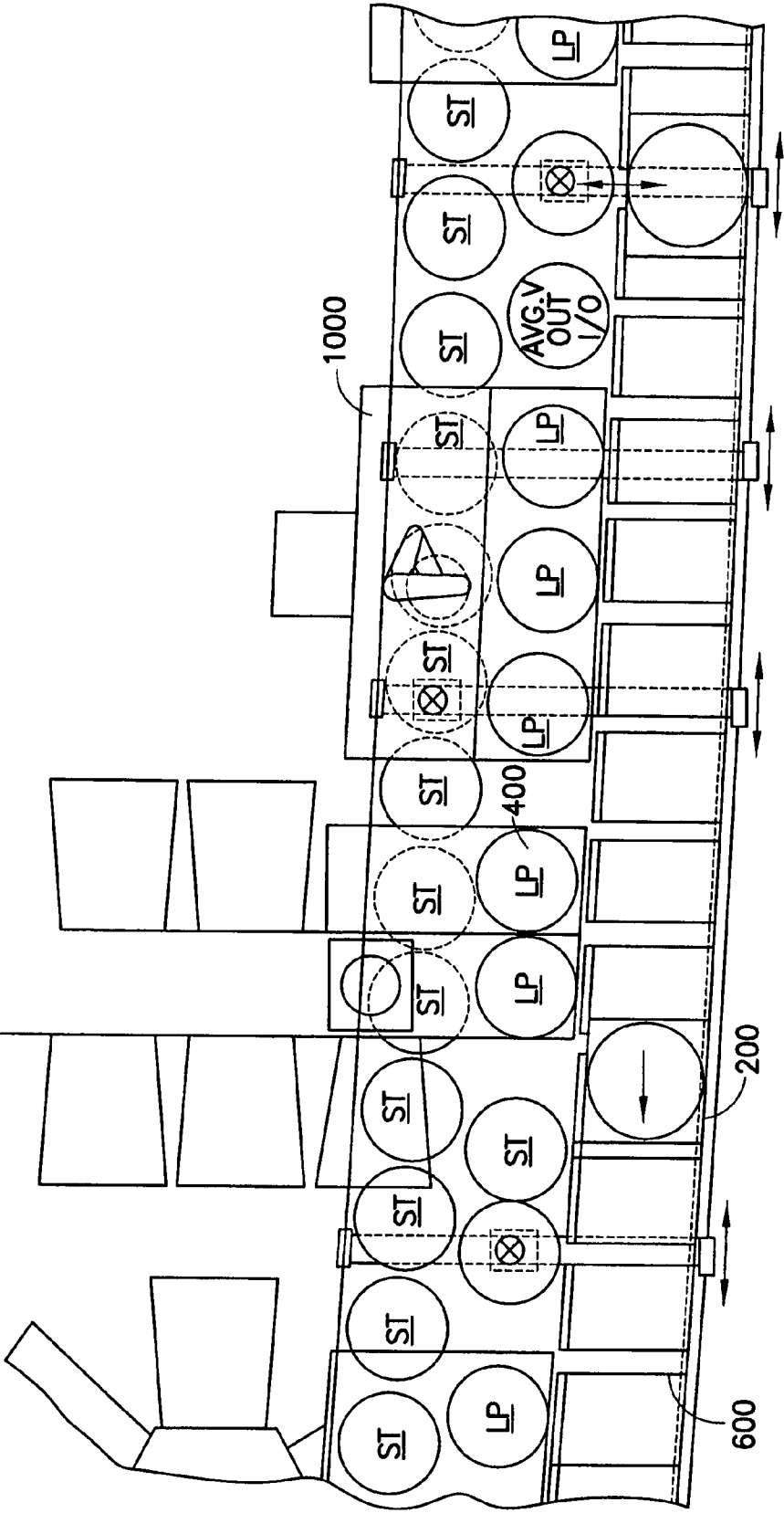
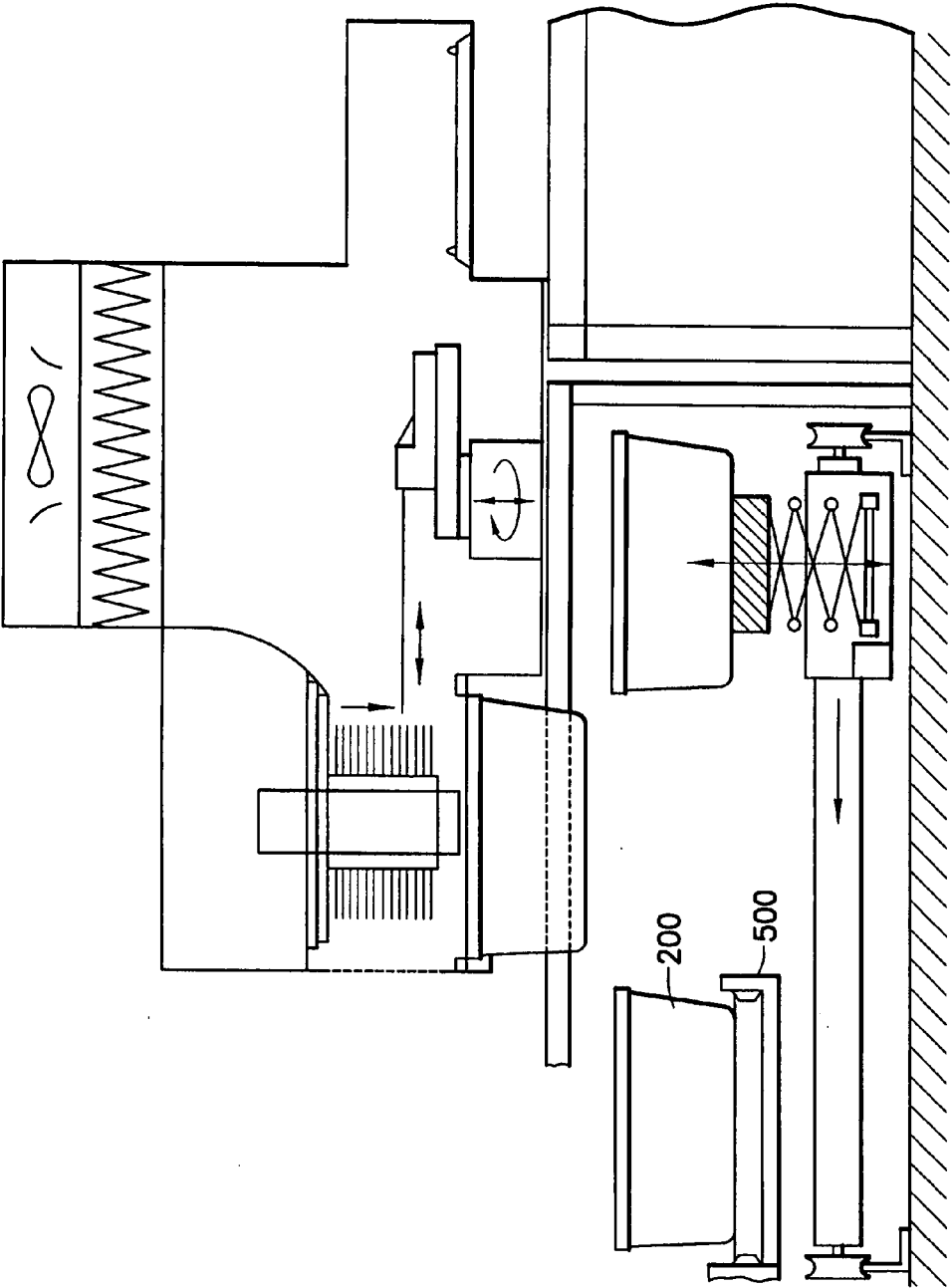


FIG. 29C



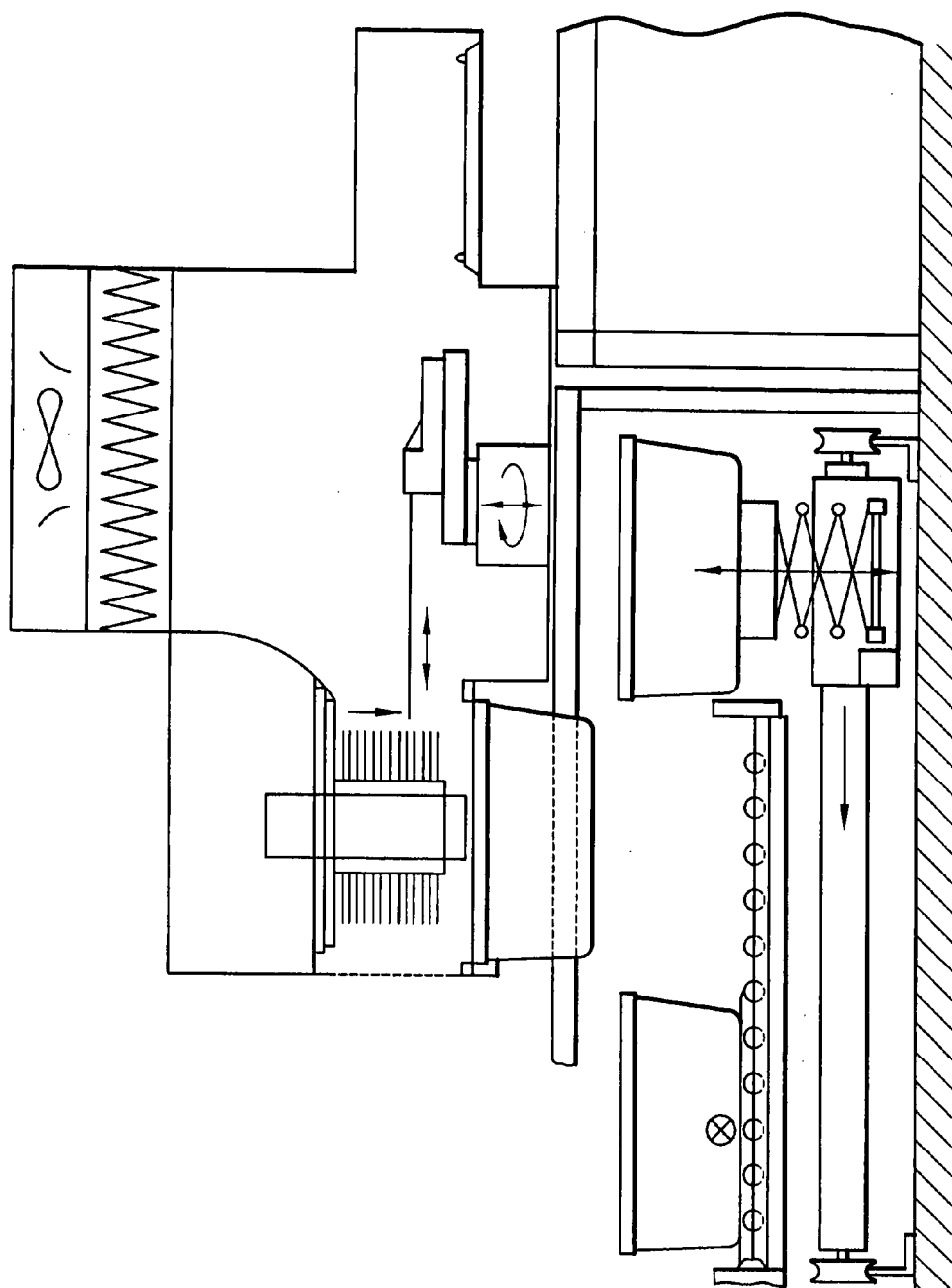


FIG. 31

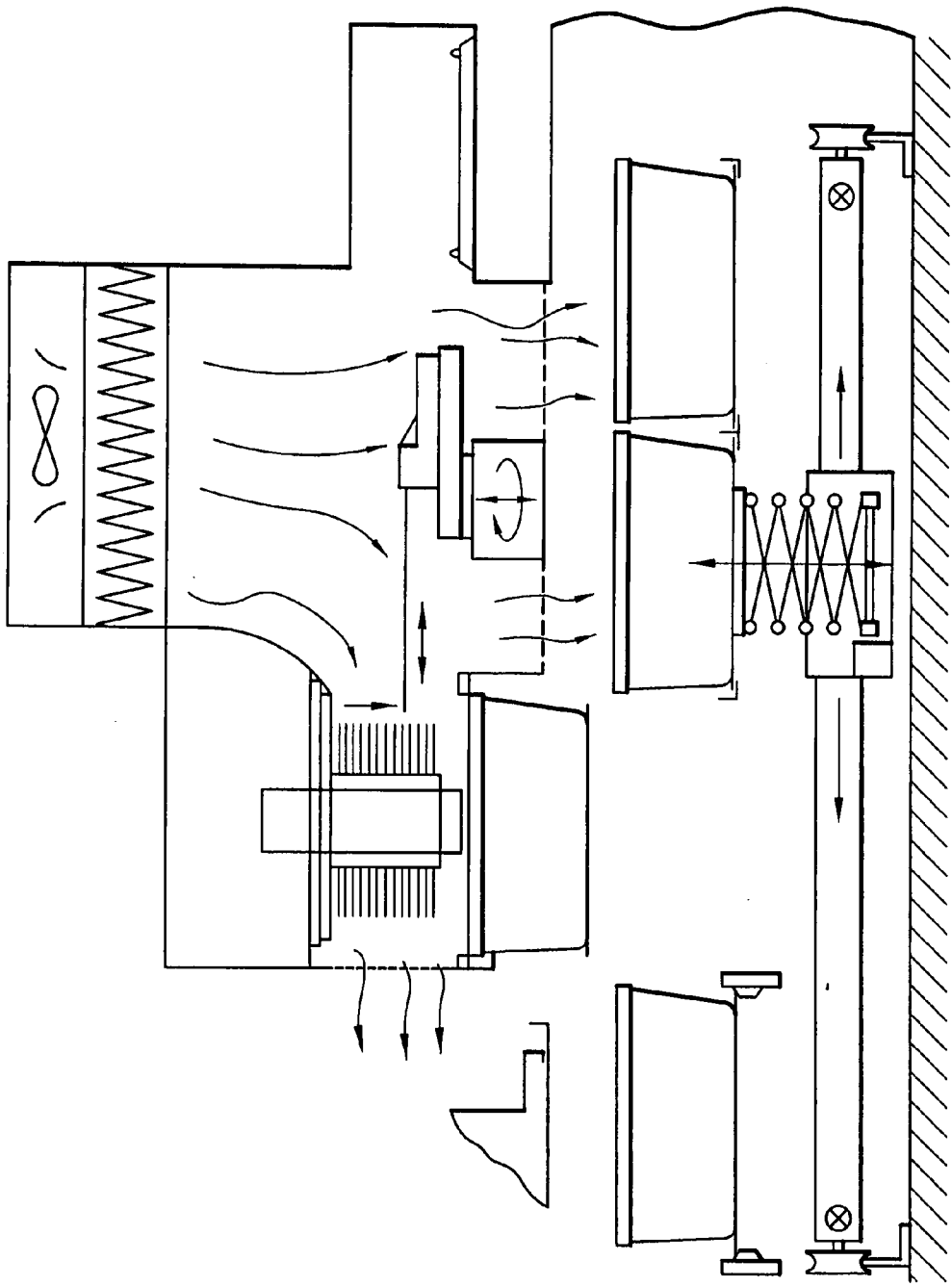


FIG. 32

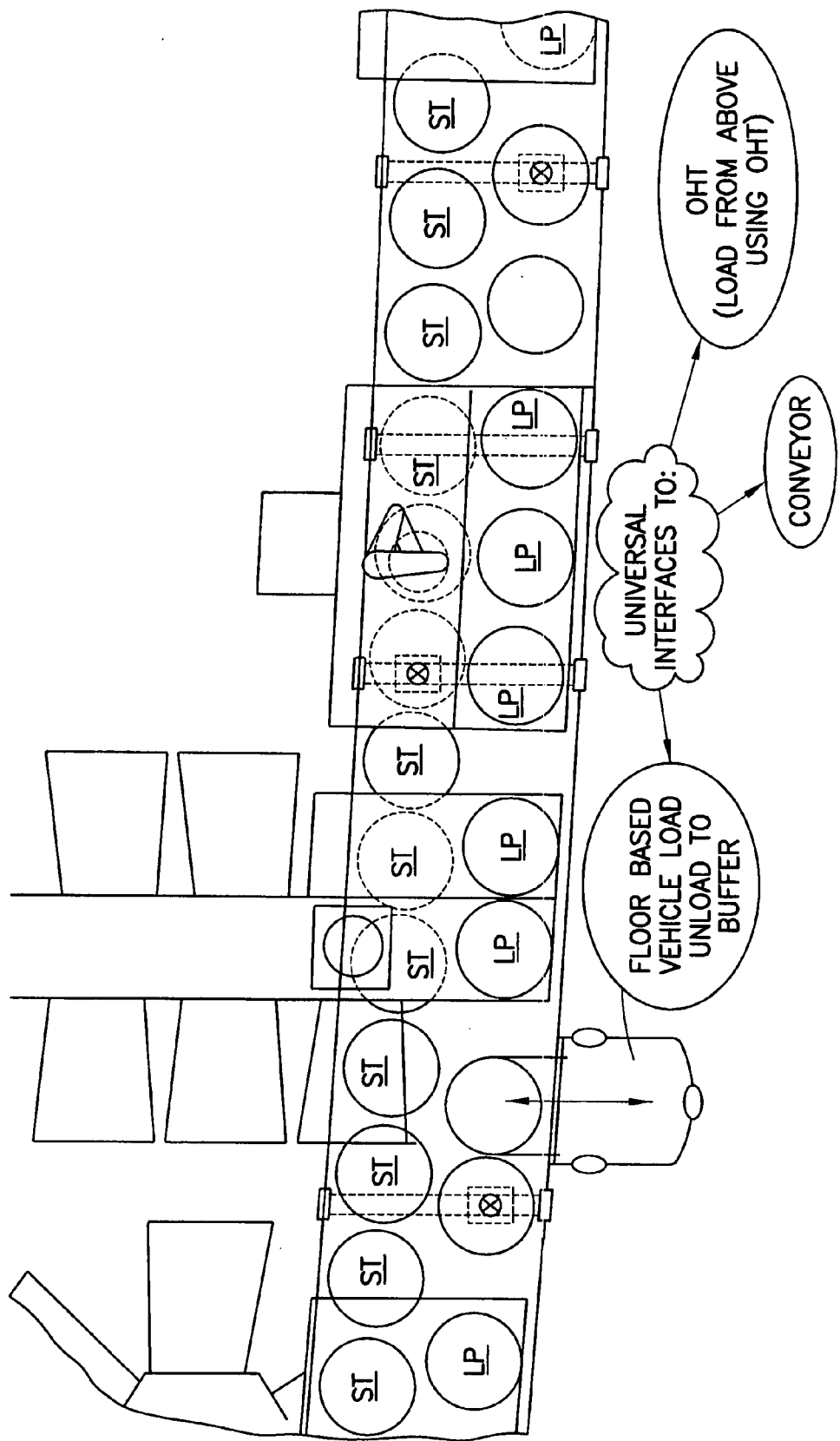


FIG.33

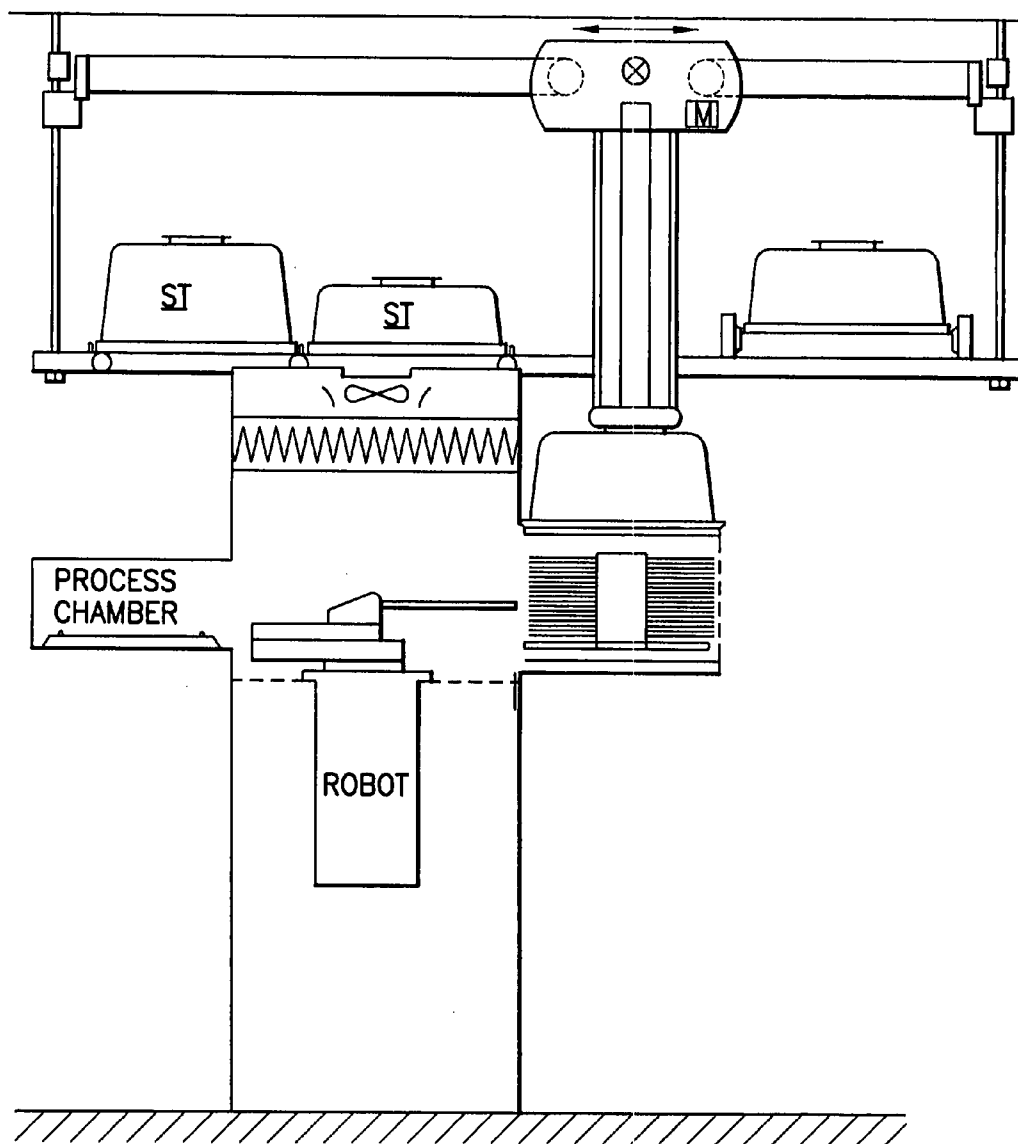
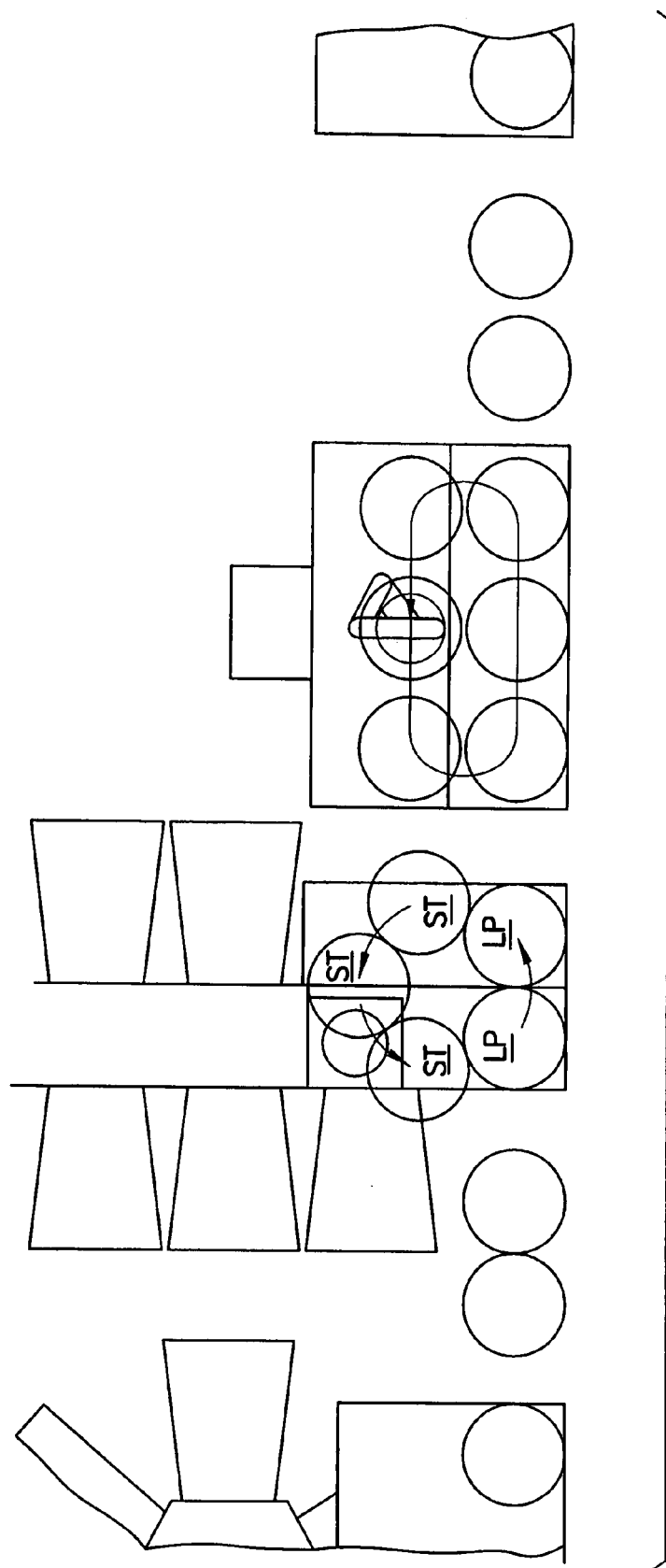


FIG.34



REDUCED CAPACITY CARRIER, TRANSPORT, LOAD PORT, BUFFER SYSTEM

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application is a claims the benefit of U.S. Provisional Application No. 60/733,813 filed Nov. 7, 2006 which is incorporated by reference herein in its entirety.

FIELD

[0002] The exemplary embodiments described herein are related to substrate processing systems and particularly to substrate transport systems, transport carriers, transport to processing tool interfaces and arrangements.

EARLIER RELATED EMBODIMENTS

[0003] The prime forces on the fabrication of electronic devices are the consumer desire for more capable, and smaller electronic devices at lower costs. The primal forces translate to an impetus on manufacturers for further miniaturization and improvements in fabrication efficiency. Manufacturers, thus seek gains wherever possible. In the case of semiconductor devices, the conventional fabrication facility or FAB has at its heart (or base organizational structure) the discrete processing tool, for example a cluster tool, for performing one or more processes to semiconductor substrates. Conventional FABs are hence organized around the processing tool, that may be arranged in desired configurations to transform the semiconductor substrates into desired electronic devices. For example, the processing tool may be arrayed in the conventional FAB in processing bays. As may be realized, between tools, substrates may be held in carriers, such as SMF's, FOUP's, so that between tools substrates in process may remain in substantially similar cleanliness conditions as within the tools. Communication between tools may be provided by handling systems (such as automated material handling systems, AMHS) capable of transporting substrate carriers to the desired processing tools in the FAB. Interface between the handling system and processing tool may be considered for example purposes as having generally two parts, interface between handling system and tool to load/unload carriers to the loading stations of the processing tool, and interface of the carriers (i.e. (individually or in groups) to the tool to allow loading and unloading of substrates between carrier and tool. There are numerous conventional interface systems known that interface the processing tools to carriers and to material handling systems. Many of the conventional interface systems suffer from complexity resulting in one or more of the process tool interface, the carrier interface or the material handling system interface having undesired features that increase costs, or otherwise introduce inefficiencies in the loading and unloading of substrates in processing tools. The exemplary embodiments described in greater detail below overcome the problems of conventional systems.

SUMMARY OF THE EXEMPLARY EMBODIMENT(S)

[0004] In accordance with an exemplary embodiment a semiconductor work piece processing system is provided. The system comprises at least one processing tool for processing semiconductor workpieces, a primary transport system, a secondary transport system and one or more

interfaces. The primary transport has one or more constant velocity transport loops. The secondary transport system has other constant velocity transport loops. The second transport system is connected to the primary transport system through queue sections. The queue sections are configured to allow movement of material between the primary transport system and the secondary transport system without disrupting the flow of the primary and secondary transport systems. The one or more interfaces are connected to the one or more transport loops of the secondary transport system through interface shunts for interfacing with at least one processing tool. The interface shunts are configured to allow movement of material between the one or more transport loops of the secondary transport system and the one or more interfaces without disrupting a flow of the secondary transport system. The flow of material along the primary and secondary transport system is continuous.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] The foregoing aspects and other features of the present invention are explained in the following description, taken in connection with the accompanying drawings, wherein:

[0006] The foregoing aspects and other features of the present invention are explained in the following description, taken in connection with the accompanying drawings, wherein:

[0007] FIG. 1 is a schematic elevation view of a workpiece carrier incorporating features in accordance with an exemplary embodiment, and a workpiece or substrate S positioned on the carrier; and FIGS. 1A-1B are respectively schematic partial plan and elevation views of a workpiece support of the carrier in accordance with another exemplary embodiment,

[0008] FIG. 2A is a schematic cross-sectional elevation view of the carrier in FIG. 1 and a tool port interface in accordance with another exemplary embodiment;

[0009] FIG. 2B is another schematic cross-section elevation of a tool port interface and carrier in accordance with another exemplary embodiment;

[0010] FIGS. 3A-3C are schematic cross-section elevation views respectively illustrating a tool port interface and carrier, in accordance with another exemplary embodiment, in three different positions;

[0011] FIG. 4 is a schematic elevation view of a carrier and tool interface in accordance with yet another exemplary embodiment, and FIGS. 4A-4C are respectively enlarged cross-sectional views of a portion of the interface between carrier and tool each illustrating the interface configuration in accordance with different exemplary embodiments,

[0012] FIGS. 5A-5C are schematic partial elevation views of a carrier and tool interface in accordance with yet another exemplary embodiment, showing the carrier and tool interface in three respective positions.

[0013] FIGS. 6A-6B are respectively schematic elevation views of workpiece carriers in accordance with other different exemplary embodiments;

[0014] FIGS. 7A-7C are schematic elevation views of a workpiece carrier, in accordance with another exemplary embodiment, respectively showing the carrier in different positions;

[0015] FIG. 8 is another schematic elevation view of tool interface and carrier in accordance with another exemplary embodiment;

[0016] FIG. 9 is another schematic elevation view of tool interface and carrier in accordance with another exemplary embodiment;

[0017] FIG. 10 is another schematic elevation view of tool interface and carrier in accordance with another exemplary embodiment, and FIG. 10A is a schematic partial elevation of a process tool and carrier interfaced therewith in accordance with another exemplary embodiment;

[0018] FIG. 11 is a schematic elevation view of a process tool section and carrier interface therewith in accordance with another exemplary embodiment;

[0019] FIGS. 12A-12B are schematic bottom views of the carrier (workpiece transfer) opening and carrier door of the carrier in FIG. 11;

[0020] FIGS. 13A-13B are schematic top plan views of the interface and a tool to carrier door interface of the tool section in FIG. 11;

[0021] FIG. 14 is a schematic elevation of a process tool and carrier interfaced therewith in accordance with still another exemplary embodiment;

[0022] FIG. 15 is a schematic elevation view of a tool interface and carrier in accordance with yet another exemplary embodiment;

[0023] FIGS. 16A-16B are schematic elevation views of a tool interface and carrier respectively shown on two different positions in accordance with another exemplary embodiment;

[0024] FIG. 17 is a schematic side view of a carrier, and FIGS. 17A-17C are other schematic elevation views of the carrier and a tool interface and a plan view of the tool interface in accordance with another exemplary embodiment;

[0025] FIGS. 18-19 are schematic elevation views of a tool interface and carrier in accordance with another exemplary embodiment;

[0026] FIG. 20 is a schematic plan view of a transport system in accordance with another exemplary embodiment;

[0027] FIGS. 20A-20B are schematic partial plan views of portions of the transport system track in FIGS. 10; and FIGS. 20C-20D are schematic bottom views of a different payloads of the transport system in accordance with other exemplary embodiments;

[0028] FIG. 21 is a schematic partial plan view of another portion of the transport system in accordance with another exemplary embodiment;

[0029] FIGS. 22-24 are other schematic partial plan views of portions of the transport system in accordance with other exemplary embodiments;

[0030] FIGS. 25A-25B respectively show different elevation views of a transport system and processing tool in accordance with another exemplary embodiment;

[0031] FIGS. 26A-26B respectively show different schematic elevation views of a transfer interface system for

transferring carriers between transport system and tool in accordance with another exemplary embodiment;

[0032] FIG. 27 is a schematic partial elevation view of a transport system in accordance with another exemplary embodiment and FIGS. 27A-27B are other schematic partial elevations of the transport system in different positions;

[0033] FIGS. 28 is another schematic elevation view of a transport system in accordance with another exemplary embodiment;

[0034] FIGS. 29A-29B are schematic plan views of transport systems in accordance with another exemplary embodiment;

[0035] FIG. 29C is a schematic plan view of a transport system and processing tools in accordance with another exemplary embodiment;

[0036] FIG. 30 is a schematic partial elevation of the transport system and processing tools in FIG. 29C;

[0037] FIG. 31 is another schematic partial elevation of the transport system;

[0038] FIG. 32 is another schematic partial elevation of the transport system in accordance with another exemplary embodiment;

[0039] FIGS. 33-34 are respectively schematic plan and elevation views of another transport system in accordance with other exemplary embodiments; and

[0040] FIG. 35 is yet another schematic plan view of a transport system in accordance with another exemplary embodiment.

DESCRIPTION OF THE EMBODIMENT(S)

[0041] Still referring to FIG. 1, the workpiece carrier 200 defines a chamber 20L in which workpieces S may be carried in an environment capable of being isolated from the atmosphere exterior to the chamber. The shape of the carrier 200 shown in FIG. 1 is merely exemplary, and in alternate embodiments the carrier may have any other desired shape. The carrier 200 may be capable of accommodating a cassette 210 inside the chamber for supporting the workpieces S within the carrier as shown. The cassette 210 generally has elongated supports 210S (in the embodiment two are shown for example) with workpiece support shelves distributed thereon to provide a row or stack of supports, or shelves on which one or more workpieces may be individually supported as shown. The cassette may be mounted or otherwise attached to the carrier structure, and will be described in greater detail below. In alternate embodiments, the carrier may not have a cassette, and the workpiece supports may be integral or formed as a unitary construction with the carrier structure. The workpieces are shown as flat/substrate elements, such as 300 mm, 200 mm or any desired size and shape semiconductor wafers, or reticles/masks or flat panels for displays or any other suitable items. The carrier may be a reduced or small lot size carrier, relative to conventional 13 or 25 wafer carriers. The carrier may be configured to carry a small lot with as few as one workpiece, or may be configured to carry small lots of less than ten workpieces. Suitable examples of reduced capacity carriers, similar to carrier 200, is described and shown in U.S. patent application Ser. No. 11/207,231, filed Aug. 19, 2005, titled

“Reduced Capacity Carrier and Method of Use”, incorporated by reference herein in its entirety. Suitable examples of interfaces of the reduced capacity carrier, similar to carrier **200**, to processing tools (e.g. semiconductor fabrication tools, stockers, sorters, etc.) and to transport systems are described and shown in U.S. patent applications Ser. No. 11/210,918, filed Aug. 23, 2005, titled “Elevator Bases Tool Loading and Buffering System”; and Ser. No. 11/211,236, filed Aug. 24, 2005, titled “Transportation System”, both of which are incorporated by reference herein in their entirety. Another suitable example of a carrier, with features similar to carrier **200**, is described and shown in U.S. application Ser. No. 10/697,528, filed Oct. 30, 2003, titled “Automated Material Handling System” and also incorporated by reference herein in its entirety. The reduced size carrier such as carrier **200**, allows reduction of work in process in the FAB as the workpieces forming smaller lots may be immediately (upon completion of processing at a given workstation) transported to following workstations in the FAB without waiting for completion of processing of other workpieces as would occur in larger lots. Though the features of the exemplary embodiments are described and shown with specific reference to small capacity carriers, the present invention applies equally to any other suitable carrier.

[0042] Referring still to FIG. 1, in the exemplary embodiment, carrier **200** may be shaped to hold the workpieces in a vertical (i.e. Z axis) stack. Carrier **200** may be a bottom or top opening or bottom and top opening carrier. In this embodiment, top and bottom are disposed along the vertical or Z axis, though in alternate embodiments top and bottom may be oriented along any other axis. Top and bottom openings, which will be described in greater detail below, means that the opening(s) **204** of the carrier (through which workpieces S moved in and out of the chamber **20L**, defined by the carrier) are substantially aligned with the planar surface of the workpieces held in the carrier (in this embodiment substantially orthogonal to Z axis). Carrier **200** as will also be seen below; generally has a casing **212** with a base and a closable or removable door. When closed, the door may be locked and sealed to the base. The seal between door and base may allow the chamber **202** to be isolated from the exterior atmosphere. The isolated chamber **202** may hold any desired isolated atmosphere, such as an inert gas, or may be capable of holding a vacuum. The door may be opened to allow workpieces to be loaded/unloaded from the carrier. In this embodiment, door means a removable or removed portion when the carrier is opened to access the workpieces/workpiece support shelves therein. In the exemplary embodiment shown in FIG. 1, casing **200** generally has a generally recessed or hollow portion (referred to hereafter as the shell) **214** capable of receiving the workpieces therein, and a wall (cap/cover, etc.) **216**. As will be described below, either wall **216**, or shell **214** may operate as the carrier door. The wall and shell are mated to close the carrier, and are separated to open the carrier. In the exemplary embodiment, the shell and wall may be metal, such as an aluminum alloy, or stainless steel made by any suitable process. The wall or shell or both may be one piece members (unitary construction). In alternate embodiments, the carrier casing may be made of any other suitable materials. Cassette **210** may be mounted to the wall **216**. Though in the embodiment shown, wall **216** is located on top of the shell, in alternate embodiments the carrier casing may have a configuration with the shell on top and wall on the bottom. In still other embodi-

ments, the shell may have a removable wall both on top and bottom (i.e. carrier with top and bottom openings).

[0043] Referring now to FIG. 2A, carrier **200** is shown positioned at a tool port interface. In the embodiment shown in FIG. 2A, the carrier **200** may be bottom loaded (i.e. moved in Z direction) to interface with the tool port as will be described below. FIG. 2A shows top wall **216** operating as the door for carrier **200**. For example, wall **216** may be connected to the port door and removed in unison with removal of the port door, for example into the tool, to open the tool port interface. Removal of the wall **216**, causes removal of the cassette (mounted thereon) and workpieces thereon from the carrier (for access by a workpiece transport/robot). Referring again to FIG. 1, the configuration of cassette **210** with opposing supports, provide access areas on more than one side of the cassette (here two sides) which workpiece robot may load/unload workpieces onto the cassette shelves. Multiside robot access to the cassette may allow workpiece hand off between robots at the cassette. Also, multisided robot access to workpieces delimits the orientation of the carrier when transported or interfaced to tool port. The carrier is closed by returning the port door to its closed position which returns the carrier wall **216** to mate with shell **214**. Referring to FIG. 2B, there is shown the interface of carrier **200** with a tool port interface in accordance with another exemplary embodiment. In this embodiment, the shell **214** of the carrier operates as the door. In the embodiment shown the tool port door may have a shape generally conformal to the carrier shell, to surround and seal around the shell in order to prevent exposure inside the tool interior to contamination on the outside of the shell. The carrier may be top loaded, (i.e. moved down along (–) Z direction) such as when the carrier is being lowered from an overhead transport system. To open the carrier **200**, the port door is moved down (direction (–)Z), for example into the tool interior, simultaneously removing the shell **214** from the carrier. This may be referred to as bottom opening the carrier, in that the carrier door here (i.e. shell **214**) is located on the bottom and opens the carrier by downward movement. The opening of the carrier, exposes the workpieces in the cassette, which remain with wall **216**. In this embodiment, the robot may be provided with degree of freedom in Z axis to access the vertically spaced cassette shelves or workpieces therein. The robot may have a mapper thereon. In alternate embodiments, the shell **216** may have an integral mapper, such as a through beam mapper allowing mapping of the cassette on removal of the shell. FIGS. 2A-2B illustrate that carrier **200** may be both top and bottom openings. In other alternate embodiments, whence the shell and wall orientation is reversed (shell on top of wall) the carrier may be top opening in a similar but mirror image to FIG. 2B (i.e. lifting shell up) and bottom opening in a manner similar but opposite to FIG. 2A (i.e. lowering wall down).

[0044] Referring again to FIGS. 1, the wall **216** and shell **214** may be passive structures, without movable elements, such as locks, movable which have the potential for generating contamination with the tool clean space. For example, the wall and shell may be magnetically locked to each other. Magnetic locks may have a reversible magnetic element that is switched (i.e. to open or close) by passing a charge through the reversible element. For example, the wall may include magnetic elements (for example ferrous material) and the shell may have a magnetic switch actuated to lock

and unlock the wall and shell. The magnetic elements in the wall, and the operable magnets in the shell may be configured to allow cooperation with magnetic locks in the port door interface so that locking the carrier door (either wall or shell, see FIGS. 2A-2B) to the port door causes unlocking of the carrier door from the rest of the carrier. In alternate embodiments, the magnetic locks between wall and shell may have any other desired configuration. The metal passive carrier and carrier door provide a clean, washable carrier that is vacuum compatible.

[0045] As noted before, the carrier door and base (i.e. wall 216 and shell 224) may be sealed to isolate the carrier chamber. Also, when the carrier is interfaced with the port of a tool, (for example a load port module), the carrier door and base may each have sealing interfaces for respectively sealing the carrier door (i.e. wall 216 or shell 214 in FIG. 1) to the port door and the carrier base to the port. Further, the port door may have a seal interface to the port. FIGS. 3A-3C show a carrier 2201, similar to carrier 220, being interfaced to tool port TP in accordance with an exemplary embodiment where the respective seal interfaces (221, carrier door to carrier, 222, carrier to port, 223' port door to port and 224' port door to carrier door) form a general X configuration (seen best in FIG. 3B). In the exemplary embodiment, the carrier 200' is illustrated as a top opening (wall 216' is door opened by lifting upwards) and the port TP is configured for bottom loading (lifter lifts carrier upwards to dock to tool port) for example purposes. The shell 214' in this embodiment may have a sealing interface 214I' generally beveled sealing faces 221C', 222C'. Though the sealing faces 222C', 221C' on the shell are shown substantially flat, in alternate embodiments the sealing faces may have inclusive or exclusive angles or other shapes formed therein for enhanced sealing though the surface is generally pitched to result in the generally x shape seal configuration. The wall 216' of the carrier in this embodiment has sealing interface 216I' beveled generally to define sealing faces 221CD' and 224CD'. As seen in FIG. 2A, the shell and wall sealing faces 221C', 221CD' are generally complementary defining seal interface 221' when wall and shell are closed. The angled faces 221C' on the carrier interface 214' form a general wedge providing a guide for the wall 216' when being seated onto the shell (see for example FIG. 3C). Also, the carrier door to carrier seal interface 221' is positioned so that the weight of the wall 216' acts to increase sealing pressure on the interface. As may be realized, the cassette and workpieces supported from the wall 216' in this embodiment and in sealing the carrier door to carrier. As seen in FIGS. 3A-3B, sealing faces 222C' and 224CD' are disposed to complement the sealing faces 222P', 224PD' respectively on the port P and port door PD. FIG. 3B shows the carrier 200' docked to the port, and seals 222', 224' closed. Closure of seals 222', 224' seals off and isolates all exposed surfaces (i.e. surfaces exterior of controlled or isolated chambers inside the carrier or tool) with potential contamination from the interior/chambers of the tool and carrier. As seen best in FIG. 3B, the generally X shape seal 220' provides for optimal cleanliness as it forms what may be referred to as a substantially zero lost volume interface. This means that the seal geometry of seal 220' does not generate substantial pockets or spaces having exterior surfaces that are exposed (i.e. become interior surfaces) when either the carrier door or the port door is opened. This is best seen in FIG. 3C, wherein removal of the

port door, thereby removing the carrier door does not cause exposure of any previously unsealed/exterior surfaces to the carrier/process tool interiors.

[0046] As seen in FIG. 3C, top opening of the carrier door, results in this embodiment in the carrier chamber 202' being located under the raised cassette supported from the wall 216'. The carrier chamber 202' is in communication with the tool interior, that may have a forced air circulation system, which may cause a general venturi flow within the carrier chamber. In this embodiment, the circulatory air flow within the carrier chamber is located below the workpieces on the raised cassette (hanging from wall 216') with minimum potential for deposition of particulates disturbed by the circulation (which settle down away from the workpieces above).

[0047] Referring now to FIG. 4, there is shown a carrier 300 in accordance with another exemplary embodiment. Carrier 300 is generally similar but inverse to carrier 200 with the shell 314 on top of wall 316. Similar to carrier 200, carrier 300 may be either top (shell operates as door) or bottom (wall operates as door) opening. In this embodiment, the carrier 300 may have integral transport. For example, the carrier shell (or wall) may have transport supports such as rollers or air bearings and a reactive member capable of being motivated by a drive or motor to cause the carrier to be self transportable (i.e. without using an independent transport vehicle) within the FAB. Carrier 300 may also have a three, four or five way "cross" seal similar to the X seal 220' shown in FIG. 3B. FIG. 4A shows a cross sectional view of the seal 320 in accordance with one embodiment. Seal 320 is a four way seal for a bottom opening configuration but otherwise generally similar to seal 220'. FIG. 4B shows another (cross-section of the seal in accordance with another exemplary embodiment. In this embodiment, seal 320' is substantially similar to seal 320. FIG. 4B further shows that the shell interface 314I' may have supporting flanges/features 326', 328'. Flange 326' in this embodiment operates wall 316' may locate a magnetic lock to hold the wall to shell 314' when the carrier door is closed. Further, feature 326' may overlap magnetic lock in the port door PD. The magnetic lock in the port door is for locking the wall 316' to the port door for carrier door removal. The position of the carrier shell feature 326' may enable the activation of the port door lock (locking wall 316' to the port door) to cause unlocking/deactivation of the wall to shell lock. Exterior feature 328' on the shell may engage a locating/centering feature of the port to locate the carrier when seated. As noted before, the X configuration of seal 320' may eliminate purging the seal interface prior to opening the carrier door because the seal interface may have substantially zero purge volume. In the embodiment shown in FIG. 4B, the port may include a purge line. FIG. 4C shows another cross section of the carrier tool interface in accordance with another embodiment. The carrier to port interface has seal 320" generally similar to seal 320 described before. In this embodiment, the carrier shell 314" may have a support 328" for seating the carrier 300" on the port without loading the port door PD (i.e. supporting the carrier 300" on the port without distributing carrier weight onto the port door) with the carrier door (wall 316"). Sealing contact at port door to carrier door seal 321" remains substantially constant when opening and closing the carrier door.

[0048] FIGS. 5A-5C illustrate a carrier 300A, similar to carrier 300, mated to a tool port in accordance with another exemplary embodiment. Carrier 300A in this embodiment is top opening and bottom loaded. Carrier shell 316A operates as the door. The seal interface 320A, seen best in FIG. 5B is what may be referred to as a three way seal, with a general Y configuration (interface 321A, wall to shell, interface 322A wall to port, interface 323A port to port door. In this embodiment, the port door is conformal to the shell 316A. Shell 316A is nested in the port door. A seal not shown may be provided between shell 316A and port door to seal the interface therebetween. As seen in FIG. 5B, the port door in this embodiment may have a vacuum port to purge the port door to carrier door volume.

[0049] Referring again to FIGS. 2A-2B, the carrier to port interface is shown herein still another configuration. Interface 220 is substantially similar in the exemplary embodiments shown in FIGS. 2A, 2B (bottom load/top opening, top load/bottom opening respectively). Seal interface 220 may be a four way seal with a general and X configuration (interface 221 wall to shell, interface 222 shell to port, interface 223 port to port door and interface 224 port door to wall 216. As seen in FIG. 2A, in this embodiment seal interfaces 222, 224 may be positioned (e.g. vertically) substantially parallel to direction of relative motion of interfacing surfaces. In other words, movement of the carrier or carrier door to closed position does not generate sealing closure. In this embodiment, one or more of the faces forming seal interfaces 222, 224, for example, may be provided with actuable seals such as inflatable seal, piezo actuated seal or shape memory members to actuate the seal sections and close the seal interface without substantial rubbing contact at the seal interface. The seal configurations described are merely exemplary.

[0050] Referring again to FIG. 1, carrier shell 214 may have external supports 240 for handling the carrier. Supports 240 are shown as handles, but may have any suitable form. Supports 240 are located on opposite side of the shell as far apart as desired to optimize handling stability of the carrier referring now to FIG. 6A, carrier shell 220A may have a perforated or recessed member, membrane or filter located proximate the bottom of the shell. The perforations or recesses in the member are sized and shaped to mitigate or reduce the strength of venturi or vortex flows induced in the shell when the carrier door is open. Carrier 200A is shown with the shell on bottom for example purposes, and in alternate embodiments the carrier may be on top. Further flow straightening spaces and/or vanes may be provided within the tool interior to aid maintaining substantially smooth/laminar flow over the workpieces inside the tool. FIG. 6B shows a carrier 200B in accordance with another exemplary embodiment. The carrier 200B may have a thermal regulator 250 for maintaining the workpieces within the chamber at a different temperature than ambient temperature. For example, the carrier shell or wall 214, 216 may have a thermoelectric module connected thermally to the workpieces, such as via the cassette supports, to heat/raise the temperature of the workpieces over ambient. Higher workpiece temperature than ambient drives particles and water molecules away from the workpiece via thermofluoresis, preventing contamination when workpieces are out of carrier. In alternate embodiments, any other desired thermal regulator may be used such as microwave energy. In other

alternate embodiments, an electrostatic field may be generated around each workpiece to repel contamination by water molecules and particulates.

[0051] Referring now to FIGS. 1A-1B, the cassette 210 may have nested shelves 210S for 360° positive restraint of the workpiece supported by the shelf. As seen in FIG. 1A, the cassette supports 210S are located so that the workpiece is straddled by the supports. Each shelf may have a raised surface to form a perimeter constraint for the workpiece seated on the shelf. The raised surface may be inclined to form a locating guide for seating the workpiece. The seating surface may be pitched to ensure contact with the bottom of the workpiece for example within the perimeter exclusion zone.

[0052] Referring now to FIGS. 7A-7B, the carrier 200C, which is similar to carrier 200 shown in FIG. 1, is shown respectively in closed and opened positions. Cassette 210B in this embodiment is capable of variable height. When the carrier 200B is closed cassette 210B may be at a min height, and when the carrier door (wall 216B) is opened, the cassette may be expanded to a maximum height. The pitch between workpiece/shelves of the cassette is increased when cassette expands from min to max height thereby allowing min carrier height, with maximum space between workpieces when accessed. In this embodiment, the cassette supports 210SB may have a general bellows configuration. The supports may be made of aluminum sheet or any other suitable material allowing sufficient flexibility without articulated joints. As shown, the cassette supports may be supported at the top to the carrier wall 216B. Top opening of the carrier (removing wall 216B as shown in FIG. 7B) or bottom opening (removing shell 214B similar to that shown in FIG. 2B) causes the cassette bellows to expand under gravity. The cassette bellows is compressed by closing the carrier door. As seen in FIG. 7C, the bellows 210S may have workpiece supports on which the workpieces rest. The workpiece supports are shaped relative to adjoining portions of the bellows to remain in a substantially constant radial position when the bellows expands/collapses. As may be realized, the bellows cassette may be collapsed so that the workpieces in the cassette are actively clamped between adjacent pleat section of the bellows. As may be realized, the upper clamping portions may contact workpiece along only the peripheral edge. As seen in FIG. 7B, a through beam mapper in the tool may be provided to determine the locations of the workpieces when the cassette is expanded. The workpiece robot may also have a sensor for detecting proximity of workpiece to ensure proper positioning for workpiece pick.

[0053] As noted before, the carrier with passive door and seal is suitable for direct interface to a vacuum capable chamber such as a load lock. FIG. 8 shows a carrier 200' (top opening) to be mated directly to a vacuum capable chamber (referred to as load lock) 400 in accordance with an exemplary embodiment. The load lock has an indexer 410 that operates to open/close the port door, and hence open/close the carrier door (in this embodiment top wall 216') and raise/lower cassette 210'. In this embodiment, the indexer 410 is configured to provide the load lock chamber with a low or minimal Z-height. The indexer 410 is positioned exterior to the load lock chamber and arranged alongside the load lock chamber to reduce overall height of chamber and load lock. The indexer 410 may have a drive section 412 and

a coupling section 414. In the embodiment shown the drive section 412 may have an electromechanical drive system with motor driving belt or screw drive to raise/lower shuttle 416. Coupling section 414 in this embodiment, is a magnetic coupling that couples the shuttle 416 on the drive section to the port door. The port door may have magnets or magnetic material located thereon forming the interior portion of the magnetic coupling. The magnetic portion of the door may also lock the port door to the door frame. As seen in FIG. 8, the chamber walls isolate the drive section 412 from the interior of the chamber. In alternate embodiments, the drive section may be linear motors (e.g. linear induction motors) that operate on a reactive portion of the port door to effect movement of the port door. The LIM may be located exterior to the chamber walls. As may be realized from FIG. 8, the respective section of the may also lock the port door and carrier door to each other. In this embodiment the port door motion may be guided by a guide that is also isolated from the chamber. For example, in the embodiment shown, a bellows connects the port door to the chamber walls and isolated the port door movement guide from the chamber. The guide in this embodiment has generally telescoping sections. The telescoping guide is shown as made from hollow cylindrical telescoping sections for example purposes, and may have any suitable configuration in alternate embodiments. In other alternate embodiments, the indexer may have any other desired configuration. For example, suitable indexing motors may be located in the chamber walls, but isolated from the chamber interior such as disclosed in U.S. patent application Ser. No. 10/624,987, filed Jul. 22, 2003, and incorporated by reference herein in its entirety, capable of effecting controlled movement of the port door without mechanical guides for the port door. The bellows may be pressurized to assist port door closure. The bellows may also house umbilical systems such as vacuum line, and power/signal lines connected to the port door. In this embodiment, the port door has a port PD10 connected to a vacuum source forming the chamber pump down port as will be described further below.

[0054] FIG. 9 shows a carrier 300 on a vacuum chamber 400' in accordance with another exemplary embodiment. In this embodiment, the port door PD is lowered into the chamber when opened. The indexer may be similar to that shown in FIG. 9. The chamber and port door may have magnetic locks for locking the door in the closed position to the chamber frame. The magnetic locks may be similar to those for locking the carrier door to the carrier described before. The permanent magnets or magnetic material on the port door that effect magnetic locking, may also provide coupling to the indexer. The chamber in the embodiment shown in FIG. 9 may also have a bellows and port door guide similar to that shown in FIG. 8. The bellows may be pressurized to assist raising the port door and maintain in closed position, especially when carrier door and cassette are seated on the port door. In alternate embodiments, the chamber may have a bellows without a port door guide therein. Vacuum may be connected to the port door to effect chamber pump down through the port door to carrier door interface. Thus, as in the embodiment shown in FIG. 8, the chamber pump down port is located in the port door.

[0055] Referring again to FIG. 8, load lock chamber pump down may be performed for example with the carrier interfaced to the chamber port and the port door moved by the indexer 410 from its closed position. As may be realized

from FIG. 8, pump down of the load lock chamber, via vacuum port PD10 in the port door, is through the carrier door to port door interface. The suction flow of chamber/carrier gas through the carrier door to port door interface generates a negative pressure on the interface preventing inadvertent escape of contaminants into the chamber. FIG. 10 illustrates load lock chamber pump down through the port door in accordance with another exemplary embodiment. In this embodiment, purge of the port door to carrier door space 430, and of the carrier chamber 202 may be performed prior to load lock chamber pump down. Purge gas may be introduced into space 430 by applying vacuum and cracking a port door to port seal (or with suitable valving). The carrier 200 may be purged by cracking the carrier door allowing load lock chamber 400 gas to enter the carrier, or again by suitable valving. As seen in FIG. 10A, the load lock chamber 400 may have a vent 440 disposed as desired in the load lock walls.

[0056] FIG. 11 illustrates an embodiment where the carrier door 314D and port door PD have mechanical "failsafe" locks. The carrier 316D, carrier door 314D, port 400D and port door PD are passive (no articulated locking parts). In this embodiment, the indexer is capable of both Z axis indexing of the port door and for rotating the port door for engaging/disengaging the lock tabs on the port door and carrier door. FIGS. 12A-12B respectively show bottom view of the carrier shell 316D and the carrier door 314D. FIGS. 13A-13B respectively show top plan views of the port in the load lock chamber 400D and the port door PD. The lower surface of the carrier shell has engagement tabs/surfaces 360D, that are engaged by engagement surfaces 362D on the carrier door PD. The carrier door 416D may have a male/female torque coupling feature complementing a torque coupling member on the carrier door.

[0057] FIG. 14 illustrates load lock chamber 400E and indexer 410E and carrier 300. In this embodiment the indexer is located axially in series with the load lock chamber. FIG. 15 shows a load lock chamber and carrier 300C having a reduced pump down volume configuration. The carrier door 316C has top 350C and bottom door to carrier shell seals. The bottom seals engage the shell when the carrier door is closed, as shown. The top seals 350C seal against the carrier shell when the carrier door is opened. The top seal 350C isolates the carrier chamber from the load lock chamber thereby reducing the pump down volume when pumping the load lock chamber to vacuum.

[0058] FIGS. 16A-16B show a carrier 300F and load lock chamber 400F respectively in docked and undocked positions. Carrier 300F has a bottom wall 316F, annular section 314F and a top wall 314PD. In this embodiment the annular section 314F operates as a carrier door. The top and bottom walls 316F, 314PD may be fixed together and the annular section 314F may have seals both top and bottom for respectively sealing to the top and bottom walls. Load lock chamber 400F may have an open port through which the carrier may be nested into the load lock chamber as seen in FIG. 16B. The load lock chamber 400F may have a recess 470F for lowering the carrier door 314F to open access to the carrier. The top wall 314PD of the carrier may seal against the load lock chamber port thereby sealing the load lock chamber and allowing pump down of the chamber. A suitable elevator/indexer may be provided to raise/lower the carrier door. FIGS. 17-17C, show another top sealing carrier

300G and load lock chamber **400G**. The carrier **300G** may have a top sealing flange and side opening (along edge on loading/unloading of workpieces). The carrier top sealing flange seats and seals against the rim of the chamber port as shown. The carrier door **314DR** may be opened by radial outward and rotational motion indicated by arrow **0** in FIG. **17C**, the carrier opening is aligned with the slot valve in the load lock chamber. Although the exemplary embodiments have been described with specific reference to a load lock chamber, the features described are equally applicable to a load port chamber such as shown in FIG. **18**. The interior of the load port chamber may have a controlled atmosphere, but may not be isolatable. FIG. **19** shows an indexer using LIM on the chamber walls.

[**0059**] Referring to FIGS. **29A** and **29B**, there is shown a schematic plan view of an automated material handling system **10, 10'**.

[**0060**] The automated material handling system **10, 10'** shown for example, in FIGS. **29A** and **29B** generally includes an intrabay transport system section **15**, an interbay transport system section **20**, bay queue sections **35**, transport sidings or shunt sections **25** and workpiece carriers or transports. The transport system sections **15, 20, 25, 35** may be nested together (i.e. one transport loop within another transport loop) and are generally arranged to allow the high-speed transfer of semiconductor workpieces, such as for example, 200 mm wafer, 300 mm wafers, flat display panels and similar such items, to and from processing bays **45** and associated processing tools **30** in the processing facility. In alternate embodiments, any suitable material may be conveyed in the automated material handling system. The transport system **10** may also allow for the redirection of workpieces from one transport section to any another transport section. An example of an automated material handling system for transporting workpieces having interbay and intrabay branches can be found in U.S. patent application entitled "Automated Material Handling System" having Ser. No. 10/697,528 and attorney docket number 390-011338-US (PAR) which is incorporated herein by reference in its entirety.

[**0061**] The configurations of the automated material handling system **10, 10'** shown in FIGS. **29A** and **29B** are representative configurations, and the automated material handling system **10, 10'** may be disposed in any suitable configuration to accommodate any desired layout of processing bays and/or processing tools in a processing facility. As can be seen in FIG. **29A**, the intrabay transport sections **15** may be located on either side of and connected to each other by any number of processing bays **45**. The intrabay transport sections **15** of FIG. **29A** may also be connected by a cross-shunt **50** that allows the movement of a workpiece transport directly between intrabay transport sections **15** without passing through a processing or fab bay **45**. In yet other alternate embodiments, the transport sections **15** may be connected to each other by additional intrabay transport sections (not shown). In other alternate embodiments, as shown in FIG. **29B**, the intrabay transport section **15** may be located between any number of processing bays **45** thereby forming a center isle between the bays **45**. In other alternate embodiments, the intrabay transport section may form a perimeter around and enclose any number of processing bays **45**. In yet other alternate embodiments, there may be any number of nested loop sections such as for example N

number of systems, such as system **10** or **10'** as shown in FIG. **29A** and **29B**, connected in parallel by transport sections that directly connect each of the intrabay transport sections **15**. In still other alternate embodiments, the transport sections **15, 20** and processing tools may have any suitable configuration. In addition, any number of intrabay/interbay systems may be joined together in any suitable configuration to form nested processing arrays.

[**0062**] The intrabay transport section **15**, may be a modular track system that provides for the movement of any suitable workpiece transport. Each module of the track system may be provided with a suitable mating means (e.g. interlocking facets, mechanical fasteners) allowing the modules to be joined together end to end during installation of the intrabay transport sections **15**. The rail modules may be provided in any suitable length, such a few feet, or in any suitable shape, such as straight or curved, for ease of handling during installation and configuration flexibility. The track system may support the workpiece transport from beneath or in alternate embodiments, the track system may be a suspended track system. The track system may have roller bearings or any other suitable bearing surface so that the workpiece transports can move along the tracks without substantial resistance over the rollers. The roller bearing may be tapered or the tacks may be angled towards the inside of a curve or corner in the track to provide additional directional stability when the workpiece container is moving along the track.

[**0063**] The intrabay transport sections **15** may be a conveyor based transport system, a cable and pulley or chain and sprocket based transport system, a wheel driven system or a magnetic induction based transport system. The motor used to drive the transport system may be any suitable linear motor with an unlimited stroke capable of moving workpiece containers along the intrabay transport sections **15**. The linear motor may be a solid state motor without moving parts. For example, the linear motor may be a brushed or brushless AC or DC motor, a linear induction motor, or a linear stepper motor. The linear motor may be incorporated into the intrabay transport sections **15** or into workpiece transports or containers themselves. In alternate embodiments, any suitable drive means may be incorporated to drive the workpiece transports through the intrabay transport system. In yet other alternate embodiments, the intrabay transport system may be a pathway for trackless wheeled autonomous transport vehicles.

[**0064**] As will be described below, the intrabay transport sections **15** generally allow for uninterrupted high-speed movement or flow of the workpiece transports along the path of the intrabay transport sections **15** through the use of queue sections and shunts. This is highly advantageous compared to conventional transport systems that have to stop the flow of material when a transport container is added or removed from a transport line.

[**0065**] The interbay transport sections **20** may form processing or fab bays **45** and are connected to the intrabay transport sections **15** through bay queue sections **35**. The bay queue sections **35** may be located on either side of the interbay or intrabay transport sections **20, 15** and allow a workpiece container to enter the interbay transport sections **20** without stopping or slowing down the flow of material along either the intrabay transport sections **15** or the flow of

material along the interbay transport sections **20**. An example of a transportation system having a travel lane and an access lane allowing selectable access on and off the travel lane can be found in U.S. patent application entitled "Transportation System" with Ser. No. 11/211,236 and attorney docket number 390P011936-US (PAR) which is incorporated herein by reference in its entirety. The interbay transport sections **20** and the bay queue sections **35** may have track systems that are substantially similar to that described above for the intrabay transport sections **15**. In alternate embodiments, the interbay transport sections **20** and the bay queue sections **35** may have any suitable configuration, shape or form and may be driven in any suitable manner. As can best be seen in FIG. 1B, the bay queue sections **35** have an input section **35A** and an output section **35B** that correspond to the direction of movement **R1**, **R2** of the intrabay and interbay transport sections **15**, **20**. As will be described below in greater detail, workpiece containers exit the intrabay transport sections **15** via the input section **35A** and enter the intrabay transport sections via the output section **35B**. The bay queue sections **35** may be of any suitable length to allow for the exiting or entering of the workpiece transports on and off the transport sections **15**, **20**.

[0066] The interbay transport sections **20** may extend within corridors or passages connecting any number of process tools **30** to the transport system **10**, **10'**. The interbay transport sections **20** may also connect two or more intrabay transport sections **15** to each other as shown in FIG. 29A and as described above. The interbay transport sections **20** are shown in FIGS. 29A and 29B as having an elliptical shape however, in alternate embodiments they may have any suitable configuration or shape and may be adaptable to any fabrication facility layout. The interbay transport sections **20** are connected to the process tools **30** through a transport siding or shunt **25**, which may be similar to the bay queue section **35**. The shunts **25** effectively take the workpiece transports "off line" and have input sections **25A** and output sections **25B** corresponding to the direction of travel **R2** of the interbay transport sections **20** as can be seen in FIG. 29A. The shunts **25** allow the workpiece transports to exit and enter the interbay transport sections **20**, through the input and output sections **25A**, **25B**, without interrupting the constant velocity flow of workpiece transports on the interbay transport sections **20**. While in the shunt **25**, the workpiece container may stop at a tool interface station (not shown) that corresponds to the location of the process tool station, so that the workpieces and/or the container itself may be transferred into the process tool load port or any other suitable workpiece staging area by or through any suitable transfer means, such as for example, an equipment front end module, sorter or any other suitable transfer robot.

[0067] The switching of the workpiece carriers or transports from and between the different sections **12**, **20**, **25**, **35** may be controlled by a guidance system connected to a controller. The guidance system may include positioning devices allowing for position determination of the transports moving along the sections **12**, **20**, **25**, **35**. The positioning devices may be of any suitable type such as continuous or distributed devices, such as optical, magnetic, bar code or fiducial strips, that extend along and across the sections **12**, **20**, **25**, **35**. The distributed devices may be read or otherwise interrogated by a suitable reading device located on the transport to allow the controller to establish the position of

the transport on the section **12**, **20**, **25**, **35** as well as the kinematic state of the transport. Alternatively, the devices may sense and/or interrogate a sensory item on the transport to identify position/kinematics. The positioning devices may also include, alone or in combination with the distributed devices, discrete positioning devices (e.g. laser ranging device, ultrasonic ranging device, or internal positioning system akin to internal GPS, or internal reverse GPS) able to sense the position of the moving transport. The controller may combine information from the guidance system with the position feed back information from the transport to establish and maintain the transport paths of the transport along and between the sections **12**, **20**, **25**, **35**.

[0068] In alternate embodiments, guidance system may include or have grooves, rails, tracks or any other suitable structure forming structural or mechanical guide surface to cooperate with mechanical guidance features on the workpiece transports. In still other alternate embodiments, the sections **12**, **20**, **25**, **35** may also include electrical lines, such as a printed strip or conductor providing electronic guidance for the workpiece transports (e.g. electrical lines sending a suitable electromagnetic signal that is detected by a suitable guidance system on the transports).

[0069] Still referring to FIGS. 29A and 29B, an exemplary operation of the transport system **10**, **10'** will now be described. A workpiece container located in a shunt **25** is to enter the transport system **10**, **10'**. Because the flow of the interbay transport section **20** is uninterrupted and moving at a constant velocity, the workpiece container cannot directly access the interbay transport section **20**. The workpiece transport accelerates within the shunt **25** so that the transport is traveling the same speed as the flow of material in the interbay transport section **20**. Because the shunt **25** allows the workpiece transport to accelerate, the transport may merge into the flow of the interbay transport section **20** without hindering that flow or colliding with any other transports traveling in the interbay transport section **20**. In merging with the interbay transport section **20**, the workpiece holder may wait in the shunt **25** for suitable headway so that it may enter the flow of the interbay transport section without colliding with any other workpiece carriers or transports. The workpiece transport continues along the interbay transport section **20** at a constant speed and switches, with the right-of-way, onto the output queue area or section **35B**. In one embodiment, if there is no room within the output queue section **35B**, the transport may continue to travel around the interbay transport section **20** until the output queue section **35B** becomes available. The transport may wait in the bay output queue section **35B** for suitable headway, then accelerate and merge into the continuous constant velocity flow of the intrabay transport section **15** in a manner substantially similar to the merge described above for the interbay transport section **20**. The transport continues at a continuous speed along the intrabay transport section **15** to a predetermined bay and is switched onto the associated bay queue input section **35A**. In one embodiment, if there is no room within the input queue section **35A**, the transport may continue to travel around the intrabay transport section **15** until the input queue section **35A** becomes available. The transport may wait in the bay input queue section **35A** for suitable headway and accelerate to merge onto a second interbay transport section **20**, the second interbay transport section **20** again having a continuous constant velocity flow. The transport is switched off of

the second interbay transport section **20** and onto the transport shunt **25** where the transport interfaces with the process tool **30**. If there is no room in the shunt **25** for the transport, due to other transports in the shunt **25**, the transport continues to travel along the interbay transport section **20**, with the right-of-way, until the shunt **25** becomes available. Because the flow of material in the intrabay transport sections **15** and the interbay transport sections **20** is uninterrupted and travels at a constant velocity, the system can maintain a high throughput of workpiece transports between processing bays and processing tools.

[0070] In alternate embodiments, the transport may travel directly between processing bays via an extension **40** that may directly connect the bay queue sections **35**, processing tools, interbay transport sections **20** or intrabay transport sections **15** together. For example, as shown in FIGS. **29A** and **29B**, extensions **40** connect the bay queue sections **35** together. However, in alternate embodiments, the extensions **40** may provide access from one processing tool to another processing tool by connecting the transport shunts **25** of each of the tools together. In yet other alternate embodiments, the extensions **40** may directly connect any number or any combination of elements of the automated material handling system together to provide a short access route. In larger nested networks, the shorter path between destinations of the transport created by the extensions **40** may cut down traveling time of the transports and further increase productivity of the system.

[0071] In still other alternate embodiments the flow of the automated material handling system **10**, **10'**, may be bi-directional. The transport sections **15**, **20**, **25**, **35**, **40**, **50** may have side by side parallel lanes of travel each moving in opposite directions with exit ramps and on ramps looping around and connecting the opposite lanes of travel. Each of the parallel lanes of the transport sections may be dedicated to a given direction of travel and may be switched individually or simultaneously so that the travel for each of the respective parallel lanes is reversed according to a transport algorithm to suit transport loading conditions. For example, the flow of material or transports along the parallel lanes of a transport section **15**, **20**, **25**, **35**, **40**, **50** may be flowing in its respective direction. However, if at a later time it is anticipated that some number of workpiece transports are situated in the facility and are going to a location where it would be more efficient to move along one of those parallel lanes in a direction opposite the current flow direction, then the travel directions of the parallel lanes may be reversed.

[0072] In alternate embodiments, the bi-directional lanes of travel may be located in stacks (i.e. one above the other). The interface between the process tool and the transport shunts **25** may have an elevator type configuration to raise or lower a transport from a shunt to the process tool load port, for example, such as where a shunt having a clockwise flow of material is located above a shunt with a counter-clockwise flow of material. In alternate embodiments, the bi-directional shunts and other transport sections may have any suitable configuration.

[0073] FIG. **20** shows a portion of a transport system track **500** for transporting carriers between tool stations. The track may have a solid state conveyor system, similar to that described in U.S. patent application Ser. No. 10/697,528 previously incorporated by reference. The track may have

stationary forcer segments cooperating with reactive portion integral to the carrier shell/casing. The carrier may thus be transported directly by the conveyor. The transport system **500** shown in an asynchronous transport system in which transport of carriers is substantially decoupled from the actions of other carriers on the transport system. The track system is configured to eliminate determining factors affecting transport rate of a given carrier due to actions of other carriers. Conveyor track **500** employs main transport paths with on/off branching paths that routes a carrier away from the main transport path to effect routing changes and/or interface with tool stations (buffer etc.) without impairing transport on main transport path. Suitable example of transport system with branching on/off paths is disclosed in U.S. patent application Ser. No. 11/211,236 previously incorporated by reference. In this embodiment segments **500A**, **C**, **D** may have winding sets for A1-D linear motor causing movement along the main travel path **500M**; this is shown in FIG. **20A** segment **500B** is illustrated as an off/exit to what may be referred to as access path **500S**. The windings of the forcer in this segment be arranged to provide in effect a 2-D planar motor to allow both motion along main path **500M** and when desired effect movement of the carrier(s) along path **500S** (see FIG. **20B**). The motor controller may be a zoned controller similar to the distributed control architecture described in U.S. patent application Ser. No. 11/178,615, filed Jul. 11, 2005 incorporated by reference herein in its entirety. In this embodiment, the drives/motors may be zoned, efficiently controlled by zone controllers with appropriate hand off between zones. The conveyor **500** may have suitable bearings to movably support carrier. For example, in segments **500A**, **500C** and **500D**, bearings (e.g. roller, bar) may allow 1 degree of freedom movement of the carrier along path **500M**).

[0074] Bearings in segment **500B** may allow 2-degree of freedom movement of the carrier. In other embodiments, bearings may be provided on the carrier. In still other embodiments air bearings may be used to movably support the carrier on the track. Guidance of the carriers between path **500M** and direction onto path **500M** may be effected by suitable guide system such as steerable or articulated wheels on the carrier, articulated guide rails on the track, or magnetic steerage as shown in FIG. **20B**.

[0075] FIG. **21** shows an intersection of the conveyor transport system. The intersection may not be oriented at 90° FIG. **20C** shows the bottom of the carrier and the reactive elements therein. As may be realized the relative elements may be arranged to coincide with the orientation of the respective forcer sections at the intersection. This allows the carrier to change tracks at the intersection substantially without stoppage. FIG. **20D** shows the reactive elements positioned on a pivotal section that may be rotated to desired position. FIG. **22** shows a beside track storage location, generally similar to the intersection in FIG. **21**. FIGS. **23-23A** show track with cutouts or openings for lift arms of a carrier lift or shuttle, described further below. The openings allow side access to the carrier for a bottom pick of the carrier from the conveyor track. FIG. **24** shows a track with the forcer located offset from carrier/track centerline.

[0076] FIGS. **25A-25B** show a linear motor conveyor (having grounded forcer segments and reaction elements embedded within the carrier) for transporting substrates within a semiconductor FAB or similar; (reference U.S.

2005/009587 A1). The conveyor is inverted, as shown such that the carrier is accessible from directly below. A magnetic retention force is employed to maintain the coupling between the conveyor and carrier. This force may arise from the linear motor coils (e.g. in a linear synchronous design) and/or via separate electromagnets and/or permanent magnets specific to that purpose. Coupling and decoupling of the carrier to the conveyor is rapid and preferably achieved without moving parts (e.g., an electromagnetic switch). Failsafe operation is assured via flux path and/or passive mechanical retention features.

[0077] Intersections and branch points (i.e., merge-diverge locations) are preferably achieved with coil switching, rather than turntables or other routing devices, as described in a separate disclosure.

[0078] The carrier is arranged such that the reaction elements are on the top, and the substrates are accessed from the bottom.

[0079] To load a tool, the conveyor positions a carrier at the tool loadport, and a dedicated vertical transfer mechanism is used to lower the carrier from the conveyor elevation to the controller environment interface. This same vertical motion device may also be used as an indexer, thereby positioning the wafers for access by a wafer-handling robot.

[0080] Alternatives: (1) a traditional powered-wheel accumulating conveyor could be used in such an inverted arrangement along with a suitable magnetic attractive force. (2) The general arrangement may be inverted such that the conveyor is below the loadport, the carrier has reaction features on the top.

[0081] FIGS. 26A-26B show other examples of direct lower/lift carriers from transport system to load port/tool interface. Though the reaction platen is integral to the carrier in the exemplary embodiment described, in other embodiments the platen may be detachable from the carrier, for example remaining on/coupled to the conveyor when the carrier is removed. In such a case, each platen in the transport system corresponds in a 1:1 relationship to the carriers in the FAB.

[0082] FIG. 27 illustrates a carrier having a conveyor vehicle hybrid configuration. Carrier vehicles are provided for automated conveyance of payloads (such as carriers containing semiconductor substrates). The vehicles may carry stored energy for self-propulsion, a steering system, at least one motor-powered drive wheel, sensors for odometry and obstacle detection, and associated control electronics. In addition the vehicles are outfitted with one or more reaction elements which can cooperate with stationary linear motor forcer segments of a conveyor similar to system 500.

[0083] When a vehicle is traveling along the path defined by one or more forcer segments, the drive motor is disconnected from the drive wheel(s), and the vehicle is passively pulled along the path via electromagnetic coupling with the reaction elements. If the stored energy device (e.g. batteries, ultracapacitors, flywheel, etc.) within the vehicle needs to recharge, the motion of the traction wheel(s) along the guideway may be used to convert energy from the linear motor to the vehicle storage. In the case of electrical energy storage, this would be accomplished by re-connecting the vehicle drive motor to be used as a generator with suitable monitoring and conditioning electronics. Such "on-the-fly"

charging has the benefit of simplicity and ruggedness, and such an arrangement affords significant flexibility and fault tolerance. For example: vehicles would be capable of driving autonomously past failed conveyor segments or around obstacles (see FIGS. 27A, 27B). The number and length of conveyor forcer segments could be tailored to an operating scheme such as a conveyor for intrabay transport, autonomous motion with the bay. Self-directed steering may be used for flexible route selection. Self-directed cornering could be used to eliminate the need for curved forcer segments. High-speed travel could be limited to conveyor runs and, if desired, separated from operators by safety barriers. Conveyor sections could be used for long runs, such as links to adjacent FABS. Conveyors can be used for grade changes, mitigating the difficulties encountered by vehicles using exclusively stored energy, etc.

[0084] FIG. 28 shows another example of an integrated carrier and transport vehicle. In contrast to conventional vehicle-based semiconductor automation, in which vehicles are dispatched to transport carriers of wafers within a FAB, each carrier here is fixedly attached to a single vehicle. The vehicle may drive directly to the loadport where wafers are to be transferred, or may be engaged by another automation component such as a tool buffer. Fixing the carrier and vehicle in this way eliminates the time waiting for a free vehicle to be dispatched when a lot transfer is required, as well as the associated deliver time variance. Elimination of such empty-car moves is also expected to reduce the total traffic on the transport network improving the system capacity. In alternate embodiments, the carrier and vehicle may have a coupling for detaching carrier from vehicle. Though vehicles in the system may be apportioned to carriers in a 1:1 relationship to eliminate delays in carrier transport awaiting for vehicles, system knowledge in a suitable controller may be used to allow separation in limited instances.

[0085] FIG. 29C shows a plan view of a horizontally arrayed buffering system that may interface between a conveyor system 500 (or any other desired carrier transport system) and tool stations 1000. The buffering system may be located under tool stations or portions thereof or above the tool stations. The buffering system may be positioned away (i.e. below or above) from operator access ways. FIG. 30 is an elevation view of the buffering system. FIGS. 29C-30 show the buffering system located on one side of conveyor 500 for example purposes. The buffering system may be extended to cover as large a portion of the FAB floor. Operator walkways may be elevated above the buffering system. Similarly, the buffering system may be extended anywhere in the FAB overhead. As seen in FIGS. 29C-30, the buffering system has shuttles (which may have suitable carrier lift or indexer) capable of at least 2-D movement. The shuttles are capable of traversing between horizontally displayed conveyor 500 (for example an access lane of the conveyor) and buffer storage ST or loading locations LP on the tool stations. The buffering system may be configured in modular form allow the system to be easily expanded or reduced. For example, each module may have storage locations and shuttle rails and coupling joints for joining to other installed modules of the buffering system. In other embodiments, the system may have buffering station modules (with one or more integral buffering stations) and shuttle rail modules allowing modular installation of the shuttle rails. As seen in FIG. 29C, the access lane of the conveyor may have shuttle access ways allowing the shuttle indexer to

access the carrier through the conveyor lane. FIG. 31 shows another elevation in which the merge/diverse lane of the conveyor is accessible by the buffering system shuttle. FIG. 32 is yet another elevation showing multiple rows of buffering stations. The buffering system may have any desired number of buffering stations in any desired number of rows. In other alternate embodiments, the buffering stations may be arrayed in multiple horizontal planes or levels (i.e. two or more levels—may be vertically separated to allow carrier height pass through). Multilevel buffering may be used with reduced capacity carriers. FIG. 33 shows another plan view of a buffering system with an interface to a guided vehicle carrier. FIG. 34 shows an elevation view of an overhead buffering system otherwise similar to the under tool buffering system described before. The overhead buffering system may be used in conjunction with the under tool buffering. The overhead buffering system is shown interfacing with an overhead conveyor. In alternate embodiments, the overhead system may interface with a floor conveyor system. Suitable control interlocks (e.g. hard) may be provided to prevent horizontal traverse of shuttle with lowered payload that may impinge walkway vertical clearances. Top shields over the walkway may be used for preventing suspended loads from crossing through walkway space.

[0086] FIG. 35 shows a looped buffering system. The buffering stations of the system may be movable, mounted on a track that moves the buffer stations between a loading position in which carriers may be loaded into the buffer stations (for example with overhead loading) and a tool interface. The tool interface may have an indexer for loading the carrier to the tool station.

[0087] It should be understood that the foregoing description is only illustrative of the invention. Various alternatives and modifications can be devised by those skilled in the art without departing from the invention. Accordingly, the present invention is intended to embrace all such alternatives, modifications and variances which fall within the scope of the appended claims.

1. An semiconductor workpiece processing system comprising:

- at least one processing tool for processing semiconductor workpieces;
- a primary transport system having one or more constant velocity transport loops;
- a secondary transport system having one or more constant velocity transport loops, the secondary transport system being connected to the primary transport system through queue sections wherein, the queue sections are configured to allow the movement of material between

the primary transport system and secondary transport system without disrupting the flow of either the primary or secondary transport systems; and

one or more interfaces connected to the one or more transport loops of the secondary transport system through interface shunts for interfacing with the at least one processing tool, wherein the interface shunts are configured to allow the movement of material between the one or more transport loops of the secondary transport system and the one or more interfaces without disrupting a flow of the secondary transport system;

wherein the flow of material along the primary and secondary transport systems is continuous.

2. The automated material handling system of claim 1 wherein the one or more constant velocity transport loops of the primary transport system are connected to each other through the one or more constant velocity transport loops of the secondary transport system.

3. The automated material handling system of claim 1 wherein the one or more constant velocity loops of the first transport system are connected to each other through one or more cross shunts.

4. The automated material handling system of claim 1 wherein the one or more constant velocity loops of the second transport system are connected to each other through one or more cross shunts.

5. The automated material handling system of claim 1 wherein at least one of the one or more constant velocity loops of the first transport system are connected to another of the one or more constant velocity loops of the first transport system through queue sections.

6. The automated material handling system of claim 1 wherein the automated material handling system is configured for the transportation of containers for holding at least one semiconductor workpiece therein for transport to and from the processing tool.

7. The automated material handling system of claim 1 wherein the primary and secondary transport systems are configured to allow a workpiece container designated to be transferred to a queue section or an interface shunt to continue traveling along the primary or secondary system until the queue section or interface shunt becomes available.

8. The automated material handling system of claim 1 wherein the primary transport system, the secondary transport system, the queue sections and the interface shunts each comprise a set of parallel tracks wherein each track of the set of parallel tracks is configured to provide transportation of workpiece carriers in opposite directions from each other.

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