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(54) COMPACT APPARATUS AND METHOD FOR STORING AND LOADING SEMICONDUCTOR WAFER CARRIERS

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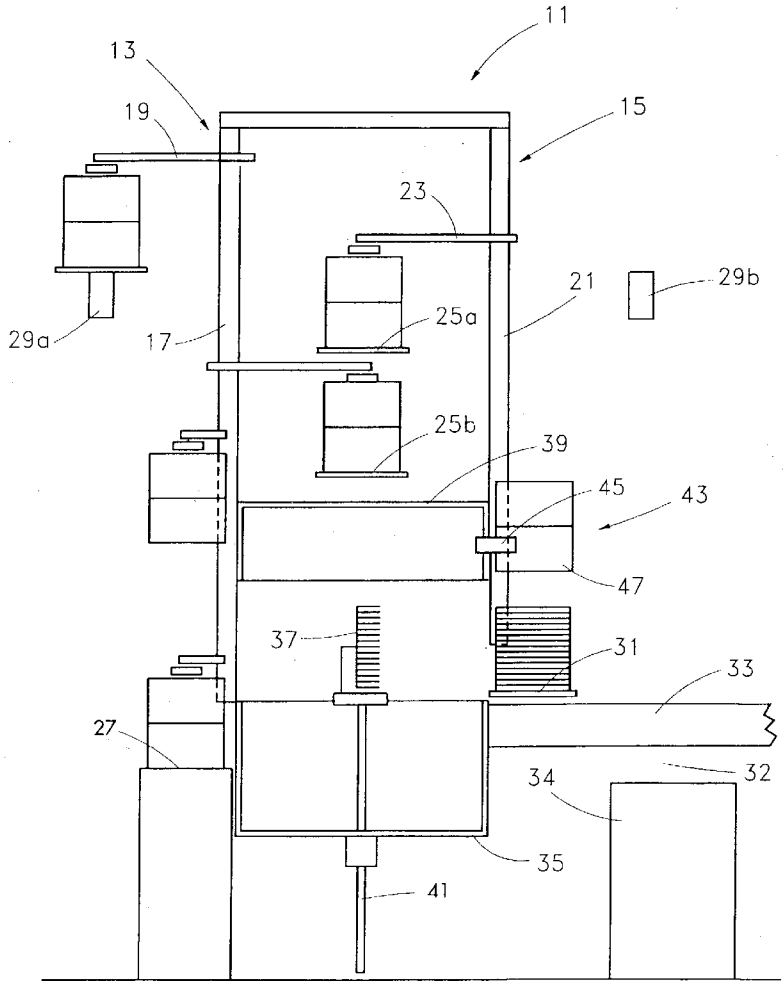
Publication Classification

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(52) **U.S. Cl.** **414/217**

(57) **ABSTRACT**

An improved apparatus and method is provided for storing semiconductor wafer carriers, and for loading wafers or wafer carriers to a fabrication tool. The apparatus preferably provides an elevated port for receipt of wafer carriers from an overhead factory transport, allows for local interconnection among a plurality of the inventive apparatuses, and enables independent loading of the factory load port and the tool load port. An inventive wafer handling method which divides a lot of wafers into sublots and distributes the sublots among tools configured to perform the same process is also provided.



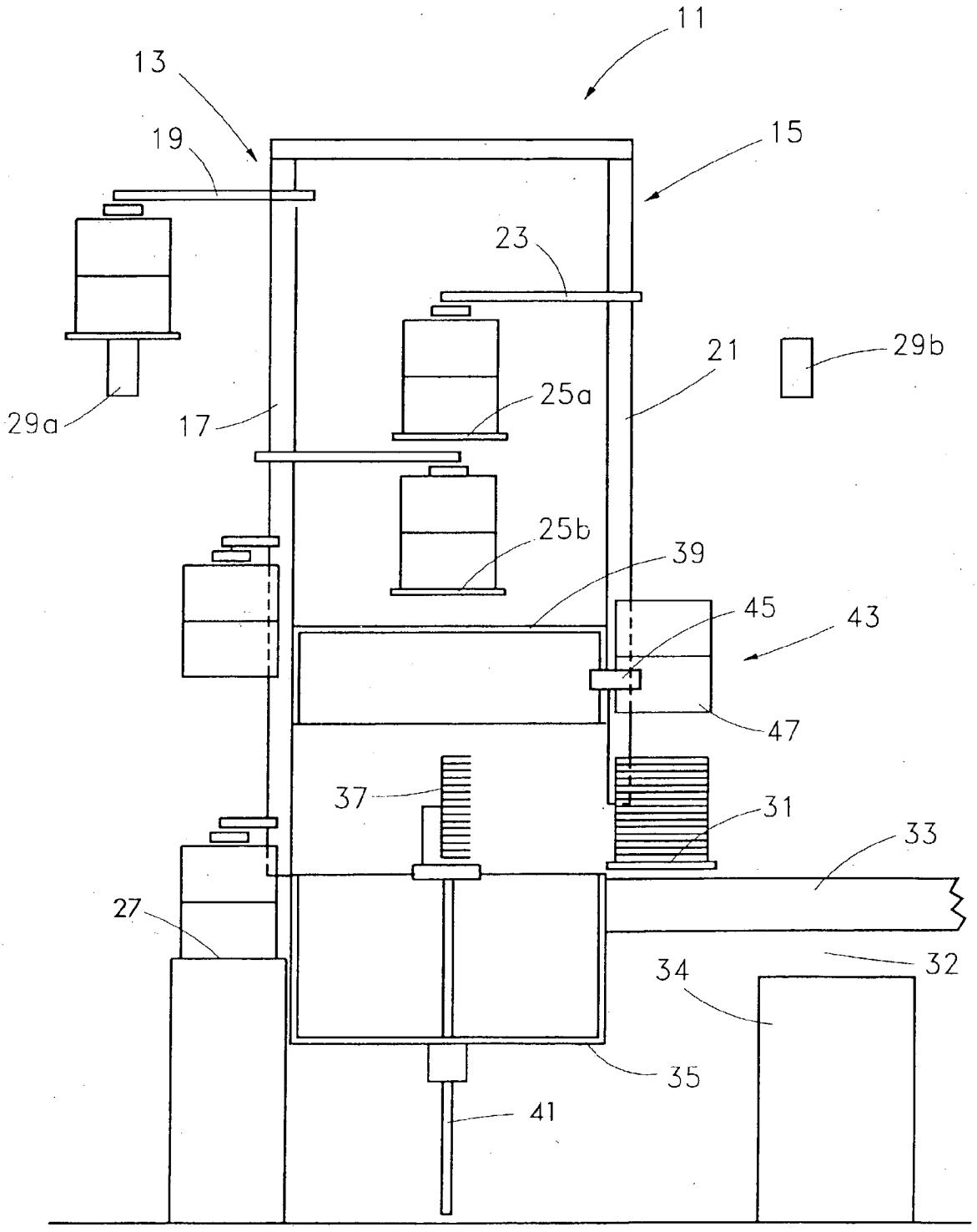

11
13
19
15
23
21
29b
29a
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25a
25b
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45
43
47
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31
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41

FIG. 1

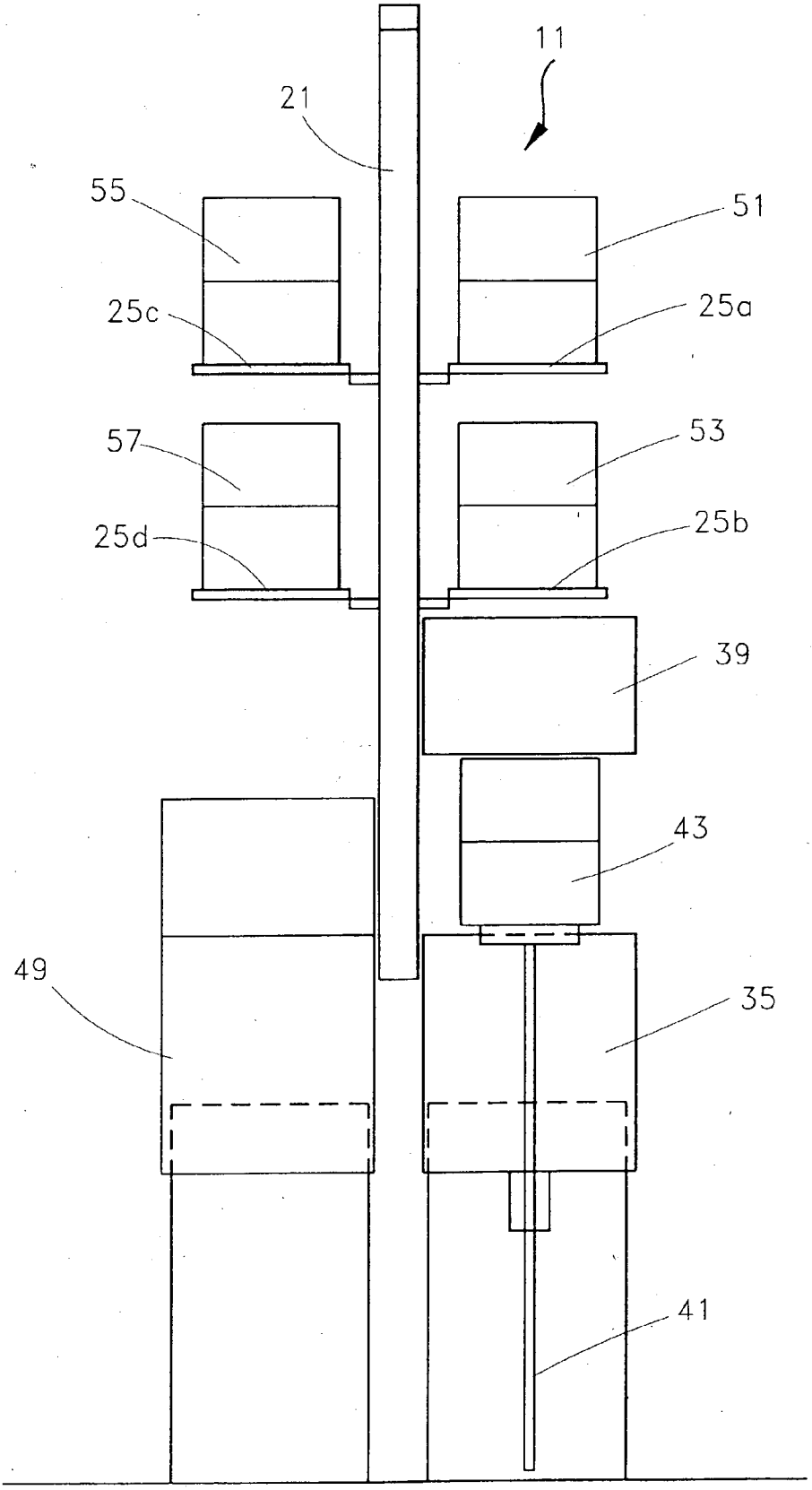


FIG. 2

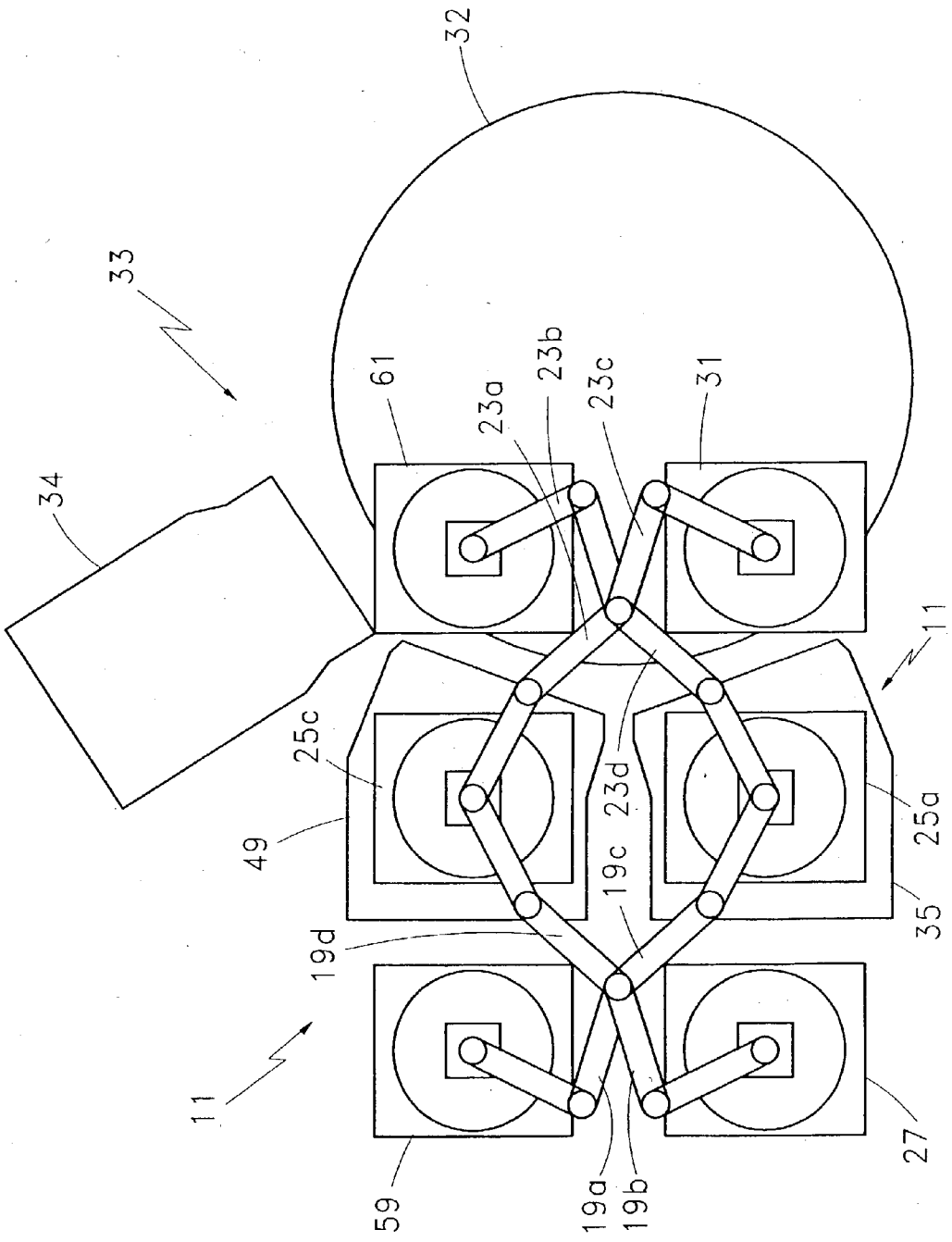

32
33
34
61
23a
23b
23c
31
11
25c
49
23d
19c
25a
35
19d
11
27
59
19a
19b

FIG. 3

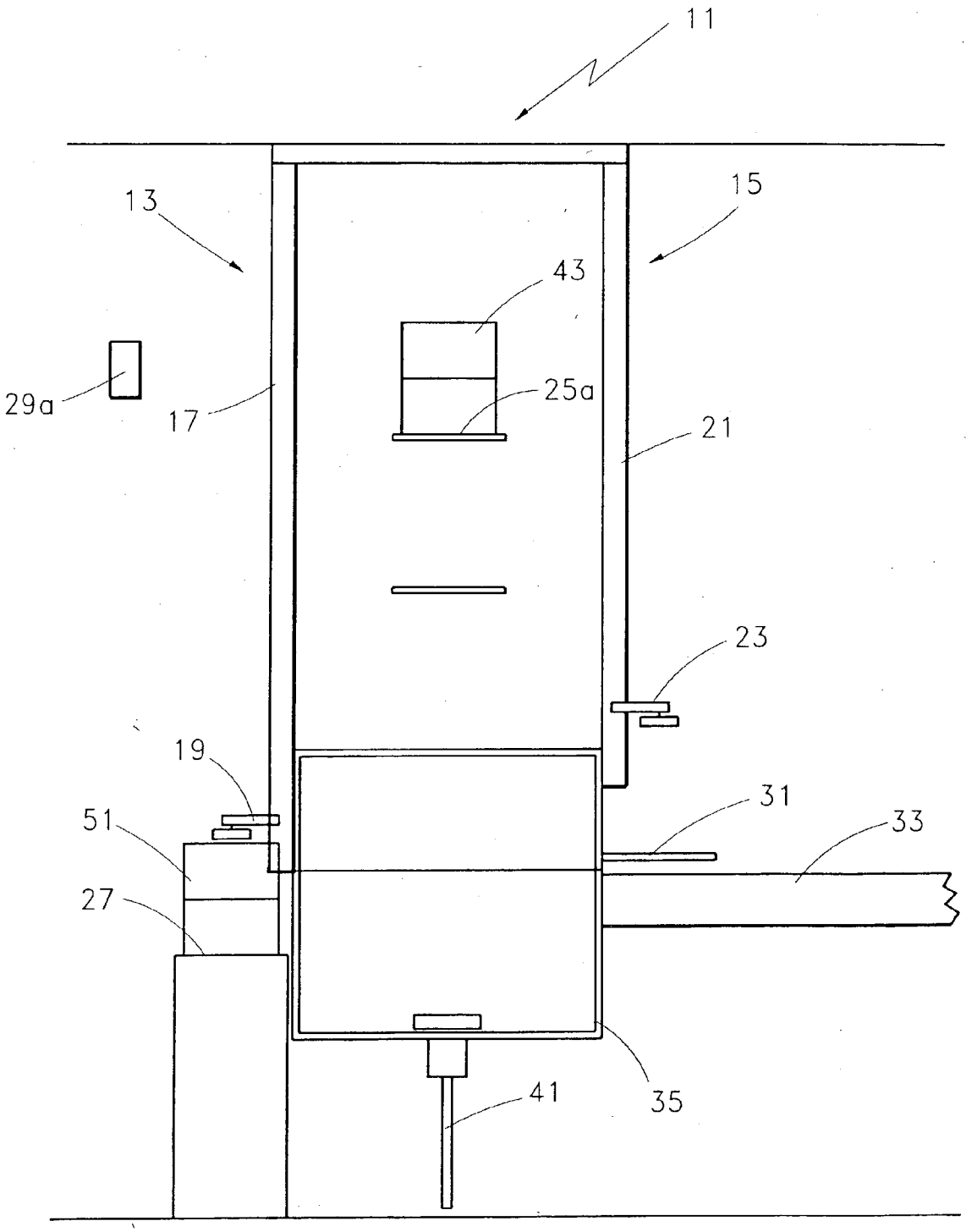


FIG. 4A

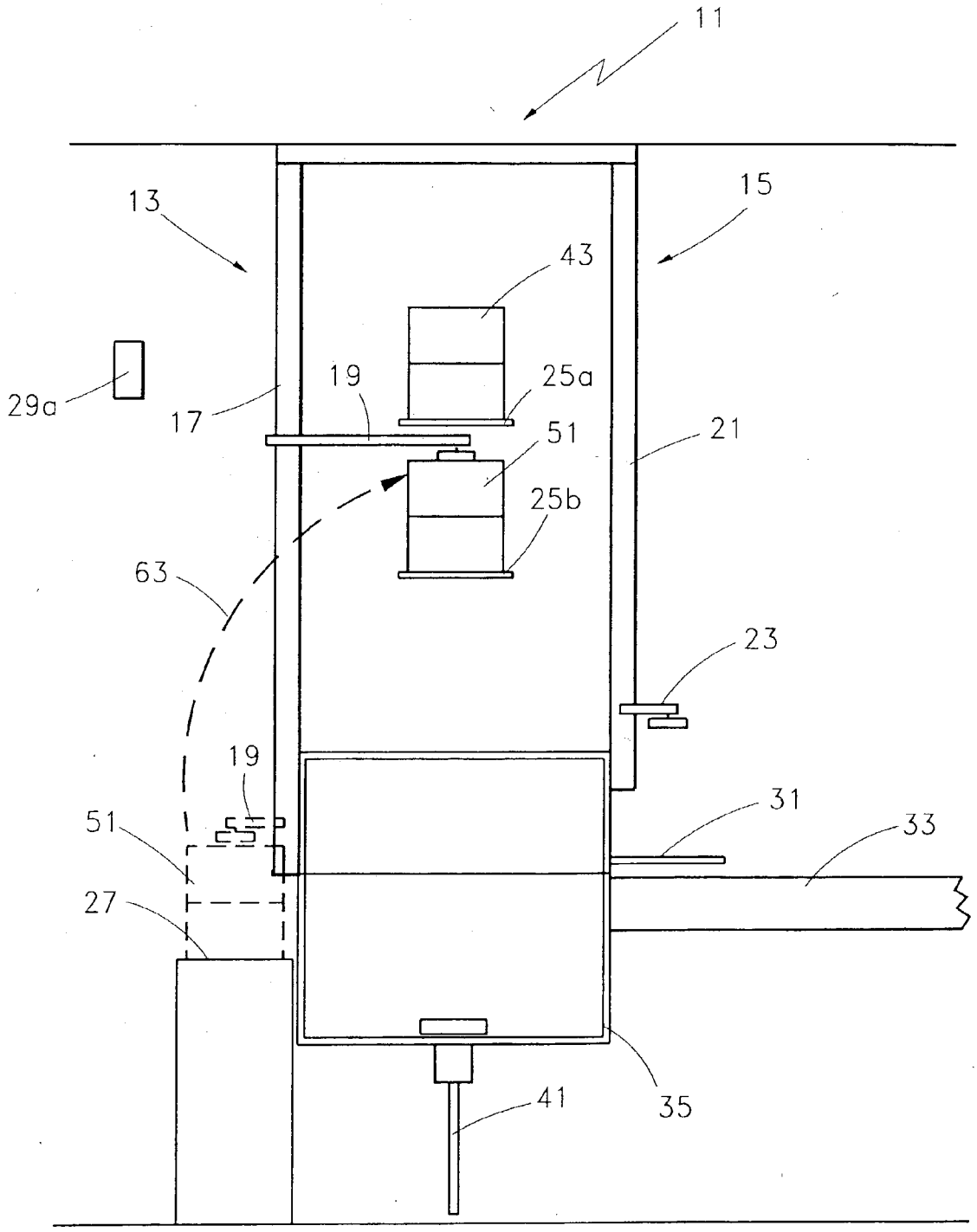


FIG. 4B

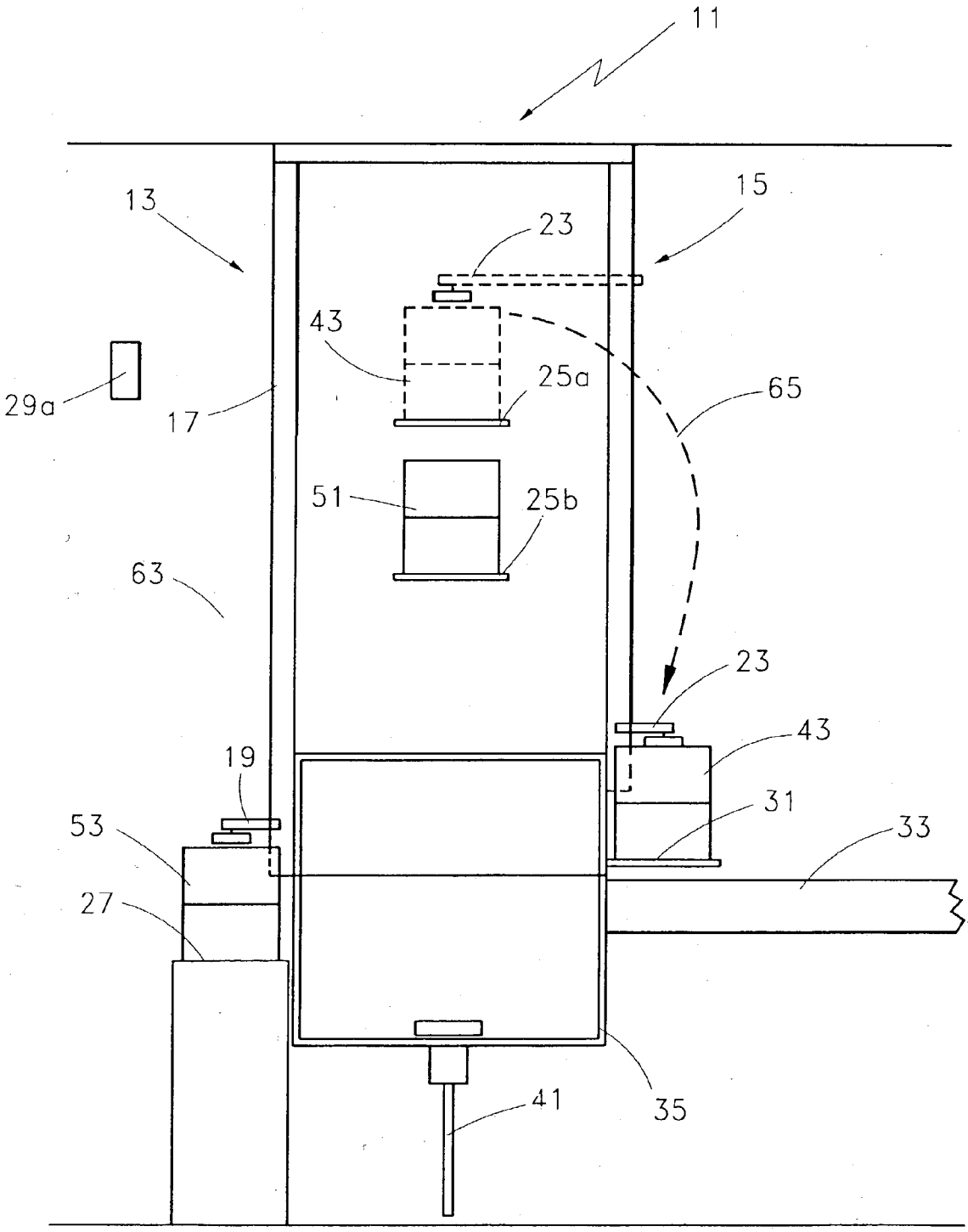


FIG. 4C

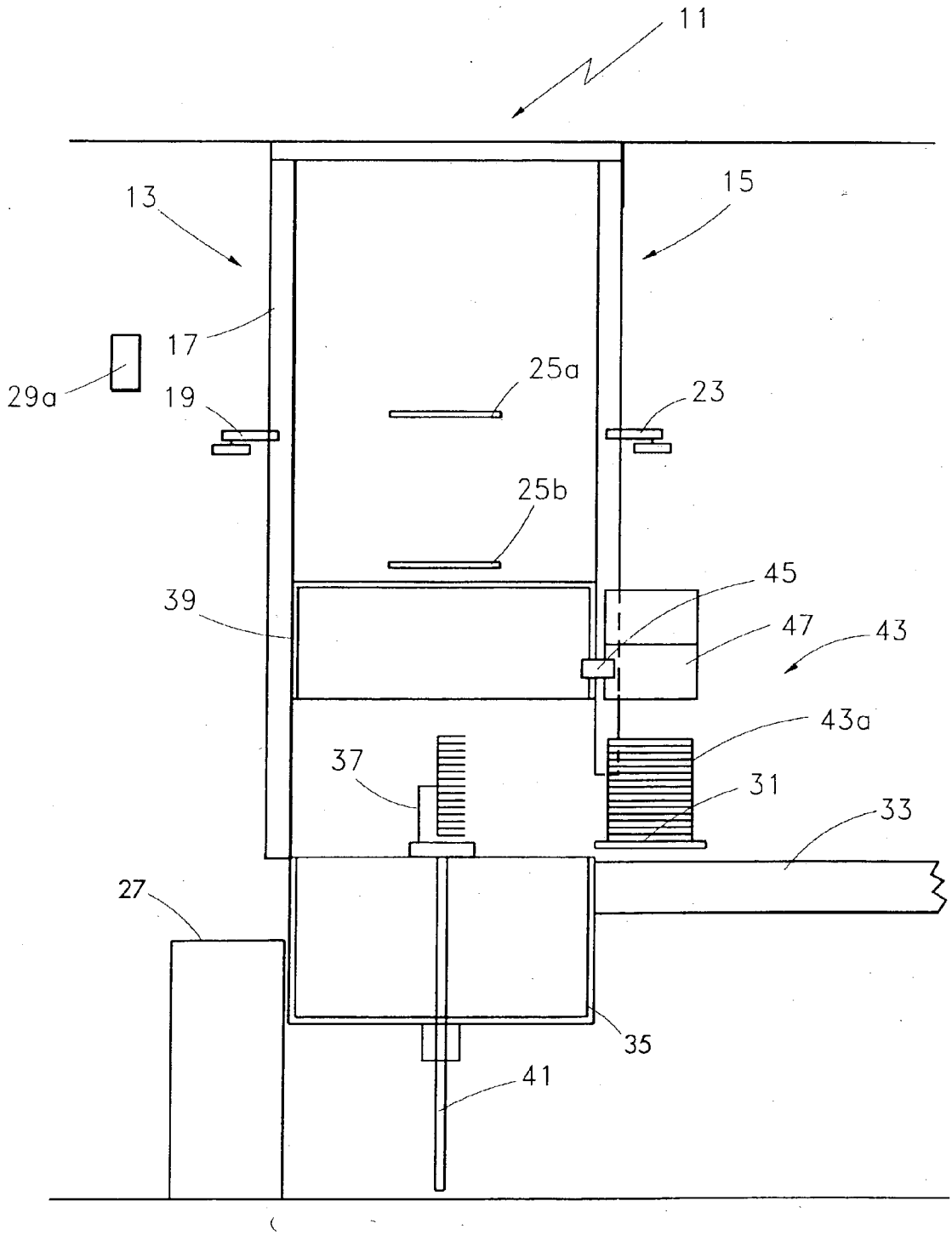


FIG. 4D

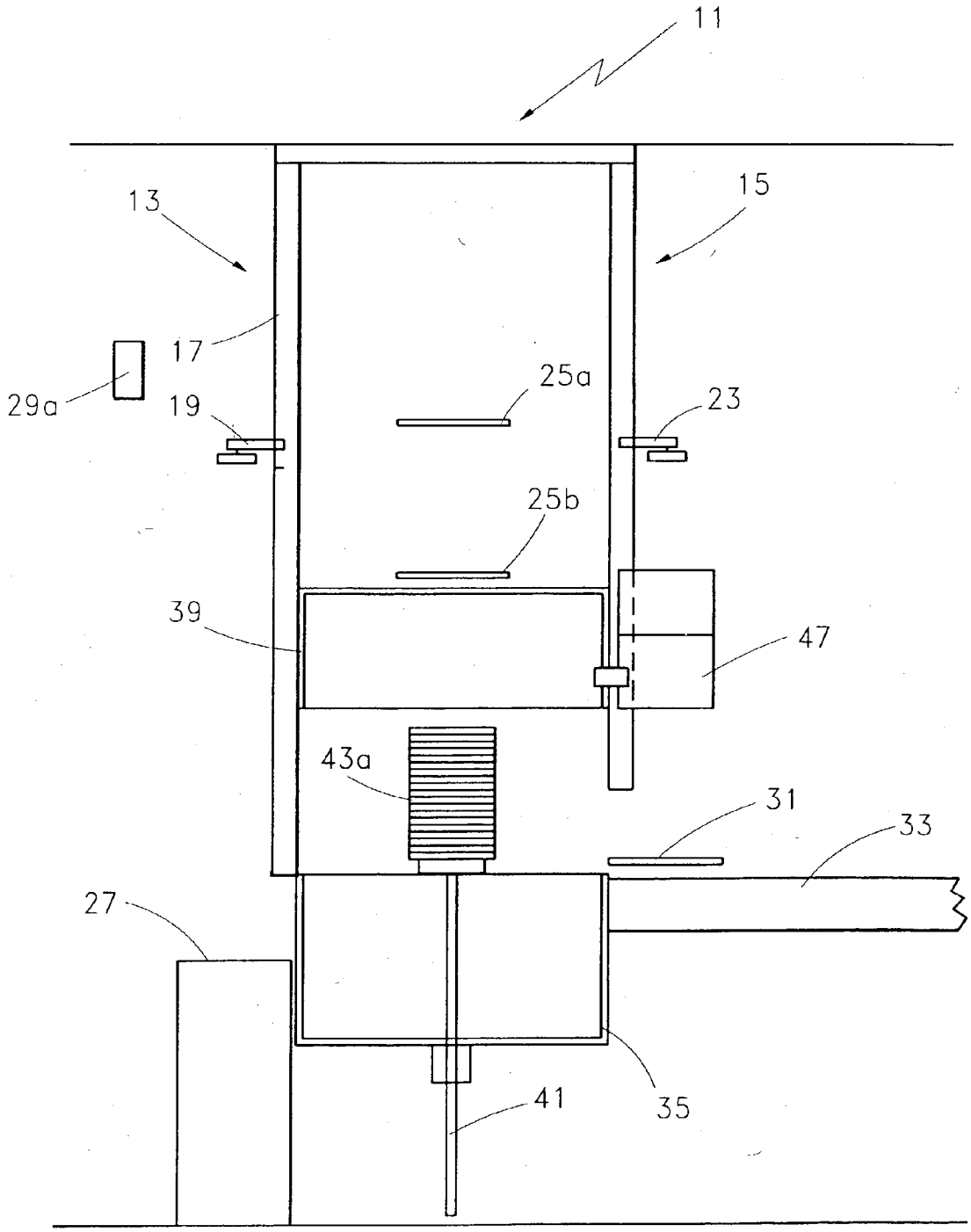


FIG. 4E

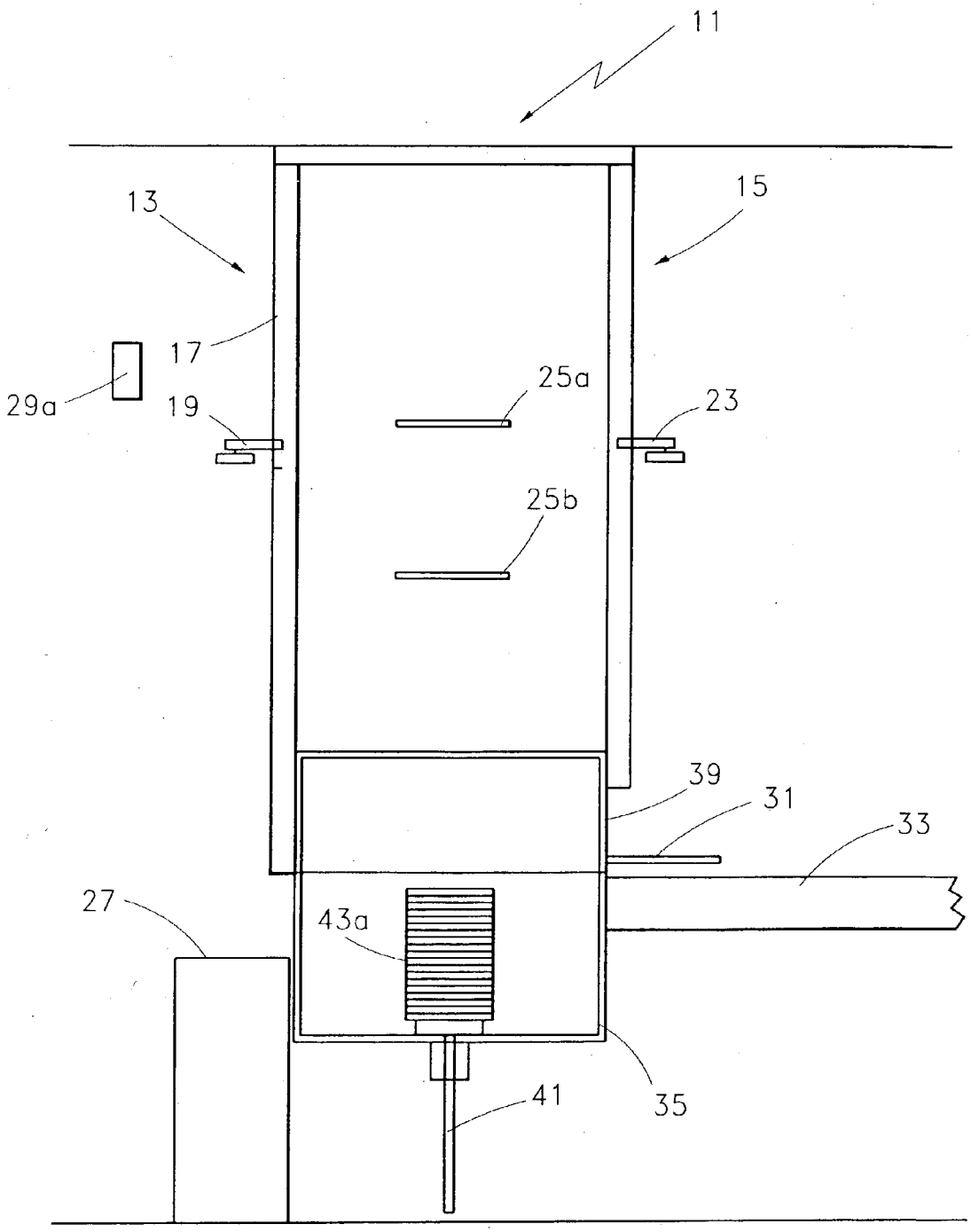


FIG. 4F

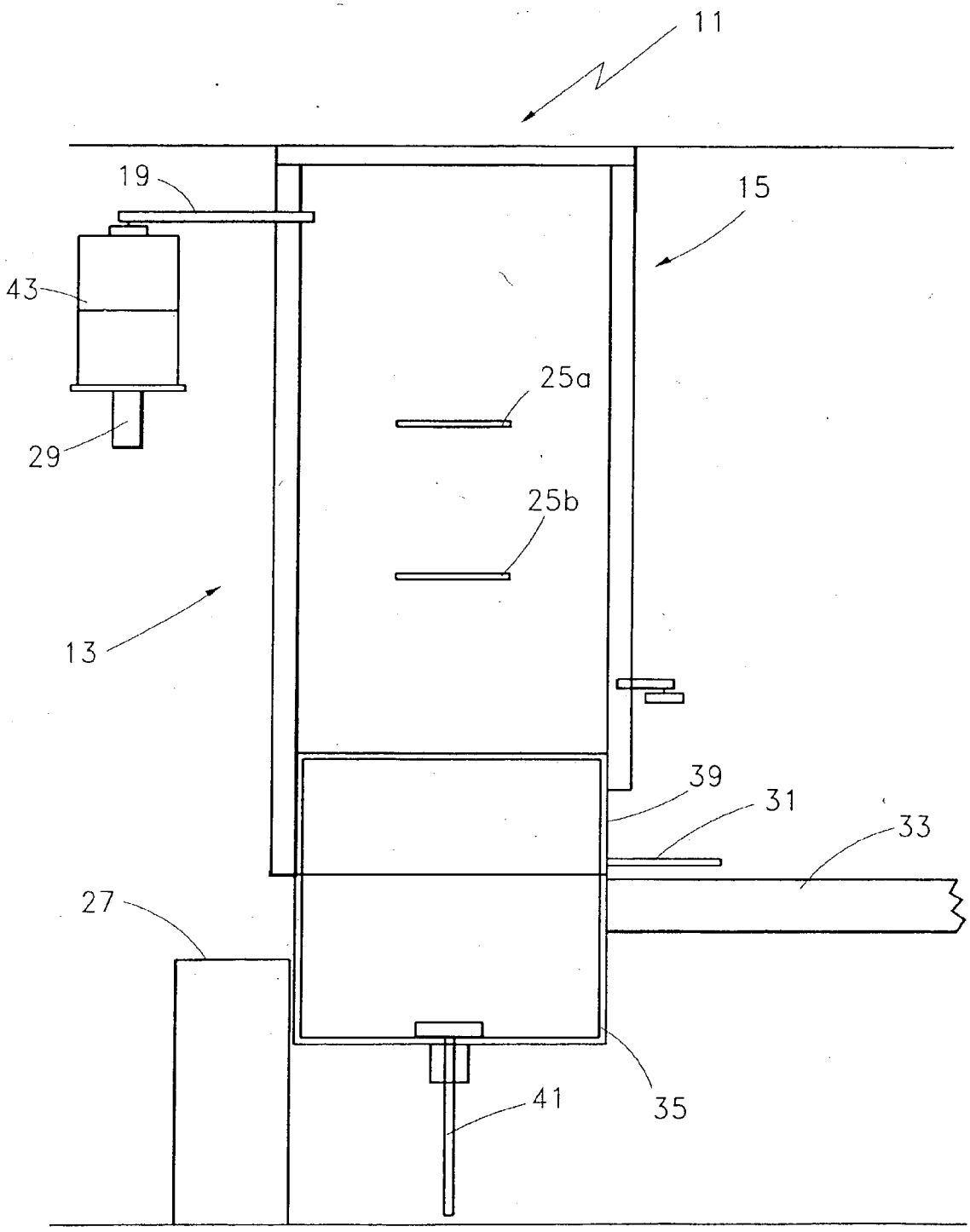


FIG. 5A

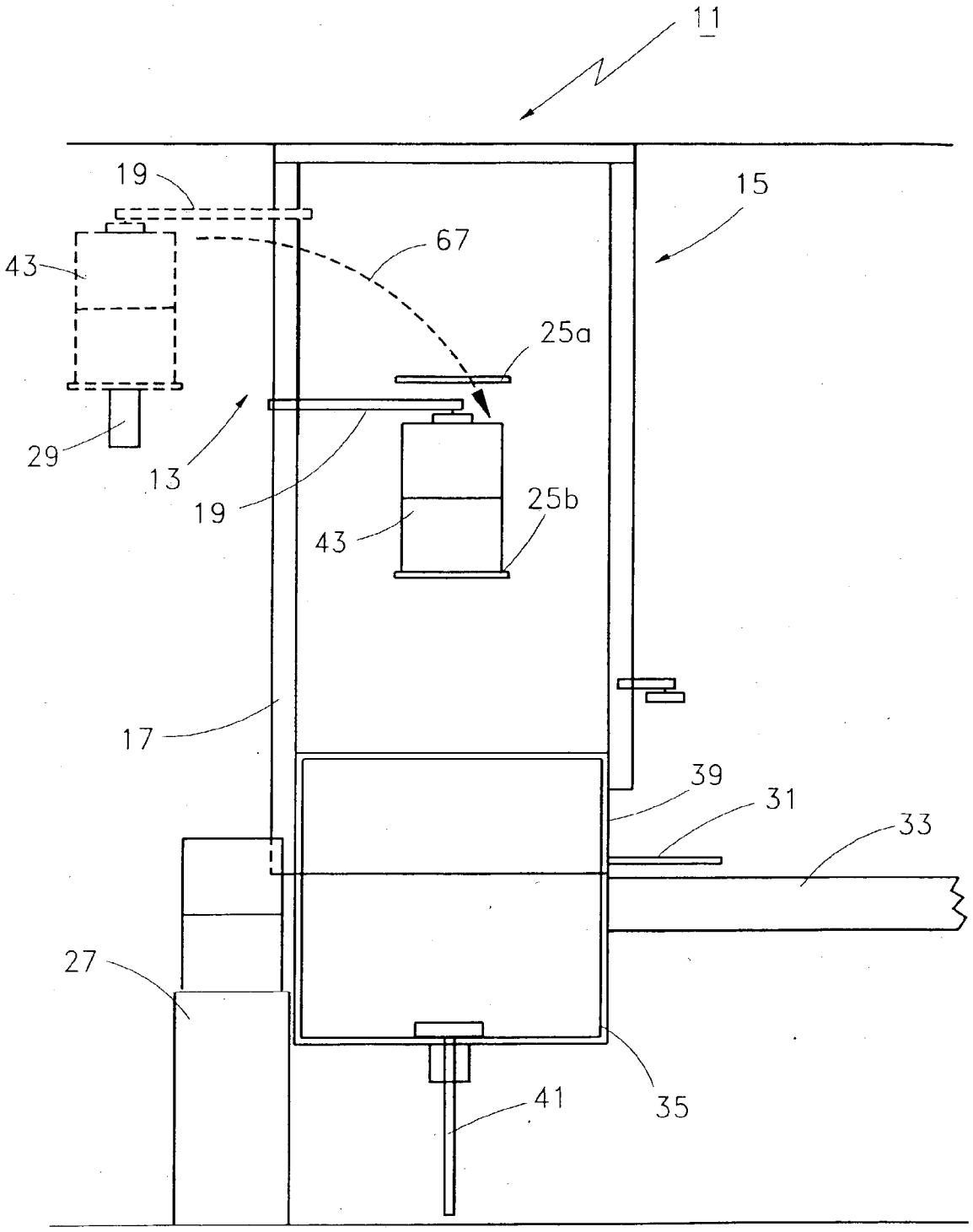


FIG. 5B

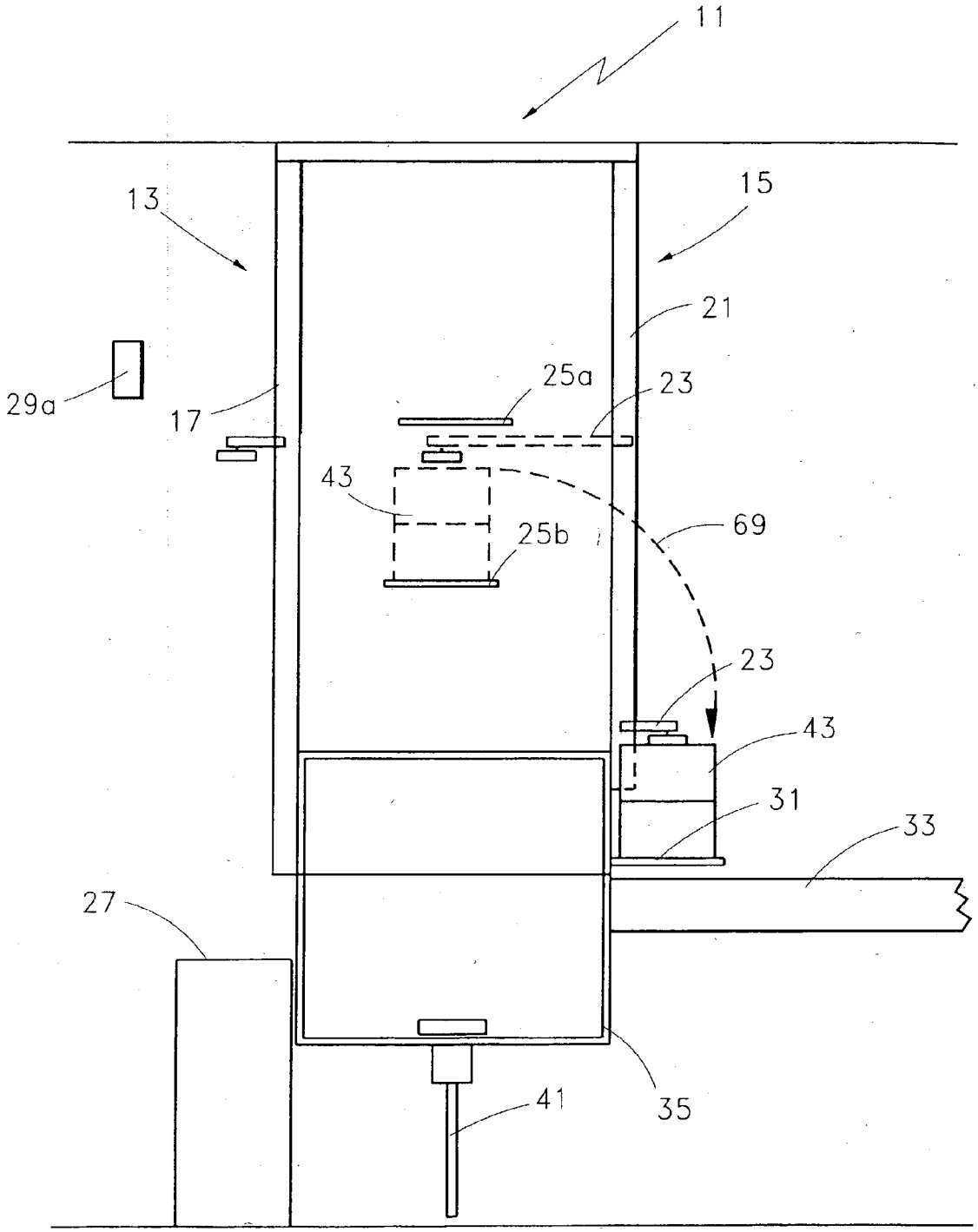


FIG. 5C

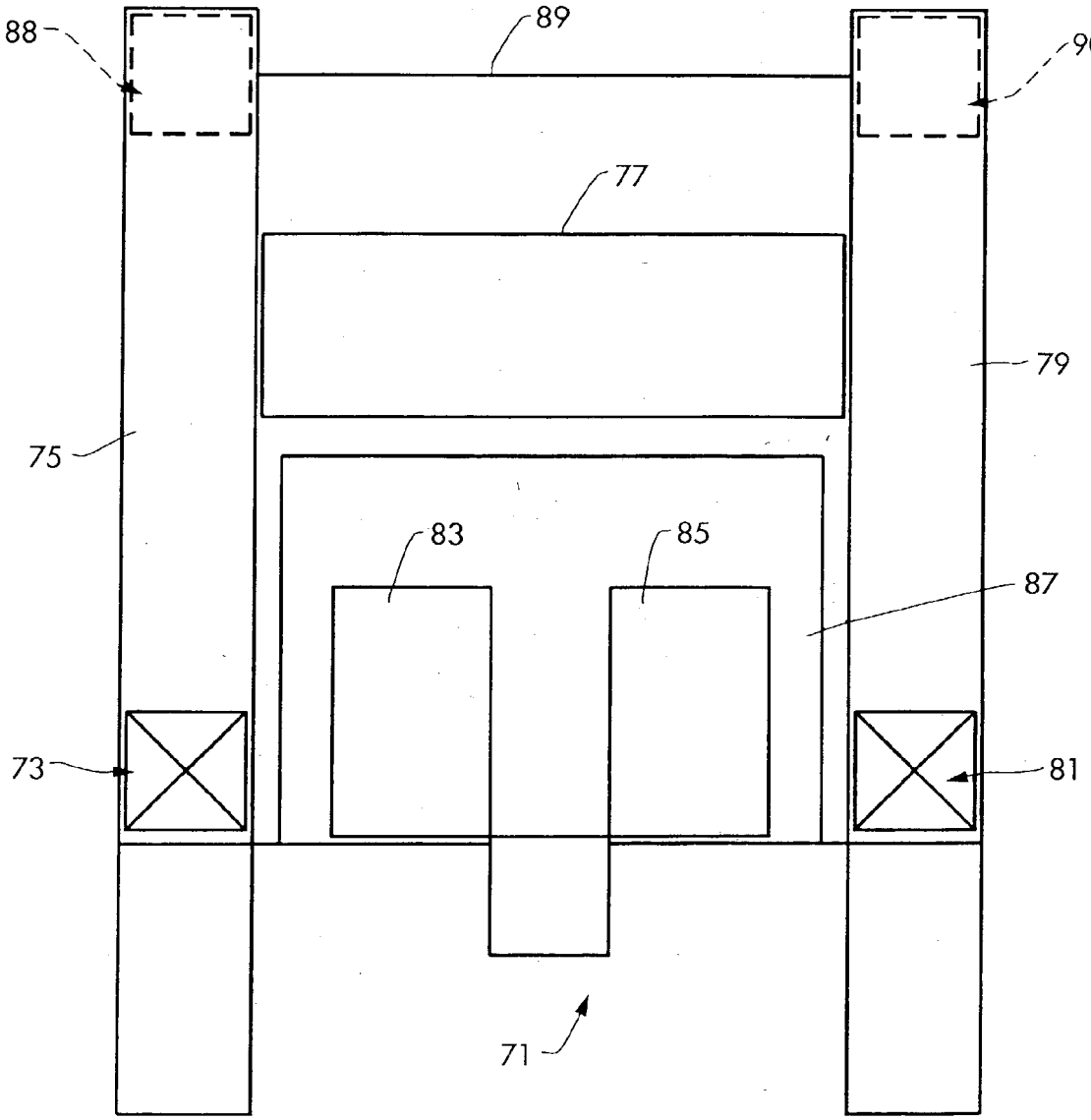


FIG. 6A

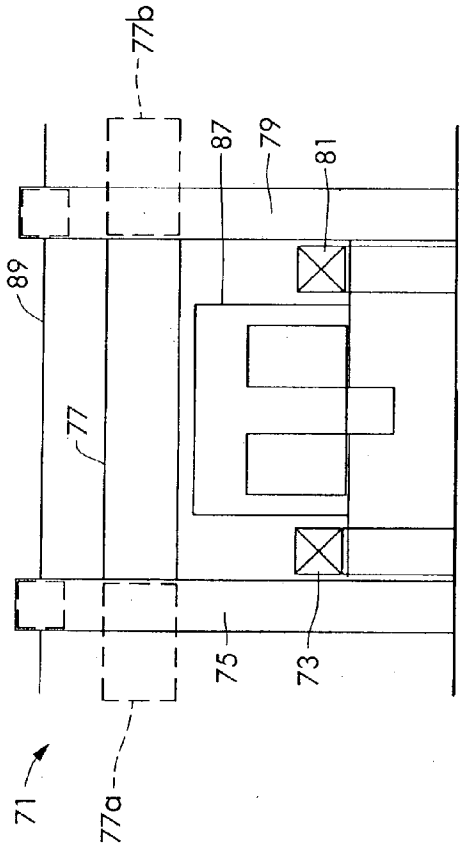

77b
87
79
81
89
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75
73
71
77a

FIG. 6B

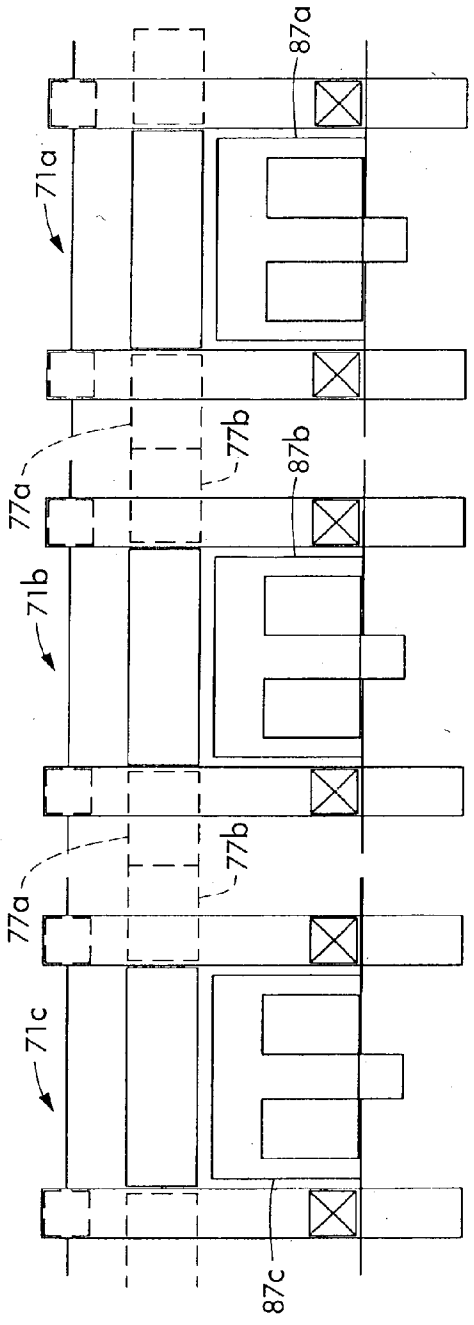

87a
71a
77b
77a
87b
71b
77b
77a
71c
87c

FIG. 6C

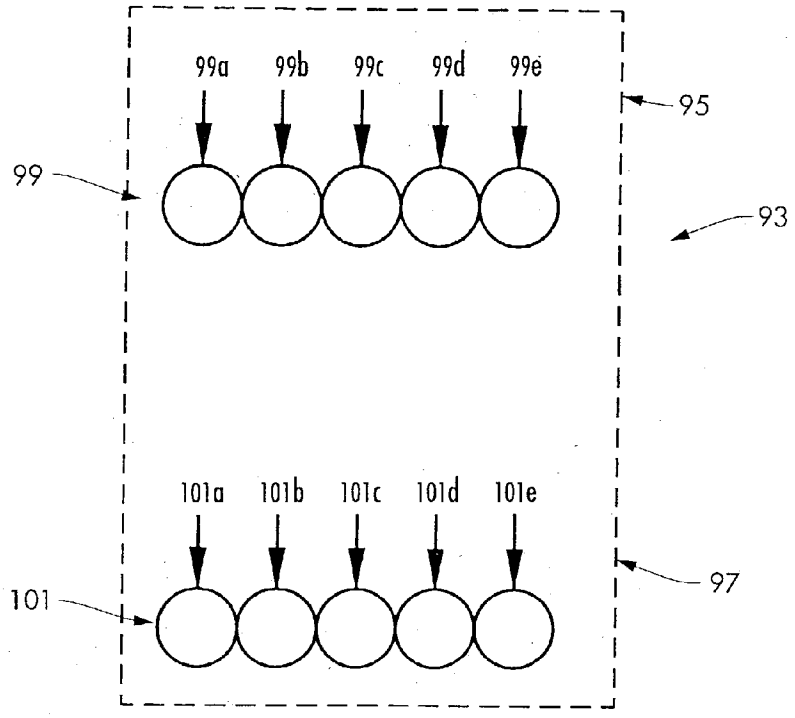

99a
99b
99c
99d
99e
95
99
93
101a
101b
101c
101d
101e
101
97

FIG. 7A

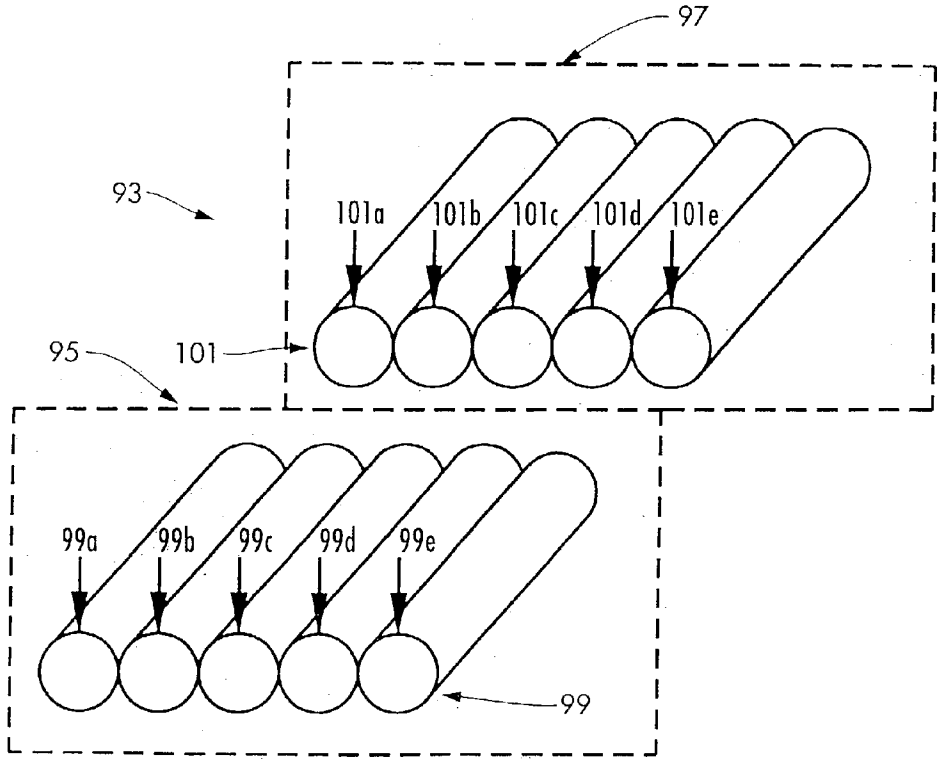

97
93
101a
101b
101c
101d
101e
95
101
99a
99b
99c
99d
99e
99

FIG. 7B

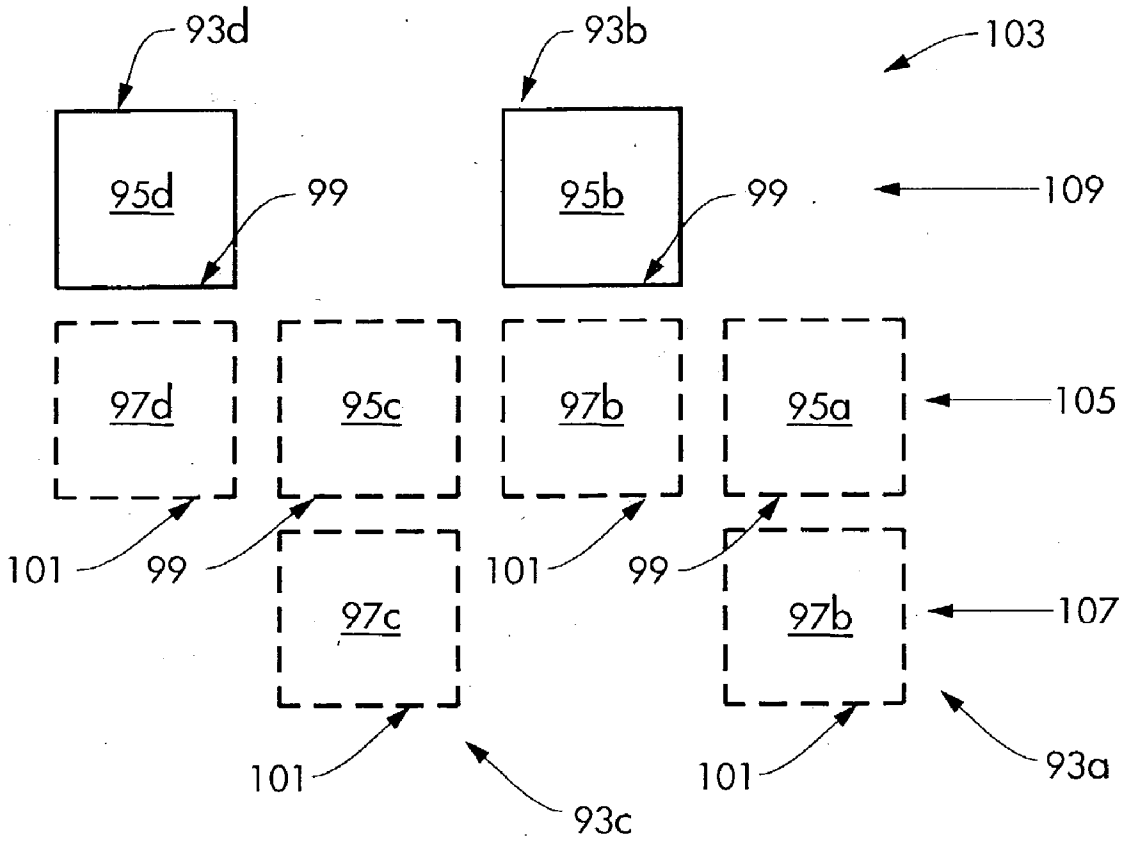

93d
93b
103
95d
99
95b
99
109
97d
95c
97b
95a
105
101
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101
99
97c
97b
107
101
101
93a
93c

FIG. 8

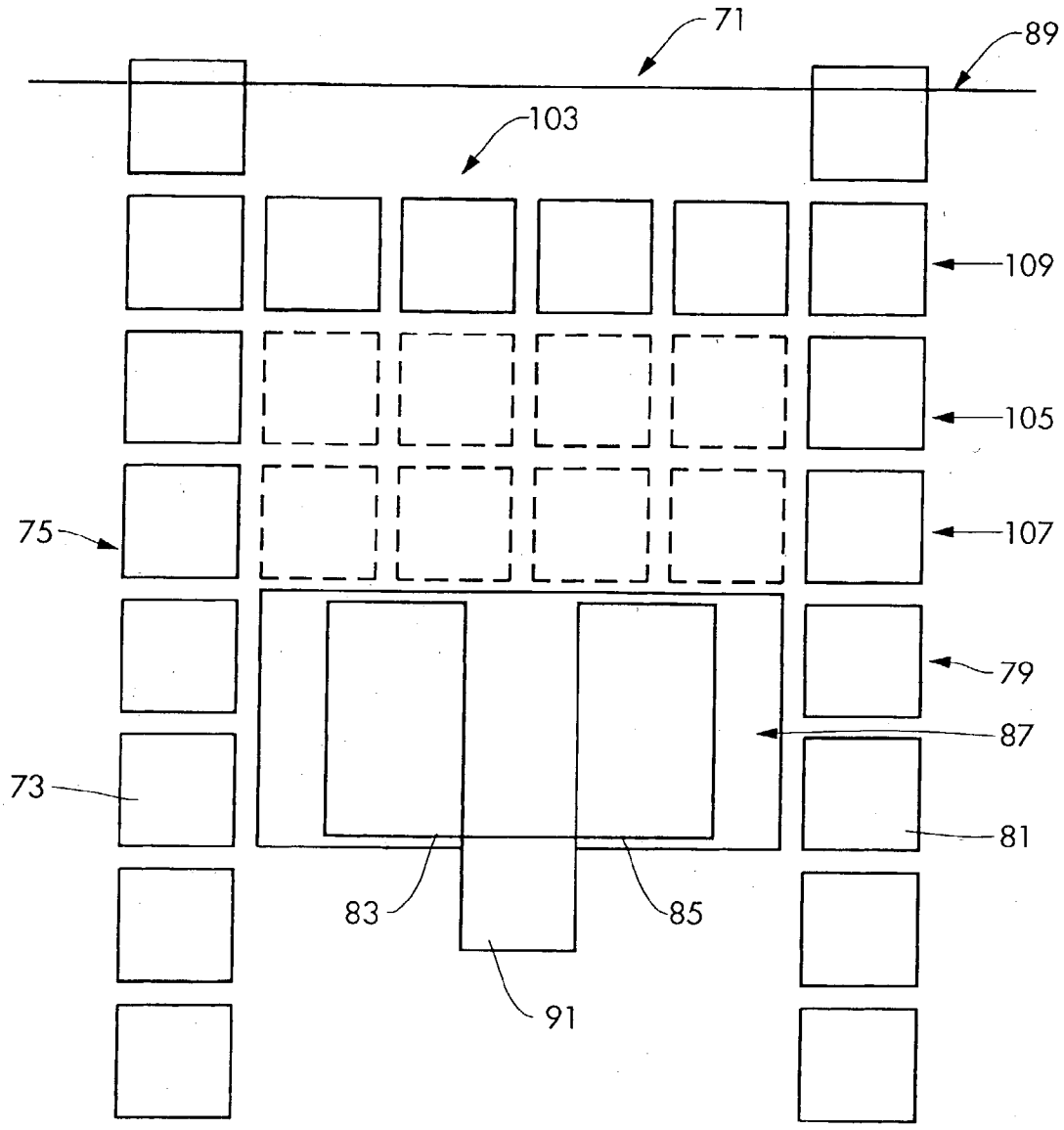


FIG. 9

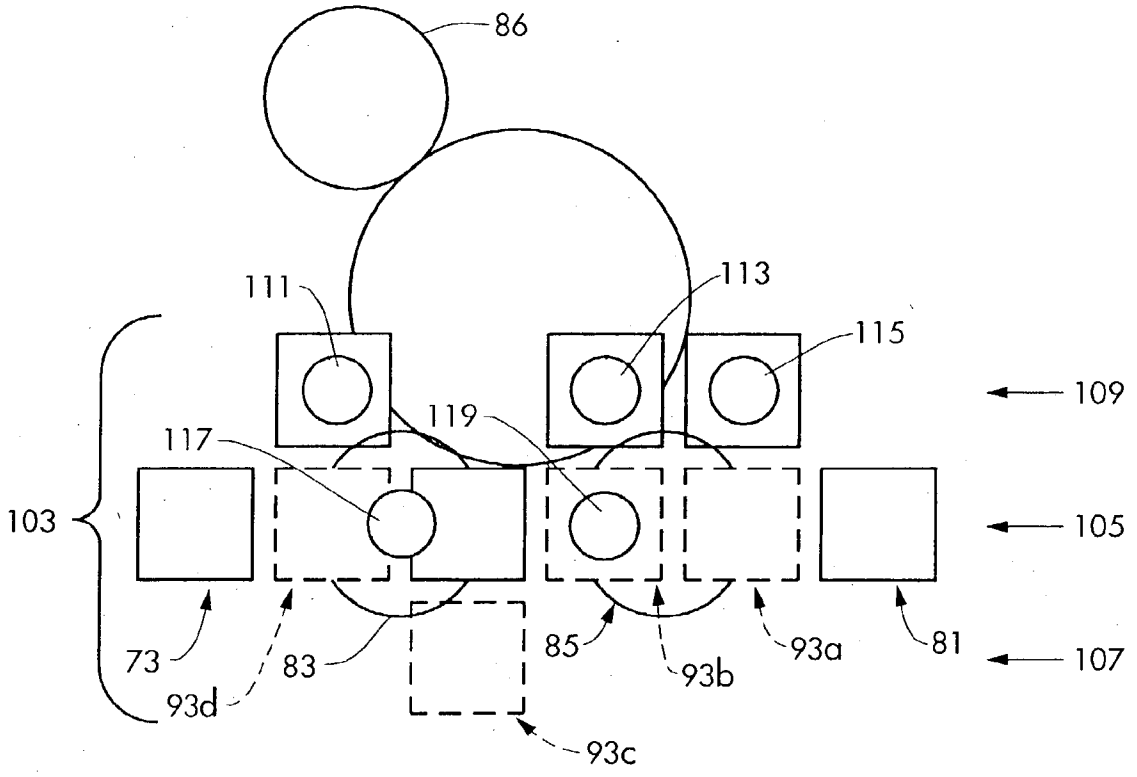


FIG. 10

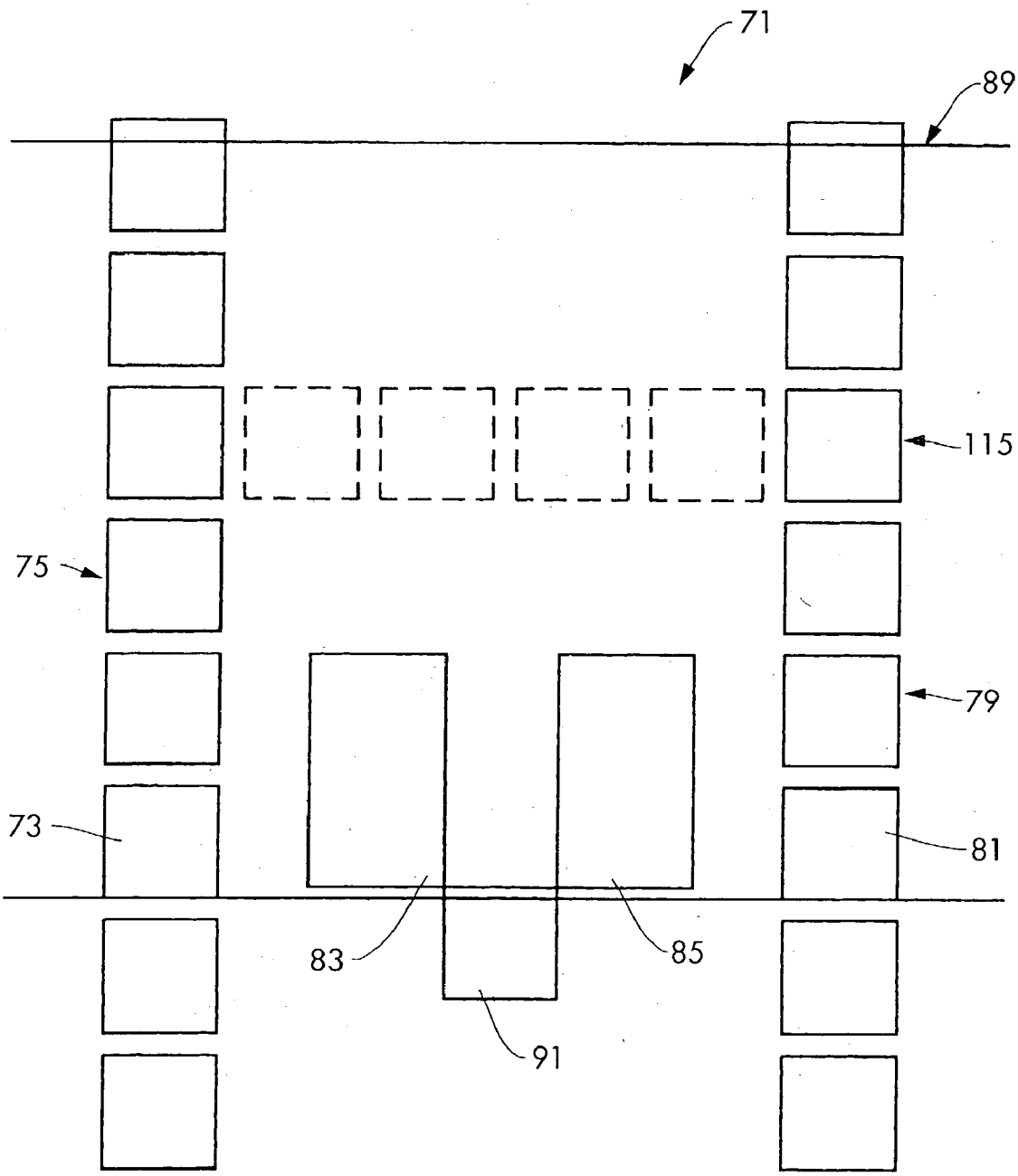


FIG. 11

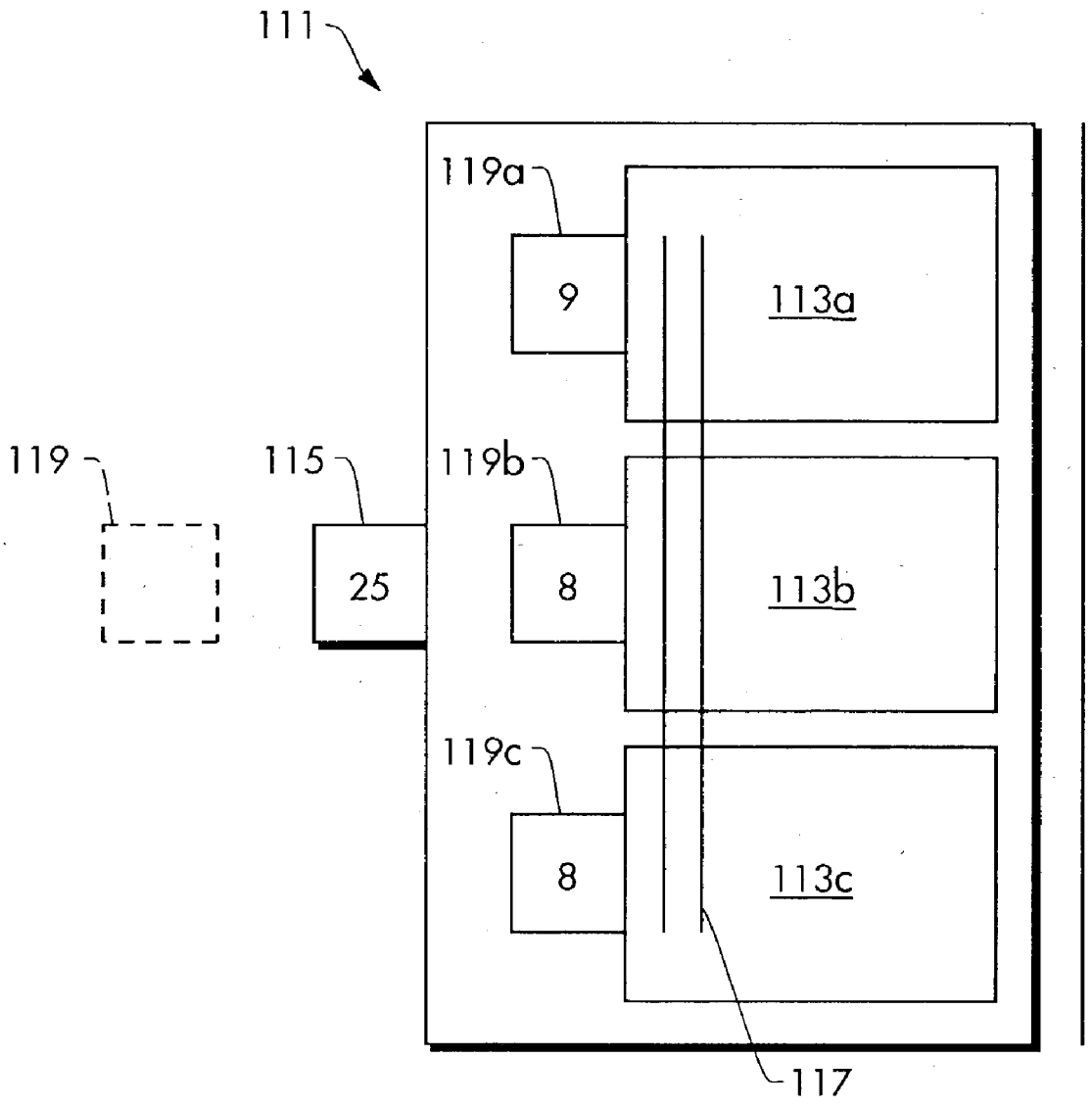


FIG. 12

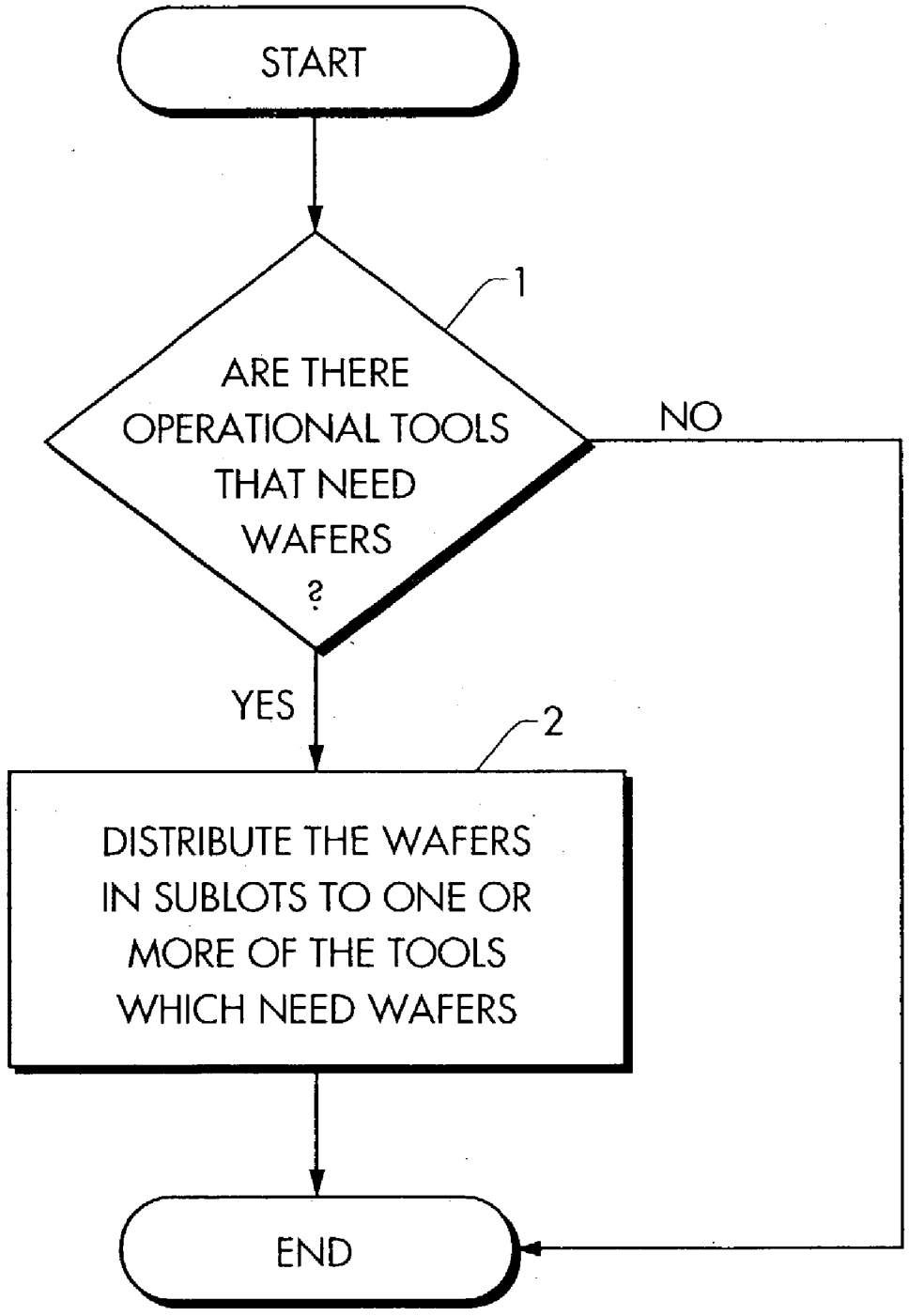

START
1
ARE THERE OPERATIONAL TOOLS THAT NEED WAFERS ?
NO
YES
2
DISTRIBUTE THE WAFERS IN SUBLOTS TO ONE OR MORE OF THE TOOLS WHICH NEED WAFERS
END

FIG. 13

COMPACT APPARATUS AND METHOD FOR STORING AND LOADING SEMICONDUCTOR WAFER CARRIERS

[0001] This application is a continuation of pending U.S. patent application Ser. No. 09/350,867, filed Jul. 9, 1999 (AMAT Docket No. 1600/P1/ATD/MBE), which is a continuation-in-part of U.S. patent application Ser. No. 08/764,661, filed Dec. 11, 1996 (AMAT Docket No. 1600/ATD/MBE), now U.S. Pat. No. 5,957,648. Both of these patent applications are hereby incorporated by reference herein in their entirety.

FIELD OF THE INVENTION

[0002] The present invention relates generally to semiconductor wafer fabrication systems, and to an improved method and apparatus for storing and loading semiconductor wafer carriers at a given semiconductor wafer fabrication tool.

BACKGROUND

[0003] The drive for reduced cost per unit wafer processed characterizes the semiconductor industry. Thus the semiconductor industry continuously searches for ways to increase wafer output and/or reduce overall equipment costs (costs of ownership). Among the factors significantly affecting cost of ownership for a given piece of equipment are clean room costs, footprint and labor costs. It is well recognized that overall semiconductor wafer fabrication system (i.e., fabrication tool) productivity increases are achieved by ensuring a constant supply of wafers at each tool. Conventionally this has been accomplished by employing a local buffer supply (i.e., a supply of wafers at the tool). For example, the "MINI BUFFER" marketed by Jenoptik/Infab is a vertical buffer which is positioned near a fabrication tool's load lock chambers. The MINI BUFFER comprises a series of vertically arranged shelves and one or more load ports for access by the tool's loader robot, and/or for access by factory transport agents (i.e., the mechanism that transfers wafer carriers from the factory to the buffer apparatus' factory load port). Conventionally one MINI BUFFER is positioned near each load lock, a distance from the load lock sufficient to accommodate the axis of rotation of a front loader robot. The loader robot may then access either MINI BUFFER to obtain a wafer carrier for loading to either load lock. Although such methods maintain a constant local buffer supply of wafer carriers, they occupy a considerable amount of floor space thus increasing the system's cost of ownership. The fact that fabrication tools are frequently maintained in a clean room environment further exacerbates the increased cost associated with the system's larger footprint.

[0004] In addition, most prior art systems do not allow simultaneous access by the tool loader and the factory transport agent, and thereby complicate factory transport scheduling, and can result in throughput reduction.

[0005] Accordingly, there is a need for apparatuses and methods which can reduce footprint and/or increase machine/factory throughput.

SUMMARY OF THE PREFERRED EMBODIMENTS

[0006] In its broadest aspect the invention comprises a load/buffer adapted to provide local storage of wafer carriers at a fabrication tool, the load/buffer comprising a first factory load port adapted to receive wafer carriers to be transferred to and from the factory, a wafer carrier store, a first wafer carrier transfer mechanism adapted to transfer wafer carriers between the factory load port and the store, a first tool load port adapted to receive wafer carriers to be accessed by a fabrication tool, and a second wafer carrier transfer mechanism adapted to transfer wafer carriers between the tool load port and the store.

[0007] The wafer carrier store may comprise for example, a shelf, shelves, or a conveyor, and the wafer carrier transfer mechanisms may comprise for example, a shelf capable of raising or lowering the wafer carrier between the wafer carrier store and the load port (in which case rollers, a wafer handler or the like may transfer the wafer carrier between the shelf and the wafer carrier store), or a wafer handler capable of transferring the wafer carriers between the port and the store. The ports may be positioned at the height set by SEMI standard E15, or may be at a height greater than that of the fabrication tool, etc. The inventive apparatus may be positioned in front of the fabrication tool, beside the fabrication tool, at least partially above the fabrication tool, etc.

[0008] To enhance throughput, a plurality of load buffers may be connected so that one fabrication tool can receive a wafer carrier from the wafer carrier store of another fabrication tool if necessary. As used herein, the term "fabrication tool" includes any tool that performs a process on a substrate, whether it be deposition, etch, heat treatment, polish, clean, etc.

[0009] To further enhance throughput an inventive wafer handling method may be employed. The inventive wafer handling method increases throughput during any non-steady-state processing period (startup, tool failure, etc.), by dividing the wafers contained in a wafer carrier among a plurality of fabrication tools that are adapted to perform the same process. In this manner, each fabrication tool can immediately begin processing wafers, and throughput is greatly increased as compared to conventional methods which allow the entire wafer carrier full of wafers to remain with a single fabrication tool. Such conventional methods force the remaining fabrication tools to idle until a wafer carrier has arrived for each fabrication tool. Because most conventional fabrication systems deliver only one wafer carrier per hour, the inventive method results in a substantial increase in throughput. Although the inventive wafer handling method is most advantageously employed within a plurality of connected load buffers, such as those described herein, it may be used within any system containing a plurality of fabrication tools which perform the same process.

[0010] Other objects, features and advantages of the present invention will become more fully apparent from the following detailed description of the preferred embodiments, the appended claims and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] **FIG. 1** is a side view of shelf-type load buffer of the invention;

[0012] **FIG. 2** is a front elevational view of the load buffer of **FIG. 1** which shows a preferred arrangement of four storage locations;

[0013] **FIG. 3** is a top plan view of the load buffer of **FIG. 1** which shows a preferred footprint thereof;

[0014] FIGS. **4A-4F** are side elevational views of the load buffer of **FIG. 1**, which are useful in explaining a first aspect of wafer carrier transport therethrough;

[0015] FIGS. **5A-5C** are side elevational views of the load buffer of **FIG. 1**, which are useful in explaining a second aspect of wafer carrier transport therethrough;

[0016] **FIG. 6A** is a side elevation view of an aspect of a conveyor-type inventive load buffer wherein the load ports are contiguous with the vertical transfer mechanisms;

[0017] **FIG. 6B** is a side elevation view of an aspect of a conveyor-type load buffer wherein the load ports are adjacent the vertical transfer mechanisms;

[0018] **FIG. 6C** is a side elevational view of a local interconnection of fabrication tools, which employs the second embodiment of the invention;

[0019] **FIG. 7A** is a side elevational view of a vertically oriented dual-compartment segment of a preferred modular conveyor employed in a conveyor-type load buffer;

[0020] **FIG. 7B** is a side perspective view of a horizontally oriented dual-compartment segment of a preferred modular conveyor employed in a conveyor-type load buffer;

[0021] **FIG. 8** is a side elevational view of a bi-level conveyor comprised of a plurality of the dual-compartment segments of **FIG. 7A**;

[0022] **FIG. 9** is a side elevation view of a preferred embodiment of the inventive load buffer wherein the transfer mechanism comprises the bi-level conveyor of **FIG. 8**;

[0023] **FIG. 10** is a top plan view of a conveyor-type load buffer, which employs the horizontally oriented dual-compartment segment of **FIG. 7B**;

[0024] **FIG. 11** is a side elevational view of a horizontally oriented conveyor-type load buffer, taken along line **1-1** of **FIG. 10**;

[0025] **FIG. 12** is a top plan view of a fabrication system that is useful in describing an inventive wafer handling method; and

[0026] **FIG. 13** is a flow diagram useful in describing the inventive wafer handling method.

DETAILED DESCRIPTION OF THE DRAWINGS

[0027] **FIG. 1** is a side view of an inventive load buffer **11**. The load buffer **11** comprises a first and second vertical transfer mechanism comprised of a first robot **13** and a second robot **15**, respectively. The first robot **13** comprises a first y-axis component **17** and a first x-axis component **19** movably coupled to the first y-axis component **17** such that the first x-axis component **19** may travel along the length of the first y-axis component **17**. Similarly, the second robot **15** comprises a second y-axis component **21** and a second x-axis component **23** movably coupled to the second y-axis component **21** such that the second x-axis component **23** may travel along the length of the second y-axis component **21**. Operatively coupled between the first robot **13** and the second robot **15** are one or more storage locations **25***a*, **25***b*.

[0028] The first robot **13** is configured such that when the first x-axis component **19** is at the lower portion of the first y-axis component **17** it may access a first load port **27** (preferably a SEMI E15 type load port) and such that when the first x-axis component **19** is at the upper portion of the first y-axis component **17** it may access a first overhead load port (not shown) which provides access to a first overhead wafer carrier transport system such as a monorail, referenced generally by the numeral **29***a* of **FIG. 1**.

[0029] The second robot **15** is configured such that when the second x-axis component **23** is at the lower portion of the second y-axis component **21** it may access a first wafer exchange port **31** and, optionally, such that when the second x-axis component **23** is at the upper portion of the second y-axis component **23** it may access an optional second overhead load port which provides access to a second overhead wafer carrier transport system such as a monorail, referenced generally by the numeral **29***b* in **FIG. 1**. Both the first x-axis component **19** and the second x-axis component **23** are configured so as to reach any of the storage locations **25***a*, **25***b*. In a preferred embodiment, each load port, each overhead load port and each wafer exchange port may simply comprise a predetermined location.

[0030] The first wafer exchange port **31** is preferably located substantially or completely above a fabrication tool **33** having at least a transfer chamber **32**, a process chamber **34** and a first load lock **35**. Most preferably the first wafer exchange port **31** is located above the transfer chamber **32** of the fabrication tool **33**. Alternatively, however, the wafer exchange port **31** may occupy other locations. The first wafer exchange port **31** is operatively coupled to the first load lock **35** via a first loader mechanism referenced generally by the numeral **37** of **FIG. 1**. The first loader mechanism **37** comprises a wafer cassette platform such as that described in co-pending U.S. application Ser. No. 08/763,604 now U.S. Pat. No. 5,833,426 (AMI Docket No. 1522 the entire disclosure of which is incorporated herein by reference) that extends outside the open load lock **35** to extract wafers from a cassette located on the first wafer exchange port **31**. The first load lock **35** has a first lid **39** and a lift-lower mechanism **41**.

[0031] In the present invention the first loader mechanism **37** is positioned on lift-lower mechanism **41**. When the first lid **39** and the lift-lower mechanism **41** are in their elevated positions, as shown in **FIG. 1**, the first loader mechanism **37** extends horizontally, extracts one or more wafers from a first wafer carrier **43** (or, alternatively, can transfer the entire wafer carrier) located on the first wafer exchange port **31** and retracts carrying the extracted wafers (or the entire cassette) into position on the lift-lower mechanism **41**. The lift-lower mechanism **41** then lowers the wafers (or the cassette) as the first lid **39** lowers.

[0032] Further, in a preferred embodiment the first lid **39** has a wafer carrier-engaging mechanism referenced generally by the numeral **45** of **FIG. 1** which will engage a second lid **47** of a first wafer carrier **43** located on the first wafer exchange port **31** causing the second lid **47** to elevate as the first lid **39** elevates. Thus, as shown in **FIG. 1**, the first wafer carrier **43** is open and ready for the first loader mechanism **37** to extract wafers for loading to the first load lock **35**.

[0033] **FIG. 2** is a front elevational view of the load buffer **11** of **FIG. 1** which shows a preferred arrangement of four

storage locations **25***a*, **25***b*, **25***c*, and **25***d*, above the first load lock **35** and a second load lock **49**. As shown in **FIG. 2**, the first load lock **35** is open with the first lid **39** elevated and the first wafer carrier **43** loaded on the lift-lower mechanism **41** for subsequent lowering into the first load lock **35**. A second wafer carrier **51**, a third wafer carrier **53**, a fourth wafer carrier **55** and a fifth wafer carrier **57** are in storage on the storage locations **25***a*, **25***b*, **25***c* and **25***d*, respectively.

[**0034**] **FIG. 3** is a top plan view of the load buffer **11** of **FIGS. 1 and 2** which shows a preferred footprint of the load buffer **11**, and which shows in pertinent part, a preferred footprint of the local area semiconductor wafer fabrication system. The four primary horizontal positions of the first x-axis component **19** and of the second x-axis component **23** are represented as **19***a*, **19***b*, **19***c*, and **19***d*, and **23***a*, **23***b*, **23***c*, and **23***d* respectively. However, it is understood that the first x-axis component **19** and the second x-axis component **23** each occupy only one of these positions at a given time. (The primary vertical positions of the first x-axis component **19** and of the second x-axis component **23** are shown sequentially in FIGS. **4**A-**4**F and FIGS. **5**A-**5**C.) As shown, the first load port **27** and a second load port **59** are advantageously positioned directly adjacent the first load lock **35** and the second load lock **49** of the fabrication tool **33**, resulting in the overall footprint of the local area semiconductor wafer fabrication system being considerably smaller than that of prior art systems which require sufficient space for a front loader robot. Such advantageous positioning of the first load port **27** and the second load port **59** is possible because wafer carriers entering the load buffer **11** via the first load port **27** or the second load port **59** are extracted from the top of the first load port **27** and the second load port **59**, respectively, rather than from the sides thereof. A number of other positions can also be employed, particularly for side opening load locks. Similarly, in this example, because the first load port **27** and the second load port **59** are loaded and unloaded from above, they may be positioned in close proximity to each other, unlike side loaded prior art systems whose load ports must be positioned a sufficient distance from each other to accommodate the loader robot's axis of rotation.

[**0035**] Further, as shown by **FIG. 3**, storage locations **25***a* and **25***c* preferably are positioned above the first load lock **35** and the second load lock **49**, respectively, and the first wafer exchange port **31** and a second wafer exchange port **61** preferably are positioned above the transfer chamber **32** of the fabrication tool **33**. The preferred location of the plurality of storage locations **25***a*-**25***d*, the first wafer exchange port **31** and the second wafer exchange port **61** above the fabrication tool allows the footprint of the inventive local area semiconductor wafer fabrication system to be significantly smaller than that of prior art systems. The smaller footprint provided by the present invention reduces the system's cost of ownership which in turn reduces the cost of each unit produced.

[**0036**] FIGS. **4**A-**4**F are side elevational views of the load buffer **11**, which are useful in explaining a first aspect of wafer carrier transport through the load buffer **11**. The components of the load buffer **11** are described above with reference to **FIG. 1** and are therefore not repeated here. Further, in the preferred embodiment, the entire load buffer apparatus **11** is maintained under a vacuum hood. However, it is understood that if the load buffer **11** were not under vacuum, the steps of opening a pod type wafer carrier and loading the wafers to the load lock would be performed within an enclosed vacuum chamber that would surround each wafer exchange port and the open load lock associated therewith.

[**0037**] As shown in **FIG. 4A** the first wafer carrier **43** is in storage at the storage location **25***a*. In operation, a second wafer carrier **51** is placed on the first load port **27** by, for example, an operator, automatic guided vehicle (AGV) or rail-guided vehicle (RGV), and the first x-axis component **19** of the first robot **13** lowers to pick up the second wafer carrier **51**, as shown in **FIG. 4A**. The second robot **15** operates independently of the first robot **13**, and may therefore be in any required position at a given time.

[**0038**] Next, as shown in **FIG. 4**B, the first x-axis component **19** lifts the second wafer carrier **51** and pivots to deposit the second wafer carrier **51** on the storage location **25***b*, as represented by arrow **63**.

[**0039**] Thereafter, as shown in the example of **FIG. 4**C, the first x-axis component **19** may pivot and lower to pick up the third wafer carrier **53** from the first load port **27**, as the second x-axis component **23** of the second robot **15** picks up the first wafer carrier **43** from the storage location **25***a*, pivots, lowers and deposits the first wafer carrier **43** at the first wafer exchange port **31**, as represented by the arrow **65**.

[**0040**] As shown in **FIG. 4D** the first lid **39** of the first load lock **35** elevates, and the wafer carrier-engaging mechanism **45**, which engages the second lid **47**, of the first wafer carrier **43**, causes the second lid **47** to elevate. Thus, the first wafer carrier **43** is open and any number of wafers or the entire cassette **43***a* (i.e., the contents of the open pod type first wafer carrier **43**) may be transferred from the first wafer exchange port **31** to the open first load lock **35**. As described with reference to **FIG. 1**, the first loader mechanism **37** may be a conventional apparatus, or, preferably, is as described in application Ser. No. 08/763,604 now U.S. Pat. No. 5,833, 426 (AMI Docket No. 1522). The apparatus described in Ser. No. 08/763,604 now U.S. Pat. No. 5,833,426 (AMI Docket No. 1522) comprises a slotted assembly which extends to position the slots beneath the wafers to be extracted. The assembly then elevates, lifting the wafers, and retracts. The assembly can be modified such that the number of slots correspond to the number of wafers to be extracted, or can be modified to extend to a position beneath the entire cassette, thus transporting the entire cassette when the assembly retracts.

[**0041**] **FIG. 4E** shows the wafer cassette **43***a* (extracted from the open first wafer carrier **43**) positioned on the lift-lower mechanism **41** for subsequent lowering into the first load lock **35**.

[**0042**] **FIG. 4F** shows the wafer cassette **43***a* positioned within the first load lock **35**, and the first lid **39** of the first load lock **35** in the closed position. Thereafter wafers may be extracted from the first load lock **35** and processed within the fabrication tool **33**. The empty first wafer carrier **43** can be closed and moved to one of the storage locations **25***a*-**25***d* or can remain positioned on first wafer exchange port **31** until wafers have been processed and returned to the first wafer carrier **43**.

[**0043**] The first robot **13** and the second robot **15** may continue to operate independently of the loading of the first wafer carrier **43** from the first wafer exchange port **31** to the

first load lock **35**. Although not shown in **FIGS. 4E and 4F**, the first robot **13** may continue transferring wafer carriers between the first load port **27** and/or the overhead load port (e.g., a predetermined location along the monorail **29**) and the plurality of storage locations **25***a*-**25***d*; and the second robot **15** is able to pick up wafer carriers as required from the plurality of storage locations **25***a*-**25***d*, and deposit them at either the first wafer exchange port **31** or the second wafer exchange port **61**, provided the particular wafer exchange port is vacant.

[**0044**] The configuration of the load buffer **11** advantageously enables independent operation of the first robot **13** and the second robot **15**, and enables independent loading and unloading of each pair of load ports (e.g., the first load port and the first wafer exchange port) and the overhead load ports. Thus, it is understood that the specific operation of the load buffer **11** described with reference to FIGS. **4**A-**4**F is merely exemplary.

[**0045**] FIGS. **5**A-**5**C are side elevational views of the load buffer of **FIG. 2**, which are useful in explaining a second aspect of wafer carrier transport therethrough. As shown in **FIG. 5A** the first x-axis component **19** of the first robot **13** pivots to pickup the first wafer carrier **43** from the monorail **29**. Thereafter as shown in **FIG. 5**B, the first x-axis component **19** lowers and pivots about the first y-axis component **17** to deposit the first wafer carrier **43** on the storage location **25***b*, as represented by the arrow **67**. Then, as shown in **FIG. 5**C, the second x-axis component **23** of the second robot **15** picks up the first wafer carrier **43** from the storage location **25***b* and pivots about the second y-axis component **21** and lowers to deposit the first wafer carrier **43** on the first wafer exchange port **31**, as represented by arrow **69**. Thereafter the first wafer carrier **43** is opened and lowered into the first load lock **35** as previously described with reference to FIGS. **4**D-**4**F. While only the first wafer carrier **43** is shown traveling through the load buffer **11**, it is understood that when the first x-axis component **19** and the second x-axis component **23** are not transporting the first wafer carrier **43**, they may be picking up, transporting, or depositing other wafer carriers at any location within load buffer **11**, as previously described. In sum, the operation of the first robot **13** and the second robot **15** may be synchronous at certain times, and also may operate asynchronously at other times. Therefore it is understood that the specific operation of the load buffer **11** described with reference to FIGS. **5**A-**5**C is merely exemplary.

[**0046**] After processing is complete and the wafers have been returned to the load lock **35**, the lid of load lock **35** elevates, the lift/lower mechanism **41** lifts the wafers to the elevation of the first wafer exchange port **31**, and the first loader mechanism **37** returns the wafers to the cassette **43** positioned on the wafer exchange port **31**. As the first lid **39** of load lock **35** lowers, lift/lower mechanism **41** lowers, and the second lid **47** of the wafer carrier **43** lowers, sealing around the cassette **43***a*. Thereafter the second robot **15** transfers the wafer carrier **43** either to a storage shelf **25** or to the second overhead load port. If the second robot **15** places the wafer carrier **43** on one of the storage shelves **25**, the first robot **13** may then transfer the wafer carrier **43** either to the first load port **27** or to the first overhead load port. Thus a wafer carrier full of processed wafers travels backward through the load buffer **11** in the same manner as a wafer carrier of unprocessed wafers travels forward through the load buffer **11**, only the direction of travel changes. Each robot elevates a wafer carrier between the respective load port or wafer exchange port and the overhead load ports or storage shelves. As used herein the term "elevate" refers to any y-axis movement and therefore includes both lifting and lowering.

[**0047**] In operation, at any given time wafer carriers may be traveling both forward and backward through the load buffer **11**. Thus, a robot may transfer a first wafer carrier to the storage shelves or to the overhead load ports, and then immediately pick up a second wafer carrier for transfer to one of the load ports or to the wafer exchange ports.

[**0048**] Although with reference to the side elevational views of FIGS. **1**, **4**A-F and **5**A-C only the first side of the load buffer **11** is shown and described (i.e., the first load port through the first wafer exchange port) it is understood that the configuration and operation of the second side of the load buffer **11** (i.e., the second load port through the second wafer exchange port) is identical to that disclosed. Further, although only a single shelf-type load buffer is disclosed, it will be understood by those of ordinary skill in the art, that the first robot **13** and/or the second robot **15** can be adapted to reach one or more shelves of an adjacent load buffer, and, central shelves may even be positioned between two adjacent load buffers so as to provide a position at which wafer carriers may be passed from one load buffer to the next.

[**0049**] **FIG. 6A** is a side elevation view of a conveyor-type load buffer **71**, wherein the load ports are contiguous with the vertical transfer mechanisms. As shown in **FIG. 6**A, the load buffer **71** comprises a first load port **73**. In the configuration shown, the first load port **73** is a port for loading wafer carriers from the factory. The first load port **73** is operatively coupled to a first elevator **75** which receives wafer carriers from the factory through the first load port **73**. The upper portion of the first elevator **75** is operatively coupled to one end of a horizontal transfer mechanism **77**, and the other end of the horizontal transfer mechanism **77** is operatively coupled to the upper portion of a second elevator **79**. A lower portion of the second elevator **79** operatively couples a second load port **81**. In the configuration shown, the second load port **81** is a port for loading wafer carriers from the load buffer **71** into either a first load lock **83** or a second load lock **85** of a fabrication tool **87**. In the most preferred embodiment, the first load port **73** is a predetermined location which the first elevator **75** occupies when it is in its lowest position, and the second load port **81** is a predetermined location which the second elevator **79** occupies when it is in its lowest position.

[**0050**] The inventive load buffer **71** shown in **FIG. 6B** is configured such that the first elevator **75** and the second elevator **79** extend to a height greater than that of the fabrication tool **87** and such that the horizontal transfer mechanism **77** is located above (i.e., at least partially overlapping) the footprint of the fabrication tool **87**. Preferably the horizontal transfer mechanism **77** is substantially above, and most preferably completely above the footprint of the fabrication tool **87**. It will be apparent to those of ordinary skill in the art that the load buffer **71** may be positioned in front of the tool, beside the tool, etc., and that a position above the fabrication tool is merely preferred. Thus, the load buffer **71** of the present invention provides wafer storage and movement within a minimized footprint. Further, the first

elevator **75** and/or the second elevator **79** may be operatively coupled to a wafer carrier transport system. The first elevator **75** and the second elevator **79** of **FIG. 6A** are shown operatively coupled to an overhead wafer carrier transport system **89** via a first overhead load port **88** and a second overhead load port **90**, respectively. In the most preferred embodiment, the first overhead load port **88** is a predetermined location which the first elevator **75** occupies when it is in its highest position, and the second overhead load port **90** is a predetermined location which the second elevator **79** occupies when it is in its highest position. As shown in **FIG. 6**B, the horizontal transfer mechanism may have an extended portion **77***a*, **77***b* which respectively extends beyond the first vertical transfer mechanism **75** and/or the second vertical transfer mechanism **81**. The extended portions **77***a*, **77***b* provide additional storage locations, and can be coupled to the horizontal transfer mechanism **77** (or to the extended portions **77***a*, **77***b*) of another fabrication tool to provide a local interconnection of fabrication tools (see **FIG. 6C**).

[**0051**] In operation an automated local area fabrication system; comprising the load buffer **71**, at least the first load lock **83**, and at least one processing chamber; receives a wafer carrier in the first load port **73**. Typically the wafer carrier will be traveling from a previous processing location (e.g., an additional automated local area fabrication system) and may be transported to and loaded into the first load port **73** via a factory automation system, an automatic guided vehicle, or an operator, etc. The wafer carrier is loaded via the first load port **73** into the first elevator **75**. The first elevator **75** elevates the wafer carrier to the upper portion of the first elevator **75** which is connected to the horizontal transfer mechanism **77**. Thereafter the wafer carrier is transferred to the horizontal transfer mechanism **77** via conventional methods, for example, the first elevator **75** may comprise an x-y robot that delivers a wafer carrier to the horizontal transfer mechanism **77** and then returns to the first load port **73**, or, the first elevator **75** may comprise a surface of rolling elements which are actuated when the surface is aligned with the horizontal transfer mechanism **77**, causing the wafer carrier to be transferred across the rolling elements to the horizontal transfer mechanism **77**.

[**0052**] After traveling though the horizontal transfer mechanism **77** the wafer carrier is transferred from the horizontal transfer mechanism **77** to the upper portion of the second elevator **79** via conventional methods. The second elevator **79** then lowers the wafer carrier to the second load port **81** where a conventional loader mechanism **91** (e.g., a robot) transfers one or more wafers, or the entire wafer carrier from the second load port **81** to either the first load lock **83** or the second load lock **85** of the fabrication tool **87**. Within the fabrication tool **87** wafers are transferred from the first load lock **83** or the second load lock **85** to one or more process chambers **86** (see **FIG. 10**) for processing. Alternatively, the first elevator **75** and/or the second elevator **79** may transfer a wafer carrier to the overhead factory transfer system **89** via the first overhead load port **88** or the second overhead load port **90**.

[**0053**] **FIG. 6B** is a side elevation view of a preferred embodiment of an inventive load buffer wherein the first load port **73** is adjacent the first vertical transfer mechanism **75**, and the second load port **81** is adjacent the second vertical transfer mechanism **79**. Each load port is coupled to the respective vertical transfer mechanism via conventional methods (e.g., a pick and place robot, a plurality of rolling elements, etc.) which transfer a wafer carrier between the respective load port and the vertical transfer mechanism. This type of adjacent configuration could be used to retrofit existing fabrication tools with the load buffer of the present invention. Except for the positioning of the load ports and the vertical transfer mechanisms, the-load buffer of **FIG. 6B** is configured and operates the same as that of **FIG. 6A**.

[**0054**] **FIG. 6C** is a side elevational view of a local interconnection of fabrication tools. As shown in **FIG. 6C, a** plurality of fabrication tools **87***a*, **87***b*, **87***c* are interconnected via the extended horizontal transfer mechanisms **77***a*, **77***b*, of load buffers **71***a*, **71***b* and **71***c*. Specifically, the extended portion **77***a* of the load buffer **71***a* is coupled to the extended portion **77***b* of the load buffer **71***b*, and the extended portion **77***a* of the load buffer **71***b* is coupled to the extended portion **77***b* of the load buffer **71***c*. In this configuration, a wafer carrier may advantageously travel directly between the interconnected load buffers, without the aid of the overhead wafer carrier transport system, an AGV or operator. Such local interconnection of fabrication tools increases the flexibility and the transaction capability of the factory material handling system.

[**0055**] **FIGS. 7A and 7B** depict individual segments of a preferred horizontal transfer mechanism. **FIG. 7A** is a side view of a dual-compartment segment **93** of a preferred modular conveyor employed in a first aspect of the conveyor-type inventive load buffer. The conveyor segment **93** comprises a first compartment **95** and a second compartment **97**, respectively having a first surface **99** comprised of a plurality of rolling elements **99***a-e* and a second surface **101** comprised of a plurality of rolling elements **101***a-e*. In a preferred embodiment a plurality of the conveyor segments **93** of **FIG. 7A** are operatively coupled to form a modular bi-level conveyor **103** (see **FIGS. 8 and 9**). Any number of dual-compartment segments **93** may be coupled together so as to form a bi-level conveyor **103** of a desired length. The bi level structure guarantees an open movement channel, and can be constructed by joining levels of conventional rolling element type conveyors such as those manufactured by Middlesex General Industries, Inc. of Woburn, Mass. and described in U.S. Pat. No. 4,793,262, entitled "Transport System For Computer Integrated Manufacturing/Storage And Drive Component Therefore," the entirety of which is incorporated herein by this reference.

[**0056**] **FIG. 7B** is a side perspective view of an alternative horizontally oriented dual-compartment segment **93** of a preferred modular conveyor employed in a second aspect of the inventive conveyor-type load buffer. Like the conveyor segment **93** of **FIG. 7**A, the conveyor segment **93** of **FIG. 7B** comprises the first compartment **95** and the second compartment **97** respectively having the first surface **99** comprised of the plurality of rolling elements **99***a-e* and the second surface **101** comprised of the plurality of rolling elements **101***a-e*. In a preferred embodiment a plurality of the conveyor segments **93** of **FIG. 7B** are operatively coupled to form a modular conveyor **103** (see **FIGS. 8 and 10**). Any number of dual-compartment segments **93** may be coupled together so as to form a conveyor **103** of a desired length.

[**0057**] **FIG. 8** is a side elevational view of a bi-level conveyor **103** comprised of a plurality of the dual-compart-

ment segments **93** of **FIG. 7**A, wherein the dual-compartment segments **93***a-d* are vertically oriented and coupled together to provide a storage and movement channel. **FIG. 8** is useful for describing two positions (a neutral position and a positive position) each dual-compartment segment **93** may assume. In **FIG. 8**, dual-compartment segment **93***a* and dual-compartment segment **93***c* are shown in the neutral position, and dual-compartment segment **93***b* and dual-compartment segment **93***d* are shown in the positive position. Three channels are defined by the two possible positions of the dual-compartment segments **93***a-d*; a move channel **105**, a shuttle channel **107** and a storage channel **109**. In the neutral position the first compartment **95** of the dual-compartment segment **93** occupies the move channel **105**, and the second compartment **97** of the dual-compartment segment **93** occupies the shuttle channel **107**.

[**0058**] In the positive position the first compartment **95** of the dual-compartment segment **93** occupies the storage channel **109** and the second compartment **97** of the dual-compartment segment **93** occupies the move channel **105**. Thus, although a given dual-compartment segment **93** may be positioned such that a compartment occupies either the shuttle channel **107** or the storage channel **109**, each dual-compartment segment **93** has a compartment which occupies the move channel **105**. Therefore the move channel **105** is a continuous channel, formed of the first compartment **95** and/or the second compartment **97** of a plurality of the dual-compartment segments **93**, through which wafer carriers may travel; and the shuttle channel **107** and the storage channel **109** are intermittently occupied by the second compartment **97** or the first compartment **95**, respectively, of one or more dual-compartment segments **93**. Thus, the shuttle channel **107** and/or the storage channel **109** may store wafer carriers without blocking the passage of wafer carriers through the move channel **105**.

[**0059**] In the preferred operation, initially each dual-compartment segment **93***a-d* is neutrally positioned A first wafer carrier (not shown) is then loaded into the first compartment **95** of dual-compartment segment **93***a* and can: 1) travel immediately along the move channel **105** to the end of the bi-level conveyor **103** where the first wafer carrier will be unloaded from the bi-level conveyor **103**; 2) travel a distance along the bi-level conveyor **103** (e.g., to dual-compartment segment **93***b*, **93***c* or **93***d*) and then be placed in storage (e.g., placed in the storage channel **109** by shifting the respective dual-compartment segment **93** to a positive position); or 3) immediately be placed in storage (e.g., by shifting dual-compartment segment **93***a* to a positive position).

[**0060**] To remove a wafer carrier from storage and return the wafer carrier to the move channel **105**, the dual-compartment segment **93** containing the wafer carrier is shifted from the positive position to the neutral position. Thereafter, the wafer carrier may continue traveling along the move channel **105**. Thus, by employing a bi-level conveyor **103** and by designating one channel for storage and one channel for movement, a first wafer carrier may be placed in storage at any point along the bi-level conveyor **103** (i.e., within any of the plurality of dual-compartment segments **93***a-d*) without obstructing the passage of a second wafer carrier through the move channel **105**. Although the move channel **105** is preferably used only for moving wafer carriers, and the storage channel **109** is preferably used only for storing wafer carriers, the storage channel **109** and/or the move channel **105** may perform a combination of storage and movement functions.

[**0061**] **FIG. 9** is a side elevation view of a preferred embodiment of an inventive load buffer **71** wherein the horizontal transfer mechanism **77** comprises the bi-level conveyor **103** of **FIG. 8**. The overall configuration of the load buffer **71** and the bi-level conveyor **103** are described with reference to **FIGS. 6 and 8**, respectively, and are therefore not repeated here. The operation of the load buffer of **FIG. 8** is described below.

[**0062**] In operation an automated local area fabrication system; comprising the load buffer **71**, at least the first load lock **83**, and at least one processing chamber; receives a wafer carrier in the first load port **73**. Typically the wafer carrier will be traveling from a previous process location (e.g., an additional automated local area fabrication system) and may be transported to and loaded into the first load port **73** via, for example, a factory automation system, an automatic guided vehicle, or an operator. The wafer carrier is loaded via the first load port **73** into the first elevator **75**. The first elevator **75** elevates the wafer carrier to the upper portion of the first elevator **75** which is connected to the bi-level conveyor **103**. Thereafter the wafer carrier is transferred to the bi-level conveyor **103** via conventional methods. An actuator (not shown) controls the bi-level conveyor **103** causing a given dual-compartment segment **93** to shift from the neutral position to the positive position and vice versa. The actuator also controls the operation of the first plurality of rolling elements **99***a-e*, and the second plurality of rolling elements **101***a-e*, selectively causing them to rotate and thus to transfer a wafer carrier from one universe of rolling elements to the next. By selectively shifting the dual-compartment segments **93***a-d* and rotating the plurality of rolling elements **99***a-e* and **101***a-e*, wafer carriers are stored in the storage channel **109** and transferred through the move channel **105**, as described previously in conjunction with **FIG. 8**.

[**0063**] After traveling though the bi-level conveyor **103** the wafer carrier is transferred from the bi-level conveyor **103** to the upper portion of the second elevator **79** via conventional methods. The second elevator **79** then lowers the wafer carrier to the second load port **81** where a conventional loader mechanism **91** (e.g., a robot) transfers one or more wafers at a time, or transfers the entire wafer carrier, from the second load port **81** to either the first load lock **83** or the second load lock **85** of the fabrication tool **87**. Within the fabrication tool **87** wafers are transferred from the first load lock **83** or the second load lock **85** to one or more process chambers **86** (see **FIG. 10**) for processing. Alternatively, the first elevator **75** and/or the second elevator **79** may transfer a wafer carrier to the overhead factory transfer system **89**, and/or the bi-level conveyor **103** may transfer a wafer carrier directly to the load buffer of a locally connected fabrication tool.

[**0064**] **FIG. 10** is a top plan view of a conveyor-type load buffer **71**, which employs the horizontally oriented dual-compartment segment **93** of **FIG. 7B**. As shown in **FIG. 10** the dual-compartment segment **93***c* is neutrally positioned (i.e., the first compartment **95** occupies the move channel **105** and the second compartment **97** occupies the shuttle channel **107**) and the dual-compartment segments **93***a*, **93***b*

and **93***d* are positively positioned (i.e., with the first compartment **95** occupying the storage channel **109** and the second compartment **97** occupying the shuttle channel **107**).

[**0065**] In the example of **FIG. 10 a** first wafer carrier **111** is stored by dual-compartment segment **93***d*, a second wafer carrier **113** is stored by dual-compartment segment **93***b*, and a third wafer carrier **115** is stored by dual-compartment segment **93***a*. A fourth wafer carrier **117** and a fifth wafer carrier **119** are moving through the move channel **105**. The fourth wafer carrier **117** is moving from the first compartment **95** of the dual-compartment segment **93***c* to the first compartment **95** of the dual-compartment segment **93***d*, and the fifth wafer carrier **119** is moving through the first compartment **95** of the dual-compartment segment **93***b*. As this example shows, a single dual-compartment segment **93** may contain wafer carriers in both the first compartment **95** and in the second compartment **97** at any given time, as does dual-compartment segment **93***b*. Also as this example shows, at any given time the move channel **105** may comprise either the first compartment **95** or the second compartment **97** of a given dual-compartment segment **93**.

[**0066**] As with the vertically oriented bi-level conveyor **103** of **FIG. 8**, in the preferred operation of **FIG. 10**, each dual-compartment segment **93** is initially neutrally positioned, a first wafer carrier is then loaded into the first compartment **95** of the dual-compartment segment **93***a* and can: 1) travel immediately along the move channel **105** to the end of the bi-level conveyor **103** where the first wafer carrier will be unloaded from the bi-level conveyor **103** and placed within the second elevator **79** (see **FIG. 11**); 2) travel a distance along the bi-level conveyor **103** (e.g., to dual-compartment segment **93***b*, **93***c* or **93***d*) and then be placed in storage (e.g., placed in the storage channel **109** by shifting the respective dual-compartment segment **93** to a positive position); or 3) immediately be placed in storage (e.g., by shifting dual-compartment segment **93***a* to a positive position).

[**0067**] To remove a wafer carrier from storage and return it to the move channel **105**, the dual-compartment segment **93** containing the wafer carrier is shifted from the positive position to the neutral position. Thereafter, the wafer carrier may continue traveling along the move channel **105**. Thus, by employing a dual-compartment conveyor **103** and by designating one channel for storage and one channel for movement, a first wafer carrier may be placed in storage at any point along the bi-level conveyor **103** (i.e., within any of the plurality of dual-compartment segments **93***a-d*) without obstructing the passage of a-second wafer carrier through the move channel **105**. Although the move channel **105** is preferably used only for moving wafer carriers, and the storage channel **109** is preferably used only for storing wafer carriers, the storage channel **109** and/or the move channel **105** may perform a combination of storage and movement functions. Although the load buffer **71** of **FIG. 10** is positioned above a fabrication tool, a person of ordinary skill in the art will recognize that it may be positioned for example, in front of, or beside, a fabrication tool.

[**0068**] **FIG. 11** is a side elevational view of the conveyor-type load buffer **71**, taken along line **1-1** of **FIG. 10**. Thus, while **FIG. 11** shows only the move channel **105**—the shuttle channel **107** and the storage channel **109** are in the plane perpendicular to the page. Except for the horizontal orientation of the bi-level conveyor **103** (described with reference to **FIG. 10**), the configuration and operation of the load buffer **71** shown in **FIG. 11** is the same as that described with reference to **FIG. 9**, further description is therefore omitted.

[**0069**] As previously stated, the load buffer embodiments described above are merely the currently preferred embodiments. Other embodiments will likewise benefit from the inventive features taught herein, such as the local interconnection of fabrication tools, the ability to receive wafer carriers from overhead factory transport mechanisms, the ability for the factory load port and the tool load port to operate independently, etc.

[**0070**] Similarly, an inventive method of wafer handling is now provided which is particularly advantageous when employed with the interconnected conveyor-type load buffers shown in **FIG. 6C**. However, it should be noted that the inventive method can be advantageously employed within any fabrication system that employs a plurality of tools for simultaneously performing a process (preferably the same process), as better understood with reference to **FIG. 12**.

[**0071**] **FIG. 12** is a top plan view of a-tool set **111** that is useful in describing an inventive wafer handling method. The tool set **111**, as an example, comprises three fabrication tools **113***a-c* each of which performs the same process. Although the inventive method is most advantageously employed with a set of tools that perform the same process, it may also be employed with a set of tools that perform various different processes.

[**0072**] In its broadest sense, the inventive method comprises receiving a wafer carrier containing a plurality of wafers (i.e., a wafer lot), at a fabrication tool, or at an incoming wafer carrier location **115** of the tool set **111**, dividing the wafer lot into a plurality of sublots and delivering these sublots to a plurality of the tools within the tool set **111**. In this manner, the plurality of tools may begin processing shortly after receipt of the first wafer lot. The sublots may be delivered to the tools **113***a-c* via the same mechanism (e.g., factory transport) which delivered the lot, or may be delivered via a local transfer mechanism (represented generally by the number **117**) such as a local connection of load buffers (e.g., those pictured in **FIG. 6C**). The wafer lot is preferably divided equally between the number of tools in the set. Thus, as shown in **FIG. 12 a** 25 wafer lot is received at incoming wafer carrier location **115**, and is divided into a 9 wafer sublot and two 8 wafer sublots, and placed in three previously empty carriers **119***a-c*, which are delivered via local transfer mechanism **117** to the fabrication tools **113***a-c*.

[**0073**] The present invention preferably provides a control program generally represented by the number **119** which may be stored in any computer readable medium (e.g., a hard disc, floppy disc, carrier wave signal, etc.). The control program may be part of the overall program that controls manufacturing execution and material control, or may be a separate program. When a separate program and an incoming wafer carrier location **115** are employed, both the manufacturing execution/material control program and the wafer handling equipment can be significantly simplified, as fewer locations (in this example a third of the locations) will need to be accessed thereby.

[**0074**] A control program for carrying out the inventive method is set forth in **FIG. 13**. As described by **FIG. 13, a**

controller checks to see if any of the fabrication tools in the set are operational (e.g., not broken, etc.) and are in need of wafers (block **1**). If an operational tool or tools exist and are in need of wafers, wafers waiting to be loaded into other tools are distributed in sublots to one or more of the tools which need wafers (block **2**). Preferably the wafers are redistributed optimally, according to an algorithm, (e.g., as close to equally as possible) among the tools in the set. Any mechanism may be used to divide the wafers into sublots and redistribute the wafers, such as the fabrication tool's front end loader robot, etc. Empty wafer carriers may be in storage waiting for sublot formation. After processing is complete, the sublots may be recombined (e.g., by the loader robot) or may proceed to the next equipment set in sublots.

[**0075**] The inventive method allows a tool set to assume steady state processing in a fraction (in this example approximately one third) the time that is required by conventional methods, and is therefore advantageous during any transient processing condition (startup, tool failure, etc.) The foregoing description discloses only the preferred embodiment of the invention, modification of the above disclosed apparatus and method which fall within the scope of the invention will be readily apparent to those of ordinary skill in the art. For instance, although only four storage locations **25***a*, **25***b*, **25***c* and **25***d* are shown, additional storage locations could be provided. Although each of the storage locations **25***a*, **25***b*, **25***c* and **25***d* is shown as being wide enough to hold only a single wafer carrier, the size of the storage locations may vary so as to hold a plurality of wafer carriers. As well, the specific apparatus employed as the first and second vertical transfer mechanism may vary, as may the specific location and coupling of components.

[**0076**] Although the dual-compartment segment **93** is shown as having only a first compartment **95** and a second compartment **97**, the dual-compartment segment **93** may have additional compartments which could provide additional storage locations or additional movement channels. Although each dual-compartment segment **93** is shown as being wide enough to hold only a single wafer carrier, the size of dual-compartment segment **93** may vary.

[**0077**] In operation, any channel may perform both storage and movement at a given time, and the first and second load ports may each function as both a factory load port and a tool load port. The horizontal transfer mechanism is not limited to the conveyor system disclosed. Other equivalent transfer mechanisms will be apparent to those of ordinary skill in the art. Although a horizontal transfer mechanism that comprises both a storage and a move channel is preferred, the horizontal transfer mechanism may comprise a single channel. Preferably the first and second load ports will conform to the specifications set forth in SEMI—E15, however, other load ports could be used.

[**0078**] The load buffer apparatus is described as transferring wafer carriers, however, it should be understood that the invention is not limited thereto, and wafers may be transferred individually, and/or in SMIF or other type pods, etc. The pods need not be of the bottom opening type, for instance, side or top opening pods may be employed within the inventive system. If used for transferring SMIF or other type pods the load buffer of the present invention preferably would include a mechanism for opening and closing the pod at the tool load port, such as those conventionally known in the art.

[**0079**] Finally, although **FIG. 12** shows the equipment set as comprising a plurality of adjacent tools, the inventive method can be used with equipment sets that are not adjacent, and are not locally connected. The tool sets may comprise any number of tools; the three tools of **FIG. 12** are merely exemplary.

[**0080**] Accordingly, while the present invention has been disclosed in connection with the preferred embodiments thereof, it should be understood that other embodiments may fall within the spirit and scope of the invention, as defined by the following claims.

What is claimed is:

1. A method of providing wafers to a fabrication tool having a wafer exchange port coupled thereto for transferring one or more wafers from a wafer carrier to the fabrication tool, comprising:

unloading a wafer carrier from an overhead wafer carrier transport system via a wafer carrier transfer mechanism;

lowering the wafer carrier via the wafer carrier transfer mechanism, to the wafer exchange port;

placing the wafer carrier on the wafer exchange port;

opening the wafer carrier; and

extracting at least one wafer from the wafer carrier

2. The method of claim 1 further comprising:

placing the wafer carrier on a storage shelf after unloading from the overhead wafer carrier transport system, and before placing the wafer carrier on the wafer exchange port.

3. A system comprising:

a fabrication tool comprising a processing chamber for performing a process on at least one wafer;

an overhead wafer carrier transport system;

a wafer exchange port adapted to open a wafer carrier such that at least one wafer can be extracted therefrom for loading to the fabrication tool; and

a wafer handler comprising an end effector and at least one vertical guide that extends between the overhead wafer carrier transport system and the wafer exchange port so that the end effector may transfer a wafer carrier therebetween.

4. The system of claim 3 further comprising a fabrication tool comprising a processing chamber for performing a process on the at least one wafer.

5. The system of claim 4 wherein the fabrication tool further comprises a load lock for receiving the at least one wafer from the wafer exchange port.

6. The system of claim 3 further comprising a storage location located between the overhead wafer carrier transport system and the wafer exchange port, such that the wafer handler may transfer a wafer carrier thereamong.

7. The system of claim 3 wherein the overhead wafer carrier transport system comprises a monorail.

8. An apparatus for supplying at least one wafer to a fabrication tool, comprising:

a wafer exchange port coupled to a fabrication tool;

an overhead load port comprising a location to which a wafer carrier is transported via an overhead wafer carrier transport system;

a storage location located at an elevation above the elevation of the wafer exchange port coupled to the fabrication tool; and

a vertical transfer mechanism adapted to transfer a wafer carrier between the overhead load port and the storage location.

9. The apparatus of claim 8 wherein the overhead load port comprises a location along the overhead wafer carrier transport system.

10. The apparatus of claim 7 wherein the overhead wafer carrier transport system comprises a monorail.

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