



US 20220063914A1

(19) **United States**

(12) **Patent Application Publication**
LANGEN

(10) **Pub. No.: US 2022/0063914 A1**

(43) **Pub. Date: Mar. 3, 2022**

(54) **WAREHOUSE SYSTEM FOR FULFILLING ORDERS**

Publication Classification

(71) Applicant: **H. J. Paul LANGEN**, Brampton (CA)

(51) **Int. Cl.**
B65G 1/137 (2006.01)
B65G 1/04 (2006.01)

(72) Inventor: **H. J. Paul LANGEN**, Brampton (CA)

(52) **U.S. Cl.**
CPC *B65G 1/1376* (2013.01); *B65G 2201/0267* (2013.01); *B65G 1/0407* (2013.01); *B65G 1/0464* (2013.01)

(21) Appl. No.: **17/459,936**

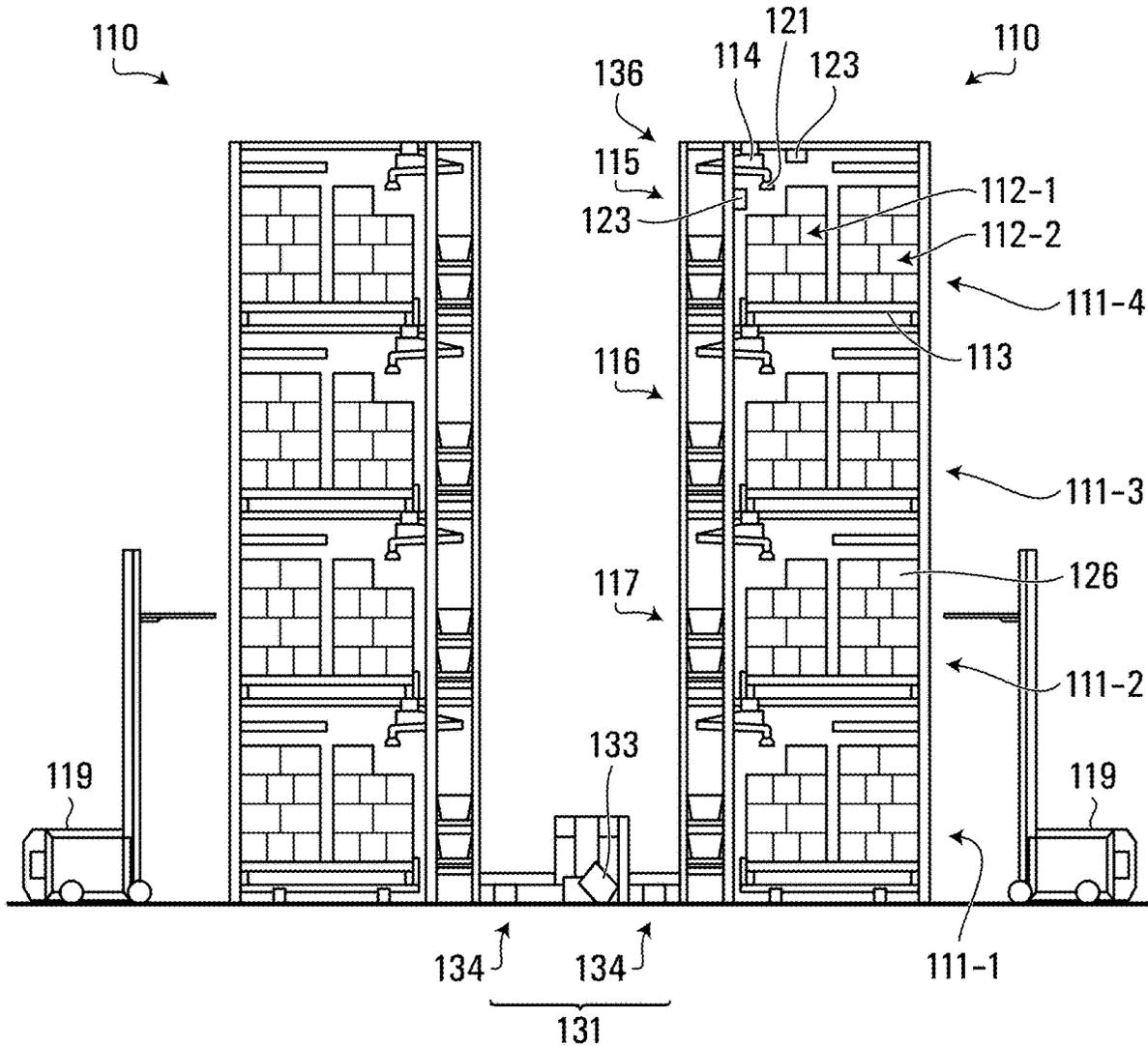
(57) **ABSTRACT**

(22) Filed: **Aug. 27, 2021**

A warehouse system and method for fulfilling orders comprising a plurality of products. As pallets containing cases of individual units are received, they are transported to a specific storage location within a warehouse. There, a picker arm is configured to retrieve individual units from the pallets and place in a tote according to a specified order. The totes are transported through the warehouse to the specific storage locations, then sent to a packing station.

Related U.S. Application Data

(60) Provisional application No. 63/072,008, filed on Aug. 28, 2020.



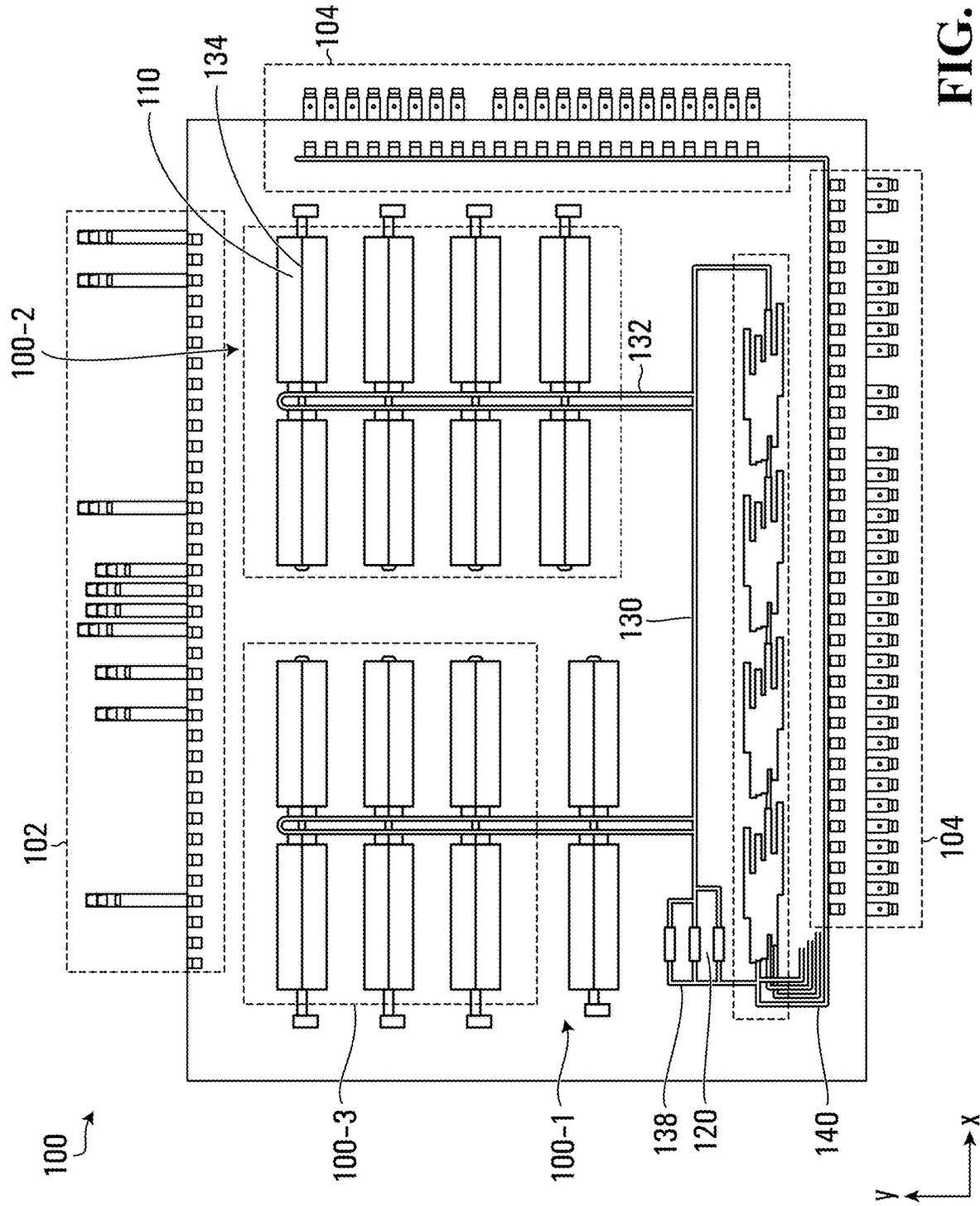


FIG. 1

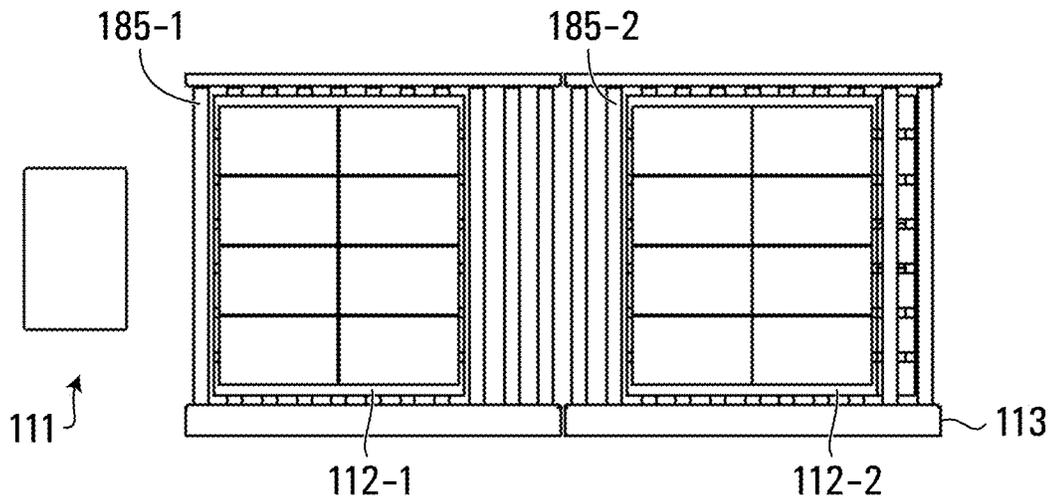


FIG. 3A

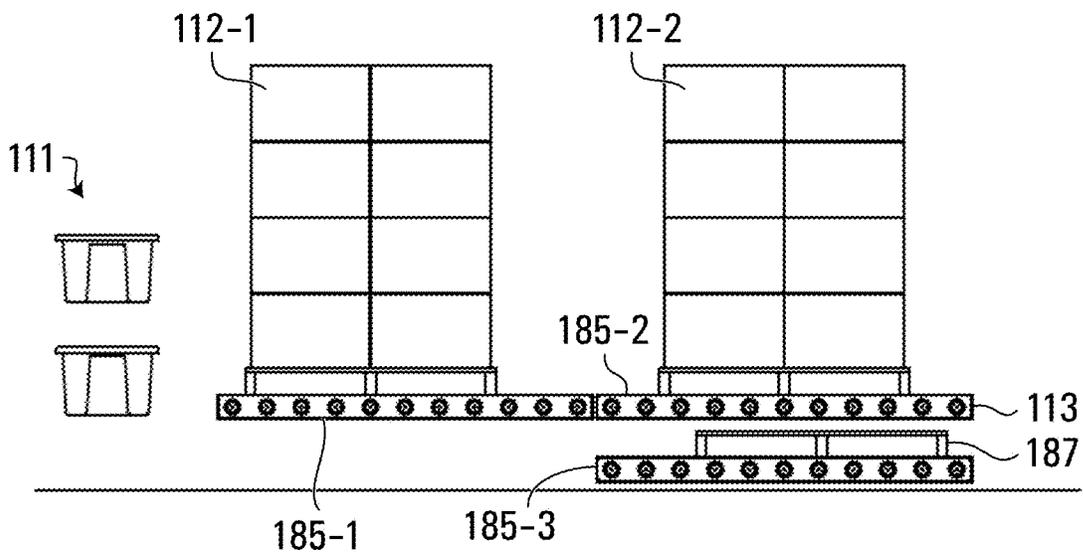


FIG. 3B

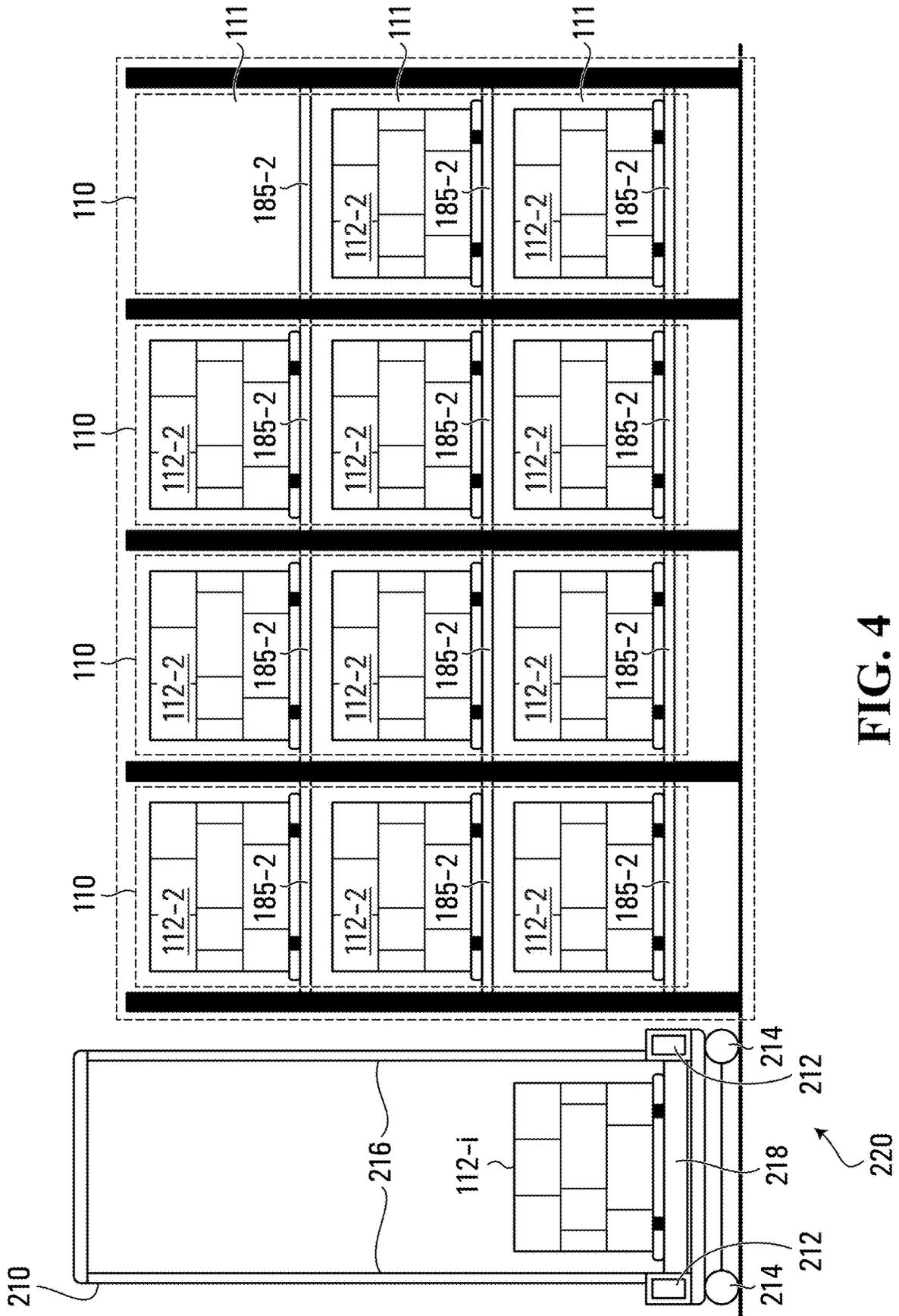


FIG. 4

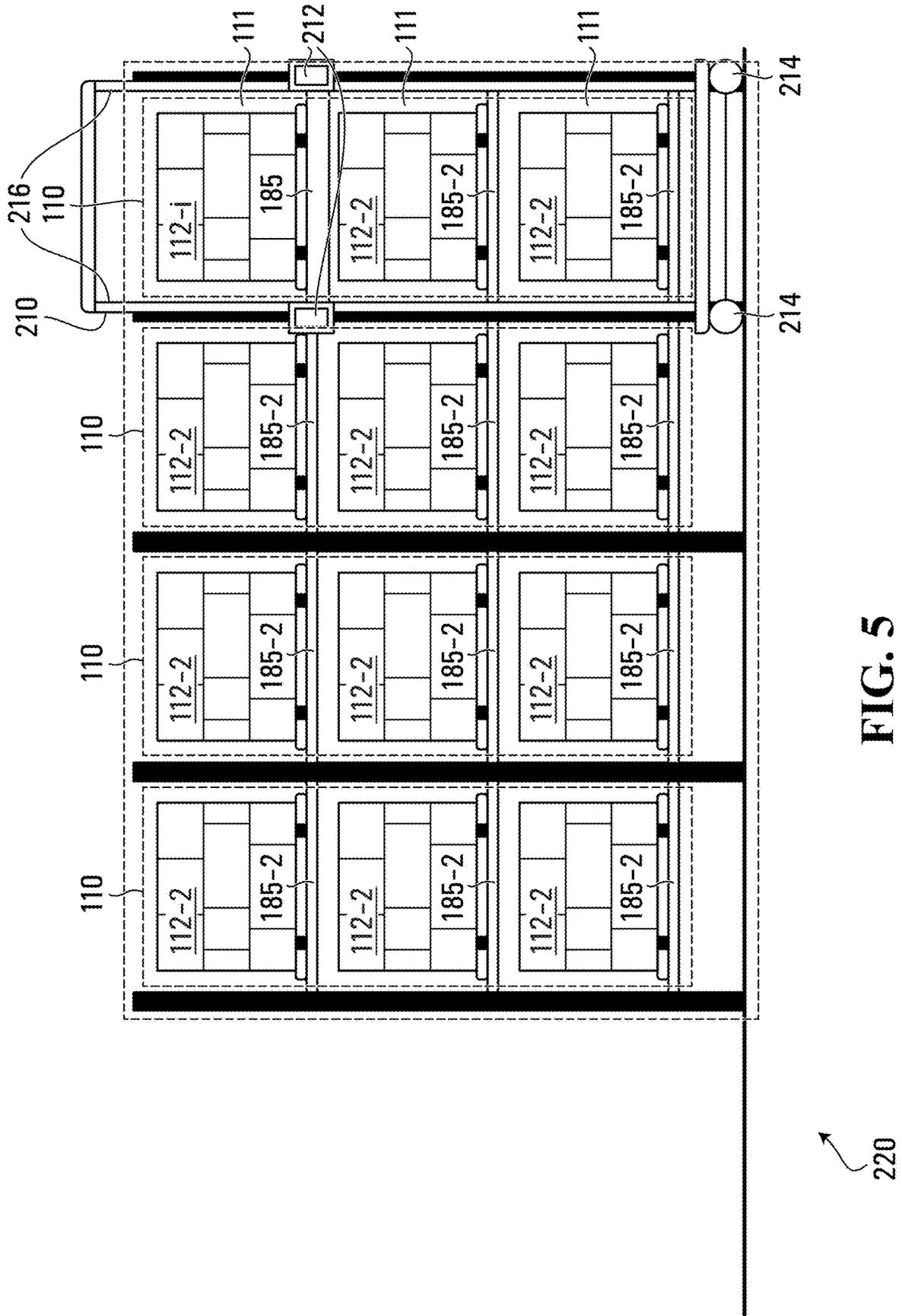


FIG. 5

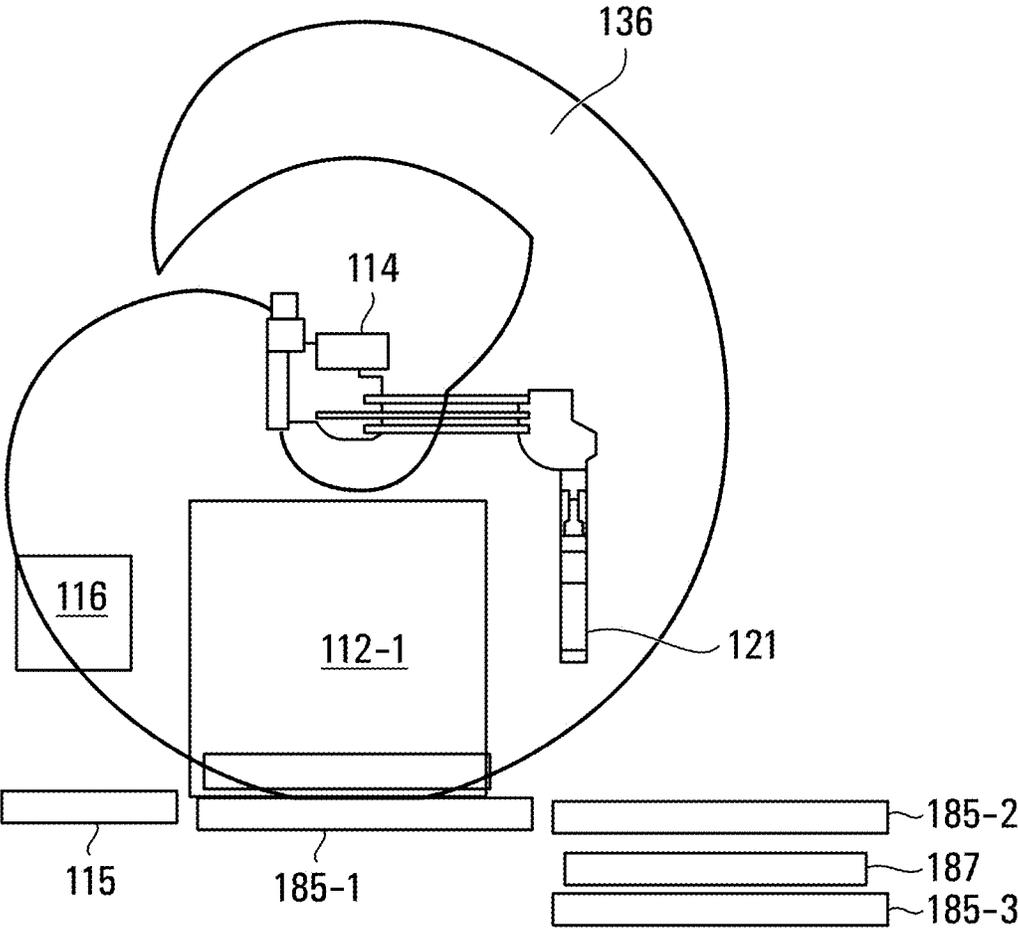


FIG. 6

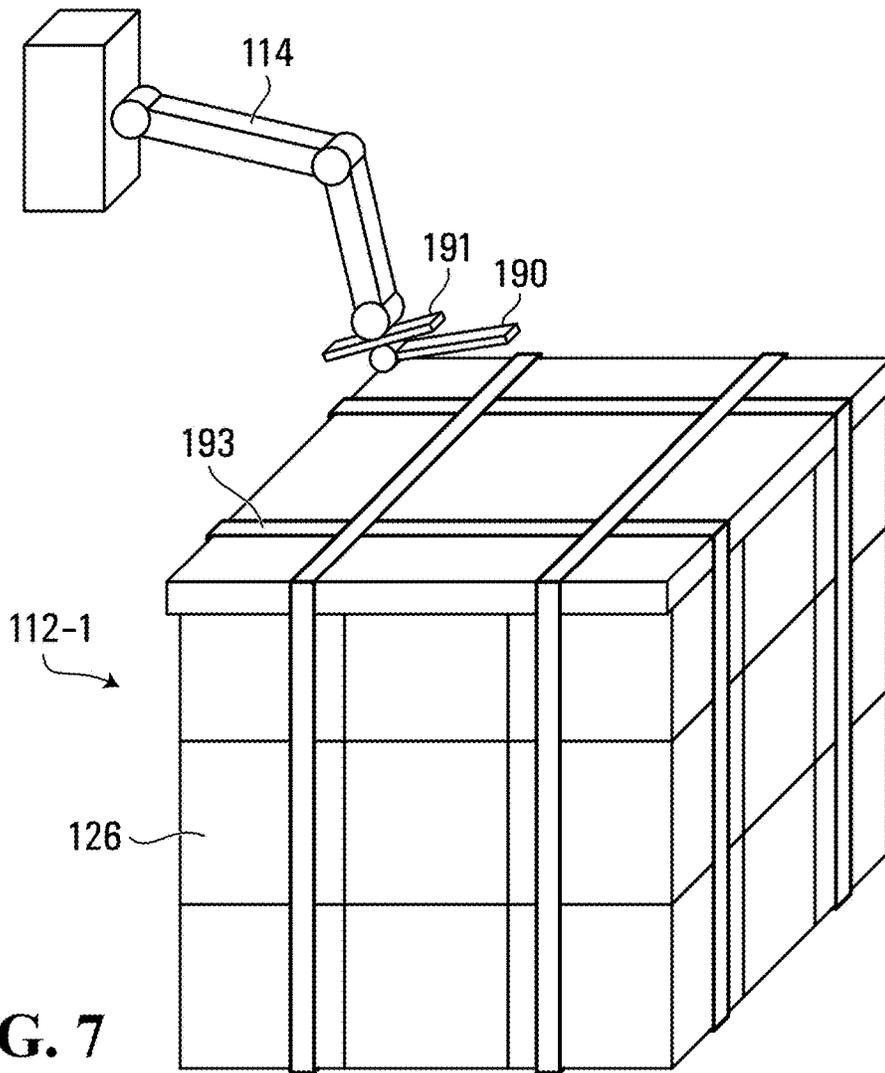


FIG. 7

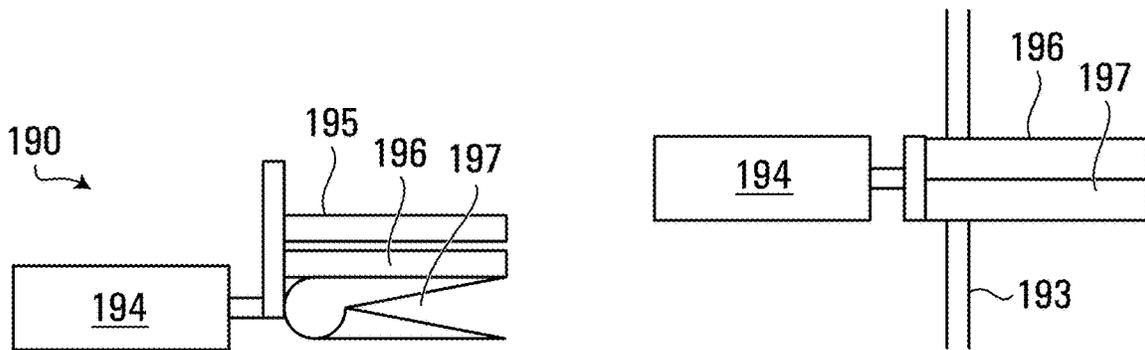


FIG. 8A

FIG. 8B

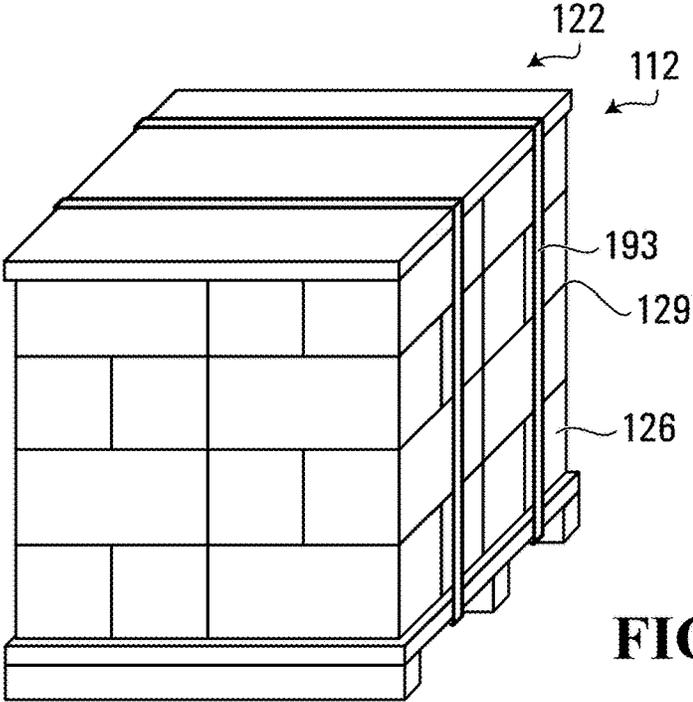


FIG. 9A

FIG. 9B

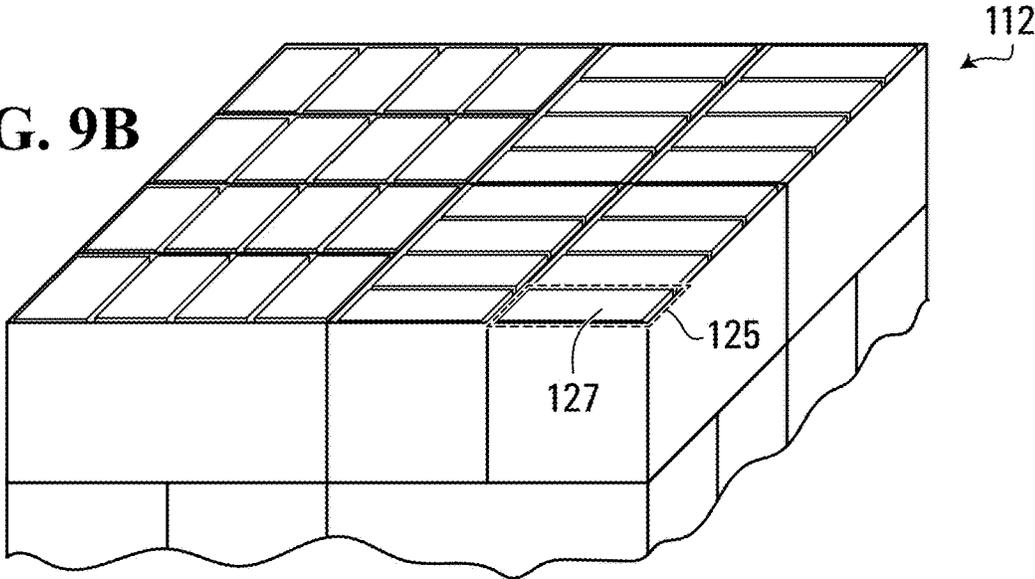
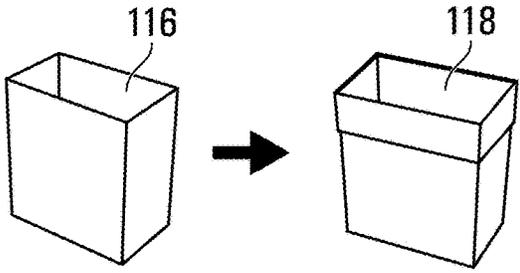


FIG. 10



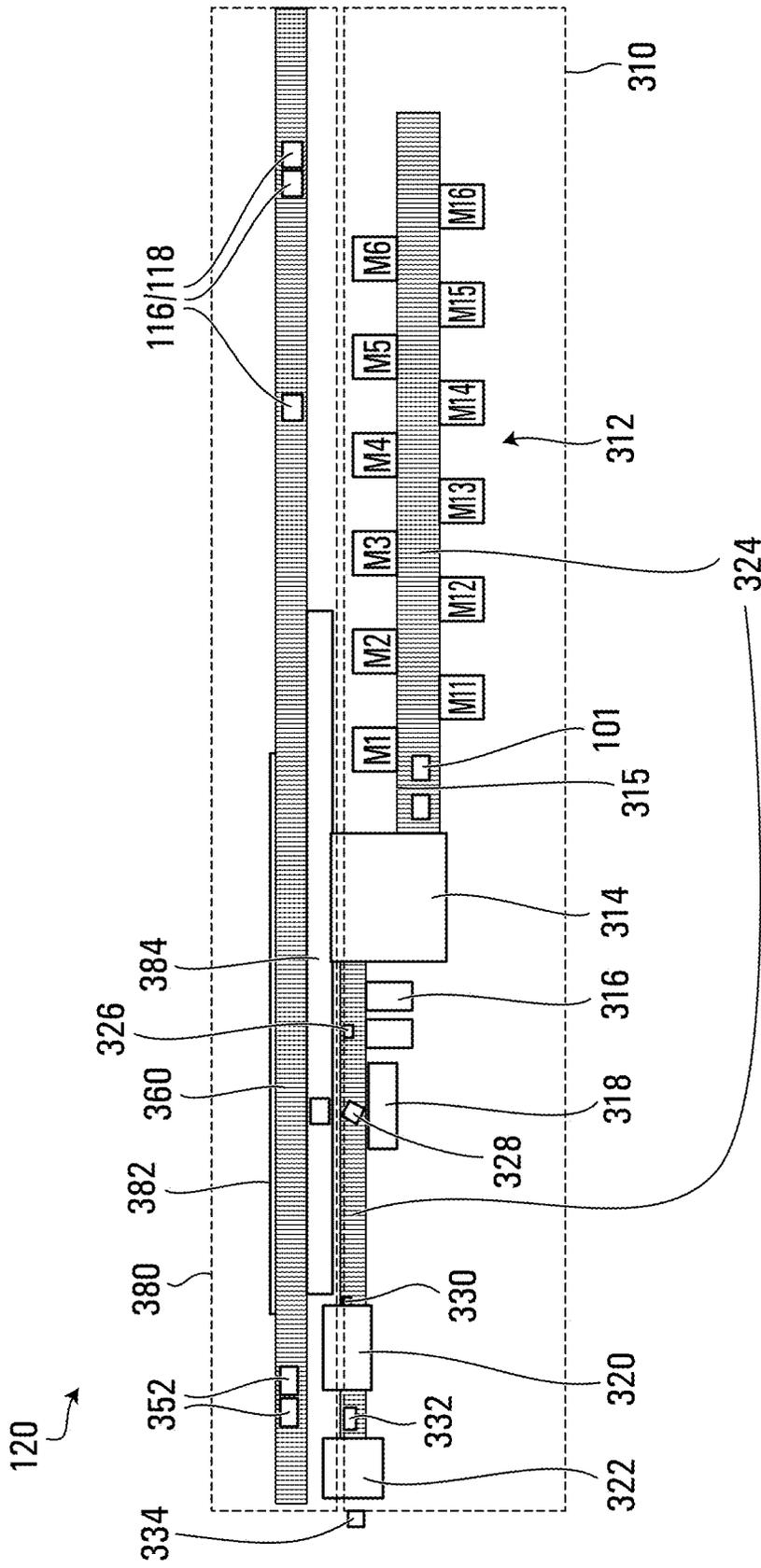


FIG. 11

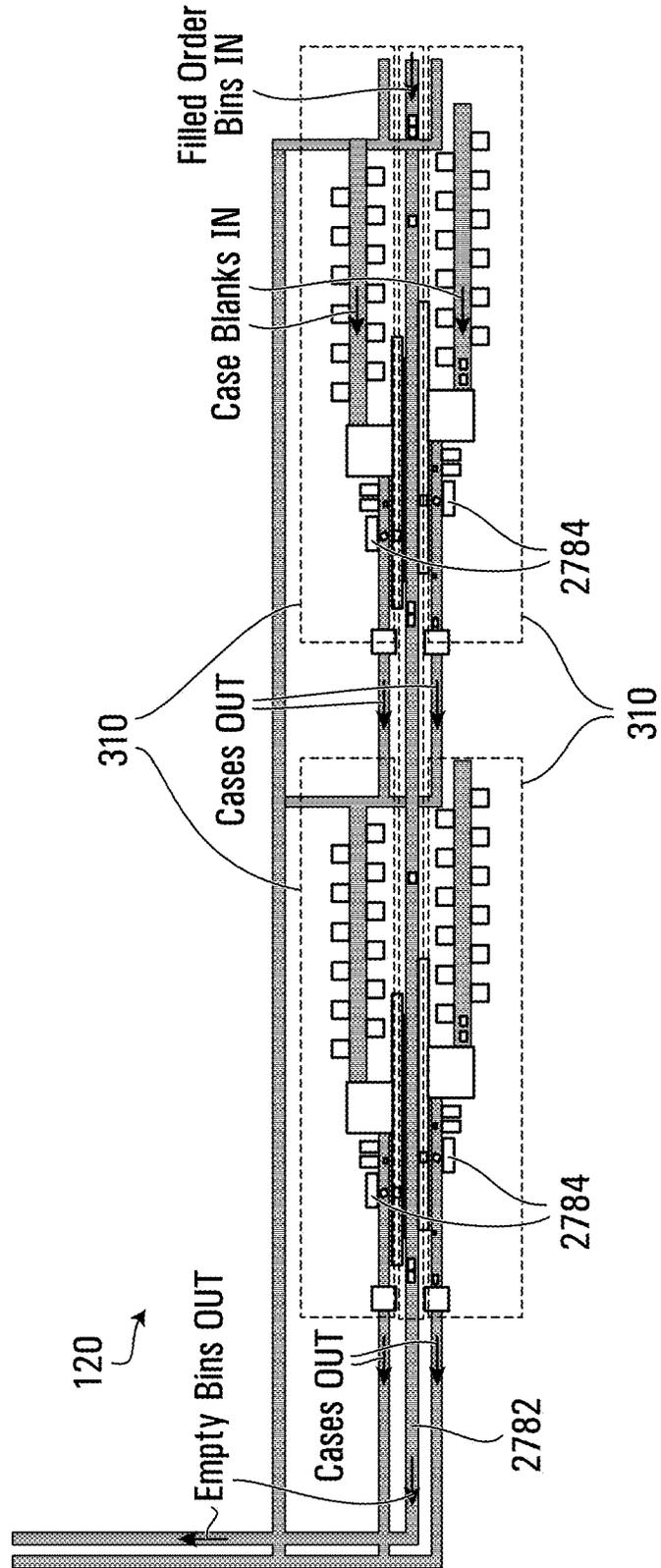


FIG. 12

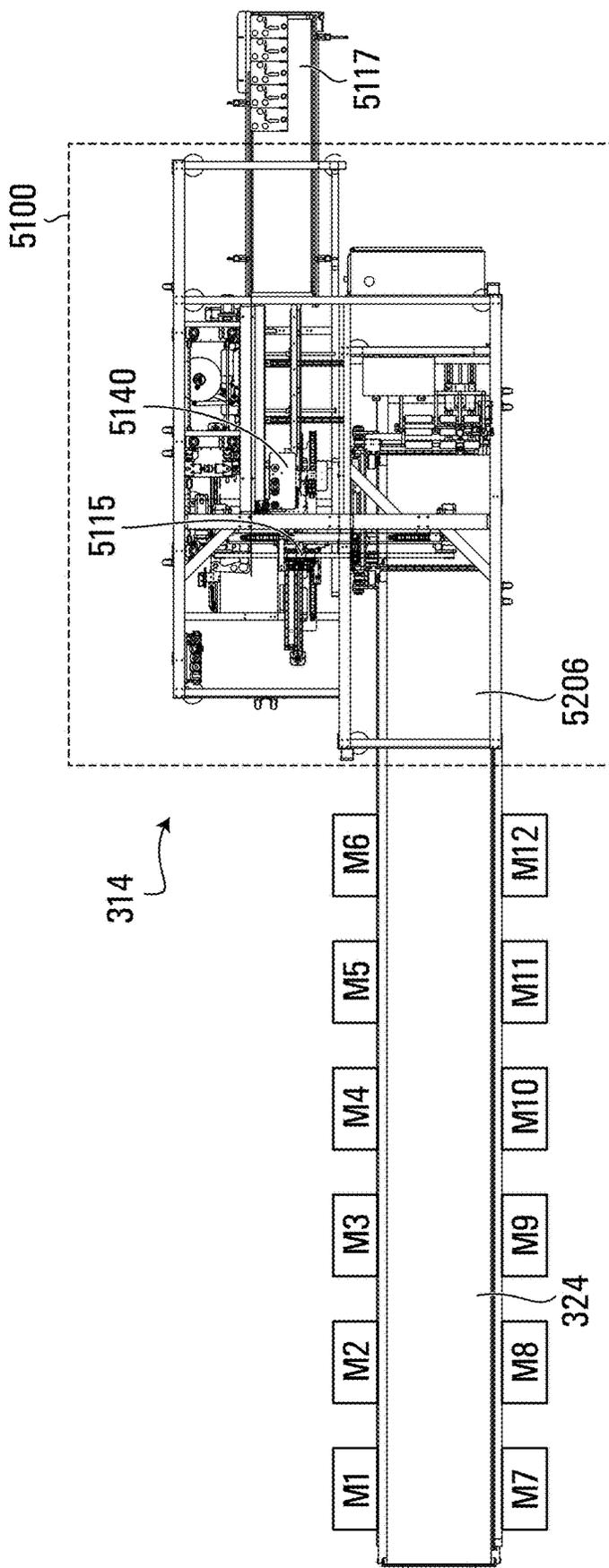


FIG. 13

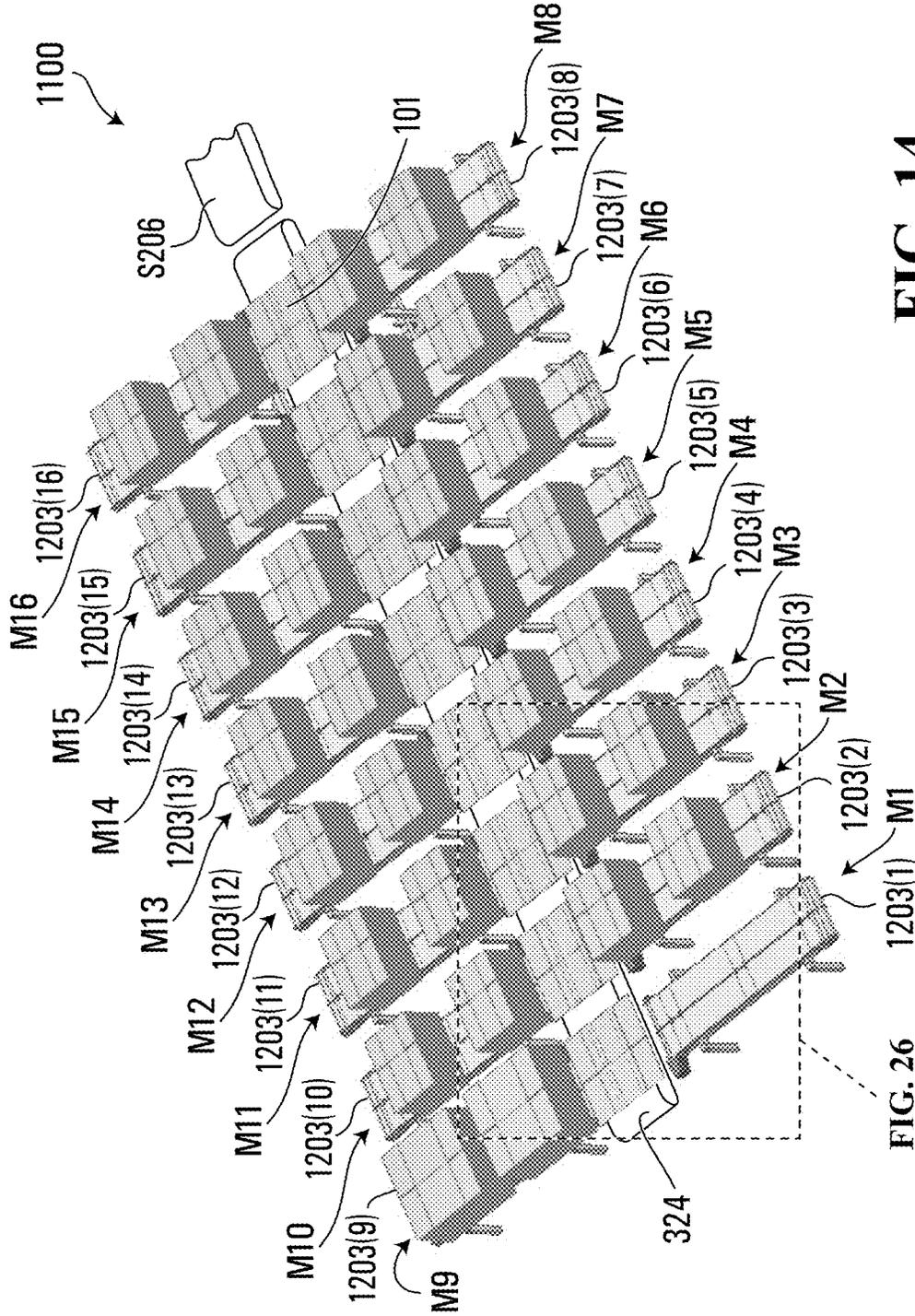


FIG. 14

FIG. 26

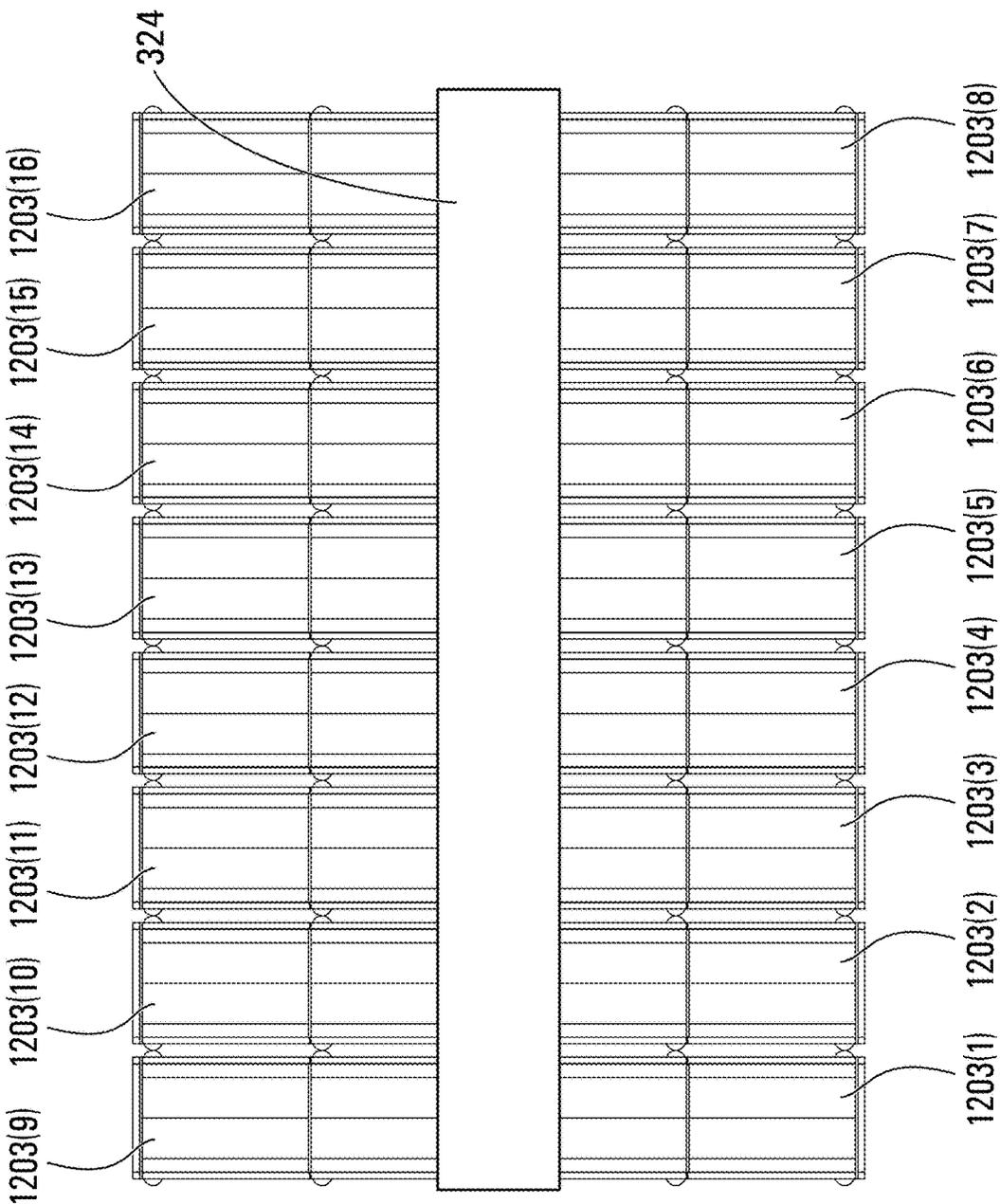


FIG. 15

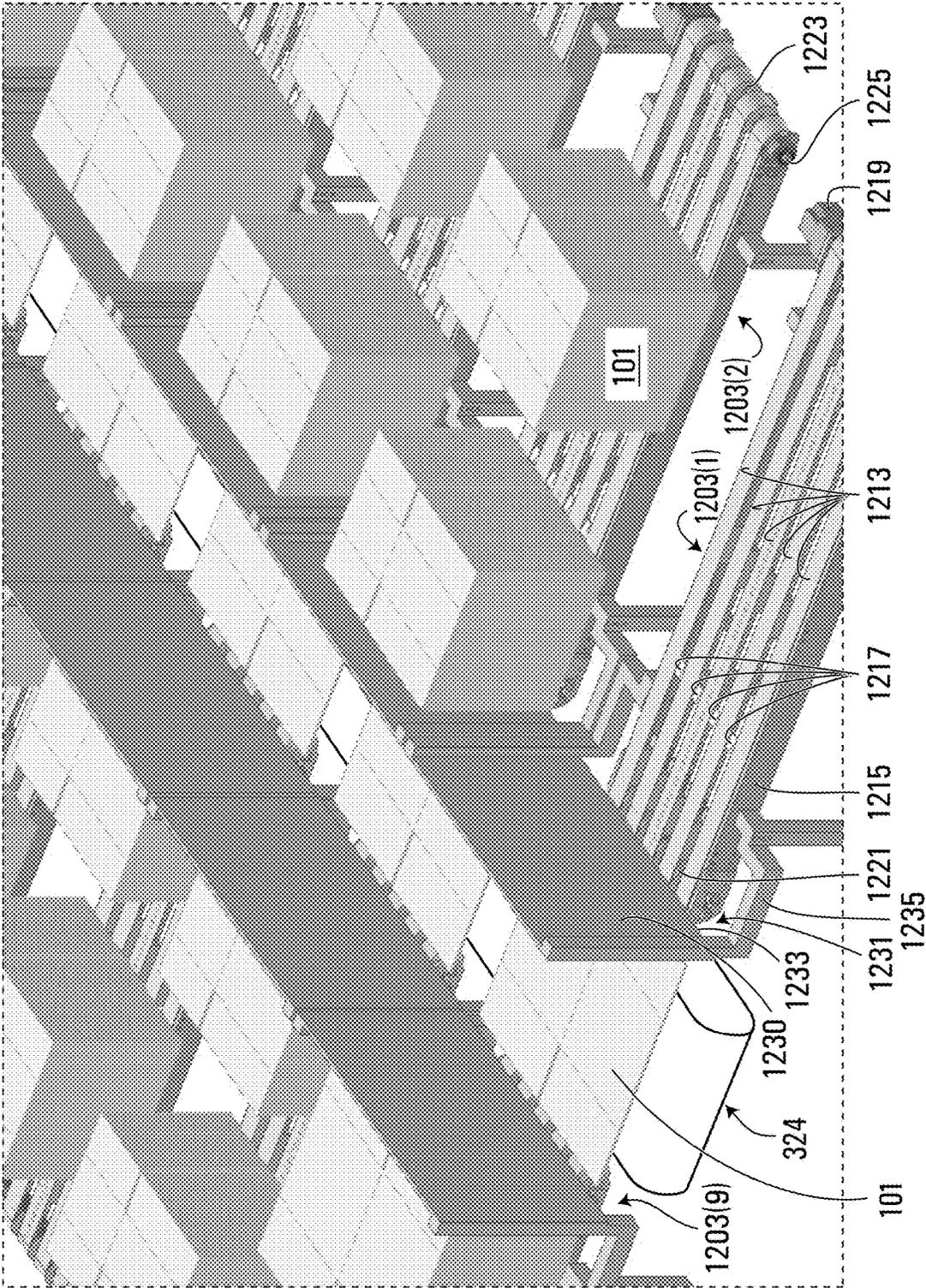


FIG. 16

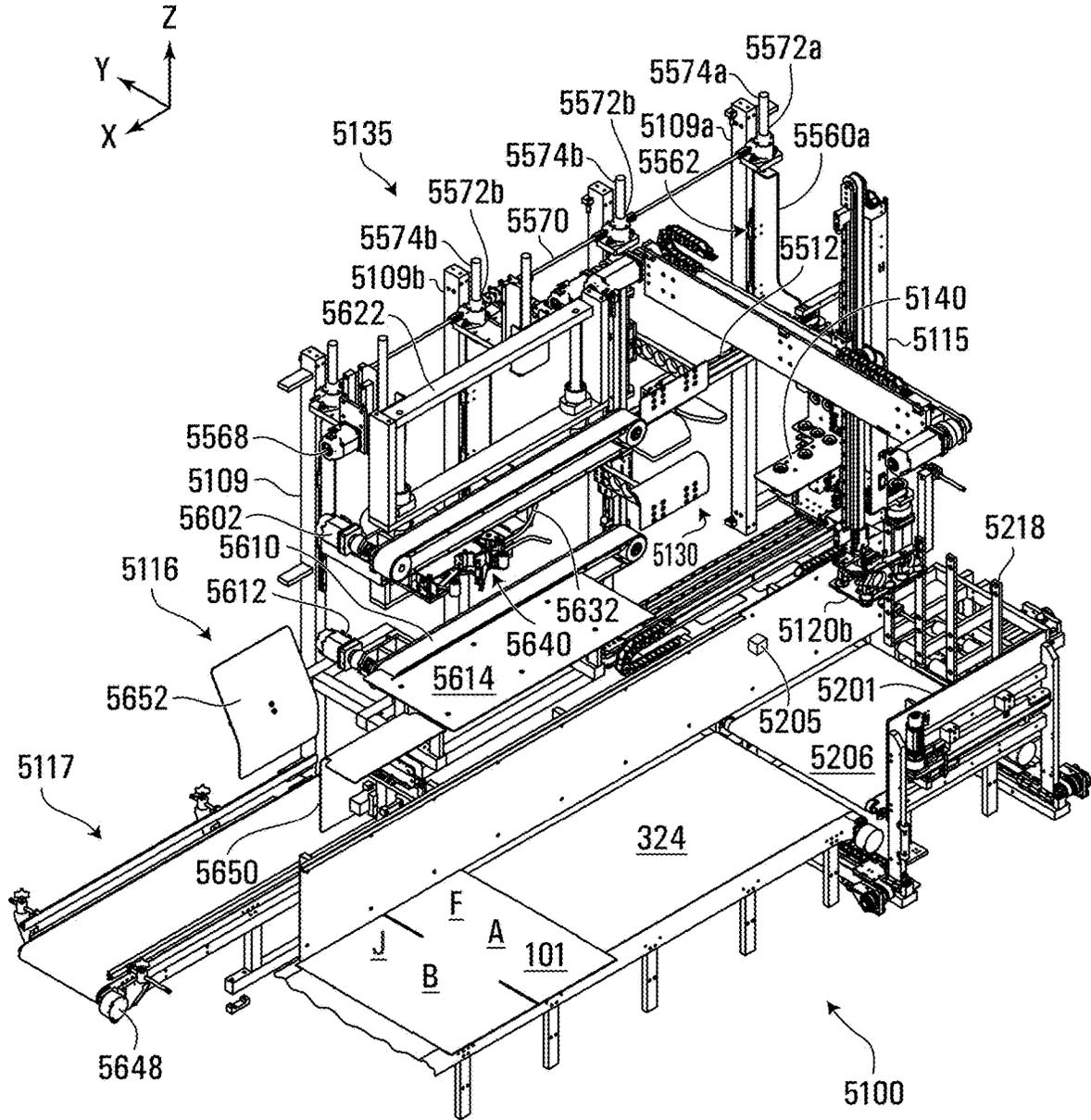


FIG. 17A

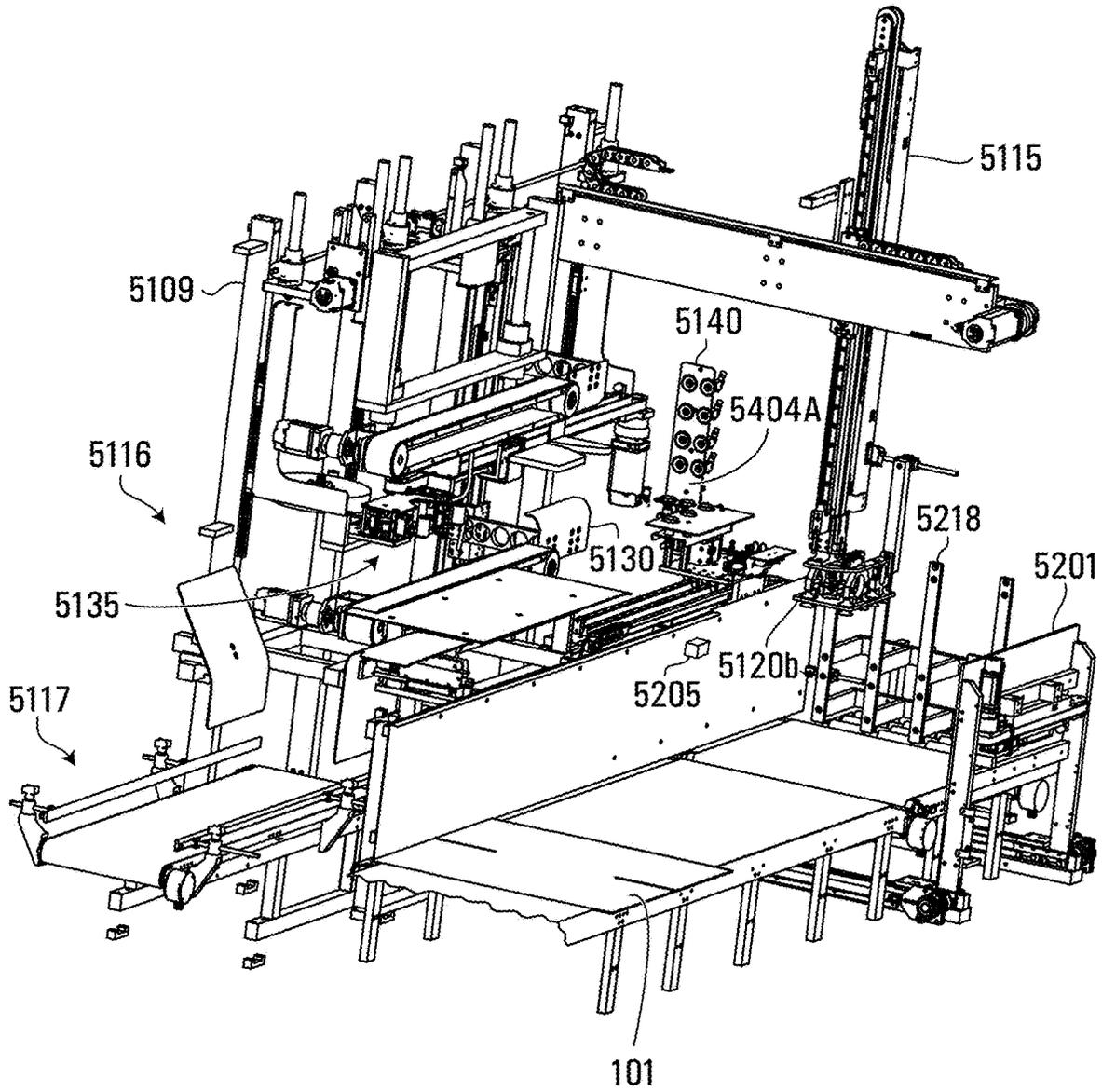


FIG. 17B

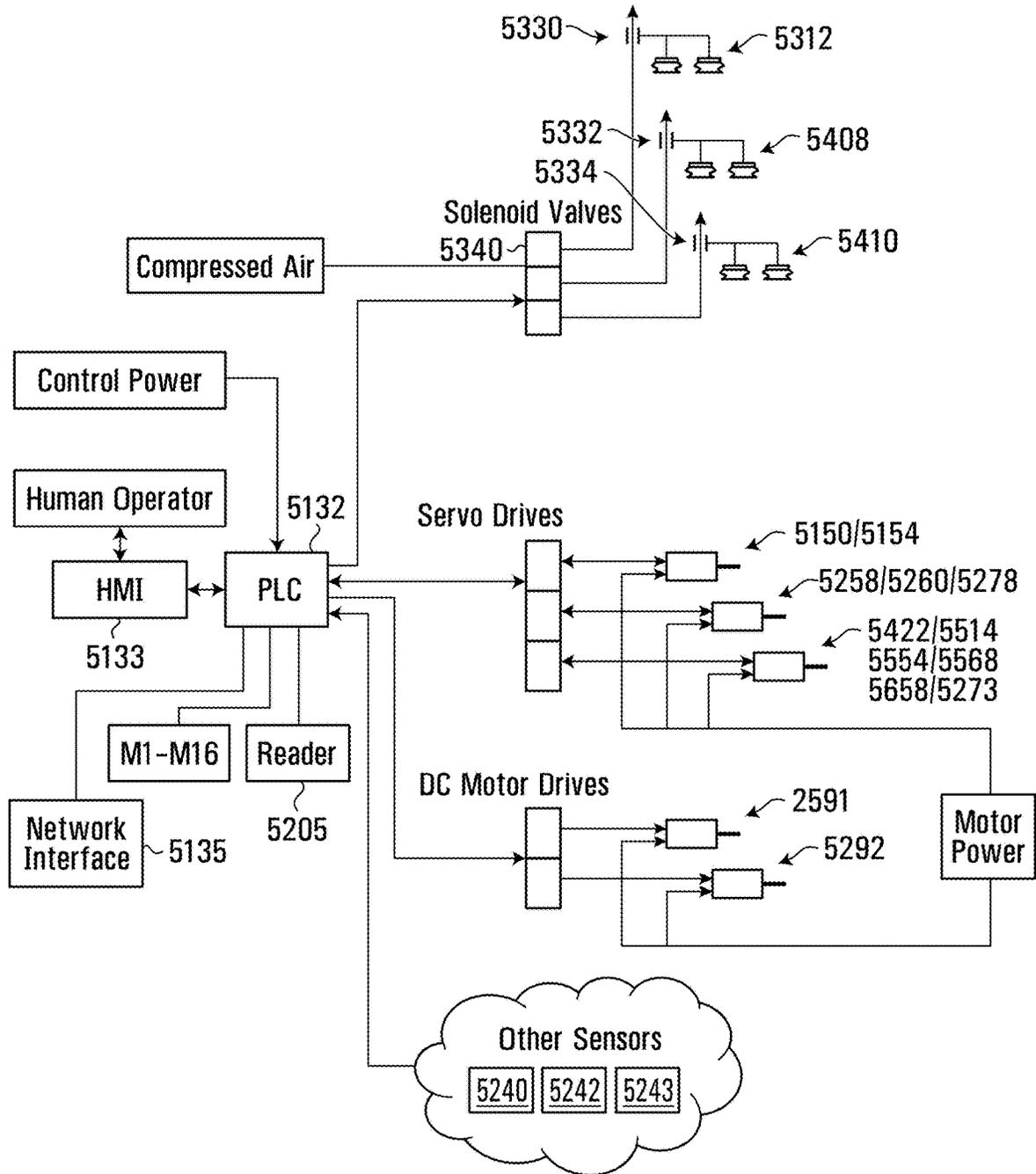


FIG. 18

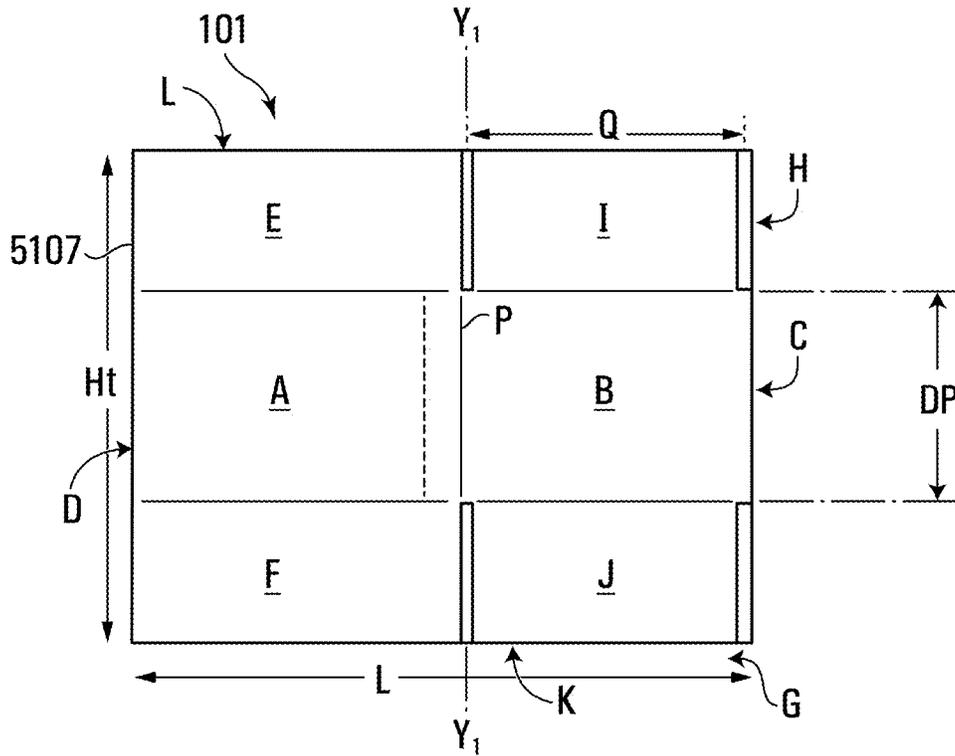


FIG. 19A

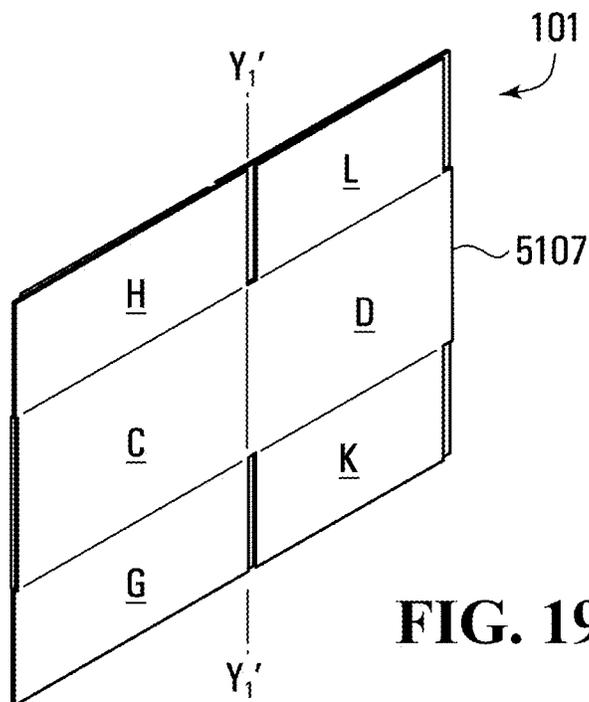


FIG. 19B

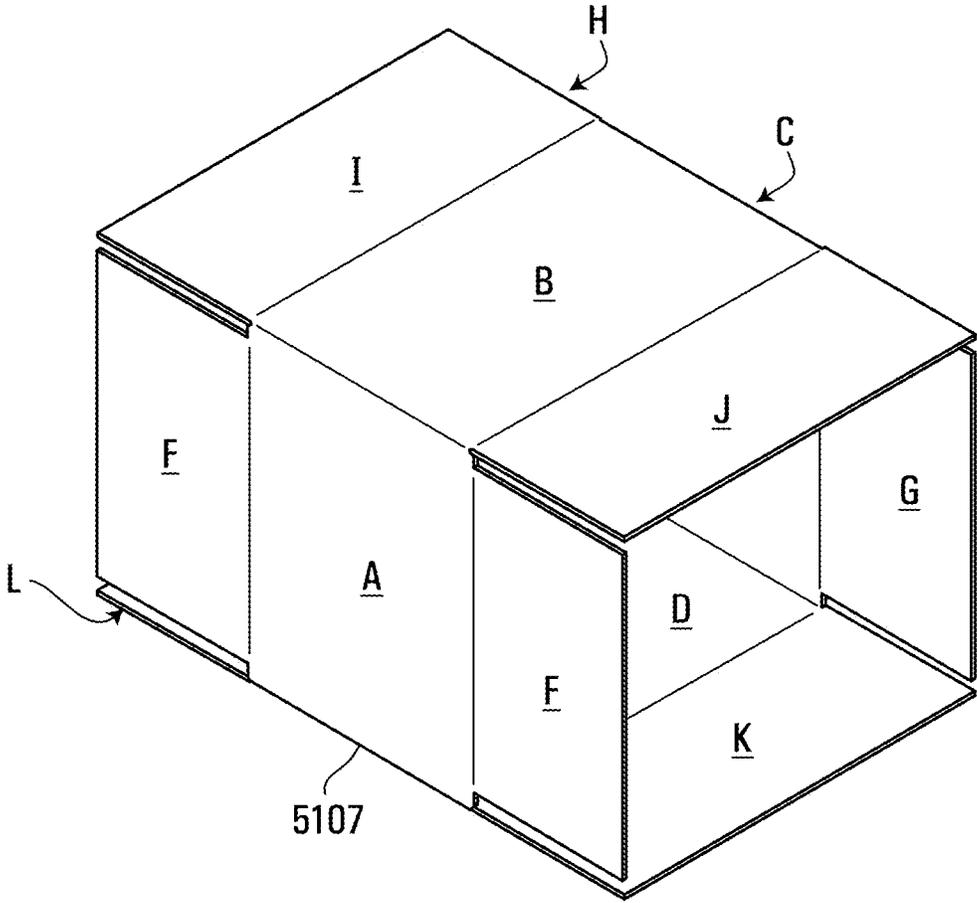


FIG. 20

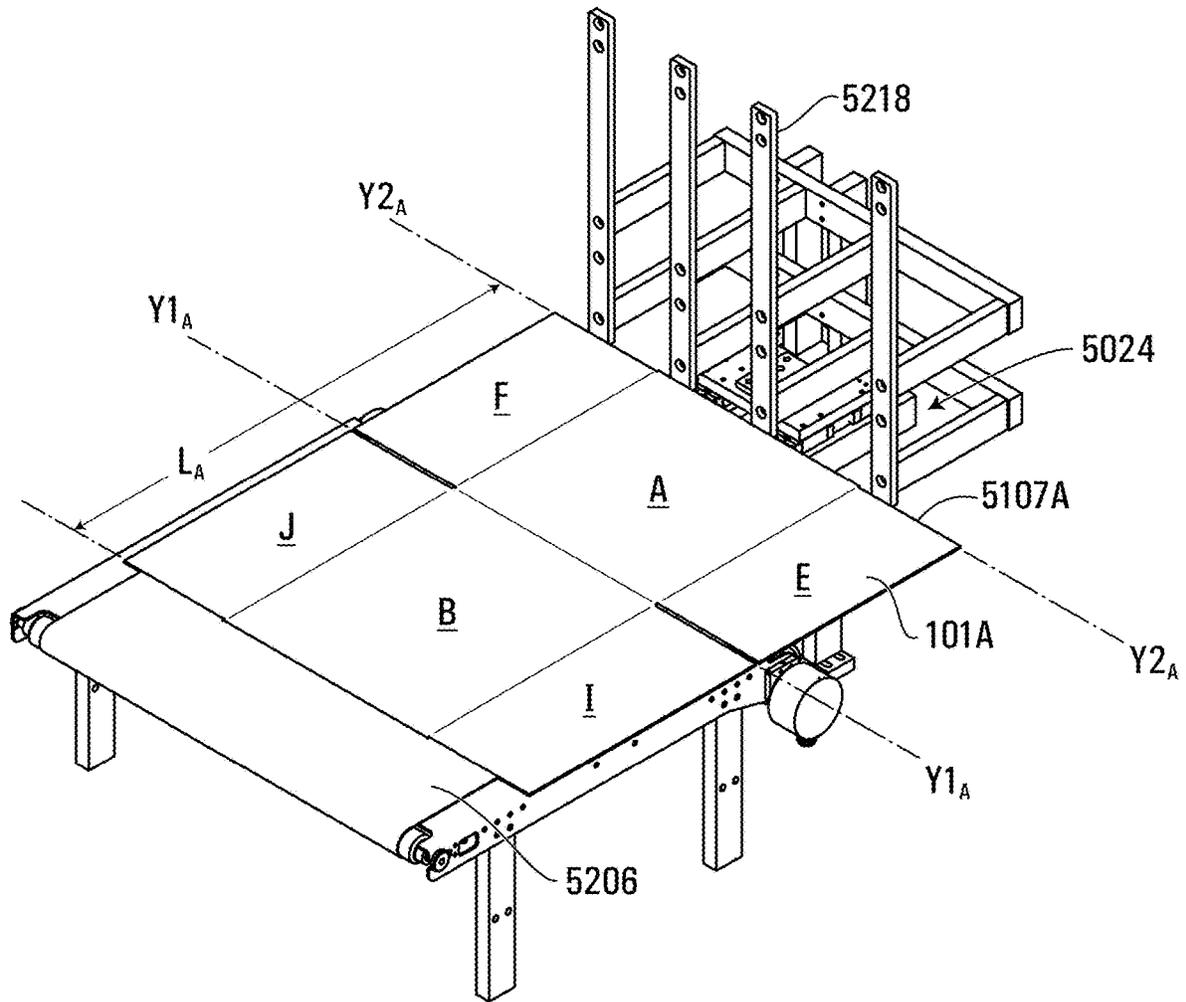


FIG. 21

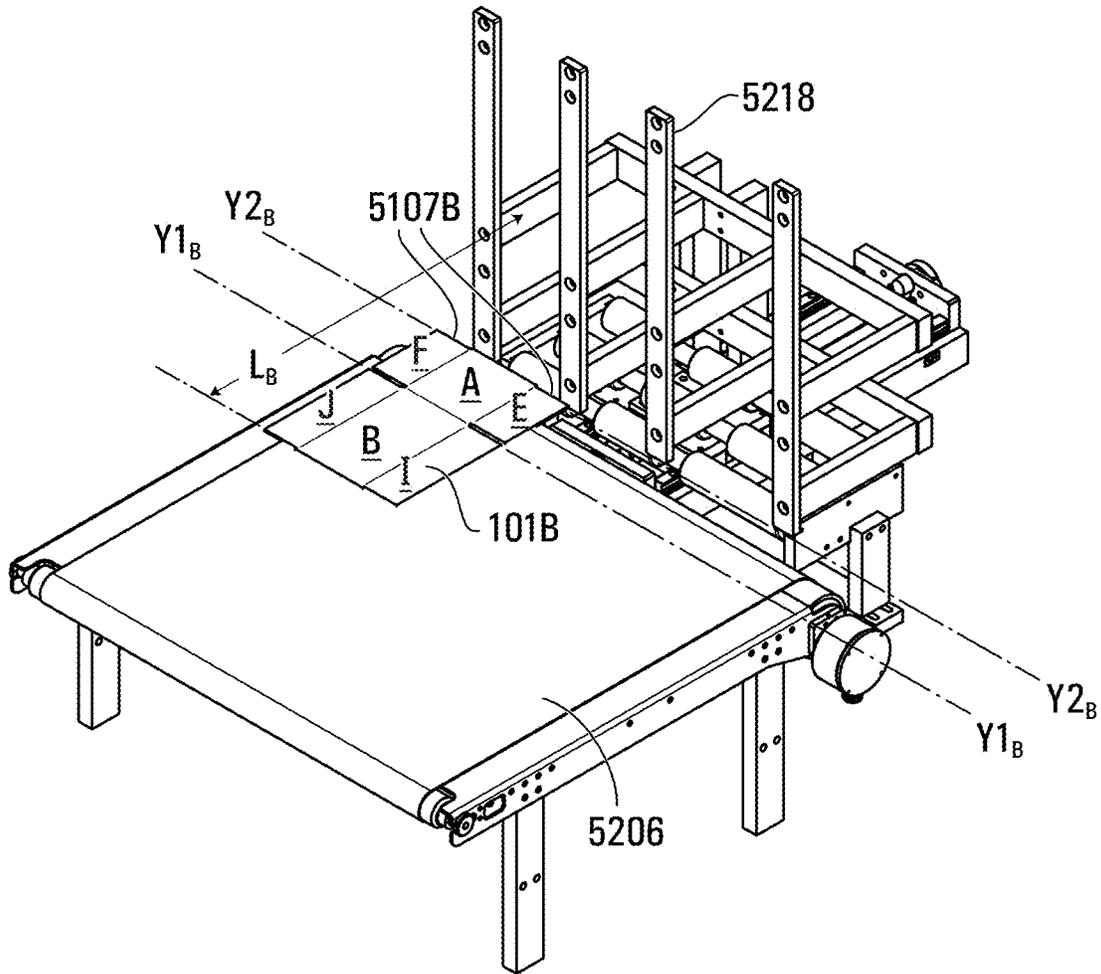


FIG. 22

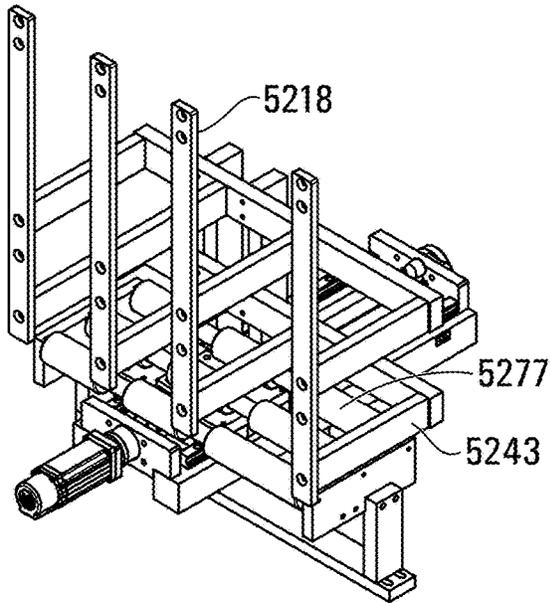


FIG. 23

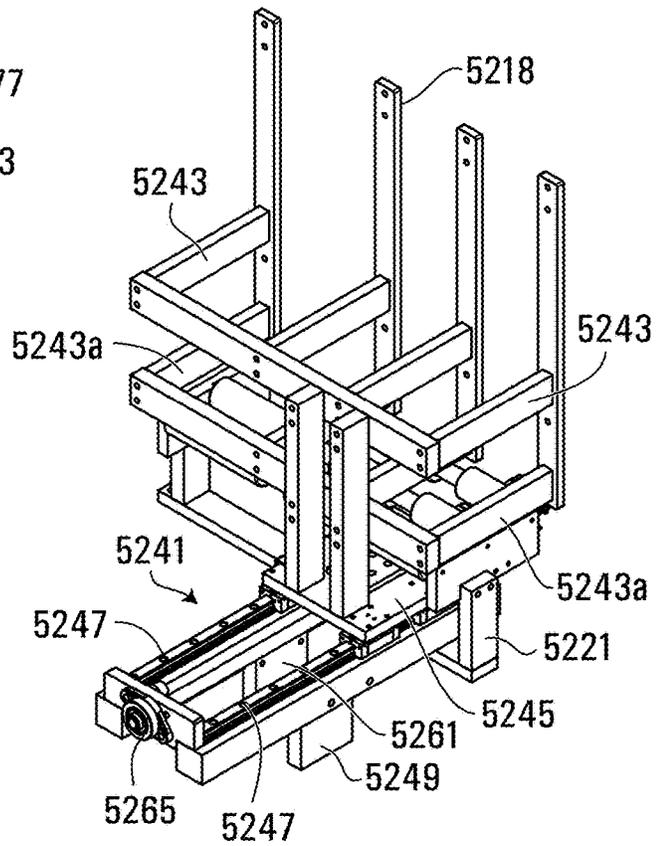


FIG. 24

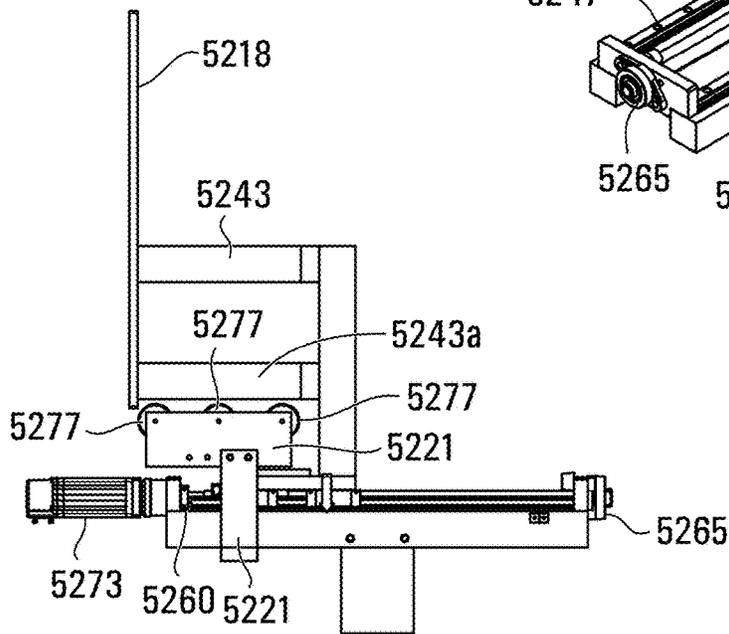


FIG. 25

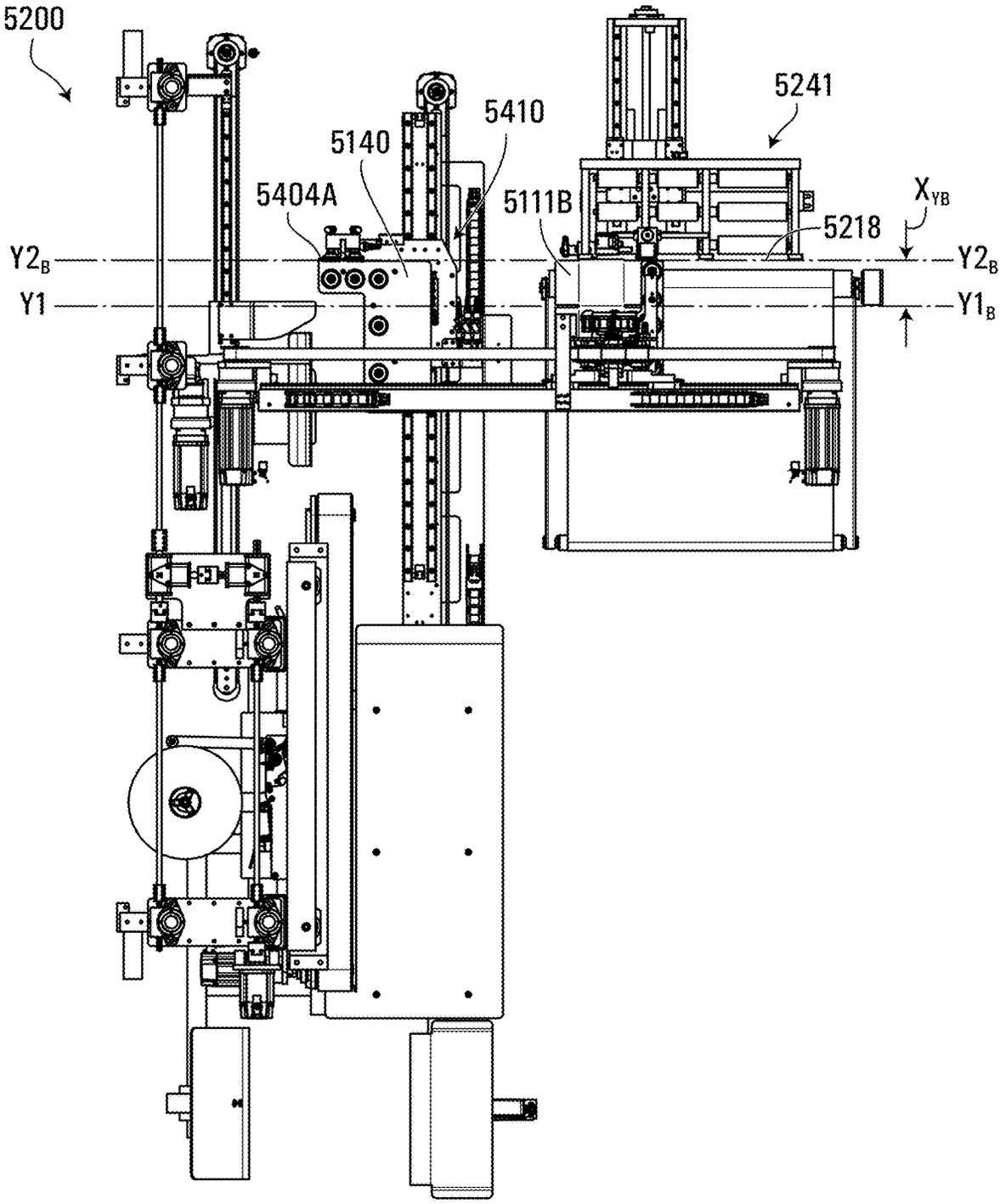


FIG. 26

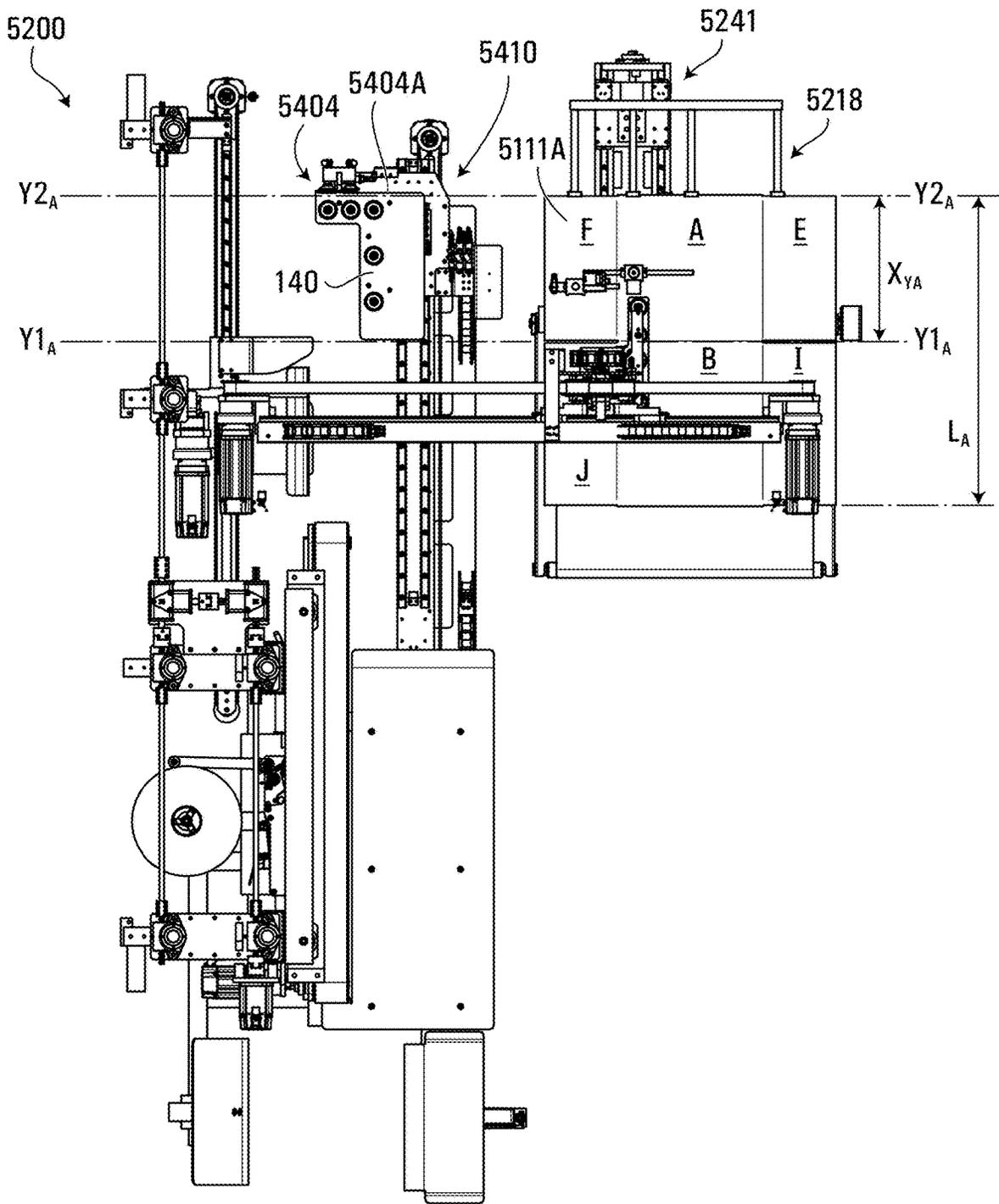


FIG. 27

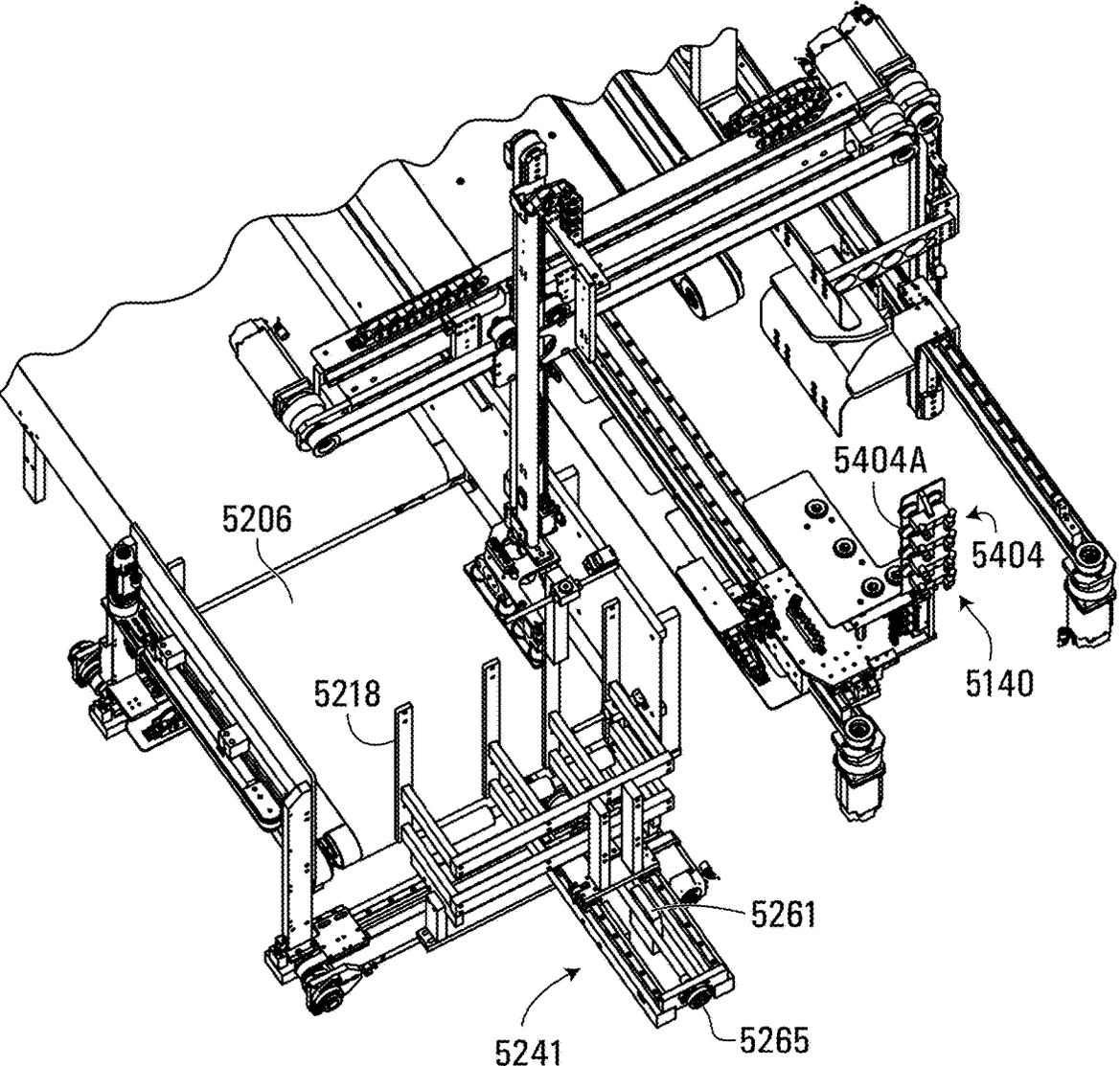


FIG. 28

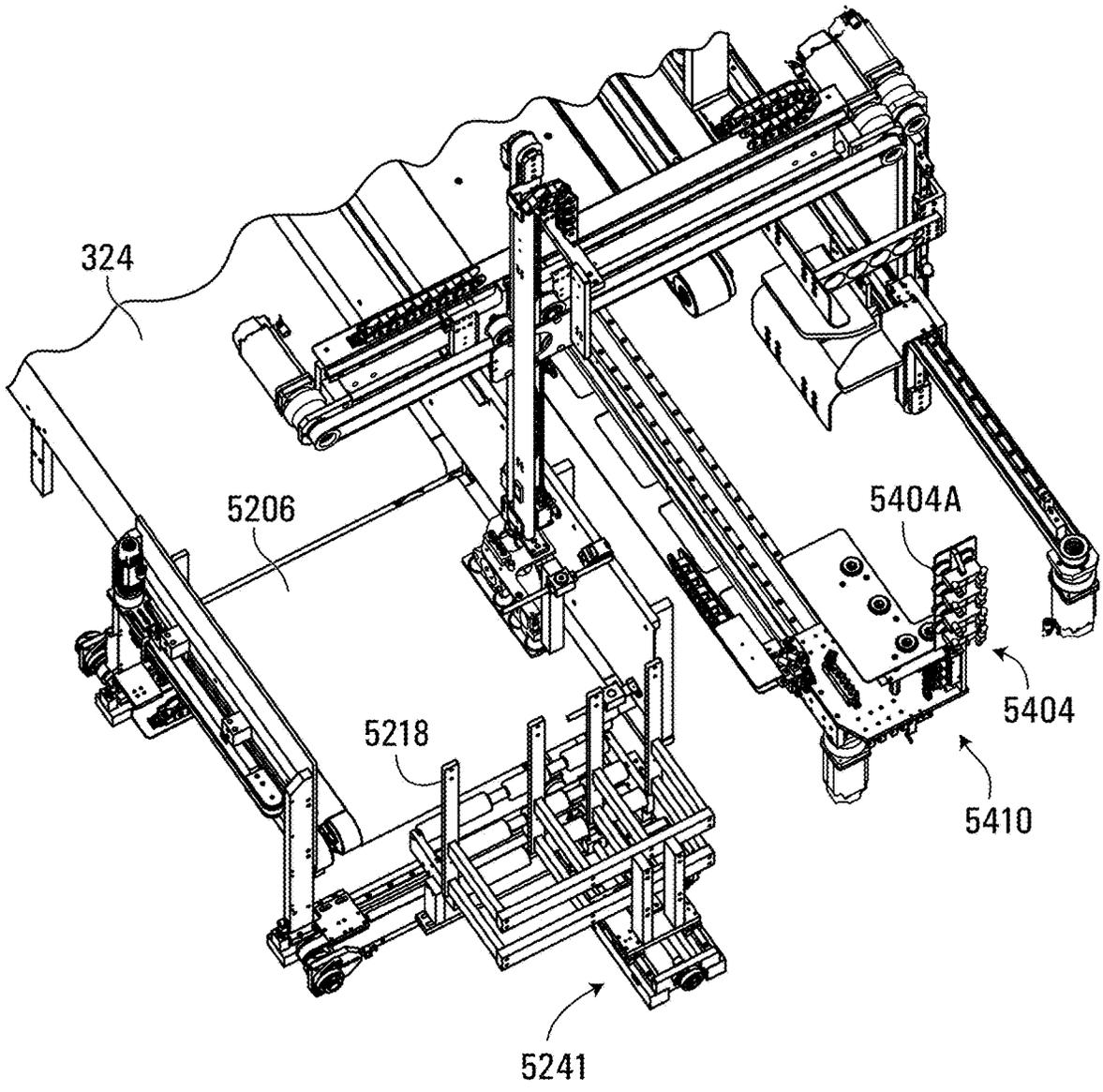


FIG. 29

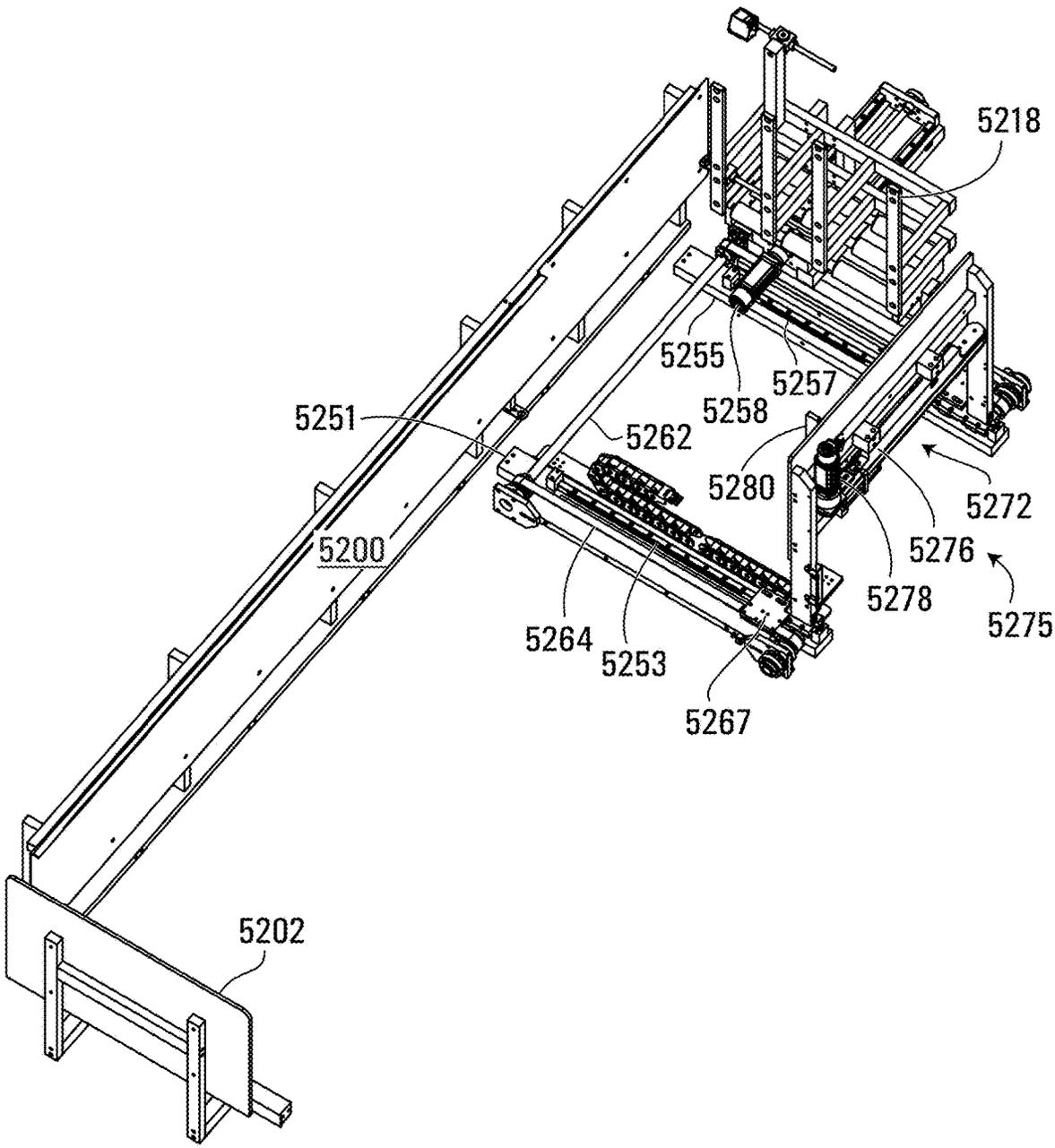


FIG. 30

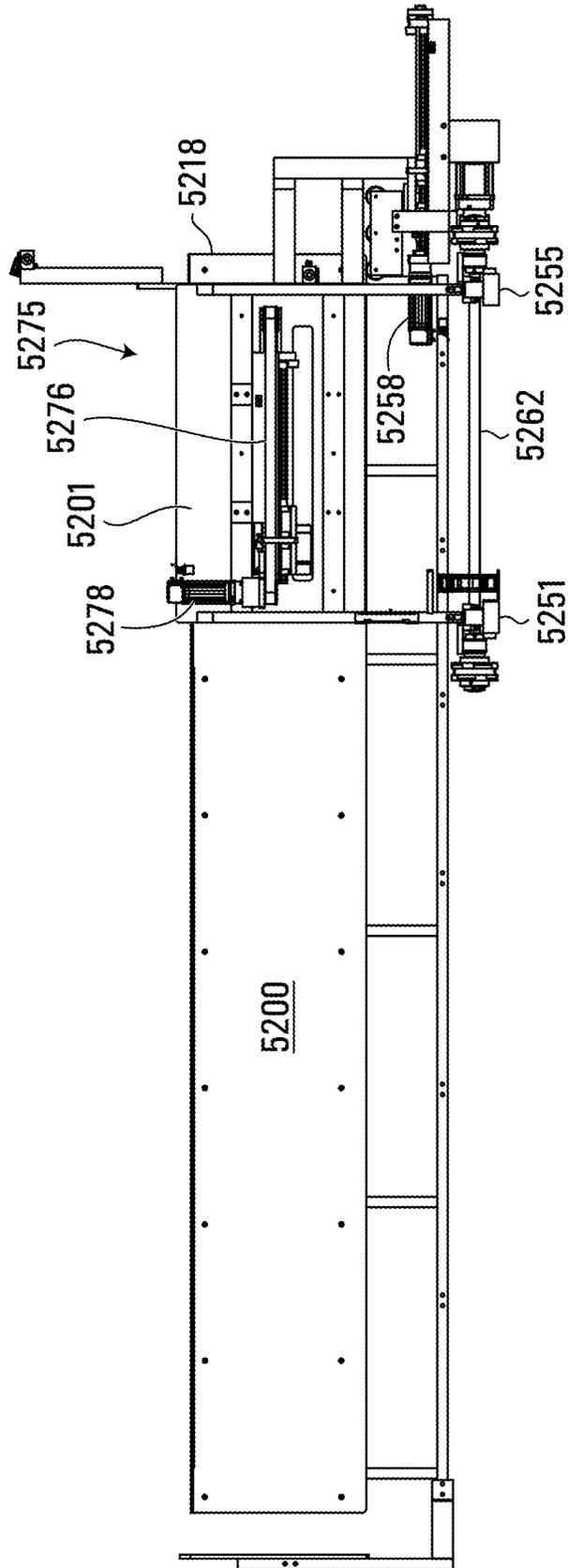


FIG. 31

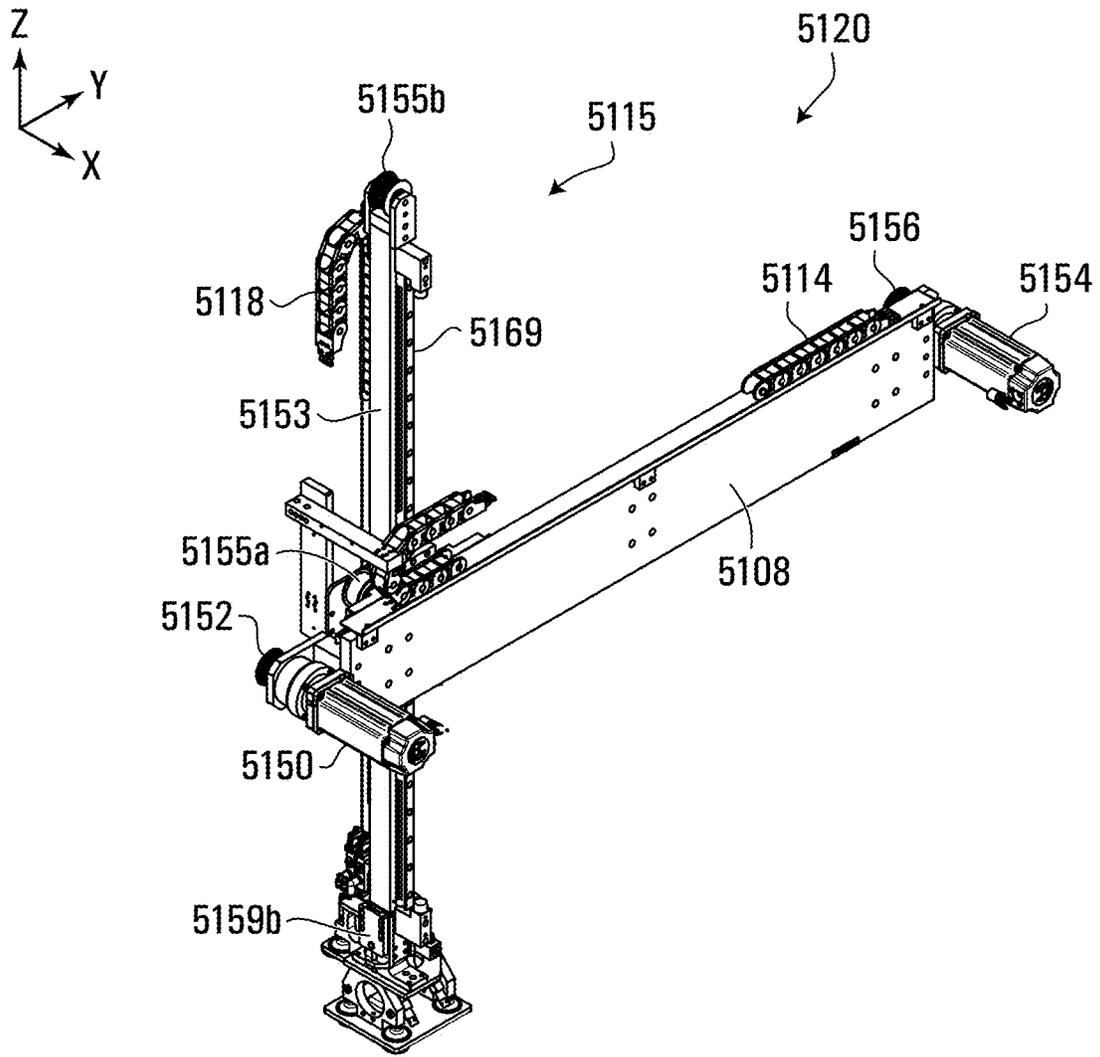


FIG. 32

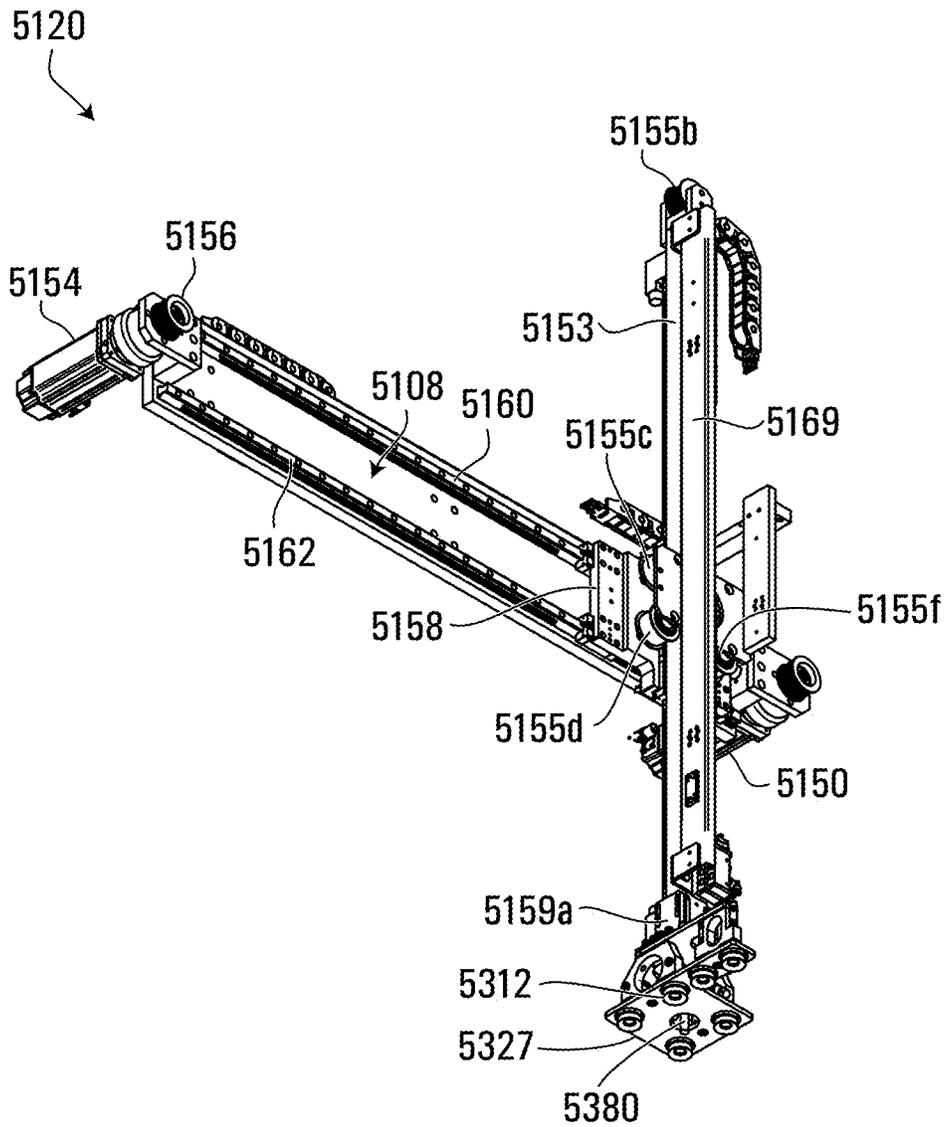


FIG. 33

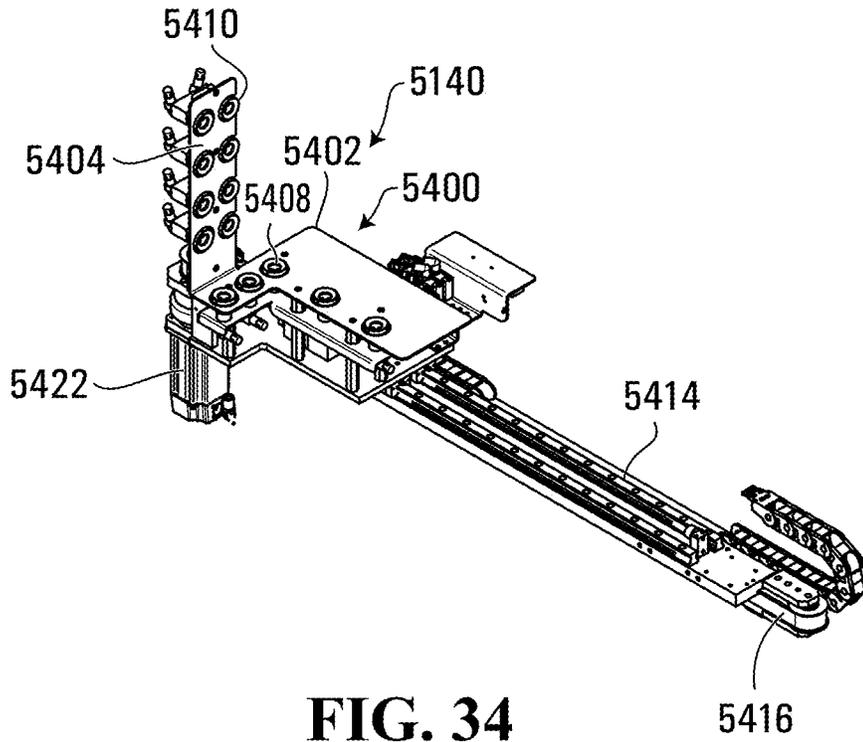


FIG. 34

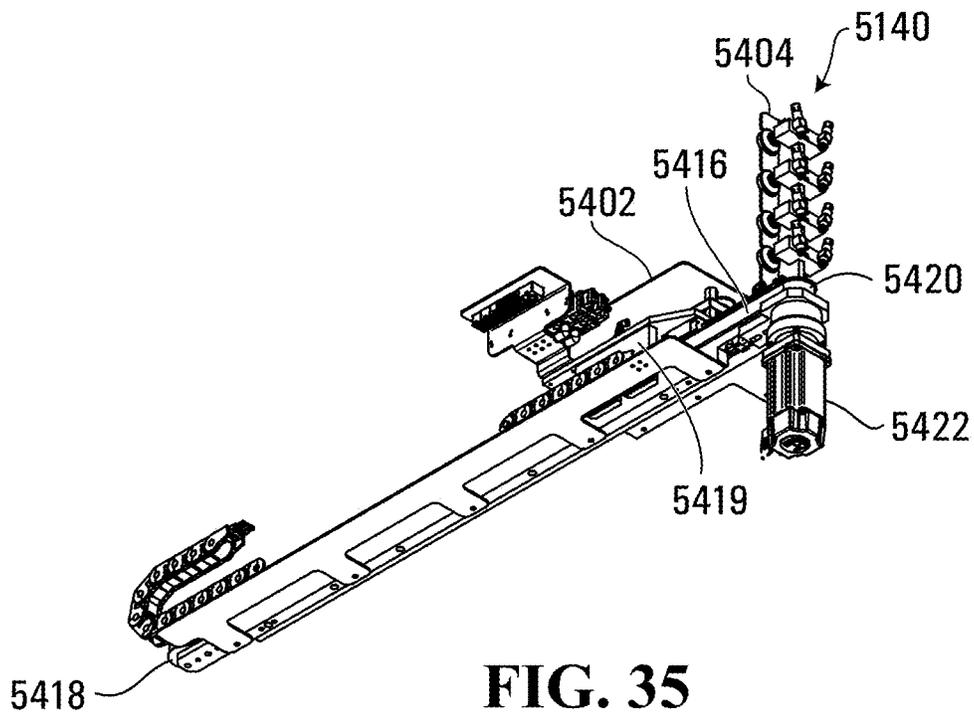


FIG. 35

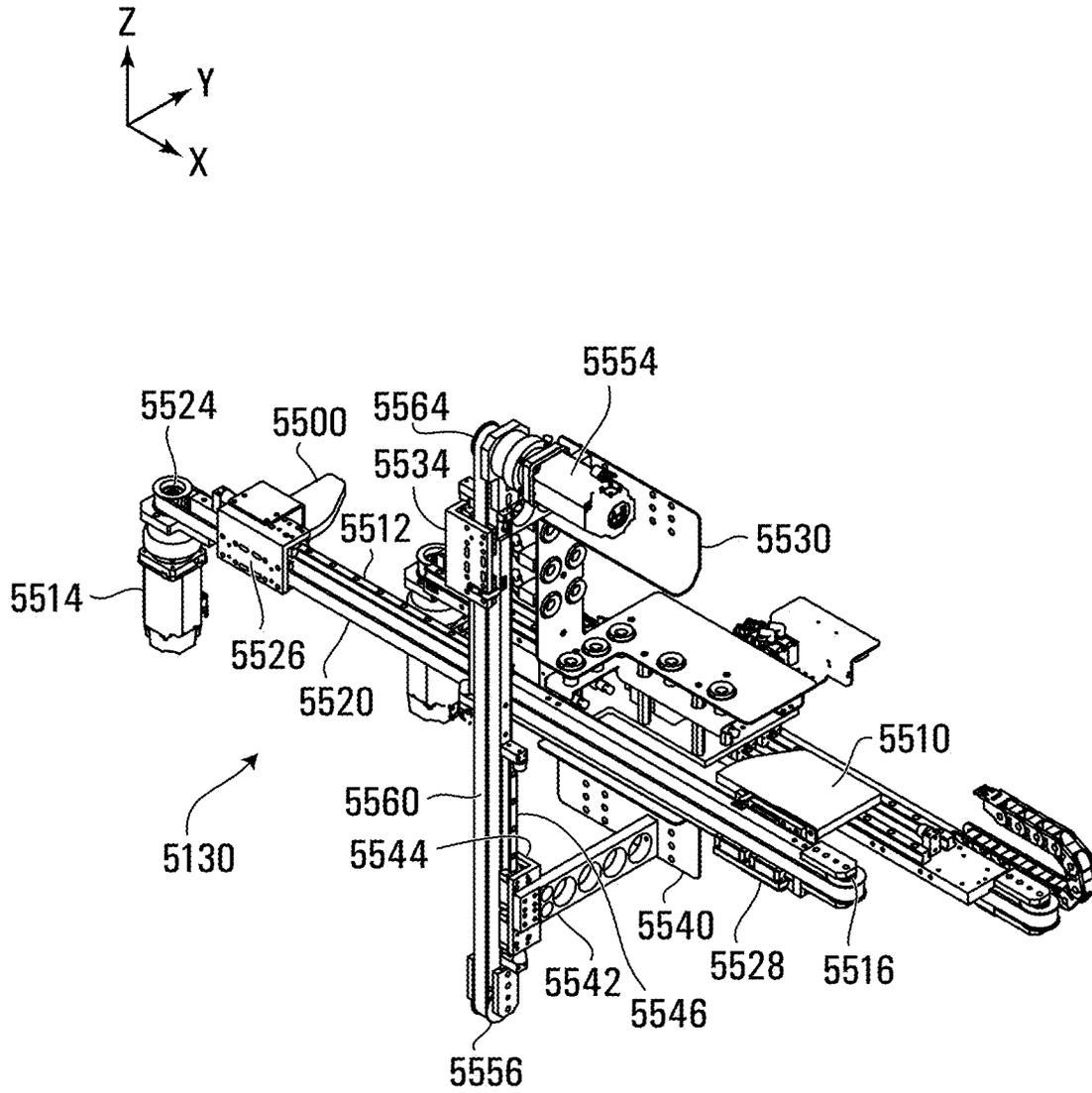


FIG. 36

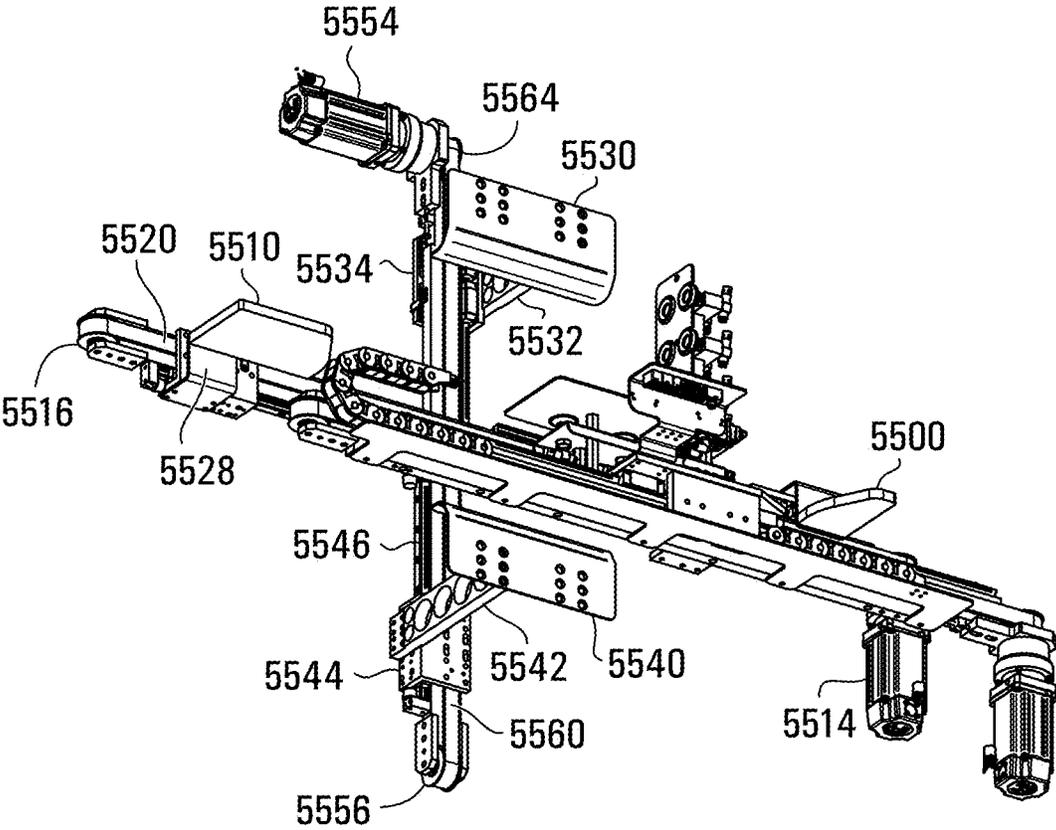


FIG. 37

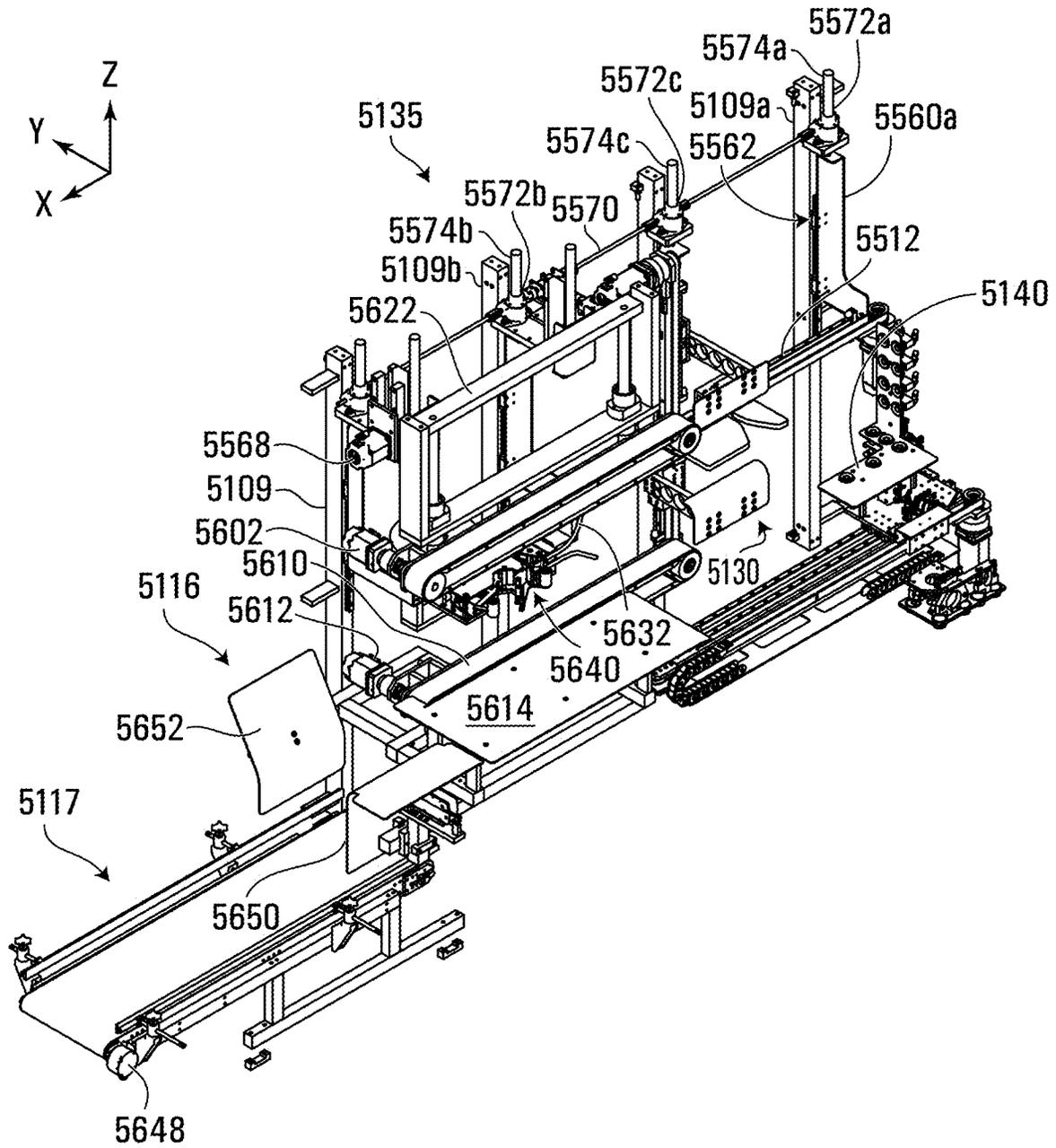


FIG. 38

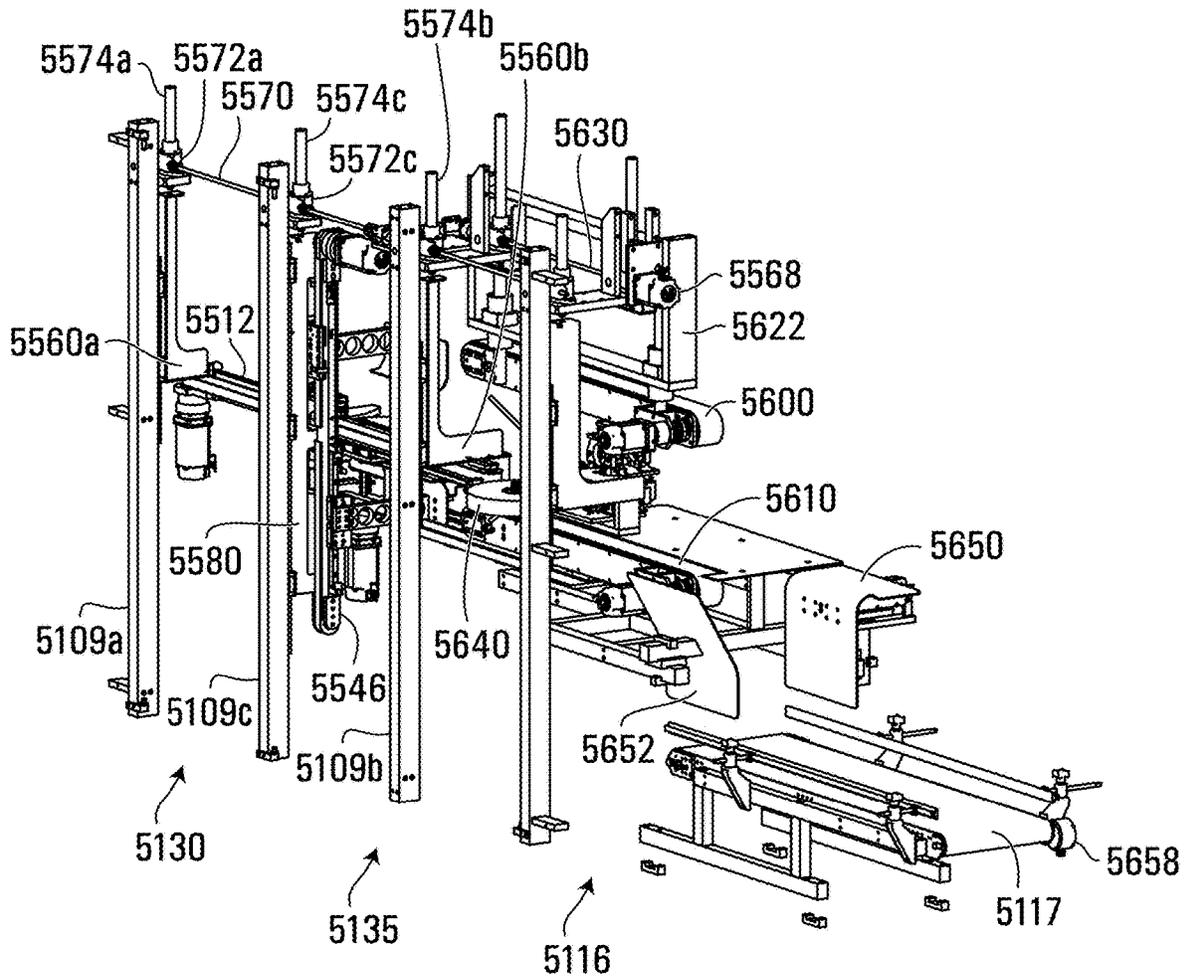


FIG. 39

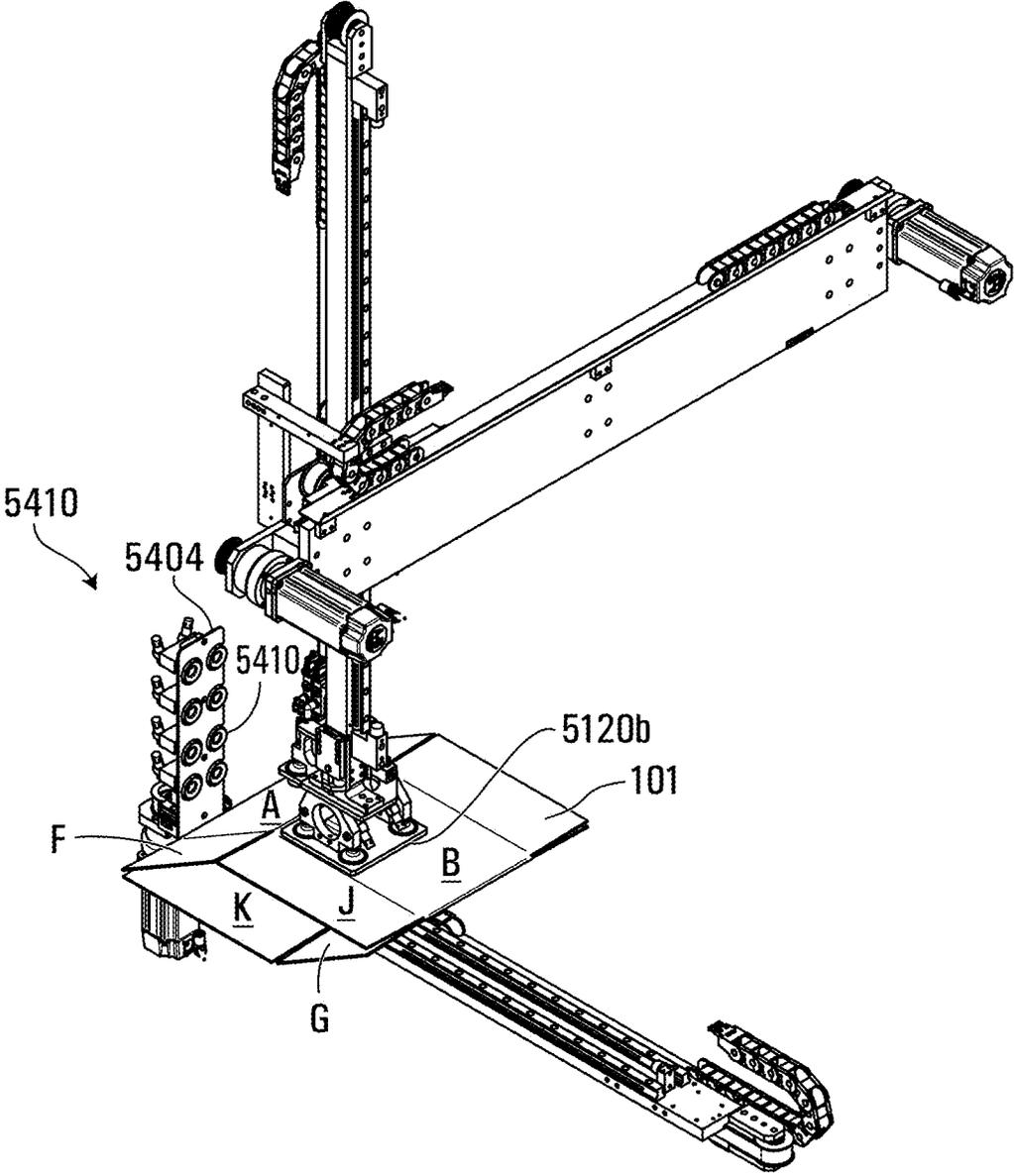


FIG. 41

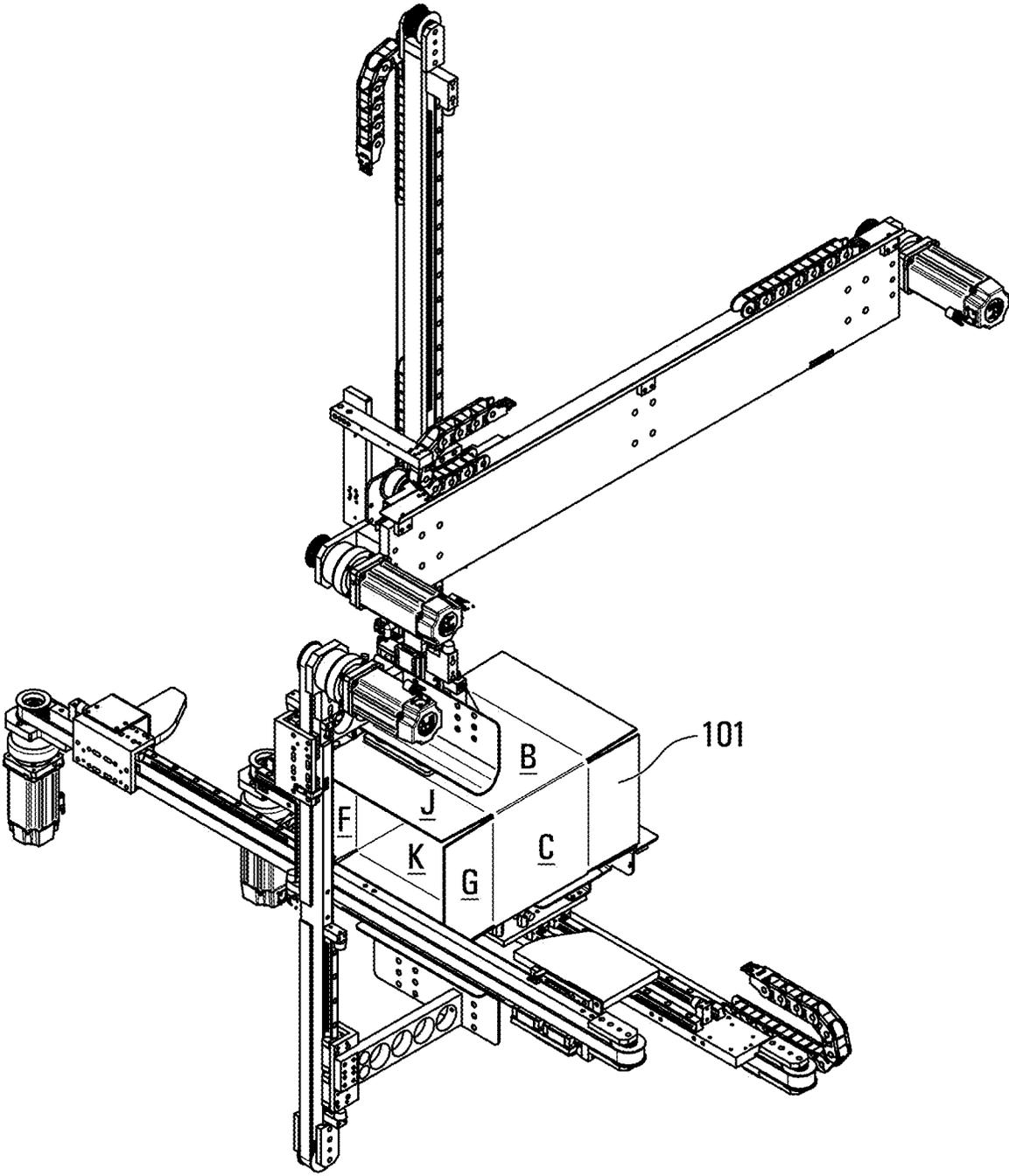


FIG. 42

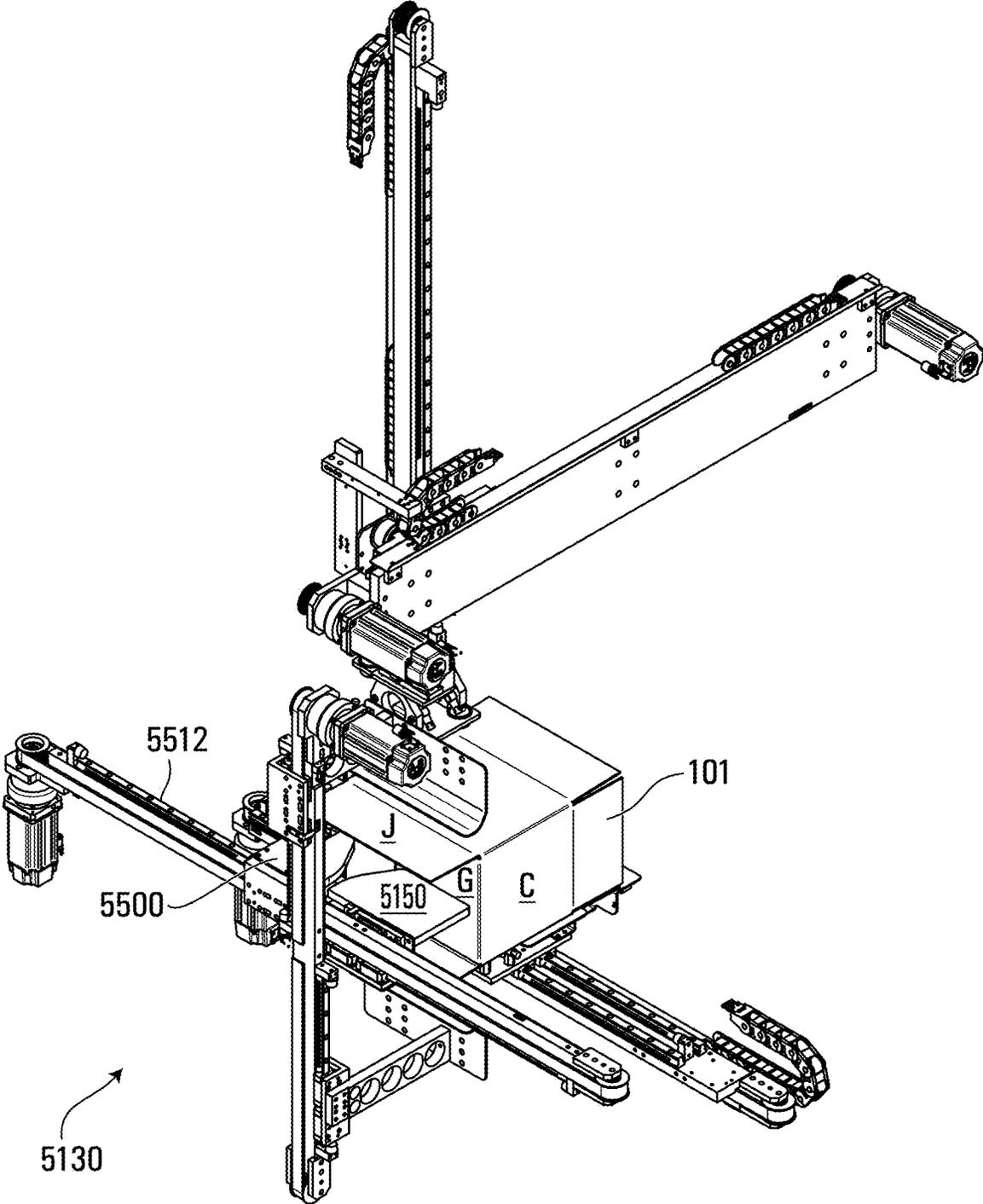


FIG. 43

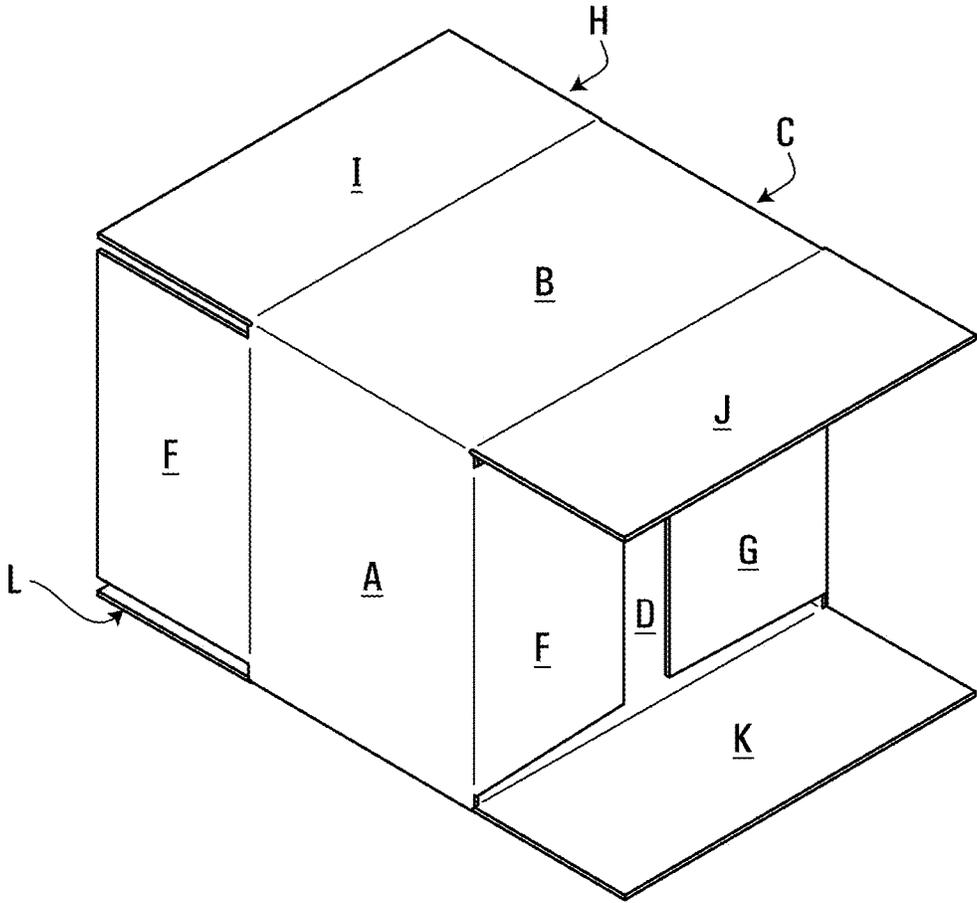


FIG. 44

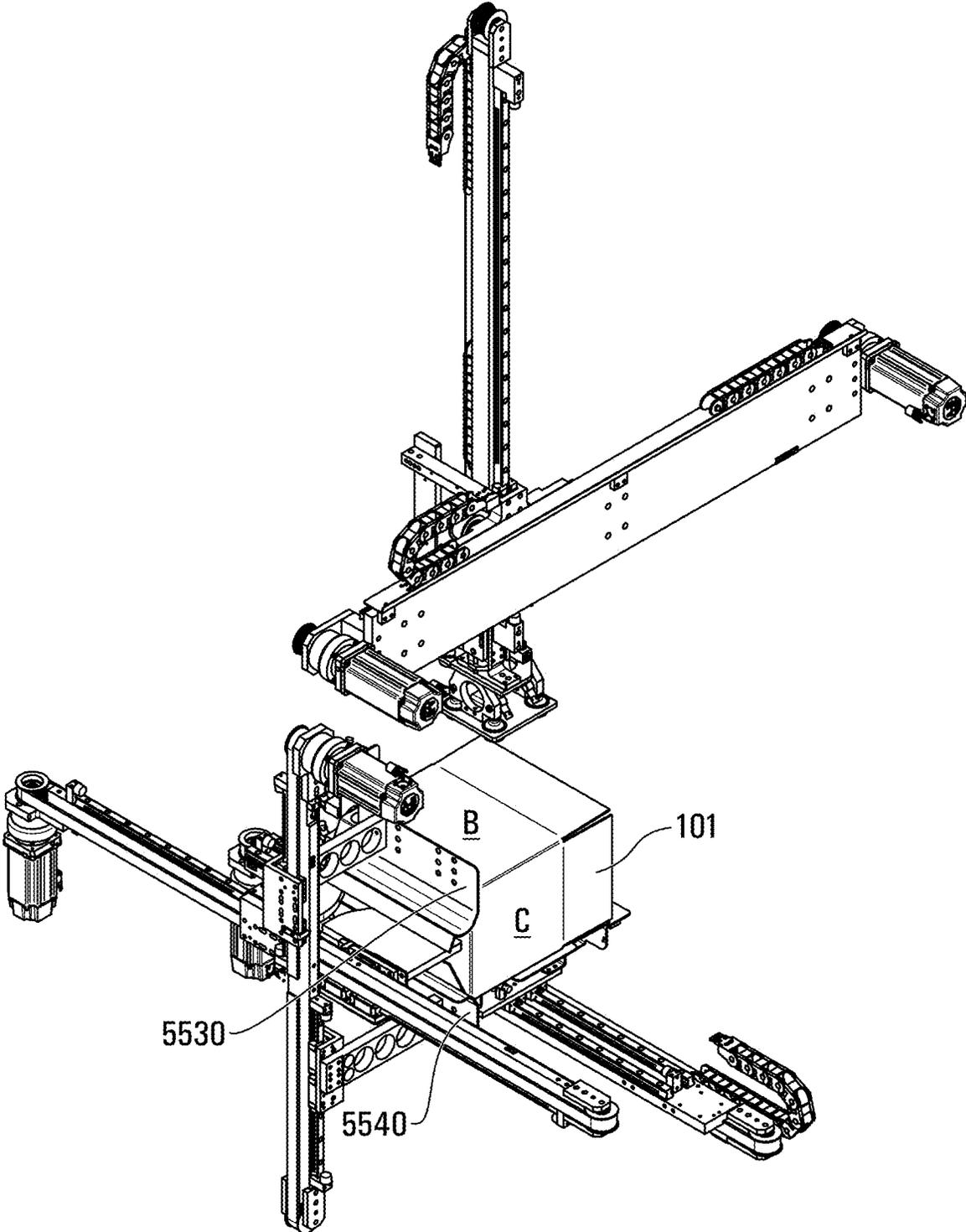


FIG. 45

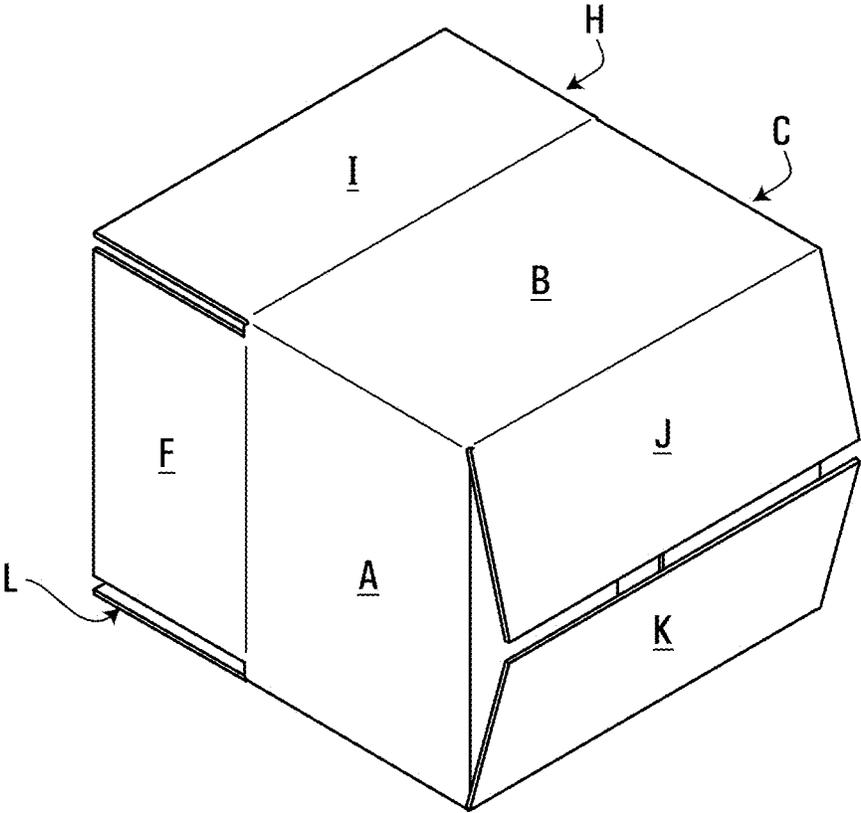


FIG. 46

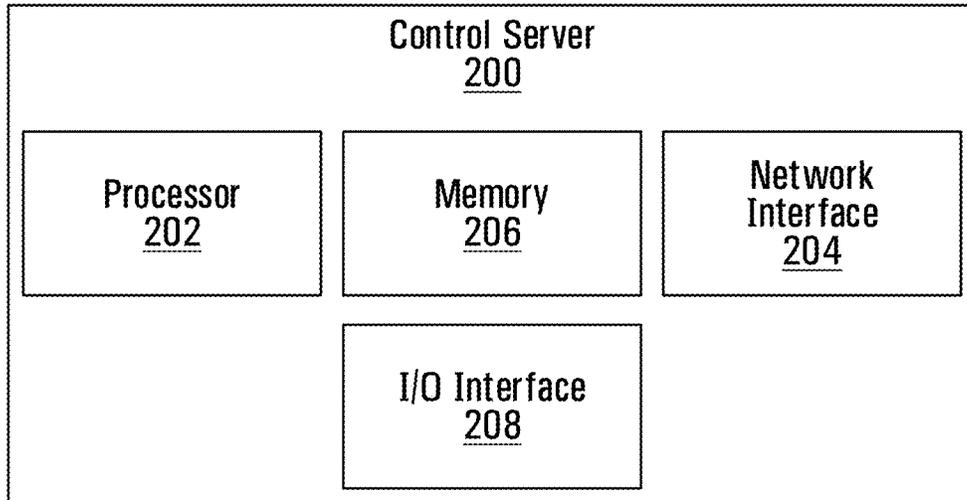


FIG. 47

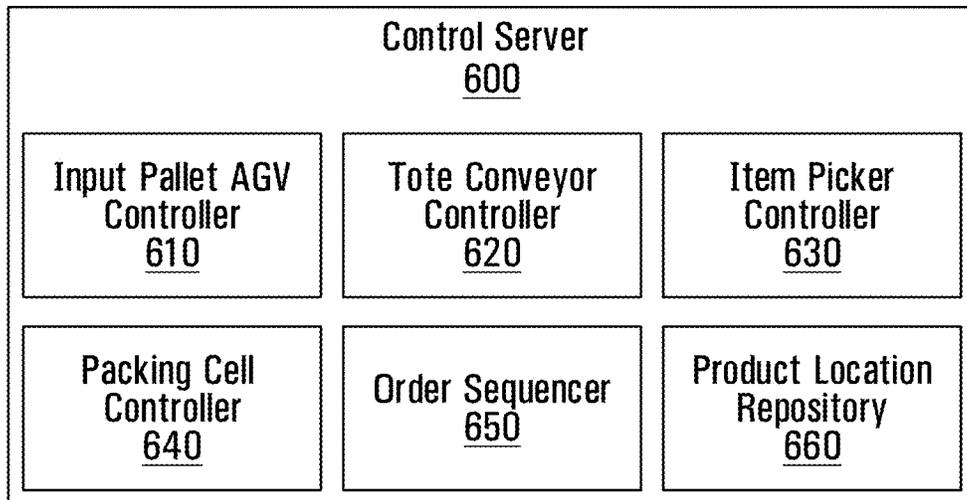


FIG. 48

1000 →

Order ID	Tote ID	Product_IDs	Case Size	Dunnage_Type	Dunnage_Length	Packing Cell
90001	9114	424234; 424234; 834588;	5	Bubble	6.35	1
9000	9117	235873; 932293;	7	Paper	2.73	6
90005	9118	578678	3	Paper	1.57	3
90006	9119	235238	8	Paper	3.47	4
90007	9120	667868; 281584; 273641;	5	Bubble	4.41	5

1002 1004 1006 1008 1010 1012 1014

FIG. 50

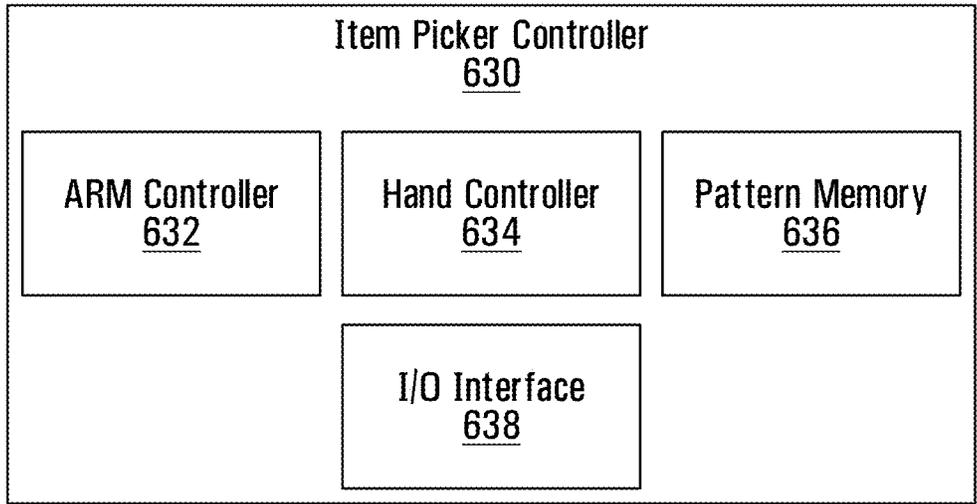


FIG. 51

1450 ↘

Case Size ID	Total Product Vol Min.	Total Product Vol Max.	Height	Width	Depth	Packing Cell
1	500	1000	10	10	10	1,2,3
2	1001	3375	15	15	15	2,3,4
3	3376	8000	20	20	20	1,3,4
4	8001	15625	25	25	25	1
5	15626	27000	30	30	30	4

Below the table, curly braces group the columns: 1452 under Case Size ID, 1454 under Total Product Vol Min., 1456 under Total Product Vol Max., 1458 under Height, Width, and Depth, and 1460 under Packing Cell.

FIG. 52

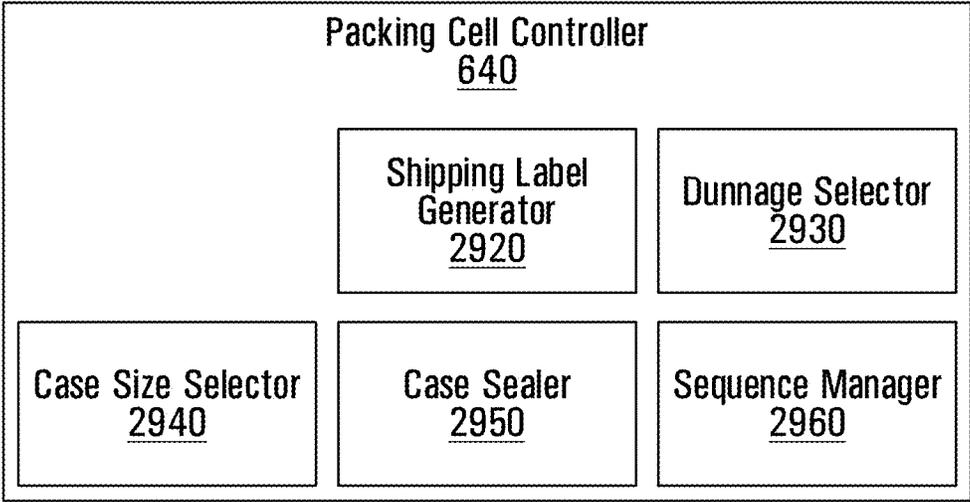


FIG. 53

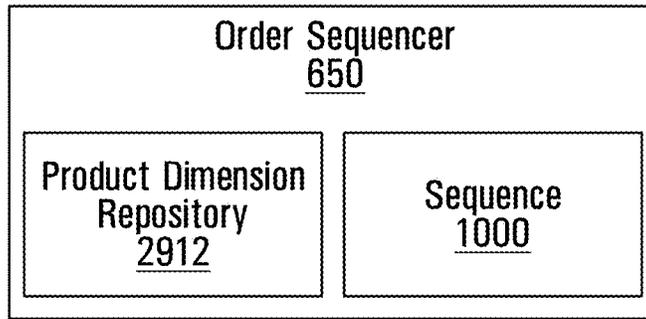


FIG. 54

2912
↘

Product_ID	Product_L	Product_W	Product_D
20576	16.8	21.5	22.8
20027	19.4	21.2	15.2
99178	23.7	28.3	27.0
62060	29.9	19.1	10.1
46097	6.4	14.7	6.7

3206

⏟

3208

⏟

FIG. 55

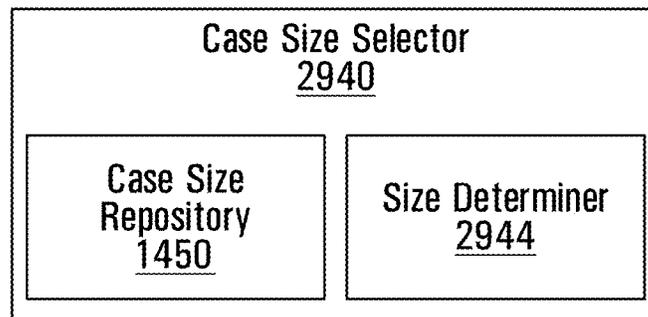


FIG. 56

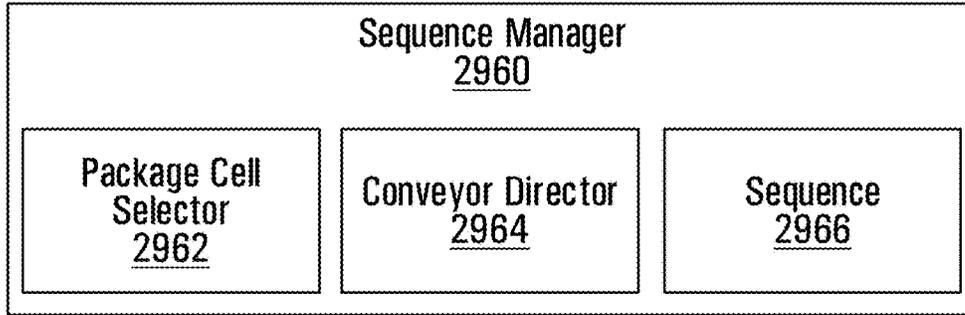


FIG. 57

2966
↘

Order ID	Bin ID	Case Size	Dunnage_Type	Dunnage_Length	Packing Cell
90011	9124	2	Paper	6.34	1
90012	9127	3	Paper	3.47	1
90013	9128	3	Paper	9.38	1
90014	9129	1	Paper	2.73	1
90015	9120	4	Paper	1.57	1

3302
3304
3308
3310
3312
3314

FIG. 58

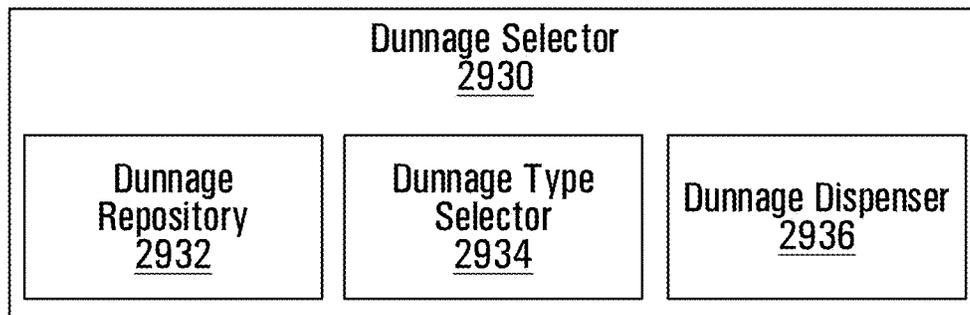


FIG. 59

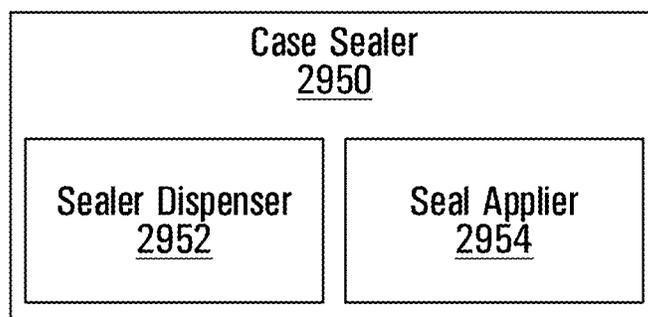


FIG. 60

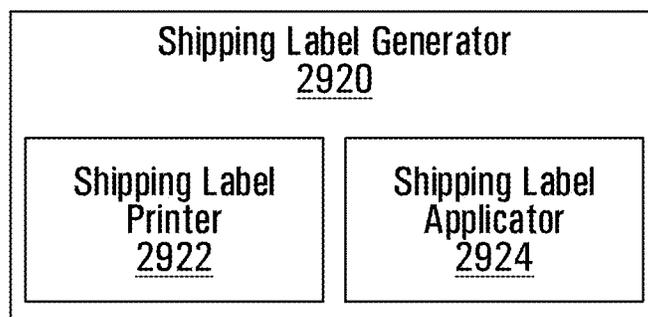


FIG. 61

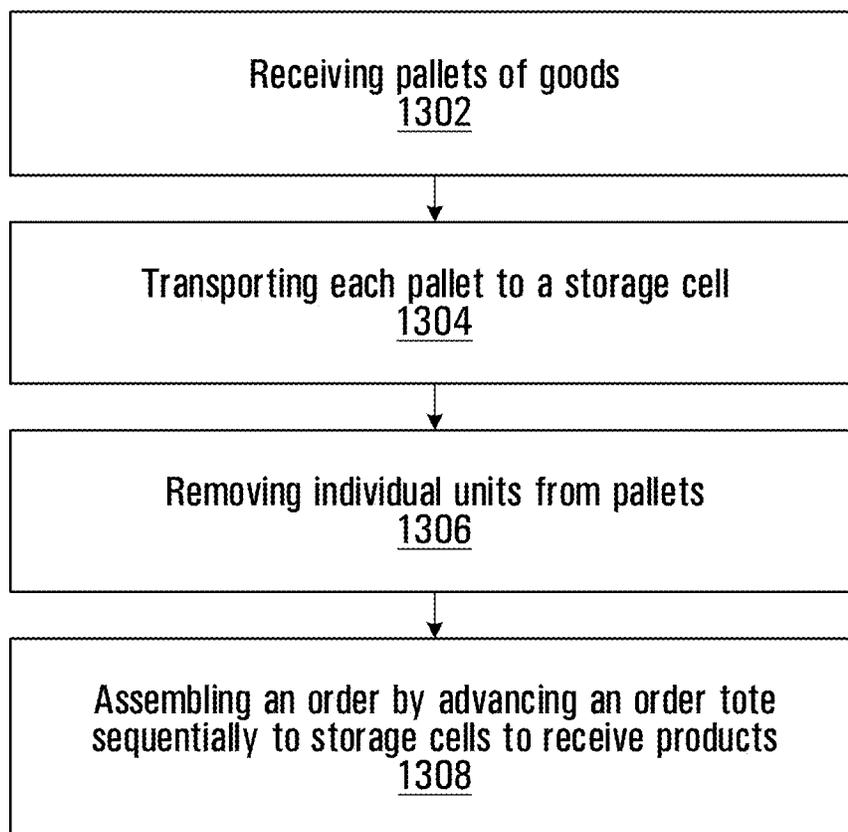


FIG. 62

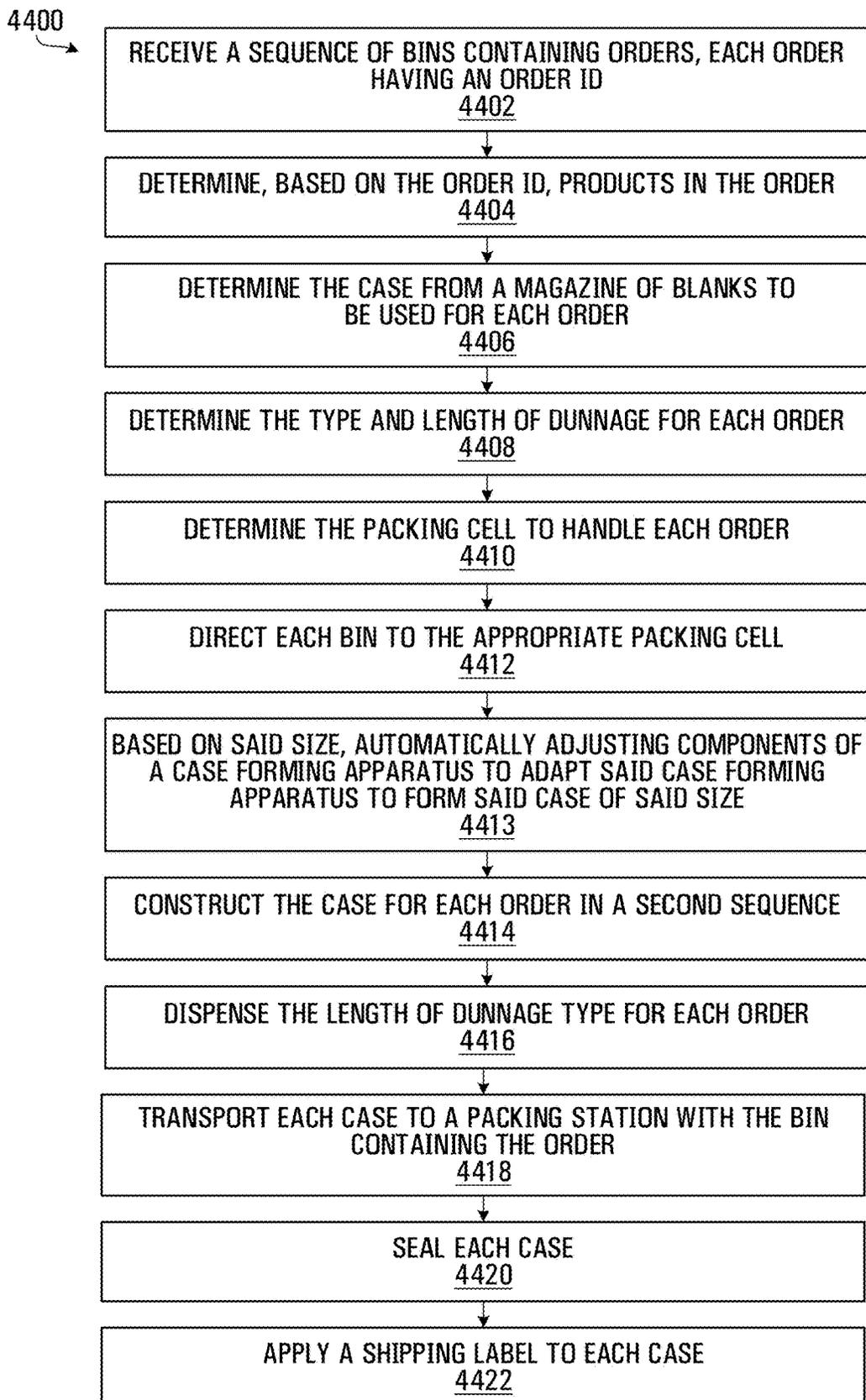


FIG. 63

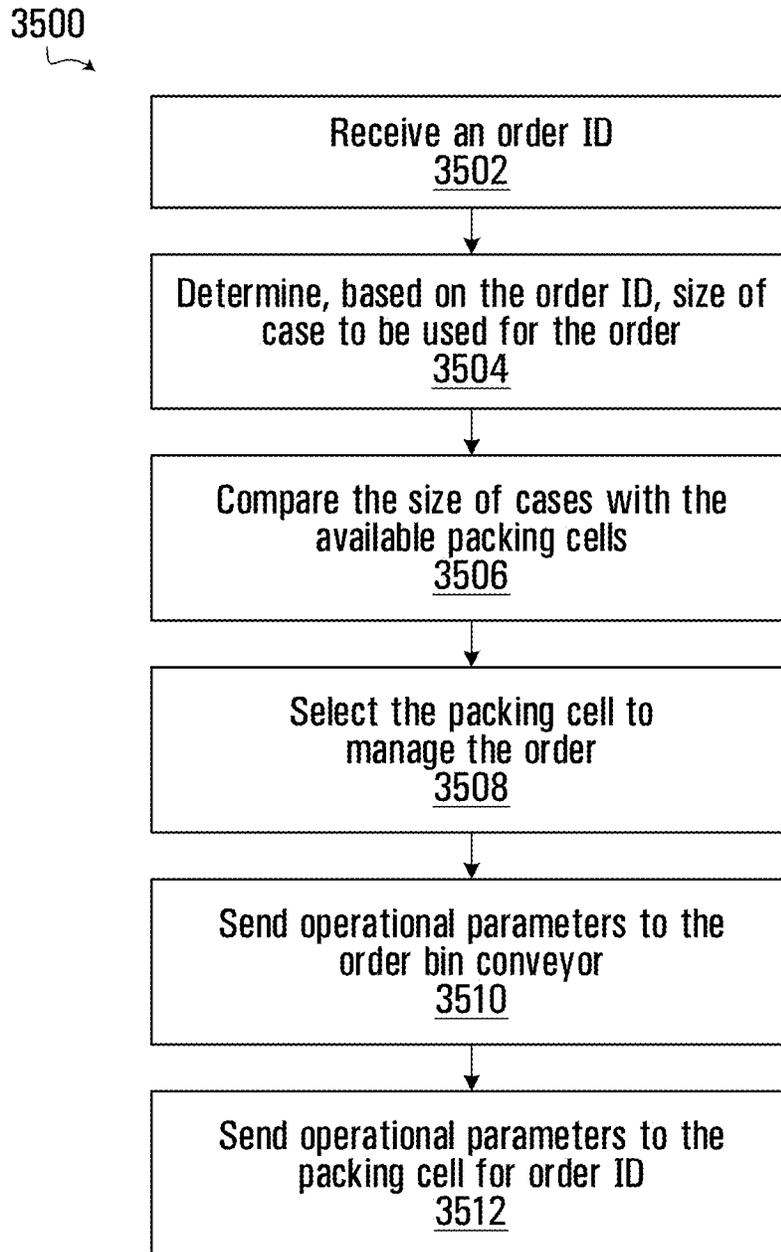


FIG. 64

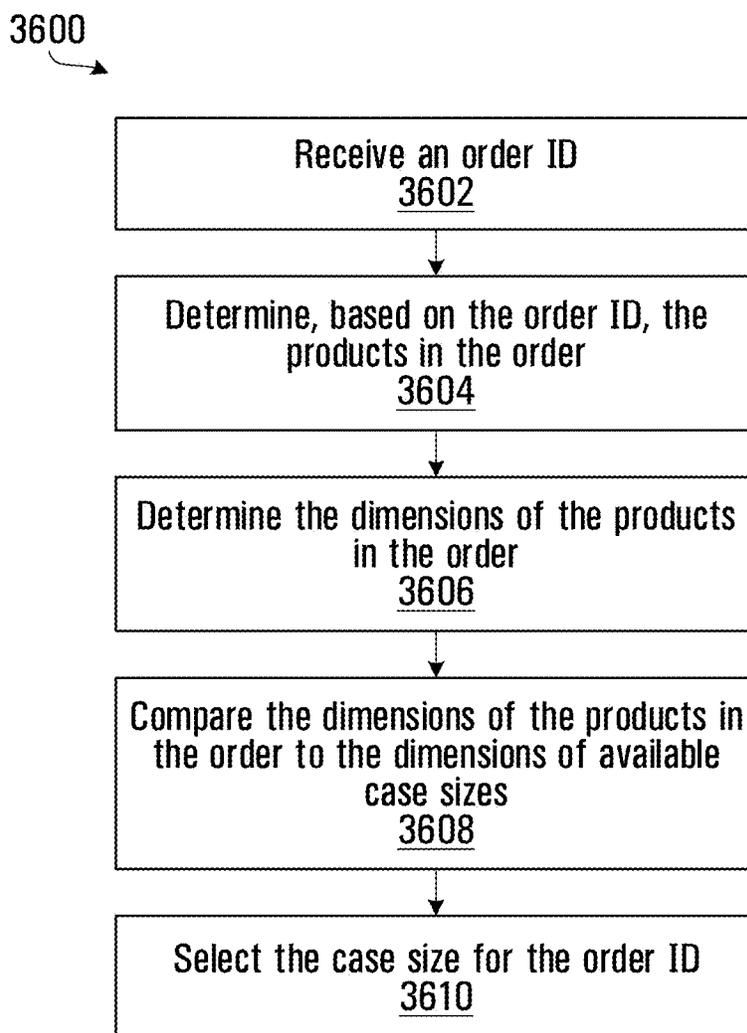


FIG. 65

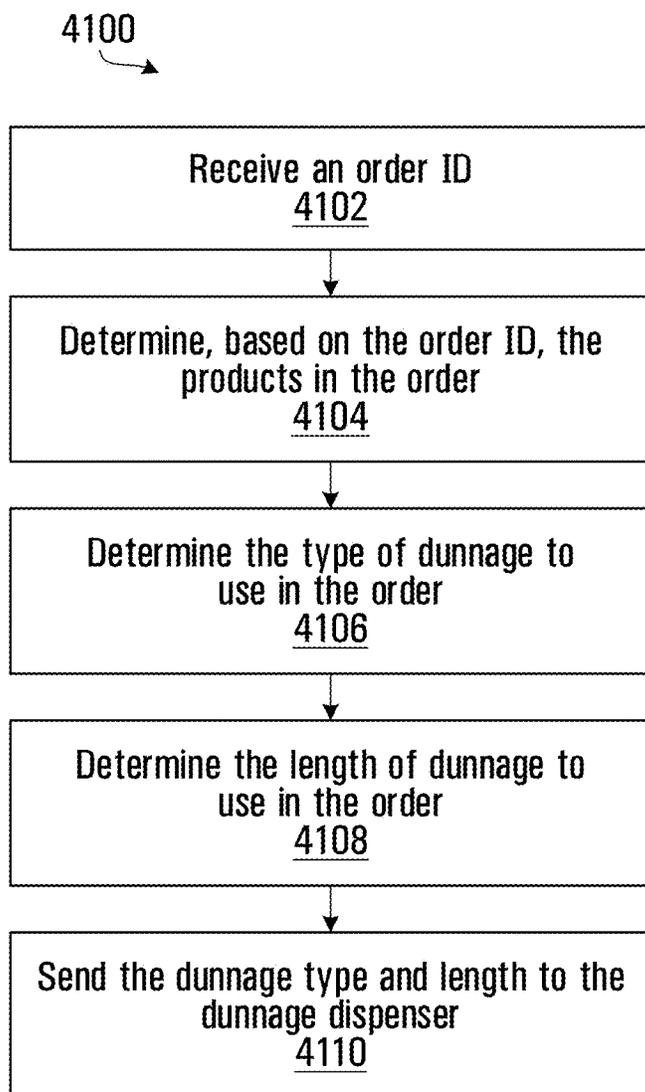


FIG. 66

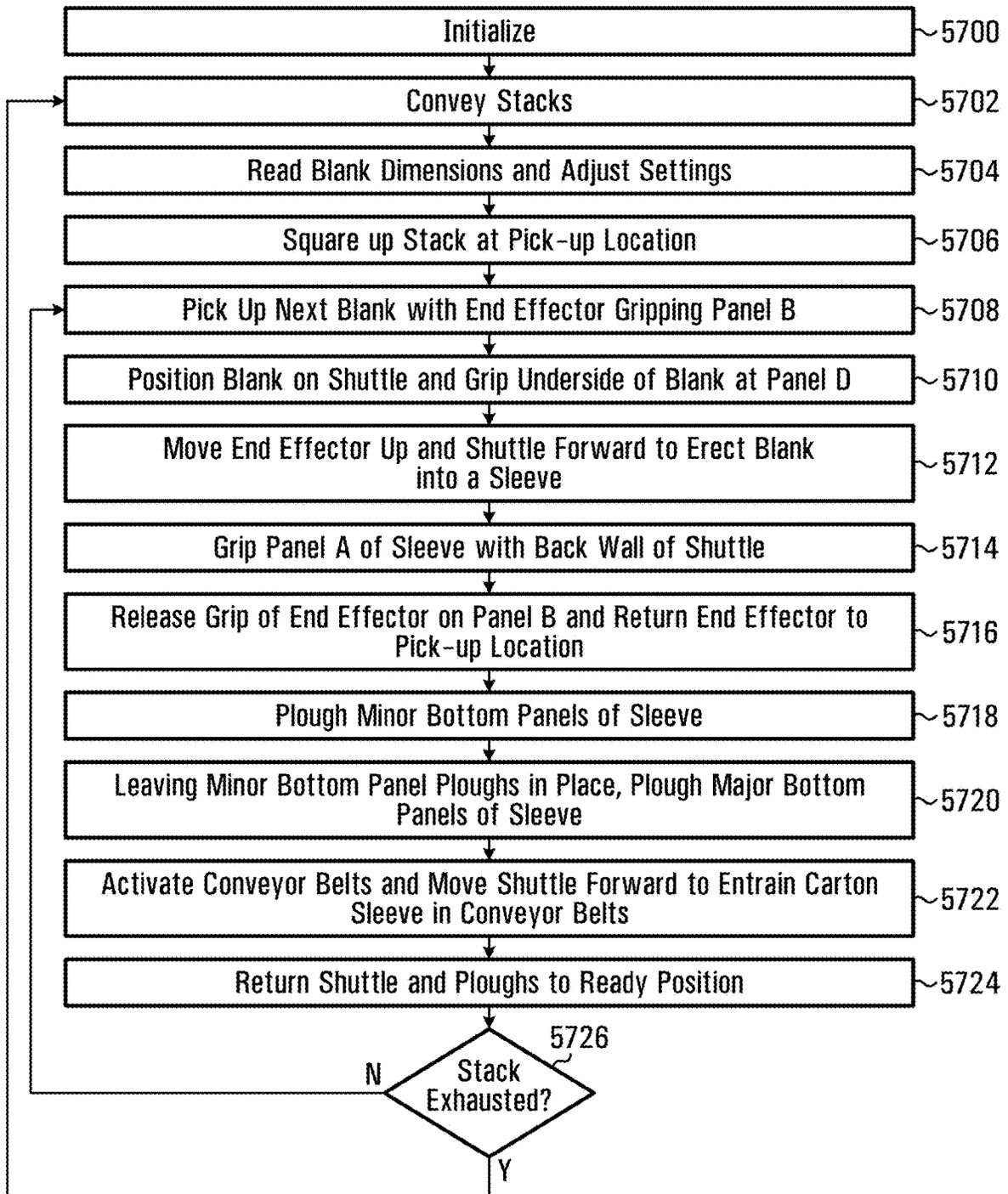


FIG. 67

WAREHOUSE SYSTEM FOR FULFILLING ORDERS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority from U.S. provisional application 63/072,008 filed on Aug. 28, 2020 and is related to U.S. application Ser. No. 16/230,979 filed on Dec. 21, 2018, U.S. application Ser. No. 16/677,139 filed on Nov. 7, 2019, and U.S. application Ser. No. 16/808,140 filed on Mar. 3, 2020, the entire contents of which are incorporated herein by reference.

FIELD

[0002] This present invention relates generally to methods and systems of warehouse operation, order fulfillment, and order packing.

BACKGROUND

[0003] Distribution warehouses are often used as a middle-ground between a manufacturer and a retailer. Manufacturers produce commercial units of a product type (herein referred to as a shop keeping unit or ‘SKU’). Multiple units of a single SKU may be grouped into a container or (‘case’), and multiple cases may be grouped onto a pallet. A pallet may refer to a stacked structure of cases, resting on a pallet base, also referred to as a skid, for handling using machines such as forklifts.

[0004] SKUs are generally shipped from manufacturer facilities to warehouses or distributions centers in single-SKU pallets. For example, each pallet typically contains a standardized number of cases of the same size, each holding the same number of individual units of a particular SKU. In a warehouse or distribution center, mixed pallets may be assembled for shipping to retail facilities. Such mixed pallets generally contain a plurality of case types, where each case type corresponds to a particular SKU.

[0005] Thus, products are typically packed and shipped from manufacturers “by the pallet”, i.e. in units of pallets. A pallet disassembly is performed at an intermediate facility to break down pallets into units of cases, which are then shipped to retail facilities. At the retail facilities, cases are disassembled into individualized units suitable for sale to end customers.

[0006] This traditional approach is inefficient and labour-intensive. Shipping units produced by manufacturers are broken down in two separate stages, and at two separate facilities in order for individual be units to be sold and transferred to customers. Moreover, this approach is not suitable for newer retail models, such as e-commerce.

SUMMARY

[0007] An example warehouse system for fulfilling orders comprising a plurality of products, comprises: a plurality of storage cells, each storage cell for receiving palletized products, the palletized products packed in cases each comprising a plurality of units, the cases arranged on a pallet in a shipping configuration; a conveyor system operable to sequentially advance a tote to a plurality of the storage cells corresponding to a plurality of products in an order, for collecting the order in the tote; a plurality of robotic pickers at the storage cells, each for engaging individual units of a

product, to transfer the individual units from the pallets to a tote of the order assembly system.

[0008] In some embodiments, the warehouse system further comprises a packing subsystem for transferring the order to a shipping case for shipping.

[0009] In some embodiments, the packaging subsystem comprises a case erector operable to erect said case.

[0010] In some embodiments, the case erector is operable to erect cases of a plurality of different sizes.

[0011] In some embodiments, the case erector is operable to erect a case of a selected one of the plurality of different sizes, based on sizes of the products of the order.

[0012] In some embodiments, the warehouse system comprises a liner insertion station adjacent to a conveyor of the conveyor system, the liner insertion station for placing a removable liner in said tote.

[0013] In some embodiments, the liner is a bag for transferring said order to said shipping case by removal of the bag.

[0014] In some embodiments, the plurality of robotic pickers comprise pickers mounted overhead at said cells.

[0015] In some embodiments, the plurality of robotic pickers comprises pickers movable between ones of the cells.

[0016] In some embodiments, the robotic pickers are operable to remove packing material from pallets at the cells.

[0017] In some embodiments, the robotic pickers are operable to cut the packing material.

[0018] In some embodiments, the robotic pickers are operable to remove empty cases from pallets at the cells.

[0019] In some embodiments, the warehouse system comprises a plurality of zones maintained at different temperature conditions.

[0020] In some embodiments, the conveyor system comprises a plurality of branching conveyors, each of the branching conveyors passing proximate a subset of the storage cells.

[0021] In some embodiments, the warehouse system comprises a plurality of diverters selectively operable direct a specific individual tote along a defined path to any of the storage cells.

[0022] An example warehousing method, comprises: receiving a plurality of pallets of goods, the pallets containing a plurality of cases, each containing a plurality of individual units of the goods; transporting each the pallet to a storage cell corresponding to goods on that pallet; removing individual units of the goods from the pallets with robotic pickers at the storage cells; assembling an order of products by advancing an order tote sequentially to a plurality of the storage cells to receive products from the robotic pickers.

[0023] In some embodiments, the warehousing method comprises transferring the order to a shipping case for shipping.

[0024] In some embodiments, the warehousing method comprises automatically erecting the shipping case.

[0025] In some embodiments, automatically erecting said case comprises selecting one of a plurality of possible case sizes based on sizes of the products of the order, and conveying a blank corresponding to the selected one of a plurality of case sizes to a case erector.

[0026] In some embodiments, the warehousing method comprises automatically inserting a removable liner in said tote.

[0027] In some embodiments, the removable liner is a bag, and transferring said order comprises placing said bag in said shipping case.

[0028] In some embodiments, the warehousing method comprises removing packing material from the pallets with said robotic pickers.

[0029] In some embodiments, the warehousing method comprises cutting the packing material with the robotic pickers.

[0030] In some embodiments, the warehousing method comprises maintaining multiple warehouse zones at different temperatures.

[0031] In some embodiments, the assembling an order comprises conveying a tote along a branching conveyor, wherein each branch of the branching conveyor passes proximate a subset of the storage cells.

[0032] In some embodiments, the warehousing method comprises defining a path for a specific individual to a storage cell by selective operation of diverters on the branching conveyor.

BRIEF DESCRIPTION OF DRAWINGS

[0033] In the Figures which illustrate example embodiments,

[0034] FIG. 1 is a top view of a floor plan of a warehouse system for fulfilling orders;

[0035] FIG. 2 is a cross-sectional view of a storage unit in the warehouse system for fulfilling orders of FIG. 1;

[0036] FIG. 3A is a top view of a shelf in the storage unit of FIG. 2;

[0037] FIG. 3B is a side view of the shelf of FIG. 2;

[0038] FIG. 4 is a rear view of a storage unit having a pallet elevator device in a first position;

[0039] FIG. 5 is a rear view of a storage unit having a pallet elevator device in a second position;

[0040] FIG. 6 is another side view of the shelf of FIG. 2;

[0041] FIG. 7 is an isometric view of an example tool used on a robotic arm in the storage unit of FIG. 2;

[0042] FIGS. 8A and 8B are a top and side view of the example tool of FIG. 7;

[0043] FIGS. 9A and 9B are isometric views of a pallet to be used in a warehouse system for fulfilling orders;

[0044] FIG. 10 is an isometric view of tote for use in a warehouse system for fulfilling orders, with and without a liner;

[0045] FIG. 11 is a packing cell in a warehouse system for fulfilling orders;

[0046] FIG. 12 is an example of an order packing system having multiple packing cells;

[0047] FIG. 13 is a top view of a random case erector used in the packing cell of FIG. 11;

[0048] FIG. 14 is an isometric view of a plurality of magazines used in the random case erector of FIG. 13;

[0049] FIG. 15 is a top view of a plurality of magazines used in the random case erector of FIG. 13;

[0050] FIG. 16 is a detailed isometric view of a blank conveyor used in the random case erector of FIG. 13;

[0051] FIGS. 17A and 17B are top perspective views of a case erector system;

[0052] FIG. 18 is a schematic control diagram for the case erector system;

[0053] FIG. 19A is a plan view of one side of a knock-down blank that may be processed by the system;

[0054] FIG. 19B is an isometric view an opposite side of the knock-down blank of FIG. 19A;

[0055] FIG. 20 is an isometric view of a case erected from the knock-down blank of FIGS. 19A and 19B;

[0056] FIG. 21 is an isometric view of a sub-assembly of the random case erector of FIG. 13;

[0057] FIG. 22 is an isometric view of a sub-assembly of the random case erector of FIG. 13;

[0058] FIG. 23 is an isometric view of a sub-assembly of the random case erector of FIG. 13;

[0059] FIG. 24 is an isometric view of a sub-assembly of the random case erector of FIG. 13;

[0060] FIG. 25 is a side elevation view of a sub-assembly of the random case erector of FIG. 13;

[0061] FIG. 26 is a top elevation view of a sub-assembly of the random case erector of FIG. 13;

[0062] FIG. 27 is a side elevation view of a sub-assembly of the random case erector of FIG. 13;

[0063] FIG. 28 is an isometric view of a sub-assembly of the random case erector of FIG. 13;

[0064] FIG. 29 is an isometric view of a sub-assembly of the random case erector of FIG. 13;

[0065] FIG. 30 is an isometric view of a sub-assembly of the random case erector of FIG. 13;

[0066] FIG. 31 is a side elevation view of a sub-assembly of the random case erector of FIG. 13;

[0067] FIG. 32 is an isometric view of a sub-assembly of the random case erector of FIG. 13;

[0068] FIG. 33 is an isometric view of a sub-assembly of the random case erector of FIG. 13;

[0069] FIG. 34 is an isometric view of a sub-assembly of the random case erector of FIG. 13;

[0070] FIG. 35 is an isometric view of a sub-assembly of the random case erector of FIG. 13;

[0071] FIG. 36 is an isometric view of a sub-assembly of the random case erector of FIG. 13;

[0072] FIG. 37 is an isometric view of a sub-assembly of the random case erector of FIG. 13;

[0073] FIG. 38 is an isometric view of a sub-assembly of the random case erector of FIG. 13;

[0074] FIG. 39 is an isometric view of a sub-assembly of the random case erector of FIG. 13;

[0075] FIG. 40 is an isometric view of a sub-assembly of the random case erector of FIG. 13;

[0076] FIG. 41 is an isometric view of a sub-assembly of the random case erector of FIG. 13;

[0077] FIG. 42 is an isometric view of a sub-assembly of the random case erector of FIG. 13;

[0078] FIG. 43 is an isometric view of a sub-assembly of the random case erector of FIG. 13;

[0079] FIG. 44 is an isometric view of a case erected from the knock-down blank of FIGS. 19A and 19B;

[0080] FIG. 45 is an isometric view of a sub-assembly of the random case erector of FIG. 13;

[0081] FIG. 46 is an isometric view of a case erected from the knock-down blank of FIGS. 19A and 19B;

[0082] FIG. 47 is a block diagram of an example hardware components of a control server;

[0083] FIG. 48 is a block diagram of an example software components of a control system;

[0084] FIG. 49 is an example cell location repository;

[0085] FIG. 50 is an example order sequence;

[0086] FIG. 51 is a block diagram of software components of the picker arm of FIG. 2;

[0087] FIG. 52 is an example case size repository for the packing station of FIG. 11;

[0088] FIG. 53 is a block diagram of software components of a case erector controller;

[0089] FIG. 54 is a block diagram of software components of an order sequencer;

[0090] FIG. 55 is an example product dimension repository;

[0091] FIG. 56 is a block diagram of software components of a case size selector;

[0092] FIG. 57 is a block diagram of software components of a sequence manager;

[0093] FIG. 58 is an example sequence;

[0094] FIG. 59 is a block diagram of software components of a dunnage selector;

[0095] FIG. 60 is a block diagram of software components of a case sealer;

[0096] FIG. 61 is a block diagram of software components of a shipping label generator;

[0097] FIG. 62 is a flowchart showing an example method for fulfilling orders;

[0098] FIG. 63 is a flowchart showing an example method of packing orders.

[0099] FIG. 64 is a flowchart showing an example method of use of the sequence manager;

[0100] FIG. 65 is a flowchart showing an example method of use of the case size selector;

[0101] FIG. 66 is a flowchart showing an example method of use of the dunnage selector; and

[0102] FIG. 67 is a flowchart showing an example method of constructing cases.

DETAILED DESCRIPTION

[0103] Disclosed herein are warehouse systems and methods that allow for efficient receiving and storage of palletized products, and shipping of mixed orders of individual product units, e.g. to consumers. Pallets comprising cases full of individual articles are dismantled in a single stage, such that individual articles can be directly removed from pallets for shipping. Packing apparatus and methods are disclosed, permitting shipping of orders in any of a variety of different shipping cases. Operation of the warehouse systems and execution of the methods may be automated, such that few or no human operators are required. Embodiments disclosed herein may be compatible with features disclosed in U.S. application Ser. No. 16/230,979, filed on Dec. 21, 2018, U.S. application Ser. No. 16/677,139 filed on Nov. 7, 2019, and U.S. application Ser. No. 16/808,140 filed on Mar. 3, 2020, the entire contents of which are incorporated herein by reference.

System Overview

[0104] FIG. 1 is a top view of a floor plan of an example warehouse system 100 for fulfilling orders. The system includes receiving bays 102, output bays 104, storage units 110, packing system 120, and a conveyor system 130. The warehouse system 100 can generally be described in terms of three axes: y and x representing longitudinal and lateral horizontal axes, and z representing a vertical axis.

[0105] In operation, pallets containing cases of products are received from a delivery trucks at receiving bays 102.

Each pallet contains products of a particular SKU. Pallets are transported from the delivery trucks to specific corresponding locations in a storage unit 110. Such transportation may be done using forklifts. The forklifts may be autonomous devices referred to as automated guided vehicles (AGVs). There, the pallet will be placed in the corresponding storage location in the storage unit 110. An example of a suitable AGV model is the narrow aisle forked automatic guided vehicle (FAGV) model made by JBT, having a capacity of 1,100 kg and lift heights up to 9.2 m. The AGV may have a load detection sensor that may verify load presence and load placement, and motors configured to allow for 180 degree turning in a specific position. Individual units may be later removed from the storage location to fulfil customer orders.

[0106] Each storage unit 110 has a number of discrete, individual storage locations, referred to as cells, each of which may be associated with a SKU. In some examples, the SKUs handled in warehouse system 100 may be a specific, defined set. In other examples, the warehouse system 100 may handle an open-ended set of SKUs, subject to physical space constraints.

[0107] Storage locations may be uniquely identified, e.g. by numbers. The numbers assigned to each location may also identify the position of the storage location in warehouse system 100 using its x, y, and z axis. For example, the x and y axis may be used to represent the horizontal position where the pallet should be placed, and the z axis may represent a cell height.

[0108] According to some embodiments, the specific storage locations in storage unit 110 may be grouped according to a property of the specific item. For example, items with similar shapes, similar sizes, or similar packages may be positioned close to one another.

[0109] Warehouse system 100 is divided into a plurality of zones. Specifically, in the depicted example, warehouse system 100 is divided into three zones 100-1, 100-2, 100-3. The zones 100-1, 100-2, 100-3 are maintained at different conditions. For example, a first zone 100-1 is maintained at moderate temperature and humidity conditions; a second zone 100-2 is maintained at reduced temperature; and a third zone 100-3 is maintained at a temperature at or below freezing. The three zones 100-1, 100-2, 100-3 provide three different storage conditions for storage of different products. For example, warehouse system 100 may house grocery goods. Non-perishable goods may be kept in zone 100-1; perishable goods such as fresh produce may be kept in zone 100-2; and frozen goods may be kept in zone 100-3.

[0110] Storage units 110 and conveyor system 130 define a branching structure. Conveyor system 130 has one or more main lines 132, also referred to as arteries. A plurality of branch lines 134 extend from main lines 132 and communicate therewith, so that articles can be transferred between the main lines 132 and branch lines 134.

[0111] Storage units 110 are positioned adjacent branch lines 134. Each branch line 134 passes adjacent a subset of storage units and cells. Goods at storage locations in storage units 110 can be transferred from the storage locations to the branch lines 134 for transportation.

[0112] Warehouse system 100 further comprises an output conveyor 140. Output conveyor 140 is a belt or roller conveyor configured to deliver completed cases 334 from order packing system 120 to specific ones of output bays 104. At each output bay 104, a delivery truck may be

positioned. According to some embodiments, completed cases 334 are delivered to the output bay 104 randomly. Alternatively, completed cases 334 may be delivered to the output bay 104 based on a delivery destination. For example, each delivery vehicle at output bay 104 may be assigned to a particular route or territory. Orders may likewise be assigned to routes or territories based on destination addresses. After packing, completed orders are sent to the corresponding output bay 104 and delivery vehicle. The completed case 334 will then be transferred from the output conveyor 140 onto the truck, either by an automated guided vehicle, by a person, or another pick-and-place electromechanical system.

[0113] The above-described components and functions of warehouse system 100 may be partially or fully automated such that the warehouse may function with very few human operators or entirely without human operators.

Storage Units

[0114] FIG. 2 is a cross-sectional view showing two storage units 110 on opposite sides of a branch line 134 of conveyor system 130. Each of the pictured storage units 110 has four shelves defining cells 111 (individually 111-1, 111-2, 111-3, and 111-4), each at a different height along axis z. A storage location is defined at each cell 111 for pallets 112 containing a single SKU.

[0115] FIGS. 3A and 3B respectively depict top and side views of an individual cell 111. In the depicted example, each cell 111 has depth sufficient to receive a plurality of pallets. For example, each cell holds a processing pallet 112-1 at a processing section 185-1, a queued pallet 112-2 at a standby section 185-2, and may hold an empty pallet 187 in a retrieval section 185-3. The processing pallet 112-1 is located at a processing position closest to branch line 134 of conveyor system 130 and is in the process of being dismantled. That is, as shown in FIG. 3A, some packaging has been removed from processing pallet 112-1 and a process of removing individual units from pallet 112-1 is in progress. Queued pallet 112-2 is in a standby position behind processing pallet 112-2, awaiting dismantling. An empty pallet 187 may be held in the retrieval position, which may be vertically above or below the standby position. Packaging on queued pallet 112-2 is intact, and no individual articles have been removed. Empty pallet 187 may have already had all individual articles, empty cases, dunnage, or slip sheets removed therefrom. At the processing position, material handling machines such as AGVs 119 may retrieve the empty pallets for disposal.

[0116] Each cell 111 is equipped with a cell conveyor 113. Pallets 112 are positioned atop the cell conveyor 113. Cell conveyor 113 has three main conveyor sections 185, namely, a processing section 185-1, a standby section 185-2 and a retrieval section 185-3, for handling pallets at the processing, standby and retrieval positions, respectively. Each section 185 of cell conveyor 113 may be, for example, a belt conveyor or roller conveyor or combination thereof. Each section 185 may be individually controllable. For example, each section may have a separate conveyor belt and the sections may be driven by separate motors controllable by a PLC or control system.

[0117] Conveyor sections 185 are configured to transport pallets to one another. Standby section 185-2 is configured to receive a standby pallet 112-2 from the material handling machine such as an AGV, and, in response to a control

signal, to advance a pallet from standby section 185-2 to be received by processing section 185-1. Processing section 185-1 is configured to position a pallet for unloading and, in response to a control signal, advance an empty pallet 187 to the retrieval section 185-3. Retrieval section 185-3 is configured to receive an empty pallet and transfer the pallet to an AGV or another robotic device for removal.

[0118] According to some embodiments as shown in FIG. 4, the material handling machine may include a separate pallet elevator device 210 configured to serve multiple cells 111 in the storage locations 110 along an individual branch line 134. The cells along each individual branch line 134 may be serviced by one or more pallet elevator devices 210. Pallet elevator device 210 may include a receiver dock 218 positioned between vertical rails 216. Pallet elevator device 210 may be configured to move horizontally using horizontal actuators 214 and to move vertically using vertical actuators 212, to position the receiver dock 218 at a selected cell 111. Receiver dock 218 may be a conveyor system configured to move a pallet from receiver dock 218 and onto the appropriate standby section 185-2. Pallet elevator device 210 may be configured to receive an input pallet 112-*i* from an AGV (such as a forklift) at a point pickup point 220, depicted in FIG. 4, and move the input pallet 112-*i* in both vertical and horizontal direction, so that the pallet elevator device can present a pallet to the standby section 185-2 at any one of multiple cells 111 at different positions along the branch line. The pallet elevator device 210 may include a track, chain, belt, lead screw, or any other motorized system. A suitable pallet elevator device 210 may include the Unit Load AS/RS made by Interlake Mecalux.

[0119] As illustrated in FIG. 5, pallet elevator device 210 and input pallet 112-*i* are positioned at a selected cell 111 (i.e. the top right cell 111). Movement of pallet elevator device 210 may include a horizontal movement using horizontal actuators 214, a vertical movement using vertical actuators 212, or both. In operation, pallet elevator device 210 may activate the horizontal actuators 214 and vertical actuators 212 sequentially or at the same time. Upon reaching the appropriate cell 111, pallet elevator device may advance input pallet 112-*i* onto the standby section 185-2 at the cell, then return to the pickup point 220 to await a new input pallet 112-*i*.

[0120] Returning to FIGS. 3A and 3B, according to some embodiments, processing section 185-1 may be movable vertically along a guide such as a rail or track. The processing section 185-1 may be movable between the heights of standby section 185-2 and retrieval section 185-3. In a first position, the processing section 185-1 may be aligned with the standby section 185-2 for receipt of the standby pallet 112-2. In a second position, the processing section 185-1 may be aligned with the retrieval section 185-3 to advance an empty pallet 187 to retrieval section 185-3.

[0121] According to some embodiments, a plurality of standby sections 185-2 may be employed. This may allow multiple standby pallets 112-2 to be received by warehouse system 100. Each standby section 185-2 may be arranged to feed into a successive standby section 185-2. The foremost standby section 185-2 may feed into a processing section 185-2, while the rearmost standby section 185-2 may receive the pallet 112-2 from a material handling machine such as an AGV. Additionally or alternatively, a standby section 185-2 may be used to receive multiple pallets to be sequentially advanced to processing section 185-1. Thereby,

greater than one standby pallet **112-2** may be held in place within warehouse system **100**. When processing pallet **112-1** is emptied, the foremost standby pallet **112-2** will be placed in the processing section **185-1**, and each standby pallet **112-2** will advance to the next standby section **185-2**.

[0122] Returning to FIG. 2, an elevator **115** is placed intermediate branch line **134** and cells **111**. Alternatively, an elevator **115** may be placed between main line **132** and branch line **134**, or at a position within the branch line **134**, wherein each branch line is configured to serve an individual height of cell **111**. One or more carriages **117** are mounted on elevator **115** and are movable along elevator **115** in the z axis between a base position adjacent branch line **134** for transfer of articles to the conveyor, and any of a plurality of cell positions adjacent cells **111** for receiving articles.

[0123] At each cell, a robotic picker such as a picker arm **114** may be provided. Picker arm **114** may be a suitable pick-and-place robot. Picker arm **114** is able to move in multiple axes. Picker arm **114** may be configured to move a payload of up to 12 kg or more, and have a reach up to or greater than 2000 mm. An example of a suitable picker arm **114** is the FANUC M-20iA/12 Series Robot having a payload of 12 Kg, reach 2009 mm and movable in six axes. Examples of suitable picker arms are ABB model IRB-1300-en, ABB model IRB-1660-ID, ABB model IRB-2660-8-2, Fanuc model M-10iA/10M and Fanuc model M-16iB/10L.

[0124] The picker arm **114** is configured to retrieve individual items from the palletized cases **126**, and place the retrieved items into a nearby tote **116**, e.g., supported on elevator **115**. Picker arm **114** may be further configured to perform de-palletizing operations. For example, each picker arm **114** may be configured to remove packing material from a pallet **112** at the corresponding storage location, or to open or dismantle cases on the pallet in order to access individual units.

[0125] Each picker arm **114** may be further configured to dispose of removed packaging material, for example by grasping material to transfer it to a disposal site such as a chute (not shown).

[0126] As depicted, each picker arm **114** is mounted above its respective cell **111**. Such mounting provides effective access to articles through the tops of cases. However, other mounting arrangements are possible. For example, picker arm **114** may be mounted below the pallet, or suspended on a side frame. According to some embodiments, the picker arm **114** can be mounted and traversable along a track, such that a picker arm **114** can be operated in a number of positions, each proximate a cell **111** for dismantling a pallet **112** at that cell. Each picker arm **114** has an operating envelope **136** defined by geometry and range or motion of the pickers. The operating envelope **136** is the spatial region in which the picker is capable of grasping or otherwise interacting with items. As is apparent from FIG. 2, the operating envelope **136** of each picker arm **114** reaches a portion of the corresponding cell **111** and elevator **115**. Specifically, elevator **115** and each processing pallet **112-1** lies within operating envelope **136**.

[0127] Turning to FIG. 6, a side view of an example operating envelope **136** for picker arm **114** is illustrated. As can be seen, the picker arm **114** may reach the bottom of processing pallet **112-2**. Additionally, the picker arm **114** can reach to tote conveyor **116**, as well as on the sides and behind processing pallet **112-1**. It can be noted that the physical constraints of picker arm **114** may provide a larger

or smaller operating envelope. Similarly, based on joints defining rotational axes of picker arm **114**, “dead zones” or “blind spots” may occur, where the picker arm is unable to articulate to. These zones may be known and defined within a control system for picker arm **114**.

[0128] According to some embodiments, processing section **185-1** may be further configured to lift processing pallet **112-1** vertically as the picker arm **114** is retrieving the individual items from the palletized cases **126**. For example, the processing pallet may be lifted as layers of cases **126** are removed, such that each successive case is processed approximately at a consistent height. In these embodiments, the picker arm **114** may not require an operating envelope **136** extending to the base of processing pallet **112-1**. Rather, the processing pallet **112-1** may be lifted to ensure that the case **126** at the top of processing pallet **112-1** is positioned with operating envelope **136**.

[0129] Each picker arm **114** is equipped with an end effector **121** suitable for selectively holding individual articles on pallets **112** and releasing the articles for transport along conveyor system **130**. The configuration of end effector **121** may depend on characteristics of articles to be moved. For example, objects with planar surfaces and relatively low weight may be effectively engaged using an end effector with one or more vacuum cups. Other objects having curved or irregular surfaces or larger weights may be grasped with claws or clamping devices of corresponding size and shape.

[0130] In some embodiments, each picker arm **114** may have a unique end effector **121**. In other embodiments, some pickers may have common end effectors. For example, a first type of end effector may be present on all picker arms **114** used to manipulate boxed articles, and a second type of end effector may be present on all pickers used to manipulate bottled articles.

[0131] According to some embodiments, multiple, interchangeable end effectors may be available. For example, the picker arm **114** may be equipped with a releasable linkage, the linkage configured to engage with or disengage with a selected one of a plurality of end effectors. The releasable linkage may include physical connection, electric communication and vacuum communication. The available end effectors may be placed in a rest position within the operating envelope **136**. When needed, picker arm **114** may move to engage, via the linkage, with a suitable end effector at the rest location, based on the characteristics of a pallet to be dismantled. Once engaged, the swappable end effector can be employed to perform a specific task. After the task has been performed, picker arm **114** may return the swappable end effector to the rest location and release the linkage.

[0132] FIG. 7 illustrates an example end effector **121**. The specific end effector is a destrapper-debander **190**. The destrapper-debander **190** is configured to remove strapping **193** that is used to secure cases **126** onto the pallet base. Strapping **193** may be metal, nylon, plastic, or any other material having tensile strength to maintain individual case **126** placement on the pallet base. The strapping **193** may be looped about the pallet.

[0133] Destraper-debander **190** may be connected (releasably or fixedly) to the robotic arm **114** via connector **191**. Connector **191** may include physical linkages, such as quick connects for electrical connections, and pneumatic connections. Connector **191** may be further configured to connect to other end effectors **121**. For example, another end effector

121 may be a suction plate or plurality of suction cups, configured to lift, move, and release plastic, paper or corrugated products.

[0134] FIGS. 8A and 8B respectively show detailed side and top views of the destrapper-debander **190**. Destrapper-debander **190** comprises a motor **194**, roller **195**, scissor **196**, and clamp **197**. In operation, robotic arm **114** positions the destrapper-debander **190** proximate the strapping **193**. Clamp **197**, using a pinching mechanism, holds strapping **193** in place. Once strapping **193** is held in place, scissor **196** slice the strapping **193**. Because clamp **197** is holding the strapping **193** in place, the strap maintains its position while the tension is released (avoiding undesired unpredictable movement). Once strapping **193** is cut, motor **194** spins destrapper-debander to wind the strapping **193** about the entire destrapper-debander **190**. Roller **195** may be a spring-loaded roller employed to maintain the position of the strapping **193** on the destrapper debander as strapping **193** is wound.

[0135] Once strapping **193** is completely wound, arm **114** may place the strap in a dunnage drop zone or chute. Specifically, the arm **114** may move destrapper-debander **190** to be positioned above a dunnage drop zone or chute. There, the clamp **197** will disengage from holding strapping **193**, and allow or push the wound reel of strapping **193** down the chute. This cycle may be repeated as necessary to remove any/all straps from processing pallet **112-1**.

[0136] An example pallet **112** is depicted in FIGS. 9A-9B. As depicted, pallet **112** includes a plurality of cases **126**, arranged in vertically-stacked layers, each layer having a defined arrangement of cases. The layers may be separated by cardboard or polymer sheets **129** referred to as slip sheets. In addition, lids **122** may be secured atop the stack of cases **126**. Binding material such as strapping **193** may be wrapped around each pallet **112** to hold cases **126** together during shipment. Cases **126** may have open or closed tops.

[0137] The cases of FIG. 9A are half-slotted cases (or 'HSCs'), namely cases with a sealed bottom and open top. An open top may be free from any flaps. Use of HSC provides open top-access to retrieve the individual packaged products from within the case. In other embodiments, cases may be sealed at both ends (e.g. regular slotted cases, "RSCs"). Picker arms **114** may be configured to open or remove case tops without removing cases from the pallet **112**.

[0138] The end effectors **121** of picker arms **114** may have other auxiliary tools for dismantling packaging. For example, end effectors may be equipped with blades for cutting binding material such as strapping **193**, and for cutting or otherwise removing tops of closed-top cases **126**. The auxiliary tools may further including auxiliary holding mechanisms for pulling packaging material away from pallets **112**. For example, an end effector may have a downward-facing suction device for holding articles and withdrawing them vertically, and a laterally-facing suction device for pulling objects such as binding material away from the sides of a pallet **112**.

[0139] According to some embodiments, removed packing material is dropped by the picker arm **114** at a specific location, such that an AGV may be able to remove the excess cardboard to a disposal location. The AGV may be configured to compact the corrugated material, along with receive an empty pallet base. In other embodiments, packing material may be placed into a receptacle for subsequent disposal.

[0140] Picker arms **114** may be operated under control of a guidance system. For example, in the depicted embodiment, picker arms **114** are optically guided, e.g. using a suitable machine vision system. The machine vision system includes one or more cameras **123** mounted proximate to each picker arm **114** to capture overhead images of pallets **112**, and one or more cameras **123** positioned laterally of each cell **111** to acquire side images of pallets **112**. Acquired images may be registered to a three-dimensional coordinate system and processed to detect locations of articles on pallets **112**. For example, suitable image processing techniques may include use of edge detection algorithms to locate contours corresponding to edges **125** of individual articles. Located edges may be matched to known article shapes to infer positions of articles **127**.

[0141] Alternatively, the picker arm **114** may be controlled according to a representation of the geometry of pallet **112**, its cases **126**, and individual articles **127**. That is, a representation may be stored for each SKU handled within warehouse system **100**, describing a standard arrangement of pallets and cases for that SKU, e.g., based on a coordinate system. The standard arrangements may be used to direct picker arms **114** and track progress of dismantling each pallet. Based on removing an individual article **127** from the case **126**, the picker arm **114** may modify the memory to indicate that the specific individual article **127** from the virtual representation of the pallet **112** has been removed.

[0142] Referring again to FIG. 1, conveyor system **130** includes a series of sub-conveyors. The conveyors may be belt conveyors, roller conveyors or a combination thereof. Disposed on the surface of conveyor system **130** are a plurality of totes. The totes may be reusable bins made of a hard plastic or similar durable material, such as the AST3220-12 made by the Obris Corporation. Each individual tote may have a unique identifying label, such as an ID, RFID Tag or bar code. The unique identifying label may be configured to be scanned and tracked by readers in warehouse system **100**. For example, each tote may have a unique RFID tag identifying the tote, and the position of each RFID tag may be tracked in real-time as totes traverse warehouse system **100**. Alternatively, totes may be identified using visual tags such as bar codes which may be tracked using a series of cameras or optical scanners within warehouse system **100**. According to some embodiments, the totes may be constructed cases made from a corrugated material.

[0143] Conveyor system **130** may be equipped with a high-friction surface, such that totes may be supported on the conveyor without inadvertent movement along the conveyor.

[0144] Conveyor system **130** operates to transport individual totes through the warehouse system **100**. Throughout operation of conveyor system **130**, the totes may be brought from a tote staging station **138** to cells **111** and to packing system **120**. From the packing system **120**, totes are returned to a tote staging station **138**.

[0145] FIG. 10 shows an example tote **116** for use in a warehouse system for fulfilling orders. According to some embodiments, a plastic liner or other bag may be placed in the tote (i.e. a lined tote **118**).

[0146] Tote staging station **138** is configured to prepare a tote for reception of an order. At tote staging station **138**, each tote may be sent through a machine configured to insert a liner into the tote. The plastic liner of lined tote **118** may

be placed inside the tote by a liner machine such as the Bagmaker inserter Flexim-31 manufactured by Pattyn. Such a liner machine may form a bag from a roll of polyethylene film or other product, automatically cut the film, and cuff the other edge of the bag around the tote edge. The liner is intended to protect against any cross contamination of products placed into tote **116**, provide a moisture containment barrier between products placed in tote and tote **116**, aid case loading at the packing system **120**, and add additional dunnage for extra product protection if the order is to be shipped. Placing liners in totes **116** also assists with handling of orders. Specifically, as products are placed in a lined tote **118**, the liner unitizes the order so that the entire order can be moved by manipulation of the liner. Accordingly, assembled orders may be very easily transferred from a lined tote **118** to a case for shipping.

[0147] Returning to FIG. 1, a main line **132** may be defined as a transport conveyor configured to transport a tote from tote staging station **138** to a specific storage unit **110**. Once tote has been delivered to a specific storage unit **110**, a branch line **134** may transport the tote within the specific storage unit **110** to a picking position at a cell **111**.

[0148] Conveyor system **130** further includes a transfer mechanism including diverters at junctions between individual conveyors. The diverters are operable to selectively direct objects on the conveyors, e.g. from a main line **132** to a specific branch line **134**, such that a specific path may be defined between arbitrary locations within conveyor system **130** by operation of the diverters. Diverters may also be employed to divert between multiple main lines **132**. For example, a path may be defined from tote staging station **138** to a first cell **111** in a first storage unit **110** to a second cell **111** in a second storage unit **110**, etc. Main lines **132** and branch lines **134** can include multiple sub-conveyors positioned at different vertical heights (in the z dimension), and vertical actuators or elevators configured to lift a tote from one sub-conveyor to another.

[0149] Responsive to an order received, conveyor system **130** is operable to transport totes via main lines **132** and branch line **134** to picking positions for cells **111** corresponding to items in the order. Once the tote has been transported to all necessary cells **111**, the tote is delivered to the packing system **120**. The order packing system **120** is configured to erect a case having specified dimensions for the specific order, pack the order, then insert packing materials (also known as 'dunnage'), seal and label the erected case for shipments.

Order Packing System

[0150] Turning to FIG. 11, an example of an order packing system **120** is depicted. The order packing system **120** comprises a random case erector **314**, an order staging subsystem **380** and a packing cell **310**. Although a single packing cell **310** is shown, embodiments may include multiple packing cells.

[0151] Order staging subsystem **380** carries a sequence of individual orders of products to be packaged and shipped. In the depicted example, each order of products is held in a container such as the tote **116** or a lined tote **118**, e.g. a reusable bin. Order staging subsystem **380** transports orders of products from the tote transportation conveyor system **130** to a packing station **318** at which products may be packed for shipping. Specifically, order staging subsystem **380** comprises a tote conveyor **382** for carrying totes **116** or

lined totes **118** to a packing station **318** and carrying out, from the packing station **318**, empty totes **352**. In the depicted example, a branch conveyor **384** is provided, onto which filled totes **116** may be diverted for packing at packing cell **310**.

[0152] The tote conveyor **382** according to some embodiments may be a series of sub-conveyors. The conveyor has multiple input and output points such that totes **116** or lined totes **118** may be introduced to or removed from the conveyor at multiple locations. An exchange mechanism including one or more diverters may be provided, such that a path for each tote **116** or lined totes **118** may be defined by selectively operating the mechanism. The tote conveyor **382**, according to some embodiments, may be configured to orient or tilt a filled tote **116** or lined totes **118** to a specific angle.

[0153] The packing cell **310** comprises a plurality of case blank magazines **312**, random case erector **314**, a dunnage dispenser **316**, a packing station **318**, a case sealer **320**, and a label station **322**. These components of the packing cell **310** are connected by a case conveyor **324**.

[0154] Multiple case blank magazines M1-M16 may be present, containing a plurality of case blanks **101** of different types. Although the depicted embodiment illustrates sixteen magazines M1-M16, more or less may be employed. Each magazine M1-M16 may contain case blanks of a single type, and each type of case blanks may have different dimensions or other properties (such as thickness or material). Random case erector **314** receives an individual blank **101** from case blank magazine M1-M16 by way of case conveyor **324**, and forms erected cases in a manner as will be described in relation to later figures.

[0155] Blanks may be released from magazines M1-M16 along case conveyor **324** in a defined order, so that cases can be erected in a sequence corresponding to a sequence of orders.

[0156] According to some embodiments, random case erector **314** is configured to construct a sequence of cases of different sizes, from the blanks of different sizes based on control instructions. Case erector may if necessary, modify its construction mechanism as will be described in relation to later figures to construct the case to said size.

[0157] Erected cases are transported by case conveyor **324** to dunnage dispenser **316** to receive dunnage. Dunnage can be generally defined as packing material to protect products during shipping. For example, types of dunnage include bubble wrap, packing peanuts, paper or corrugated cardboard inserts. Dunnage dispenser **316** may include any mechanisms suitable for providing dunnage of one or more types. For example, dunnage dispenser **316** may include one or more of: rolls for dispensing wrap such as bubble wrap, or hoppers for dispensing particles such as packing peanuts. At dunnage dispenser **316**, according to some embodiments, the type of dunnage, the length or amount of dunnage are selected, and the dunnage is dispensed into the constructed case.

[0158] Next, cases with dunnage **328** are transported by case conveyor **324** to the packing station **318** to become packed cases **330**.

[0159] At packing station **318**, products from a filled tote **116** or lined tote **118** at packing position **360** are removed from the tote and placed into the constructed case with dunnage **328**. Products may be manually transferred from filled tote **116** to the constructed and dunned case **328** by a

human operator, or automatically transferred by a suitable machine, or a combination thereof. In an example, the products may be transferred by a mechatronic system including a robotic arm.

[0160] After being packed at packing station 318, the packed cases 330 are transported by case conveyor 324 to sealing station 320 to be closed and sealed. Sealing station 320 is configured to control the selection, dispensing, and application of the sealing material. For example, a type of tape may be selected and applied to a case. Sealing station 320, according to some embodiments, may be a robotic articulated arm, or any other electromechanical device that can apply the seal to the box. According to some embodiments, sealing station 320 can include individual or combined electromechanical systems for dispensing of a sealing material and the application of the sealing material to a case.

[0161] Sealed cases 332 are transported by a case conveyor 324 to label station 322 to be labelled for shipment. Cases outputted from label station 322 are completed cases 334, ready for postal/courier distribution. The label station is configured to generate the shipping label, print the shipping label, and apply the shipping label. A shipping label can include information such as the postal address, and the method of shipping to be applied to the case. According to some embodiments, shipping information may be encoded in a barcode or any other encoded visual data structure. Label station 322, may be a robotic articulated arm, or any other electromechanical device that can apply the shipping label to the case. According to some embodiments, label station 322 can include individual or combined electromechanical systems for printing the shipping label and the application of the shipping label to a case.

[0162] The tote conveyor 382 and the case conveyor 324 are configured to deliver to the packing station 318 the totes and constructed cases in corresponding sequences. That is, a case may be selected for each order, based on the physical size or weight of the products in the order. As will be described in greater detail, the sequence of orders and cases presented at packing station 318 may be matched to one another such that a case that corresponds to the size of each order is brought to the packing station along with the tote containing that order.

[0163] As shown in FIG. 12, the order packing system 120 comprises four packing cells 310. Each packing cell 310 may contain the components as described in relation to FIG. 11. However, any number of packing cells may be present, subject to space and logistical limitations. As depicted, the four packing cells are commonly fed by a single order bin conveyor 2782. However, in other embodiments, multiple separate order bin conveyors may be provided.

[0164] Increasing the number of packing cells 310 may enable greater throughput of orders through the system. Further, the plurality of packing cells 310 may enable optimization through configuration of the individual packing cells. For example, when multiple packing cells 310 are present, a greater range of case and dunnage types and sizes may be accommodated. For example, certain packing cells 310 may only have case blanks 101 corresponding to smaller cases, to be used for totes that contain smaller products.

[0165] Order packing system 120, according to some embodiments, may further include branch conveyors 2784 to feed the various packing cells 310. The order packing system 120 and packing cell 310 may also use the branch conveyor 2784 and the order bin conveyor 2782 to transport

the empty totes for reuse, and the case conveyor 2724 to transport the completed orders (i.e. with a constructed case from a selected blank, filled with dunnage and products, sealed and labelled) towards an output for delivery to a customer.

[0166] According to some embodiments, order bin conveyor 2782 may orient the totes at an angle for easy unloading of the contents from the tote. For example, totes may be oriented with an opening facing packing position 318.

[0167] Order packing system 120, branch conveyors 2784 and packing cells 310, may be controlled by a control system, which will be described in relation to later figures. For example, the control system may dictate any of the speed and position of orders and cases within the system, and the sequences of totes and cases that are presented at packing station 318 of any given packing cell. Control system may be implemented in any combination of programmable logic controllers (PLCs) and computing devices such as PCs. Each PLC associated with a particular packing cell 310 can form part of control system.

[0168] As shown, a sequence or queue of totes is formed on branch conveyor 384 by diverting totes from the tote conveyor 382. The sequence of totes are positioned so that the tote at the front of the sequence is located proximate packing position 360. Similarly, a sequence or queue of constructed cases is formed on the case conveyor 324 approaching the packing position 360. Each case in the sequence of cases corresponds to a filled tote 116 containing products. The size of the case constructed in the sequence of cases is based on the products in the corresponding filled tote 116.

[0169] FIG. 13 is a random case erector 314 used in the warehouse system of FIG. 1, within a packing cell 310. As illustrated, this random case erector 314 has 12 magazines M1-M12 feeding to case forming system 5100. Once the tote has been filled with all the order items according to specification, the tote is transported via the conveyor system 130 to the packing station 218. In the random case erector 314, a plurality of magazines M1-M12 may be supported by one or more frame structures above a common case conveyor 324. Magazines M1-M12 may be arranged in spaced longitudinal relation to each other vertically above case conveyor 324. Case conveyor 324 feeds an alignment conveyor 5206.

[0170] It may be observed in FIG. 13 that the overall configuration of random case erector 314 provides for a generally S-shaped path (or, if mirrored, a Z-shape) for case blanks through random case erector 314. More specifically, incoming blanks are conveyed on case conveyor 324 in a downstream X-axis direction to the case discharge conveyor 5117, to pick-up location. However, any other configuration (such as a C-shape) may be employed.

[0171] Magazines M1-M12 may each contain one or more stacks of product packaging, such as case blanks, with at least some and possibly each of the magazines M1-M16 containing different types/sizes and/or configurations of packaging/case blanks compared to other magazines. The size, configurations and types of case blanks (and the cases that can be formed therefrom) can vary to provide a range of case sizes, configurations and types that can be automatically processed by the random case erector 314 without the need for any manual intervention to modify any components of the system. A PLC 5132 (FIG. 18) of random case erector

314 may be programmed such that the particular dimensions/overall size/configuration (e.g. such as regular slotted case or “RSC”)/type of each of the blanks held in each one of the magazines M1-M12 is stored in the memory of the PLC **5132** (FIG. **18**).

[**0172**] Each magazine M1-M12 may provide a vertical stack of case blanks above case conveyor **324** and be operable to dispense single case blanks on demand under the control of PLC **5132** (FIG. **18**), in a flattened orientation onto case conveyor **324**. An example arrangement of a suitable type of vertical case dispensing magazine, is the magazine that forms part of the 310E case erector made by Wepackit Inc. of Orangeville, Ontario, Canada (<http://www.wepackitmachinery.com/310E/310E.pdf>).

[**0173**] PLC **5132** (FIG. **18**) may give an instruction to form a case, and if required, PLC **5132** (FIG. **18**) may cause one of magazines M1-M12 to dispense a blank of an appropriate configuration/size onto case conveyor **324** for delivery to alignment conveyor **5206**. PLC **5132** (FIG. **18**) is able to selectively move and transfer a single blank at a time onto case conveyor **324** from any one of magazines M1-M12. Therefore, separate individual case blanks may be fed in series and longitudinally in a desired sequence by case conveyor **324** to alignment conveyor **5206**. The particular sequence/order of case blanks that are placed onto case conveyor **324** of random case erector **314** may be determined and selected by PLC **5132** (FIG. **18**) or another control system as described hereinafter, such that case blanks may arrive at alignment conveyor **5206** in such a desired sequence in which it is desired to process the blanks within random case erector **314**.

[**0174**] PLC **5132** (FIG. **18**) may maintain in its memory, each available blank **111** size, the quantity of blanks **111** in each magazine M1-M16, and the dimensions of each available blank **111**. Additionally, PLC **5132** may store a sequence of cases to construct, in the form of a queue.

[**0175**] Once transferred from case conveyor **324** to alignment conveyor **5206**, the alignment conveyor **5206** may then under the control of PLC **5132** (FIG. **18**) move each blank sequentially to a packing location.

[**0176**] A sensor (not shown) such as an electronic eye model 42KL-D1LB-F4 made by ALLEN BRADLEY, may be positioned and operable to detect the presence of the front edge of a blank as each blank approaches the end of case conveyor **324** and start of alignment conveyor **5206**. Upon detecting the front edge, sensor may send a digital signal to PLC **5132** (FIG. **18**) signalling that a particular blank (the size/configuration/type of which PLC **5132** (FIG. **18**) is aware) has moved to a position where alignment conveyor **5206** can start to move. PLC **5132** (FIG. **18**) can then cause the motor for alignment conveyor **5206** to be activated to move the blank downstream. In this way, there can be a “hand-off” of each blank from case conveyor **324** to alignment conveyor **5206**.

[**0177**] Once the rear edge of each blank passes the sensor, a signal may be sent to PLC **5132** (FIG. **18**) which can then respond by sending a signal to shut down the motor driving case conveyor **324**. Case conveyor **324** is then in a condition to await a further signal thereafter to feed the next blank in the series of blanks on case conveyor **324** to alignment conveyor **5206**. Meanwhile random case erector **314** can be operated to move the blank on alignment conveyor **5206** to the packing location.

[**0178**] Optionally, and as in the system described above, in random case erector **314**, PLC **5132** (FIG. **18**) may verify that the type/size/configuration of the case blank at the pick-up location matches the expected case blank. For example, the top surface of each case blank may include a bar code identifying its type/size/configuration, and this bar code may be read at the pick-up location by a suitably positioned bar code reader. The type/size/configuration of the case blank read from this bar code may be compared to the expected type/size/configuration of case blank, which may be determined from a record of the next scheduled case blank stored in memory of the PLC, as described above. Verification is successful when there is a match. When there is not a match, PLC **5132** (FIG. **18**) may issue a signal requesting manual operator intervention.

[**0179**] FIGS. **14** and **15** illustrate the input end a plurality of magazines M1-M16 that may be configured to feed to a common case conveyor **324**. The case conveyor **324** feeds to alignment conveyor **5206**. Alignment conveyor **5206** is configured to output a blank to a case forming system, which will be described in relation to later figures.

[**0180**] A sensor (not shown) may be provided in at each magazine M1-M16 to monitor each supply of blanks **101**. Sensor may be operable to send a warning signal to PLC **5132** (FIG. **18**) that can alert an operator that the magazine is low and needs to be replenished. The sensor may be a part number 42GRP-9000-QD made by Allen Bradley.

[**0181**] With reference now to FIG. **16**, by way of representative example of the construction of a magazine, magazine conveyor **1203(1)** may include a frame **1215** that supports five, generally parallel, and spaced continuous belts **1213** that may be made of any suitable flexible material such as Ropanyl. The belts **1213** may each extend between rotatable idler wheels **1221** mounted on a freely rotatable shaft and rotatable drive wheels **1223**. Drive wheels **1223** may be mounted for rotation with and to a common drive shaft **1225** of a servo motor **1219** that may be interconnected via and in communication with a servo drive to the PLC **5132** (FIG. **18**) of case forming system **5100**. Conveyor belts **1213** may each have an upper belt portion that together may support one or more stacks of blanks **101** thereon. PLC **5132** (FIG. **18**) may give an instruction to form a case, and if required, PLC **5132** (FIG. **18**) may cause upper belt portion of belt **1213** to move towards case conveyor **324** by operation of servo motor **1219** rotating drive wheels **1223**. In this way belt **1213** can, if necessary, move a blank **101** to a position adjacent to the case conveyor **324**.

[**0182**] Positioned proximate the end of each magazine conveyor **1203** adjacent case conveyor **324** may be a vertically and longitudinally oriented plate. Each plate **1230** may be supported by a plurality of plate support members **1235** that may be part of frame **1215**. A lower longitudinally extending edge **1233** of plate **1230** may be positioned so that only the bottom blank in a stack of blanks (i.e. the blank that is immediately above the upper portions of the belts) can pass through a slot provided beneath lower edge **1233** of plate **1230** and the horizontal plane formed by the upper surface of the upper portions of the belts **1213**. In this way, a slot **1231** can be provided that can permit a single blank at a time from the bottom of the stack to be pushed transversely through the slot and onto the case conveyor **324**.

[**0183**] A pushing mechanism may be provided to respond to signals from PLC **5132** (FIG. **18**) of the case former to push a blank in a magazine from the bottom of the stack

though the slot 1231 and onto case conveyor 324. The pushing mechanism may be any suitable type of device and may for example include a plurality of lugs 1217 located in the spaces between belts 1213. The lugs may be driven in a cyclical path by a common type crank mechanism (not shown) that may include a common pneumatic or hydraulic cylinder with a piston controlled by PLC 5132 (FIG. 18) by activating appropriate valves to suitably control the flow of pressurized air/hydraulic fluid to the cylinder. The cylinder may have a piston arm attached to a longitudinally oriented bar member that may be mounted for rotation. The crank mechanism may be configured to provide a path for the lugs 1217 that commences in a position behind the bottom blank in a stack, then moves transversely between the belts 1213 while engaging the rear side edge of the bottom blank thereby pushing the bottom blank through the slot 1231. Once the crank mechanism reaches the end of the stroke, the lugs 1217 will descend downwards beneath the stack of blanks and move transversely in an opposite direction back to the starting position, while at the same time not engaging the next bottom blank on the stack and passing beneath the stack. The path returns the lugs 1217 back to the start position so that when signalled by PLC 5132 (FIG. 18) to load another blank onto case conveyor 324, the operation can be repeated.

[0184] In summary, PLC 5132 (FIG. 18) can thus control motor 1219 and thus the movement of each conveyor 1203 as well as the movement of the lugs 1217, and thus is able to selectively move and transfer a single blank at a time onto case conveyor 324 from any one of magazines M1 to M16.

[0185] Therefore, in a multi-magazine system, separate individual case blanks may be fed in series and longitudinally by case conveyor 324 to alignment conveyor 5206. The particular sequence/order of case blanks that are placed onto case conveyor 324 of case forming system 5100 may be determined and selected by PLC 5132 (FIG. 118) such that case blanks may arrive at alignment conveyor 5206 in such a desired manner in which it is desired to process the blanks at least within case forming system 5100.

[0186] Further, PLC 5132 (FIG. 118) may maintain in its memory records of case blanks that have been placed onto case conveyor 324. For example, this information may include the type/size/configuration of the case blank and, where the case forming system 5100 includes a labeller, the label information to be applied to the case blank. A new record can be added each time a request for a new case is received and, optionally, records can be removed once a case has been formed (and labelled). Thus, such records may be organized and maintained in sequence in the memory of PLC 5132 (FIG. 18) using a conventional shift registering technique. In this way, the record for the next case blank scheduled to arrive at alignment conveyor 5206 may be provided at the output of the shift registers as that case blank arrives, and the type/configuration/size of that case blank and the label information for that case blank may be determined from the provided output.

[0187] The belt of case conveyor 324 may be driven by a suitable motor such as a DC motor or a variable frequency drive motor 2591/5292 (see FIG. 18) controlled through a DC motor drive (all sold by Oriental under model AXH-5100-KC-30) by PLC 5132.

Case Forming System

[0188] FIGS. 17A to 46 illustrate case forming system 5100. Case forming system 5100 may be used in the random case erector 314 at the packing station 120.

[0189] With reference initially to FIGS. 17A and 17B, a case forming system 5100 is illustrated. Case forming system 5100 may be connected to multiple magazines in a configuration as described in relation to FIGS. 13 to 16. Case forming system may receive blanks 101 via case conveyor 324, at a pickup area. There, an end effector 5120 for retrieving the knock-down case blanks may pick up the blank 101 from the pick-up area and place the blank 101 on a shuttle 5140. As will be described hereinafter, the end effector 5120 and shuttle 5140 co-operate to manipulate the knock-down blanks in such a way as to erect them into sleeves.

[0190] Case forming system 5100 may also include a folding apparatus generally designated 5130, configured to fold one or more flaps of each sleeve, and a sealing station 5135 at which flaps of the cases are sealed. Case forming system 5100 may also include a case re-orienting station 5116 and a case discharge conveyor 5117 for receiving and moving cases away once they have been fully erected.

[0191] An example of a scheme for the power and data/communication configuration for system case forming 5100 is illustrated in FIG. 18. The operation of the components of case forming system 5100 may be controlled by a programmable logic controller (“PLC”) 5132, which may receive instructions from or be integrated with a control server 600 for warehouse system 100. PLC 5132 may be accessed by a human operator through a Human Machine Interface (HMI) module 5133 secured to a frame 5109 (FIG. 17A) of the system. HMI module 5133 may be in electronic communication with PLC 5132. PLC 5132 may be any suitable PLC and may for example include a unit chosen from the Logix 5000 series devices made by Allen-Bradley/Rockwell Automation, such as the ControlLogix 5561 device. HMI module 5133 may be a Panelview part number 2711P-T15C4D1 module also made by Allen-Bradley/Rockwell Automation. PLC 5132 may be in communication with other control components by way of a network interface 5135 for sending and receiving information and instructions. In some embodiments PLC 5132 may be implemented as a virtualized device, e.g. on a PC.

[0192] Electrical power can be supplied to PLC 5132/HMI 5133, and to all the various servo motors and DC motors that are described further herein. Compressed/pressurized air can also be supplied to the vacuum generators and pneumatic actuator through valve devices such as solenoid valves that are controlled by PLC 5132, all as described further herein. Servo motors may be connected to and in communication with servo drives that are in communication with and controlled by PLC 5132. Similarly, DC motors may be connected to DC motor drives that are in communication with and controlled by PLC 5132, again all as described further herein. Additionally, various other sensors are in communication with PLC 5132 and may (although not shown) also be supplied with electrical power.

[0193] With reference now to FIGS. 19A, 19B, and 20, an example of one kind of knock-down case blank 101 that can be processed by case forming system 5100 to form a regular slotted case (RSC) is disclosed. Other types of knock-down case blanks, and knock-down case blanks of different sizes can also be processed by case forming system 5100.

[0194] Each case blank **101** may be generally initially formed and provided in a knock-down configuration—i.e., a flattened tubular configuration—as shown in FIGS. **19A** and **19B**. Each blank **101** has a height dimension “H”; a length dimension “L”; and a major panel Length “Q” (see FIG. **19A**). By inputting each of these three dimensions for a blank to be processed by case forming system **5100** into PLC **5132**, PLC **5132** can determine if the case forming system **5100** can process that size blank without the necessity for manual intervention to make an adjustment to one or more components of the case forming system **5100**. If PLC **5132** determines that the adjustment can be made without human intervention, the PLC may make the necessary adjustments to positions and/or movements of at least some of the components forming case forming system **5100**.

[0195] Blank **101** may have opposed major side panels A and C integrally interconnected to a pair of opposed minor side panels B and D to form a sleeve, seen in FIG. **20**, when opened. An overlap strip of case blank material may be provided between panel B and panel A that can be sealed by conventional means such as a suitable adhesive, to provide an overlapping seam joint in the vicinity of “P” (see FIG. **19A**). This seam joint at the overlap forms a knock-down case blank in which the panels A, B, C and D are joined into a continuous blank that is of generally flattened tubular configuration, as shown in FIGS. **19A** and **19B**.

[0196] Also, as shown in FIGS. **19A**, **19B** and **20**, are major and minor end flaps E, H, L, I that are provided at one end of the respective major and minor side panels A-D. A second set of major and minor end flaps F, G, K and J are provided on the opposite, lower/bottom end of the major and minor side panels A-D. However, in other embodiments, cases having other panel configurations can be formed. The panels and flaps are connected to adjacent flaps and/or panels by predetermined fold/crease lines as shown in FIGS. **19A** and **19B**. These fold/crease lines may for example be formed by a weakened area of material and/or the formation of a crease with a crease forming apparatus. The effect of the fold lines is such that one panel such as for example panel A can be rotated relative to an adjacent panel such as D or B along the fold lines. Flaps may also fold and rotate about fold lines that connect them to their respective panels.

[0197] As will be described hereinafter, case blank **101** may be transformed from a knock-down blank (i.e., a generally flattened tubular configuration) to an open sleeve (open tubular configuration) and the flaps may be folded and sealed to form the desired erected case configuration. Case forming system **5100** is configured to deliver each case with an upwardly facing opening suitable for top loading. In another embodiment, case forming system **5100** may be configured to deliver each case with a sideways facing opening suitable for side loading.

[0198] Case blanks **101** may have flaps that provide material that can, in conjunction with a connection mechanism (such as for example with application of an adhesive, sealing tape or a mechanical connection such as is provided in so-called “Klick-Lok™” case blanks) interconnect flap surfaces, to join or otherwise interconnect, flaps to adjacent flaps (or in some embodiments flaps to panels), to hold the case in its desired erected configuration.

[0199] Case blanks **101** may be made of any suitable material(s) configured and adapted to permit the required folding/bending/displacement of the material to reach the desired configuration. Examples of suitable materials are

chipboard, cardboard or creased corrugated fiber-board. It should be noted that the blank may be formed of a material which itself is rigid or semi-rigid, and not easily foldable but which is divided into separate panels and flaps separated by creases or hinge type mechanisms so that the case can be erected and formed.

[0200] Turning to FIGS. **32** and **33**, end effector **5120** has a dedicated, independently driven and controlled movement apparatus **5115** that allows end effector **5120** to move in a plane defined by both vertical axis Z and horizontal axis Y in FIG. **32**. Thus, movement of the end effector **5120** can only be in the vertical Z and horizontal Y directions (i.e. directions parallel to axes Z and Y in FIG. **32**)—the end effector cannot move in a horizontal X direction (i.e. a direction parallel to axis X in FIG. **32**). If the movement of the end effector **5120** is restricted to only Z and Y directions, a moving apparatus can be constructed that is relatively less complex than if movement in all three directions is required.

[0201] Movement apparatus **5115** includes a vertically oriented support tube **5169** that may be generally rectangular in cross section to which end effector **5120** is mounted by mounting blocks **5190** so that end effector **5120** moves in space with support tube **5169**.

[0202] The support tube **5169** is slidably mounted to a slide block **5158** for vertical movement and slide block **5158** is, in turn, mounted to a horizontal rail system for horizontal movement. More specifically, slide block **5158** has a pair of spaced, longitudinally and horizontally extending short inner blocks, each one fitting on one longitudinally extending rail **5160**, **5162** that holds the blocks securely but allows blocks to slide horizontally relative to the rails. An example of a suitable rails system is the Bosch Rexroth ball rail system in which the rails are made from steel and the blocks have a race of ceramic balls inside allowing the block to slide on the rails. Rails **5160**, **5162** are generally oriented horizontally are attached to a horizontally extending beam **5108** that is connected to frame **5109**. Slide block **5158** may be mounted to rails **5160** or **5162** for horizontal sliding movement along the rails. Slide block **5158** has a rail system allow support tube **5169** to be connected to it so as to be able to move vertically relative to slide block **5158**. More specifically, a rail extends vertically along a back surface of tube **5169** and is interconnected to a runner of slide block **5158**. Again, a suitable rail system is the Bosch Rexroth ball rail system referenced above. Thus, support tube **5169** can slide vertically relative to slide block **5158** and will move horizontally with the slide block.

[0203] To drive the end effector **5120** horizontally and vertically, a drive apparatus is provided which includes a left side servo motor **5150** and a right side drive motor **5154** (both of which may be servo motors such as the model MPL-B330P-MJ24AA made by Allen Bradley) mounted to either end of beam **5108**. Servo motor **5150** has a drive wheel **5152** and servo motor **5154** has a drive wheel **5156**. Both servo motors **5150** and **5154** can be independently driven in both directions at varying speeds by PLC **5132** (FIG. **18**) through servo drives. In this regard, both servo motors **5150** and **5154** may be provided with two separate ports, one for connection to a power line and the other for connection to a communication line to provide communication with the servo drive and PLC **5132**. Servo motors **5150**, **5154** may also have a third input which may provide

input for an electric braking mechanism. It should be noted that all of the servo motors described herein may be similarly equipped.

[0204] Four freely rotatable pulley wheels **5155a**, **5155c**, **5155d** and **5155f** are secured to the front face of the slider block **5158** and a further freely rotatable pulley wheel **5155b** is attached to the upper end of support tube **5169**. One end of a drive belt **5153**—that may for example be made from urethane with steel wires running through it—is fixedly attached to the bottom of support tube **5169** by a belt block **5159b**. From there the belt extends upwardly to block pulley **5155f**, around the upper side of block pulley **5155f** and then horizontally to servo drive wheel **5152**. The belt loops around the servo drive wheel **5152** and extends around the underside of pulley **5155a** and then upwards to pulley **5155b**. From there belt extends around pulley **5155b**, downwards to block pulley **5155c**, around block pulley **5155c** and then to servo drive wheel **5156**. After passing around servo drive wheel **5156**, belt **5153** extends to the upper side of block pulley **5155d**. From block pulley **5155d**, belt **5153** then extends vertically downwards to the bottom of the support tube **5169** where it attached to the support tube by a belt block **5159a**. With this arrangement, by adjusting the relative rotations of servo drive wheels **5152** and **5156** through the operation of the servo motors **5150** and **5154**, the vertical position of support tube **5169** relative to slide block **5158** can be adjusted. Additionally, by adjusting the relative rotations of servo drive wheels **5152** and **5156**, the horizontal position of slide block **5158** on rails **5160**, **5162** can be adjusted thus altering the horizontal position of support tube **5169** and end effector **5120**. It will thus be appreciated that by adjusting the direction and speeds of rotation of drive wheels **5152**, **5156** relative to each other the support tube **5169** can be moved vertically and/or horizontally in space within the physical constraints imposed by among other things the position of the servo drive wheels **5152** and **5156**, the length of the belt **5153**, and the length of support tube **5169**. The following will be appreciated in particular:

[0205] If wheels **5152** and **5156** both remain stationary then the position of support tube **5169** will not be altered;

[0206] If wheels **5152** and **5156** both rotate in the same clockwise direction and at the same speed relative to each other, then support tube **5169** (and thus end effector **5120**) will move horizontally from right to left;

[0207] If wheels **5152** and **5156** both rotate in the same counter-clockwise direction and at the same speed relative to each other, then support tube **5169** (and thus end effector **5120**) will move horizontally from left to right;

[0208] If wheel **5152** rotates counter-clockwise, and wheel **5156** rotates in opposite clockwise rotational directions, but both wheels rotate at the same rotational speed relative to each other, then support tube **5169**, and thus end effector **5120**, will move vertically downwardly;

[0209] If wheel **5152** rotates clockwise, and wheel **5156** rotates in opposite counter-clockwise rotational directions, but both wheels rotate at the same rotational speed relative to each other, then plates **5164**, **5166** will move vertically upwardly.

[0210] It will be appreciated that if the speeds and directions of the two servo motors are varied in different manner, then the motion of the support tube **5169** (and thus end effector **5120**) can be created that has both a vertical component as well as a horizontal component. Thus any

desired path within these two degrees of freedom (vertical in the Z direction and horizontal in the Y direction) can be created for support tube **5169**—and thus for the end effector **5120** (such as a path having curved path portions). Thus, by controlling the rotational direction and speed of the servo motors **5150**, **5154** independently of each other, PLC **5132** can cause support tube **5169** (and thus end effector **5120**) to move along any path within these two degrees of freedom, within the physical constraints imposed by the spacing of the drive wheels **5152**, **5156** and pulley wheel **5155b**, and the bottom of support tube **5169**.

[0211] An encoder may be provided for each of the servo motors **5150** and **5154** and the encoders may rotate in relation to the rotation of the respective drive wheels **5152**, **5156**. The encoders may be in communication with, and provide signals through the servo drives to PLC **5132**. Thus PLC **5132** can in real time know/determine/monitor the position of the belt **5153** in space and thus will determine and know the position of the end effector **5120** in space at any given time. The particular types of encoders that may be used are known as “absolute” encoders. Thus the system can be zeroed such that due to the calibration of both encoders of both servo motors **5150** and **5154**, the zero-zero position of the end effector in both Z and Y directions is set within PLC **5132**. The zero-zero position can be set with the end effector at its most horizontally left and vertically raised position. PLC **5132** can then substantially in real time, keep track of the position of the end effector **5120** as it moves through the processing sequence for a blank **101**.

[0212] Also associated with moving apparatus **5115** is a first, generally horizontally oriented caterpillar device **5114** and a second generally vertically oriented caterpillar device **5118**. Each of the caterpillars **5114** and **5118** have a hollow cavity housing hoses and wires carrying pressurized air/vacuum and electrical/communication wires. Caterpillar **5114** allows such hoses and wires to move longitudinally as the support tube **5169** and erector head **5120b** are moved longitudinally. Caterpillar **5118** allows such hoses and wires to move vertically as the support tube **5169** and erector head **5120b** are moved vertically. The caterpillars allow hoses and wires to supply end effector **5120**. In this way both pressurized air/vacuum and/or electrical communication wires may be brought from locations external to the frame **5109** onto the moving end effector **5120**. An example of suitable caterpillar devices that could be employed is the E-Chain Cable Carrier System model #240-03-055-0 made by Ignus Inc. It should be noted that electrical communication between the PLC **5132** and the end effector **5120** could in other embodiments be accomplished using wireless technologies that are commercially available.

[0213] End effector **5120** has a bottom suction plate **5327** with a generally square shape and four peripheral flanged openings, each receiving a suction cup **5312**. It should be noted that while many types of suction cups may be employed on the end effector, a preferred type of suction cup is the model B40.10.04AB made by Piab. Each suction cup **5312** is connected to an outlet from a vacuum generator **5330** (FIG. 18). The vacuum generator may be any suitable vacuum generator device such as for example the model VCH12-016C made by Pisco. Vacuum generators each have an inlet interconnected to a hose (not shown) that can carry pressurized air from an air compressor or other vacuum source to the vacuum generator. The vacuum generator converts the pressurized air supplied to the inlet port into a

vacuum at one of the outlet ports. That vacuum outlet port is interconnected to a suction cup **5312** so that the suction cup can have a vacuum force. A solenoid valve device **5340** (FIG. **18**) is interposed along the pressurized air channel running between each vacuum generator and the source of pressurized air. The solenoid valve device **5340** may for example be a model CPE14-M1BH-5L-1/8 made by Festo. Valve device **5340** is in electronic communication with PLC **5132** and controlled by PLC **5132**. In this way PLC **5132** can turn on and off the supply of vacuum force to the suction cups **5312**.

[0214] End effector **5120** also has a reciprocating sensor rod **5380** which, when not in contact with a case blank, extends downwards through a central aperture in plate **5327**, below the level of the plane of suction cups **5312**. When the end effector **5120** is brought vertically downwards to retrieve a blank **101**, the erector head's movement just prior to suction cups **5312** contacting with the upper surface of the blank will be generally vertically downwards. Prior to the suction cups **5312** contacting the surface of a top panel of a blank, sensor rod **5380** will impact the top panel and cause sensor rod **5380**, which may be resiliently displaced due to a spring mechanism biasing the rod downwards, to be pushed upwards. This movement upwards of sensor rod **5380** relative to plate **5327** will cause a sensor (not shown) to be activated and send a signal to PLC **5132**. The sensor may be an inductive proximity sensor where a metal cylinder fixed on the rod is sensed by the sensor's circuitry due to changes in the inductance of an induction loop inside the sensor. Such a sensor may be an 871FM-D8NP25-P3 sensor made by ALLEN BRADLEY. When the PLC **5132** receives a signal from the sensor, it may respond to that signal by causing servo drive motors **5150** and **5154** to slow down so that the final few centimeters (e.g. 3.5 cm) of movement downwards towards contact between suction cups **5312** and the top panel of the blank occurs at a much slower rate. The sensor also allows the PLC to know how much further vertically downwards end effector **5120** must be lowered to establish proper contact between suction cups **5312** and the top panel of the case blank. It should also be noted that sensor rod **5380** and its associated sensor device can also be used to ensure that PLC **5132** is aware of whether, once a blank has been engaged, it remains engaged with the end effector **5120** until it is intentionally released.

[0215] Turning to FIGS. **34** and **35**, shuttle **5140** of case forming system **5100** has an L-shaped bed **5400** with a horizontally extending base **5402** and a vertically extending back wall **5404**. The base has openings receiving suction cups **5408** which are coupled to a solenoid controlled vacuum generator **5332** (FIG. **18**). Similarly, back wall **5404** has openings receiving suction cups **5410** coupled to a solenoid controlled vacuum generator **5334** (FIG. **18**). The shuttle rides on a horizontal rail **5414** extending in the X-direction. Rail **5414** is supported on the factory floor. The shuttle has a depending belt block **5419** attached to an endless drive belt **5416**. From the belt block, the drive belt extends along rail **5414** to free-wheel **5418** located at one end of rail **5414**, around the free-wheel **5418** and back along the rail **5414** to the its other end where the belt passes around drive wheel **5420** of a servo motor **5422** and then returns along the rail **5414** again to the belt block **5419**. Given this arrangement, operating the servo motor in a counter-clockwise direction will move the shuttle in a downstream direction (toward the free-wheel **5418**) and operating the servo

motor in a clockwise direction will move the shuttle in an upstream direction (toward servo motor **5422**).

[0216] FIGS. **36**, **37**, and **45** detail folding apparatus **5130**. Turning to these Figures, the folding apparatus has opposed horizontally reciprocating fin ploughs, namely an upstream fin plough **5500** and a downstream fin plough **5510**. These fins are slidably supported on a horizontal rail **5512** that extends in the X-direction. A servo motor **5514** is attached to the upstream end of rail **5512** and a free-wheel **5516** is attached to the downstream end of the rail. A continuous drive belt **5520** runs around the drive wheel **5524** of servo motor **5514** and the free-wheel **5516**. Upstream fin **5500** has a back plate **5526** which is attached to the drive belt and downstream fin **5510** has a front plate **5528** attached to the drive belt. With this arrangement, if the servo motor **5514** is operated in a counter-clockwise direction, fins **5500**, **5510** move toward each other and when servo motor is operated in a clockwise direction, fins **5500**, **5510** move away from each other. The folding apparatus also has opposed vertically reciprocating folding ploughs, namely an upper plough **5530** and a lower plough **5540**. Each folding plough has a planar base terminating in a curved ploughing face. The ploughs **5530**, **5540** are mounted to the ends of respective support arms **5532**, **5542** and the arms are mounted to carriages **5534**, **5544** slidably supported on a vertical rail **5546** (i.e., a rail extending in the Z-direction). A servo motor **5554** is attached to the upper end of vertical rail **5546** and a free-wheel **5556** is attached to the lower end of the rail. A continuous drive belt **5560** runs around the drive wheel **5564** of the servo motor **5554** and the free-wheel **5556**. A back of the upper carriage **5534** is attached to belt **5560** and a front of lower carriage **5544** is attached to the belt. With this arrangement, if the servo motor **5554** is operated in a counter-clockwise direction, folding ploughs **5530**, **5540** move toward each other and if the servo motor is operated in a clockwise direction, folding ploughs **5530**, **5540** move away from each other.

[0217] Referencing FIGS. **17A** and **17B** along with FIGS. **38**, **39**, **45** and **46**, the horizontal rail **5512** on which fins **5500**, **5510** run is attached at either end to the base of L-shaped supports **5560a**, **5560b**. The L-shaped supports ride in channels **5562** of vertical ribs **5109a**, **5109b** of frame **5109**. A servo motor **5568** is geared to a common drive shaft **5570** to turn pinions (not shown) inside hubs **5572a**, **5573A**. The pinions mesh with ring gear portions of shafts **5574a**, **5574b** in order to turn, and thereby adjust, the vertical position of the shafts. The shafts are rotatably connected to the top of L-shaped supports **5560a**, **5560b**. The result is that operation of the servo motor **5568** in one rotational direction raises the L-shaped supports **5560a**, **5560b**—and therefore fins **5500**, **5510**—and operation of the servo motor **5568** in the opposite rotational direction lowers the L-shaped supports **5560a**, **5560b**.

[0218] Similarly, vertical rail **5546** on which folding ploughs **5530**, **5540** run via support arms **5532**, **5542** and carriages **5534**, **5544** is attached to a linear support **5580** that rides in a channel of vertical rib **5109c** of frame **5109**. Common drive shaft **5570** also turns a pinion (not shown) inside hub **5572c** and this pinion meshes with a ring gear portion of shaft **5574c** in order to turn, and thereby adjust, the vertical position of shaft **5574c**. The shaft is rotatably connected to the top of linear support **5580**. The result is that operation of the servo motor **5568** in one rotational direction raises the linear support **5580**—and therefore folding

ploughs **5530**, **5540**—and operation of the servo motor **5568** in the opposite rotational direction lowers the linear support **5580**. Moreover, since all of supports **5560a**, **5560b**, and **5580** are adjusted by common drive shaft **5570**, these supports are all adjusted to the same vertical extent by operation of servo motor **5568**.

[0219] Referring to FIGS. 17A, 38, and 39 the sealing station **5135** has a tape sealer **5640** and flap folding rods **5632** which are supported by fin supporting rail **5512** and so move vertically with fins **5500**, **5510**. The sealing station also has a pair of opposed conveyor belts, upper conveyor belt **5600** driven by servo motor **5602** and lower conveyor belt **5610** driven by servo motor **5612**, with the tape sealer **5640** disposed between the conveyor belts **5600**, **5610**. The lower conveyor belt **5610** and a supporting platform **5614** are supported by the factory floor. The upper conveyor belt is mounted to a sub-frame **5622**. Servo motor **5568** has a second drive shaft **5630** that is operatively associated with a drive train (not shown) so that operation of the servo motor **5568** adjusts the vertical position of sub-frame **5622** and, therefore, the upper conveyor belt **5600** with respect to the lower conveyor belt **5610**. Moreover, it will be noted that drive shaft **5630** and common drive shaft **5570** are driven by the same servo motor, motor **5568**, such that a vertical adjustment of upper conveyor belt **5600** is mirrored by a vertical adjustment of fins **5500**, **5510** and ploughs **5530**, **5540**. However, the drive train is configured with a 2:1 drive ratio so that the drive shaft **5630** rotates twice for any rotation of common drive shaft **5570**. The result is that a vertical adjustment of n cm of the fins, folding ploughs, tape sealer and flap supporting rods results in a vertical adjustment of $2n$ cm of the upper conveyor belt **5610**. This ensures that the centreline of a case sleeve remains at the level of the fins and tape sealer for any position of the upper conveyor belt **5600**.

[0220] The sealing station terminates at case re-orienting station **5116**. The case re-orienting station has a pair of deflection plates **5650**, **5652** which re-orient a case as it falls off the end of the sealing station to the discharge conveyor **5117** from a position lying on its side at the sealing station **5135** to an upright position on the discharge conveyor with its open top facing upwardly. The discharge conveyor **5117** is a simple endless belt conveyor driven by a servo motor **5658**.

[0221] A sensor **5243** (FIG. 18) such as an electronic eye model 42KL-P2LB-F4 made by ALLEN BRADLEY may be located at the input of the discharge conveyor. Sensor **5243** may be positioned and operable to detect the presence or absence of an erected case at the input to the discharge conveyor **5117**. In this way, PLC **5132** can be digitally signalled if an erected case blank **101** remains at the input of the discharge conveyor such that another erected case cannot be discharged. If so, the case forming system **5100** can be stopped by PLC **5132** until any fault at discharge conveyor **5117** can be rectified.

[0222] A sensor (not shown) such as an electronic eye model 42KL-D1LB-F4 made by ALLEN BRADLEY, may be located within the horizontal gap between case conveyor **324** and alignment conveyor **5206**. The sensor may be positioned and operable to detect the presence of the front edge of a blank as each blank in turn begins to move over the gap between the conveyors. Upon detecting the front edge, sensor may send a digital signal to PLC **5132** signalling that a particular blank (the size/configuration/type of

which PLC **5132** is aware) has moved to a position where conveyor **5206** can start to move. PLC **5132** can then cause the motor for conveyor **5206** to be activated to move the blank downstream. In this way, there can be a “hand-off” of each blank from case conveyor **324** to alignment conveyor **5206**.

[0223] Once the rear edge of each blank passes the sensor, a signal may be sent to PLC **5132** which can then respond by sending a signal to shut down the motor driving conveyor **324**. Conveyor **324** is then in a condition to await a further signal thereafter to feed the next blank in the series of blanks on the conveyor **324** to alignment conveyor **5206**. Meanwhile case forming system **5100** can be operated to move the blank on alignment conveyor **5206** to the pick-up location in the manner described in conjunction with case forming system **5100** so that processing of the blank can continue as described in conjunction with case forming system **5100**.

[0224] Optionally, PLC **5132** may verify that the type/size/configuration of the case blank at the pick-up location matches the expected case blank. For example, the top surface of each case blank may include a bar code identifying its type/size/configuration, and this bar code may be read at the pick-up location by a suitably positioned bar code reader. The type/size/configuration of the case blank read from this bar code may be compared to the expected type/size/configuration of case blank, which may be determined from a record of the next scheduled case blank stored in memory of the PLC, as described above. Verification is successful when there is a match. When there is not a match, PLC **5132** may issue a signal requesting manual operator intervention.

[0225] The system has been described as having a PLC **5132**. Optionally, any other suitable controller may be substituted, such as a programmed general purpose computer.

[0226] The case blank **101**, and resulting sleeve, has been described as being gripped with suction cups. Of course, any other suitable grippers may be employed

[0227] As noted above, it is contemplated that within a certain range of types/sizes/shapes of blanks, case forming system **5100** can process different types/sizes/shapes of blanks (within certain constraints/limits) without manual adjustment of any components of case forming system **5100**. Also, it is contemplated that PLC **5132** in case forming system **5100** may store information about the dimensions of different types/sizes/shapes of blanks **101** (e.g. a height dimension “Ht”; a length dimension “L”; a major panel Length “Q” and also a case depth DP—as shown in FIG. 19A) and then PLC **5132** can determine adjustments, if any, that need to be made to (a) the components of the magazine; (b) the movement of the end effector **5120**; (c) the movement of the shuttle **5140**; and (d) at least some of the components of the folding apparatus **5130** and some components at the sealing station **5135** to be able to process a particular blank. The result is that case forming system **5100** may be able to automatically process several different types of blanks to form different size/shape/type cases, without having to make manual operator adjustments to any components of case forming system **5100**.

[0228] With reference to FIG. 19A, it is contemplated that, by way of example only, that case forming system **5100** can process case blanks have the following ranges of dimensions:

[0229] Height H_t —in the range of 7" to 30" (17.78 cm to 76.2 cm)

[0230] Length L —in the range of 9" to 40" (22.86 cm to 101.6 cm)

[0231] Depth DP —in the range of 4.5" to 20" (11.43 cm to 50.8 cm)

[0232] Major Panel Length Q —in the range of 4" to 20" (10.16 cm to 50.8 cm).

[0233] To further assist in the handling of case blanks **101** of different sizes/types/shapes, case forming system **5100** may include some additional features, as described herein after. With reference to FIGS. **21**, and **22**, a case blank **101A** is shown resting in a pick-up position on alignment conveyor **5206**, with a leading edge **5107A** defined by the aligned, front horizontal and transverse edges of top panels **F**, **A** and **E** and opposite bottom panels **L**, **D**, and **K** (see also corresponding edges **5107** in FIGS. **19A** and **19B**). Leading transverse edge **5107A** is proximate to, and preferably abuts up against the facing surfaces of picket wall **5218** such that leading transverse edge **5107A** is substantially aligned with a transverse horizontal axis Y_{2A} which extends along the facing surfaces of front picket wall **5218** (also referred to herein as blank front edge guide **5218**). Axis Y_{2A} also continues to run transversely and horizontally parallel to axis Y through case forming system **5100** including, preferably, along the forward facing surface **5404A** (FIGS. **28** and **29**) of back wall **5404** of shuttle **5140** when the shuttle is in the longitudinal start position before it commences its advancement to open the case blank—in the manner as described above.

[0234] The adjacent inner horizontal and transverse edges of upper panels **F**, **A** and **E** and respective adjacent upper panels **J**, **B**, and **I**, form a transverse horizontal crease line that is substantially aligned with a transverse horizontal axis Y_{1A} which runs transversely and horizontally, and parallel to axis Y_{2A} through case forming system **5100**. A corresponding, but slightly lower, axis Y_{1A}' (that is vertically aligned with and parallel to axis Y_{1A}) also runs through inner horizontal and transverse edges of opposite lower panels **L**, **D**, and **D** and respective adjacent lower panels **H**, **C**, and **G** to form a corresponding lower crease line. These two crease lines typically will lie in the same vertical and transverse plane. Axis Y_{1A} and axis Y_2 are separated by a distance X_{YA} (FIG. **27**).

[0235] By contrast, with reference to FIG. **22**, a blank **101B** (which has generally smaller dimensions than blank **101A**—including a length L_B that is shorter than length L_A , and which may also have a height H_t that is shorter than height H_t of blank **101A**) is shown resting in a pick-up position on conveyor **5206**, with a leading transverse edge **5107B** defined by the aligned, front edges of panels **I**, **B** and **J**. Leading transverse edge **5107B** of blank **101B** is also positioned proximate to, and preferably is in abutment with the facing surfaces of picket wall **5218** such that leading edge **5107B** is substantially aligned with a transverse horizontal axis Y_{2B} which extends along the forward edge surfaces of front picket wall **5218**. Axis Y_{2B} also continues to run transversely and horizontally parallel to axis Y through case forming system **5100** including also preferably, along the front surface of back wall **5404** of shuttle **5140**, when in the longitudinal start position before it commences its advancement to open the second case blank—as

described above. Axis Y_{1B} and axis Y_{2B} are separated by a distance X_{YB} (FIG. **26**). Distance X_{YB} is shorter than distance X_{YA} .

[0236] The adjacent inner horizontal and transverse edges of upper panels **F**, **A** and **E** and respective adjacent upper panels **J**, **B** and **I**, form a transverse crease line that is substantially aligned with a transverse horizontal axis Y_{1B} which runs transversely and horizontally and parallel to axis Y and to axis Y_{2A} through case forming system **5100**. A corresponding, but slightly lower, axis Y_{1B}' (that is vertically aligned with and parallel to axis Y_{1B}) also runs through inner horizontal and transverse edges of opposite lower panels **L**, **D**, and **K**, and respective adjacent lower panels **H**, **C** and **G** to form another transverse crease line. These two crease lines typically will lie in the same vertical and transverse plane.

[0237] During the operation of case forming system **5100** in processing blanks having different lengths L_A , L_B , the longitudinal axes Y_{1A} and Y_{1B} of the two differently sized blanks **101A**, **101B** are co-linear (the crease lines in both blanks run along the same transverse line/axis—or at least run in the same vertical transverse plane). Similarly, the longitudinal axes Y_{1A}' and Y_{1B}' of the two differently sized blanks **101A**, **101B** are co-linear (the crease lines may also run along the same transverse line/axis—or at least run in the same vertical transverse plane). Thus, in case forming system **5100**, no matter what length L of case blank that is being processed, a transverse and vertical plane through the crease lines between panels **I**, **B** and **J** and respective adjacent panels **E**, **A** and **F** remains in a constant longitudinal (ie. X direction) position, and similarly, a transverse and vertical plane through the crease lines between panels **L**, **D** and **K**, and respective adjacent panels **H**, **C** and **G** will also typically remain in a constant longitudinal (i.e. X direction) position.

[0238] It will be appreciated however, that in case forming system **5100**, for blanks **101A**, **101B**, with different lengths L , the transverse axes Y_2 and Y_{2A} will not be not co-linear (e.g. the front edges of the case blanks do not run along the same line/axis parallel to axis Y or through the same vertical and transverse plane). Therefore, in case forming system **5100**, if the length L of a case blank that is being erected during operation, changes from case blank to the next case blank, the transverse axis Y_2 at the front edge of panels **E**, **A** and **F** will be in a different longitudinal (i.e. X direction) position.

[0239] When end effector **5120** is positioned by the control of PLC **5132** at the pick-up location (such as shown in FIG. **40**) the end effector is located directly over panel **B** of a blank **101A** and preferably right behind, or a short distance behind, in the X direction, the crease line axis Y_{1A} and when, when end effector **5120** is positioned by the control of PLC **5132** at the pick-up location (such as shown in FIG. **40**) the end effector is directly over panel **B** of a blank **101B** the end effector **5120** will be the distance in the X direction behind the crease line axis Y_{1B} .

[0240] Therefore, in order to accommodate case blanks of different lengths L , the forward-facing surfaces of front picket wall/front edge guide **5218**, and typically also the start position of the front surface **5404A** of back wall **5404** of shuttle **5140** will have to be moved to corresponding different longitudinal start positions. Adjustment of the start position of shuttle **5140** can be controlled by servo motors

5258 and **5278** controlled by PLC **5132**, and the corresponding stroke of shuttle **5140** may also be adjusted by PLC **5132**.

[0241] In order to provide a corresponding varying, appropriate pick-up positions of case blank **101A** and case blank **101B**, on conveyor **5206**, the longitudinal (i.e. in direction of axis X) position of picket wall/front edge guide **5218**, must also be adjusted by PLC **5132**. Accordingly, a longitudinal, picket wall movement mechanism **5241** may be provided in case forming system **5100**. Picket wall movement mechanism **5241** may be controlled by PLC **5132** which can adjust the longitudinal position of picket wall **5218** to provide a proper pick up position for a case blank on conveyor **5206**, to ensure that the crease line between panels I, B and J and respective adjacent panels E, A and F (e.g. axes $Y1_A$ and $Y1_B$) will be in the same longitudinal (X axis) position through case forming system **5100**, regardless of the length L of case blank **101** that is being processed at any particular time by case forming system **5100**. Thus, when end effector **5120** is positioned by the control of PLC **5132** at the pick-up location (such as shown in FIG. **40**) the end effector is directly over panel B of a blank **101A** a short distance in the X direction behind the crease line axis $Y1_A$ and when, when end effector **5120** is positioned by the control of PLC **5132** at the pick-up location (such as shown in FIG. **40**) the end effector is directly over panel B of a blank **101B** the end effector **5120** will be the same short distance in the X direction behind the crease line axis $Y1_B$.

[0242] It should be noted that if the height Ht of the cases also vary (such as between case blank **101A** and case blank **101B**) the transverse, pick-up position of the end effector **5120** on the blank while on conveyor **5206**, and the transverse, lowering down position of the end effector for lowering the blank onto the base **5402** of shuttle **5140**, may vary in the transverse direction (Y direction) by PLC **5132** so that the end effector **5120** is properly positioned transversely at both the pick-up, and lowering, of the blank. When picking up a blank, the end effector **5120** may be positioned movement apparatus **5115** directly over the central area in the transverse position in the Y direction of panel B, dependent upon the height Ht of the respective blank **101A**, **5111B**—which may vary between blank **101A** and blank **101B**. PLC **5132** can also adjust the transverse movement of movement apparatus **5115** so that when the end effector **5120** descends towards the base **5402** of bed **5400** of shuttle **5140** such that the front edge **5107** is positioned against the vertically extending back wall **5404** of the shuttle **5140**, the end effector will be generally directly above the base **5402** and the blank properly positioned transversely on the bed **5402**.

[0243] With reference also to FIGS. **23**, **24** and **25**, picket wall **5218** may be supported by a support frame generally designated **5243**. Support frame **5243** has lower longitudinal members **5243a** which may rest on a plurality of transverse rollers **5277** that are supported on a sub-frame **5221**. Support frame **5243** is also mounted to a slidable carriage **5245**. Carriage **5245** may be operable to ride/slide on a pair of horizontal, longitudinally extending rails **5247** extending in the X-direction. Rails **5247** may be supported by a sub-frame **5249** on the factory floor. Carriage **5245** may have a depending belt block **5261** attached to an endless drive belt from the belt block **5261**, the drive belt extends along rails **5247** to free-wheel **5265** device located at one end of rails **5247**, around the free-wheel device **5265** and back along the rails **5247** to the its other end where the belt passes around

drive wheel of a servo motor **5273** and then returns along the rails **5247** again to the belt block **5261**. According to some embodiments, as shown in FIG. **23**, the drive belt may include an acme screw arrangement. According to other embodiments, screw type actuators may be alternatively implemented with drive belts for high-speed actuations. Given this arrangement, PLC **5132** may operate the servo motor **5273** to move the belt block **5261**, and thus carriage **5245** and also picket wall **5218** (which is supported in such movement by support frame **5243** riding on rollers **5277**) such that picket fence **5218** can be moved in forward/backward directions (in the X direction) in order to properly position the picket wall **5218** in the correct longitudinal position for the particular sized case blank to be processed and erected into a case. Thus PLC **5132** can adjust the longitudinal positions of both picket wall **5218** and shuttle **5140**, to accommodate changes in the lengths L of the case blanks that are being fed in series by conveyor **5206** to the pick-up location.

[0244] In case forming system **5100**, a plurality of magazines M1-M16 may be supported by one or more frame structures above a common case conveyor **324** (which may be constructed generally like case conveyor **324**, including as depicted in FIGS. **14**, **15** and **16**). Magazines M1-M16 may be arranged in spaced longitudinal relation to each other vertically above case conveyor **324**. Case conveyor **324** feeds an alignment conveyor **5206** (which may be like alignment conveyor **5206** described above).

[0245] Magazines M1-M16 may each contain one or more stacks of product packaging, such as case blanks which each may generally be like blanks **111** processed by case forming system **5100**, with at least some and possibly each of the magazines M1-M16 containing different types/sizes and/or configurations of packaging/case blanks compared to other magazines. The size, configurations and types of case blanks (and the cases that can be formed therefrom) can vary to provide a range of case sizes, configurations and types that can be automatically processed by the case forming system **5100** without the need for any manual intervention to modify any components of the system. PLC **5132** of case forming system **5100** may be programmed such that the particular dimensions/overall size/configuration (e.g. such as regular slotted case or “RSC”)/type of each of the blanks held in each one of the magazines M1-M16 is stored in the memory of the PLC **5132**.

[0246] Each magazine M1-M16 may provide a vertical stack of case blanks above case conveyor **324** and be operable to dispense single case blanks on demand under the control of PLC **5132**, in a flattened orientation onto case conveyor **324**. An example arrangement of a suitable type of vertical case dispensing magazine, is the magazine that forms part of the 310E case erector made by Wepackit Inc. of Orangeville, Ontario, Canada (<http://www.wepackitmachinery.com/310E/310E.pdf>).

[0247] PLC **5132** may give an instruction to form a case, and if required, PLC **5132** may cause one of magazines M1-M16 to dispense a blank of an appropriate configuration/size onto case conveyor **324** for delivery to alignment conveyor **5206**. PLC **5132** is able to selectively move and transfer a single blank at a time onto case conveyor **324** from any one of magazines M1 to M16. Therefore, separate individual case blanks may be fed in series and longitudinally in a desired sequence by case conveyor **324** to alignment conveyor **5206**. The particular sequence/order of case

blanks that are placed onto case conveyor **324** of case forming system **5100** may be determined and selected by PLC **5132** or another control system as described hereinafter, such that case blanks may arrive at alignment conveyor **5206** in such a desired sequence in which it is desired to process the blanks within case forming system **5100**.

[0248] PLC **5132** may maintain in its memory records of the sequence of case blanks that have been placed onto case conveyor **324**. For example, this information may include the type/size/configuration of the case blank and, where the case forming system **5100** includes a labeller, the label information to be applied to the case blank. A new record can be added each time a request for a new case is received and, optionally, records can be removed once a case has been formed (and labelled). Thus, such records may be organized and maintained in sequence in the memory of PLC **5132** using a conventional shift registering technique. In this way, the record for the next case blank scheduled to arrive at alignment conveyor **5206** may be provided at the output of the shift registers as that case blank arrives, and the type/configuration/size of that case blank and the label information for that case blank may be determined from the provided output.

[0249] Once transferred from case conveyor **324** to alignment conveyor **5206**, the alignment conveyor **5206** may then under the control of PLC **5132** move each blank sequentially to the pick-up location in the manner described previously with respect to case forming system **5100**.

[0250] As described above, a sensor (not shown) such as an electronic eye model 42KL-D1LB-F4 made by ALLEN BRADLEY, may be located within the horizontal gap between case conveyor **324** and alignment conveyor **5206**. The sensor may be positioned and operable to detect the presence of the front edge of a blank as each blank in turn begins to move over the gap between the conveyors. Upon detecting the front edge, sensor may send a digital signal to PLC **5132** signalling that a particular blank (the size/configuration/type of which PLC **5132** is aware) has moved to a position where conveyor **5206** can start to move. PLC **5132** can then cause the motor for conveyor **5206** to be activated to move the blank downstream. In this way, there can be a “hand-off” of each blank from case conveyor **324** to alignment conveyor **5206**.

[0251] Once the rear edge of each blank passes the sensor, a signal may be sent to PLC **5132** which can then respond by sending a signal to shut down the motor driving case conveyor **324**. Case conveyor **324** is then in a condition to await a further signal thereafter to feed the next blank in the series of blanks on the case conveyor **324** to alignment conveyor **5206**. Meanwhile case forming system **5100** can be operated to move the blank on alignment conveyor **5206** to the pick-up location in the manner described in conjunction with case forming system **5100** so that processing of the blank can continue as described in conjunction with case forming system **5100**.

[0252] Optionally, and as in the system described above, in case forming system **5100**, PLC **5132** may verify that the type/size/configuration of the case blank at the pick-up location matches the expected case blank. For example, the top surface of each case blank may include a bar code identifying its type/size/configuration, and this bar code may be read at the pick-up location by a suitably positioned bar code reader. The type/size/configuration of the case blank read from this bar code may be compared to the expected

type/size/configuration of case blank, which may be determined from a record of the next scheduled case blank stored in memory of the PLC, as described above. Verification is successful when there is a match. When there is not a match, PLC **5132** may issue a signal requesting manual operator intervention.

[0253] The generally S-shaped path may be achieved by generally reversing the orientation of shuttle **5140** and its components (on an X direction axis), including L-shaped bed **5400** with its horizontally extending base **5402** and vertically extending back wall **5404** such that the shuttle is oriented in a the same downstream—X axis—direction as case conveyor **324** and alignment conveyor **5206**. Additionally, end effector **5120** may be positioned so as to engage on a top surface of panel A, —so that during that during opening of the case blank **101**, the shuttle **5140** will push against the rearward edges of panels J, B and I, while end effector **5120** lifts panel vertically, causing panel B to rotate from a horizontal orientation to a vertical orientation (See FIGS. **41** and **42**). Alternatively, each blank **101** may be fed to the alignment conveyor in an opposite direction (i.e. so that panels J, B and I are leading panels and panels F, A and E are the trailing panels). Thus, the end effector **5120** may then pick up the case blank **101** on panel B and the shuttle **5140** will push against the rearward edges of panels F, A and E, while end effector **5120** lifts panel B vertically, causing panel A to rotate from a horizontal orientation to a vertical orientation. In each such arrangement, the transverse axis through the crease lines Y1 of the panels will remain the same longitudinal position during operation, regardless of the length of the case blank **101**.

[0254] Case forming system **5100** may also have its a folding apparatus generally designated **5130**, configured to fold one or more flaps of each sleeve, and a sealing station **5135** at which flaps of the cases are sealed arranged in an opposite direction. Case forming system **5100** may also include a case re-orienting station **5116** and a case discharge conveyor **5117** arranged in an opposite longitudinal direction—as shown. Thus, case forming system **5100** is operable to feed an erected case to a case re-orienting station **5116** and a case discharge conveyor **5117** which are also oriented in the same downstream—longitudinal X-axis—direction from the case erecting station, as depicted in FIG. **42**.

[0255] The use of case forming case forming systems **5100** described above, has the ability to process a relatively large number of different size case blanks from a relatively small footprint on a factory floor. By moving case blanks in their flattened configuration, on conveyor systems to the end effector **5120** where they are translated transversely, also in their flattened state, and only opened in the combined movements of the shuttle and the end effector, provides a very technically efficient mechanism for erecting cases of different sizes. It will be noted that several steps of the case forming process are able to be performed at the same time (in parallel to each other). For example, the systems may be configured such that infeed and alignment conveyors may be moving to the pick-up position one case blank, while another case blank is being moved transversely by the end effector (of the end effector is at least being moved), while an erected case is completing its sealing/labelling steps. The result is that it is believed that case forming system **5100** may be able to process in the order of at least 20-30 cases per minute.

[0256] According to some embodiments, modifications to the case forming case forming system **5100** based on the size

of the constructed case and blank may relate additional downstream equipment. For example, with reference to FIG. 39, the distance between upper conveyor belt 5600 and lower conveyor belt 5610. This distance may be adjusted by placing one or both of upper conveyor belt 5600 and lower conveyor belt 5610 (along with its various sub-components) on a vertical actuator. Based on the total height of the constructed case, an operational signal from PLC 5132 will instruct a vertical actuator or actuators to adjust the distance between the two, to either increase or decrease. Similarly, actuators and rails positioned to fold major and minor flaps in the constructed case may be configured to change positioned based on the size of constructed case. For example, the folding apparatus 5130 may be fixed on an actuator configured to adjust upstream fin plough 5500, downstream fin plough 5510, and folding ploughs 5530, 5540 to intersect with a midpoint of the major and minor flaps of the case as necessary. Finally, case sealer 320 and label station 322 may adjust to ensure that the seal and label are placed in a specific position on the constructed case (i.e. along a seam for sealing, or on a visible panel for labelling).

Control System and Methods

[0257] FIG. 47 is a block diagram of example hardware components of a control server 200. Control server 200 may be hosted on a computer including processor 202, network interface 204, a suitable combination of persistent storage memory 206, random access memory and read only memory and one or more I/O interfaces 208. Processor 202 may be an Intel x86, PowerPC, ARM processor or the like. Network interface 204 interconnects control server 200 to a network (not shown). Memory 206 may be organized using a conventional filesystem. Control server 200 may include input and output peripherals interconnected to control server 200 by one or more I/O interfaces 208. These peripherals may include a keyboard, display, mouse and one or more devices such as DVD drives, USB ports and the like for reading computer-readable storage media. Software components exemplary of embodiments of the present invention may be loaded into memory 206 over network interface 204 or from one or more peripheral devices.

[0258] FIG. 48 is a block diagram of simplified organization of example components stored at a computing device of control server 200 to provide a control system 600. Components depicted in FIG. 48 may be implemented in a combination of software and hardware. The control server 200 can include functional modules to control individual components of the warehouse fulfillment system. As depicted, the modules include input pallet AGV controller 610, tote conveyor controller 620, item picker controller 630, packing cell controller 640, order sequencer 650, and product location repository 660. Each functional module in control system 600 able to interface with the electromechanical components of the warehouse fulfillment system via one or more PLCs to cause physical operations to occur as described herein. Further, the software components are able to communicate with each other and to access any appropriate database required to complete the functions as will be described. For example, the software components may be configured to communicate with each other via individual function calls between software components or requests to access the information stored at locations in a memory 206.

[0259] Each software component may be configured to communicate with the various hardware components within

the floor plan. For example, tote conveyor controller 620 may communicate a route or series of commands to transport a tote along main lines 132, branch lines 134, and elevators 117 of conveyor system 130. Item picker controller 630 may communicate with picker arms 114, packing cell controller 640 may communicate with the packing system 120, and input pallet AGV controller 610 may communicate to the forklifts. Communications between hardware and software components may include transmitting operational commands, as well as to receive real-time feedback. This may be used to determine optimized performance in scheduling future events.

[0260] Input pallet AGV controller 610 coordinates the forklift automatic guided vehicle movement throughout the warehouse system 100. The input pallet AGV controller 610 receives, as an input, new locations and operations in from order sequencer 650. These locations correspond to either a new shipment coming in, wherein the location includes a specific loading bay 102, and operations for lifting a pallet 112, or for a specific storage location in the warehouse system 100, and operations for lowering the pallet 112 from the AGV. According to some embodiments, the input pallet AGV controller 610 may be used to control multiple automated guided forklifts 119 in the warehouse system 100. Alternatively, for each forklift, a single input pallet AGV controller 610 may be employed. In embodiments including a pallet elevator device 210, input pallet AGV controller 610 may be further configured to control the pallet elevator device 210 to receive the appropriate pallet from the AGV, and bring the pallet to the specific storage location.

[0261] Tote conveyor controller 620 is configured to send commands to the conveyor system 130 to transport totes 116 through the warehouse. This includes bringing the totes 116 to each specific product location within the warehouse system 100, and to the packing system 120. Tote conveyor controller 620 can receive, as an input, specific product locations corresponding to items in an individual order. As an output, tote conveyor controller 620 may generate a series of instructions for specific main lines 132, branch lines 134, and elevators 117.

[0262] Item picker controller 630 sends operational commands to each picker arm 114. The item picker controller 630 receives indication from tote conveyor controller 620 indicative of the tote being placed in a picking position (i.e. that the necessary route has been completed), then sends instructions to the robotic arm to retrieve an item from the case and place the item in the tote. Once item picker controller 630 has determined that a case has been emptied, the item picker controller 630 will instruct picker arm 114 to move excess cardboard 128 of other waste product off of the pallet and drop to the appropriate waste area.

[0263] Packing cell controller 640 sends operational commands to the packing system comprising at least one random case erector 314 and sub-components thereof. The packing cell controller 640 will send commands to erect a case corresponding to each individual order. Using order sequencer 650, each tote being brought to the packing system with its erected cases simultaneously.

[0264] Order sequencer 650 receives both the incoming pallets and individual orders for products from the warehouse. Order sequencer 650 instructs the software components of the specific order they should operate. Order sequencer 650 has access to a plurality of repositories and databases which will be described in relation to later figures,

that instruct the series of individual operations of other software components of control system 600. These are used to generate a queue for operation of the conveyor system 130, picker arms 114, and packing system 120.

[0265] Finally, product location repository 660 stores a database comprising the locations of each pallet in the warehouse system 100. The form of these locations may be in (x, y, z) components, or in another computer-readable format. The locations stored in product location repository 660 are used by order sequencer 650 to guide the input pallet AGV controller 610 and tote conveyor controller 620. As new pallets are received in the warehouse, the order sequencer 650 will query product location repository 660 for the specific product location to leave the pallet 112. Once determined, the input pallet AGV controller 610 may communicate with the forklift 119 or material handling machine to pick up and drop off the pallet 112 from loading bay 102 to specific location as determined. Similarly, when an order is received by control system 600, order sequencer 650 will query product location repository 660 for the specific product locations, and instruct tote conveyor controller 620 to transport a tote 116 to the location, then item picker controller will instruct picker arm 114 to pick an item from pallet 112 stored at the location. After all items in an order have been picked, order sequencer 650 will transport a tote 116 to a packing cell for packing and shipping.

[0266] FIG. 49 is an example of data stored at the product location repository 660. The product location repository 660 includes, for each product ID 1402, a specific product location 1410, comprising a value in x, y, and z dimensions. Alternatively or additionally, a unique identifier for each location may be used, wherein the identifier logically identifies each product and is associated with a specific spatial location. Entries in the product location repository 660 may be pre-defined or entered manually. According to some embodiments, product location repository 660 may further include data related to an amount of stock left in an individual product ID 1402, and the specific location within a palletized pattern or structure for a picker end effector 121 to select the next item for the next order.

[0267] Upon receiving a new pallet 112 at loading bay 102, control system 600 will receive an indication of a product ID 1402 associated with the individual items on the pallet. This may be entered by a user into a user interface of an electronic device using a keyboard or touch screen, or by scanning a bar code (or other machine-readable data format) from the pallet 112. If the product ID 1402 associated with the pallet 112 exists in the product location repository 660, a forklift 119 may be instructed by input pallet AGV controller 610 to lift and transport the pallet 112 to the appropriate cell 111 location as defined in the product location repository 660. If the product ID does not exist, a new entry in the product location repository 660 may be defined for the pallet. According to embodiments where a pallet elevator device 210 is used to bring a pallet to the specific storage location, forklift 119 may bring the pallet 112 to an input of the pallet elevator device 210. The pallet elevator device may then transport the pallet 112 to the appropriate cell 111.

[0268] FIG. 50 is an example of sequence 1000 for operation managed by the order sequencer 650. Sequence 1000 functions to keep a record of all orders in the system. An order includes at least one product, and can comprise multiple products to be shipped to a location. As depicted,

the sequence 1000 is a list used to track the orders having an order ID, to be filled in totes 116, each tote having a tote ID 1004. The specific product ID 1006 for each order ID 1002 will correspond to a product ID stored in product location repository 660 (and thereby on a specific cell 111). Each order ID 1002 may also include additional information such as a shipping address for the order ID 1002, any shipping preferences, and financial information. The order ID 1002 may be used to query additional databases or repositories for associated information. The sequence 1000 may additionally include for each order, a shipping address to send the order to, or may link to another table including shipping addresses. Additionally, sequence 1000 may include shipping preferences (such as, for example, if there is a preference to use a particular carrier, packaging material, or dunnage type).

[0269] For each order ID 1002, tote conveyor controller 620 will instruct conveyor system 130 to transport a lined tote 118 from tote staging system 138 to the product location 1410 corresponding to the cell 111 containing the pallet 112 for each product in the order ID 1002. There, picker arm 114 will place an item from the palletized stack into the lined tote 118. Conveyor controller 620 will generate a path to each product cell location 1410, and instruct conveyor system 130 to transport the tote via the path for products in the order. As noted, electronic sensors such as barcode scanners or RFID sensors may be employed to detect where a lined tote 118 is within the conveyor system 130. Based on a detection and identification of lined tote 118, tote conveyor controller 620 may instruct a diverter how to transport the specific tote for a route. Once all the lined tote 118 has been filled with all items in the order ID 1002, conveyor controller 620 will instruct conveyor system 130 to transport the tote to a specific packing cell 1014 in packing system 120. [0270] Order sequencer 650 may be configured to deliver the filled totes 116 (i.e. totes 116 that have completed traversal through all necessary storage units, and have been filled with all products in the order) to the order packing system 120 and the chosen packing cell 1014 simultaneously as the packing cell 1014 constructs an appropriate case for the order ID 1002.

[0271] New orders may be added to sequence 1000 upon receipt by the order sequencer. Orders may be removed from sequence 1000 upon being transferred to an output bay 104.

[0272] Packing cell controller 640 may determine a case size 1008 for the order ID 1002, as well as additional considerations such as a dunnage type 1010 and length 1012, along with a specific packing cell 1014 for packing the order ID 1002. Based on this determination, order sequencer 650 may determine when operational parameters will be communicated from packing cell controller 640, such as case size 1008, dunnage type 1010, dunnage length 1012. Accordingly, the operation of the specific packing cell 1014 will be synchronized with the conveyor system 130.

[0273] Order sequencer 650 may further assign a delivery vehicle for the order ID 1002 based on previously completed orders, and communicate a delivery path to a user interface on a vehicle for the vehicle to take. Based on this, output conveyor 140 will transport the sealed case to the delivery vehicle. The communicated delivery route for the delivery vehicle may be used by a delivery vehicle driver or autonomous driving system for case delivery.

[0274] FIG. 51 is a block diagram illustrating a detailed view of the software components of the item picker controller 630 of FIG. 10. The item picker controller 630

includes an arm controller 632, an end effector controller 634, a pattern memory 636, and an I/O interface 638. When item picker controller 630 receives indication that a tote 116 has been placed in the picking position, arm controller 632 will send operational signals to motors of the picker arm 114 to position the end effector 121 over an available item for picking. Then, hand controller 634 will send operational signals to the end effector 121 to pick up the item. After, the arm controller 632 will send signals to picker arm 114 to position end effector 121 over tote 116, and send signals to end effector 121 to release the item. In some embodiments, picker arm 114 is guided based on a stored representation of a pallet, stored in pattern memory 636. The representation may depict the locations of objects and boundaries thereof in a coordinate system. Pattern memory 636 is also able to track, using the pattern and previous order history, the amount of product left in a single case on a pallet 112. Additionally or alternatively, picker arm 114 may be guided using machine vision. Specifically, one or more optical sensors may acquire images of pallet 112 and its contents. Image processing techniques such as edge detection and pattern matching may be employed to determine object locations and boundaries in a two-dimensional or three-dimensional coordinate system.

[0275] Similarly, when item picker controller 630 has determined that there is no product left in a case (either by use of a vision system or virtual representation), the case will be discarded. When the item picker controller 630 has determined that there are no cases left on a pallet, the pallet base will be discarded. This is accomplished in a similar fashion to picking a specific item from the case itself. Picker arm 114 is positioned, and end effector 121 engages, moves, and disengages with the waste.

[0276] FIG. 52 is an example of case size repository 1450 used by order controller 650. As depicted, case size repository is a database table. Each case size is identifiable by a unique case size ID 1452. For each case size ID 1452, case dimensions 1458 for height, width, and depth are defined. Optionally, additional capacity parameters may be recorded. For example, as shown, case size repository includes a volume minimum 1454 and volume maximum 1456. Additionally or alternatively, other suitable parameters could be recorded such as minimum and maximum order weights. Case size repository further includes an indicator 1460 of which packing cells 310 includes blanks in magazines M1-M16 corresponding to the case size having ID 1102. Packing cell controller 640 may access the case size repository to determine the appropriate size case and packing configuration for the order ID 1002. Packing cell controller 640 sends operational commands to the packing system comprising a random case erector 314. The packing cell controller 640 will send commands to erect a case corresponding to each individual order. The sequence of commands sent to the random case erector 314 may be communicated such that as a completed order tote arrives at a packing station, the appropriate case has already been constructed and filled with dunnage.

[0277] FIG. 53 is a block diagram of simplified organization of example software components of packing cell controller 640. The packing cell controller 640 can include functional modules to control individual components of one or more packing cells. As depicted, the modules include shipping label generator 2920, dunnage selector 2930, case size selector 2940, and case sealer 2950 and sequence

manager 2960, each are able to interface with the components of one or more packing cells 310 and order packing system 120 via one or more PLCs (such as PLC 5132) to cause physical operations to occur as described herein. Further, the software components are able to communicate with each other and to access any appropriate database required to complete the functions as will be described. For example, the software components may be configured to communicate with each other via individual function calls between software components or requests to access the information stored at locations in a memory 206.

[0278] Order sequencer 650 maintains records of orders being fulfilled and details, e.g. physical dimensions, of products within such orders.

[0279] As shown in FIG. 54, the order sequencer 650 includes a product dimension repository 2912 (e.g. a database or database table) and sequence 1000 (e.g. a database or database table). Sequence 1000 may have the same or similar structure to sequence 1000 of FIG. 50. The product dimensions repository 2912 can include the dimensions of each product, such as height, width, and depth. Individual products may have a unique SKU ID number associated with them. According to some embodiments, the database is stored locally in memory 206. According to other embodiments, this database is stored in a memory accessible on another server by way of a network. According to some embodiments, the order sequencer 650 further includes weights for each product and an indication of the product fragility.

[0280] FIG. 55 is an example of a product dimension repository 2912 stored in the order sequencer 650, made up of information about the products in the order and their dimensions. As depicted, product dimension repository 2912 is a database table. The product dimension repository 2912 comprises products each having a unique product ID 3206. Each product ID 3206 has dimensions 3208. The product dimension repository 2912 would have entries for each possible product that could be used in orders within the order packing system 120.

[0281] Order sequencer 650 may also access sequence 1000, (FIG. 50). For example, sequence 1000 is stored as a table to track a sequence of orders having an order ID 1002, wherein each order corresponds to an individual tote containing at least one product 1006. Each product 1006 corresponds to a product that can be found in product dimensions 2912. Each individual tote may be tracked using an individual bin ID 1004. The order database, as will be described later, can also keep track of the case size 1008 selected to be constructed from the case construction apparatus, the dunnage type 1010 to be used in packing the case, the dunnage length 1012 to be used when packing the case, and the specific packing cell 1014 that the tote will be transported to. The case size 1008, dunnage type 1010, dunnage length 1012, and packing cell 1014 can serve as operational parameters delivered to order packing system 120 and a packing cell 310.

[0282] As will be apparent, product dimension repository 2912 and sequence 1000 may be linked tables within a database schema of order sequencer 650.

[0283] Case size selector 2940, as shown in FIG. 56 comprises a case size repository 1450 (FIG. 52) and size determiner 2944. In operation, case size repository 1450 comprises a database of available case sizes and the volume of the constructed case, along with the packing cell or cells

310 that includes blanks for the case size. Size determiner **2944** receives an input comprising an order ID **1002**, including the product IDs **1006** and the individual product dimensions **3208**, and calculates a volume for the order. Based on the order volume, the most appropriate case size is selected for use for the order.

[0284] FIG. 57 is a block diagram showing sequence manager **2960**, comprising a packing cell selector **2962**, conveyor director **2964**, and sequence **2966**. The packing cell selector **2962** functions to select, based on the case size or any other optimization algorithm, the appropriate packing cell **310** to manage the order fulfilment. Sequence manager **2960**, using the packing cell selector **2962**, will generate and modify a sequence **2966** of cases constructed in the packing cell **310**. The conveyor director **2964**, based on input from the packing cell selector **2962**, will supply operational signals to conveyors (such as order bin conveyor **2782** and case conveyor **324**) to transport the blanks from case magazine **M1-M16** in sequence **2966** to the appropriate packing cell **310**. In operation, the filled totes **116/118** will be directed towards the packing cell **310**, where each corresponding case will be transported by the tote conveyor **382** to the packing station **318**.

[0285] The conveyor director **2964** can define a path, i.e. a set of conveyors to be traversed for the case or tote to take to reach the appropriate packing cell. At intersections of conveyors, the system may include a diverter mechanism, to divert a tote or case from one conveyor path to a next conveyor path.

[0286] FIG. 58 is an example of sequence **2966** for a chosen packing cell **3314** managed by the sequence manager **2960**. As depicted, the sequence **2966** is a list to track the filled totes, and the properties of the corresponding erected case **326**. Sequence manager **2960** will generate an individual sequence **2966** for each packing cell **310** in the order packing system **120**. The sequence **2966** may be linked to product dimension repository **2912** and sequence **1000** within a database schema of order sequencer **650**.

[0287] As new orders **3302** having bins **3304** enter the order packing system **120**, the sequence manager **2960** can add the order ID **3302** to the sequence **2966** for the chosen packing cell **3314**. As completed cases **334** and empty totes **352** leave the chosen packing cell **3314**, sequence manager **2960** can remove the order ID **3302** from the sequence **2966**. In the same order as the sequence **2966**, the filled totes will be delivered by order packing system **120** to the chosen packing cell **3314**. Similarly, in the same order as the sequence **2966**, the chosen packing cell **3314** will be given operational parameters for the order **3302**, such as case size **3308**, dunnage type **3310**, dunnage length **3312**.

[0288] FIG. 59 is a block diagram showing components of the dunnage selector **2930**. Dunnage selector **2930** includes a dunnage repository **2932**, a dunnage type selector **2934** and dunnage dispenser **2936**. In operation, an order ID **3302** is provided to dunnage selector **2930**. Based on order information such as product dimensions **3208**, weights and fragility, a type of dunnage and quantity of dunnage is determined, then dispensed. Examples of dunnage types include bubble wrap, packing peanuts, or loose paper. In some embodiments, dunnage types or quantities may be selected based on customer preference in addition to the product information (such as size or weight). For example paper dunnage may be selected for orders by customers who have expressed a preference for eco-friendly packaging.

[0289] The dunnage repository **2932** stores the types of dunnage available to be dispensed, and quantity increments in which it may be dispensed. For example, packing peanuts may be dispensed in defined volume increments and bubble wrap may be dispensed in discrete sheet sizes. Dunnage type selector **2924**, based on the information in the order sequencer **650**, determines the type and length to be dispensed by the dunnage dispenser **2926** of a packing cell **310**. Determinations by the dunnage selector **2930** can be passed as operational parameters to a packing cell **310**.

[0290] Case sealer **2950**, as shown in FIG. 60, operates to seal the constructed cases once they have been filled at packing station **318**. Case sealer **2950** includes sealer dispenser **2952** and seal applier **2954**. In operation, seal dispenser **2952** will dispense the appropriate amount of sealing material (such as tape, for example) for the seal applier **2952** to apply to the constructed case.

[0291] Case sealer **2950**, in operation, will receive an order ID **3302**. The order ID **3302** can be used to query a database stored in a memory in a network for additional information. The database can include product information such as weight, or a case size previously determined for the order. Based on this information, case sealer will determine the appropriate amount of sealing material to dispense. For example, based on the order ID **3302**, the case sealer **2950** can determine that the box has a depth of 50 cm, and then instruct the seal dispenser **2952** to dispense 50 cm of tape for the seal applier **2954** to apply.

[0292] Shipping label generator **2920**, as shown in FIG. 61, operates to print and apply shipping labels to the sealed cases for shipping. Shipping label generator **2920** includes shipping label printer **2922** and shipping label applicator **2924**. In operation, shipping label printer **2922** will print the necessary details, for example a shipping address or bar code, for an order to a paper or sticker that can be applied to the case. Shipping label applicator **2924** will take the printed shipping label and apply the label to the sealed case.

[0293] Shipping label generator **2920**, in operation, will receive an order ID **3302**. The order ID **3302** can be used to query a database stored in a memory (such as the repositories in order sequencer **650**) in a network for additional information. The database can include information such as shipping address, shipping type, and any information. Based on this information, shipping label printer **2922** will print the appropriate label for the shipping label applicator **2924** to apply to the case. Methods

[0294] FIG. 62 is a flowchart illustrating a method for fulfilling orders and operating a fulfillment centre such as a warehouse.

[0295] At block **1302**, a plurality of pallets **112** of goods is received. The pallets **112** contain a plurality of cases, each case containing a plurality of individual units of the goods. The pallet may be received at a loading bay **102**, and lifted by a forklift **119** operating as an automated guided vehicle (AGV) configured to detect the pallet **112** location. The received pallet will have a unique identifier corresponding to the SKU the pallet holds. The unique identifier may be entered into an electronic device, either manually using a touch screen or keyboard, or by scanning a bar code or similar means. Based on the unique identifier for the pallet, a location within the product location repository **660** associated to the pallet is determined.

[0296] At block **1304**, each pallet is transported to a storage cell corresponding to goods on the pallet. Input

pallet AGV controller **610** may communicate operational commands (such as a route or specific location) to direct a forklift **119** to transport the pallet **112** to a specific storage cell or location as indicated in the product location repository **660**. There, the forklift **119** will automatically disengage from the pallet base. According to some embodiments, multiple pallets may be stored at a specific location, and a pallet conveyor may be employed to transport a pallet to a picking position. According to embodiments where a pallet elevator device **210** is used to bring a pallet to the specific storage location, input pallet AGV controller **610** may be configured to instruct the forklift **119** to bring the pallet **112** to the pickup point **220** for the pallet elevator device **210**. Then, input pallet AGV controller **610** may instruct the pallet elevator device **210** to transport the pallet to the specific storage location as indicated in product location repository **660**.

[0297] According to some embodiments, responsive to a new order entering the system, a tote may be sent to tote staging system **138**. There, tote may be lined by a liner machine. Once lined, totes may be transported along a route in tote conveyor system **130** via main lines, branch lines, and conveyors to a specific cell associated with an item in the order. When a tote has been delivered to a picking position (i.e. within an operable radius of the picker arm **114**, picker arm may determine an individual item to remove from the pallet **112**, using a vision system or a virtual representation of items and cases in the pallet **112**.

[0298] At block **1306**, individual units of goods from the pallet **112** are removed with picker arms **114** at the storage cell. Based on the determined individual item to remove from the pallet **112**, the picker arm **114** will move to a position to engage with the individual item. An end effector **121** of the picker arm may be configured to engage with the individual item to lift, then move to the tote **116**, and disengage, placing the item in the tote.

[0299] The cases **126** on pallet **112** may be half slotted cases or regular slotted cases. If the cases are regular slotted cases, the picker arm **114** may be configured to have an end effector **121** operable to cut open cases **126** to access the item inside. Similarly, picker arm **114** may be further configured to have an end effector **121** capable of slicing any packaging, shrink wraps, strapping etc.

[0300] According to some embodiments, when a case **126** or pallet **112** is completely picked, the picker arm **114** may discard of any waste product, pallet base, or excess cardboard such as a slip sheet.

[0301] At block **1308**, an order of products is assembled by advancing an order tote sequentially to a plurality of storage cells to receive products from the robotic pickers. The individual products corresponding to the individual orders may be specified in the order received. An order sequencer **650** may be configured to communicate with tote conveyor controller **620** and product location repository **660** to determine a route from a previous picking position to a next picking position, and instruct tote conveyor system **130** the appropriate movements along branch lines **134** and main lines **132** to deliver the tote from a first position to a second position. Once there, the picker arm at the second position may engage with and transfer a second object from a case stored in a palletized form into the lined tote **118**. This step may be repeated for all products within an order. If a product

has more than one quantity of a single item, the picker arm will transfer multiple items, one at a time, at the same picking position.

[0302] Once the order has been completely assembled, the tote may be transported to a packing station. There, the products will be removed from the tote, and placed into an erected cardboard box for shipment. According to embodiments where the tote has a liner, the entire liner may be removed from the tote and placed, with the order items inside, into the erected cardboard box. The erected cardboard box may include dunnage and a printed shipping label according to the order specification. The box will then be sealed, labelled and placed on a delivery vehicle at output bay **104** for delivery.

[0303] According to some embodiments, the delivery may be selected according to a determined route, the route then provided to a computer interface on a delivery vehicle for driver instruction. According to some embodiments, the delivery vehicle may be an autonomous vehicle guided by the determined route as defined.

[0304] FIG. **63** is flowchart illustrating an example method **4400** of packing product orders.

[0305] At block **4402**, a unique sequence of totes containing orders, each order having corresponding order ID **3302**, are received via order bin conveyor **2782**. Each order ID **3302**, is associated with information about the order, for example the products in the order, their dimensions, their weight, the shipping address for the order, etc.

[0306] Accordingly, at block **4404**, based on the product ID, products in the order are determined. This can be done by querying a database or repository (such as those in order sequencer **650**) for the products in each order.

[0307] Next, at block **4406**, based on the products in the order, a case from a magazine of blanks is selected for use with the order. This can be done by a case size selector **2940** as described above with reference to the method **3600** of FIG. **65**. The case size selector **2940** will determine, based on the products in the order determined at block **4404**, and the available case sizes to case constructors in packing cells **310**, the appropriate case size to be constructed for the order.

[0308] Next, at block **4408**, the type and length of dunnage are selected. The available case volume from the case determined at block **4406**, along with the fragility and weight of the products in the order are considered when selecting the type and amount of dunnage to dispense. An example method of dunnage selection is described in greater detail with reference to FIG. **66**.

[0309] Next, at block **4410**, based on the size of case, type of dunnage, and any optimization algorithm, a packing cell **310** is selected by the sequence manager **2960** for fulfilling the order as described above with reference to the method **3500** of FIG. **64**. For example, if the size of cases is only available at a specific packing cell **310**, this will be the packing cell **310** selected.

[0310] The determinations of steps **4406**, **4408**, and **4410**, may be given to the order bin conveyor **2782**, case conveyor **324**, and packing cell **310** as operational parameters. For example, such parameters may be passed to the respective controllers of order bin conveyor **2782**, case conveyor **324** and packing cell **310**.

[0311] At block **4412**, each tote is directed to the appropriate packing cell **310**. According to embodiments where order bin conveyor **2782** comprises multiple sub-conveyors, the path instructions and diversion mechanisms will be

defined for delivering the tote to the packing cell 310. The totes will be delivered in a sequence.

[0312] At block 4413, if necessary, components of the modified case forming system 5100 is adjusted to adapt the modified case forming system 5100 to form the case of the appropriate size. It is noted that components of the modified case forming system 5100 may not need to be adjusted in all situations, for example when selected case size is the same or similar to the size of the case most recently constructed prior to the selected case size in the sequence.

[0313] According to some embodiments, at block 4413, a position of an alignment component of a case blank alignment device is set so that when said case blank abuts said alignment component, said case blank has a predetermined position.

[0314] Additionally or alternatively, at block 4413, based on said size of said case, a stroke of a second alignment component may be adjusted. The first alignment component, according to some embodiments, is a laterally moveable first side guide for abutting a first side of said case blank in order to set a predetermined lateral position of said case blank and wherein the second alignment component is a laterally moveable second side guide for urging said case blank into abutment with said first side guide.

[0315] Next, at block 4414, modified case forming system 5100 constructs a sequence of cases. The sequence of cases corresponds to the totes being delivered from block 4412. That is, for each order at a particular packing cell 310, a corresponding case will be constructed of the size determined at block 4406. In operation, a blank will be transported by a conveyor from a magazine storing a plurality of case blanks to a case construction apparatus able to construct cases of various sizes.

[0316] Next, at block 4416, the length of dunnage type is dispensed for each order. The case is transported from case construction apparatus to a dunnage dispenser. The length and type of dunnage dispensed into a constructed case will correspond to that determined at block 4408.

[0317] At block 4418, each case is transported to a packing station with the tote containing the order that corresponds to that case. At the packing station, products are transferred from the tote to the constructed case. According to some embodiments, product transfer can be done by a person. According to other embodiments, product transfer can be done by a robotic device.

[0318] Next, at block 4420, each case is transported to a case sealer, configured to seal the case with the appropriate amount and type of sealer. The type of seal can be determined based on the case size.

[0319] Finally, at block 4422, a shipping label is applied to each case. The shipping label can include information such as the shipping address, a barcode, and any other information required to ship the case.

[0320] FIG. 64 is flowchart illustrating an example method 3500 for the use of the sequence manager 2960.

[0321] At block 3502, an order ID 3302 corresponding to a filled tote on order bin conveyor 2782 is received.

[0322] Next, at block 3504, the size of case to be used for the order is determined. This can be done using a case size selector 2940 and the method as shown in FIG. 65.

[0323] Next, at block 3506, the case size for the order from block 3904 is compared with the cases available at each of packing cells 310. This can be done by case size repository 1450 (FIG. 52) across the different packing cells 310. The

packing cells 310 that have magazines containing blanks for the case size determined from block 3904 are identified.

[0324] Next, at block 3508, a packing cell 310 to handle the order is selected. According to embodiments where there are multiple packing cells 310, it is possible that the different packing cells 310 may be configured based on specific sizes of cases (i.e. a specific packing cell 310 for smaller cases, and a specific packing cell 310 for larger cases). Alternatively, in other non-limiting embodiments, the packing cell 310 selected may be random or evenly distributed.

[0325] Next, at block 3510, parameters are sent to the order bin conveyor to direct the filled tote to the selected packing cell 310 selected at block 3508. The individual path for the tote across the conveyors will be defined and any instructions for intersection conveyors or diverter mechanisms may also be defined and communicated.

[0326] Finally, at block 3512, operational parameters are sent to the packing cell 310 for the order ID 3302. This can include the case size to construct as determined in block 3504, among any other operational parameters.

[0327] FIG. 65 is flowchart illustrating an example method 3600 of selecting a case size. First, at block 3602, an order ID 3302 is received. The order ID 3302 may be a unique identifier for an individual order such as, for example, a purchase of products from an online marketplace. The order ID 3302 can be used to query a database stored in a memory in a network for additional information.

[0328] At block 3604, the products in the order are determined, based on the order ID 3302. This may be done, for example, by querying sequence 1000 (FIG. 54) stored in a memory on a network to return all product IDs 3306 for the individual order ID 3302.

[0329] At block 3606, the dimensions of the products in the order are determined. This may be done, for example, by performing a lookup in product dimension repository 2912 (FIG. 55) to return the dimensions 3208 for each individual product ID 3206 in for the product IDs 3306 associated with individual order ID 3302.

[0330] At block 3608, a query of case size repository 1450 (FIG. 52) is performed to identify candidate case types, namely, those case types that are capable of holding the products in the order. In an example, the dimensions of the products in the order are compared with the dimensions of available case sizes. Candidate cases may, for example, be those with length, width and height greater than the largest product in the order. Candidate cases may be filtered according to other capacity values. For example, according to some embodiments, a total volume of the products in the order is calculated and compared that to the total volume available in all cases in case size repository 1450. Cases with internal volume less than the total volume of products in the order, or with internal volume less than a defined multiple of the total product volume (e.g. 1.5x) may be eliminated as candidates. According to other embodiments the individual product dimensions are compared to those of cases in case size repository 1450.

[0331] Finally, at block 3610, the case size for the order ID 3302 is selected. According to some embodiments, the candidate case with the smallest internal volume is selected as the generated case size to use for the order. According to other embodiments, the case size selected as the case size for the order ID 3302 is the case in case size repository 1450

with the smallest maximum dimension, i.e. the case for which the maximum of its length, weight or height is the smallest.

[0332] An example approach for selecting case size is disclosed in U.S. Pat. No. 6,876,958 to Chowdhury et al., issued to assignee New Breed Corporation on Apr. 5, 2005 (hereinafter, "Chowdhury"), the contents of which is hereby incorporated by reference herein in its entirety. In particular, Chowdhury's product packaging utility processes each order placed by a customer to automatically identify, from available case types/sizes/configurations, a type/size/configuration of suitable case (or cases) suitable for packaging the products in the order. Chowdhury's a product packaging utility identifies/determine suitable case(s) according to an algorithm/function that accesses and uses one or more electronically-stored characteristics of each product in the order (e.g., dimensions, weight, etc.) and one or more electronically-stored characteristics of available case types (e.g., dimensions, size, configuration, type, maximum volume that can be held, maximum weight that can be held, etc.). This algorithm identifies suitable cases such that a minimum number of cases and the smallest size cases suitable for packaging the products in the order may be provided. Thus, identification of suitable case types/sizes/configurations can be optimized to provide an optimal case type/size/configuration which minimizes packaging material used and to minimize empty space in cases, and a case identified as suitable may be referred to as an "optimal" case. It will be appreciated that identification of suitable case types/sizes/configurations may also be identified or optimized according other pre-defined criteria. The case identification algorithm of Chowdhury's product packaging utility may also take into account other factors and constraints such as, e.g., the availability of each type/size/configuration of case, the maximum fill ratio of each type/size/configuration of case, the maximum number of products that can be placed into each type/size/configuration of case, and whether certain products are pre-packaged together and therefore must be placed in the same case. Thus, using Chowdhury's product packaging utility, case size selector **2940** may process a customer order for specific products by accessing information in it memory and utilizing an algorithm/function to identify a suitable case (or cases) for packaging those products from a plurality of available cases.

[0333] It should be noted that the size of the case may be the overall internal available volume of the case in which items may be held. The size may also be the specific dimensions of the case. The type of case may include the reference to what material the blanks is made from (e.g. paperboard or corrugated cardboard). Its configuration may an indication of it being a top opening case which is generally cuboid in shape when closed, or another configuration such as a regular slotted case, etc.

[0334] Chowdhury's product packaging utility may also generate, for each case of a particular type/size/configuration identified to fulfil an order, a packing list indicating the order in which each of the products is to be preferably placed into the case, as well as placement information indicating where each product is to be preferably placed in the case. For example, this placement information may be expressed using coordinates (e.g., 0, 0, 0) in a coordinates system defined for the case and/or descriptors of locations in the case (e.g., front, right hand side, second layer, etc.). Thus, when order the case size selector **2940** includes a product

packaging utility such as Chowdhury's product packaging utility, case size selector **2940** may generate a packing list and/or placement information for each identified case. Case size selector **2940** may also generate a diagram illustrating a desired optimal physical arrangement of the products in each case. Such a diagram may be readily generated using placement coordinates for each product, as provided by Chowdhury's product packaging utility.

[0335] The generated case size can be inputted as an operational parameter to one of packing cells **310**, wherein the selected case size corresponds to a case blank **101** stored in one of the associated magazines M1-M16. The generated case size can be recorded in the corresponding record of sequence **1000**.

[0336] FIG. **66** is flowchart illustrating an example method **4100** for selecting dunnage.

[0337] At block **4102**, an order ID **3302** is received.

[0338] At block **4104**, the products in the order are determined, based on the order ID **3302**. This may be done, for example, by querying a database stored in a memory on a network to return all products IDs **3206** associated with the individual order ID **3302**. Individual products, as shown in FIG. **55**, may themselves have unique identifiers **3206** and individually recorded dimensions **3208**. In some embodiments, blocks **4102**, **4104** may be performed based on a single instruction message received by dunnage selector **2930**. For example, the instruction message may include order ID **3302** along with all of the corresponding record of sequence **1000**. Alternatively, an instruction received at **4102** may include only an order ID **3302** and dunnage selector may responsively query for product information from sequence **1000**.

[0339] At block **4106**, the type of dunnage to use in the order is determined. Examples of dunnage types include bubble wrap, packing peanuts, or loose paper. Dunnage types may be selected based on the product information (such as size or weight), or based on information stored in the database about a user who has made the order, for example that they would prefer an eco-friendly dunnage type.

[0340] At block **4108**, the quantity (e.g. length or volume) of dunnage to use in the order is determined. According to some embodiments, quantity of dunnage to use in the order may be a function of the empty space left in the case, including the space occupied by the products in the order.

[0341] Finally, at block **4110**, instructions are sent to the packing cell **310** for the order ID **3302**. This can instruct the packing cell **310** that for each case in the sequence of constructed cases, to dispense the amount and type of dunnage determined by the method **4100**.

[0342] The overall operation of case forming system **5100** will now be described further in conjunction with FIG. **67**, which is a flowchart of the sequence of operations of the PLC.

[0343] To prepare case forming system **5100** for operation, one or more stacks of knock-down case blanks **101** may be placed at the input end of case conveyor **324**. In this regard, it is assumed the blanks are placed on the case conveyor **324** with panels A and B, and flaps E, F, I, and J facing up, as shown in FIG. **19A**, and the common edge of end flaps F and J facing side wall **5200** as shown by the blank **101** in FIG. **17A**. Case forming system **5100** may then be activated, such as by PLC **5132** being instructed through HMI **5133** to commence the processing of blanks **101**. As an

initial step PLC 5132 may initialize the system by ensuring that all components are put in their “start” positions (step 5700). PLC 5132 may then send an instruction to the drive motor of case conveyor 324 causing stack(s) of blanks 101 to be conveyed downstream in the X-direction (step 5702) toward an identification reader. An identifier on the first stack may then be read by the identification reader 5205 which identifies the dimensions of the blanks in the first stack. With this information and in order to adapt case forming system 5100 to process blanks of the size in the first stack, the PLC adjusts the stroke of both the outer side wall 5201 and the shuttle 5140, the path of end effector 5120, the vertical position of the folding fins 5500, 5510, the folding ploughs 5530, 5540, the tape sealer 5640 and flap folding rods 5632, and upper conveyor 5600 (step 5704).

[0344] Sometime prior to a blank reaching alignment conveyor 5206, the outer side guide wall 5201 under control of PLC 5132 will be driven by servo motor 5260 to expand wide enough to allow the blank to enter alignment conveyor 5206, even if the stack is misaligned and/or the blanks in the stack are not perfectly square with each other. The stack(s) of blanks moves downstream, until the front edge of the (first) blank passes the downstream edge of case conveyor 324 at which time sensor 5242 sends a signal to PLC 5132 indicating that the front edge of the stack has reached the input to alignment conveyor 5206. In response, PLC 5132 may stop case conveyor 324 and send an instruction to the drive motor of alignment conveyor 5206 to cause the blank 101 to move downstream towards end picket wall 5218. Once the front edge of the blank 101 reaches end wall 5218, sensor 5240 will send a signal to PLC 5132 indicating that the front edge of the blank has reached end wall 5218. In response, PLC 5132 can then move the outer side wall 5201 inwardly to straighten the stack laterally and initiate the tamping sequence to “square up” the blank longitudinally, as detailed above (step 5706).

[0345] In review, the sequence for ensuring the blanks are properly squared up at the pick-up location may include the following steps. The side guide wall 5201 moves inwardly to make contact with the side of the blank and press the stack against the left hand side guide wall 5200. This aligns the blanks so the lateral edges of the blanks are aligned with each other. This also moves the tamping plate 5280 in behind the stack. The tamping plate 5280 may then move forwardly to press the stack forward against the picket wall 5218, thereby aligning the blanks in the stack longitudinally so that their front and rear edges are vertically aligned with each other. The blank 101 is then properly positioned at the pick-up location so that the end effector 5120 can begin picking up blanks from the stack.

[0346] End effector 5120 will be positioned by the control of PLC 5132 over movement apparatus 5115, at the zero position calibrated for the end effector 5120. PLC 5132 may then cause servo motors 5150 and 5154 to be operated to achieve the following sequence of operations.

[0347] First the end effector 5120 may be moved to the pick-up location as shown in FIG. 14A such that the end effector is directly over panel B of the top blank in the blank at the pick-up location.

[0348] As the end effector 5120 is brought vertically downwards to retrieve the top blank on the blank 101, the end effector’s movement just prior to suction cups 5312 contacting with the upper surface of the blank will be generally vertically downwards. Prior to the suction cups

5312 contacting the surface of a panel B of a blank, sensor rod 5380 will contact the surface of panel B and be pushed upwardly. This upward movement of sensor rod 5380 relative to plate 5327 will cause a sensor to be activated and send a signal to PLC 5132. PLC 5132 responds to that signal by causing servo motors 5150 and 5154 to slow down so that the final few centimeters (e.g. 3.5 cm) of movement downwards towards contact between cups 5312 and the upper surface of panel B occurs at a much slower rate. Also, PLC knows how much further vertically downwards the end effector 5120 must be lowered to establish proper contact between suction cups 5312 and panel B. PLC 5132 will then operate the valve device 5330 on end effector 5120 to cause suction force to be developed at suction cups 5312. Sensor rod 5380 and its associated sensor device can also be used to ensure that PLC 5132 is aware of whether, once a blank has been engaged in the magazine, it remains engaged with end effector 5120 until it is intentionally released.

[0349] With the end effector 5120 in the pick-up location and the suction force being applied at suction cups 5312, the end effector 5120 engages panel B of the top blank and then lifts the blank lift upwards (step 5708).

[0350] When the end effector 5120 has reached a determined height it is moved laterally in the Y-direction until it is positioned over shuttle 5140.

[0351] Next, with reference to FIG. 40, the end effector descends until the blank sits on the bed 5400 of the shuttle with the hinge line R between side panel A and side panel D (FIG. 19B) positioned against the vertically extending back wall 5404 of the shuttle 5140. The PLC then activates the suction cups 5408 at the base 5402 of the shuttle bed to grip the underside of the blank, and specifically side panel D of the blank (step 5710). Notably, side panel D, being the panel directly underneath side panel A in the knock-down blank, is not directly hinged to panel B, which panel is gripped by the end effector.

[0352] The end effector 5120 is then raised vertically in the Z-direction while, simultaneously, the shuttle 5140 is moved forwardly in the X-direction. In consequence of these operations, provided the simultaneous motions of the end effector and shuttle are appropriately co-ordinated, since underside panel D of the blank is gripped at the base of the shuttle and top panel B of the blank is gripped by the end effector, the blank begins to open up as illustrated in FIG. 41.

[0353] The end effector 5120 continues to move vertically upwardly and the shuttle simultaneously continues to move forwardly until the blank is fully erected into a case sleeve as illustrated in FIG. 42. The PLC will recognize this end point due to its knowledge of the dimensions of the sleeve. With the blank formed into a case sleeve, panel A of the sleeve (seen in FIG. 41) abuts the back wall 5404 of the shuttle 5140 (step 5712).

[0354] With panel A abutting the back wall 5404 of the shuttle, the suction cups 5410 of the back wall are activated so that panel A is gripped by the back wall 5404 of the shuttle (step 5714). With both panels A and D held by the shuttle, the case sleeve is held in its erect position without need of support from end effector 5120. Therefore, at this stage, the suction cups 5312 of the end effector 5120 are de-activated and the end effector is moved away from the shuttle 5140 back to the pick-up location (step 5716).

[0355] Next, with shuttle 5140 held stationary, fin ploughs 5500, 5510 are moved toward one another until they are adjacent one another as shown in FIG. 33 (step 5718). This

has the effect of folding minor bottom end panels F and G of the case sleeve inwardly, as shown in FIG. 44. In this regard, it will be recalled that the vertical position of the fin ploughs 5500, 5510 was set based on the size of the blank. This setting is so as to result in the fin ploughs contacting panels F and G at their midpoint.

[0356] With the shuttle remaining stationary and the fin ploughs remaining adjacent one another, the upper and lower ploughs 5530, 5540 are next moved toward one another until these ploughs are positioned at a small stand off from fin ploughs 5500, 5510 as shown in FIG. 45 (step 5720). This has the effect of folding major bottom flaps J and K of the case sleeve inwardly, as shown in FIG. 46.

[0357] Leaving all of the ploughs in place, the PLC next activates conveyor belts 5600, 5610 and moves the shuttle 5140 downstream until the belts frictionally grip side panels B and D of the case sleeve and pull it downstream, extracting it from the ploughs (step 5722).

[0358] As the sleeve is pulled downstream from the ploughs 5500, 5510, 5530, 5540, the outside surface of major bottom flaps J and K are brought into contact with folding rods 5632 which progressively complete the fold of flaps J and K. The case sleeve is then pulled past tape sealer 5640 by conveyor belts 5600, 5610 at which sealer the seam between flaps J and K is taped in order to tape closed the bottom of the case sleeve to form a case. The case is then ejected to the re-orienting station where it is deflected by deflector plates 5650, 5652 as it falls onto the discharge conveyor 5117 so that the bottom of the case (i.e., flaps J and K) rest on the discharge conveyor. The discharge conveyor then conveys the case to the output of case forming system 5100.

[0359] Once the case sleeve has moved downstream from the ploughs 5500, 5510, 5530, 5540, these ploughs are retracted from one another and the shuttle 5140 is returned to its initial position in order to prepare case forming system 5100 for processing the next case blank (step 5724); the end effector can then pick up the next blank in the stack (step 5726).

[0360] After exhausting the current blank 101, the next stack is conveyed to the information reader 5205 and the PLC will read the dimensions of blanks in the next stack (step 5726). Thereafter, once the last blank in the current stack has moved downstream of the conveyor belts 5600, 5610, if the blanks in the next stack have different dimensions from the dimensions of blanks in the now exhausted stack, the PLC adjusts the stroke of the outer side wall 5201 and the shuttle 5140, the path of end effector 5120, and the vertical position of the folding fins 5500, 5510, the folding ploughs 5530, 5540, tape sealer 5640 with folding rods 5632, and upper conveyor 5600. Case forming system 5100 is then readied to handle the next stack and it is moved to the pick-up location and the described processing operations repeated.

[0361] The system provides a relatively high processing capacity in part due to the relatively short “stroke” (i.e. longitudinal distance) that the end effector and shuttle must travel when carrying out the blank retrieval and erection. This means that the components do not have to travel such a great distance as in conventional case erectors.

[0362] The system also has a relatively small footprint due to the U-shaped path provided for cases blanks erected into cases by the system. More specifically, incoming blanks are conveyed in an upstream X-direction to the pick-up location.

These blanks are then conveyed in a Y (and Z) direction to the shuttle where they are then conveyed downstream in the X-direction.

[0363] Many variations of the embodiments described above are possible. By way of example the system may employ a second movement apparatus and end effector, identical in construction to movement apparatus 5115 and end effector 5120, but a mirror image thereof. With such an arrangement, the two devices may be mounted side-by-side with the two end effectors operating in the same plane. Collisions between the two end effectors can be avoided by operating the two movement apparatus such that the two end effectors are always 180° out of phase with one another.

[0364] Once transferred from case conveyor 324 to alignment conveyor 5206, the alignment conveyor 5206 may then under the control of PLC 5132 move each blank sequentially to the pick-up location in the manner described previously with respect to case forming system 5100.

[0365] Of course, the above described embodiments are intended to be illustrative only and in no way limiting. The described embodiments of carrying out the invention are susceptible to many modifications of form, arrangement of parts, details and order of operation. The invention, rather, is intended to encompass all such modification within its scope, as defined by the claims.

[0366] As described above, data structures are depicted as database tables. However, other types of data structures or methods of storing information may be used. For example, data repositories described herein may be stored in text files or other delimited files or other information storage structures. As another example, graph databases, key-value stores, wide column stores, document stores, or any other form may be used.

[0367] Although physical control and input/output devices may have been described and depicted above, such devices may be implemented using virtualised versions. For example, PLCs may be implemented using a virtual PLC system. Similarly, network interfaces and I/O interfaces may be implemented virtually.

[0368] When introducing elements of the present invention or the embodiments thereof, the articles “a,” “an,” “the,” and “said” are intended to mean that there are one or more of the elements. The terms “comprising,” “including,” and “having” are intended to be inclusive and mean that there may be additional elements other than the listed elements.

[0369] Of course, the above described embodiments are intended to be illustrative only and in no way limiting. The described embodiments of carrying out the invention are susceptible to many modifications of form, arrangement of parts, details and order of operation. The invention, rather, is intended to encompass all such modification within its scope, as defined by the claims.

[0370] When introducing elements of the present invention or the embodiments thereof, the articles “a,” “an,” “the,” and “said” are intended to mean that there are one or more of the elements. The terms “comprising,” “including,” and “having” are intended to be inclusive and mean that there may be additional elements other than the listed elements.

What is claimed is:

1. A warehouse system for fulfilling orders comprising a plurality of products, comprising:

a plurality of storage cells, each storage cell for receiving palletized products, the palletized products packed in cases each comprising a plurality of units, said cases arranged on a pallet in a shipping configuration;

a conveyor system operable to sequentially advance a tote to a plurality of said storage cells corresponding to a plurality of products in an order, for collecting said order in said tote;

a plurality of robotic pickers at said storage cells, each for engaging individual units of a product, to transfer said individual units from said pallets to said tote.

2. The warehouse system of claim 1, further comprising a packing subsystem for transferring said order to a shipping case for shipping.

3. The warehouse system of claim 2, wherein said packaging subsystem comprises a case erector operable to erect said case.

4. The warehouse system of claim 3, wherein said case erector is operable to erect cases of a plurality of different sizes.

5. The warehouse system of claim 4, wherein said case erector is operable to erect a case of a selected one of the plurality of different sizes, based on sizes of said products of said order.

6. The warehouse system of claim 2, comprising a liner insertion station adjacent to a conveyor of said conveyor system, said liner insertion station for placing a removable liner in said tote.

7. The warehouse system of claim 2, wherein said liner is a bag for transferring said order to said shipping case by removal of said bag.

8. The warehouse system of claim 1, wherein said plurality of robotic pickers comprise pickers mounted overhead at said cells.

9. The warehouse system of claim 8, wherein said plurality of robotic pickers comprises pickers movable between ones of said cells.

10. The warehouse system of claim 1, wherein said robotic pickers are operable to remove packing material from pallets at said cells.

11. The warehouse system of claim 10, wherein said robotic pickers are operable to cut said packing material.

12. The warehouse system of claim 10, wherein said robotic pickers are operable to remove empty cases from pallets at said cells.

13. The warehouse system of claim 1, comprising a plurality of zones maintained at different temperature conditions.

14. The warehouse system of claim 1, wherein said conveyor system comprises a plurality of branching con-

veyors, each of said branching conveyors passing proximate a subset of said storage cells.

15. The warehouse system of claim 14, comprising a plurality of diverters selectively operable direct a specific individual tote along a defined path to any of said storage cells.

16. A warehousing method, comprising:

receiving a plurality of pallets of goods, said pallets containing a plurality of cases, each containing a plurality of individual units of said goods;

transporting each said pallet to a storage cell corresponding to goods on that pallet;

removing individual units of said goods from said pallets with robotic pickers at said storage cells;

assembling an order of products by advancing an order tote sequentially to a plurality of said storage cells to receive products from said robotic pickers.

17. The warehousing method of claim 16, comprising transferring said order to a shipping case for shipping.

18. The warehousing method of claim 16, comprising automatically erecting said shipping case.

19. The warehousing method of claim 18, wherein automatically erecting said case comprises selecting one of a plurality of possible case sizes based on sizes of said products of said order, and conveying a blank corresponding to said selected one of a plurality of case sizes to a case erector.

20. The warehousing method of claim 17, comprising automatically inserting a removable liner in said tote.

21. The warehousing method of claim 20, wherein said removable liner is a bag, and wherein transferring said order comprises placing said bag in said shipping case.

22. The warehousing method of claim 16, comprising removing packing material from said pallets with said robotic pickers.

23. The warehousing method of claim 22, comprising cutting said packing material with said robotic pickers.

24. The warehousing method of claim 16, comprising maintaining multiple warehouse zones at different temperatures.

25. The warehousing method of claim 16, wherein said assembling an order comprises conveying a tote along a branching conveyor, wherein each branch of said branching conveyor passes proximate a subset of said storage cells.

26. The warehousing method of claim 25, comprising defining a path for a specific individual to a storage cell by selective operation of diverters on said branching conveyor.

* * * * *