US012103796B2

(12) **United States Patent**
Felton et al.

(10) **Patent No.: US 12,103,796 B2**
(45) **Date of Patent: Oct. 1, 2024**

(54) **AUTONOMOUS MULTI-TIER RACKING AND RETRIEVAL SYSTEM FOR DELIVERY VEHICLE**

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(73) Assignee: **MONOTONY.AI, INC.**, Watertown, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 443 days.

(21) Appl. No.: **17/504,988**

(22) Filed: **Oct. 19, 2021**

(65) **Prior Publication Data**

US 2022/0119210 A1 Apr. 21, 2022

Related U.S. Application Data

(60) Provisional application No. 63/191,012, filed on May 20, 2021, provisional application No. 63/093,785, filed on Oct. 19, 2020.

(51) **Int. Cl.**
B65G 67/24 (2006.01)

(52) **U.S. Cl.**
CPC ***B65G 67/24*** (2013.01)

(58) **Field of Classification Search**
CPC B65G 67/24
(Continued)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,832,636 A 4/1958 Black
4,139,109 A 2/1979 Murphy
(Continued)

FOREIGN PATENT DOCUMENTS

AT 14048 U1 3/2015
DE 19802761 A1 7/1999
(Continued)

OTHER PUBLICATIONS

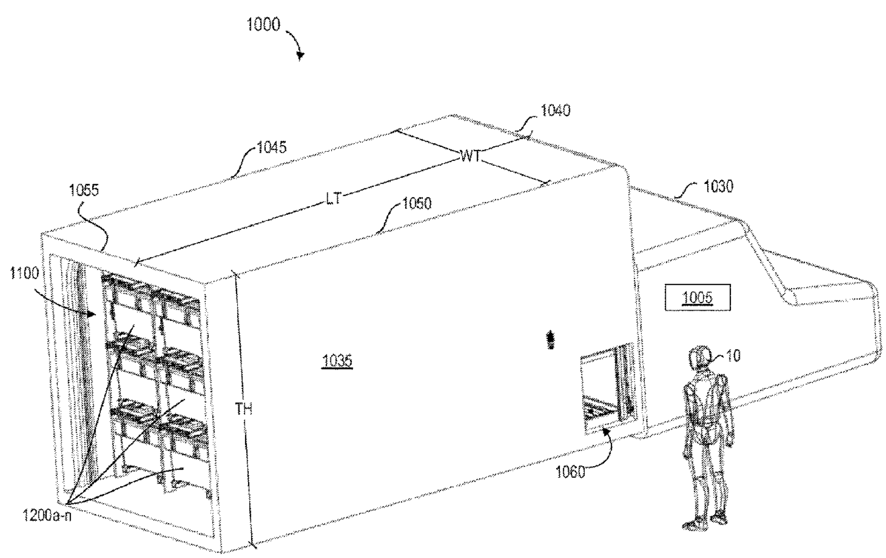
International Search Report and Written Opinion for PCT/US2021/055566 mailed Feb. 7, 2022, 17 pages.
(Continued)

Primary Examiner — Saul Rodriguez
Assistant Examiner — Willie W Berry, Jr.
(74) *Attorney, Agent, or Firm* — Myers Bigel, P.A.

(57) **ABSTRACT**

An autonomous racking system for use with a mobile delivery vehicle includes an array of flow racks configured to receive thereon a plurality of containers each of which associated with a single customer and a plurality of pushers configured to push each one of the containers past a front end of the array. An elevator abuts the front end of the array to receive one or more containers from at least one of the array and a vehicle side access portal, and to deliver one or more containers to one or more of the plurality of flow racks from the portal. The elevator comprises a plurality of loading pushers configured to push a container off of the movable carriage and onto the array. A controller is operable communication with a plurality of pusher drives, an elevator drive motor, and one or more elevator position sensors.

34 Claims, 81 Drawing Sheets



(58) **Field of Classification Search**
USPC 414/507
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,701,086	A	10/1987	Thorndyke	
5,092,721	A	3/1992	Prince	
5,915,913	A	6/1999	Greenlaw et al.	
5,931,262	A	8/1999	Greenlaw et al.	
2008/0089769	A1	4/2008	Cook	
2016/0318722	A1*	11/2016	Cervelli	B65F 3/001
2019/0143872	A1*	5/2019	Gil	B60P 1/54 211/86.01
2019/0287051	A1	9/2019	Heinla	
2020/0209865	A1	7/2020	Jarvis et al.	
2020/0265665	A1	8/2020	Nandakumar	
2020/0270066	A1	8/2020	Almogy et al.	
2020/0317340	A1	10/2020	Gil et al.	
2020/0376670	A1	12/2020	Diankov et al.	

FOREIGN PATENT DOCUMENTS

EP	3511886	A1	7/2019
WO	2014092145	A1	6/2014
WO	2020104568	A1	5/2020

OTHER PUBLICATIONS

Storage-retrieval machine for bins, cartons and trays—Schafer Miniload Crane, uploaded from YouTube: https://www.youtube.com/watch?v=NRO98Rm58-k, Jan. 26, 2015.

* cited by examiner

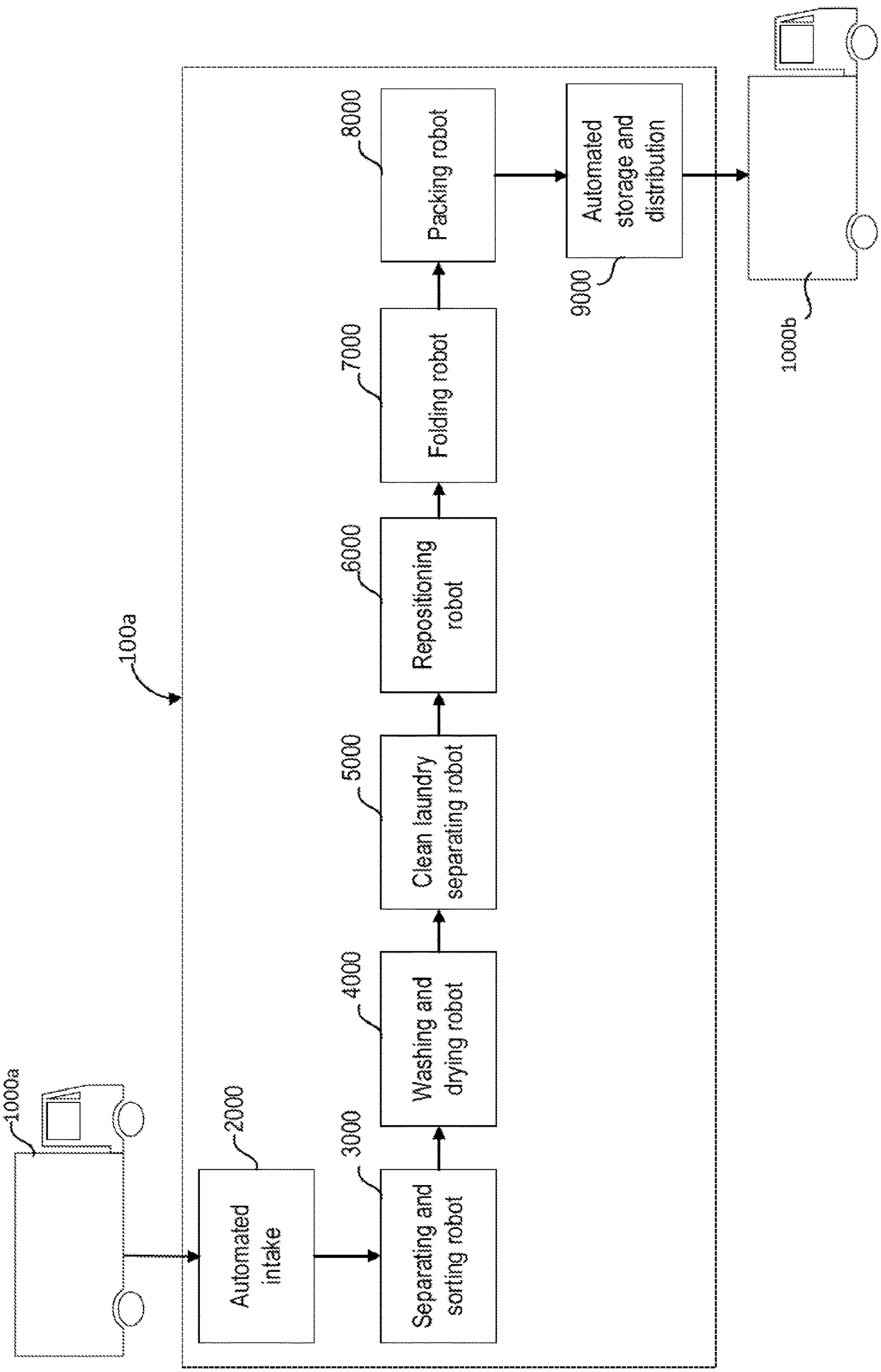

100a
1000a
2000
Automated intake
3000
Separating and sorting robot
4000
Washing and drying robot
5000
Clean laundry separating robot
6000
Repositioning robot
7000
Folding robot
8000
Packing robot
9000
Automated storage and distribution
1000b

FIG. 1

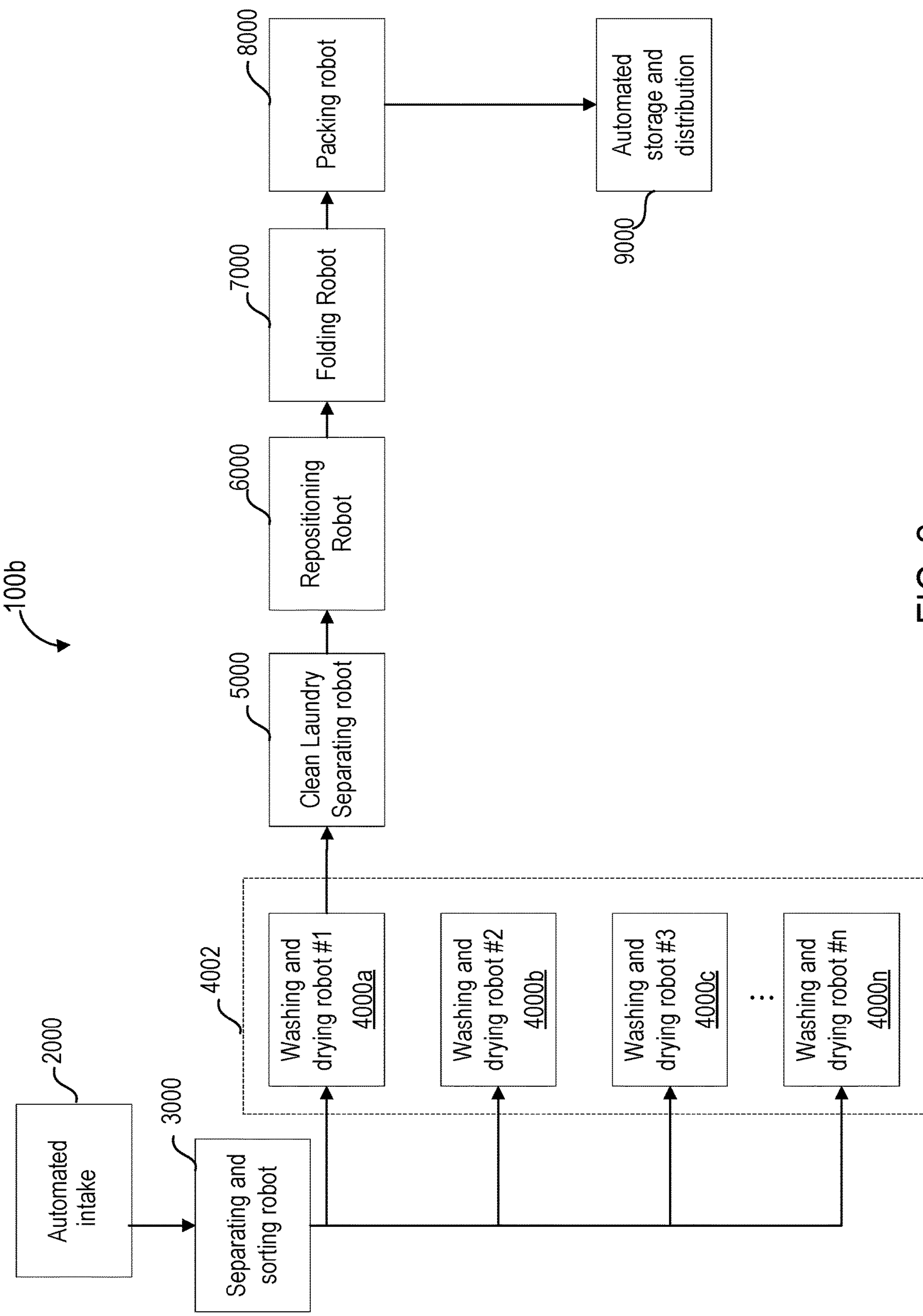

100b
2000
Automated intake
3000
Separating and sorting robot
4002
Washing and drying robot #1 4000a
Washing and drying robot #2 4000b
Washing and drying robot #3 4000c
...
Washing and drying robot #n 4000n
5000
Clean Laundry Separating robot
6000
Repositioning Robot
7000
Folding Robot
8000
Packing robot
9000
Automated storage and distribution

FIG. 2

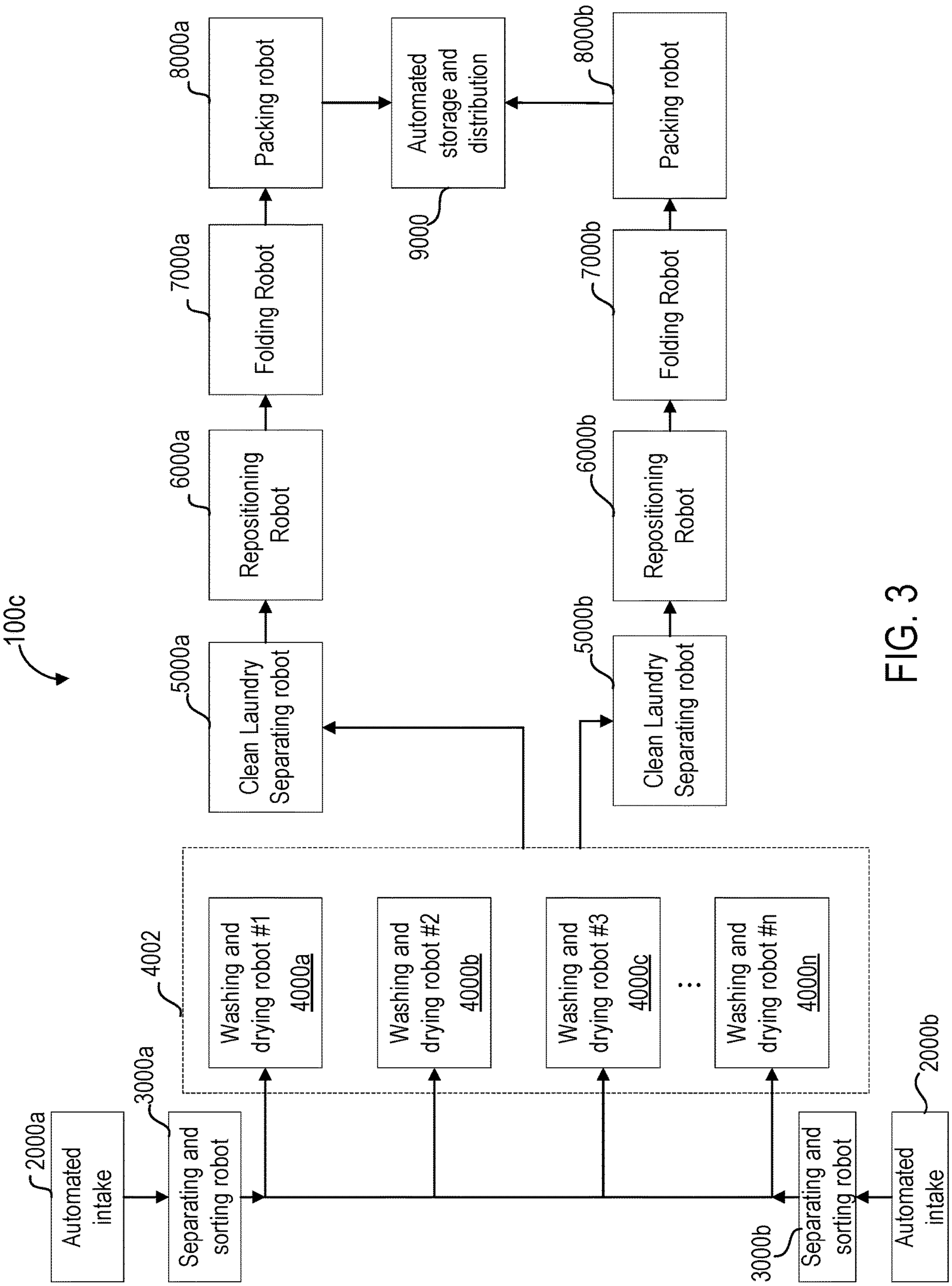

100c
Automated intake
2000a
Separating and sorting robot
3000a
4002
Washing and drying robot #1 4000a
Washing and drying robot #2 4000b
Washing and drying robot #3 4000c
...
Washing and drying robot #n 4000n
Separating and sorting robot
3000b
Automated intake
2000b
Clean Laundry Separating robot
5000a
Repositioning Robot
6000a
Folding Robot
7000a
Packing robot
8000a
Automated storage and distribution
9000
Clean Laundry Separating robot
5000b
Repositioning Robot
6000b
Folding Robot
7000b
Packing robot
8000b

FIG. 3

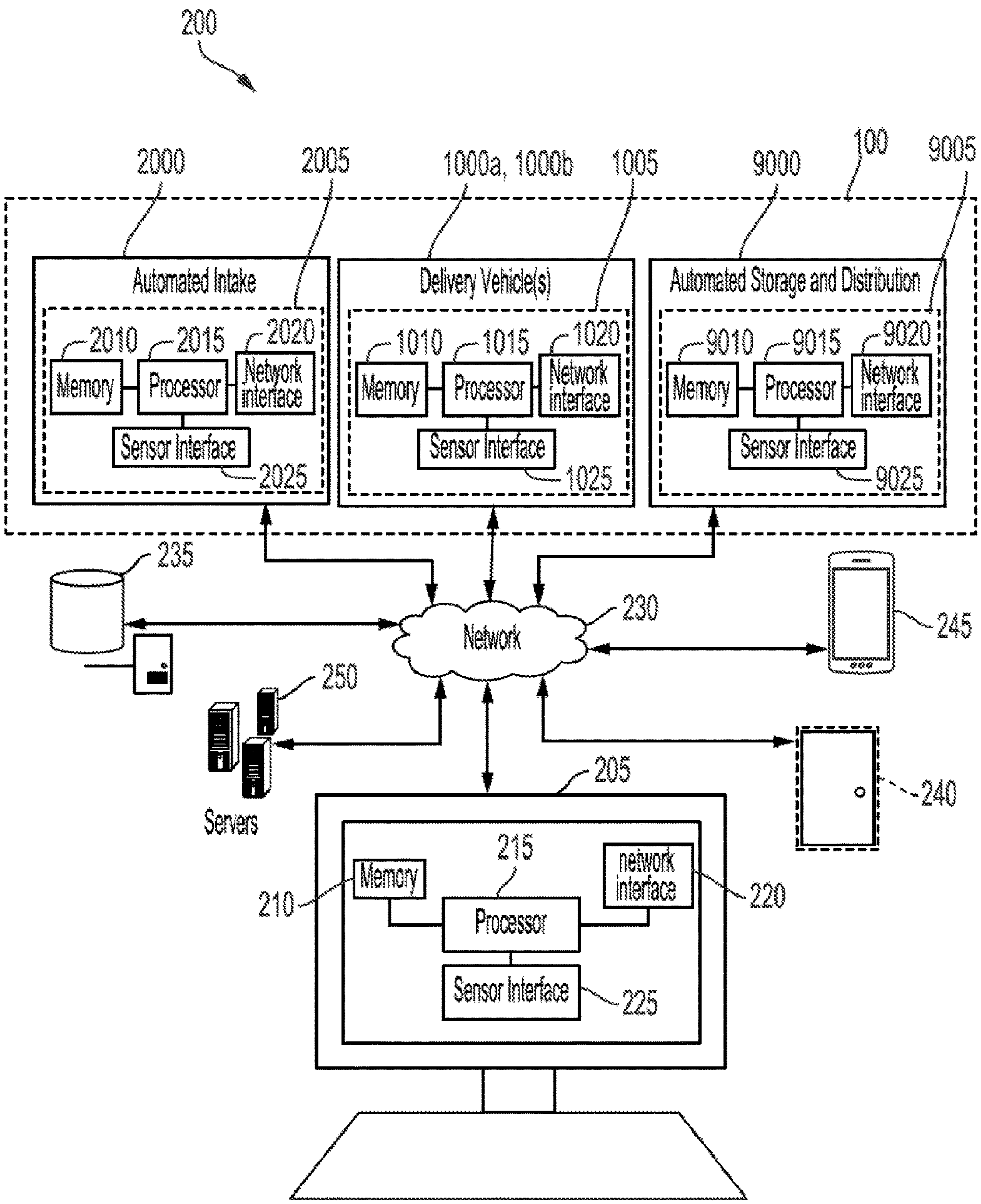

200
2000
2005
1000a, 1000b
1005
9000
100
9005
Automated Intake
2010
2015
2020
Memory
Processor
Network interface
Sensor Interface
2025
Delivery Vehicle(s)
1010
1015
1020
Memory
Processor
Network interface
Sensor Interface
1025
Automated Storage and Distribution
9010
9015
9020
Memory
Processor
Network interface
Sensor Interface
9025
235
230
Network
245
250
Servers
205
240
215
Memory
network interface
210
220
Processor
Sensor Interface
225

FIG. 4

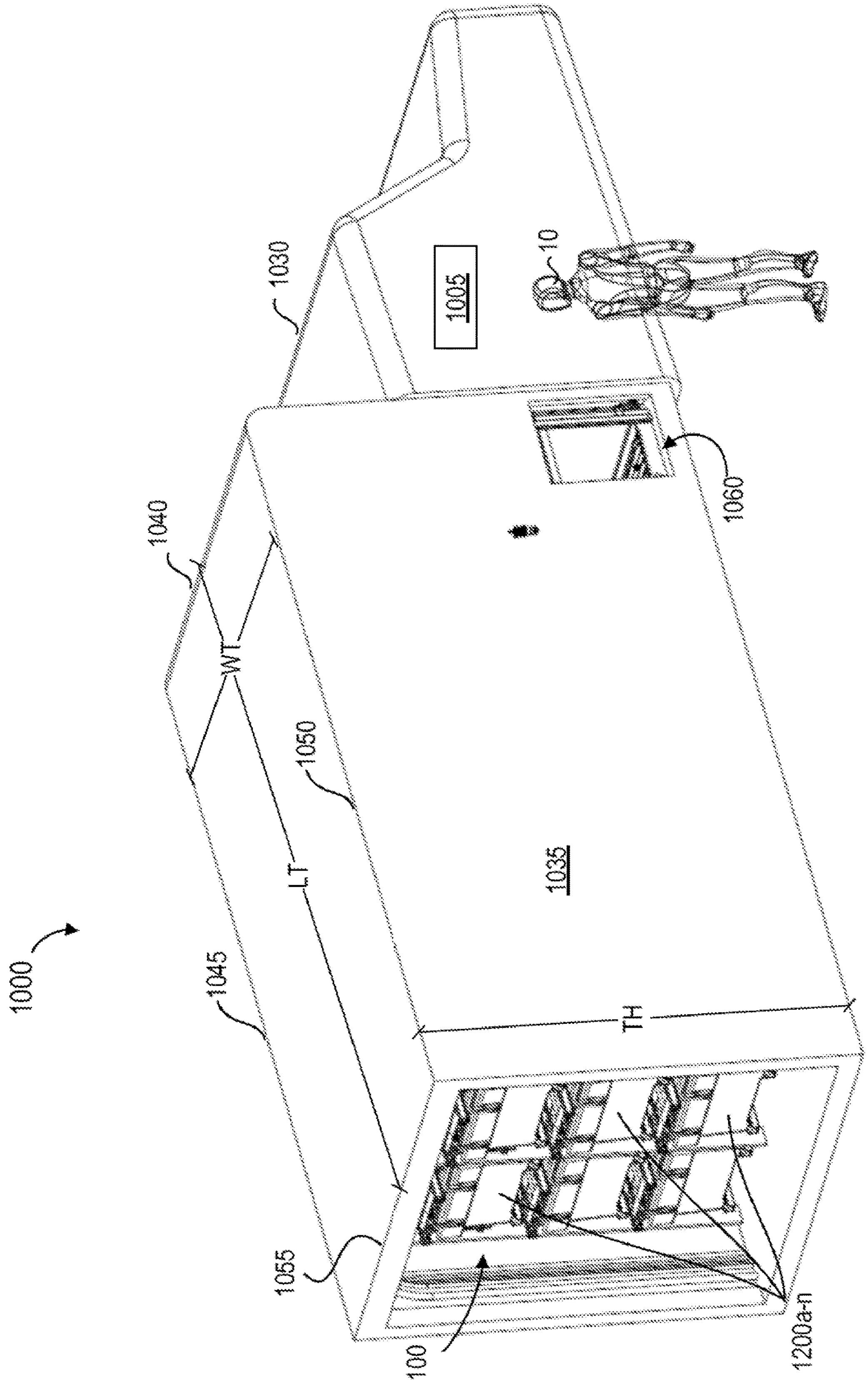

1000
1030
1005
10
1060
1040
WT
1050
LT
1035
1045
TH
1055
1100
1200a-n

FIG. 5

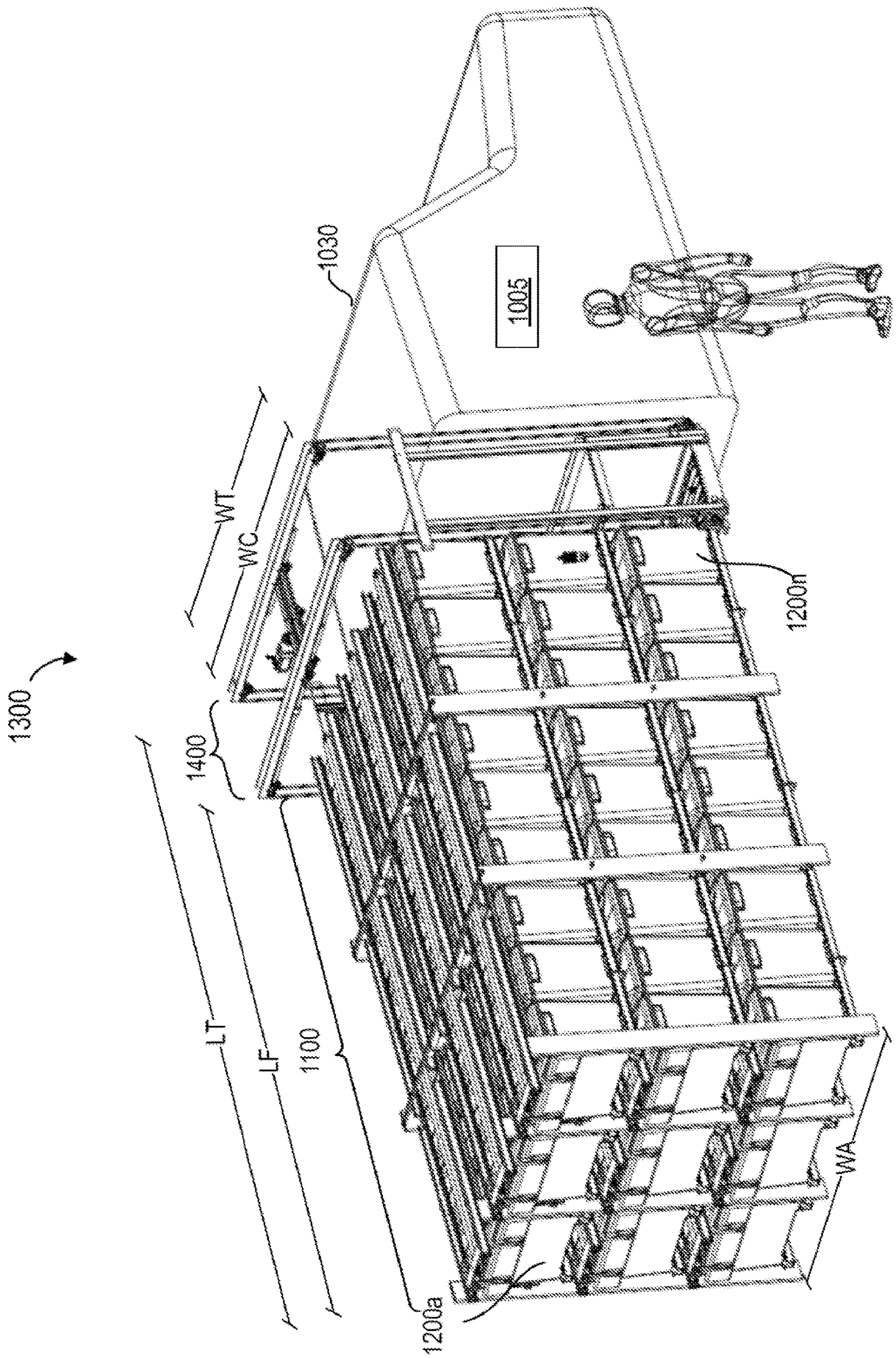


FIG. 6

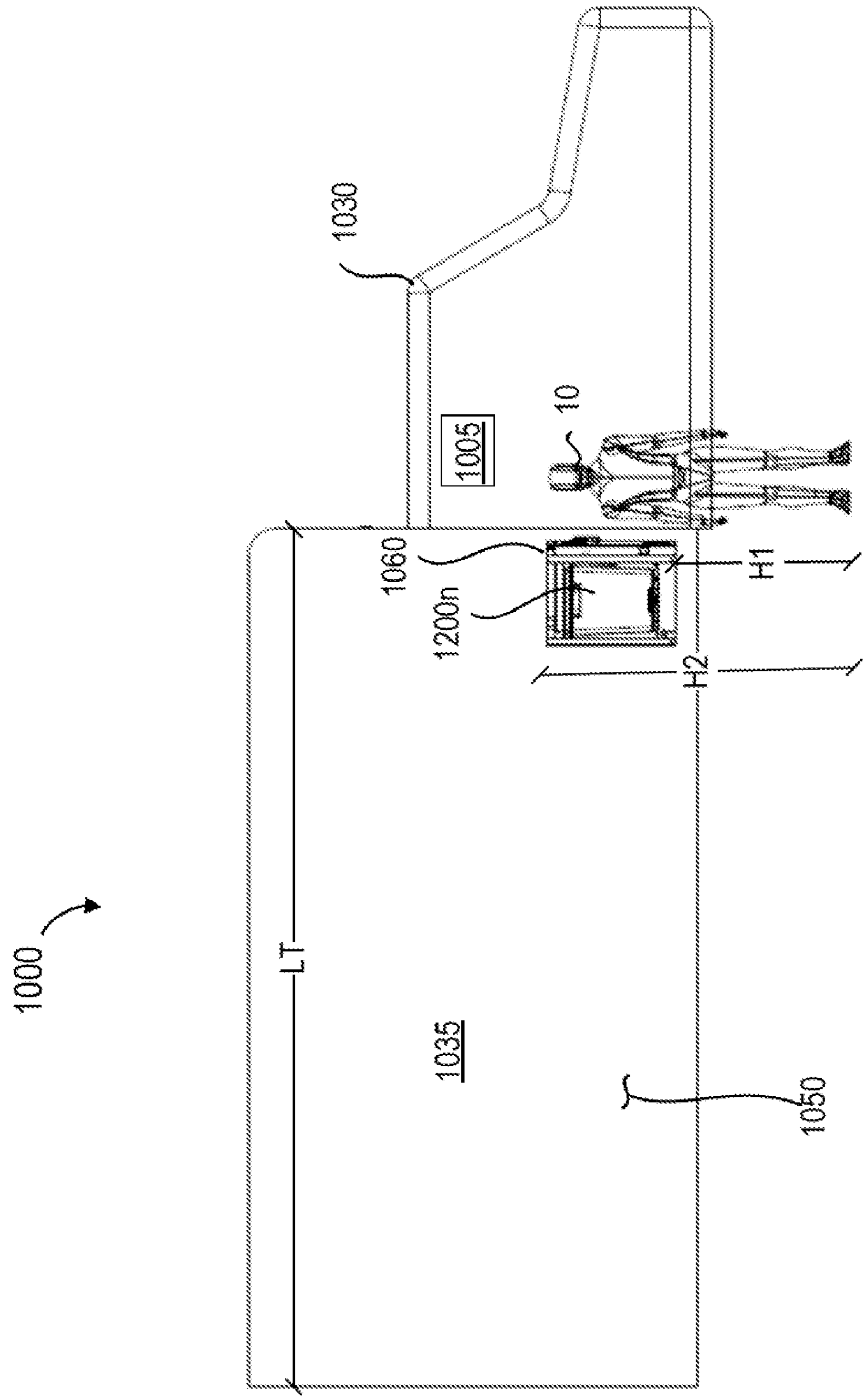


FIG. 7

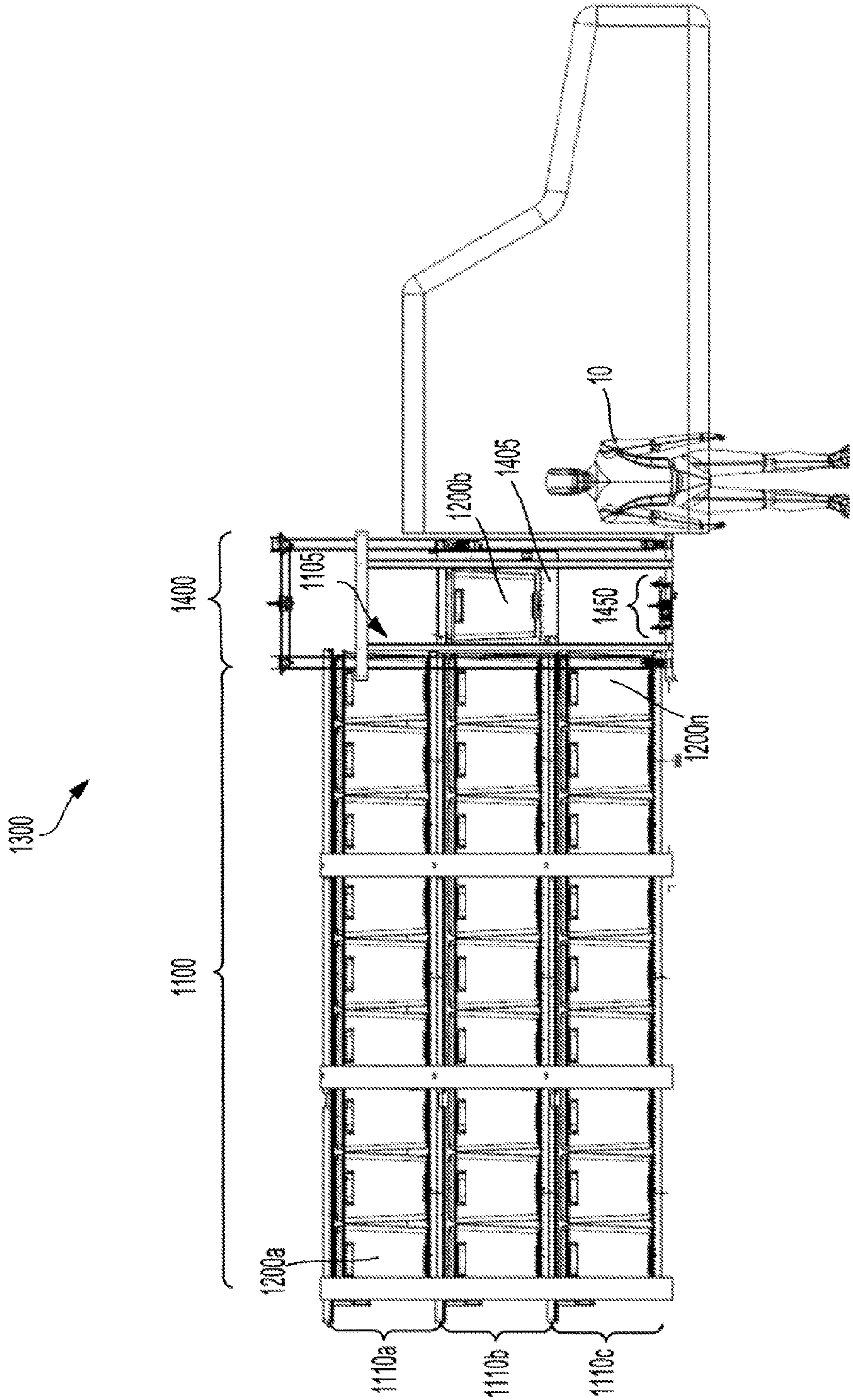
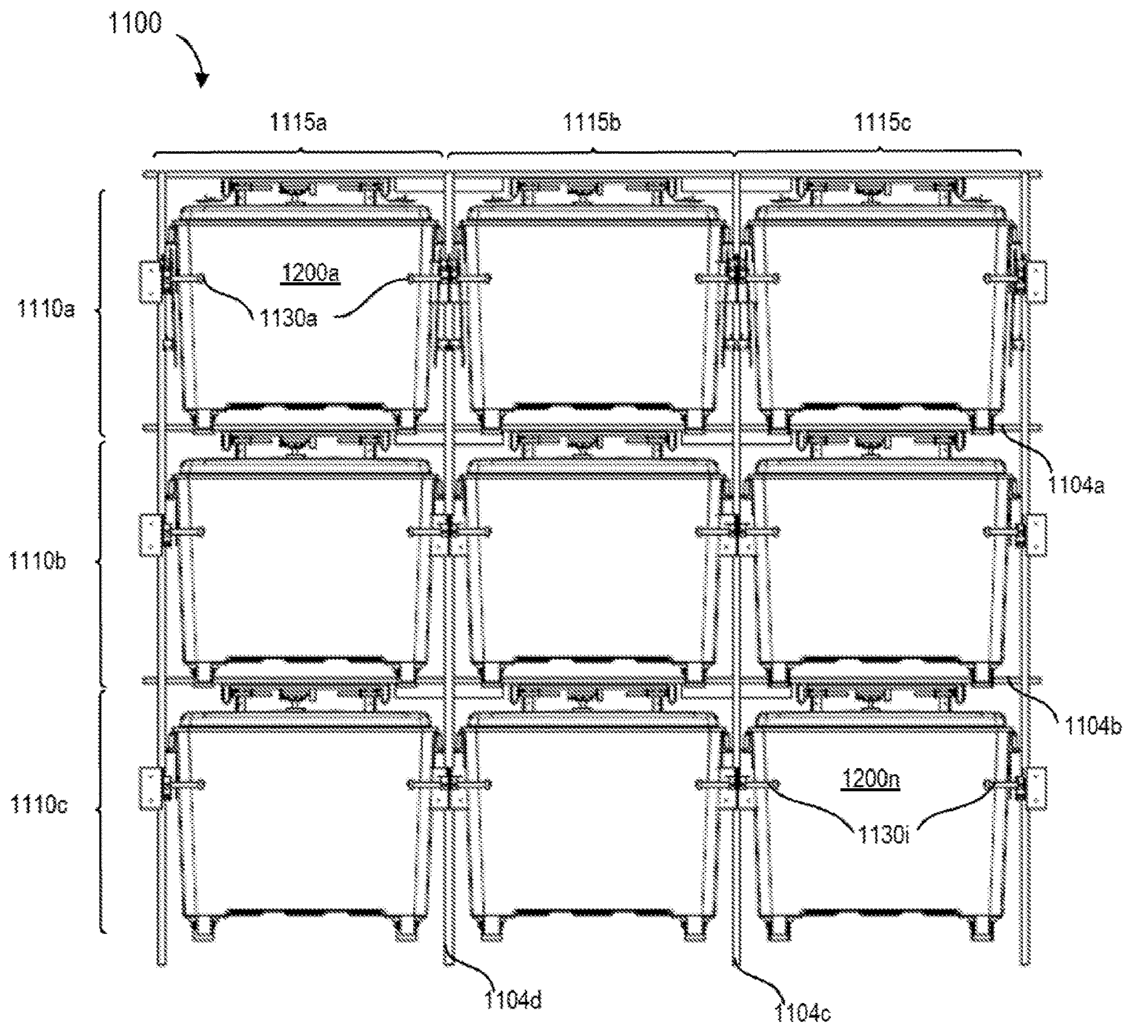

1300
1400
1100
1105
1200b
1405
10
1450
1200n
1200a
1110a
1110b
1110c

FIG. 8



1100
1115a
1115b
1115c
1200a
1130a
1110a
1104a
1110b
1104b
1110c
1200n
1130i
1104d
1104c

FIG. 9A

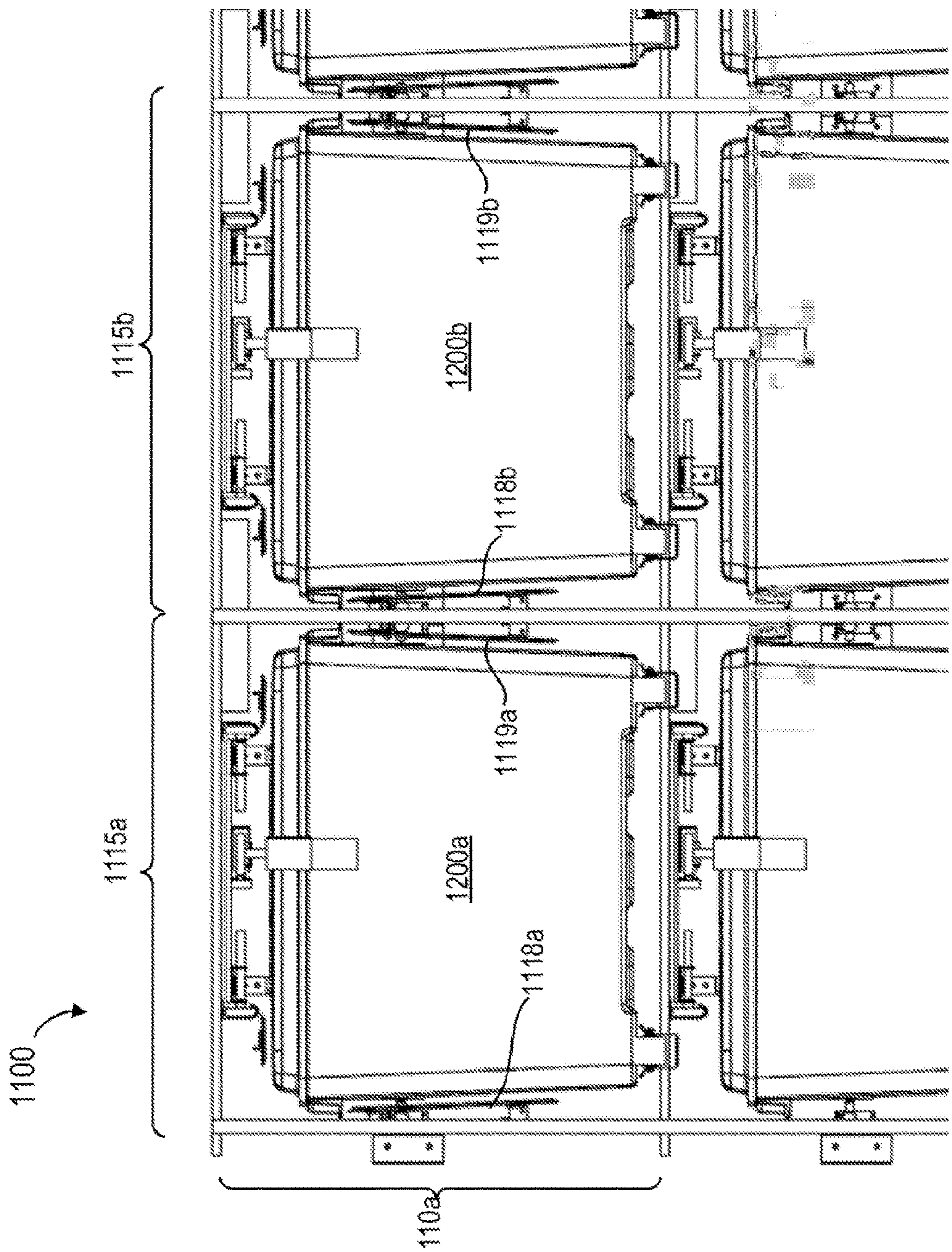


FIG. 9B

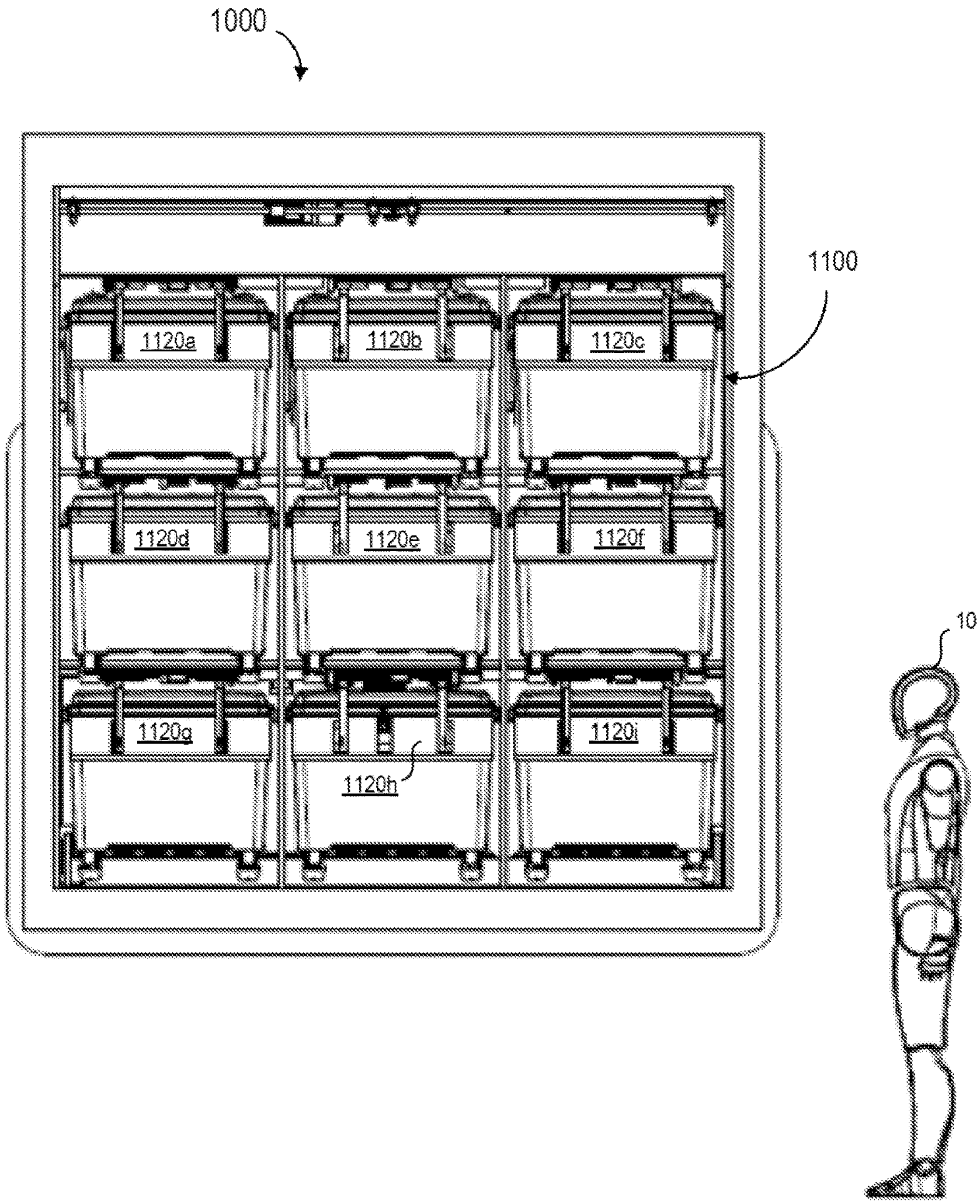

1000
1100
1120a
1120b
1120c
1120d
1120e
1120f
1120g
1120h
1120i
10

FIG. 10

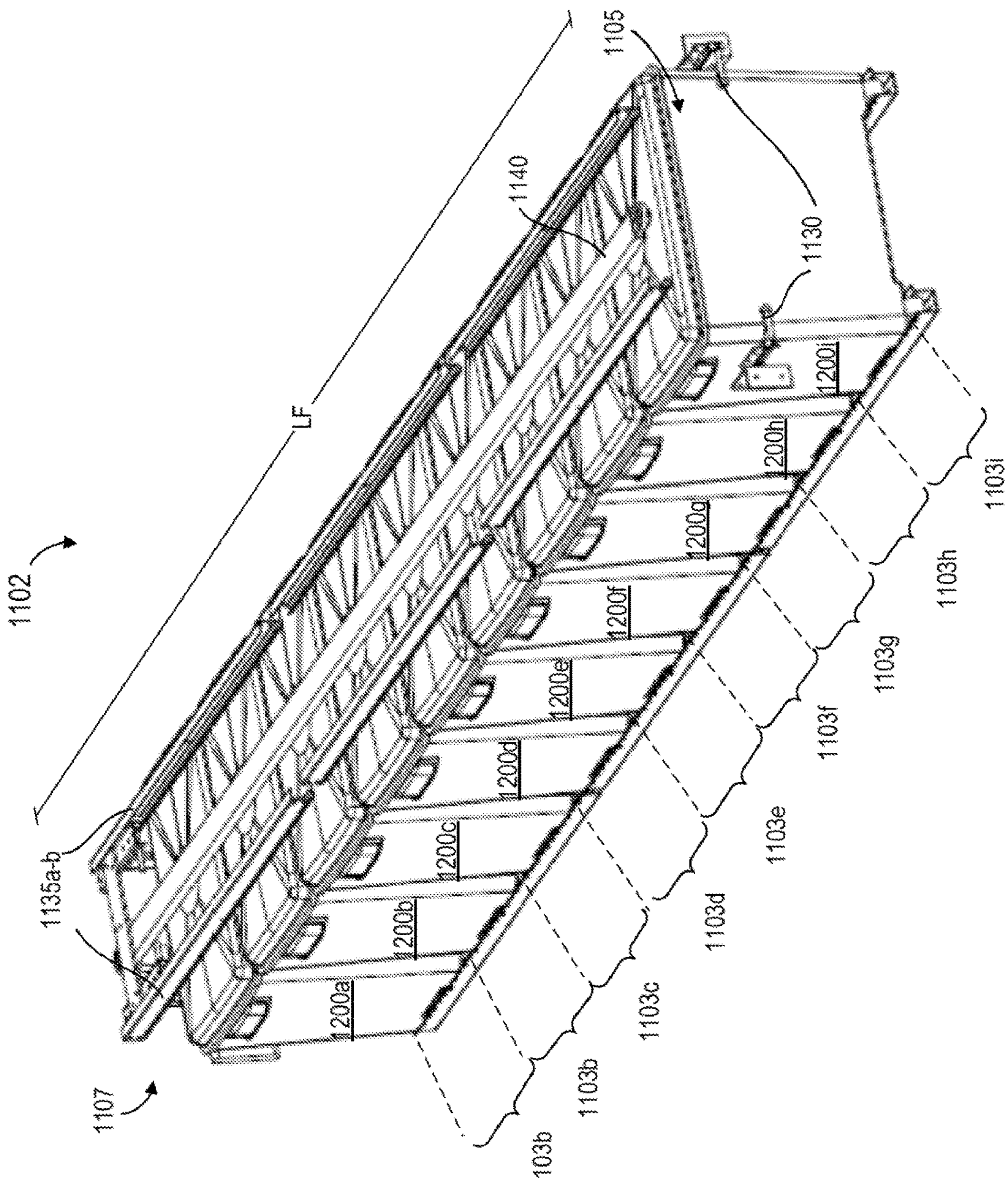

1102
1105
1140
LF
1130
1135a-b
1107
1200a
1200b
1200c
1200d
1200e
1200f
1200g
1200h
1200i
1103b
1103b
1103c
1103d
1103e
1103f
1103g
1103h
1103i

FIG. 11

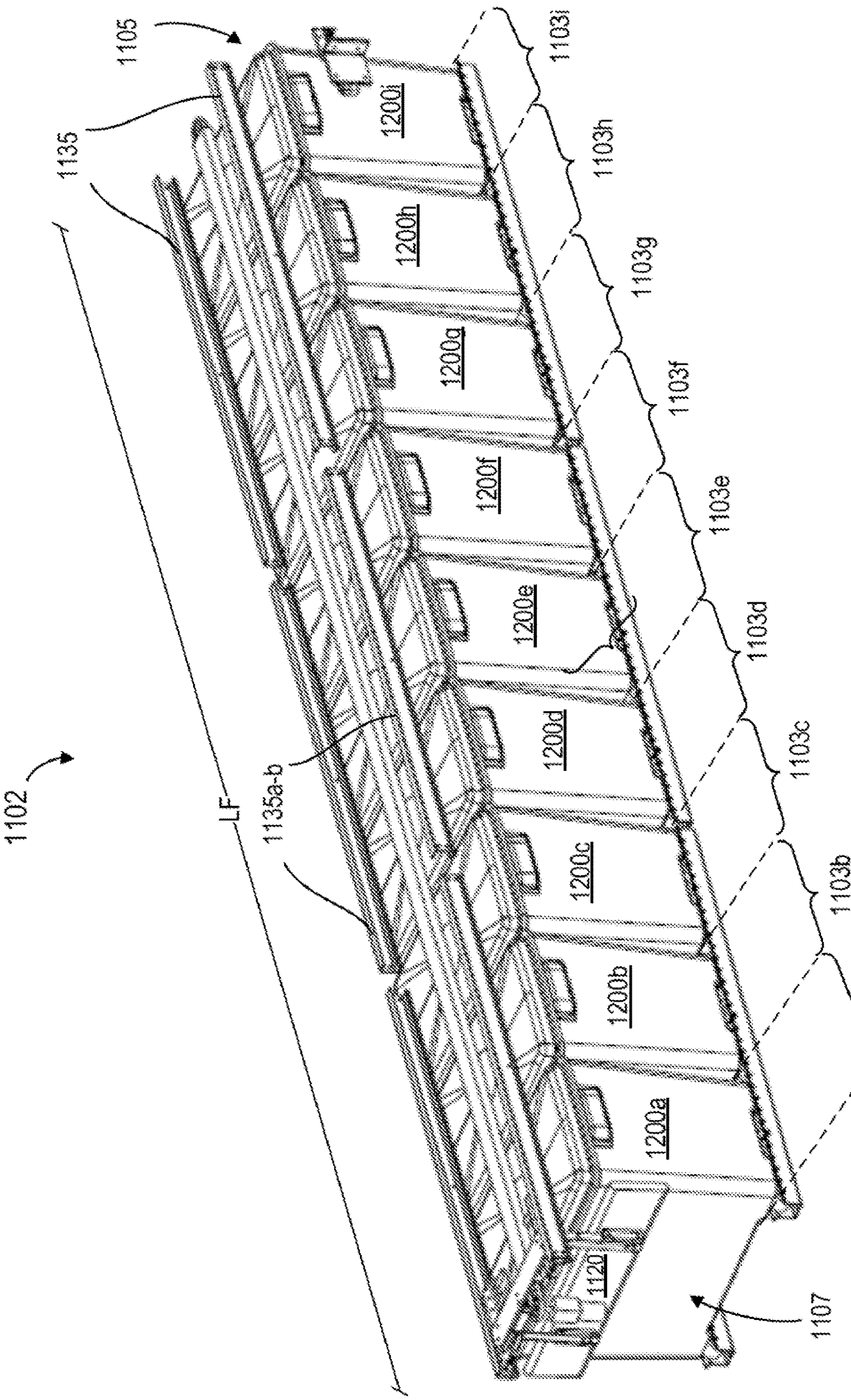

1105
1135
1102
LF
1135a-b
1200i
1200h
1200g
1200f
1200e
1200d
1200c
1200b
1200a
1120
1107
1103i
1103h
1103g
1103f
1103e
1103d
1103c
1103b
1103a

FIG. 12

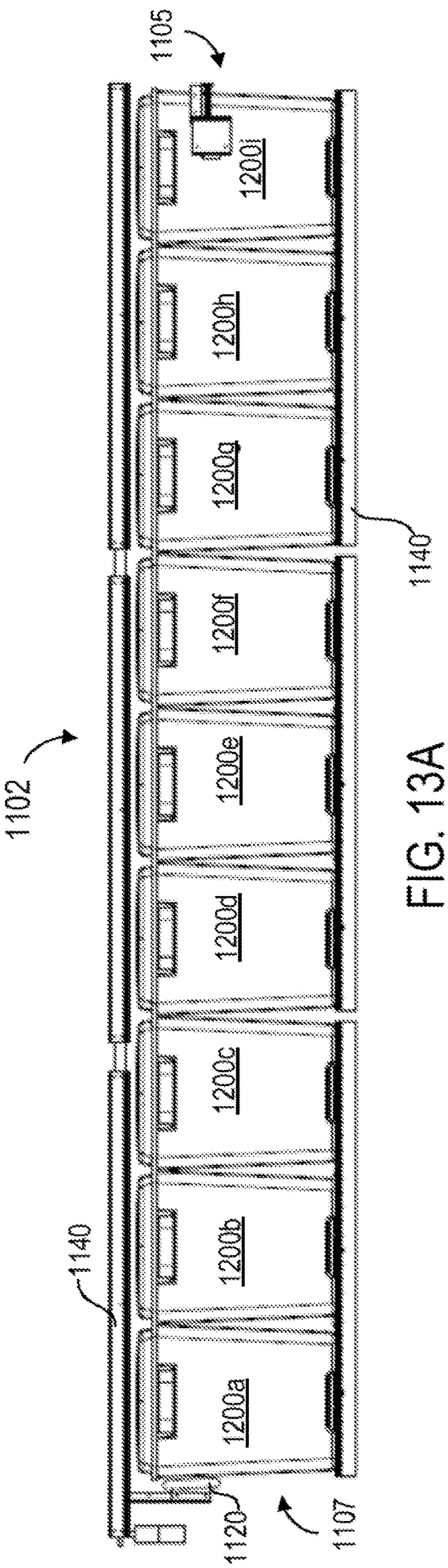


FIG. 13A

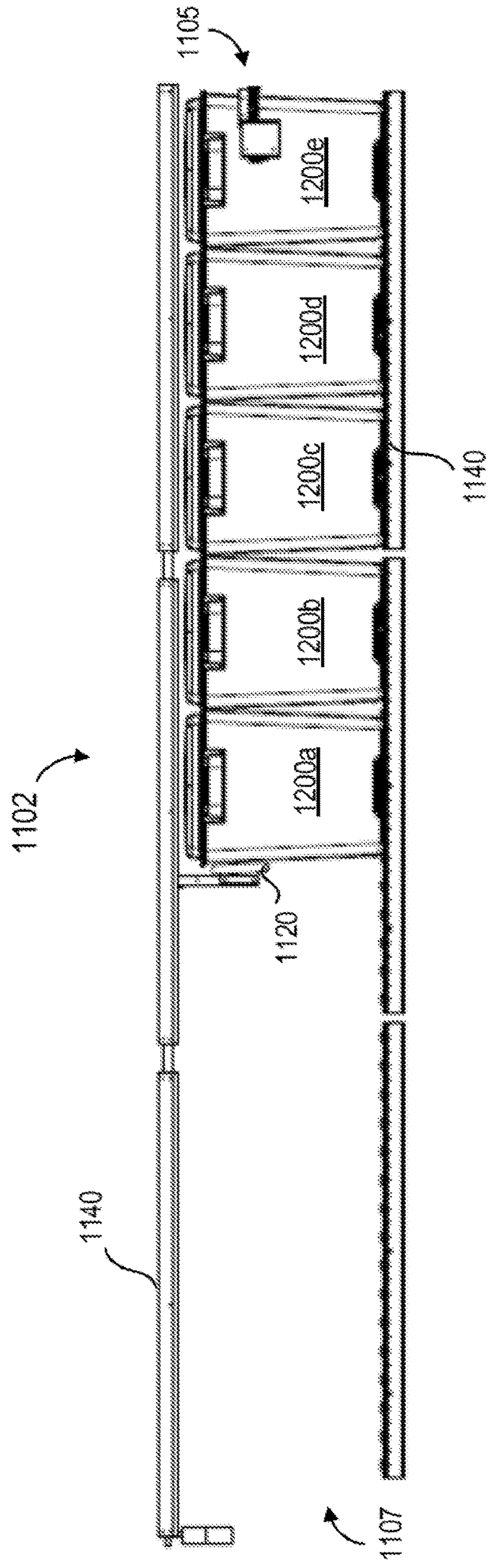


FIG. 13B

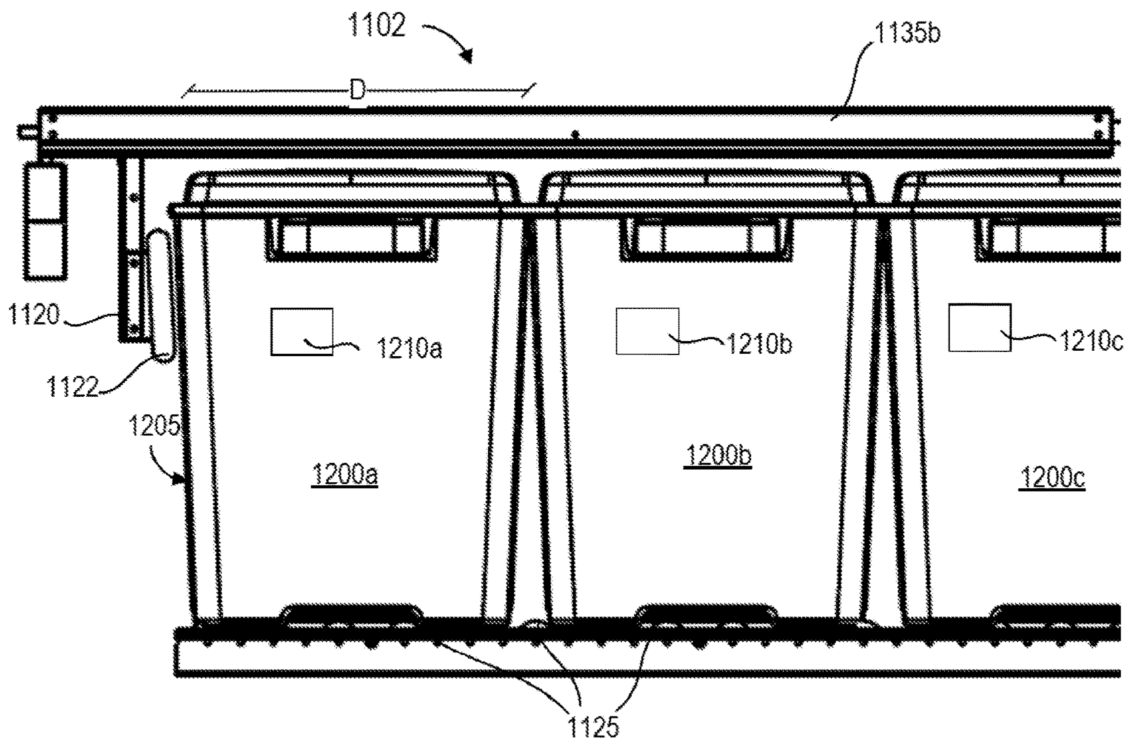


FIG. 14A

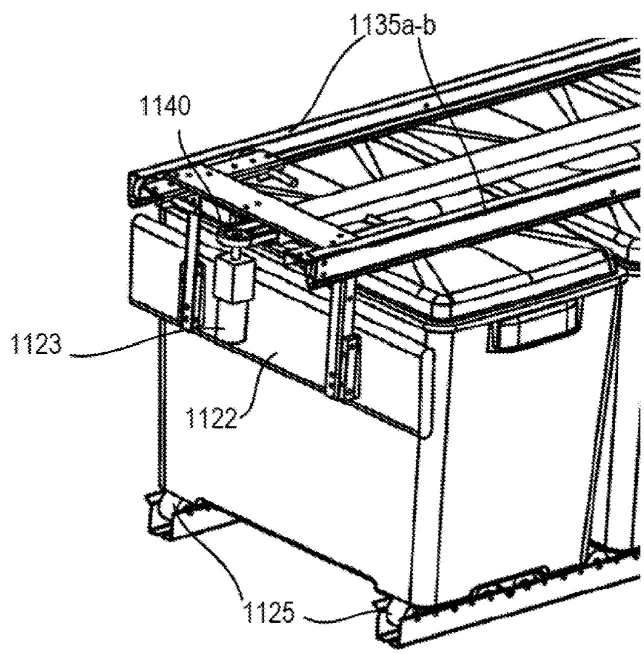


FIG. 14B

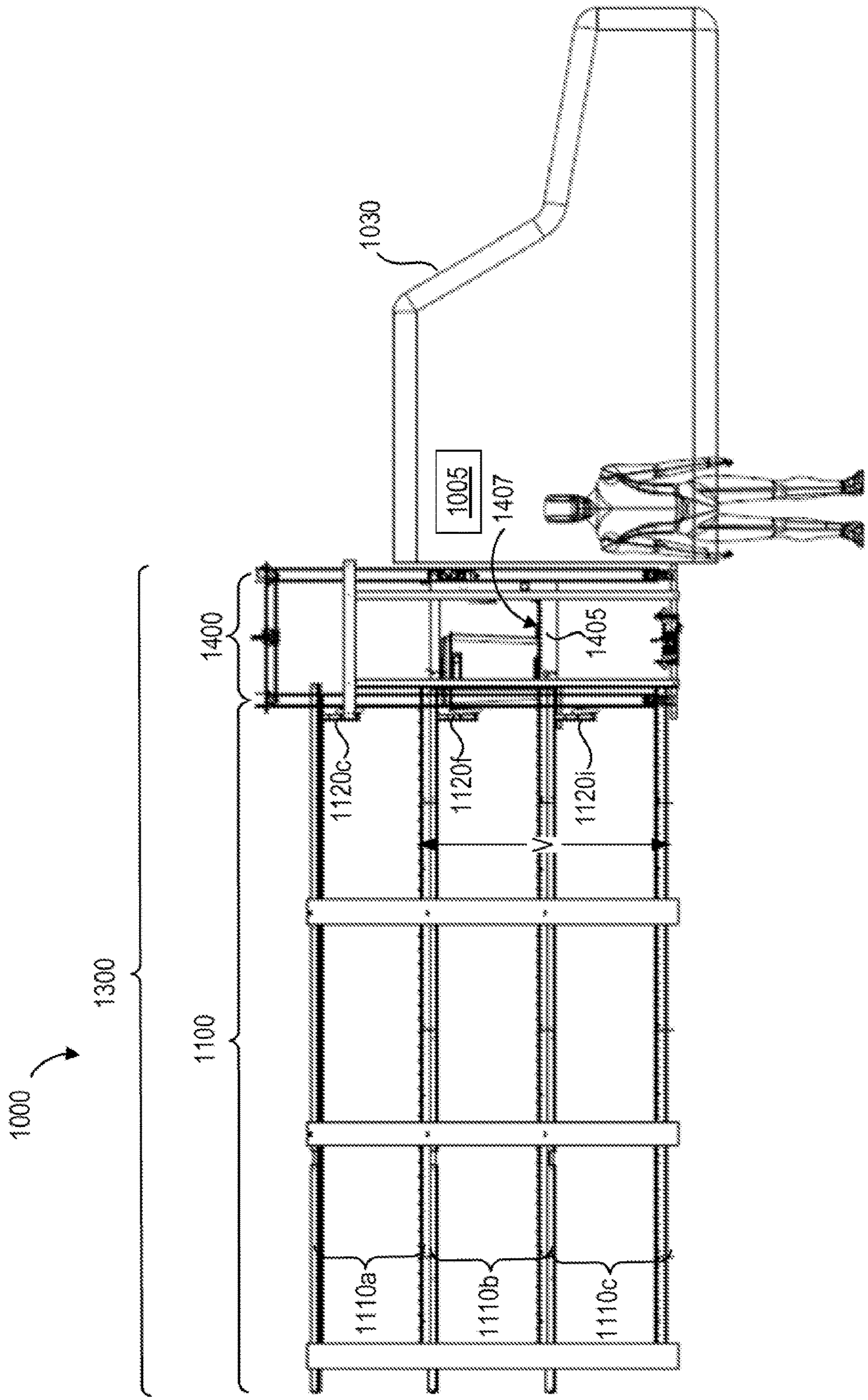

1000
1300
1100
1400
1030
1005
1407
1405
1120c
1120f
1120i
V
1110a
1110b
1110c

FIG. 15

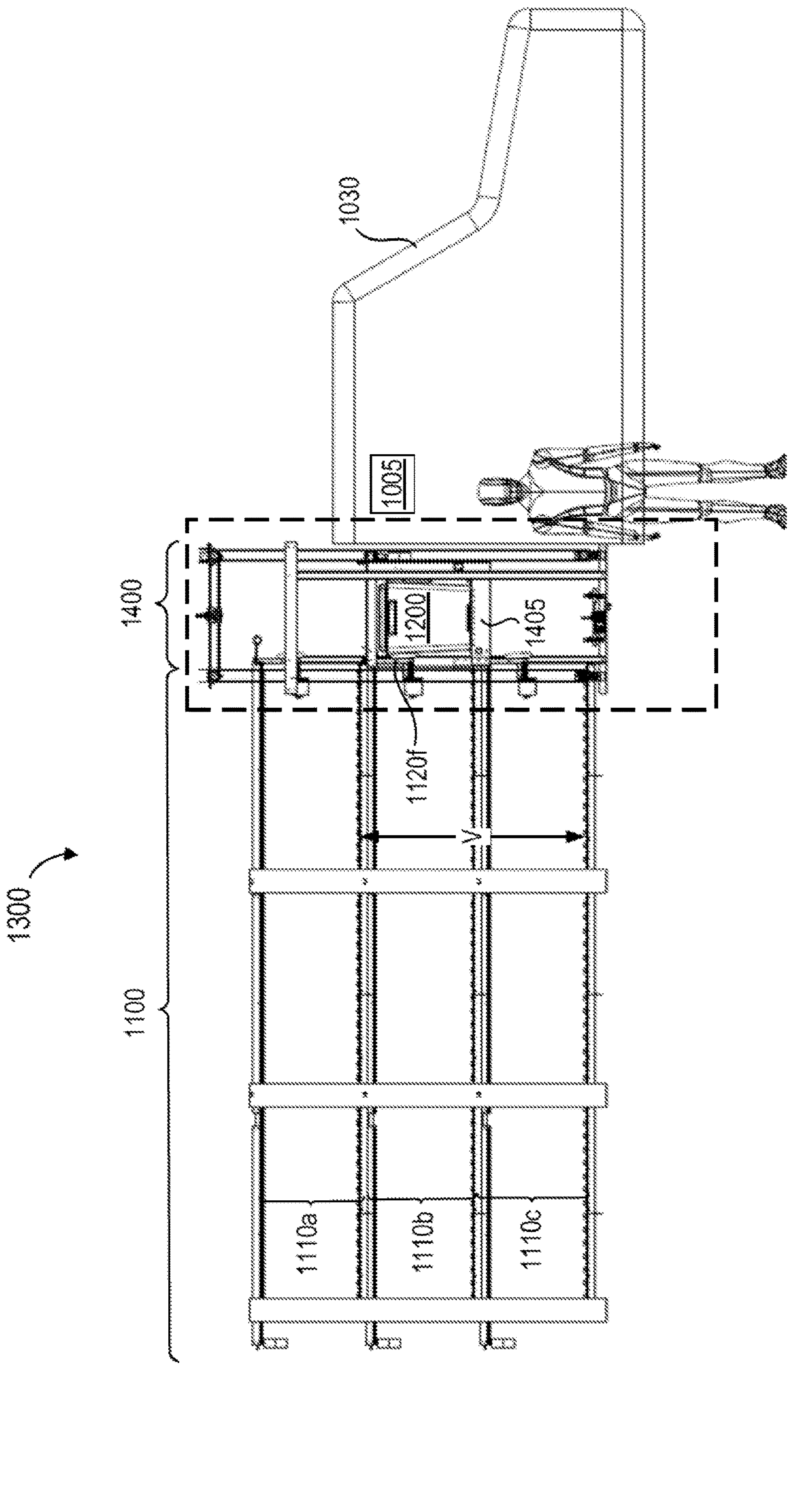


FIG. 16

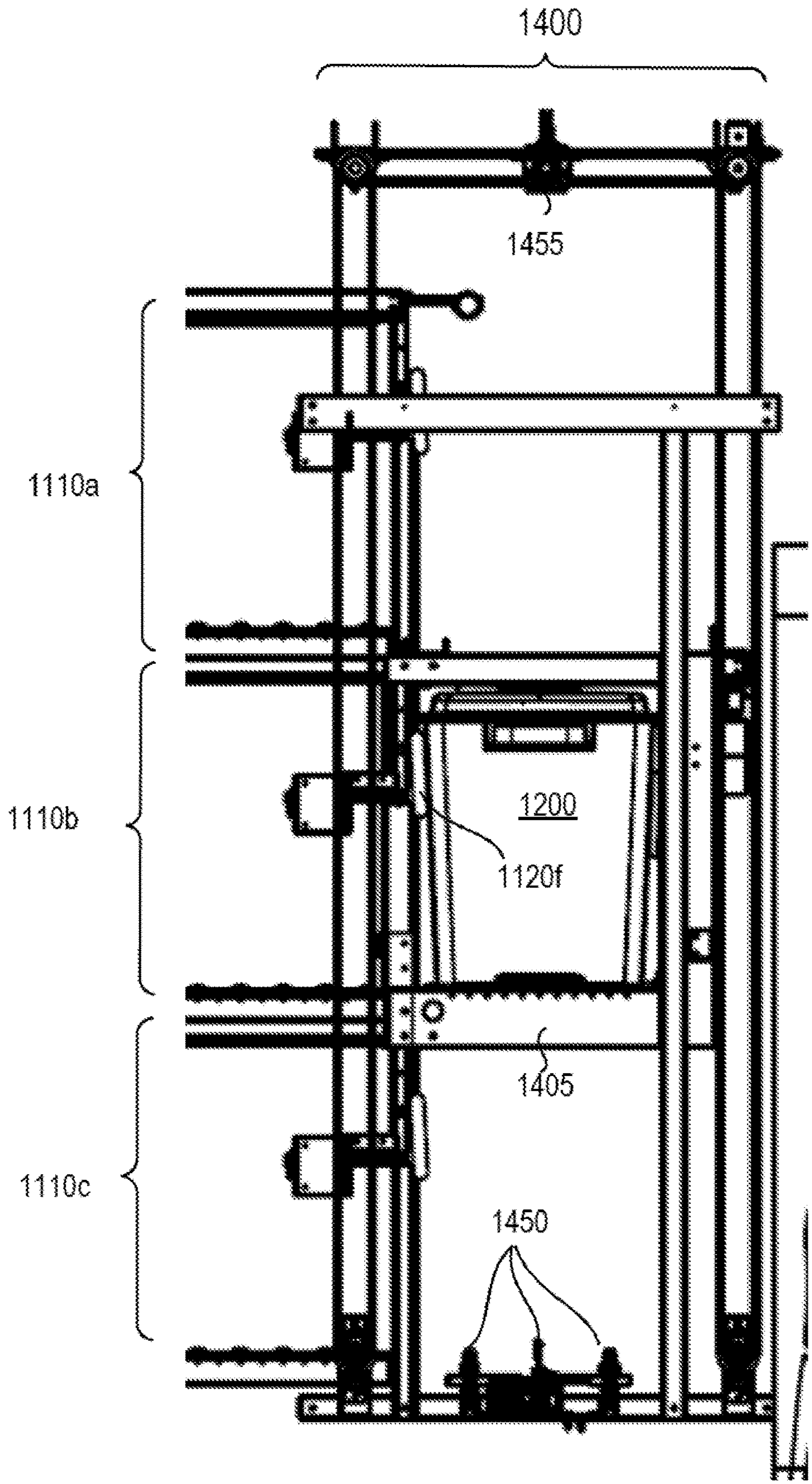


FIG. 17

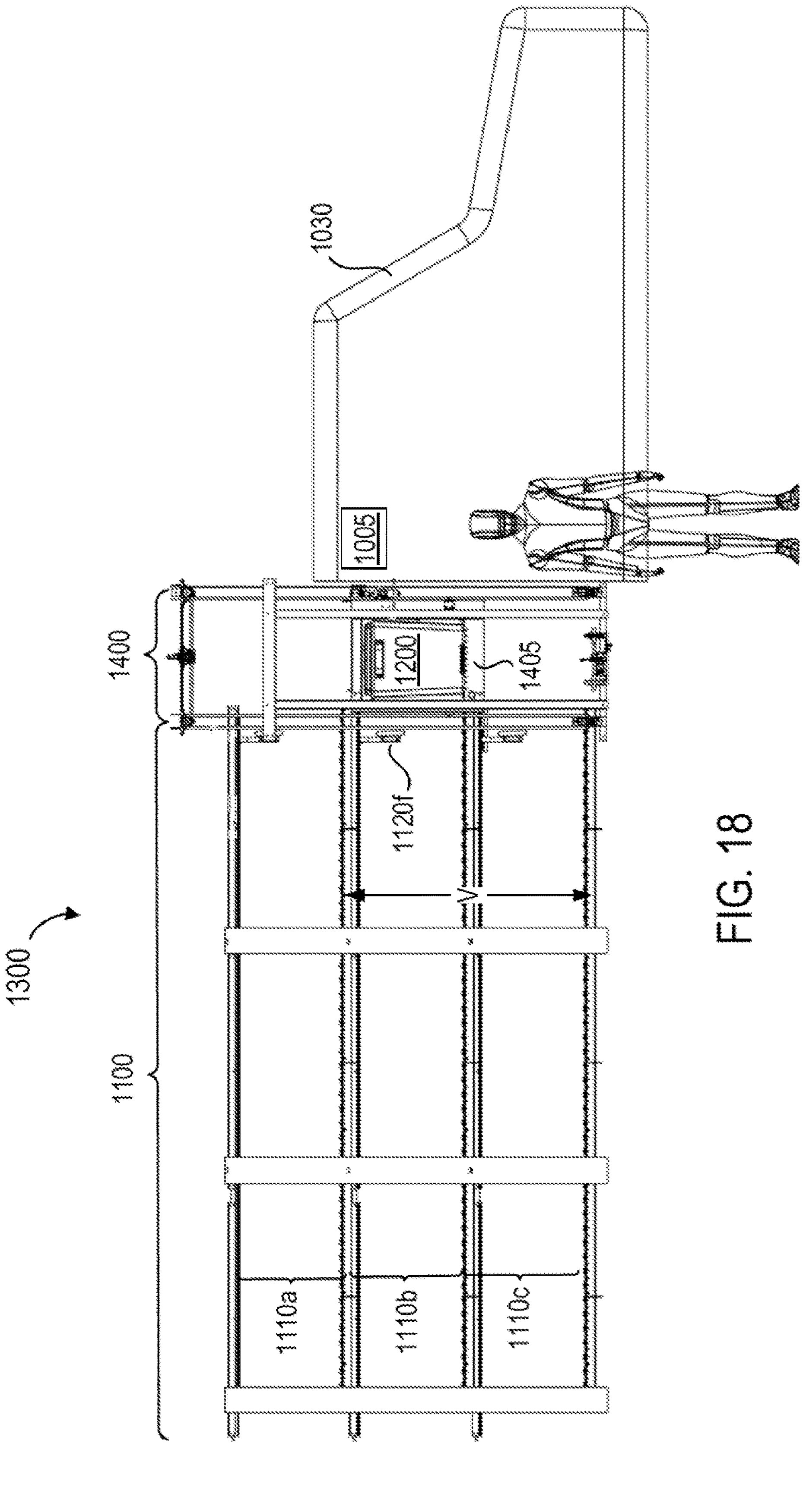


FIG. 18

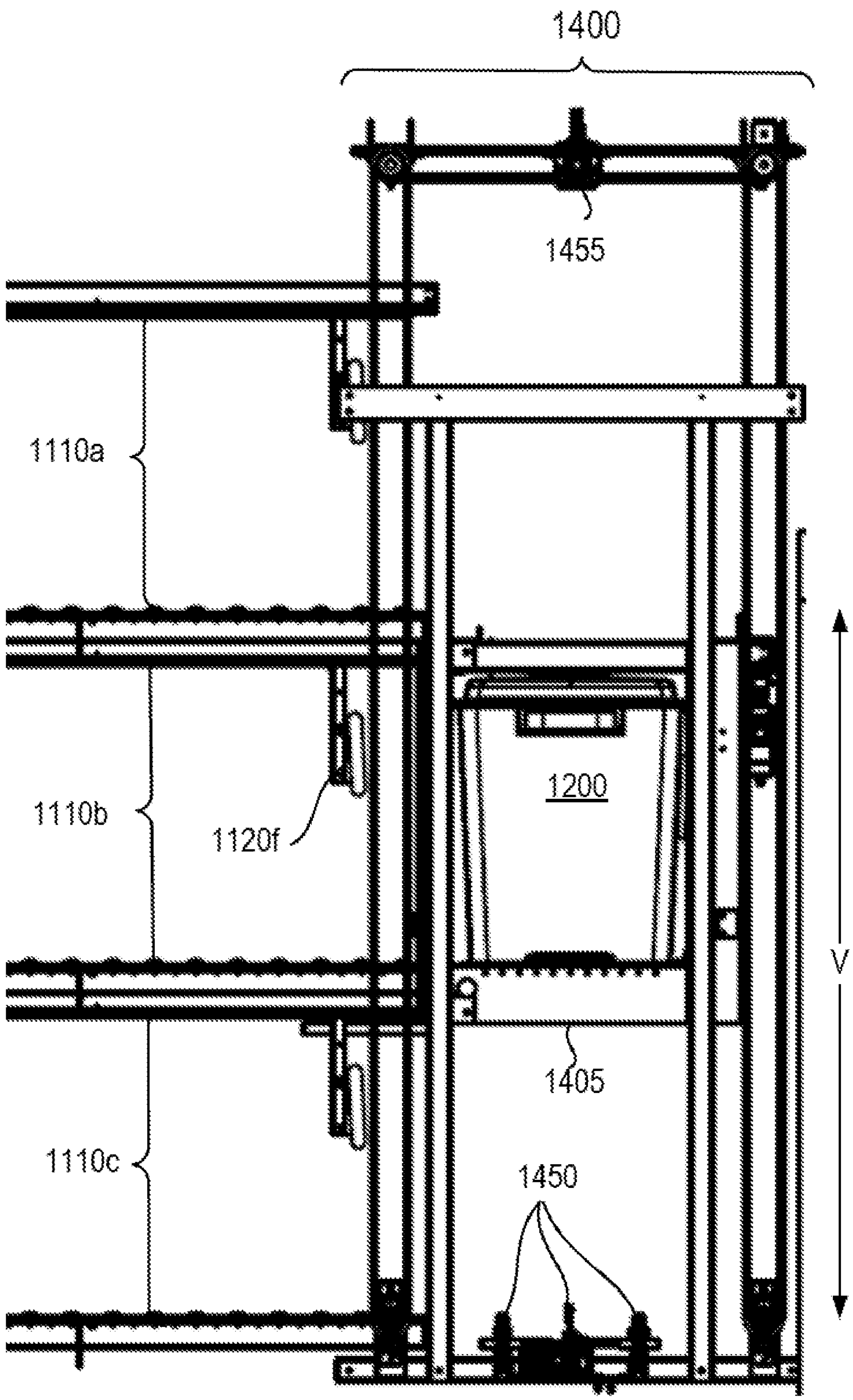


FIG. 19

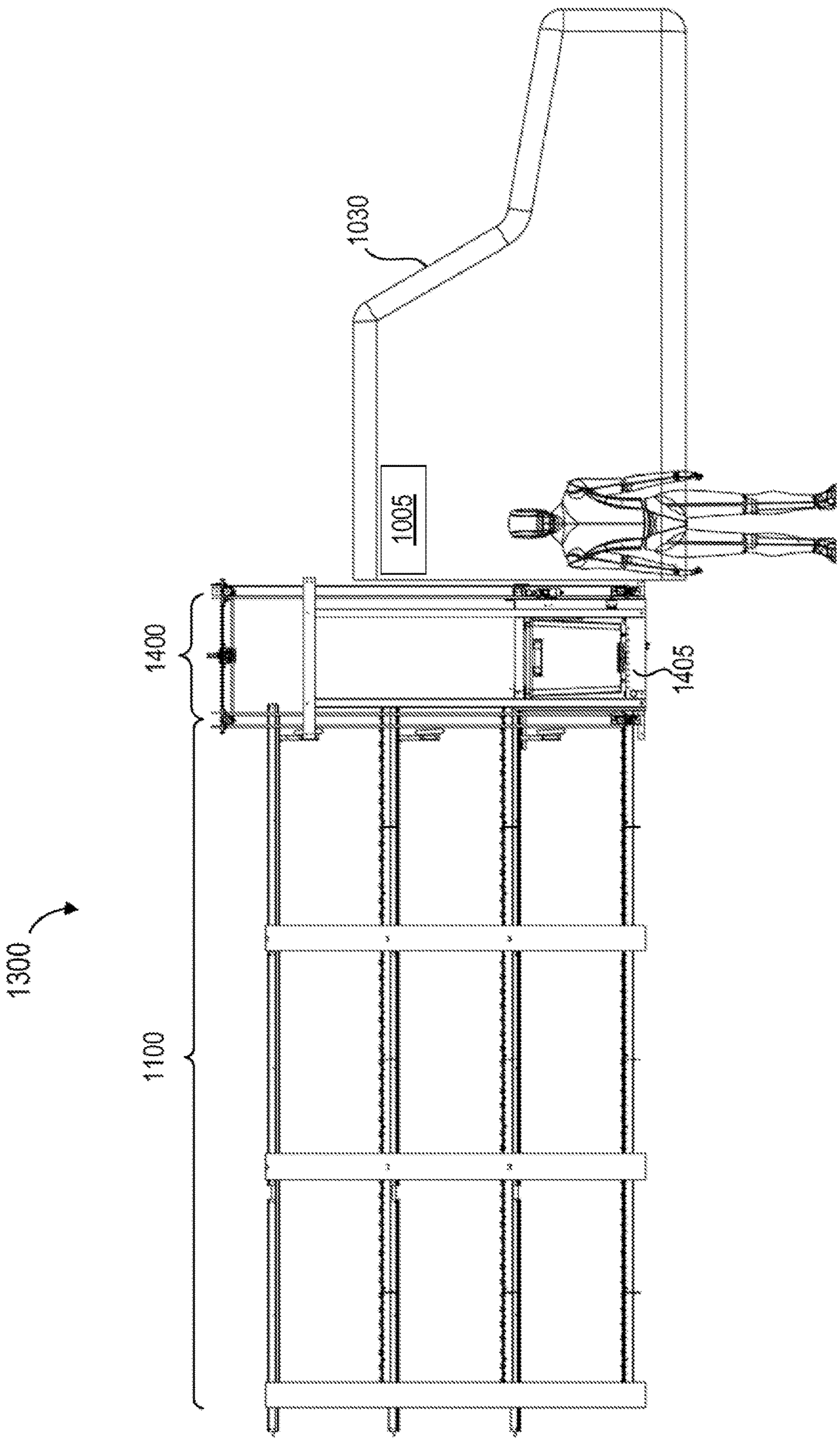


FIG. 20

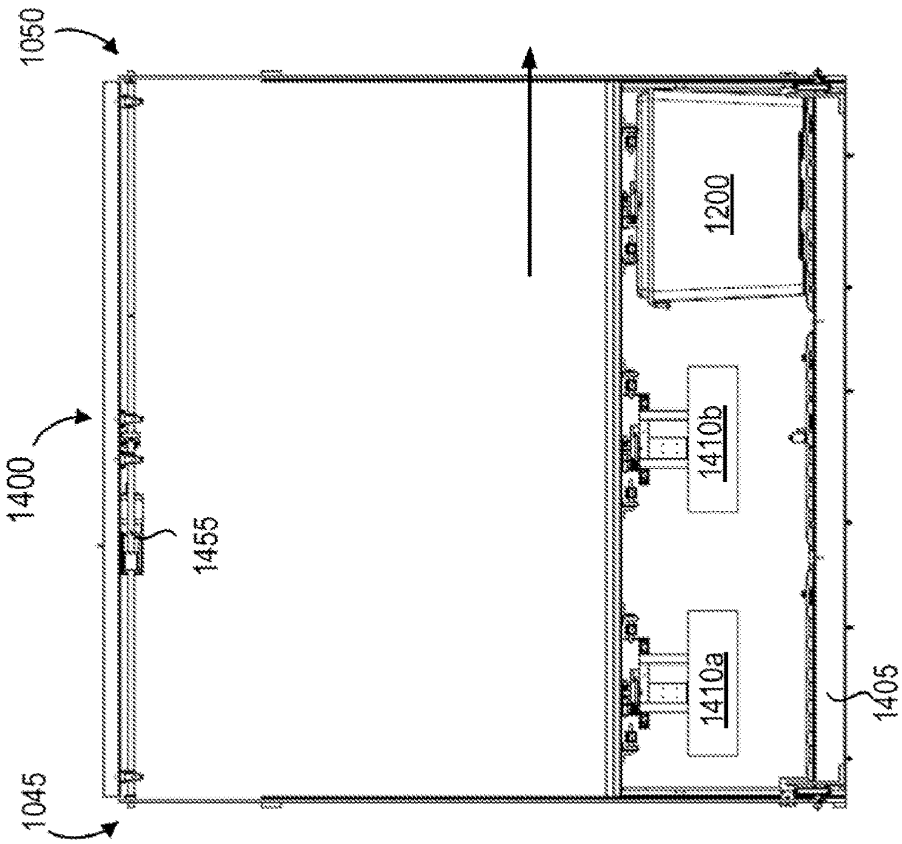


FIG. 21B

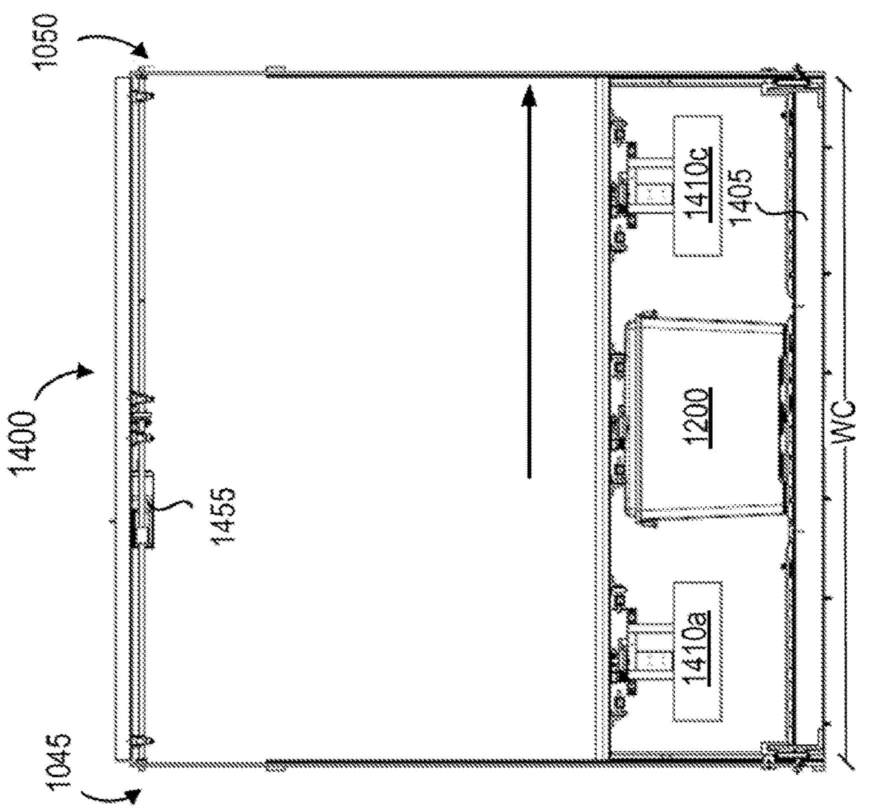


FIG. 21A

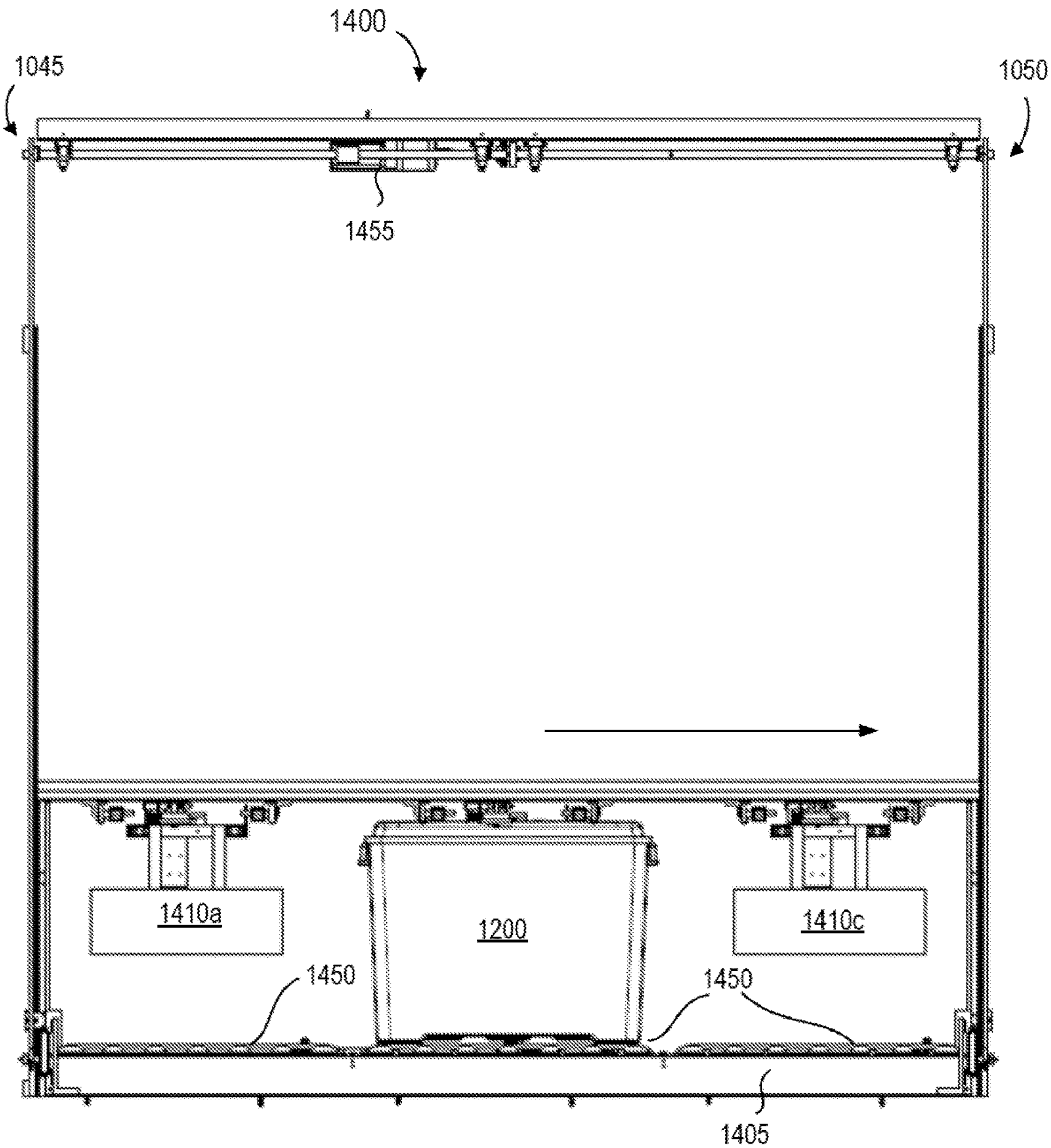


FIG. 22

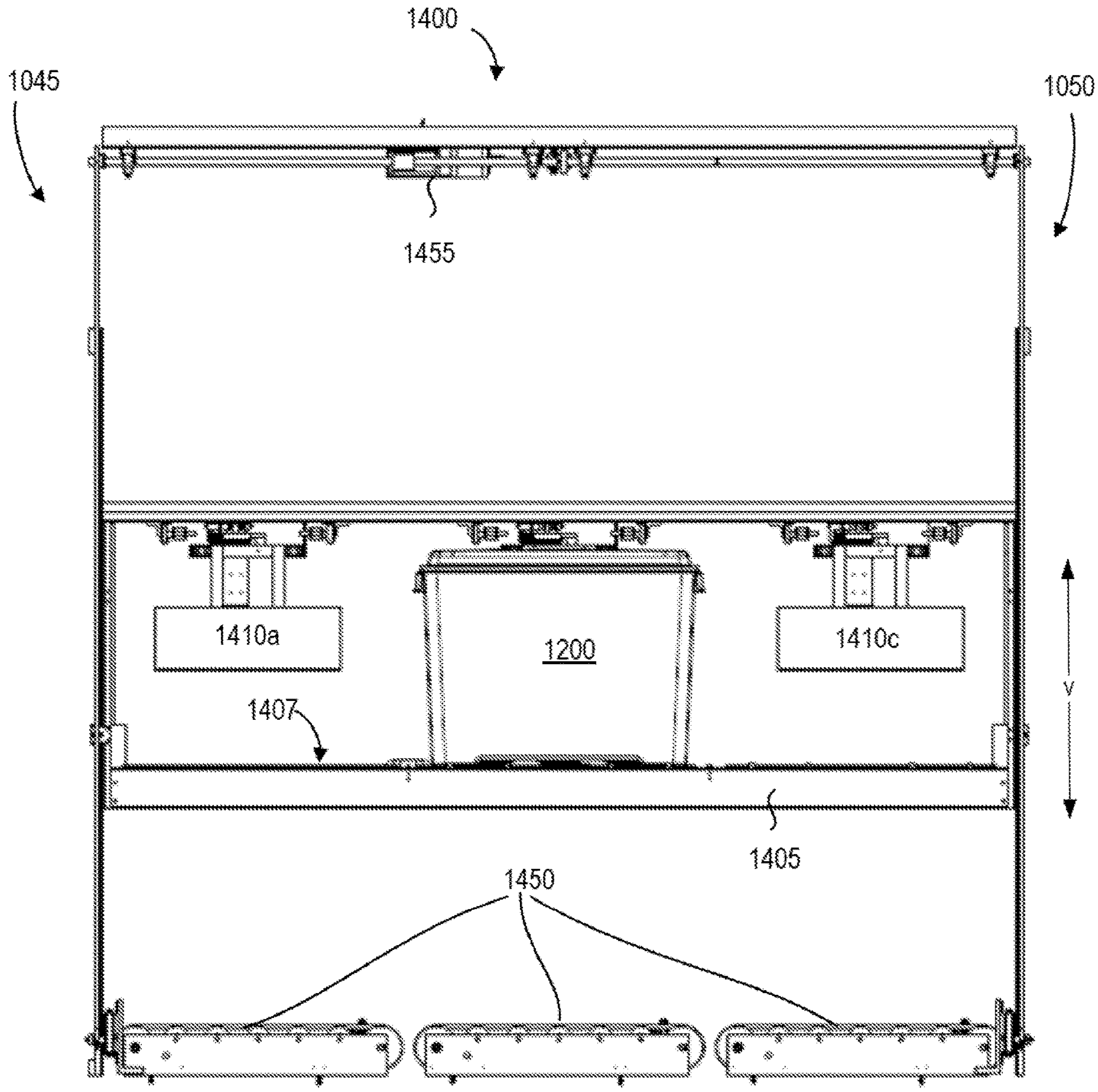


FIG. 23

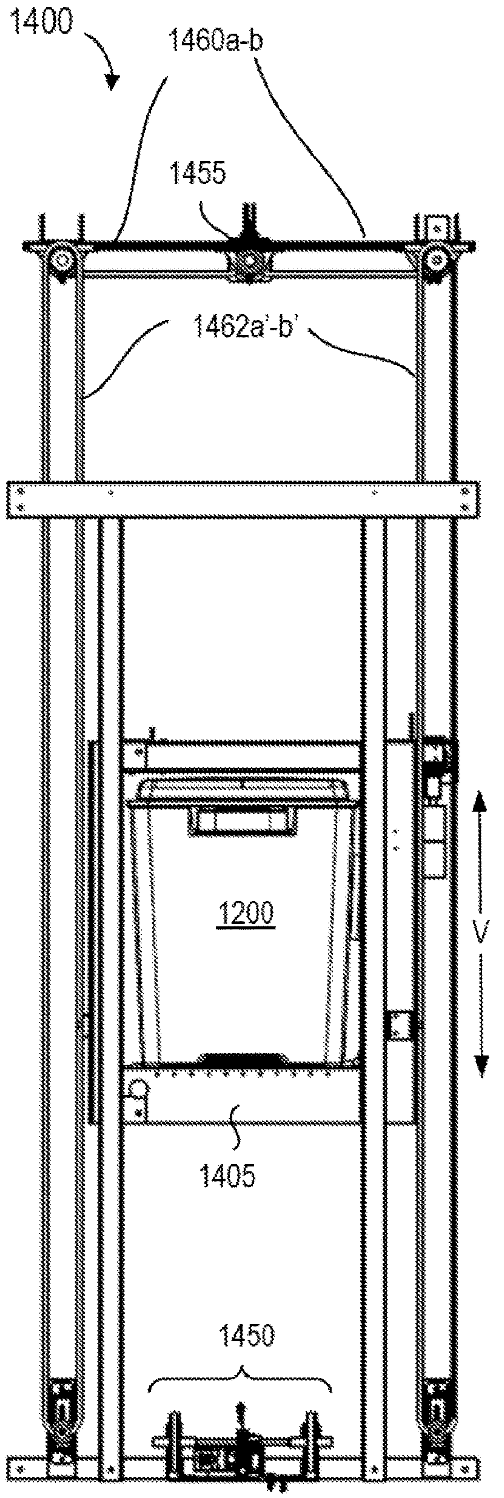


FIG. 24A

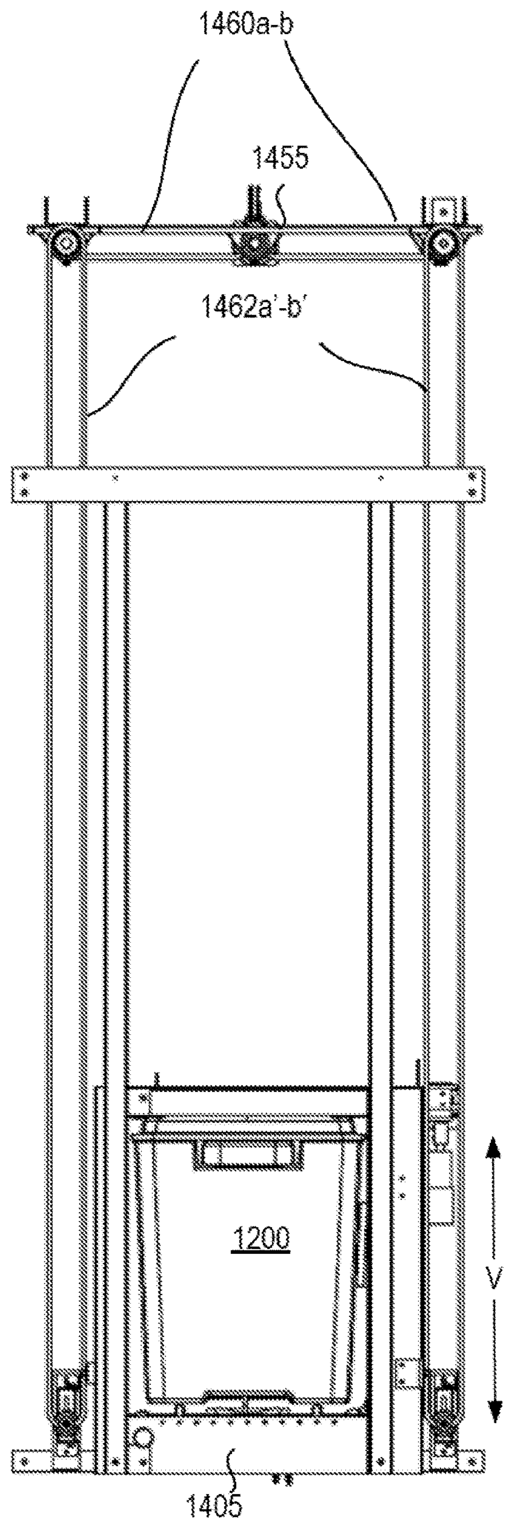


FIG. 24B

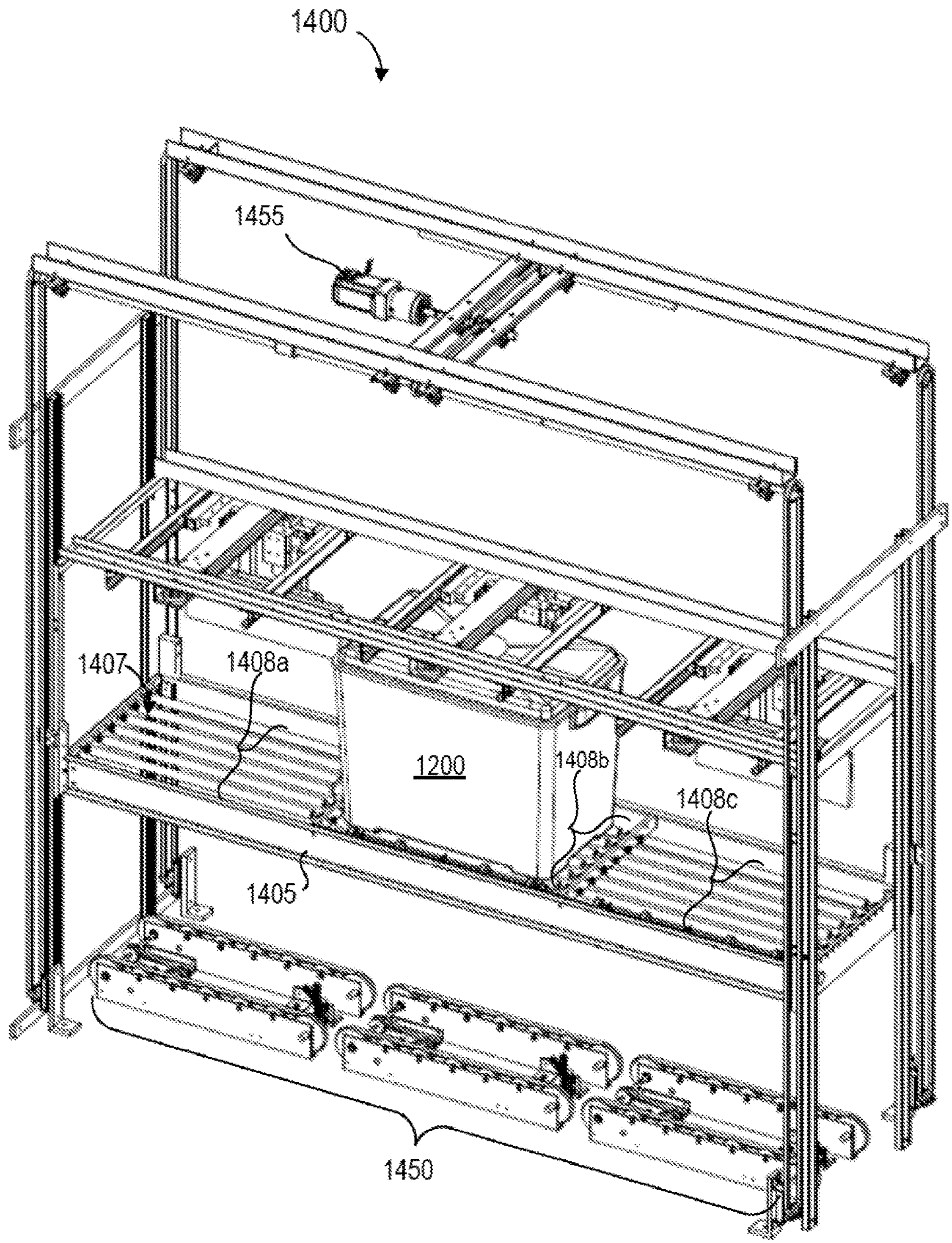


FIG. 25

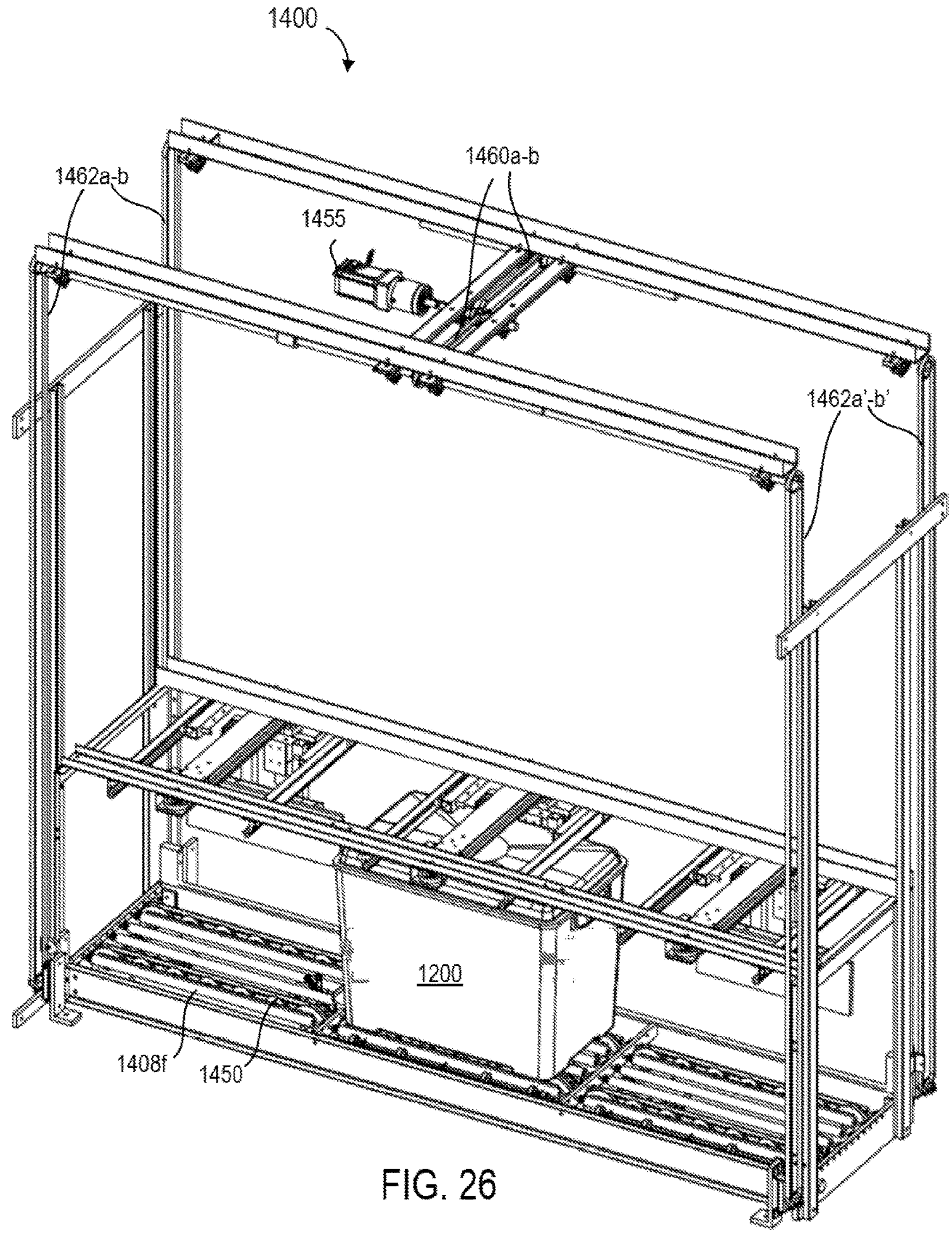


FIG. 26

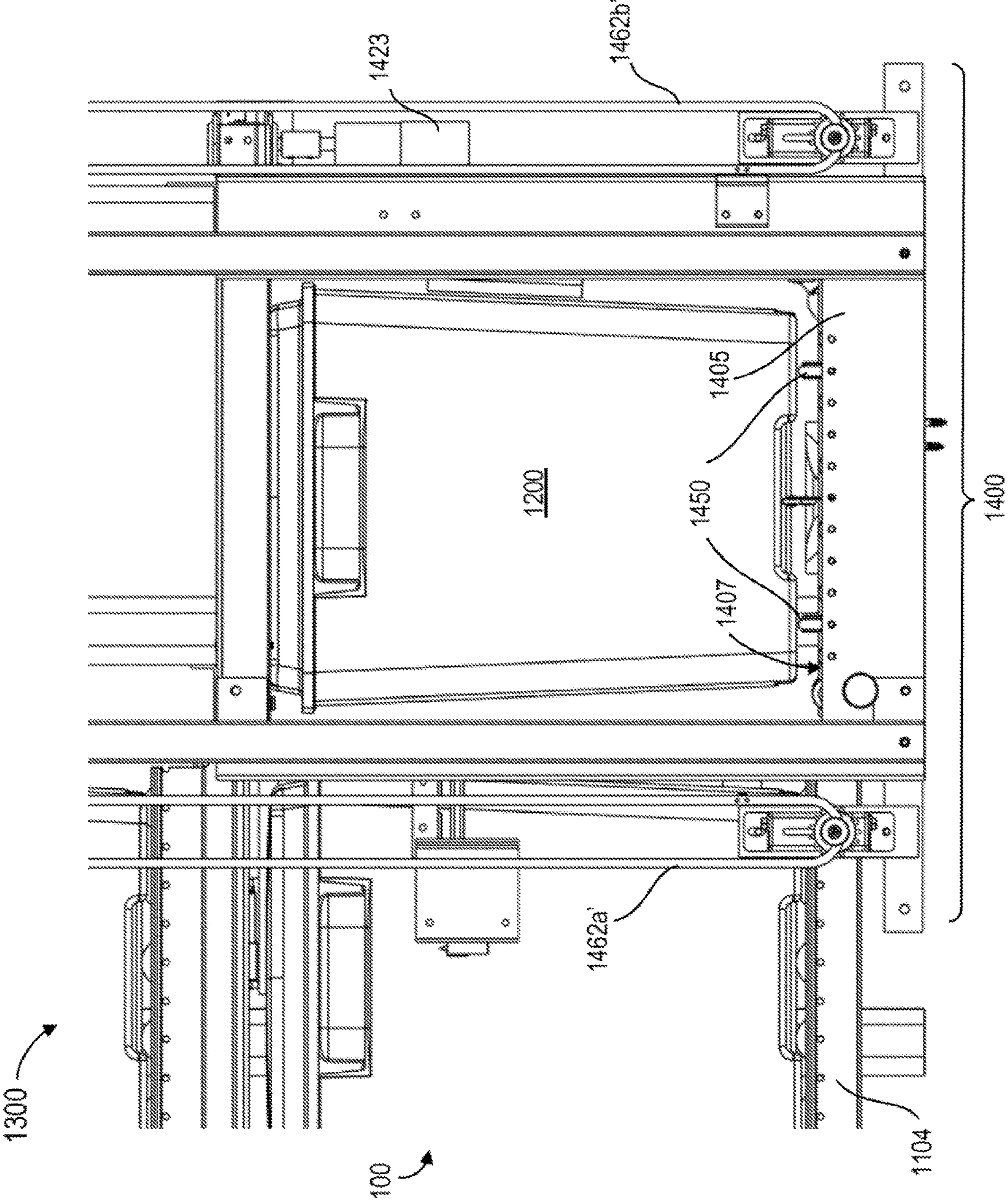


FIG. 27

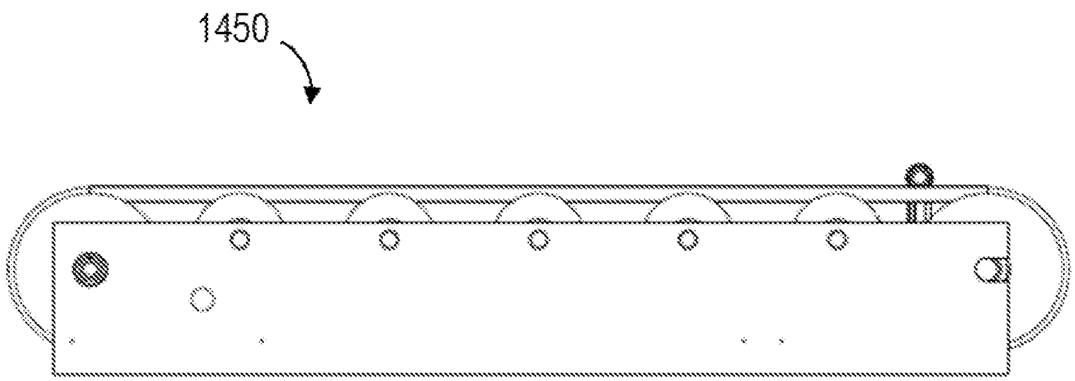


FIG. 28A

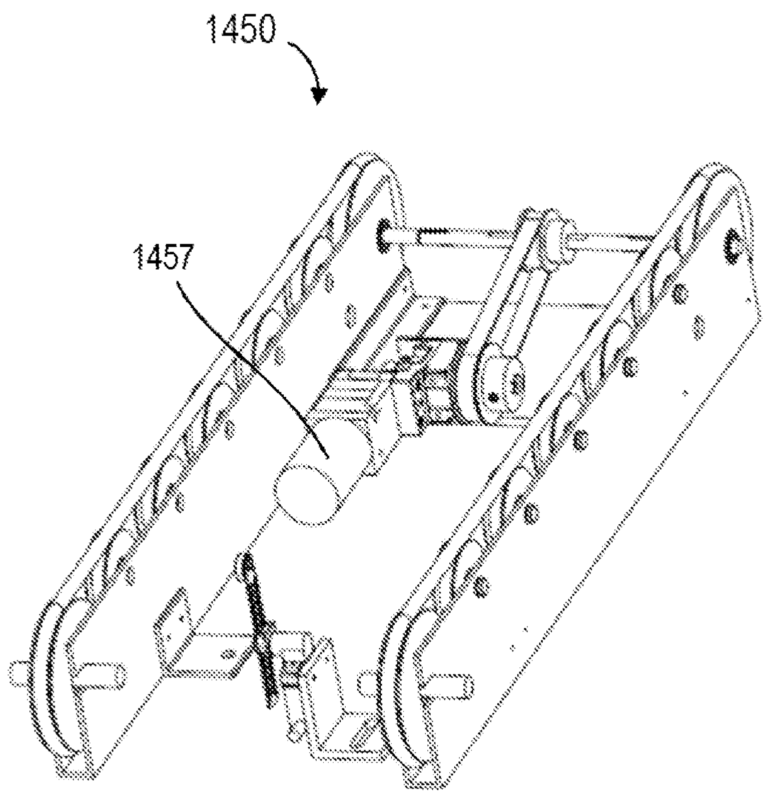


FIG. 28B

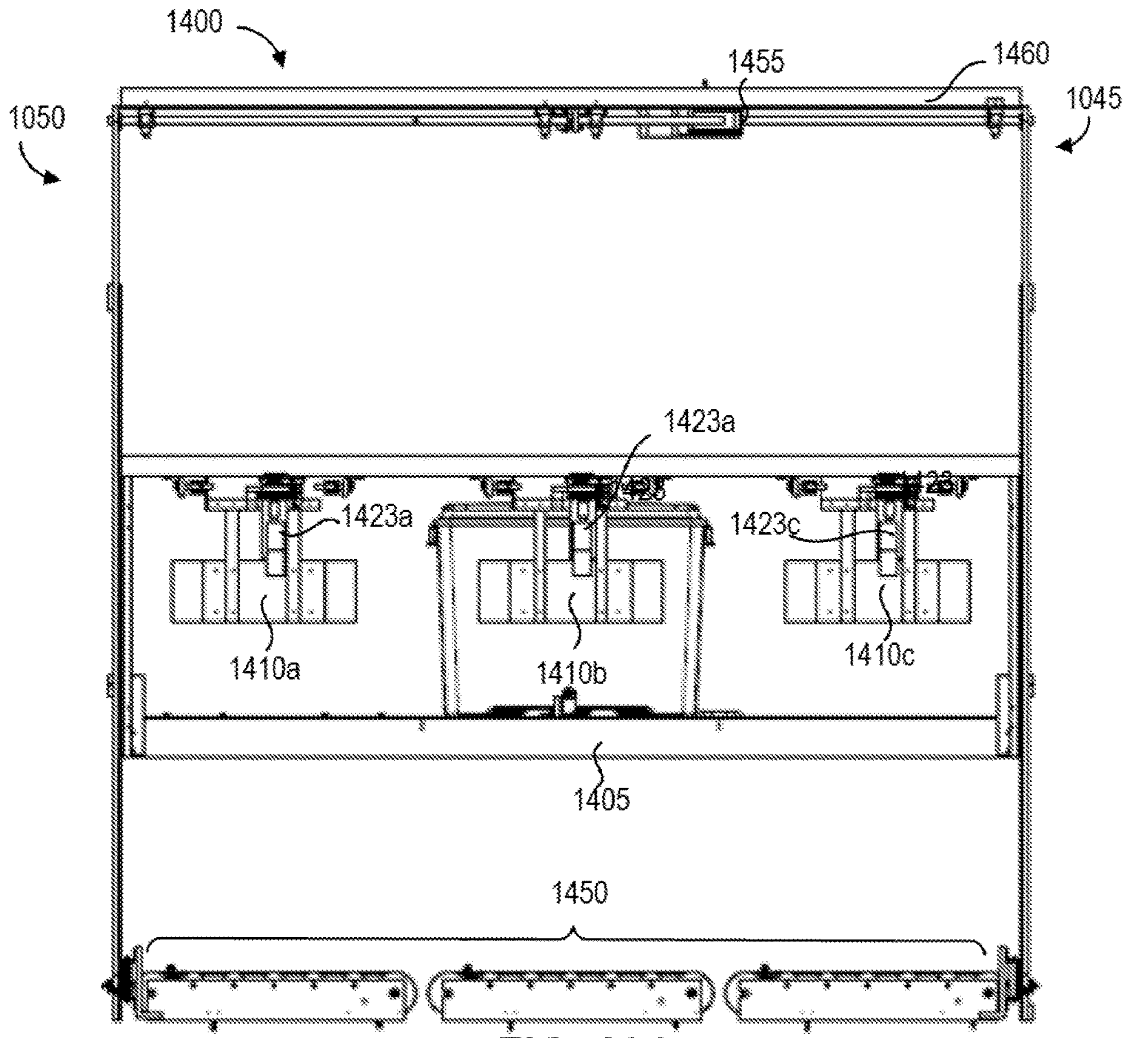


FIG. 29A

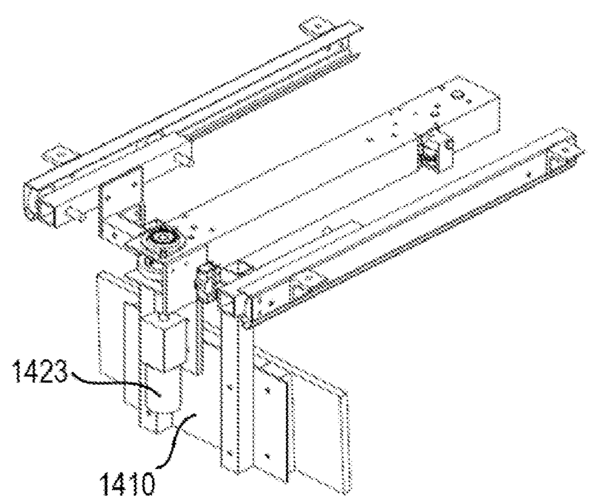
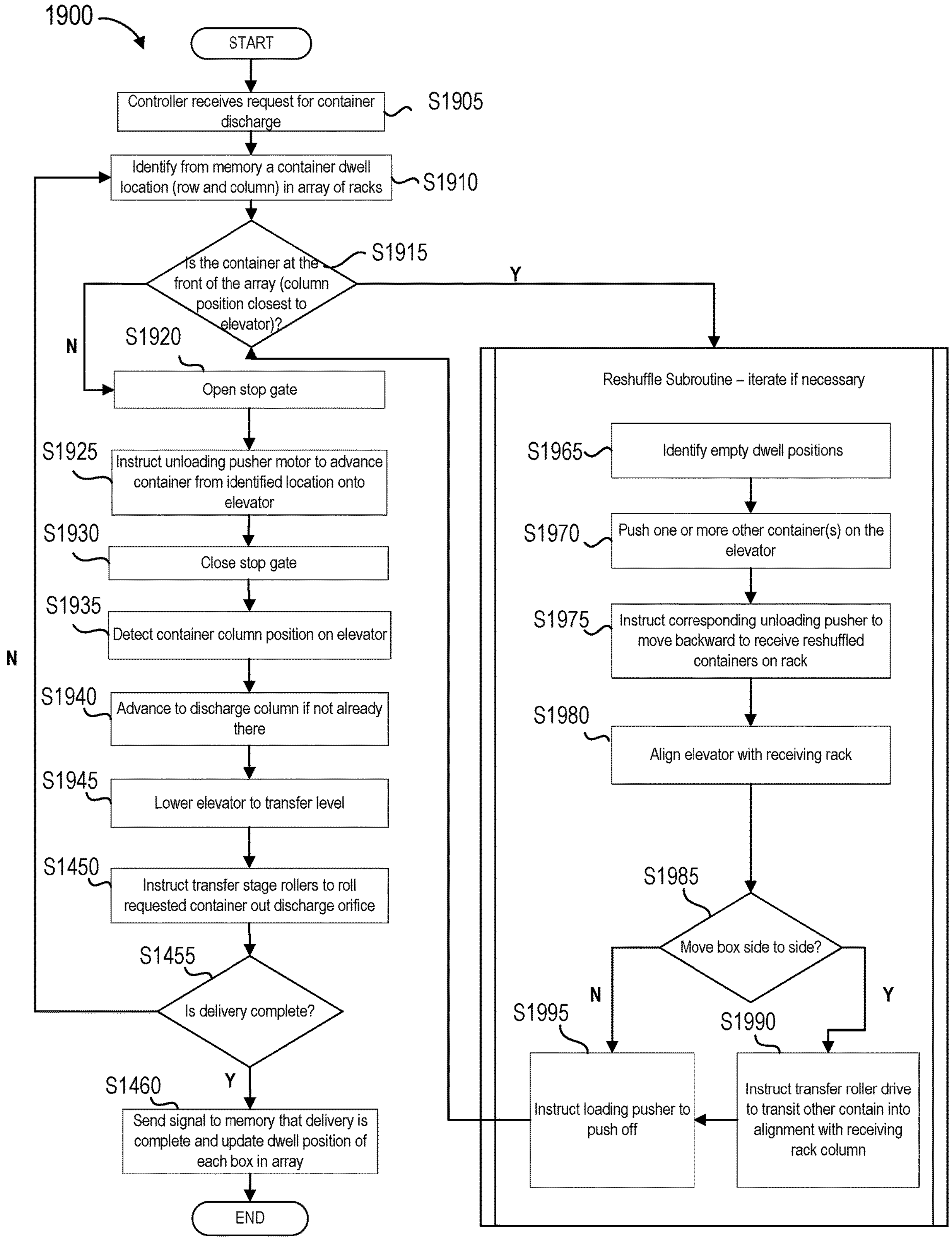


FIG. 29B

FIG. 30


1900
START
Controller receives request for container discharge
S1905
Identify from memory a container dwell location (row and column) in array of racks
S1910
Is the container at the front of the array (column position closest to elevator)?
S1915
Y
N
S1920
Open stop gate
S1925
Instruct unloading pusher motor to advance container from identified location onto elevator
S1930
Close stop gate
S1935
Detect container column position on elevator
S1940
Advance to discharge column if not already there
S1945
Lower elevator to transfer level
S1450
Instruct transfer stage rollers to roll requested container out discharge orifice
S1455
Is delivery complete?
N
Y
S1460
Send signal to memory that delivery is complete and update dwell position of each box in array
END
Reshuffle Subroutine – iterate if necessary
S1965
Identify empty dwell positions
S1970
Push one or more other container(s) on the elevator
S1975
Instruct corresponding unloading pusher to move backward to receive reshuffled containers on rack
S1980
Align elevator with receiving rack
S1985
Move box side to side?
N
Y
S1995
Instruct loading pusher to push off
S1990
Instruct transfer roller drive to transit other contain into alignment with receiving rack column

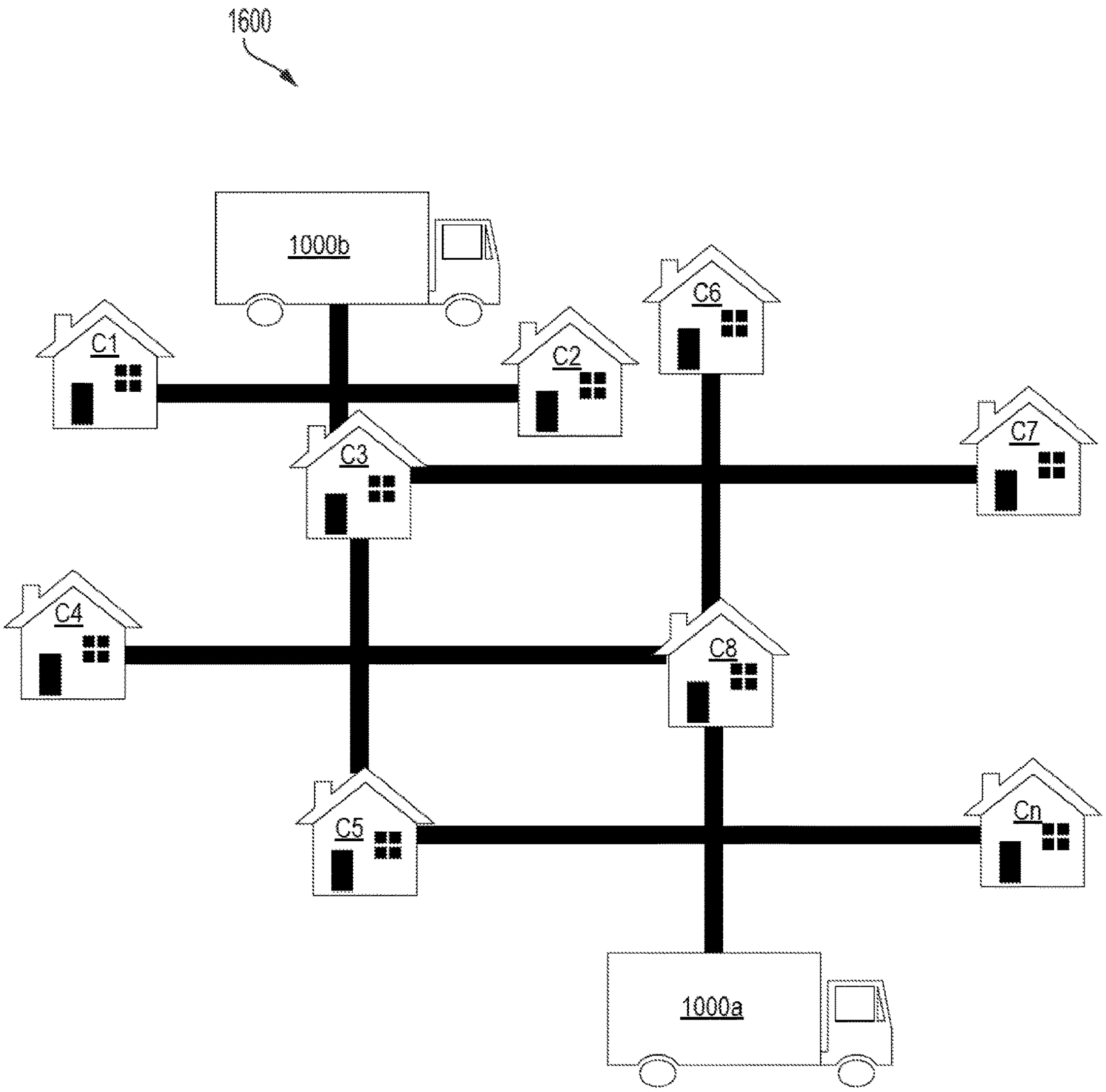


FIG. 31

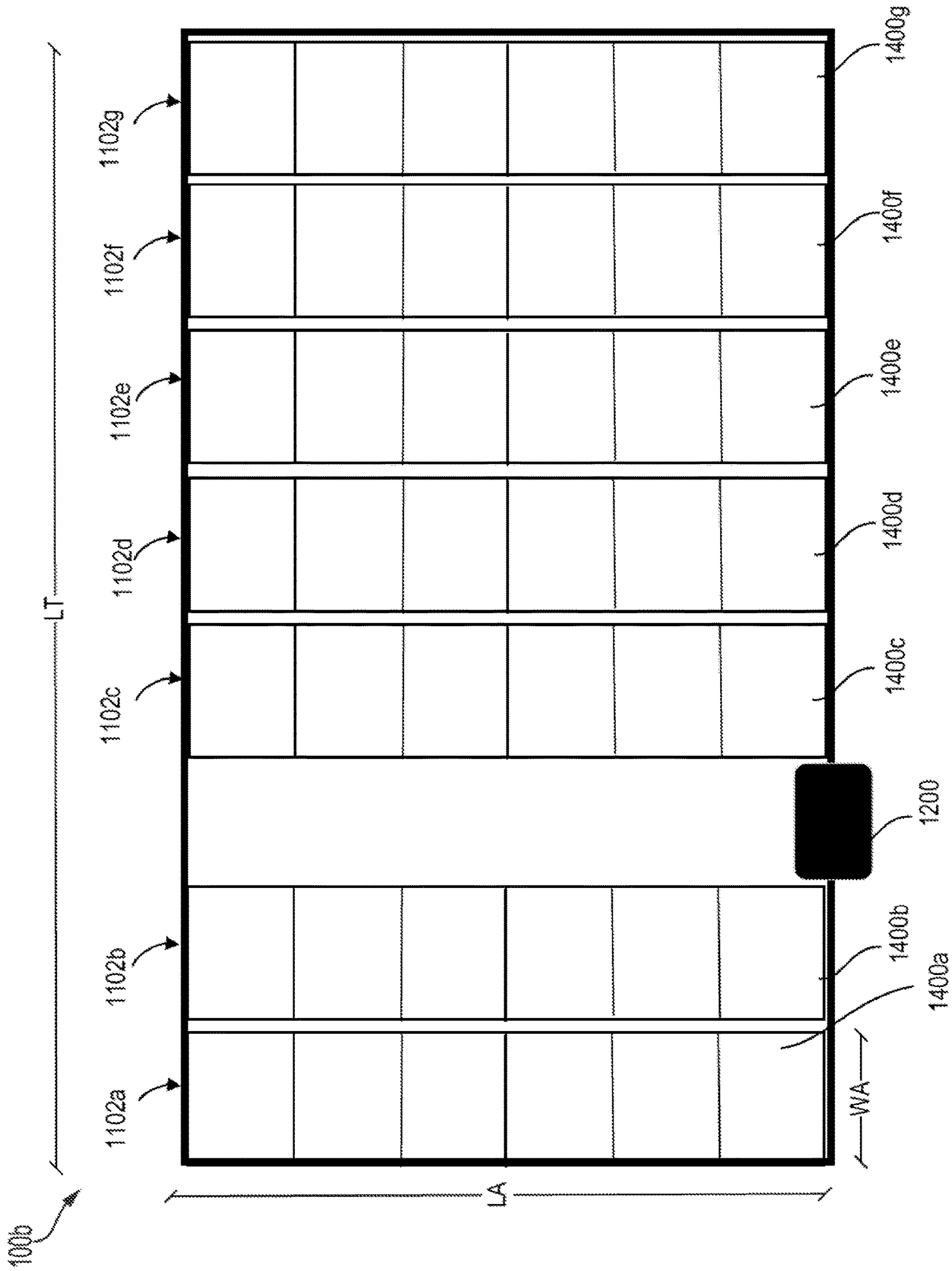

1100b
LT
LA
WA
1102a
1102b
1102c
1102d
1102e
1102f
1102g
1200
1400a
1400b
1400c
1400d
1400e
1400f
1400g

FIG. 32

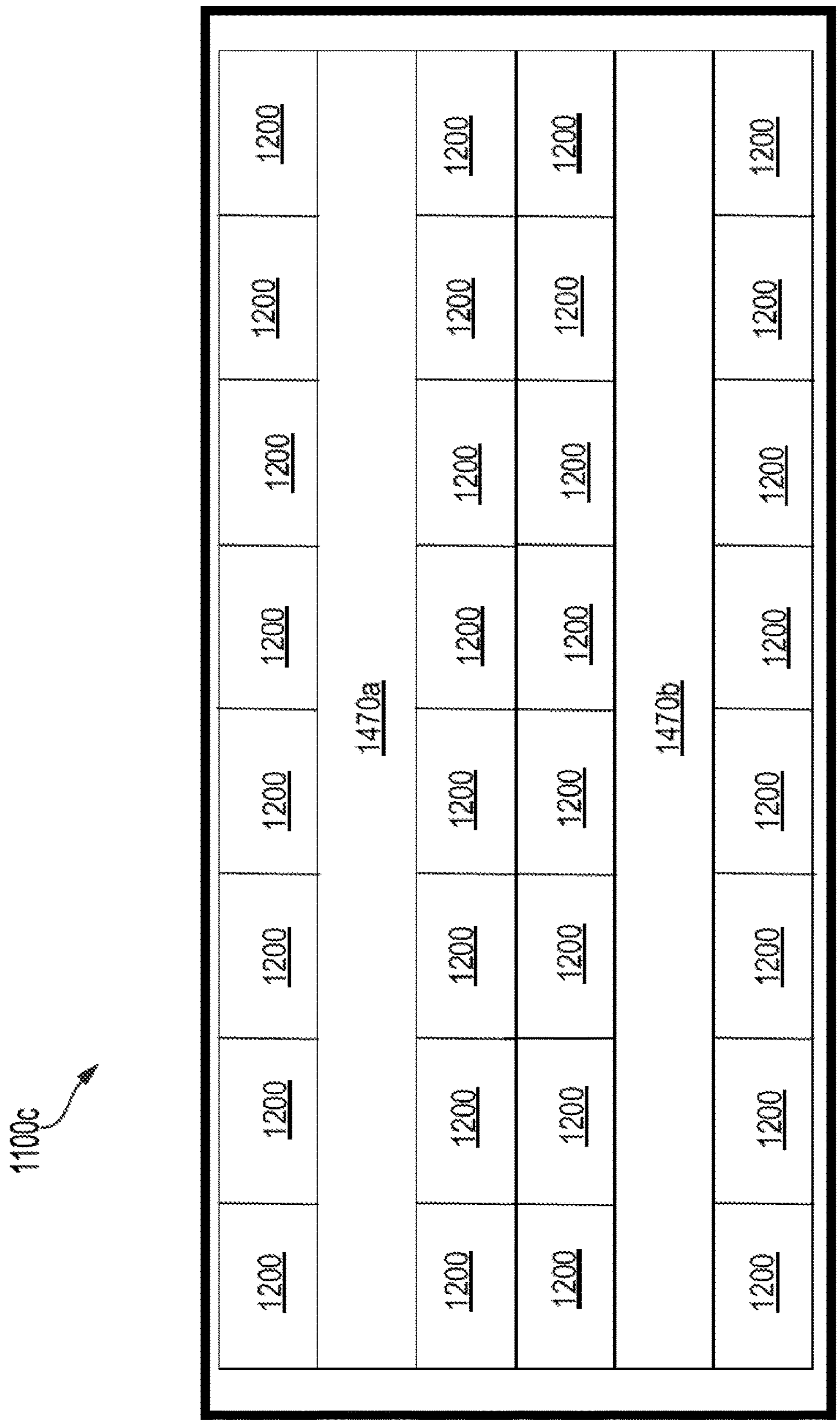


FIG. 33

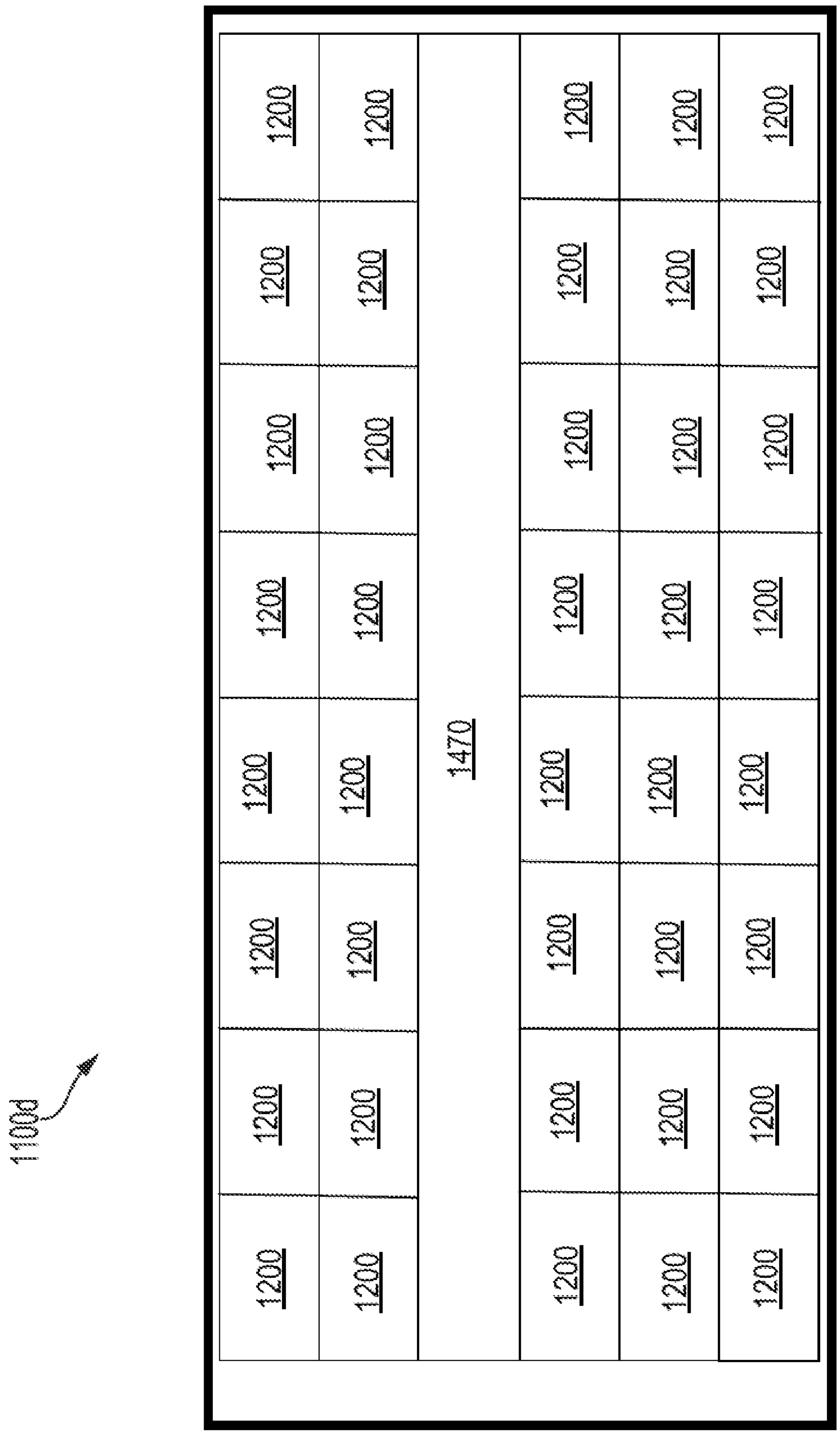


FIG. 34

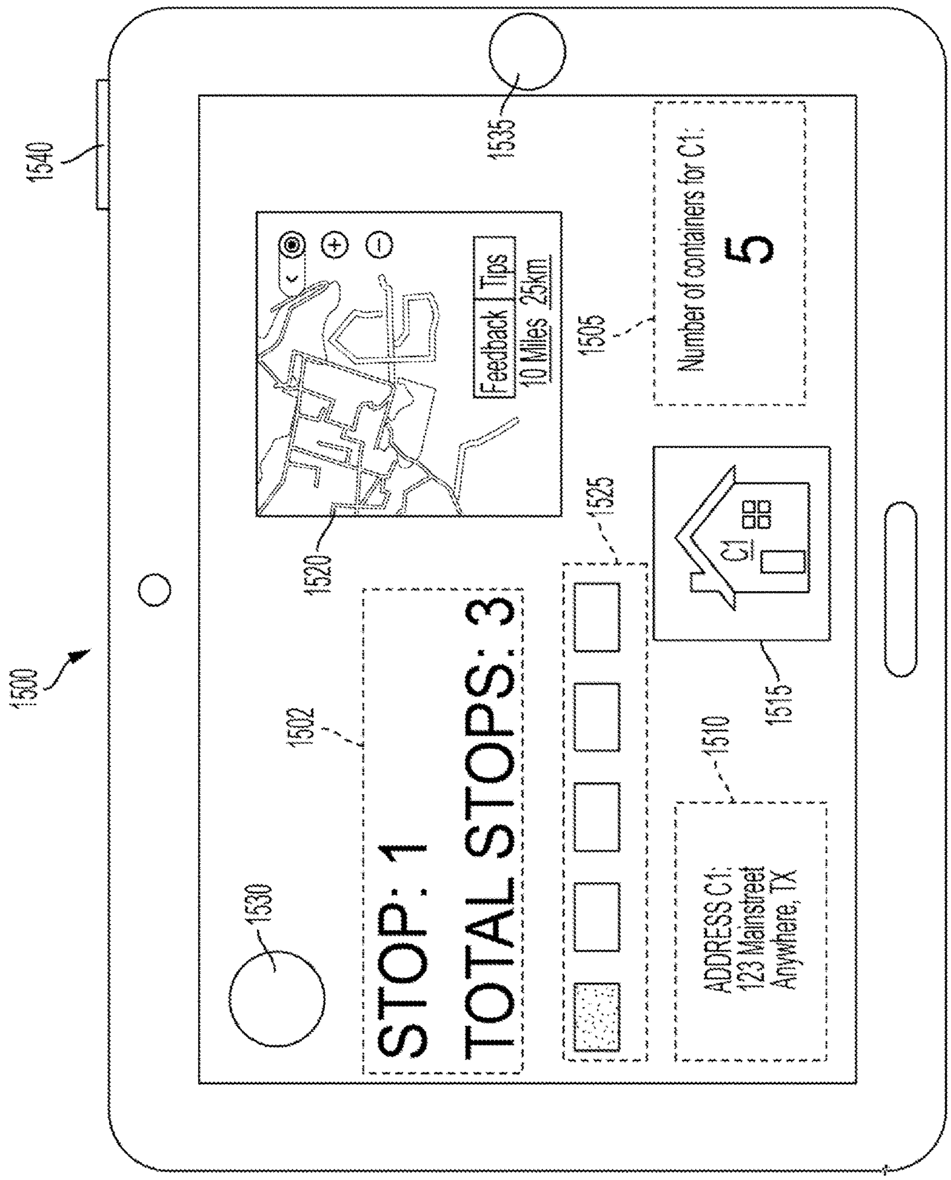

1500
1540
1535
1530
1502
1520
1525
1505
1510
1515
STOP: 1
TOTAL STOPS: 3
Feedback
Tips
10 Miles
25km
Number of containers for C1:
5
C1
ADDRESS C1:
123 Mainstreet
Anywhere, TX

FIG. 35

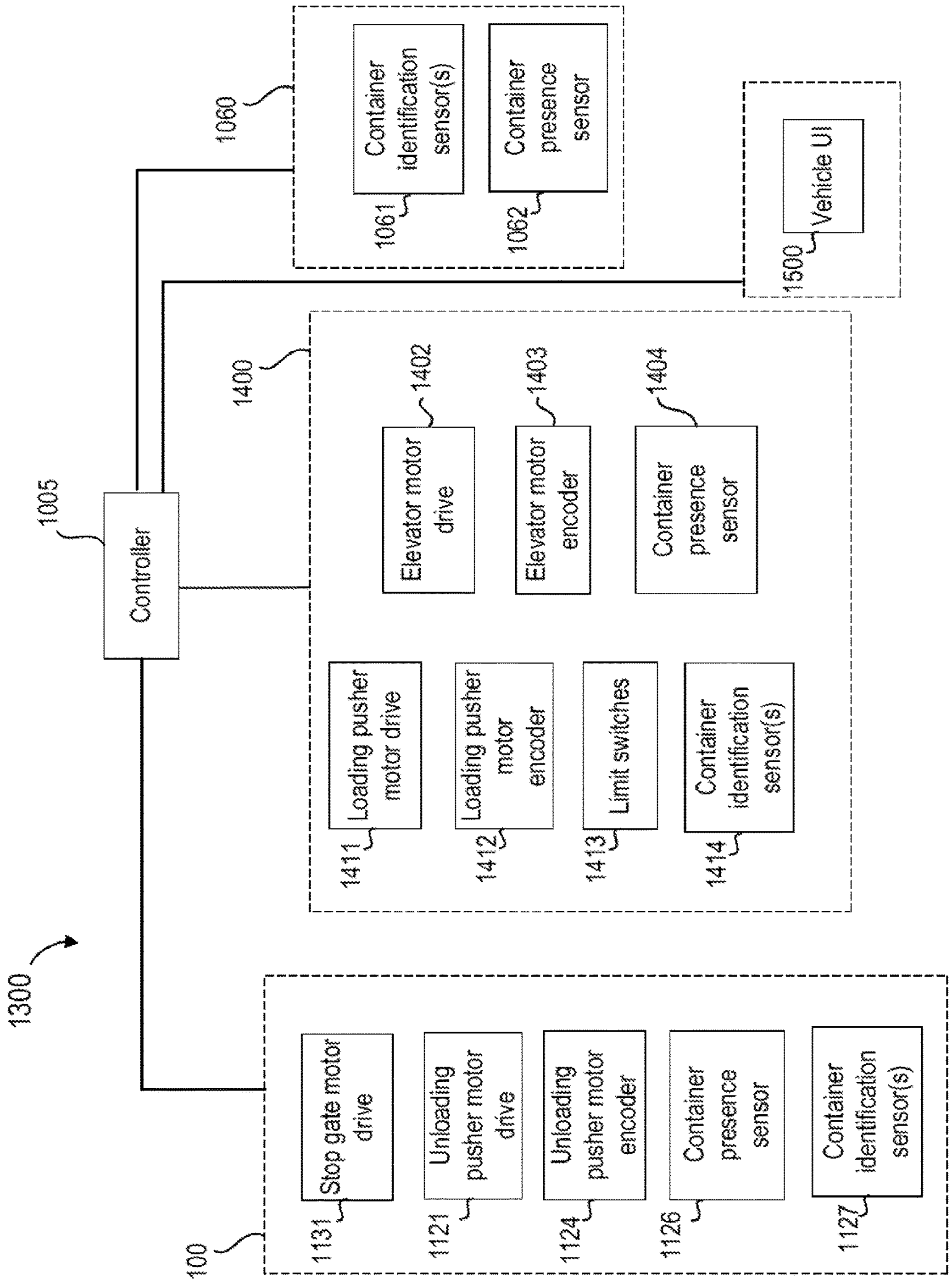

1300
1005
Controller
1060
Container identification sensor(s)
1061
Container presence sensor
1062
1500
Vehicle UI
1400
Elevator motor drive
1402
Elevator motor encoder
1403
Container presence sensor
1404
Loading pusher motor drive
1411
Loading pusher motor encoder
1412
Limit switches
1413
Container identification sensor(s)
1414
1100
Stop gate motor drive
1131
Unloading pusher motor drive
1121
Unloading pusher motor encoder
1124
Container presence sensor
1126
Container identification sensor(s)
1127

FIG. 36

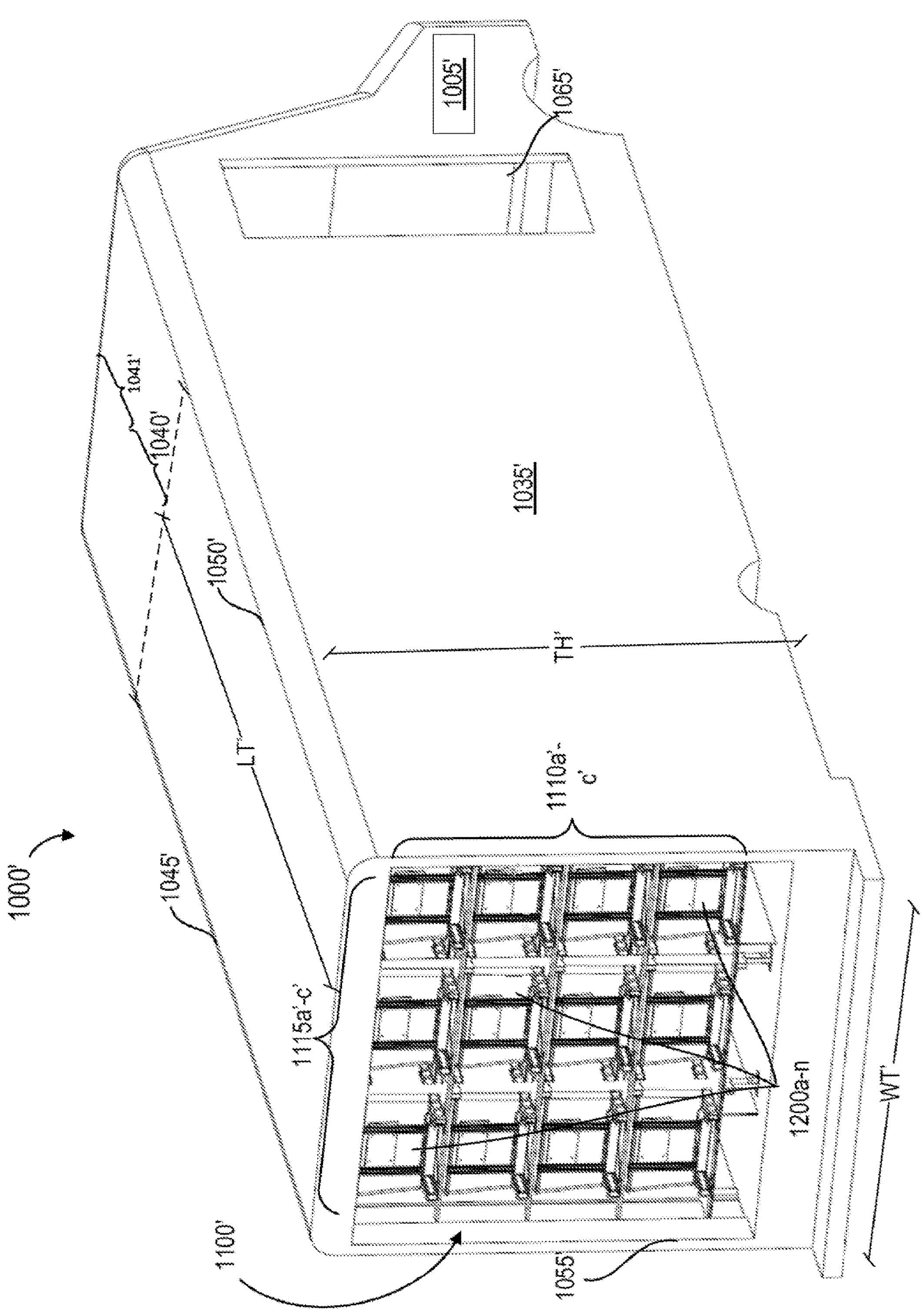

1000'
1005'
1065'
1041'
1040'
1035'
1050'
1045'
LT'
TH'
1110a'-c'
1115a'-c'
1200a-n
WT'
1100'
1055'

FIG. 37

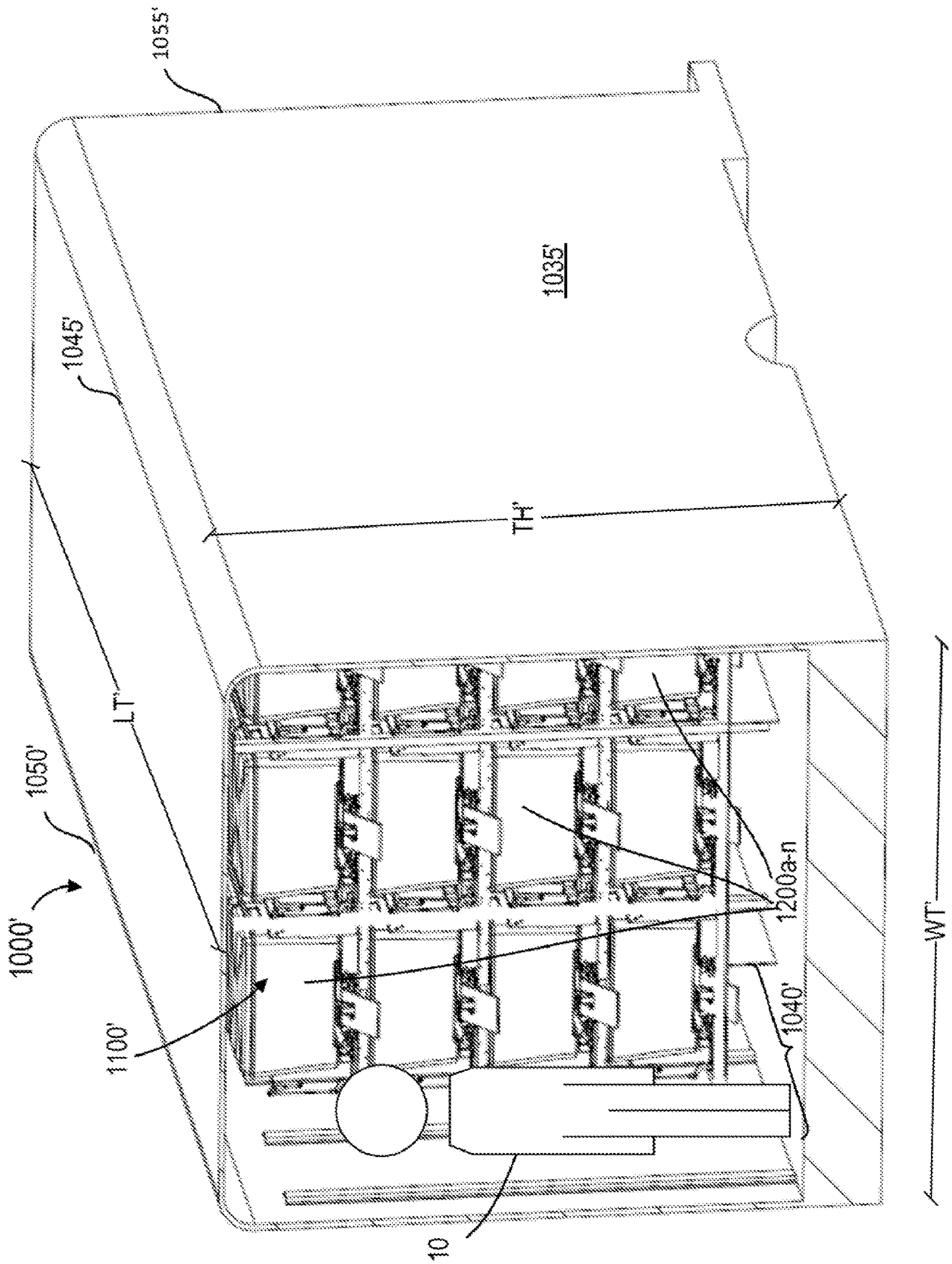


FIG. 38

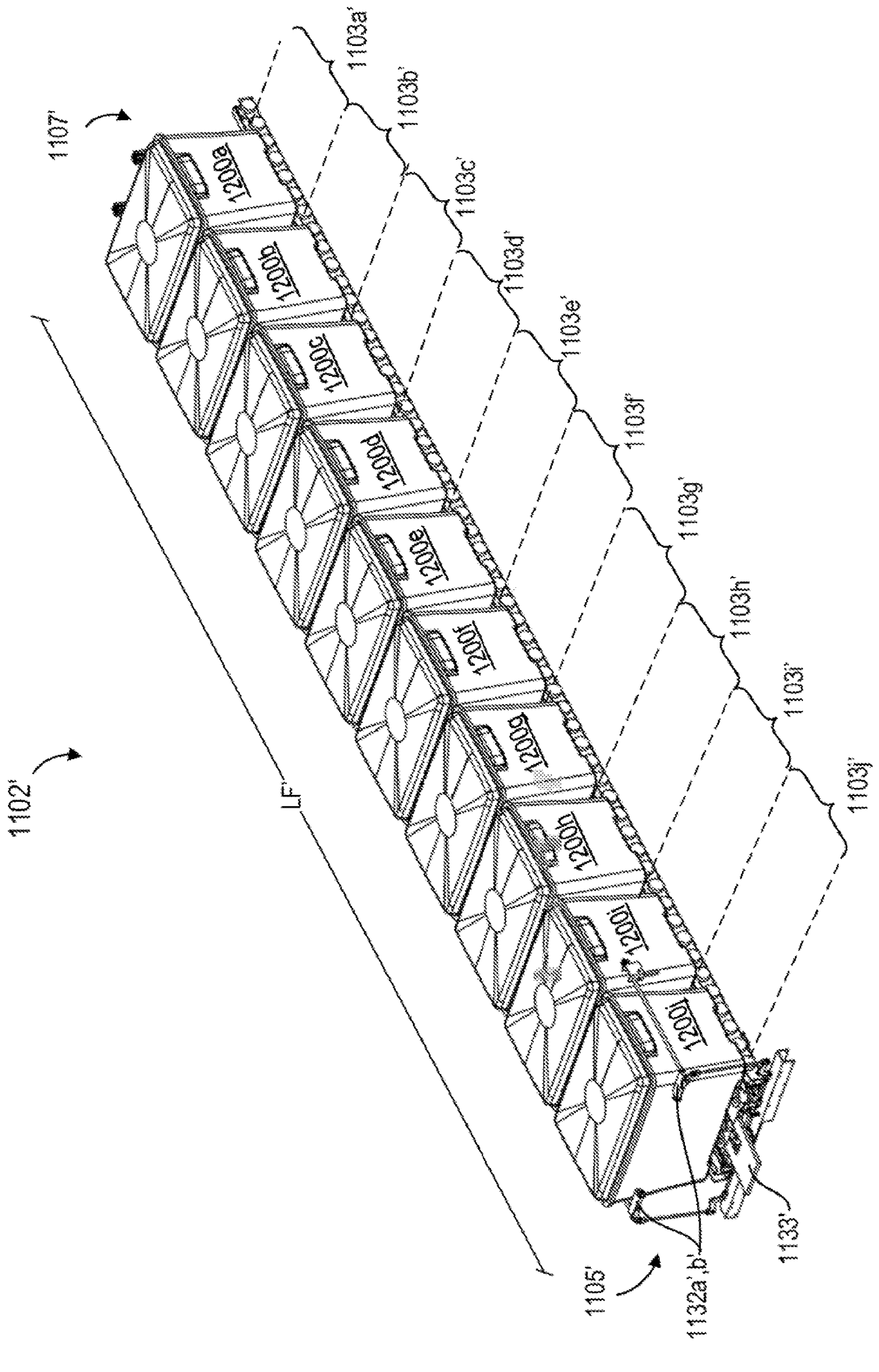

1103a'
1103b'
1103c'
1103d'
1103e'
1103f'
1103g'
1103h'
1103i'
1103j'
1107'
1102'
LF'
1200a
1200b
1200c
1200d
1200e
1200f
1200g
1200h
1200i
1200j
1105'
1132a',b'
1133'

FIG. 39

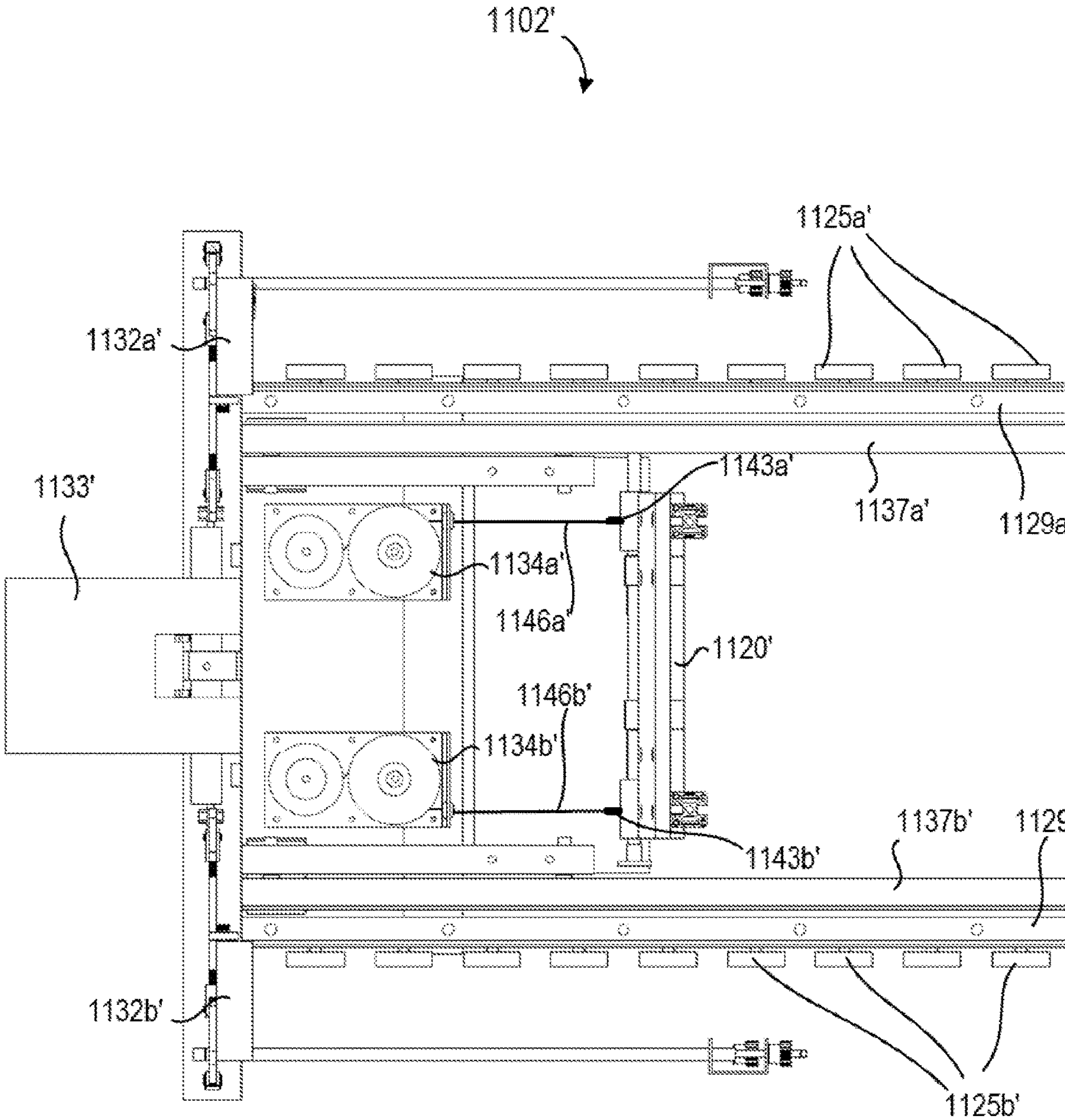

1102'
1125a'
1132a'
1133'
1143a'
1137a'
1129a'
1134a'
1146a'
1120'
1146b'
1134b'
1137b'
1129b'
1143b'
1132b'
1125b'

FIG. 40

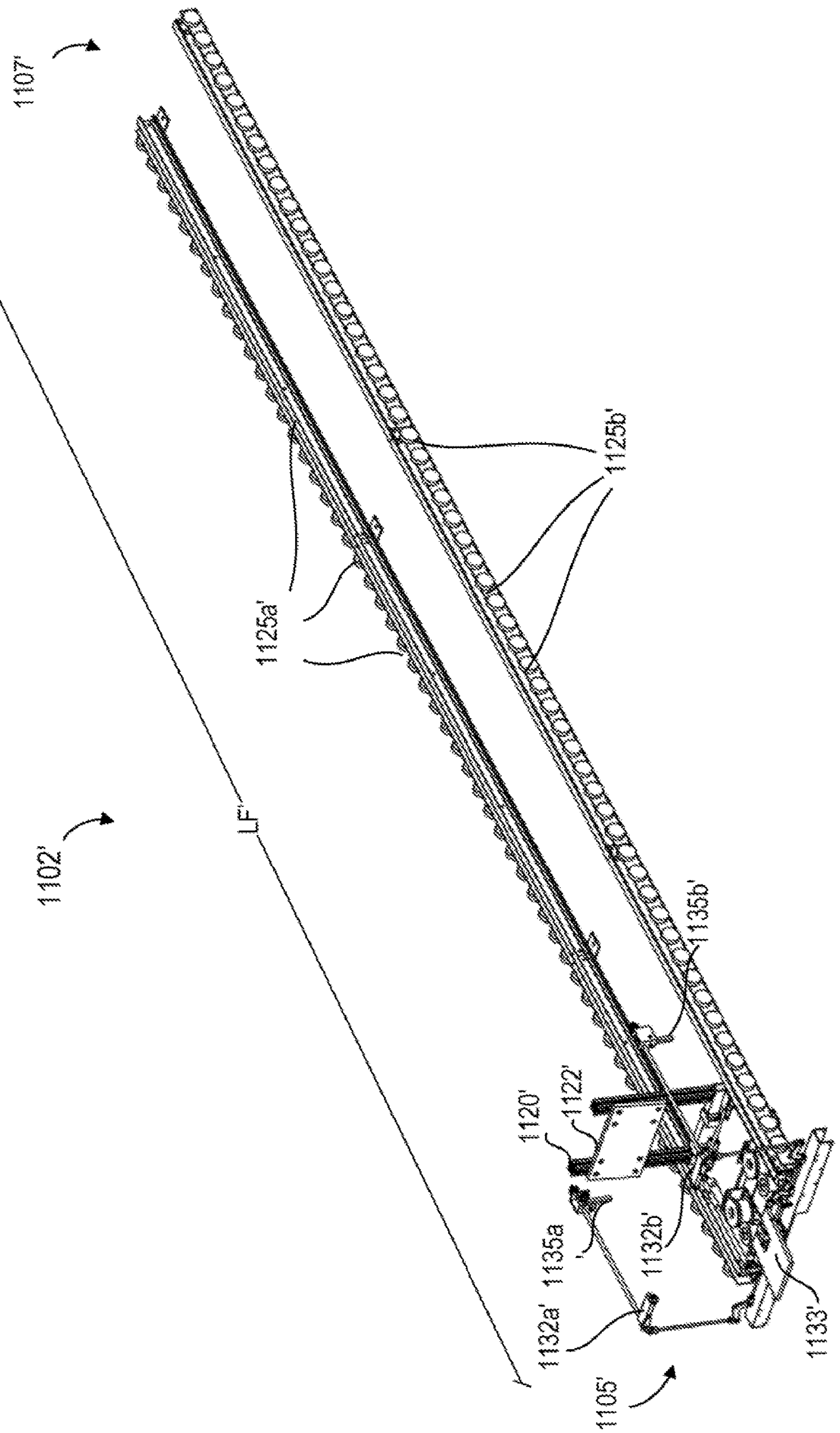

1107'
1125b'
1125a'
1102'
LF'
1135b'
1120'
1122'
1135a'
1132b'
1132a'
1133'
1105'

FIG. 41

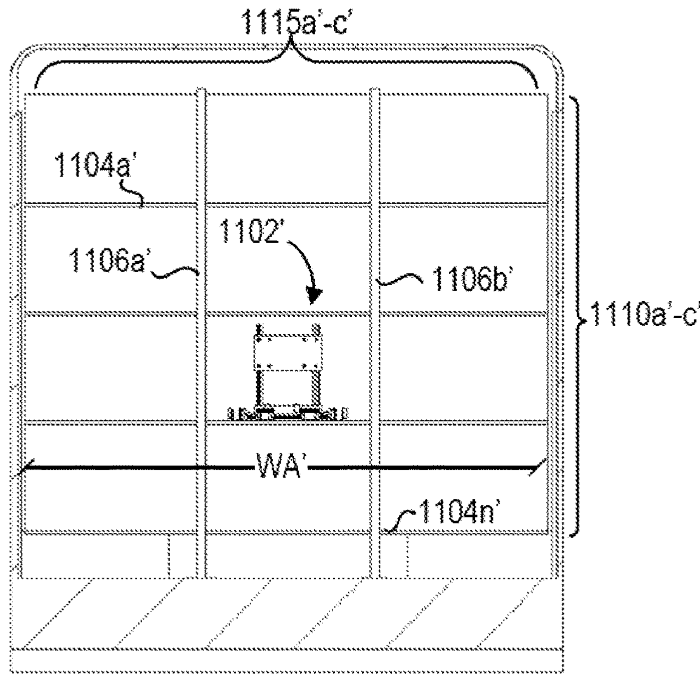


FIG. 42A

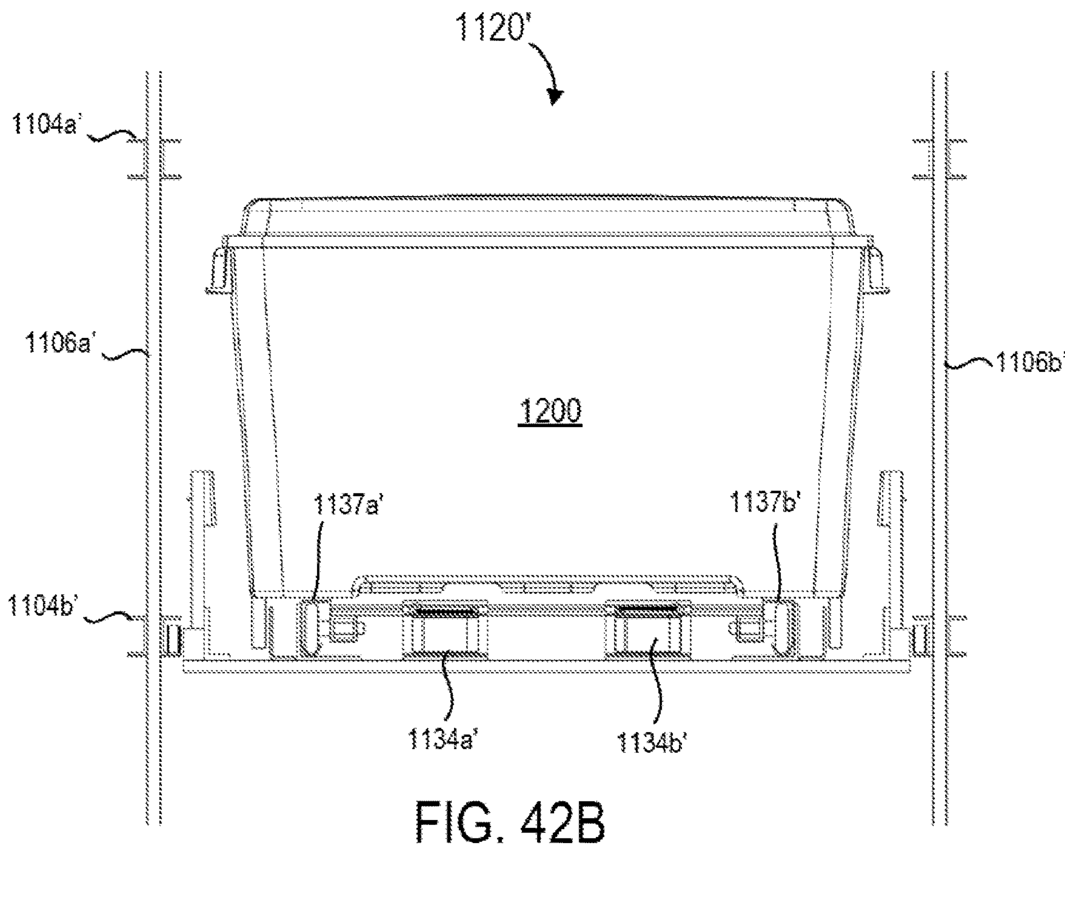


FIG. 42B

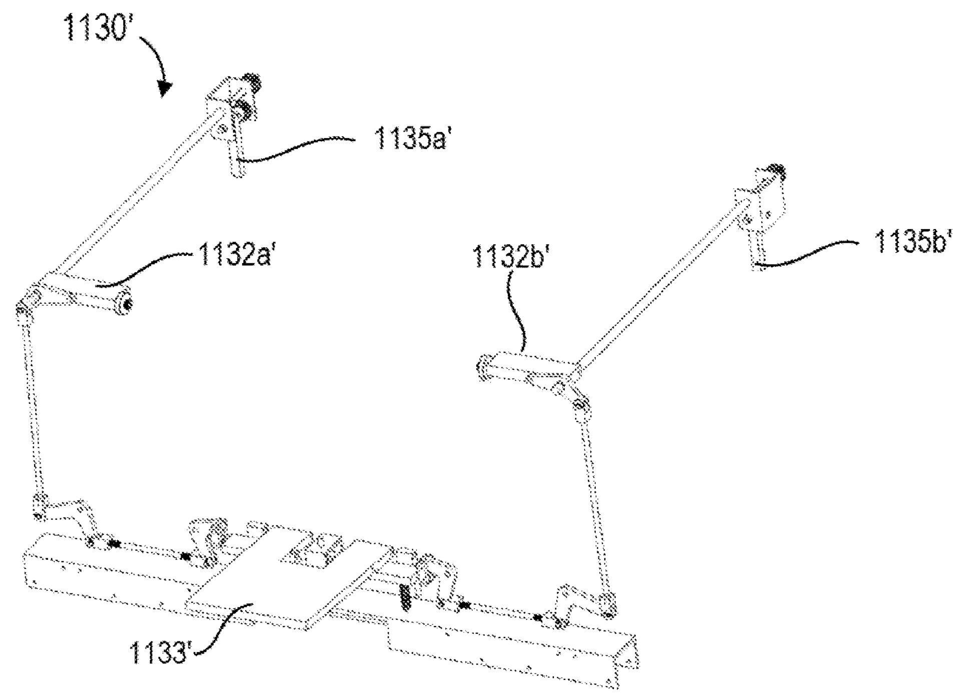


FIG. 43A

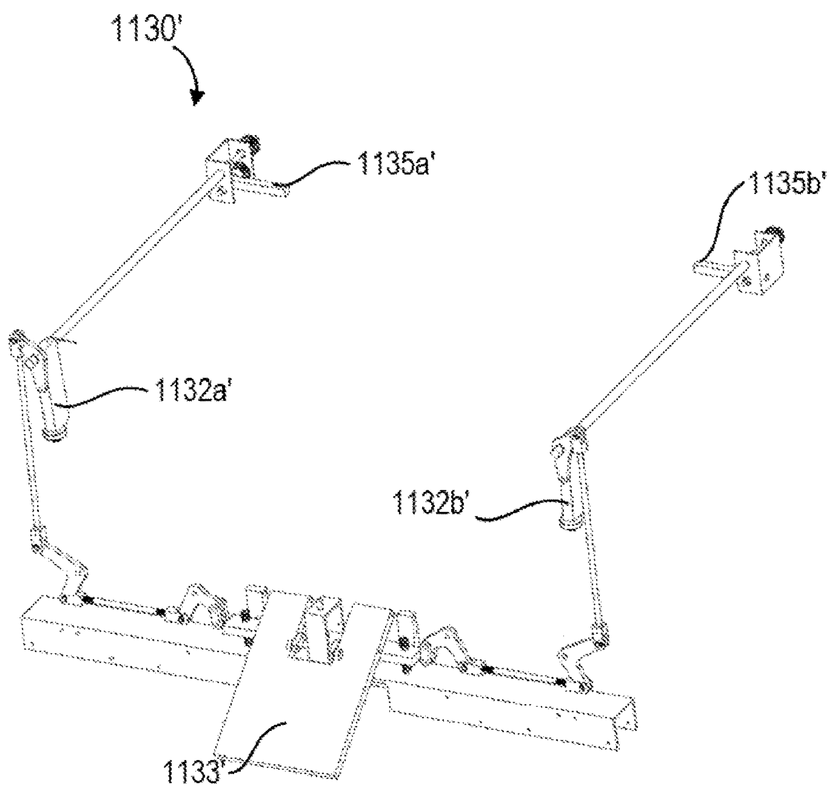


FIG. 43B

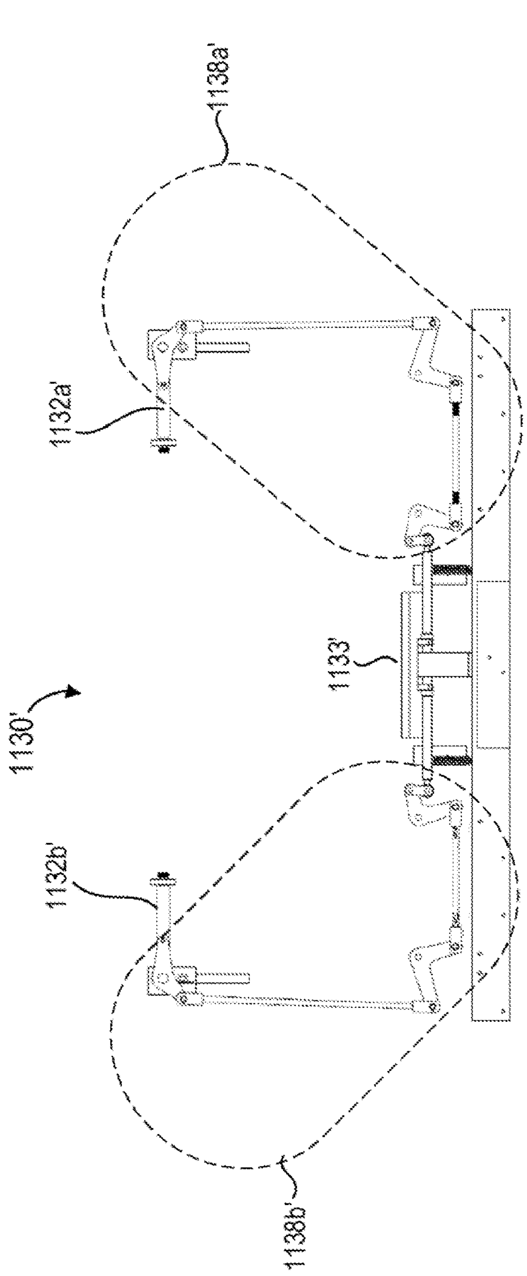


FIG. 44A

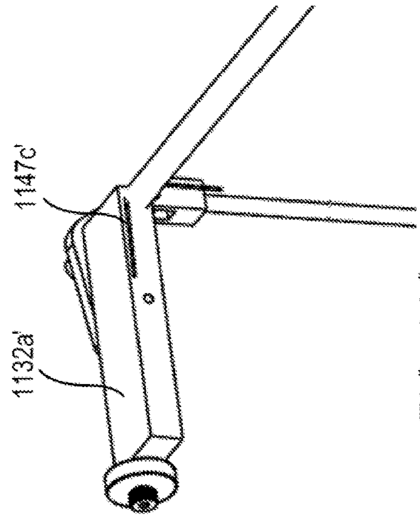


FIG. 44C

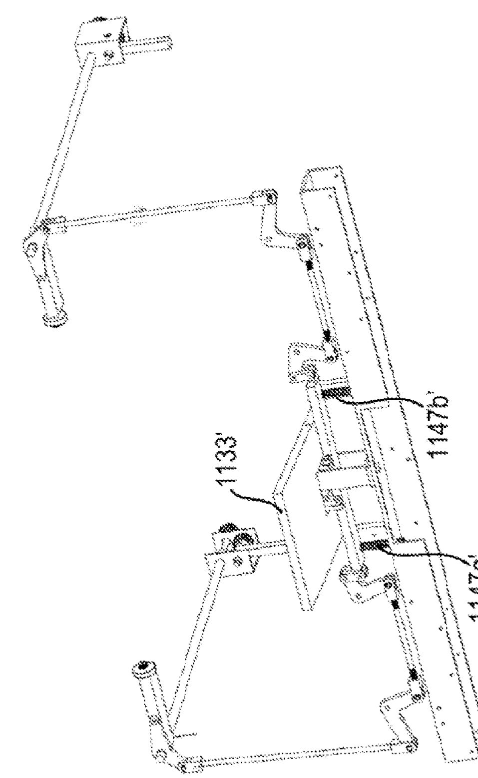


FIG. 44B

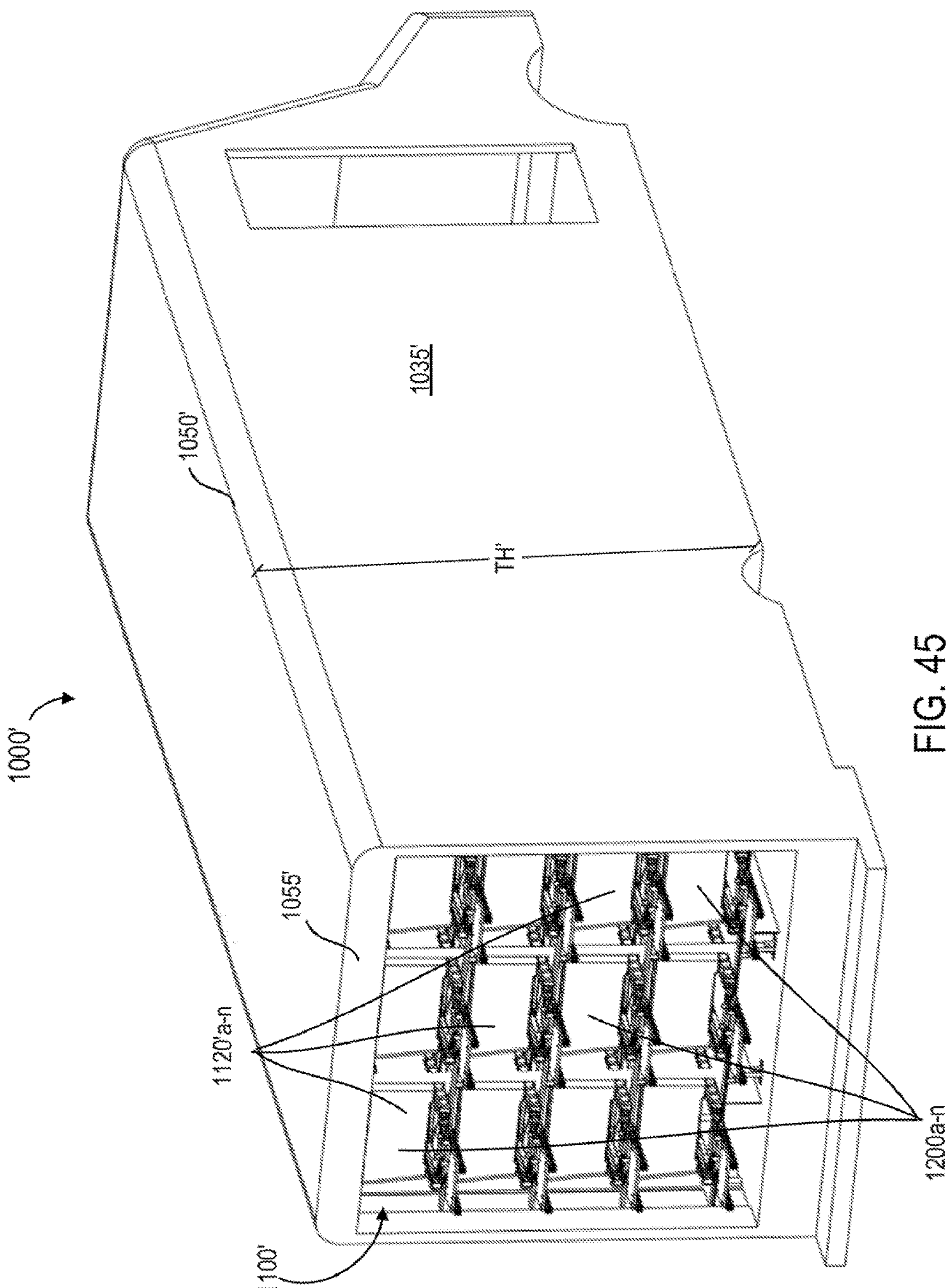


FIG. 45

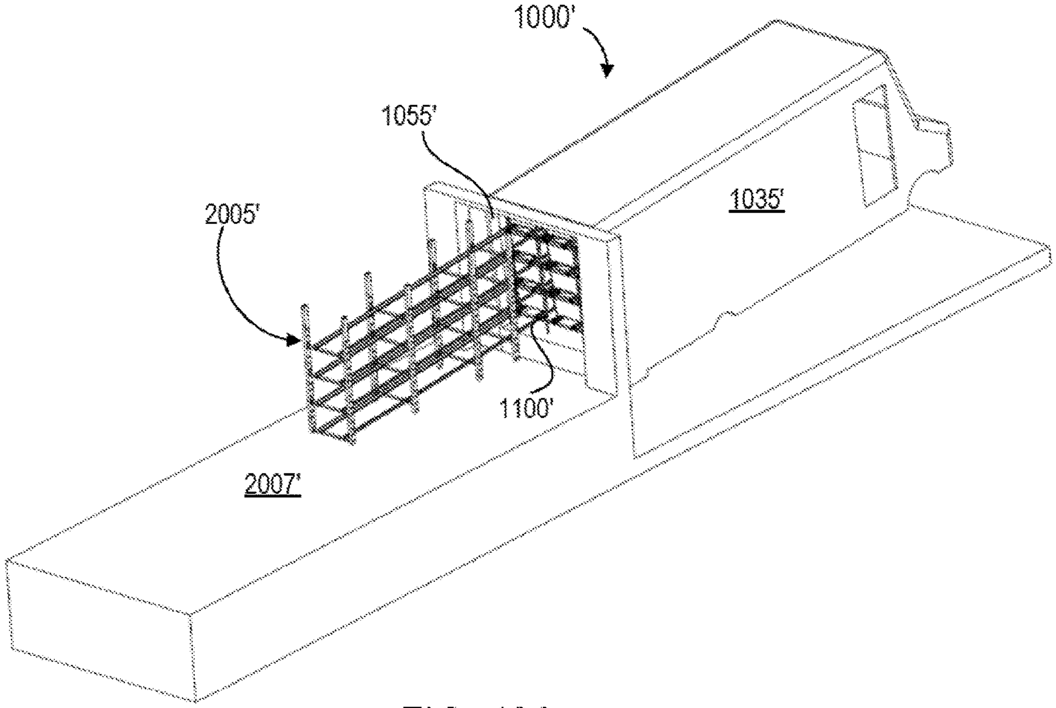


FIG. 46A

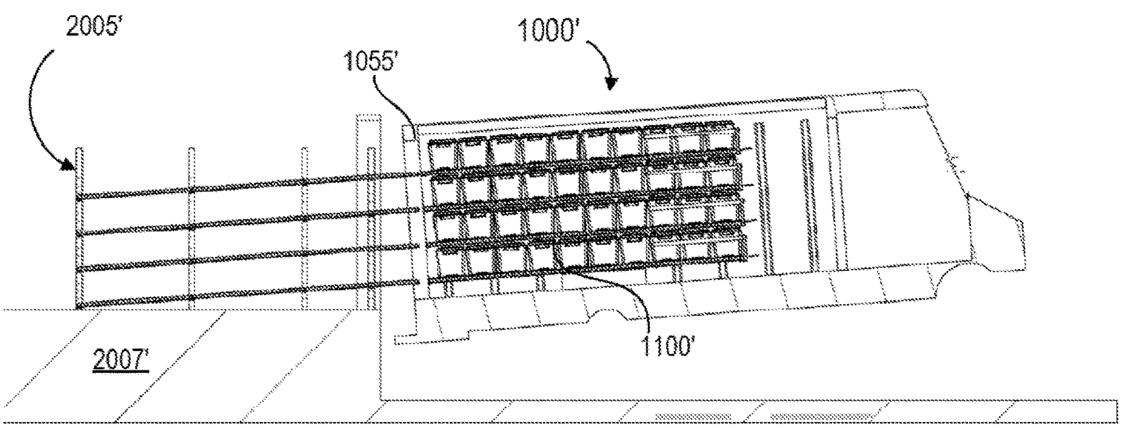


FIG. 46B

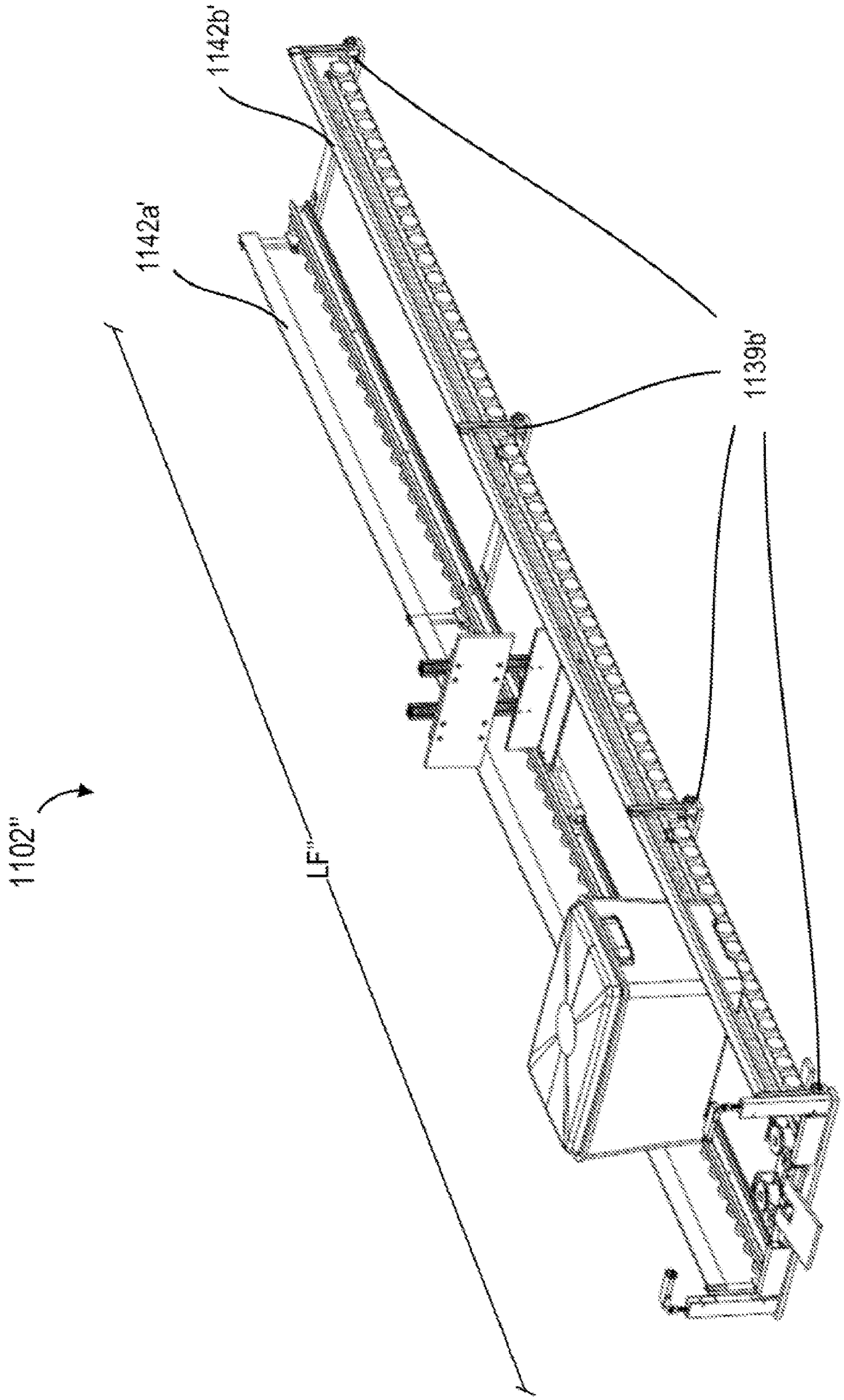


FIG. 47

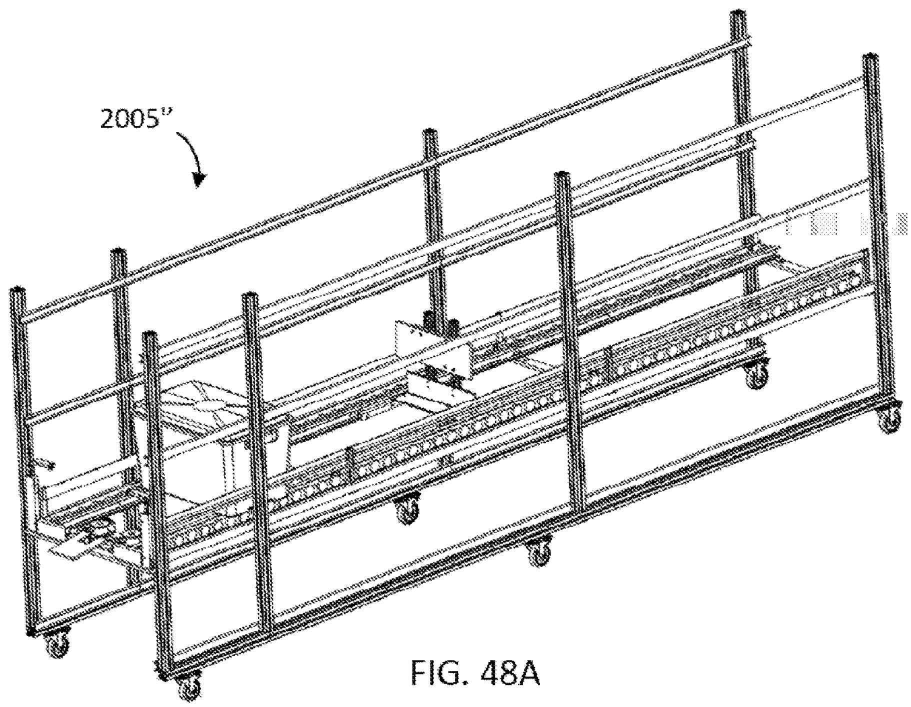


FIG. 48A

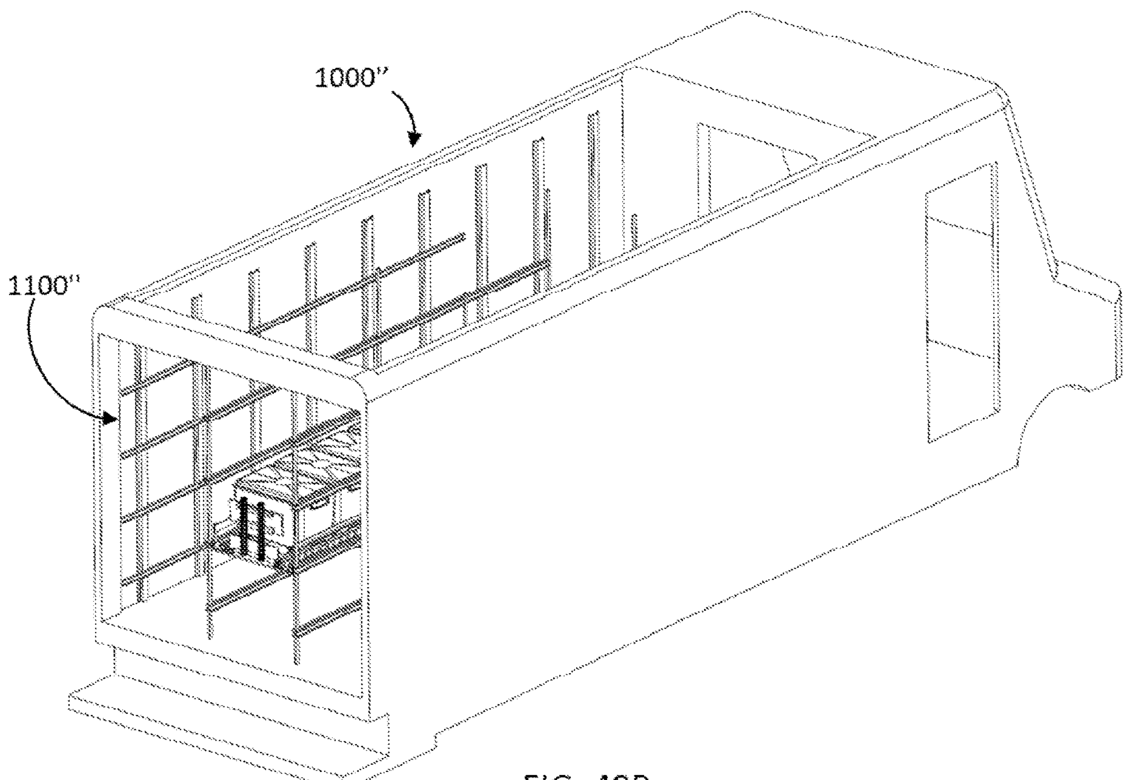


FIG. 48B

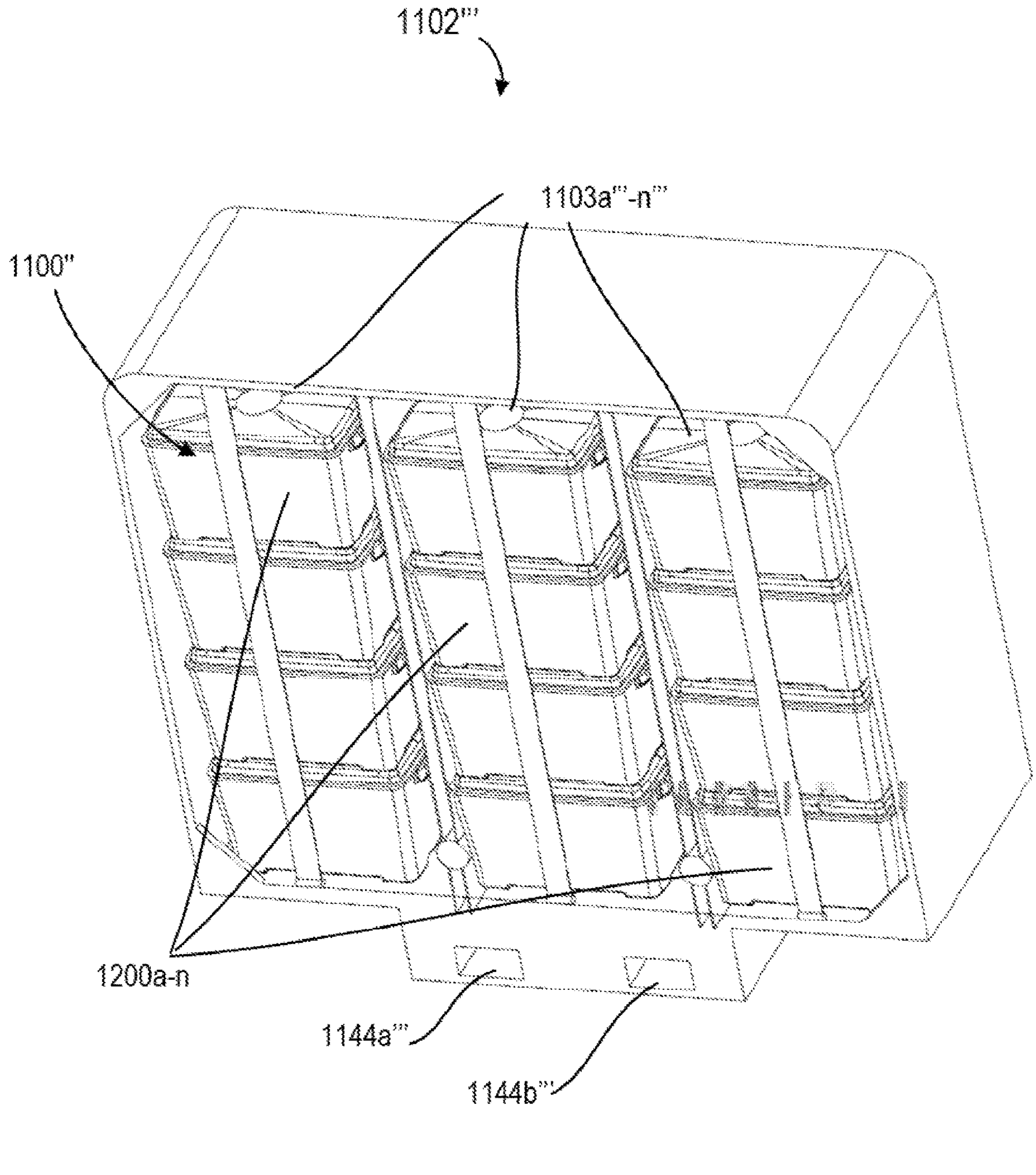


FIG. 49

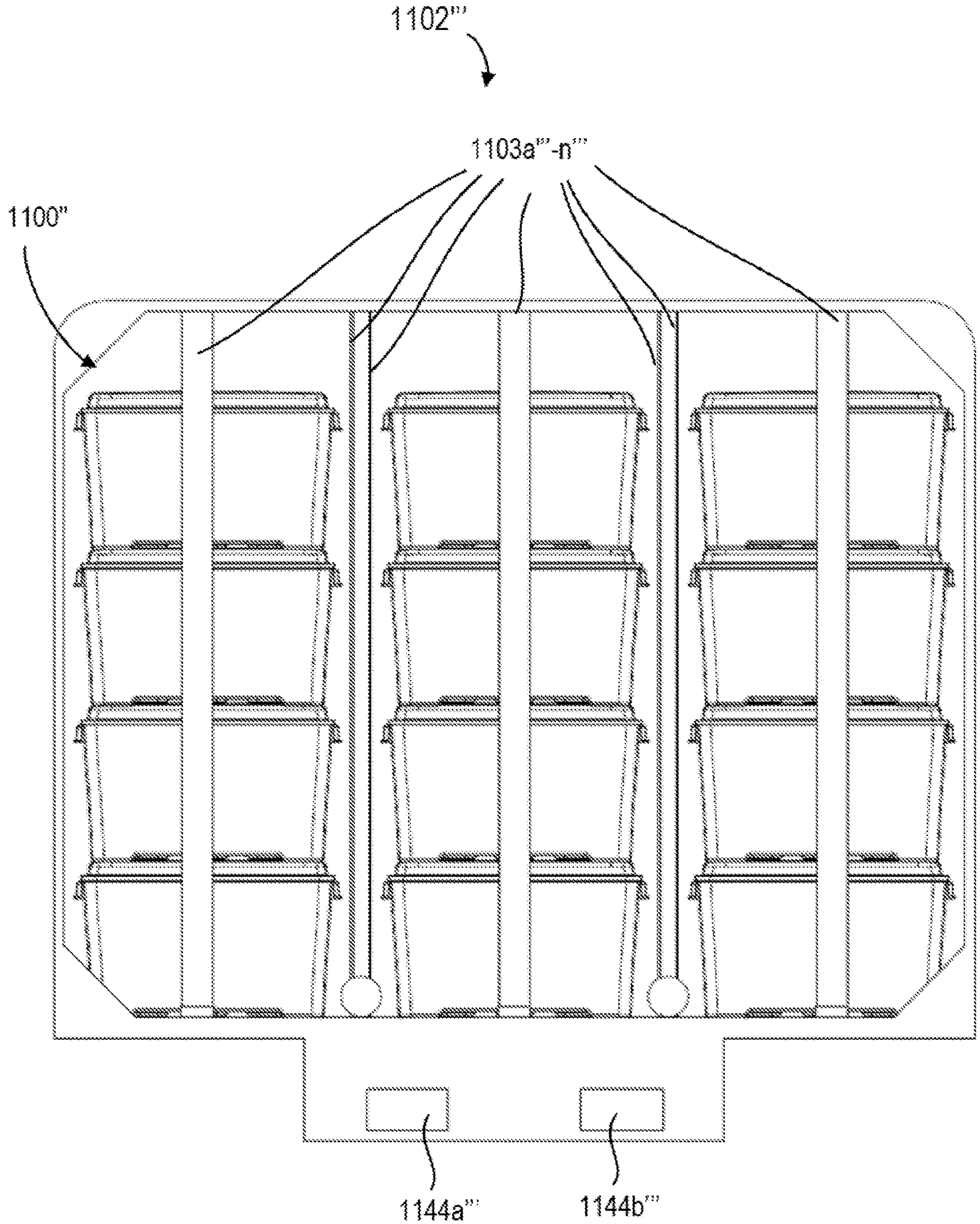


FIG. 50

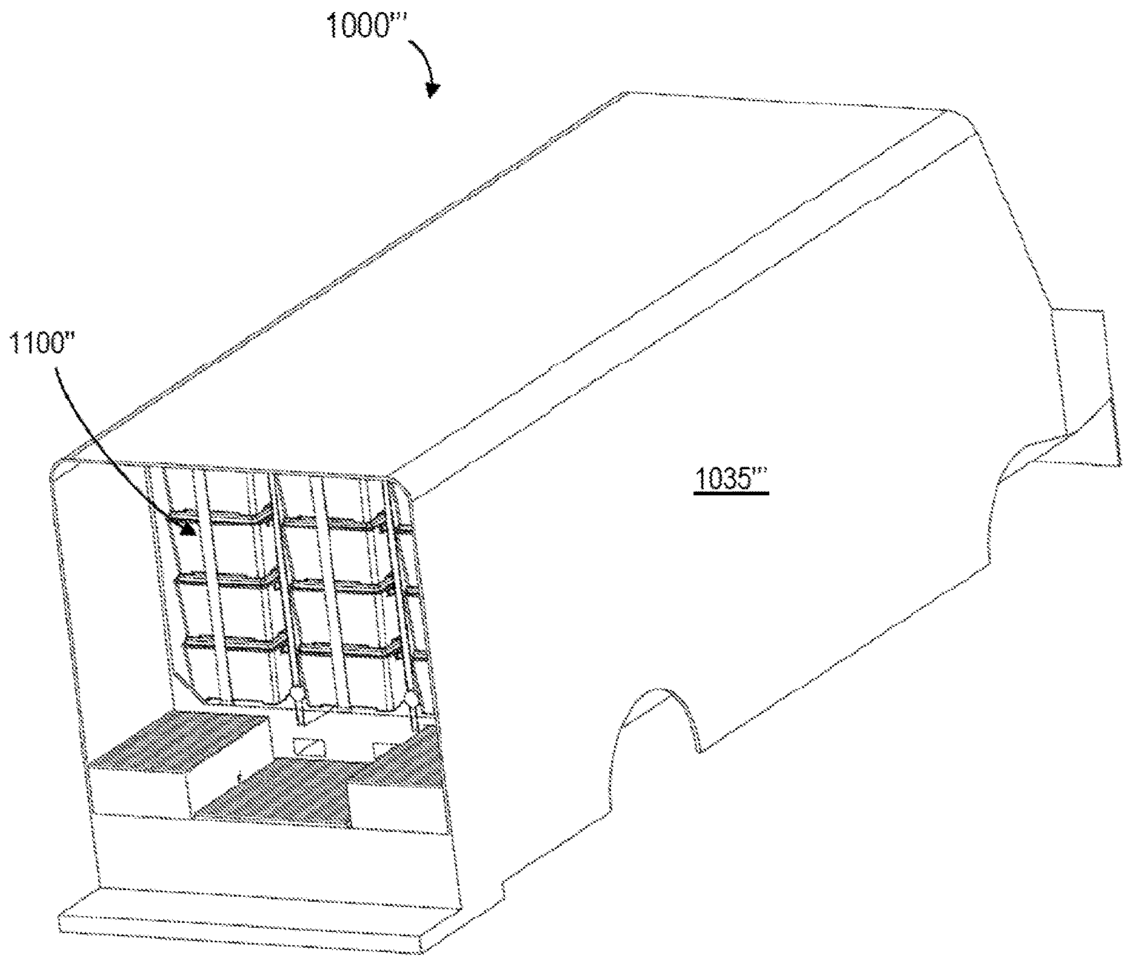


FIG. 51

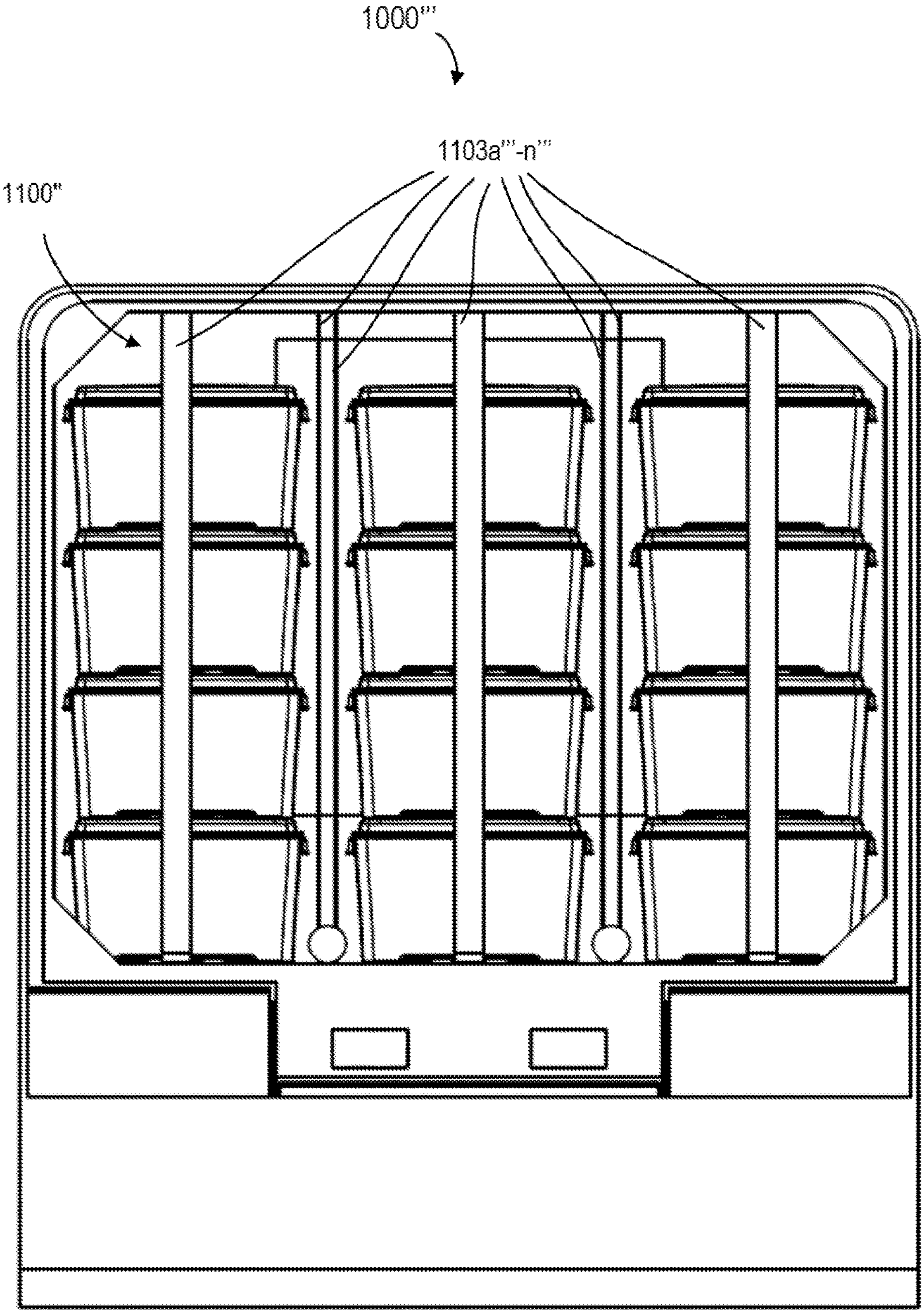


FIG. 52

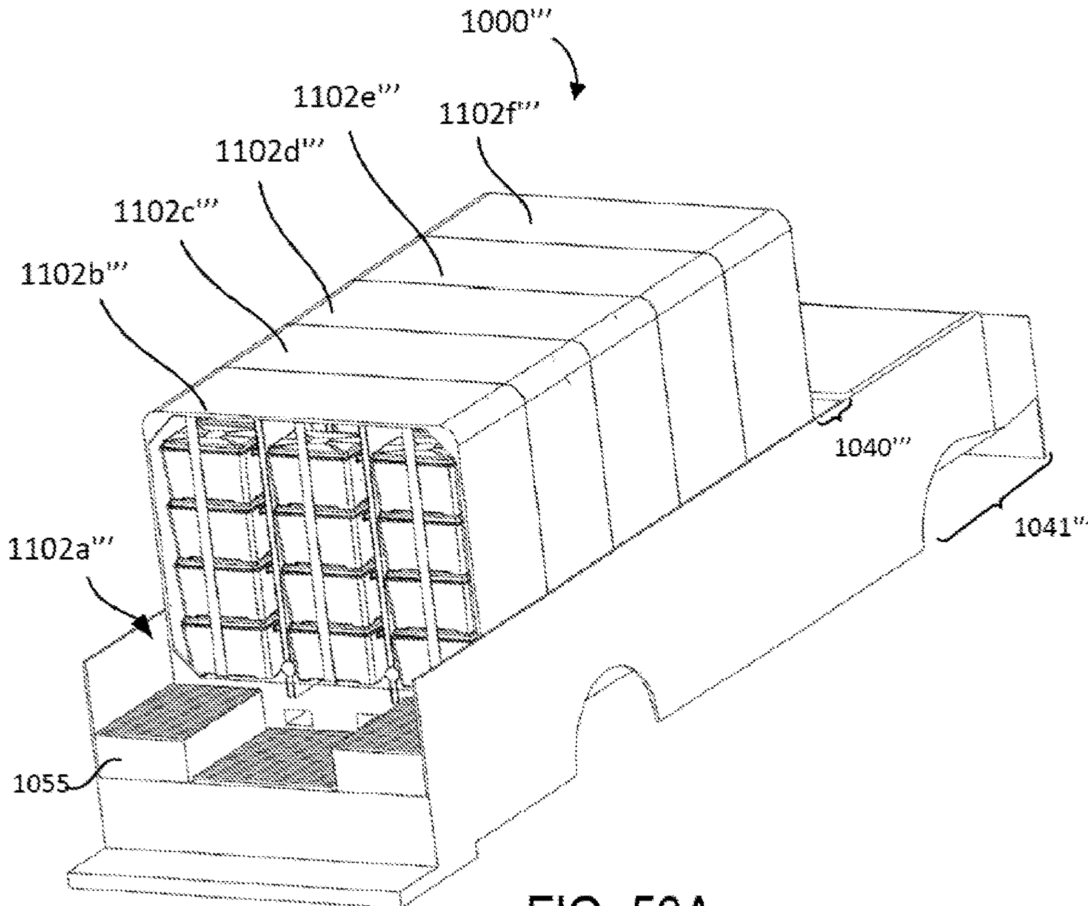


FIG. 53A

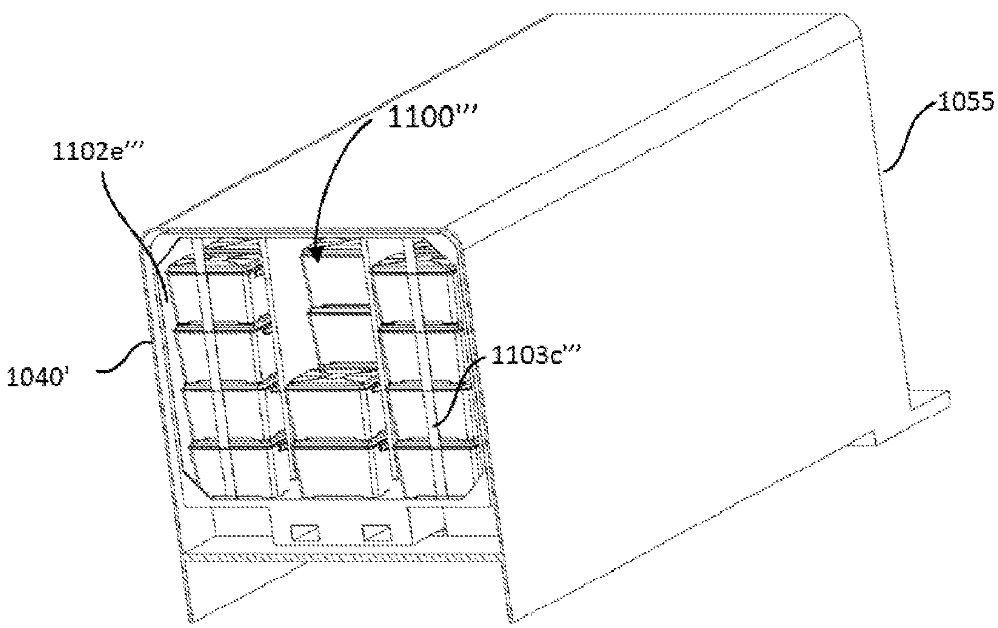


FIG. 53B

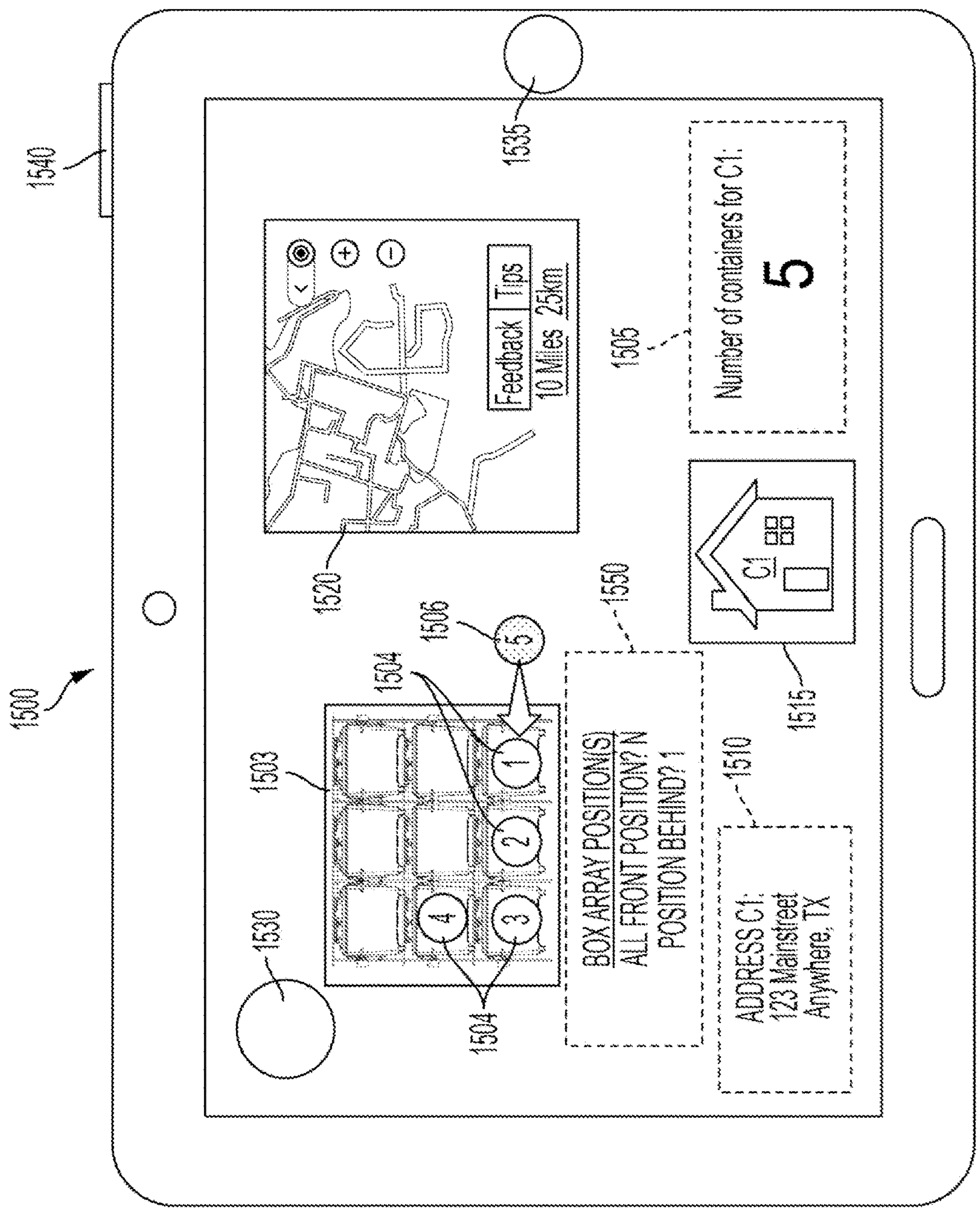

1500
1540
1535
1530
1503
1504
1506
1520
1550
1505
1510
1515
1504
5
1
2
3
4
Feedback
Tips
10 Miles 25km
Number of containers for C1:
5
C1
BOX ARRAY POSITION(S)
ALL FRONT POSITION? N
POSITION BEHIND? 1
ADDRESS C1:
123 Mainstreet
Anywhere, TX

FIG. 54

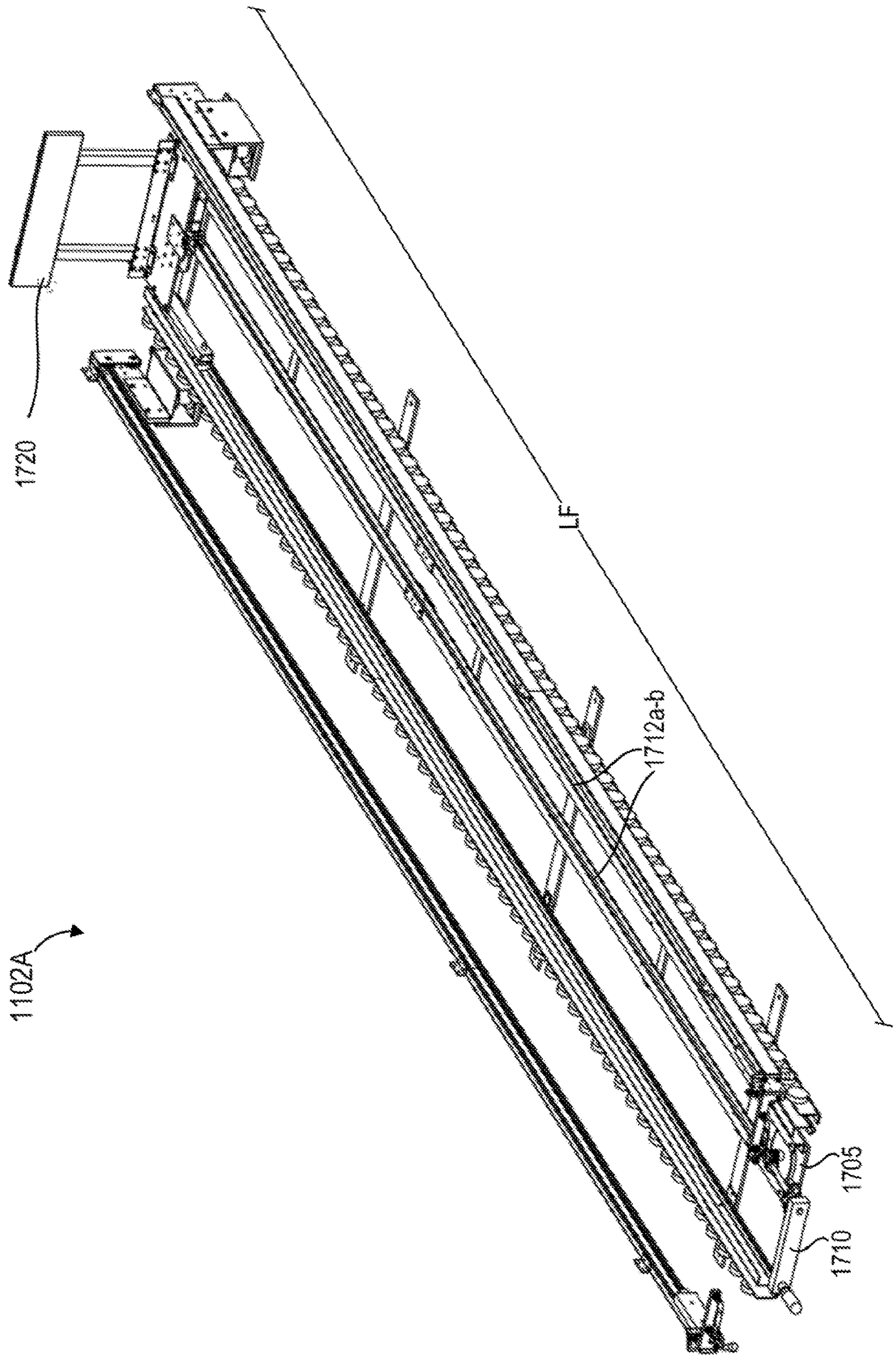


FIG. 55

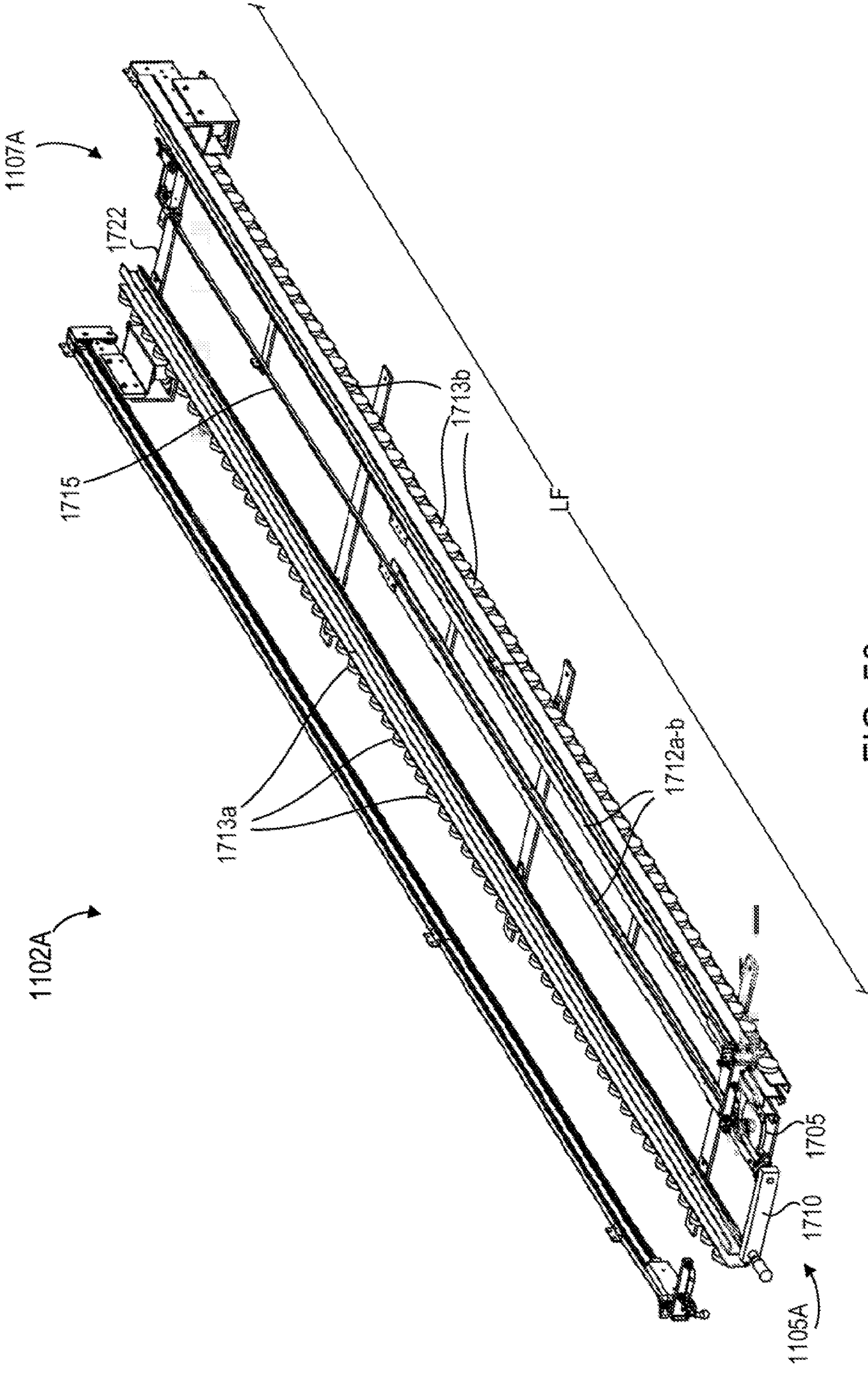


FIG. 56

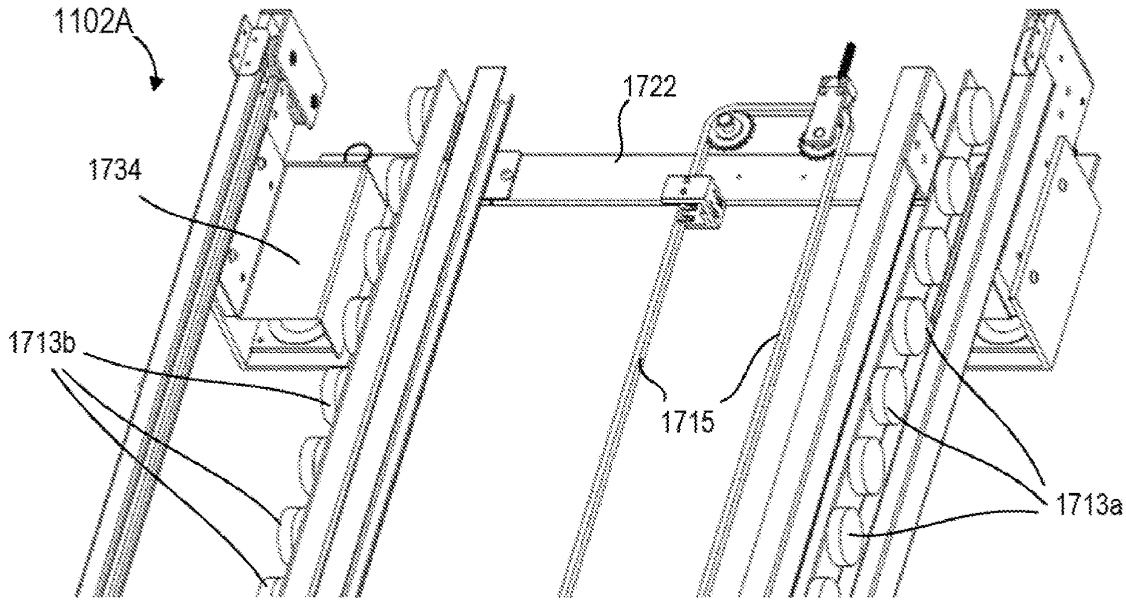


FIG. 57A

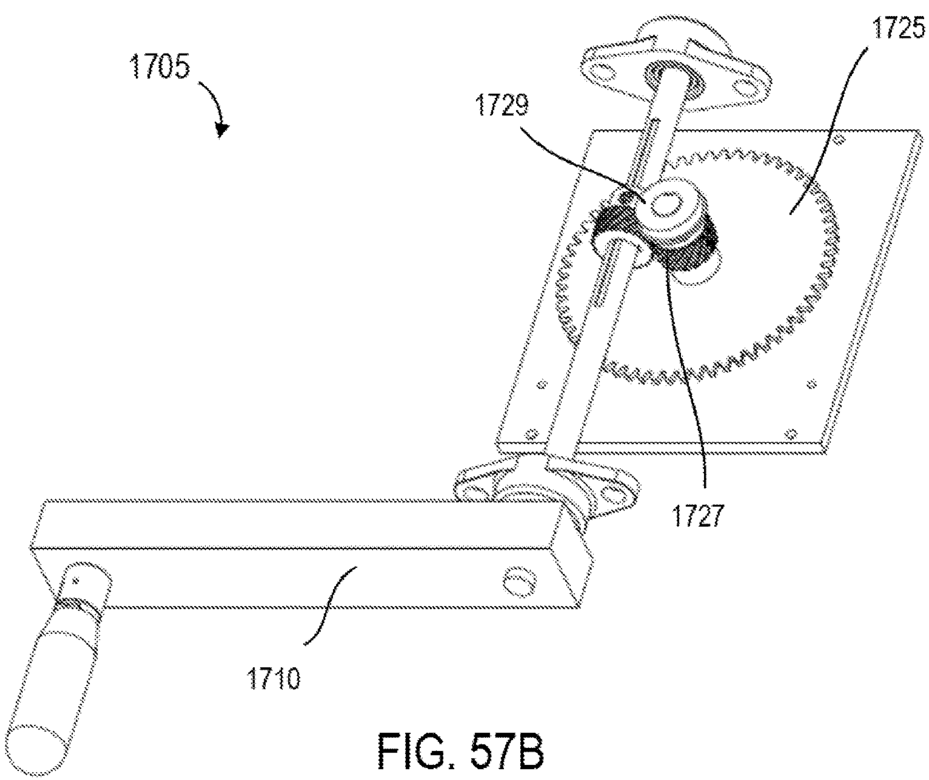


FIG. 57B

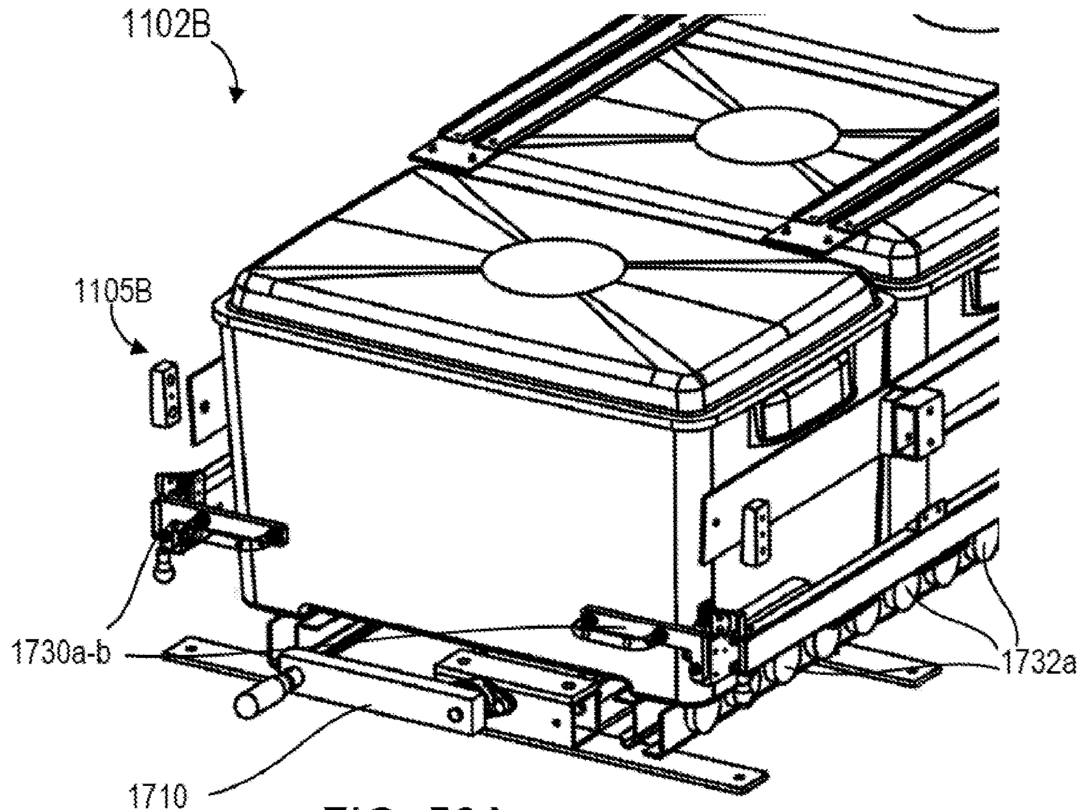


FIG. 58A

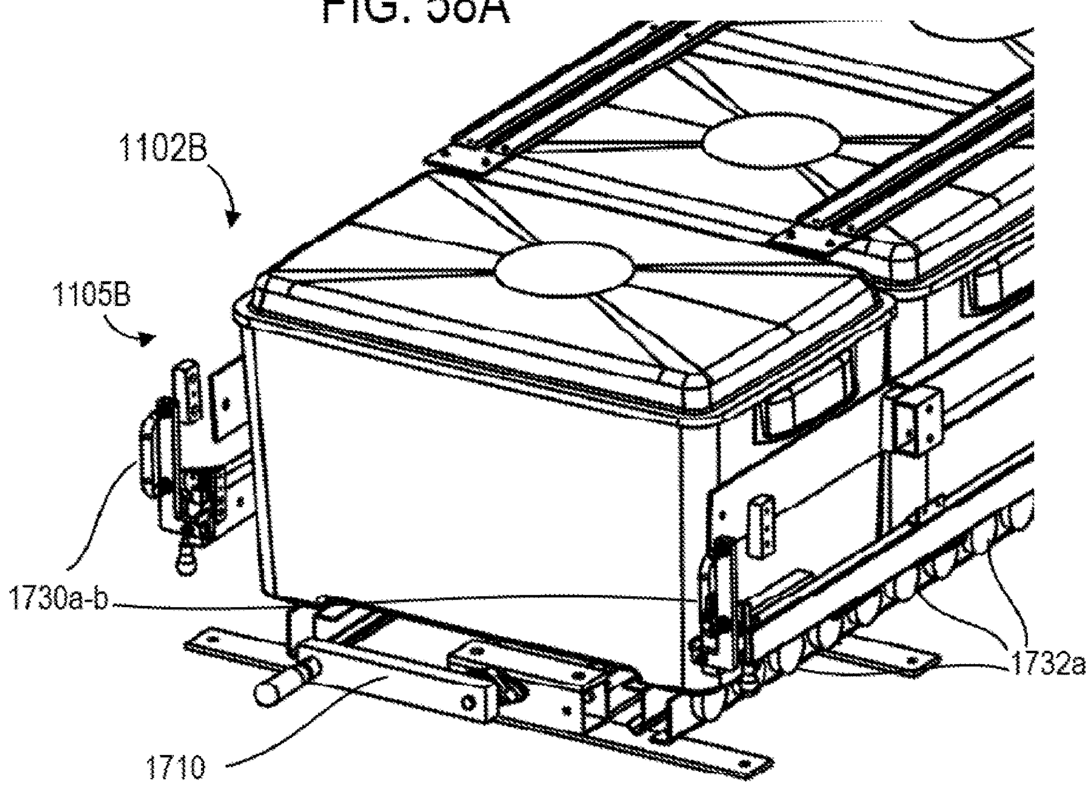


FIG. 58B

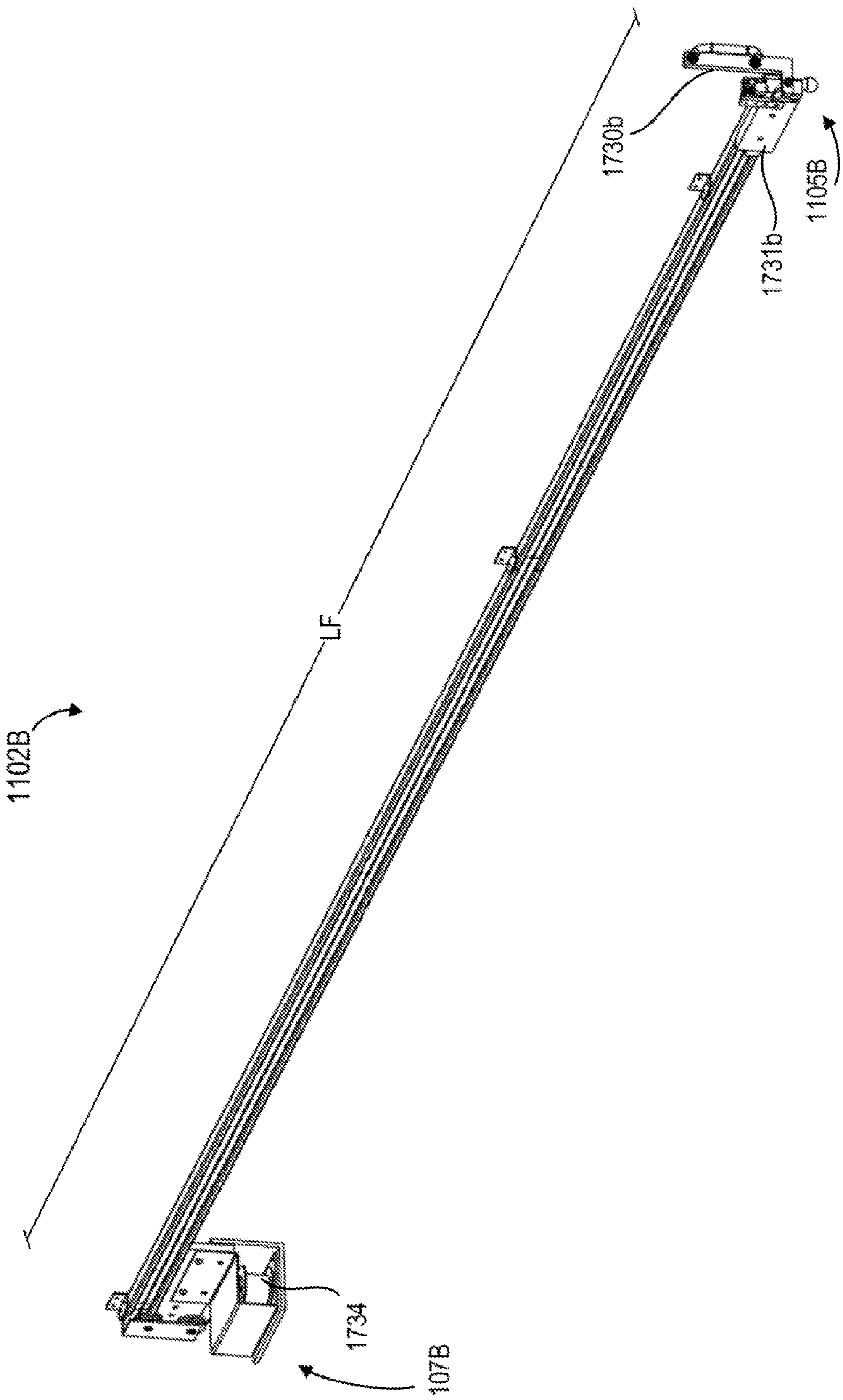


FIG. 59

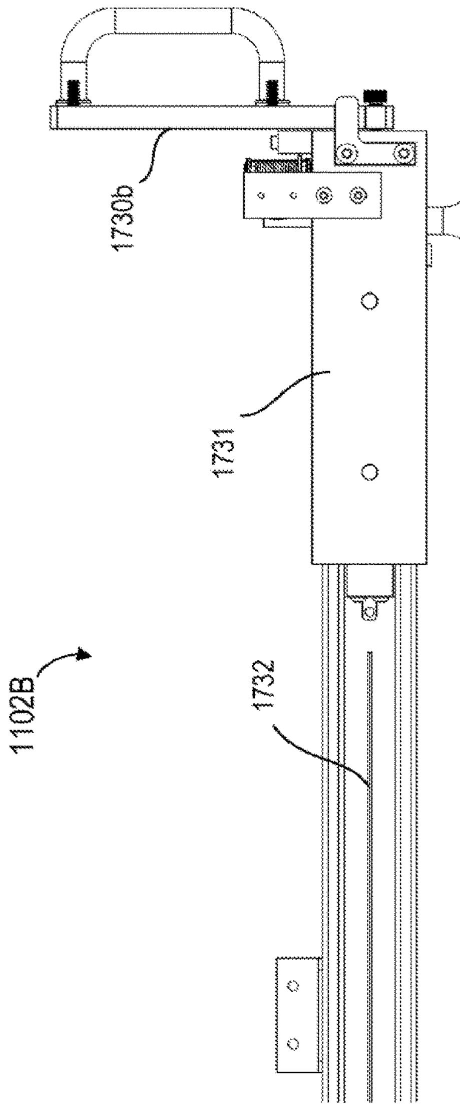


FIG. 60A

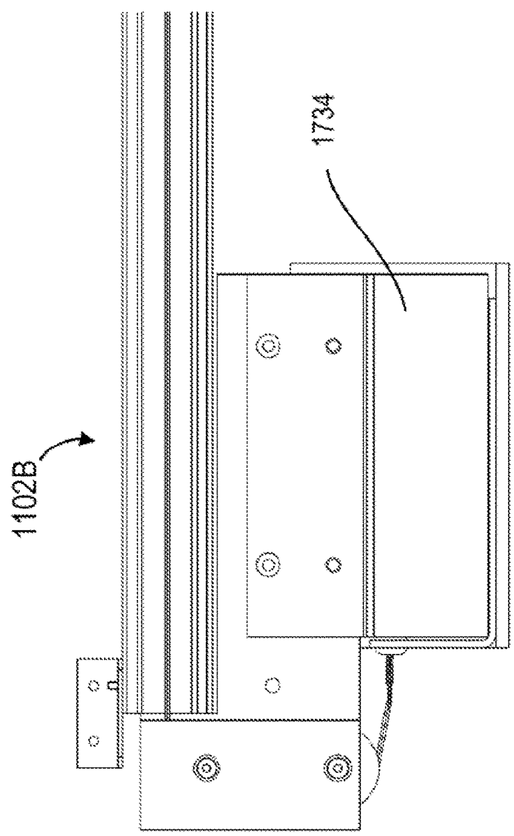


FIG. 60B

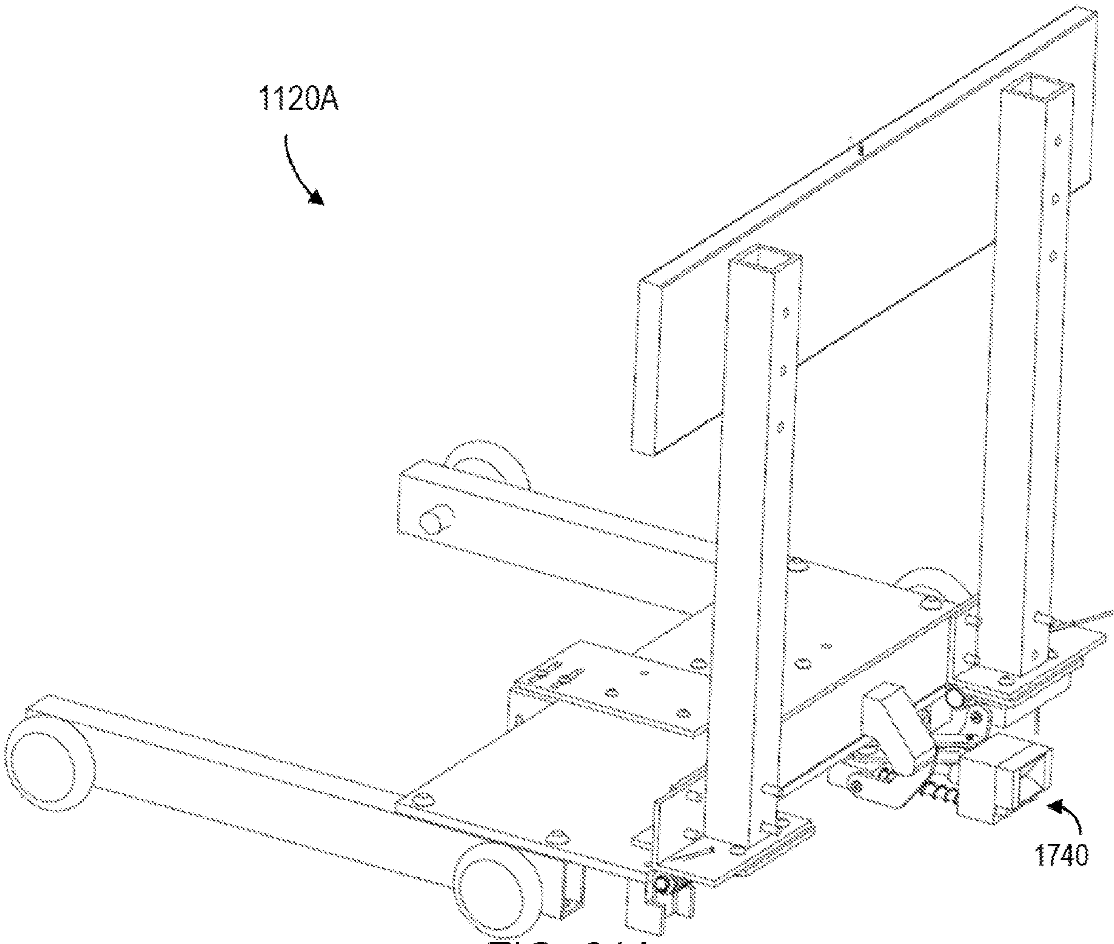


FIG. 61A

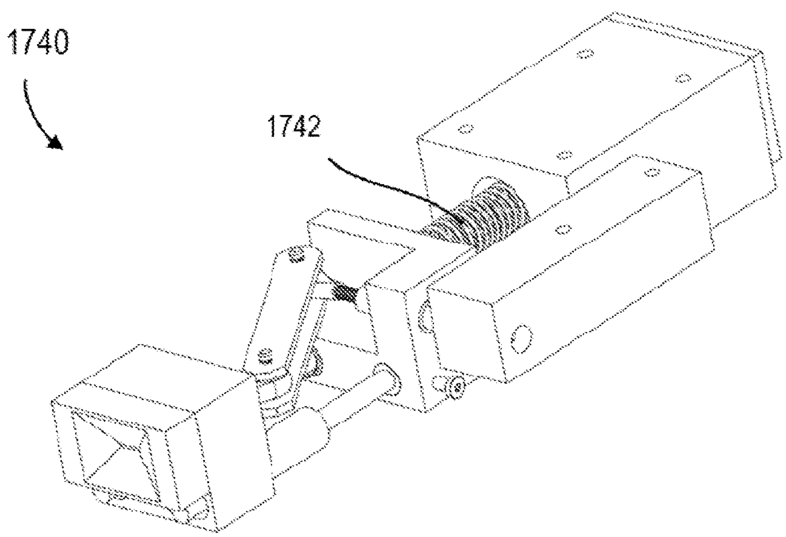


FIG. 61B

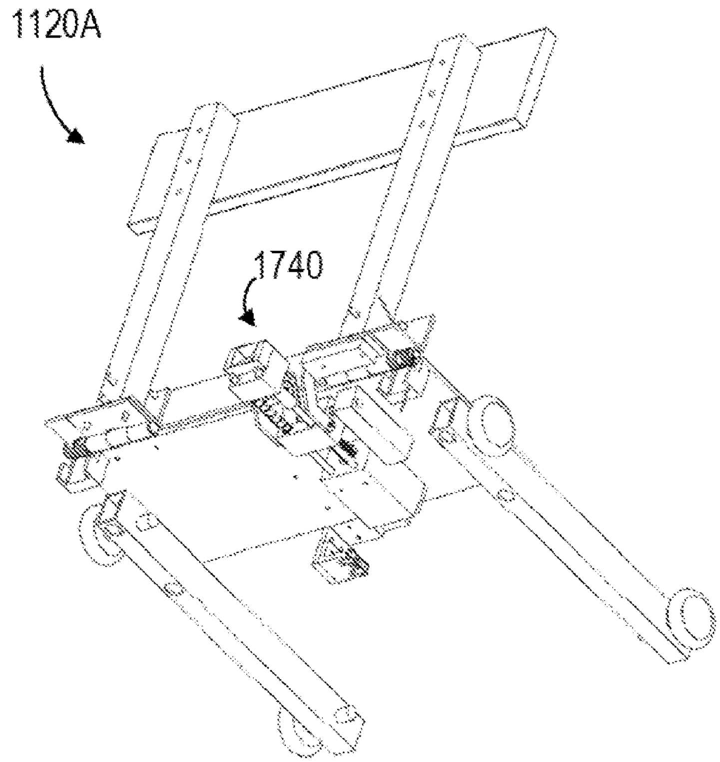


FIG. 62A

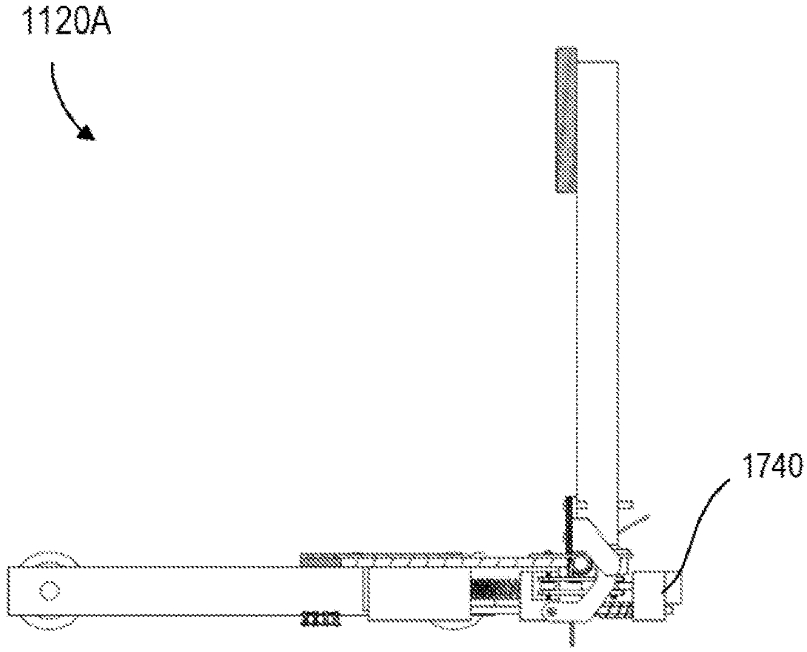


FIG. 62B

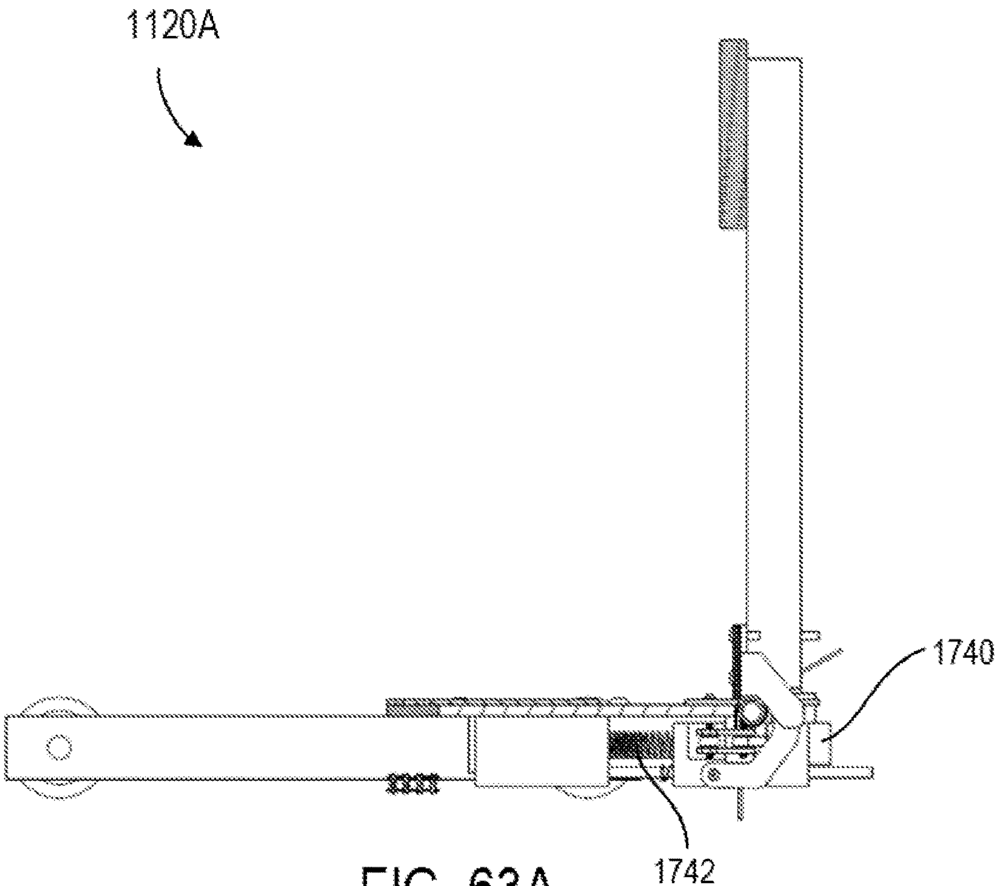


FIG. 63A

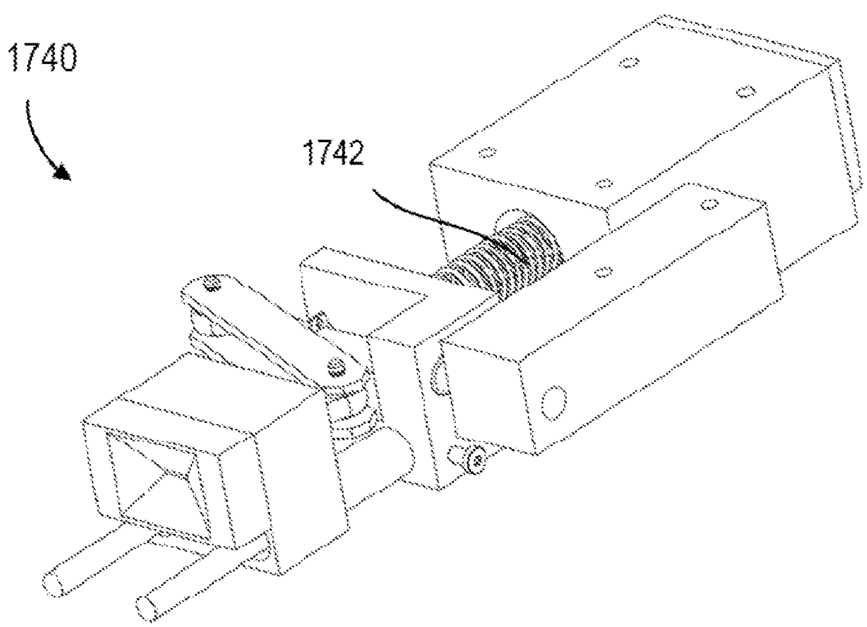


FIG. 63B

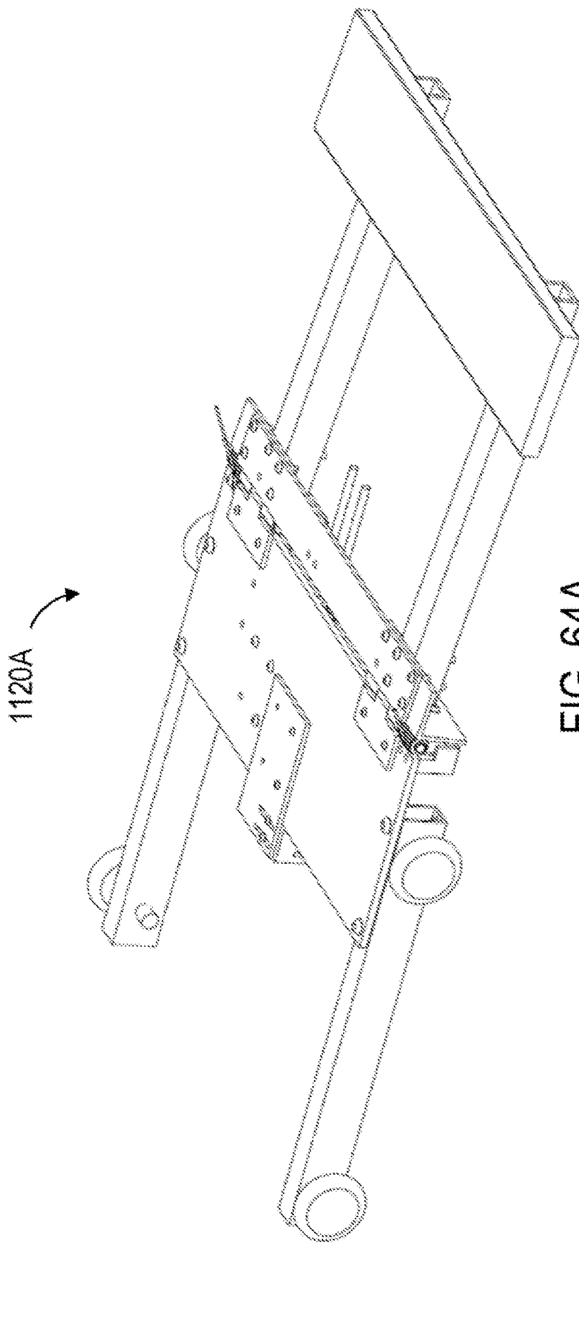


FIG. 64A

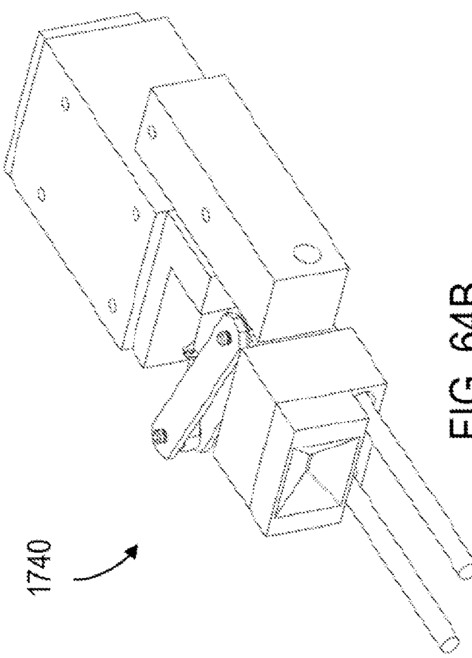


FIG. 64B

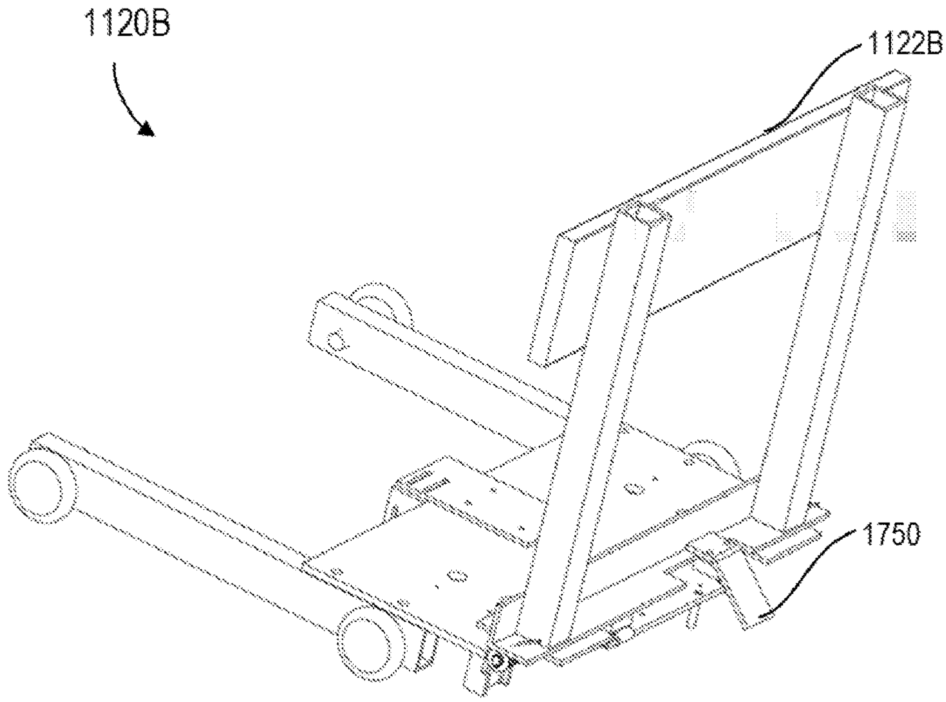


FIG. 65A

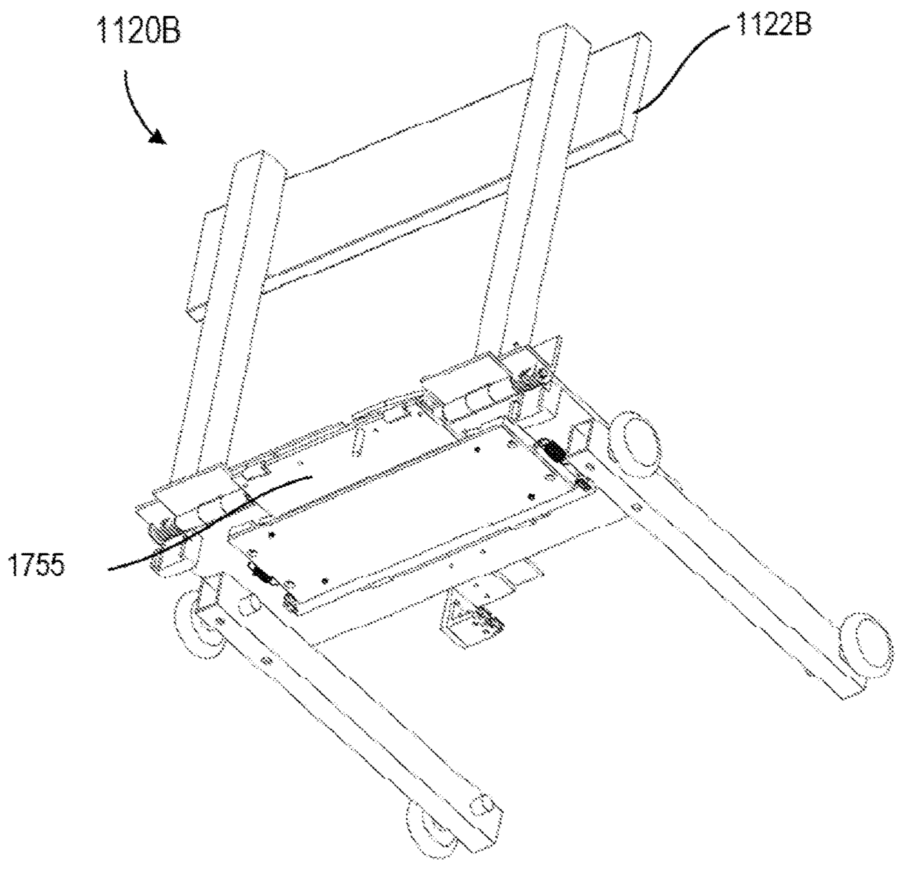


FIG. 65B

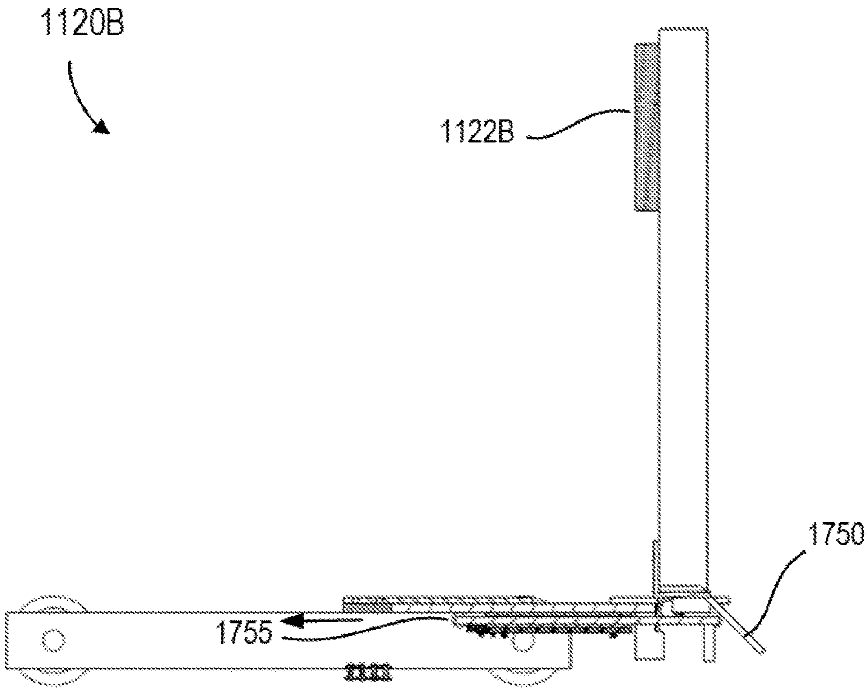


FIG. 66A

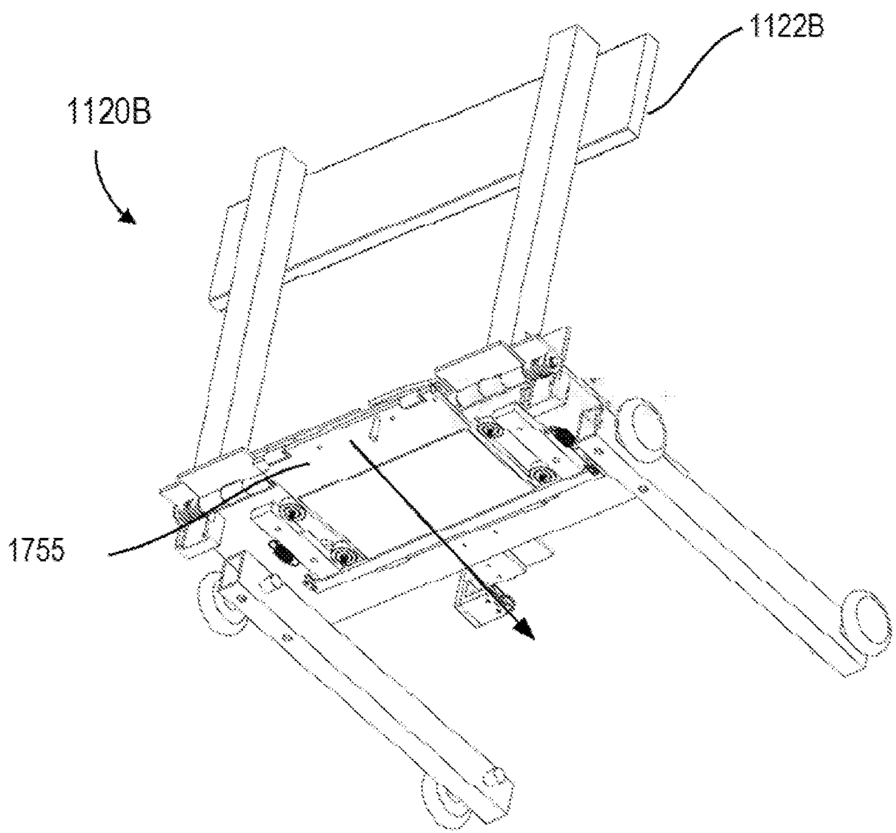


FIG. 66B

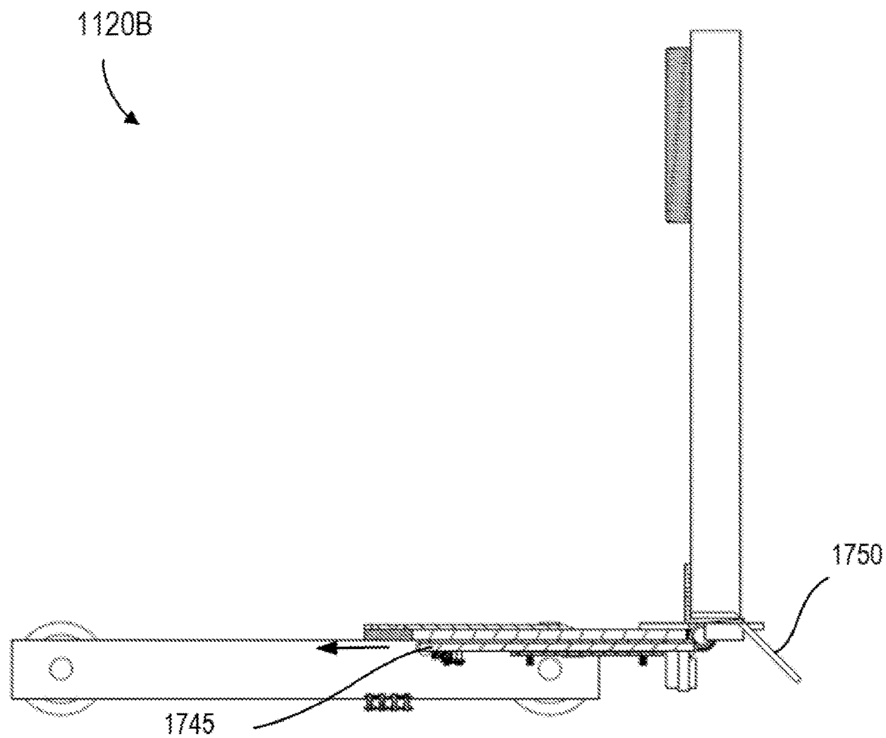


FIG. 67A

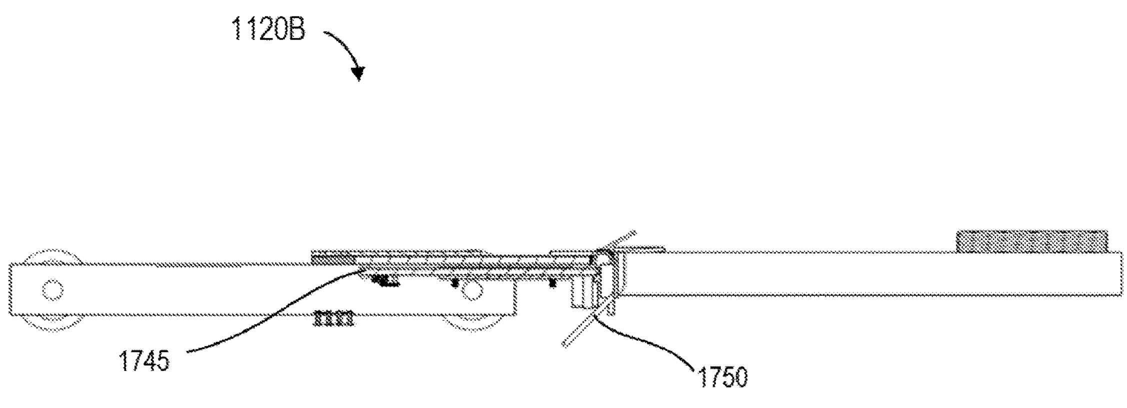


FIG. 67B

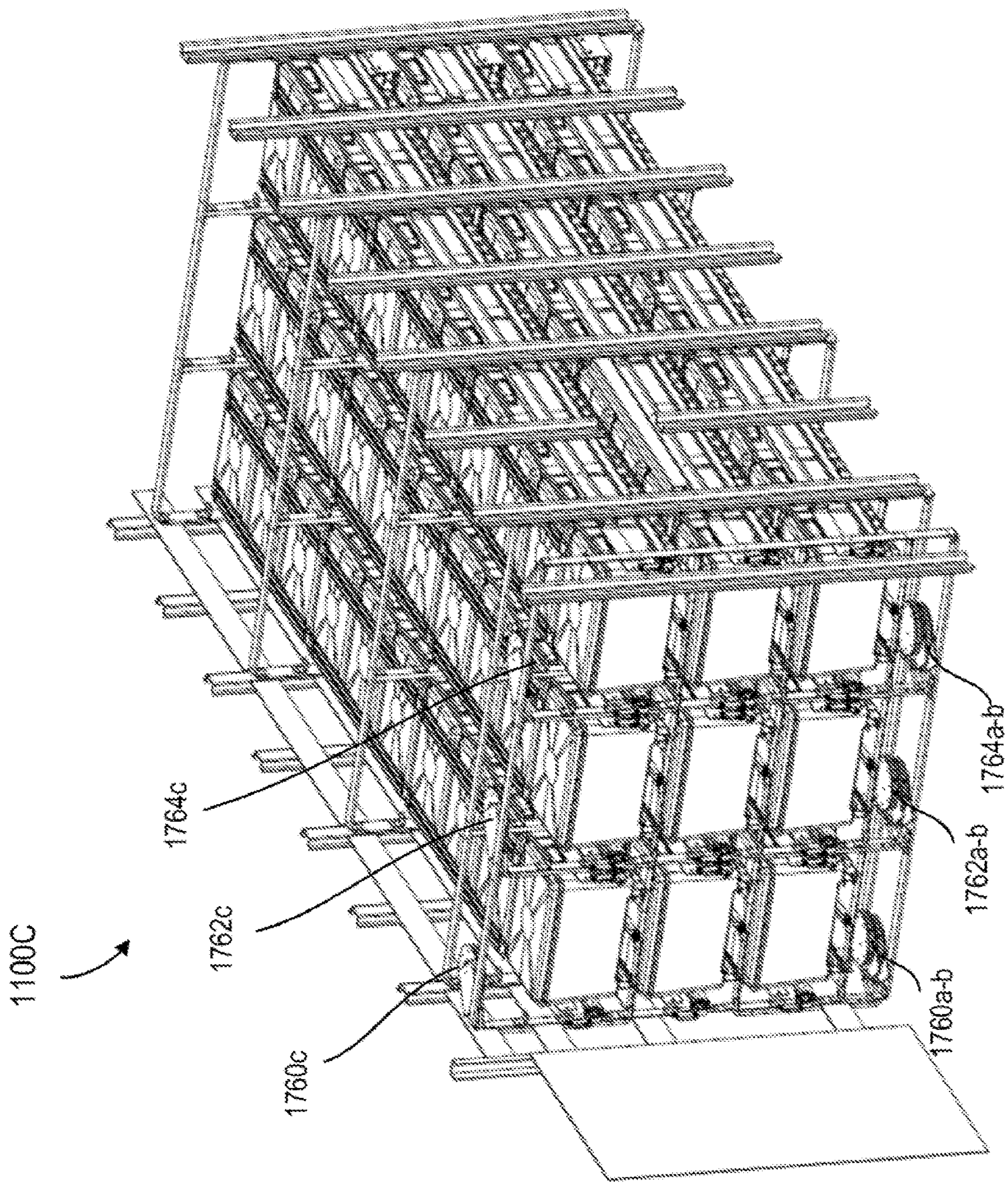


FIG. 68

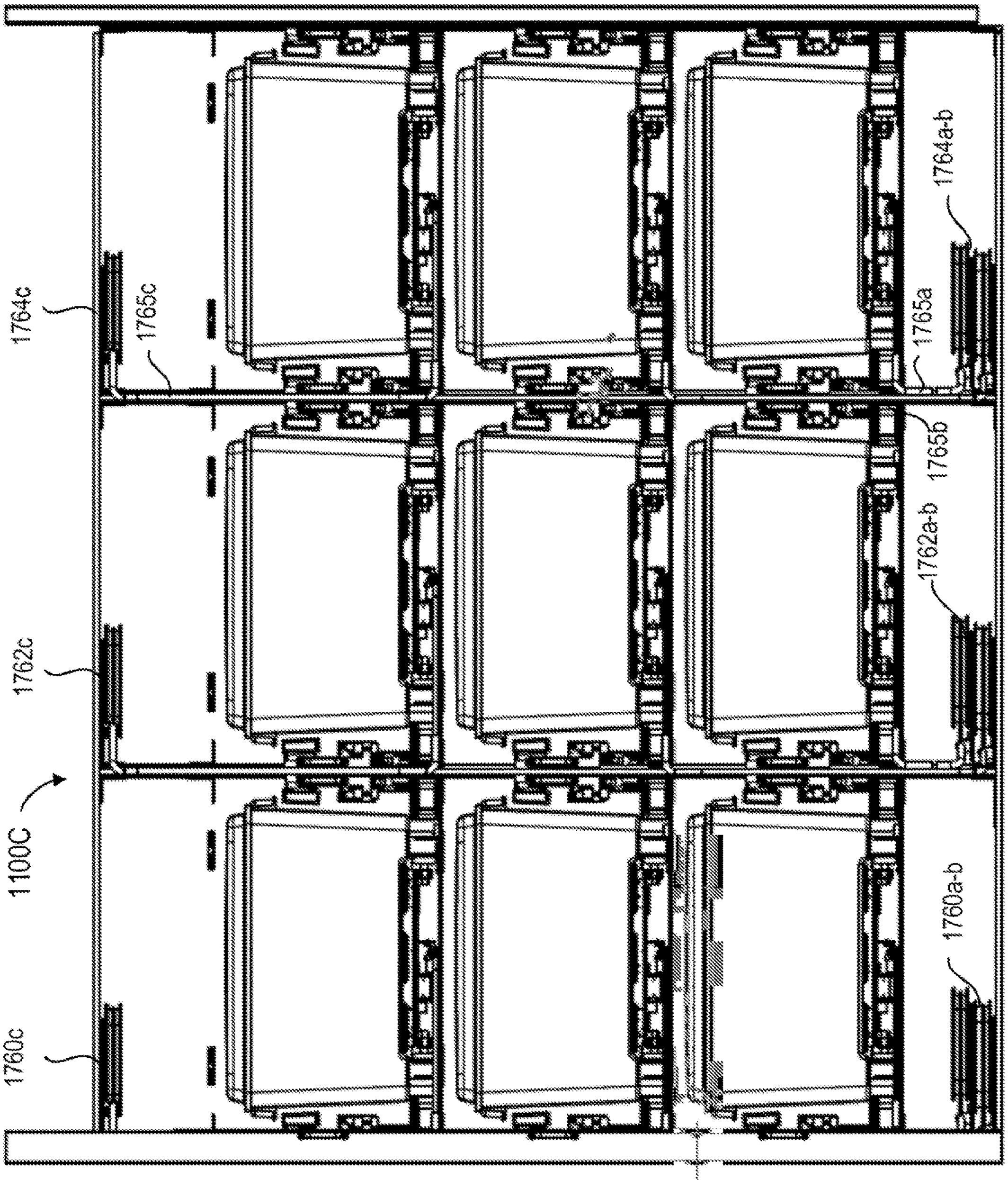

1764c
1765c
1762c
1100C
1760c
1764a-b
1765a
1765b
1762a-b
1760a-b

FIG. 69

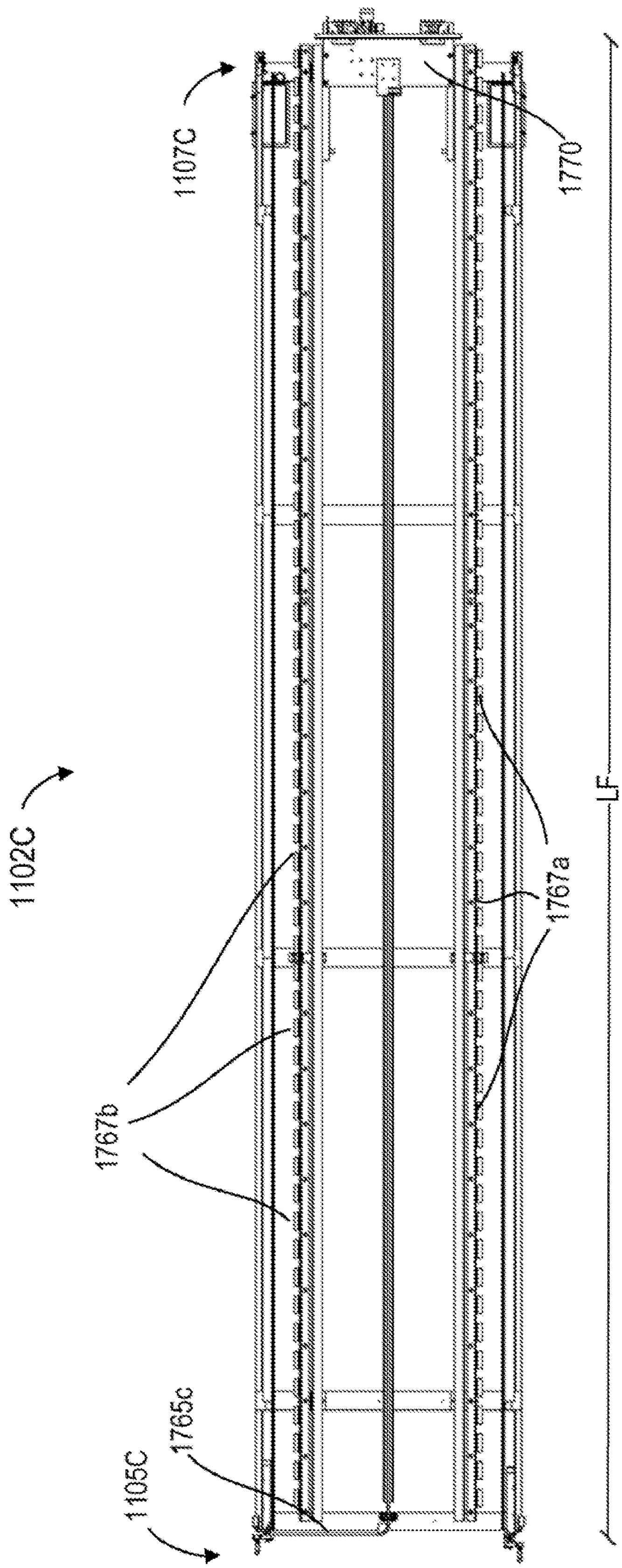


FIG. 70

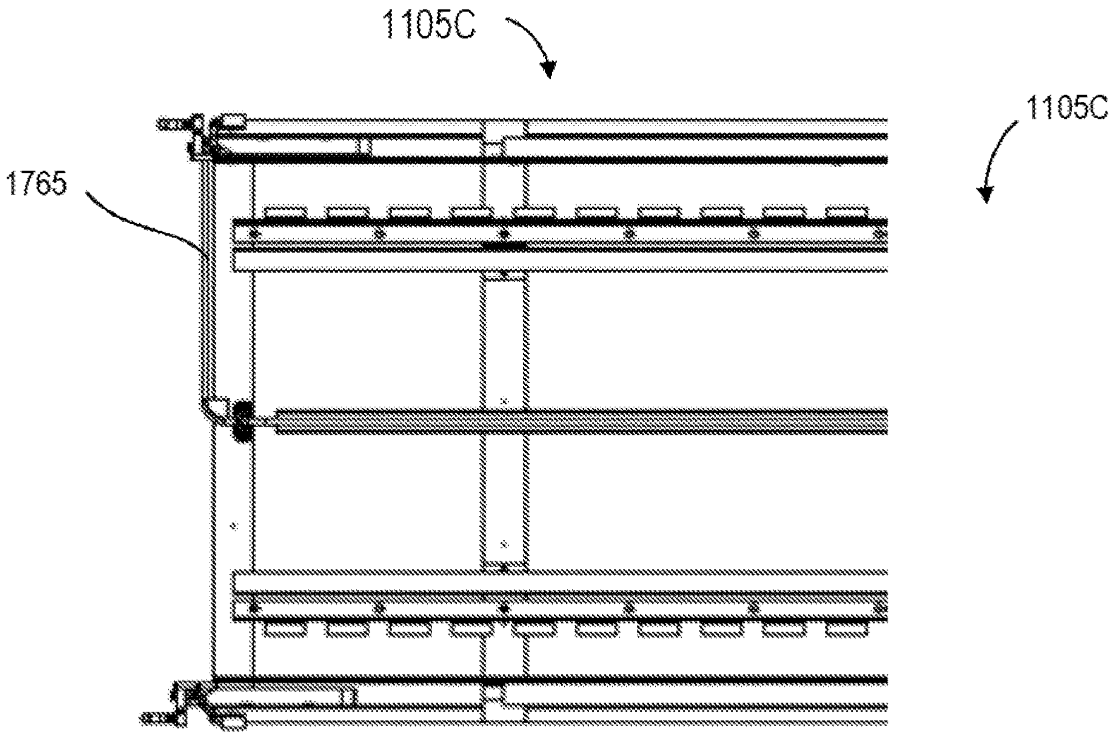


FIG. 71A

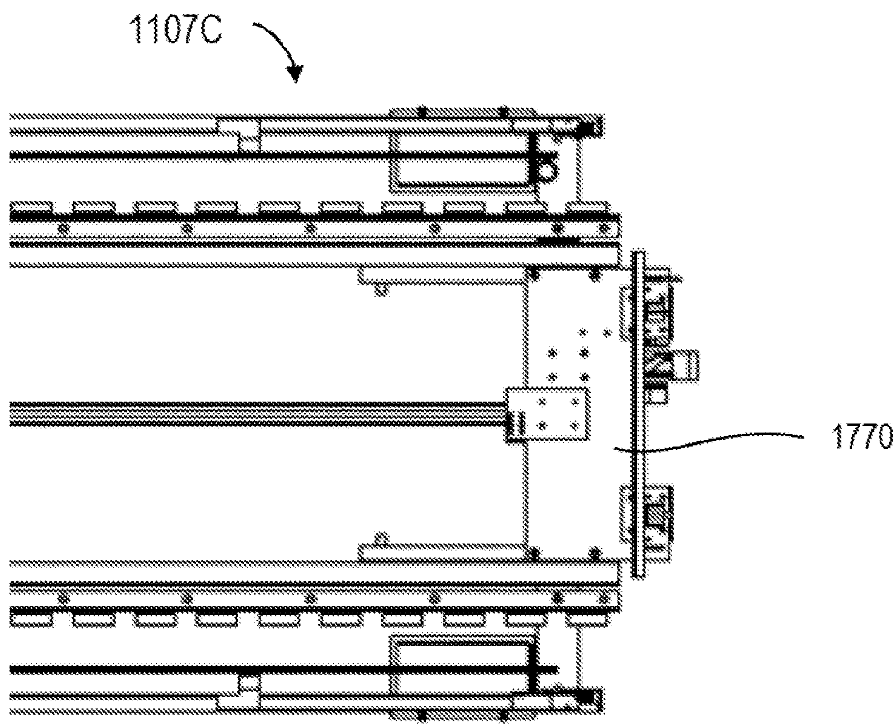


FIG. 71B

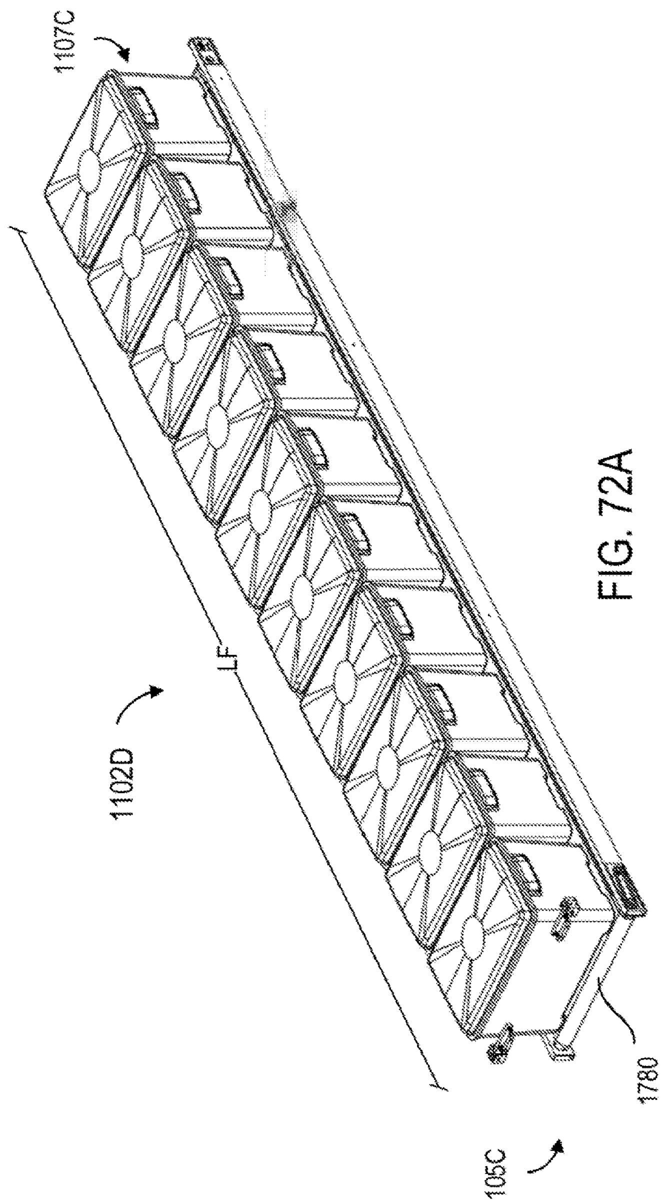


FIG. 72A

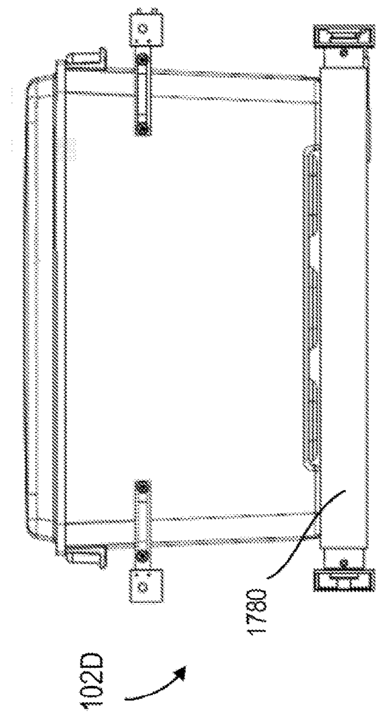


FIG. 72B

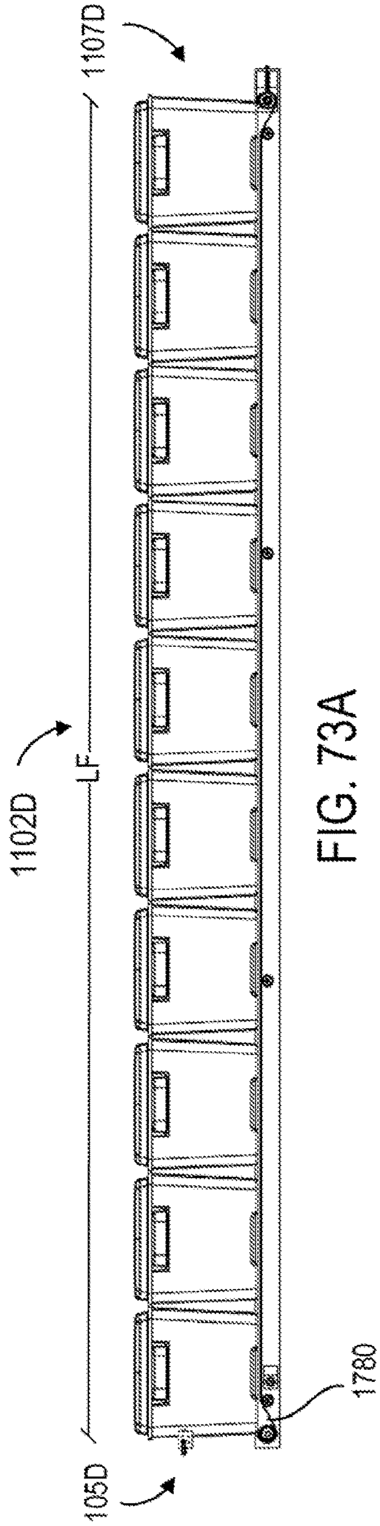


FIG. 73A

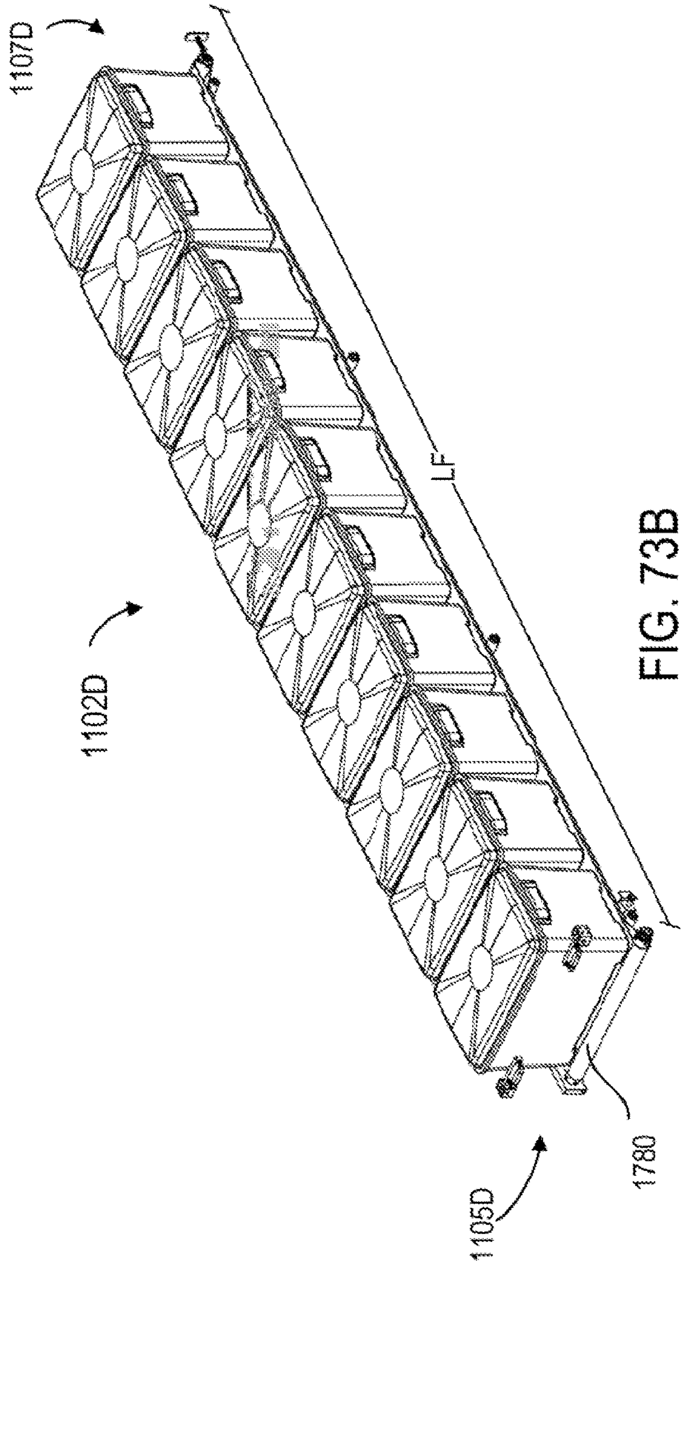


FIG. 73B

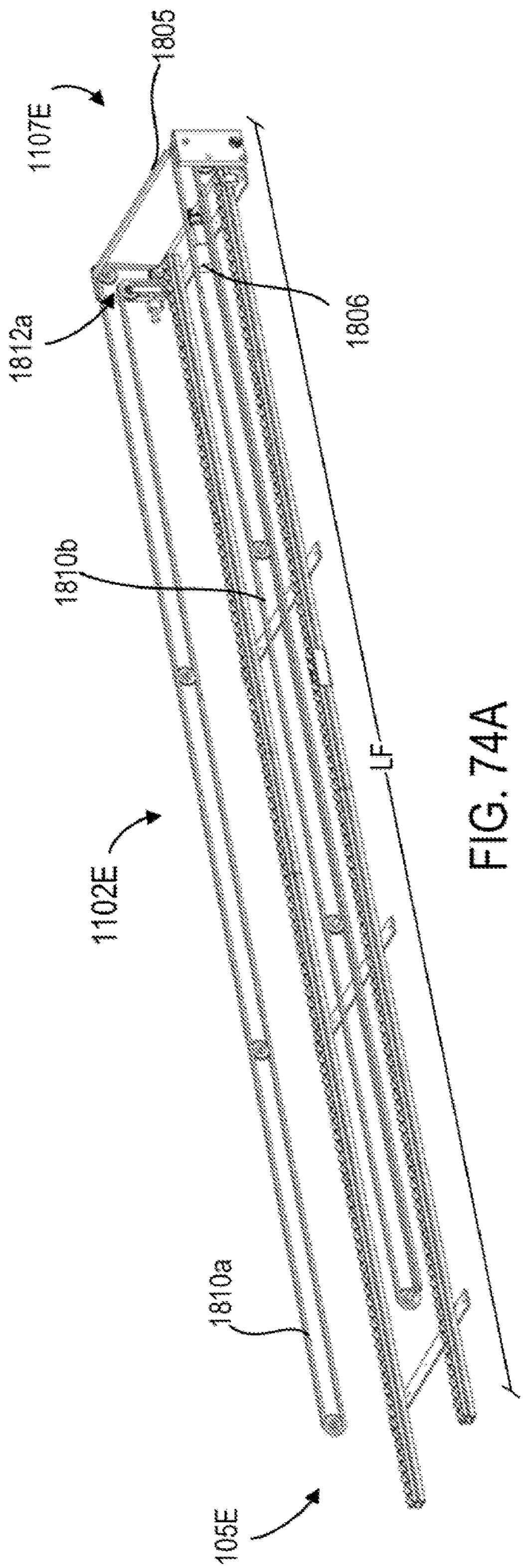


FIG. 74A

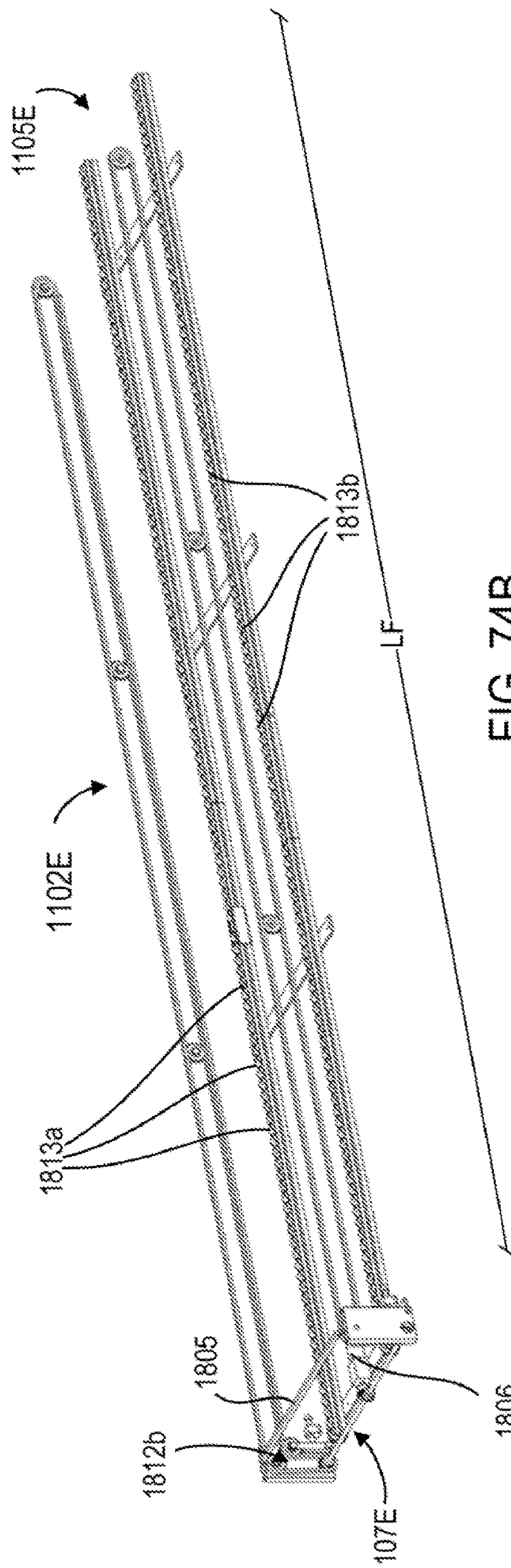


FIG. 74B

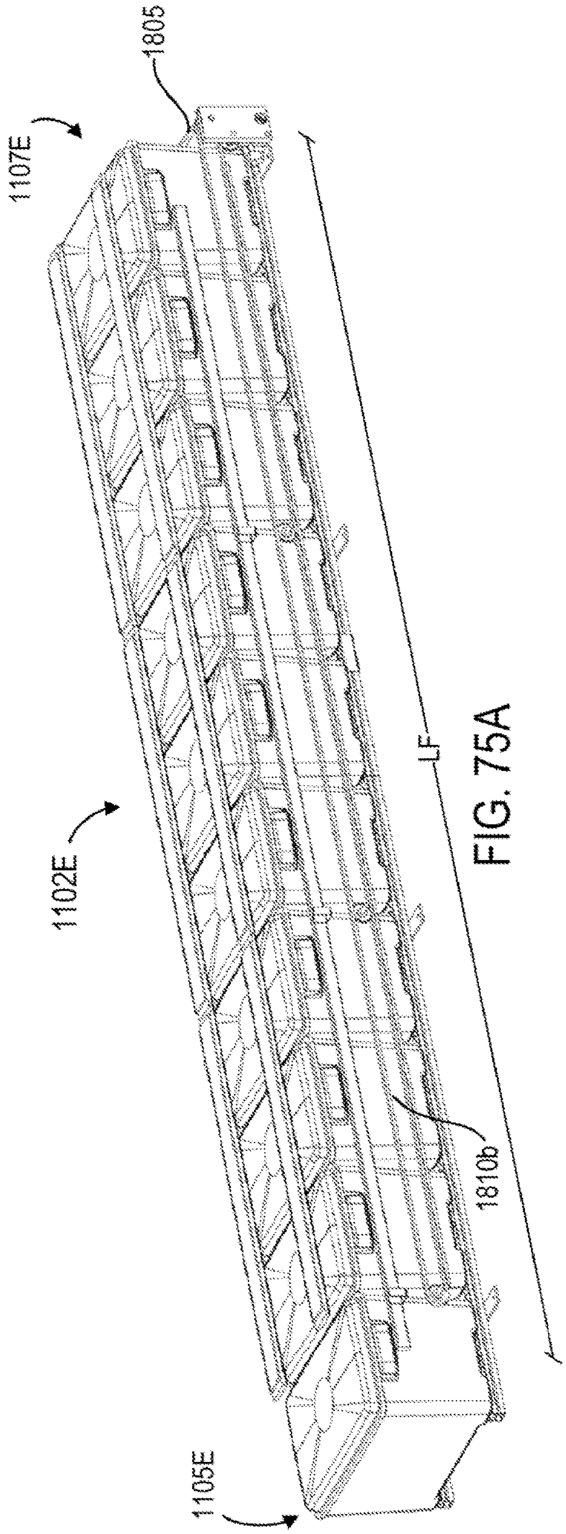


FIG. 75A

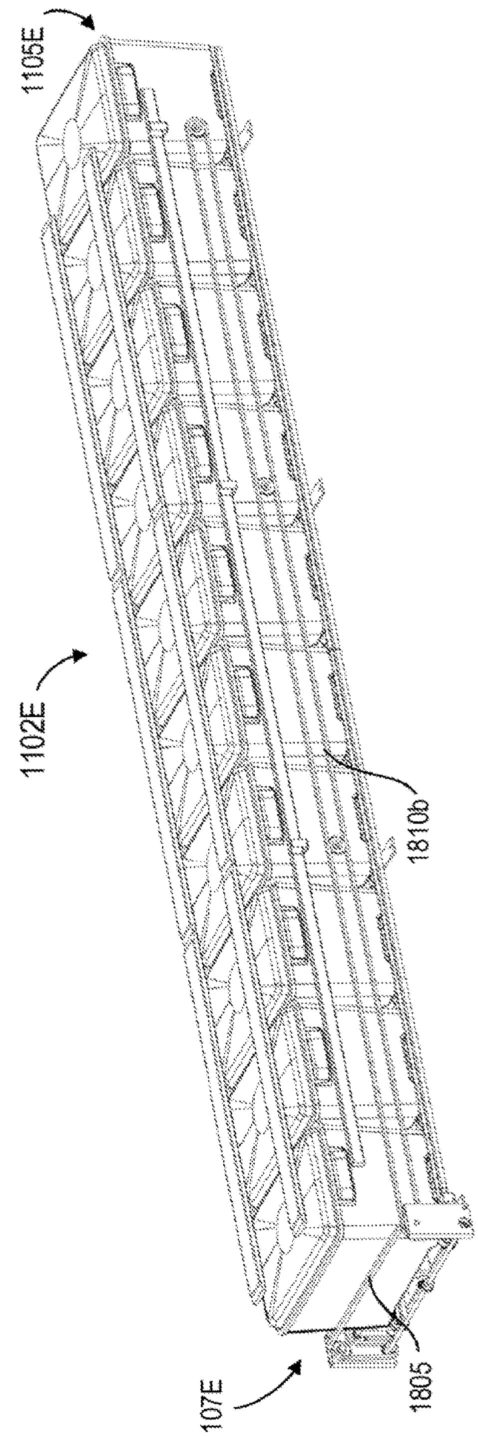


FIG. 75B

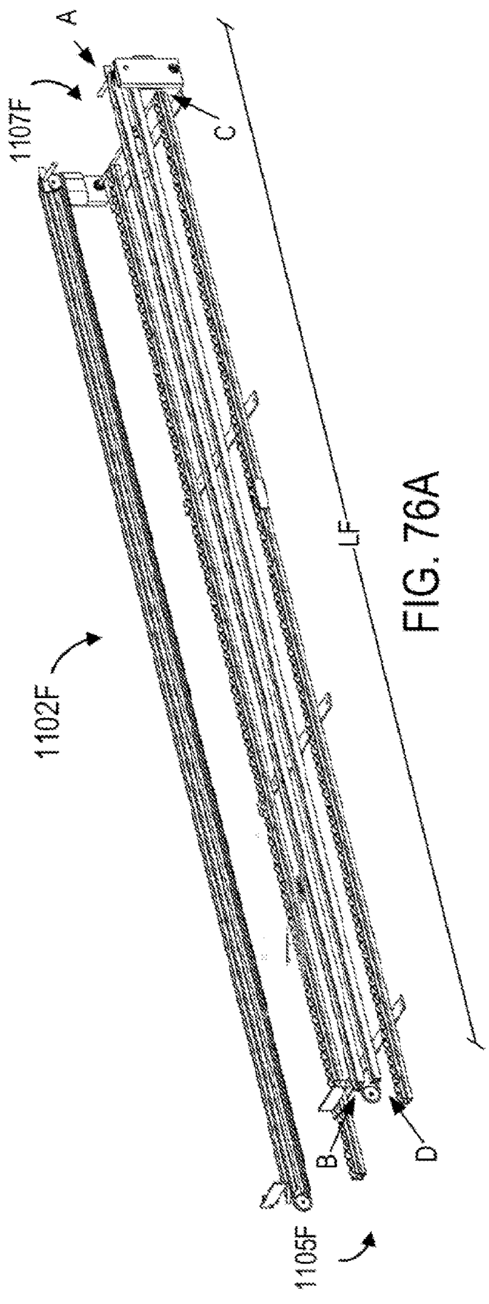


FIG. 76A

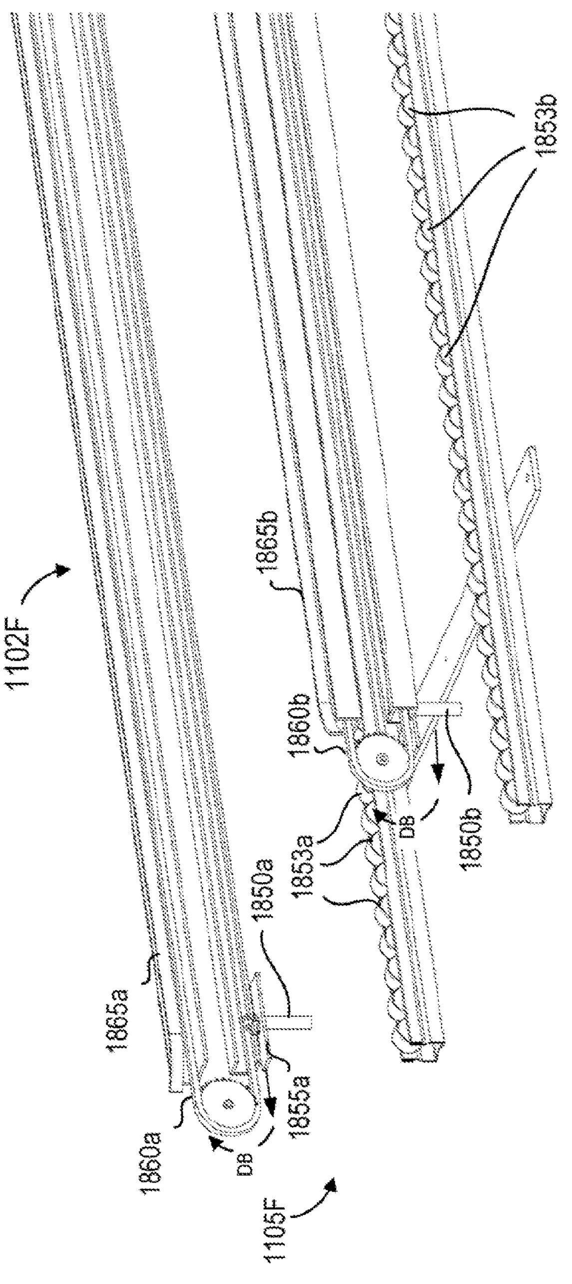


FIG. 76B

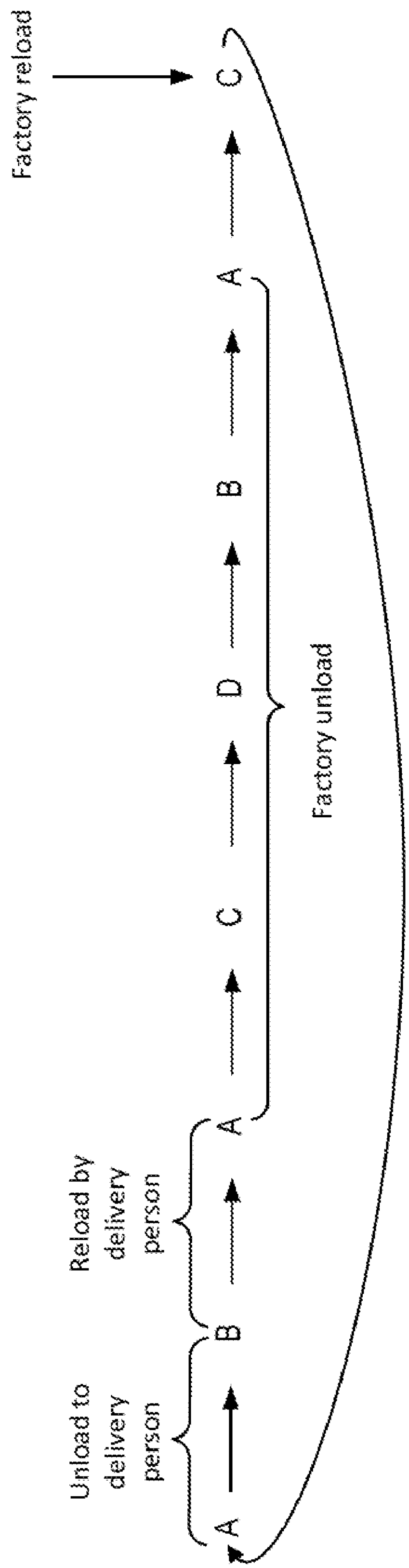

Factory reload
Unload to delivery person
Reload by delivery person
Factory unload
A
B
A
C
D
B
A
C

FIG. 77

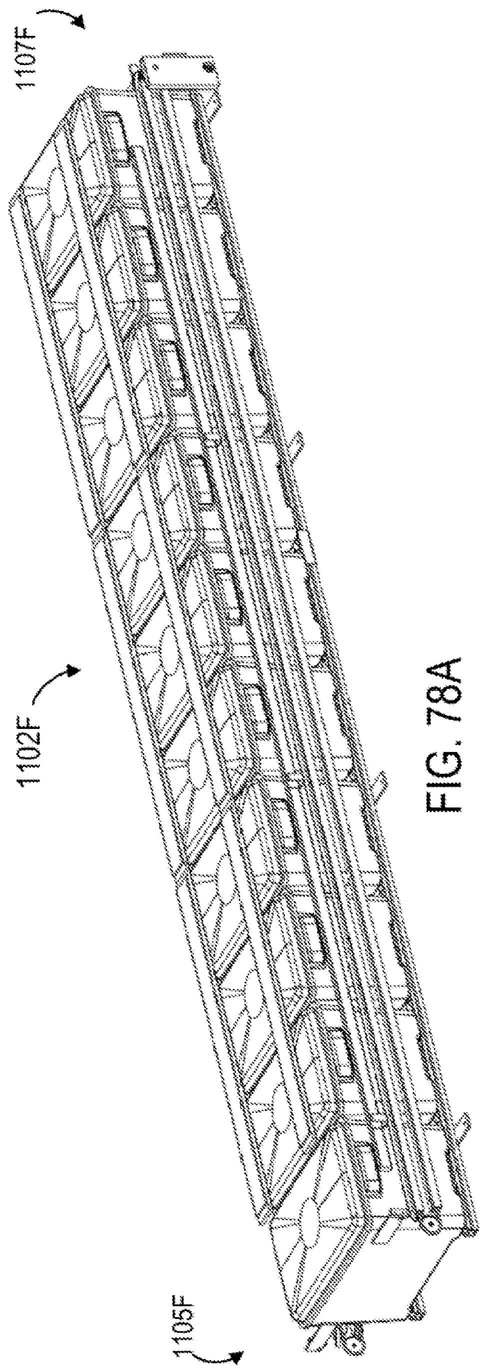


FIG. 78A

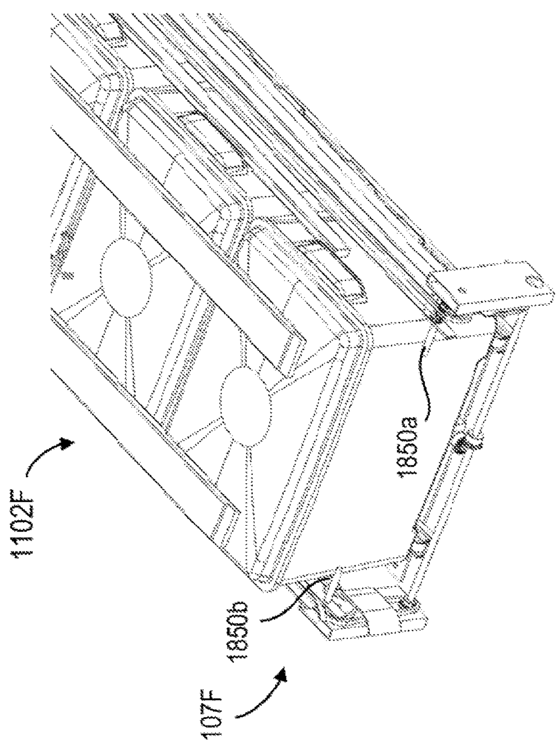


FIG. 78B

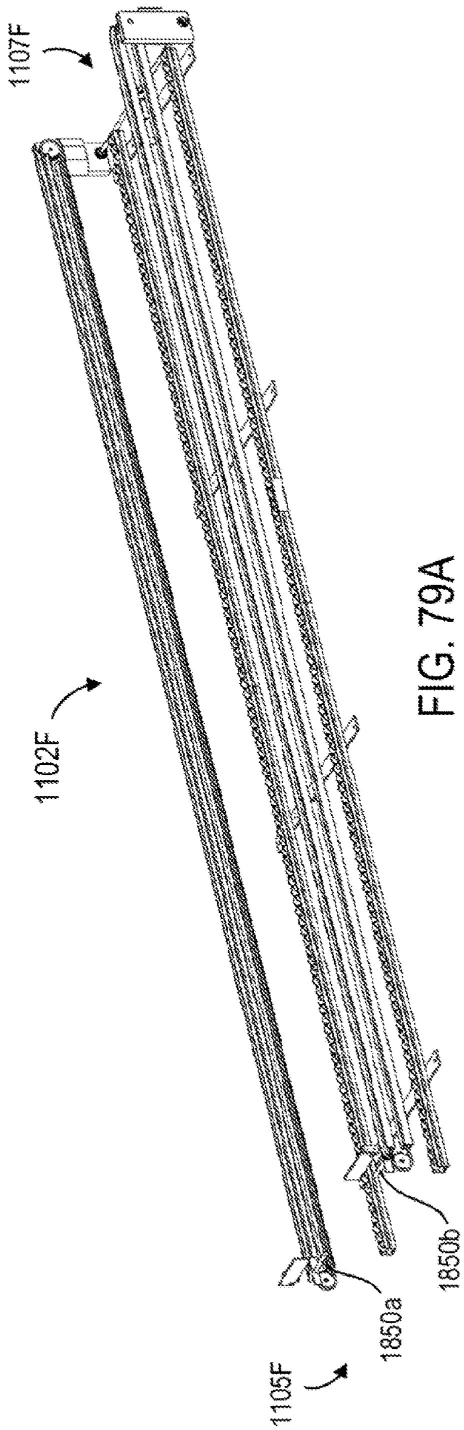


FIG. 79A

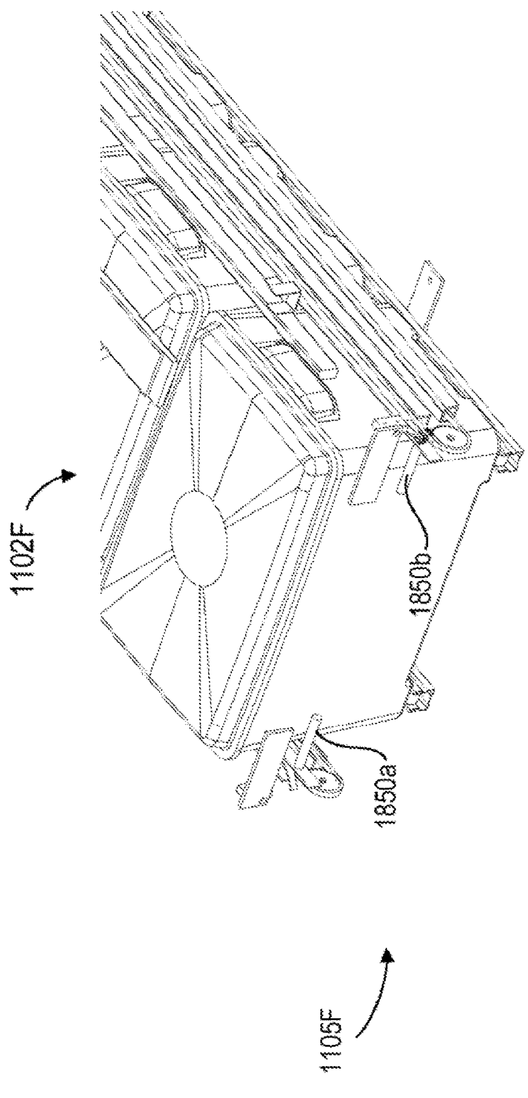


FIG. 79B

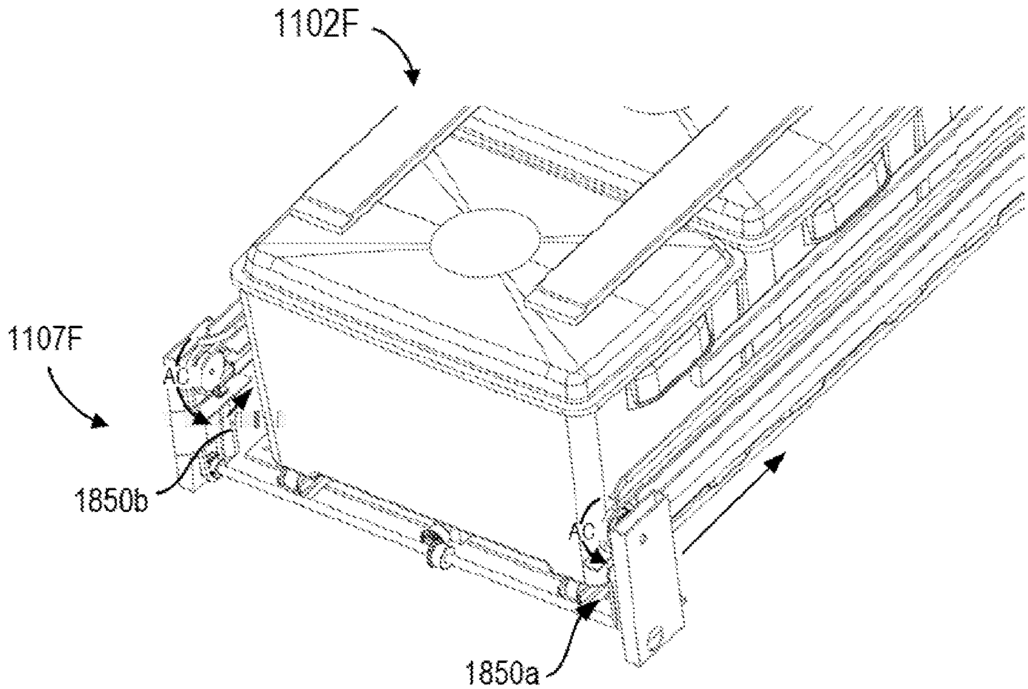


FIG. 80A

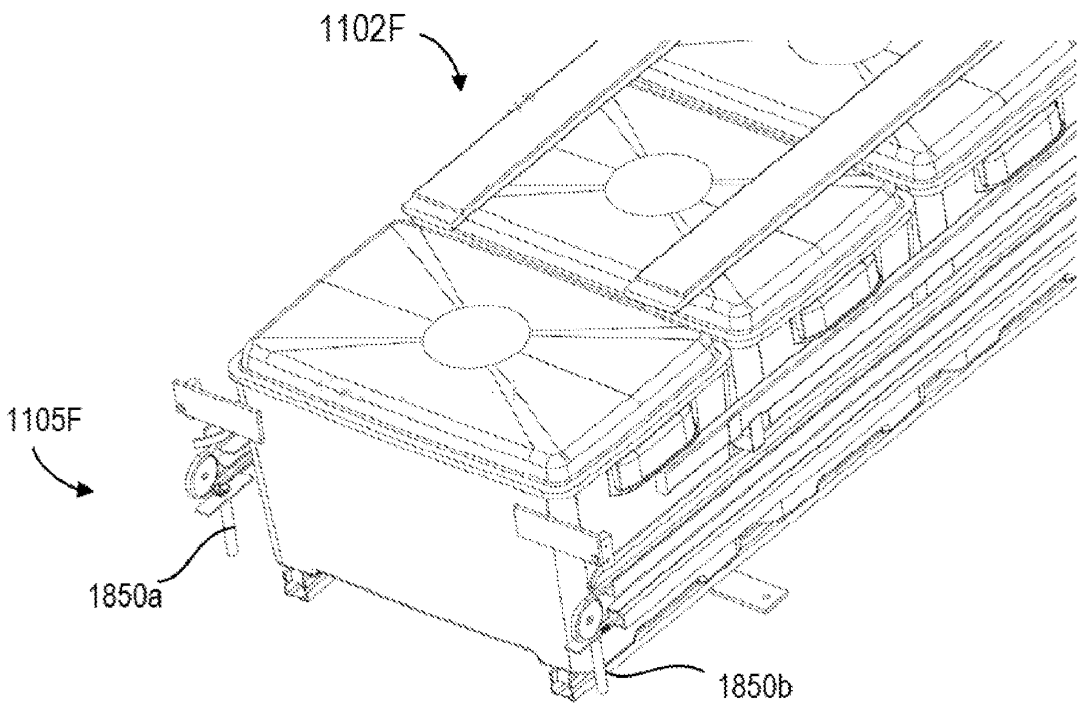


FIG. 80B

AUTONOMOUS MULTI-TIER RACKING AND RETRIEVAL SYSTEM FOR DELIVERY VEHICLE

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority under 35 U.S.C. § 119(e) to U.S. Provisional Patent Application Ser. No. 63/093,785 filed Oct. 19, 2020, titled "Autonomous Multi-Tier Racking and Retrieval System for Delivery Vehicle," and U.S. Provisional Patent Application Ser. No. 63/191,012 filed May 20, 2021, titled "Autonomous Multi-Tier Racking and Retrieval System for Delivery Vehicle," the entirety of each of which applications is hereby incorporated by reference.

BACKGROUND

The present disclosure is directed to autonomous multi-tier racking and retrieval devices, systems, and methods for integration with an autonomous robotic laundry service.

Automating and outsourcing mundane, time-consuming household chores to robotic devices is increasingly common. Time saving home robots include, for example, floor vacuuming and floor washing robots. Outsourcing responsibilities include, for example, engaging grocery shopping and delivery services, and manually operated and human-operator dependent laundry washing and dry-cleaning pick up and return services.

Many homes are appointed with a dedicated washer and dryer for family use. Domestic washers and dryers are increasingly sophisticated and include IoT connectivity features and push notifications for alerting users about cycle progress and energy and resource usage. These technologically advanced machines, however, require human interaction and cannot eliminate the time required for processing loads of laundry in the home. Although more modern, "high efficiency" machines are equipped with sensors for metering water usage and dryer temperatures, the efficiency gains are capped by the constraints of sequentially processing single loads of laundry. Grey water is output to the city water and sewer system for mitigation with each load of laundry processed. Energy is consumed with each load of laundry washed and dried.

Households can outsource laundry chores to laundromat facilities for a fee in exchange for time. Laundromats offering residential mixed load laundering services, however, require human interaction for intake and sorting of dirty laundry, transferring loads from washer to dryer, and then manually folding clean laundry. These are costly processes as measured in time, energy consumption, water consumption, and wastewater output, and they rely on human intervention to keep the process running at every transition and throughout several process steps. This invites delays at every stage. Because these processes are human-dependent and inefficient, the costs are passed along to customers outsourcing their laundry for cleaning. Human-reliant laundering services also require that employees touch the belongings of the customer, potentially exposing the employee to contaminants in the dirty laundry and potentially exposing the clean laundry to transferable pathogens, dust, hair, and other debris emanating from a laundromat employee. In addition to potentially introducing undesirable contact contamination from the employees processing the loads of laundry, a privacy barrier is breached. Outsourcing household laundry to a laundromat involves employees interacting with customers' personal belongings including bodily worn garments.

Industrial laundry services exist for handling uniform business-related items, such as hospital bed sheets, medical scrubs, and hotel towels. Such industrial machines are tailor-made to accept one type of laundry item of one size or style. For example, unique folding machines exist to accept a dedicated one of washed flat sheets, fitted sheets, hotel towels, and hotel bathrobes. These machines require human operators to load the washed article into its dedicated machine, which is sized and designed to fold that one type and size of article. This type of process line relies on a human operator for properly aligning and loading the clean article into the machine, which could introduce bodily contaminants, bacteria, and viral matter into the clean articles. Like laundromat services, these industrial services rely on human intervention and potentially introduce bio-contaminants into clean loads of laundry. Because these services are only profitable by processing large volumes of like items, these industrial processors are generally subscription-based services for large clients like hotels and hospitals producing standard-size, repeat laundry articles and are not available to consumers at an individual household level. Additionally, these services are configured to combine laundry from more than one source and are not configured to isolate and process separate loads for individual households.

Returning personal belongings from a subscribed service facility requires care so that personal items, such as a customer's clothing, are not lost or damaged. Returning such daily worn articles to customers in a timely, efficient manner is a high priority for maintaining customer satisfaction. Because loads of household laundry can be heavy and copious, pick up and delivery systems must attend to the challenges associated with lifting, racking, and unloading variable numbers of containers and container weights for each customer.

Autonomous robotic devices and systems are provided to process and handle loads of household laundry and efficiently return clean loads of household laundry to one or more customers. Such devices eliminate direct human contact with deformable laundry articles and minimize physical burdens associated with delivery services. As such, the devices and systems are designed to be efficient and reliable for replacing the common, human-dependent chores of laundry processing, and loading and unloading delivery vehicles.

SUMMARY

In one example, an autonomous racking system for use with a mobile delivery vehicle, includes an array of flow racks, an elevator abutting the front end (e.g., loading/unloading access end) of the array of flow racks, and a controller in operable communication with one or more motor drivers and memory stores. The array of flow racks includes a plurality of rows and a plurality of columns, each one of the flow racks of the array of flow racks configured to receive thereon a plurality of containers each associated with a single household. The array of flow racks includes a plurality of unloading pushers. Each one of the plurality of unloading pushers is disposed at a back end of one or more of the plurality of containers disposed on each of the flow racks the array and being configured to push each one of the plurality of containers past a front end of the array of flow racks. A plurality of unloading pusher drives are in operable communication with one of the plurality of unloading push-

ers for moving the corresponding one of the unloading pushers toward the front end of the array of flow racks. The elevator is configured to receive one or more containers from at least one or more of the plurality of flow racks and a vehicle side access portal, and deliver one or more containers to one or more of the plurality of flow racks. The elevator includes a movable carriage extending across the plurality of columns. The movable carriage is in operable communication with an elevator drive motor configured to move the carriage up and down to align a carriage support surface with at least of one of the plurality of rows and a lower edge of the vehicle side access portal disposed in a range of between about 0.25 to 2.25 meters from a ground upon which the delivery vehicle is disposed. The elevator includes one or more elevator position sensors configured to detect a vertical location of the movable carriage and output a position signal, a plurality of loading pushers, each one of which is aligned with one of the plurality of columns and configured to push a container off of the movable carriage and onto one of the aligned plurality of columns, and a plurality of loading pusher drives. Each one of the loading pusher drives is in operable communication with one of the plurality of loading pushers for moving the corresponding one of the loading pushers toward the front end of the array of flow racks. The controller is in operable communication with plurality of unloading pusher drives, the plurality of loading pusher drives, the drive motor of the movable carriage, and the one or more elevator position sensors. The controller is configured to instruct the drive motor to move the movable carriage to align the carriage support surface with one of the plurality of rows, receive the position signal, and determine whether the carriage support surface is aligned with the one of the plurality of rows.

Implementations of the system may include one or more of the following features.

In examples, the controller is further configured to instruct a drive of the one of the plurality of unloading pushers associated with the aligned one of the plurality of rows and one of the plurality of columns to retract by a distance equal to a depth of a container, and instruct a drive of an opposing one of the one of the plurality of loading pushers associated with the one of the plurality of columns to advance the one of the plurality of loading pushers to the front end of the array.

In examples, the controller is further configured to instruct a drive of the one of the plurality of unloading pushers associated with the aligned one of the plurality of rows and one of the plurality of columns to advance by a distance equal to a depth of a container.

In examples, the flow racks include a movable support for receiving one or more of the plurality of containers thereon. In implementations, the movable support comprises a conveyor configured to rotate toward the front end of the array. The conveyor can be motor driven and configured to operate simultaneously with the unloading pusher drive motor. Alternatively, the conveyor can be configured to rotate upon application of force from an associated one of the plurality of pushers to one or more of the plurality of containers disposed on the conveyor. In implementations, the movable support comprises a plurality of rollers disposed continuously along the length of each one of the array of flow racks, the plurality of rollers being configured to roll one or more of the plurality of containers disposed thereon toward the front end. The plurality of rollers rotate freely under application of a push force. Additionally or alternatively, the plurality of rollers can be interconnected to rotate simultaneously. In implementations, the plurality of rollers rotate under an application of pushing force from an associated one of the plurality of unloading pushers.

In examples, the plurality of rows comprises 3 rows and the plurality of columns comprises 3 columns.

In examples, the array has a length extending substantially parallel to a length of a transport volume of the delivery vehicle and a width extending substantially perpendicular to the length of the transport volume and substantially parallel to one or more vehicle wheel axles. The movable carriage has a longitudinal axis substantially perpendicular to the length of the transport volume and substantially parallel to the one or more vehicle wheel axles. In implementations, each flow rack of the array of flow racks is interlinked by at least one shared structural beam along the length of the array with at least one other adjacent flow rack of the array of flow racks.

In examples, each flow rack of the array of flow racks further includes a movable stop gate disposed at the front end and configured to restrain one or more racked containers. In examples, the system further includes a stop gate motor in operable communication with the controller, the stop gate motor being configured to retract the movable stop gate upon the controller instructing a corresponding one of the plurality of unloading pusher drives to move the associated pusher toward the front end. In implementations, the stop gate motor includes at least one of a servo motor and a linear motor.

In examples, each one of the plurality of unloading pushers comprises a contact face configured to engage a back wall of a container disposed at the back end of the one or more of the plurality of containers disposed on each of the flow racks the array. The contact face includes a contact material that is at least one of durable, damping, and non-marking. The contact face is configured to enter the elevator upon pushing the container disposed at the back end of a flow rack on the elevator.

In examples, each one of the plurality of unloading pusher drives includes a motor. Each one of the motors includes an operably linked encoder in communication with the controller and configured to output a signal indicative of pusher position between the front end and the back end.

In examples, the system further includes at least one rail disposed at a top of each flow rack of the array of flow racks. The at least one rail is configured to receive thereon in slidable engagement an associated one of the plurality of unloading pushers. In implementations, the at least one rail is configured to extend into the elevator.

In examples, a connector extends between each one of the plurality of pushers and a corresponding one of the plurality of unloading pusher drives. The connector can include a roller chain.

In examples, each one of the plurality of flow racks of the array of flow racks has a length extending parallel to a length of a transport volume of the delivery vehicle, and each one of the flow racks comprises a plurality of container positions along the length each configured to receive one of the plurality of containers. In implementations, the plurality of container positions comprises a range of between about 5-15 positions. In implementations, each one of the plurality of containers weighs between about 5 to 50 lbs. Each one of the plurality of containers weighs about 30 lbs. A collective weight of a plurality of containers disposed on the array of flow racks is in a range of between about 50 to 100 percent of the weight of a structure defining the array of flow racks. In such implementations, when the array of flow racks is empty of containers, the weight delta in the transport volume has no significant impact on performance of the vehicle

1000. In examples, each one of the plurality of containers comprises outer envelope dimensions of 12 inches by 22 inches by 14 inches.

In examples, each one of the plurality of containers comprises a matching bottom surface length and width so that they occupy identical surface areas on a flow rack. Additionally or alternatively, one or more of the plurality of containers includes one common dimension across the width of a flow rack and one or more variable dimensions comprising at least one of a height and a length parallel to the length LF of the array of flow racks.

In examples, each one of the plurality of containers is associated with a single customer. The array of flow racks is configured to receive one or more containers associated with one or more of a plurality of customers. Each one of the plurality of customers is associated with a physical location along a delivery and pickup route transited by the delivery vehicle. In implementations, the controller is further configured to record in a memory in wired or wireless communication with the controller each location in the array of flow racks of one or more containers associated with each one of the plurality of customers. The controller can be further configured to record in the memory which one or more containers have been unloaded from the array of flow racks along the route transited by the delivery vehicle. In examples, a delivery route transited by the delivery vehicle is predetermined based on an order in which the order in which each of the one or more containers associated with each one of the plurality of customers is received into the array of flow racks. Additionally or alternatively, in implementations, each of the containers comprises an identification marker for associating with one of the plurality of customers. The identification marker can include at least one of a machine-readable serial number, a machine-readable barcode, a machine-readable QR code, an RFID code, and a NFC tag. The system further includes one or more sensors disposed on at least one of the array, the elevator, and the vehicle side access portal, the one or more sensors being configured to detect the identification marker and output a signal to the controller indicative of the identification marker associated with a customer.

In examples, each container of the plurality of containers is rigid and reusable.

In examples, each container has an ingress protection rating of at least one of IP56, IP57, IP58, IP66, IP67, and IP68 in accordance with Ingress Protection Code, IEC standard 60529.

In examples, each container of the plurality of containers has two or more tapered sidewalls so that the surface area at the container top is larger than the surface area at the container bottom. In examples, the system further includes angled guides disposed on each flow rack of the array of flow racks that match the tapered sidewalls to hold each container upright.

In examples, the system further includes one or more sensors for detecting at least one of the loading and unloading of one or more of the plurality of containers on to at least one of the elevator and the array of flow racks. The one or more sensors can include at least one of an IR break beam sensor, an encoder, a limit switch, and a Hall-effect sensor. The one or more sensors can be disposed at least one of at the vehicle side access portal, at the front of each flow rack in the array of flow racks, and at each container dwell position along a length of each flow rack in the array of flow racks.

In examples, the elevator further includes a plurality of bidirectionally driven transfer wheels disposed at a transfer level and configured to move one or more containers across a width of the vehicle in a travel direction comprising at least one of travel from the elevator to the vehicle side access portal and travel from the vehicle side access portal onto an elevator position aligned with one of the plurality of columns. In examples, the carriage support surface includes a plurality of flow wheels configured to rotate in a direction parallel to a length of the transport volume of the delivery vehicle. The plurality of bidirectionally driven transfer wheels are configured to occupy gaps between adjacent ones of the plurality of flow wheels and protrude above a top surface of the plurality of flow wheels when the movable carriage is lowered to a loading and unloading height. The loading and unloading height is beneath the bottom row of the plurality of rows of flow racks such that the bidirectionally driven transfer wheels are not engaged with the flow wheels when the carriage support surface is aligned with the bottom row of the array of flow racks. In examples, the elevator further includes a drive motor for rotating the plurality of bidirectional transfer wheels.

In examples, the elevator further includes one or more sensors for detecting a columnar location of the container traveling from side to side on the plurality of bidirectional transfer wheels. The one or more sensors can include at least one of an IR break beam sensor, an encoder, a limit switch, and a hall sensor.

In examples, the elevator further includes at least one of an encoder and limit switches in communication the elevator drive motor and configured to output a signal to the controller while moving up and down, the output signal being indicative of vertical location of the carriage support surface relative the plurality of rows of flow racks.

In examples, each one of the plurality of unloading pusher drives comprises a motor. In implementations each one of the motors includes an operably linked encoder in communication with the controller and configured to output a signal indicative of pusher position between the front end and the back end.

In examples, a flow wheel of the movable carriage adjacent an edge abutting the front end of the array is at least one of larger than and higher than the remainder of the plurality of flow wheels of the carriage support surface such that a container disposed on the carriage support surface cannot roll back onto the front end of the array. Additionally or alternatively, in implementations, the carriage support surface further comprises a detent configured to retain a container loaded on the carriage support surface from the array of flow racks.

In examples, the plurality of loading pusher drives are configured to move each one of the plurality of loading pushers independently. Additionally or alternatively, in implementations, the plurality of loading pusher drives are configured to move all of the plurality of loading pushers simultaneously.

In examples, each one of the plurality of loading pusher drives includes a motor. In implementations, each one of the motors includes an operably linked encoder in communication with the controller and configured to output a signal indicative of one of two pusher positions.

In examples, the array of flow racks is configured to be disposed within an enclosed transport volume of the delivery vehicle.

In examples, the mobile delivery vehicle is configured to deliver and retrieve the plurality of containers from one or more customer destinations associated with a subscription delivery service. In implementations, each one of the retrieved plurality of containers is configured to contain dirty household laundry and each one of the delivered plurality of containers contains clean household laundry.

In examples, the controller is in wired or wireless communication with a communication network. The controller is configured to transmit and receive information to one or more remote devices regarding the receipt and disgorgement of the plurality of containers to and from the array of flow racks. The one or more remote devices can be a handheld Internet enabled device configured to receive input from a driver of the mobile delivery vehicle. Additionally or alternatively, the one or more remote devices can be a terminal or handheld device located at a laundering facility. In implementations, the one or more remote devices is at least one of a computer terminal and a handheld device located at a customer delivery and pickup location and configured to receive customer input.

In one example, a method of autonomously unloading a container from an array of racked containers disposed with in a truck transport volume includes receiving at a controller a request for retrieving a container including an identifier. The controller is in operable communication with a memory storing one or more identifiers and associated rack column and row positions within the array, a drive of a plurality of pushers each positioned at one of a plurality of rows, an elevator drive configured to raise and lower a receiving surface, and one or more transverse drives configured to move a container across the receiving surface in alignment with the rack columns. The method includes identifying from the memory a rack and row position of the requested container, and determining whether the identified rack and row position is adjacent the elevator receiving surface. The method includes instructing a stop gate to open upon determining the identified rack and row position is adjacent the elevator receiving surface, and instructing a drive of a pusher of the plurality of pushers that is associated with the row position to advance the requested container from the identified column and rack position onto the receiving surface of the elevator. The method includes determining whether the identified column is adjacent an orifice of a truck transport volume, instructing an elevator to lower the receiving surface to alignment with the orifice upon determining the identified column is adjacent the orifice, and instructing the one or more transverse drives to advance the container through the orifice.

Implementations of the method may include one or more of the following features.

In examples, the method includes closing the stop gate once the requested container is received onto the receiving surface of the elevator. In examples, the controller is configured to receive one or more signals from a presence sensor disposed at least one of on and adjacent the receiving surface for detecting a presence of a container on the receiving surface. The presence sensor can be configured to output a signal to the controller via a communication network. The communication network can be at least of wired and wireless.

In examples, the method includes storing a datum in the memory indicative of the requested container being delivered to an associated household. The controller further can update in the memory an updated row and column position of one or more other containers in the row.

In examples, the method includes determining whether delivery is complete and iterating at identifying column and row position of a next container.

In examples, if the controller determines the requested container is not adjacent the receiving surface, the method further includes reshuffling one or more other containers within the array by identifying open spots in the array and pushing the one or more other containers off and onto the array via the elevator to occupy one or more rows including the identified open spots in the array. The method further includes identifying row and column positions of one or more open container positions within the array.

In examples, the receiving surface of the elevator is below a lowest support surface of the array during alignment with the orifice.

In examples, the identifier is at least one of a data marker stored in software and a detectable identifier configured to be detected communicated to the controller via output signal of a sensor disposed on the one or more racks of the array.

In one example, as system of interconnected vehicle racks for receiving, constraining, and disgorging a plurality of customer containers from front and back ends of a vehicle transport volume, includes a plurality of racks interconnected in a constrained array. Each rack includes a support surface configured to receive and transit a plurality of containers thereon between a back end of the rack and a front end of the rack, a movable pusher disposed at the back end of the rack, the movable pusher being configured to engage a back surface of a rear most container disposed on the surface and move bidirectionally between the back end and the front end, and at least one selectively deactivated stop gate disposed at a front of the rack for engaging a front surface of a front most container disposed on the surface, the stop gate configured to retain one or more containers on the support surface.

Implementations of the system may include one or more of the following features.

In examples, the movable pusher is further configured to drop away from the back end during unloading of one or more containers from the support surface out the back end of the rack.

In examples, the movable pusher is dropped away from the back end during unloading of one or more containers out the back end of the rack.

In examples, the at least one stop gate moves away from the front end and loses contact with the front most container when deactivated during retrieval of the front most container from the support surface.

In examples, the support surface includes a plurality of flow rollers. At least one flow roller of the plurality of flow rollers can be driven.

In examples, the support surface includes a driven conveyor.

In examples, the pusher is spring loaded and is driven at least one of manually or by a drive motor to transit wheels of the pusher along side rails of the rack.

In examples, the pusher includes a pull rope.

In examples, the pusher is manually operated and includes at least one of a crank, a chain, a belt, a rope, and a spring loaded connector configured to transit wheels of the pusher along channels extend between front and back ends of the rack.

In examples, the pusher includes a spring loaded hinge configured to lay the pusher flat of the back end.

In examples, the pusher includes at least one horizontally oriented bar configured to ride on a looped belt.

In examples, a container is configured to be loaded and unloaded out either the front or the back end of the rack without disrupting an order of one or more containers disposed on the support surface.

In examples, the pusher and the stop gate are configured to constrain one or more containers on the support surface and maintain an order of the one or more containers during loading, transport, and unloading out either of the front end or back end.

In examples, the system further includes a light to pick system configured to illuminate a light disposed on or adjacent to a rack containing a particular customer container for retrieving at a delivery destination.

In examples, the system further includes a controller in communication with the light to pick system for operating the light, the controller in communication with a memory storing ordered locations of one or more containers associated with a delivery destination along a delivery route.

In examples, the containers are at least one of rigid and a uniform size.

In examples, the system further includes at least one of a top rail configured to constrain a top surface of the containers disposed on the rack and a pair of side rails configured to be disposed adjacent the sides of the containers oriented perpendicular to the front and back ends of the rack.

In examples the plurality of racks are densely packed racks disposed in a dense array within the vehicle transport volume.

In examples, a controller is configured to identify an unloading rack at each delivery destination.

In examples, the system further includes one or more sensors disposed on the rack for detecting an ordered positions of one or more containers disposed on the support surface and a status of container positions as containers are loaded and unloaded from one or more racks, shifting the remaining containers thereon forward or backward on the rack without changing their relative order.

In examples, the system further includes at least one of a physical button disposed on the racks and a touch screen button on a user interface to communicate with a controller upon adding or removing a customer container from the rack.

In examples, the user interface is configured to receive an input indicative of a number of boxes added or removed from a rack, the rack location in an array of racks, and a customer identifier (e.g., at least of a name, address, unique customer identification number, etc.).

In examples, a plurality of rigid containers disposed on the support surface each include two or more uniform dimensions including at least a length and width defining a footprint area of the containers.

In examples, densely packed includes a state of maximized occupancy of the plurality of containers within the vehicle transport volume. Each densely packed rack in an array of racks can share one or more structural support members with at least three other racks such that the tiers of racks are interconnected without free space therebetween. In examples, the one or more of the structural support members is secured to one or more structural support beams or surfaces of the transport volume such that the array is secured to prevent sliding, rotation, leaning or other structural compromise with loading, unloading, and transport within a moving vehicle along a delivery and pick up route.

In examples, a plurality of containers disposed on the support surface are densely packed to include small (e.g., less than 5 cm) or no gaps between container dwell locations along the length of the rack.

In examples, the racks support surface is configured to receive thereon a range of between about 5-15 containers.

In examples, each one of the containers disposed on the support surface weighs between about 5 to 50 lbs.

In examples, each one of the plurality of containers disposed on the rack includes outer envelope dimensions of at or around 12 inches by 22 inches by 14 inches.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** depicts a schematic of an example autonomous robotic laundry process line comprising automated loading and unloading of transport vehicles.

FIG. **2** depicts a schematic example of a system for controlling an autonomous robotic process line.

FIG. **3** depicts a schematic of a plurality of autonomous robotic laundry process lines including a plurality of intakes and outputs and a plurality of washing and drying robots.

FIG. **4** depicts a schematic example of a system for controlling an autonomous robotic laundry process line.

FIG. **5** depicts a perspective view of an implementation of a mobile delivery vehicle.

FIG. **6** depicts a cut away view showing an implementation of a racking system of the mobile delivery vehicle of FIG. **5**.

FIG. **7** depicts a side view of the mobile delivery vehicle of FIG. **5**.

FIG. **8** depicts a side view of an implementation of an autonomous racking system for use with a mobile delivery vehicle.

FIG. **9**A depicts a front view of an example flow rack array of the autonomous racking system of FIG. **8**.

FIG. **9**B depicts a close-up partial view of the example flow rack array of FIG. **9**A with some structural elements removed and with stop gates shown.

FIG. **10** depicts a rear view of an example flow rack array of the autonomous racking system of FIG. **8**.

FIG. **11** depicts a front perspective view of a single flow rack of the autonomous racking system of FIG. **8**.

FIG. **12** depicts a rear perspective view of a single flow rack of the autonomous racking system of FIG. **8**.

FIG. **13**A depicts side view of a fully loaded single flow rack of the autonomous racking system of FIG. **8**.

FIG. **13**B depicts a side view of the flow rack of **13**A in a partially unloaded state.

FIG. **14**A depicts a side view of a pusher portion of the autonomous racking system of FIG. **8**.

FIG. **14**B depicts a perspective rear view of a pusher portion of the autonomous racking system of FIG. **8**.

FIG. **15** depicts a schematic side view of a container being unloaded from a flow rack array onto an elevator.

FIG. **16** depicts a schematic side view of the container if FIG. **15** being fully moved onto the elevator with the unloading pushers positioned within the elevator.

FIG. **17** depicts the elevator portion of FIG. **16**.

FIG. **18** depicts a schematic side view of a container being unloaded from a flow rack array onto an elevator with the unloading pushers being withdraw into the rack array.

FIG. **19** depicts the elevator portion of FIG. **18**.

FIG. **20** depicts a schematic side view of the elevator of FIG. **19** being lowered to an unloading transfer height.

FIG. **21**A depicts an example unloading stage of an elevator portion of the autonomous racking system of FIG. **8** receiving an unloaded container from the rack array onto a middle position of the elevator.

FIG. **21**B depicts the elevator of FIG. **21**A with the container moved to a side position of the elevator for unloading.

FIG. **22** depicts a front view of FIG. **21**B showing the rollers of the elevator being lowered into gaps between side-to-side transfer wheels.

FIG. 23 depicts a front view of the elevator raised above the transfer wheels.

FIG. 24A depicts a side view of FIG. 23.

FIG. 24B depicts a side view of FIG. 22.

FIG. 25 depicts a perspective view of FIG. 23 showing the elevator raised above transfer wheels.

FIG. 26 depicts the perspective view of FIG. 25 with the elevator lowered to a discharge height such that the transfer wheels extend above the elevator rollers.

FIG. 27 is a magnified view of a container supported by the transfer rollers.

FIG. 28A depicts a side view of a transfer roller of the elevator of FIG. 27.

FIG. 28B depicts a perspective view of a pair of transfer rollers of FIG. 28A driven by a motor.

FIG. 29A depicts a rear view of an example elevator and container thereon.

FIG. 29B depicts a perspective rear view of a pusher portion of the autonomous elevator of FIG. 29A.

FIG. 30 depicts an example method of unloading a container from a rack array onto an elevator for discharge from a delivery vehicle.

FIG. 31 depicts a schematic example of a travel route for a mobile delivery vehicle.

FIG. 32 depicts an alternate example of an autonomous racking system of the mobile delivery vehicle.

FIG. 33 depicts an alternate example of an autonomous racking system of the mobile delivery vehicle.

FIG. 34 depicts an alternate example of an autonomous racking system of the mobile delivery vehicle.

FIG. 35 depicts an example UI screen of a handheld device in communication with a controller of an autonomous racking system of a mobile delivery vehicle.

FIG. 36 depicts a schematic system diagram of an autonomous racking and elevator system.

FIG. 37 depicts a rear perspective view of an array of spring-loaded flow racks in a mobile delivery vehicle and loaded with containers.

FIG. 38 depicts a front, cutaway perspective view of the mobile delivery vehicle of FIG. 37.

FIG. 39 depicts a front perspective view of a manually operated spring-loaded implementation of a single flow rack of an autonomous racking system loaded with a plurality of containers loaded.

FIG. 40 depicts a top view of the single flow rack of FIG. 39 without containers loaded.

FIG. 41 depicts the front perspective view of the single flow rack of FIG. 39 without containers loaded and with a flow gate portion of the single flow rack in a closed state.

FIG. 42A depicts an end view of the single flow rack of FIG. 39 disposed in a mobile delivery vehicle without containers loaded.

FIG. 42B depicts an augmented close-up view of the single flow rack and pusher of FIG. 39.

FIG. 43A depicts a flow gate of FIG. 39 in a closed, container retention state.

FIG. 43B depicts the flow gate of FIG. 43A in an open, container release state.

FIG. 44A depicts an end view of the flow gate of FIG. 43A in a closed state.

FIG. 44B depicts an implementation of one or more return springs disposed proximate a lever of the flow gate of FIG. 44A.

FIG. 44C depicts an implementation of a return spring disposed proximate a restraining arm of the flow gate of FIG. 44A.

FIG. 45 depicts the rear perspective view of FIG. 37 with container pushers in a folded down state for container unloading from the rear of the mobile delivery vehicle into a laundry facility.

FIG. 46A depicts a rear perspective view of the mobile delivery vehicle of FIG. 43 positioned for loading and/or unloading containers into or out of the array.

FIG. 46B depicts a side view of the mobile delivery vehicle of FIG. 43 positioned for loading and/or unloading containers into or out of the array.

FIG. 47 depicts a perspective end view of the single removable flow rack.

FIG. 48A depicts the removable flow rack of FIG. 47 removed from a mobile delivery vehicle and loaded on a wheeled cart.

FIG. 48B depicts the removable flow rack of FIG. 47 disposed within a mobile delivery vehicle.

FIG. 49 depicts a perspective view of an implementation of a pallet for holding an array of shipping containers for use in a mobile delivery vehicle.

FIG. 50 depicts an end view of the pallet of FIG. 49.

FIG. 51 depicts a rear perspective view of a mobile delivery vehicle loaded with the pallet of FIG. 49.

FIG. 52 depicts end view of FIG. 51.

FIG. 53A depicts a partial cut away view of the loaded mobile delivery vehicle of FIG. 51.

FIG. 53B depicts a front perspective view of the mobile delivery vehicle of 53A with a driver's cab removed.

FIG. 54 depicts an example UI screen of a handheld device in communication with a controller of an autonomous racking system of a mobile delivery vehicle.

FIG. 55 depicts a manually operated pusher comprising a hand turned handle at the front of a flow rack.

FIG. 56 depicts the flow rack of FIG. 55 with cover plates removed.

FIG. 57A depicts a close up back end of the flow rack of FIG. 56.

FIG. 57B depicts a close up of the hand turned handle of FIGS. 55 and 56 with a top plate removed to expose a gearing and sprocket mechanism.

FIG. 58A depicts a front end of a spring eject rack with stop gates down for retaining containers on the rack.

FIG. 58B depicts a front end of a spring eject rack of FIG. 58A with stop gates up for removing a container from the rack.

FIG. 59 depicts a side rail and spring loaded gate of the rack of FIGS. 58A-B.

FIG. 60A depicts a front end of the side rail of FIG. 59.

FIG. 60B a back end of the side rail of FIG. 59.

FIG. 61A depicts a side perspective view of an example pusher comprising a spring loaded pin drop down mechanism.

FIG. 61B depicts the spring loaded pin drop down mechanism of FIG. 61A.

FIG. 62A depicts a bottom perspective view of the example pusher of FIG. 61A.

FIG. 62B depicts a side view of the example pusher of FIG. 62A with the spring loaded pin in a first compression stage.

FIG. 63A depicts a side view of the example pusher of FIG. 62B with the spring loaded pin in a second compression stage.

FIG. 63B depicts the spring loaded pin drop down mechanism of FIG. 63A.

FIG. 64A depicts a side perspective view of the pusher of FIGS. 61A-63B in a lay flat state.

FIG. **64**B depicts the spring loaded pin drop down mechanism of FIG. **64**A in a fully compressed state.

FIG. **65**A depicts a rear perspective view of an example pusher comprising a spring loaded plate drop down mechanism.

FIG. **65**B depicts rear bottom perspective view of the example pusher of FIG. **65**A with a cover removed to show the spring loaded plate.

FIG. **66**A depicts a side view of the pusher of FIG. **65**B with the plate in a first compression position.

FIG. **66**B depicts a bottom perspective view of the pusher of FIG. **66**A.

FIG. **67**A depicts a side view of the pusher of FIG. **66**A with the plate in a second compression position.

FIG. **67**B depicts a side view of the pusher of FIG. **67**A with the plate in a fully compressed position and the pusher in a lay flat state.

FIG. **68** depicts a perspective view of an example racking array of containers manually advanced by pull ropes from a transport volume of a vehicle.

FIG. **69** depicts a front end view of the example racking array of FIG. **68** comprising a take up reel for each rope of each rack.

FIG. **70** depicts a top view of a rack of the array of FIGS. **68** and **69** showing a pull rope extending from a front end to a pusher at the back end of the rack.

FIG. **71**A depicts a close up of the front end of the rack of FIG. **70**.

FIG. **71**B depicts a close up of the back end of the rack of FIG. **70**.

FIG. **72**A depicts a perspective view of a conveyor rack supporting a plurality of containers for use in a transport volume racking array.

FIG. **72**B depicts a front end view of the conveyor rack of FIG. **72**A.

FIG. **73**A depicts a side view of the conveyor rack of FIGS. **72**A-B with a side plate removed to show the conveyor drive and tensioning rollers.

FIG. **73**B depicts a front perspective view of FIG. **73**A.

FIG. **74**A depicts a front perspective view of a side chain driven flow rack without containers disposed thereon.

FIG. **74**B depicts a rear perspective view of a side chain driven flow rack of FIG. **74**A.

FIG. **75**A depicts a front perspective view of the side chain driven flow rack of FIG. **74**A with containers disposed thereon.

FIG. **75**B depicts a rear perspective view of the loaded flow rack of FIG. **75**A.

FIG. **76**A depicts a front perspective view of a side chain driven flow rack with bidirectional push tabs without containers disposed thereon and with various tab positions A-D labeled at top and bottom positions of only one side of the rack for clarity.

FIG. **76**B depicts a close up of the front end of the rack of FIG. **76**A.

FIG. **77** depicts a schematic flow of a pair of bidirectional pusher tabs transiting a length LF of a flow rack in both directions, from back to front and front to back.

FIG. **78**A depicts a front perspective view of the flow rack of FIG. **76**A with boxes loaded thereon and a pair of bidirectional pusher tabs disposed at a rear end of the rack.

FIG. **78**B depicts a close up view of the rear end of the rack of FIG. **78**A.

FIG. **79**A depicts a front perspective view of the flow rack of FIG. **76**A with a pair of bidirectional pusher tabs disposed at a front end of the rack in a horizontal position.

FIG. **79**B depicts a close up view of the front end of the rack of FIG. **79**A with a container loaded thereon.

FIG. **80**A depicts a close up view of the rear end of the rack of FIG. **79**A with containers loaded thereon and the pair of bidirectional pusher tabs in dropped down lower position C.

FIG. **80**B depicts a close up view of the front end of the rack of FIG. **79**A with containers loaded thereon and the pair of bidirectional pusher tabs in dropped down lower position D.

DETAILED DESCRIPTION

This disclosure relates to autonomous robotic devices, systems, and methods for collecting, processing, and returning residential loads of laundry. An autonomous racking system for use with a mobile delivery vehicle is configured to transport a plurality of containers of laundry to and from a laundry processing facility. The facility comprises one or more autonomous process lines comprising a plurality of autonomous robotic devices configured to work in concert to process one or more dirty loads of household laundry from a collection of dirty, non-uniform articles to individually separated, cleaned, folded, and packed laundry articles. The one or more autonomous process lines include an autonomous intake system and autonomous storage and distribution system for interacting with the autonomous racking system of one or more of a plurality of mobile delivery vehicles in a fleet. The plurality of autonomous robotic devices and the autonomous racking system operate without human intervention to receive, launder, and redistribute a plurality of customers' loads of household laundry efficiently and effectively. In implementations, a mobile delivery vehicle comprises at least one of an electric vehicle and a hybrid electric vehicle for minimizing energy consumption and overall environmental impact. In implementations, the at least one of electric vehicles and hybrid electric vehicles employ regenerative breaking to charge batteries. Additionally or alternatively, rooftop solar powers on the at least one of electric vehicles and hybrid electric vehicles in a fleet provide clean energy to batteries of operating drive motors of the vehicles and automated racking, loading, and discharging systems contained therein. The efficient loading, routing, and unloading of containers enabled by the present invention further reduces environmental impact associated with operating delivery vehicles.

In implementations, the autonomous racking system includes a plurality of densely packed shelves and an automated elevator racking and retrieval device in wired or wireless communication with a controller configured to direct intelligent and autonomous racking and retrieval of one or more particularly identified customer containers matching a household location along a vehicle travel route. The autonomous racking system is designed for maximizing packing density to reduce delivery costs associated with driver labor and vehicle operation and maintenance. Maximizing packing density reduces the number of delivery vehicles and drivers required to retrieve and redistribute loads of laundry. The racking system is automated to enable speedy access to accurately identified containers, and faster delivery reduces driver hours and lower costs to customers subscribed to a laundry service. The autonomous intake, storage and distribution racking systems eliminate drivers exerting themselves through physical interaction with heavy containers and prevent lifting from ergonomically disadvantageous positions.

In other implementations, the autonomous racking system includes a plurality of densely packed flow racks or conveyors comprising guided rails for constraining the plurality of densely packed containers during loading, unloading, and transport. The autonomous racking system is designed for maximizing packing density to reduce delivery costs associated with driver labor and vehicle operation and maintenance. Maximizing packing density reduces the number of delivery vehicles and drivers required to retrieve and redistribute loads of laundry. More consolidated delivery reduces driver hours and lower costs to customers subscribed to a laundry service. As will be described subsequently with regard to implementations, the racking system eliminates drivers exerting themselves through extraneous physical interaction with heavy containers and prevent lifting from ergonomically disadvantageous positions.

In yet other implementations, the autonomous racking system includes a plurality of densely packed pallets containing an array of containers. The pallets maximize packing density and facilitate loading and unloading a mobile delivery vehicle as will be described subsequently with regard to implementations.

In implementations, as shown subsequently in Table 1, the autonomous racking system includes manual and automated flow rack systems as will be described subsequently. A manual system comprises at least one of a manual chain-driven flow rack, a manual spring driven flow rack, and a manual rope pull system for advancing one or more boxes out of a flow rack. An automated flow rack comprises at least one of a motorized chain-driven flow rack, a motorized spring-driven flow rack, a motorized belt conveyor, and motorized, side chain driven pushers. In implementations, an automated flow rack comprises at least one of a motorized flow rack driven comprising a belt drive, such as a time belt or round belt drive, particularly useful in vehicles with shorter transport volumes. The automated elevator racking and retrieval device can be implemented with any implementation of a motorized flow rack described herein with regard to implementations. Additionally, all pusher drop and spring eject mechanisms described herein are applicable for combined use with flow rack implementations described herein with the exception of a motorized belt conveyor implementation and a motorized side chain driven pushers.

All implementations herein are designed to address one or more of the following challenges associated with racking, transport, and unloading within and to/from a confined truck or van transport volume: Implementations of systems and devices presented herein are required to restrain one or more load customer boxes throughout physical disturbances associated with transport, starting, and stopping which maintaining one or more racked boxes in secured alignment and order. Implementations of systems and devices presented herein are required to move one or more customer boxes forward and backward along a flow rack on varying slopes, both positive and negative, associated with parking on residential city streets. Implementations of systems and devices presented herein not employing an automated elevator racking and retrieval device are required to accommodate removing individual customer boxes one at a time from one end (e.g., front of the rack to an internal transport volume) and accommodating individual or bulk removal of a plurality of customer boxes from the other end (e.g., back of the transport volume, out a rear door). All implementations of systems and devices presented herein are designed to function in a space-constrained environment associated with transport vehicles. All implementations of systems and devices presented herein are designed to function within weight limit restrictions associated with transport vehicles and account for weight shifting during loading and unloading and subsequent distribution of forces on transport vehicle axles. All implementations of manually operated systems and devices presented herein are designed to function under forces reasonably generated by a delivery person. All implementations of racking systems presented herein are designed for uninterrupted constraint of one or more containers remaining on a rack during removal of another container from the rack. Implementations of racks of the racking systems described herein are designed to be continually constraining of one or more containers disposed thereon. The continual constraint persists even during movement of the containers along a length of a rack such that a delivery person need not expend time and energy resecuring non-delivered containers at each delivery location. Additionally advantages will be presented throughout with regard to implementations.

As shown in FIG. **1**, in implementations of the system, a process line **100***a* in a facility (e.g., a laundry cleaning facility) comprises a plurality of autonomous robots configured to operate in series without human intervention to process and transport dirty laundry through the cleaning process, folding and repackaging the clean laundry for return to a household. Dirty laundry is collected from customers using one or more mobile delivery vehicles **1000***a*, such as trucks or vans having loading racks (e.g., a plurality of flow racks) or pallets therein. In implementations, the mobile delivery vehicles **1000***a* are configured to contain flow racks and an intelligent, automated racking system therein. A customer places laundry in one or more containers received into the vehicle **1000***a*. When the vehicle **1000***a* arrives at the facility, the one or more containers of dirty laundry are automatically unloaded from the vehicle **1000***a* by an automated intake robot **2000** and provided to at least one separating and sorting robot **3000** and one or more intermediate queues configured to feed the at least one separating and sorting robot **3000**. Such intermediate queues can comprise at least one of a first-in-first-out (FIFO) queue, an intelligent buffer rack, and an automated storage and retrieval system (ASRS) etc. In one implementation, the process line **100***a* comprises an automated intake robot **2000** for receiving a load of dirty household laundry comprising a plurality of deformable laundry articles from one or more delivery vehicles **1000***a*. The automated intake robot **2000** can comprise at least one of one or more automated rails, one or more rack surfaces, and one or more conveyors. In implementations, the back and/or side of the vehicle **1000***a* opens to allow automated retrieval of one or more containers. In implementations, the automated intake robot **2000** is configured to log and track the one or more containers upon receipt. In implementations, as will be described subsequently, a unique identifier (e.g., an identification marker) associated with and disposed on or in each of the containers is configured to be scanned at least one of wirelessly and visually and a location and state is updated in a memory store in communication with one or more controllers of the automated robots **1000**-**9000**. While connected to a processing or distribution plant during unloading of the one or more containers, a vehicle **1000***a* may be simultaneously or sequentially re-fueled as needed by charging its internal batteries with electricity, swapping its batteries, and/or by supplying gasoline or another type of fuel.

The deformable laundry articles can be non-uniform in type, size, shape, color, and fabric. For example, the plurality of deformable laundry articles can include items commonly laundered in homes, such as sheets, towels, table cloths, and adult and children's garments, for example, tee shirts, pants, socks, undergarments, dresses, dress shirts, and blouses. The autonomous intake robot **2000** is configured to introduce the plurality of deformable laundry articles to a separating and sorting robot **3000** configured to separate out each one of the deformable laundry articles of the plurality of deformable laundry articles. In implementations, the separating and sorting robot **3000** is configured to sort each one of the separated deformable laundry articles into one or more related batches for washing. In implementations, the separating and sorting robot **3000** is configured to intelligently batch the separated each one of the deformable laundry articles according to a programmed sorting algorithm based, for example, on criteria including at least one of material color, material type, article size, customer washing preference, water temperature requirements, and load size (e.g., weight and/or physical volume). In implementations, the separating and sorting robot **3000** is configured to identify and record the number and types of garments in the load of laundry and provide this information to one or more robots of the process line **100***a*.

The separating and sorting robot **3000** outputs one or more intelligently sorted batches of deformable laundry articles to one or more washing and drying robots **4000** for laundering. The one or more washing and drying robots **4000** output the clean laundry articles to a clean laundry separating robot **5000**. Implementations of the clean laundry separating robot **5000** can be similar or identical to the separating and sorting robot **3000**. The clean laundry separating robot **5000** is configured to separate a load of clean laundry into individual deformable laundry articles for introduction into a repositioning robot **6000**. In implementations, the repositioning robot **6000** receives a single deformable laundry article and manipulates and repositions it for automated introduction into a folding robot **7000**, which automatically folds the laundry article for introduction to a packing robot **8000**. In implementations, the packing robot **8000** automatically and autonomously packs the clean load of laundry comprising the plurality of clean and folded deformable laundry articles in a shipping container for automated redistribution to the customer. In implementations, the shipping container is a reusable container. In implementations, the shipping container is a disposable container. In implementations, the shipping container is a non-deformable container with an ingress protection rating that includes an intrusion protection rating of 5 or 6 and a moisture protection rating of any and all of 1 through 6 in accordance with the Ingress Protection Code, IEC standard 60529. In reusable implementations, the shipping container can be washable.

Implementations of the process line **100***a* of household laundry cleaning robots can comprise one or more of each of the robots depicted in FIG. **1**. For example, as shown in FIG. **2**, each autonomous process line **100***b* can include a plurality, or cluster **4002**, of washing and drying robots **4000***a-n* clustered together with shared services (e.g., water, wash chemicals, heat, dirty clothes delivery assembly and clean clothes carry off assembly). In other implementations, as shown in FIG. **3**, the autonomous process line **100***c* includes a cluster **4002** of washing and drying robots **4000***a-n* shared by two or more sets of automated intake robots **2000***a-b* and dirty laundry separating and sorting robots **3000***a-b* and two or more sets of clean laundry separating robots **5000***a-b*, repositioning robots **6000***a-b*, folding robots **7000***a-b*, and packing robots **8000***a-b*. Additionally, two or more of the robots can be combined in a single module in alternate implementations. In implementations, one or more of the robots in the process line **100***a-c* are configured to communicate over wired connections or wireless communication protocols. For example, in implementations, one or more robots in the process line **100***a-c* can communicate with another one or more robots in the process line **100***a-c* over a wired BUS, LAN, WLAN, 4G, 5G, LTE, Ethernet, BLUETOOTH, or other IEEE 801.11 standard.

Referring to FIG. **4**, an example of a system **200** of operatively connected robots is shown. FIG. **4** depicts a schematic implementation of a portion of an autonomous robotic process line **100**, **100***a-c*. An automated intake robot **2000** is in operative communication with a mobile delivery vehicle **1000***a* configured to provide a plurality of containers of dirty laundry items from one or more customers (e.g., household) to the process line. The automated intake robot **2000** transits the plurality of containers to at least one of an intermediate queue and the dirty laundry separating and sorting robot **3000** configured to provide sorted and batched loads of dirty deformable laundry articles to the washing and drying robot **4000** for washing and drying. The washing and drying robot **4000** is in operative communication with a clean laundry separating robot **5000** and outputs a load of clean laundry for separation by the clean laundry separating robot **5000**, which delivers the clean laundry to one or more repositioning robots **6000**, folding robots **7000**, and packing robots **8000**. The one or more packing robots **8000** deliver one or more containers of clean, folded laundry to the automated storage and distribution robot **9000**.

Additionally or alternatively, the one or more packing robots **8000** can deliver the one or more containers of clean, folded laundry to an intermediate queue, like that of the intake robot **2000**, prior to delivery to the automated storage and distribution robot **9000**. The intermediate queue comprises at least one of a first-in-first-out (FIFO) queue, an intelligent buffer rack, and an automated storage and retrieval system (ASRS) etc. The containers in the queue or the buffer can be organized according to predetermined travel routes of one or more outgoing vehicles **1000***b*. In implementations, the containers of cleaned laundry that are to be delivered by the same vehicle **1000***b* are grouped together in the intermediate queue. In implementations, the vehicle **1000***a* delivering dirty laundry containers and the vehicle **1000***b* receiving cleaned laundry containers are the same vehicle. In other implementations, the incoming and outgoing vehicles **1000***a-b* are separate vehicles in a fleet of a plurality of vehicles.

The automated storage and distribution robot **9000** can comprise at least one of one or more automated rails, one or more rack surfaces, and one or more conveyors. In one example configuration, the back and/or side of a receiving vehicle **1000***b* opens to allow automated loading of one or more containers. In implementations, the automated storage and distribution robot **9000** is configured to log and track the one or more containers upon loading into the outgoing vehicle **1000***b*. In implementations, as will be described subsequently, a unique identification marker of each of the containers is configured to be scanned at least one of wirelessly and visually and a location and state is updated in a memory store in communication with one or more controllers of the vehicle **1000***a-b* and automated robots **2000-9000**.

Returning to FIG. **4**, in implementations, each delivery vehicle **1000***a-b* (e.g., vehicle automated racking system), and robot **2000**, **9000** includes a controller **1005***a-b*, **2005***a-b*, **3005***a-b* configured to operate the associated robot. For example, in implementations, the mobile delivery vehicle **1000***a-b* includes a controller **1005**. The controller **1005** includes a processor **1015** in communication with a memory **1010**, a network interface **1020**, and a sensor interface **1025**. The processor **1015** can be a single microprocessor, multiple microprocessors, a many-core processor, a microcontroller, and/or any other general purpose computing system that can be configured by software and/or firmware. In implementations, the memory **1010** contains any of a variety of software applications, data structures, files and/or databases. In one implementation, the controller **3005** includes dedicated hardware, such as single-board computers, application specific integrated circuits (ASICs), and field programmable gate arrays (FPGAs).

A network interface **1020** is configured to couple the controller **1005** to a network **230**. The network **230** may include both private networks, such as local area networks, and public networks, such as the Internet. It should be noted that, in some examples, the network **230** may include one or more intermediate devices involved in the routing of packets from one endpoint to another. In implementations, the network interface **1020** is coupled to the network **230** via a networking device, such as a bridge, router, or hub. In other implementations, the network **230** may involve only two endpoints that each have a network connection directly with the other. In implementations, the network interface **1020** supports a variety of standards and protocols, examples of which include USB (via, for example, a dongle to a computer), TCP/IP, Ethernet, Wireless Ethernet, BLUETOOTH, ZigBee, M-Bus, CAN-bus, IP, IPV6, UDP, DTN, HTTP, FTP, SNMP, CDMA, NMEA and GSM. To ensure data transfer is secure, in some examples, the controller **1005** can transmit data via the network interface **1020** using a variety of security measures including, for example, TLS, SSL or VPN. In implementations, the network interface **1020** includes both a physical interface configured for wireless communication and a physical interface configured for wired communication. According to various embodiments, the network interface **1020** enables communication between the controller **1005** of the mobile delivery vehicle **1000***a-b* and at least one of the plurality of robots **2000**, **3000**, **4000**, **5000**, **6000**, **7000**, **8000**, **9000** of the process line **100**, **100***a-c*.

Additionally or alternatively, the network interface **1020** is configured to facilitate the communication of information between the processor **1015** and one or more other devices or entities over the network **230**. For example, in implementations, the network interface **1020** is configured to communicate with a remote computing device such as a computing terminal **205**, database **235**, server **240**, smartphone **245**, and server farm **250**. In implementations, the network interface **3020** can include communications circuitry for at least one of receiving data from a database **235** and transmitting data to a remote server **240**, **250**. In some implementations, the network interface **3020** can communicate with a remote server over any of the wired protocols previously described, including a WI-FI communications link based on the IEEE 802.11 standard.

In some examples in accordance with FIG. **4**, the network **230** may include one or more communication networks through which the various autonomous robots and computing devices illustrated in FIG. **4** may send, receive, and/or exchange data. In various implementations, the network **230** may include a cellular communication network and/or a computer network. In some examples, the network **230** includes and supports wireless network and/or wired connections. For instance, in these examples, the network **230** may support one or more networking standards such as GSM, CMDA, USB, BLUETOOTH®, CAN, ZigBee®, Wireless Ethernet, Ethernet, and TCP/IP, among others. In implementations, the network **230** can implement broadband cellular technology (e.g., 2.5 G, 2.75 G, 3 G, 4 G, 5 G cellular standards) and/or Long-Term Evolution (LTE) technology or GSM/EDGE and UMTS/HSPA technologies for high-speed wireless communication.

Although the controller **1005** is described herein in particular, one or more of the plurality of robots **2000**, **3000**, **4000**, **5000**, **6000**, **7000**, **8000**, **9000** of the process line **100**, **100***a-c* includes similar components having similar functionality.

Turning now to FIG. **5**, in implementations, the delivery vehicle **1000***a-b* (collectively referred to herein as vehicle **1000**) is a truck or van configured to transport a plurality of boxes, or containers **1200***a-n*, of laundry between a plurality of customers and a laundry processing facility comprising a process line **100** of autonomously operating devices **2000**-**9000**. In implementations, an array of racks **1100** (e.g., flow racks or conveyors) is configured to be disposed within an enclosed transport volume **1035** of the delivery vehicle **1000**. In implementations, the transport volume **1035** has a length LT extending from a front end **1040** to a back end **1055** and a width WT extending between a left side **1045** and a right side **1050**. In implementations, the enclosed transport volume **1035** comprises a width in a range of between about 6 to 8.5 feet and a height TH in a range of between about 6 to 10 feet. In implementations, the transport volume **1035** is 8 feet wide and in a range of between about 8 to 9 feet tall. In implementations, the delivery vehicle **1000** is at least one of a delivery van, a walk in van, a class 3 box truck, a class 4 box truck, a class 5 box truck, and a class 6 box truck. In implementations, the vehicle **1000** is an electric vehicle. In implementations, the vehicle **1000** is a hybrid electric vehicle.

In implementations, the mobile delivery vehicle **1000** is configured to deliver and retrieve the plurality of containers **1200***a-n* from one or more customer destinations associated with a delivery service such as an ad-hoc or subscription delivery service. In implementations, each one of the retrieved plurality of containers **1200***a-n* is configured to contain dirty household laundry and each one of the delivered plurality of containers **1200***a-n* contains clean household laundry. The containers **1200***a-n* comprise a maximum retention volume and will be filled with one or more articles up to the maximum retention volume. A weight of one or more containers **1200***a-n* disposed in the array will vary depending on occupied volume therein. Therefore, the aggregate weight of the containers **1200***a-n* in an array can vary and the distribution of weight throughout the array can vary. Additionally, the distribution of weight throughout an array will vary throughout the loading and unloading process. As will be described subsequently with regard to implementations, an autonomous racking system adjusts positions of the containers **1200***a-n* in part to optimally position filled containers above vehicle axles during transport.

In examples, the controller **1005** of an autonomous racking system is collocated at the vehicle **1000** and is in at least one of wired or wireless communication with a communication network **230** as previously described with regard to FIG. **4**. The controller **1005** is configured to transmit and receive information to one or more remote devices regarding the receipt and disgorgement of the plurality of containers **1200***a-n* to and from the array of flow racks **1100**. The one or more remote devices can be a handheld, Internet-enabled device (e.g., laptop, tablet, smart phone, smart watch, etc.) configured to receive input from a driver of the mobile delivery vehicle **1000**. Additionally or alternatively, the one or more remote devices can be a computer terminal or handheld device located at a laundering facility. In implementations, the one or more remote devices is at least one of a computer terminal and a handheld device located at a customer delivery and pickup location. In implementations, the one or more remote devices are configured to receive customer input such as pick-up and delivery location, delivery and/or pick up time preferences, and other handling preferences and logistics details (e.g., where to leave the one or more customer containers **1200**).

In implementations, as shown in FIGS. **6-13**, an autonomous racking system **1300** for use with a mobile delivery vehicle, includes an array of flow racks **1100**, an elevator **1400** abutting the front end **1105** (e.g., loading/unloading access end) of the array of flow racks **1100**, and a controller **1005** in operable communication with one or more motor drivers and memory stores. As shown for example in FIG. **9**A, the array of flow racks **1100** comprises a plurality of rows **1110***a-c* (e.g., tiers) and a plurality of columns **1115***a-c*. As shown in FIGS. **11-13**, each one of the flow racks **1102** of the array of flow racks **1100** is configured to receive thereon a plurality of containers **1200***a-i* each associated with a single household, where "i" indicates the total number of containers in the array of flow racks **1100**. As shown in FIG. **10**, the array of flow racks **1100** includes a plurality of unloading pushers **1120***a-i*. As shown in the close up view of FIG. **14**, each one 1120 of the plurality of unloading pushers **1120***a-i* is disposed at a back surface **1205** of one or more of the plurality of containers **1200***a* disposed on each of the flow racks **1102** the array **1100**. As shown in FIGS. **13**A-B, each pusher **1120** is configured to push each one 1200 of the plurality of containers **1200***a-i* past a front end **1105** of the array of flow racks **1102**. A plurality of unloading pusher drives **1121** (see FIG. **36**) are in operable communication with one of the plurality of unloading pushers for moving the corresponding one of the plurality of unloading pushers **1120***a-i* toward the front end **1105** of the array of flow racks **1100**. In implementations, the front end **1105** is toward a front end of the vehicle **1000** such that a total weight of the plurality of containers **1200***a-n* disposed on the array of flow racks **1100** is continuously pushed forward toward within the transport volume. Continuously shifting the total weight of the plurality of remaining containers forward enables more consistent vehicle **1000** handling while in transit and prevents the containers from freely sliding around when the vehicle **1000** is driving or parked on unlevel and/or uneven ground.

As shown in FIGS. **15-20**, the elevator **1400** is configured to receive one or more containers **1200** from at least one or more of the plurality of flow racks **1102** in the array of flow racks **1100** and a vehicle side access portal **1060** (see FIG. **7**). Additionally, the elevator **1400** is configured to deliver one or more containers **1200** to at least one or more of the plurality of flow racks **1102** in the array of flow racks **1100** and a vehicle side access portal **1060**. In implementations, the elevator **1400** is configured to receive and deliver one or more containers **1200** from and to at least one or more of the plurality of flow racks **1102** in the array of flow racks **1100** and from and to a vehicle cab access portal (not shown), for example in an implementation in which the vehicle is a step van. The cab access portal in a step van opens to enable a delivery person to enter the transport volume from the driver's cab without having to exit the vehicle **1000**. As will be described subsequently with regard to implementations, an elevator **1400** can eject one or more containers **1200** into the driver's cab directly through the portal without the delivery person exiting the driver's cab. The elevator includes a movable carriage **1405** extending across a width of the plurality of columns **1115***a-c*. The movable carriage **1405** is in operable communication with an elevator drive **1402** of an elevator drive motor **1455** (e.g., FIGS. **24**A-**26**) configured to move the carriage **1405** up and down in the direction of double arrow V to align a carriage support surface **1407** with at least of one of the plurality of rows **1110***a-c* and a lower edge of the vehicle side access portal **1060** disposed at a height H**1** (see FIG. **7**) in a range of between about 0.25 to 2.25 meters from a ground upon which the delivery vehicle **1000** is disposed. In implementations, the drive motor **1455** is configured to raise and lower the carriage **1405** via a plurality of interconnected pulleys **1460***a-b*, **1462***a-b*, **1462***a'-b'* evenly distributed to the corners of the carriage **1405** for level raising and lowering under power of the drive motor **1455**.

As will be described subsequently with regard to implementations, the elevator **1400** comprises one or more elevator position sensors configured to detect a vertical location of the movable carriage **1405** and output a position signal. In implementations, as shown in FIGS. **21**A-**21**B, the elevator **1400** comprises a plurality of loading pushers **1410***a-c* (individually, loading pusher **1410**), each one of which is aligned with one of the plurality of columns **1115***a-c* and configured to push a container **1200** from the movable carriage **1405** onto one of the aligned plurality of columns **1115**, **1115***a-c* of the array **1100**. In implementations, the elevator **1400** comprises a plurality of loading pusher drives **1411***a-c* (see FIG. **36**). Each one of the loading pusher drives is in operable communication with one of the plurality of loading pusher drive motors **1423***a-c* (FIG. **29**) for moving the corresponding one of the loading pushers **1410***a-c* toward the front end **1105** of the array of flow racks **1100** to load a container **1200** into the array **1100**. The controller **1005** thus is in operable communication with a plurality of unloading pusher drive motor **1123** for the unloading pushers **1120***a-i*, the plurality of loading pusher drives **1402**, the drive motor **1455** of the movable carriage **1405**, and the one or more elevator position sensors **1413**. The controller **1005** is configured to instruct the drive motor **1455** to move the movable carriage **1405** to align the carriage support surface **1407** with one of the plurality of rows **1110***a-c*, receive the position signal, and determine whether the carriage support surface **1407** is aligned with the one of the plurality of rows **1110***a-c* for at least one of receiving and delivering a container **1200**.

In implementations, the controller **10005** is configured to load a container **1200** onto a flow rack **1102** from the movable carriage **1405**. In implementations, the controller **1005** is further configured to instruct a drive of the one of the plurality of unloading pushers **1120***a-i* associated with the aligned one of the plurality of rows **1110***a-c* and one of the plurality of columns **1115***a-c* to retract by a distance equal to a depth D (see FIG. **14**) of a container **1200**, and instruct a drive of an opposing one of the one of the plurality of loading pushers **1410***a-c* associated with the one of the plurality of columns **1115***a-c* to advance the one of the plurality of loading pushers **1410***a-c* to the front end **1105** of the array **1100**.

In implementations, the controller **1005** is configured to load a container **1200** onto the movable carriage **1405** from a flow rack **1102**. In examples, the controller **1005** is further configured to instruct a drive of the one of the plurality of unloading pushers **1120***a-i* associated with the aligned one of the plurality of rows **1110***a-c* and one of the plurality of columns **1115***a-c* to advance by a distance equal to a depth D of a container **1200**.

In implementations, each of the plurality of flow racks **1102** include a movable support for receiving one or more of the plurality of containers **1200***a-n* thereon. In implementations, the movable support comprises a conveyor configured to rotate toward the front end of the array. In implementations, the conveyor can be motor driven and operate without a pusher. In other implementations, the conveyor can be motor driven and configured to operate simultaneously with the unloading pusher drive motor **1123** (see FIG. **14**B). Alternatively, the conveyor can be configured to rotate upon application of force from an associated one of the plurality of pushers to one or more of the plurality of containers disposed on the conveyor.

In implementations, as shown in FIG. **14**A, the movable support comprises a plurality of rollers **1125** disposed continuously along the length LF of each one of the array of flow racks. The plurality of rollers **1125** rotate freely in either rotational direction and are configured to roll one or more of the plurality of containers **1200***a-i* disposed thereon toward the front end **1105** under application of a push force from the unloading pushers **1120***a-i*. Additionally or alternatively, the plurality of rollers **1125** can be interconnected to rotate simultaneously. In implementations, the plurality of rollers **1125** rotate under an application of pushing force on the one or more containers **12***a*-I in a row from an associated one of the plurality of unloading pushers **1120***a-i*. Alternatively, in implementations, one roller can be powered and the others passively connected such that all of the rollers simultaneously rotate when the powered roller is rotated by a drive motor.

In implementations, as shown in FIGS. **9**A-**10**, the plurality of rows **1110***a-c* comprises 3 rows and the plurality of columns **1115***a-c* comprises 3 columns. The number of rows and columns can increase and decrease to fit various vehicle holding volumes and the 3×3 array **1100** is shown by way of example as one implementation. In examples, as shown in FIG. **6**, the array **1100** has a length LF extending substantially parallel to a length LT of a transport volume of the delivery vehicle and a width WA extending substantially perpendicular to the length LT of the transport volume and substantially parallel to one or more vehicle wheel axles. The movable carriage **1405** has a longitudinal axis WC substantially perpendicular to the length LT of the transport volume and substantially parallel to the one or more vehicle wheel axles. As shown in FIG. **9**A, in implementations, each flow rack **1102** of the array of flow racks **1100** is interlinked by at least one shared structural beam **1104***a-d* along the length LF of the array **1100** with at least one other adjacent flow rack **1102** of the array of flow racks. The flow racks **1102** therefore are compactly stacked with no gaps therebetween. Because a racking array and elevator system **1300** (FIGS. **15**-**20**) comprises an elevator **1400**, an array **1100**, and a container tagging system (which will be described subsequently), delivery personnel **10** need not enter the transport volume to manually retrieve any of the plurality of containers **1200***a-n*.

In implementations, as shown in FIGS. **9**A and **11**, each flow rack **1102** of the array of flow racks further includes a movable stop gate **1130** (also herein referred to as "flow gate") disposed at the front end **1105** and configured to restrain one or more racked containers **1200***a-i*. In implementations, the system further includes a stop gate motor (and motor drive **1131**) in operable communication with the controller **1005**, the stop gate motor being configured to retract the movable stop gate **1130** upon the controller instructing a corresponding one of the plurality of unloading pusher drives to move the associated pusher **1120** toward the front end **1105**. In implementations, the stop gate motor includes at least one of a servo motor and a linear motor. Alternatively, as will be described subsequently, in implementations the stop gate **1130** comprises a manual and/or spring-loaded activation and deactivation mechanism to prevent the flow of containers **1200** out of a rack **1102**.

In implementations, as shown in FIGS. **14**A-B, each one of the plurality of unloading pushers **1120** comprises a contact face **1122** configured to engage a back surface **1205** of a container **1200***a* disposed at the back end of the one or more of the plurality of containers **1200***a-i* disposed on each of the flow racks **1102** the array **1100**. The contact face **1122** includes a contact material that is at least one of compliant and non-marking. Additionally or alternatively, in implementations, the contact face includes a contact material that is durable and wear resistant, and that provides damping against any collisions. The contact material can comprise at least one of silicone, rubber, nylon, and rigid polyurethane foam. As shown in FIGS. **16**-**17**, the contact face **1122** is configured to enter the elevator **1400** upon pushing the container **1200** disposed at the back end of a plurality of containers **1200** onto the elevator **1400**.

In implementations, as shown in FIG. **14**B, each one of the plurality of unloading pusher drives includes a motor **1123**. In implementations, for example, the motor can be a DC motor that nominally runs at 12V and 6 A. This is a non-limiting example and is intended as one of many potential options for this infrequently run motor. In implementations, each one of the motors includes an operably linked encoder **1124** in communication with the controller **1005** and configured to output a signal indicative of pusher position between the front end **1105** and the back end **1107**. Additionally or alternatively, in implementations, each flow rack **1102** comprises at least one of one or more IR break beam sensors, one or more limit switches, and one or more Hall-effect sensors for determining a position of a corresponding unloading pusher **1120** along the length of the a rack **1102** between the front end **1105** and the back end **1107**.

In implementations, as shown in FIGS. **11**-**12**, each flow rack **1102** of the system **1300** further includes at least one rail **1135***a-b* disposed at a top of each flow rack **1102** of the array of flow racks **1100**. The at least one rail **1135***a-b* is configured to receive thereon in slidable engagement an associated one of the plurality of unloading pushers **1120**. In implementations, the at least one rail **1135***a-b* is configured to extend into the elevator **1400** such that the unloading pusher **1120** enters the elevator **1400** (FIG. **17**) for fully pushing a container **1200** onto the movable carriage **1405**. In subsequently described implementations of the at least one rail being beneath the pusher for receiving pusher wheels and corresponding rails on the elevator **1400** for receiving the pusher wheels such that the pusher enters the elevator **1400** during unloading from the array of racks **1100**.

In implementations, as shown in FIGS. **12** and **14**B, a connector **1140** extends between each one of the plurality of pushers and a corresponding one of the plurality of unloading pusher drive motors **1123**. The connector can include at least one of a belt and a roller chain. In implementations, each one of the plurality of pushers can be driven by a motor mounted directly on the pusher. For example, an ASRS implementation (FIGS. **33**-**34**) can include a motor mounted directly on the pusher. In implementations, each one of the plurality of pushers can be pushed from behind by a corresponding pneumatic bladder. Alternatively, in implementations, each one of the plurality of pushers can be driven by a cable and an antagonistic spring. Additionally or alternatively, in implementations, the pusher is motor driven view a rotary-to-linear drive mechanism, for example a rack and pinion or chain driven mechanism.

In implementations, each one of the plurality of flow racks **1102** of the array of flow racks **1100** has a length LF extending parallel to a length LT of a transport volume of the delivery vehicle **1000**, and each one of the flow racks **1102** comprises a plurality of container positions along the length LF each configured to receive one of the plurality of containers **1200***a-i*. In implementations, the plurality of container positions comprises a range of between about 5-15 positions. In implementations, each one of the plurality of containers **1200***a-i* weighs between about 5 to 50 lbs. Each one of the plurality of containers weighs about 30 lbs. A collective maximum weight of a plurality of containers **1200***a-i* disposed on the array of flow racks **1100** is in a range of between about 50 to 100 percent of the weight of a structure defining the array of flow racks **1100**. In examples, each one of the plurality of containers **1200***a-i* comprises outer envelope dimensions of at or around 12 inches by 22 inches by 14 inches.

In implementations each one of the plurality of containers **1200***a-i* comprises a matching bottom surface length and width so that the individual ones of the plurality of containers **1200***a-i* each occupy identical surface areas on a flow rack **1102**. Additionally or alternatively, one or more of the plurality of containers **1200***a-i* comprises one common dimension across the width of a flow rack **1102** (parallel to the width WT of the truck **1000**) and one or more variable dimensions comprising at least one of a height and a length (parallel to the length LF of the array of flow racks **1100**).

In examples, each one of the plurality of containers **1200***a-i* is associated with a single customer, and a single customer (e.g., delivery and pick up address) may be associated with more than one container **1200** in an array of flow racks **1100**. The array of flow racks **1100** is configured to receive one or more containers **1200***a-i* associated with a plurality of customers. As shown in FIG. **31**, each one of the plurality of customers is associated with a physical location C**1**-Cn along a delivery and pickup route **1600** transited by the delivery vehicle **1000**. Locations comprise, for example, residential addresses and workplace addresses associated with customers. In implementations, the controller **1005** is further configured to record in a memory in wired or wireless communication with the controller **1005** each location within the array of flow racks **1100** of one or more containers **1200** associated with each one of the plurality of customers. The controller **1005** can be further configured to record in the memory which one or more containers **1200** have been unloaded from the array of flow racks **1100** along the route transited by the delivery vehicle **1000**. In implementations, a delivery route transited by the delivery vehicle **1000** is predetermined based on an order in which each of the one or more containers **1200***a-n* associated with each one of the plurality of customers is received into the array of flow racks **1100**.

Additionally or alternatively, in implementations as shown in FIG. **14**, each of the containers **1200** comprises an identification marker **1210** for associating with one of the plurality of customers. The identification marker **1210** is at least one of externally visible and embedded within the container **1200**. In implementations, an externally visible identifier comprises at least one of colored tape, colored boxes, and a manually adjustable color indicator for associating one or more boxes with a particular customer. In implementations, the controller **1005** can determined based on a delivery route and customer color indicators that containers belonging to two customers with similar or identical colors identifiers are not adjacent on a rack **1102**. This is especially helpful for delivering to one or more customers at a shared address, such as an apartment complex or duplex house sharing a single route stop. Additionally or alternatively, in implementations, the identification marker **1210** can include at least one of a machine-readable serial number, a machine-readable barcode, a machine-readable QR code, an RFID code, a NFC tag, and a digital display. Such programmable markers **1210** can be reprogrammed for subsequent use with different ones of the plurality of customers. The racking array and elevator system **1300** further comprises one or more identification sensors **1127**, **1414**, **1061** (FIG. **36**) disposed on or adjacent at least one of the array **1100**, the elevator **1400**, and the vehicle side access portal **1060** for detecting and/or reading the identification marker **1210** of each container **1200** and outputting a signal to the controller **1005** indicative of the identification marker **1210** associated with a customer as the container **1200** passes by the sensor. The one or more identification sensors can be in wired or wireless communication with the controller **1005**. The controller **1005** therefore is able to keep track of at least one of an array location, delivery status, and pick-up status of each of the plurality of containers **1200***a-n*. In implementations, the one or more sensors disposed on the array **1100** for detecting and/or reading each of the identification markers **1210** are disposed at each dwell position **1103**, **1103***a-i* (FIGS. **11-12**). Additionally or alternatively, the one or more identification sensors disposed on the array **1100** for detecting and/or reading each of the identification markers **1210** are disposed at a front **1105** of each flow rack **1102**. The controller **1005** can provide an audible and/or visible alert to a delivery person as to the container status on at least one of a readable display on the container and on a portable device (e.g., a tablet, smartphone, smartwatch, computer display screen, delivery vehicle dashboard display screen) having audio and visual display capabilities.

In implementations, as previously described, each container **1200** of the plurality of containers is durable. Additionally or alternatively, each container **1200** of the plurality of containers is reusable. Additionally or alternatively, in implementations, each container is rigid. In reusable implementations, each container **1200** can be washable. In implementations, each container **1200** is a non-deformable, durable, reusable, washable container with an ingress protection rating that includes an intrusion protection rating of 5 or 6 and a moisture protection rating of any and all of 1 through 6 in accordance with the Ingress Protection Code, IEC standard 60529. In implementations, each container **1200** has an ingress protection rating of at least one of IP56, IP57, IP58, IP66, IP67, and IP68 in accordance with Ingress Protection Code, IEC standard 60529. In implementations, the one or more of the plurality of containers is recyclable. Additionally or alternatively, one or more of the plurality of containers is disposable and biodegradable. In implementations, each container **1200** comprises a material such as plastic, metal, cardboard, lined cardboard, and silicone.

In implementations, each container **1200** of the plurality of containers has two or more tapered sidewalls so that the surface area at the container top is larger than the surface area at the container bottom. In examples, as shown in FIG. **9**B in the partial cut away view of an array of flow racks of FIG. **9**A, the system further includes pairs of angled guides **1118***a-i*, **1119***a-i*. The pairs of angled guides are disposed lengthwise along each side of an interior cavity of each flow rack **1102** of the array of flow racks **1100** to match the tapered container sidewalls and hold each container **1200** upright during loading, unloading, and transport. The pairs of angled guides **1118***a*-**1119***a-i* can be made of a durable, rigid material, such as a thin metal, wood, or plastic (e.g., ¼" or ½" thick).

In implementations, as indicated in the system schematic of FIG. **26**, in addition to or alternative to the one or more identification sensors, the system **1300** further includes one or more presence sensors **1126**, **1404**, **1062** for detecting at least one of the loading and unloading of one or more of the plurality of containers **1200** through the vehicle side access portal **1060**, onto or off of at least one of the elevator **1400**, and onto or off of the array of flow racks **1100**. The one or more presence sensors comprises at least one of an IR break beam sensor, an encoder, a limit switch, and a Hall-effect sensor. The one or more presence sensors **1126**, **1404**, **1062** can be disposed at least one of at the vehicle side access portal **1060**, at the front **1105** of each flow rack **1102** in the array of flow racks **1100**, and at each container dwell position **1103**, **1103***a-i* (FIGS. **11**-**12**) along a length LF of each flow rack **1102** in the array of flow racks **1100**.

Returning now to the elevator **1400** portion of the racking and elevator system **1300**, in implementations, as shown throughout FIGS. **22**-**29**, the elevator **1400** further includes a plurality of bidirectionally driven transfer wheels **1450** disposed at a transfer level and configured to move one or more containers **1200** across a width of the vehicle. As shown in FIGS. **21**A-B, the bidirectionally driven transfer wheels move a container **1200** in a travel direction from the elevator **1400** to the vehicle side access portal **1060** at the transfer level. In implementations, the bidirectionally driven transfer wheels move a container **1200** in a travel direction from the vehicle side access portal **1060** onto an elevator position aligned with one of the plurality of columns in the rack array **1100**. In implementations, as shown in FIG. **25**, a carriage support surface **1407** includes a plurality of one or more sets of flow wheels **1408***a-c* configured to rotate in a direction parallel to a length LT of the transport volume of the delivery vehicle **1000**. In implementations, the one or more sets flow wheels **1408** comprise interconnected (e.g., by a belt and/or gears) rollers that rotate simultaneously. In implementations, one roller (e.g., a roller closest to the array **1100**) can be powered and the others passively connected such that all of the rollers simultaneously rotate when the powered roller is rotated by a drive motor.

As shown in FIGS. **26** and **27**, the plurality of bidirectionally driven transfer wheels **1450** are configured to occupy gaps between adjacent ones of the plurality of flow wheels **1408***a-c* and protrude above a top surface (e.g., support surface **1407**) of the plurality of flow wheels **1408***a-c* when the movable carriage **1405** is lowered to a loading and unloading height H**1** (e.g., the transfer level). As shown in FIGS. **7** and **27**, the loading and unloading height H**1** is beneath the bottom row of the plurality of rows **1110***a-c* of flow racks **1102** such that the bidirectionally driven transfer wheels **1450** are not engaged with the flow wheels when the carriage support surface **1407** is aligned with the bottom row of the array of flow racks **1100**. In examples, as shown in FIGS. **28**B and **29**, the elevator **1400** further includes one or more drive motors **1457**, **1457***a-c* for rotating the plurality of bidirectional transfer wheels **1450**. The one or more drive motors **1457** can be at least one of disposed in line with the plurality of transfer wheels **1450** and mounted at the top of the elevator **1400** and connected to the transfer wheels **1450** with a drive belt.

In implementations, the elevator **1400** further includes one or more sensors for detecting a columnar location of the container traveling from side-to-side on the plurality of bidirectional transfer wheels **1450**. The one or more sensors can include at least one of an IR break beam sensor, an encoder, a limit switch, and a Hall-effect sensor.

Implementations, the elevator further includes at least one of an encoder **1403** (see FIG. **36**) and limit switches **1404** in communication the elevator motor drive **1402** and configured to output an elevator position signal to the controller **1005** while moving up and down, the output signal being indicative of vertical location of the carriage support surface **1407** relative to each of the plurality of rows of flow racks **1102***a-i*.

In implementations, as shown in FIGS. **30**A and **30**B, each one of the plurality of loading pushers **1410***a-c* is analogous to the unloading pushers of FIG. **14**B. In implementations, each of the loading pushers **1410***a-c* comprises a drive motor **1423***a-c* in operable communication with the controller **1005** via a loading pusher motor drive **1411**. In implementations, the drive motor **1423** can be a DC motor that nominally runs at 12V and 6 A. This is a non-limiting example and is intended as one of many potential options for this infrequently run motor. In implementations, each one of the motors includes an operably linked encoder **1412** in communication with the controller **1005** and configured to output a signal indicative of pusher position between retracted and extended positions for respectively receiving a container **1200** onto and pushing a container off of the movable carriage **1405** of the elevator **1400**.

In implementations, the vehicle **1000** comprises at least one side access portal **1060** on a curb side of the vehicle. Additionally or alternatively, the at least one side access portal comprises an opening on a driver's side of the vehicle **1000**. The elevator **1400** allows containers **1200** from all of the flow racks in the array of flow racks **1100** to reach a delivery person **10** at least one side of the vehicle **1000**. Having an option for selecting a discharge side of the vehicle accommodates for variation in terrain, one way streets, and other drive preferences. Additionally or alternatively, as previously described with regard to step van implementations, an elevator **1400** can eject one or more containers **1200** into the driver's cab directly through a cab access portal without the delivery person exiting the driver's cab. The cab access portal in a step van opens to enable a delivery person to enter the transport volume from the driver's cab without having to exit the vehicle **1000**.

In implementations, as shown in FIG. **26**, a flow wheel **1408***f* of the movable carriage **1405** adjacent an edge abutting the front end of the array is at least one of larger than and higher than the remainder of the plurality of flow wheels **1408** of the carriage support surface such that a container **1200** disposed on the carriage support surface **1407** cannot roll back onto the front end of the array **1100**. Additionally or alternatively, in implementations, the carriage support surface further comprises a detent (not shown) configured to retain a container loaded on the carriage support surface from the array of flow racks.

In implementations, each one of the plurality of loading pusher drives **1411***a-c* is configured to move each one of the plurality of loading pushers **1410***a-c* independently. Additionally or alternatively, in implementations, the plurality of loading pusher drives **1411***a-c* are configured to move two or more of the plurality of loading pushers **1410***a-c* simultaneously.

In implementations, all or some of the motors of the plurality of unloading pushers **1120***a-i*, the plurality of loading pushers **1410***a-c*, the stop gate **1130**, the elevator **1400**, and the transfer rollers **1450** are configured to be rechargeable. In implementations, the vehicle is an electric vehicle and all some of the aforementioned motors can be charged off of the battery which can be charged by regenerative braking, for example. Additionally or alternatively, the power system of the electric vehicle can be charged by another environmentally-friendly power generation system. For example, one or more solar panels disposed on the vehicle **1000** can harness solar energy for powering the vehicle and some or all of the motors of the autonomous racking and elevator system **1300**.

Although implementations of an autonomous racking and elevator system **1300** have been described as comprising an actuated array of flow racks oriented length wise from front to back of a delivery vehicle **1000** and having a single elevator **1400** traversing a width of the vehicle **1000** across an end of the array **1100** for side-loading the vehicle, other racking systems are contemplated. Implementations, such as the schematic array **1100***b* of FIG. **32**, comprise a side-loaded vehicle having a transport volume length LT occupied by a plurality of flow racks **1102***a-g* oriented width wise and each comprising a dedicated elevator **1400***a-g* at a loading end.

In other implementations, the autonomous racking system can include a plurality of gravity driven flow-racks. In other implementations, at least one gravity driven and actuated flow rack can be loaded at a back opening of the vehicle. In implementations, loading the vehicle comprises opening a back door and inserting an entire loaded array of flow racks into the transport volume of the vehicle **1000**.

In implementations, such as the schematic systems of FIGS. **33** and **34**, the autonomous racking system comprises an automated storage and retrieval system (ASRS) system. In implementations, the ASRS system can be one of full and multi-depth. As shown in FIG. **33**, a back-loaded ASRS system **1100***c* comprises two shuttles **1470***a-b* configured to access any container **1200***a-n* at any time. As shown in FIG. **34**, in implementations a back-loaded multi-depth ASRS racking system **1100***d* comprises one shuttle **1470** configured to access all containers **1200***a-n*.

In implementations, such as that of FIG. **35**, the system **1300** comprises a delivery vehicle interface **1500** that comprises a screen (e.g., a touch screen), one or more buttons, and/or a keypad to aid a delivery person **10** in determining how many containers **1200** to retrieve from or return to any given customer location C**1**-Cn. In implementations, the user interface **1500** provides information about progress along a travel route as displayed in a delivery stop count **1502**, and information regarding a quantity **1505** of containers **1200** to retrieve from or return to any given location. For example, an address **1510** for delivery and/or pickup is displayed on the screen for the next destination along a travel route. An image or representation **1515** of the premise or location(s) for delivery and/or pickup is provided. The image **1515** can be obtained by a method including at least one of the controller **1005** retrieving an image from a street view image service, the controller **1005** receiving an image input by a customer at a terminal in communication with a network **230**, the controller **1005** receiving an image input into a memory store (e.g., database) by a building management firm, and the controller **1005** receiving an image input into a memory by delivery personnel **10** on a prior visit to the location address **1510**. In implementations, the user interface **1500** displays a map **1520** of the travel route.

In implementations, the user interface **1500** comprises a display of a quantity **1505** of containers that are being ejected or deposited through the vehicle access portal **1060** and/or another vehicle access point. In this example, 5 containers that are being ejected or deposited through the access portal **1060**. The user interface **1500** can display a visual progress indicator **1525** showing the progress of ejecting or depositing containers from or to the portal in graphic format. In this example, one of five containers has been ejected or deposited through the access portal.

In implementations, a dynamic button **1530** or hamburger menu icon is provided to allow the delivery person **10** to select among a number of functions, such as at least one of a start, proceed, or end sequence for ejecting or depositing the containers **1200**.

In implementations, the user interface **1500** can indicate a color associated with a color-coded indicia on all of the containers **1200** being delivered to a customer. The delivery person **10** can double check that the color on the one or more ejected containers **1200** matches the color assigned with the customer location C as indicated in the user interface **1500**. The color-coded indicia can be, for example, a sticker or an adhesive seal applied to a cover of the container **1200** to indicate the items within have not been accessed since they were loaded into the container **1200** at the processing facility housing the one or more process lines **100**, **100***a-c*. For addresses **1510** comprising a multi-unit dwelling with two or more distinct customers, the color-coded indicia assists the delivery person **10** in quickly identifying which one or more containers **1200** belong to which customers.

In implementations, the user interface **1500** comprises one or more physical buttons **1535** to enable the operator/delivery person **10** to select among a number of functions. In implementations, a first physical button **1535** is provided to enable the delivery person **10** to select among the functions including at least one of a start, proceed, or end sequence for ejecting or depositing the containers **1200**. Another physical button **1540** can be provided to enable the operator to toggle options as necessary. The one or more physical buttons **1535**, **1540** can be easier to activate as compared to a touch screen in certain wet and/or cold weather conditions along a travel route and/or while wearing gloves.

On unloading at a customer location C**1**-Cn, the autonomous system **1300** may automatically retrieve and disgorge through one or multiple vehicle access portals **1060** the one or more containers destined to that location. The system **1300** may disgorge the containers one at a time or more than one at a time upon request. The controller **1005** of the vehicle will know which containers are loaded into the transport volume and where each container is located in the array of racks **1100**. As previously described with regard to implementations, one or more sensors in communication with the controller **1005** can read each container during loading into the vehicle and onto the array of racks **1100** and record in memory a storage location in the array of racks **1100**. At each customer location along a travel route, the controller **1005** will recognize which one or more containers need to be unloaded next and actuate a pusher **1120** of the appropriate rack **1102**. In implementations, the controller **1005** can operate automatically using GPS, actuating a pusher to disgorge a container upon recognizing a vehicle stop location as matching one or more containers **1200**. Additionally or alternatively, the one or more containers **1200** can be retrieved manually by the delivery person **10**. For example, implementations, the delivery person **10** can interact with the user interface **1500** to indicate a location along the travel route. Additionally or alternatively, the controller can memorize the planned route and correlate one or more containers in the array of flow racks **1100** with an associated stop number **1502**. In implementations, upon determining arrival at a location, the controller **1005** operates a flow rack **1102** to push a single container **1200** onto the elevator **1400**. The elevator lowers onto the transfer wheels that move the container from side-to-side, and the transfer wheels shift the container to the side access portal where the delivery person **10** will grab the container at an ergonomically desirable height. In implementations, the access portal **1060** comprises at least one of a hatch that folds down to support the container during ejection and an actuatable gate in operable communication with the controller **1005** for holding a container in place at the access portal until a delivery person **10** is present and ready to lift the container **1200**.

Additionally, in implementations, the autonomous racking system **1300** accounts for variations in a travel route that requires unloading one or more containers out of order from the array of flow racks **1100**. For example in implementations the autonomous racking system comprises an array of flow racks **1100** as described herein throughout with regard to implementations and an automated storage, and a distribution robot **9000** loads the vehicle **1000** in a last-in, first out order in accordance with a pre-planned travel route. Additionally or alternatively, the system **1300** accommodates variations in a pre-planned unloading order by shuffling one or more containers from one flow rack onto another flow rack and/or the elevator in order to unload containers associated with a location. In implementations, the controller **1005** tracks one or more flow racks **1102** having one or more unoccupied dwell positions for receiving shuffled containers. The controller **1005** then moves the undesired containers one-by-one from one flow rack **1102***a*, onto the elevator **1400**, and onto to one or more other flow racks **1102***b-i* having one or more available dwell positions for accommodating the one or more shuffled containers. The controller **1005** stores in a memory the one or more new locations of the one or more shuffled containers in the array of flow racks **1100**. This touchless shuffling accommodates missed stops, unavailable locations, detours, and other travel route aberrations.

Although the forgoing methods and systems are described herein with regard to the collection, cleaning, and return of laundry associated with a plurality of customers (e.g., households), the methods and systems are applicable to other businesses delivering packages to residences and businesses along a driven route. For example, the autonomous racking devices, systems, and methods as described herein with regard to implementations can be used with a grocery delivery business and an online retail service. In implementations, each container is a reusable, durable container configured to receive one or more unpackaged goods from an online retail service, thereby reducing the amount of packaging waste associated with outer packing and fill materials. In implementations, the autonomous racking devices, systems, and methods as described herein are configured to deliver one or more items mailed or shipped between residential senders and recipients.

In implementations, the flow rack can be a spring-loaded rack that requires no motorized actuators. Turning now to FIG. **37**, the delivery vehicle **1000'** is a truck or step van configured to transport a plurality of containers **1200***a-n* of laundry between a plurality of customers and a laundry processing facility comprising a process line **100** of autonomously operating devices **2000-9000**, as described previously with regard to alternative implementations. In implementations, an array **1100'** of spring-loaded flow racks **1102'** is configured to be disposed within an enclosed transport volume **1035'** of the delivery vehicle **1000'**. In implementations, the transport volume **1035'** has a length LT' extending from a front end **1040'** to a back end **1055'** and a width WT' extending between a left side **1045'** and a right side **1050'**. In implementations, the enclosed transport volume **1035'** comprises a width in a range of between about 6 to 8.5 feet and a height TH' in a range of between about 6 to 10 feet. In implementations, the transport volume **1035** is 8 feet wide and in a range of between about 8 to 9 feet tall. In implementations, the delivery vehicle **1000** is at least one of a delivery van, a walk in van (e.g., step van), and a box truck. In implementations, the vehicle **1000'** is an electric vehicle. In implementations, the vehicle **1000'** is a hybrid electric vehicle.

In the implementation of FIGS. **37** and **38**, the front end **1040** comprises a walkable volume disposed between the array **1100'** and the driver's compartment **1041'** at the front of the vehicle **1000'**. As shown in the implementation of FIGS. **37** and **38**, a delivery person **10** can exit the driver's compartment and enter the enclosed transport volume **1035** through a door disposed between the two volumes. The delivery person **10** then releases one or more containers **1200***a-n* from one or more of the spring-loaded racks **1102'** in the array **1100'** and exits through a side door **1065** of the driver's compartment or through side door (not shown) in the transport volume. The front end **1040'** therefore comprises a volume configured to enable the delivery person **10** to walk, reach, retrieve, and carry one or more containers **1200***a-n* for removal from the vehicle **1000'** without impediment.

In implementations, the array **1100'** comprises a plurality of densely packed spring-loaded flow racks **1102'**, as shown for example in FIGS. **39-41**. As previously described, the racking system is designed for maximizing packing density to reduce delivery costs associated with driver labor and vehicle operation and maintenance. Maximizing packing density reduces the number of delivery vehicles and drivers required to retrieve and redistribute loads of laundry. More consolidated delivery reduces driver hours and lower costs to customers subscribed to a laundry service. The spring-loaded racking system eliminates drivers exerting themselves through extraneous physical interaction with heavy containers and prevent lifting from ergonomically disadvantageous positions. Additionally, the densely packed spring-loaded racks **1102'** hold the containers securely in place so that they are undisturbed by the forces associated with driving a truck in variable terrain conditions, speed ranges, and inclines. Additionally, the delivery person need not rearrange racked containers as other containers are retrieved and the delivery person need not exert time and emergent manually adjusting any restraints. The delivery person **10** therefore need only exert a minimal manual effort when retrieving one or more containers for delivery. Additionally, as will be described subsequently herein with regard to implementations, the controller **1005** can be configured to guide the delivery person to the correct rack (e.g., via a light to pick system) for removing one or more containers for delivery and, additionally in implementations, the controller can receive a sensor signal indicative of the delivery person having retrieved a correct one or more containers for delivery at a particular customer location.

In implementations, as shown in FIGS. **39-41**, the spring-loaded flow rack **1102'** comprises a plurality of dwell positions **1103***a*' j' along a length LF' of the flow rack, each dwell position being configured to receive a container **1200***a-j* thereon. The flow rack **1102'** comprises parallel lengths of conveyor rails **1129**a'-b' each comprising a plurality of rollers **1125**a'-b' on which the containers are disposed for advancing toward the delivery person **10** upon actuation of a spring-loaded pusher **1120'**. In addition to the pusher **1120'**, the spring-loaded flow rack of FIG. **39** comprises a manually actuated flow gate **1132**a'-b' as will be described subsequently with regard to implementations.

As described previously with regard to alternative implementations, the array **1100'** comprises a plurality of rows **1110**a'-c' and a plurality of columns **1115**a'-c' comprises 3 columns (see FIGS. **37** and **42**A). In implementations, the array **1100'** has a length LF' (FIG. **29**) extending substantially parallel to a length LT' of a transport volume of the delivery vehicle and a width WA' extending substantially perpendicular to the length LT' of the transport volume and substantially parallel to one or more vehicle wheel axles. In implementations, each flow rack **1102'** of the array of flow racks **1100'** is interlinked by at least one shared structural beam **1104**a'-n' along the length LF' of the array **1100'** with at least one other adjacent flow rack **1102'** of the array of flow racks and two or more shared vertical structural beams **1106**a'-b'. The flow racks **1102'** therefore are compactly stacked with no gaps therebetween.

Turning back to FIGS. **39**-**41**, in implementations, the spring-loaded pusher **1120'** comprises at least one of one or more constant force springs and one or more double wrapped torsion springs **1134**a'-b' disposed at the front **1105'** of the rack **1102'** and affixed to an underside of the pusher **1120'** for applying constant retraction force in the direction of the front **1105'** of the rack **1102'** without interfering with any container(s) **1200**a-j on the rack **1102'**. In implementations, as shown in FIG. **40**, the one or more springs **1134**a'b' are each configured to be attached to the pusher **1120'** by one or more associated lanyards or wires **1146**a'-b'. The one or more wires **1146**a'-b' can be fixedly attached to corresponding one or more springs and releasably attached to the pusher **1120'** with a clip or carabiner **1143**a'-b' engaged with a rod or one or more eyelets on the pusher **1120'**. The releasably attached clip **1143**a'-b' enables servicing or replacing the pusher **1120'**. In implementations, the spring-loaded pusher **1120'** applies a retraction force in a range of between about 1-30 lb of force. The spring-loaded pusher **1120'** is configured to be under constant force and is configured to push against the rear most container **1200**n in the rack **1102'**. When a delivery person **10** manually activates the flow gate **1132**a'-b' of the rack **1102'** to the open state, a container **1200**a closest to the front end **1105'** is ejected from the rack **1102'** under force of the pusher **1120'**. FIG. **41** depicts an empty flow rack with the spring-loaded pusher in the forward position.

FIGS. **42**A-B depict a single empty spring-loaded flow rack **1102'** disposed in a delivery vehicle **1000'**. Only one spring-loaded flow rack **1102'** is depicted for clarity, but in implementations, each of the row and column grid positions in the array **1100'** are configured to retain therein one of a plurality of spring-loaded flow racks **1102'** as previously described. In implementations, as shown in the magnified end view of FIG. **42**B, the spring-loaded pusher **1120'** comprises wheels **1136**a'-b' riding in tracks or channels **1137**a'-b' on either side of the flow rack **1102'** and the pair of springs **1134**a'-b' evenly applies force to pull the pusher **1120'** along the channels **1137**a'-b' without binding. In implementations, as shown in FIGS. **42**A-B, each one of the plurality of unloading pushers **1120'** comprises a contact face **1122'** configured to engage a back surface **1205'** of a container **1200** disposed at the back end of the one or more of the plurality of containers **1200**a-j disposed on each of the flow racks **1102'** the array **1100'**. The contact face **1122'** includes a contact material that is at least one of compliant and non-marking. Additionally or alternatively, in implementations, the contact face includes a contact material that is durable and wear resistant, and that provides damping against any collisions. The contact material can comprise at least one of silicone, rubber, nylon, and rigid polyurethane foam.

FIGS. **43**A-**44** depict an implementation of a flow gate disposed at the front end **1105'** of the flow rack **1102'**. FIG. **43**A depicts the flow gate in a closed position such that restraining arms **1132**a'-b' are substantially horizontal, blocking the opening through which a container **1200** would be ejected. Additionally, in some implementations, the flow gate comprises rear bars **1135**a'-b' for preventing a container (e.g., container **1200**i in FIG. **39**) behind the front most container (e.g., container **1200**j in FIG. **39**) from sliding forward when the restraining arms **1132**a'-b' are in an open position. In a vertical position the rear bars prevent the container behind the front most container from sliding forward to the front most position after the front most bin has been ejected from the spring-loaded flow rack **1102'**. This enables a delivery person **10** to remove one container at a time in a controlled manner. FIG. **43**B depicts the flow gate in an open position. The restraining arms **1132**a'-b' are linked to lever **1133'** such that when a delivery person pushes down on the lever **1133'** with either a foot or a hand, the restraining arms bend down to allow the front most container to roll out of the opening under the force of the spring-loaded pusher **1120'**. Simultaneously, the rear bars **1135**a'-b', mechanically linked to the rotating restraining arms **1132**a'-b', rotate up from their vertical resting position to a horizontal, closed state, blocking all but the front most container from moving forward through the opening of the flow rack **1102'** and ensuring that multiple containers do not eject at once.

FIG. **44**A depicts an implementation of the linkages **1138**a'-b' between the lever **1133'** and the restraining arms **1132**a'-b'. As shown in FIGS. **44**B-C, in implementations one or more return springs **1147**a'-b', **1147**c' are disposed proximate at least one of the lever **1133'** and one or more of the restraining arms **1132**a'-b' for returning the stop gate **1130'** to a closed position once a front most container exits the flow rack **1102'**. As shown in FIG. **44**B, for example, when the front most container exits the flow rack, one or more return springs **1147**a'-b' push the lever **1133'** back up which moves the linkages **1138**a'-b' to push the restraining arms **1132**a'-b' back to a closed, horizontal state. Additionally or alternatively, one or more return springs **1147**c' disposed on one or more of the restraining arms **1132**a'-b' drives the restraining arm and adjoined linkage **1138**a'-b' back to a closed state. In implementations of the flow gate comprising rear bars **1135**a'-b', the linkages, under force of the one or more return springs **1147**a'-b', **1147**c' also return the rear bars **1135**a'-b' to an open, vertical state so that the pusher **1120'** can slide the next queued container forward to the forward most position, awaiting ejection.

Additionally, in implementations, the restraining arms **1132**a'-b' further comprise one-way hinges (not shown) so that they can bend inward toward the rear **1107'** of the flow rack **1102'** but not outwards past the front **1105'**. This enables a delivery person **10** to push a new contained into the flow rack **1102'** without needing to actuate the gate (e.g., press the lever **1133'**). Additionally or alternatively, in implementations not having rear bars **1135**a'-b', the delivery person **10** can actuate the lever **1133'** to move the restraining arms **1132**a'-b' to an open state, enabling the delivery person **10** to load one or more containers onto the flow rack **1102'** through the front end **1105'** with the lever **1133'** being pressed.

As described above with regard to implementations, each flow rack **1102***a-n'* of the array of flow racks **1100'** is interlinked by at least one shared structural beam **1104***a'-d'* along the length LF' of the array **1100'** with at least one other adjacent flow rack **1102'** of the array of flow racks. The array **1100'** of flow racks **1102***a'-l'* therefore is securely affixed to one another and affixed within the transport volume **1035'**. Turning to FIGS. **45-46**B, in implementations, the affixed array **1100'** of spring-loaded flow racks **1102***a'-n'* is configured for loading and unloading from a back end **1055'** of the mobile delivery vehicle **1000'**.

In implementations, as depicted in FIG. **45**, the pushers **1120'** are configured to fold down at a selectively actuated hinge to allow the containers **1200***a-j* in the array **1100'** to be unloaded from a selectively sealed opening in the back end **1055'** of the mobile delivery vehicle **1000'**. With the pushers **1120'** folded down, the containers **1200***a-j* roll out of the backs **1107***a-l'* of their flow racks **1102***a-l'* one at a time into a loading/unloading rack **2005'** as shown in FIGS. **46**A-B. As shown in FIGS. **46**A-B the mobile delivery vehicle **1000'** is disposed adjacent a facility loading dock **2007'**. The mobile delivery vehicle **1000'** can be disposed at an incline or adjusted to an inclined position such that gravity pushes the containers **1200***a-n* out of their respective flow racks **1102***a'-n'*. The loading/unloading rack **2005'** is angled to act as a gravity flow rack within the facility. FIG. **46**B shows a side view cross section of the array **1100'** of flow racks **1102***a'-n'* within the mobile delivery vehicle **1000'** and the loading/unloading rack **2005'** aligned with the openings of the spring-loaded flow racks **1102***a'-n'* for receiving containers thereon. Although only one loading/unloading rack **2005'** is shown for clarity, a plurality of loading/unloading racks **2005'** can be aligned with the array **1100'** for simultaneously receiving containers **1200***a-n* from the flow racks **1102***a'-n'* of the array **1100'**. Additionally or alternatively, as will be subsequently described with regard to implementations, a spring or hand-powered crank can be used with an antagonistic pusher to force the containers **1200***a-n* out of their respective flow racks **1102'**. In implementations, the loading/unloading rack **2005'** can be used for both loading and unloading containers **1200***a-n* from the array **1100'**.

In other implementations, as shown in FIGS. **47-48**B, the spring-loaded flow racks are removable flow racks **1102***a''-l''* configured for complete removal from the mobile delivery vehicle **1000''** onto a loading/unloading rack **2005''**. In implementations, a removable flow rack **1102''** comprises external roller wheels **1139***a'-b'* on which the rack **1102''** slidably rolls into and out of the array **1100''** and onto and off of a loading/unloading rack **2005''**. In implementations, the removable flow rack **1102''** further comprises a pair of raised rails **1142***a'-b'* along the length LF'' of the flow rack **1102''** for preventing containers thereon (not shown) from sliding side-to-side during removal and loading of the rack **1102''**.

In implementations, as described previously with regard to delivering one or more containers to a household address, an autonomous racking and elevator system **1300** can automatically retrieve one or more containers and disgorge the one or more containers through one or multiple vehicle access portals **1060** through a side of the transport volume of the vehicle. The system **1300** may disgorge the containers one at a time or more than one at a time upon request. In implementations, a driver positions the one or more vehicle access portals **1060** against an intake portal in a factory wall and the autonomous system **1300** retrieves and disgorges the one or more containers through the vehicle access portal **1060** and directly through the wall of the factory to a receiving conveyor or rack therewithin for autonomous queuing to one or more process lines **100**, **100***a-c*. Additionally or alternatively, in implementations the system **1300** disgorges one or more containers through the vehicle access portal **1060** onto a conveyor or rack routed through a factory portal for autonomous queuing to one or more process lines **100**, **100***a-c*.

In yet other implementations, as depicted in FIGS. **49-53**, the autonomous racking system includes a plurality of densely packed pallets **1102***a'''-f'''* containing an array of containers **1200***a-n*. Each pallet **1102'''** maximizes packing density and facilitates loading and unloading a mobile delivery vehicle **1000'''**. In implementations, as shown in the perspective end view of FIG. **49** and the front-end view of FIG. **50**, a pallet **1102'''** comprises a plurality of removable retention straps **1103***a'''-n'''* configured to restrain the containers **1200***a-n* at one of at least their front and back sides and their left and right sides. The pallet **1102'** further includes, in implementations, one or more holes **1144***a'''-b'''* at the bottom of the pallet **1102'''** for receiving a standard pallet jack for lifting and moving into and out of a delivery vehicle **1100'''**.

In implementations, as shown in FIGS. **51-53**B, a plurality of pallets **1102***a'''-f'''* are configured to be loaded into a transport volume **1035'''** of the mobile delivery vehicle **1000'''**. In implementations the mobile delivery vehicle **1000'''** comprises a plurality of rollers (not shown) disposed on the floor of the transport volume for rollably receiving the plurality of pallets **1102***a'''-f'''* thereon. As with the previously described implementations of spring-loaded flow racks **1102'**, **1102''**, the transport volume **1035'''** comprises a front end **1040'''** volume between the driver's compartment and the plurality of pallets **1102***a'''-f'''* such that a delivery person can enter the transport volume and walk, reach, retrieve, and carry one or more containers **1200***a-n* for removal from the vehicle **1000'''** without impediment. FIG. **53**B depicts a perspective front view cross section of the vehicle **1000'''** with the driver's compartment **1041'''** removed. A front pallet **1102***f'''* is partially unloaded with a portion of the front facing plurality straps **1103***a-n'''* removed for accessing the containers **1200***a-n*.

Any of the preceding implementations can additionally comprise one or more devices and methods for assisting a delivery person **10** with identifying and retrieving the correct container or containers when making a delivery to a destination address.

For example, in implementations, mobile delivery vehicle **1000'**, **1000''**, **1000'** can further comprise a visible light-to-pick system in operable communication with the controller **1005-1005'''** for actuating a light disposed proximate to and/or aimed at the one or more containers **1200***a-n* in an array **1100'**, **1100''**, **1100'''** requiring delivery at a destination.

As described previously with regard to FIG. **14**, in implementations, each of the containers **1200** comprises an identification marker **1210** for associating with one of the plurality of customers. The identification marker **1210** can include at least one of a machine-readable serial number, a machine-readable barcode, a machine-readable QR code, an RFID code, and a NFC tag. Such programmable markers **1210** can be reprogrammed for subsequent use with different ones of the plurality of customers. The system **1300** further comprises one or more sensors disposed on at least one of the array **1100'**, **1100''**, **1100'''** for detecting and/or reading the identification marker **1210** of each container **1200** and outputting a signal to the controller **1005'**, **1005''**, **1005'''** indicative of the identification marker **1210** associated with a customer as the container **1200** is proximate to the sensor. The controller **1005'**, **1005''**, **1005'''** therefore is able to keep track of at least one of a location, delivery status, and pick status of each of the plurality of containers **1200***a-n*. In implementations, the one or more sensors disposed on the array **1100'**, **1100''**, **1100'''** for detecting and/or reading each of the identification markers **1210** are disposed at each dwell position **1103'**, **1103***a'-j'* (e.g., see FIG. **39**).

Additionally or alternatively, the one or more sensors disposed on an array **1100'**, **1100''**, **1100'''** for detecting and/or reading each of the identification markers **1210** are disposed ata front **1105'**, **1105''**, **1105'''** of each flow rack **1102'**, **1102''** or pallet **1102'''**.

Additionally or alternatively, in implementations, such as that of FIG. **54**, the system **1300** comprises a delivery vehicle interface **1500** that comprises a screen (e.g., a touch screen), one or more buttons, and/or a keypad to aid a delivery person **10**, in determining how many containers **1200***a-n* to retrieve from or return to any given location C**1**-Cn. In implementations, the user interface **1500** provides information regarding a quantity **1505** of containers **1200** to retrieve from or return to any given location C1-Cn and a visual indication **1503** of the container positions in the array **1100**, **1100'**, **1100''**, **1100'''**. The locations can be identified with at least one of a colored icon **1504** and a number. In implementations in which one or more containers are loaded front to back on a single rack, a separate identifier **1506** can be displayed in a unique color or grayscale with a number and an indicator (e.g., directional arrow) displaying where the container (e.g., "5") is loaded behind another (e.g., "4").

In implementations, the display of FIG. **54** is a sub-screen to the GUI display screen of FIG. **35** and is accessible through the dynamic button **1530** or hamburger menu icon to toggle between displaying the container location identifier **1503** and information **1502** about delivery progress. In implementations, toggling between screens retains some or all of the informative display elements. For example, the user interface **1500** can continually display of a quantity **1505** of containers that require delivery at an address. In this example, 5 containers require delivery, and their 5 locations are identified in the visual indication of container positions.

Returning now to alternate embodiments of the flow racks, FIGS. **55-57**B depict a manually operated implementation of an unloading pusher **1720**. In implementations, a manually operated flow rack **1102**A comprises a handle **1710** at a front end **1105** of the rack **1102**A. The handle **1710** is operably connected to a pull chain **1715** as shown in the partially exposed view of FIG. **56**. As shown in FIG. **56** and the close-up rear end views of the flow rack **1102**A of FIG. **57**A, the pull chain **1715** extends the length of the flow rack LF to engage with a bottom portion **1722** of the unloading pusher **1720**. As shown in FIG. **57**B, the handle **1710** is operably connected to a drive gear **1725** that engages the pull chain **1715** via one or more bearings **1729** and gears **1727**. A top place of the gear assembly **1705** is removed to in FIG. **57**B and in practice, in implementations, the assembly **1705** would be covered to prevent deterioration and jamming of the gears, sprocket, and chain therein. Alternatively, in implementations, the handle is connected to a belt or shaft drive configured to manually retract and extend the pusher **1720**.

Turning now to FIGS. **58**A-**60**B, in implementations, a flow rack **1102**B comprise a spring eject mechanism and manual folding/unfolding stop gates **1730***a-b* that permit a delivery person to select when to allow the container(s) on the flow rack to roll through a front end **1105**B. In implementations, the gates **1730***a-b* fold up when a delivery person **10** wants to remove a container **1200**. In implementations, the gates **1730***a-b* comprise one or more magnet detents to keep them in an upright position until the delivery person is ready to close the gates **1730***a-b*. Additionally or alternatively the gates **1730***a-b* comprise at least one of a bistable mechanism, such as a bistable spring, for holding the gates upright and out of the way of the front end **1105**B or the gates can be held upright by gravity. In implementations, as shown in FIGS. **59** and **60**A-B each of the gates **1730** is attached to a carriage **1731** that can slide the length of the rack LF, and is pulled back by a spring **1734** or other retraction mechanism housed at a back end **1107**B of the rack **1102**B and connected to the carriage **1731** by a cable **1732**.

Turning now to FIGS. **61**A-**64**B, in implementations, a flow rack pusher **1120**A comprises a manually operated drop mechanism for unloading a flow rack from the rear, as shown for example in FIG. **45**. In implementations, as shown in FIGS. **61**A-B and **62**A-B, the pusher **1120**A comprises a manually engaged spring loaded release pin **1740**, shown in a fully extended state in FIG. **61**B in a pusher locked position. The drop mechanism is two part: First, as shown in FIGS. **63**A-B, the pin **1740** mechanism is disengaged by compressing the pin **1740** a first distance. Second, as shown in FIGS. **64**A-B the pusher pad is rotated down when the fully compressed pin **1740** engages a lever or linkage mechanism for folding the pusher pad flat behind and lower than the rails of the rack on which it rides.

In other implementations, as shown in FIGS. **65**A-**67**B, a mechanically operated drop mechanism for unloading a flow rack **1102**B from the rear, (for example, unloading into a laundry factory comprising one or more process lines **100**, **100***a-c*) comprises a sliding plate **1755** and tab **1750** for extending a pusher **1120**B to a lay flat state. The drop mechanism is configured to be operated by at least one of the delivery person and an extraction mechanism moved into engagement with the drop mechanism. As shown in FIGS. **65**A-B, when the plate is in the rear position, it blocks the pusher contact face **1122**B from tilting. As shown in FIGS. **66**A-B in particular with a bottom cover of the pusher **1120**B removed, an external mechanism such as an extraction rack (in the factory, not shown) engages with the rear edge of plate **1755**, sliding it forward in the direction of the arrow and opening a path for the pusher contact face **1122**B to tilt backwards such that the pusher **1120**B is in a lay flat state (FIG. **67**B). A second external mechanism, either a portion of the extraction rack or a standalone device, pushes on a tab **1750** that tilts the pusher contact face **1122**B backwards to open flat for removing one or more containers **1200** from a back end **1107**B of a rack **1102**B. When the external mechanisms are removed, springs force the pusher contact face **1122**B and sliding plate **1755** back into their original, upright pushing positions as shown in FIGS. **65**A-B.

Turning now to FIGS. **68-71**B, in implementations, a flow rack **1102**C comprises a manually operated pusher for advancing one or more containers out of the array **1100**C. In implementations, each flow rack **1102**C comprises a manually pulled rope extending between a front end **1105**C to a back end **1107** of a flow rack **1102**. As the delivery person **10** pulls the rope **1765**, slack is taken up by a dedicated spool **1760***a-b*, **1762***a-c*, **1764***a-b* (FIG. **69**). A delivery person **10** is able to manually pull one container **1200** at a time off the end of the rack **1102** as the containers thereon roll on the flow wheels **1767***a-b* running the length of the rack LF.

As described previously with regard to implementations, the plurality of boxes **1200***a-n* in a rack can be advanced to a front end **1105** by a pusher pushing the plurality of boxes along rotating wheels. Alternatively, in implementations, each one of the plurality of racks in an array comprises a bidirectional driven conveyor **1780** that can be driven forward and in reverse to advance one or more containers **1200** thereon toward one or the other of a front end **1105**C and back end **1107**C for unloading. The conveyor **1780** can be driven by a motor in operable communication with the controller **1005**. In implementations, the delivery person **10** can operate one or more conveyors upon request. For example, during unloading of containers of dirty laundry into a factory for laundering, the controller can rotate some or all of the conveyors in an array upon receiving a request to empty come or all of the racks onto a receiving conveyor, rack, or array of conveyors or racks. Although a conveyor may not comprise a pusher for pushing one or more containers along the conveyor, in implementations, the conveyor **1780** comprises an immobile backstop (not show) at the back end **1107**C for preventing one or more containers **1200** thereon from falling off the back end **1107**. In implementations, the back stop comprises at least one of a rail, a wall, or an bar configured to interfere with a back surface of the rear most container on the conveyor.

As shown in FIGS. **74**A-**75**B, in implementations, a chain driven pusher bar **1805** can advance one or more containers off a front end **1105**E of a flow rack. In implementations, a pair of side mounted chains **1810***a-b* run the length of the rack LF. At a back end **1107**E, each chain **1810** takes a 90 degree turn. The pusher bar **1805** is configured to ride on the side mounted chains **1810***a-b* driven simultaneously by single motor **1806** on the bottom of the rack **1102**E. In implementations, the delivery person **10** can operate the motor **1806** at the push of a physical button located at least one of on the flow rack **1102**E and a touch screen button displayed on a user interface screen in wired or wireless communication with the controller **1005** for operating the motor **1806**. In implementations, a single button is configured to operate the motor **1806** of every rack in an array to move the pusher bar **1805** of each rack to the back end **1107** when loading containers **1200** into the rack **1102**E. In implementations, the bar drops down below level of the container at the push of a single button during loading and unloading at the back end **1107**E of the rack **1102**E at a laundry facility. In implementations, when unloading containers at a washing factory housing the one or more process lines **100**, **100***a-c* (e.g., laundry facility), no eject mechanism pushes the containers out from the other side. In implementations, when unloading contains at a laundry facility, a spring loaded eject mechanism pushes one or more containers off each rack. Alternatively, an operator and/or the delivery person remove the containers from the rack **1102**E with an extraction arm. In some implementations, the array of flow racks **1102**E comprises a pick to light system. In other implementations, the rack is used with an elevator **1400**.

As shown in FIGS. **76**A-**80**B, in implementations, a pair of bidirectional pusher tabs **1850***a-b* are configured to advance one or more containers off a front end **1105**F of a flow rack **1102**F during unloading by a delivery person and off the back end **1107**B during unloading into a laundry factory. Taking FIGS. **76**A and **77** together, the pair of bidirectional pusher tabs **1850***a-b* move between a rear upper position A at the back end **1107**F of the rack **1102**F, a front upper position B at the front end **1105**F of the rack **1102**F, a rear lower position C at the back end **1107**F and a front lower position D at the front end **1105**F. Only one side of the rack **1102**F is labeled for clarity however it is understood that positions A-D apply to both rails **1865***a-b* and rotating chains **1860***a-b* of the rack **1102**F. As shown in FIG. **76**B, the pair of bidirectional pusher tabs **1850***a-b* ride on corresponding rotating chains **1860***a-b* and are held in place against rails **1865***a-b* to keep each chain retained in a corresponding guide channel along the length of the rack **1102**F and the pair of the pair of bidirectional pusher tabs **1850***a-b* are configured to ride their respective chain **1860***a-b* around the bends DB at the front end **1105**F and the bends AC (FIG. **80**A) at the back end **1107**F of the rack **1102**F and raise and lower as they move from the bottom to the top and the top to the bottom of their respective chains **1860***a-b*.

As indicated in the schematic flow of FIG. **77**, the pair of bidirectional pusher tabs **1805***a-b* is configured to transit the length LF of the flow rack **1102**F in both directions, from back end **1107**F to front end **1105**F and in reverse from front end to back end **1107** during various stages of delivery and receipt at customer locations and factory unloading and factory loading at a laundry facility housing one or more process lines **100**, **100***a-c*. The pair of bidirectional pusher tabs **1805***a-b* is configured to move from position A to position B, outstretched horizontally and pushing against a rear most container in the rack **1102**F as a plurality of containers (e.g., containers of clean laundry being returned to customer locations along a delivery route) disposed on the rack **1102**F are advanced out the front end **1105**F. As one or more containers (e.g., containers of dirty laundry retrieved from customer locations) are reloaded into the rack **1102**F, the horizontally outstretched bidirectional pusher tabs **1805***a-b* are configured to be pushed back from upper position B (FIG. **79**A-B) to upper position A at the back end **1107**F of the rack **1102**F. When the dirty containers **1200***a-n* are unloaded in a factory for washing, the bidirectional pusher tabs **1805***a-b* can move from position A (FIG. **78**A-B) around the front bends AC to position C (FIG. **80**A) with the tabs dropped down in a vertical orientation so that they do not interfere with the dirty containers **1200***a-n* disposed in the rack **1102**F and transit the length LF of the rack **1102**F to position D. At position D (FIG. **80**B), the bidirectional pusher tabs **1805***a-b* round the front bends DB to upper position B at which position the bidirectional pusher tabs **1805***a-b* return to a horizontal alignment. The horizontally aligned bidirectional pusher tabs **1805***a-b* are then configured to contact a front surface of a front most container **1200** for pushing the plurality of containers disposed on the rack **1102**F off the back end **1107**F of the rack until the bidirectional pusher tabs **1805***a-b* reach the rear upper position. The bidirectional pusher tabs **1805***a-b* can then round the rear bends AC to drop the bidirectional pusher tabs **1805***a-b* to vertical and enable reloading the rack **1102**F through the back end **1107**F at the factory. In this way, the bidirectional pusher tables are able to engage with the containers selectively for pushing them off either the front or rear end of the rack **1002**F and drop down out of the way when transiting the length of an occupied rack **1102**F.

FIGS. **78**A-**80**B depict the pair of bidirectional pusher tabs **1850***a-b* at the various positions described with regard to the schematic of FIG. **77**. As described above, the pair of bidirectional pusher tabs **1850***a-b* are configured to travel the entire length of the rack **1102**F, pushing containers **1200***a-n* off the front end **1105**F during delivery to customers. They are also configured to change orientation when driven towards the back end **1107**F, swinging around and down to a lower portion of the looped chain as shown in FIG. **80**A. In this orientation, they can travel from the back end **1107**F to the front end **1105**F (as shown in FIG. **76**B) without disturbing the containers **1200***a-n* disposed on the rack **1102**F, for example during loading of containers of clean laundry at the factory for return to customers. When the pair of bidirectional pusher tabs **1850***a-b* round the bend DB at the front end **1105**F of the rack **1102**F, the pair of bidirectional pusher tabs **1850***a-b* are forced back into a horizontal pushing orientation as shown in FIG. **78**B. In this state, they can then push the one or more containers **12***a-n* backwards, ejecting them out of the back of the delivery vehicle **1000** and into the factory. Once all containers **1200***a-n* are ejected from the rack **1102**F, the bidirectional pusher tabs **1850***a-b* continue transiting around the rear bend AC at the back end **1107**F, flipping down and allowing new containers to be loaded into the rack **1102**F from the factory. Once the rack **1102**F is fully loaded, the bidirectional pusher tabs **1850***a-b* can rotate back around the back end **1107**F from position C to A and flip back to the horizontal orientation, at the ready for pushing one or more containers off the front end **1105**F during return delivery to one or more customers.

In implementations, the pair of bidirectional pusher tabs **1850***a-b* comprise a hinge comprising only a 90 degree range such that each tab **1850** drops under gravity while rounding a bend BD and AC from top to bottom positions (B to D and A to C) at the ends of the flow rack **1102**F. Each one of the pair of bidirectional pusher tabs **1850***a-b* comprises a plate **1855***a-b* that slides on corresponding rails **1865***a-b* and prevents the chain **1860** from derailing under 30 lbs of force. In implementations, the pair of bidirectional pusher tabs **1850***a-b* further comprise a roller and bearing. In implementations, the pair of bidirectional pusher tabs **1850***a-b* comprise a v-groove roller pin configured to engage with a tube disposed on each of the rails **1865***a-b*.

In implementations, a container ejection mechanism comprises of at least one of the following: (1) a parallel chain-driven or spring-driven pusher or pusher tabs applying a force backwards (e.g., in the direction from the front end **1105** to the back end **1107** of a flow rack) to unload boxes at the factory, wherein **1105** and **1107** collectively represent all implementations of racks described herein; (2) a fixed or telescoping plunger that is pushed directly by the driver against the containers during unloading; (3) a fixed or telescoping arm with active or passive grippers on the end, that arm reaching into the truck transport volume from the rear vehicle and being grounded at a loading station (e.g. loading dock); and (4) a truck ramp that tilts the truck so that gravity pulls the boxes out.

Table 1 presents implementations of possible combinations of at least one manual and motorized flow racks, an elevator, a container eject mechanism, and a pusher drop down. Figure numbers referenced in Table 1 comprise example implementations, and the combinations herein are exemplary and non-exhaustive:

TABLE 1

	Rack pusher/puller	Compatible with elevator?	Compatible with Spring eject?	Compatible with pusher drop-down?	forward motion	reverse motion
Motorized	Spring-actuated (FIGS. 37-45, 47-48B)	Y	Y	Y	spring pulls pusher	motor reels in pusher
	belt-driven (FIGS. 72A-73B)	Y	N	N	motor-driven belt	motor-driven belt
	top/bottom chain with pusher (FIGS. 11-14B, 55-57B)	Y	Y	Y	motor-driven chain (or belt, shaft, etc.)	motor-driven chain (or belt, shaft, etc.)
	side chain with crossbar (FIGS. 74A-75B)	Y	Y	N	motor-driven chain	motor-driven chain
	side chain with tab (FIGS. 76A-77B)	Y	N	N	motor-driven chain	motor-driven chain
Manual	Spring-actuated (FIGS. 37-45, 47-48B)	N	Y	Y	spring pulls pusher	operator pushes on boxes
	top/bottom chain with pusher (FIGS. 11-14B, 55-57B)	N	Y	Y	crank-driven chain (or belt, shaft, etc.)	crank-driven chain (or belt, shaft, etc.)
	side chain with crossbar (FIGS. 74A-75B)	N	Y	N	crank-driven chain	crank-driven chain
	side chain with tab	N	N	N	crank-driven	crank-driven

TABLE 1-continued

Rack pusher/puller	Compatible with elevator?	Compatible with Spring eject?	Compatible with pusher drop-down?	forward motion	reverse motion
(FIGS. 76A-77B)				chain	chain
pull rope (FIGS. 68-71B)	N	Y	Y	operator pulls pusher w rope	operator pushes on boxes

Referring now to FIG. **30**, any of the examples and implementations described previously with regard to an autonomous racking and elevator system **1300** are applicable to implementations described herein with regard to a method **1900** of autonomously unloading a container **1200** containing one or more clean or dirty deformable articles **12**. Any of the methods described hereinafter are applicable in combination with any and all of the processes, devices, and systems described previously with regard to implementations mechanically compatible with an elevator **1400**.

In implementations, a method **1900** of autonomously unloading one or more containers **1200** of deformable laundry articles from an array of racked containers disposed within a truck transport volume comprises receiving **51905**, at a controller **1005**, a request for retrieving a container **1200***a* having a mechanical, software tagged, and/or machine-readable identifier. In implementations, the identifier is at least one of a data marker stored in software and a detectable identifier configured to be detected and communicated to the controller via output signal of a sensor disposed on the one or more racks of the array. In implementations, the controller is in operable communication with a memory storing one or more identifiers and associated rack column and row positions within the array **1100**, a drive of a plurality of pushers each positioned at one of a plurality of rows **1110***a-c*, an elevator drive configured to raise and lower a receiving surface **1407** of an elevator **1400**, and one or more transverse drive rollers **1450** configured to move a container across the receiving surface in alignment with the rack columns. The method comprises identifying **1910** from the memory a rack and row position of the requested container **1200***a* within the array. The method comprises determining S**1915** whether the identified rack and row position is at a front of the array, in a column adjacent the elevator.

Upon determining the identified rack and row position of the requested container **1200***a* is adjacent to the elevator **1400**, the method comprises opening S**1920** a stop gate **1130**, instructing S**1925** the unloading pusher of the identified row to push the container **1200***a* from the identified row and column position onto the elevator receiving surface. Optionally the stop gates close **51930** once the container **1200***a* is no longer supported by the identified row **1110**. As previously described with regard to implementations, the controller **1005** is configured to receive one or more signals from a presence sensor disposed at least one of on and adjacent the receiving surface of the elevator **1400** for detecting a presence of a container on the receiving surface, the presence sensor outputting a signal to the controller via a communication network. The communication network is at least one of wired and wireless.

The method comprises detecting S**1935** a container column position on the elevator. The method comprises advancing **51940** the container to a discharge column if not already there. The method comprises lowering S**1945** the elevator to a transfer level and instructing S**1450** one or more transfer rollers **1450** to roll the requested container **1200***a* out a discharge orifice **1060** (e.g., vehicle side access portal **1060**). In implementations, the receiving surface **1407** of the elevator **1400** is below a lowest support surface of the array during alignment with the discharge orifice **1060**. Once the requested container **1200***a* is discharged from a vehicle transport volume, the method comprises determining **51455** whether delivery is complete to the household or whether more containers are disposed on the array for delivery to the household. If delivery is complete the controller **1005** can send S**1460** a signal to the memory that the requested container is delivered and update the row and column positions (e.g., dwell positions) corresponding to one or more remaining containers in the array.

In implementations, if the controller determines S**1915** the requested container **1200***a* is not at the front of the array, the controller **1005** can execute one or more iterations of a reshuffling subroutine to move one or more blocking containers off the array, onto the elevator, and back onto the array at various new positions within rows having extra space for receiving the one or more blocking containers blocking the requested container from reaching the front of the array **1100**. The reshuffling routine comprises identifying S**1965** one or more open positions by a column and row location (dwell position) within the array, instructing a row pusher drive to push S**1970** the one or more blocking containers onto the elevator **1400**, and instructing S**1975** an unloading pusher of a row identified as having extra space for receiving the one or more blocking containers to move backward to receive the one or more blocking containers from the elevator **1400**. In implementations, the method comprises opening the stop gate prior to receiving the one or more blocking contains into the row identified as having extra space. The method comprises aligning S**1980** the elevator receiving surface with the row (e.g., receiving rack) identified as having extra space for receiving the one or more blocking containers.

The method comprises determining S**1985** whether each one of the one or more blocking containers received onto the elevator is in columnar alignment with the row identified as having extra space. If necessary, the method comprise instructing a transfer roller drive to transit the one or more blocking containers into alignment with a column corresponding to that of the row identified as having extra space before instructing a loading pusher **1410** of the elevator to push a blocking container off of the elevator and onto the row identified as having extra space. In implementations, the method then returns to determining S**1915** whether the requested container is at the front of the array. If so, the method proceeds to unload the container and if not, the method will execute another iteration of the reshuffling routine.

As described previously with regard to implementations, one or more elevator position sensors are configured to detect a vertical location of the movable carriage **1405** and output a position signal. In implementations, as shown in FIGS. **21**A-**21**B, the elevator **1400** comprises a plurality of loading pushers **1410***a-c* (individually, loading pusher **1410**), each one of which is aligned with one of the plurality of columns **1115***a-c* and configured to push a container **1200** from the movable carriage **1405** onto one of the aligned plurality of columns **1115**, **1115***a-c* of the array **1100**. In implementations, the elevator **1400** comprises a plurality of loading pusher drives **1411***a-c* (see FIG. **36**). Each one of the loading pusher drives is in operable communication with one of the plurality of loading pushers drive motors **1423***a-c* (FIG. **29**) for moving the corresponding one of the loading pushers **1410***a-c* toward the front end **1105** of the array of flow racks **1100** to load a container **1200** into the array **1100**. The controller **1005** thus is in operable communication with a plurality of unloading pusher drive motor **1123** for the unloading pushers **1120***a-i*, the plurality of loading pusher drives **1402**, the drive motor **1455** of the movable carriage **1405**, and the one or more elevator position sensors **1413**. The controller **1005** is configured to instruct the drive motor **1455** to move the movable carriage **1405** to align the carriage support surface **1407** with one of the plurality of rows **1110***a-c*, receive the position signal, and determine whether the carriage support surface **1407** is aligned with the one of the plurality of rows **1110***a-c* for at least one of receiving and delivering a container **1200**.

In addition to the method **1900** of autonomously unloading one or more containers from an autonomous racking and elevator system **1300**, the devices, systems, and methods herein additionally or alternatively comprise loading and unloading rigid containers **12***a-n* of laundry articles into and out of a plurality of densely packed racks **1102** without an elevator. These methods apply to any of the racks previously described with regard to implementations. In implementations, the densely packed racks are disposed in a dense array **1100** within the vehicle transport volume **1035**, and the controller **1005** is configured to identify an unloading position at each customer location along a delivery route as described previously with regard to implementations. In addition to unloading one or more specific customer containers for delivery along a travel route, methods comprise unloading containers of dirty laundry articles from the densely packed racks **1102** in the vehicle transport volume **1035** into a laundry facility (e.g., factory housing one or more process lines **100**, **100***a-c*).

The racks **1102** of the array **1100** enable dense packing of a plurality of containers **1200** within a vehicle transport volume **1035** while allowing for ergonomic and swift access to one or more containers in the array. In implementations, the racks in an array **1100** comprise any of the sensors previously described with regard to implementations for detecting dwell positions of one or more containers and a status of the individual container positions as containers are loaded and unloaded from one or more racks, repositioning the remaining containers thereon. Additionally or alternatively, in implementations, a delivery person **10** interacts with at least one of a physical button disposed on one or more racks and a touch screen button on a user interface to communicate with the controller upon adding or removing a customer container from the array **1100**. The delivery person can indicate a number of boxes added or removed, the rack location, and the customer identifier (e.g., at least of a name, address, unique customer identification number, etc.). The racks **1102** are configured to secure the containers during transport, loading, and unloading without a delivery person having to do more than open and close a gate at the front end **1105**. This includes securing the containers after an arbitrary set of boxes has been removed, and as mechanical disturbances shake the racks, such as a vehicle hitting potholes during transit. The racks **1102** are also designed to operate within a range of orientations, including when tilted backwards and forwards up to 15 degrees or to either side, such as when a delivery vehicle is on a slope. Implementations of the racks **1102** therefore enable uninterrupted constraint and securing of the containers thereon without the added time and physical effort associated with tie downs and straps between interactions with the racks **1102**.

For example, in implementations, removing a container **1200** from one or more of the implementations of racks **1102** described herein comprises a delivery person **10** entering the transport volume **1035** of a delivery vehicle **1000** at the front of the array **1100** of racks **1102** densely mounted within the transport volume for maximum holding capacity of a plurality of rigid containers. In implementations, as previously described the rigid containers **1200** comprise two or more uniform dimensions comprising at least a length and width defining a footprint area of the containers. In implementations, the controller **1005** is in operable communication with a pick light system installed in the transport volume for identifying which rack or racks from which one or more containers **1200** should be removed for delivery. The pick to light system can comprise at least one of lights, alphanumeric displays and bottoms collocated and disposed at the front ends **1105** of the racks **1102** in an array **1100**. For example, the controller **1005** can illuminate a light at the end of a rack **1102** and display a number of containers to remove from the front end **1105** for delivery to a customer at the currently entered or detected (e.g., GPS) location along a travel route. While the densely packed array **1100** enables securely retaining and transporting a plurality of containers **1200** associated with specific ones of a plurality of customers, the controller-assisted picking system reduces or eliminates opportunities for a delivery person to retrieve an incorrect container for delivery to a customer to whom the container does not belong. Additionally, in implementations of wheeled flow racks **1102**, the wheels enable quick and efficient loading and unloading off the front end **1105** when a container is guided off or on by a delivery person.

With a racks identified as containing the container or containers destined for a current delivery location, the delivery person opens the gate or gates **1130**, **1132**, **1730**, retrieves a front container, and advances a pusher **1120** to slide one or more remaining containers forward on the rack. The delivery person **10** will repeat these steps until all identified customer containers associated with a delivery location are retrieved for delivering to a customer's door. The delivery person then closes the gate or gates **1130**, **1132**, **1730**, and advances the pusher **1120** until a front most container of the remaining containers in the rack is flush with the gate.

Similarly, in implementations, the racks **1102** herein described with regard to implementations enable a delivery person to load one or more containers (e.g., containers of retrieved dirty laundry articles) into one or more racks **1102** in a densely packed array **1100** within a transport volume **1035**. In implementations, loading a container into a rack **1102** comprises moving a pusher **1120** of the rack **1102** back one space such that the pusher is spaced apart from a container closes to the back end **1107** by a distance of at least one container depth (e.g., width dimension parallel to the length of the flow rack LF). In implementations the delivery person **10** pushes on the front container of the rack to move the one or more containers on the rack back to the pusher, making room for another container loaded thereon. The delivery person then inserts the container and repeats these steps until all containers are loaded into the rack **1102**. The delivery person **10** then closes the gate **1130**, **1132**, **1730** to retain the containers **1200***a-n* on the rack **1102** during transport within the vehicle transport volume **1035**, preventing them from sliding, rolling, bouncing off the front end **1105**.

In implementations described herein, densely packed comprises a state of maximized occupancy of the plurality of containers **1200** within the vehicle transport volume. In implementations, as described previously with regard to implementations, each densely packed rack **1102** in an array **1100** of racks **1102** shares one or more structural support members with at least three other racks **1102** such that the tiers of racks are interconnected without free space therebetween. One or more of the structural support members is secured to one or more structural support beams or surfaces of the transport volume **1035** such that the array **110** is secured to prevent sliding, rotation, leaning or other structural compromise with loading, unloading, and transport within a moving vehicle **1000** along a delivery and pick up route. In addition to the array **1100** comprising densely packed tiers of racks, the racks **1102** in an array are also densely packed with one or more containers thereon comprising small (e.g., less than 5 cm) or no gaps between dwell locations along the length of the rack **1102** as described previously with regard to implementations.

As previously described with regard to implementations, each of the racks **1102** comprises a range of between about 5-15 dwell positions configured to receive and retain a corresponding 5-15 containers **1200** thereon. In implementations, each one of the plurality of containers **1200** weighs between about 5 to 50 lbs. In implementations, each one of the plurality of containers weighs about 30 lbs. In implementations, a collective maximum weight of a plurality of containers **1200***a-i* disposed on the array of flow racks **1100** is in a range of between about 50 to 100 percent of the weight of a structure defining the array of flow racks **1100**. In examples, each one of the plurality of containers **1200***a-i* comprises outer envelope dimensions of at or around 12 inches by 22 inches by 14 inches. The flow racks **1102** are therefore designed such that a delivery person can easily lift each of the filled containers from the racks in an array in accordance with ergonomic lifting practices for delivery persons.

Returning now to the methods of loading and unloading the racks **1102** described previously with regard to implementations, a method of unloading one or more racks of an array **1100** at a laundry facility comprises emptying containers **1200***a-n* out a back end of a delivery vehicle **1000** and therefor off a back end **1107** of one or more racks **1102** in an array **1100** within the vehicle transport volume **1035**. In implementations, a delivery person backs the vehicle **1000** into a loading dock or dock house at the laundry facility and opens rear doors of the vehicle. The delivery person or a facility operator aligns an extraction unit (e.g., a racking system, conveyor, flow rack, etc.) into alignment with the back of the vehicle and engages the extraction unit with the array **1100** to automatically actuate one or more pushers of the array to lower to a lay flat state or otherwise move to expose the back end **1107** of the rack **1102**. Alternatively, a delivery person or facility operator can manually disengage the one or more pushers to lower them to a lay flat state.

With the pushers no longer blocking the back end **1107** of each rack **1102** in an array **1100**, an eject mechanism (e.g., of bidirectional pusher tabs **1850***a-b*) pushes containers **1200** out of the one or more racks **1002** into an extraction unit. Additionally or alternative, as described previously with regard to implementations, (e.g., FIGS. **45-46**) no eject mechanism is required and the plurality of racks are configured to be unloaded by at least one of tilting the delivery vehicle on an incline at an unloading dock and pushing on a front end of the containers in an array with hands or a tool to unload the containers from the array. Once all containers are unloaded from the one or more racks, new containers are pushed into the racks **1102** in the array for outgoing delivery, forcing the eject mechanisms to move back if necessary. Once the racks are loaded for outgoing delivery, the pushers **1120** of the racks in an array are either manually or automatically raised and returned to a resting, upright position. The one or more pushers can be spring loaded, for example. The extraction unit and or loading unit retracts back into the facility and the delivery person closes the doors on the rear of the vehicle. Additionally, in implementations, the delivery person adjusts the one or more pushers **1120** such that the rear most container on a rack is in contact with the pusher of that rack regardless of whether the rack is fully loaded thereby ensuring a container being pushed to the front position of each rack in an array for minimizing reach required to extract each container at a delivery location along a delivery route.

All of the methods and tasks described herein may be performed and fully automated by a computer system. The computer system may, in some cases, include multiple distinct computers or computing devices (e.g., physical servers, workstations, storage arrays, etc.) that communicate and interoperate over a network to perform the described functions. Each such computing device typically includes a processor (or multiple processors or circuitry or collection of circuits, e.g., a module) that executes program instructions or modules stored in a memory or other non-transitory computer-readable storage medium. The various functions disclosed herein may be embodied in such program instructions, although some or all of the disclosed functions may alternatively be implemented in application-specific circuitry (e.g., ASICs or FPGAs) of the computer system. Where the computer system includes multiple computing devices, these devices may, but need not, be co-located. The results of the disclosed methods and tasks may be persistently stored by transforming physical storage devices, such as solid state memory chips and/or magnetic disks, into a different state.

Although the subject matter contained herein has been described in detail for the purpose of illustration, it is to be understood that such detail is solely for that purpose and that the present disclosure is not limited to the disclosed embodiments, but, on the contrary, is intended to cover modifications and equivalent arrangements that are within the spirit and scope of the appended claims. For example, it is to be understood that the present disclosure contemplates that, to the extent possible, one or more features of any embodiment can be combined with one or more features of any other embodiment.

Other examples are within the scope and spirit of the description and claims. Additionally, certain functions described above can be implemented using software, hardware, firmware, hardwiring, or combinations of any of these.

Features implementing functions can also be physically located at various positions, including being distributed such that portions of functions are implemented at different physical locations.

What is claimed is:

1. An autonomous racking system for use with a mobile delivery vehicle, comprising an array of a plurality of flow racks comprising:

a plurality of rows each comprising two or more side-by-side flow racks and a plurality of columns each comprising two or more stacked flow racks, each one of the flow racks of the array of flow racks configured to receive thereon a plurality of containers each one of which is associated with a household,

a plurality of unloading pushers, each one of the plurality of unloading pushers being disposed at a back end of one or more of the plurality of containers disposed on each of the flow racks the array and being configured to push each one of the plurality of containers past a front end of the array of flow racks, and

a plurality of unloading pusher drives, each one of the unloading pusher drives being in operable communication with one of the plurality of unloading pushers for moving a corresponding one of the unloading pushers toward the front end of the array of flow racks;

a plurality of rollers disposed continuously along a length of each one of the flow racks in the array of flow racks, the plurality of rollers being configured to roll one or more of the plurality of containers disposed thereon toward the front end;

an elevator abutting the front end of the array and configured to receive one or more containers from at least one or more of the plurality of flow racks and a vehicle side access orifice, and deliver one or more containers to one or more of the plurality of flow racks, the elevator comprising

a movable carriage, the movable carriage extending across the plurality of columns and being in operable communication with an elevator drive motor configured to move the carriage up and down to align a carriage support surface with at least of one of the plurality of rows and a lower edge of the vehicle side access orifice disposed in a range of between about 0.25 to 2.25 meters from a ground upon which the delivery vehicle is disposed,

one or more elevator position sensors configured to detect a vertical location of the movable carriage and output a position signal,

a plurality of loading pushers, each one of the plurality of pushers being aligned with one of the plurality of columns and being configured to push a container off of the movable carriage and onto one of the aligned plurality of columns, and

a plurality of loading pusher drives, each one of the loading pusher drives being in operable communication with one of the plurality of loading pushers for moving the corresponding one of the loading pushers toward the front end of the array of flow racks; and

a controller in operable communication with plurality of unloading pusher drives, the plurality of loading pusher drives, the drive motor of the movable carriage, and the one or more elevator position sensors, wherein the controller is configured to

instruct the drive motor to move the movable carriage to align the carriage support surface with one of the plurality of rows,

receive the position signal, and

determine the carriage support surface is aligned with the one of the plurality of rows.

2. The system of claim **1**, wherein the controller is further configured to

instruct a drive of the one of the plurality of unloading pushers associated with the aligned one of the plurality of rows and one of the plurality of columns to retract by a distance equal to a depth of a container, and

instruct a drive of an opposing one of the one of the plurality of loading pushers associated with the one of the plurality of columns to advance the one of the plurality of loading pushers to the front end of the array.

3. The system of claim **1**, wherein the controller is further configured to

instruct a drive of the one of the plurality of unloading pushers associated with the aligned one of the plurality of rows and one of the plurality of columns to advance by a distance equal to a depth of a container.

4. The system of claim **1**, wherein the plurality of rollers are interconnected to rotate simultaneously.

5. The system of claim **1**, wherein the plurality of rollers are configured to rotate under an application of pushing force from an associated one of the plurality of unloading pushers.

6. The system of claim **1**, wherein the array comprises a length extending substantially parallel to a length of a transport volume of the delivery vehicle and a width extending substantially perpendicular to the length of the transport volume and substantially parallel to one or more vehicle wheel axles.

7. The system of claim **6**, wherein the movable carriage comprises a longitudinal axis substantially perpendicular to the length of the transport volume and substantially parallel to the one or more vehicle wheel axles, and wherein each flow rack of the array of flow racks is interlinked by at least one shared structural beam along the length of the array with at least one other adjacent flow rack of the array of flow racks.

8. The system of claim **1**, wherein each flow rack of the array of flow racks further comprises a movable stop gate disposed at the front end.

9. The system of claim **1**, wherein each one of the plurality of unloading pushers comprises a contact face configured to engage a back wall of a container disposed at the back end of the one or more of the plurality of containers disposed on each of the flow racks the array.

10. The system of claim **9**, wherein the contact face is configured to enter the elevator upon pushing the container disposed at the back end of a plurality of containers on a flow rack onto the elevator.

11. The system of claim **1**, wherein each one of the plurality of unloading pusher drives comprises a motor, and wherein each one of the motors comprises an operably linked encoder in communication with the controller, the encoder configured to output a signal indicative of pusher position between the front end and the back end.

12. The system of claim **1**, wherein each one of the plurality of flow racks of the array of flow racks comprises a length extending parallel to a length of a transport volume of the delivery vehicle, wherein each one of the flow racks comprises a plurality of container positions along the length each configured to receive one of the plurality of containers, and wherein the plurality of container positions comprises a range of between about 5 to 15 positions.

13. The system of claim **12**, wherein each one of the plurality of containers comprises a matching bottom surface

length and width, wherein each one of the plurality of containers is associated with a single customer, and wherein the array of flow racks is configured to receive one or more containers associated with one or more of a plurality of customers.

14. The system of claim **13**, wherein the controller is further configured to record in a memory in wired or wireless communication with the controller each location in the array of flow racks of one or more containers associated with each one of the plurality of customers, and wherein the controller is further configured to record in the memory which one or more containers have been unloaded from the array of flow racks along a route transited by the delivery vehicle.

15. The system of claim **13**, wherein each of the containers comprises an identification marker for associating with one of a plurality of customers.

16. The system of claim **15**, wherein the identification marker comprises at least one of a machine-readable serial number, a machine-readable barcode, a machine-readable QR code, an RFID code, and a NFC tag.

17. The system of claim **16**, further comprising one or more identification sensors disposed on at least one of the array, the elevator, and the vehicle side access orifice, the one or more sensors being configured to detect the identification marker and output a signal to the controller indicative of the identification marker associated with a customer.

18. The system of claim **1**, wherein each container of the plurality of containers is rigid and reusable.

19. The system of claim **1**, further comprising one or more presence sensors for detecting at least one of the loading and unloading of one or more of the plurality of containers onto at least one of the elevator and the array of flow racks, and wherein the one or more sensors comprise at least one of an IR break beam sensor, an encoder, a limit switch, and a Hall-effect sensor, and wherein the one or more sensors is disposed at least one of at the vehicle side access orifice, the front of each flow rack in the array of flow racks, and at each container dwell position along a length of each flow rack in the array of flow racks.

20. The system of claim **1**, wherein the elevator further comprises a plurality of bidirectionally driven transfer wheels disposed at a transfer level and configured to move one or more containers across a width of the vehicle in a travel direction comprising at least one of travel from the elevator to the vehicle side access orifice and travel from the vehicle side access orifice onto an elevator position aligned with one of the plurality of columns.

21. A method of autonomously unloading a container from an ordered array of racked containers disposed with in a truck transport volume, comprising:

- receiving at a controller a request for retrieving a container comprising an identifier, the controller being in operable communication with a memory storing one or more identifiers and associated rack column and row positions within the array, a drive of a plurality of pushers each positioned at one of a plurality of rows, an elevator drive configured to raise and lower a receiving surface, and one or more transverse drives configured to move a container across the receiving surface in alignment with the rack columns;
- identifying from the memory a rack and row position of the requested container;
- determining whether the identified rack and row position is adjacent the elevator receiving surface;
- instructing a stop gate to open upon determining the identified rack and row position is adjacent the elevator receiving surface,
- instructing a drive of a pusher of the plurality of pushers that is associated with the row position to advance the requested container from the identified column and rack position onto the receiving surface of the elevator;
- determining whether the identified column is adjacent an orifice of a truck transport volume;
- instructing an elevator to lower the receiving surface to alignment with the orifice upon determining the identified column is adjacent the orifice; and
- instructing the one or more transverse drives to advance the container through the orifice.

22. The method of claim **21**, further comprising closing the stop gate once the requested container is received onto the receiving surface of the elevator.

23. The method of claim **22**, wherein the controller is configured to receive one or more signals from a presence sensor disposed at least one of on and adjacent the receiving surface for detecting a presence of a container on the receiving surface, the presence sensor outputting a signal to the controller via a communication network.

24. The method of claim **23**, wherein the communication network is at least of wired and wireless.

25. The method of claim **21**, further comprising storing a datum in the memory indicative of the requested container being delivered to an associated household.

26. The method of claim **25**, furthering comprising updating in the memory updated row and column positions of one or more other containers in the row.

27. The method of claim **21**, further comprising determining whether delivery is complete and iterating, and if not complete, identifying column and row position of a next container.

28. The method of claim **27**, wherein if the controller determines the requested container is not adjacent the receiving surface, the method further comprises reshuffling one or more other containers within the array by identifying open spots in the array and pushing the one or more other containers off and onto the array via the elevator to occupy one or more rows comprising the identified open spots in the array.

29. The method of claim **28**, further comprising identifying row and column positions of one or more open container positions within the array.

30. The method of claim **21**, wherein the receiving surface of the elevator is below a lowest support surface of the array during alignment with the orifice.

31. The method of claim **21**, wherein the identifier is at least one of a data marker stored in software and a detectable identifier configured to be detected communicated to the controller via output signal of a sensor disposed on the one or more racks of the array.

32. A system of interconnected vehicle racks for receiving, constraining, and disgorging a plurality of customer containers from front and back ends of a vehicle transport volume, each rack comprising:

- a support surface configured to receive and transit a plurality of containers thereon between a back end of the rack and a front end of the rack;
- a movable pusher disposed at the back end of the rack, the movable pusher being configured to engage a back surface of a rear most container disposed on the surface and move bidirectionally between the back end and the front end;

a plurality of rollers disposed continuously along the support surface, the plurality of rollers being configured to roll one or more of the plurality of containers disposed thereon toward the front end; and

at least one selectively deactivated stop gate disposed at a front of the rack for engaging a front surface of a front most container disposed on the surface, the stop gate configured to retain one or more containers on the support surface.

33. The system of claim **32**, wherein a container is configured to be loaded and unloaded out either the front or the back end of the rack without disrupting an order of one or more containers disposed on the support surface.

34. The system of claim **32**, wherein the movable pusher and the stop gate are configured to constrain one or more containers on the support surface and maintain an order of the one or more containers during loading, transport, and unloading out either of the front end or back end.

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