



EUROPEAN PATENT APPLICATION

(43) Date of publication:
07.06.2017 Bulletin 2017/23

(51) Int Cl.:
B65H 3/12 (2006.01) **B07C 1/04** (2006.01)
B65H 3/46 (2006.01) **B65H 3/52** (2006.01)
B65H 3/54 (2006.01)

(21) Application number: **16197418.3**

(22) Date of filing: **11.03.2014**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR

(30) Priority: **12.03.2013 US 201313797731**
12.03.2013 US 201313797698
12.03.2013 US 201313797291
13.03.2013 US 201313801749
14.03.2013 US 201313827122

(62) Document number(s) of the earlier application(s) in accordance with Art. 76 EPC:
14779918.3 / 2 969 267

(71) Applicant: **United States Postal Service**
Washington, DC 20260-1135 (US)

(72) Inventors:
• **BROWN, John, W.**
Manassas, VA Virginia 20110-7906 (US)
• **HOUSTON, Edward, F.**
Bristow, VA Virginia 20136 (US)
• **ROMAN, Juan, A.**
Fairfax, VA Virginia 22030 (US)
• **SHIU, Leung, M.**
Gaithersburg, MD Maryland 20878-7812 (US)
• **MAYHALL, Riley, H.**
Germantown, MD Maryland 20874 (US)
• **MCCONNELL, William, P.**
Woodstock, MD Maryland 21163 (US)

- **GOOD, Matthew, G.**
Eldersburg, MD Maryland 21784 (US)
- **HUME, Robert, E.**
Woodstock, MD Maryland 21163 (US)
- **HILLERICH, Thomas, A.**
Louisville, KY Kentucky 40299 (US)
- **HA, Long, K.**
Washington, DC District of Columbia 20260-1135 (US)
- **TIMM, Jacob, L.**
Pasadena, MD Maryland 21122 (US)
- **BADRI, Reza**
Towson, MD Maryland 21286 (US)
- **SCHLENDER, Robert, L.**
Columbia, MD Maryland 21045 (US)
- **AUSTIN, Christopher, D.**
Parkville, MD Maryland 21234 (US)
- **DICKEY, Darin**
Owings Mills, MD Maryland 21117 (US)

(74) Representative: **Freeman, Jacqueline Carol**
WP Thompson
138 Fetter Lane
London EC4A 1BT (GB)

Remarks:

This application was filed on 04-11-2016 as a divisional application to the application mentioned under INID code 62.

(54) **SYSTEM AND METHOD OF AUTOMATIC FEEDER STACK MANAGEMENT**

(57) Embodiments of a system and method for singulating articles in an automatic stack feeder are disclosed. The automatic stack feeder has a plurality of belts (120) and at least one paddle (150, 160), a vacuum powered singulation device (140) and a sorting section (180). The automatic stack feeder receives a stack of flats from a container (190), moves the stack along the belts toward the vacuum powered singulation device, and the stack is singulated and sorted.

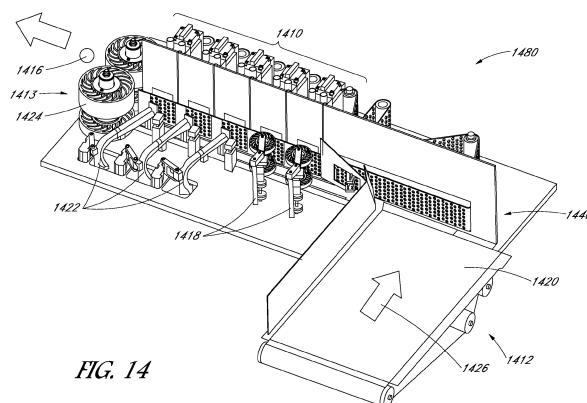


FIG. 14

Description

CROSS REFERENCE TO RELATED APPLICATIONS

5 **[0001]** This application claims priority to and the benefit of U.S. Application Nos. 13/797,291, filed March 12, 2013, entitled SYSTEM AND METHOD OF AUTOMATIC FEEDER STACK MANAGEMENT; 13/797,731, filed March 12, 2013, entitled SYSTEM AND METHOD OF UNLOADING A CONTAINER OF ITEMS; 13/797,698, filed March 12, 2013, entitled ARTICLE FEEDER WITH A RETRACTABLE PRODUCT GUIDE; 13/801,749, filed March 13, 2013, entitled ANTI-ROTATION DEVICE AND METHOD OF USE; and 13/827,122, filed March 14, 2013, entitled SYSTEM AND METHOD
10 OF ARTICLE FEEDER OPERATION.

BACKGROUND OF THE DEVELOPMENT

Field of the Development

15 **[0002]** The disclosure relates to the field of automatic feeding and sorting of items. More specifically, the present disclosure relates to an automatic stack feeder which can shingulate, singulate, and sort articles obtained from a bulk stack and/or from a container, and has a retractable product guide.

Description of the Related Art

20 **[0003]** Articles, such as items of mail, are frequently provided in bulk and must be sorted into individual articles or items for processing or routing. This sorting into individual items, or singulation, can be done automatically by placing a bulk stack of items or articles into a feeder. However, frequently, articles to be sorted are flimsy and must be supported
25 while in the feeder. If the stack of articles in the feeder is not positioned correctly, or if it slumps, the singulation process may be slowed down or hampered with errors, such as picking more than one article at a time. Articles are often provided in bulk containers, whose contents or fullness can be difficult to predict. As containers are unloaded onto a sorting apparatus, the articles both on the sorting apparatus and in the container may slump, or fall into a position which is not ideal for singulation. The containers are deposited onto a conveyor belt of an automatic stack feeder, and are positioned
30 flush with the stack guide. The containers have a sidewall of a certain thickness, and when the stack of articles is unloaded from the container, due to the thickness of the container's sidewall, the stack of articles may not be in contact with the stack guide.

[0004] The singulated articles may be sorted into various sorter windows on the feeder. Sorters operate at high speeds and produce available sorter windows for insertion of articles at a high rate. An article feeder may not properly sort the
35 articles into the various sorter windows if the article feeder operation and the sorter are not synchronized with one another. Furthermore, damage to the articles and selection of more than one article in the singulation process, or double feeding, may occur if the article feeder is not configured to operate at a high rate.

[0005] Further, during singulation or shingulation, feeders use a vacuum to exert a force on articles in the feeder. The articles are then moved along conveyor belts. This may cause a problem when sorting articles with unbound edges, as
40 the vacuum and conveyor belts operate to move different portions of the article in different directions.

[0006] Accordingly, systems and methods are needed for automatic shingulation, singulation, and sorting of articles from a bulk stack of articles to maximize article feed rate and minimize damage and double feeding. There is also a need to ensure that the stack of articles, once unloaded from the container, is able to be in contact with the stack guide, so the stack of articles can be properly supported as the stack advances along the automatic stack feeder.
45

SUMMARY

50 **[0007]** Some embodiments described herein relate to a system for managing articles in an automatic stack feeder comprising a frame configured to support a stack of articles; a perforated drive belt assembly comprising: a drive belt having an opening therein; a first end and a second end, wherein the first end of the perforated drive belt assembly is pivotably attached to the frame and the second end of the perforated drive belt assembly is pivotable about an axis of rotation defined by the attachment of the first end of the perforated drive belt assembly, and wherein the drive belt extends rotationally about the first and second ends; a conveyor connected to the frame and configured to move the stack of articles with respect to the drive belt; a sensor in proximity to the perforated drive belt assembly, the sensor
55 configured to detect a force exerted on a portion of the perforated drive belt assembly by the stack of articles; and a controller configured to receive an input from the sensor and configured to control the conveyor based on the received input.

[0008] In some embodiments, the perforated drive belt assembly comprises a vacuum unit configured to apply a

vacuum through the opening in the drive belt.

[0009] In some embodiments, the pivotable attachment of the perforated drive belt assembly comprises a spring configured to resist movement of the perforated drive belt assembly due to the force of the stack of articles.

[0010] In some embodiments, the sensor is configured to sense a pressure exerted on the perforated drive belt assembly by the stack of articles.

[0011] In some embodiments, the sensor is connected to the first end of the perforated drive belt assembly so as to sense the pressure exerted on the perforated drive belt assembly according to the movement of the second end of the perforated drive belt assembly about the axis of rotation defined by the attachment of the first end.

[0012] In some embodiments, the sensor is configured to sense angular displacement of the perforated drive assembly relative to the frame according to the force exerted by the stack of articles.

[0013] In some embodiments, the conveyor comprises a belt and a paddle, the belt and the paddle being independently moveable, and wherein the paddle is configured to provide vertical support for the stack of articles and the belt is configured to convey the stack of articles toward or away from the perforated drive belt assembly.

[0014] In some embodiments, the controller is configured to control adjustment of the position of the paddle or move the belt in response to the input received from the sensor.

[0015] In some embodiments, the system further comprises a photoelectric sensor located so as to detect an angle of the stack of articles relative to the frame.

[0016] In some embodiments, the controller is configured to receive an input from the photoelectric sensor.

[0017] Some embodiments disclosed herein relate to a method of automatic feeder stack management comprising placing one or more articles in contact with a conveyor; operating a drive belt assembly comprising a drive belt having an opening therein, wherein an end of the drive belt assembly is pivotably attached to the frame, and a free end of the drive belt assembly is rotatable about an axis of rotation defined by the attached end; sensing a force exerted on the perforated drive assembly by the one or more articles; and controlling the position of the conveyor based on the sensed force, thereby controlling the position of the stack of articles.

[0018] In some embodiments, the method further comprises singulating an article from the one or more articles using a vacuum applied to the perforated drive belt assembly.

[0019] In some embodiments, the pivotable attachment of the perforated drive belt comprises a spring which resists movement of the perforated drive belt assembly due to the force exerted by the one or more articles.

[0020] In some embodiments, sensing a force comprises sensing the pressure exerted by the one or more articles on the perforated drive belt assembly.

[0021] In some embodiments, sensing the pressure exerted by the one or more articles on the perforated drive belt assembly comprises sensing the pressure exerted on the perforated drive belt assembly according to the movement of the perforated drive belt assembly about the axis of rotation defined by the attachment of the attached end.

[0022] In some embodiments, sensing a force comprises sensing an angular displacement of the free end of the perforated drive belt assembly in reference to the frame, according to the force exerted by the one or more articles.

[0023] In some embodiments, the conveyor comprises a belt and a paddle, which are independently moveable, and wherein the belt is configured to convey the one or more articles toward or away from the perforated drive belt assembly and wherein the paddle is configured to support the stack of articles.

[0024] In some embodiments, controlling the conveyor comprises moving at least one of the belt, or the paddle to adjust the position of the one or more articles relative to the perforated drive belt assembly.

[0025] In some embodiments, the system further comprises sensing an angle of the one or more articles relative to the frame using a photoelectric sensor.

[0026] In some embodiments, the system further comprises controlling the conveyor in response to the sensed angle of the one or more articles.

[0027] Some embodiments described herein relate to a system for singulating articles comprising a frame configured to support a stack of articles; a perforated drive belt assembly; means for sensing a pressure exerted on a portion of the perforated drive belt assembly by the stack of articles; means for conveying the stack of articles toward or away from the perforated drive belt assembly; and means for controlling the means for conveying the stack of articles based on input received from means for sensing the pressure.

[0028] In some embodiments, the perforated drive belt assembly comprises a means for providing a vacuum force which attracts a lead article in the stack of articles toward the perforated drive belt assembly.

[0029] Some aspects of the present disclosure include a stack feeder comprising a frame; a singulator connected to one end of the frame; a conveyor disposed on the frame, the conveyor configured to receive a stack of articles and a container, the conveyor further configured to move the stack of articles and the container toward the singulator; a motor connected to the frame; a stack guide connected to the motor and aligned substantially parallel to the belt, wherein the stack guide comprises a continuous, surface configured to contact an edge of the stack of articles; and wherein the motor is operable to move the stack guide from a first position to a second position to accommodate receiving the container onto the conveyor.

[0030] In some embodiments, the stack feeder further comprises a sensor configured to detect the presence of the container on the conveyor; and a controller in communication with the sensor and the motor, the controller configured to control movement of the motor to move the stack guide between the first position and the second position in response to detection of the presence of the container on the conveyor.

[0031] In some embodiments, the sensor is further configured to detect the absence of the container on the conveyor, and wherein the controller is configured to control the movement of the stack guide between the second and the first positions in response to detection of the absence of the container.

[0032] In some embodiments, when the stack guide is in the first position, the stack guide is in contact with the stack of articles.

[0033] In some embodiments, when the stack guide is in the second position, the stack guide is in contact with the container and not with the stack of articles.

[0034] In some embodiments, when the presence of the container is detected, the controller is configured to control movement of the stack guide from the first position to the second position.

[0035] In some embodiments, when the absence of the container is detected, the controller is configured to control movement the stack guide from the second position to the first position.

[0036] In some embodiments, the stack guide is moveable among a plurality of positions between the first position and the second position.

[0037] In another aspect, a system for unloading a container comprises a container configured to hold articles; an automatic stack feeder comprising: a singulator; a conveyor configured to receive a first stack of articles and the container, wherein the container has a second stack of articles therein, the conveyor further configured to move the first stack of articles and the container toward the singulator; a stack guide aligned substantially parallel to the conveyor, wherein the stack guide comprises a continuous, substantially vertical surface configured to contact an edge of the first and second stacks of articles, and wherein the stack guide is moveable from a first position to a second position; a sensor configured to detect the presence of the container on the conveyor; and a controller, in communication with the sensor, and configured to control movement of the stack guide between the first position and the second position in response to the presence of the container on the conveyor.

[0038] In some embodiments, the stack guide is configured to be in contact with the first stack of articles when the stack guide is in the first position.

[0039] In some embodiments, the stack guide is configured to be in contact with the container, and not in contact with the first stack of articles, when the stack guide is in the second position.

[0040] In some embodiments, the stack guide further comprises a motor in communication with the controller, and wherein the motor is configured to move the stack guide between the first and second positions.

[0041] In some embodiments, the sensor is further configured to detect the absence of the container on the conveyor, and wherein the controller is configured to control the movement of the stack guide between the second and the first position in response to the absence of the container.

[0042] In some embodiments, when the presence of the container is detected, the controller is configured to move the stack guide from the first position to the second position.

[0043] In some embodiments, when the absence of the container is detected, the controller is configured to move the stack guide from the second position to the first position.

[0044] In some embodiments, the stack guide is moveable among a plurality of positions between the first and the second positions.

[0045] In another aspect, a method of sorting articles comprises operating a stack feeder comprising a stack guide; receiving a container having a first stack of articles therein onto a conveyor of the automatic stack feeder; detecting the presence of the container on the conveyor; moving the stack guide in response to the detected presence of the container; unloading the first stack of articles from the container; detecting the absence of the container; and moving the stack guide in response to the absence of the container.

[0046] In some embodiments, moving the stack guide in response to the detected presence of the container comprises moving the stack guide from a first to a second position.

[0047] In some embodiments, moving the stack guide in response to the absence of the container comprises moving the stack guide from the second position to the first position.

[0048] In some embodiments, unloading a second stack of articles from the container comprises: moving the first stack of articles out of the container onto the conveyor; combining the first stack of articles with a second stack of articles already on the conveyor; and removing the container from the conveyor.

[0049] In some embodiments, the method further comprises contacting the stack guide with the combined first and second stacks of articles with the stack guide in the first position.

[0050] In some embodiments, before detecting the presence of the container, the stack guide is in contact with the first stack of articles when the stack guide is in the first position.

[0051] In some embodiments, the stack guide is in contact with the container, and not in contact with the first stack of

articles, when the stack guide is in the second position.

[0052] In some embodiments, the stack guide is connected to a motor which moves the stack guide from the first position to the second position and from the second position to the first position.

[0053] Some embodiments disclosed herein relate to an automatic stack feeder. The automatic stack feeder may include a shingulating device configured to receive a stack of articles and to produce a positively lapped stack of articles, a plurality of picking devices configured to pick one or more articles from the positively lapped stack of articles and to produce one or more singulated articles, and one or more synchronization devices configured to deliver the one or more singulated articles to one or more sorter windows.

[0054] In some embodiments, the shingulating device comprises a bottom transport belt having a transport surface extending in a first direction; a shearing device; and a perforated belt having a surface extending in a second direction different than the first direction, the perforated belt being adjacent to the bottom transport belt, wherein the bottom transport belt and the perforated belt are configured to move the stack of articles toward the shearing device, and wherein the shearing device is configured to apply a shearing force on a portion of the stack of articles to produce the positively lapped stack of articles. In some embodiments, the automatic stack feeder may include a vacuum system configured to apply suction through one or more openings in the perforated belt.

[0055] In some embodiments, the shingulating device comprises a plurality of bottom transport belts, each bottom transport belt having a transport surface extending in a first direction; a shearing device; and a plurality of perforated belts, each perforated belt having a surface extending in a second direction different than the first direction and being adjacent to at least one of the plurality of bottom transport belts, wherein at least one of the plurality of bottom transport belts and at least one of the plurality of perforated belts are configured to move the stack of articles toward the shearing device, and wherein the shearing device is configured to apply a shearing force on a portion of the stack of articles to produce the positively lapped stack of articles.

[0056] In some embodiments, the each of the plurality of picking devices comprises a vertically oriented perforated belt having one or more openings in its surface, the perforated belt configured to be driven by a motor; a vacuum manifold adjacent to the perforate belt; a vacuum unit configured to apply suction through the vacuum manifold, wherein the vacuum manifold is configured to apply the suction through the one or more openings in the surface of the perforated belt; and a vacuum valve configured to control the amount of suction applied by the vacuum unit to the vacuum manifold. In some embodiments, each of the plurality of picking devices is configured to pick an article from the positively lapped stack of articles, including opening the vacuum valve and exposing the vacuum manifold to the suction from the vacuum unit, the vacuum manifold applying the suction through the one or more openings in the perforated belt to attach the article to the perforated belt; and produce a singulated article, including separating the article from the positively lapped stack of articles by driving the perforated belt with the attached article forward using the motor.

[0057] In some embodiments, the plurality of picking devices are configured in a row, wherein a downstream most picking device in the row that is substantially completely covered by the positively lapped stack of articles is configured to pick the article from the positively lapped stack of articles and to produce the singulated article.

[0058] In some embodiments, each of the plurality of picking devices is located in a respective picking zone, each respective picking zone including a picking device and an anti-doubling device opposite the picking device, the anti-doubling device configured to prevent more than one article at a time from being picked from the positively lapped stack of articles. In some embodiments, the anti-doubling device includes a presence sensor configured to detect a first article; an edge detector sensor positioned upstream from the presence sensor and configured to detect an edge of a second article; and a vacuum unit configured to apply suction to the second article when the presence sensor detects the first article during a time period in which the edge detector detects the edge of the second article. In some embodiments, the presence sensor includes a photoelectric sensor. In some embodiments, the perforated belt is driven by a single servo motor.

[0059] In some embodiments, the one or more synchronization devices includes a group of paired pinch wheels driven at a variable speed by a pinch wheel motor.

[0060] In some embodiments, the automatic stack feeder further comprises a controller configured to control movement of each article of the stack of articles to synchronize a first time when each of the one or more singulated articles reaches an exit point with a second time when a sorter window reaches the exit point. In some embodiments, the synchronization of the first time with the second time is based on one or more of a location of a first article being picked by a first picking device, a velocity of the first article, a location of the sorter window, a velocity of the sorter window, an acceleration rate of each of a plurality perforated belts included in each of the plurality of picking devices, an acceleration rate of the one or more synchronization devices, a maximum velocity allowed for each of the plurality perforated belts included in each of the plurality of picking devices, a maximum velocity allowed for a perforated belt included in the shingulating device, a maximum velocity allowed for the one or more synchronization devices, a length of each of the plurality of perforated belts included in each of the plurality of picking devices, a length of the perforated belt included in the shingulating device, a number of perforated belts, a length of the one or more synchronization devices, and a number of the one or more synchronization devices.

[0061] Some embodiments disclosed herein relate to a method of managing articles in an article feeder. The method comprises receiving a stack of articles at a shingulating device and producing a positively lapped stack of articles; picking one or more articles from the positively lapped stack of articles using one or more picking devices and producing one or more singulated articles; and delivering the one or more singulated articles to one or more sorter windows using one or more synchronization devices.

[0062] In some embodiments, producing the positively lapped stack of articles comprises moving the stack of articles toward a shearing device using a bottom transport belt and a perforated belt of the shingulating device, the bottom transport belt having a transport surface extending in a first direction and the perforated belt having a surface extending in a second direction different than the first direction; and applying a shearing force on the stack of articles using the shearing device.

[0063] In some embodiments, the method further comprises applying suction through one or more openings in the perforated belt using a vacuum system.

[0064] In some embodiments, picking the one or more articles from the positively lapped stack of articles comprises opening a vacuum valve of a first picking device to expose a vacuum manifold of the first picking device to suction from a vacuum unit; applying the suction from the vacuum manifold through one or more openings in a perforated belt of the first picking device to one of the one or more articles; and attaching the article to the perforated belt using the suction through the one or more openings. In some embodiments, producing the one or more singulated articles comprises separating an article from the positively lapped stack of articles by driving the perforated belt with the attached article forward using a motor. In some embodiments, the singulated article is picked and produced by a downstream most picking device in a row of picking devices that is substantially completely covered by the positively lapped stack of articles.

[0065] In some embodiments, the method further comprises preventing more than one article at a time from being picked from the positively lapped stack of articles using an anti-doubling device located in a respective picking zone, each respective picking zone including a respective picking device. In some embodiments, the method further comprises detecting a first article using a presence sensor of the anti-doubling device; detecting an edge of a second article using an edge detector sensor of the anti-doubling device, the edge detector sensor being positioned upstream from the presence sensor; and applying suction to the second article using the vacuum unit when the presence sensor detects the first article during a time period in which the edge detector detects the edge of the second article.

[0066] In some embodiments, the method further comprises controlling movement of each article of the stack of articles to synchronize a first time when each of the one or more singulated articles reaches an exit point with a second time when a sorter window reaches the exit point. In some embodiments, synchronization of the first time with the second time is based on one or more of a location of a first article being picked by a first picking device, a velocity of the first article, a location of the sorter window, a velocity of the sorter window, an acceleration rate of each of a plurality perforated belts included in each of the plurality of picking devices, an acceleration rate of the one or more synchronization devices, a maximum velocity allowed for each of the plurality perforated belts included in each of the plurality of picking devices, a maximum velocity allowed for a perforated belt included in the shingulating device, a maximum velocity allowed for the one or more synchronization devices, a length of each of the plurality of perforated belts included in each of the plurality of picking devices, a length of the perforated belt included in the shingulating device, a number of perforated belts, a length of the one or more synchronization devices, and a number of the one or more synchronization devices.

[0067] Some embodiments disclosed herein relate to an automatic stack feeder having a sorting section comprising a plurality of picking devices, at least one of the plurality of picking devices configured to receive a stack of articles and produce a positively lapped stack of articles; pick one or more articles from the positively lapped stack of articles and produce one or more singulated articles; and deliver the one or more singulated articles to one or more sorter windows.

[0068] The present disclosure describes devices and methods used to reduce rotation of an article during singulation of a bulk stack of articles. In some embodiments, the devices and methods disclosed herein are intended to apply a frictional force to a back surface of an article, while suction and an accelerating force are applied to a front surface of the article. In some such embodiments, the frictional force is intended to hold the article together, to resist tearing, and cause the article to move as a single, unitary article. Some embodiments disclosed herein reduce the amount of folding, tearing, or other damage experienced by articles during the article separation and sorting process.

[0069] The embodiments disclosed herein each have several innovative aspects, no single one of which is solely responsible for the desirable attributes of the invention. Without limiting the scope, as expressed by the claims that follow, the more prominent features will be briefly disclosed here. After considering this discussion, one will understand how the features of the various embodiments provide several advantages over current singulation methods and devices.

[0070] One aspect of the disclosure relates to a device for reducing rotation of an article during singulation of a stack of articles. In some embodiments, the device includes a torsion element connected directly or indirectly to a base, a rotatable member coupled to the torsion element and rotatable about an inner axis of the torsion element between at least a first position and a second position, and a revolving member coupled to the rotatable member and configured to revolve about a central axis extending angularly relative to an elongated axis of the rotatable member. In the first position of the rotatable member, an outer surface of the revolving member is in contact with a drive belt. In the second position

of the rotatable member, the torsion element applies a torque to the rotatable member and the revolving member, and the outer surface of the revolving member is in contact with, and applies a force to, a back face of an article, the article having a front face in contact with the drive belt.

[0071] In some embodiments, the torsion element is a torsion bar connected to the base. In other embodiments, the torsion element is a helical torsion spring disposed within or around a structural support member, and the structural support member is connected to the base.

[0072] In various embodiments, the rotatable member is configured to transition from the first position toward the second position when the drive belt brings the article in contact with the revolving member. The rotatable member of some embodiments is a lever arm.

[0073] In some embodiments, the central axis, which the revolving member is configured to spin about, extends perpendicularly relative to the elongated axis of the rotatable member.

[0074] In some embodiments, the force applied by the revolving member to the back face of the article includes a frictional force.

[0075] The revolving member of some embodiments includes a plurality of wheels. In some embodiments, the device also includes a shaft positioned along the central axis. The shaft is coupled to the rotatable member, and the revolving member is disposed about, and configured to spin relative to, the shaft. In other embodiments, the revolving member includes a shaft portion and an extended wheel portion fixed to the shaft portion. The shaft portion and the extended wheel portion are configured to spin about the central axis, and the shaft portion is coupled to the rotatable member.

[0076] An additional aspect of the disclosure relates to a system for singulating a stack of articles while reducing damage to each article. The system of various embodiments includes a conveyor belt configured to move a stack of articles forward, a drive belt configured to laterally accelerate an article in the stack of articles, and an anti-rotation device configured to provide a frictional force to a back face of the article to resist upward motion of the back face during lateral acceleration of the article. The anti-rotation device includes a torsion element connected directly or indirectly to a base, a rotatable member coupled to the torsion element and rotatable about an inner axis of the torsion element between at least a first position and a second position, and a revolving member coupled to the rotatable member and configured to revolve about a central axis extending angularly relative to an elongated axis of the rotatable member. In the first position of the rotatable member, an outer surface of the revolving member is in contact with the drive belt. In the second position of the rotatable member, the torsion element applies a torque to the rotatable member and the revolving member. Also in the second position, the outer surface of the revolving member is in contact with the back face of the article, the front face of the article being in contact with the drive belt.

[0077] In some such embodiments, the drive belt and the conveyor belt are positioned on different, non-parallel planes. The drive belt of some embodiments is perforated. In some embodiments, the system also includes an air-moving component configured to apply a suction force to the front face of the article in order to couple lateral movement of the drive belt with lateral movement of the article.

[0078] A further aspect of the disclosure relates to another system for singulating a stack of articles while reducing damage to each article. The system includes means for moving a stack of articles forward, means for separating and laterally accelerating a forward-most article from the stack of articles, and means for applying friction to a back face of the article to resist upward motion of the back face during lateral acceleration of the article.

[0079] In some embodiments, the means for moving the stack of articles forward includes a first conveyor belt. In some embodiments, the means for separating the article from the stack of articles includes an air-moving apparatus and a second conveyor belt having an air hole. The air-moving apparatus of some such embodiments includes a vacuum; in other embodiments, the air-moving apparatus includes a forward-blowing fan. In some embodiments, the means for applying friction comprises a revolving member indirectly coupled to a torsion element.

[0080] In another aspect of the disclosure, a method of singulating a stack of articles is provided, which reduces damage to the articles in the stack. In various embodiments, the method includes moving a stack of articles forward, separating and laterally accelerating a forward-most article from the stack of articles, and applying a force to the forward-most article in order to resist upward motion of the back face during lateral acceleration of the forward-most article. The force is applied to the back face by a revolving member indirectly coupled to a torsion element.

[0081] In some embodiments of the method, the force comprises a frictional force. The frictional force of some such embodiments is applied by the revolving member when a lever arm coupled to the revolving member rotates about an elongated inner axis of the torsion element from a first position to a second position and the torsion element exerts a torque on the lever arm. In some such embodiments, the torsion element is a torsion bar or a helical torsion spring.

BRIEF DESCRIPTION OF THE DRAWINGS

[0082] The foregoing and other features of the disclosure will become more fully apparent from the following description and appended claims, taken in conjunction with the accompanying drawings. Understanding that these drawings depict only several embodiments in accordance with the disclosure and are not to be considered limiting of its scope, the

disclosure will be described with additional specificity and detail through use of the accompanying drawings.

FIG. 1 is a perspective view of one embodiment of an automatic stack feeder and singulation apparatus.

FIG. 2A depicts a perspective view of an embodiment of a lower paddle assembly of the automatic stack feeder of FIG. 1.

FIG. 2B is a perspective view of the z-axis component of the lower paddle assembly of FIG. 2A.

FIG. 2C is a perspective view of the lower paddle assembly and the conveyor of the automatic stack feeder of FIG. 1.

FIG. 3 depicts a side elevation view of the lower tines and the upper tines of an automatic stack feeder.

FIG. 4 depicts a perspective view of an embodiment of a container for use on an automatic stack feeder.

FIG. 5 depicts a perspective view of an embodiment of a stack guide of the automatic stack feeder of FIG. 1.

FIG. 6A is a top plan view of a stack of articles in an automatic stack feeder.

FIG. 6B is a top plan view of a stack of articles and a container in an automatic stack feeder.

FIG. 6C is a top plan view of a combined stack of articles after unloading a stack of articles from the container depicted in FIG. 6B.

FIG. 7A depicts a side view of a container on an automatic stack feeder with its door closed.

FIG. 7B depicts a side view of a container on an automatic stack feeder with its door open.

FIG. 8 is a schematic diagram of a controller's connections to components of the automatic stack feeder.

FIGS. 9A-D are perspective views of an automatic stack feeder depicting a sequence for unloading a container using an upper and lower paddle.

FIG. 10A is a top plan view of one embodiment of a perforated drive belt assembly in a first position.

FIG. 10B depicts a top view of one embodiment of a perforated drive belt assembly in a second position.

FIG. 11 is a side elevation view of one embodiment of a stack of articles and perforated drive belt assembly.

FIG. 12 is a schematic illustration of one embodiment of a controller for use in an automatic stack feeder.

FIG. 13A is a side elevation view of a stack of articles in an automatic stack feeder.

FIG. 13B is a side elevation view of a stack of articles exhibiting slump in an automatic stack feeder.

FIG. 13C is a side elevation view of a stack of articles leaning forward in an automatic stack feeder.

FIG. 14 is a perspective view of one embodiment of a sorting section of the automatic stack feeder of FIG. 1.

FIG. 15 illustrates a perspective view of an exemplary stack of articles.

FIG. 16 illustrates a top plan view of an example of a shingulated stack of articles with one or more positively lapped articles.

FIG. 17 is a perspective view of one embodiment of a shingulating device.

FIG. 18A is a perspective view of another embodiment of a shingulating device and sorting section.

FIG. 18B is a side plan view taken along line 18B-18B' of FIG. 18A.

FIG. 19A is a perspective view of one embodiment of a sorting section including picking devices and anti-doubling devices.

FIG. 19B is an enlarged portion of a picking device as indicated by the dashed line 19B of FIG. 19A.

FIG. 20A is a perspective view of one embodiment of a sorting section including a group of picking zones.

FIG. 20B is a side plan view taken along line 20B-20B' of FIG. 7A, and illustrating an example of detecting a shingulated stack of articles or an attached group of articles approaching a picking zone.

FIG. 21 is a perspective view of one embodiment of a synchronization device.

FIG. 22 is a side elevation view of one embodiment of an anti-rotation device.

FIG. 23 is a perspective view of one embodiment of an anti-rotation device.

FIG. 24 is a schematic diagram illustrating the forces applied to an open article during singulation when one embodiment of an anti-rotation device is present.

FIG. 25 is a side elevation view of one embodiment of a torsion rod found within an embodiment of an anti-rotation device.

FIG. 26A is a side elevation view of one embodiment of a torsion element.

FIG. 26B is a top plan view of another embodiment of a torsion element.

FIG. 26C is a side elevation view of one embodiment of a structural support member found within an embodiment of an anti-rotation device.

FIG. 27 is a flowchart depicting a process using a moveable stack guide.

FIG. 28 is a flow chart depicting one embodiment of a method for controlling singulation in an automatic stack feeder.

FIG. 29A is a top plan view of a sorting section with a floating pick point.

FIG. 29B is a top plan view illustrating an exemplary sorting section operating using virtual windows.

FIG. 29C is a top plan view of a pulley system for driving a perforated belt of a picking device.

FIG. 29D is a perspective view of a perforated timing belt.

FIG. 30 is a flow chart depicting one embodiment of a method of determining a velocity or movement profile.

FIG. 31 is a side plan view of a sorting section using virtual windows for synchronization of an article with a sorting

window.

FIG. 32A is a schematic diagram illustrating an example of a method of controlling a virtual axis.

FIG. 32B is a side plan view of a sorting section and illustrating an example of a method of synchronizing an article with a sorter window using a pick zone operation.

FIG. 32C is a side plan view of a sorting section and illustrating an example of a method of coordinating the operation of picking zones with master and slave axes to control the picking of an article.

FIG. 33A is a side plan view of a sorting section including picking zones and sensors.

FIG. 33B is a side plan view of a sorting section and illustrating an example of a method of variably controlling picking zone vacuum systems based on the sensor feedback.

FIG. 34 is a side plan view of sorting section using a pick zone operation for correction control.

FIG. 35 is a flow chart depicting one embodiment of a method of managing articles in an automatic stack feeder.

DETAILED DESCRIPTION OF EMBODIMENTS

[0083] In the following detailed description, reference is made to the accompanying drawings, which form a part thereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. Thus, in some embodiments, part numbers may be used for similar components in multiple figures, or part numbers may vary depending from figure to figure. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented here. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the Figures, can be arranged, substituted, combined, and designed in a wide variety of different configurations, all of which are explicitly contemplated and made part of this disclosure.

[0084] As used herein, the term singulation may mean the separation of a stack of articles into single articles that move into a sorting or picking machine in a line of single articles. The term shingulation may mean the separation of articles from a bulk stack, but wherein the articles are not entirely segregated from the other articles of the stack. Shingulated articles partially overlap each other, similar to the overlapping pattern of shingles on a roof, and move into a sorting or picking machine in an overlapping, continuous line of articles. As used herein, a singulator may be capable of both singulation and shingulation a stack of articles; the use of the term singulator is used to describe both processes for convenience and ease of description. As used herein, positive lapped or positive lapping may refer to the organization of the position of the leading edges of the articles of the stack. Details relating to shingulation and positive lapping will be described further below. As used herein, the term singulation may also refer to picking articles from the positively lapped shingulated stack to produce individual articles.

[0085] The term motor is used herein to refer to any device which provides a mechanical or electrical motive force to a component of the automatic high speed flats feeder. The motors described herein may be mechanically or electrically driven, or may be a source of pneumatic or hydraulic pressure, or may be any other type of motors. The system described herein provides for faster and more efficient unloading of containers holding stacks of articles intended for separation, singulation, or shingulation of bulk articles, such as, for example, articles of mail. Articles such as mail comprising magazines and catalogs, which are too long in one direction to be considered a standard sized letter, are often called flats. Flats are often flexible and may sometimes be flimsy, which can cause problems in automatic stack feeders during singulation or shingulation. These articles or flats may be processed as a stack. As used herein, the term stack may refer to a single article or to one or more articles grouped together, and the term may be used in an automatic stack feeder. Although the present disclosure describes systems and devices for sorting and/or singulating articles of mail, catalogs, and magazines, it will be apparent to one of skill in the art that the disclosure presented herein is not limited thereto. Articles or flats may be provided in containers which must be unloaded onto automatic stack feeders for singulation. In order to ensure proper singulation or shingulation, proper stack pressure must be maintained throughout the container unloading process. The embodiments described herein provide for a system and method of ensuring sufficient stack pressure is maintained while unloading articles from a container.

[0086] As used herein, the terms horizontally and vertically are used with reference to the general layout of an automatic stack feeder. The horizontal direction refers to the direction which is generally parallel to the surface on which the automatic stack feeder sits in its normal configuration (e.g., the floor or ground). The horizontal direction is also referred to as the x-axis. A direction or movement described as being in the vertical direction is in a direction that is generally perpendicular to the horizontal direction, but need not be exactly perpendicular to the horizontal direction. The vertical direction may be one that extends generally away from the horizontal surface of the automatic stack feeder, as will be described more fully herein. The vertical direction is also referred to as the z-axis.

[0087] As used herein, the term singulation may mean the separation of a stack of articles into single articles that move into a sorting or picking machine in a line of single articles. The term shingulation may mean the separation of articles from a bulk stack, but wherein the articles are not entirely segregated from the other articles of the stack. Shingulated articles partially overlap each other, similar to the overlapping pattern of shingles on a roof, and move into

a sorting or picking machine in an overlapping, continuous line of articles. As used herein, a singulator may be capable of both singulating and shingulating a stack of articles; the use of the term singulator is used to describe both processes for convenience and ease of description.

[0088] To assist in the description of the devices and methods described herein, some relational and directional terms are used. "Connected" and "coupled," and variations thereof, as used herein include direct connections, such as being contiguously formed with or attached directly to, on, within, etc. another element, as well as indirect connections where one or more elements are disposed between the connected elements. "Connected" and "coupled" may refer to a permanent or non-permanent (i.e., removable) connection.

[0089] "Secured" and variations thereof as used herein include methods by which an element is directly fastened to another element, such as being glued, screwed or otherwise affixed directly to, on, within, etc. another element, as well as indirect means of attaching two elements together where one or more elements are disposed between the secured elements.

[0090] The system described herein provides for faster and more efficient unloading of containers holding stacks of articles intended for separation, singulation, or shingulation, such as, for example, articles of mail. Articles such as mail comprising magazines and catalogs, which are too long in one direction to be considered standard sized letters are called flats. Flats are often flexible and may sometimes be flimsy, which can cause problems in automatic stack feeders during singulation or shingulation. These articles or flats may be processed as a stack. As used herein, the term stack may refer to a single article or to one or more articles grouped together, and the term may be used in an automatic stack feeder. Articles, such as flats, may have varying dimensions, including long dimension or edge, a short dimension or edge, a front side, and a back side. Generally, when processed on an automatic stack feeder, the long dimension, which is often the binding edge of the articles or flats in the stack is disposed parallel to the floor, and the front of each article, or flat, is disposed facing the same direction, and the individual articles in the stack are disposed front to back. The short edge is usually aligned with a vertical wall, or stack guide, while being processed in the automatic stack feeder.

[0091] The system described herein provides for faster and more efficient separation or singulation of bulk articles, such as, for example, articles of mail. Articles of mail such as magazines and catalogs, which are too long in one direction to be considered a standard sized letter, are often called flats. Flats are often flexible and may sometimes be flimsy, which can cause problems in automatic stack feeders during singulation. These articles or flats may be processed as a stack. As used herein, the term stack may refer to a single article or to one or more articles grouped together, and may be used in an automatic stack feeder 100. Although the present disclosure describes systems and devices for sorting and/or singulating articles of mail, catalogs, and magazines, it will be apparent to one of skill in the art that the disclosure presented herein is not limited thereto. For example, the development described herein may have application in a variety of manufacturing, assembly, or sorting applications.

[0092] FIG. 1 depicts a perspective view of an embodiment of an automatic stack feeder 100. The automatic stack feeder 100 comprises a frame 110, a plurality of belts 120, a singulator 140, a lower paddle assembly 150, an upper paddle assembly 160, a carrier 170, and a sorting section 180.

[0093] The frame 110 provides support for the belts 120, the lower paddle assembly 150, and the singulator 140. Generally, the frame 110 is roughly table shaped, being elevated off the ground by a plurality of legs (not shown) or by other means known in the art. The frame 110 has a first end 111 and a second end 112. The frame 110 supports the singulator 140, which is connected at the second end 112 of the frame 110. The singulator 140 comprises a vertical portion 142 which is mounted at a right angle to the generally flat horizontal surface of the frame 110. The singulator 140 may be attached directly to a flat surface at the second end 112 of the frame 110. In some embodiments, the singulator 140 may be disposed in close proximity to the second end 112 of the frame 110 and within the vertical portion 142 such that the second end 112 of the frame 110 is located near or in contact with the singulator 140. The major plane surface of the singulator 140 is disposed generally vertically, at a right angle to the generally horizontal plane of the frame 110. The singulator 140 comprises a singulation belt 144 with perforations 145 disposed therein such that air flow is possible through the singulation belt 144, while the belt maintains its structural integrity. A vacuum force is applied through the perforations in the belt of the singulator 140, so that as articles located on the belts 120 are moved forward into contact with the singulation belt 144 as the vacuum force acts on the adjacent article's surface. The vacuum force applied through the singulation belt 144 is sufficient to attract the lead article in a stack of articles, and maintain the lead article in position against the singulation belt 144. The singulator 140 may be disposed within the vertical portion 142 such that a surface of the singulation belt 144 is aligned in the same plane as a surface of the vertical portion 142. The singulator 140 is configured to perform singulation or shingulation, as desired. For ease of description, the component capable of singulation and shingulation is referred to only as a singulator. The processes of singulation and shingulation will be described in more below.

[0094] Frame 110 also comprises a stack guide 130, attached on one side of the frame, and extending parallel to and alongside the belts 120, which has a smooth vertical surface 133 provided to align and guide articles, items, or a container when placed on the belts 120.

[0095] The belts 120 are continuous loops disposed on rollers (not shown), located near the first end 111 and the

second end 112 of the frame 110, and which are rotatably attached to the frame 110. The rollers are attached to a motor and are configured to rotate, thus causing the belts 120 to move like a standard conveyor belt. The belts 120 are generally aligned parallel to each other and are separated by a distance, as shown in FIG. 1. The belts 120 run lengthwise along the automatic stack feeder 100 from the first end 111 to the second end 112. Thus, there may be openings 122 between the belts 120 corresponding to the space between the belts 120. The belts 120 can be, for example, independently driven, or driven together. Top surfaces 121 of the belts 120 are disposed within the same plane as the generally horizontal flat surface of the frame 110.

[0096] The upper paddle assembly 160 comprises an upper paddle 161 and upper tines 165 which are secured to the upper paddle 161 at their upper portion, and the lower portions of which extend downward beyond the upper paddle 161, and toward the generally flat, horizontal surface of the frame 110. The upper paddle assembly 160 is connected to a track, cable, rail, or drive belt, which is in turn, connected to an x-axis motor (not shown), all of which are disposed above the generally flat, horizontal surface of the frame 110. As the motor operates, the track or drive belt moves, which, in turn, moves the upper paddle assembly 160. The motor is configured to move the upper paddle assembly 160 in a horizontal direction toward or away from the second end 112 of the frame 110. The upper paddle assembly 160 is moveable along the length of the frame 110.

[0097] The upper paddle assembly 160 is also moveable such that the vertical position of the upper paddle 161 and the upper tines 165 is adjustable. The upper paddle assembly 160 is connected to a z-axis motor via a slidable track, rail, or guide (not shown), that can move the upper paddle assembly 160, including the upper paddle 161 and the upper tines 165 toward or away from the top surfaces 121 of the belts 120. The upper paddle assembly 160 is disposed such that the upper paddle 161 and the tines upper tines 165 are disposed at an angle relative the belts 120. The z-axis motor connected to the upper paddle assembly 160 is configured to extend the upper paddle 161 downward toward the top surfaces 121 of the belts 120, so that the upper tines 165 may be positioned to provide vertical support for a stack of articles located on the belts 120. The z-axis motor connected to the upper paddle assembly 160 is also configured to move the upper paddle 161 assembly and the upper tines 165 upward away from the surface of the belts 120, so that the upper tines 165 are in position which will not interfere with the movement of a stack of articles located on the belts 120.

[0098] A door opener 162 is connected to a rearward facing portion of the upper paddle assembly 160. The door opener 162 comprises a hook, latch, or other similar device capable of releasably engaging a door of a container and opening or removing the door. The door opener 162 is connected to the upper paddle assembly 160 via a moveable connection which is driven by a z-axis motor and a gear, cable, cord, pneumatic or hydraulic piston, or any other desired mechanism. The door opener 162 is vertically moveable such that the door opener 162 may extend below the upper paddle 161 to engage a latch, hook, or receiver in a door of a container, which has been placed on the belts 120, and then retracts the door vertically, thereby opening the container. This process will be described in greater detail below.

[0099] Frame 110 also provides support for a carrier 170. The carrier 170 is attached on one side to a moveable linear guide (not shown) which runs parallel to the frame 110 and the belts 120, opposite the stack guide 130. The carrier 170 comprises a first surface 171 which is disposed generally parallel to the belts 120 and a second surface 172 which is generally vertical and which is disposed perpendicular to the belts 120. The carrier 170 is attached to the frame 110 such that the carrier 170 does not make contact with the belts 120. In some embodiments, a space exists between the bottom of the carrier 170 and the top surfaces 121. The carrier 170 is configured to receive a container (not shown). The container rests on the first surface 171 and abuts the second surface 172 on a rear surface of the container. In this way, the container can be moved back and forth along the frame 110 by the carrier 170, independent of the movement of the belts 120.

[0100] FIG. 2A depicts a perspective view of an embodiment of the lower paddle assembly 150. The lower paddle assembly 150 comprises a support member 151 which is connected to a cross member 152. Cross member 152 comprises rollers 153 disposed at one end, and is connected to the drive connector 155 at the other end. The rollers 153 moveably engage a rail 154, which is connected to the frame 110 and extend parallel to and below the belts 120. The drive connector 155 moveably engages a drive member 156. The drive member 156 is supported by the frame 110. In some embodiments, the drive member 156 may be a belt, a track, a cable, a gear, a pneumatic or hydraulic piston, or other similar device to which the drive connector 155 may moveably connect. The drive member 156 is, in turn, attached to an x-axis motor (not shown). As the x-axis motor operates, the drive member 156 is moved along the track, belt, gear, cable, etc., which, in turn, moves the whole lower paddle assembly 150 in the horizontal direction parallel to the path of the belts 120. The lower paddle assembly 150 is moveable along the length of the frame 110. The lower paddle assembly 150, together with the belts 120 may be termed a conveyor for ease of description.

[0101] As depicted in FIG. 2B, the lower paddle assembly 150 further comprises a z-axis member 157 which is moveably connected to the support member 151. The z-axis member 157 may be moveably connected to the support member 151 using a track, cable, gear, piston, or other similar connection method. The z-axis member is moveably attached to the support member 151 and to a z-axis motor (not shown) configured to move the z-axis member 157 up and down, along the z-axis, in relation to the horizontal surface of the frame 110. A lower paddle 158 is attached to the z-axis member, and one or more lower tines 159 are attached to and extend upward from the lower paddle 158.

[0102] FIG. 2C depicts the lower paddle assembly 150 positioned within the frame 110. As depicted, the lower paddle assembly 150 is generally disposed below the plane of the horizontal surface of the frame 110. The lower tines 159 protrude upward through the spaces or openings 122 between or around the belts 120.

[0103] As described above, the lower paddle assembly 150 is moveable in a horizontal or x-axis direction. In other words, the lower paddle assembly is moveable horizontally between the first end 111 and the second end 112 of the frame 110. To move the lower paddle assembly 150 from the first end 111 to the second end 112, or from the second end 112 to the first end 111, the x-axis motor is operated. The operation of the x-axis motor moves the drive member 156, (e.g., a drive belt, a track, a gear, or other similar device) to which the drive connector 155, is attached. Therefore, as the motor operates, the drive connector 155 moves between the first end 111 and the second end 112 of the frame 110. Whereas the drive connector 155 is attached to the support member 151, the z-axis member 157, the lower paddle 158, and the lower tines 159 all move together in a horizontal direction as the motor operates. The motor is connected and configured to move the lower paddle assembly 150 in a direction toward or away from the second end 112 of the frame 110. Thus, the lower paddle assembly 150 is moveable along the length of the frame 110. The frame 110 has voids or spaces in its surface corresponding to openings 122, disposed in the areas around or between the belts 120. The lower tines 155 are aligned with the openings 122, and the tines 155 can move within the openings 122, along the length of the frame 110, as the lower paddle assembly 150 moves. Generally, the lower paddle assembly 150 is moveable along the length of frame 110 in order to provide support to a stack of articles (not shown) and maintain sufficient stack pressure to ensure proper singulation or shingulation.

[0104] In addition to horizontal movement, the lower paddle 158 and the lower tines 159 are moveable in a vertical direction as the z-axis motor operates. The z-axis member 157 is connected to the support member 151 such that the z-axis member can vertically move, using a track, cable, belt, gear, pneumatic or hydraulic piston, or other similar device, as described herein. As the z-axis motor operates, z-axis member 157 moves along the support member 151, thus causing vertical motion of the lower paddle 158 and the lower tines 159. The z-axis member 157 is sized and is connected to the support member 151 at a location which enables the lower tines 159 to be disposed entirely below the horizontal surface of the frame 110 at the first extent of operation, and to enable the lower tines 159 vertically to protrude through the openings 122 sufficiently to allow the lower tines to provide front or back support to a stack of articles on the top surfaces 121 of belts 120.

[0105] The vertical movement of the z-axis member 157 need not be perpendicular to the horizontal surface of the frame 110. As described above, the term vertical is used to denote a direction generally perpendicular, but not necessarily exactly perpendicular, to the horizontal movement, or x-axis, of the lower paddle assembly 150. In some embodiments, the z-axis member 157 may be connected to the support member 151 such that the z-axis member 157 and the lower paddle 158 are disposed at an angle other than a right angle to the horizontal surface of the frame 110. For example, in some embodiments, the z-axis member 157 may be connected to the support member 151 to form an angle θ with a surface of the belt or belts 120 (not depicted). In some embodiments, the angle θ may be greater than 90° , such as, 91° , 92° , 93° , 94° , 95° , 100° , 110° , or more, or any angle therebetween. In some embodiments, the z-axis member 157 and the lower paddle 158 move such that the angle θ is maintained constant.

[0106] During operation of the automatic stack feeder 100, a stack of articles (not shown) is disposed on the belts 120, and is supported on its rear facing side by either the upper tines 165, the lower tines 159, or both. The upper paddle 161 and the lower paddle 158 are moveable independent of each other and independent of the belts 120. The belts 120 are configured to move the stack of articles either toward or away from the singulator 140, as required. Generally, the belts 120 advance the stack of articles toward the singulator 140 such that the lead article of the stack impinges on the singulator 140. As the stack of articles is advanced toward the singulator 140 by the belts 120, the upper paddle 161 or the lower paddle 158 moves along with the stack in order to maintain vertical support and the stack pressure of the stack of articles against the adjacent face of the singulator 140.

[0107] The stack of articles may be made of a variety of articles or items. For example, the stack of articles may be made up of magazines, catalogs, mail, containers, tiles, boards, stackable components or materials, or other articles that are desired to be singulated or shingulated. In some embodiments of the automatic static feeder 100, the stack of articles can be positioned such that some articles in the stack of articles are closer to the singulator 140 than other articles. Thus, the stack may comprise a leading article, which is the article in the stack located closest to the singulator 140.

[0108] FIG. 3 depicts a side elevation view of the lower tines 159 of the lower paddle 158 and the upper tines 165 of the upper paddle assembly 160. As depicted, the lower tines 159 and upper tines 165 are configured and sized such that when a container 190 is placed on the carrier 170, flush against the stack guide 130, the upper tines 165 do not extend beyond the sides of the container 190 and/or the stack guide 130, as depicted. In some embodiments, one or more of the lower tines 159 may be vertically aligned with a corresponding one or more of the upper tines 165, as depicted. In some embodiments, the lower tines 159 and the upper tines 165 of the upper paddle assembly 160 may be disposed such that the lower tines 159 and the upper tines 165 are offset from each other so as to mesh, with the lower tines aligned with the spaces between the upper tines 165. In some embodiments, as the lower paddle 158 and

the upper paddle assembly 160 move toward each other, the lower tines 159 and the upper tines 165 do not contact each other.

[0109] FIG. 4 depicts a perspective view of an embodiment of the container 190. The container 190 comprises an open top 191, a plurality of sides 192, a bottom, and a door 195, which together enclose a stack of articles 196. In some embodiments, the container may have an enclosed top having perforations or slots (not shown) disposed therein corresponding to the locations of the upper tines 165. The perforations or slots in the top of the container 190 allow the upper tines 165 to be inserted into the container 190. The door 195 is disposed on one side of the container 190. The door 195 is a vertically removable piece. In some embodiments, the door 195 has a ridge, lip, or other protrusion disposed on at least two edges of the door 195 which are removably held within corresponding slots, grooves, or other indentations in the sides 192 of the container 190.

[0110] One of the sides 192, specifically, the side 192 which is opposite door 195, has grooves or notches 193 disposed in the side, which extend vertically downward from the top of the container 190. The grooves or notches 193 do not extend the entire vertical length of the side 192 in which they are disposed. The notches are sized and positioned to align with the upper tines 165 such that the upper tines 165 can move through the grooves or notches 193, and contact the stack of articles 196 disposed within the container 190.

[0111] FIG. 5 depicts a perspective view of an embodiment of a stack guide of the automatic stack feeder of FIG. 1. The stack guide 130 is connected to the frame on bearings and is disposed generally alongside and parallel to the belts 120. The stack guide 130 has a first end 131, disposed generally near the first end 111 of the frame 110, and has a second end disposed generally near the second end 112 of the frame 110. In the illustrated embodiment, the stack guide 130 comprises a vertical surface 133 extending substantially vertically, and at a right angle from the horizontal plane of the frame 110 and the belts 120. The stack guide 130 is configured to provide support to an edge of a stack of articles (not shown) when the stack of articles is located on the belts 120, as it is processed by the automatic stack feeder 100.

[0112] The stack guide 130 comprises a vertical portion 510 which is configured to be in contact with the stack of articles. The stack guide 130 is configured to move the vertical portion 510 between a first position and a second position. In some embodiments, the stack guide 130 is configured to move the vertical portion 510 between a variety of positions. The vertical portion 510 has a back side 512 to which is attached to one or more braces 520. The braces 520 are fixedly attached to the back side 512 of the vertical portion 510 at intervals along the length of the vertical portion 510. The braces 520 are also attached to one or more bearings 530. In some embodiments, not all of the braces 520 are attached to a bearing 530. The bearings 530 are connected to a guide support 540. The guide support 540 is fixedly connected to the frame 110 (not shown) so as to be parallel and alongside the belts 120. The bearings 530 are configured to allow the braces 520 to slidably move in a linear direction. As the braces 520 move, the vertical portion 510 of the stack guide 130 also moves. In some embodiments, the direction of movement allowed by the bearings 530 is in a direction perpendicular to the length of the stack guide 130 and the frame 110, as will be described in more detail below.

[0113] The stack guide 130 further comprises a motor 550 which is configured to move the vertical portion 510 of the stack guide 130. The motor 550 is connected to a piston 560. The piston 560 is connected to the motor 550 such that as the motor 550 operates, the piston 560 moves. In some embodiments, the motor 550 is a pneumatic cylinder powered by an air supply generating sufficient energy to move the piston 560 from a first position to a second position, or to any position therebetween. In some embodiments, the piston 560 extends vertically from the motor and engages a ring gear 570. In some embodiments, the piston 560 comprises teeth on one end which engage with the gear teeth on the ring gear 570. The ring gear 570, in turn, is connected to a crank shaft 580. The crank shaft 580 is a cylindrical rod which runs lengthwise in a direction parallel to the vertical portion 510, along the back side 512 of the vertical portion 510. The ring gear 570 encircles the crank shaft 580, and, together with the piston 560, provides the mechanical linkage and/or gear system which translates the linear, vertical motion of the piston 560 into a rotational movement of the crank shaft 580, along the long axis of the crank shaft 580.

[0114] The crank shaft 580 comprises one or more cams 590 attached at the ends of the crank shaft 580 and, in some embodiments, at intervals along the length of the crank shaft 580. The crank shaft is supported in housings 581 which comprise bearings that support the crank shaft 580 and also enable it to rotate about its long axis. The housings 581 are attached to the guide support 540 and support the crank shaft 580.

[0115] The cams 590 may be ovoid, egg shaped, hourglass shaped, may comprise various combinations of linkages, or may be of any other desired shape or type. The cams 590 may further comprise tie rods 591 rotatably connected to the cams 590. The tie rods 591 are connected to the back side 512 of the vertical portion 510. The cams 590 and tie rods 591 are connected to each other and to the vertical portion 510 so as to be capable of translating the rotational motion of the crank shaft 580 into linear motion of the vertical portion 510.

[0116] For example, while unloading a stack of items from a container, it may be desirable to move the vertical portion 510 of the stack guide 130. The movement of the vertical portion 510 will now be described. The vertical portion 510 is in an original, or first position, where a front side of the vertical portion 510 may be in contact with an edge of a stack of articles. To move the vertical portion 510, a control signal is sent from a controller to the motor 550. The control signal may be an electrical signal, a pneumatic signal, or any other desired signal capable of initiating motor operation. In some

embodiments, the motor is a pneumatic cylinder, and therefore a pneumatic signal is sent to the motor 550. The pneumatic signal causes the motor 550 to operate, which moves the piston 560. The piston 560 moves linearly upward. The gear teeth on the piston 560 engage with gear teeth on the ring gear 570. As the piston 560 moves upward, the enmeshing gear teeth cause the ring gear 570 to rotate. The ring gear 570 then rotates the crank shaft 580, which rotates about the axis extending along the length of the crank shaft 580 and running through the center of the crank shaft 580.

[0117] The rotation of the crank shaft 580 causes cams 590 to rotate, and as the cams 590 rotate, the tie rods 291 move. The tie rods 591 are attached to the vertical portion 510, such that the movement of the tie rods 591 causes the vertical portion 510 to move to a second position.

[0118] When the pneumatic signal is removed from the motor 550, or is applied to a different port on the pneumatic cylinder, the piston 560 moves downward, and the above process repeats, but in reverse, and the vertical portion 510 moves back to its original position.

[0119] The distance the vertical portion 510 travels upon actuation of the motor 550 may be equivalent to the thickness of a wall of the container 190. In some embodiments, the motor is configured such that the vertical portion 510 is positionable at a plurality of locations or positions. This may be accomplished by moving the piston 560 a specified amount, and holding the position of the piston 560 through operation of the motor 550, thus maintaining the position of the vertical portion 510. By having a plurality of possible positions, the vertical portion 510 of the stack guide 130 may be used for a variety of containers 190 whose wall thickness varies. In some embodiments, the distance the vertical portion 510 of the stack guide 130 moves is programmable using a controller which will be described in greater detail below.

[0120] It will be understood that the above description is exemplary only. A person of skill in the art will understand that the movement of the vertical portion may be accomplished by other means, such as an electric motor, a different gearing system, or any other desired method.

[0121] In some embodiments, the stack guide moves 130. In some embodiments, the entire stack guide 130 does not move, but some of the components of the stack guide 130 move, including the vertical portion 510.

[0122] FIG. 6A depicts a top view of an embodiment of an automatic stack feeder 600 with a stack of articles. A first stack 670 of articles is located on a belt 620, and is supported along its rearward face by a vertical support member 650, and along one of the short edges or short dimensions a stack guide 630. The paddle 650 is in contact with the trailing article 672 in the first stack 670, and operates as described elsewhere herein. The first stack 670 is supported on an edge 675 by the stack guide 630. By maintaining the edge 675 of first stack 670 in contact with the stack guide 630, a uniform edge 675 when the articles in the stack are present at the singulator 140, which reduces the possibility of misfeeds, damage to the articles, and other errors in singulation.

[0123] The stack guide 630 is depicted in a first position where the stack guide is in contact with the edge 675 of the first stack 670. The edge 675 of the first stack 670 is aligned against the stack guide 630, and the first stack 670 is in flush contact with the stack guide 630. The stack guide 130 keeps the edge 675 aligned as the first stack 670 is moved toward the singulator 640.

[0124] FIG. 6B depicts a top plan view of an embodiment of the automatic stack feeder of FIG. 6A, additionally having a container. The container 660 encloses a second stack 680 of articles. The second stack 680 of articles is generally positioned within the container 660 such that an edge of the articles having the shorter dimension is in contact with a wall 665 of the container. The wall 665 against which the stack 680 is positioned is located on the side of the container which will be in contact with the stack guide 630 when the container 660 is placed on the belt 620.

[0125] The container 660 is placed on the carrier 665 so that the stack 680 can be unloaded onto the belt 620 for singulation. In some embodiments, the articles are unloaded using a paddle (not shown) which pushes the stack 680 forward, through an open door 662 of the container 660.

[0126] The container 660 comprises at least one wall 665 which has a thickness D1. When placing the container 660 on the belt 620, the stack guide 630 is moved to accommodate the thickness D1 of the wall 665. This ensures that the second stack 680 aligns with the first stack 670 when the second stack 680 is unloaded from the container 660, FIG. 6B shows the stack guide 630 in a second position, the stack guide 630 being moved to accommodate the container 660. When the container 660 is unloaded, the stack 680 is pushed through the open door 662. At this point, the stack 680 is not aligned with the stack guide 630, but is disposed away from the stack guide 630 at a distance equal to the thickness D1 of the wall 665.

[0127] FIG. 6C depicts the automatic stack feeder of FIGS. 6A and 6B following the removal of the container 660. The stack guide 630 is shown in the first position, having been moved following removal of the container 660. After removal from the container 660, the second stack 680 is merged with the first stack 670, by moving the second stack 680 forward until the leading article in the second stack 680 contacts the trailing article 672 in the first stack 670, to form a merged stack 685. With the stack guide 630 initially in the second position, the merged stack 685 is not in flush contact with the stack guide 630. Following removal of the container from the belt 620, the stack guide 630 is moved back to the first position, whereupon the stack guide 630 makes contact with and provides support to the merged stack 685, thus helping to ensure efficient and accurate singulation of the articles in the merged stack 685.

[0128] FIGS. 7A and 7B are provided to illustrate one option for unloading containers onto an automatic stack feeder

as described herein, or of the process of unloading containers for use in an automatic stack feeder. This description should in no way be construed as limiting any of the disclosure contained herein, but is provided merely as one example of unloading containers in automatic stack feeder technology.

[0129] Referring to FIG. 7A, an automatic stack feeder 700 is depicted. The automatic stack feeder 700 comprises a first end 702 and a second end 704, and a belt 720. The second end 704 comprises a singulator 740. The automatic stack feeder 700 has a paddle 750 which supports a first stack of articles 741, providing sufficient stack pressure for proper singulation or shingulation of the first stack of articles 741. Stack pressure is defined as the pressure exerted by the stack on the singulator 740. If stack pressure is not properly maintained, the stack may slump, or fall forward or backward, which hampers singulation and shingulation. Maintaining proper stack pressure ensures a sufficient surface area of the lead article in a stack makes contact with the singulator 740 to ensure efficient and accurate singulation or shingulation of the stack. In the automatic stack feeder 700, the belt 720 moves the first stack of articles 721 toward the singulator 740, and the paddle 750 provides vertical support, and moves with the first stack of articles 721 to maintain the stack pressure. If the first stack of articles 721 is not maintained with sufficient pressure on the singulator 740, the first stack of articles 721 may begin to slump or fall, which hinders efficient singulation or shingulation.

[0130] As the belt 140 moves the first stack of articles 121 toward the singulator 106, a container 790 is received in a carrier (not shown), which moves the container 790 into a position behind the first stack of articles 121. The container 790 has a door 795 which is positioned behind the paddle 750. The container 790 contains a second stack of articles 742. As depicted in FIG. 7A, the door 730 is closed when the container 790 is first positioned above the belt 720.

[0131] FIG. 7B depicts the automatic stack feeder 700 wherein the door 730 of the container 790 has been opened. The paddle 750 opens the door 730 by vertically removing the door 795 from the container 790. Paddle 750 must move in the vertical direction along with the door 795 in order to allow the second stack of articles 742 a path to exit the container 790. When the door 795 is opened, and the paddle 750 moves in a vertical direction away from the first stack of articles 741, the first stack of articles 741 loses vertical support, and the first stack of articles 741 may slump or fall into the container 790, as depicted, and thus, sufficient stack pressure is not maintained. The operation of paddle 750 will be described in greater detail below.

[0132] FIG. 8 depicts a schematic diagram of a controller and its connections to various components of the automatic stack feeder 100. The automatic stack feeder 100 may comprise an automatic control system 800 under the direction of a processor-based controller 810. The controller may be controllably connected to the x-axis and z-axis motors described herein. The connections of controller 810 to the various motors described herein may be an electrical connection, either wired or wireless, or any other desired type of connection configured to send control signals to the various components, and to receive signals from the various components. The controller 810 is connected to the lower paddle assembly x-axis motor 820, lower paddle assembly z-axis motor 830, the belt motor 840, the upper paddle x-axis motor 850, the upper paddle z-axis motor 860, the door opener motor 870, and the carrier motor 880. The controller is configured to coordinate the various components and motors of the automatic stack feeder 100 to accomplish the unloading of the container 190 as will be described with reference to FIGS. 9A-9D.

[0133] FIGS. 9A-9D depict a side view of the stages of a container unloading process, illustrating the movements and positions of an upper paddle 965 and a lower paddle 959 during an unloading process of a container 990. As depicted in FIG. 8A, an automatic stack feeder 900 may hold a first stack of articles 915 on belts 920 while those articles are undergoing singulation or shingulation at a singulator 940. During singulation or shingulation, the articles may be supported along their rearward face by either the lower tines 959 or the upper tines 965. As the articles are singulated or shingulated at the singulator 940, the upper tines 965 or lower tines 959 support the first stack of articles 915 as the first stack of articles 915 moves toward the singulator 940. The first stack of articles 915 may be moved toward the singulator 940 by the movement of the belts 920.

[0134] Referring to FIG. 9A, prior to placing the container 990 onto carrier 970 in the automatic stack feeder 900, a z-axis member 957 is extended vertically such that the lower tines 959 protrude vertically through openings 922 between the belts 920. The lower tines 959 support the first stack of articles 915 and move with the belts 920, toward the singulator 940, in order to maintain stack pressure. The x-axis motor 820 operates under the direction of the controller 810. In some embodiments, the controller 810 coordinates the movement of the x-axis motor 820 with the belts motor 840, in order to maintain stack pressure between the first stack of articles 915 and the lower tines 959, as the first stack of articles 915 moves toward the singulator 940. The controller 810 also coordinates the movement of the belt 920 and the lower paddle assembly 950 such that the first stack of articles 915 is maintained at approximately the same angle relative to the belts 920 as the first stack of articles 915 moves toward the singulator 940.

[0135] The container 990 is placed onto the carrier 970, and the carrier 970 positions the container 990 at or near a first end 911, such that the first stack of articles 915 is disposed between the container 990 and the singulator 940. Once placed on the carrier 970, the container 990 is moveable toward or away from the first stack by the carrier 970.

[0136] Referring now to FIG. 9B, the upper paddle 960 is positioned above the door 995 of container 990. When the container 990, which encloses the second stack 916 is placed on the belts 920, the upper paddle 960 is moved into position above the door 995, by the x-axis motor 850 attached to the upper paddle 960. In some embodiments, the

container 990 and the carrier 970 may be moved along with the belts 920, or at the same speed as the belts. The controller 810 can synchronize the movement of the carrier 970 with the belt motor 840. In order to maintain the upper paddle 860 above the door 995, the controller 810 may synchronize the x-axis motor 850, the and the carrier motor 850. This synchronization allows the paddle to stay in the correct position to open the door 995 as the container 990 is moved along by the carrier 970. When the upper paddle 960 is in position above the door 995, the controller signals z-axis motor 870 to cause a door opener 962, to extended downward and to engage the door 995 via the hook or latch or other similar mechanism on the door opener 962. FIG. 9B depicts the door opener 962 extended below the upper paddle 960 and the upper tines 965, engaged with the door 995. The door opener 962 is then retracted vertically, removing the door 995 from the container 990. As described elsewhere herein, the term vertically docs not necessarily require the door to be removed straight up, but may be removed at an angle, for example, as depicted in FIG. 9B.

[0137] As described above, when the container 990 is placed on the carrier 970, the first stack of articles 915 is supported by the lower tines 959. Because the first stack of articles 915 is supported by the lower tines 959 when the door 995 is opened or removed, the first stack of articles 915 docs not slump or fall into the open space in container 990.

[0138] Referring now to FIG. 9C, following removal of the door 995, the controller 810 signals the x-axis motor 850 to position the upper paddle 960 behind the container 990, and then signals the z-axis motor 860 to extend the upper tines 965 downward into a position behind the container 990, which is more proximate the first end 911 than the container 990. The x-axis motor 850 moves the upper tines 965 forward toward the second end 912, with the upper tines 965 passing through the grooves or notches in the container 930 similar to those described elsewhere herein, and into the container 990. The upper tines 965 then contact the trailing or last article in the second stack of articles 916. Once the upper tines 965 are in contact with the second stack of articles 916, the x-axis motor 850 moves the upper tines 965 forward until the upper tines 965 are providing the vertical support for the second stack of articles 916. The upper tines 965 are moved further forward in the container 990, toward the opening formed by removal of the door 995. The upper tines 965 push the second stack of articles 916 forward, causing the lead article in the second stack of articles 916 to make contact with the lower tines 959, and thus apply a stack pressure to the second stack of articles 916. The stack pressure applied by the upper tines 965 to the second stack of articles 916 is sufficient to compress the second stack of articles 916 so that upon later removal of the lower tines 959, the second stack of articles 916 will expand to fill the void left by the lower tines 959, and the resulting stack pressure, after expansion of the second stack of articles 916, will be appropriate for singulation or shingulation operations FIG. 9C depicts this stage of the container unload process, where the second stack of articles 916 is supported by the upper tines 965, and is in contact with both the upper tines 965 and the lower tines 959.

[0139] After the second stack of articles 916 is brought into contact with the lower tines 959, and the upper tines 965 apply a sufficient stack pressure to the second stack of articles 916, the carrier 970 is then moved backwards away from the second stack of articles 916, and thus, the container 990 is then withdrawn from the automatic feeder 900. As the container 990 is withdrawn from the automatic feeder 900, the second stack of articles 916 contacts the belts 920. The controller 810 signals the z-axis motor 830 to retract the lower tines 959 down through the openings 922 in the belts 920. As the lower tines 959 are retracted, the stack pressure applied to the second stack of articles 916 causes the second stack of articles 916 to expand into the void left by the lower tines 959. The second stack of articles 916 and the first stack 915 are merged into a combined stack 917, vertically supported only by the upper tines 965, and the resulting stack pressure on the combined stack 917 is a stack pressure suitable for efficient and accurate singulation or shingulation. By combining the stacks of articles in this manner, a stack pressure is continuously maintained on the stack of articles throughout the container unloading process. This is depicted in FIG. 9D, which shows the lower tines 959 retracted below the horizontal surface of the belts 920. The second stack of articles 916 and the first stack of articles 915 have become the combined stack 917, which is vertically supported by the upper tines 965.

[0140] To repeat the process, the controller 810 signals x-axis motor 820 to move the lower tines 959 behind the combined stack 917, and the controller 810 signals the z-axis motor 830 to extended the lower tines 959 through the openings 922 in the belts 920. The x-axis motor 820 moves the lower tines 959 forward to contact the trailing article in the combined stack 917, and the lower tines 959 mesh with upper tines 965, as described with reference to FIG. 4. Once the lower tines 959 are providing vertical support and stack pressure for the combined stack 917, the controller 810 signals the z-axis motor 860 to retract vertically the upper tines 965. The container unloading process may then be repeated.

[0141] FIG. 10A depicts a top view of an embodiment of a perforated drive belt assembly such as in the singulator 140. The perforated drive belt assembly 1010 comprises a first end 1011, a second end 1012, and a perforated drive belt 1044. The first end 1011 comprises a first spindle 1013, and the second end 1012 comprises a second spindle 1014. The first spindle 1013 and the second spindle 1014 are connected to each other via connecting arms (not shown), which maintain a fixed distance between the first and second spindles 1013 and 1014, and allow for rotation of the first and second spindles 1013 and 1014 about vertical axes running through the center of first and second spindles 1013 and 1014. The connecting arms and the first and second spindles 1013 and 1014 create a rigid form on which the perforated drive belt 1044 is disposed.

[0142] The perforated drive belt 1044 has perforations 1045 disposed therein. As used herein, the term perforated drive belt may mean a drive belt having an opening or plurality of openings such that air flow is possible through the drive belt, while the perforated drive belt 1044 maintains its structural integrity. In some embodiments, the perforated drive belt 1044 has a plurality of small holes extending between the front and back surfaces, the holes being distributed generally uniformly over the surface of the perforated drive belt 1044. In some embodiments, the perforated drive belt 1044 may have one or more elongate holes arranged in lines parallel or perpendicular to the length of the perforated drive belt 1044. In some embodiments the holes may have other suitable shapes. The perforations 1045 may be concentrated in one region or area of the perforated drive belt 1044 or may be uniformly distributed over the surface of the perforated drive belt 1044.

[0143] The first end 1011 of the perforated drive belt assembly 1010 is pivotably attached to the frame 110 such that the first end 1011 of the perforated drive belt assembly 1010 pivots around an axis. The second end 1012 is not attached to the frame 110, but is connected to the first end via the connecting arms which connect the first and second spindles 1013 and 1014 together. As the first end 1011 pivots around a vertical axis 1070, the second end 1014 moves in an arc centered around an axis 1070. The pivotable attachment mechanism of the first end 1011 may comprise a spring or similar device which applies a restorative force which resists rotational motion about the axis 1070. This resistance prevents free movement of the second end 1012, and constrains the perforated drive belt assembly 1010 to be in a predetermined orientation when no external forces are applied, for example, as depicted in FIG. 10A.

[0144] The perforated drive belt 1044 is a continuous loop belt which is disposed on the external circumferential surfaces of the first spindle 1013 and the second spindle 1014. The first spindle 1013 and the second spindle 1014 are configured to rotate around axes running lengthwise through the center of first and second spindles 1013 and 1014. In some embodiments, the first spindle 1013 is mechanically connected to a driving mechanism or motor (not shown) which rotates the first spindle 1013. The perforated drive belt 1044 is in contact with the external circumferential surfaces of the first spindle 1013 and the second spindle 1014 sufficient to cause the perforated drive belt 1044 to move as the first spindle 1013 is rotated by the driving mechanism or motor, thereby causing the perforated drive belt 1044 to move. As the perforated drive belt 1044 is moved by the first spindle 1013, the movement of the perforated drive belt 1044 also causes the second spindle 1014 to move.

[0145] As described above, when the automatic stack feeder 100 is in operation, a stack of articles rests or sits on the belts 120. A weight sensor (not shown) may be attached to the frame 110 or to the belts 120 or their rollers. The weight sensor is disposed underneath the frame 110, and is attached to either the frame 110 or the rollers which operate the belt 140. The weight sensor is configured to sense the weight of the stack on the frame 110 or on the belts 120. The weight sensor may be one of many weight sensors which are known in the art. For example, the weight sensor may be a scale, a load cell, a force sensor, a strain gauge, or any other known sensor capable to detecting a force or weight and output an electrical signal. The weight sensor may sense the weight or force applied to the frame 110 or to the rollers which are connected to the belts 120. The weight sensor may provide an indication of whether a stack is present on the belts 120 or the frame 110.

[0146] Also as described above, the lower paddle assembly 150 is attached to a track or drive belt which is attached to the frame 110. The paddle 150 is moveable along the length of the frame 110, and is configured to provide vertical support a stack of articles as the stack moves toward the singulator 140, and the perforated drive belt assembly 1010. Generally, the belts 120 advance the stack of articles toward the perforated drive belt assembly 1010 such that the lead article of the stack impinges on the perforated drive belt 1044 and is singulated. The lead article of the stack may be the article in the stack which is closest to the perforated drive belt assembly 1010.

[0147] As the stack impinges on the perforated drive belt 1044, the stack applies a force to the perforated drive belt assembly 1010. This force is resisted by a spring or similar device in the attachment of the first end 1011. The spring or other resisting force may have a predetermined value which can be used in calculating a pressure exerted by the stack on the perforated drive belt assembly 1010 based on the displacement of the perforated drive belt assembly 1010 from its position when no force is applied.

[0148] Singulation is accomplished as the stack, pushed or pulled along by the belts 120 moves toward the perforated drive belt assembly. As will be described in greater detail below, when the lead article of the stack impinges on the perforated drive belt assembly 1010, the lead article is held to the surface of the perforated drive belt 1044 by a vacuum force exerted on the leading article through the perforations in the perforated drive belt 1044. The leading article of the stack, held against the perforated drive belt 1044, is thus moved in the direction of movement of the perforated drive belt 1044, thereby separating an individual article from the bulk the stack.

[0149] Referring to FIGS. 3A and 3B, the frame provides a surface which is in the plane of the surface of the perforated drive belt 1044 which faces the stack of articles. The vertical portion of the frame includes a void or hole 1035, located such that the bottom of the void or hole 1035 is aligned with the generally flat horizontal surface of the frame 110. The void or hole 1035 corresponds to the dimensions of the perforated drive belt assembly 110.

[0150] The perforated drive belt assembly 1010 comprises a vacuum unit 1018. The vacuum unit 1018 is located between first and second spindles 1013 and 1014, and is disposed such that the inner surface of the perforated drive

belt 1044 is capable of being in close proximity to, or is in direct contact with the vacuum unit 1018. The vacuum unit 1018 generates a vacuum which exerts a force directed toward the vacuum unit 1018. The vacuum unit 1018 provides a securing force upon the articles in the stack, and holding the adjacent surface of the article in the stack against the surface of the perforated drive belt 1044 facilitates efficient singulation of the stack, as the surface of the article is held in sufficient contact with the perforated drive belt 1044 to allow the vacuum force to hold the article against the perforated drive belt 1044. More specifically, the vacuum unit 1018 provides a vacuum force which is communicated through the perforated drive belt 1044 via the perforations 1045. The vacuum unit 1018 develops a vacuum force which acts through the perforations in the perforated drive belt 1044 to pull air, articles, or whatever is in range of the vacuum force toward the perforated drive belt 1044.

[0151] As the stack moves toward the perforated drive belt assembly 1010 at least a portion of the leading article in the stack nears or contacts the perforated drive belt 1044. As the leading article of the stack nears or contacts the perforated drive belt 1044, the vacuum force generated by the vacuum unit 1018 draws the leading article from the stack and to the belt. The vacuum force acting through the perforations 1045 holds the lead article flush against the outer surface of the perforated drive belt 1044.

[0152] The perforated drive belt 1044 moves in response to the rotation of spindles 1013 and 1014, and the article or flat which is held against the outer surface of the perforated drive belt 1044 is thus separated from the stack, and is transported away from the stack. In some embodiments, the article is transported to the sorting section 180.

[0153] The perforated drive belt assembly 1010 comprises a sensor 1019. In some embodiments the sensor 1019 is located in proximity to the perforated drive belt assembly 1010. In some embodiments the sensor 1019 is mechanically attached to the second end 1012 via a depressible linkage which is attached to a top portion of spindle 1014, as depicted in FIGS. 10A-10B. The sensor 1019 is configured to sense a force exerted on the perforated drive belt assembly 1010 by the stack. As the stack impinges on the perforated drive belt 1044, the second end 1012 of the perforated drive belt assembly 1010 may displace, which depresses the depressible linkage, as depicted in FIG. 10B, thereby generating a measurable force. In some embodiments, the sensor 1019 may sense the displacement by using the depressible linkage in conjunction with a spring assembly. As the depressible linkage is depressed against a spring within the sensor 1019, the depression of the depressible linkage is measured and the depression is translated to an electrical signal, corresponding to a pressure exerted on the perforated drive belt assembly 1010 by the stack. Although one type of sensor is described here, a person of skill in the art will recognize that other types of sensors configured to sense a pressure or a force may be used in various configurations to accomplish the purpose of sensing the force exerted by the stack on the perforated drive belt assembly 1010.

[0154] For example, in some embodiments, the displacement may be sensed by a spring sensor 1017, which is attached to the spindle 1013 located in the first end 1011 via a displacement spring (not shown). In this case, as the perforated drive belt assembly 1010 displaces and rotates about the axis 1070, the spring in the spring sensor 1017 is compressed or expanded. The compression or expansion of this spring may be measured and electrically or electronically translated to a measure of pressure. In some embodiments, the displacement of the depressible linkage and/or the compression or expansion of the spring is not electrically translated to a pressure reading. For example, in some embodiments, an electronic signal related to the displacement of the perforated drive belt assembly 1010 may be transmitted to the controller. In some embodiments, the perforated drive belt assembly 1010 may have both the sensor 1019 and the spring sensor 1017. Having both the sensor 1019 and the spring sensor 1017 may provide a redundant pressure reading or sensor, or may increase the accuracy of the pressure or force measurements.

[0155] In some embodiments, the sensor 1019 or the spring sensor 1017 sense a change in angular position of the perforated drive belt assembly 1010 relative to the frame 1010, denoted as angle ϕ , rather than a pressure. In these embodiments, rather than generating a pressure signal, the sensor 1019 and the spring sensor 1017 generate an electrical signal which corresponds to the change in the angle ϕ . A person of skill in the art will understand that the same functionality can be provided by measuring either pressure or the angle ϕ . This functionality will be described later herein. Although FIGS 10A-B depict the sensor 1019 and/or the spring sensor 1017 connected to the second end 1012, it will be understood by those skilled in the art that the sensor 1019 and/or the spring sensor 1017 may be placed in various locations on the perforated drive assembly 1010. For example, the sensor 1019 and/or the spring sensor 1017 may be attached to the first end 1011, or to any position between the first end 1011 and the second end 1012. The sensor 1019 and/or the spring sensor 1017 is configured to output a sensed quantity, e.g., pressure, position, displacement, etc., for use in controlling the operation of the automatic stack feeder 100. The sensor 1019 and/or the spring sensor 1017 may be calibrated to output an appropriate or useable signal based on its position on the perforated drive belt assembly 1010.

[0156] Referring to FIG 11 depicts a side view of a stack of articles on the belts 120 near the perforated drive belt assembly 1010 of an automatic stack feeder 100. For optimal singulation of the stack 1060, an angle denoted as θ , which is the angle between the plane of belts 120 and the articles in the stack 1060 should be maintained in a desired range. In some embodiments, the angle θ is maintained at less than 10 degrees variance from 90 degrees. In some embodiments, the angle θ is maintained less than 100 degrees and greater than 90 degrees. The angle θ can be adjusted by moving the lower paddle assembly 150 either toward or away from the perforated drive belt assembly 1010, while

not moving the belts 120. Angle θ can also be adjusted by moving the belts 120 either toward or away from perforated drive assembly 1010 while not moving the lower paddle assembly 150. Angle θ may also be adjusted by moving the lower paddle assembly 150 in a first direction and moving the belts 120 in a second direction, opposite to the direction in which the lower paddle assembly 150 is moving.

[0157] In some embodiments, the paddle may maintain the stack 1060 at an angle θ which is slightly greater than 90° . However, if, for example, angle θ is too much greater than 90° , or, if the stack is leaning too far backward, as the leading edge of the leading article in the stack 1060 is moved forward to contact the bottom of the perforated drive belt assembly 1010, an insufficient portion of the surface of the leading article will make contact with the surface of the perforated drive belt 1044, and singulation will be hindered. As the stack 1060 presses on perforated drive belt assembly 1010, the perforated drive belt assembly 1010 resists movement. It should be noted that while the perforated drive belt assembly 1010 resists movement, it does not resist movement entirely, and there may be a deflection of the second end 1012 as the stack 1060 impinges on the perforated drive belt 1044.

[0158] The leading article and the other articles in the stack 1060 can be brought into a more vertical position by speeding the advance of the lower paddle assembly 150 or the belts 120 toward the perforated drive belt assembly 1010. If the angle θ is less than 90° , or, if the stack 1060 is leaning forward, as the leading edge of the leading article in the stack 1060 is moved forward to contact the top of the perforated drive belt assembly 1010, the perforated drive belt assembly 1010 resists movement, and the leading article and the articles behind in the stack 1060 can be brought into a more vertical position by accelerating the advance of or moving the lower paddle assembly 150.

[0159] In some embodiments, when the stack is leaning to far back toward the lower paddle assembly 150, or is slumping, the stack 1060 can be brought into a more vertical position by maintaining the position of the lower paddle assembly 1050, and moving the belts 120 away from the perforated belt assembly 1010. In some embodiments, the stack 1060 may be brought into a more vertical position by accelerating the movement of the lower paddle assembly 150 toward the perforated drive belt assembly 1010 and slowing the movement of the belts 120 toward the perforated drive belt assembly 1010. The mismatch of speed between the lower paddle assembly 150 and belts 120 may reorient the articles in the stack 1060 into the proper position. A similar method of changing the speed or direction of movement of the lower paddle assembly 150 and the belts 120 relative to each other may be used to correct the stack 1060 if it is leaning to far forward, or if the angle θ is less than about 90° .

[0160] In some embodiments, the singulator 1040 has a photoelectric sensor 1090. The photoelectric sensor 1090 may be disposed in proximity to the frame 110 such that it has a view of the angle of the stack 1060. In some embodiments, the photoelectric sensor 1090 may be attached to the vertical portion 142 of the frame 110. The photoelectric sensor 1090 is positioned and configured to sense the angle θ , or a similar corresponding or complementary angle indicative of the position of the stack 1060 relative to the belts 120 or the frame 110. The angle of the stack detected by the photoelectric sensor 1090 may be used as an input to control the automatic stack feeder 100, as will be described herein.

[0161] FIG. 12 is a schematic diagram of one embodiment of a controller circuit of the automatic stack feeder 100. The controller 1200 can be part of the control system described with reference to FIG. 8, or may be a part of a separate control system. The controller 1200 receives an input from the spring sensor 1017 and/or the sensor 1019. In some embodiments the controller 1200 also receives an input from the photoelectric sensor 1090. The input from the spring sensor 1017 and/or the sensor 1019 and/or the photoelectric sensor 1090 is received and used to assess the condition of the stack 1060 in the automatic stack feeder 100, and to develop control signals to the conveyor 130. The controller 1200 may have a pre-loaded algorithm which determines how to adjust the position the belts 120 and/or the lower paddle assembly 150 according to a particular input from the sensor 1019. Once the control signals are developed, the controller 1200 can transmit the signals to the belt/paddle controller 1203. The belt/paddle controller 1203 may similar to the controller described herein with reference to FIG 8.

[0162] As described above, in some embodiments, the sensor 1019 may be configured to sense the pressure exerted by the stack 1060 on the perforated drive belt assembly 110. The controller 1200 may be configured to maintain the pressure exerted by the stack 1060 on perforated drive belt 1044 within a specified range. For example, as the pressure sensed by the sensor 1019 increases, the controller 1200 may slow down or stop the forward movement of the stack 1060 by slowing or stopping either the movement of the belts 120 or the lower paddle assembly 150, or both. Conversely, when the pressure sensed by the spring sensor 1017 and/or the sensor 1019 decreases below a set point, the controller 1200 may speed up the movement of the stack 1060 toward the perforated drive belt assembly 110, in order to maintain the pressure sensed by the spring sensor 1017 and/or the sensor 1019 within an optimal band.

[0163] The controller 1200 may also receive input from the photoelectric sensor 1090. The photoelectric sensor 1090 determines the angle of the stack 1060, and uses the angle as an input to the controller. In response to the input from the spring sensor 1017, the sensor 1019, and/or the photoelectric sensor 1090, the controller 1200 may generate signals to control the speed or direction of the belts 120. Additionally, the controller 1200 may generate signals to control the movement or angle of the lower paddle assembly 150.

[0164] The controller 1200 may receive an input signal from the weight sensor 110 attached to the frame 110 or the belts 120. When the weight sensor 1201 senses the weight of the stack 1060 resting on the belts 120 or the frame 110,

the weight sensor 1201 sends a signal to the controller that the stack 1060 is present and that the stack 1060 has not been entirely singulated. When the weight sensor 1201 does not sense the presence of the stack 1060, the weight sensor 1201 sends this signal to the controller 1200. When the controller 1200 receives the signal that there is no stack on the frame 110 or the belts 120 in the automatic stack feeder 100, then the controller 1200 may send a signal to the belts 120, the lower paddle assembly 150, or both to stop.

[0165] In some embodiments, the vacuum unit 1018 comprises a vacuum sensor 1202. The vacuum sensor 1202 is positioned within the air stream created by the vacuum unit 1018, and senses the speed, velocity, flowrate, or other suitable parameter of the air flowing through the perforations on the perforated drive belt 1044 and into the vacuum unit 1018. When vacuum sensor 1202 senses that airflow is impeded or lessened, this may indicate that the lead article of the stack 1060 is positioned flush with the perforated drive belt 1044. When the vacuum sensor 1202 senses airflow or speed is unimpeded or is at its maximum value, this may indicate that there are no articles being singulated, and that singulation has yet to commence, or that the stack 1060 is entirely singulated.

[0166] The vacuum sensor 1202 may provide an input to the controller 1200. The controller 1200 can use this input alone or in combination with the other signals it receives, to determine whether singulation is ongoing, or whether the stack 1060 has been entirely singulated. With this information, the controller 1200 can send appropriate control signals to operate the perforated drive belt assembly 1010 and/or other system components.

[0167] In an automated stack feeder 100, conditions may develop where the stack is not aligned for optimal singulation. Typically, the articles in the stack 1060 are arranged such that the longer dimension of the article or flat is positioned generally parallel to the belts 120, and the shorter dimension is positioned generally perpendicular to the belts 120, and generally parallel to the perforated drive belt assembly 1010. Some examples of non-alignment are illustrated in FIGS. 13A-13C. Referring to FIG. 13A, the stack 1060 comprises a stack of articles or flats. The stack 1060 rests against the lower paddle assembly 150, and sits on the belts 120. The belts 120 moves the stack 1060 toward the perforated drive belt assembly 1010 in the direction of the arrow. If the stack 1060 fails to maintain sufficient pressure on the perforated drive belt assembly 1010, or if the belts 120 or the lower paddle assembly 150 are moving too slowly to keep up with singulation, the stack 1060 may begin to slump. As the stack 1060 slumps, the angle A may increase. As the angle A increases, it becomes increasingly difficult for an article to make sufficient contact with a surface of the perforated drive belt assembly 1010. If an article cannot make sufficient contact with perforated drive belt assembly, the vacuum cannot attract and hold the leading article in the stack 1060 to the perforated drive belt 1044, and, therefore, singulation is hindered. This may result in misfeeds, improper singulation, or breakdown of the automatic stack feeder 100. Slump in the stack 1060 may also result in damage to the articles of the stack 1060. In some embodiments, the stack 1060 may be slumping if the angle A is greater than 10° from vertical.

[0168] The stack slump illustrated in FIG. 13A can be detected by the spring sensor 1017 and/or the sensor 1019. When either the spring sensor 1017 or the sensor 1019 senses a pressure below a certain threshold acting on the perforated drive belt assembly, alone or in combination with a photoelectric sensor sensing the angle of the stack, the spring sensor 1017, the sensor 1019, and/or the photoelectric sensor 1090 may transmit the detected pressure or angle of deflection to the controller 1200. The set-point of the control system may be set to recognize that when a pressure is below a certain threshold, the belts 120, the lower paddle assembly 150, or both must be advanced to correct a slumping stack. This correction is accomplished by controlled movement of one or both of the belts 120 and the lower paddle assembly 150, as was previously described above, referring to the angle θ .

[0169] FIG. 13B illustrates a second kind of slump that may occur in an automatic stack feeder. Where articles in the stack 1060 are flimsy, they may bend and create voids 1065 in the stack 1060. Bent articles may not be able to make sufficient contact with the perforated drive belt assembly 1010 such that vacuum force cannot hold the article to the perforated drive belt 1044 in order to facilitate singulation. As described above, improper stack alignment may result in damage to the articles, misfeeds, improper singulation, or breakdown of the automatic stack feeder.

[0170] A slumping stack 1060 having voids 1065 may exert a pressure on the perforated drive belt assembly 1010 outside the pre-set threshold pressure, as sensed by the spring sensor 1017 and/or the sensor 1019. The photoelectric sensor 1090 may also be used to detect the slumping stack as depicted in FIG. 13B. As the stack slumps, the pressure is sensed on the perforated drive belt assembly 1010 by the spring sensor 1017 and/or the sensor 1019, the pressure is transmitted to the controller 1200, and the controller compares the transmitted pressures to internally stored or pre-set set-points or threshold values, established for proper operation for the automatic stack feeder 100. If the transmitted pressures are outside the threshold or set-point values, the controller 1200 provides signals to move the belts 120, the lower paddle assembly 150, or both, to straighten the slumping stack 1060 for optimal singulation.

[0171] FIG. 13C depicts the stack 1060 which is leaning forward, such that it is no longer being vertically supported by the lower paddle assembly 150. In this case, too, singulation cannot be properly accomplished, since the leading article in the stack 1060 does not make adequate surface contact with the perforated drive belt assembly 1010 for the force generated by the vacuum unit 1018 to effectively hold the article in contact with the perforated drive belt 1044.

[0172] The stack 1060 which is leaning forward may exert a pressure on the perforated drive belt assembly 1010. The spring sensor 1017 and/or the sensor 1019 may sense the pressure exerted on an upper portion the perforated drive

belt assembly 110 which is greater than a threshold pressure, indicating that the stack 1060 is improperly positioned. The photoelectric sensor 1090 may also sense that the stack is leaning forward, and may supply the stack angle signal indicating this condition to the controller 1200.

[0173] When the spring sensor 1017 and/or the sensor 1019 detect a pressure higher or lower than a threshold pressure, the controller 1200 may direct the belts 120, the lower paddle assembly 150, or both to move to put the stack 1060 back in its optimal configuration for singulation. In some embodiments, the controller receives the input from the spring sensor 1017 and/or the sensor 1019, and the photoelectric sensor 1090, and uses these inputs to generate control signals to the belts 120 or the lower paddle assembly 150, or both.

[0174] In some embodiments, the perforated drive belt assembly 1010 may have two pressure sensors. One such sensor may be attached to the top portion of one of the spindles 1013 and 1014. A second sensor may be attached to the bottom portion of the same one of the spindles 1013 and 1014. In this arrangement, the pair of pressure sensors may be capable of detecting a differential pressure between the top and the bottom of the perforated drive belt assembly.

[0175] Where the stack 1060 is leaning forward, the pressure exerted by the stack 1060 may be exerted on a top portion of the perforated drive belt assembly. In this embodiment, as the stack 1060 leans forward, the sensor attached to the top portion of one of the spindles 1013 and 1014 may sense a greater pressure than the sensor attached to the bottom portion of the same spindle 1013 or 1014. Thus, if the pressure exerted on the bottom of perforated belt were above a threshold value, the controller 1200 could identify the problem and differentiate it from a case where the pressure exerted on the top of the perforated drive belt is above a threshold value. In these two cases of stack misalignment, different actions may be taken to correct the two different problems, such as those described above.

[0176] Although specific problems that may arise regarding the stack 1060 have been described here, a person skilled in the art will recognize that the described problems are exemplary. Embodiments of the present disclosure may be configured to address stack misalignment issues in addition to those specifically described. A method of controlling the stack slump will be described in greater detail below.

[0177] Referring again to FIG. 1, the automatic stack feeder 100 comprises a sorting section 180. Articles may be singulated into individual articles for processing or routing, which may be done automatically by placing the stack of articles into an article feeder that may route the articles to various sorter windows. The sorting section operates at high speed and presents available sorter windows for insertion of the articles at a high rate. Errors may occur if the article feeder operation and the sorting section are not synchronized with one another. For example, the automatic stack feeder 100 may not properly sort the articles into the various sorter windows or may miss the windows completely. Furthermore, damage to the articles and/or selection of more than one article in the singulation process, or double feeding, may occur if the article feeder is not properly configured to operate at a high rate. Accordingly, systems and methods are described for automatic shingulation, singulation, and sorting of articles from a bulk stack of articles including synchronization of article feeder operation. For example, articles from a bulk stack of articles may be singulated, and the movement of the singulated individual articles may be synchronized such that they can be delivered into individual cells.

[0178] FIG. 14 depicts an embodiment of the sorting unit 180 of FIG. 1, for use in the automatic stack feeder of FIG. 1. As described above, the automatic stack feeder comprises a plurality of belts 1420. These belts are similar to those described elsewhere herein. For ease of illustration, only a single belt is depicted in FIG. 14, and description of other components of the automatic stack feeder 100 is omitted here. The sorting section comprises a group of picking devices 1410, an anti-doubling device 1422, one or more anti-rotation devices 1418, and a synchronization device 1424. The sorting section 1480 has a first end 1412 and a second end 1413.

[0179] As described elsewhere herein, the belts 1420 are configured to move in a direction 1426 toward the singulator 1440. The singulator 1440 is arranged generally perpendicularly relative to the belts 1420. Different embodiments of the singulator 1440 will be described in further detail below.

[0180] The one or more anti-rotation devices 1418, the picking devices 1410, and the anti-doubling devices 1422 are located downstream from the singulator 1440. As used herein, the term downstream may refer to a direction from the first end 1412 to the second end 1413 of the sorting section. Various sensors may also be located in proximity to the anti-doubling devices, which will be described in further detail below. The picking devices 1410, the anti-doubling devices 1424, the sensors, and/or the anti-rotation devices 1418 may be collectively referred to herein as a picking zone. The one or more anti-rotation devices 1418 may be located adjacent to the first two picking devices 1410. The anti-doubling devices 1422 may be located downstream from the anti-rotation devices 1418 and may be adjacent to the remaining three picking devices 1410. While five picking devices are illustrated in FIG. 14, a person of skill in the art will recognize that any other number of picking devices may be included as part of the sorting section 1480. Different embodiments of the picking zones will be described in further detail below.

[0181] The synchronization device 1424 is located downstream from the picking devices 1410. The synchronization device 1424 includes one or more paired pinch wheels. The synchronization device 1424 will be described in further detail below.

[0182] FIG. 15 illustrates an example of a stack of articles 1502. Each article of the stack 1502 includes a front side, a back side, two lateral sides, a top, and a bottom. The stack of articles 1502 may be placed on the belts 1420 with the

bottom of each article making contact with the belts 1420 and the front side of each article positioned to move in the direction of the arrows illustrated in FIGs. 14 and 15. Each article of the stack 1502 includes a binding 1504 along the bottom of each article that is aligned substantially parallel to the belts 1420. The front side of each article is aligned substantially parallel to each of the other articles in the stack 1502, and the front side of each article is aligned to face in the same direction. The front and back sides of each article are aligned to be substantially perpendicular to the belts 1420. In some embodiments, the stack of articles 1502 may be angled relative to the belts 1420 at any suitable angle. For example, the stack 1502 may be positioned at an angle of 0 to 10 degrees relative to the conveyor. The articles of the stack 1502 are also aligned front to back, with each article touching and supporting a neighboring article in the stack 1502.

[0183] The different components of the sorting unit 1480 are used to shingulate, singulate, and synchronize the stack 1502. In some embodiments, the singulator 1440 is configured to shingulate the stack 1502. As used herein, the term shingulation may refer to the process of extruding the stack 1502 to produce a positively lapped stack of articles traveling toward the group of picking devices 1410. As used herein, positive lapping may refer to the organization of the position of the leading edges of the articles of the stack 1502. For example, FIG. 16 illustrates a shingulated stack of articles 1502 with one or more positively lapped articles 1604, including the leading edge of each article being positioned downstream relative to the leading edge of an adjacent article. As the articles of the stack 1502 travel toward the singulator 1440 in direction 1606, the articles are shingulated by the singulator 1440 to produce the positively lapped stack of articles 1602. After being shingulated, the positively lapped stack of articles 1502 travel in direction 1608 toward the group of picking devices 1410.

[0184] FIG. 17 illustrates an example of a singulator 1440. As the belts 1420 moves, the stack of articles 1502 travels along the belts 1420 in the direction 1426 toward the singulator 1440. As noted above, a support structure or arm may provide support for the stack 1502 as the stack 1502 travels along the belts 1420. The singulator 1440 receives the stack 1502 and operates to shingulate the articles to produce the positively lapped stack of articles 1502.

[0185] The singulator 1440 includes a bottom transport belt 1704, a shearing device 1708, and a perforated belt 1706. The bottom transport belt 1704 has a transport surface extending in a first direction. The first direction may be a substantially horizontal direction. The bottom transport belt 1704 is configured to be moved in a downstream direction toward the shearing device 1708 using one or more belt drives 1710. In some embodiments, the shearing device 1708 is spring loaded. The perforated belt 1706 includes one or more openings. In some embodiments, the one or more openings include a plurality of small holes distributed generally uniformly over the surface of the perforated belt 1706. In some embodiments, the one or more openings include one or more elongate holes arranged in lines parallel or perpendicular to the length of the perforated belt 1706. In some embodiments the openings may have other suitable shapes. The openings may be concentrated in one region or area of the perforated belt 1706 or may be uniformly distributed over the surface of the perforated belt 1706. The perforated belt 1706 further includes a surface extending in a second direction different than the first direction. The second direction may be a substantially vertical direction relative to the bottom transport belt 1704. For example, the perforated belt 1706 may be at a right angle relative to the generally horizontal direction of the bottom transport belt 1704. The perforated belt 1706 is adjacent to the bottom transport belt 1704 and is configured to be moved in the downstream direction toward the shearing device 1708 using one or more belt drives 1710.

[0186] The singulator 1440 further includes a vacuum system similar to those described elsewhere herein. With the vacuum force holding an article against the perforated belt 1706, the bottom transport belt 1704 and the perforated belt 1706 are configured to move the stack 1502 in the downstream direction toward the shearing device 1708. The shearing device 1708 is configured to apply a shearing force on a portion of the stack of articles to produce the positively lapped stack of articles 1604. The stack 1502 rests on the bottom belt 404 and is also coupled to the perforated belt 1706 via the suction provided through the one or more openings. For example, the articles are held to the surface of the perforated belt 404 by a vacuum force exerted on the article through the one or more openings in the perforated belt 404, as described above. The stack 1502, being held against the perforated belt 1706 and resting on the bottom transport belt 1704 are thus moved in the downstream direction. As these belts are moved forward in the downstream direction, the stack 1502 is pressed against the shearing device 1708, which imparts a shearing force on the stack 1502. For example, the shearing device 1708 may impart a shearing force on the stack 1502 by applying constant pressure on the stack 1502 and forcing only a portion of the stack 1502 at a time to enter the first pick point 1722. In some embodiments, the shearing device 1708 is spring loaded and may impart the shearing force using a spring to apply pressure to the stack 1502. By imparting the shearing force on the stack 1502, the shearing device 1708 effectively extrudes and creates a positive lapped configuration of the stack 1502, resulting in the positively lapped shingulated stack of articles 1604.

[0187] The singulator 1440 may be configured to deliver the stack of articles in a positively lapped configuration at a system rate to a first pick point 1722, which is the point at which the articles begin transition from being shingulated to being singulated. In some embodiments, the bottom transport belt 1704 and the perforated belt 1706 may move at a slower, more continuous speed relative to the belts of the picking devices 1410, which will be described below. In some embodiments, the shingulating belts may not start and stop with each picked article. In some embodiments, bottom transport belt 1704 and the perforated belt 1706 of the singulator 1440 may automatically turn off when no articles are

within a certain distance from the belts. When the stack 1502 makes contact with or is within a certain distance from the bottom transport belt 1704 and/or the perforated belt 1706, the belts may automatically turn on in preparation for the shingulation of the stack 1502. The stack 1502 may be sensed by a sensor, such as an infrared or optical photo-eye or proximity sensor.

[0188] FIG. 18A illustrates another example of a singulator 1440. The singulator 1440 includes bottom transport belts 1804 and 1806. Each transport belt 1804 and 1806 has a transport surface extending in a first direction, such as a substantially horizontal direction. The sorting unit 1480 further includes a plurality of perforated belts 1808, each of the perforated belts including one or more openings, similar to those described elsewhere herein. Each of the perforated belts 1808 has a surface extending in a second direction that is different than the first direction. The second direction may be a substantially vertical direction relative to the bottom transport belts 1804 and 1806. For example, perforated belts 1808 may be at a right angle relative to the generally horizontal direction of the bottom transport belts 1804 and 1806. The plurality of perforated belts 1808 are adjacent to at least one of the plurality of bottom transport belts 1804 and 1806. The sorting unit 1480 further includes a shearing device 1810 that is used to impart a shearing force on the stack 1502. As the belts 1420 moves forward, the stack 1502 rests on the bottom transport belts 1804 and 1806 and articles in the stack 1502 are also coupled to each of the perforated belts 1808 via suction provided through the one or more openings of each perforated belt. As the bottom transport belt 1804 and the first two perforated belts are moved forward, the stack 1502 is pressed against the shearing device 1810 to create a positive lapped configuration of the stack 1502.

[0189] FIG. 18B illustrates another embodiment of a sorting unit 1480, illustrating a side elevation view taken along line 18B-18B' of FIG. 5A. The sorting unit 1480 includes a perforated belt 1808A located in a shingler zone and a perforated belt 1808B located in an intermediate zone. The bottom transport belt 1804 illustrated in FIG. 18A may be located in the shingle zone along with the perforated belt 1808A. The bottom transport belt 1806 illustrated in FIG. 18A may be located in the intermediate zone along with the perforated belt 1808B. In some embodiments, the bottom transport belt 1804, the perforated belt 1808A, and/or the corresponding vacuum(s) may automatically turn off when no articles are within a certain distance from the belts. When the stack 1502 makes contact with or is within a certain distance from the bottom transport belt 1804 and/or the perforated belt 1808A, the belts and vacuum(s) may automatically turn on in preparation for the shingulation of the stack 1502. The stack 1502 may be sensed by a sensor, such as an infrared or optical photo-eye or proximity sensor, located at a point at the beginning of the bottom transport belt 1804 and/or the perforated belt 1808A.

[0190] In some embodiments, the bottom transport belt 1804, the perforated belt 1808A, and the corresponding vacuums may be variably controlled in order to control the flow of articles to the perforated belt 1808B and the bottom transport belt 1806. For example, the bottom transport belt 1804 and/or the perforated belt 1808A may be started or stopped, or the speed of the bottom transport belt 1804 and/or 1808A may be increased or decreased, at a first time depending on the number of articles that are located in the intermediate zone at the first time. For example, a thickness sensor 1814 may determine the thickness of the stack of articles in the intermediate zone. For example, the thickness sensor 1814 may be a scale, a load cell, a force sensor, a strain gauge, or any other known sensor capable of detecting a force or weight and outputting an electrical signal. In response, the bottom transport belt 1804 and/or the perforated belt 1808A may be controlled (e.g., started, stopped, slowed down, sped up, etc.) based on the sensed thickness. For example, if the thickness sensor 1814 indicates that too many articles are located in the intermediate zone as determined by a thickness threshold, the bottom transport belt 1804, the perforated belt 1808A, and/or the corresponding vacuum(s) may be stopped so that the bottom transport belt 1806 and the perforated belt 1808B in the intermediate zone can reduce the amount of articles in the intermediate zone by passing the articles to the picking devices 1812 and 1816. After the amount of articles is reduced below the threshold level, the belts 1804 and 1808A and the vacuum(s) may be started again. In some embodiments, a sensor 1818 may be located at the first picking device 1812 and may be used to determine the speed at which to operate the bottom transport belt 1804 and/or the perforated belt 1808A. For example, if no articles are sensed by the sensor 1818, the speed of the bottom transport belt 1804 and/or the perforated belt 1808A may be increased until an article is sensed. The sensor 1818 may be configured to detect the leading edge of an article and may include any suitable sensor, such as an infrared or optical photo-eye or proximity sensor.

[0191] In some embodiments, the bottom transport belt 1806, the perforated belt 1808B, and the corresponding vacuum(s) may be variably controlled in order to control the flow of articles to the picking devices 1812 and/or 1816. For example, if no articles are sensed by the sensor 1818, indicating that no articles are located at the first picking device 1812, the bottom transport belt 1806 and/or the perforated belt 1808B may be started and/or sped up. If one or more articles are sensed by the sensor 1818, the intermediate perforated belt 1808B may be stopped or may be slowed down until the sensor is clear. The vacuum(s) may be started or stopped with the belts in response to the results of the sensor 1818.

[0192] In some embodiments, the sensor 1818 may be configured to count the number of articles that are detected. The bottom transport belt 1806, the perforated belt 1808B, and/or the corresponding vacuum(s) may be variably controlled according to the number of sensed articles. In some aspects, a controller, processor, and/or memory may be coupled

to the sensor 1818 and may be used to count the number of articles that are detected or sensed by the sensor 1818. For example, if the sensor 1818 indicates that one article has been detected, an intermediate zone vacuum (not shown) may be turned on as well as the bottom transport belt 1806 and the perforated belt 1808B. Similarly, if the sensor 1818 indicates that no articles are detected, the intermediate zone vacuum and the belts 1806 and 1808B may be turned on.

On the other hand, for example, if the sensor 1818 indicates that two or more articles are detected, the intermediate zone vacuum may be turned off and the bottom transport belt 1806 and the perforated belt 1808B may be stopped. The controller or processor may be implemented with any combination of general-purpose microprocessors, microcontrollers, digital signal processors (DSPs), field programmable gate array (FPGAs), programmable logic devices (PLDs), controllers, state machines, gated logic, discrete hardware components, dedicated hardware finite state machines, or any other suitable entities that can perform calculations or other manipulations of information. The memory may include a Random Access Memory (RAM) circuit, an Electrically Erasable Programmable Read Only Memory (EEPROM), an Electrical Programmable Read Only Memory (EPROM), a Read Only Memory (ROM), an Application Specific Integrated Circuit (ASIC), a magnetic disk, an optical disk, and/or other types of memory well known in the art.

[0193] As a result of the variably controlled belts and vacuum(s), the singulator 1440 may be configured to deliver the stack of articles in a positively lapped configuration at a system rate to a first picking device 1812, which is the point at which the articles begin transition from being shingulated to being singulated.

[0194] Returning to FIG. 14, each of the picking devices 1410 is configured to singulate one or more of the articles from the shingulated stack of articles 1502. Here, singulation may refer to picking articles from the positively lapped shingulated stack 1604 to produce individual articles. One or more of the picking devices 1410 may include an anti-rotation device 1418 or an anti-doubling device 1422. The anti-rotation devices 1418 may ensure that the stack of articles stay in a stacked configuration and do not sag as they are singulated and/or sorted. FIG. 19A illustrates another example of an sorting unit 1480 including picking devices 1910 and anti-doubling devices 1922. The anti-doubling devices 1922 include edge detector sensors 1911 and presence sensors 1912. Details regarding the anti-doubling devices 1922, edge detector sensors 1911, and presence sensors 1912 will be discussed below with respect to FIGs. 20A and 20B.

[0195] FIG. 19B illustrates an enlarged portion of a picking device 1910 as indicated by the dashed line 19B of FIG. 19A. The picking device 1910 includes a perforated belt 1906, a perforated belt drive pulley 1914, a vacuum manifold 1908 located adjacent to the perforated belt 1906, a vacuum unit (not shown), and a vacuum valve 1916. A bottom transport belt 1904 may be located adjacent to the picking device 1910 to support the articles as they move. In some embodiments, the bottom transport belt 1904 may be the same bottom transport belt 1704 illustrated in FIG. 17. In some embodiment, the sorting device 1480 does not include the bottom transport belt 1904 located adjacent to the picking device 1910 so that only the perforated belt 1906 is included to transport articles in a downstream direction. In some embodiments, the picking devices 1910 are configured in a row, and a downstream most picking device in the row that is substantially completely covered by the positively lapped stack of articles is configured to pick the article from the positively lapped stack of articles and to produce the singulated article. As used herein, substantially completely covered may refer to a picking device that has a particular number of sensors blocked by one or more articles. For example, if each picking device includes four sensors (e.g., photoelectric sensors, proximity sensors, infrared sensors, optical sensors, and the like), and three of the four sensors are blocked by one or more articles, that picking zone may be considered substantially completely covered. As another example, a picking device is substantially completely covered if all sensors for that picking device are blocked by one or more articles.

[0196] The perforated belt 1906 may be vertically oriented and may have one or more openings in its surface through which a vacuum source may be applied. As used herein, vertically oriented may refer to a substantially vertical angle. As another example, vertically oriented may refer to any other suitable angle, such as an angle anywhere from 50-60° (e.g., 50°, 60°, 70°, 80°). The perforated belt 1906 is moved or driven using the perforated belt drive pulley 1914. The perforated belt drive pulley 1914 may be driven by a motor, such as a single servo motor. The vacuum unit may be configured to apply a suction force through the vacuum manifold 1908 and the vacuum manifold 1908 may be configured to apply the suction through the one or more openings in the surface of the perforated belt 1906. The vacuum valve 1916 may be configured to control the amount of suction applied by the vacuum unit to the vacuum manifold 1908.

[0197] The singulation, or picking, may be accomplished as the stack 1502 moves toward the perforated belt 1906 by opening the vacuum valve 1916 and exposing the vacuum manifold 1908 to a vacuum force. The vacuum force may pull a leading article of the stack 1502 through the one or more openings of the perforated belt 1906 to effectively connect the lead article to the perforated belt 1906. The lead article is the article in the stack 1502 located closest to the perforated belt 1906. Accordingly, as the lead article of the stack 1502 impinges on the surface of the perforated belt 1906, the vacuum valve 1916 may expose the vacuum manifold 1908 to the vacuum force (if not already applied). The lead article is held to the surface of the perforated belt 1906 by the vacuum force exerted on the lead article 0 through the one or more holes in the perforated belt 1906. The lead article, held against the perforated belt 1906, is thus moved in the direction of movement of the perforated belt 1906 using the perforated belt drive pulley 1914, thereby separating the lead article from the shingulated positively lapped stack 1604.

[0198] Multiple picking devices 1910 may be used, each including a perforated belt, a perforated belt drive pulley, a

vacuum manifold, a vacuum valve, and a vacuum unit, as described herein. For example, five picking devices may be used to singulate the stack of articles 1502. A person of skill in the art will recognize that any other number of picking devices may be used to accomplish the purpose of singulating the stack 1502.

[0199] The picking devices allow individual articles to be singulated from the stack 1502 while also exposing the singulated article stream to anti-doubling devices 1422. The anti-doubling devices 1422 help to ensure the fidelity of the singulated article stream. For example, articles may stick together for various reasons when picked by one of the picking devices, and attaching only one side of the article to the perforated belt may not prevent another article from sticking to the other side of the attached article opposite the perforated belt 1906. In the event that one or more articles are simultaneously picked from the stack 1502, an anti-doubling device 1422 may be used to expose the article attached to the other side of the desired article to a vacuum source. The vacuum source applied to the attached article is used to separate the attached article from the desired article.

[0200] FIG. 20A illustrates an example of a sorting section 1480 including a group of picking zones 2004. The picking zones 2004 include anti-doubling devices 2022A and 2022B and picking devices 2010. The anti-doubling devices 2022A and 2022B include edge detector sensors and presence sensors (not shown in FIG. 20A), similar to edge detector sensors 1911 and presence sensors 1912 illustrated in FIG. 19A. The edge detector sensor 1910 may be positioned upstream from the presence sensor 1912 and may be configured to detect an edge of an article. In some embodiments, the presence sensor 1912 includes a photoelectric sensor or photo-sensor. Although a certain type of sensor is described herein, a person of skill in the art will recognize that other suitable types of sensors may be used in various configurations to accomplish the purpose of sensing the presence of an article.

[0201] Three anti-doubling devices 2022A and 2022B may be used to ensure that the picking devices 1410 properly singulate the articles from the stack 302. In some embodiments, some combination of the anti-doubling devices 1422A and/or 112B will have a low level of constant vacuum to encourage the articles to be shingulated prior to being singulated by one of the picking devices. For example, if the sorting section 1480 does not include a dedicated singulator 1440, the first two anti-doubling devices 2022A may have a constant level of vacuum at all times in order to effectively shingulate the stack 1502. As another example, even if a dedicated singulator 1440 is included in the sorting section 1480, the picking zones 2004 may be used to re-shingulate the stack of articles in the event that the articles have shifted during transport. A particular level of constant vacuum pressure may be measured and used to ensure that the articles are not damaged as they are shingulated.

[0202] In some embodiments, the first two anti-doubling devices 2022A may be triggered by one or more edge detector sensors (not shown) that detect the presence of a shingulated stack of articles or the presence of an article that is attached to a desired article to be singulated. When one or more edge detectors indicate that a shingulated stack or an attached article is located at the particular picking zone, an anti-doubling device 2022A and/or 2022B may be turned to a high vacuum level to attempt to hold back the other articles of the shingulated stack or the attached article from the desired article that is to be singulated. FIG. 20B illustrates an example of an anti-doubling device 1422 detecting a shingulated stack of articles or an attached group of articles approaching a picking zone. At time 1 (T1), a first article 2002 crosses an edge detector sensor 1910. In response, it is determined that an edge is found. For example, a controller or processor may receive an indication that an edge is detected by the edge detector sensor 1910. The controller or processor may be implemented with any combination of general-purpose microprocessors, microcontrollers, digital signal processors (DSPs), field programmable gate array (FPGAs), programmable logic devices (PLDs), controllers, state machines, gated logic, discrete hardware components, dedicated hardware finite state machines, or any other suitable entities that can perform calculations or other manipulations of information. At T1, the presence sensor 1912 is not blocked. Accordingly, it is determined that only a first edge has been detected, indicating that only a single article is present in the picking zone. As a result, the vacuum pressure is not increased to a high vacuum at T1.

[0203] At time 2 (T2), the first article 2002 crosses the presence sensor 1912. A second edge has not been reported by the edge detector sensor 1910 at T2, thus the vacuum pressure is not increased at T2. At time 3 (T3), the second article 2004 breaks the plane of the edge detector sensor 1910, which reports the edge of the second article 2004 to the controller or processor. At T3, the presence sensor 1912 is also blocked by the first article 2002. As a result, it is determined that there is more than one article, one of which needs strong anti-doubling in order to properly singulate the desired article. Accordingly, the anti-doubling device 2022 is turned on to full vacuum in order to separate any articles from the desired article to be singulated by the picking zone. For example, in the event more than one article is simultaneously separated from the shingulated stack, the anti-doubling device 2022 may be turned to full vacuum in order to separate the desired article from the other articles. As illustrated in FIG. 20B, the downstream edge 2006 of the anti-doubling device 2022 body is positioned just downstream from the edge detector sensor 1910 so the sensor 1910 is known to be acting only on the second article 2004.

[0204] Returning again to FIG. 14, the sorting section 1480 further includes a synchronization device 1424. FIG. 21 illustrates an example of a synchronization device 1424 that includes a group of paired pinch wheels 2104. The synchronization device 1424 may be located downstream from the last picking zone 2106. The pinch wheels 2104 may be driven at a variable speed by one or more pinch wheel motors (not shown). A pinch wheel motor may include a servo

motor or any other suitable motor for driving the pinch wheels. While a certain number of pinch wheel pairs is illustrated in FIG. 21, a person of skill in the art will recognize that any other number of pinch wheels may be used to accomplish the purpose of transferring articles from the sorting section 1480 to the rendezvous point 1416. The rendezvous point 1416 may also be referred to herein as an exit point. The rendezvous point 1416 is the point at which an article leaves the sorting section 1480 for depositing into a sorter window of a sorter. This process will be described in greater detail below.

[0205] Returning to FIG. 14, the sorting unit 1480 comprises an anti-rotation device 1418. Figure 22 provides a side plan view of one embodiment of an anti-rotation device 2200. In some embodiments, the anti-rotation device 2200 includes a torsion element, such as, for example, a torsion bar 2210. The torsion bar 2210 is connected to a base 2205. The base 2205 may be any supportive, component or surface of the stack feeder. In some embodiments, the torsion bar 2210 is a generally straight rod pivotably connected to the base 2205 such that the torsion bar 2210 pivots about an axis of rotation 2212 running through the center of the torsion bar 2210. In some embodiments, the torsion bar 2210 is made of an elastic material which allows for rotational flexibility or elasticity of the torsion bar 2210. The pivotable connection between the torsion bar 2210 and the base 2205 allows a pivot between at least a first relaxed position and a second, twisted position in which a torque is applied to at least portion of the torsion bar 2210. In the second, twisted position, potential energy is stored in the torsion bar 2210, motivating the torsion bar 2210 to return to the first configuration. In some embodiments, as will be described below in greater detail, the torsion bar comprises a rotation resistance member, or is otherwise configured to resist rotational movement.

[0206] The anti-rotation device of some embodiments comprises a rotatable member, such as, for example, a lever arm 2220. In the depicted embodiment, the lever arm 2220 has a threaded through hole 2222 on a proximal portion of the lever arm 2220. The threads of the through hole are configured to be disposed around, and securely engage, complementary threads (not visible) disposed on at least a portion of an outer surface of the torsion bar 2210. In some embodiments, any other suitable engagement mechanism known to one of skill in the art may be utilized to secure the lever arm 2220 to the torsion bar 2210. For example, in some embodiments, a snap fit, a rivet, a screw, a friction fit, or permanent melding or welding, or any other desired engagement mechanism may be used. In some embodiments, the torsion bar 2210 and the lever arm 2220 may be distinct portions of the same unitary object and are integrally formed, as a non-limiting example, by means of injection molding. As the lever arm 2220 is attached to the torsion bar 2210, the lever arm 2220 is rotatable about the axis of rotation 2212 of the torsion bar 2210 between at least a first position and a second position. The anti-rotation device 2200 of Figure 22 is shown in the first, non-rotated position. In some embodiments, the extent of rotation between the first position and the second position is only a couple degrees or less. In other embodiments, the extent of rotation between the first position and the second position may be 5 degrees, 15 degrees, or any value therebetween. In some embodiments, the range of rotation between the first position and the second position may be greater than 15 degrees. In some embodiments, the lever arm 2220 rotates about the axis of rotation 2212 of the torsion bar 2210 within a plane of rotation that is substantially parallel with the base 2205.

[0207] Some embodiments of the anti-rotation device comprise a revolving member coupled to a distal portion of the lever arm 2220. For example, the anti-rotation device 2200 comprises a plurality of wheels 2240 coupled to the distal portion of the lever arm 2220. In some embodiments, the plurality of wheels 2240 is coupled to the distal portion of the lever arm 2220 by means of a wheel shaft 2230. The wheels 2240 are disposed around the wheel shaft 2230 and rotate relative to the wheel shaft 2230 via low friction bearings which are disposed at intervals on the wheel shaft 2230.

[0208] The wheel shaft 2230 is coupled to a distal portion of the lever arm 2220 via threads (not visible) positioned on a bottom end of the wheel shaft's outer surface. The threads are configured to securely engage complementary threads disposed around a through hole 424 in a distal portion of the lever arm 2220. In other embodiments, any other suitable engagement mechanism known to one of skill in the art may be utilized to secure the wheel shaft 2230 to the lever arm 2220. For example, in some embodiments, a snap fit a rivet, a screw, a friction fit, or permanent melding or welding, or any other desired engagement mechanism may be used. In some embodiments, the wheel shaft 2230 and the lever arm 2220 may be distinct portions of the same unitary object.

[0209] In some embodiments, the wheels 2240 are non-movably fixed to the wheel shaft 2230 and the wheel shaft 2230 is coupled to the lever arm 2220 via a low friction bearing. In such embodiments, the wheel shaft 2230 is configured to rotate relative to the lever arm 2220, which in turn, rotates the wheels 2240. In some embodiments, a rotating cylinder or other revolving member may couple to the lever arm 2220 via a wheel bracket or via a shaft portion extending from one end of the revolving member. In various embodiments, the revolving member spins about an axis extending angularly relative to an elongated axis of the rotatable member.

[0210] In some embodiments, each of the plurality of wheels 2240 has an equal diameter and shares an axis of rotation 2445. The wheels 2240 spin about the wheel shaft 2230 around axis of rotation 2445, which is positioned perpendicularly to an elongated axis 426 of the lever arm 2220.

[0211] Figure 23 provides a perspective view of an embodiment of an anti-rotation device 2300, shown in the first position. The anti-rotation device 2300 may be similar to the anti-rotation devices described with regard to Figure 22. As described above, the anti-rotation device 2300 may be configured to rotate between at least a first position and a

second position. In the first position, the torsion bar 2310 is in an initial state. The torsion bar 2310 is pivotably connected to a base 2305, and the pivotable connection is disposed near the drive belt 2350. The lever arm 2320 extends from the torsion bar 2310 at an angle which places an outer surface 2342 of the wheels 2340 in contact with a drive belt 2350. The wheels 2340 are rotatably connected to the wheel shaft 2330. The proximity of the pivotable connection between the torsion bar 2310 and the base 2305 allows the wheels 2340 to rest in contact with the drive belt 2350 without creating significant losses of energy of the drive belt 2350 due to friction.

[0212] The outer surface 2342 of the wheels 2340 are configured to rotate. Thus, when the drive belt 2350 moves, the friction between the outer surface 2342 of the wheels 2340 and the drive belt 2350 causes the wheels 2340 to rotate around wheel shaft 2330. As described above, the drive belt 2350 may be used to singulate an article using a vacuum force exerted through one or more openings in the drive belt 2350.

[0213] As described above, the drive belt 2350 is configured to move an article 2360, for example, an open article such as a magazine, catalog, or any other article, laterally into the stack feeder as part of the process of singulation. As the drive belt 2350 moves the article 2360, the article 2360 contacts a portion of the outer surface 2342 of the wheels 2340, the article 2360 applies a force to the lever arm 2320, which causes the torsion bar 2310 to rotate. The rotation of the torsion bar 2310 allows the wheels 2340 to move away from the belt 2350, and to roll onto an outer, back cover of the article 2360. The lever arm 2320 is pushed by the laterally moving mail article 2360 into the second position, thereby making room for the article 2360 to pass between the drive belt 2350 and the outer surface 2342 of the wheels 2340. The push from the moving mail article 2360 causes the lever arm 2320 to angularly rotate within its plane of rotation, which is parallel to the base 2305 and the floor. This rotation of the lever arm 2320 applies torque to a portion of the torsion bar 2310, causing the torsion bar 2310 to twist or rotate about an axis. As will be described below, the torsion bar 2310 is configured to resist such motion, and the twisting generates tension or potential energy in the torsion bar 2310. The tension causes the torsion bar 2310 to apply a counter-torque to the lever arm 2320, thereby resisting the rotation, and biasing the lever arm 2320 back towards the first position. The rotation, tension, counter-torque and resulting forces generated by the twisting torsion bar 2310 cause the wheels 2340 to apply a force onto the article 2360, which effectively pushes the article 2360 into the drive belt 2350, and pushes a back cover 2362 towards a front cover of the mail article 2360.

[0214] Figure 24 depicts at least some of the forces acting on an article 2400 when an anti-rotation device having wheels 2440 is present in a stack feeder. In various embodiments, each wheel 2440 has a high friction outer surface 2442, which resists any upward motion of a back cover 2402 of the article 2400 due to the force applied to the front cover. Specifically, the lateral acceleration force 2410 is applied to a front cover of the article 2400 and inertial forces 2412 act on the back cover 2402 in the opposite direction, when the article undergoes singulation or shingulation. The interplay of these forces may result in the back cover 2402 pivoting about an upstream corner 2406 of a binding 2404. To counter act this pivoting, the wheels 2440 apply a counter-force to the back cover 2402 of the article 2400, which prevents twisting of the binding 2404. By holding the front cover and back cover 2402 of the mail article 2400 together and providing a downward reaction force 2416 on the back cover 2402, the anti-rotation device distributes the torque 614 generated due to the lateral acceleration force 2410 and the inertial force 2412 over both the front and back covers and reduces the shearing stresses exerted on the binding 2404 of the article 2400.

[0215] Moreover, by pushing the back cover 2402 toward the front cover using the wheels 2440 and the resistance of the torsion bar, friction is created within the article 2400 between the covers, and the friction acts to resist inertial shearing forces generated on either one of the covers. Thus, the anti-rotation device of various embodiments allows acceleration forces 610 to be applied to the article 2400 without damaging the binding 2404, the front cover or the back cover 2402. Additionally, the wheels 2440 rotate freely about the wheel shaft 2430 via low-friction wheel bearings so that the presence of the wheels 2440 does not add any new significant shearing forces to the article 2400.

[0216] Figure 25 depicts a portion of an embodiment of an anti-rotation device 2500. In Figure 25, a torsion bar 2510 and a portion of a lever arm 2520 are in a second position. As shown, rotating the lever arm 2520 from a first position to a second position through angle 2502 causes the torsion bar 2510 to twist. As described in detail above, the twisting generates a reaction torque in the torsion bar 2510, motivating the torsion bar 2510 and the coupled lever arm 2520 back toward the first position. The torsion bar 2510 can be formed of any suitable elastic material known to one skilled in the art. In some embodiments of an anti-rotation device, the torsion bar may be comprise, at least in part, by a helical torsion spring. In other embodiments, any other torsion element known to one skilled in the art may be used.

[0217] One embodiment of a torsion element, specifically, a helical torsion spring 2600, is depicted in Figures 26A and 26B. As shown in Figure 26A, the helical torsion spring 2600 is formed of a coiled rod or wire 2602 made of any suitable elastic material known to one skilled in the art, such as metal, steel, plastic, or other desired material. The torsion spring 2600 includes a top end 2604, a bottom end 2608, and a plurality of coils 2606. As shown in Figure 26B, when a sideways force, also referred to as a bending moment or a torque, is applied to the top end 2604, the top end 2604 rotates inward, for example, from a first position 2600a to a second position 2600b, and the plurality of coils 2606 coil tighter. The rotation generates a reaction torque in the torsion spring 2600, motivating the torsion spring 2600 and a coupled lever arm 2620 (shown in Figure 26C) back toward the first position 2600a.

[0218] In anti-rotation device embodiments having a torsion spring 2600, such as, for example, the anti-rotation device partially depicted in Figure 26C, the torsion spring 2600 is disposed within or around a structural support member 2610. The structural support member 2610 is immovable and connected to a base 2605. In some embodiments, the torsion spring 2600 is at least partially disposed within the structural support member 2610, with a top end 2604 protruding from the structural support member 2610 and integrated into the lever arm 2620. In some embodiments, the top end 2604 may be embedded in the lever arm 2620, or may be fastened by mechanical means such as a weld, a bracket, a screw, a rivet, or any other suitable fastening mechanism. The bottom end 2608 of torsion spring 2608 may be fixedly attached to the base or a non-moving torsion bar 2610.

[0219] In operation, an article exerts a force felt on the lever arm, and the movement of the lever arm 2620 results in movement of the top end 2604 of the torsion spring 2600. The bottom end 2608 is fixedly attached, and thus, does not move. The movement of the top end 2604 compresses the tension spring and stores potential mechanical energy within torsion spring 2608, and resists the movement of the lever arm 2620. In some embodiments, the torsion spring 2600 is affixed to, and disposed around, the structural support member 2610, within a bearing surrounding the structural support member 2610. In such embodiments, a top end 2604 of the torsion spring 2600 is again integrated into, or coupled to, the lever arm 2620 such that movement of the lever arm 2620 from a first position 2600a to a second position 2600b causes the top end 2604 of the torsion spring 2600 to move accordingly. Such movement generates tension within the torsion spring 2600 and causes the torsion spring 2600 to apply a force to the lever arm 2620 which resists rotational movement of the lever arm 2620.

[0220] FIG. 27 is a flow chart describing an exemplary process for controlling the position of the stack guide 130. Process 2700 begins at block 2702, wherein the position of the container is received as described above with reference to FIGS. 5 and 6. If the container is present, the process 2700 moves to block 2704, wherein the stack guide is moved away from the stack of articles, or from a first position to a second position. With the stack guide 130 moved away from the stack of articles, the process 2700 moves to block 2706, wherein the container is unloaded. The controller 810 may coordinate the movement of the belt motor 840, lower paddle assembly x-axis motor 820, lower paddle assembly z-axis motor 830, and the carrier motor 880 to accomplish the container unload, as described elsewhere herein.

[0221] The process 2700 next moves to decision state 2708, wherein it is determined whether the container has been removed. This determination may be made as described above. If it is determined that the container 190 has not been removed from the belt 120, the process waits until the container 190 has been removed. If the container 190 has been removed, the process 2700 moves to block 2710, wherein the stack guide 130 is moved back to its original position, in contact with the stack of articles.

[0222] The process 2700 next proceeds to decision state 2712, wherein it is determined whether there is another container 190 to be unloaded. This determination may be made based on a predetermined number of containers to be unloaded which was input into the controller 810, and the controller 810 may count the number of containers 190 which have been unloaded. In some embodiments, this decision may be made based on receiving sensor input, manual input, or any other desired input following the unloading of each container 190. If another container 190 is to be unloaded, the process 2700 returns to block 2702. If there are no more containers 190 to unload, the process 2700 ends in block 2714.

[0223] FIG. 28 is a flowchart of an embodiment of a process 2800 for controlling an automatic stack feeder 100. Process 2800 may commence when a stack of articles is placed in the automatic stack feeder 100. The process 2800 proceeds to block 2802 wherein singulation of the stack of articles commences. Singulation, as described herein, uses a vacuum force to attract and hold an article to the perforated drive belt 144, which transports a single article along to the sorting section 180. During singulation the belts 120 and the lower paddle assembly 150 may both move, independently or in concert, to advance the stack for singulation.

[0224] In block 2804, the pressure exerted by the stack of articles on the perforated drive belt assembly is sensed. As described herein with regard to FIGS. 10A-B, the pressure may be sensed by the spring sensor 1017 and/or the sensor 1019 connected to the perforated drive belt assembly 1044. The sensed pressure is transmitted to the controller 1200. At decision block 2806, it is determined whether the sensed pressure is either within a certain range or above or below a specified threshold. If the pressure is within the specified range and/or threshold, this may indicate that the stack is properly aligned, and that no adjustments are needed. If it is determined in decision state 2806 that the sensed pressure is outside a specified range, or is above or below a given threshold, this may indicate a problem with the stack, its position, or with the singulation process.

[0225] If the answer to decision block 2806 is no, then the process 2800 proceeds to block 2810 wherein the controller 2800 produces signals causing adjustment of the position or speed of the lower paddle assembly 150, the belts 120, or both, in order to correct the position of the stack. These adjustments may be similar to those described elsewhere herein. If the answer to decision block 2806 is yes, then process 2800 proceeds to block 2808 where no adjustments are needed, and the belt and paddle continue their operations unchanged.

[0226] From block 2808, the process 2800 proceeds to block 2812 wherein the photoelectric sensor 1090 senses the angular position of the stack 1060. The angular position is transmitted to the controller 1200. The process 2800 next proceeds to decision block 2814 wherein it is determined whether the angle of the stack 1060 is within the specified

range or above or below a certain threshold. If the sensed angular position is not within the specified range or threshold, the process 2800 proceeds from block 2814 to block 2810, and proceeds as indicated above.

[0227] If the sensed angular position is within the specified threshold, the process 2800 proceeds from block 2814 to block 2816 wherein singulation of the stack continues without adjustment.

[0228] The process 2800 proceeds from either block 2810 or 2816 to decision block 2818 wherein it is determined whether the stack 1060 is completely singulated. This determination may be accomplished in response to the weight sensor 1201 sensing the weight of the stack 1060 on the belts 120. Or the absence of the stack 1060 may be determined by sensing whether the vacuum air flow is unobstructed by any articles using vacuum sensor 1202. These ways described herein to sense whether the stack is completely singulated are only illustrative. A person of skill in the art will understand that there are other ways to sense whether the stack is completely singulated or not. For example, sensing whether the stack is completely singulated may be performed by an optical sensor, a timing circuit, a counter, or any other desired method.

[0229] If the stack 1060 is not completely singulated, process 2800 returns from block 2818 to block 2804, and the process repeats. This loop can continue until the stack 1060 is entirely singulated, such that process 2800 is able to control the rate and position of the belt and paddle continuously throughout the singulation process. Once the stack is completely singulated, and no articles remain, the process proceeds from block 2818 to block 2820 wherein the singulation process is terminated.

[0230] A person of skill in the art will recognize that processes 2700 and 2800 need not be performed in the exact order specified, and that some blocks of processes 2700 and 2800 may be omitted, or other steps performed in addition to those described.

[0231] The operation of the sorting unit 180 will now be described. Referring back to FIG. 14, in some embodiments, synchronization of the various articles with the sorter windows may be accomplished by the synchronization device 1424, as well as by the picking zones as the articles are picked and transported from picking zone to picking zone. In some embodiments, as described further below, synchronization may be accomplished using only the picking zones. For proper synchronization, the leading edge of an article should be delivered to the rendezvous point 1416 at a line speed within a small timing window into the sorter. For example, the line speed may be 3.15 m/s and the sorter window may be at ± 15 msec. In some embodiments, once the article has been delivered to the rendezvous point 1416 within the timing window, the velocity of the article may remain constant throughout the rest of the process as it is transported to and inducted into the sorting window of the sorter. Once the system is synchronized, the article and the sorter window are coupled with one another so that the article is accurately placed in the window. Synchronization of the articles and the sorter windows may allow accurate processing of the articles at a desired rate. For example, synchronization may allow the articles to be processed at a rate of six or more articles per second. A person of skill in the art will recognize that other rates may be achieved using the sorting section and the synchronization process, as desired for the particular application.

[0232] The flow of the shingulated stack of articles should match the output rate of the system in order to achieve proper synchronization. Controlling the feed rate of the shingulated stack of articles may be challenging due to the positively lapped configuration of the articles. This challenge is due to the fact that the feed rate may be determined with the same method as that used for the singulated articles, which uses the velocity of the article flow and the distance between leading edges of the articles. In the case of the singulated article stream, leading edges can be easily identified using sensors (e.g., photoelectric sensors) because there are gaps between each article. In the case of a shingulated stack of articles, gaps do not exist because the article is positively lapped. The amount of article lapping determines the front to front spacing, and this lapping amount varies from moment to moment as the articles move downstream.

[0233] In order to overcome this control issue, the sorting section 1480 may allow the pick point to float or vary. As used herein, the term pick point may refer to the point at which the positively lapped stack of articles 1502 transitions from being shingulated to being singulated. The pick point may be varied by allowing all picking devices 1410 to act both in a shingulation capacity and in a picking (singulation) and synchronization capacity. In some embodiments, synchronization of the articles with the sorter windows may be accomplished using only picking devices 1410 and/or picking zones that perform shingulation, picking (singulation), and synchronization without the use of a shingulating device or synchronization device.

[0234] FIG. 29A illustrates an overhead view of portion of a sorting section 1480 that allows the pick point to float and that allows continuous synchronization of the each article with a desired sorting window. In some embodiments, the automatic stack feeder 100 may not include a dedicated shingulating device 1440 or a dedicated synchronization device 1424 as in FIG. 14. In these embodiments, the picking zones including the picking devices 1410 and anti-doubling devices 1422 may be used to shingulate, pick, singulate, and synchronize the articles as they are transported downstream. Accordingly, as an article is picked and singulated by a picking device, the shingulation feed-to point and the pick point will be changed to that picking device and will thus float or vary. In some embodiments, as each article is picked and singulated from a more downstream picking device than the previous article, the rate of the shingulating device may be retarded (e.g., the velocities of the bottom transport belt and/or the perforated belt may be lowered). In some embodiments,

when an article is picked from a more upstream picking device than the previous article, the rate of shingulating device may be increased. As a result, the pick point floats or varies based on where the previous article was picked. The nominal pick point may be located in a picking device that is located in the middle of the picking devices. Details regarding FIG. 29A will be discussed in more detail below.

[0235] A software program or controller may be used to determine if an article being picked can be synchronized to the next available sorter window based on various criteria. The criteria that may be taken into account includes, but is not limited to, the location of the current article being picked by a picking device, the current velocity of the article being picked, the location of the sorter window for which the article is being synchronized, the velocity of the sorter window, the design acceleration rate allowed for the perforated belts of the picking devices and/or the shingulating device, the design acceleration rate allowed for the synchronization device, the maximum velocity allowed for the perforated belts of the picking devices and/or the shingulating device, and the maximum velocity allowed for the synchronization device. In some embodiments, the velocity of the sorter window may be constant. Other constraints may include the design geometries of the various components of the sorting section, such as the length of the perforated belts of the picking devices and/or the shingulating device, the number of perforated belts, the length of the synchronization device, and the number of pinch wheels in the synchronization device. Trajectory calculations may be used to ensure article synchronization with the sorter. For example, the following standard linear motion with uniform acceleration/deceleration equations may be used to determine if an article can be synchronized given various initial conditions:

$$\text{Distance} = \text{Velocity} \times \text{Time} \quad (\text{Equation 1})$$

$$\text{Distance} = \text{Time} \times (\text{V}_{\text{final}} + \text{V}_{\text{initial}})/2 \quad (\text{Equation 2})$$

$$\text{Time} = (\text{V}_{\text{final}} - \text{V}_{\text{initial}})/\text{Acceleration} \quad (\text{Equation 3})$$

[0236] Equations 1-3 may be expanded as follows to develop a velocity or movement profile for an article based on initial conditions of the sorting section:

$$D_w = V_w \times T_{rp} \quad (\text{Equation 4})$$

$$D_m = [T_{ap} \times \{(\text{V}_{\text{fap}} + \text{V}_{\text{iap}})/2\}] + [T_{dp} \times \{(\text{V}_{\text{fdp}} + \text{V}_{\text{idp}})/2\}] + [T_c \times V_c] + [T_{as} \times \{(\text{V}_{\text{fas}} + \text{V}_{\text{ias}})/2\}] + [T_{ds} \times \{(\text{V}_{\text{fds}} + \text{V}_{\text{ids}})/2\}] \quad (\text{Equation 5})$$

$$D_w + D_m = d_P \quad (\text{Equation 6})$$

$$T_{ap} = (\text{V}_{\text{fap}} - \text{V}_{\text{iap}})/a_p \quad (\text{Equation 7})$$

$$T_{dp} = (\text{V}_{\text{fdp}} + \text{V}_{\text{idp}})/d_p \quad (\text{Equation 8})$$

$$T_{as} = (\text{V}_{\text{fas}} + \text{V}_{\text{ias}})/a_s \quad (\text{Equation 9})$$

$$T_{ds} = (\text{V}_{\text{fds}} + \text{V}_{\text{ids}})/d_s \quad (\text{Equation 10})$$

Where,

D_w = Distance from sorter window to rendezvous point

Vw = Velocity of sorter window, which may be constant in some embodiments

Trp = Time to rendezvous point for sorter window and the article

Dm = Distance from article to rendezvous point

Tap = Time for article to accelerate in picking zone

Tdp = Time for article to decelerate in picking zone

Tc = Time for article to run at constant speed in either picking zone or synchronization device

Tas = Time for article to accelerate in synchronization device

Tds = Time for article to decelerate in synchronization device

Trp = Time for the article to reach the rendezvous point ($Trp = Tap + Tdp + Tc + Tas + Tds$)

Vfap = Final velocity after acceleration move in the picking zone

Viap = Initial velocity before acceleration move in the picking zone

Vfdp = Final velocity after deceleration move in the picking zone

Vidp = Initial velocity before deceleration move in the picking zone

Vc = Constant velocity for article in either picking zone or synchronization device

Vfas = Final velocity after acceleration move in the synchronization device

Vias = Initial velocity before acceleration move in the synchronization device

Vfds = Final velocity after deceleration move in the synchronization device

Vids = Initial velocity before deceleration move in the synchronization device

dP = Distance between the article and the sorter window

ap = Acceleration rate in the picking zone

as = Acceleration rate in the synchronization device

dp = Deceleration rate in the picking zone

ds = Deceleration rate in the synchronization device

[0237] The above equations may be solved, for example, using a controller or processor, to determine if an article can be assigned to a sorter window, which means the article can be synchronized to the sorter window based on the initial conditions. The controller or processor may be implemented with any combination of general-purpose microprocessors, microcontrollers, digital signal processors (DSPs), field programmable gate array (FPGAs), programmable logic devices (PLDs), controllers, state machines, gated logic, discrete hardware components, dedicated hardware finite state machines, or any other suitable entities that can perform calculations or other manipulations of information. If the initial conditions do not allow synchronization of the article with the currently available sorter window, the article may wait for the next available window or may be rejected in the event the article is too close to the end of the sorting section. If it is determined that the article can be synchronized with a sorter window, the velocity profile is determined. The above set of expanded equations (Equations 4-10) may be solved to determine the velocity profile required for the article to be synchronized based on the initial conditions. The travel times for the sorter window and the article to reach the rendezvous point are the same starting from the initial conditions. The travel distances for the sorter window and the article will vary based on the initial conditions.

[0238] The system may adjust the velocity profile of each article with each scan of the control logic as conditions change. For example, the expanded set of equations (Equations 4-10) may be used to adjust the velocity profile of the article as the article travels downstream based on sensor feedback. Sensors may include edge detector sensors, such as photoelectric or photo-eye sensors or a proximity sensor. Because the motivation for the articles is not positive, the articles may slip as they move toward the exit of the sorting section. Sensors may be positioned along the article path so that the leading edge position of each article may be determined and/or confirmed. This position feedback ensures a high degree of synchronization accuracy between the article and the sorter window. Accordingly, the synchronization may be based on article position feedback from sensors located along the article flow path, which may sense the position of the article as it is conveyed downstream by the picking zones and the synchronization device. Thus, the velocity profile for an article may be adjusted based on its position through the picking zones and the synchronizer (if present).

[0239] FIG. 30 is a flow chart depicting one embodiment of a method 3000 of determining a velocity or movement profile. At block 3002, a next controller scan is started. At each scan of the control logic, the method continues to block 3004 and solves equation 4 for Trp to obtain the equation $Trp = Dw/Vw$. As noted above, Trp is the time for the article to reach the rendezvous point, Dw is the distance from the next sorter window to the rendezvous point, and Vw is the velocity of the next sorter window, which is constant. Dw and Vw are known and are used to calculate Trp.

[0240] At block 3006, equation 5 may be solved for Vfap, Vfdp, Vc, Vfas, Vfds, Tap, Tdp, Tc, Tas, and Tds. Equation 5 defines the velocity or motion profile of the article at any given point. Equations 6-10 may be used to solve equation 5 for these variables. Dm is the distance from the article to rendezvous point, and is known, for example, based on one or more sensors located proximate to the picking zones along the article flow path. The acceleration rate in a given picking zone (ap), the distance between the article and the next sorter window (dp), the acceleration rate in the synchronization device (as), and the deceleration rate in the synchronization device (ds) are all known and are all constants.

Trp is known from block 3004. Furthermore, it is known that $Trp = Tap + Tdp + Tc + Tas + Tds$. Tap is the time for the article to accelerate in a picking zone, Tdp is the time for the article to decelerate in the picking zone, Tc is the time for the article to run at a constant speed in either the picking zone or a synchronization device, Tas is the time for the article to accelerate in the synchronization device, and Tds is the time for article to decelerate in the synchronization device. The initial velocity conditions Viap, Vidp, Vias, and Vids are also known. Viap is the initial velocity before being accelerated in the picking zone, Vidp is the initial velocity before being decelerated in the picking zone, Vids is the initial velocity before being decelerated in the synchronization device, and Vias is the initial velocity before being accelerated in the synchronization device.

[0241] At block 3008, equation 5 may be used to determine and/or adjust the velocity or motion profile of the article at any given point using these known constants and variables. In particular, equation 5 may be used to determine and/or adjust the velocity or motion profile of the article by solving for the final velocity for the article after being accelerated in the picking zone (Vfap), the final velocity for the article after being decelerated in the picking zone (Vfdp), the constant velocity for the article in either the picking zone or the synchronization device (Vc), the final velocity for the article after being accelerated in the synchronization device (Vfas), the final velocity for the article after being decelerated in the synchronization device (Vfds), the time for the article to accelerate in the picking zone (Tap), the time for article to decelerate in the picking zone (Tdp), the time for the article to run at constant speed in either the picking zone or the synchronization device (Tc), the time for the article to accelerate in the synchronization device (Tas), and the time for article to decelerate in synchronization device (Tds).

[0242] From block 3008, the process 3000 returns to block 3002 when a next controller scan begins. For example, the method may adjust the velocity or movement profile of each article with each scan of the control logic as conditions change so that the velocity profile for an article may be adjusted based on its position through the picking zones and the synchronizer (if present).

[0243] Returning to FIG. 29A, The sorting section 1480 allows for a floating or varying pick point and also for the continuous synchronization of the each article with a desired sorting window based on feedback from sensors 2912, 2914, and 2920. The sensors may include proximity sensors or edge detector sensors, such as photoelectric, photo-eye, infrared, optical sensors, and the like. The sorting section 1480 includes a belt that carries a stack 1502 moving in the direction of the arrow 1426. The stack 1502 is at a distance 2908 from an article guide. The sorting section 1480 includes a plurality of picking devices 1410, including picking devices S1-S5 that each includes a perforated belt 606 and a vacuum system 2916, including vacuum systems V1-V5. Each of vacuum the systems V1-V5 may include a vacuum unit, a vacuum manifold 1908, and a vacuum valve 1916, as illustrated in FIG. 19A. Each of the picking devices may further include a vacuum unit and a vacuum valve, as described above. The sensors 2912, 2914, and 2920 may be used to provide feedback. For example, sensor 2912 may be used to detect a leading edge of the stack 1502. The remaining sensors 2914 and 2920 may be used to continuously indicate a position of the stack 1502 and/or the position of a singulated article picked by one of the picking devices S1-S5.

[0244] In some embodiments, the picking devices S1-S5 may perform parallel shingulation, singulation, and/or synchronization while allowing for anti-doubling using one or more anti-doubling devices 1422 located across from one or more picking devices. In some embodiments, the sorting section 1480 may include both a dedicated shingulating device and a dedicated synchronization device to assist in the shingulation and synchronization, similar to that illustrated in FIG. 14.

[0245] In some embodiments, virtual windows may be used to synchronize each article with a sorter window. FIG. 29B illustrates an example of an sorting section 1480 operating using virtual windows. The sorting section 1480 includes picking zones P1-P5, sensors 2904, and virtual windows 2902 and 2906. Each of the sensors 2904 may correspond to any of the sensors 2914, 2920, and 2912 of FIG. 29A. Each of the picking zones P1-P5 may include vacuum systems 2916, including V1-V5. Each of vacuum systems V1-V5 may include a vacuum unit, a vacuum manifold 1908, and a vacuum valve 1916, as illustrated in FIG. 19B. Each of the picking zones P1-P5 also includes a picking device, such as that described above with respect to FIGs. 19B and/or 29A. One or more of the picking zones P1-P5 may include an anti-doubling device opposite the picking device. As described above with respect to FIGs. 20A-20B, some combination of the anti-doubling devices may have a low level of constant vacuum to promote shingulation of the articles. For example, picking devices S1 and S2 of FIG. 29A may have a low level of constant vacuum power to shingulate the articles. As the edge detector sensor 1910 and the presence sensor 1912 detect more than one article (e.g., if an undesired article is stuck to a desired article after being picked and singulated), an anti-doubling device associated with one of the picking devices S3-S5 may be turned on to full vacuum in order to separate any articles from the desired article that is to be singulated by the picking zone.

[0246] Each of the picking devices further includes a perforated belt 1906 (not shown in FIG. 29B). Each of the perforated belts 1906 may be driven using a dedicated motor and/or gearbox (not shown). For example, a servo-motor may be used, such as a KollMorgen C042B high-torque, low-speed, bearing-less, direct-drive cartridge motor or a Koll-Morgen C041B motor. FIG. 29C illustrates an example of a pulley system for driving a perforated belt 1906 of a picking device 1410. A drive pulley 2922, a tensioner pulley 2924, and two front idler pulleys 926 under the control of a controller

or processor (not shown) may be used to drive the belt 1906 of each of the picking devices in order to coordinate the movement of a group of articles. The controller or processor may be implemented with any combination of general-purpose microprocessors, microcontrollers, digital signal processors (DSPs), field programmable gate array (FPGAs), programmable logic devices (PLDs), controllers, state machines, gated logic, discrete hardware components, dedicated hardware finite state machines, or any other suitable entities that can perform calculations or other manipulations of information.

[0247] In some embodiments, a flat belt may be used as the perforated belt 1906 that does not include any tracking or teeth along the middle of the belt. In some embodiments, a perforated timing belt may be used as the perforated belt 1906. A perforated timing belt is easy to tension, will not slip on the drive pulley 2922, has a built-in tracking feature, and does not require a take-up pulley. FIG. 29D illustrates an example of a perforated timing belt 2928. The built-in tracking feature 2930 along the center of the timing belt may remove the need for crowned pulleys which may decrease cost of the system. The built-in tracking feature 2930 may include timing teeth to allow the use of a plain metal drive pulley rather than a lagged pulley, which may also decrease cost. In some embodiments, a plain rib may be used on the timing belt 2928 instead of the timing teeth, which may provide a better tracking feature at the expense of pulley grip. The majority of the tension in the timing belt 2928 is transmitted through the timed center built-in tracking feature 2930. Accordingly, larger holes may be included in the remainder of the perforated timing belt 2928 because this portion of the timing belt 2928 is not primarily used to move the belt.

[0248] Returning to FIG. 29B, each of the virtual windows 2902 and 2906 includes a position on the sorting unit 1480 at which a leading edge of an article (e.g., article 2910) must be located in order for the article to be deposited into a corresponding sorter window. The above equations 1-10 may be used to program a controller or processor to cause the sorting unit 1480 to align the leading edge of each article with a current un-booked virtual window. The controller or processor may be implemented with any combination of general-purpose microprocessors, microcontrollers, digital signal processors (DSPs), field programmable gate array (FPGAs), programmable logic devices (PLDs), controllers, state machines, gated logic, discrete hardware components, dedicated hardware finite state machines, or any other suitable entities that can perform calculations or other manipulations of information. The picking process may start from a standstill at any given picking zone while maintaining synchronization with a virtual window 2902 and/or 2906. The system may provide continuous synchronization with the virtual windows 2902 and/or 2906 to provide efficient and continuous feeding of articles. For example, each picking zone P1-P5 may monitor a next un-booked virtual window position in relation to its own position along the article picking route. The picking zones P1-P5 may be configured to coordinate synchronized movement with one another in order to translate the articles so that the leading edge of each article is on target with one of the virtual windows 2902 and/or 2906. The velocity profiles described above may be used to coordinate the synchronized movement of the picking zone components. The sensors 2904 along the article travel path may provide feedback regarding the exact position of the leading edge of each article at a given point in time. The leading edge feedback position may be compared to the position where the article should be in relation to the corresponding virtual window 2902 or 2906. This data may be used to modify the current article velocity profile to reposition and resynchronize the article with the virtual window.

[0249] FIG. 31 illustrates an example of a sorting section 1480 that may be used to properly synchronize each of the articles with a sorting window using virtual windows. The sorting section 1480 includes a pick zone operation 3104 for controlling the picking zones 3108, including picking zones 1-5. The picking zone operation 3104 includes vacuum control, correction control, doubles detection, and error monitoring. The sorting section 1480 further includes virtual window detection and virtual axis manager 3106. The pick zone operation 3104 and the virtual window detection and virtual axis manager 3106 may be implemented using a controller or processor (not shown). The controller or processor may be implemented with any combination of general-purpose microprocessors, microcontrollers, digital signal processors (DSPs), field programmable gate array (FPGAs), programmable logic devices (PLDs), controllers, state machines, gated logic, discrete hardware components, dedicated hardware finite state machines, or any other suitable entities that can perform calculations or other manipulations of information. For example, one or more software or computer programs may be developed to cause the controller or processor to implement the pick zone operation 3104 and the virtual window detection and virtual axis manager 3106.

[0250] FIG. 32A illustrates an example of controlling a virtual axis using the virtual window detection and virtual axis manager 3106. The master virtual axis 3202 may be the reference point upon which the virtual windows 3204-3208 are based upon. For example, virtual window (VW) pulses 1-3 for each of the virtual windows 3204-3208 may be generated at a fixed interval at the line speed rate (e.g., 3.15 m/s) using the master virtual axis 3202 as a reference point. Based on the master virtual axis 3202, all components of the sorting sections described above may be controlled in order to synchronize each article with a sorter window by aligning the leading edge of each article with a corresponding virtual window.

[0251] FIG. 32B illustrates an example of synchronizing an initial article 3210 with a sorter window using the pick zone operation 3204. As the process of picking one or more articles from a stack 1502 begins, the sorting section 1480 is started and the initial article 3210 is ready to be picked. As the system is started, the virtual axis is error free and is

moving at the line speed rate (e.g., 3.15m/s), and the virtual windows are detected. The downstream picking zones, the vacuum systems 2916 (e.g., vacuum unit, a vacuum manifold, and a vacuum valve), the belts, and the synchronization device(s) (if present) are clear and ready to begin operation.

[0252] After the picking process has begun, the picking and singulation of each article takes place on a zone available basis, such that the downstream most available picking zone is selected to pick an article. The next available virtual window is assigned to the furthest upstream article to be picked so that the leading edge of that article is aligned with the virtual window. The position of each of the articles is known based on the feedback from the sensors. One or more of the picking zones work together in the synchronization process. Each of the picking zones operate independently of each other, but may be simultaneously handed down motion commands by the pick zone operation 3104 to achieve synchronization among the picking zones. The pick zone operation 3104 instruct one or more of the picking zones to turn on and control the speed at which each of the picking zones operate in order to align the leading edge of the article 3210 with the virtual window 3204. For example, the pick zone operation 3204 may command a picking zone to operate at a particular gear ratio between the master axis and each of the slave axes from a synchronization point onward. The gear ratio may provide the acceleration and deceleration of the perforated belt of each picking device to speed up and slow down the article 3210 as it moves across the picking zones. FIG. 32C illustrates an example of coordinating the operation of the picking zones with master and slave axes to control the picking of the article 3210. A master synchronization point 3212, master start distance 3214, slave start distance 3216, and acceleration and velocity limitations define how the slave axis for each particular picking zone moves at the commanded master speed according to a final gear ratio determined for that picking zone. The picking zones operate by detecting a leading edge of next picked article based on the sensors located at each picking zone. The available picking zones that are available to take part in the synchronization are determined along with parameters for start distances and synchronization positions. Once the available picking zones and the parameters are determined, the pick zone operation 3104 commands the available picking zones to translate the article 3210 being picked in synchronization with the assigned virtual window. As a virtual window 3204 passes through a picking zone and/or an article 3210 is cleared through the picking zone, the zone may be un-gearred and stopped, the vacuum systems 2916 may be turned off, and the picking zones are prepared for the next virtual window if that picking zone is chosen in the picking and synchronization of an article with that virtual window.

[0253] The vacuum systems 2916 of each picking zone may be variably controlled by the pick zone operation 3104 according to the position of the articles sensed by the various sensors at each picking zone.

[0254] FIG. 33A illustrates picking zones 3304 and sensors 3306. The sensors 3306 may include proximity sensors or edge detector sensors, such as photoelectric, photo-eye, infrared, optical sensors, and the like, as described elsewhere herein. Each of the sensors 3306 may correspond to any of the sensors 2914, 2920, and 2912 of FIG. 29A and/or sensors 2904 of FIG. 29B. As illustrated in FIG. 33A, four sensors are provided for each picking zone. A person of skill in the art will understand that more or less sensors may be included as needed. The vacuum systems 2916 operate to hold the articles against the perforated transfer belts during synchronization as the article being picked is transferred downstream along the sorting section. The third downstream sensor of each picking zone operates to cause actuation of the vacuum of each zone. As a result, a picking zone cannot be turned on to take control of an article until the third sensor of that picking zone has been blocked by an article. For example, a picking zone may be actuated when a leading edge of an article blocks the third downstream sensor of that picking zone. The picking zone cannot give up control of article until the fourth downstream sensor of the next picking zone has been blocked. The vacuum valve outputs and travel path sensor inputs may be controlled and monitored via high speed input/outputs.

[0255] FIG. 33B illustrates an exemplary process of variably controlling the vacuum systems 2916 of the picking zones based on the sensor feedback in order to transfer the article 3308 downstream along the sorting section 1480. As noted above, each of the vacuum systems 2916 may include a vacuum unit, a vacuum manifold, and a vacuum valve. At time 1 (T1), the article 3308 crosses over and blocks sensor 3, which is the third downstream sensor of the picking zone 1. Accordingly, sensor 3 operates to cause actuation of the vacuum of picking zone 1. Because picking zone 1 is the first picking zone, the system waits for next approaching virtual window and gives picking zone 1 a response notice time period to develop the vacuum. During the response notice time period, the picking zone 1 vacuum is enabled and is developed to full vacuum strength. Once full vacuum strength is developed, picking zone 1 has control of the article 3308. Each picking zone may include a picking device and may also include an anti-doubling device. As described above with respect to FIG. 19B, a picking device may include a perforated belt, a perforated belt drive pulley, and the vacuum system. As the article 3308 moves toward the perforated belt, the vacuum valve is opened to develop the full vacuum strength and the vacuum manifold is exposed to the vacuum force. The vacuum force is used to pull the article 3308 from a stack of articles (if not already singulated) through the one or more openings of the perforated belt to effectively connect the article 3308 to the perforated belt. The article 3308 is held to the surface of the perforated belt by the vacuum force exerted on the article through the one or more holes in the perforated belt and is accelerated forward by an acceleration amount. In some embodiments, the pick zone operation 3104 may instruct the picking zone 1 to decelerate in order to synchronize the article 3308 with the virtual window.

[0256] At time 2 (T2), the article 3308 crosses over sensor 7, which is the third downstream sensor of picking zone 2.

At this point, the vacuum system of picking zone 2 is actuated. However, picking zone 1 still has control of the article 3308. Thus, the vacuum of picking zone 2 is actuated prior to picking zone 2 taking control of the article 3308 from picking zone 1. The time period from when picking zone 1 has control of the article 3308 to the point when picking zone 1 relinquishes control to picking zone 2 gives time for the vacuum of picking zone 2 to develop sufficient vacuum strength to drive the article 3308 downstream.

[0257] As noted above, picking zone 1 cannot give up control of article 3308 until the fourth downstream sensor of the next picking zone (picking zone 2) has been blocked. At time 3 (T3), the article 3308 crosses over sensor 8, which is the fourth downstream sensor of picking zone 2. Once sensor 8 is blocked, picking zone 1 may relinquish control of the article 3308 to picking zone 2. At this point, the vacuum of picking zone 1 is turned off. In some embodiments, the remaining components of picking zone 1 may be turned off, including the pulleys and gears driving the perforated belt and the anti-doubling device (if present in picking zone 1). At T3, the vacuum of picking zone 2 is at a sufficient strength so that picking zone 2 has full control and is responsible for driving the article 3308 downstream.

[0258] At time 4 (T4), the article 3308 crosses over and blocks sensor 11. Because sensor 11 is the third downstream sensor of picking zone 3, the vacuum of picking zone 3 is actuated to give the vacuum sufficient time to develop enough vacuum force to control the article 3308. Picking zone 2 still has full control of the article 3308, and does not pass control to picking zone 3 until the fourth downstream sensor of picking zone 3 is blocked.

[0259] At time 5 (T5), the article 3308 crosses over sensor 12, causing picking zone 2 to relinquish control of the article 3308 to picking zone 3. At this point, the vacuum of picking zone 2 is turned off. The remaining components of picking zone 2 may also be turned off, including the pulleys and gears driving the perforated belt and the anti-doubling device (if present in picking zone 2). At T5, the vacuum of picking zone 3 is at a sufficient strength to allow picking zone 3 to have full control of the article 3308. At this point, picking zone 3 is responsible for driving the article 3308 downstream to the next picking zone.

[0260] The process of variably controlling the vacuum systems of the picking zones continues until the article 3308 reaches the most downstream picking zone. For example, if five picking zones are present, the process continues through picking zone 5 until the article 3308 transitions to either the sorting window or to a synchronization device pinch wheel (if present in the sorting section).

[0261] The pick zone operation 3104 further provides correction control in order to ensure that an article is synchronized with a virtual window. The movement using the motors and gear ratio of the picking zone perforated belts 1906 can be precisely controlled using the virtual window detection and virtual axis manager 3106 so that the belts 1906 stay synchronized with the virtual window. However, the position of the articles on the perforated belts 1906 cannot be guaranteed due to various effects upon the articles as they move along the belts 1906, such as slippage of the articles, gusts of air, slumping, and the like.

[0262] FIG. 34 illustrates an example of using the pick zone operation 3104 for correction control. The sensors 3306 may be used to detect the position of the article 3404 as it is synchronized through the sorting section 1480. The sensors 3306 may include proximity sensors or edge detector sensors, such as photoelectric, photo-eye, infrared sensors, optical sensors, and the like. The position of the article 3404, as detected by one or more of the sensors 3306, may be compared to the corresponding virtual window position at the trigger of each sensor in order to determine the absolute error of article 3404 position. This error value may be fed into a picking zone controller or processor (not shown), and the pick zone operation 3104 may operate to position and re-track the article 3404 so that the article 3404 is re-synchronized with the corresponding virtual window. For example, the pick zone operation 3104 may instruct one or more picking zones to accelerate or decelerate the article 3404 and may control the vacuums accordingly as described above in order to re-synchronize the article 3404 and the virtual window. The picking zone controller or processor may be implemented with any combination of general-purpose microprocessors, microcontrollers, digital signal processors (DSPs), field programmable gate array (FPGAs), programmable logic devices (PLDs), controllers, state machines, gated logic, discrete hardware components, dedicated hardware finite state machines, or any other suitable entities that can perform calculations or other manipulations of information.

[0263] The absolute error is updated by the pick zone operation 3104 on each cycle of a triggered sensor and may be stored to a particular value. Each of the picking zones participating in the synchronized motion for synchronizing the article 3404 with the virtual window may receive the same value storing the absolute error. The participating picking zones may use the value to execute an offset to synchronize the article 3404 back in line with the virtual window. In some embodiments, a maximum error limit may be determined based on the position of the article 3404 and the corresponding error relative to the virtual window. If the absolute error as detected by the sensors 3306 indicates that this maximum error limit has been exceeded, the pick zone operation 3104 may determine that the article 3404 needs to give up on the current virtual window and may assign the article 3404 to the next available window.

[0264] By providing for correction control, the sorting section 1480 may provide real time error compensation at high speed using the feedback from the sensors 3306 so that positive and negative shifts of the article 3404 can be compensated for.

[0265] In some embodiments, the sensors 3306 may be used to aid in anti-doubling. For example, the sensors 3306

may detect if an article appears to be getting longer or if an article appears to turn into two articles during travel due to an attached article to the desired article. The anti-doubling devices may be used to separate the attached article, which may be assigned to the next available virtual window.

[0266] In some embodiments, movement profiles may be generated in order to reduce acceleration damage to the articles as they are moved along the sorting sections described above. In some embodiments, the movement profile may be the same as the velocity profile described above, and may be calculated using equations 1-10 and/or according to FIG. 30 described above. For example, article damage may occur as the article is accelerated and/or decelerated along the shingulating and/or picking devices. For example, mail pieces with covers that have less structural integrity, such as mail with thin glossy staple bound covers, may damage more easily. As another example, open mail may damage more easily than mail that is in an envelope. As used herein, open mail refers to an article (e.g., a periodical, magazine, and the like) that is bound along one edge only and is open along the other three edges. As described above, the articles are accelerated from the stack of articles to a velocity required for synchronization with a sorter window (e.g., using virtual windows). As the processing rate and the length of the articles increases, the design acceleration and deceleration must be increased. The perforated belts of the picking devices translate the articles by accelerating and decelerating the articles from one side of the article, and high acceleration or deceleration rates may cause high inertial forces. These inertial forces are proportional to the acceleration and deceleration rate. As an article is accelerated or decelerated, the inertial forces generated in the main body of the article resist the change in velocity. This resistance imparts shearing forces and torque on the side being translated by the picking device, which may cause damage to the article.

[0267] The movement profiles may be designed to cause the sorting section to operate with the lowest possible constant acceleration and deceleration rates while allowing the system to meet the overall desired design rate with the longest article. In order to reduce the effective acceleration and/or deceleration experienced by an article when picked and singulated, the movement profile may stop the perforated belt for each pick, open the vacuum valve and wait for the vacuum to develop, and accelerate the article being picked at the lowest possible acceleration rate while assuming the longest possible article is being picked. The article is accelerated at the lowest possible acceleration rate by gradually ramping up the speed of the perforated belt in a controlled manner. The vacuum is not energized as the perforated belt is accelerated because if the vacuum does not develop quickly enough, the effective acceleration may be higher than the rate executed by the motor of the belt. Instead, the acceleration is not ramped up until the vacuum has developed. The system may sense the vacuum level in the manifold after the valve is energized. The feedback regarding the vacuum level may be generated using a valve with spool sensors and/or a vacuum gauge. Once the vacuum has been established, the motor may execute the movement profile. The lowest acceleration is determined by the longest design article and the design processing rate, which determines the rate at which articles are singulated from the stack of articles. If a dedicated synchronization device is present, the articles can be more aggressively accelerated in the synchronization device because the articles are stabilized by being pushed together and driven on both sides by the pinch wheels. Accordingly, in some embodiments, the movement profiles may only be used with the shingulating and picking devices.

[0268] Use of the movement profiles may result in less article damage. The movement profiles may also allow for more precise article motion along the sorting section because the vacuum system may be used more efficiently. The more precise motion of the articles along the system may help in synchronizing the articles with the sorting windows.

[0269] FIG. 35 is a flowchart of an embodiment of a process 1400 for managing articles in the sorting section 1480. Process 3500 may commence when the stack 1502 is placed on the belts 1420. The process 3500 proceeds to block 3502 a stack 1502 is received at a shingulating device 1440 and a positively lapped stack of articles 1604 is produced. The stack 1502 is shingulated to produce the positively lapped stack of articles 1604. Any of the embodiments of the shingulating device 108 described above may be used to shingulate the stack of articles. As used herein, the term shingulate or shingulation may refer to the process of extruding the stack 1502 to produce a positively lapped stack of articles 1604. At block 3504, one or more articles are picked from the positively lapped stack of articles 1502 using one or more picking devices 1410 and one or more singulated articles are produced. Any of the singulating devices disclosed herein may be used to pick and singulate an article from the stack 1502. Singulation, as described herein, uses a vacuum force to attract and hold an article to the perforated belt, which transports a single article downstream along the article feeder. At block 3506, the one or more singulated articles are delivered to one or more sorter windows using one or more synchronization devices 1424. The synchronization device 1424 described above may be used to deliver the singulated articles to the sorter windows.

[0270] In some embodiments, producing the positively lapped stack of articles 1604 comprises moving the stack 1502 toward a shearing device 1708 using a bottom transport belt 1704 and a perforated belt 1706 of the shingulating device 1440 and applying a shearing force on the stack of articles using the shearing device 1708. The bottom transport belt 1704 has a transport surface extending in a first direction and the perforated belt 1706 has a surface extending in a second direction different than the first direction. The first direction may be a substantially horizontal direction and the second direction may be a substantially vertical direction relative to the bottom transport belt. For example, the perforated belt 1706 may be at a right angle relative to the generally horizontal direction of the bottom transport belt 1704. The perforated belt 1706 is adjacent to the bottom transport belt 1704 and may be configured to be moved in the downstream

direction toward the shearing device 1708 using one or more belt drives 1710.

[0271] In some embodiments, the process 3500 further comprises applying suction through one or more openings in the perforated belt 1706 using a vacuum system. For example, one or more articles may be held to the surface of the perforated belt 1706 by a vacuum force exerted on the article through the one or more openings in the perforated belt 1706. The stack 1502, being held against the perforated belt and resting on the bottom transport belt, may be moved in the downstream direction toward the shearing device 1708.

[0272] In some embodiments, picking the one or more articles from the positively lapped stack of articles 1604 comprises opening a vacuum valve 1916 of a first picking device 1410 to expose a vacuum manifold 1908 of the first picking device 1410 to suction from a vacuum unit, applying the suction from the vacuum manifold 1908 through one or more openings in a perforated belt 1906 of the first picking device 1410 to one of the one or more articles, and attaching the article to the perforated 1906 belt using the suction through the one or more openings. In some embodiments, producing the one or more singulated articles comprises separating an article from the positively lapped stack of articles 1604 by driving the perforated belt 1906 with the attached article forward using a motor. In some embodiments, the singulated article is picked and produced by a downstream most picking device in a row of picking devices that is substantially completely covered by the positively lapped stack of articles.

[0273] In some embodiments, the process 3500 further comprises preventing more than one article at a time from being picked from the positively lapped stack of articles 1502 using an anti-doubling device 1422 located in a respective picking zone, each respective picking zone including a respective picking device 1410 and an anti-doubling device 1422. An anti-doubling device 112, such as that described above, may be used to prevent more than one article from being picked at a time using, for example, the process described above with respect to FIG. 20B. For example, the process 3500 may further comprise detecting a first article using a presence sensor 1912 of the anti-doubling device, detecting an edge of a second article using an edge detector sensor 1910 of the anti-doubling device, the edge detector sensor 1910 being positioned upstream from the presence sensor 1912, and applying suction to the second article using a vacuum unit of the anti-doubling device 1422 when the presence sensor 1912 detects the first article during a time period in which the edge detector sensor 1910 detects the edge of the second article.

[0274] In some embodiments, the process 3500 further comprises controlling movement of each article of the stack of articles to synchronize a first time when each of the one or more singulated articles reaches an exit point with a second time when a sorter window reaches the exit point. The exit point corresponds to the rendezvous point 1416 described above. For example, the virtual windows described above may be used to synchronize an article with a sorting window. In some embodiments, the synchronization of the first time with the second time is based on one or more of a location of a first article being picked by a first picking device, a velocity of the first article, a location of the sorter window, a velocity of the sorter window, an acceleration rate of each of a plurality perforated belts included in each of the plurality of picking devices, an acceleration rate of the one or more synchronization devices, a maximum velocity allowed for each of the plurality perforated belts included in each of the plurality of picking devices, a maximum velocity allowed for a perforated belt included in the shingulating device, a maximum velocity allowed for the one or more synchronization devices, a length of each of the plurality of perforated belts included in each of the plurality of picking devices, a length of the perforated belt included in the shingulating device, a number of perforated belts, a length of the one or more synchronization devices, and a number of the one or more synchronization devices.

[0275] In some embodiments, the shingulation, picking and shingulation, and synchronization of process 3500 may be accomplished using only the picking zones, including the picking devices 1410, anti-doubling devices 1422, edge detector sensors 1911, and/or presence sensors 1912. For example, as described above, an sorting section may allow the pick point at which the stack of articles transitions from shingulated to singulated to float or vary using variably controlled picking zones.

[0276] The technology is operational with numerous other general purpose or special purpose computing system environments or configurations. Examples of well-known computing systems, environments, and/or configurations that may be suitable for use with the invention include, but are not limited to, personal computers, server computers, handheld or laptop devices, multiprocessor systems, microprocessor-based systems, programmable consumer electronics, network PCs, minicomputers, mainframe computers, distributed computing environments that include any of the above systems or devices, and the like.

[0277] As used herein, instructions refer to computer-implemented steps for processing information in the system. Instructions can be implemented in software, firmware or hardware and include any type of programmed step undertaken by components of the system.

[0278] A microprocessor may be any conventional general purpose single- or multi-chip microprocessor such as a Pentium® processor, a Pentium® Pro processor, a 8051 processor, a MIPS® processor, a Power PC® processor, or an Alpha® processor. In addition, the microprocessor may be any conventional special purpose microprocessor such as a digital signal processor or a graphics processor. The microprocessor typically has conventional address lines, conventional data lines, and one or more conventional control lines.

[0279] The system may be used in connection with various operating systems such as Linux®, UNIX® or Microsoft

Windows®.

[0280] The system control may be written in any conventional programming language such as C, C++, BASIC, Pascal, or Java, and ran under a conventional operating system. C, C++, BASIC, Pascal, Java, and FORTRAN are industry standard programming languages for which many commercial compilers can be used to create executable code. The system control may also be written using interpreted languages such as Perl, Python or Ruby.

[0281] Those of skill will further recognize that the various illustrative logical blocks, modules, circuits, and algorithm steps described in connection with the embodiments disclosed herein may be implemented as electronic hardware, software stored on a computer readable medium and executable by a processor, or combinations of both. To clearly illustrate this interchangeability of hardware and software, various illustrative components, blocks, modules, circuits, and steps have been described above generally in terms of their functionality. Whether such functionality is implemented as hardware or software depends upon the particular application and design constraints imposed on the overall system. Skilled artisans may implement the described functionality in varying ways for each particular application, but such embodiment decisions should not be interpreted as causing a departure from the scope of the present invention.

[0282] The various illustrative logical blocks, modules, and circuits described in connection with the embodiments disclosed herein may be implemented or performed with a general purpose processor, a digital signal processor (DSP), an application specific integrated circuit (ASIC), a field programmable gate array (FPGA) or other programmable logic device, discrete gate or transistor logic, discrete hardware components, or any combination thereof designed to perform the functions described herein. A general purpose processor may be a microprocessor, but in the alternative, the processor may be any conventional processor, controller, microcontroller, or state machine. A processor may also be implemented as a combination of computing devices, e.g., a combination of a DSP and a microprocessor, a plurality of microprocessors, one or more microprocessors in conjunction with a DSP core, or any other such configuration.

[0283] If implemented in software, the functions may be stored on or transmitted over as one or more instructions or code on a computer-readable medium. The steps of a method or algorithm disclosed herein may be implemented in a processor-executable software module which may reside on a computer-readable medium. Computer-readable media includes both computer storage media and communication media including any medium that can be enabled to transfer a computer program from one place to another. A storage media may be any available media that may be accessed by a computer. By way of example, and not limitation, such computer-readable media may include RAM, ROM, EEPROM, CD-ROM or other optical disk storage, magnetic disk storage or other magnetic storage devices, or any other medium that may be used to store desired program code in the form of instructions or data structures and that may be accessed by a computer. Also, any connection can be properly termed a computer-readable medium. Disk and disc, as used herein, includes compact disc (CD), laser disc, optical disc, digital versatile disc (DVD), floppy disk, and Blu-ray disc where disks usually reproduce data magnetically, while discs reproduce data optically with lasers. Combinations of the above should also be included within the scope of computer-readable media. Additionally, the operations of a method or algorithm may reside as one or any combination or set of codes and instructions on a machine readable medium and computer-readable medium, which may be incorporated into a computer program product.

[0284] The foregoing description details certain embodiments of the systems, devices, and methods disclosed herein. It will be appreciated, however, that no matter how detailed the foregoing appears in text, the systems, devices, and methods can be practiced in many ways. As is also stated above, it should be noted that the use of particular terminology when describing certain features or aspects of the invention should not be taken to imply that the terminology is being re-defined herein to be restricted to including any specific characteristics of the features or aspects of the technology with which that terminology is associated.

[0285] It will be appreciated by those skilled in the art that various modifications and changes may be made without departing from the scope of the described technology. Such modifications and changes are intended to fall within the scope of the embodiments. It will also be appreciated by those of skill in the art that parts included in one embodiment are interchangeable with other embodiments; one or more parts from a depicted embodiment can be included with other depicted embodiments in any combination. For example, any of the various components described herein and/or depicted in the Figures may be combined, interchanged or excluded from other embodiments.

[0286] With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

[0287] It will be understood by those within the art that, in general, terms used herein are generally intended as "open" terms (e.g., the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such

introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and indefinite articles such as "a" or "an" (e.g., "a" and/or "an" should typically be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should typically be interpreted to mean *at least* the recited number (e.g., the bare recitation of "two recitations," without other modifiers, typically means *at least* two recitations, or *two or more* recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to "at least one of A, B, or C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (e.g., "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B."

[0288] All references cited herein are incorporated herein by reference in their entirety. To the extent publications and patents or patent applications incorporated by reference contradict the disclosure contained in the specification, the specification is intended to supersede and/or take precedence over any such contradictory material.

[0289] The term "comprising" as used herein is synonymous with "including," "containing," or "characterized by," and is inclusive or open-ended and does not exclude additional, unrecited elements or method steps.

[0290] All numbers expressing quantities of ingredients, reaction conditions, and so forth used in the specification and claims are to be understood as being modified in all instances by the term "about." Accordingly, unless indicated to the contrary, the numerical parameters set forth in the specification and attached claims are approximations that may vary depending upon the desired properties sought to be obtained by the present invention. At the very least, and not as an attempt to limit the application of the doctrine of equivalents to the scope of the claims, each numerical parameter should be construed in light of the number of significant digits and ordinary rounding approaches.

[0291] The above description discloses several methods and materials of the present invention. This invention is susceptible to modifications in the methods and materials, as well as alterations in the fabrication methods and equipment. Such modifications will become apparent to those skilled in the art from a consideration of this disclosure or practice of the invention disclosed herein. Consequently, it is not intended that this invention be limited to the specific embodiments disclosed herein, but that it cover all modifications and alternatives coming within the true scope and spirit of the invention as embodied in the attached claims.

[0292] The following clauses comprise the original claims of the parent application EP 14779918.3 and are included for complete and clear disclosure.

CLAUSES

[0293]

1. An automatic stack feeder comprising:

a frame;

a plurality of belts located with respect to each other on the frame so as to define openings therebetween, the plurality of belts configured to support a container enclosing a stack of articles;

a lower support moveably connected to the frame, the lower support being moveable to partially extend through at least one of the openings between the plurality of belts, and wherein the lower support is moveable between at least a portion of a first end of the plurality of belts and at least a portion of a second end of the plurality of belts;

an upper support configured to open the container and to supply supporting pressure to a side of the stack of articles, wherein the upper support is moveable between at least a portion of the first and second ends of the plurality of belts; and

a controller configured to coordinate the movements of the plurality of belts, the lower support, and the upper support.

2. The feeder of clause 1, wherein the upper support comprises upper tines extending downward from the upper support, and wherein the lower support comprises lower tines extending upward from the lower support.

3. The feeder of clause 2, wherein the upper and lower tines are offset from each other such that the upper and lower tines mesh within the same plane, without impinging on each other.

4. The feeder of clause 2 wherein the lower support is disposed below the plurality of belts, and wherein the lower tines are axially aligned with at least one of the openings between the plurality of belts.

5. The feeder of clause 4 wherein the lower tines are connected to a drive mechanism operable to drive the tines upward through the openings between the plurality of belts.

6. The feeder of clause 2, wherein the upper tines are connected to a drive mechanism operable to drive the upper tines downward toward the plurality of belts, and operable to retract the upper tines upward toward the upper support.

7. The feeder of clause 1, wherein the upper support comprises a door opening member configured to extend downward from the upper paddle and engage a door of the container while the container is positioned on the belt assembly.

8. A system for unloading a container comprising:

a container configured to enclose a stack of articles, the container comprising a door and at least one channel formed in a side surface of the container;

a feeder comprising:

a frame having a first end and a second end, the second end comprising a singulator;

a belt assembly disposed on the frame, the belt assembly having at least one opening disposed therein, wherein the belt assembly is configured to support the container and the stack of articles, and to move the stack of articles toward the singulator;

a lower paddle disposed generally below the belt assembly, wherein a portion of the lower paddle is moveable through the opening of the belt assembly, and

an upper paddle disposed generally above the belt assembly, at least a portion of the upper paddle being configured to extend through the at least one channel formed in the side surface of the container;

wherein the upper paddle and the lower paddle are configured to provide supporting pressure to the stack of articles when the stack of articles is on the belt assembly.

9. The system of clause 8, wherein the belt assembly comprises a plurality of parallel belts having openings disposed therebetween.

10. The system of clause 9 wherein the lower paddle comprises a plurality of lower tines aligned with the openings disposed between the plurality of parallel belts.

11. The system of clause 8, wherein the upper paddle comprises at least one upper tine aligned with the at least one channel formed in the side of the container.

12. The system of clause 8, wherein the upper paddle comprises a door opener configured to extend downward from the upper paddle and engage the door of the container as the container is positioned on the belt assembly.

13. The system of clause 8 wherein at least the lower paddle, the upper paddle, and the belt assembly are connected to drive mechanisms, and wherein the system comprises a controller configured to control the drive mechanisms which are respectively connected to the lower paddle, the upper paddle, the belt assembly.

14. The system of clause 13 further comprising a controller connected in communication with the drive mechanisms, wherein the controller is configured to direct the movement of the drive mechanisms.

15. The system of clause 13, wherein the drive mechanism connected to the lower paddle is operable to move the lower paddle in a first direction and a second direction.

16. The system of clause 15, wherein the first direction is generally parallel to the belt assembly, and the second direction is generally perpendicular to the belt assembly.

17. The system of clause 13 wherein the drive mechanism connected to the upper paddle is operable to move the upper paddle in a first direction and a second direction.

18. The system of clause 17, wherein the first direction is generally parallel to the belt assembly, and the second direction is generally perpendicular to the belt assembly.

19. The system of clause 14, wherein the controller is configured to synchronize the movement of the upper paddle, the lower paddle, and the belt such that the belt may move substantially continuously as the container is unloaded.

20. A method of unloading a container comprising:

operating a feeder, the feeder comprising:

a frame having a first end and a second end, the second end comprising a singulator;

a belt disposed on the frame, the belt having an opening therein,

wherein the belt is configured to move an article toward the second end and into contact with the singulator;

an upper paddle disposed above the belt;
a lower paddle moveably connected to the frame and disposed at least partially below the belt;

extending at least a portion of the lower paddle upward through an opening disposed in the belt, at a location
more proximal to the second end of the belt than the location of the container;
receiving a container enclosing a stack of articles onto the first end of the belt, wherein the container comprises
a door and a rear surface with at least one channel formed therein;
opening the door of the container using the upper paddle, wherein the upper paddle is moveable between the
first end and the second end of the feeder;
moving at least a portion of the upper paddle through the channel in the rear surface of the container;
supporting the stack of articles in the container with the portion of the upper paddle; and
moving the upper paddle toward the second end of the feeder, thereby pushing the stack of articles through
the door of the container, and impinging a lead article in the stack of articles against the portion of the lower
paddle which extends above the belt.

21. The method of clause 20 further comprising:

removing the container from the feeder while leaving the stack of articles sandwiched between the upper paddle
and the lower paddle;
withdrawing the lower paddle through the opening disposed in the belt;
advancing the stack of articles toward the singulator using the belt and supporting the stack of articles with the
at least a portion of the upper paddle.

22. The method of clause 20, wherein the portion of the lower paddle extending above the belt supports a second
stack of articles prior to receiving the container on the first end of the belt.

23. The method of clause 22, wherein withdrawing the lower paddle comprises merging the stack of articles from
the container and the second stack of articles into a single stack of articles.

24. The method of clause 20 further comprising synchronizing the movement of the lower paddle and the belt such
that the stack of articles is maintained at approximately the same angle relative to the belt as the stack of articles
moves toward the second end of the feeder.

25. The method of clause 24 further comprising synchronizing the movement of the upper paddle with the movement
of the belt and the lower paddle such that the steps of opening the container and supporting the stack of articles in
the container are performed without altering the movement of the belt.

26. A system for managing articles in an automatic stack feeder comprising:

a frame configured to support a stack of articles;
a perforated drive belt assembly comprising:

a drive belt having an opening therein;
a first end and a second end, wherein the first end of the perforated drive belt assembly is pivotably attached
to the frame and the second end of the perforated drive belt assembly is pivotable about an axis of rotation
defined by the attachment of the first end of the perforated drive belt assembly, and wherein the drive belt
extends rotationally about the first and second ends;

a conveyor connected to the frame and configured to move the stack of articles with respect to the drive belt;
a sensor in proximity to the perforated drive belt assembly, the sensor configured to detect a force exerted on
a portion of the perforated drive belt assembly by the stack of articles; and
a controller configured to receive an input from the sensor and to control the conveyor based on the received input.

27. The system of clause 26, wherein the perforated drive belt assembly comprises a vacuum unit configured to
apply a vacuum through the opening in the drive belt.

28. The system of clause 26, wherein the pivotable attachment of the perforated drive belt assembly comprises a
spring configured to resist movement of the perforated drive belt assembly due at least in part to the force thereon
from the stack of articles.

29. The system of clause 26, wherein the sensor is configured to sense a pressure exerted on the perforated drive
belt assembly by the stack of articles.

30. The system of clause 29, wherein the sensor is connected to the first end of the perforated drive belt assembly
so as to sense the pressure exerted on the perforated drive belt assembly due, at least in part, to the movement of

the second end of the perforated drive belt assembly about the axis of rotation defined by the attachment of the first end.

31. The system of clause 26, wherein the sensor is configured to sense angular displacement of the perforated drive assembly relative to the frame according, at least in part, to the force exerted by the stack of articles.

32. The system of clause 26 wherein the conveyor comprises a belt and a paddle, the belt and the paddle being independently moveable, and wherein the paddle is configured to provide vertical support for the stack of articles and the belt is configured to convey the stack of articles toward or away from the perforated drive belt assembly.

33. The system of clause 32, wherein the controller is configured to control adjustment of the position of the paddle or to move the belt in response to the input received from the sensor.

34. The system of clause 26 further comprising a photoelectric sensor located so as to detect an angle of the stack of articles relative to the frame.

35. A method of automatic stack feeder management comprising:

receiving one or more articles onto a conveyor;

operating a drive belt assembly comprising a drive belt having an opening therein, wherein an end of the drive belt assembly is pivotably attached to a frame, and a free end of the drive belt assembly is rotatable about an axis of rotation defined by the attached end;

sensing a force exerted on the drive belt assembly by the one or more articles; and

controlling the position of the conveyor based on the sensed force, thereby controlling the position of the stack of articles.

36. The method of clause 35, further comprising singulating an article from the one or more articles using a vacuum applied via the drive belt assembly.

37. The method of clause 35, wherein the pivotable attachment of the perforated drive belt comprises a spring which resists movement of the perforated drive belt assembly due, at least in part, to the force exerted thereon by the one or more articles.

38. The method of clause 35, wherein sensing a force comprises sensing the pressure exerted by the one or more articles on the perforated drive belt assembly.

39. The method of clause 38, wherein sensing the pressure exerted by the one or more articles on the perforated drive belt assembly comprises sensing the pressure exerted on the perforated drive belt assembly due, at least in part, to the movement of the perforated drive belt assembly about the axis of rotation defined by the attachment of the attached end.

40. The method of clause 35, wherein sensing a force comprises sensing an angular displacement of the free end of the perforated drive belt assembly in reference to the frame, according, at least in part, to the force exerted by the one or more articles.

41. The method of clause 35, wherein the conveyor comprises a belt and a paddle, which are independently moveable, and wherein the belt is configured to convey the one or more articles toward or away from the perforated drive belt assembly and wherein the paddle is configured to support the stack of articles, and wherein controlling the conveyor comprises moving at least the belt or the paddle to adjust the position of the one or more articles relative to the perforated drive belt assembly.

42. The method of clause 35, further comprising sensing an angle of the one or more articles relative to the frame using a photoelectric sensor and controlling the conveyor in response to the sensed angle of the one or more articles.

43. A stack feeder comprising:

a frame;

a singulator connected to the frame;

a conveyor disposed on the frame, the conveyor configured to receive a stack of articles and a container, the conveyor further configured to move the stack of articles and the container toward the singulator;

a motor connected to the frame;

a stack guide connected to the motor and aligned substantially parallel to the belt, wherein the stack guide comprises a continuous surface configured to contact an edge of the stack of articles; and

wherein the motor is operable to move the stack guide from a first position to a second position to accommodate receiving the container onto the conveyor.

44. The stack feeder of clause 43 further comprising:

a sensor configured to detect the presence of the container on the conveyor; and

a controller in communication with the sensor and the motor, the controller configured to control movement of

the motor to move the stack guide between the first position and the second position in response to detection of the presence of the container on the conveyor.

45. The stack feeder of clause 44, wherein, when the stack guide is in the first position, the stack guide is in contact with the stack of articles and when the stack guide is in the second position, the stack guide is in contact with the container and not with the stack of articles.

46. The stack feeder of clause 45, wherein when the presence of the container is detected, the controller is configured to control movement of the stack guide from the first position to the second position.

47. The stack feeder of clause 45, wherein when the absence of the container is detected, the controller is configured to control movement the stack guide from the second position to the first position.

48. A system for unloading a container comprising:

a container configured to hold articles;

an automatic stack feeder comprising:

a singulator;

a conveyor configured to receive a first stack of articles and the container, wherein the container has a second stack of articles therein, the conveyor further configured to move the first stack of articles and the container toward the singulator;

a stack guide aligned substantially parallel to the conveyor, wherein the stack guide comprises a continuous, substantially vertical surface configured to contact an edge of the first and second stacks of articles, and wherein the stack guide is moveable from a first position to a second position;

a sensor configured to detect the presence of the container on the conveyor; and

a controller, in communication with the sensor, and configured to control movement of the stack guide between the first position and the second position in response to the presence of the container on the conveyor.

49. The system of clause 48, wherein the stack guide further comprises a motor in communication with the controller, and wherein the motor is configured to move the stack guide between the first and second positions.

50. The system of clause 48, wherein the sensor is further configured to detect the absence of the container on the conveyor, and wherein the controller is configured to control the movement of the stack guide between the second and the first position in response to the absence of the container.

51. The system of clause 48, wherein when the presence of the container is detected, the controller is configured to move the stack guide from the first position to the second position, and when the absence of the container is detected, the controller is configured to move the stack guide from the second position to the first position.

52. A method of sorting articles comprising:

operating a stack feeder comprising a stack guide;

receiving a container having a first stack of articles therein onto a conveyor of the automatic stack feeder;

detecting the presence of the container on the conveyor;

moving the stack guide in response to the detected presence of the container;

unloading the first stack of articles from the container;

detecting the absence of the container; and

moving the stack guide in response to the absence of the container.

53. The method of clause 52, wherein moving the stack guide in response to the detected presence of the container comprises moving the stack guide from a first to a second position and wherein moving the stack guide in response to the absence of the container comprises moving the stack guide from the second position to the first position.

54. The method of clause 52 wherein unloading a second stack of articles from the container comprises:

moving the first stack of articles out of the container onto the conveyor;

combining the first stack of articles with a second stack of articles already on the conveyor; and

removing the container from the conveyor.

55. An automatic stack feeder comprising:

a shingulating device configured to receive a stack of articles and to produce a positively lapped stack of articles;

a plurality of picking devices configured to pick one or more articles from the positively lapped stack of articles

and to produce one or more singulated articles; and

one or more synchronization devices configured to deliver the one or more singulated articles to one or more sorter windows.

56. The automatic stack feeder of clause 55, wherein the shingulating device comprises:

a bottom transport belt having a transport surface extending in a first direction;
a shearing device; and
a perforated belt having a surface extending in a second direction different than the first direction, the perforated belt being adjacent to the bottom transport belt, wherein the bottom transport belt and the perforated belt are configured to move the stack of articles toward the shearing device, and wherein the shearing device is configured to apply a shearing force on a portion of the stack of articles to produce the positively lapped stack of articles.

57. The automatic stack feeder of clause 56, further comprising a vacuum system configured to apply suction through one or more openings in the perforated belt.

58. The automatic stack feeder of clause 55, wherein the shingulating device comprises:

a plurality of bottom transport belts, each bottom transport belt having a transport surface extending in a first direction;
a shearing device; and
a plurality of perforated belts, each perforated belt having a surface extending in a second direction different than the first direction and being adjacent to at least one of the plurality of bottom transport belts, wherein at least one of the plurality of bottom transport belts and at least one of the plurality of perforated belts are configured to move the stack of articles toward the shearing device, and wherein the shearing device is configured to apply a shearing force on a portion of the stack of articles to produce the positively lapped stack of articles.

59. The automatic stack feeder of clause 55, wherein each of the plurality of picking devices comprises:

a vertically oriented perforated belt having one or more openings in its surface, the perforated belt configured to be driven by a motor;
a vacuum manifold located adjacent to the perforate belt;
a vacuum unit configured to apply suction through the vacuum manifold, wherein the vacuum manifold is configured to apply the suction through the one or more openings in the surface of the perforated belt; and
a vacuum valve configured to control the amount of suction applied by the vacuum unit to the vacuum manifold.

60. The automatic stack feeder of clause 59, wherein each of the plurality of picking devices is configured to:

pick an article from the positively lapped stack of articles, including opening the vacuum valve and exposing the vacuum manifold to the suction from the vacuum unit, the vacuum manifold applying the suction through the one or more openings in the perforated belt to attach the article to the perforated belt; and
produce a singulated article, including separating the article from the positively lapped stack of articles by driving the perforated belt with the attached article forward using the motor.

61. The automatic stack feeder of clause 59, wherein each of the plurality of picking devices is located in a respective picking zone, each respective picking zone includes a picking device and an anti-doubling device opposite the picking device, the anti-doubling device configured to prevent more than one article at a time from being picked from the positively lapped stack of articles.

62. The automatic stack feeder of clause 61, wherein the anti-doubling device includes:

a presence sensor configured to detect a first article;
an edge detector sensor positioned upstream from the presence sensor and configured to detect an edge of a second article; and
a vacuum unit configured to apply suction to the second article when the presence sensor detects the first article during a time period in which the edge detector detects the edge of the second article.

63. The automatic stack feeder of clause 55, wherein the one or more synchronization devices includes a group of paired pinch wheels driven at a variable speed by a pinch wheel motor.

64. The automatic stack feeder of clause 55, further comprising a controller configured to control movement of each

article of the stack of articles to synchronize a first time when each of the one or more singulated articles reaches an exit point with a second time when a sorter window reaches the exit point.

65. The automatic stack feeder of clause 64, wherein the synchronization of the first time with the second time is based on one or more of a location of a first article being picked by a first picking device, a velocity of the first article, a location of the sorter window, a velocity of the sorter window, an acceleration rate of each of a plurality perforated belts included in each of the plurality of picking devices, an acceleration rate of the one or more synchronization devices, a maximum velocity allowed for each of the plurality perforated belts included in each of the plurality of picking devices, a maximum velocity allowed for a perforated belt included in the shingulating device, a maximum velocity allowed for the one or more synchronization devices, a length of each of the plurality of perforated belts included in each of the plurality of picking devices, a length of the perforated belt included in the shingulating device, a number of perforated belts, a length of the one or more synchronization devices, and a number of the one or more synchronization devices.

66. A method of managing articles in an automatic stack feeder, the method comprising:

receiving a stack of articles at a shingulating device and producing a positively lapped stack of articles; picking one or more articles from the positively lapped stack of articles using one or more picking devices and producing one or more singulated articles; and delivering the one or more singulated articles to one or more sorter windows using one or more synchronization devices.

67. The method of clause 66, wherein producing the positively lapped stack of articles comprises:

moving the stack of articles toward a shearing device using a bottom transport belt and a perforated belt of the shingulating device, the bottom transport belt having a transport surface extending in a first direction and the perforated belt having a surface extending in a second direction different than the first direction; and applying a shearing force on the stack of articles using the shearing device.

68. The method of clause 67, further comprising applying suction through one or more openings in the perforated belt using a vacuum system.

69. The method of clause 66, wherein picking the one or more articles from the positively lapped stack of articles comprises:

opening a vacuum valve of a first picking device to expose a vacuum manifold of the first picking device to suction from a vacuum unit; applying the suction from the vacuum manifold through one or more openings in a perforated belt of the first picking device to one of the one or more articles; and attaching the article to the perforated belt using the suction through the one or more openings.

70. The method of clause 69, wherein producing the one or more singulated articles comprises separating an article from the positively lapped stack of articles by driving the perforated belt with the attached article forward using a motor.

71. The method of clause 70, wherein the singulated article is picked and produced by a downstream most picking device in a row of picking devices that is substantially completely covered by the positively lapped stack of articles.

72. The method of clause 70, further comprising preventing more than one article at a time from being picked from the positively lapped stack of articles using an anti-doubling device located in a respective picking zone, each respective picking zone including a respective picking device.

73. The method of clause 72, further comprising:

detecting a first article using a presence sensor of the anti-doubling device; detecting an edge of a second article using an edge detector sensor of the anti-doubling device, the edge detector sensor being positioned upstream from the presence sensor; and applying suction to the second article using the vacuum unit when the presence sensor detects the first article during a time period in which the edge detector detects the edge of the second article.

74. The method of clause 66, further comprising controlling movement of each article of the stack of articles to synchronize a first time when each of the one or more singulated articles reaches an exit point with a second time when a sorter window reaches the exit point.

75. The method of clause 74, wherein the synchronization of the first time with the second time is based on one or more of a location of a first article being picked by a first picking device, a velocity of the first article, a location of

the sorter window, a velocity of the sorter window, an acceleration rate of each of a plurality perforated belts included in each of the plurality of picking devices, an acceleration rate of the one or more synchronization devices, a maximum velocity allowed for each of the plurality perforated belts included in each of the plurality of picking devices, a maximum velocity allowed for a perforated belt included in the shingulating device, a maximum velocity allowed for the one or more synchronization devices, a length of each of the plurality of perforated belts included in each of the plurality of picking devices, a length of the perforated belt included in the shingulating device, a number of perforated belts, a length of the one or more synchronization devices, and a number of the one or more synchronization devices.

76. The automatic stack feeder of clause 56 further comprising an anti-rotation device.

77. The automatic stack feeder of clause 76, wherein the anti-rotation device comprises:

a base;

a torsion element connected to the base, disposed in proximity to the perforated belt;

a rotatable member coupled to the torsion element, the rotatable member rotatable between at least a first position and a second position about an axis which extends through the center of the torsion element; and

a revolving member coupled to the rotatable member and configured to revolve about an axis perpendicular to the base; wherein:

when the rotatable member is in the first position, an outer surface of the revolving member is in contact with the perforated belt, and

when the rotatable member is in the second position, the torsion element applies a torque to the revolving member via the rotatable member, and the outer surface of the revolving member is in contact with, and applies a force to, an article which is also in contact with the perforated belt.

78. The device of clause 77, wherein the torsion element is a helical torsion spring disposed within or around a structural support member which is connected to the base.

79. The device of clause 77, wherein the rotatable member is configured to transition from the first position toward the second position when the drive belt brings the article into contact with the revolving member.

80. The device of clause 77, wherein the central axis extends perpendicularly relative to the elongated axis of the rotatable member.

81. The device of clause 77, wherein the force applied by the revolving member to the article comprises a frictional force.

82. The device of clause 77, wherein the revolving member comprises a plurality of wheels rotatably disposed on a wheel shaft, the wheel shaft being coupled to the rotatable member.

83. A method of singulating a stack of articles while reducing damage to each article, the method comprising:

moving a stack of articles forward;

separating and laterally accelerating a forward-most article from the stack of articles; and

applying a force to a back face of the forward-most article to resist upward motion of the back face during lateral acceleration of the forward-most article, wherein the force is applied to the back face by a revolving member indirectly coupled to a torsion element.

84. The method of clause 83, wherein the force comprises a frictional force applied by the revolving member when a lever arm coupled to the revolving member rotates from a first position to a second position about an axis extending through the torsion element thereby causing the torsion element to exert a torque on the lever arm.

Claims

1. An automatic stack feeder comprising:

a shingulating device configured to receive a stack of articles and to produce a positively lapped stack of articles; a plurality of picking devices configured to pick one or more articles from the positively lapped stack of articles and to produce one or more singulated articles; and

one or more synchronization devices configured to deliver the one or more singulated articles to an exit point at a predetermined time.

2. The automatic stack feeder of claim 1, wherein the shingulating device comprises:

a bottom transport belt having a transport surface extending in a first direction;
a shearing device; and
a perforated belt having a surface extending in a second direction different than the first direction, the perforated
belt being adjacent to the bottom transport belt, wherein the bottom transport belt and the perforated belt are
configured to move the stack of articles toward the shearing device, and wherein the shearing device is configured
to apply a shearing force on a portion of the stack of articles to produce the positively lapped stack of articles.

3. The automatic stack feeder of claim 1, wherein the shingulating device comprises:

a plurality of bottom transport belts, each bottom transport belt having a transport surface extending in a first
direction;
a shearing device; and
a plurality of perforated belts, each perforated belt having a surface extending in a second direction different
than the first direction and being adjacent to at least one of the plurality of bottom transport belts, wherein at
least one of the plurality of bottom transport belts and at least one of the plurality of perforated belts are configured
to move the stack of articles toward the shearing device, and wherein the shearing device is configured to apply
a shearing force on a portion of the stack of articles to produce the positively lapped stack of articles.

4. The automatic stack feeder of claim 1, wherein each of the plurality of picking devices comprises:

a vertically oriented perforated belt having one or more openings in its surface, the perforated belt configured
to be driven by a motor;
a vacuum manifold located adjacent to the perforate belt;
a vacuum unit configured to apply suction through the vacuum manifold, wherein the vacuum manifold is con-
figured to apply the suction through the one or more openings in the surface of the perforated belt; and
a vacuum valve configured to control the amount of suction applied by the vacuum unit to the vacuum manifold.

5. The automatic stack feeder of claim 4, wherein each of the plurality of picking devices is configured to:

pick an article from the positively lapped stack of articles, including opening the vacuum valve and exposing
the vacuum manifold to the suction from the vacuum unit, the vacuum manifold applying the suction through
the one or more openings in the perforated belt to attach the article to the perforated belt; and
produce a singulated article, including separating the article from the positively lapped stack of articles by driving
the perforated belt with the attached article forward using the motor.

6. The automatic stack feeder of claim 4, wherein each of the plurality of picking devices is located in a respective
picking zone, each respective picking zone includes a picking device and an anti-doubling device opposite the
picking device, the anti-doubling device configured to prevent more than one article at a time from being picked
from the positively lapped stack of articles.

7. The automatic stack feeder of claim 6, wherein the anti-doubling device includes:

a presence sensor configured to detect a first article;
an edge detector sensor positioned upstream from the presence sensor and configured to detect an edge of a
second article; and
a vacuum unit configured to apply suction to the second article when the presence sensor detects the first article
during a time period in which the edge detector detects the edge of the second article.

8. The automatic stack feeder of claim 1, wherein the one or more synchronization devices includes a group of paired
pinch wheels driven at a variable speed by a pinch wheel motor.

9. The automatic stack feeder of claim 1, further comprising a controller configured to control movement of each article
of the stack of articles to synchronize a first time when each of the one or more singulated articles reaches the exit
point with the predetermined time when a sorter window reaches the exit point.

10. The automatic stack feeder of claim 9, wherein the synchronization of the first time with the predetermined time is
based on one or more of a location of a first article being picked by a first picking device, a velocity of the first article,
a location of a sorter window, a velocity of the sorter window, an acceleration rate of each of a plurality perforated

belts included in each of the plurality of picking devices, an acceleration rate of the one or more synchronization devices, a maximum velocity allowed for each of the plurality perforated belts included in each of the plurality of picking devices, a maximum velocity allowed for a perforated belt included in the shingulating device, a maximum velocity allowed for the one or more synchronization devices, a length of each of the plurality of perforated belts included in each of the plurality of picking devices, a length of the perforated belt included in the shingulating device, a number of perforated belts, a length of the one or more synchronization devices, and a number of the one or more synchronization devices.

11. A method of managing articles in an automatic stack feeder, the method comprising:

receiving a stack of articles at a shingulating device;
 producing a positively lapped stack of articles;
 picking one or more articles from the positively lapped stack of articles using one or more picking devices;
 producing one or more singulated articles; and
 delivering the one or more singulated articles to one or more exit points at a predetermined time using one or more synchronization devices.

12. The method of claim 11, wherein producing the positively lapped stack of articles comprises:

moving the stack of articles toward a shearing device using a bottom transport belt and a perforated belt of the shingulating device, the bottom transport belt having a transport surface extending in a first direction and the perforated belt having a surface extending in a second direction different than the first direction; and
 applying a shearing force on the stack of articles using the shearing device.

13. The method of claim 11, wherein picking the one or more articles from the positively lapped stack of articles comprises:

opening a vacuum valve of a first picking device to expose a vacuum manifold of the first picking device to suction from a vacuum unit;
 applying the suction from the vacuum manifold through one or more openings in a perforated belt of the first picking device to one of the one or more articles; and
 attaching the article to the perforated belt using the suction through the one or more openings.

14. The method of claim 13, wherein producing the one or more singulated articles comprises separating an article from the positively lapped stack of articles by driving the perforated belt, with the attached article, forward using a motor.

15. The method of claim 14, wherein the singulated article is picked and produced by a downstream-most picking device in a row of picking devices that is substantially completely covered by the positively lapped stack of articles.

16. The method of claim 14, further comprising preventing more than one article at a time from being picked from the positively lapped stack of articles using an anti-doubling device located in a respective picking zone, each respective picking zone including a respective picking device.

17. The method of claim 16, further comprising:

detecting a first article using a presence sensor of the anti-doubling device;
 detecting an edge of a second article using an edge detector sensor of the anti-doubling device, the edge detector sensor being positioned upstream from the presence sensor; and
 applying suction to the second article using the vacuum unit when the presence sensor detects the first article during a time period in which the edge detector detects the edge of the second article.

18. The method of claim 11, further comprising controlling movement of each article of the stack of articles to synchronize a first time when each of the one or more singulated articles reaches the exit point with the predetermined time when a sorter window reaches the exit point.

19. The method of claim 18, wherein the synchronization of the first time with the predetermined time is based on one or more of a location of a first article being picked by a first picking device, a velocity of the first article, a location of a sorter window, a velocity of the sorter window, an acceleration rate of each of a plurality perforated belts included in each of the plurality of picking devices, an acceleration rate of the one or more synchronization devices, a maximum

EP 3 176 114 A1

velocity allowed for each of the plurality perforated belts included in each of the plurality of picking devices, a maximum velocity allowed for a perforated belt included in the shingulating device, a maximum velocity allowed for the one or more synchronization devices, a length of each of the plurality of perforated belts included in each of the plurality of picking devices, a length of the perforated belt included in the shingulating device, a number of perforated belts, a length of the one or more synchronization devices, and a number of the one or more synchronization devices.

5

10

15

20

25

30

35

40

45

50

55

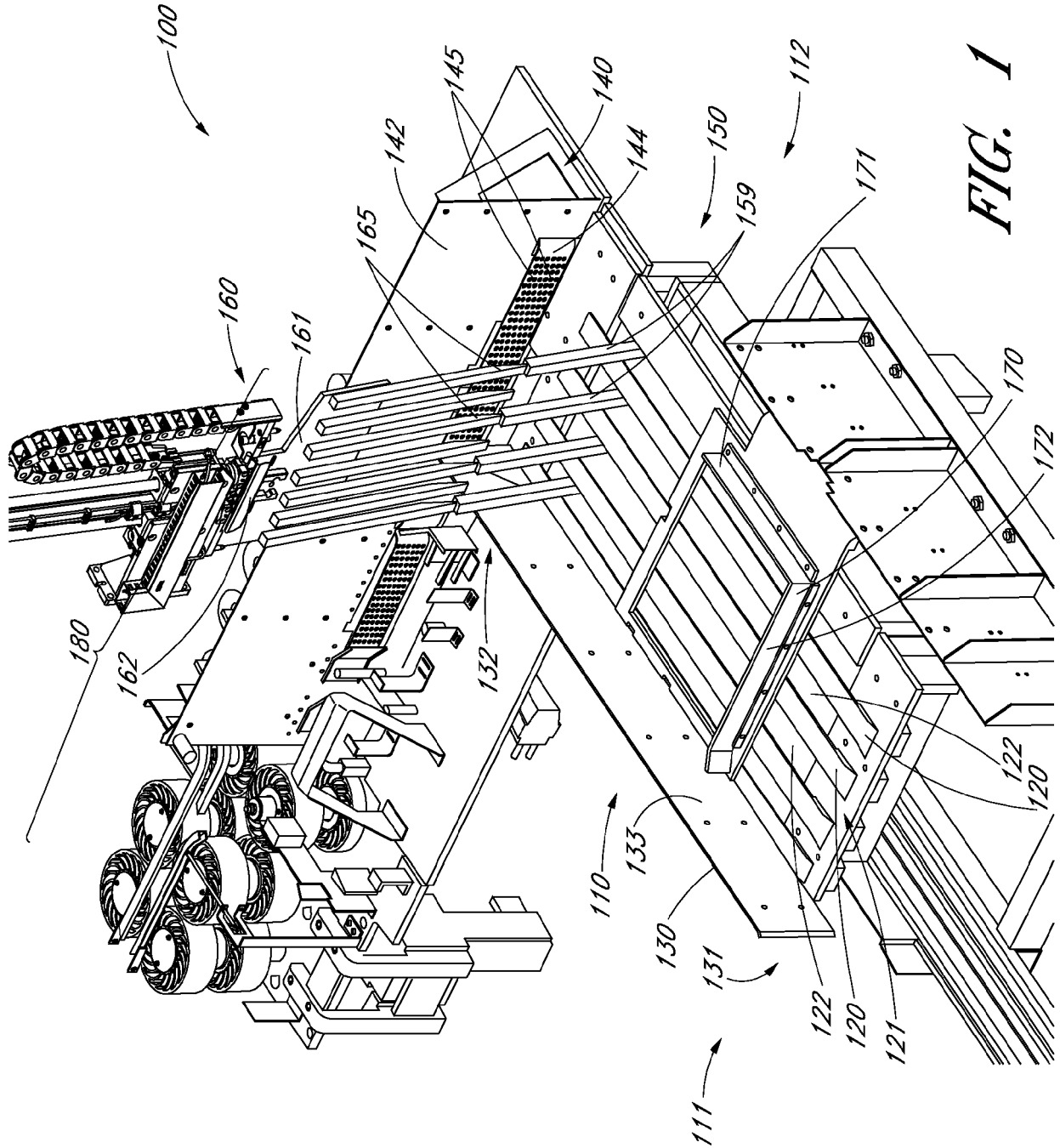


FIG. 1

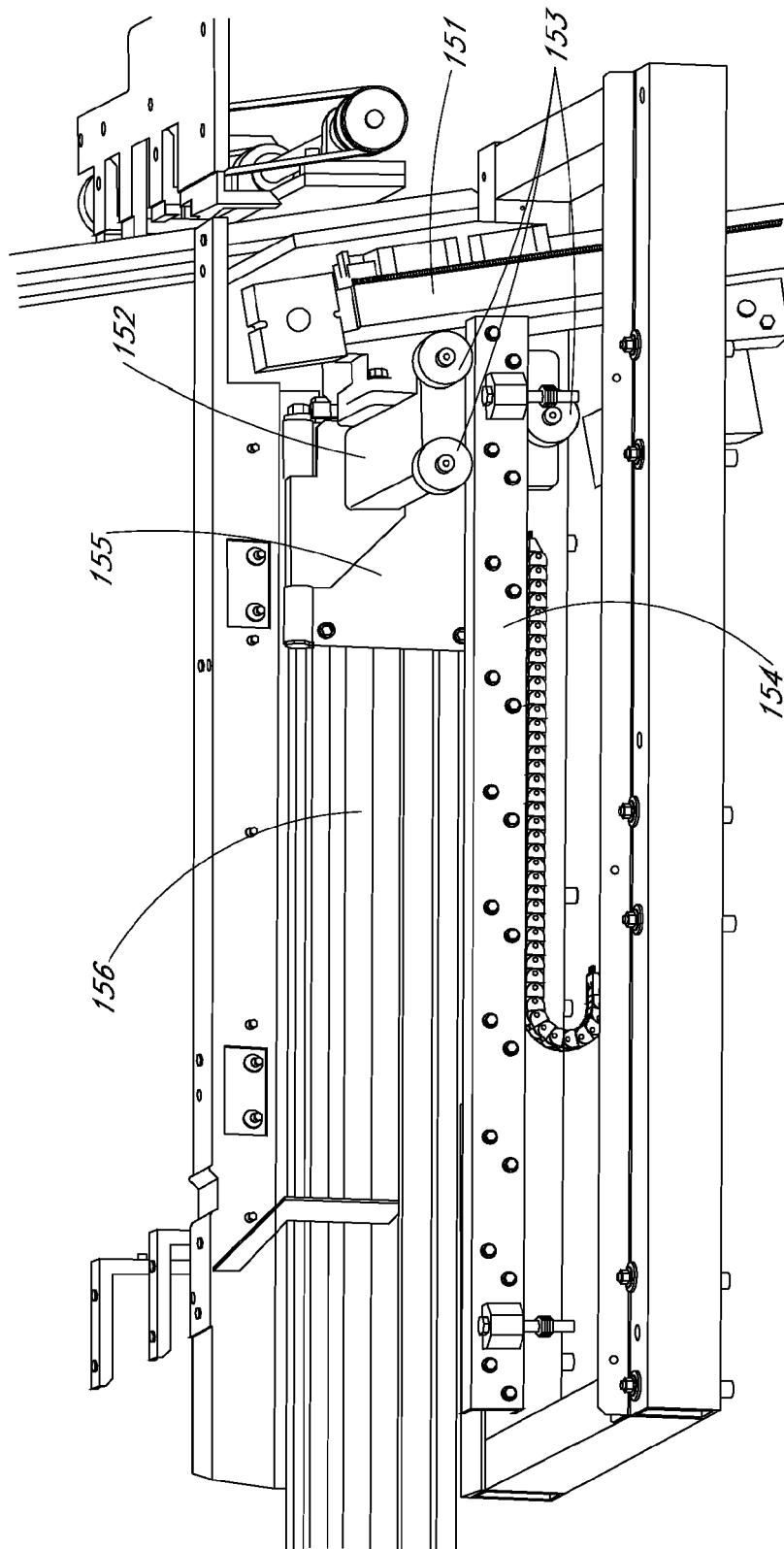


FIG. 2A

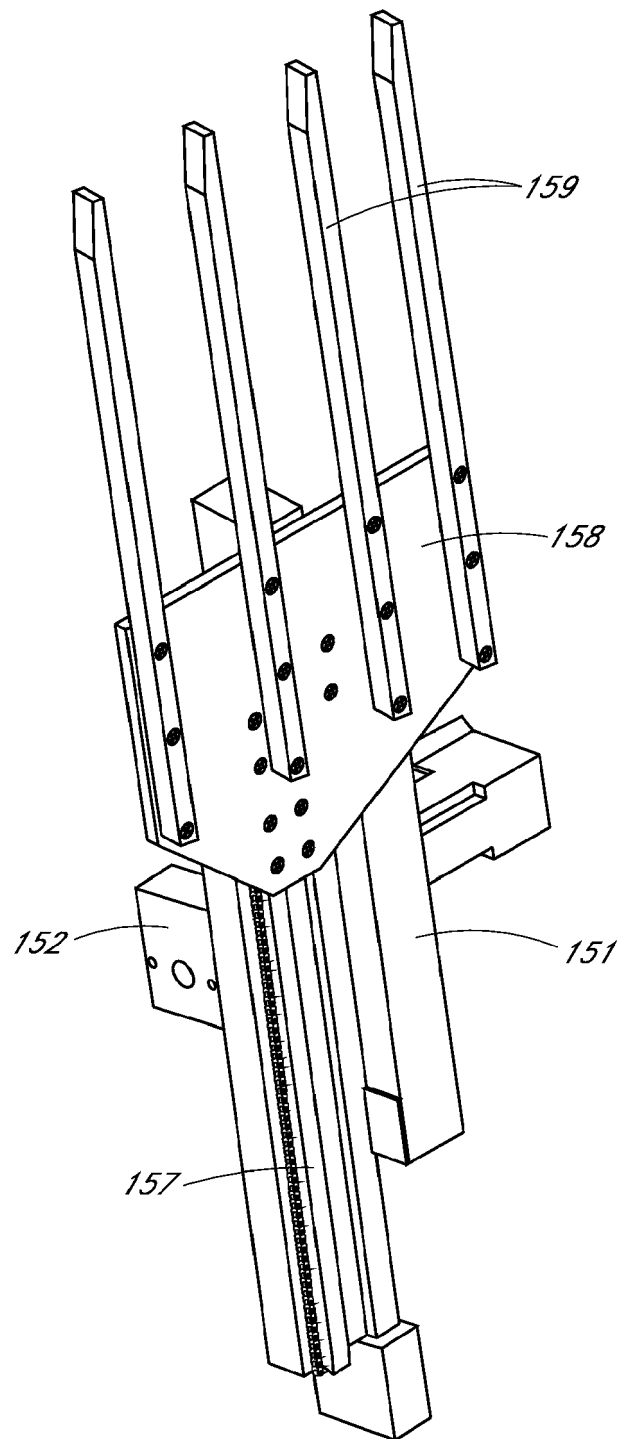


FIG. 2B

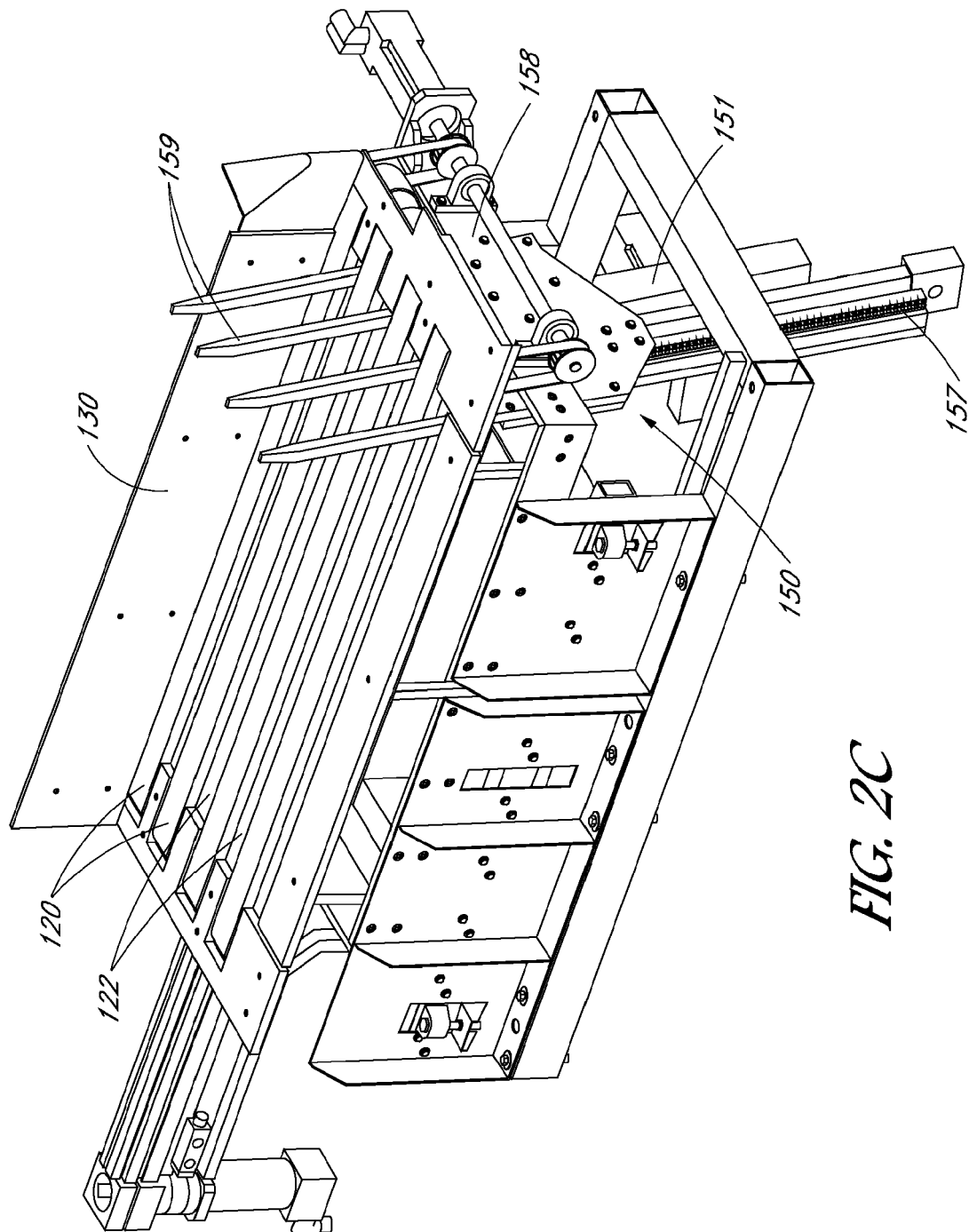


FIG. 2C

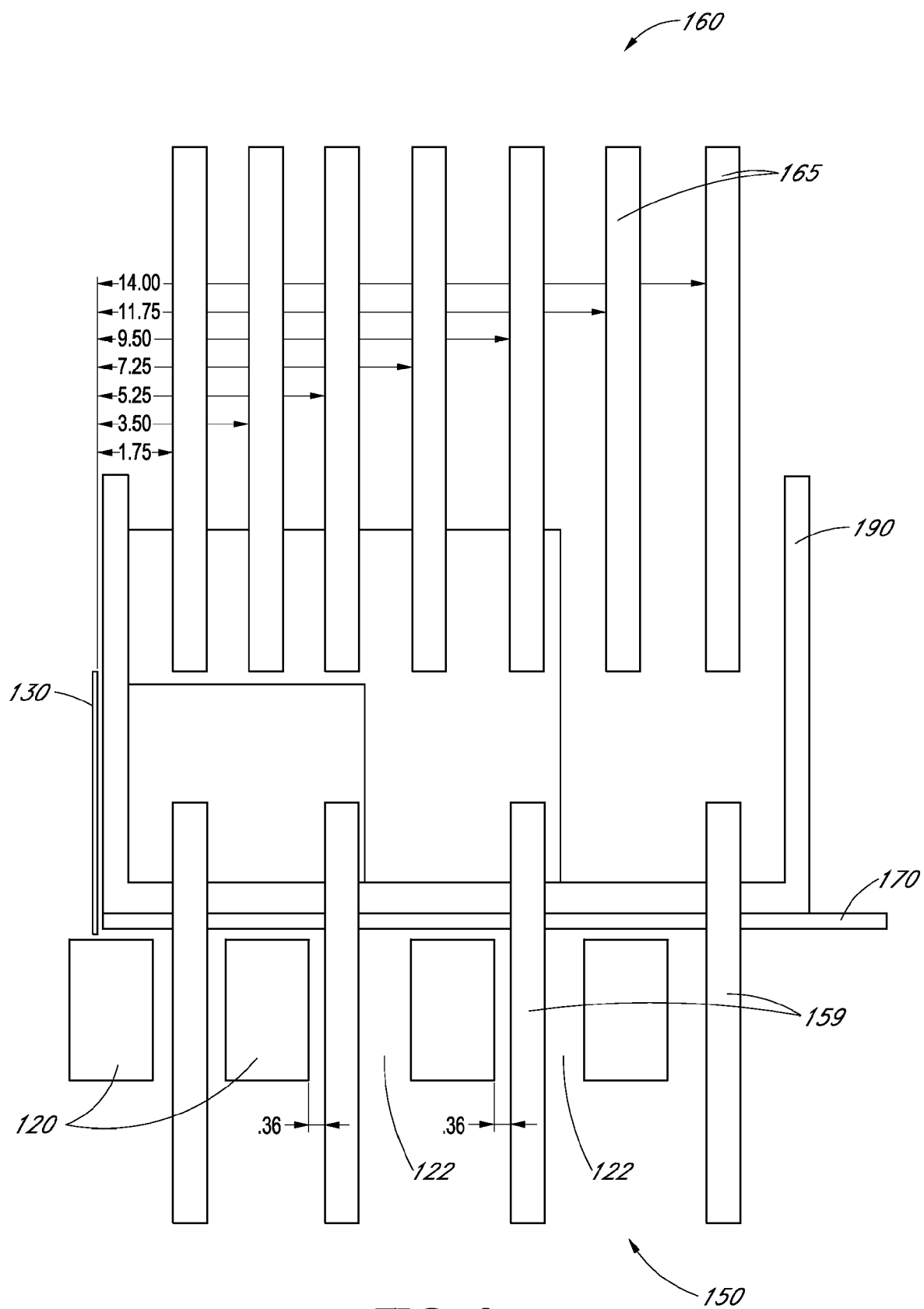


FIG. 3

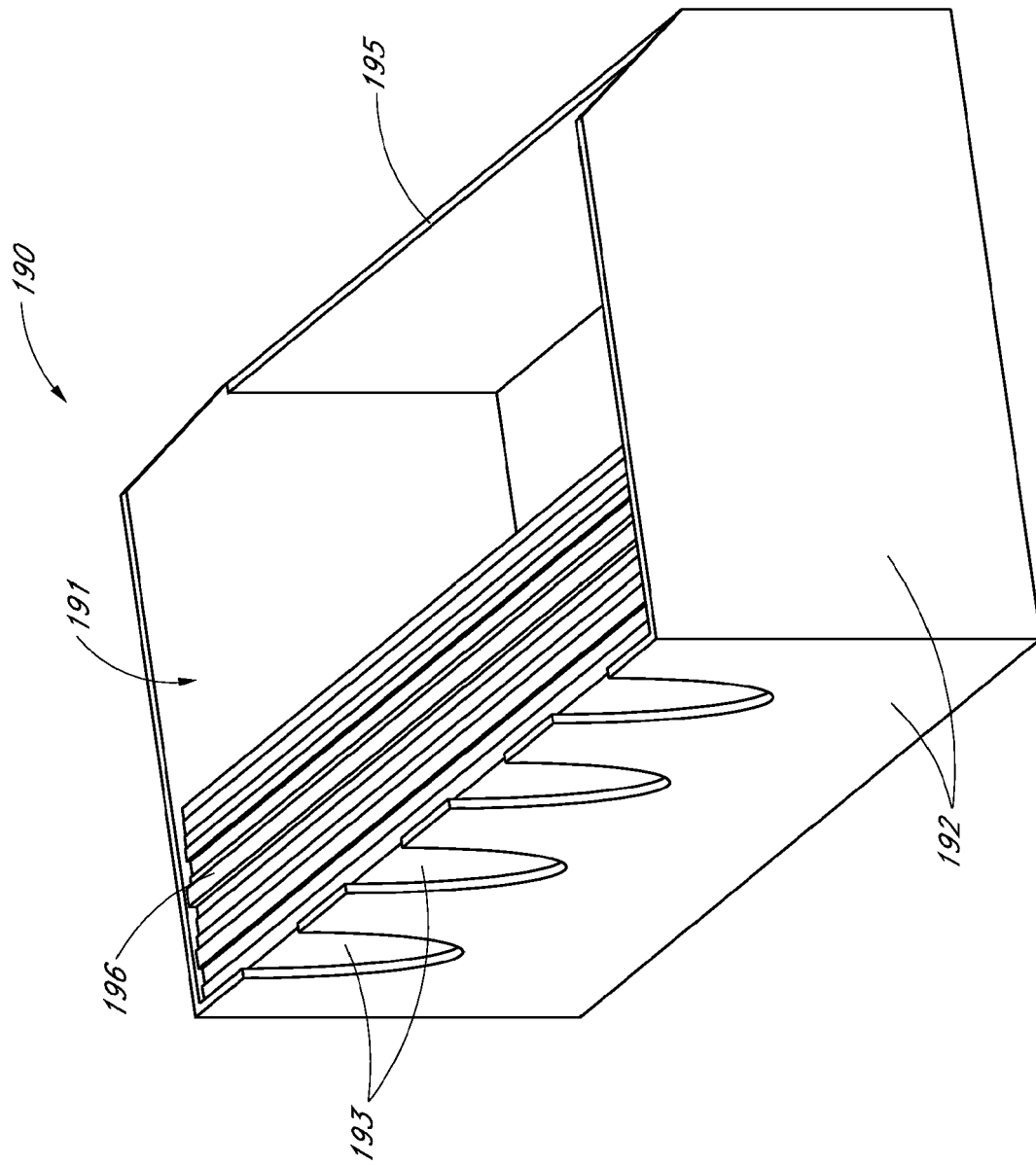


FIG. 4

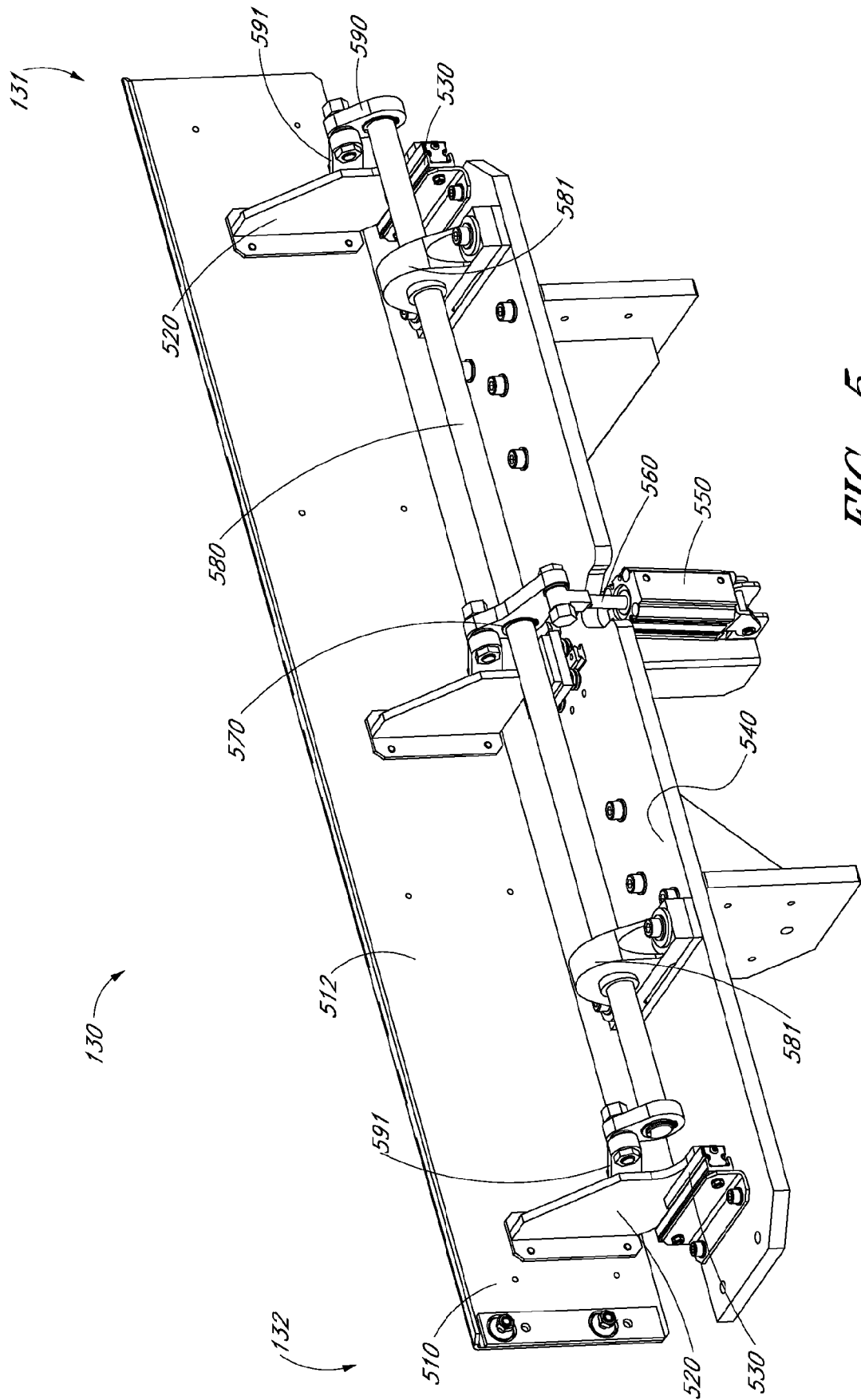


FIG. 5

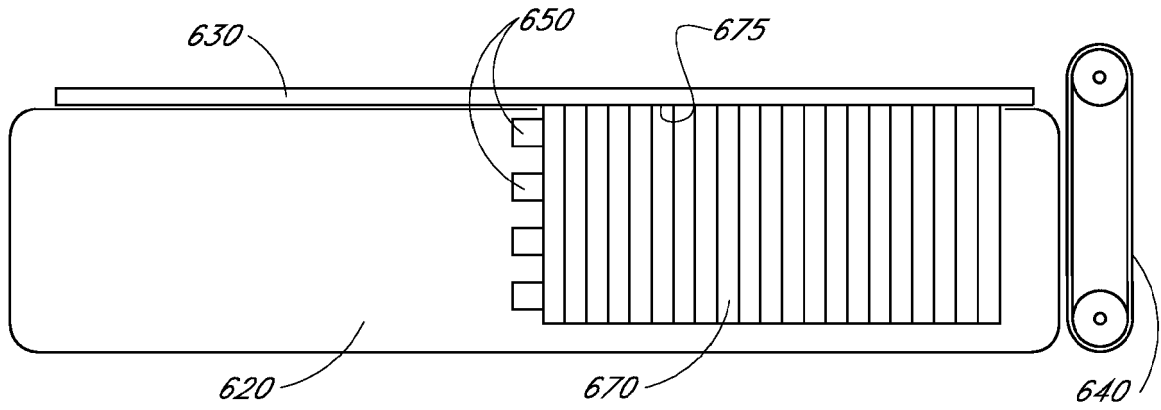


FIG. 6A

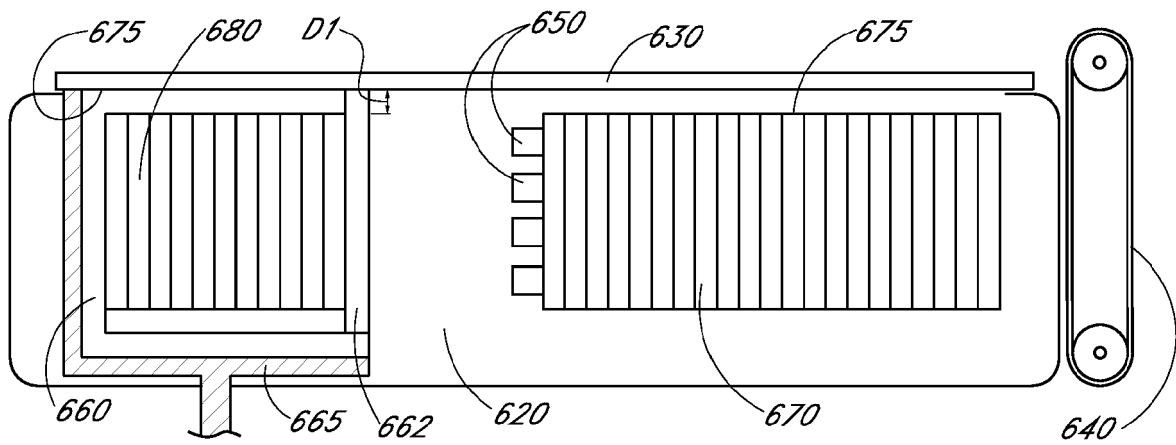


FIG. 6B

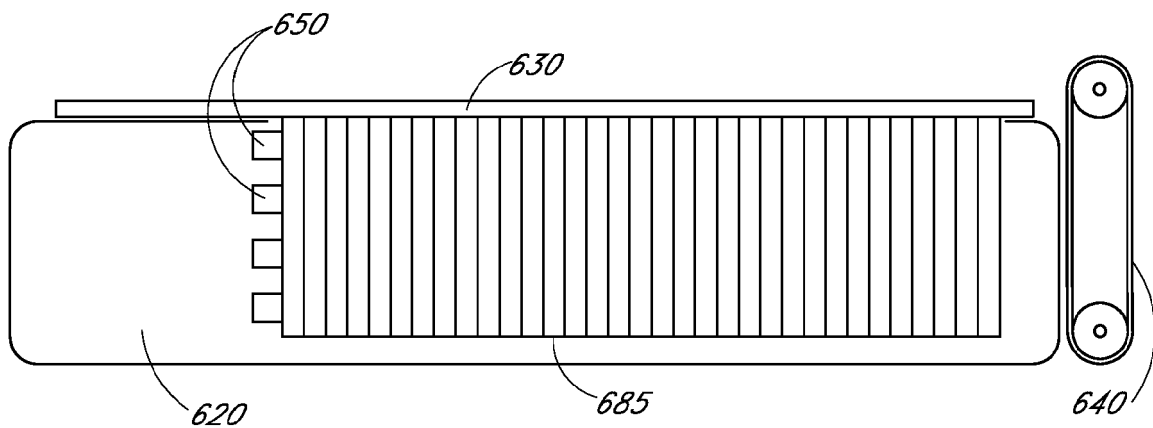


FIG. 6C

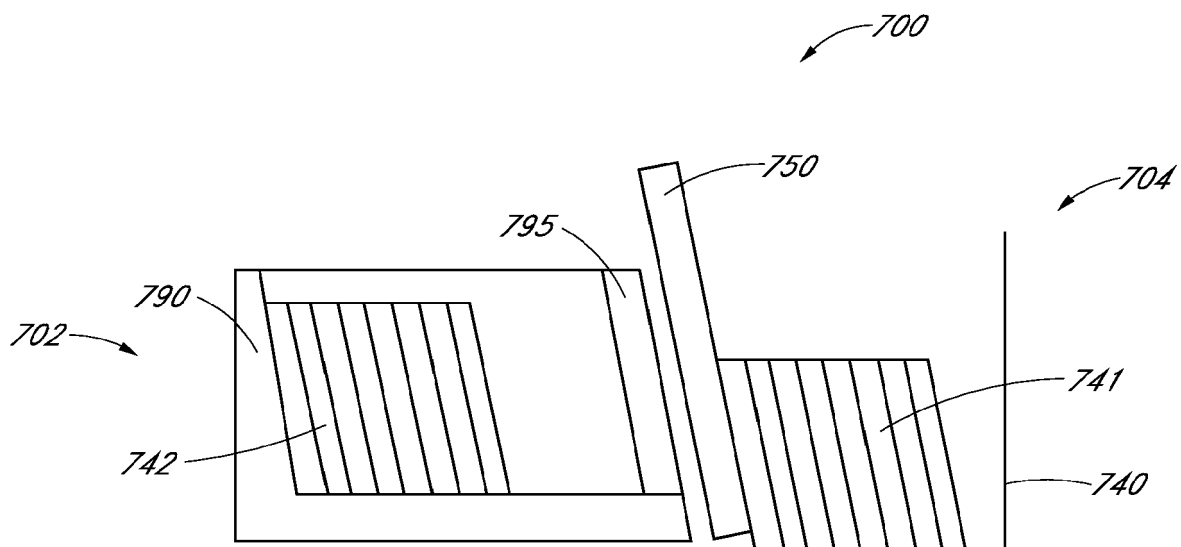


FIG. 7A

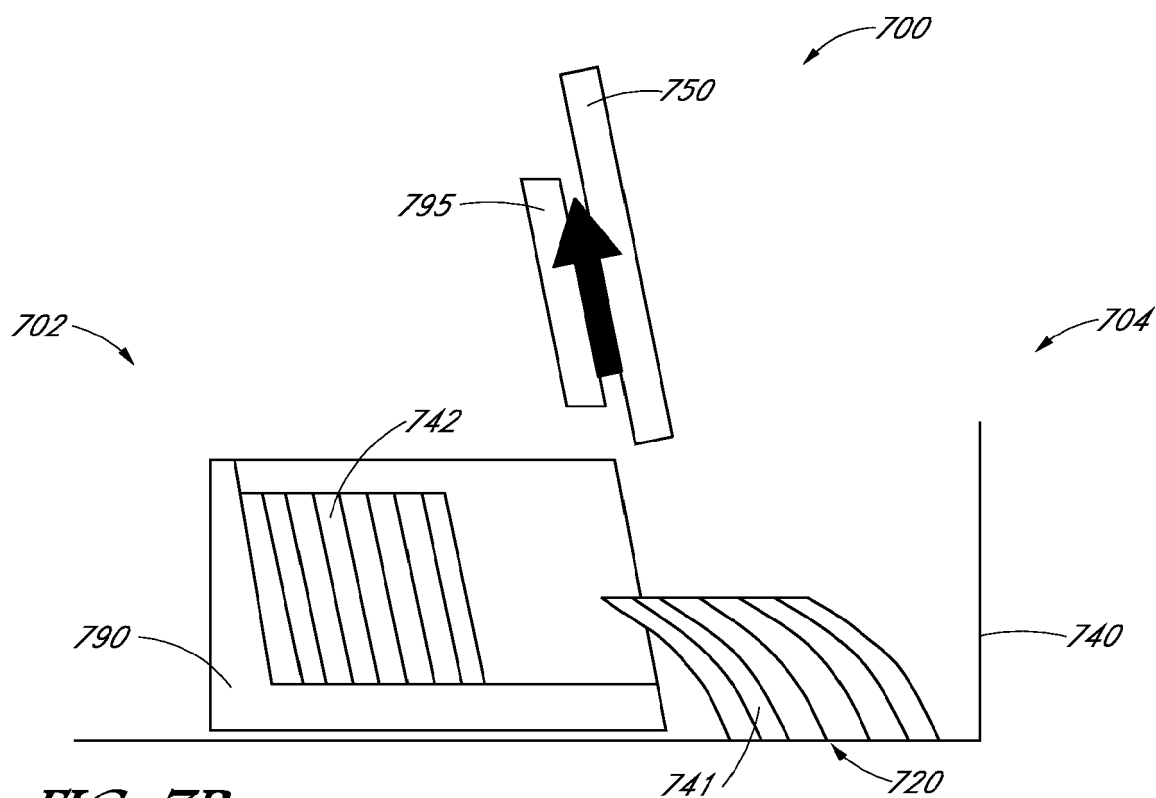


FIG. 7B

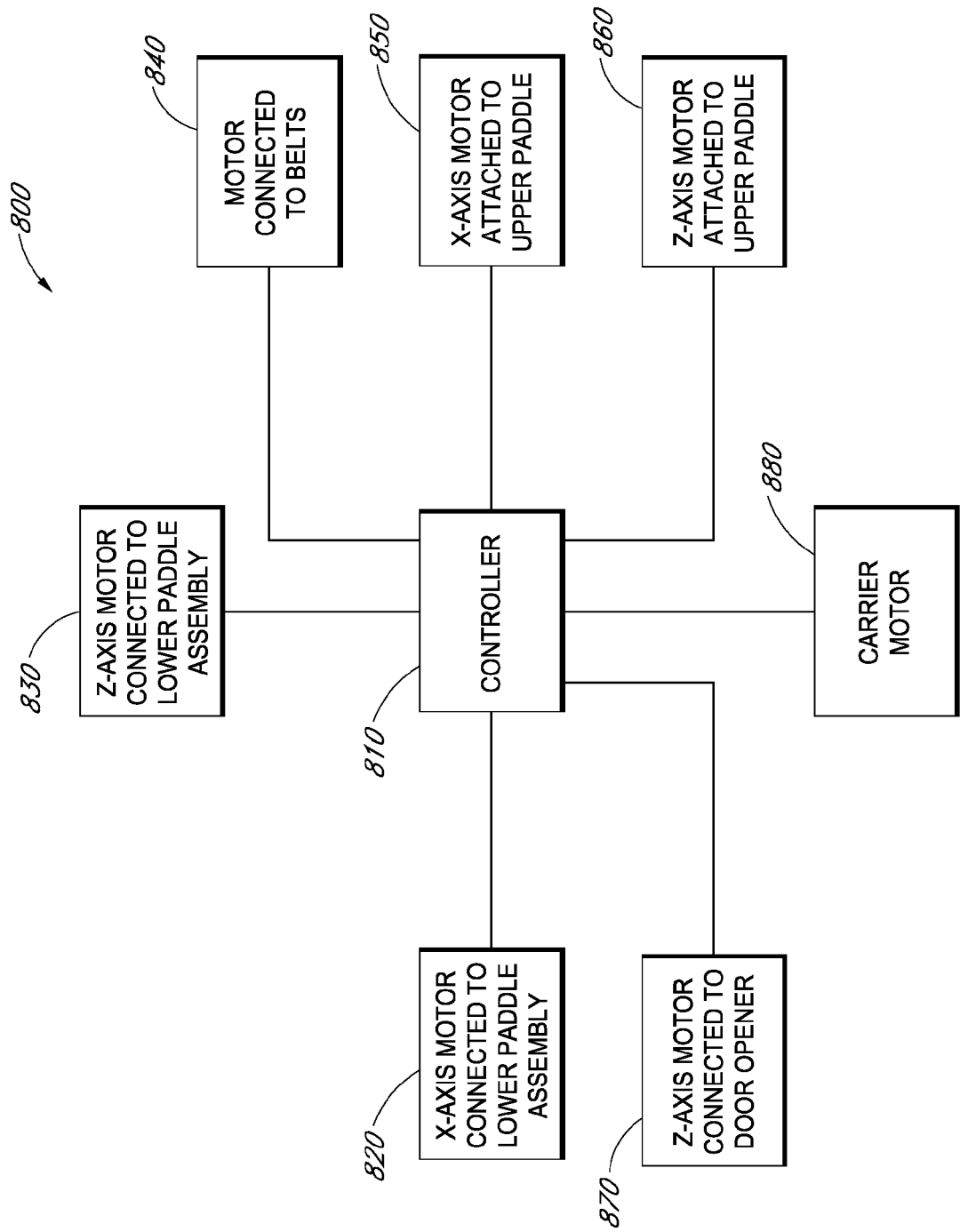


FIG. 8

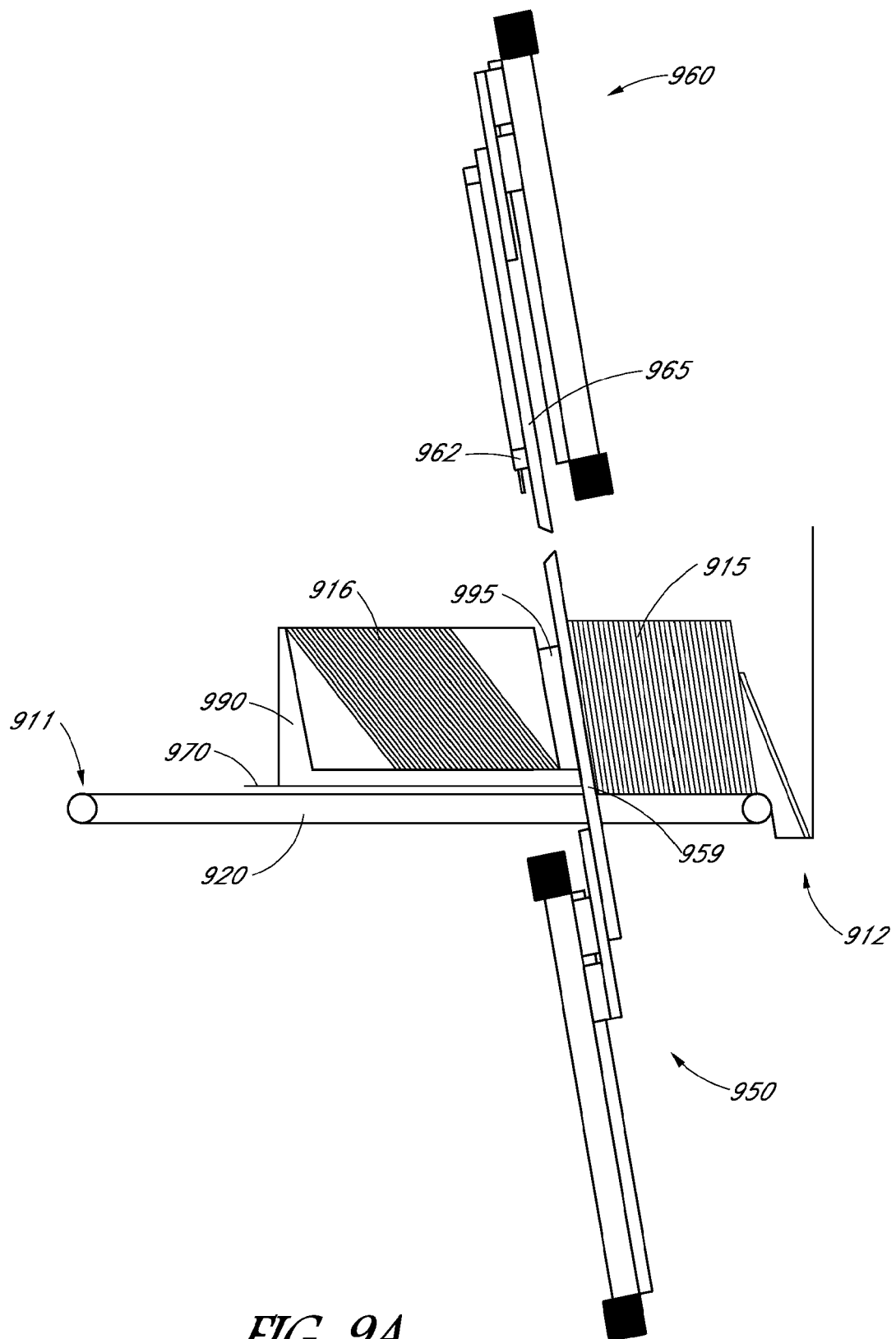


FIG. 9A

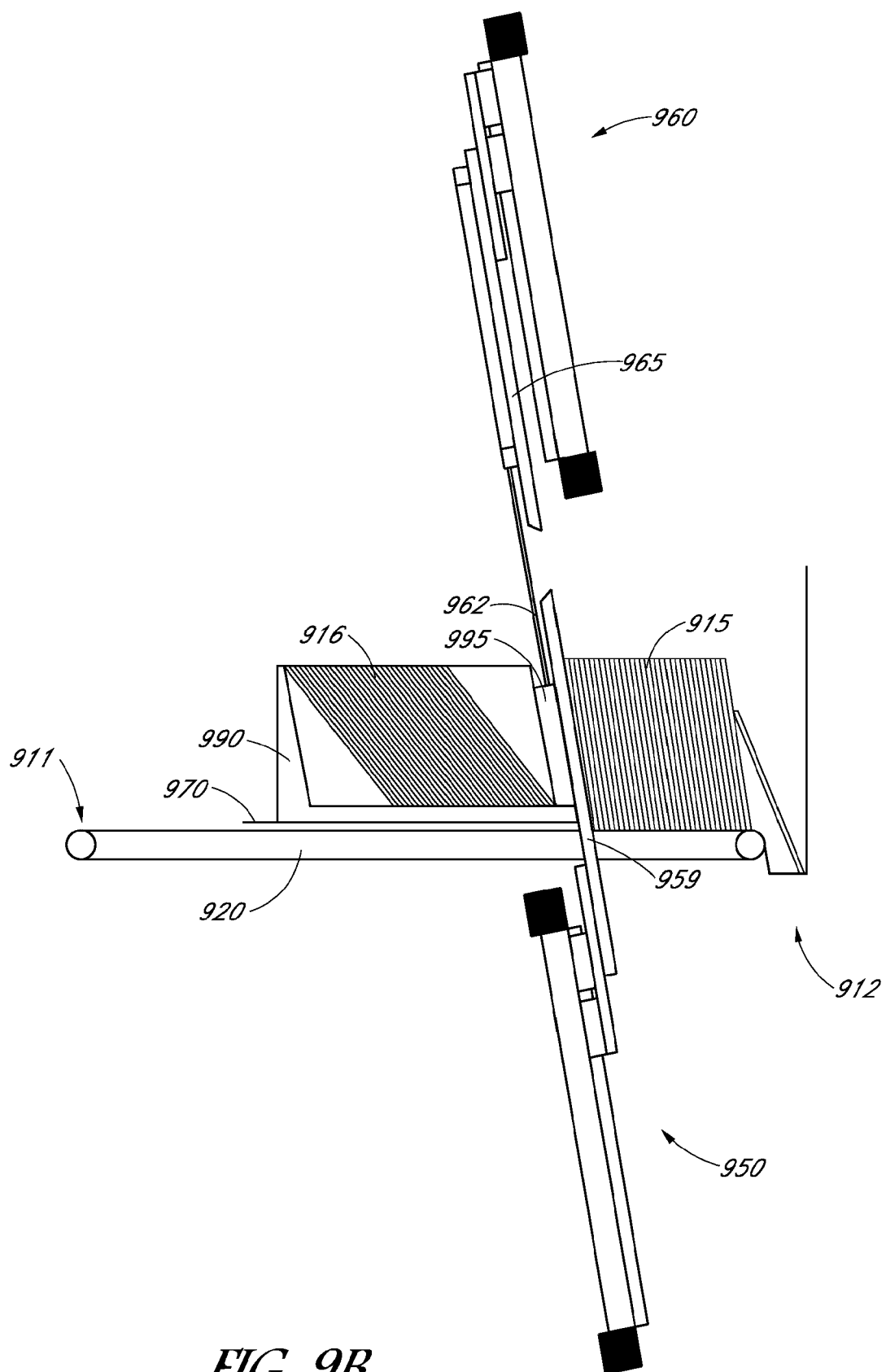
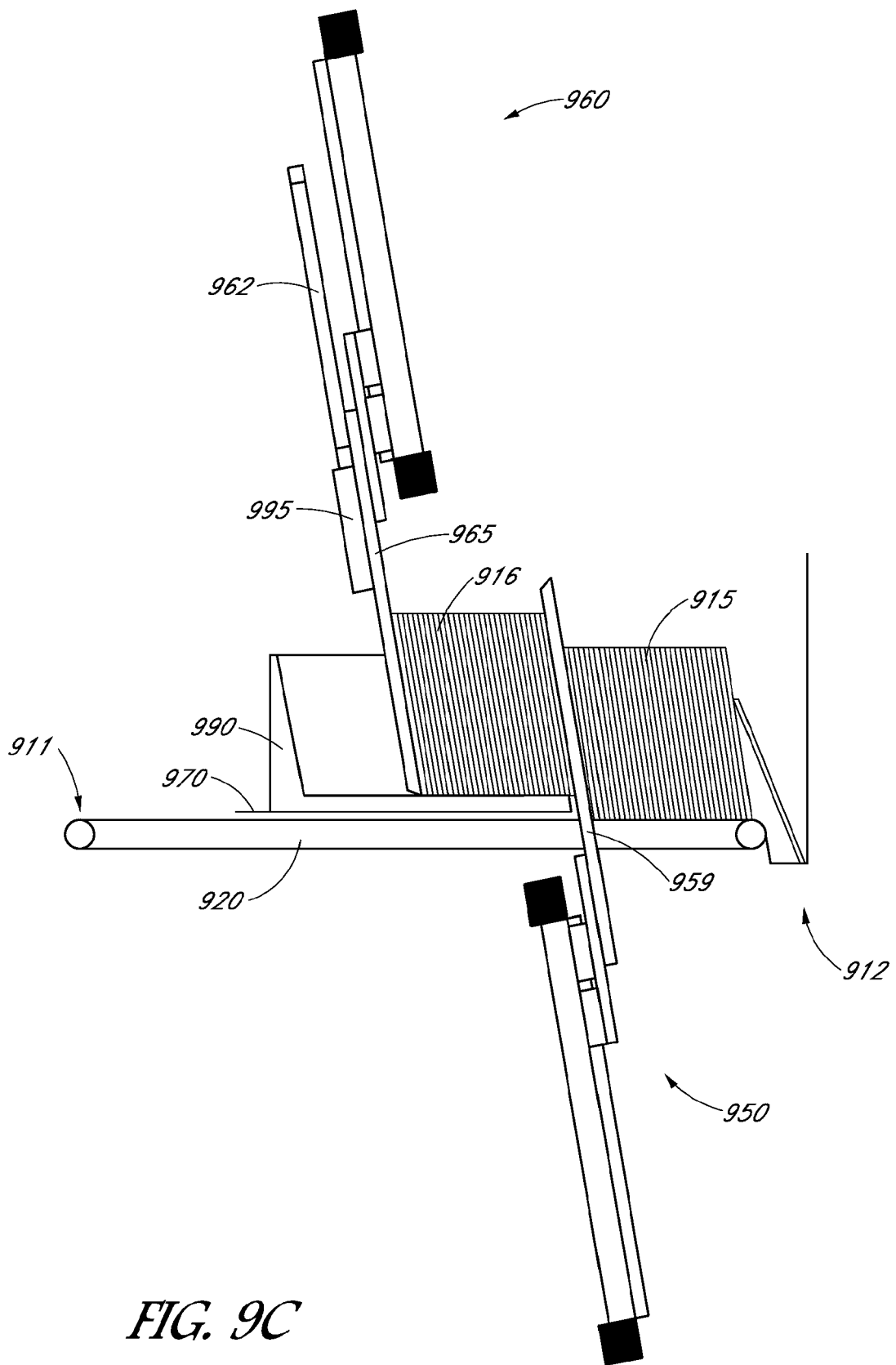
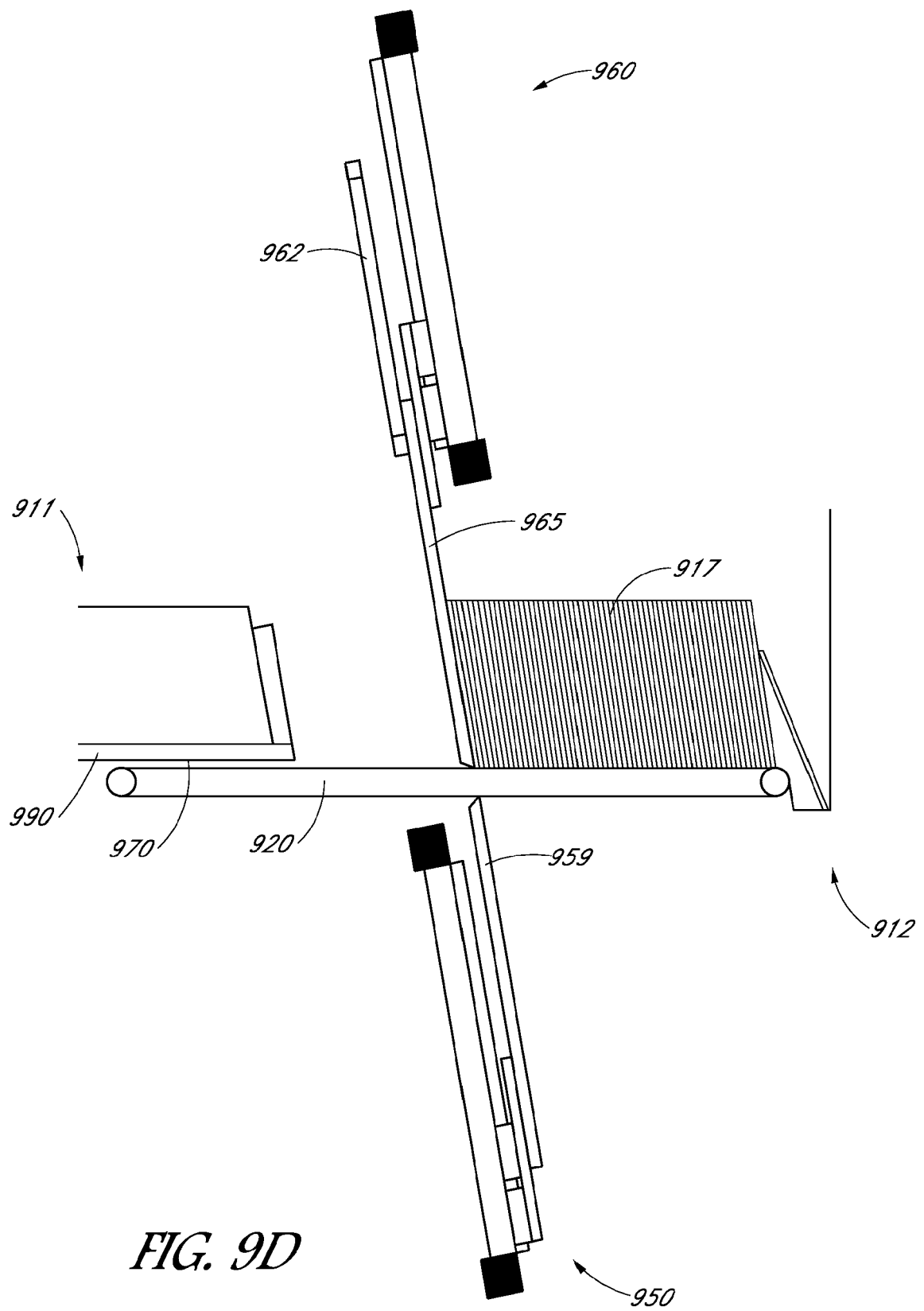


FIG. 9B





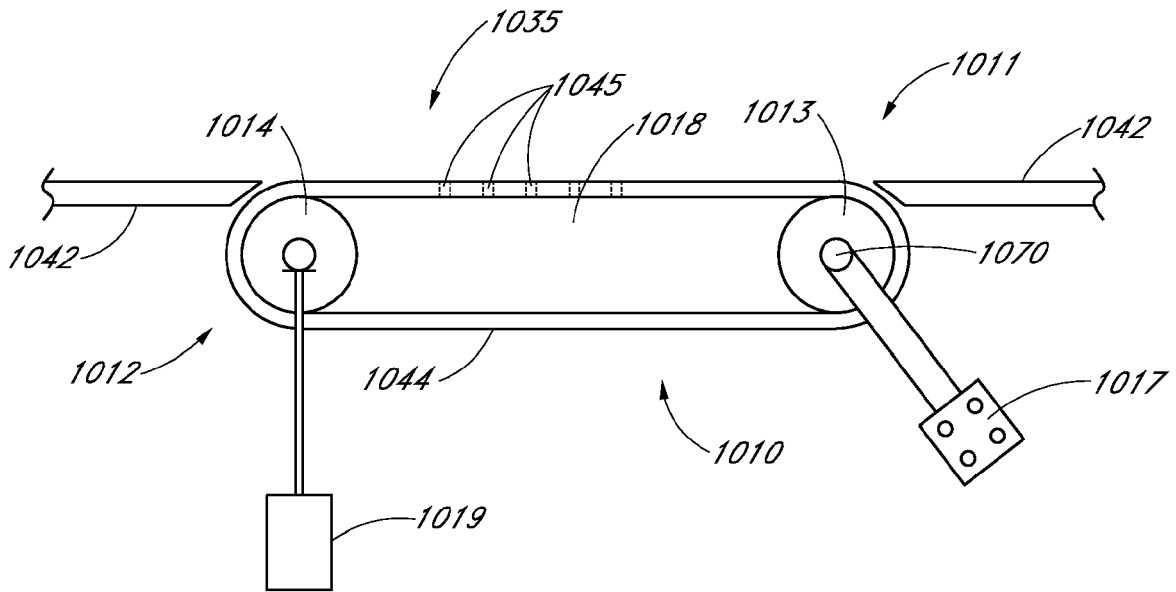


FIG. 10A

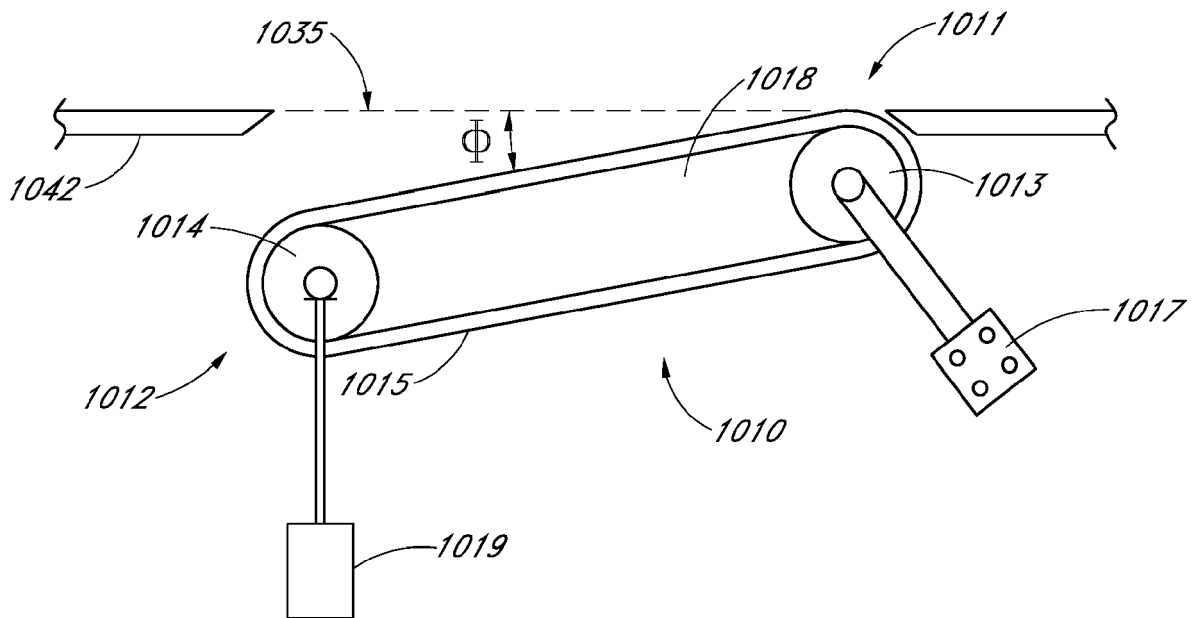


FIG. 10B

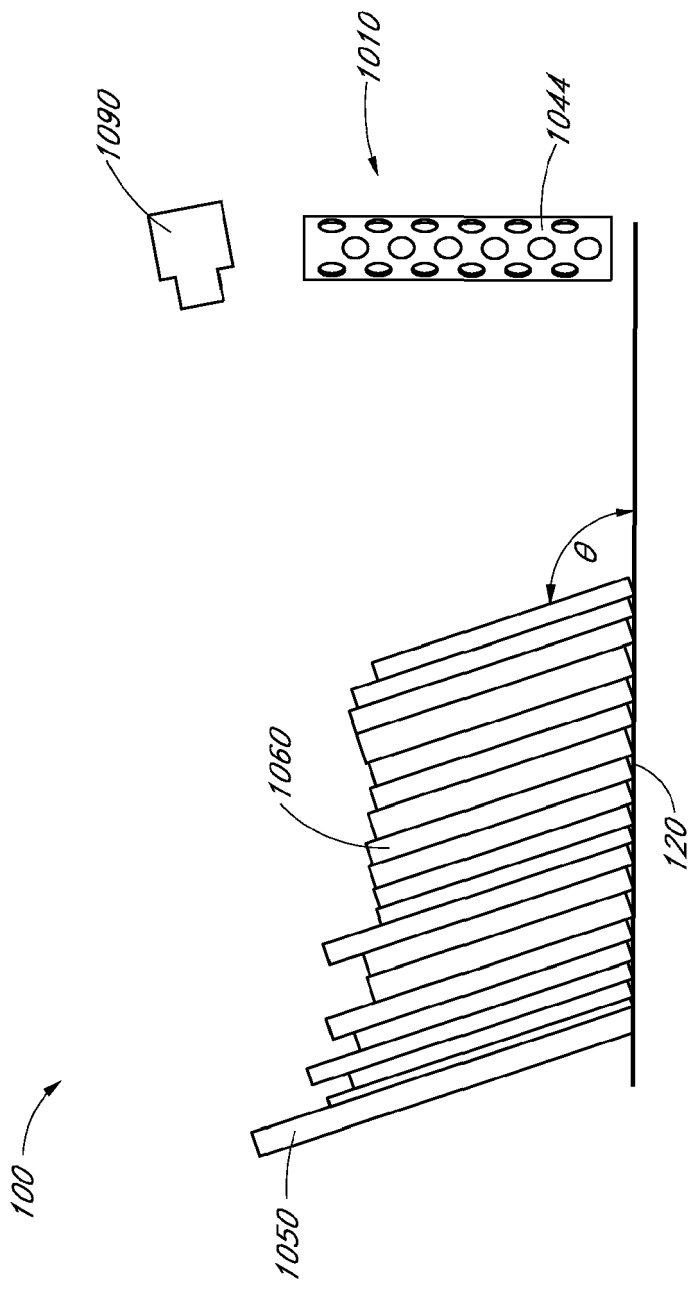


FIG. 11

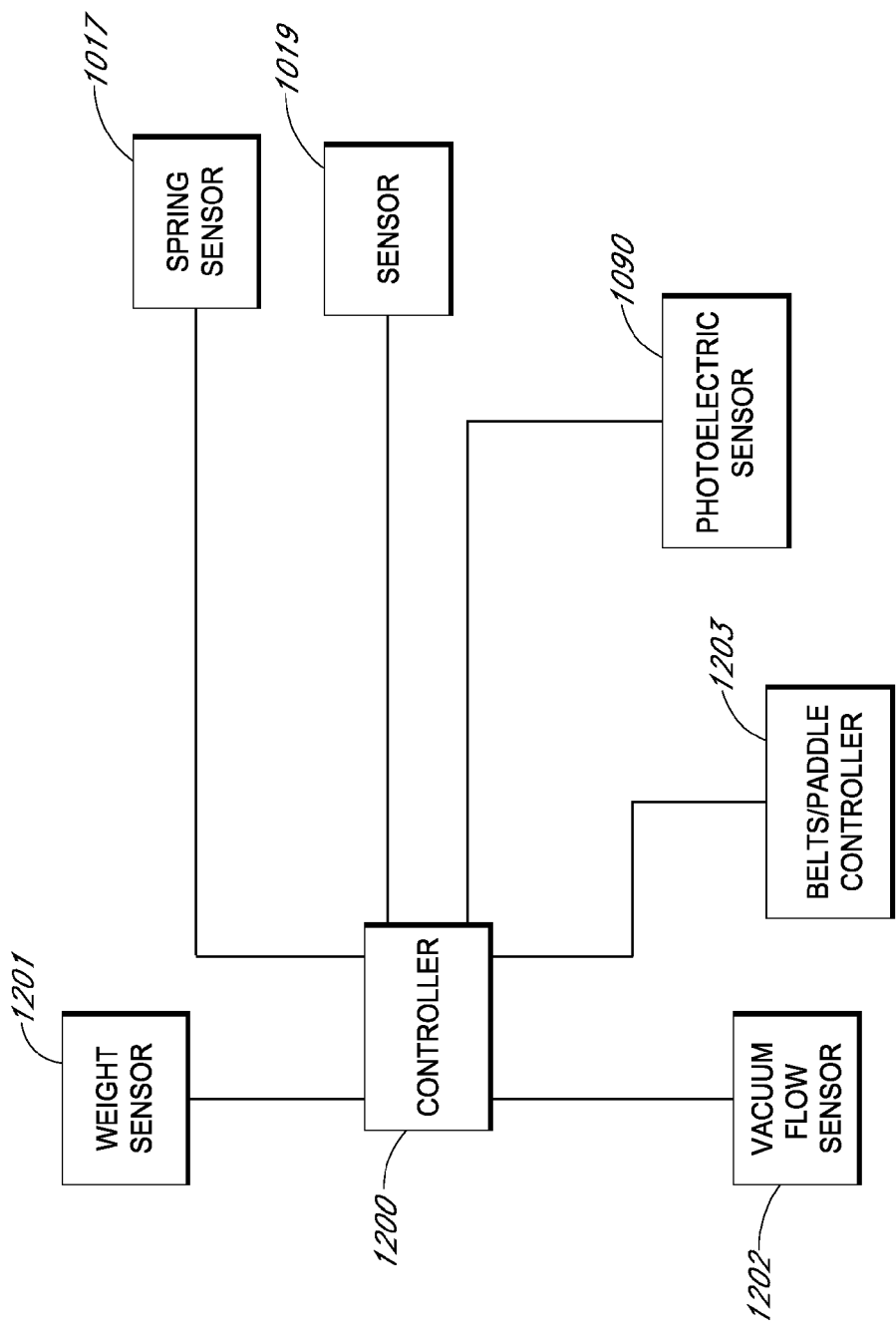


FIG. 12

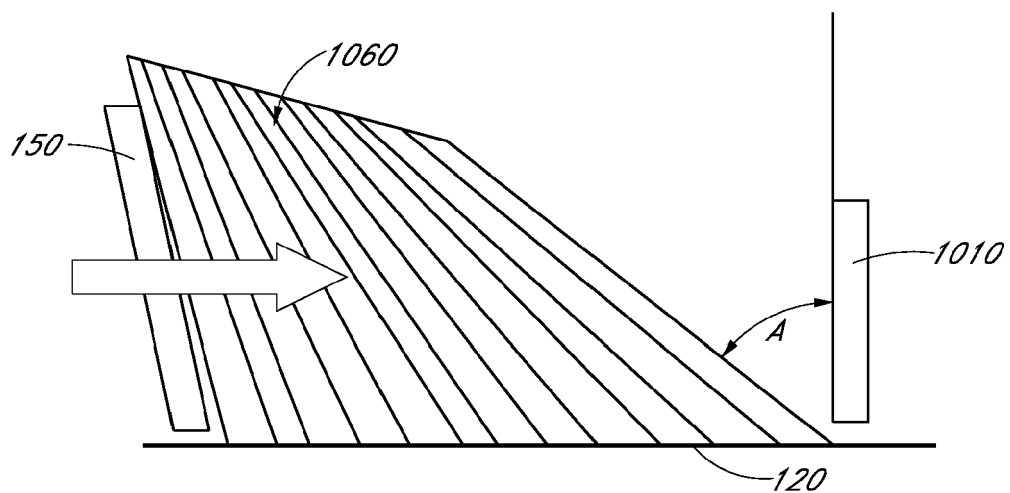


FIG. 13A

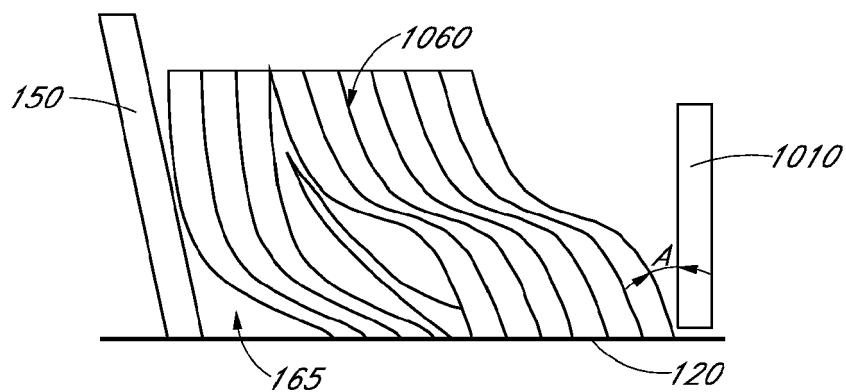


FIG. 13B

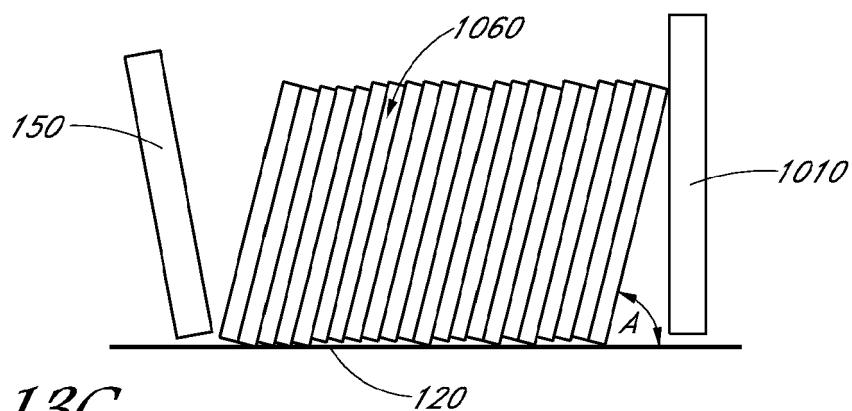


FIG. 13C

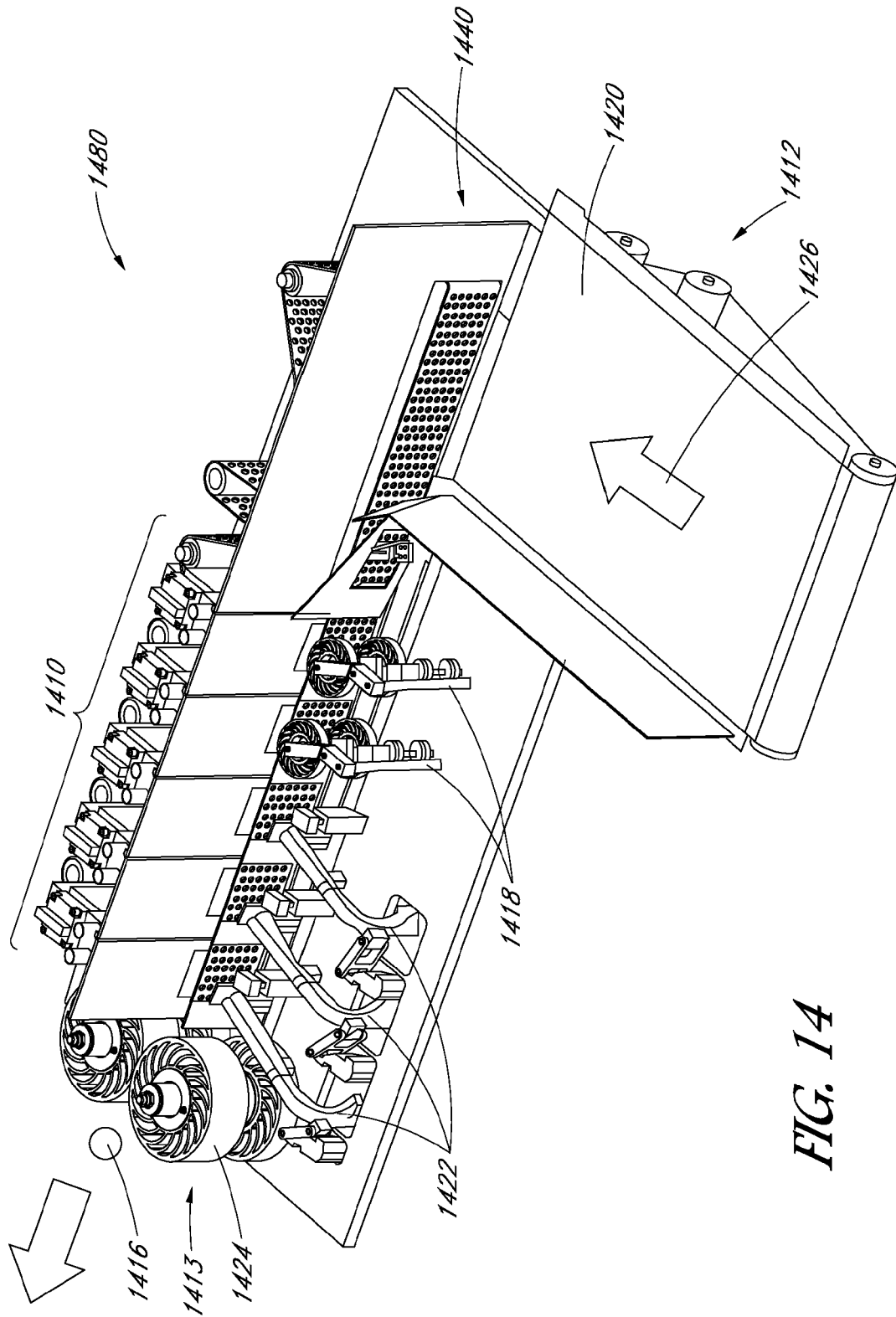


FIG. 14

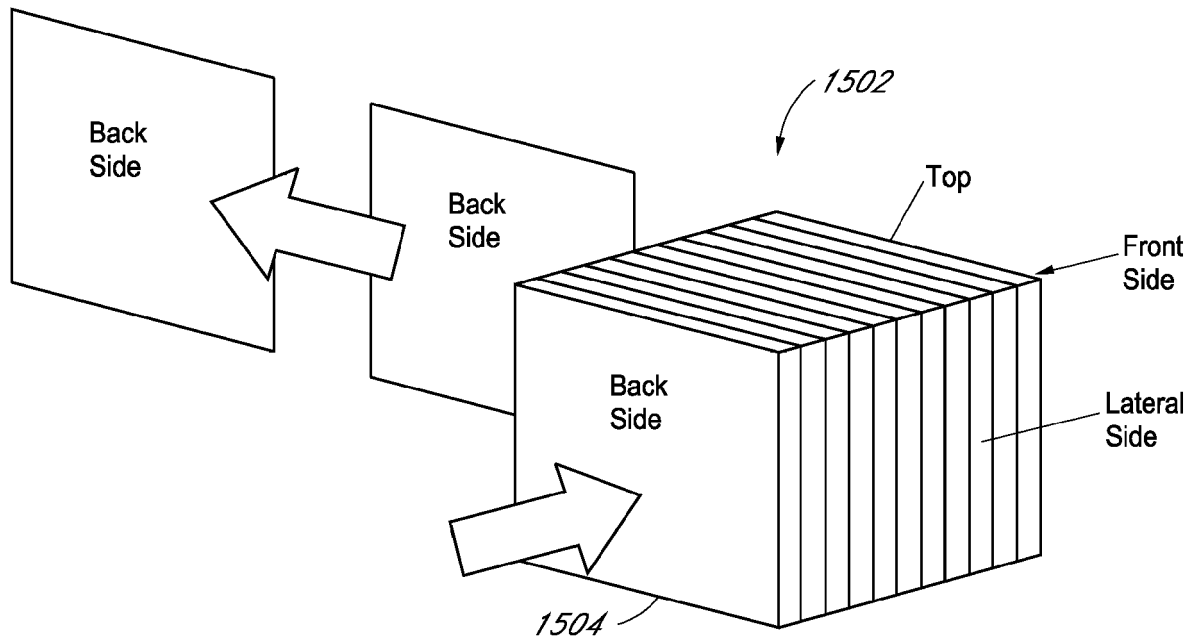


FIG. 15

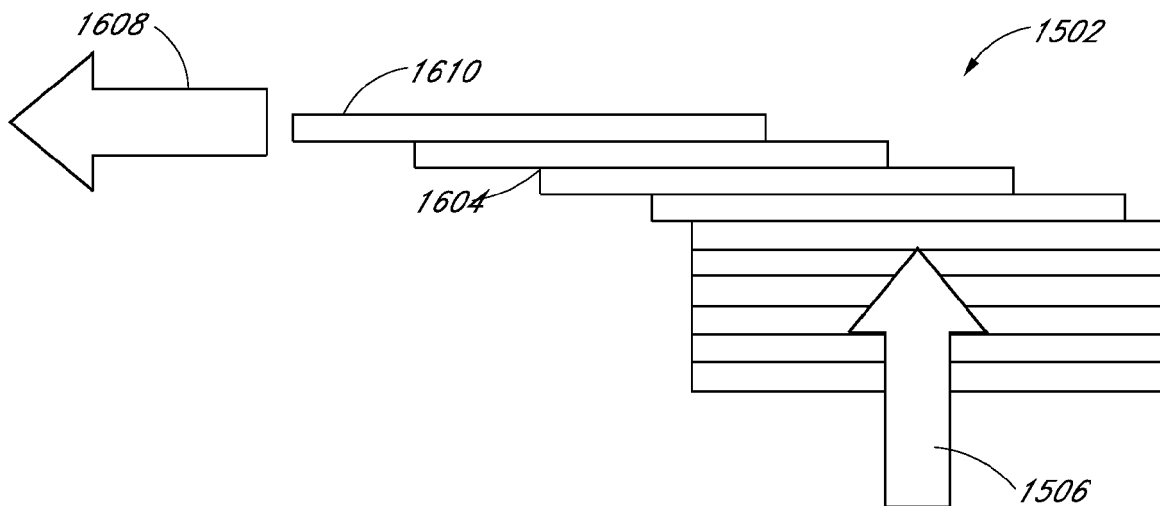
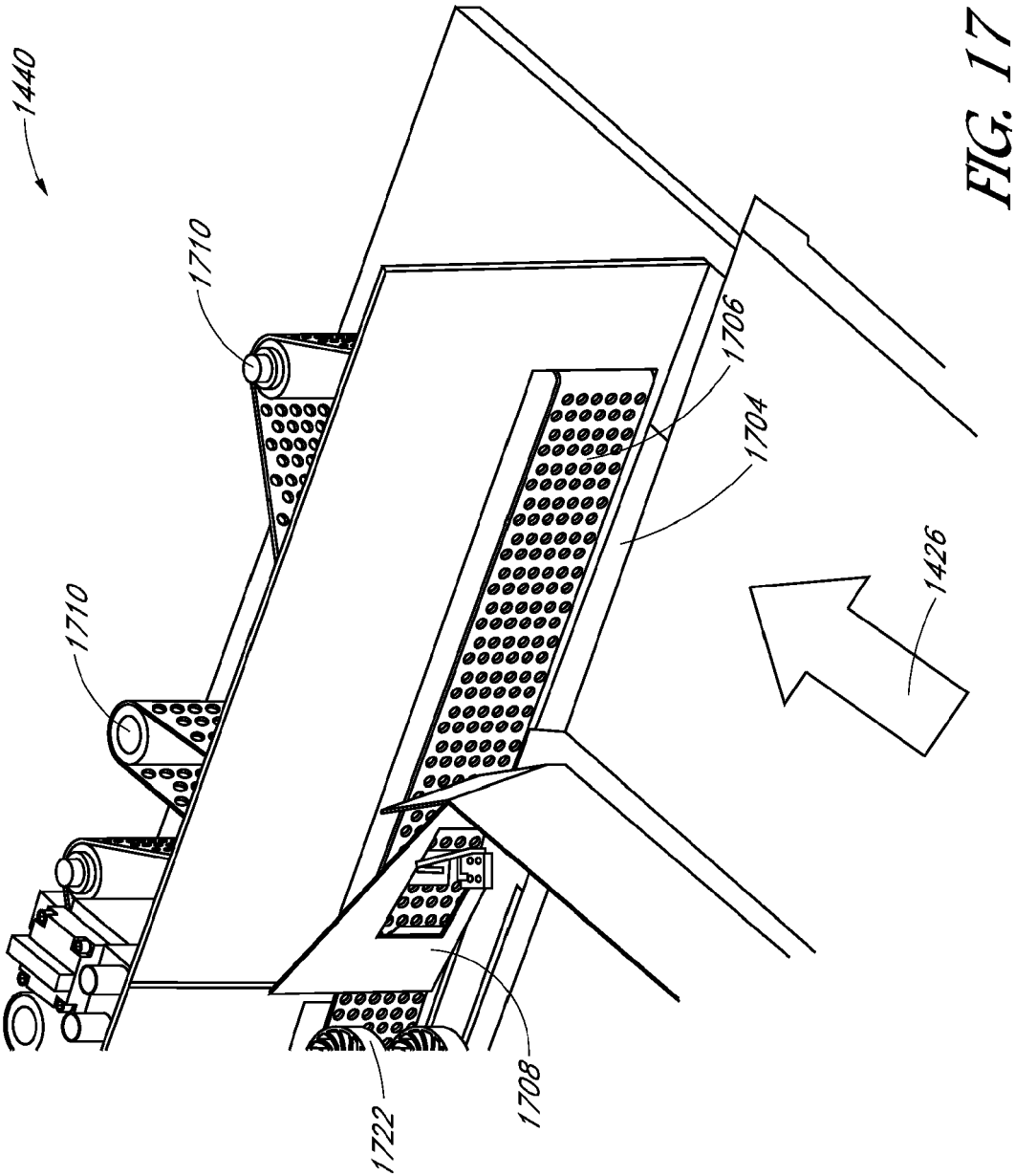
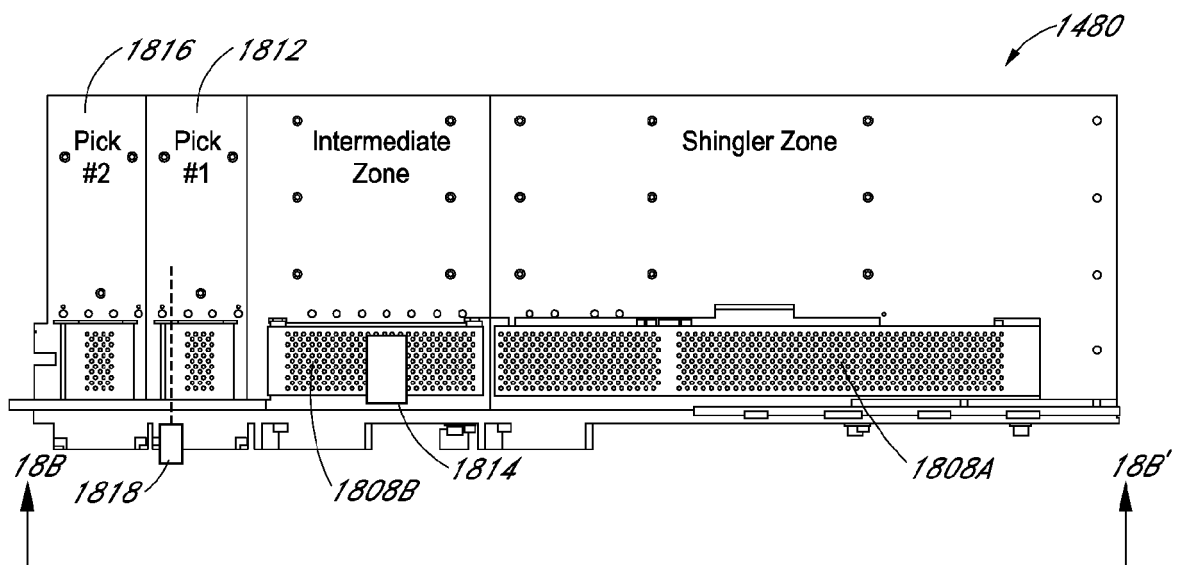
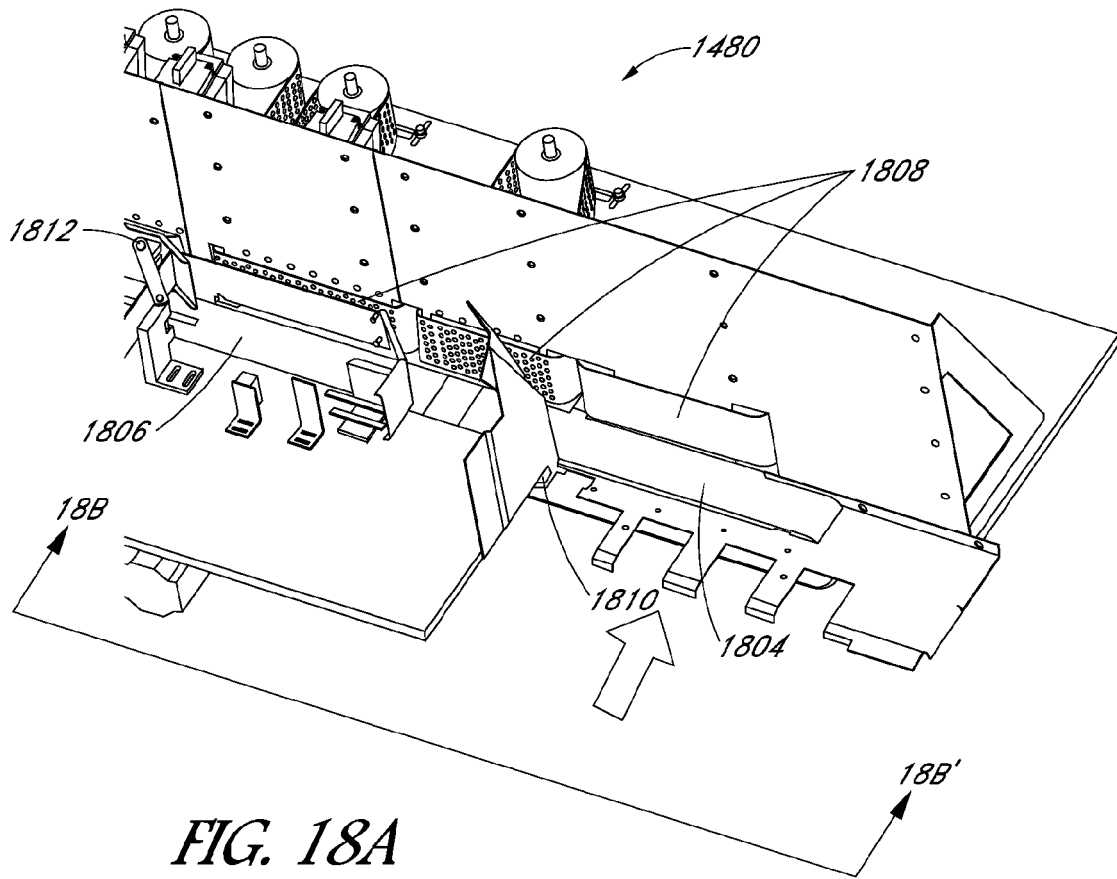


FIG. 16





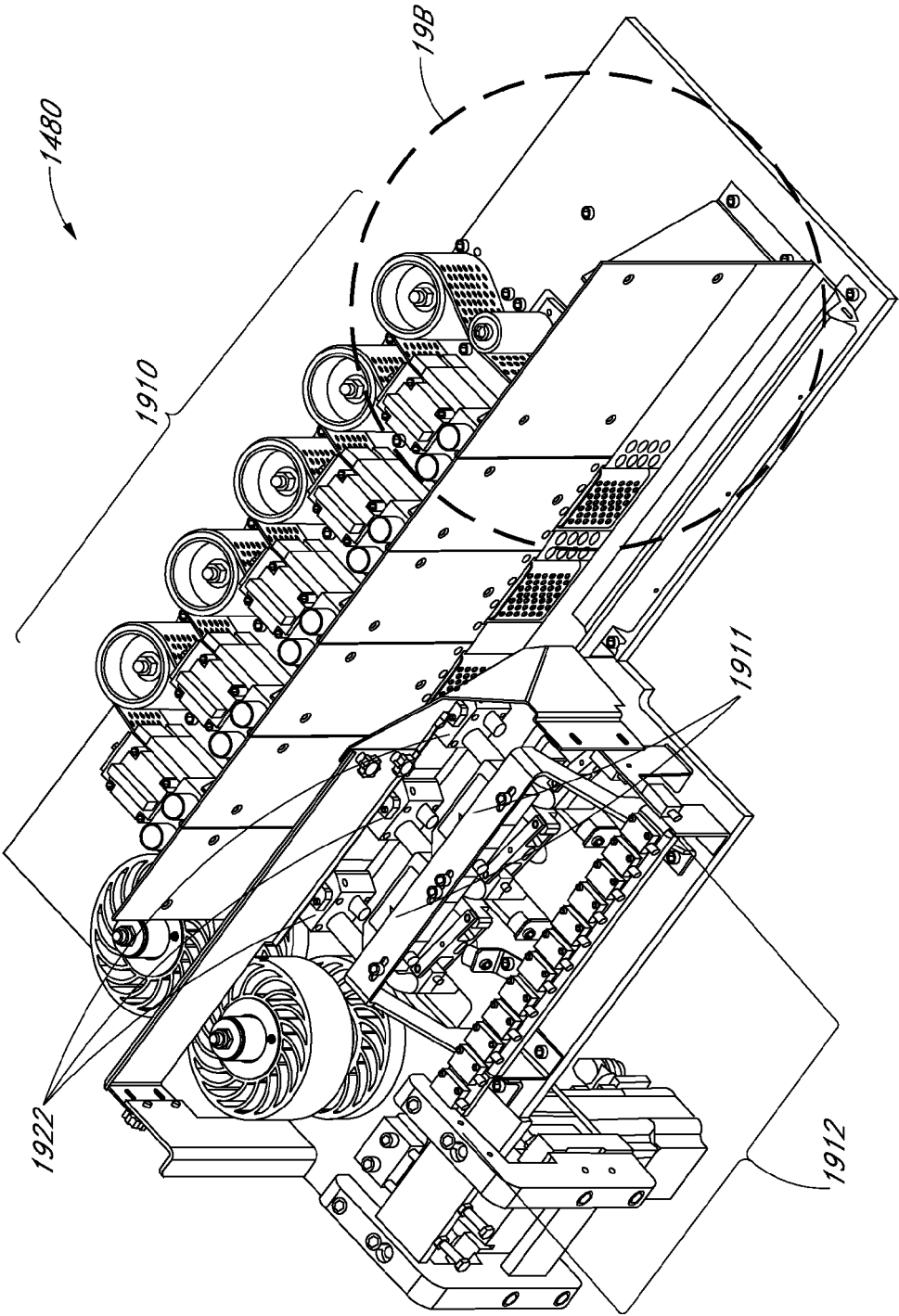


FIG. 19A

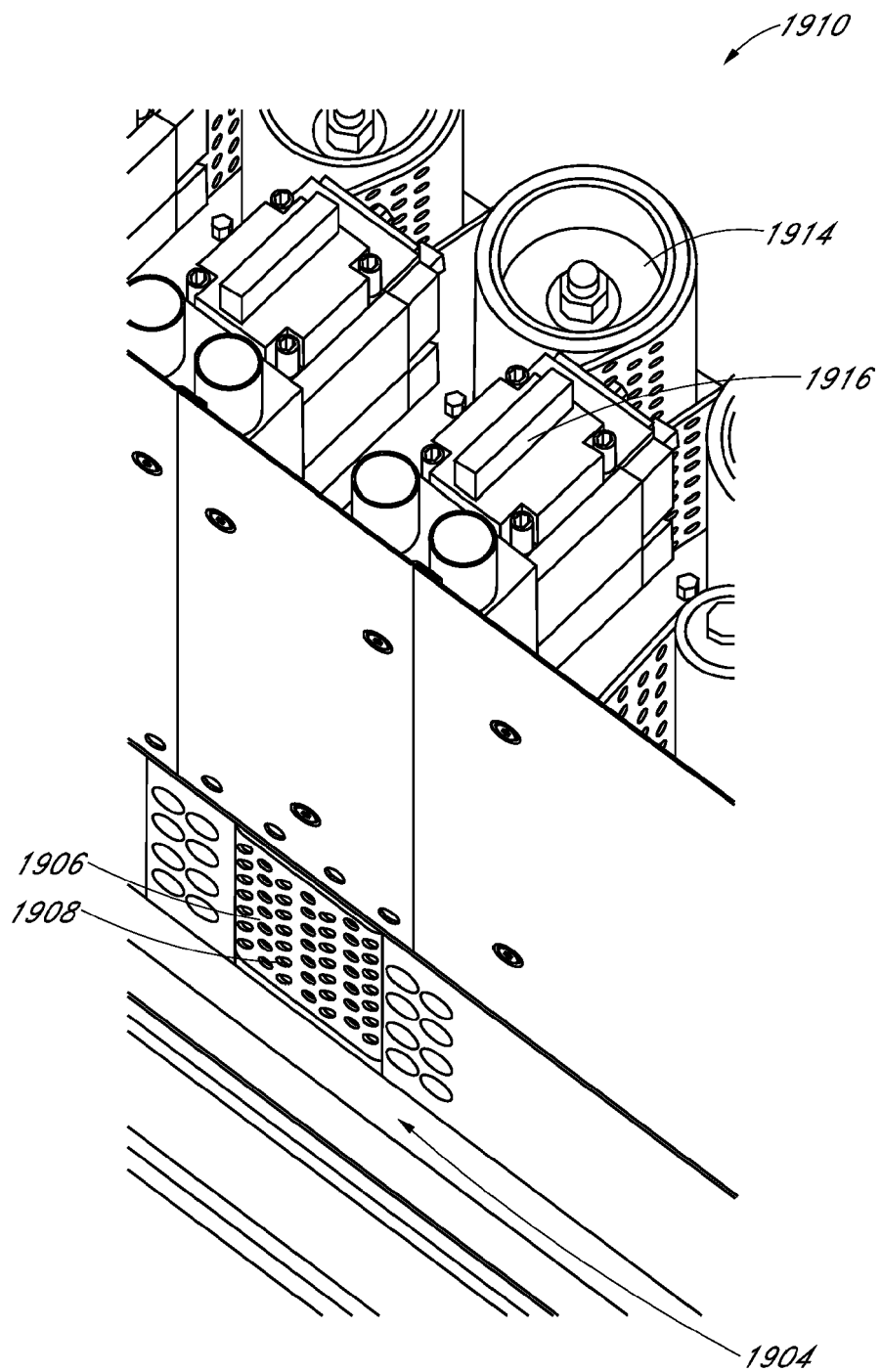


FIG. 19B

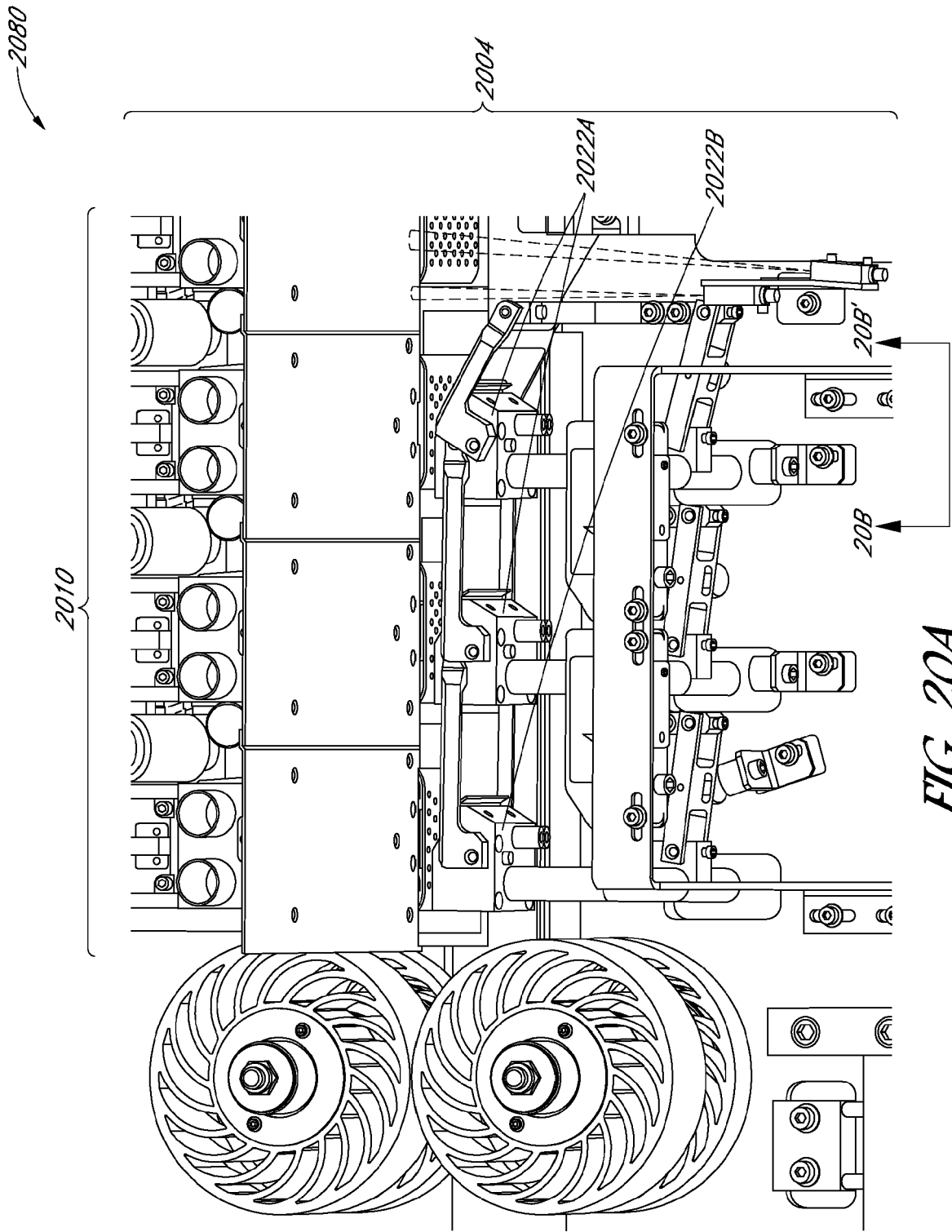


FIG. 20A

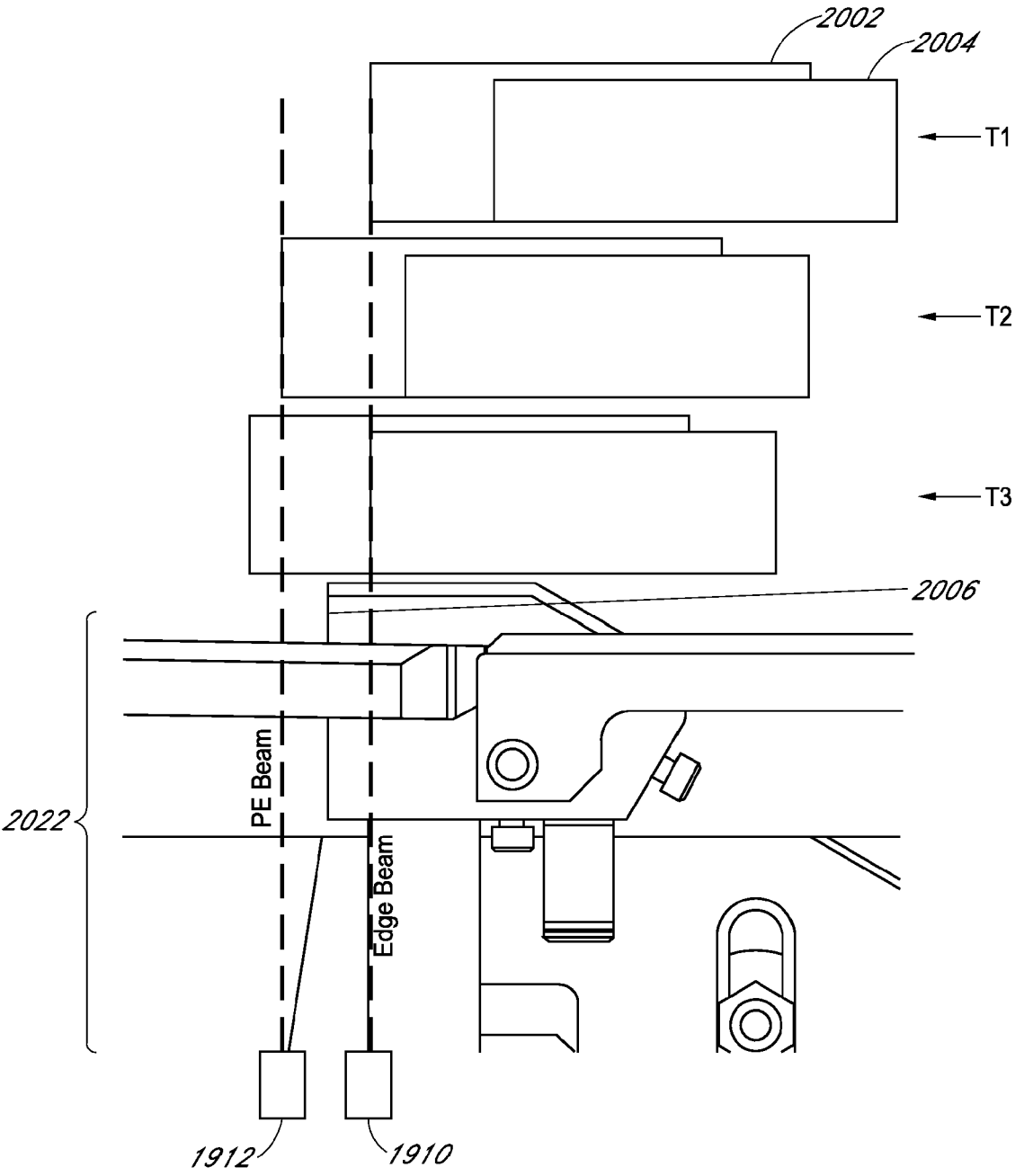
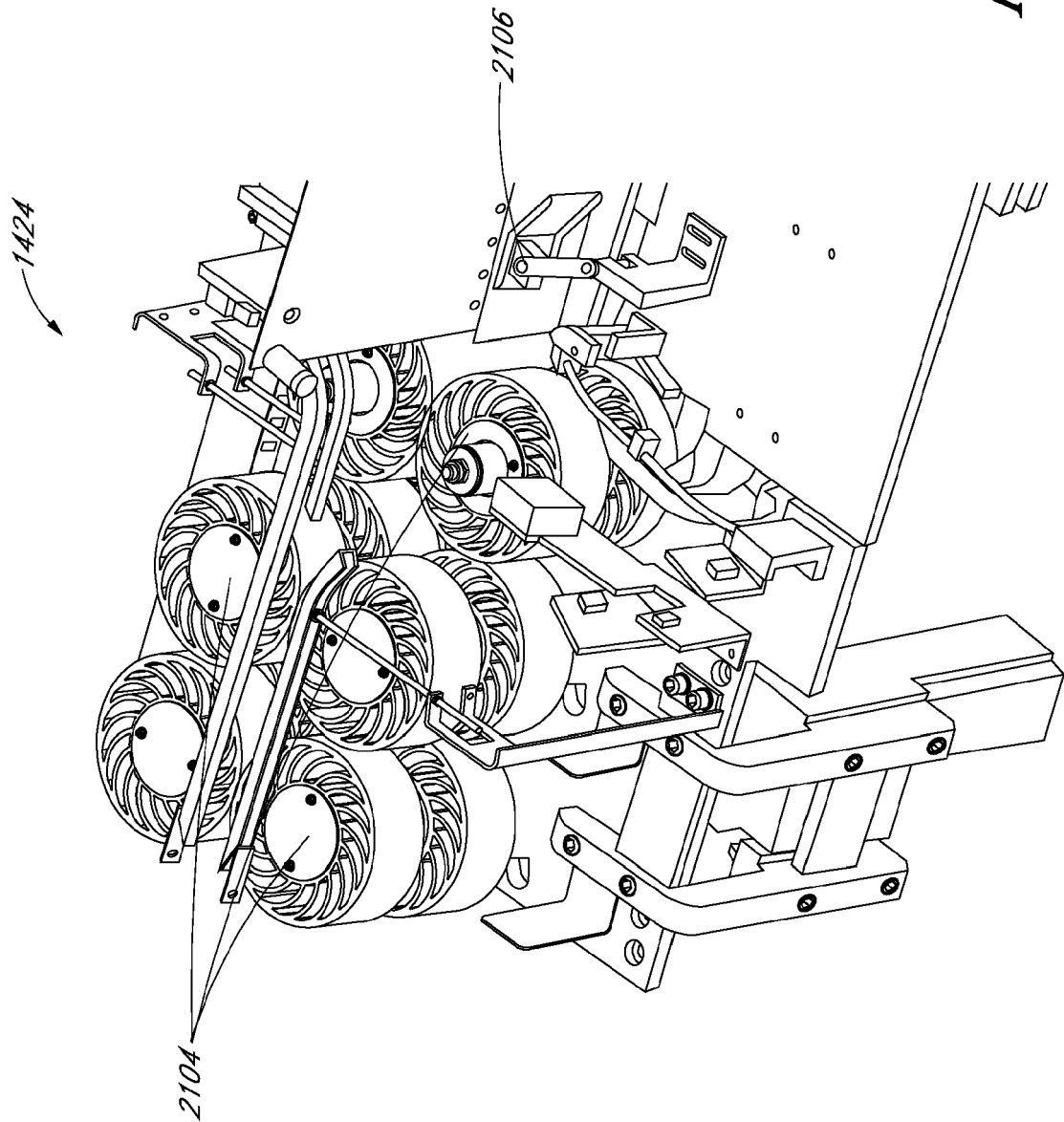


FIG. 20B

FIG. 21



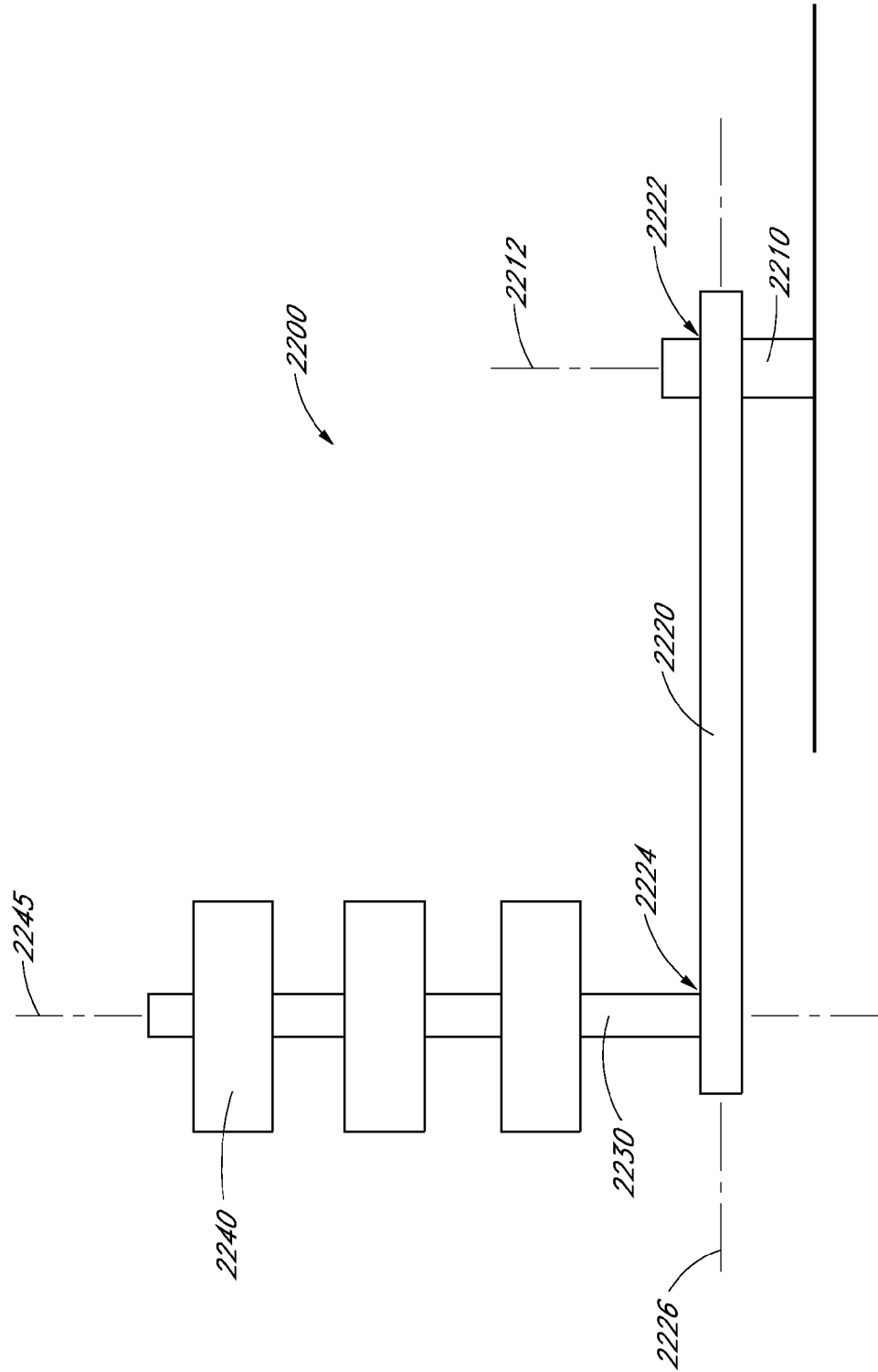


FIG. 22

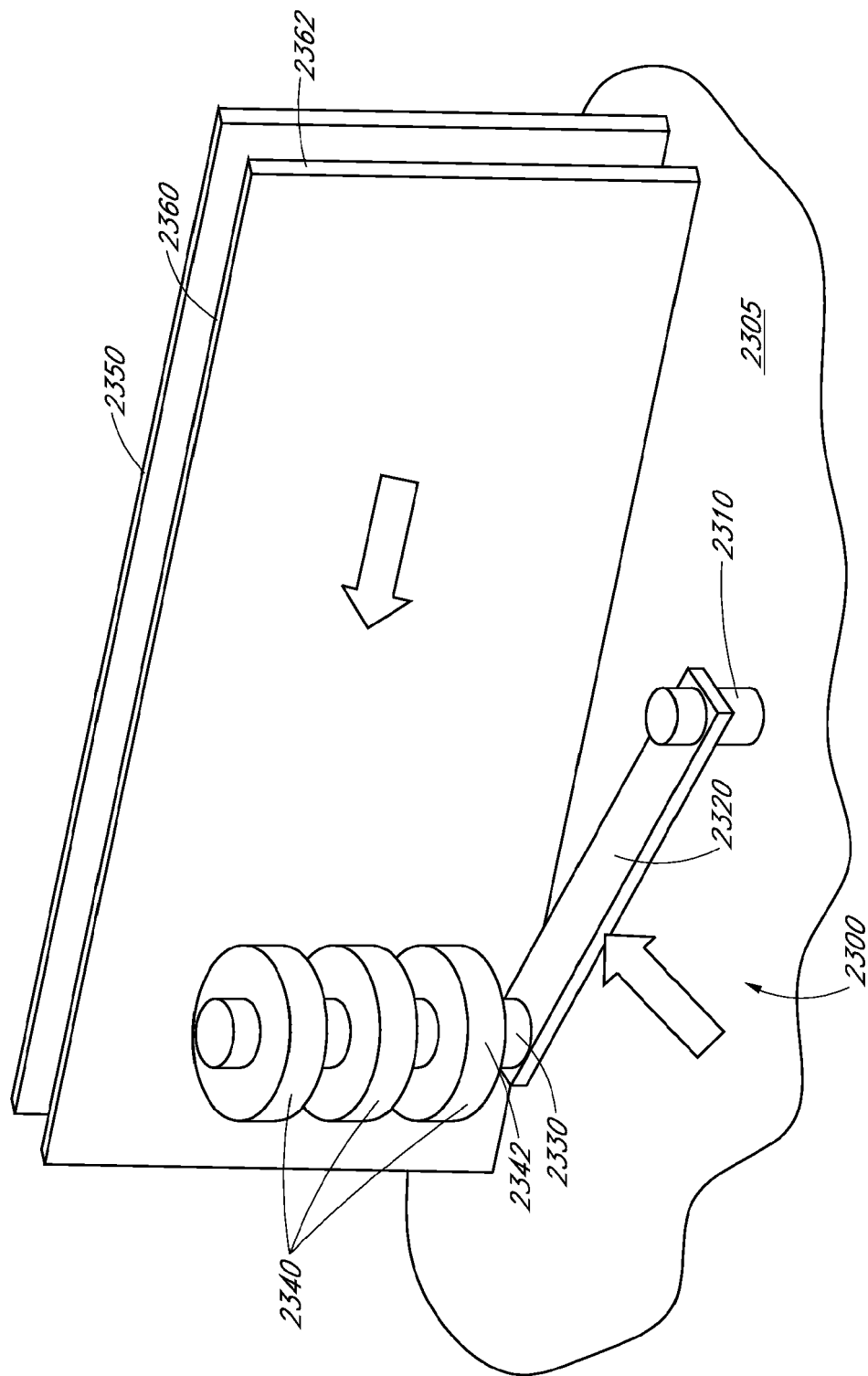


FIG. 23

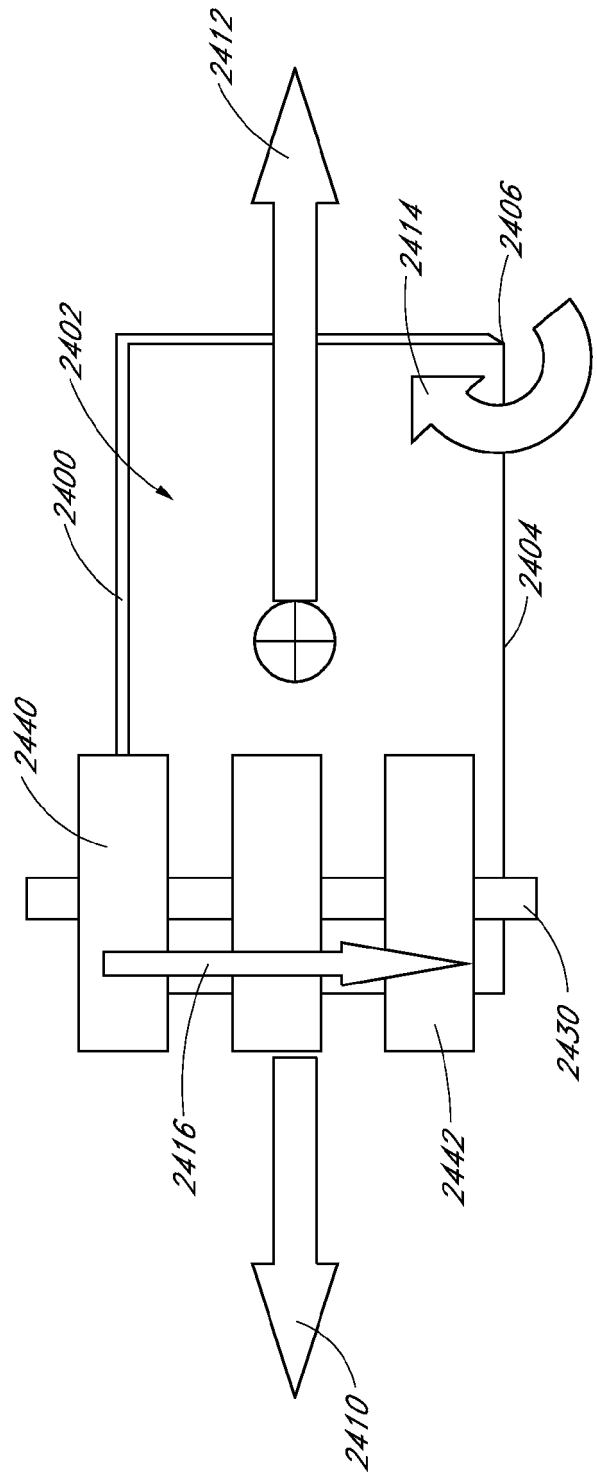


FIG. 24

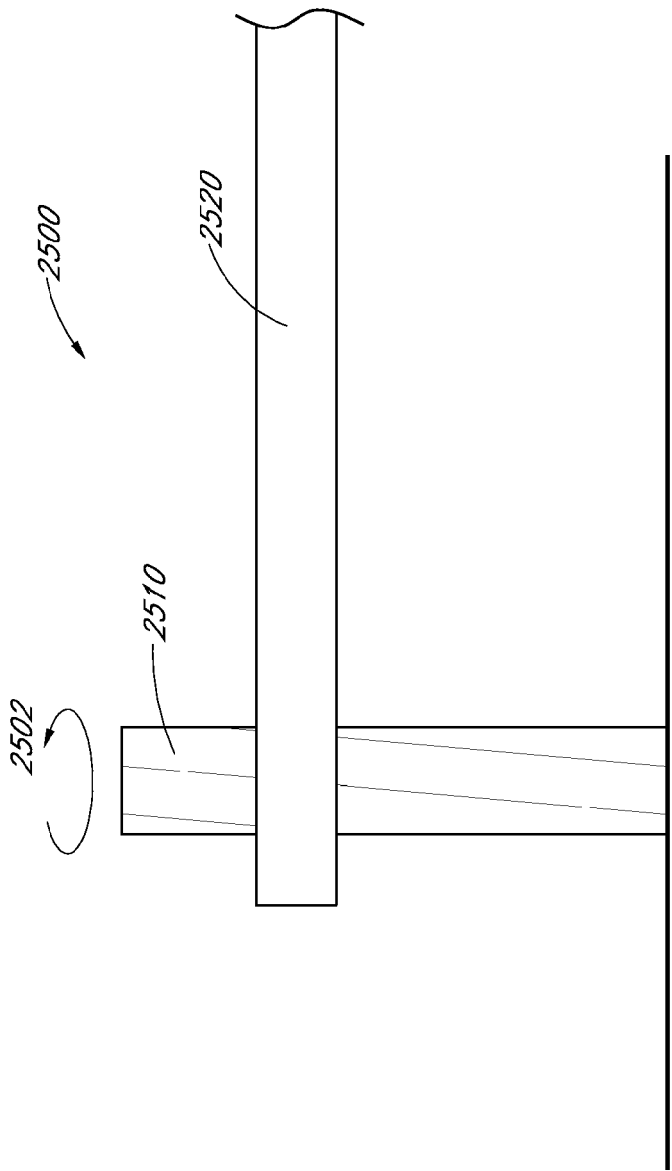


FIG. 25

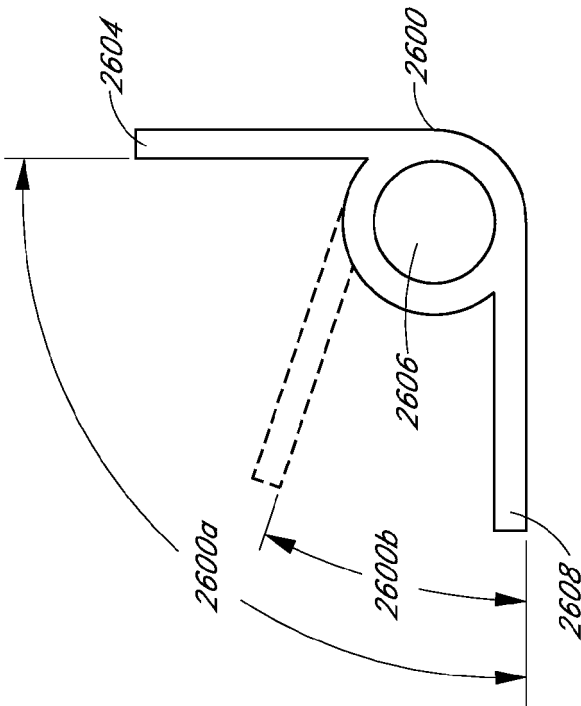


FIG. 26A

FIG. 26B

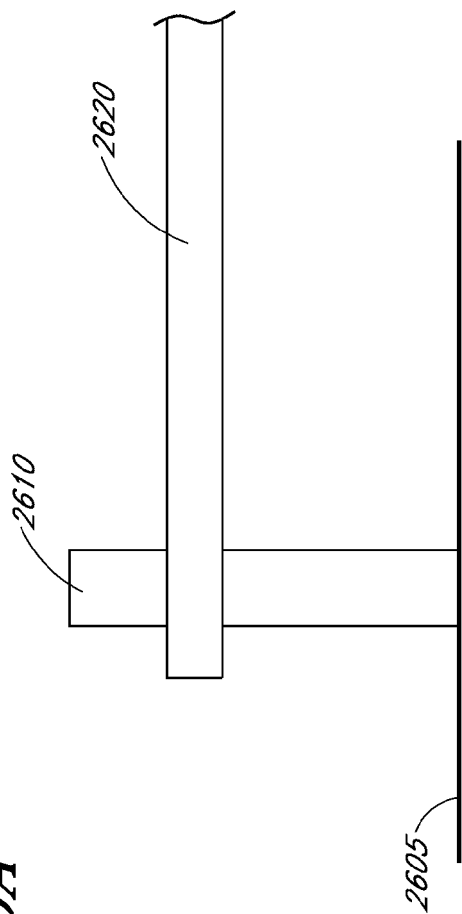
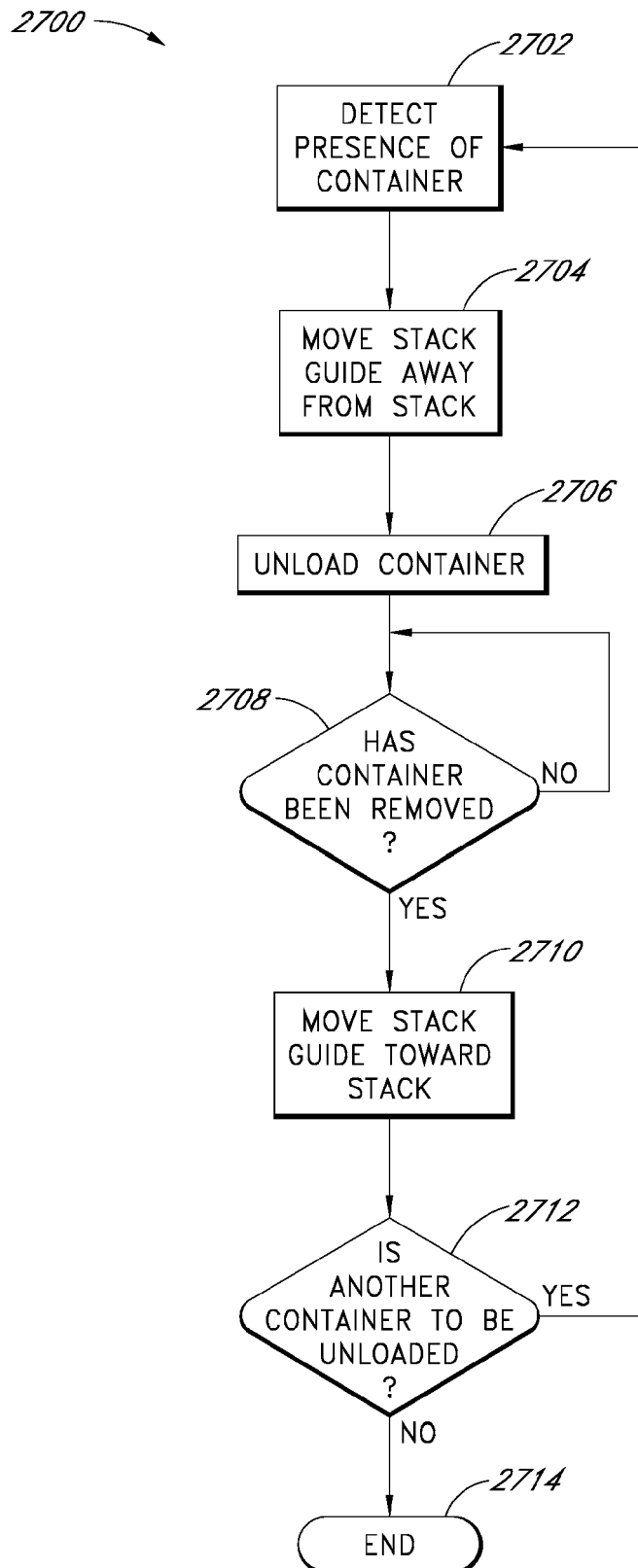
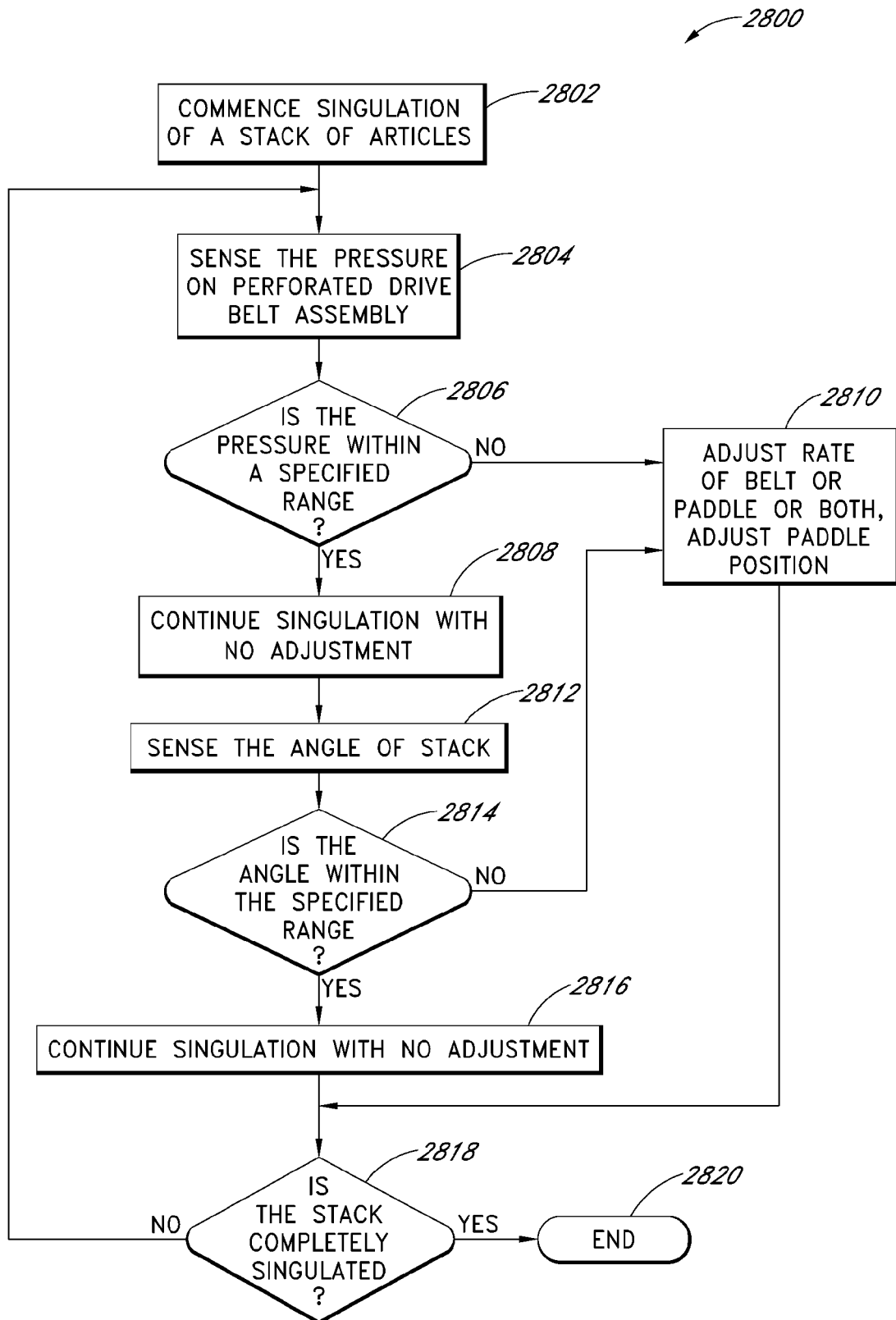


FIG. 26C

*FIG. 27*

*FIG. 28*

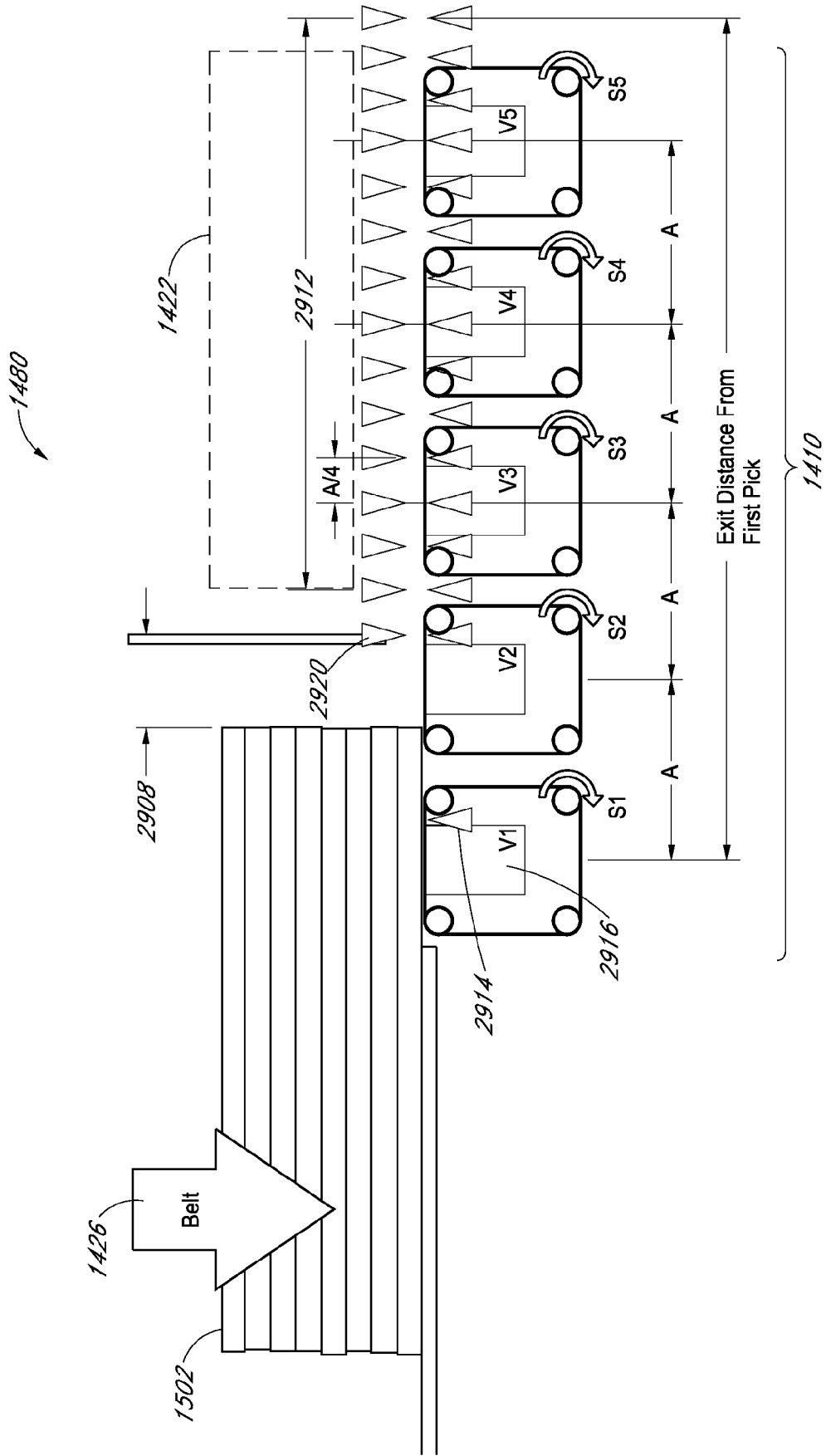


FIG. 29A

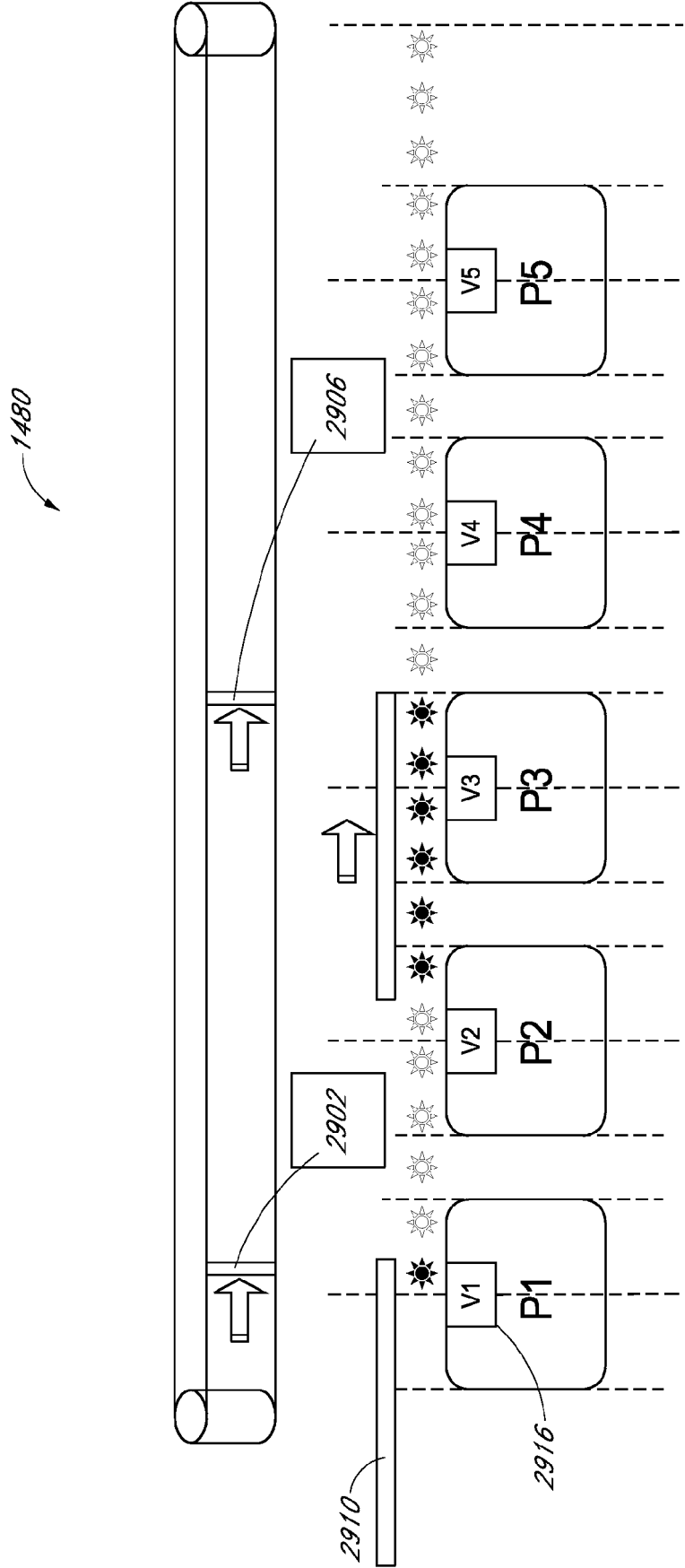


FIG. 29B

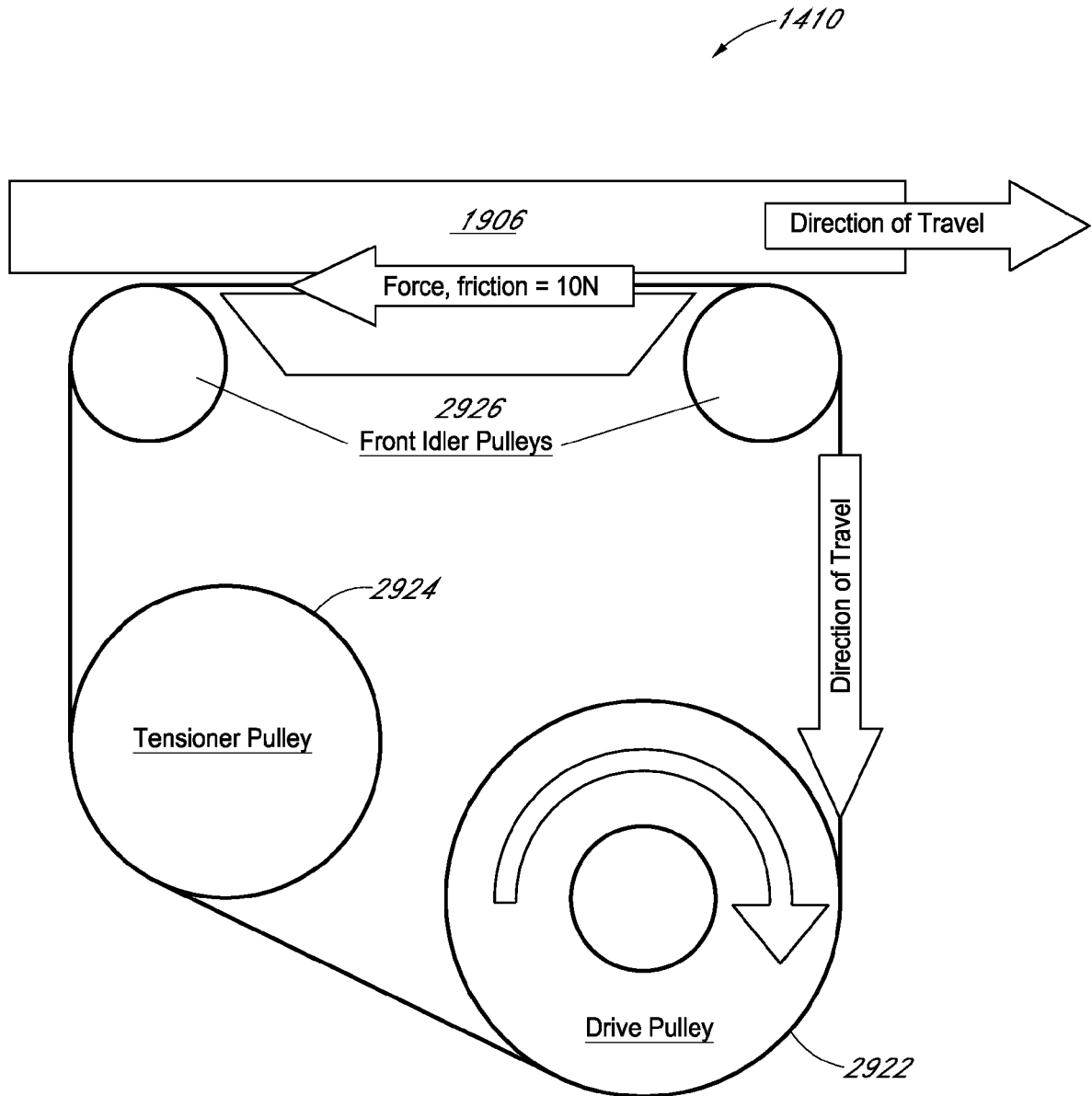


FIG. 29C

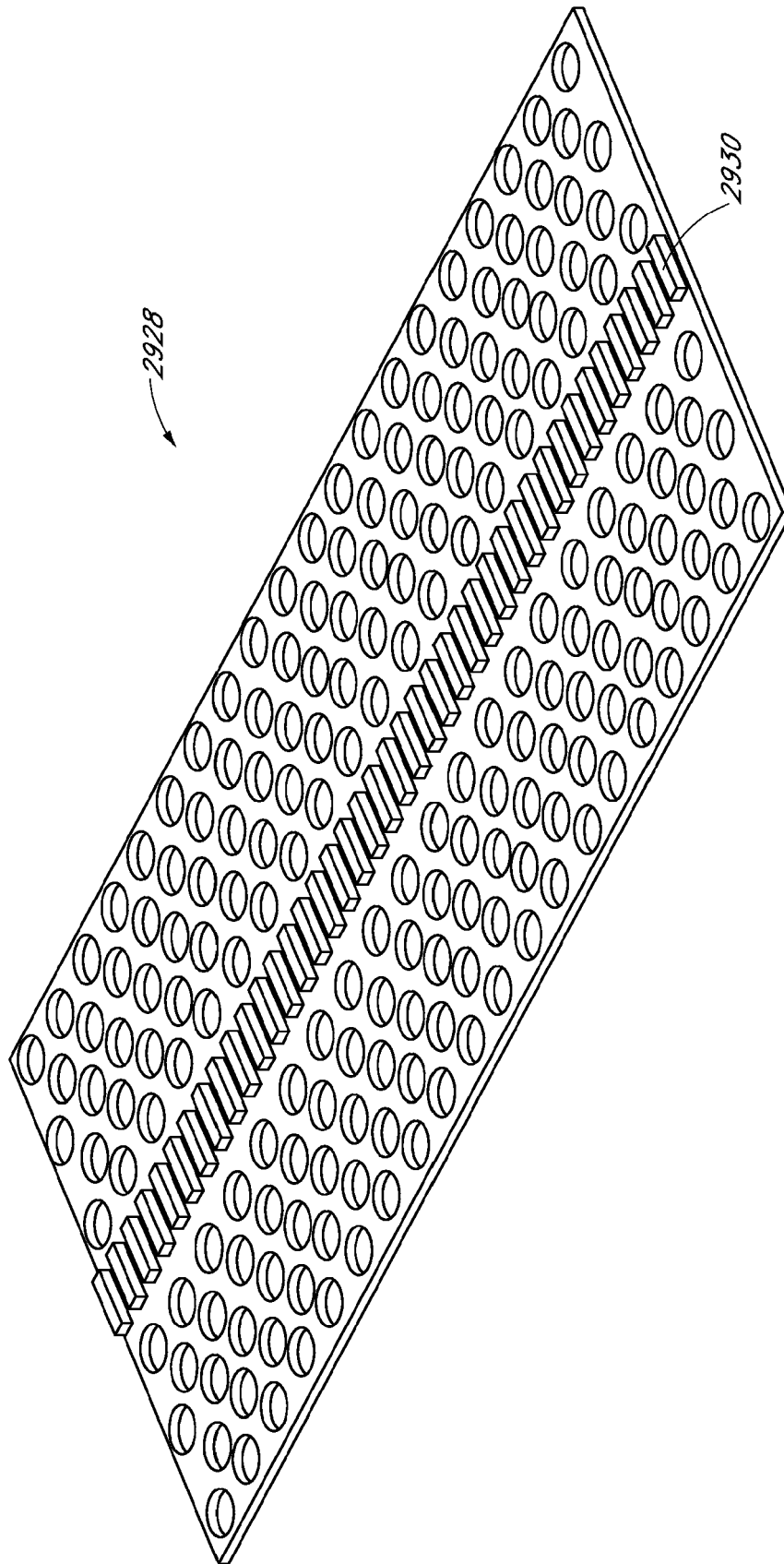


FIG. 29D

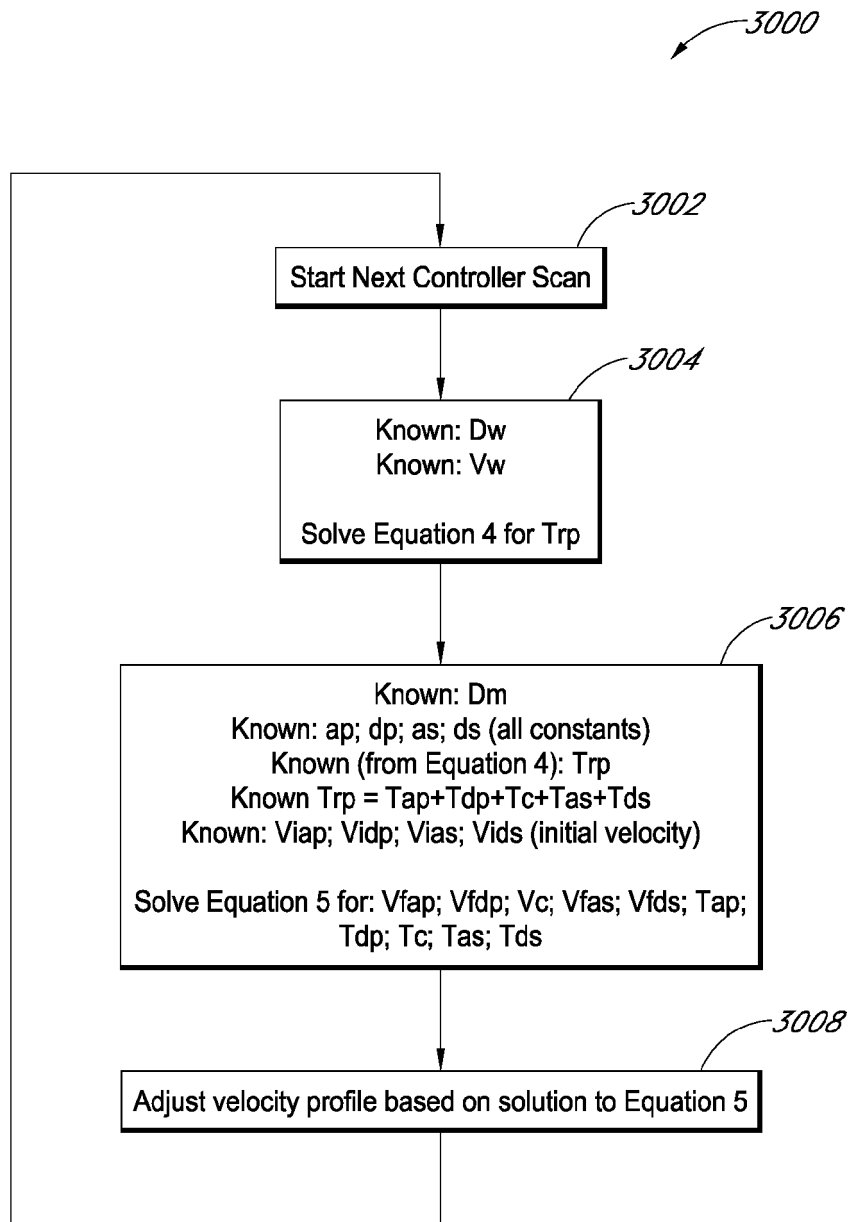


FIG. 30

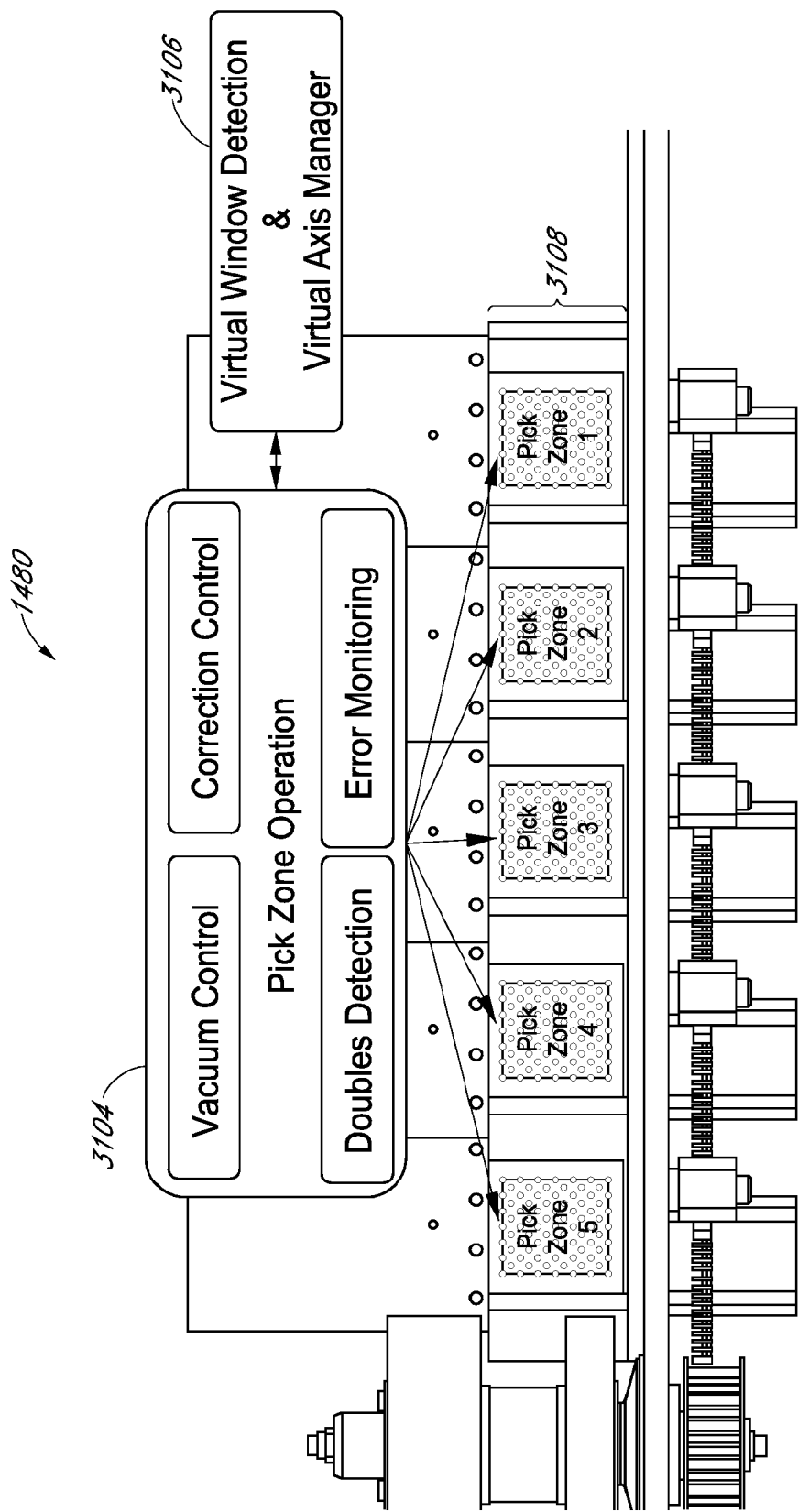


FIG. 31

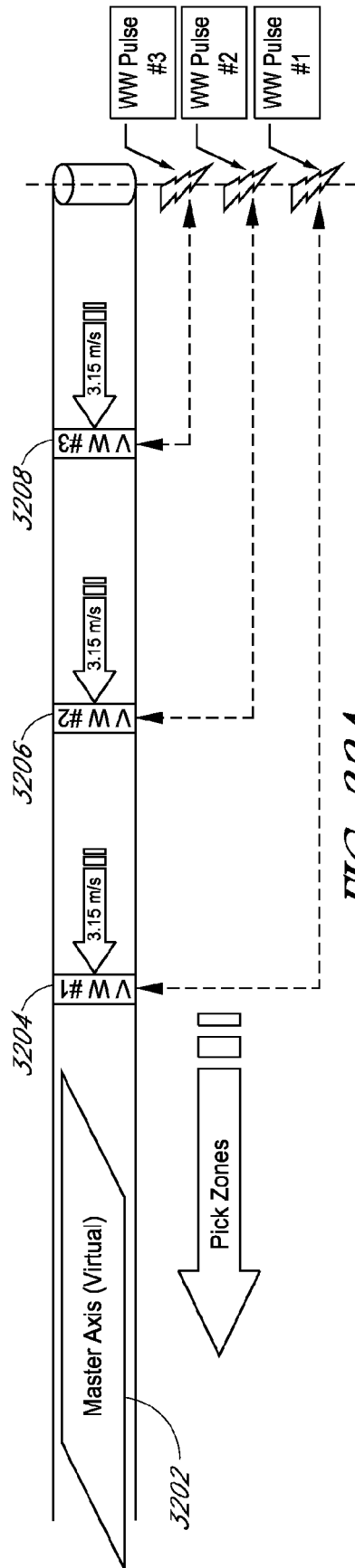


FIG. 32A

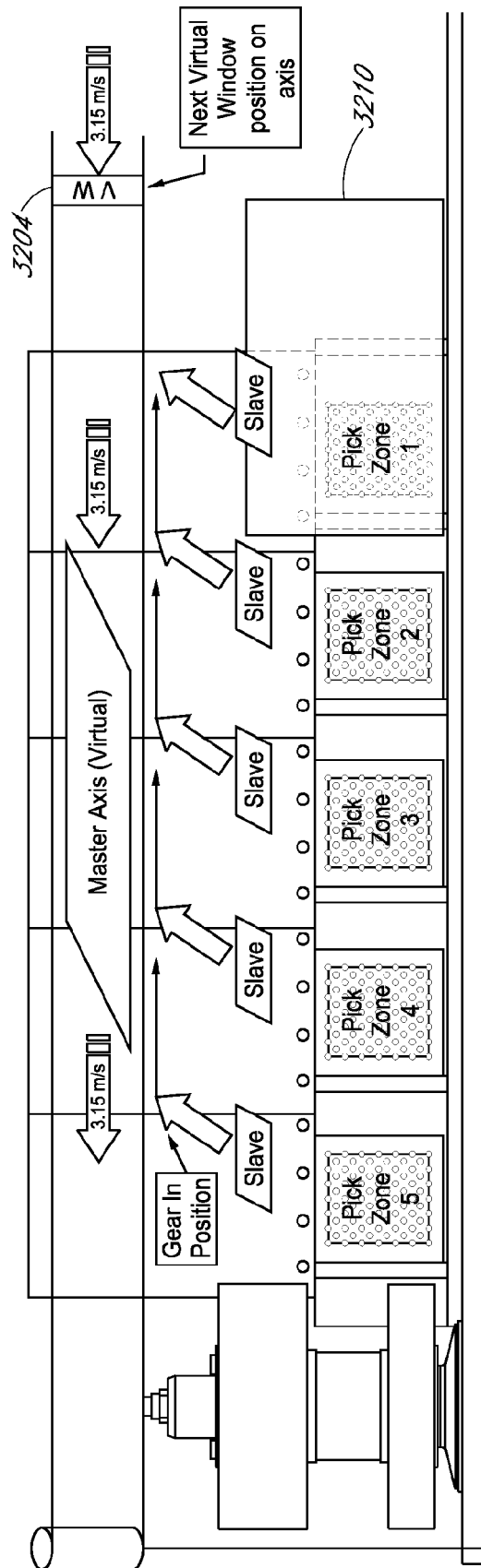


FIG. 32B

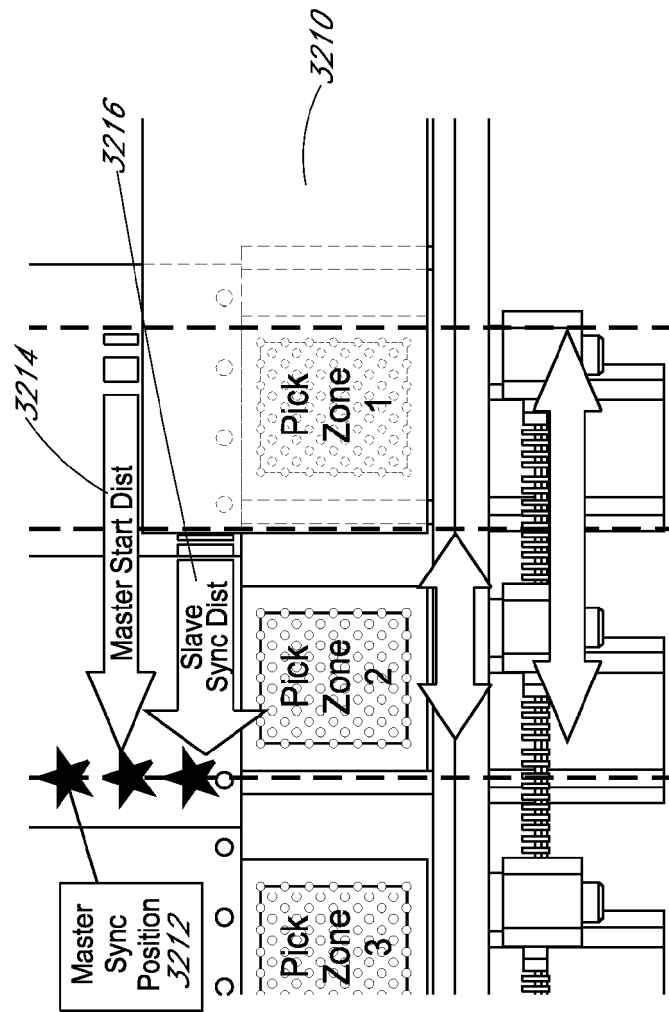


FIG. 32C

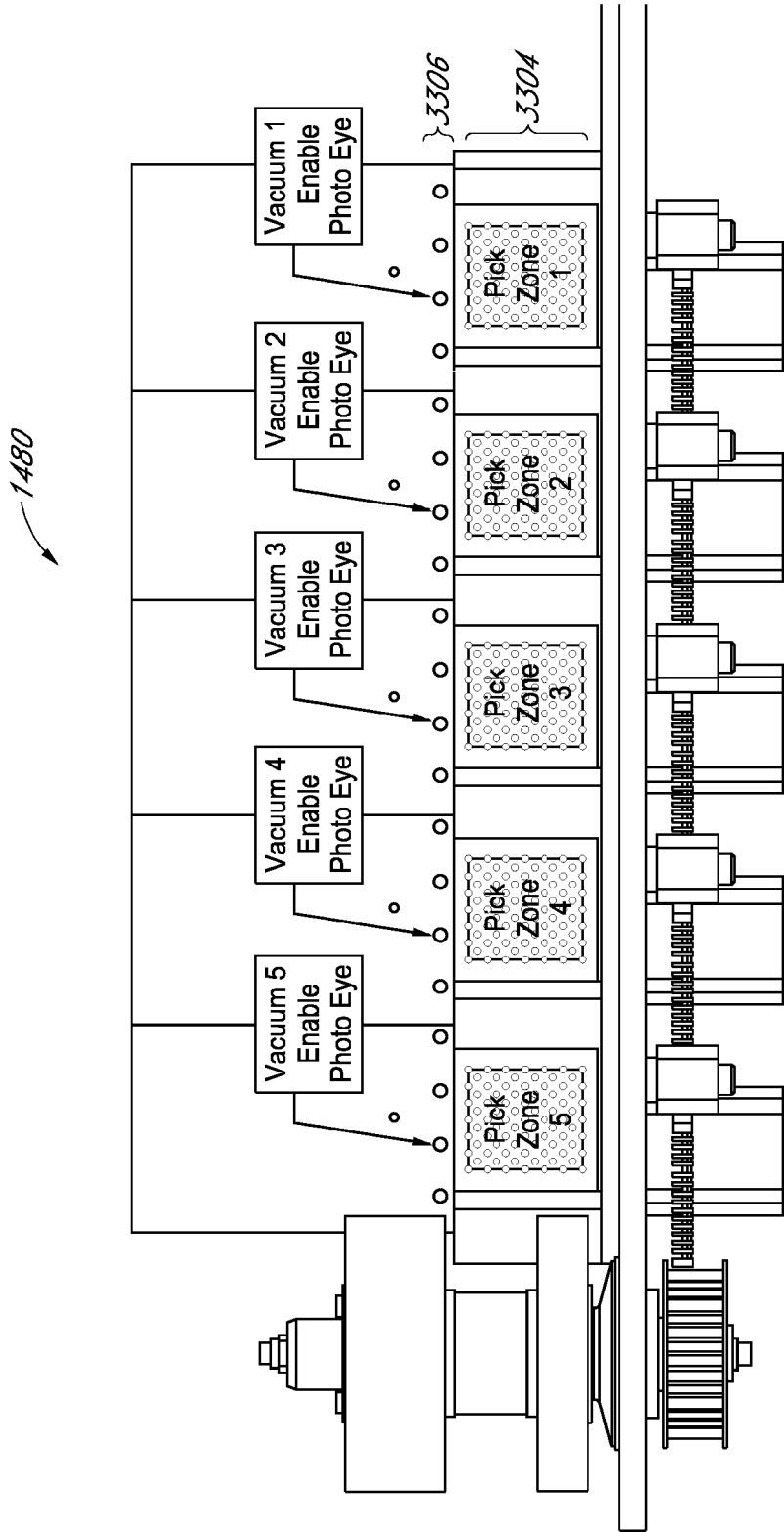


FIG. 33A

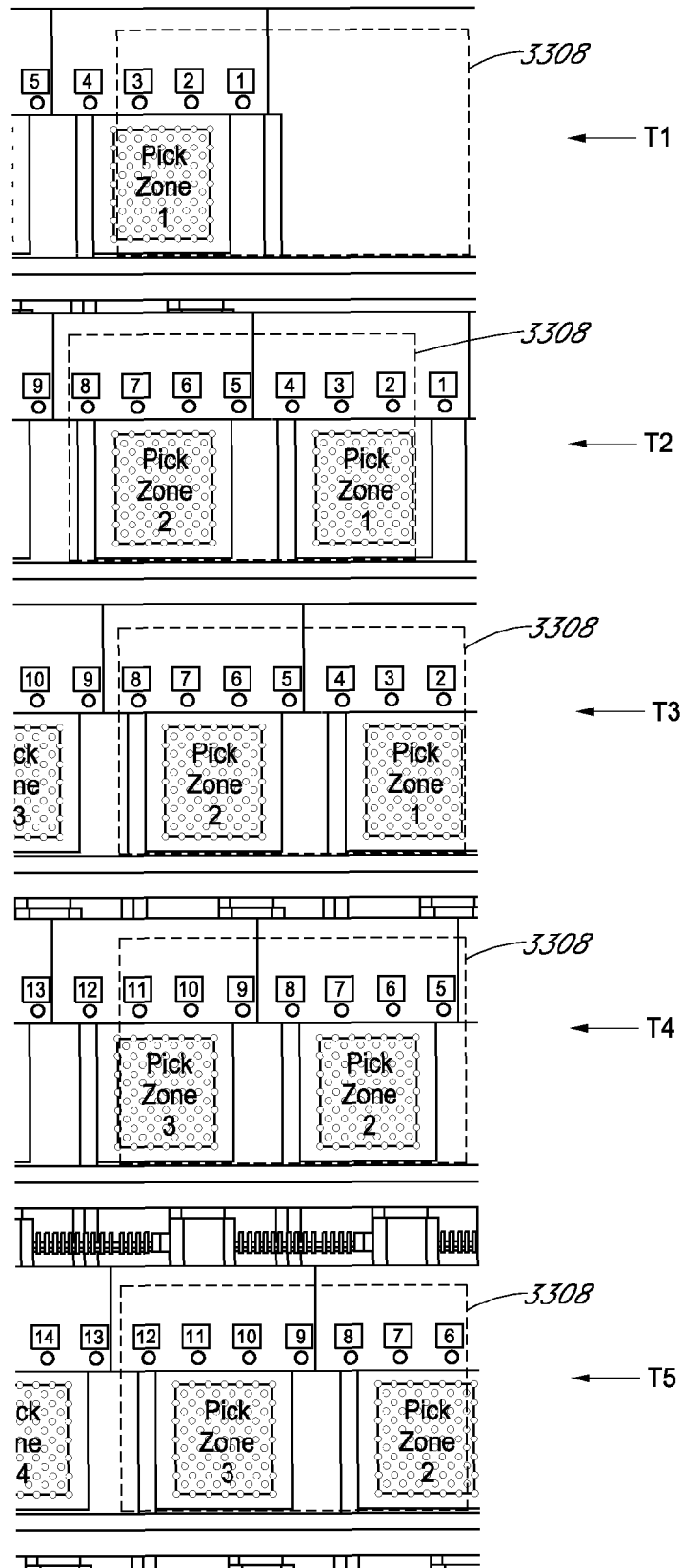


FIG. 33B

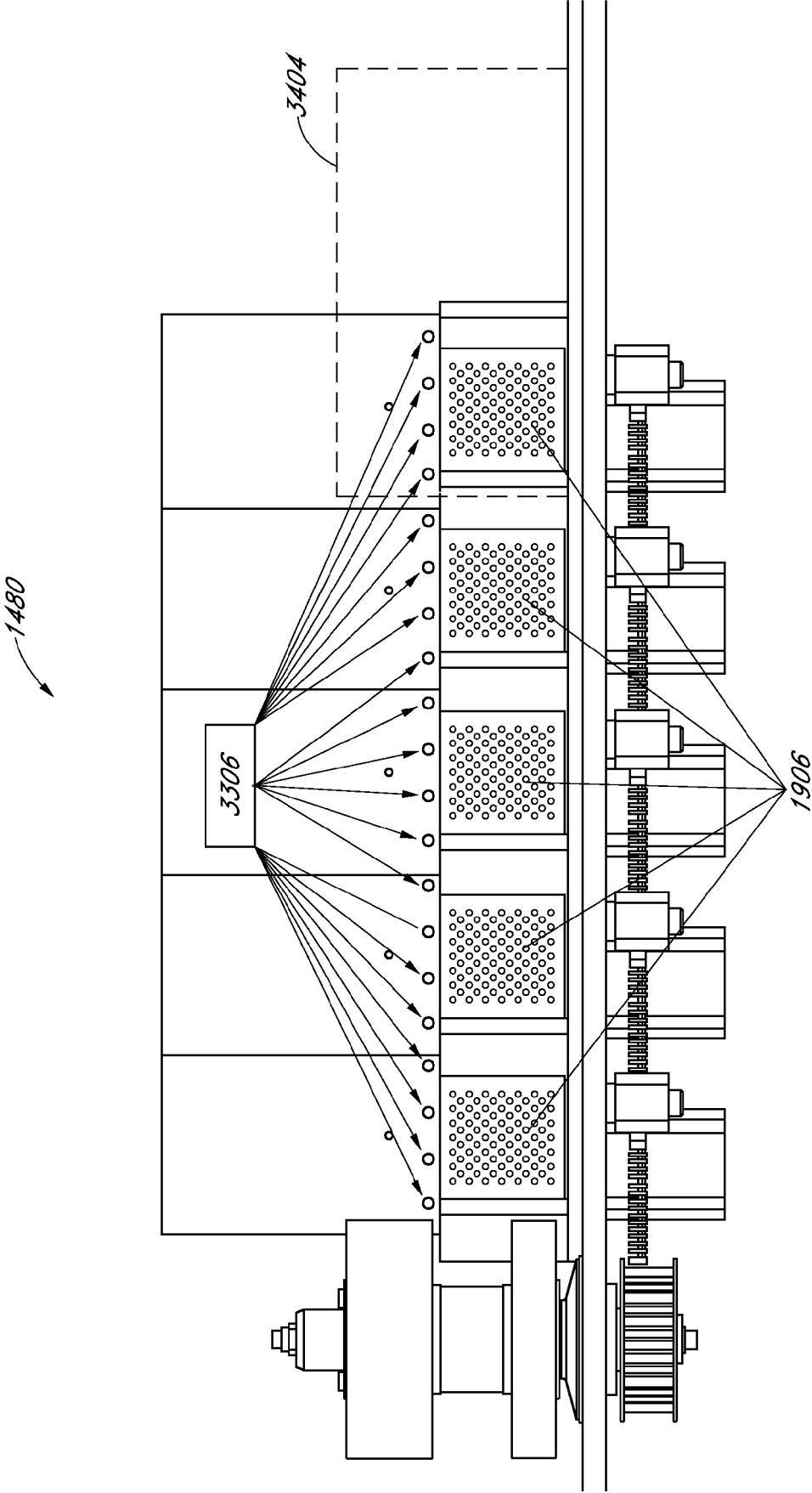


FIG. 34

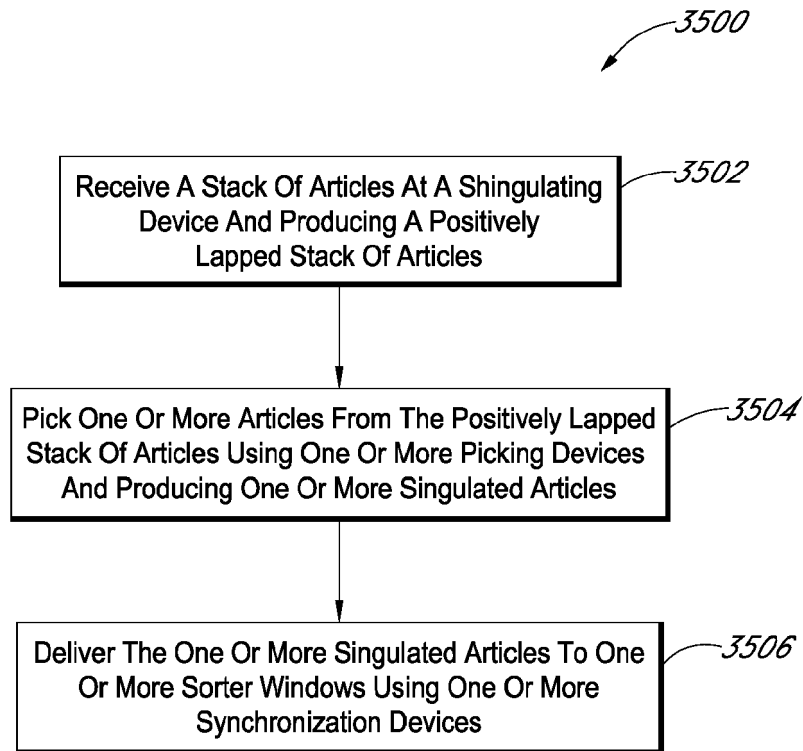


FIG. 35



EUROPEAN SEARCH REPORT

Application Number
EP 16 19 7418

5

10

15

20

25

30

35

40

45

50

55

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2012/013064 A1 (SAMAIN STEPHANE [FR] ET AL) 19 January 2012 (2012-01-19)	1-6, 8-16, 18, 19	INV. B65H3/12 B07C1/04 B65H3/46 B65H3/52 B65H3/54
A	* the whole document * -----	7, 17	
X	DE 103 50 623 B3 (SIEMENS AG [DE]) 14 April 2005 (2005-04-14)	1-6, 8-16, 18, 19	
A	* the whole document * -----	7, 17	
X	EP 0 926 085 A1 (PITNEY BOWES INC [US]) 30 June 1999 (1999-06-30) * the whole document * -----	1, 11	
A	US 2012/013065 A1 (AMBROISE STEPHANE [FR] ET AL) 19 January 2012 (2012-01-19) * the whole document * -----	1, 11	
			TECHNICAL FIELDS SEARCHED (IPC)
			B65H
The present search report has been drawn up for all claims			
Place of search The Hague		Date of completion of the search 13 April 2017	Examiner Athanasiadis, A
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

EPO FORM 1503 03.02 (P04C01)

**ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.**

EP 16 19 7418

5

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

13-04-2017

10

15

20

25

30

35

40

45

50

55

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 2012013064	A1	19-01-2012	AU 2011231435 A1	06-09-2012
			DK 2550216 T3	02-02-2015
			EP 2550216 A1	30-01-2013
			FR 2957906 A1	30-09-2011
			PT 2550216 E	29-12-2014
			RU 2012145347 A	27-04-2014
			US 2012013064 A1	19-01-2012
			WO 2011117508 A1	29-09-2011

DE 10350623	B3	14-04-2005	CN 1874944 A	06-12-2006
			DE 10350623 B3	14-04-2005
			EP 1678065 A1	12-07-2006
			JP 2007533569 A	22-11-2007
			KR 20060112655 A	01-11-2006
			US 2007252321 A1	01-11-2007
			WO 2005042386 A1	12-05-2005

EP 0926085	A1	30-06-1999	CA 2249480 A1	16-06-1999
			DE 69814576 D1	18-06-2003
			DE 69814576 T2	18-03-2004
			EP 0926085 A1	30-06-1999
			US 6135441 A	24-10-2000

US 2012013065	A1	19-01-2012	AU 2011234331 A1	23-08-2012
			CA 2794133 A1	06-10-2011
			EP 2552813 A1	06-02-2013
			FR 2958276 A1	07-10-2011
			JP 3184858 U	25-07-2013
			RU 130981 U1	10-08-2013
			US 2012013065 A1	19-01-2012
			WO 2011121204 A1	06-10-2011

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- US 79729113 A **[0001]**
- US 13797698 B **[0001]**
- US 13801749 B **[0001]**
- US 13827122 B **[0001]**
- EP 14779918 A **[0292]**