

ABSTRACT

The present disclosure generally relates to elongate pallet runners, pallets comprising a plurality of elongate pallet runners and methods, systems and apparatuses for forming said elongate pallet runners and pallets. The elongate pallet runners each comprise a plurality of
5 panels, where each panel is bent relative to an adjacent panel to form a continuous spiral structure having a cross-sectional profile that is nested. Each panel has a planar surface that abuts against a planar surface of another panel.

PALLET AND PALLET FORMING SYSTEM AND METHOD

TECHNICAL FIELD

[0001] This invention relates generally to methods and systems for forming pallets and in particular to methods and systems for forming corrugated pallets.

5 BACKGROUND

[0002] Pallets are commonly used to handle loads of material such that they can be stored, stacked and transported. A typical pallet includes a flat surface for supporting the load having parallel elongate runners secured to the underside. The runners provide strength to the pallet to support the load whilst the spacing of the runners permits the forks of equipment
10 such as a front-end loader or forklift truck to be inserted in between the runners such that the pallet and its supported load may be lifted and moved.

[0003] Pallets currently in use may be capable of supporting loads of up to 3000 kg and currently, many pallets are commonly manufactured from wood secured together by nails or other fasteners. Whilst relatively cheap to produce, the use of wood in the manufacture of
15 pallets has several drawbacks. Firstly, the nails or other fasteners used to secure the pallet together may cause damage to the supported load and present a hazard to people handling the pallets. Whilst strong, wooden pallets are heavy, which adds to the cost of transportation. This may especially be problematic as once used, they are not easily recycled on site and must be transported to a recycling facility or landfill. In some jurisdictions landfill disposal may
20 be economically unviable due to increasing disposal fees, limiting disposal limits to very low percentages or even unavailable due to being banned completely. Additionally, when transporting goods internationally, wooden pallets may require additional inspections or even a quarantine period due to ecological concerns arising from the potential of the wood to harbor non-native insects or other biological hazards.

[0004] As an alternative to wooden pallets, paperboard sheets and/or corrugated cardboard may be used to produce a corrugated pallet. In a corrugated pallet, a corrugated top deck is supported by a combination of parallel runners or support block constructed from a paper material such as for example a honeycomb block or compressed cardboard material. Corrugated pallets may be up to 75% lighter than wooden pallets and may be produced from
30 recyclable material whilst being recyclable themselves. However, especially in comparison to

wooden pallets, existing designs of corrugated pallets require complex and expensive equipment to manufacture and operate at slow production rates. In many known systems, formation of the runners commonly involves a complex sequence where more than one feedstock is combined in a multi-step sequence. Therefore, it remains challenging to economically produce a sufficiently strong and durable corrugated pallet.

[0005] Accordingly, it is desirable to provide improved pallets and pallet runners, and methods and apparatuses for forming the same.

SUMMARY

[0006] An embodiment as disclosed herein relates to an elongate pallet runner comprising a plurality of panels, each panel bent relative to an adjacent panel to form a continuous spiral structure having a cross-sectional profile that is nested, each panel having a planar surface that abuts against a planar surface of another panel.

[0007] In some embodiments, the cross-sectional profile comprises nested layers of bent panels, each nested layer having a same geometric shape.

[0008] In some embodiments, each panel is orientated perpendicular to its adjacent panel.

[0009] In some embodiments, each panel is separated from its adjacent panel by a respective fold line. In some embodiments, each panel is folded relative to its adjacent panel about the respective fold line.

[0010] In some embodiments, at least some of the abutting panels are adhered to each other by an adhesive.

[0011] In some embodiments, the plurality of adjacent panels are integrally formed.

[0012] In some embodiments, the elongate pallet runner has a rectangular cross-sectional profile.

[0013] In some embodiments, the elongate pallet runner is formed of corrugated cardboard.

[0014] In some embodiments, an innermost panel of the spiral structure includes a diagonal portion that does not abut against the planar surface of another panel.

[0015] Another embodiment as disclosed herein relates to a pallet comprising a deck having a top side and a bottom side and a plurality of elongate pallet runners secured to the bottom side of the deck. Each of the plurality of elongate pallet runners comprises a plurality of panels, each panel bent relative to an adjacent panel to form a continuous spiral structure having a cross-sectional profile that is nested, each panel having a planar surface that abuts against a planar surface of another panel.

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[0019] In some embodiments, at least some of the abutting panels are adhered to each other by an adhesive.

[0020] In some embodiments, the plurality of adjacent panels are integrally formed.

[0021] In some embodiments, each elongate pallet runner has a rectangular cross-sectional profile.

[0022] In some embodiments, each elongate pallet runner is formed of corrugated cardboard.

[0023] In some embodiments, the pallet comprises three elongate pallet runners.

[0024] In some embodiments, the deck and plurality of elongate pallet runners are made from corrugated cardboard.

[0025] In some embodiments, the deck is a first deck and wherein the corrugated pallet further comprises a second deck having a top side and bottom side, wherein the plurality of elongate pallet runners are secured to the top side of the second deck.

[0026] Another embodiment as disclosed herein relates to a method of forming a corrugated pallet. The method comprises affixing a plurality of elongate pallet runners to the same side of a deck. Each of the plurality of elongate pallet runners comprises a plurality of panels, each panel bent relative to an adjacent panel to form a continuous spiral structure having a cross-sectional profile that is nested, each panel having a planar surface that abuts against a planar surface of another panel.

10 **BRIEF DESCRIPTION OF THE DRAWINGS**

[0027] In drawings which illustrate embodiments of the invention,

[0028] FIG. 1 is a top plan view of a runner blank according to an embodiment of the present disclosure;

[0029] FIG. 2 is a schematic flow chart of an example method of forming a pallet runner from a runner blank, such as the runner blank of FIG. 1;

[0030] FIGS. 3A-D are top right perspective and end views of a pallet runner formed from the runner blank of FIG. 1;

[0031] FIGS. 4A-C are top left perspective, bottom plan and end views of a corrugated pallet according to an embodiment of the present disclosure;

20 **[0032]** FIGS. 5A and 5B are top right and top left front perspective views of a pallet forming system according to an embodiment of the present disclosure;

[0033] FIG. 6 is a top right front perspective view of the pallet formation subsystem of the pallet forming system of FIGS. 5A and 5B;

25 **[0034]** FIGS. 6A-D are enlarged perspective views of portions of the pallet formation subsystem of FIG. 6;

- [0035]** FIG. 7 is a schematic diagram of a control system of the pallet forming system of FIGS. 5A and 5B;
- [0036]** FIG. 8 is a top right front perspective view of the runner blank conveyor of the pallet forming system of FIGS. 5A and 5B;
- 5 **[0037]** FIG. 9A is a top right front perspective view of a movement apparatus and engagement head of the pallet formation subsystem of FIG. 6;
- [0038]** FIG. 9B is a bottom right front perspective view of the movement apparatus and engagement head of FIG. 9A;
- [0039]** FIG. 9C is a top left front perspective view of the movement apparatus and
10 engagement head of FIG. 9A;
- [0040]** FIG. 9D is a bottom left front perspective view of the movement apparatus and engagement head of FIG. 9A;
- [0041]** FIG. 9E is a top right front perspective view of a portion of the movement apparatus of FIG. 9A, with some components omitted;
- 15 **[0042]** FIG. 9F is a bottom left front perspective view of a portion of the movement apparatus of FIG. 9A, with some components omitted;
- [0043]** FIG. 9G is a top right rear perspective view of a portion of the movement apparatus of FIG. 9A, with some components omitted;
- [0044]** FIG. 9H is a bottom right rear perspective view of a portion of the movement
20 apparatus of FIG. 9A, with some components omitted;
- [0045]** FIG. 9I is a top right front perspective view of the engagement head of FIG. 9A;
- [0046]** FIG. 10A is a top right front perspective view of a runner forming station of the pallet formation subsystem of FIG. 6;
- [0047]** FIG. 10B is a top left front perspective view of the runner forming station of FIG.
25 10A;

- [0048]** FIG. 10C is a bottom right front perspective view of the runner forming station of FIG. 10A;
- [0049]** FIG. 11 is a top right front perspective view of an adhesive applicator apparatus;
- [0050]** FIG. 12 is a top right front perspective view of a panel rotating apparatus of the
5 runner forming station of FIG. 10A;
- [0051]** FIG. 12A is an enlarged top right front perspective view of the panel rotating apparatus of FIG. 12;
- [0052]** FIG. 12B is an enlarged bottom left rear perspective view of the panel rotating apparatus of FIG. 12;
- 10 **[0053]** FIG. 12C is an front end view of the panel rotating apparatus of FIG. 12;
- [0054]** FIGS. 13A-13K are schematic views showing a runner forming station in various stages of forming a pallet runner from a runner blank;
- [0055]** FIG. 14 is a top right front perspective view of the deck conveyor of the pallet forming system of FIGS. 5A and 5B;
- 15 **[0056]** FIG. 15A is a top right front perspective view of an engagement head of the pallet forming system of FIGS. 5A and 5B;
- [0057]** FIGS. 15B and 15C are bottom right front and top left front perspective views of the engagement head of FIG. 15A;
- [0058]** FIG. 16 is a top right front perspective view of the takeaway conveyor of the pallet
20 forming system of FIGS. 5A and 5B;
- [0059]** FIGS. 17A-C are top right perspective and end views of a pallet runner according to another embodiment;
- [0060]** FIG. 18 is a bottom perspective view of a corrugated pallet according to another embodiment; and

[0061] FIG. 19 is a bottom perspective view of a corrugated pallet according to another embodiment.

DETAILED DESCRIPTION

[0062] With reference to FIG. 1, a flat runner blank 100 is illustrated that is suitable thereafter to be reconfigured from a generally planar shape to form an elongate pallet runner. Blank 100 may be made from a single sheet of corrugated material or other sheet material and/or be formed in a way that is flexible such that it may be reconfigured into a pallet runner through engagement with a panel rotating apparatus, as will be described hereinafter.

[0063] Runner blank 100 may be cut from a single sheet of corrugated material or other sheet material and may be divided into a series of adjacent elongate rectangular panels A-X, which may be transverse, and which may be integrally formed and/or fixedly connected with adjacent panels. Runner blank 100 may be made from an assortment of foldable materials, including cardboard, paperboard, plastic materials, composite materials, or the like and possibly even combinations thereof.

[0064] As shown in FIG. 1 panel A may be located adjacent to a first vertical side edge of panel B, the second vertical side edge of panel B may be adjacent to a first vertical side edge of panel C, the second vertical side edge of panel C may be adjacent to a first vertical side edge of panel D, the second vertical side edge of panel D may be adjacent to a first vertical side edge of panel E, the second vertical side edge of panel E may be adjacent to a first vertical side edge of panel F, the second vertical side edge of panel F may be adjacent to a first vertical side edge of panel G, the second vertical side edge of panel G may be adjacent to a first vertical side edge of panel H, the second vertical side edge of panel H may be adjacent to a first vertical side edge of panel I, the second vertical side edge of panel I may be adjacent to a first vertical side edge of panel J, the second vertical side edge of panel J may be adjacent to a first vertical side edge of panel K, the second vertical side edge of panel K may be adjacent to a first vertical side edge of panel L, the second vertical side edge of panel L may be adjacent to a first vertical side edge of panel M, the second vertical side edge of panel M may be adjacent to a first vertical side edge of panel N, the second vertical side edge of panel N may be adjacent to a first vertical side edge of panel O, the second vertical side edge of panel O may be adjacent to a first vertical side edge of panel P, the second vertical side edge of panel P may be adjacent to a first vertical side edge of panel Q, the second vertical side edge of panel Q may be adjacent to a first vertical side edge of

panel R, the second vertical side edge of panel R may be adjacent to a first vertical side edge of panel S, the second vertical side edge of panel S may be adjacent to a first vertical side edge of panel T, the second vertical side edge of panel T may be adjacent to a first vertical side edge of panel U, the second vertical side edge of panel U may be adjacent to a first vertical side edge of panel V, the second vertical side edge of panel V may be adjacent to a first vertical side edge of panel W and the second vertical side edge of panel W may be adjacent to a first vertical side edge of panel X.

[0065] During formation of a pallet runner, fold lines 102-146 (shown in solid lines in FIG. 1) may be formed in blank 100 between adjacent panels to define each panel. Fold lines 102-146 may extend along the entire length of the vertical side edges of each panel. In some embodiments, the fold lines may be formed by the formation of a crease with a crease forming apparatus. In other embodiments the fold lines may be formed by a weakened area of material, such as created by a score line in runner blank 100. The effect of the fold lines are such that for example, when panel A is bent relative to adjacent panel B, the panels A and B will tend to be pivoted relative to each other along the common fold line 102. This may enable a sharp and precise corner (i.e., not rounded) to be formed between adjacent panels so that size, shape and strength of runner 150 is precisely controlled.

[0066] With reference to FIG. 2 and as will be described hereinafter, panels A-X may be folded to form pallet runner 150 through an example sequence of steps 100(1) to 100(5). At step 100(1) an individual runner blank 100 is provided, which may be selected from a stack of blanks 100 (not shown in FIG. 2). At step 100(2) the scoring of fold lines 102-146 by a suitable scoring apparatus may begin starting with fold line 102 and proceeding in numerical order. Scoring of fold lines 102-146 may continue throughout steps 100(2) and 100(5).

[0067] At step 100(3), the leading edge of panel A, i.e., the first vertical (outer) edge of panel A may be engaged by a panel rotating apparatus and is rotated in a clockwise direction such that panel A is pivoted relative to panel B. Between steps 100(3) and 100(4), continued engagement and rotation of panel A by the panel rotating apparatus in a clockwise direction occurs and continues between steps 100(3) and 100(5) to form a pallet runner 150.

[0068] Runner 150 is depicted in greater detail in FIGS. 3A-D and may have a generally rectangular cross section with a length l , width w and height h . When formed into pallet runner 150, each consecutive panel of blank 100 may be bent along the respective fold line (i.e., each

panel bent relative to an adjacent panel) such that each panel is perpendicular to the preceding and following panel in order to form the continuous spiral structure having a continuous cross-sectional profile that is nested, as shown in FIGS. 3A-D. In this configuration, with a nested cross-sectional profile there is minimal open space between panels in the internal structure, increasing strength and rigidity. The nested layers of bent panels have a same geometric shape (which in the illustrated embodiment is rectangular). When blank 100 is formed into runner 150, panels A, C, E, G, I, K, M, O, Q, S, U and W may form the longer vertical sides and panels B, D, F, H, J, L, N, P, R, T, V and X may form the shorter horizontal sides of runner 150. Each panel in runner 150 has a planar surface that abuts against a planar surface of another panel to provide a contact area between panels. For example, with reference to FIG. 3B, the outwards facing planar surface of panel A abuts the inner planar surface of panel E. In some embodiments, each panel in runner 150 has a planar surface that abuts against a full planar surface of another panel. For example, with reference to FIG. 3B, the outwards facing planar surface of panel E abuts the full inner planar surface of panel I. This may be beneficial when a layer of adhesive is applied between adjacent layers as the contact area for the adhesive will be maximized. By “full” planar surface it is meant substantially the whole planar surface of the panel, omitting the small area around the bend where there may be a degree of curving causing a small gap due to the bending of the material having thickness t .

[0069] As will be understood, in order to form the spiral cross-sectional profile of runner 150, the width of panels that are parallel to each other in pallet runner 150 (such as panels A, E, I, M, Q, U, panels B, F, J, N, R, V, panels C, G, K, O, S, W and panels D, H, L, P, T, X) must increase in size in an outwards direction from the centre of runner 150 in order to accommodate the increasing size of runner 150. The progression of the increase in width between adjacent parallel panels in an outwards direction as viewed in FIG. 3B may be equivalent to about double the thickness of blank 100.

[0070] For example, as can be seen in FIG. 1, panel E has a width that is greater than panel A, panel I has a width that is greater than panel E, panel M has a width that is greater than panel I, panel Q has a width that is greater than panel M and panel U has a width that is greater than panel Q. With reference to FIG. 3D, if panel A has a width w_A , and blank 100 has a thickness t , then panel E may have a width w_E of $(w_A + 2t)$, panel I may have a width w_I of $(w_E + 2t)$ (or $(w_A + 4t)$), panel M may have a width w_M of $(w_I + 2t)$ or $((w_A + 6t))$, panel Q may have a width w_Q of $(w_M + 2t)$ or $((w_A + 8t))$ and panel U have a width w_U of $(w_Q + 2t)$ (or $(w_A + 10t)$).

[0071] It will be appreciated that the thickness (or flute size) of blank 100 will have an effect on the height and width of the completed runner. Generally speaking, as the thickness of blank 100 increases, the height and width of runner 150 will also increase, providing that the panel widths remains the same. In an embodiment, runner 150 may have a height of between
5 about 3 inches and about 4.5 inches and may preferably have a height of about 3.75 inches.

[0072] In the embodiment shown in FIGS. 3A-D, pallet runner 150 may have a height h that is greater than the width w . This may be achieved through variations in the sizing of alternate panels of blank 100. In other embodiments, pallet runner may have other cross-sectional shapes, such as triangular, square, pentagonal, hexagonal, heptagonal or octagonal.

[0073] With particular reference to FIGS. 4A-C in various embodiments, a number of runners may thereafter be combined to form a corrugated pallet, such as corrugated pallet 160. Pallet 160 may include a deck 170 combined with three runners 150a, 150b and 150b, which may be similar to runner 150 and may be spaced apart in a parallel arrangement and secured to lower surface 172 of deck 170. Similar to a conventional pallet, corrugated pallet 160 is
15 configured to support a load on upper surface 174 of deck 170 and to permit the forks of equipment such as a front-end loader or forklift truck to be inserted in the space between runners 150a, 150b, 150c such that the pallet and its supported load may be lifted and moved. The rectangular shape for runner 150 provides a flat surface for runner 150 to be secured to deck 170 and an opposed flat surface to support and evenly distribute the load of any items on
20 corrugated pallet 160. As explained above, runner 150 has a continuous spiral structure, where each panel is orientated perpendicular both to the preceding and following panel. This provides a strong and rigid structure in all directions.

[0074] Runners 150a, 150b, 150c may be secured to deck 170 by any suitable method, such as by a layer of adhesive or a mechanical fastener such as staples, clips or screws. Deck
25 170 may be any suitable shape, such the square configuration shown in FIGS. 4A-C and may be made from any suitable material such as carboard or corrugated fiber board. In other embodiments, deck 170 may be made from a plastic, such as polyethylene (including high density polyethylene (HDPE), and medium density polyethylene (MDPE)), polypropylene (PP), polycarbonate, polytetrafluoroethylene, polyethylene terephthalate, polystyrene, cyclic olefin
30 polymer, cyclic olefin copolymer, crystal zenith olefinic polymer, polyvinyl chloride (PVC) and nylon. Plastics may include bioplastics and plastics containing a proportion of recycled plastics. In other embodiments, deck 170 may be made from a metal such as steel or aluminium.

[0075] With reference to FIGS. 5A-B, in overview a pallet forming system 200 is shown and may include runner blank conveyor 202, deck conveyor 204, pallet formation subsystem 206 and takeaway conveyor 208. Pallet formation subsystem 206 may include a runner forming station 210 and a pallet assembly station 212.

5 **[0076]** As shown in FIGS 6-6D and described hereinafter, pallet formation subsystem 206 is configured to receive a plurality of blanks 100 from runner blank conveyor 202 and to form one or more runners 150 at runner forming station 210. The one or more formed runners 150 are combined with one or more decks 170 from deck conveyor 204 at pallet assembly station 212 to form a pallet 160, which is delivered to takeaway conveyor 208. Runner blanks 100 and
10 deck 170 may be cut from a single sheet of corrugated material and may be received by system 100 without the need to pre-form any fold lines.

[0077] Pallet formation subsystem 206 may include a frame 214 and may utilize one or more engagement heads configured to engage and move components such as blank 100, runner 150, deck 170 or pallets 160. Pallet formation subsystem 206 may include first engagement
15 head 216a for retrieving a runner blank 100 from runner blank conveyor 202 and moving blank 100 to runner forming station 210, a second engagement head 216b for retrieving a formed runner 150 from runner forming station 210 and moving runner 150 to pallet assembly station 212 and third engagement head 216c for retrieving corrugated pallets 160 from pallet assembly station 212 and moving to takeaway conveyor 208.

20 **[0078]** Engagement heads 216a-c may be any suitable apparatus configured to releasably engage a component (e.g., runner blank 100, runner 150, deck 170 or corrugated pallet 160) of system 100 and may each be moved by a movement subsystem, which may include one or more movement apparatuses. For example, first engagement head 216a may be mounted to and moved by a first movement apparatus 218a. Second engagement head 216b
25 may be mounted to and moved by a second movement apparatus 218b. Third engagement head 216c may be mounted to and moved by a third movement apparatus 218c. Movement apparatuses 218a-c may be any suitable apparatus configured to move their respective engagement head in one or more directions.

[0079] An example of a scheme for the power and data/communication configuration for
30 pallet forming system 200 is illustrated in FIG. 7. The operation of the components of pallet forming system 200, and of system 100 as a whole, may be controlled by a programmable logic

controller ("PLC") 500. PLC 500 may be accessed by a human operator through a Human Machine Interface (HMI) module 510 secured to frame 214. HMI module 510 may be in electronic communication with PLC 500. PLC 500 may be any suitable PLC and may for example include a unit chosen from the Logix 5000™ series devices made by Allen-Bradley™ /
5 Rockwell Automation™, such as the ControlLogix 5561 device. HMI module 510 may be a Panelview part number 2711P-T15C4D1 module also made by Allen-Bradley™ / Rockwell Automation™. It should be noted that not all of the sensors, motors, servo motors, drives, vacuums, vacuum generators and vacuum cups described hereinafter are specifically identified in FIG. 7.

10 **[0080]** Electrical power can be supplied to PLC 500/HMI 510, and to all the various servo motors and DC motors that are described further herein. Compressed/pressurized air can also be supplied to the vacuum generators through valve devices such as solenoid valves that are controlled by PLC 500, all as described further herein. Servo motors may be connected to and in communication with servo drives that are in communication with and controlled by PLC 500.
15 Similarly, DC motors may be connected to DC motor drives that are in communication with and controlled by PLC 500; again all as described further herein. Additionally, various other sensors are in communication with PLC 500 and may (although not shown) also be supplied with electrical power.

Runner blank conveyor 202

20 **[0081]** Runner blank conveyor 202 is shown in isolation in FIG. 8 and may be configured to receive, hold and move, in the y-direction, a plurality of runner blanks 100 stacked in a substantially flat orientation. Runner blank conveyor may include a support frame 230 configured to retain a series of transversely and horizontally oriented rollers 232. Rollers 232 allow for generally horizontal longitudinal movement of the stack in the direction indicated by arrow 234 in
25 FIG. 8.

[0082] The stack of runner blanks 100 may be loaded onto runner blank conveyor 202 at a first position 236. The stack of runner blanks 100 may be conveniently loaded onto conveyor 202 on pallet 242, such as by a fork lift truck. In other embodiments, blanks 100 may be placed directly onto conveyor 202. The stack of runner blanks 100 may be advanced in direction 234 to
30 a second (or pickup) position 238, where a blank 100 may be engaged by first engagement head 216a of pallet formation subsystem 206 and moved by first movement apparatus 218a to runner

forming station 210. Once all blanks 100 of the stack of runner blanks 100 have been moved from second position 238, the remaining pallet 242 may be moved to third position 240 and stacked by pallet stacking apparatus 244, which is configured to stack empty pallets 242 into vertical stacks for removal.

5 **[0083]** A conveyor belt (not shown) may be provided that may be driven by a suitable motor such as a DC motor or a variable frequency drive motor 228a. The motor may be DC motor and may be controlled through a DC motor drive (all sold by Oriental™ under model AXH-5100-KC-30) by PLC 500 (FIG. 7). The conveyor belt may have an upper belt portion supported on the rollers 232. Once PLC 500 is given an instruction (such as by a human operator through
10 the HMI module 510), an upper belt portion of the belt may move longitudinally in direction 234. In this way the belt can move a stack of blanks 100 longitudinally downstream, with the stack of blanks being supported on the rollers 232. PLC 500 can control the drive motor through the motor drive and thus conveyor 202 can be operated to move and transfer the stack of runner blanks 100 on pallet 242 from first position 236 to second position 238 and move the empty pallet
15 242 to the third position 240. An encoder may be provided to monitor and control the position of the conveyor belt.

[0084] The presence of a stack of blanks 100 at the pickup position 238 may be detected by a sensor 540 (FIG. 7). The sensor 540 may detect the presence of the front edge of a stack of blanks 100 at the second/pickup position 238 and may send a digital signal to PLC 500
20 signalling that a stack is at the pickup position 238.

Pallet formation subsystem 206

[0085] The presence of a stack of blanks at the second or pick up location 238 may be detected by sensor 540. The sensor may send a digital signal to PLC 500 signalling a stack of blanks are at the pick-up position. Referring back to FIGS. 6-6B, single blanks 100 may be
25 retrieved from the stack of blanks 100 by engagement of first engagement head 216a with the upper surface of the upper most blank in the stack followed by movement of the engaged blank and first engagement head 216a by first movement apparatus 218a from pick up position 238 to runner forming station 210.

First Engagement Head 216a

[0086] First engagement head 216a is shown in greater detail in FIG. 9I and may be mounted to and moved by first movement apparatus 218a. First engagement head 216a may include a longitudinally extending member 246 affixed at a first end to the lower end of first movement apparatus 218a. Member 246 may be configured to connect to a series of transversely extending arms 248a, 248b, 248c, 248d and a longitudinally extending arm 248e. Arms 248a-d may be operable to slidably move along pairs of spaced apart tracks in the surface or member 246. For example, arms 248a and 248b may be slidably movable along tracks 250a, 250b. Similarly, longitudinally extending arm 248e may be slidably movable along a single track 252 in the upper surface of member 246. When in the desired position, arms 248a-e may be fixed in position, such as by bolts (not shown in FIGS). This adjustable positioning of 248a, 248b, 248c, 248d is a feature of pallet forming system 200 that enables pallet forming system 200 to be easily modified when changing over from handling one type/configuration of blank to another type/configuration of blank.

[0087] In other embodiments arms 248a-e may be permanently affixed to or formed as an integral part of member 246.

[0088] At the distal end of each of arms 248a-e may be one or more suction cups 254 (not shown in FIG. 9I but shown in FIG. 7) which, when activated, provide a suction force to the upper surface of blank 100 sufficient to allow first engagement head 216a to pick up blank 100. It should be noted that while many types of suction cups may be employed on the end effector, a preferred type of suction cup is the model B40.10.04AB made by Piab™. Each suction cup 254 is connected to an outlet from a vacuum generator 520 (not shown in FIG. 9I but shown in FIG. 7). Each vacuum generator 520 may be any suitable vacuum generator device such as for example the model VCH12-016C made by Pisco™ may be in close proximity to, or integrated as part of, suction cups 254. Each of the vacuum generators 520 have an inlet interconnected to a hose (not shown) that can carry pressurized air from an air compressor or other vacuum source to the vacuum generator. Each vacuum generator 520 converts the pressurized air supplied to the inlet port into a vacuum at one of the outlet ports. That vacuum outlet port is interconnected to a suction cup 254 so that the suction cup can have a vacuum force. For simplicity, electrical cables and hoses for pressurized air are not shown on first engagement head 218a.

[0089] A solenoid valve device 530 (FIG. 7) is interposed along the pressurized air channel running between each vacuum generator and the source of pressurized air. The solenoid valve device 530 may for example be a model CPE14-M1BH-5L-1/8 made by Festo™ Valve device 530 is in electronic communication with PLC 500 and controlled by PLC 500. In this way PLC 500 can turn on and off the supply of vacuum force to the suction cups 254.

[0090] In other embodiments, a vacuum pump mounted externally may generate vacuum externally and then vacuum can be supplied through the aforementioned air channels.

[0091] Returning to FIG. 9I, the arms 248a-e may be positioned to provide adequate support of blank 100 and prevent any deformation/damage during engagement with first movement apparatus 218a. Through providing a degree of adjustability of the position of longitudinal positions of arms 248a-e relative to member 246, first engagement head 216a may be easily adjusted to accommodate different sizes of blank 100.

[0092] In other embodiments, first movement apparatus 218a may be configured with any suitable number and configurations of arms similar to arms 248a-e as required to engage a blank.

First movement apparatus 218a

[0093] First engagement head 216a and first movement apparatus 218a are shown in isolation in FIGS. 9A to 9I. First engagement head 216a may have a dedicated movement apparatus, first movement apparatus 218a that allows first engagement head 216a to move in both the vertical Z and horizontal X/Y directions (i.e., directions parallel to axes Z, X and Y in FIG. 9A).

[0094] First movement apparatus 218a includes a vertically orientated support tube 256a that may be generally rectangular in cross section to which first engagement head 216a is mounted by mounting brackets 258 (FIG. 9A) such that first engagement head 216a moves in space with support tube 256a.

[0095] Support tube 256a is slidably mounted to a pair of slide blocks 260, 262, each mounted on opposing sides of support tube 256a (FIG. 9B). Slide blocks 260, 262 are in turn mounted to horizontal rail system for horizontal movement in the X-direction. Slide blocks 260, 262 may each include a pair of spaced, longitudinally and horizontally extending short inner

blocks, each one fitting on one longitudinally extending rail 264, 266 that holds the blocks securely but allows the blocks to slide horizontally relative to the rails. For example, with reference to FIGS. 9E and 9F, slide block 262 is secured to rail 266 by inner blocks 263a and 263b. Similarly, with reference to FIGS. 9G and 9H, slide block 260 is secured to rail 264 by inner blocks 261a and 261b. An example of a suitable rails system is the Bosch Rexroth™ ball rail system in which the rails are made from steel and the blocks have a race of ceramic balls inside allowing the block to slide on the rails. Rails 264, 266 are generally oriented horizontally and are attached at either end to support plates 268, 270 (FIG. 9B). Support plates 268, 270 are in turn which are in turn affixed to longitudinally extending members 292, 294 of frame 214 of pallet formation subsystem 206 (FIG. 6).

[0096] Support tube 256a has a generally vertically orientated rail system to allow support tube 256a to be connected slide blocks 260, 262 such that support tube 256a may move vertically relative to slide blocks 260, 262. More specifically, rails 275, 277 extend vertically along opposed sides of tube 256a. Rail 275 is secured to slide block 262 by inner blocks 279a, 279b (FIG. 9E and 9F). Similarly, with reference to FIGS. 9G and 9H, rail 277 is secured to slide block 260 by inner blocks 281a, 281b (FIG. 9G and 9H). Again, a suitable rail system is the Bosch Rexroth™ ball rail system referenced above. Thus, support tube 256a can slide vertically relative to slide blocks 260, 262 and will move horizontally with slide blocks 260, 262 (relative to rails 264, 266).

[0097] In order to drive first movement apparatus 218a horizontally (in the X-direction in FIG. 9A) and vertically (in the Y-direction in FIG. 9A), a drive apparatus is provided which includes a left side drive motor 272a and a right side drive motor 274a (both of which may be servo motors such as the model MPL-B330P-MJ24AA made by Allen Bradley™ mounted to respective support plates 268, 270. Drive motor 272a has a drive wheel 276 and drive motor 274a has a drive wheel 278. Both servo motors 272a and 274a can be independently driven in both directions at varying speeds by PLC 500 (FIG. 7) through servo drives (such as a 2094-BC01-MP5-S also made by Allen Bradley™ and gear head AE050-010 FOR MPL-A1520 made by Apex™. In this regard, both servo motors 272a and 274a may be provided with two separate ports, one for connection to a power line and the other for connection to a communication line to provide communication with the servo drive and PLC 500. Servo motors 272a, 274a may also have a third input which may provide input for an electric braking mechanism. It should be noted that all of the servo motors described herein may be similarly equipped.

[0098] Four freely rotatable pulley wheels 280a, 280b, 280c and 280d are secured between the inner vertical faces of slide blocks 260, 262 and a further freely rotatable pulley wheel 280e is attached to the upper end of support tube 256a.

[0099] One end of a drive belt 282, which may for example be made from urethane with steel wires running through it is fixedly attached to the bottom of support tube 256a by a belt block 284a (FIG. 9B). From there the belt extends upwardly to pulley wheel 280b, around the upper side of pulley wheel 280b and then horizontally to drive wheel 276 of drive motor 272a (FIG. 9A). Belt 282 loops around the drive wheel 276 and extends around the underside of pulley wheel 280a and then upwards to pulley 280e. From there belt 282 extends around pulley 280e, downwards to block pulley 280c, around pulley wheel 280 and then to drive wheel 278 of drive motor 274a (FIG. 9C). After passing around drive wheel 278, belt 282 extends to the upper side of pulley wheel 280d. From pulley wheel 280d, belt 282 then extends vertically downwards to the bottom of the support tube 256a where it attached to the support tube by a belt block 284b (FIG. 9D).

[00100] With this arrangement, by adjusting the relative rotations of drive wheels 276 and 278 through the operation of motors 272a and 274a, the vertical position of support tube 256a relative to slide blocks 260 and 262 can be adjusted. Additionally, by adjusting the relative rotations of drive wheels 276 and 278, the horizontal position of slide blocks 260 and 262 on rails 264, 266 can be adjusted thus altering the horizontal position of support tube 256a and first engagement head 216a. It will thus be appreciated that by adjusting the direction and speeds of rotation of drive wheels 276 and 278 relative to each other the support tube 256a can be moved vertically and/or horizontally in space within the physical constraints imposed by among other things the position of the drive wheels 276 and 278, the length of the belt 282, and the length of support tube 256a. The following will be appreciated in particular:

[00101] - If drive wheels 276 and 278 both remain stationary then the position of support tube 256a will not be altered;

[00102] - If drive wheels 276 and 278 both rotate in the same clockwise direction and at the same speed relative to each other, then support tube 256a (and thus first engagement head 216a) will move horizontally from left to right (as viewed in FIG. 9A);

[00103] - If wheels 276 and 278 both rotate in the same counter-clockwise direction and at the same speed relative to each other, then support tube 256a (and thus first engagement head 216a) will move horizontally from right to left (as viewed in FIG. 9A);

5 **[00104]** - If wheel 276 rotates counter-clockwise, and wheel 278 rotates in an opposite clockwise rotational direction, but both wheels rotate at the same rotational speed relative to each other, then support tube 256a, and first engagement head 216a, will move vertically downwardly;

10 **[00105]** - If wheel 276 rotates clockwise, and wheel 278 rotates in opposite counter-clockwise rotational directions, but both wheels rotate at the same rotational speed relative to each other, then plates 164, 166 then support tube 256a, and first engagement head 216a, will move vertically upwardly.

[00106] In some embodiments, first movement apparatus 218a may also be configured such that first engagement head 216a may also move in the Y-direction (i.e., directions parallel to the Y axis in FIG. 9A). In order to drive first movement apparatus 218a horizontally in the Y-direction, a drive apparatus is provided which includes a central drive motor 286a (which may be
15 a servo motor such as the model MPL-B330P-MJ24AA made by Allen Bradley™) mounted to longitudinally extending member 294 of frame 214 through motor mount 295 (FIG. 9A). Servo motor 286a can be driven in both directions at varying speeds by PLC 500 (FIG. 7) through servo drives.

20 **[00107]** As described above, at either end rails 264, 266 may be affixed to and supported by support plates 268, 270 (FIG. 9A). Each of support plates 268, 270 are mounted to a respective upper surface thereof rails 288, 290 which are in turn affixed to longitudinally extending members 292, 294 of frame 214 of pallet formation subsystem 206 (FIG. 6). Support plates 268, 270 may each include a pair of spaced, longitudinally and horizontally extending short inner blocks, each one fitting on one longitudinally extending rail 288, 290 that holds the blocks
25 securely but allows blocks (and support plates 268, 270) to slide horizontally relative to the rails. An example of a suitable rails system is the Bosch Rexroth™ ball rail system in which the rails are made from steel and the blocks have a race of ceramic balls inside allowing the block to slide on the rails.

30 **[00108]** Servo motor 286a may be mounted to a gearbox 296 which is in turn interconnected to longitudinally extending driveshaft 298 such that driveshaft 298 can be driven

in both directions at varying speeds by PLC 500. The opposed ends of drive shaft 298 are connected to pulleys 300a, 300b, which each drive continuous belts 302a, 302b.

[00109] Belt 302a may extend in a transverse direction from the lower side of pulley 300a, generally following rail 288 to the lower side of a pulley 304a, mounted above the opposite end of rail 288 to pulley 300a. From there belt 302a extends to the upper side of pulley 304a and in a transverse direction to the upper side of pulley 300a. Belt 302a is also connected to support plate 268, such movement of belt 302a will drive movement of support plate 268 along rail 288.

[00110] Similarly, belt 302b may extend in a transverse direction from the lower side of pulley 300b, generally following rail 290 to the lower side of a pulley 304b, mounted above the opposite end of rail 290 to pulley 300b. From there belt 302b extends to the upper side of pulley 304b and in a transverse direction to the upper side of pulley 300b. Belt 302b is also connected to support plate 268, such movement of belt 302b will drive movement of support plate 270 along rail 290.

[00111] With this arrangement, through operation of servo motor 286a the horizontal position in the Y-direction of support plates 268, 270 and thus rails 264, 266, support tube 256a and first engagement apparatus 216a can be adjusted relative to rails 288, 290. Movement in the Y direction may be desirable for example, in order to facilitate changeovers of components of pallet forming system 200 (such as components of first engagement head 216a) to allow access to components of system 200, to align blank 100 correctly in the Y-direction on conveyor 220 or to transfer a blank to/from another location. This may be especially beneficial when using different sized blanks with system 200, such that first engagement apparatus 216a can successfully engage and transfer the blank to the correct position on conveyor 220.

[00112] The following will be appreciated in particular:

[00113] - If servo motor 286a is not operated then driveshaft 298 will not rotate the position of rails 264, 266 and interconnected support tube 256a / first engagement apparatus 216a in the Y1/Y2 directions (FIG. 9A) will not be altered;

[00114] - If servo motor 286a is operated such that driveshaft 298 rotates in the clockwise direction (as indicated by arrow 306 in FIG. 9A), then pulleys 300a, 300b will also both rotate in the same clockwise direction and at the same speed relative to each other, causing horizontal

movement or rails 264, 266 and interconnected support tube 256a / first engagement apparatus 216a in the Y1 direction (as shown in FIG. 9A) through slidable movement on rails 288, 290.

[00115] - If servo motor 286a is operated such that driveshaft 298 rotates in the counter clockwise direction (as indicated by arrow 308 in FIG. 9A), then pulleys 300a, 300b will also both
5 rotate in the same counter clockwise direction and at the same speed relative to each other, causing of horizontal movement of rails 264, 266 and interconnected support tube 256a / first engagement apparatus 216a in the Y2 direction (as shown in FIG. 9A) through slidable movement on rails 288, 290.

[00116] It will be appreciated that if the speeds and directions of the motors 272a, 274a, 278 are varied in different manner, then the motion of the support tube 256a (and thus first engagement head 216a) can be created that has both a vertical component as well as a horizontal component. Thus, any desired path within these three degrees of freedom (vertical in the Z direction and horizontal in the X and Y directions) can be created for support tube 256a -- and thus for first engagement head 216a (such as a path having curved portions). Thus, by
10 controlling the rotational direction and speed of the motors 272a, 274a, 278 independently of each other, PLC 500 can cause support tube 256a (and thus first engagement head 216a) to move along any path within these two degrees of freedom, within the physical constraints imposed by the spacing of the wheels 276, 278 in the X direction, the spacing of pulley wheel 280e, and the bottom of support tube 256a in the Z direction and the spacing between pulleys
15 300a, 300b and pulleys 304a, 304b in the Y direction.
20

[00117] An encoder may be provided for each of the servo drive motors 272a, 274a and the encoders may rotate in relation to the rotation of the respective drive wheels 276, 278. The encoders may be in communication with, and provide signals through the servo drives to PLC 500. Thus PLC 500 can in real time know/determine/monitor the position of the belt 282 in space
25 and thus will determine and know the position of the first engagement head 216a in space at any given time.

[00118] Similarly, an encoder may be provided for servo drive motor 286 which rotates in relation to the rotation of driveshaft 298. The encoder may be similar to the encoders described above may be in communication with, and provide signals through the servo drives to PLC 500.
30 Thus PLC 500 can in real time know/determine/monitor the belts 302a, 302b in space and thus will determine and know the position of the first engagement head 216a in the Y direction.

[00119] The particular types of encoders that may be used are known as “absolute” encoders. Thus the system can be zeroed such that due to the calibration of both encoders of both servo drive motors 272a, 274a, 286a the zero-zero position of the end effector in both X, Y and Z directions is set within PLC 500. The zero-zero position can be set with the end effector at its most horizontally left (in the X direction), most horizontally back (i.e., furthest in the Y2 direction) and vertically raised position. PLC 500 can then substantially in real time, keep track of the position of the end effector 500 as it moves through the processing sequence for a blank 100.

[00120] Also associated with first movement apparatus 218a is a first, generally horizontally oriented caterpillar device 310 and a second generally vertically oriented caterpillar device 312 (FIG. 9B). Each of the caterpillars 310 and 312 have a hollow cavity housing hoses and wires carrying pressurized air/vacuum and electrical/communication wires. Caterpillar 310 allows such hoses and wires to move longitudinally as the support tube 256a and first engagement head 216a are moved longitudinally. Caterpillar 312 allows such hoses and wires to move vertically as the support tube 256a and first engagement head 216a are moved vertically.

[00121] Also associated with first movement apparatus 218a are third and fourth, generally horizontally orientated caterpillar devices 314a, 314b (FIG. 9B). Each of the caterpillars 314a and 314b have a hollow cavity housing hoses and wires carrying pressurized air/vacuum and electrical/communication wires. Caterpillars 314a, 314b allows such hoses and wires to move longitudinally as rails 264, 266 and interconnected support tube 256a / first engagement apparatus 216a are moved longitudinally.

[00122] The caterpillars allow hoses and wires to supply first engagement head 216a. In this way both pressurized air/ vacuum and/or electrical communication wires may be brought from locations external to the frame 214 onto the moving first engagement head 216a. An example of suitable caterpillar devices that could be employed is the E-Chain Cable Carrier System model # 240-03-055-0 made by Igus Inc . It should be noted that electrical communication between the PLC 500 and the first engagement head 216a could in other embodiments be accomplished using wireless technologies that are commercially available.

[00123] Through operation of first movement apparatus 218a as described above, first engagement head 216a may be moved towards a stack of blanks at second (or pick up) position 238 on runner blank conveyor 202 (FIG. 5A). There, the upper surface of the upper most blank

in the stack may be engaged by the one or more suction cups 254 at the distal end of each of arms 248a-e of first engagement head 216a. The air suction force that may be developed at the outer surfaces of suction cups 254 will be sufficient so that when activated they can engage blank 100, as first movement apparatus 218a moves first engagement head 216a with an engaged blank 100 from the stack of blanks at second (or pick up) position 238 to conveyor 220 of runner forming station 210, where the suction cups 254 will disengage and release the engaged blank 100.

Runner forming station 210

[00124] Runner forming station 210 is depicted in isolation in FIGS. 10A to 10C and includes a conveyor 220, scoring roller 222, adhesive applicator apparatus 224, and panel rotating apparatus 226. Runner forming station 210 is configured to form a pallet runner 150 from a blank 100 through a sequence of steps such as steps 1000(1) to 1000(10) as depicted in FIGS. 13A to 13J, which may generally incorporate steps 100(1) to 100(5) in FIG. 2 described above, where some steps have been expanded to depict greater detail.

Conveyor 220

[00125] Conveyor 220 may have a continuous belt 316 which may be supported for longitudinal movement at opposite ends by a drive pulley and an idle wheels (not shown in FIGS). The drive pulley may be connected to a drive motor 317 (FIG. 7), such as a DC drive motor (not shown in FIGS) operated by PLC 500 through a drive mechanism. An encoder may be provided to monitor and control the position of the belt 316. Belt 316 of conveyor 220 may be made from any suitable material such as for example Ropanyl.

[00126] Belt 316 may include a first engagement feature, such as first outwardly projecting ridge 318a configured to engage an edge 100a of a blank 100 that is placed on conveyor 220 by first movement apparatus 218a, as depicted schematically in FIG. 13A. Ridge 318a is configured to prevent movement of blank 100 from left to right (as viewed in FIG. 10A) relative to conveyor 220. This is especially important when blank 100 is engaged by other components of runner forming station 210, as will be explained in greater detail below. Similarly, belt 316 may include second engagement feature, such as a second outwardly projecting ridge 318b (FIG. 10C) on the opposite side of belt 316 to first ridge 318a. Second ridge 318b substantially performs the

same function as first ridge 318a when ridge 316b is positioned on the upper side of runner forming station 210 due to movement of belt 316

[00127] With reference to FIG. 13A, at step 1000(1) runner forming station 210 and blank 100 are shown in an initial configuration. In this configuration, first movement apparatus 218a has placed a blank 100 on conveyor 220 such that edge 100a abuts ridge 318a (or ridge 318b depending on the position of belt 316). Through operation of PLC 500, the position of belt 316 (through operation of the DC drive motor) may be controlled such that either ridge 318a or 318b is positioned such that when first movement apparatus 218a moves first engagement head 216a with an engaged blank 100 to conveyor 220 of runner forming station 210, edge 100a of the engaged blank 100 will be placed adjacent to ridge 318a or 318b.

Scoring Roller 222

[00128] With reference to FIG. 13B, between steps 1000(1) and 1000(2) blank 100 is advanced in the direction indicated by arrow 229 through movement of belt 316 of conveyor 220. As previously described, edge 100a of blank 100 may be in abutment with ridge 318a such that blank 100 does not shift relative to belt 316. As blank 100 is advanced on conveyor 220, the upper surface will contact scoring roller 222, which is configured to score a series of fold lines (such as fold lines 102-146 described above) in the upper surface of blank 100.

[00129] Scoring roller 222 may be any suitable scoring apparatus operable to form one more fold lines on blank 100. The fold lines may comprise a weakened area of material, such a crease, a score line or a series of spaced apart perforations in blank 100. The weakened area of material may allow blank 100 to be folded about each fold line, as will be described in more detail below. In the embodiment shown in FIGS. 10A to 10C and 13A to 13E, scoring roller 222 may comprise a generally cylindrical drum 320, which has on its outer surface a series of outwardly extending protrusions 322. Protrusions 322 may narrow at their distal end to create a tip for engaging the upper surface of panel 100.

[00130] In some embodiments, the fold lines may not be continuous. For example, one of more of the fold lines may be intermittent/stippled across blank 100. Further, the fold lines may not extend transversely entirely along blank 100. The aforementioned fold line configurations may be dictated by the shape and length of protrusions 322 of scoring roller 222.

[00131] Whilst the embodiment shown in the FIGS. illustrates a scoring roller, the scoring apparatus may be any suitable apparatus configured to form one or more fold lines as described above on blank 100. For example, the scoring apparatus may comprise a mechanical press or cutting apparatus configured to move vertically (in the z-direction) at a particular frequency (or changing frequency) to apply a desired pattern of creases, score lines or perforations at a desired spacing on blank 100. In an embodiment, the scoring apparatus comprises a steel rule die.

[00132] At one end of drum 320, scoring roller 222 may be connected to a servo motor 324 through a gearbox 326 such that scoring roller 222 is configured for rotational movement about a generally horizontal axis of rotation 327 (parallel to the Y-axis on FIG. 10A) through operation of motor 324. Servo motor 324 may be operated through PLC 500 such that the direction and speed of rotation of servo motor 324 and therefore scoring roller 222 may be controlled. Through adjustment of the speed of rotation of scoring roller relative to the speed of movement of blank 100 on conveyor 220, the spacing between adjacent fold/score lines may be adjusted.

[00133] As blank 100 is advanced in direction 229 one of the protrusions 322 on scoring roller 222 may engage a portion of the upper surface of blank 100 to form a fold line across the width of blank 100 (generally parallel to the Y-axis in FIG. 10A). In some embodiments the fold line created by scoring roller 222 may be a score line in blank 100, that is a cut in blank 100 extending partially through the thickness of blank 100. For example, when blank 100 is made from corrugated cardboard the score line may only extend through the deck of the corrugated sheet. In other embodiments, the fold line created by scoring roller 222 may be a crease in blank 100, that is an indentation in blank 100 that does not cause any cutting or penetration through the upper surface of blank 100. By providing creases or score lines, when blank 100 is formed into pallet runner 150, the weakened area of material along each fold line will result in sharper corners (i.e., not rounded) being created along each of the fold lines such that pallet runner may be formed into a generally rectangular (or square) configuration.

[00134] The depth of the crease or score lines formed in blank 100 may be affected by the distance between scoring roller 222 and conveyor 220 and the thickness of blank 100. The profile of the tip at the distal end of each of the protrusions may also affect the crease or score line formed in blank 100. Generally speaking, a wider tip at distal end of each of the protrusions 322 may favour forming a crease in blank 100 rather than a score line. Conversely a narrower

tip at distal end of each of the protrusions 322 may favour forming a score line in blank 100 rather than a crease.

5 **[00135]** Throughout steps 1000(2) and 1000(8), as blank 100 is further advanced in direction 229 through movement of conveyor 220, scoring roller 222 will also rotate such that protrusions 322 will continue to engage portions of the upper surface of blank 100, creating a series of fold lines may be formed on blank 100, such as fold lines 102-146, thereby dividing blank 100 into panels A-X (as shown in FIG. 1).

10 **[00136]** The spacing of each of the adjacent fold lines formed in blank 100 may be dependent on factors such as the speed of movement of conveyor 220 (and therefore the speed of movement of blank 100 in direction 229) and speed of rotation of scoring roller 222 relative to each other. Both may be controlled by PLC 500 to create the desired spacing between adjacent fold lines. As the spacing between fold lines formed on a blank affects the dimensions of the pallet runner formed from the blank, PLC 500 may be programmed to create a desired a spacing of fold lines to form a pallet runner of desired dimensions.

15 **[00137]** Whilst not shown in the FIGS., runner forming station 210 may include one or more sensor in communication with PLC 500. In various embodiments, a sensor may monitor the position and speed of rotation of conveyor 220, the speed of rotation of scoring roller 222, the position of protrusions 322 of scoring roller 222, the position of blank 100/runner 150 on conveyor 220 and/or the position of mandrel 336. PLC 500 may make adjustments to runner
20 forming station 210 based on the signal(s) received from one or more of these sensors.

[00138] Whilst scoring roller 222 as depicted in the FIGS. is shown with four protrusions 322, in various embodiments scoring roller 222 may have any number of projections. The number of protrusions may be beneficial in forming different numbers or different spacing of fold lines in a blank such as blank 100.

25 Adhesive applicator 224

[00139] As blank 100 is further advanced in direction 229 through movement of conveyor 220 adhesive may be applied to some or all of the upper surface of blank 100 by any suitable adhesive applicator apparatus such as adhesive applicator apparatus 224. In an embodiment, adhesive may be applied to all of the upper surfaces of the panels of blank 100.

[00140] Applicator apparatus 224 is shown in greater detail in FIG. 11 and may include a transversely oriented support beam 328, fixedly connected to frame 214 to which may be mounted a plurality of adhesive applicators 330a to 330i. Adhesive applicators 330a-i may each be provided with nozzles 332a-i respectively. Individual adhesive applicators 330a to 330i can be appropriately positioned transversely along support beam 328 such that adhesive applicators 330a-i can provide a suitable adhesive pattern to the upper surface of certain panels of a blank 100 on conveyor 220 as blank passes adhesive applicator apparatus 224. The operation of each adhesive applicator 330a-i may be controlled by PLC 500 by for example suitable wire connections that pass through frame 214. Applicators 330a-i can apply a suitable adhesive to the upper surface of certain panels of a blank 100 at an appropriate time so that when the panels are folded as described herein, the panels can be held in the desired configuration.

[00141] In other embodiments, adhesive applicator apparatus may have any suitable number or arrangement of nozzles.

[00142] An example of a suitable adhesive applicator apparatus 224 that can be employed is the model ProBlue-7 hot melt application system made by Nordson™ Inc. which includes adhesive tank, nozzles/guns and hoses as well as solid state temperature control for the tank, guns and hoses.

[00143] Various types of adhesives may be employed in adhesive applicator apparatus 224. A particular class of adhesives that may be suitable are adhesives in the class of “Hot Melt Adhesives” (referred to as a “HMA”). HMAs may be a thermoplastic adhesive / glue which may be heated in an applicator such as applicators 330a-i by respective heating elements and then expelled from the applicators while hot and tacky onto surfaces which are to be adhered to other surfaces. Depending upon the particular formulation of the HMA selected, the adhesive may for example remain tacky and capable of bonding two surfaces together for, from perhaps a second or a few seconds, to up to a minute or more. In runner forming station 210, an HMA may be applied to the upper surface of certain panels of a blank 100 by applicators 330a-i , to form adhesive lines such as adhesive lines extending transversely across blank 100.

[00144] One particular type of HMAs are pressure sensitive HMAs which may remain tacky and capable to bonding two surfaces together until pressure is applied to the HMA, such as when the HMA is compressed between two surfaces of two panels of a blank 100 as the two

panels are brought together. Such pressure sensitive HMAs may remain tacky and capable of bonding two surfaces together for a long period of time until pressure is applied to the HMA.

5 **[00145]** An example of a suitable adhesive that could be employed on a blank 100 made of cardboard is Cool-Lok adhesive made by Nacan™ Products Limited or a suitable pressure sensitive HMA made by Henkel™ Corporation.

[00146] In other embodiments, the adhesive applicator apparatus 224 may be pressurized cold seal glue system such as those manufactured by Nordson™ Inc.

10 **[00147]** One particular type of adhesive that may be applied to blank 100 may be a pressure sensitive adhesive or cold seal adhesive material. Such materials are known and may comprise a quick-drying, adhesive (for e.g. latex rubber, an acrylic resin, a polyurethane resin, a silicone resin, an acrylonitrile-butadiene or isoprene copolymer resin) that once dried, will create a surface with essentially no tackiness and will only adhere to other surfaces coated with the same adhesive and when placed under pressure. Such a pressure or cold seal adhesive may be capable of being applied to a substrate material at a relatively high rate of production (e.g. 15 such as during a paperboard converting process when multiple blanks are being formed) and of drying relatively quickly. As a result, such a cold seal adhesive applied to blank 100 enables blanks 100 to be manufactured at relatively high production rates. Examples of such pressure sensitive adhesives and cold seal adhesives are discussed in Treatise on Adhesion and Adhesives Vol. 2, "Materials", R.I. Patrick, Ed., Marcel Dekker, Inc., N.Y. (1969); Adhesion and 20 Adhesives, Elsevier Publ. Co., Amsterdam, Netherlands (1967); Handbook of Pressure-Sensitive Adhesive Technology, Donates Satas, Ed., VanNostrand Reinhold Co., N.Y. (1982); EP 0372756 B1; and US Patent No. 8,895,656 the entire contents of which are hereby incorporated herein by reference. Suitable cold seal adhesives that may be employed are available from Henkel Corporation.

25 **[00148]** Adhesive applicators 330a-i may be individually secured and adjusted by use of releasable adjustment mechanisms 334a-i which releasably secures the applicators 330a-i to support beam 328, at positions suitable dependent upon which particular type/configuration of case blank 100 that is being processed. This adjustable positioning of adhesive applicators 330a-i is a feature of pallet forming system 200 that enables pallet forming system 200 to be 30 easily modified when changing over from handling one type/configuration of blank to another type/configuration of blank.

[00149] In some embodiments, small portions of a HMA may be applied to a panel of blank 100 in order to tack adjacent panels in place during the subsequent folding steps and a cold seal adhesive may also be applied along the length of the panel. The HMA will initially secure the adjacent panels in place until the cold seal adhesive is dried and adhered.

5 **[00150]** In some embodiments, the adhesive applicator apparatus may be configured to selectively stamp or roll adhesive onto one or more panels of blank 100.

Panel Rotating Apparatus 226

[00151] Referring back to FIG. 13B, as conveyor 220 advances blank 220, at step 1000(2), the edge 100b of blank 100 (which is the opposite edge of edge 100a described above) is engaged by panel rotating apparatus 226.

10 **[00152]** Panel rotating apparatus 226 is depicted in isolation in FIGS. 12-12C and includes a gripper around which the panels of blank 100 are folded and rotated. In the illustrated embodiment, the gripper comprises a mandrel 336 and the mandrel 336 is moved by a mandrel movement apparatus 338. As will be outlined in more detail herein, mandrel 336 is configured to engage panel A of blank 100 and through a series of rotational and vertical movements, form the spiral structure of runner 150.

[00153] Mandrel 336 includes a first portion 340 and a second portion 342, which may both be elongated structures with a generally triangular cross sectional shape. First portion 340 and second portion 342 may be or solid or tubular. First portion 340 may have a cross-sectional shape in the form of a right angle triangle, with outer facing sides 340a and 340b and an inner facing side (or hypotenuse) 340c. Similarly, second portion 342 has a cross-sectional shape in the form of a right angle triangle, with outer facing sides 342a and 342b and an inner facing side (or hypotenuse) 342c. Generally speaking, whilst first portion 340 may be larger in cross sectional area than second portion 342, the ratio of the lengths of each side may be the same, i.e. the ratio of the length of side 340a to side 340b to side 320c is the same as the ratio of the length of side 342a to side 342b to side 324c.

25 **[00154]** The first end 344 of mandrel 336 may be affixed to inner pulley 346 of mandrel movement apparatus 338 by any suitable method such as bolts or welding such that mandrel 336 will rotate and translate with inner pulley 346. Whilst not shown in the FIGS., the second

end 347 of mandrel 336 may be supported for rotational and translational movement by any suitable attachment mechanism.

[00155] As depicted in FIG. 12C, the outer facing sides 340a and 340b of first portion 340 and the outer facing sides 342a and 342b of second portion 342 may generally define a rectangular outline 348. As will become apparent, the rectangular outline 348 may form a template for panels A to D of the formed pallet runner 150.

[00156] Further, the respective inner sides 340c, 342c of first and second portions 340, 342 define a blank receiving slot 350. Blank receiving slot 350 may have a first configuration for receiving/releasing blank 100 and a second configuration for holding blank 100. In the first configuration blank receiving slot 350 may be slightly larger than the thickness of blank 100. In the second configuration, through movement of first portion 340 and/or second portion 342 of mandrel 336, the gap between inner facing side 340c and inner facing side 342c (FIG. 12C) is decreased, i.e. blank receiving slot 350 is narrowed such that inner facing sides 340c, 342c may engage a portion of a blank 100 such that the blank 100 is securely held by mandrel 336 using pressure. Alternatively, blank 100 may be releasably engaged by mandrel 336 through any other suitable attachment mechanism. For example the blank 100 could be securely held in mandrel 336 using a vacuum source, such as one or more suction cups positioned on either of the inner facing sides 340c, 342 configured to realisably engage a portion of blank 100.

[00157] With reference to FIG.12A, mandrel movement apparatus 338 is configured to allow mandrel 336 to move in both the vertical Z and horizontal Y and X directions (i.e., directions parallel to axes Z, Y and Y in FIGS. 10A and 12A) and to allow mandrel to rotate about a generally horizontally orientated axis of rotation 352 shown in FIG. 12.

[00158] Mandrel movement apparatus 338 includes a vertically orientated support tube 354 that may be generally rectangular. Inner pulley 346 (to which mandrel 336 is connected to) is rotatably mounted to support tube 354 (FIG. 12A) such that mandrel 336 moves in space with support tube 354.

[00159] Affixed to the rear of support tube 354 is a vertically extending rail 356 (FIG. 12B), to which a pair of slide blocks 357, 358 (FIG. 12A) are mounted to rail 356. Slide blocks 357, 358 are each affixed to support bracket 360 (FIG. 12B), which is in turn affixed to frame 214. Slide blocks 357, 358 may each include a vertically extending short inner block, each fitting on

vertically extending rail 356 that holds the blocks securely but allows rail 356 (and therefore support tube 354 and mandrel 336) to slide vertically relative to the blocks (and therefore frame 214). An example of a suitable rail system is the Bosch Rexroth™ ball rail system in which the rails are made from steel and the blocks have a race of ceramic balls inside allowing the block to slide on the rails.

[00160] In order to move mandrel 336 vertically (in the Z-direction in FIG. 12), a drive motor 362 (which may be a servo motor such as the model MPL-B330P-MJ24AA made by Allen Bradley™) is mounted to the top end of rail 354. Drive motor 362 drives drive wheel 364 through gearbox 363 and can be independently driven in both directions at varying speeds by PLC 500 (FIG. 7) through servo drives. A continuous belt 366 may extend downwards in a vertical direction from the left side (as viewed in FIG. 12) of drive wheel 364, generally following support tube 354 to the left side of outer pulley 365. From there, belt 366 loops around outer pulley 365 and extends upwards in the vertical direction to the right side of drive wheel 364. Belt 366 is also connected to the left side 368 of support bracket 360.

[00161] With reference to FIG. 12C, outer pulley 365 may be configured such that inner pulley 346 (to which mandrel 336 is attached) is housed within outer pulley 365, where inner pulley 346 is operable for free rotation relative to outer pulley 365.

[00162] With this arrangement, operation of servo motor 362 will drive movement of belt 366 causing movement of support tube 354 relative to support bracket 360 (along rail 356) such that the vertical position in the Y-direction of support tube 354 and interconnected mandrel 336 can be adjusted relative to frame 214.

[00163] The following will be appreciated in particular:

[00164] - If servo motor 362 is not operated then drive wheel 364 will not rotate and the position of support tube 354 and interconnected mandrel 336 will not be altered;

[00165] - If servo motor 362 is operated such that drive wheel 364 rotates in the clockwise direction (as viewed in FIG. 12), then pulley 365 will also rotate in the same clockwise direction and at the same speed relative to each other, causing of vertical movement of support tube 354 and interconnected mandrel 336 in the Z1 direction (as shown in FIG. 12) through slidable movement on rail 356.

[00166] - If servo motor 362 is operated such that drive wheel 364 rotates in the counter clockwise direction (as viewed in FIG. 12), then pulley 365 will also rotate in the same counter clockwise direction and at the same speed relative to each other, causing of vertical movement of support tube 354 and interconnected mandrel 336 in the Z2 direction (as shown in FIG. 12) through slidable movement on rail 356.

[00167] Also associated with mandrel movement apparatus 338 is a generally vertically oriented caterpillar device 374 which may be generally similar to caterpillar devices 310 and 312 described above. Caterpillar device 374 may have a hollow cavity housing hoses and wires carrying pressurized air/vacuum and electrical/communication wires. Caterpillar device 374 allows such hoses and wires to move longitudinally as the support tube 354 is moved vertically and horizontally.

[00168] The caterpillars allow hoses and wires to supply mandrel movement apparatus 338. In this way both pressurized air/ vacuum and/or electrical communication wires may be brought from locations external to the frame 214 onto the moving mandrel movement apparatus 338. An example of suitable caterpillar devices that could be employed is the E-Chain Cable Carrier System model # 240-03-055-0 made by Icus™ Inc. It should be noted that electrical communication between the PLC 500 and the mandrel movement apparatus 338 could in other embodiments be accomplished using wireless technologies that are commercially available.

[00169] As previously referenced, mandrel movement apparatus 338 is also configured such that mandrel 336 may rotate about a generally horizontally orientated axis of rotation 352 shown in FIG. 12. At a lower end of support tube 354, a servo motor 370 may be attached via a bracket 372, affixed to the lower end of support tube 354. Motor 370 may be similar to the servo motors described above and is connected to inner pulley 346 through gearbox 371 such that servo motor 370 can drive rotational movement of mandrel about axis 352 in either direction. Servo motor 370 may be operated through PLC 500 such that the direction and speed of rotation of servo motor 370 and therefore mandrel 336 may be controlled.

[00170] In some embodiments, mandrel movement apparatus 338 may also be configured to allow mandrel 336 to move in the horizontal Y directions, i.e., in the Y1, Y2 directions indicated in FIG. 12. For example, mandrel movement apparatus 338 could be itself be mounted to a second mandrel movement apparatus, which may be similar to mandrel movement apparatus 338, but is configured to move mandrel movement apparatus 338 in the

Y1, Y2 directions. In other embodiments, mandrel 336 could be mounted to a different movement apparatus such as one similar to movement apparatuses 218a, 218b, 218c described above, which are operable to move mandrel 336 in the X, Y and Z directions.

[00171] It will be appreciated that if the speeds and directions of the motors 362, 370 are varied in different manner, then the motion of the support tube 354 (mandrel 336) can be created that has both a vertical component as well as a horizontal component. Thus, any desired path within these two degrees of freedom (vertical in the Z direction and horizontal in the Y direction) can be created for support tube 354 -- and thus for mandrel 336 (such as a path having curved path portions). At the same time, through operation of motor 370, mandrel 336 may rotate about axis 352. Thus, by controlling the rotational direction and speed of the motors 362, 370 independently of each other, PLC 500 can control movement of mandrel 336 along any path within these two degrees of freedom, within the physical constraints imposed by a pair of bump stops 376, 378 at either end of rail 356 (FIG. 12B) in the Z direction. Similarly, PLC 500 may control movement of mandrel 336 in the horizontal direction (Y1 and Y2 directions in FIG. 12) through control of the second mandrel movement apparatus.

[00172] Encoders may be provided for motors 362, 370 which may be in communication with, and provide signals through the servo drive to PLC 500. The encoder may be similar to as described above for motor 286a. Thus PLC 500 can in real time know/determine/monitor the position of the belt 366 in space and thus will determine and know the position of the mandrel 336 in the Z-direction at any given time and will also determine and know the rotational position of mandrel 336 about axis 352.

[00173] The sequence of steps 1000(1) to 1000(10) in FIGS. 13A to 13J, will now be described whereby runner forming station 210 forms a pallet runner 150 from a runner blank 100.

[00174] At step 1000(1), through control of mandrel movement apparatus 338 by PLC 500, mandrel 336 may be positioned as shown, such that blank receiving slot 350 is generally orientated horizontally and is also horizontally aligned with blank 100 on conveyor 220. Blank receiving slot 350 may also be in its first configuration as described above.

[00175] At step 1000(2), as blank 100 is advanced on belt 316 direction 229, edge 100b of blank 100 will enter blank receiving slot 350. At the same time, as blank 100 advances past scoring roller 222 and adhesive applicator apparatus 224, through operation by PLC 500, folds

102-112 are formed scoring roller 222 and adhesive may be applied by adhesive applicator apparatus 224 to the portions upper surface of blank 100 as described above. As a portion of blank 100 enters blank receiving slot 350, blank receiving slot 350 may move to its second configuration as described above such that mandrel 336 engages a portion of panel A of blank
5 100.

[00176] With reference to FIG. 13C-I, at steps 1000(3) to 1000(9) a sequence steps of folding panels A-X of blank 100 occurs to form the runner 150 may occur through a sequence of rotational and translational movements of mandrel 336. These movements of mandrel 336 are through a combination of rotation of mandrel 336 about horizontal axis of rotation 352 and vertical
10 movement (in the Z-direction) through operation of mandrel movement apparatus 338 as described above and controlled by PLC 500. During steps 1000(3) to 1000(9), blank 100 will also continue to be advanced in direction 229 through movement of conveyor 220 and as this occurs, scoring roller 222 will continue to engage the upper surface of blank 100 in order to create fold lines. Adhesive applicator apparatus 224 may also continue to apply adhesive to portions
15 of the upper surface of blank 100. As will become apparent, adhesive may not be applied to panels A-D in order to prevent panels A-D being bonded to mandrel 336 in subsequent steps.

[00177] First, through steps 1000(2) to 1000(4) (FIGS. 13B to 13D), mandrel 336 may rotate approximately 225 degrees in a clockwise direction, to the position shown in step 1000(4). During rotation of mandrel 336, panel A may be rotated 90 degrees relative to panel B about the
20 fold line 102 between adjacent panels A and B. A 45 degree fold may also be formed in panel A about the intercept of sides 342a and 342c of second portion 342 of mandrel 336 to yield the configuration shown at 1000(4).

[00178] At step 1000(4) (FIG. 13D), mandrel 336 is positioned such that side 342b (FIG. 12C) of second portion 342 is in contact with panel B. Mandrel 336 may then rotate 90 degrees
25 in a clockwise direction to the position shown at 1000(5). During rotation of mandrel 336, panel B may be rotated 90 degrees relative to panel C about the fold line 104 between adjacent panels B and C such that side 340a of first portion 340 is in contact with panel C.

[00179] Mandrel 336 may then rotate a further 90 degrees in a clockwise direction to the position shown at 1000(6). During rotation of mandrel 336, panel C (along with panels A and B)
30 may be rotated 90 degrees relative to panel D about the fold line 106 between adjacent panels C and D such that side 340b of first portion 340 is in contact with panel D.

[00180] The configuration in 1000(6) is shown in more detail in FIG. 13K where panel A is partially located in blank receiving slot 350, wraps around second portion 342 and is contact with side 342a of second portion 342, the now inwardly facing side of panel B is in contact with side 342b of second portion 342, the now inwardly facing side of panel C is in contact with side 340a of first portion 340 and the now inwardly facing side of panel D is in contact with side 340b of first portion 340. Thus, the rectangular shape formed by panels A-D generally conforms to the rectangular outline 348 of first and second portions 340, 342 (FIG. 13A).

[00181] Subsequently, mandrel 336 may rotate a further 90 degrees in a clockwise direction to the position shown at 1000(7). During rotation of mandrel 336, panel D (along with panels A, B and C) may be rotated 90 degrees relative to panel E about the fold line 108 between adjacent panels D and E. As shown in FIG. 13G, the outer face of panel A is in contact with the inner face of panel E and panels A and E may be bonded together due to the adhesive applied to panel E by adhesive applicator apparatus 224.

[00182] Through control of mandrel movement apparatus 338 by PLC 500 during the 90 degree rotational movement of mandrel 336 between 1000(6) and 1000(7) and each 90 degree rotation thereafter mandrel 336 may also move vertically in the Z1 direction (FIG. 12) by a distance approximately equal to the thickness of blank 100 in order to accommodate the increasing size of the partially formed runner., i.e., as a panel is added to the partially formed runner the length or width of the partially formed runner will increase by the thickness of blank 100 and position of vertical of the mandrel will be adjusted to account for this This vertical movement may occur during rotational movement of mandrel 336 or after.

[00183] In some embodiments, rather than mandrel 336 moving vertically in the Z1 direction as described above, conveyor 220 may be configured to move vertically in the Z2 direction (FIG. 10A) in order to accommodate the increasing size of the partially formed runner.

[00184] Following each rotational and vertical (in the Z1 direction) movement of mandrel 336 and before the subsequent rotational and vertical (in the Z1 direction) movement, mandrel 336 may also move vertically in the Z2 direction in order to compress parallel panels that have just been placed into contact with each other. This may ensure sufficient contact between parallel panels such that the adhesive may secure the two panels together. In some embodiments, movement of mandrel 336 may be paused to allow the adhesive to dry or cure sufficiently.

[00185] Through steps 1000(7) to 1000(9) (FIGS. 13G to 13I), the above described sequence of 90 degree rotational and vertical movements of mandrel 336 may be repeated in order to sequentially fold adjacent panels F-X of the partially completed pallet runner form a completed pallet runner 150 shown in FIG. 13J.

5 **[00186]** At step 1000(10), mandrel 336 may disengage from panel A (i.e., by moving from its second configuration to its first configuration) and may also be moved in the Y1 (FIG. 12) direction by mandrel movement apparatus 338 to remove first and second portions 340, 342 from the interior of pallet runner 150. A signal may be sent to PLC 500 to indicate that runner 150 is complete such that runner 150 may then be engaged by second engagement head 216b and
10 moved by second movement apparatus 218b to pallet assembly station 212.

[00187] Under control of PLC 500, mandrel 336 may then be moved in the Y2 and Z2 directions and also be rotated about axis 352 back to the position of step 1000(1) by mandrel movement apparatus 338 and conveyor may move such that ridge 318 or 318b is in the position shown at step 1000(1). Another blank 100 may then be positioned on conveyor 210 by first
15 movement apparatus 218a and the steps 1000(1) to 1000(10) may be repeated in order to form another pallet runner 150.

[00188] In some embodiments, the one or more fold lines may be formed on blank 100 prior to the application of adhesive. In other embodiments, adhesive may be applied to blank 100 prior to formation of the one or more fold lines.

20 **[00189]** In some embodiments, blanks 100 may arrive at runner forming station 210 (or at runner blank conveyor 202) with some or all of the fold lines already formed and/or an adhesive already applied. For example, system 200 may include a separate scoring subsystem to form the one or more fold lines and/or a separate adhesive application subsystem to apply adhesive to some or all of the upper surface of blank 100.

25 **[00190]** In some embodiments, it may not be necessary for mandrel 336 to be moved in the Z1/Z2 directions. For example, if conveyor belt 316 ended prior to mandrel 336, such that mandrel 336 is not positioned over belt 316 (i.e., mandrel 336 is positioned adjacent to belt 316), the unfolded portion of blank 100 may flex to compensate for the growing thickness of the partially formed runner.

[00191] In embodiments where conveyor belt 316 ends prior to mandrel 336, such that mandrel 336 is positioned adjacent to belt 316, the formed runner 150 may simply fall off mandrel 336 or be pulled off mandrel 336. The runner 150 may be pulled off mandrel 336 by a suitable apparatus, such as by another conveyor operating in a generally perpendicular direction to conveyor 220 (i.e., the Y2 direction in FIG. 10A). This may remove the requirement for mandrel 336 to be moveable in the Y1 and Y2 directions as described above.

[00192] The mandrel 336 is only one example of a gripper that may be used to rotate the panels. In some embodiments, the gripper may be configured to engage blank 100 in different manner than described above. For example, the gripper may be configured to engage a smaller portion of panel A only, for example at one end, before rotating as described above to form runner 150. In some embodiments, the gripper may be configured to engage and rotate opposed ends of panel A only.

[00193] In some embodiments, the gripper may be configured to engage a runner template. The runner template may be an elongated structure, that is affixable to panel A (such as by adhesive) which is rotated by the gripper. For example, the runner template may be a rectangular tubular structure made from cardboard or plastic. Once the runner template is affixed to panel A, the gripper will rotate the runner template and the affixed panel A to form a runner, i.e., the runner template substantially performs the same function as mandrel 336, but also forms an integral part of the runner. The runner template may add additional strength and rigidity to the formed runner. Further, if it is desirable to manufacture runners with different cross-sectional profiles, it may be easier, quicker and more economical to change to use a different runner template rather than a different mandrel.

[00194] In other embodiments, runner forming station 210 may be configured to form runners of different cross sectional profiles, such as runner 150' depicted in FIGS. 17A-C. Runner 150' may generally be similar to runner 150 described above, having a generally rectangular cross section with a length l, width w and height h, and formed from a series of adjacent elongate rectangular panels A'-X' (which may be similar to panels A-X of runner 150 described above). Each consecutive panel of runner 150' may be bent along the respective fold lines 102'-144' to form a continuous spiral structure having a continuous cross-sectional profile that is nested, as shown in FIGS. 17A-C. In comparison to runner 150, where panel A includes a 45 degree bend such that a portion of panel A is orientated diagonally across the inner opening of runner 150 (FIG. 3B), in runner 150 the whole of panel A' is generally planar and is orientated

parallel to panels C', E' G', I', K', M', O', Q', S', U' and W'. As will be appreciated, where runners 150 and 150' are generally the same size, panel A' will have a shorter width than panel A.

[00195] In order to form runner 150', panel rotating apparatus 226 may still include a gripper configured to engage panel A' and through a series of rotational and vertical movements, form the spiral structure of runner 150'. However, mandrel 336 may be configured in a different manner to as described above to form runner 150. For example, the mandrel may instead comprise a single portion with a generally rectangular cross section with an outer surface which is configured to engage panel A (such as by one or more suction cups on the outer surface of the mandrel). Similar to as described above for the mandrel may, through a series of rotational and vertical movements, form the spiral structure of runner 150'.

Pallet assembly Station 212

[00196] At pallet assembly station 212 one or more runners 150 may be secured to a deck 170 on deck conveyor 204 to form a corrugated pallet 160. Completed pallets 160 may be transferred and stacked on takeaway conveyor 208.

Deck Conveyor 204

[00197] Deck conveyor 204 is shown in isolation in FIG. 14 and may be configured to receive, hold and move, in the y-direction, a stack of decks 170 stacked in a substantially flat orientation. Deck conveyor 204 may be substantially the same as runner blank conveyor 202 described above and may be configured to move the stack of deck 170 loaded at a first position 380 on a pallet 242 to a second position, also referred to as pallet assembly station 212. A conveyor belt (not shown) may be provided that may be driven by a suitable motor 228b (not shown in FIGS.) such as a DC motor or a variable frequency drive motor, which may be similar to motor 228a described above and may be controlled through a DC motor drive by PLC 500 (FIG. 7). Once all of the decks 170 of the stack of decks 170 have been moved from second position 212, the remaining pallet 242 may be moved to third position 382 and stacked by pallet stacking apparatus 244, which is configured to stack empty pallets 242 into vertical stacks for removal. Similar to runner blank conveyor 202, PLC 500 can control the drive motor of deck conveyor 204 through the motor drive and thus deck conveyor 204 can be operated to move and transfer the stack of decks 170 from first position 380 to second position 212 and move the empty pallet 242 to the third position 382.

[00198] The presence of a stack of decks 170 at the second position 212 may be detected by a sensor 550 (FIG. 7). The sensor 550 may detect the presence of the front edge of a stack of decks 170 at the second position 212 and may send a digital signal to PLC 500 signalling that a stack is at the second position 212.

5 Second engagement head 216b

[00199] Second engagement head 216b may be configured to engage a complete runner 150 from runner forming station 210 and, through second movement apparatus 218b transfer runner 150 to pallet assembly station 212.

10 **[00200]** With reference to FIG. 6C, second engagement head 216b may be mounted to and moved by second movement apparatus 218b that allows second engagement head 216a to move in both the vertical Z and horizontal X/Y directions (i.e., directions parallel to axes Z, X and Y in FIG. 6C).

15 **[00201]** Second engagement head 216b is shown in greater detail in FIGS. 15A-C and may include a pair of spaced apart suction plates, upper suction plate 402 and lower suction plate 404. Upper and lower suction plates 402, 404 may be generally rectangular but may have any other suitable shape, such as square or circular. Upper plate 402 may include a series of spaced apart openings therethrough and lower suction plate 404 may include a series of larger spaced apart openings therethrough. The openings in upper and lower suction plates 402, 404 are configured to receive a plurality of suction cups 410.

20 **[00202]** Suction cups 410 may be similar to suction cups 254 described above and may each be interconnected to a vacuum generator 520 as described above. Each vacuum generator 520 be interconnected to a hose (not shown) that is in turn interconnected to one or more vacuum solenoid valve devices 530, which operate as described above and are in electronic communication with PLC 500 and controlled by PLC 500 such that PLC 500 can turn on and off
25 the supply of vacuum force to the suction cups 410.

[00203] In some embodiments, upper and lower suction plates 402, 404 (and suction cups 410) may be configured rotational movement about a generally vertical axis of rotation 408 (FIG. 15A). This may be achieved through coupling plates 402, 404 to a sprocket 406. Sprocket 406 may in turn be rotationally coupled to the lower end of second movement apparatus 218b
30 such that rotation of sprocket 406 will also rotate upper and lower suction plates 402, 404, suction

cups 410 and any items engaged with suction cups 410 about axis 408. As shown in FIG. 15C, a drive motor 414 may drive rotational movement of sprocket 406 through pulley 416 and toothed belt 418. Drive motor 414 may be similar to any of the servo motors described herein.

[00204] In some embodiments, second engagement head 216b may include a shock absorbing mechanism 420 which functions to absorb forces between upper and lower suction plates 402, 404 and sprocket 406. This may be beneficial in preventing damage to the components of second engagement head 216b, second movement apparatus 218b and any items engaged by second engagement head 216b during operation. Shock absorbing mechanism 420 may be any suitable mechanism operable to perform these functions, such as a spring mechanism.

Second movement apparatus 218b

[00205] Similar to first engagement head 216a, second engagement head 216b may also have a dedicated movement apparatus, second movement apparatus 218b. Second movement apparatus 218b may generally be configured similarly to first movement apparatus 218a described above such that second engagement head 216b may move in both the vertical Z and horizontal X/Y directions (i.e., directions parallel to axes Z, X and Y in FIG. 6C), controlled by PLC 500. With reference to FIG. 6B, second movement apparatus 218b includes a vertically orientated support tube 256b, which may generally be similar to support tube 256a described above. Second engagement head 216b is mounted to support tube 256b by mounting brackets 436 (FIG. 6C) such that second engagement head 216b moves in space with support tube 256b.

[00206] In order to drive second movement apparatus 218b horizontally (in the X-direction in FIG. 6C) a drive apparatus is provided which includes a left side drive motor 272b and a right side drive motor 274b, which may be similar to motors 272a, 274a described above. In order to drive second movement apparatus 218b horizontally in the Y-direction, a drive apparatus is also provided which includes a central drive motor 286b, which may be similar to motor 286a described above.

Pallet Assembly Station 212

[00207] With reference to FIGS. 5A and 5B, at pallet assembly station 212, multiple pallet runners 150 may be combined with a deck 170 to form a completed corrugated pallet 160.

Movement of second engagement head 216b in the foregoing may be affected by second movement apparatus 218b and controlled by PLC 500.

[00208] Through operation of second movement apparatus 218b, second engagement head 216b may be moved towards a completed pallet runner 150 at runner forming station 210 (FIG. 6B), where the upper surface of runner 150 may be engaged one or more of the suction cups 410. The air suction force that may be developed at the outer surfaces of suction cups 410 will be sufficient so that when activated they can engage runner 150 and as second movement apparatus 218b moves second engagement head 216b with an engaged pallet runner 150 from the runner forming station 210 to pallet assembly station 212. Pallet runner 150 may then be brought into contact with deck 170.

[00209] In some embodiments, pallet runner 150 may have a layer of adhesive applied to the surface being brought into contact with deck 170. Alternatively or additionally, deck 170 may have layer(s) of adhesive applied on surface 172 where pallet runners(s) will be situated. The layer of adhesive may be applied by a suitable adhesive applicator apparatus 422 (not shown in FIGS). The adhesive application apparatus may be similar to adhesive applicator apparatus 224 described above and may apply a layer of any suitable adhesive such as those described above.

[00210] As runner 150 is brought into contact with deck 170, downwards pressure may be applied to pallet runner 150, through second engagement head 216b by downwards movement of support 256b of second movement apparatus 218b in order to ensure that the later of adhesive contacts both of the surfaces being brought into contact. This may be desirable when the later of adhesive comprises a pressure sensitive HMA. At this stage, second movement apparatus 218b may pause movement and hold pallet runner 150 in place on deck 170 for a period of time (also known as the contact time). Depending on the type of adhesive being used, this may be necessary to allow the adhesive to cure or set such that surface of pallet runner 150 and deck 170 are adhered together.

[00211] Suction cups 410 will then disengage and release the engaged pallet runner 150 from engagement with second engagement head 216b. The steps described above, where second engagement head 216b returns to runner forming station 210 to pick up another completed runner 150 and places the runner 150 on deck 170 may be repeated until corrugated panel 160 is completed. Once corrugated pallet 160 is completed, second engagement head

216b may move to a home or idle position so as not to interfere with the subsequent movement of corrugated pallet 160.

[00212] Whilst as shown in FIG. 5A, completed runner 150 at runner forming station 210 is placed on deck 170 in the same horizontal orientation i.e. runner 150 only requires movement in the Z and X directions, in some embodiments runner 150 may also be rotated prior to placement on deck 170. This may be achieved through rotation of upper and lower suction plates 402, 404 (and suction cups 410) about axis of rotation 408 as described above. Thus, the orientation of runner 150 may be altered for different configurations/designs of pallets.

[00213] Whilst corrugated pallet 160 as shown in the FIGS is comprised of three runners 150 and a deck 170, in some embodiments the pallet may also include an additional deck such that the runners 150 are sandwiched on opposed sides by a deck 170. A second deck 170 may be introduced using any suitable method. For example, a second stack of decks (which may be generally the same size as decks 170) may be introduced by a separate panel conveyor (which may be similar to blank conveyor 204 described above) and a single deck may be transferred engagement with a suitable engagement head (which may be similar to second engagement head 216b), moved by a suitable movement apparatus (which may be similar to second movement apparatus 218b) into contact with the runners 150 that have already been assembled with deck 170. Adhesive may be applied to the deck or the contacting surfaces of runners 150 as described above.

20 Takeaway conveyor 208

[00214] Takeaway conveyor 208 is shown in isolation in FIG. 16 and may be configured to receive, hold and move, in the y-direction, a plurality of completed corrugated pallets 160. Takeaway conveyor 208 similar to runner blank and deck conveyors 202, 204 described above and may receive one or more corrugated pallets 160 from runner forming station 210 to form a stack of corrugated pallets 160 at a first position 438 and to move the stack of corrugated pallets 160 to a second position 440. A conveyor belt (not shown) may be provided that may be driven by a motor 228c such as a DC motor or a variable frequency drive motor, which may be similar to motor 228a described above and may be controlled through a DC motor drive by PLC 500 (FIG. 7). At second position 440, the stack of corrugated pallets 160 may be offloaded by any suitable method for onwards use or storage, such as by using a fork lift truck. Similar to runner blank and deck conveyors 202, 204, PLC 500 can control the drive motor of deck conveyor 204

through the motor drive and thus deck conveyor 204 can be operated to move and transfer the stack of corrugated pallets 160 from first position 438 to second position 440.

5 **[00215]** The presence of a stack of corrugated pallets 160 at the at first position 438 may be detected by a sensor 560 (FIG. 7). The sensor 560 may detect the presence of an edge of a stack of corrugated pallets 160 at the at first position 438 and may send a digital signal to PLC 500 signalling a stack is at the at first position 438. In some embodiments, sensor 560 may send a digital signal to PLC 500 once the stack reaches a predetermined number of corrugated pallets 160, which may cause PLC 500 to send a signal to motor 228c of takeaway conveyor 208 to move the stack to second position 440.

10 **[00216]** In some embodiments, completed corrugated pallets 160 may be transferred by takeaway conveyor 208 for the loading/packaging of items onto each pallet 160.

15 **[00217]** In some embodiments, corrugated pallets 160 may be transferred by takeaway conveyor 208 for additional manufacturing/processing steps, such as for example the addition of additional panels or runners to corrugated pallet 160 or for the application of a protective coating to pallets 160.

Third engagement head 216c/Third movement apparatus 218c

[00218] Transfer of corrugated pallets from pallet assembly station 212 to the first position 438 of takeaway conveyor 208 may be affected by third engagement head 216c and third movement apparatus 218c.

20 **[00219]** With reference to FIG. 6D, third engagement head 216c may be any apparatus configured to releasably engage a completed corrugated pallet 160. In some embodiments, third engagement head 216c is generally similar to second engagement head 216b described above. Third engagement head 216c may include one or more suction cups 442, each in communication with a vacuum generator 520 and a solenoid valve device 530 similar to as described for suction cups 254 and 410. Each valve device 530 is in electronic communication with PLC 500 and controlled by PLC 500. In this way PLC 500 can turn on and off the supply of vacuum force to the suction cups 442 (FIG. 7).

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[00220] Similar to first and second engagement heads 216a, 216b, third engagement head 216c may also have a dedicated movement apparatus, third movement apparatus 218c.

With reference to FIG. 6D, third movement apparatus 218c includes a vertically orientated support tube 256c, which may generally be similar to support tube 256a described above and to which third engagement head 216c is mounted to such that third engagement head 216c moves in space with support tube 256c.

5 **[00221]** Third movement apparatus 218c may generally be configured similarly to first and second movement apparatuses 218a, 218b described above such that third engagement head 216c may move in both the vertical Z and horizontal X/Y directions (i.e., directions parallel to axes Z, X and Y in FIG. 6D), controlled by PLC 500 (FIG. 7). In order to drive third movement apparatus 218c horizontally (in the X-direction in FIG. 6D) a drive apparatus is provided which
10 includes a left side drive motor 272c and a right side drive motor 274c, which may be similar to motors 272a, 274a described above. In order to drive third movement apparatus 218c horizontally in the Y-direction, a drive apparatus is provided which includes a central drive motor 286c, which may be similar to motor 286a described above.

[00222] In operation, through operation of third movement apparatus 218c, third
15 engagement head 216c may be moved towards a completed corrugated pallet 160 at pallet assembly station 212, where a portion of corrugated pallet 160 may be engaged one or more suction cups on third engagement head 216. The air suction force that may be developed at the outer surfaces the suction cups will be sufficient so that when activated they can engage corrugated pallet 160 and as third movement apparatus 218c moves third engagement head
20 216c with engaged corrugated pallet 160 from the runner forming station 210 to the first position 438 of takeaway conveyor 208. This process may be repeated as additional corrugated pallets 160 are completed at pallet assembly station 212, forming a stack of corrugated pallets 160 at the first position 438 of takeaway conveyor 208. Once the stack reaches a predetermined number of pallets 160, takeaway conveyor 208 may be activated to move the stack from the first
25 position 438 to the second position 440.

[00223] The operation of system 100 will now be described in detail. A plurality of runner blanks 100 may be presented in vertically and transversely oriented stacked arrangement on a
pallet 242 at first position 236 on runner blank conveyor 202 (FIG. 8). A plurality of decks 170 may be presented in vertically and transversely oriented stacked arrangement on a pallet 242 at
30 first position 380 on deck conveyor 204 (FIG. 14).

[00224] PLC 500 causes runner blank conveyor 202 to be operated to move and transfer the stack of runner blanks 100 on pallet 242 from first position 236 to second position 238 (FIG. 8). Next, under control of PLC 500, first movement apparatus 218a is activated to move first engagement head 216a to the uppermost blank 100 in the stack of blanks at second position 238. PLC 500 then activates suction cups 254 such that first engagement head 216a engages and holds a blank 100. First movement apparatus 218a then moves the engaged blank 100 to runner forming station 210 and places blank 100 on belt 316 of conveyor 220. PLC 500 then deactivates suction cups 254 such that first engagement head 216a can disengage from blank 100. First movement apparatus 218a may then move first engagement head 216a away from runner forming station 210 and may return to pick up another blank 100 from second position 238.

[00225] At this stage, runner forming station 210 may be configured as shown in FIG. 13A. Next, as described above and under control of PLC 500 steps 1000(1) to 1000(10) are performed to form a pallet runner 150 from blank 100.

[00226] At this stage, PLC 500 has also operated deck conveyor 204 such that the stack of decks on pallet 242 have been moved from first position 380 to second position 212.

[00227] Next, under control of PLC 500, second movement apparatus 218b is activated to move second engagement head 216b to the completed runner 150 at runner forming station 210. PLC 500 then activates suction cups 410 such that second engagement head 216b engages runner 150. Second movement apparatus 218b then moves the engaged runner to pallet assembly station 212 and places runner 150 on the uppermost deck 170 in the stack of decks at second position/ pallet assembly station 212.

[00228] As second movement apparatus 218b moves an engaged runner to pallet assembly station 212, PLC may activate applicator apparatus 422 to apply a layer adhesive to a surface of the engaged runner and/or to a portion of the upper surface of the uppermost deck 170 in the stack of decks.

[00229] Further, as second movement apparatus 218b moves an engaged runner to pallet assembly station 212, under control of PLC 500 second movement apparatus 218b may rotate second engagement head 216b and the engaged runner about axis 408 (FIG. 15A) through operation of motor 414. This may be necessary to change the horizontal orientation of

the runner, depending on the configuration of the corrugated pallet being produced by system 200.

5 **[00230]** Once runner 150 is placed on deck 170, second engagement head 216b may remain engaged to runner 150 and second movement apparatus 218b may pause movement for a period of time, in order to allow the layer of adhesive between the contacting surfaces sufficient time to adhere. In some embodiments, the second movement apparatus 218b may be operated by PLC 500 such that runner 150 exerts a degree of downward pressure on deck 170 to ensure the adhesive will sufficiently adhere to the contacting surfaces of runner 150 and deck 170.

10 **[00231]** Next, PLC 500 then deactivates suction cups 410 such that second engagement head 216b can disengage from runner 150. Second movement apparatus 218b may then move second engagement head 216b away from runner forming station 210 and may return to pick up another runner 150 from runner forming station 210.

15 **[00232]** The above steps may be repeated until the required number of runners have been orientated and added to deck 170 and a completed corrugated pallet 160 is formed.

20 **[00233]** Next, under control of PLC 500, third movement apparatus 218c is activated to move third engagement head 216c to the completed corrugated pallet 160 at pallet assembly station 212. PLC 500 then activates suction cups 442 such that third engagement head 216c engages corrugated pallet 160. Third movement apparatus 218c then moves the engaged pallet to the first position 438 of takeaway conveyor 208 and places corrugated pallet 160 at first position 438.

25 **[00234]** Next, PLC 500 then deactivates suction cups 442 such that third engagement head 216c can disengage from corrugated pallet 160. Third movement apparatus 218b may then move third engagement head 216c away from first position 438 of takeaway conveyor 208 and may return to pallet assembly station 212 to pick up another corrugated pallet 160.

30 **[00235]** The foregoing cycle can be repeated multiple times to form multiple corrugated pallets 160. It is anticipated that corrugated pallets may be formed at a rate of in the range of about 10 to about 20 corrugated pallets per minute depending on the overall dimensions and configuration (e.g., number or runners or decks) of the corrugated pallets and the size of the machine but other rates of operation are also possible and contemplated.

[00236] After the stack of blanks 100 on pallet 242 at second position of runner blank conveyor 202 is exhausted, PLC 500 may cause runner blank conveyor 202 to be operated to move and transfer the empty pallet 242 from second position 238 to third position 240 to be stacked by pallet stacking apparatus 244. In some embodiments, sensor 540 (FIG. 7) or another similar sensor may detect that the stack of blanks 100 is exhausted and send a digital signal to PLC 500.

[00237] Similarly, after the stack of decks 170 on pallet 242 at second position/ pallet assembly station 212 of runner deck conveyor 202 is exhausted, PLC 500 may cause deck conveyor 202 to be operated to move and transfer the empty pallet 242 from second position 238 to third position 382. In some embodiments, sensor 550 (FIG. 7) or another similar sensor may detect that the stack of blanks 100 is exhausted and send a digital signal to PLC 500.

[00238] Sensor 560 (FIG. 7) of takeaway conveyor 208 (or another similar sensor) may detect once the stack of corrugated pallets 160 at the first position 438 reaches a predetermined number of corrugated pallets 160 and send a digital signal to PLC 500. As a result, PLC 500 may cause takeaway conveyor 208 to move the stack to second position 440 and a fresh stack of corrugated pallets 160 can be started at the at first position 438 as described above.

[00239] The stack of corrugated pallets at second position 440 may be moved away to another location and may subsequently be loaded with one or more items/articles.

[00240] In some embodiments, PLC 500 may be programmed, such as by a user at HMI 510 with the number of runner blanks 100 and/or the number of decks 170 provided and system 200 may operate until all runner blanks 100 and/or of decks 170 have been exhausted.

[00241] PLC 500 may be configured to coordinate the components of system 200, such that system 200 may continuously and efficiently produce corrugated pallets 160. By way of example, PLC may ensure that as a runner 150 is completed at runner forming station 210, second engagement head 216a is in position to engage the completed runner, through coordination of runner forming station 210 and second movement apparatus 218b. At the same time, first movement apparatus 218a may position first engagement head 216a, with an engaged runner blank 100 proximal to runner forming station 210, such that runner forming station 210 can quickly receive runner blank 100 after a completed runner 150 is removed.

[00242] In some embodiments, runners 150 may be arranged in different configurations on a corrugated pallet, for example using different numbers or arrangements of runners 150 on deck 170. This may be desirable for a number of reasons, for example to increase the strength of the corrugated pallet or to accommodate different forks of lifting equipment. For example,
5 when a pallet is required to support a heavier load, a greater number of runners may be used.

[00243] Furthermore, in some embodiments the thickness of runner blank 100 and/or deck 170 may be varied to alter the properties of corrugated pallet 160. For example, a thicker material may be used to increase the strength and/or durability of corrugated pallet 160. PLC
10 500 may be pre-programmed to make adjustments to the operation of other components in system 200 to account for changes in the thickness of runner blank 100 and/or deck 170, in particular to the operation of motors 362 and 370 of panel rotating apparatus and motor 324 of scoring roller 320.

[00244] In some embodiments, system 200 may be configured to produce a four way pallet that may be accessed from any side by a fork lift. In such configurations the pallet may
15 include shortened runners. These runners may be produced from runner blanks having a shorter length or by the cutting a longer runner (such as runner 150). The runner may be cut using any suitable method, such as die cutting.

[00245] An example of a four way pallet 660 is shown in FIG. 18. Pallet 660 may include a deck 670 (which may be similar to deck 170 described above) with three spaced
20 apart rows of pallet runner blocks 662a, 662b, 662c secured to lower surface 672 of deck 670. Row 662a may include pallet runner blocks 650a, 652a, 652a, row 662b may include pallet runner blocks 650b, 652b, 652b and row 662c may include pallet runner blocks 650c, 652c, 652c.

[00246] When assembled, pallet 660 includes a pair of spaced apart parallel openings 664 (similar to pallet 160) and also a pair of spaced apart parallel openings 666, defined by the
25 spaces between adjacent pallet runner blocks. Through this arrangement the forks of equipment such as a front-end loader or forklift truck to be inserted either of the spaces 664, 666 such that the pallet and its supported load may be lifted and moved.

[00247] In various embodiments, the spacing and length of pallet runner blocks 650a-c, 652a-c and 654a-c may be varied.

[00248] Each of the pallet runner blocks 650a-c, 652a-c and 654a-c may be constructed and formed in a similar manner to pallet runner 150 described above. In an embodiment, pallet runner blocks 650a-c, 652a-c and 654a-c are formed from a pallet runner 150 that has been cut into smaller blocks, such as by die cutting. In other embodiments, pallet runner blocks 650a-c,
5 652a-c and 654a-c may be formed individually on a pallet forming system, such as pallet forming system 200 described above from a suitably sized blank.

[00249] Another example of a four way pallet 760 is shown in FIG. 19. Pallet 760 may include a deck 770 (which may be similar to deck 170 described above) with three runners 750a, 750b and 750b, spaced apart in a parallel arrangement and secured to lower surface 772
10 of deck 770. Runners 750a, 750b and 750b may be similar to runner 150 described above but each include a pair of spaced apart cut out portions sized to accommodate the forks of equipment such as a front-end loader or forklift truck. Runner 750a includes cut out portions 752a, 754a, runner 750b includes cut out portions 752b, 754b and runner 750c includes cut out portions 752c, 754c. Cut out portions 752a-c, 754a-c may be formed by cutting removing a section from a
15 formed pallet runner 150, such as by die cutting. Alternatively, the blank used to form pallet runners 750a-c may be similar to blank 100 but may include a series of cut out portions such that when the blank is formed into pallet runners 750a-c (such as on pallet forming system 200), the runner is formed with cut-out portions 752a-c, 754a-c.

[00250] In various embodiments, the spacing and depth of cut out portions 752a-c, 754a-c
20 c may be varied.

[00251] When assembled, pallet 760 includes a pair of spaced apart parallel openings 764 (similar to pallet 160) and also a pair of spaced parallel openings 766, defined by the spaces between adjacent pallet runner blocks. Through this arrangement the forks of equipment such as a front-end loader or forklift truck to be inserted either of the spaces 764, 766 such that the
25 pallet and its supported load may be lifted and moved.

[00252] Pallets 660, 670 may be manufactured from planar blanks on a pallet forming system, such as a modified version of pallet forming system 200.

[00253] In some embodiments pallets 660, 760 may comprise a second deck secured to the opposite side of the runners/runner blocks to that of decks 670, 770.

30 **[00254]** In some embodiments, runner blank 100 may be a different material to deck 170.

[00255] In some embodiments, blank 100 is a single wall “A” flute sheet that is between about 20 and about 46 inches long and between about 24 inches and about 54 inches wide. In an embodiment blank 100 is about 38 inches long and about 46 inches wide.

5 **[00256]** In some embodiments runner 150 is between about 30 and about 46 inches long, between about 2 inches and about 5 inches high and between about 1.5 inches and about 3.5 inches wide. In an embodiment blank 100 is about 46 inches long, about 2.5 inches high and about 2.5 inches wide.

10 **[00257]** In some embodiments, deck 170 is “BC” flute sheet that is between about 36 and about 50 inches long and between about 40 inches and about 62 inches wide. In an embodiment blank 100 is about 42 inches long and about 48 inches wide.

15 **[00258]** In various embodiments, system 200 may be configured to form corrugated pallets 160 having a length of between about 30 inches and about 50 inches, a width of between about 30 inches and about 50 inches and a height of between about 2.75 inches and about 5 inches. In an embodiment pallet 160 has a length of 40 inches, a width of 40 inches and a height of 3.5 inches.

20 **[00259]** In some embodiments where system 200 is configured to produce corrugated pallets where the runners 150 are sandwiched by a deck 170 on opposed sides, the pallet may have a length of between about 38 inches and about 54 inches, a width of between about 34 inches and about 50 inches and a height of between about 3 inches and about 5 inches. In an embodiment the pallet has a length of 46 inches, a width of 42 inches and a height of 4.1 inches.

25 **[00260]** As discussed above, when it is desired to change the type/configuration of runner and/or corrugated pallet to be formed, using a different type/configuration of runner blank, pallet forming system 200 can be quite easily modified. For example, one mandrel 336 can be replaced by a differently configured mandrel. By using a mandrel with a different cross-sectional profile (i.e., different to the rectangular outline 348 described above for mandrel 336), pallet runners of different sizes of cross sectional shapes may be formed such as triangular, square, pentagonal or hexagonal. PLC 500 may be pre-programmed to make adjustments to the operation of other components, in particular to the operation of motors 362 and 370 of panel rotating apparatus and motor 324 of scoring roller 320. Thus by an interchange of
30 mandrel 336 to provide for alternate configurations of the pallet runner, PLC 500 and its

operation components of runner forming station 210 may be appropriately programmed and thus different sized and configurations of pallet runners may be formed.

[00261] Of particular note, each stack of blanks 100 on runner blank conveyor 202 may have associated information that can be read by an information reader 570 (FIG. 7) such as electronic or an optical reading device. For example, a machine-readable code, such as a bar code or QR code may be provided on each stack of blanks 100, such as on the top or bottom blank of the stack. The machine-readable code may be read by a reader associated with runner blank conveyor 202. The reader may be in communication with PLC 500. The machine-readable code may provide information indicative of a characteristic of the blanks in the stack. For example, the machine-readable code may identify the size and/or type of blank in a particular stack. Other information indicators may be used such as for example RFID tags/chips and RFID readers. The information can then be automatically provided by the information reader to PLC 500 which can determine whether the current configuration of system 200 can handle the processing the particular type/size of blanks without having to make manual adjustments to any of the components. It is contemplated that within a certain range of types / sizes of blanks, system 200 is able to handle the processing of different types/sizes of blanks without manual adjustment of any components of system 200. The machine-readable code/RFID tag may provide the information about the dimensions of the blank as discussed above and then PLC 500 can determine adjustments, if any, that need to be made to components of system 200. The same may be applicable for each stack of decks 170 on runner deck conveyor 204. The result is that system 200 may be able to automatically process at least some different types of blanks to form pallet runners and/or corrugated pallets, without having to make manual operator adjustments to any components of system 200.

[00262] The structural/mechanical components of system 200 may be made from any suitable materials. For example, frame members, and many of the parts that make up the engagement heads 216a-c, movement apparatuses 218a-c, conveyors 202, 204, 206 may be made of steel or aluminium, or any other suitable materials. Aluminum is particularly suitable for most parts. However, plates that hold the suction cups on the engagement heads and flanges that mount on gearbox shafts can be made from stainless steel for strength and hardness. Parts and components may be attached together in conventional ways such as for example by bolts, screws, welding and the like.

[00263] An embodiment as disclosed herein relates to a method of forming an elongate pallet runner from a planar blank comprising a plurality of adjacent panels. The method comprises: engaging a first panel of the plurality of adjacent panels at a first end of the blank with a gripper, rotating the gripper and the engaged first panel, causing rotation of each of the plurality of adjacent panels relative to its adjacent panel, to thereby form an elongate pallet runner around an outer portion of the gripper with a continuous spiral structure that is nested, each panel having a planar surface that abuts against a planar surface of another panel, and disengaging the first panel from the gripper.

[00264] In some embodiments, the method further comprises engaging an upper surface of the planar blank with a scoring apparatus to form the plurality of adjacent panels by scoring a plurality of parallel spaced apart fold lines, a respective fold line separating each of the adjacent panels.

[00265] In some embodiments, the method further comprises applying an adhesive to a surface of at least one of the plurality of adjacent panels.

[00266] In some embodiments, the gripper comprises a mandrel.

[00267] In some embodiments, as the gripper is rotated, the gripper is also moved vertically in a direction perpendicular to an upper surface of the planar blank. In some embodiments, for each 90 degree rotation of the gripper, the gripper is moved vertically a distance equal to about a thickness of the planar blank.

[00268] An embodiment as disclosed herein relates to an apparatus for forming an elongate pallet runner from a planar blank comprising a plurality of adjacent panels. The apparatus comprises a gripper configured to engage a first panel of the plurality of adjacent panels at a first end of the blank, wherein rotation of the gripper and the engaged first panel causes rotation of each of the plurality of adjacent panels relative to its adjacent panel, so as to form an elongate structure with a continuous spiral structure that is nested, each panel having a planar surface that abuts against a planar surface of another panel.

[00269] In some embodiments, the apparatus further comprises a scoring apparatus configured to form the plurality of adjacent panels by scoring a plurality of parallel spaced apart fold lines, a respective fold line separating each panel and its adjacent panel. In some embodiments, the scoring apparatus comprises a scoring roller.

[00270] In some embodiments the apparatus further comprises an adhesive applicator apparatus configured to apply an adhesive to a surface of at least one of the plurality of adjacent panels.

5 **[00271]** In some embodiments the apparatus further comprises a conveyor configured receive the planar blank and to advance the planar blank in a linear direction towards the gripper. In some embodiments, the conveyor comprises an engagement feature to retain the planar blank in position on the conveyor.

10 **[00272]** In some embodiments, the gripper is rotated by a movement apparatus. In some embodiments, the movement apparatus is also configured to move the gripper vertically in a direction perpendicular to an upper surface of the planar blank

[00273] In some embodiments, the gripper comprises a mandrel. In some embodiments, the mandrel has an outer portion having a cross-sectional shape that provides a template for the elongated pallet runner to be formed around. In some embodiments, the mandrel comprises a first portion and second portion, wherein the first and second portion
15 define a blank receiving slot configured to receive a portion of the first panel.

[00274] In some embodiments, the blank receiving slot has a first configuration and a second configuration, wherein in the first position the first panel is disengaged with the mandrel and in the second position the first panel is engaged with the mandrel.

[00275] An embodiment as disclosed herein relates to a system for forming a pallet.
20 The system comprises a runner forming station operable to receive a plurality of planar blanks and form a plurality of elongate pallet runners from the planar blanks. Each of the elongate pallet runners comprises a plurality of panels, each panel bent relative to an adjacent panel to form a continuous spiral structure having a cross-sectional profile that is nested, each panel having a planar surface that abuts against a planar surface of another panel. The system
25 further comprises a pallet assembly station operable to receive a deck and a plurality of pallet runners from the runner forming station, a first engagement head operable to engage one of the plurality of pallet runners and a first movement apparatus operable to move the first engagement head between the runner forming station and the pallet assembly station to move the engaged pallet runner from the runner forming station to the pallet assembly station and
30 to place the engaged pallet runner on a surface of the deck.

[00276] In some embodiments, the system further comprises a second engagement head configured to engage a planar blank from a stack of planar blanks and a second movement apparatus configured to move the second engagement head between the stack of planar blanks and the runner forming station to move the engaged planar blank from the stack
5 of planar blanks to the runner forming station.

[00277] In some embodiments, the system further comprises a third engagement head configured to engage a pallet at the pallet assembly station and a third movement apparatus configured to move the third engagement head between the pallet assembly station and a stack of pallets to move the engaged pallet from the pallet assembly station to the stack of
10 corrugated pallets.

[00278] In some embodiments, the system further comprises an adhesive applicator apparatus configured to apply an adhesive to a surface of the engaged pallet runner or to the surface of the deck before the engaged pallet runner is placed on the surface of the deck by the first movement apparatus.

[00279] The above-described embodiments are intended to be illustrative only and in no way limiting. The described embodiments of carrying out the invention are susceptible to many modifications of form, arrangement of parts, details and order of operation. Other variations are possible.

[00280] When introducing elements of the present invention or the embodiments thereof, the articles “a,” “an,” “the,” and “said” are intended to mean that there are one or more
20 of the elements. The terms “comprising,” “including,” and “having” are intended to be inclusive and mean that there may be additional elements other than the listed elements.

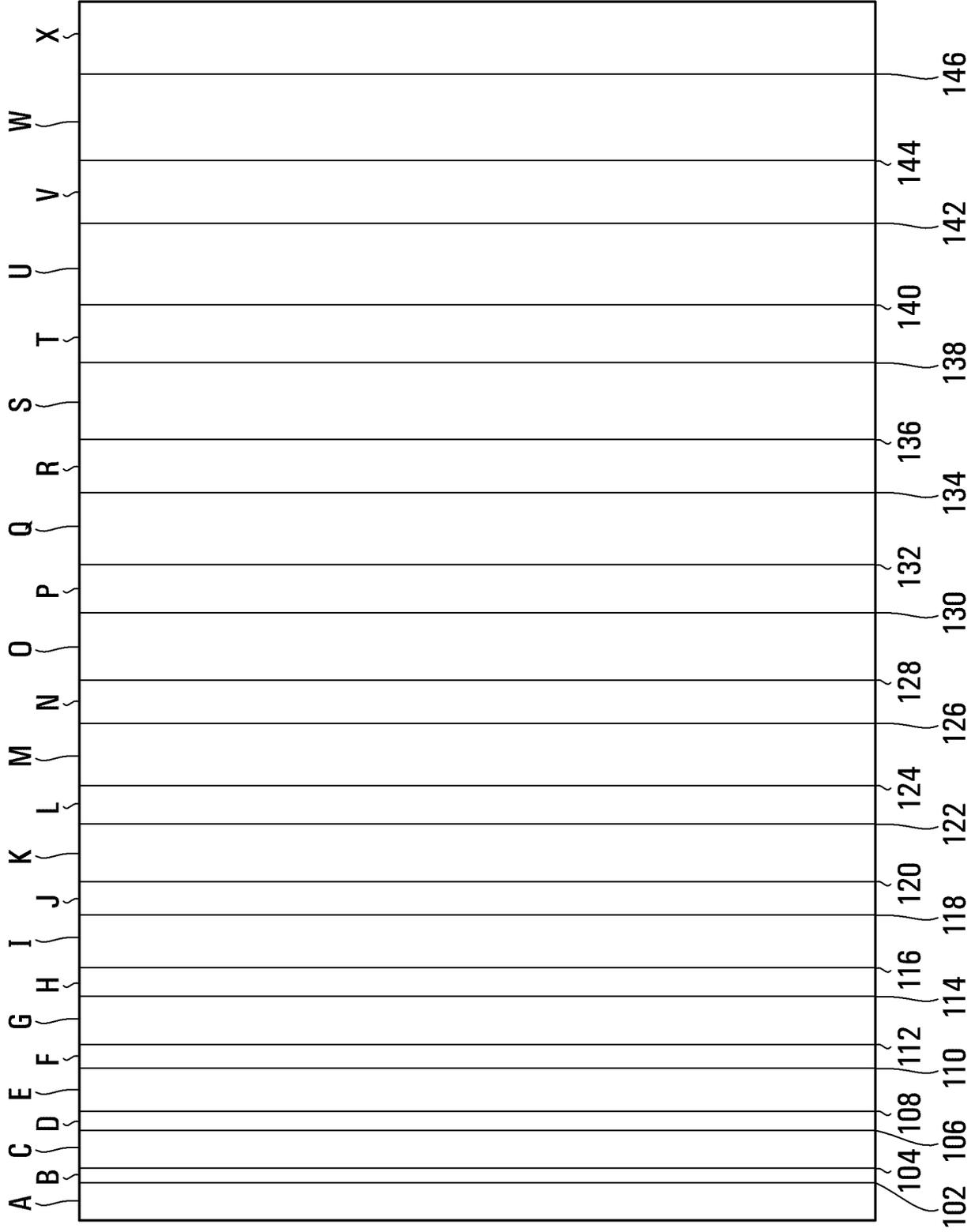


FIG. 1

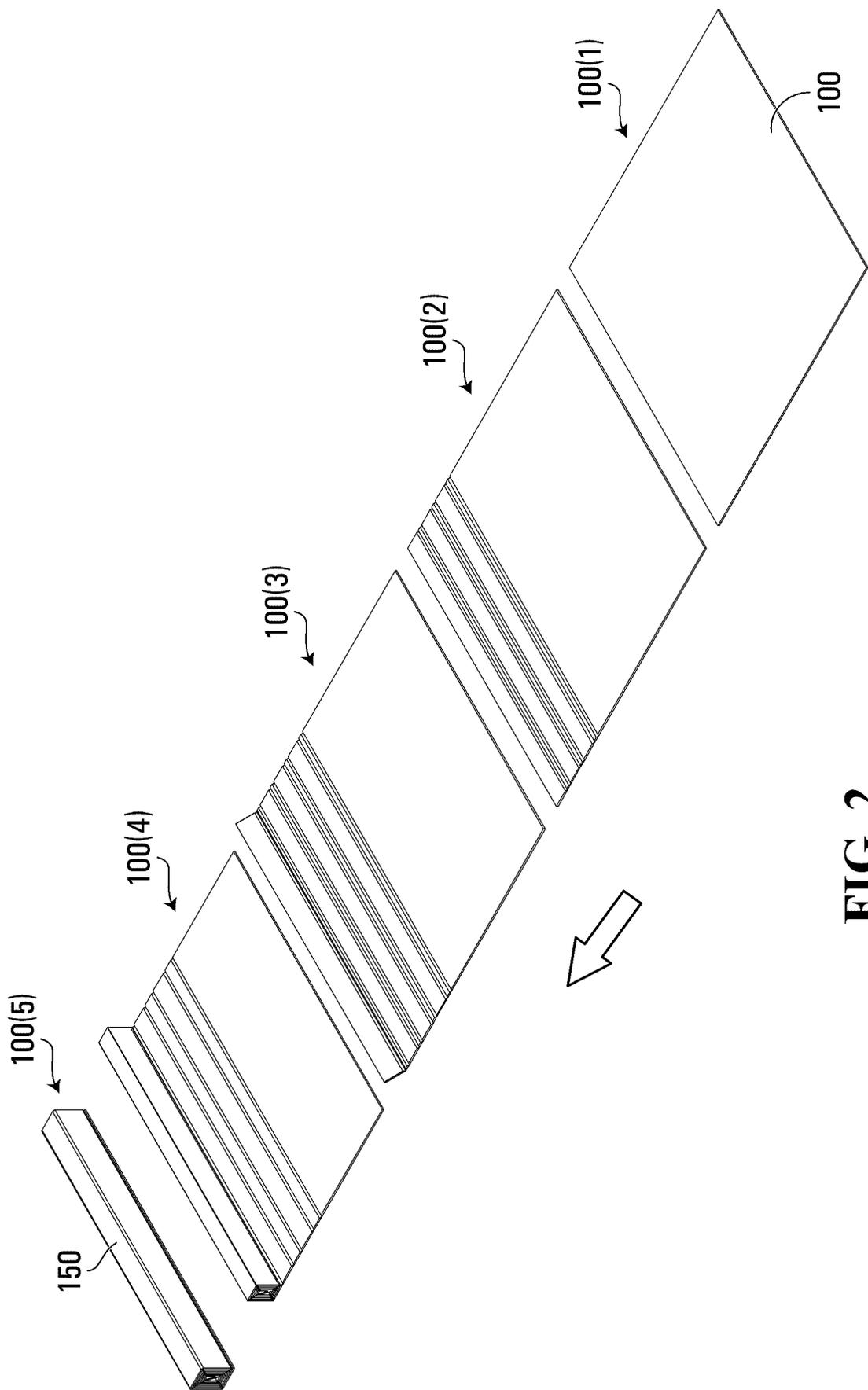


FIG. 2

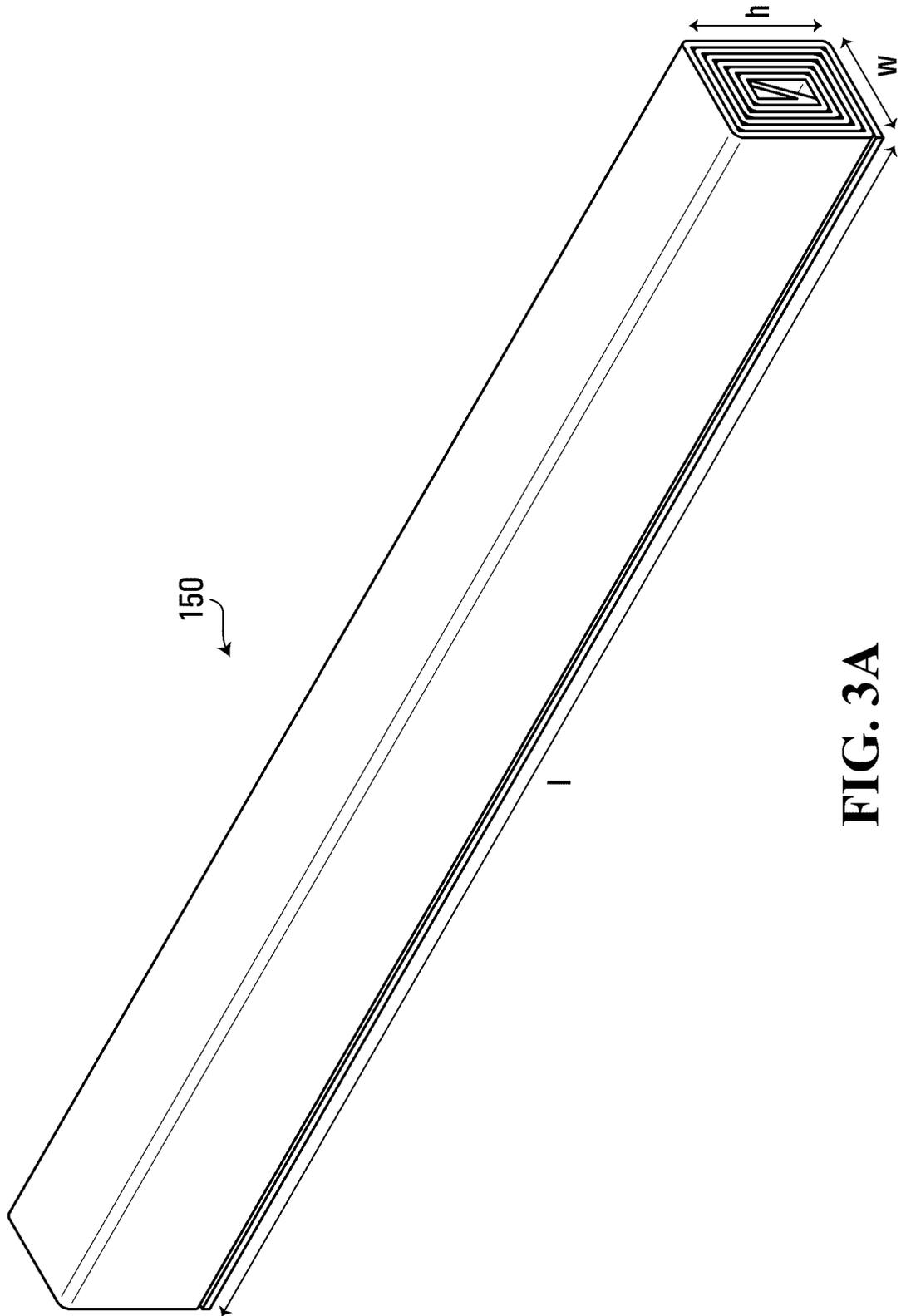


FIG. 3A

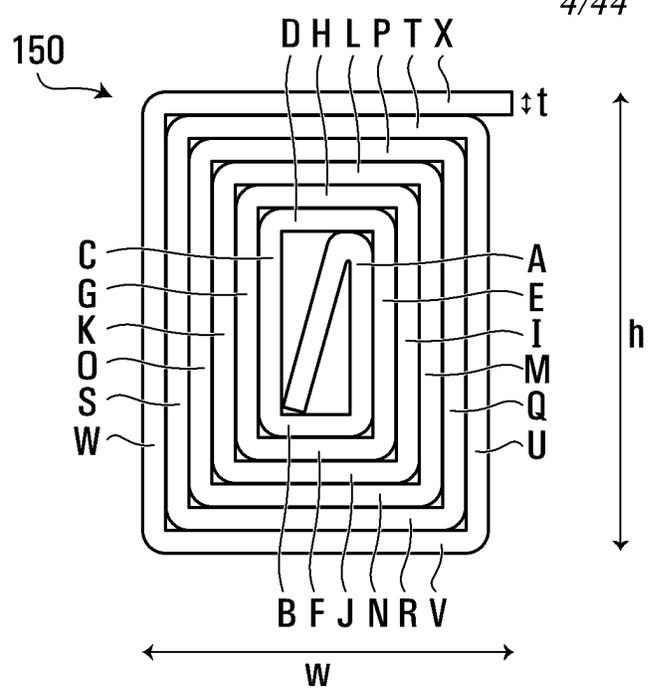


FIG. 3B

FIG. 3C

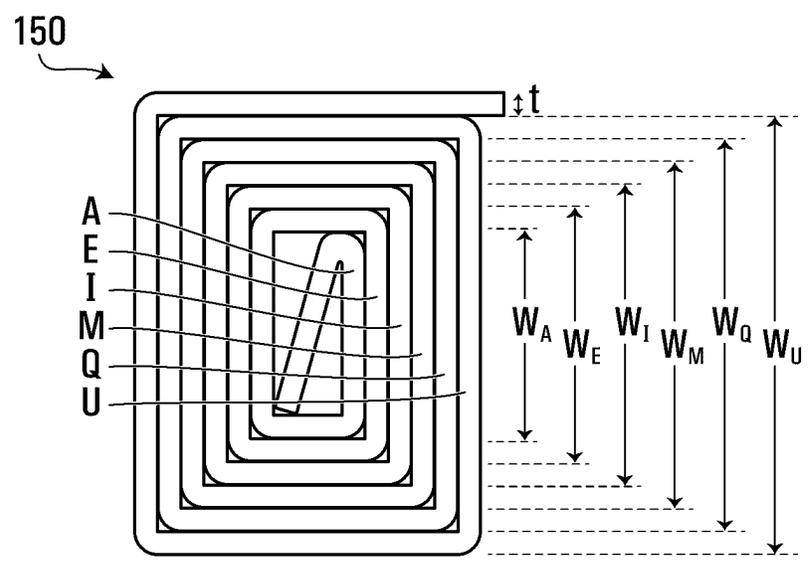
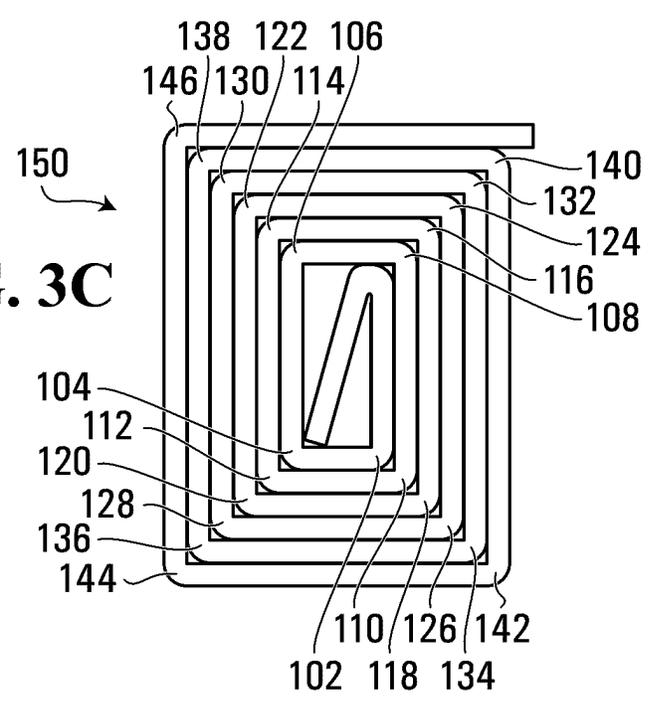


FIG. 3D

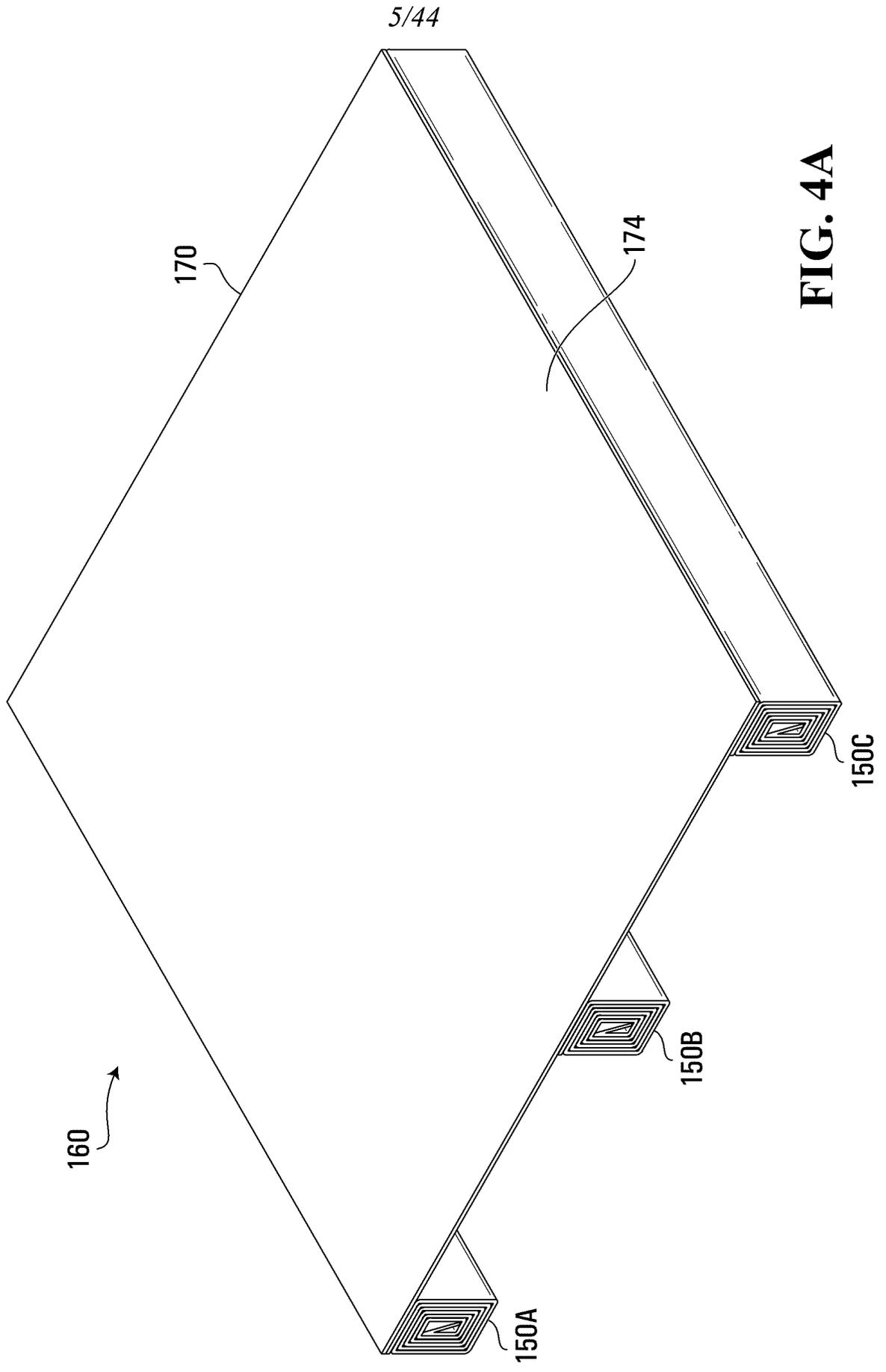


FIG. 4A

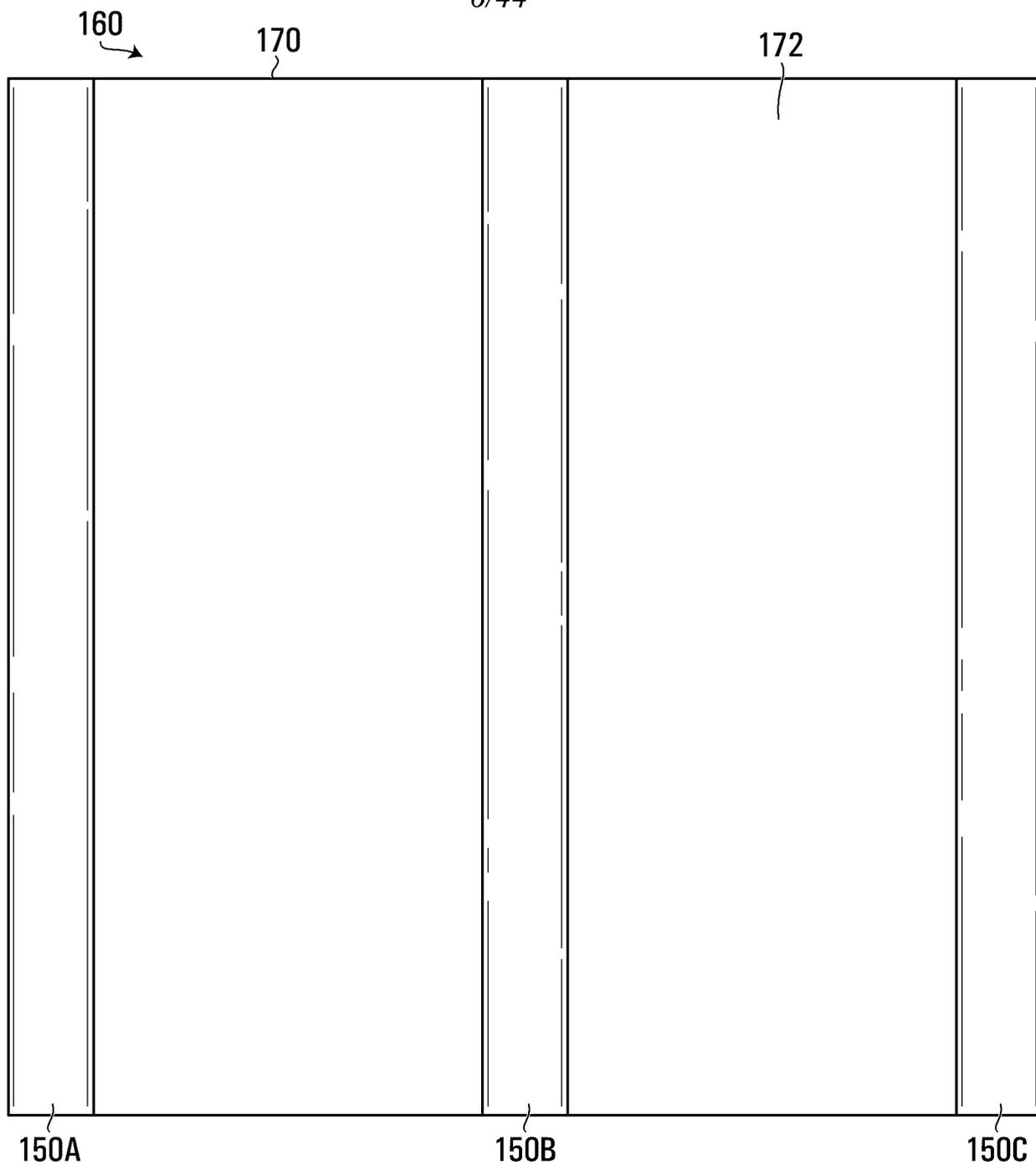


FIG. 4B

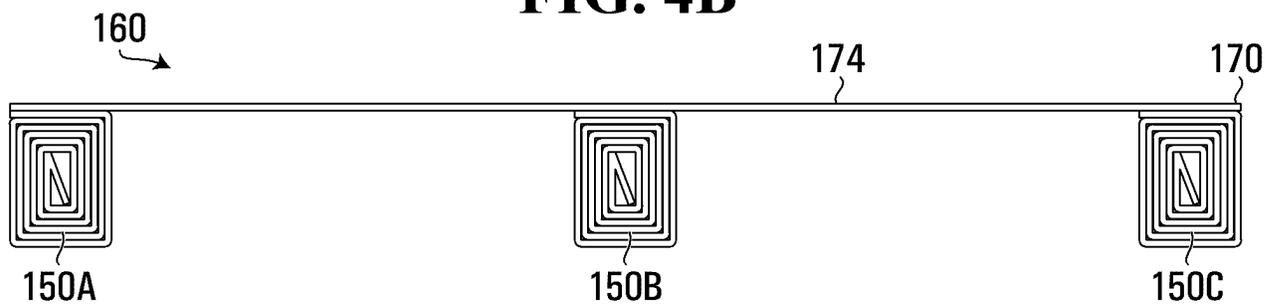


FIG. 4C

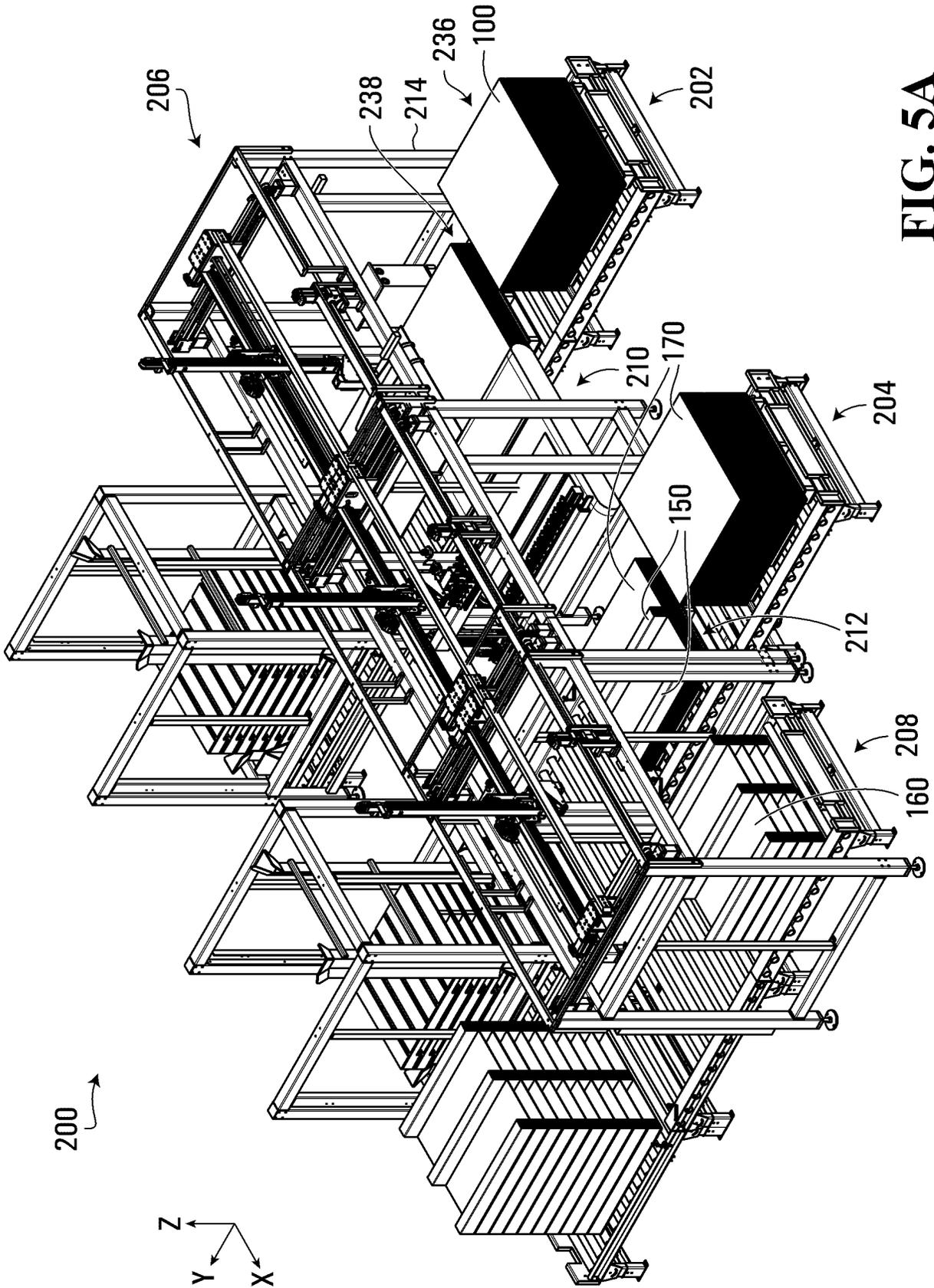


FIG. 5A

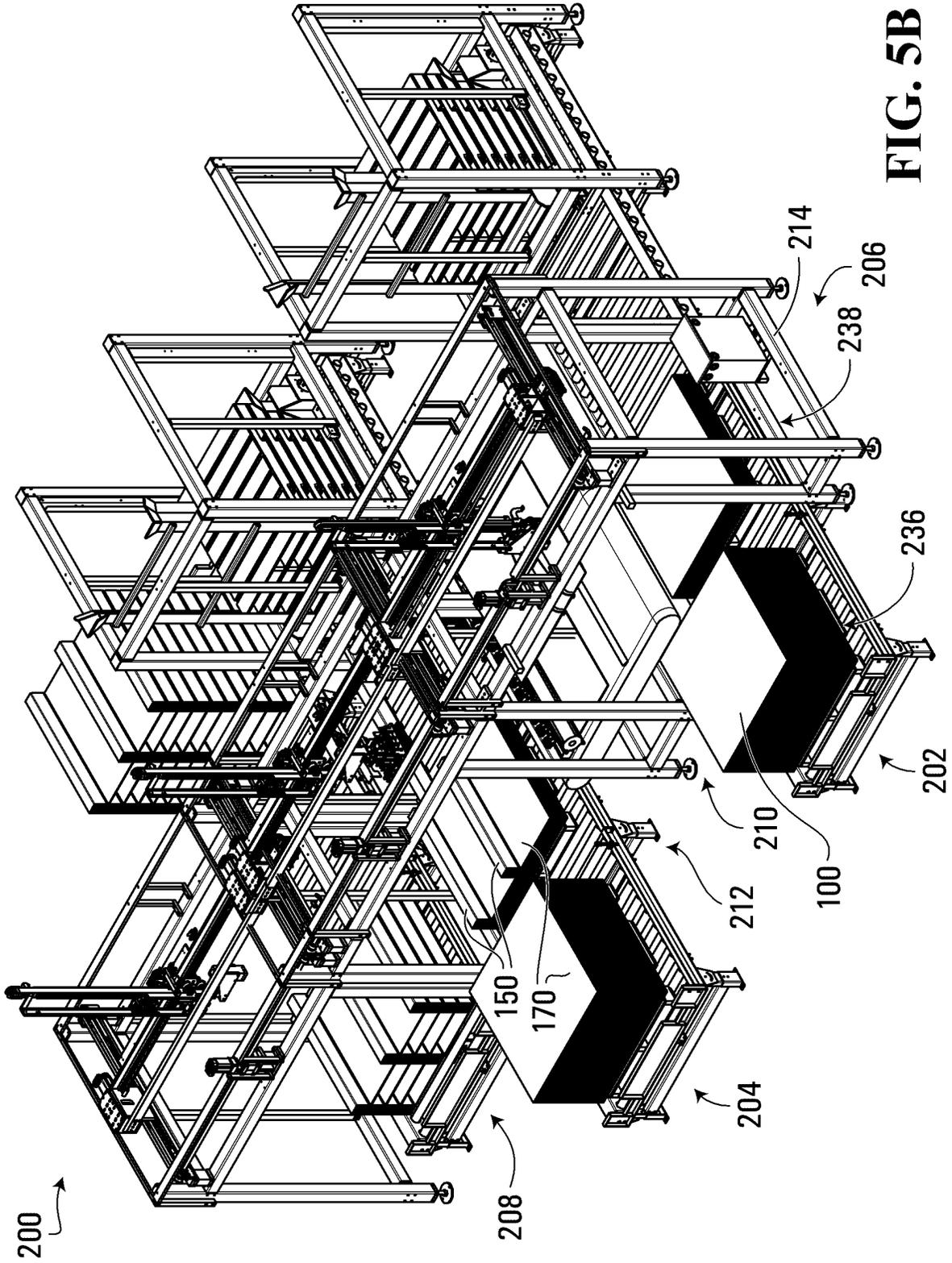


FIG. 5B

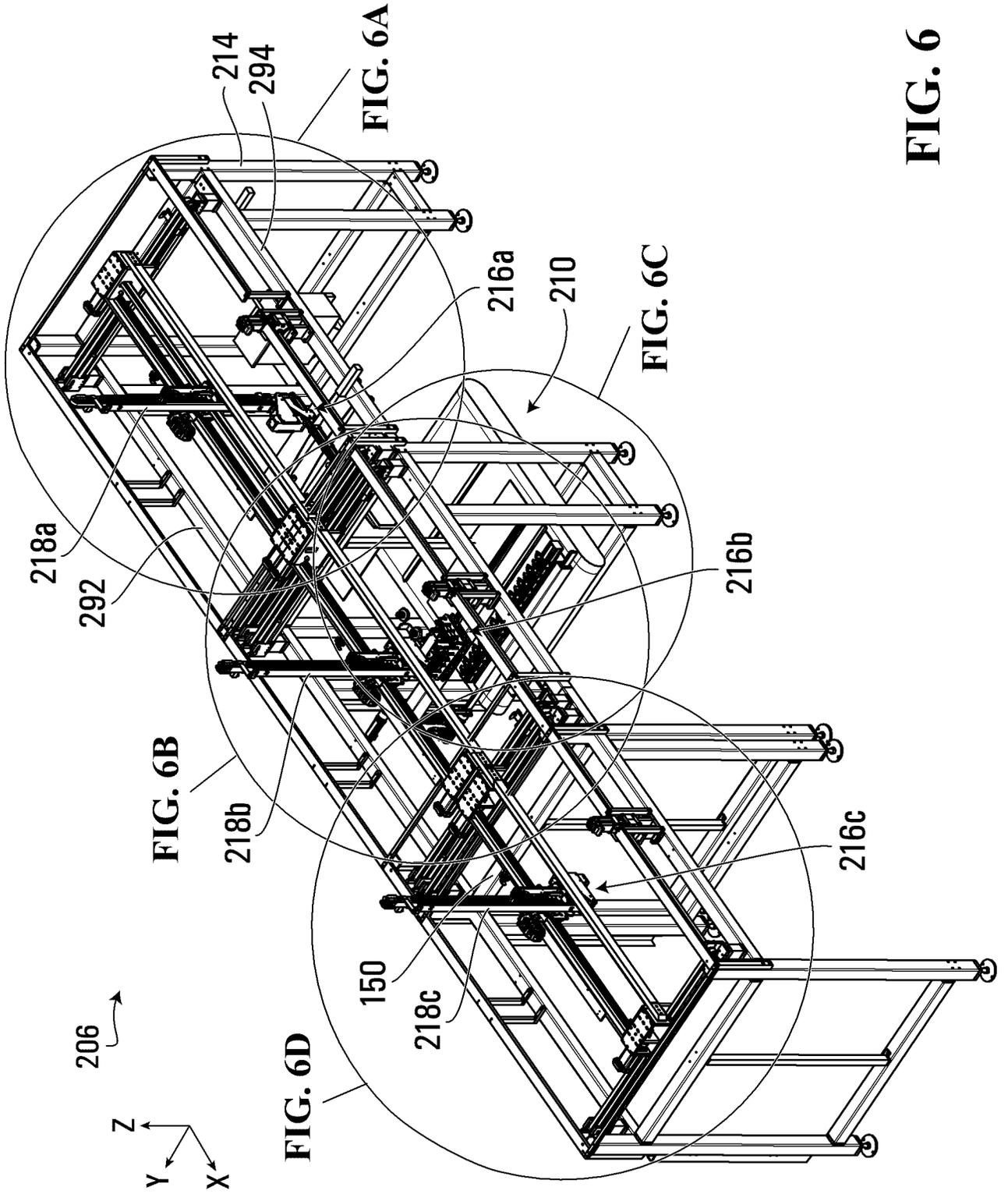


FIG. 6

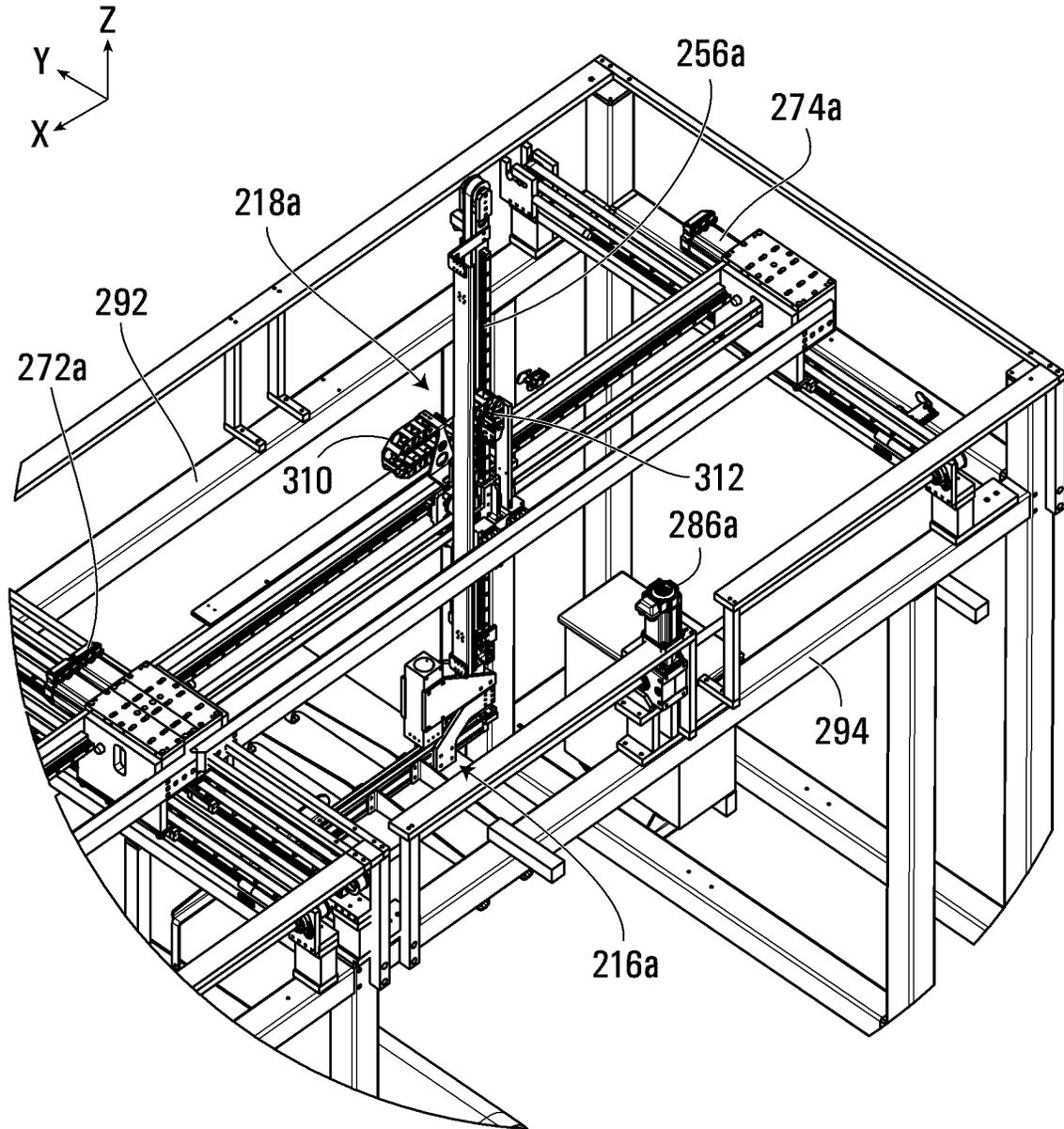


FIG. 6A

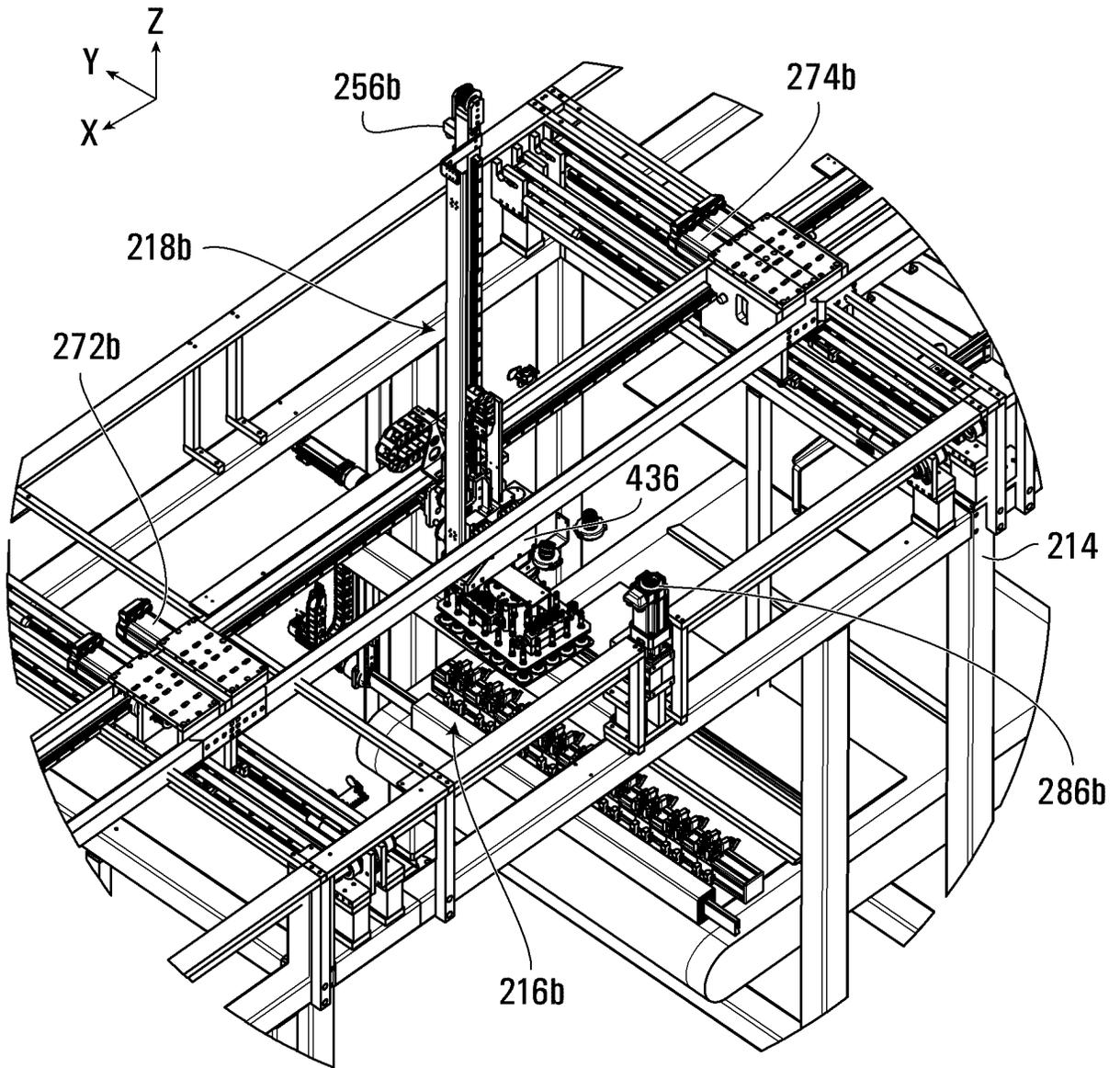


FIG. 6B

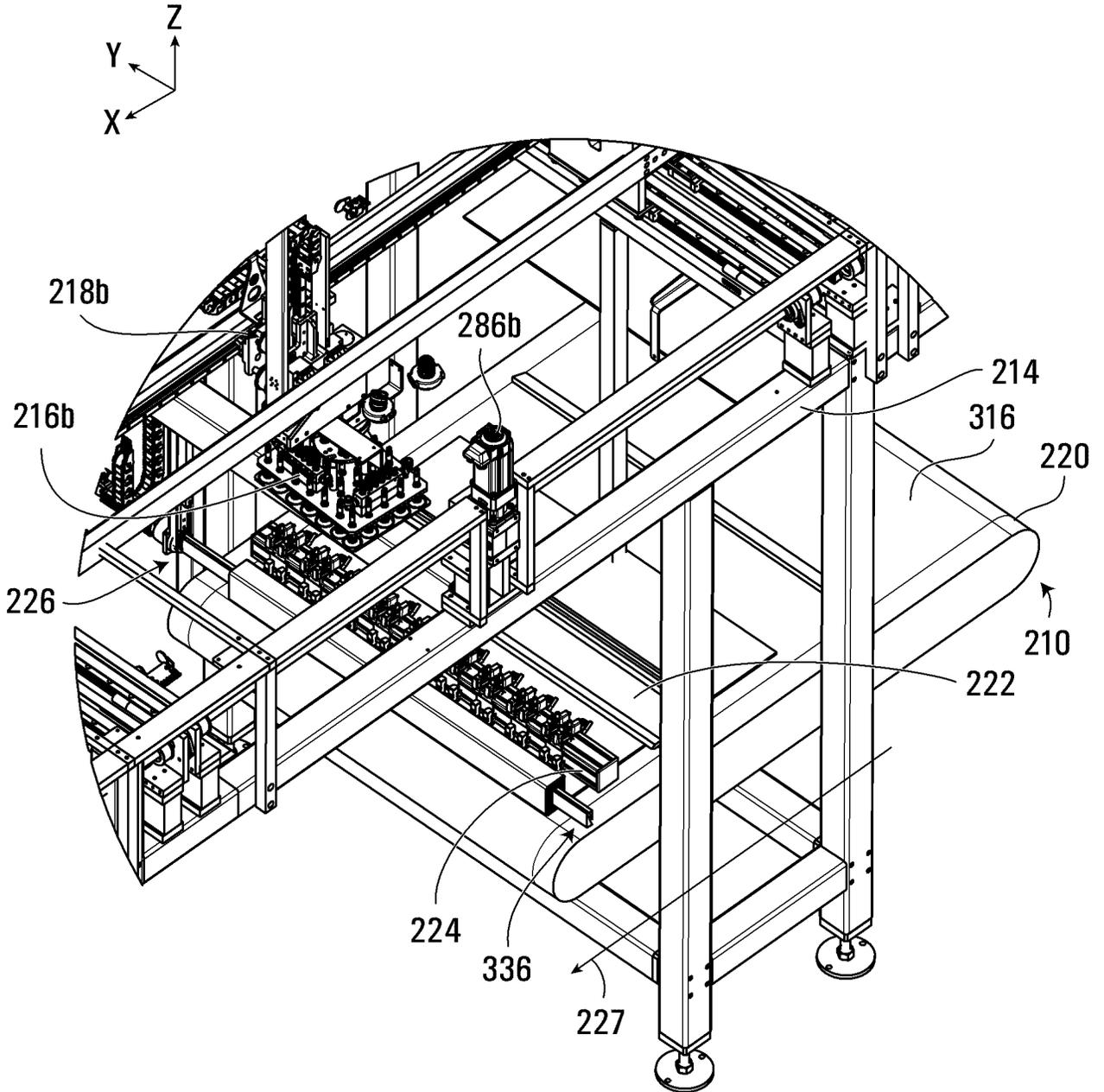


FIG. 6C

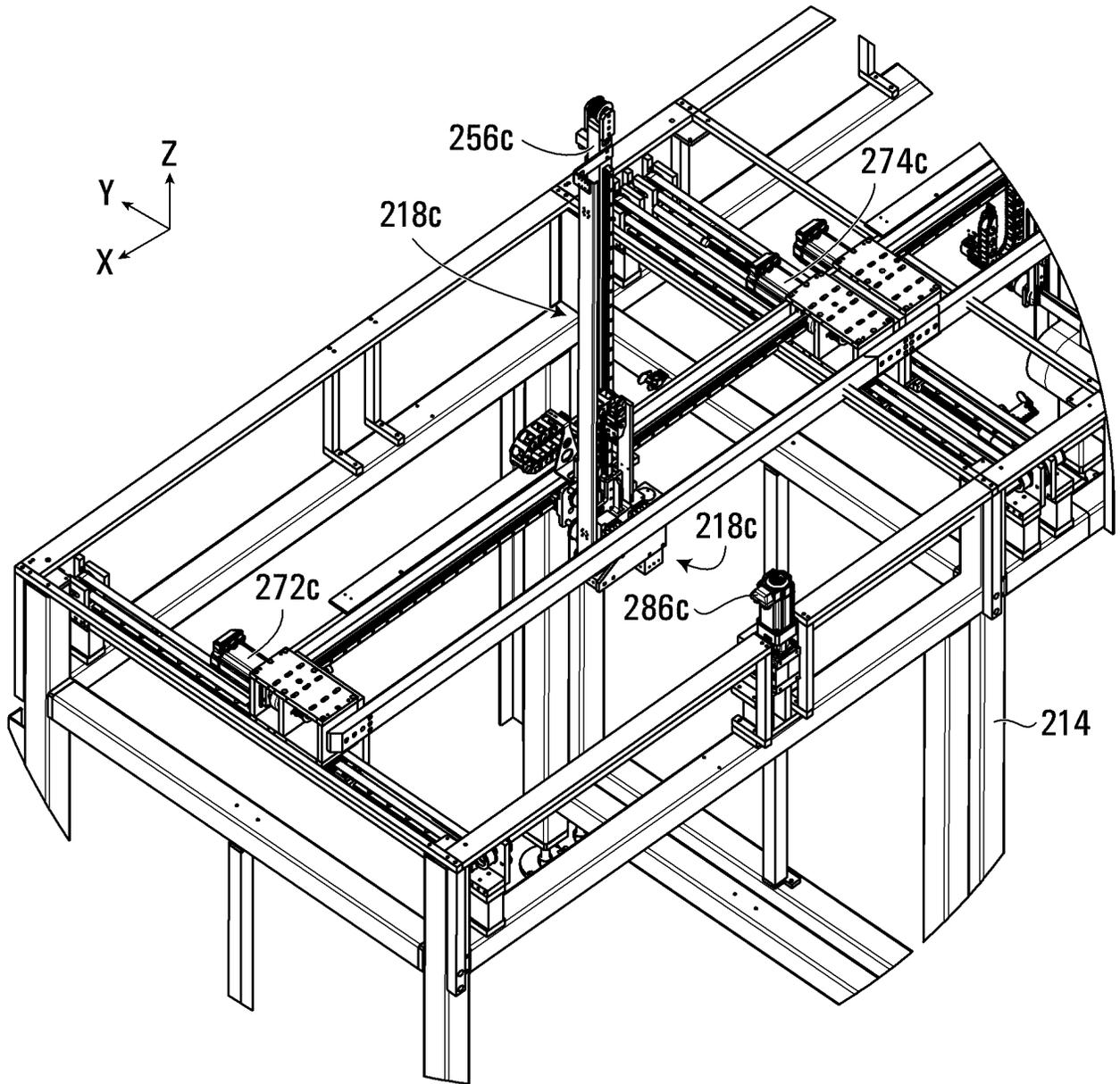


FIG. 6D

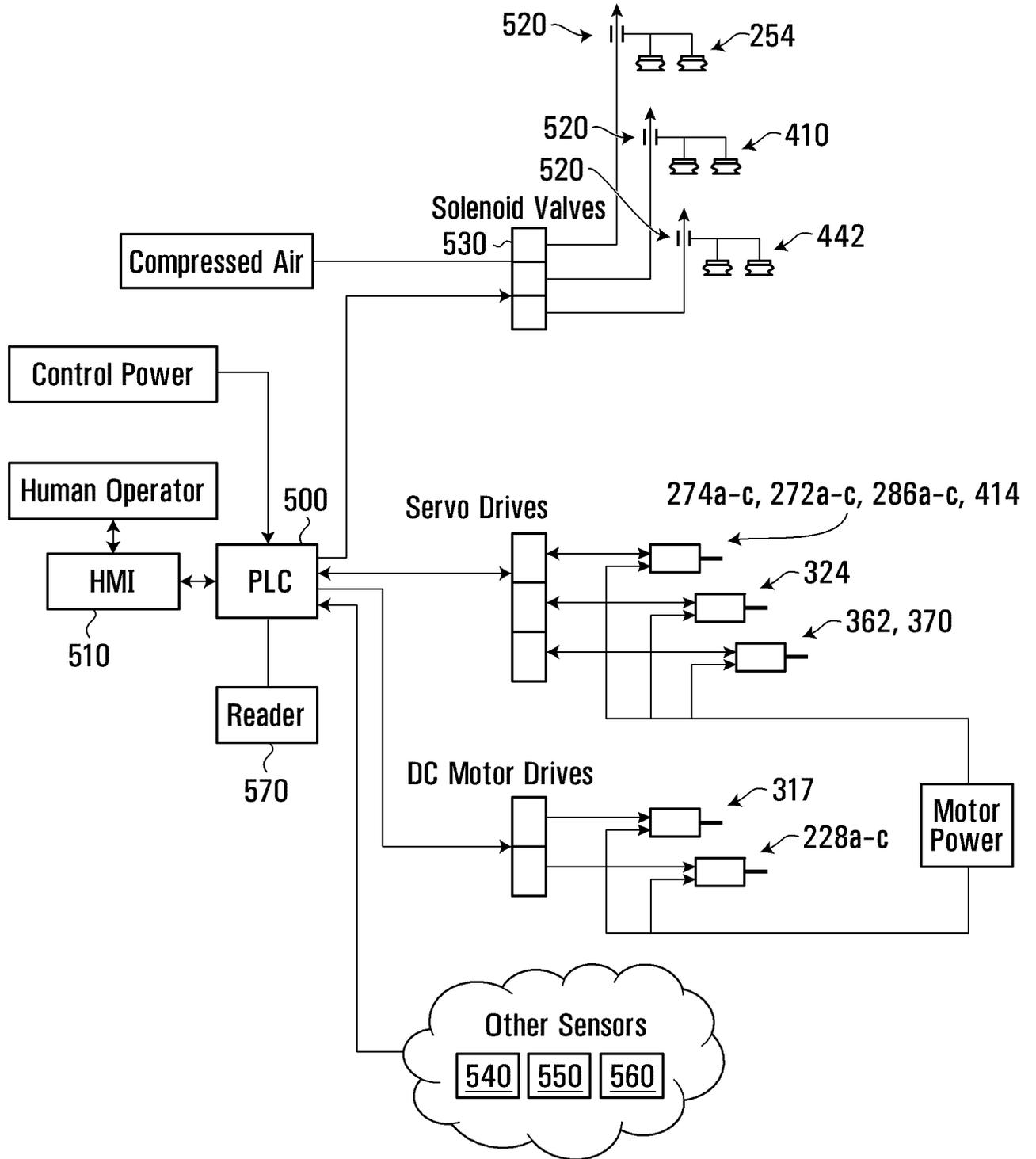


FIG. 7

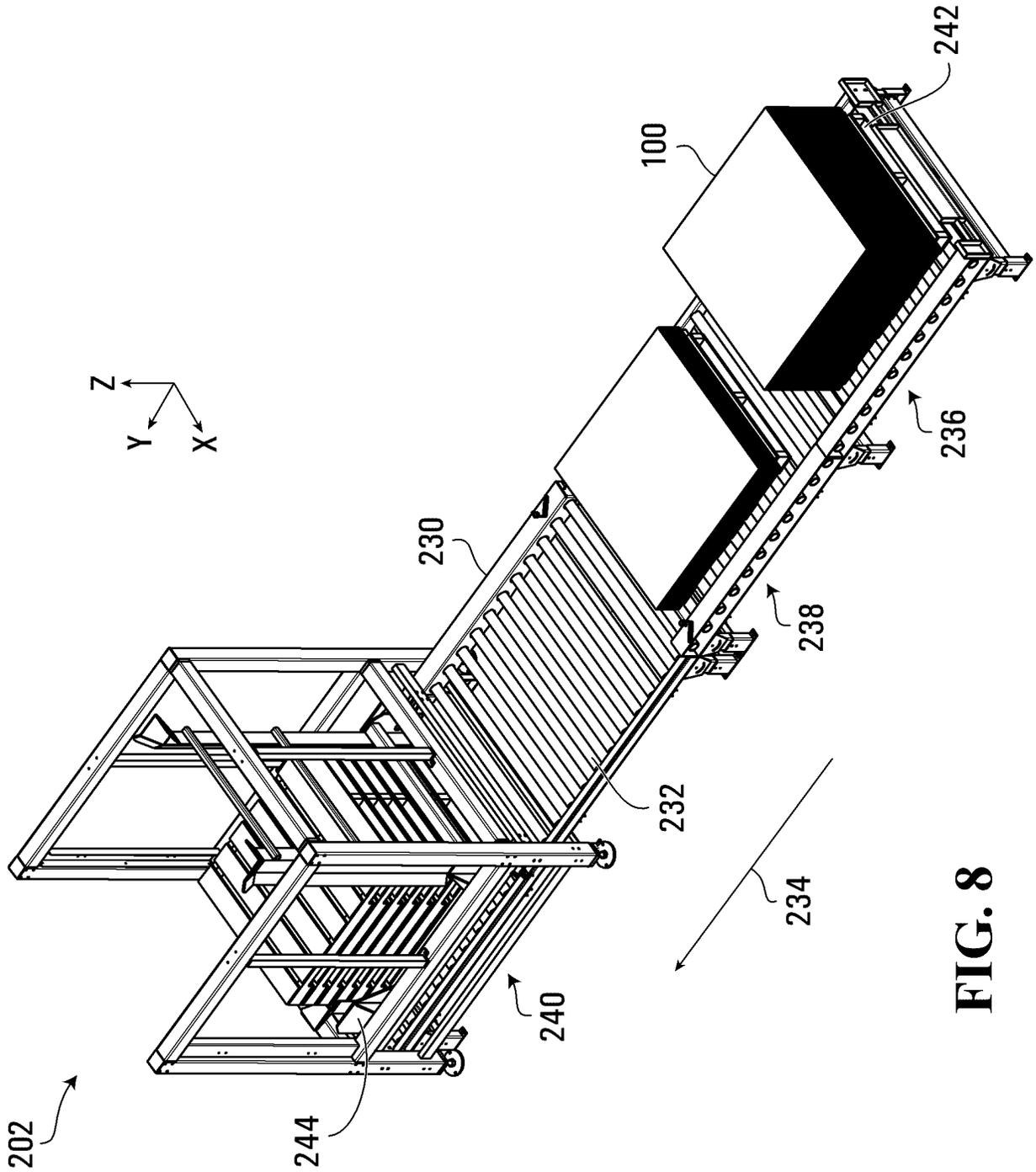


FIG. 8

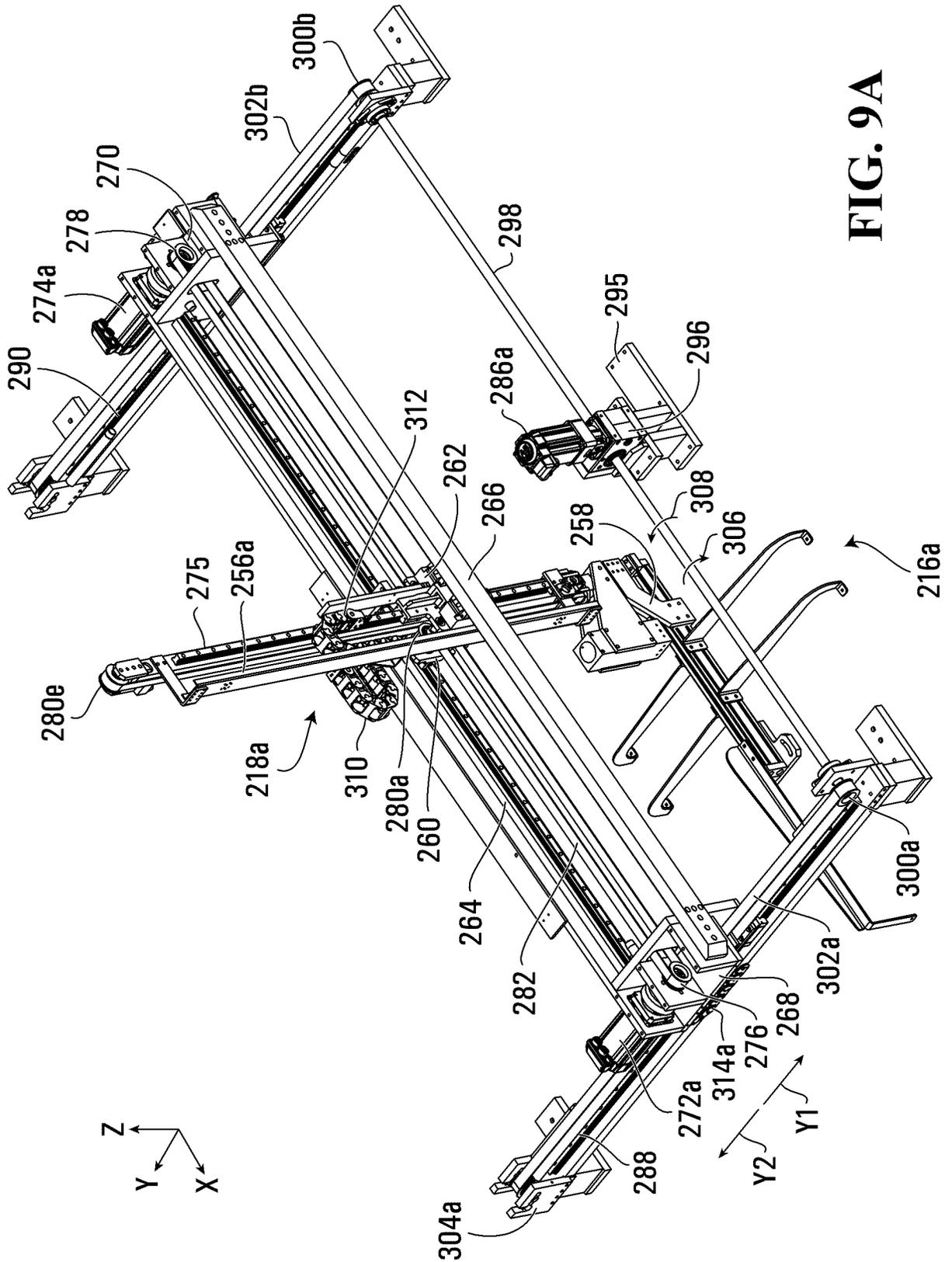
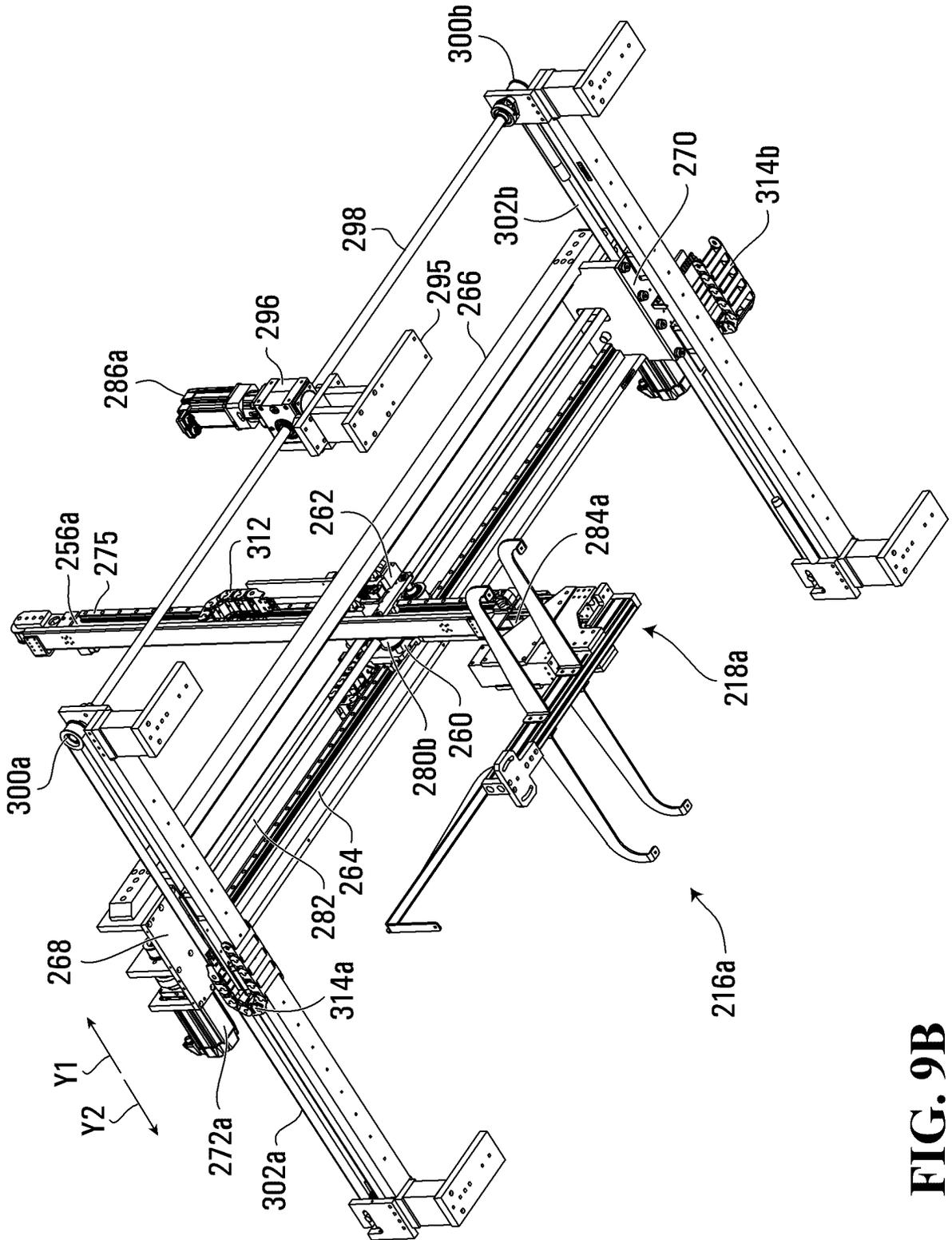


FIG. 9A



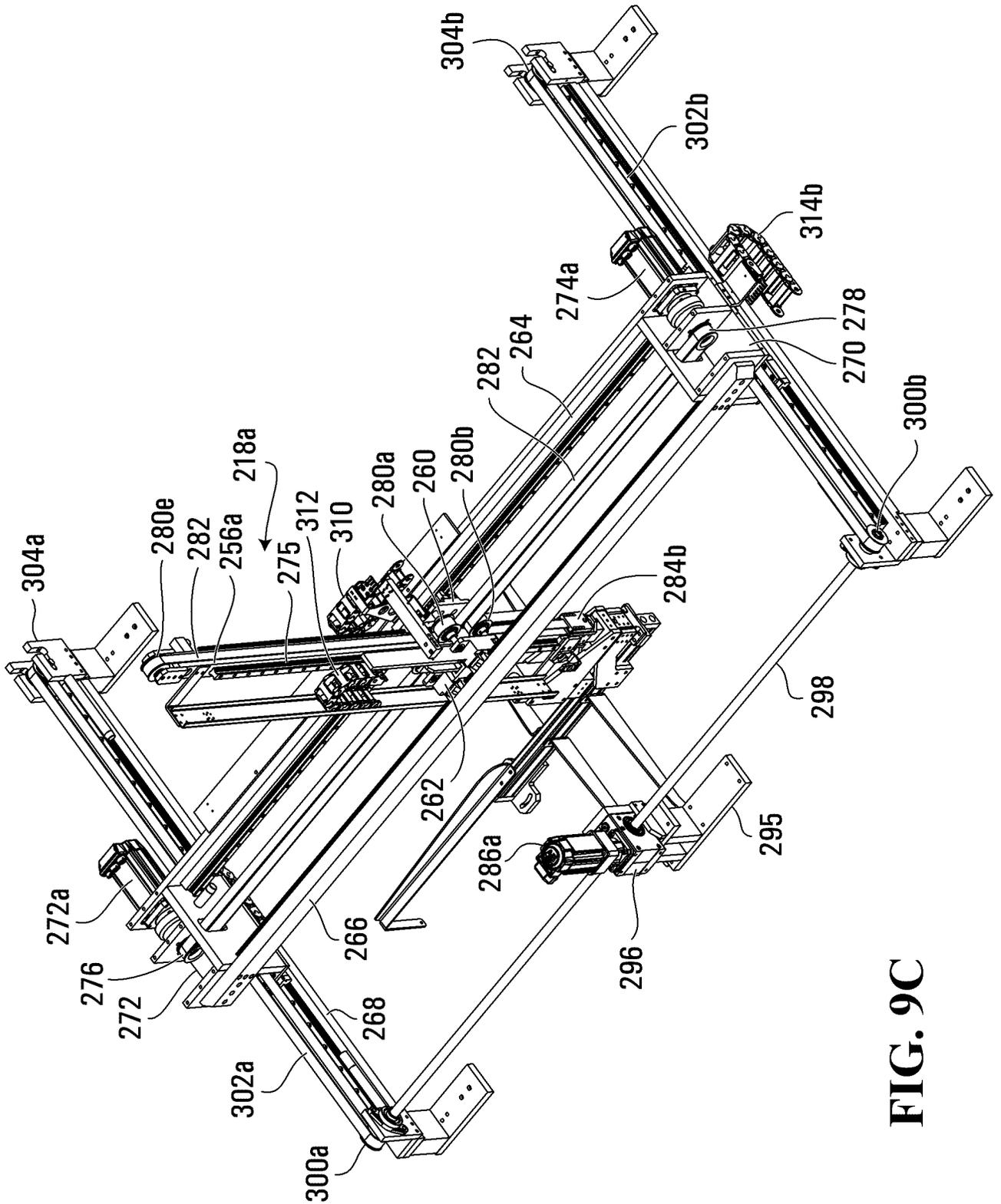


FIG. 9C

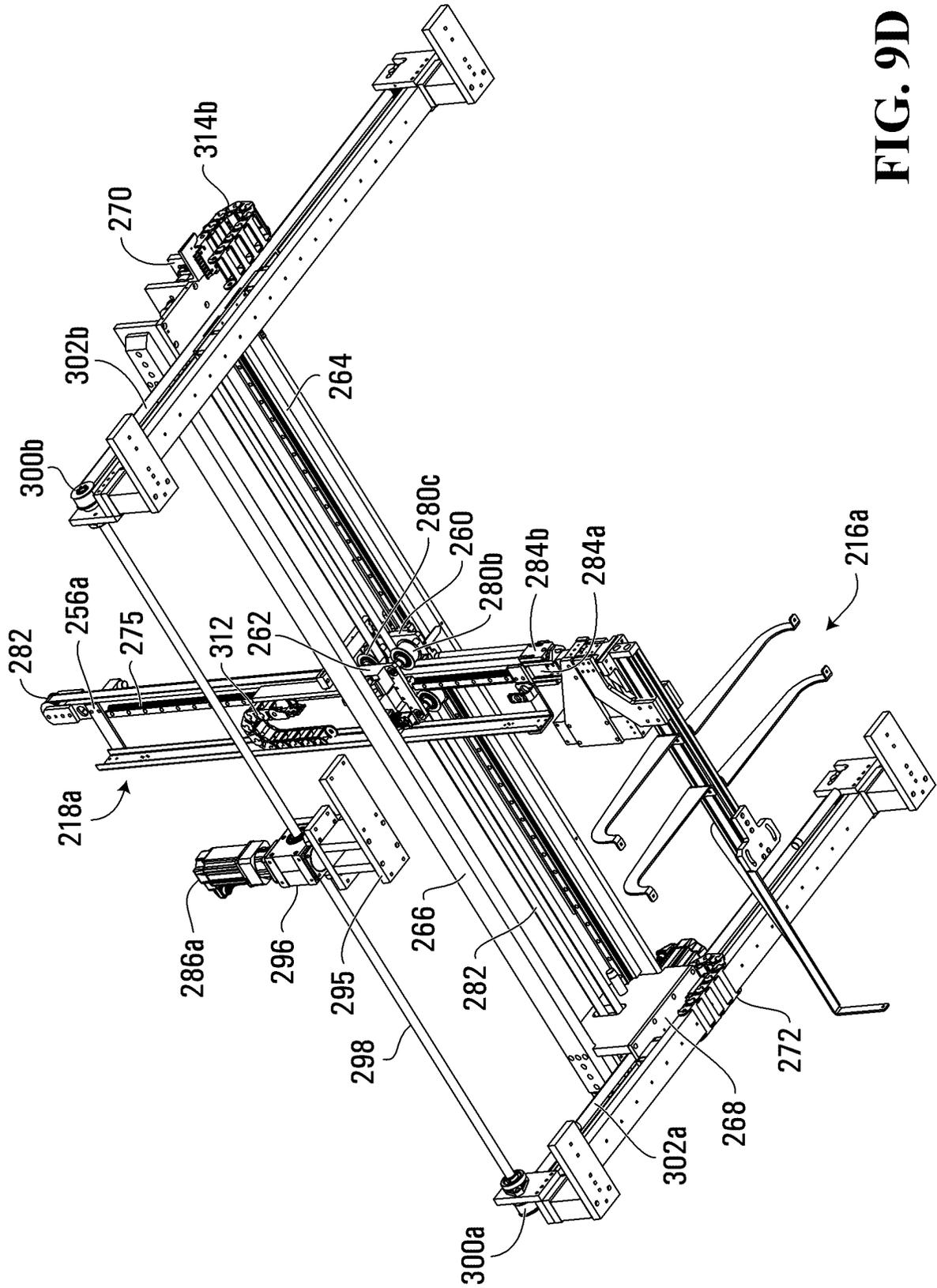


FIG. 9D

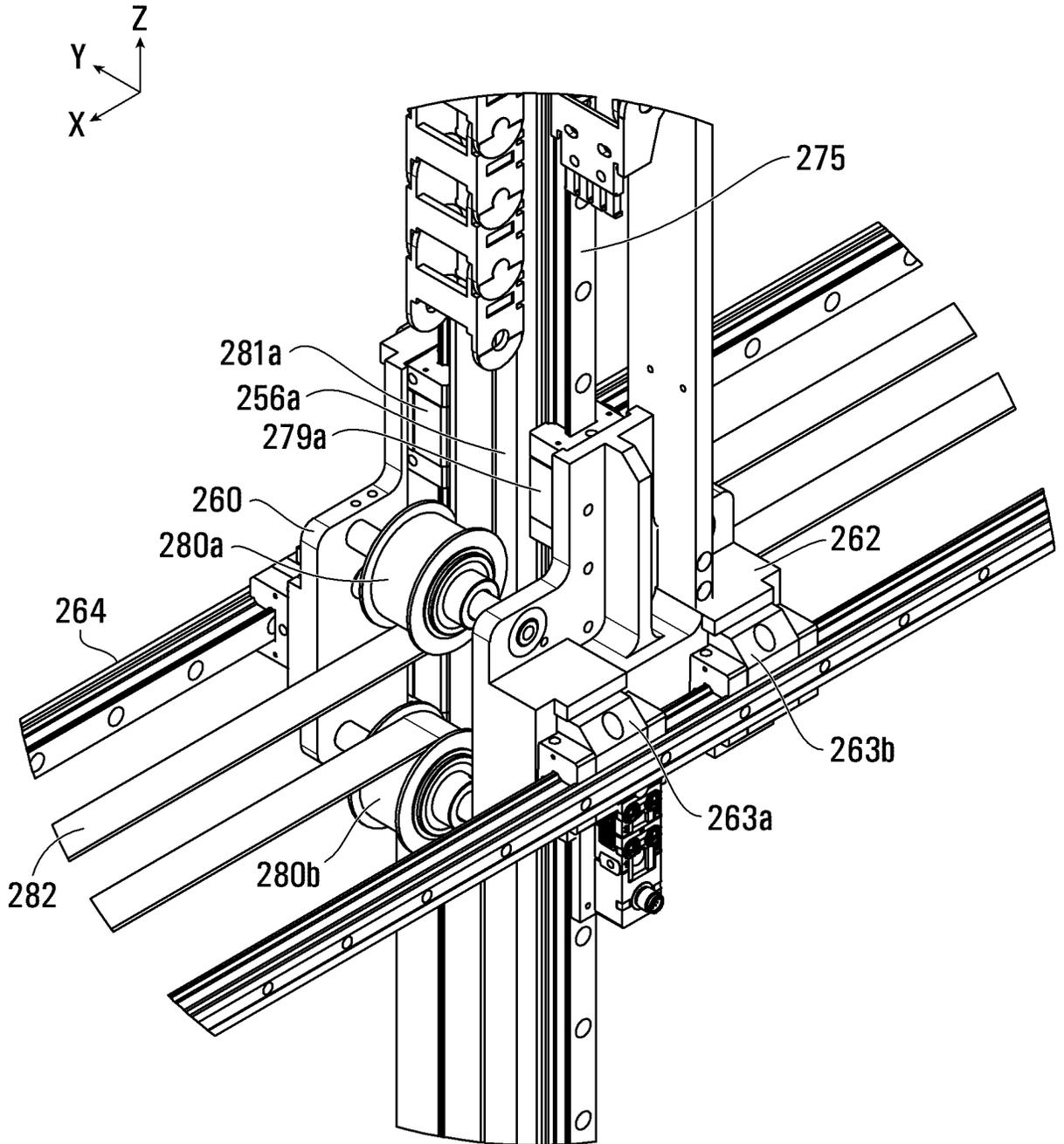


FIG. 9E

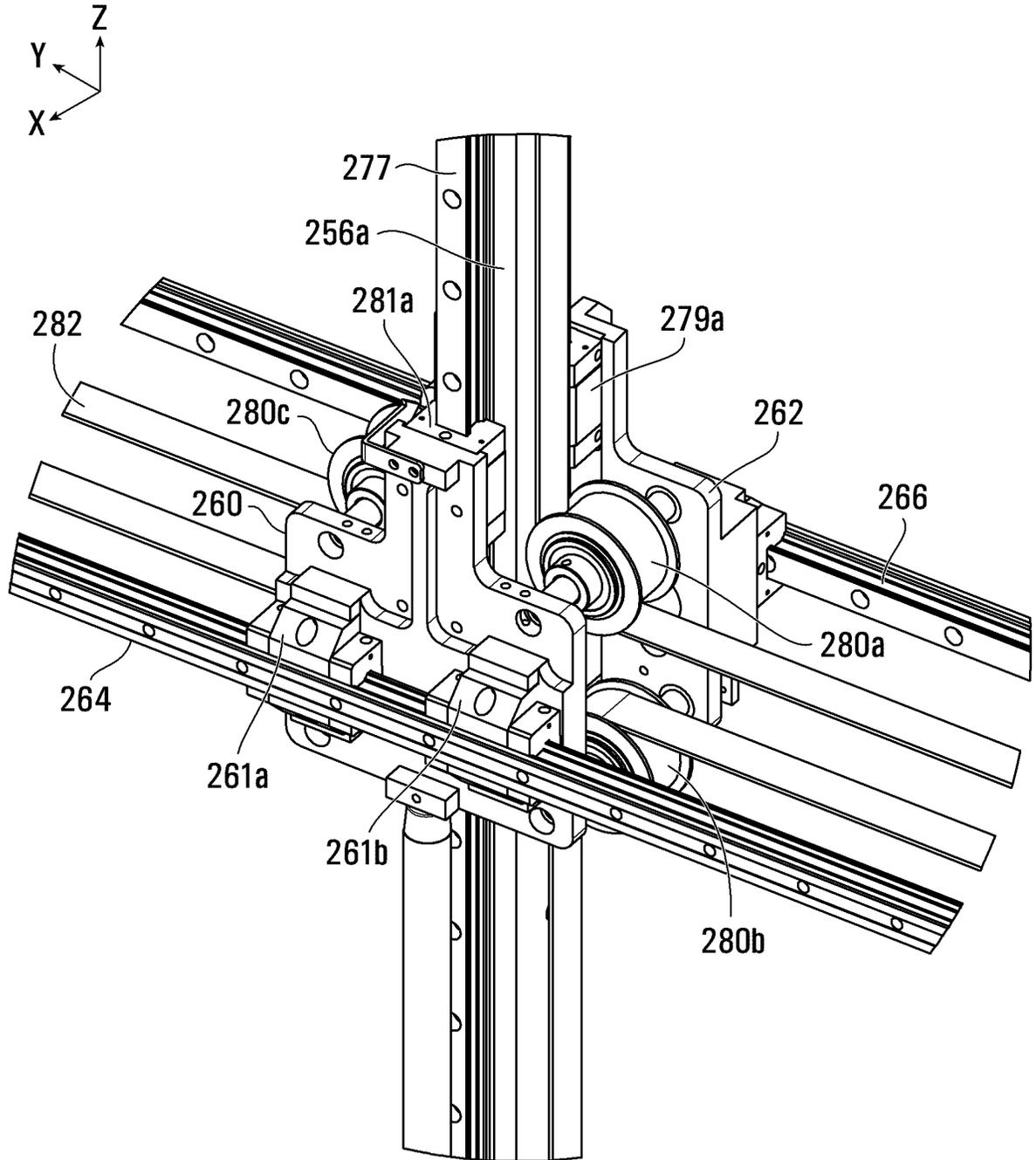


FIG. 9G

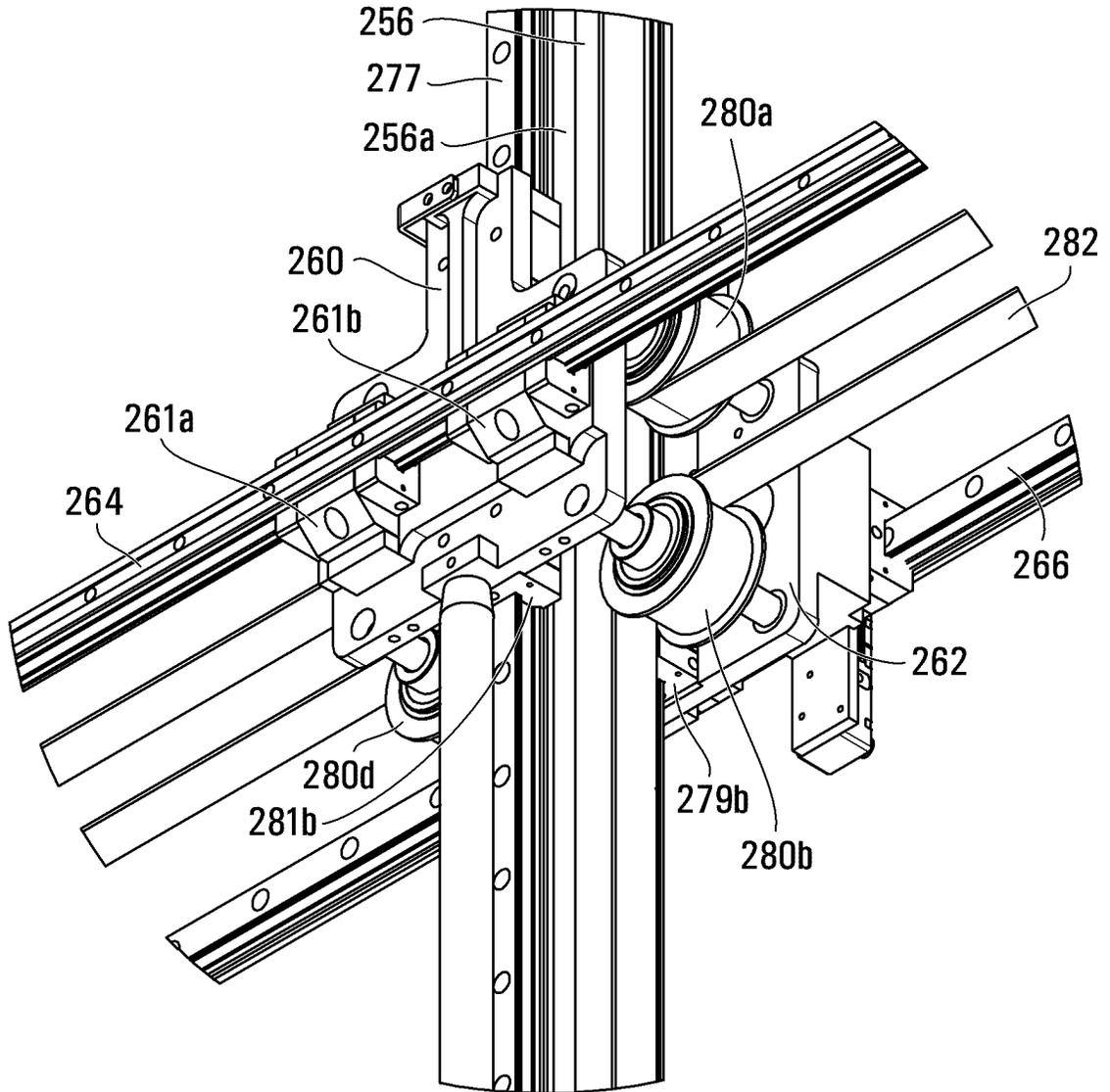
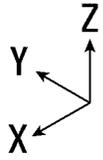


FIG. 9H

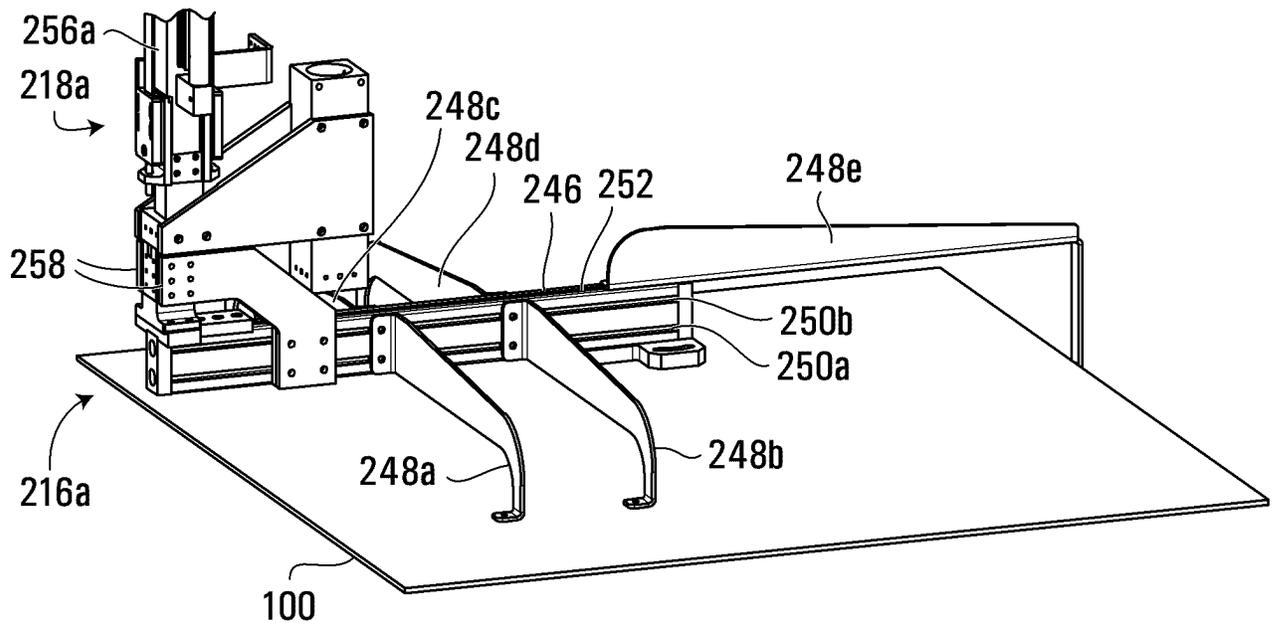


FIG. 9I

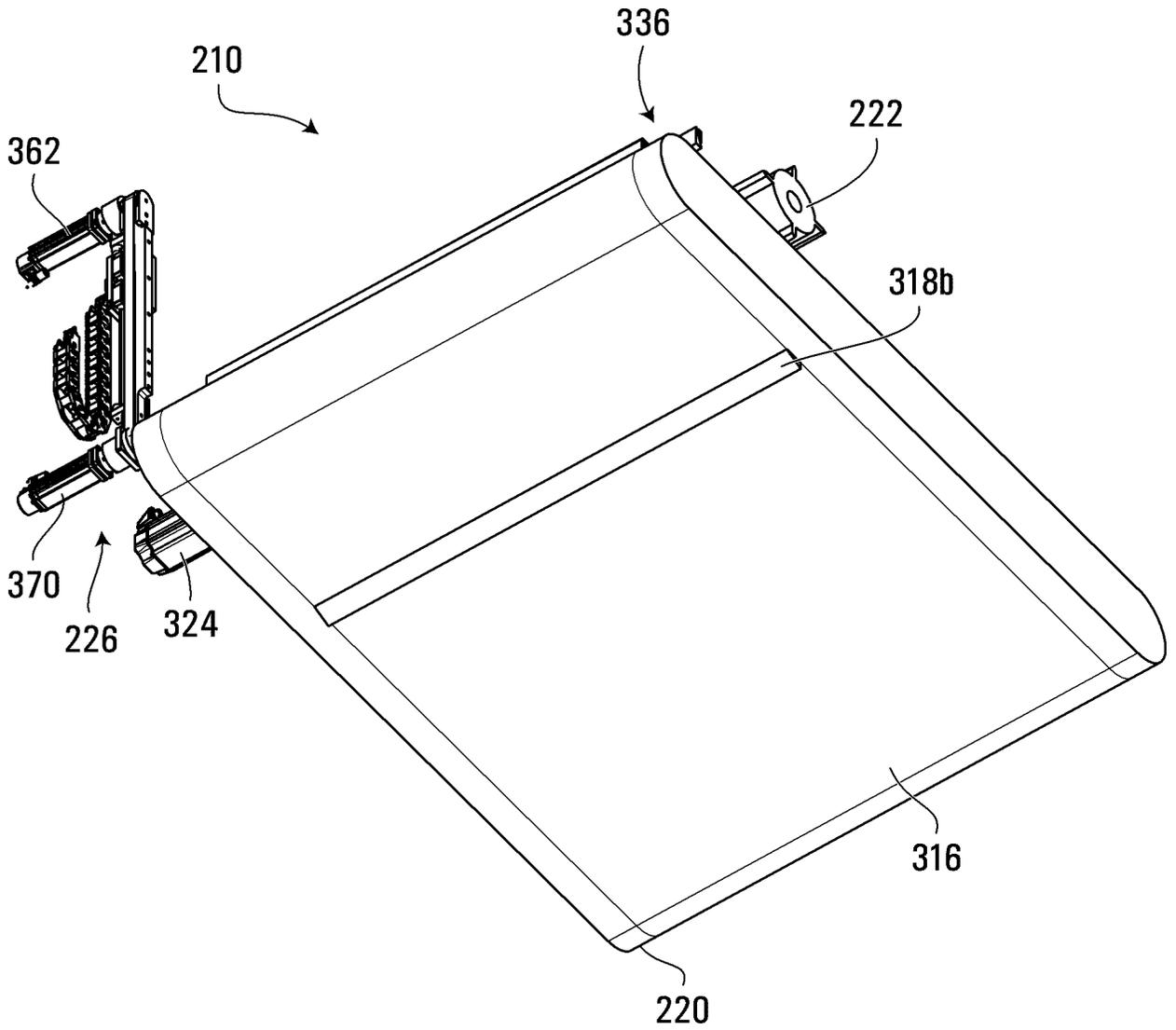


FIG. 10C

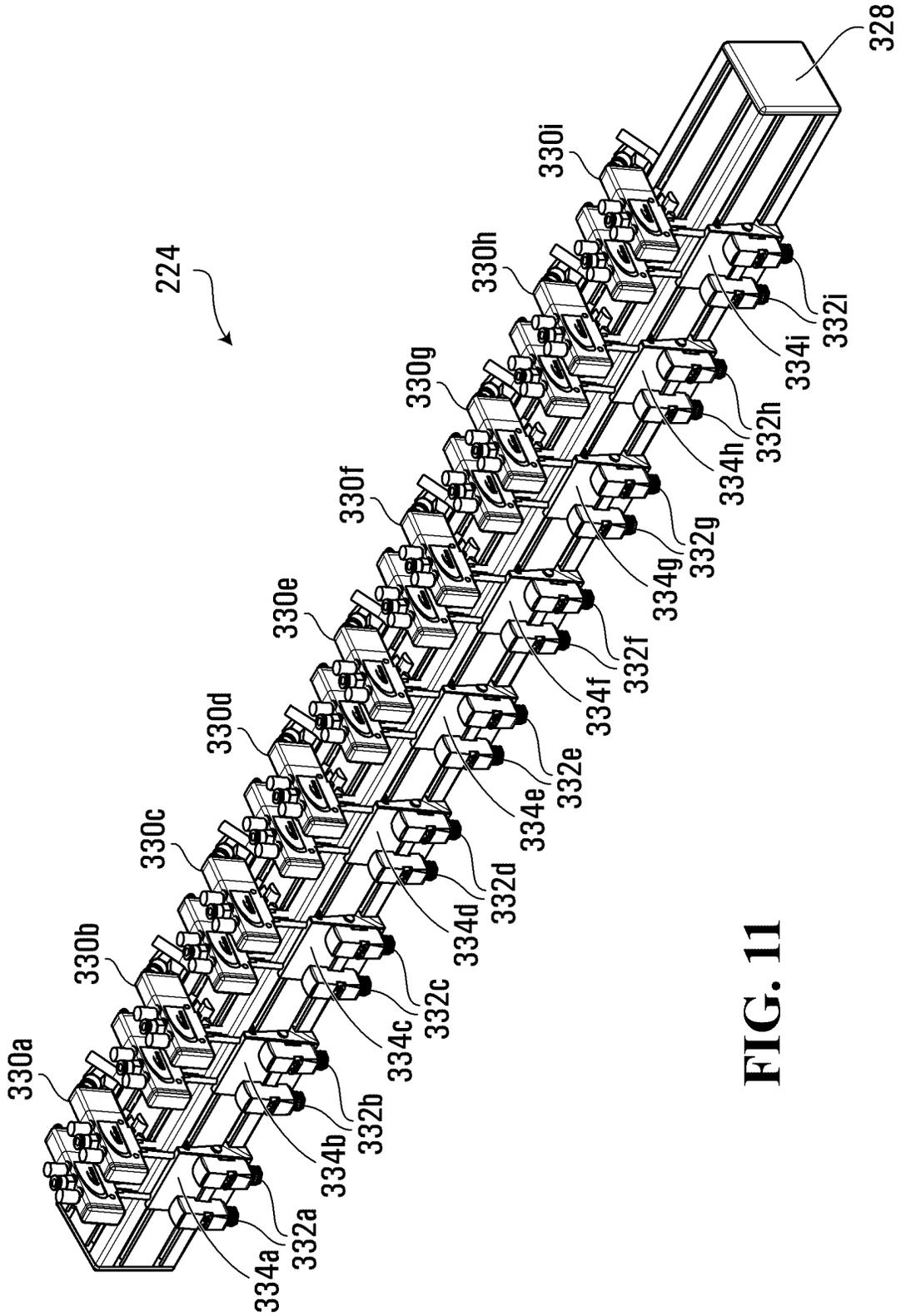


FIG. 11

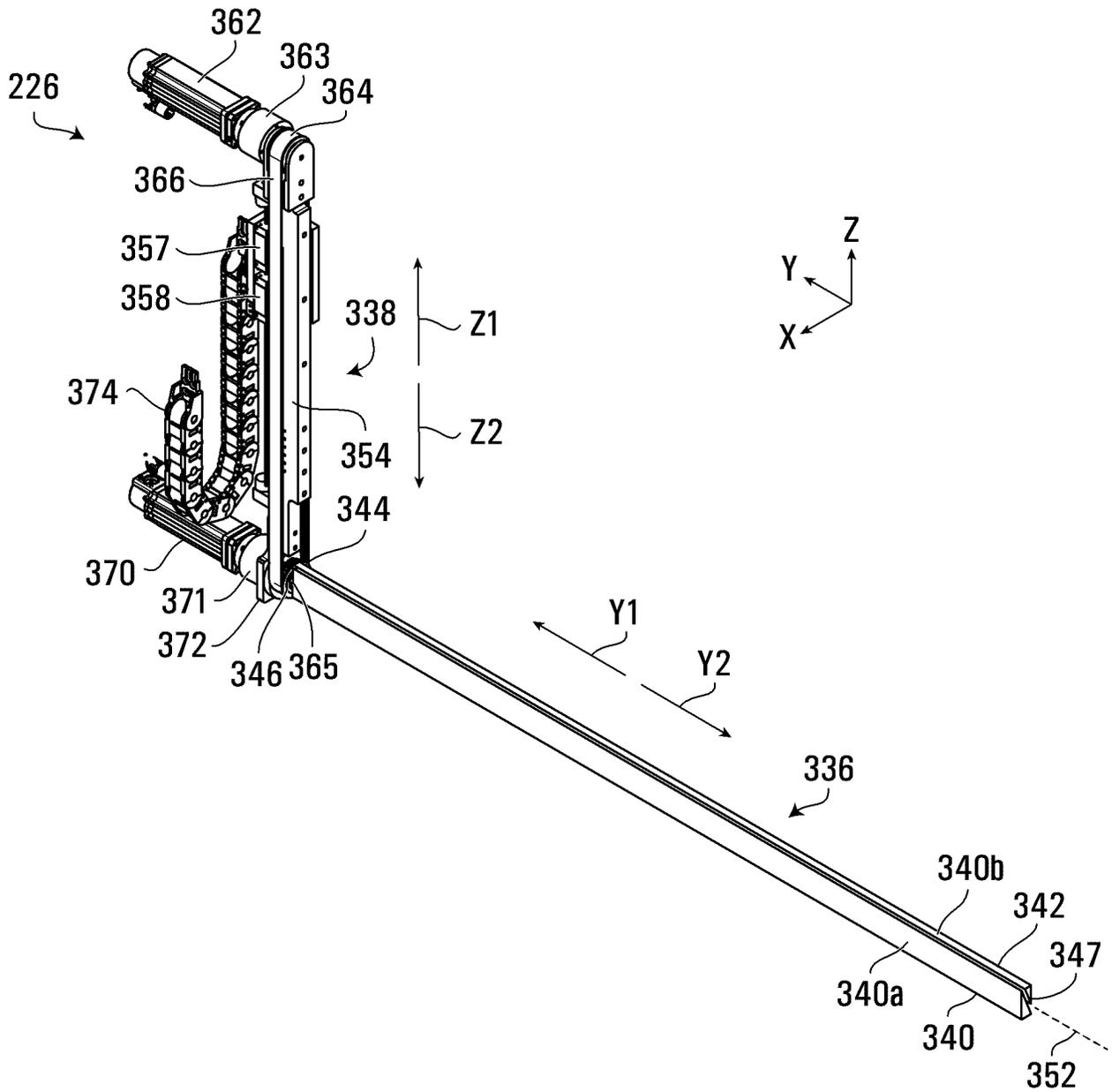


FIG. 12

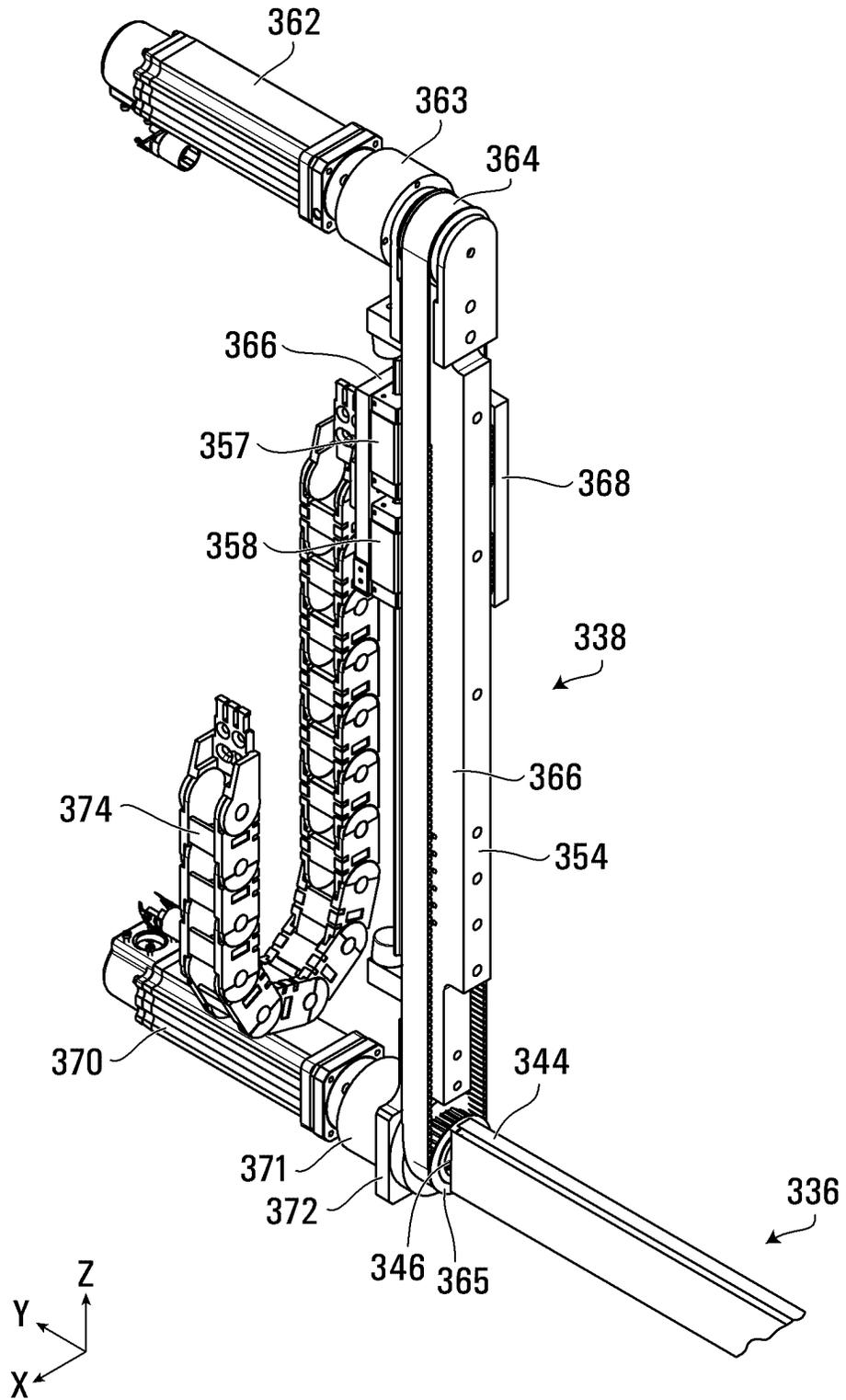


FIG. 12A

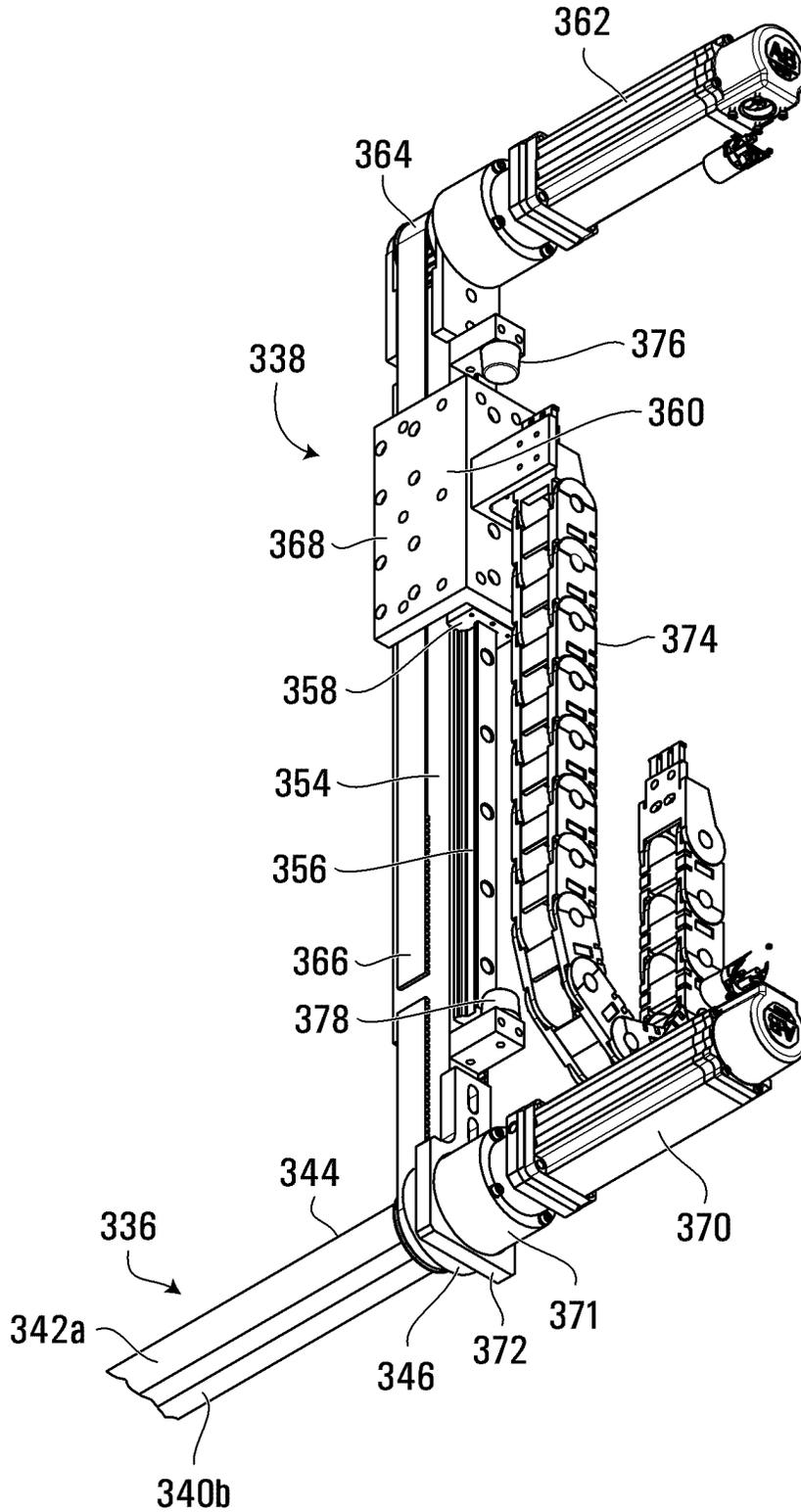


FIG. 12B

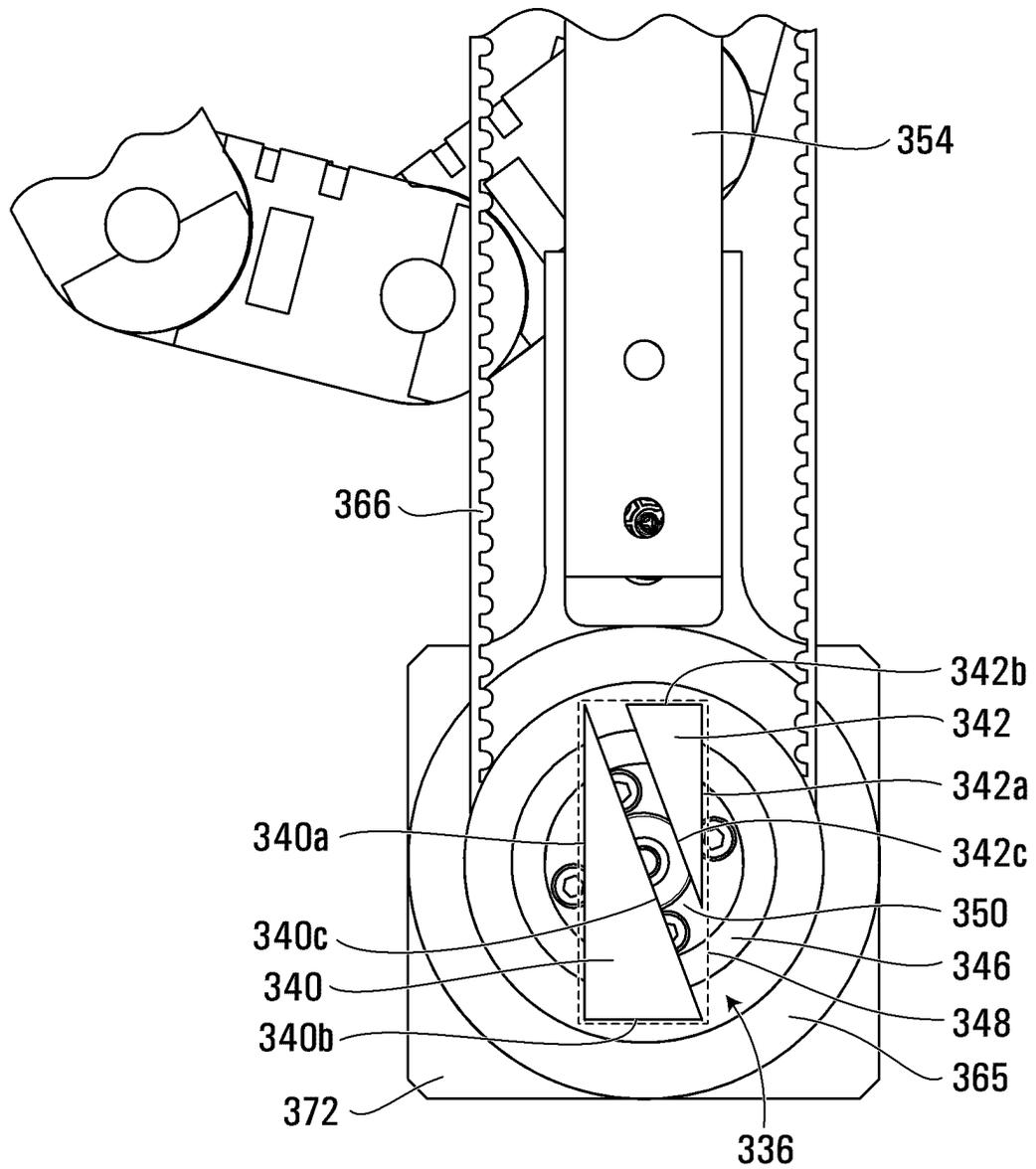


FIG. 12C

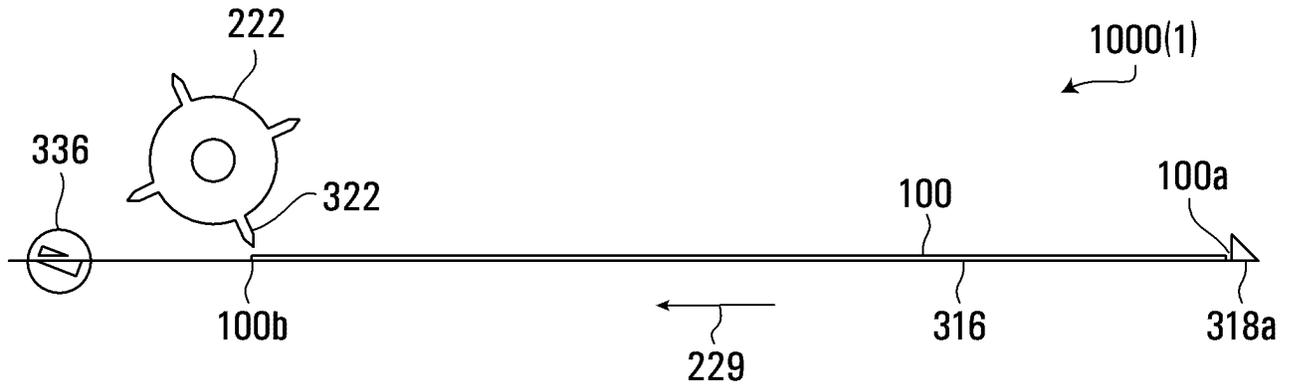


FIG. 13A

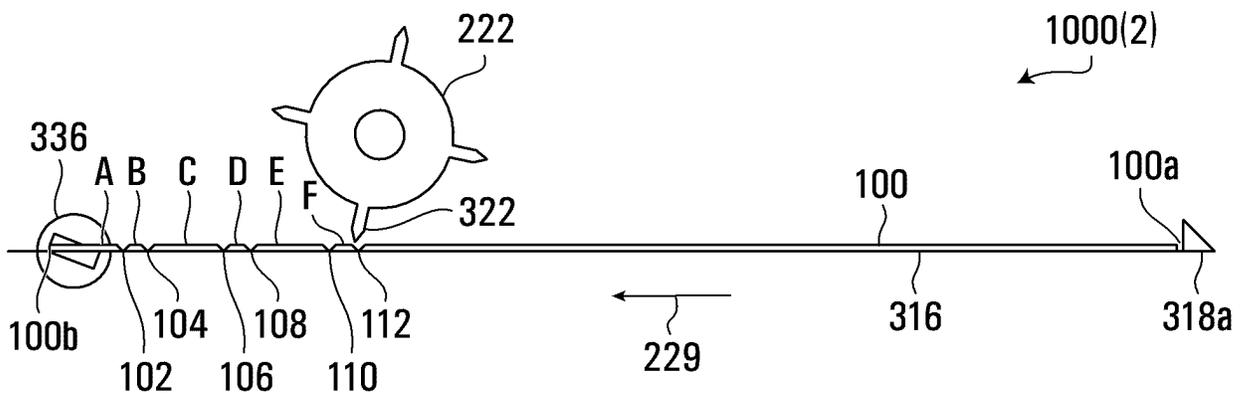


FIG. 13B

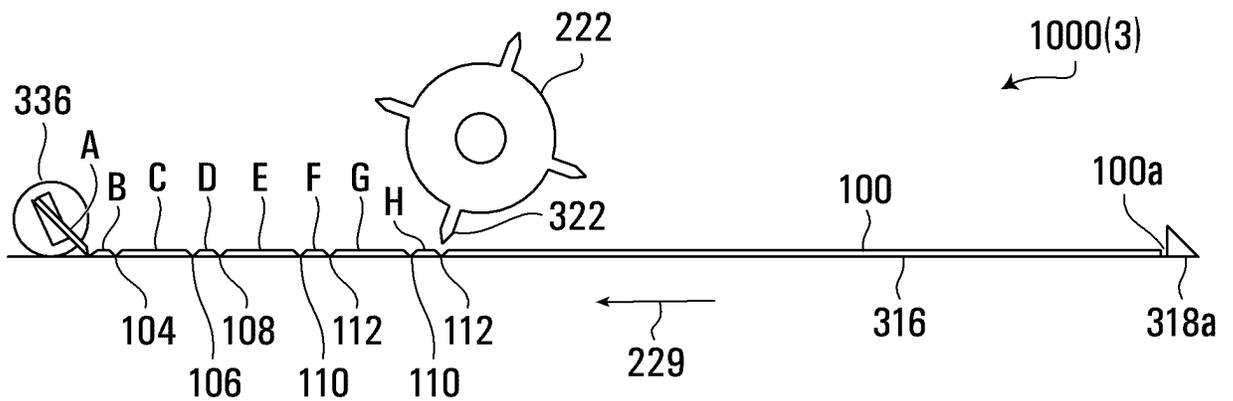


FIG. 13C

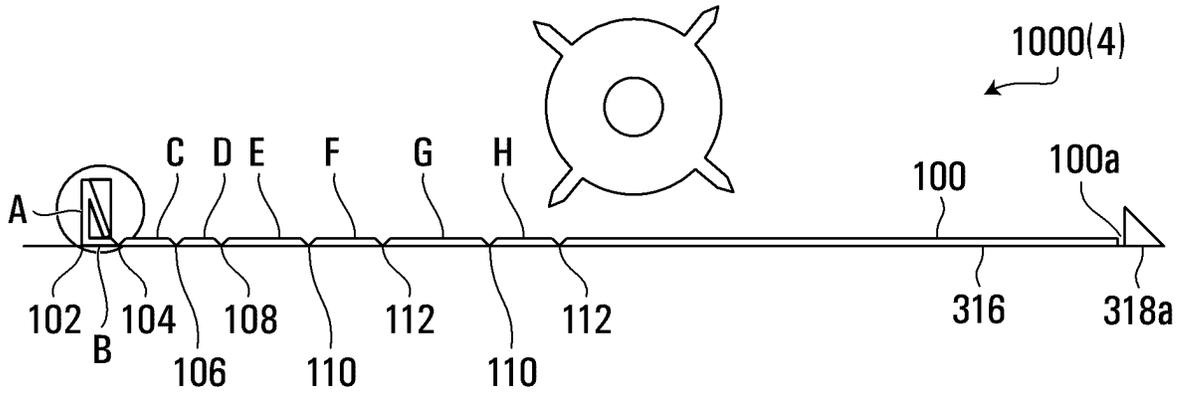


FIG. 13D

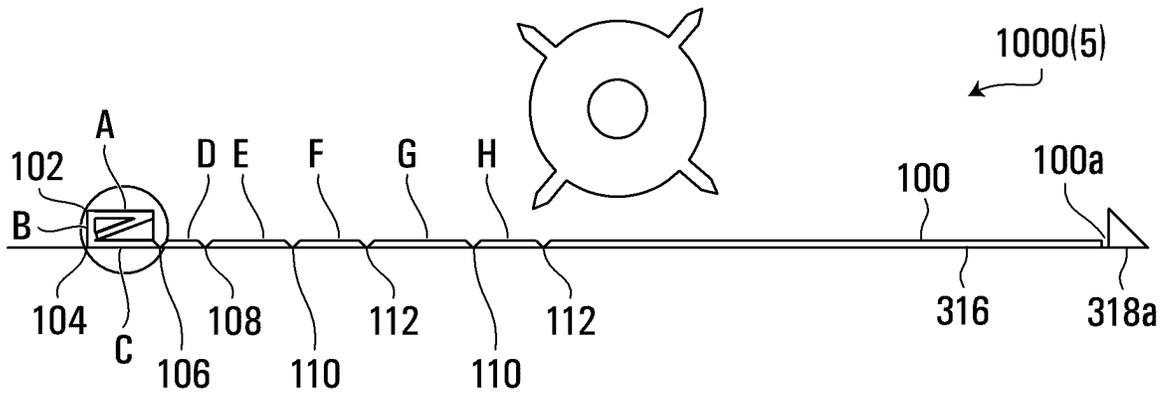


FIG. 13E

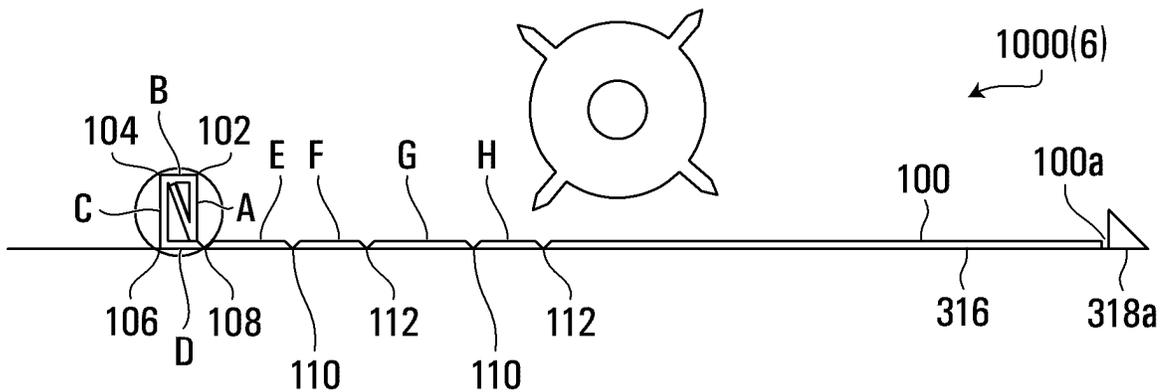


FIG. 13F

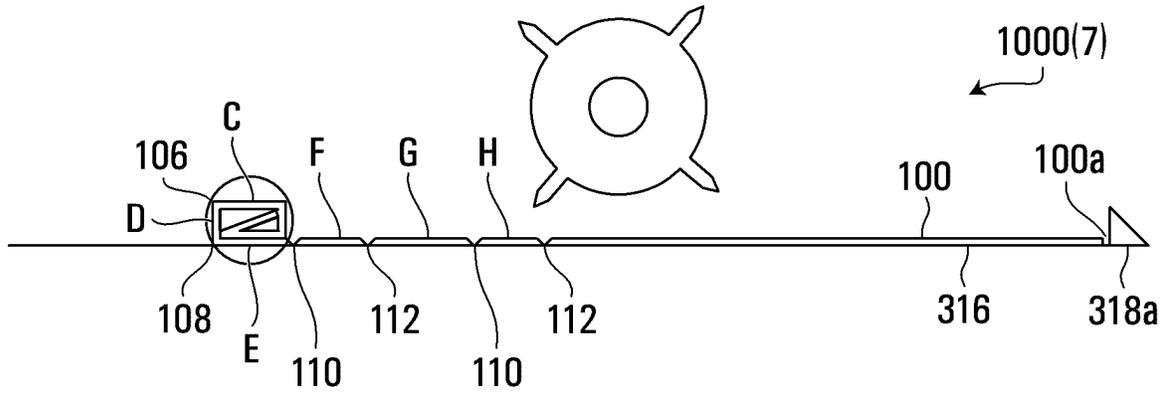


FIG. 13G

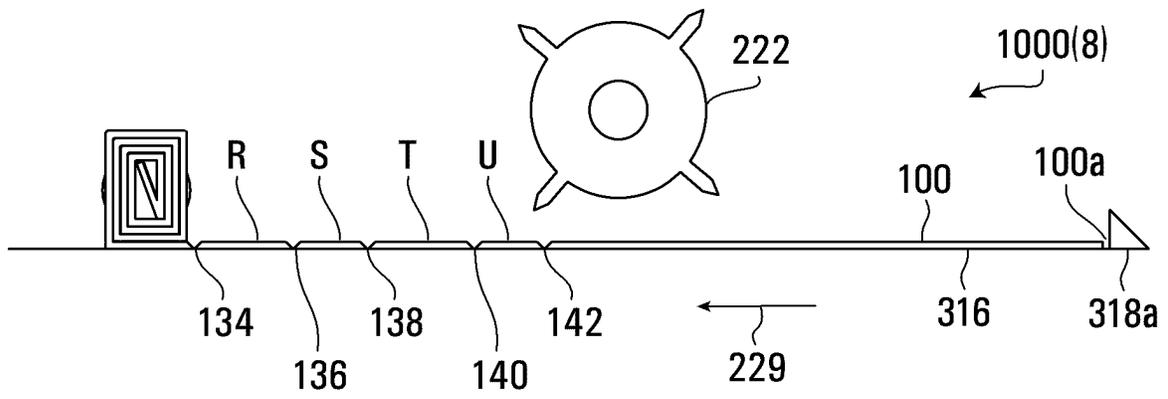


FIG. 13H

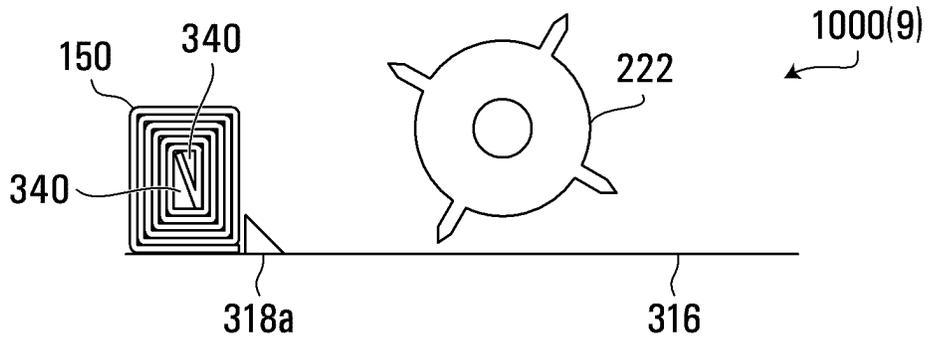


FIG. 13I

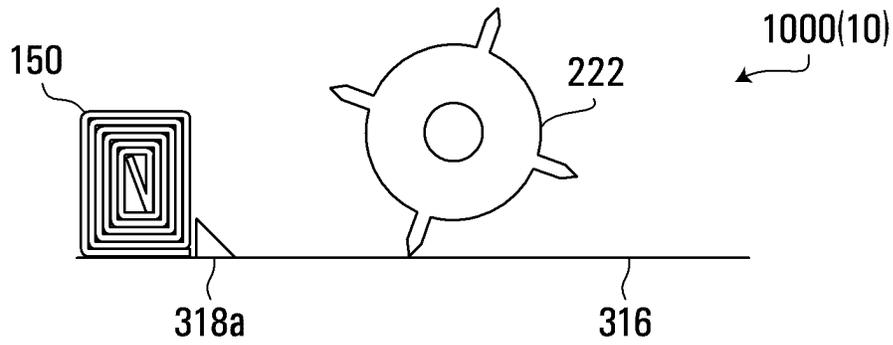


FIG. 13J

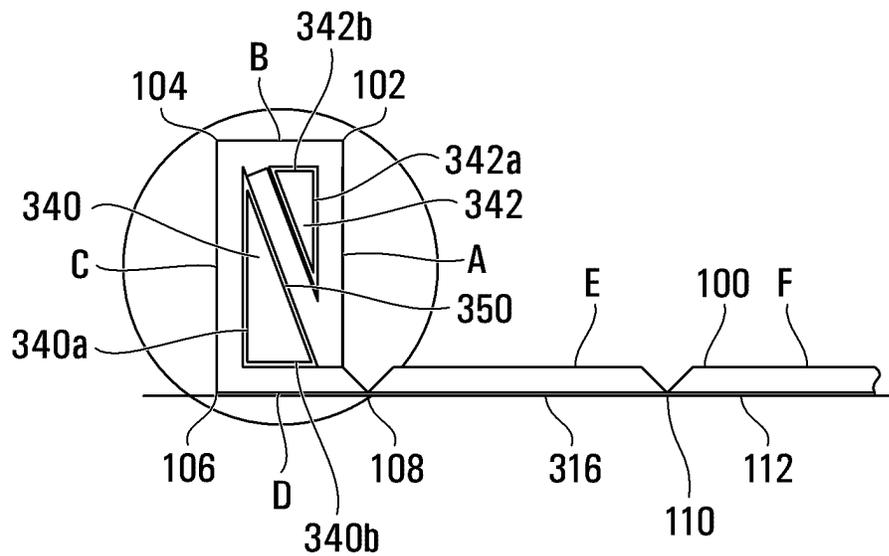


FIG. 13K

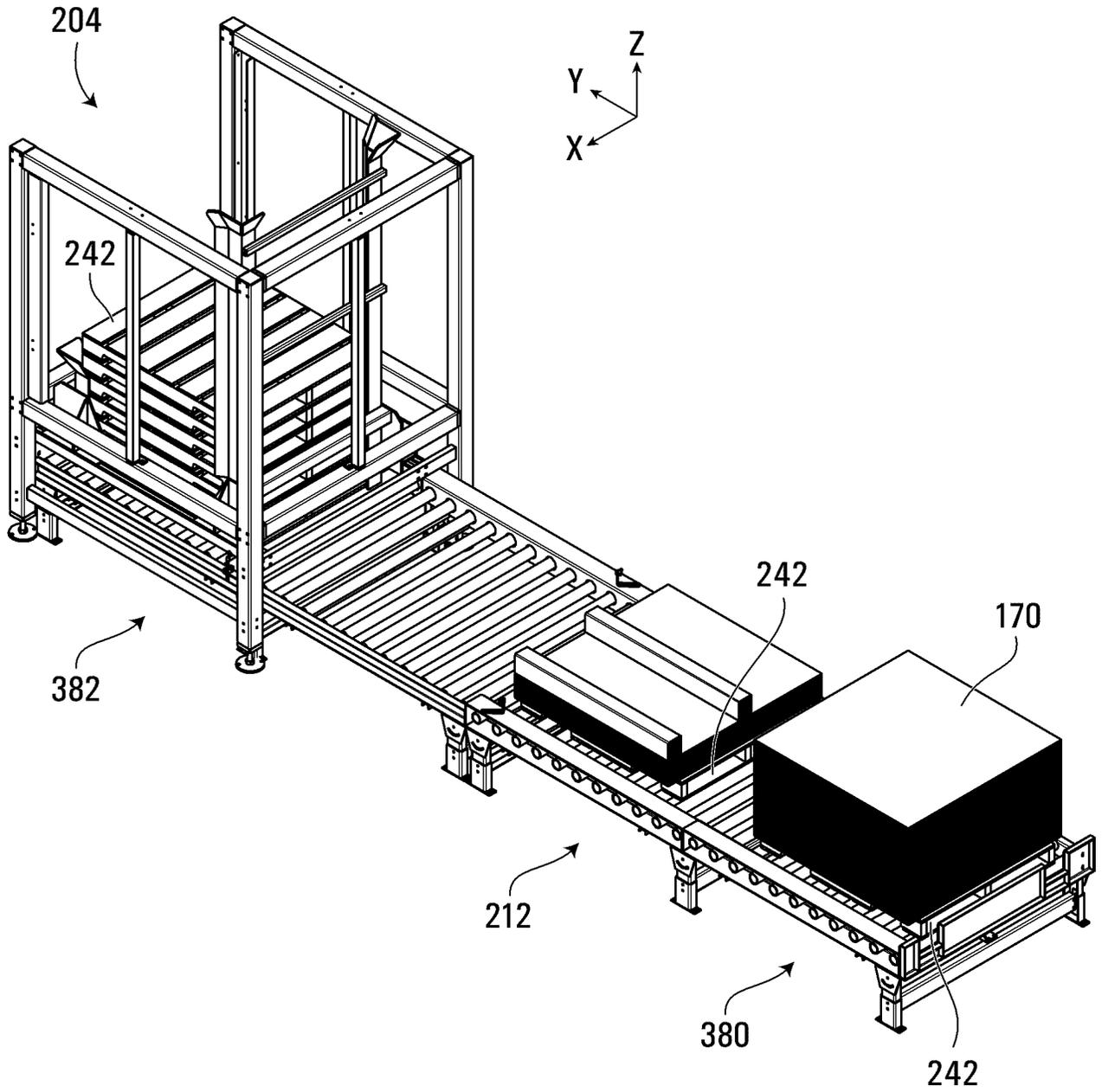


FIG. 14

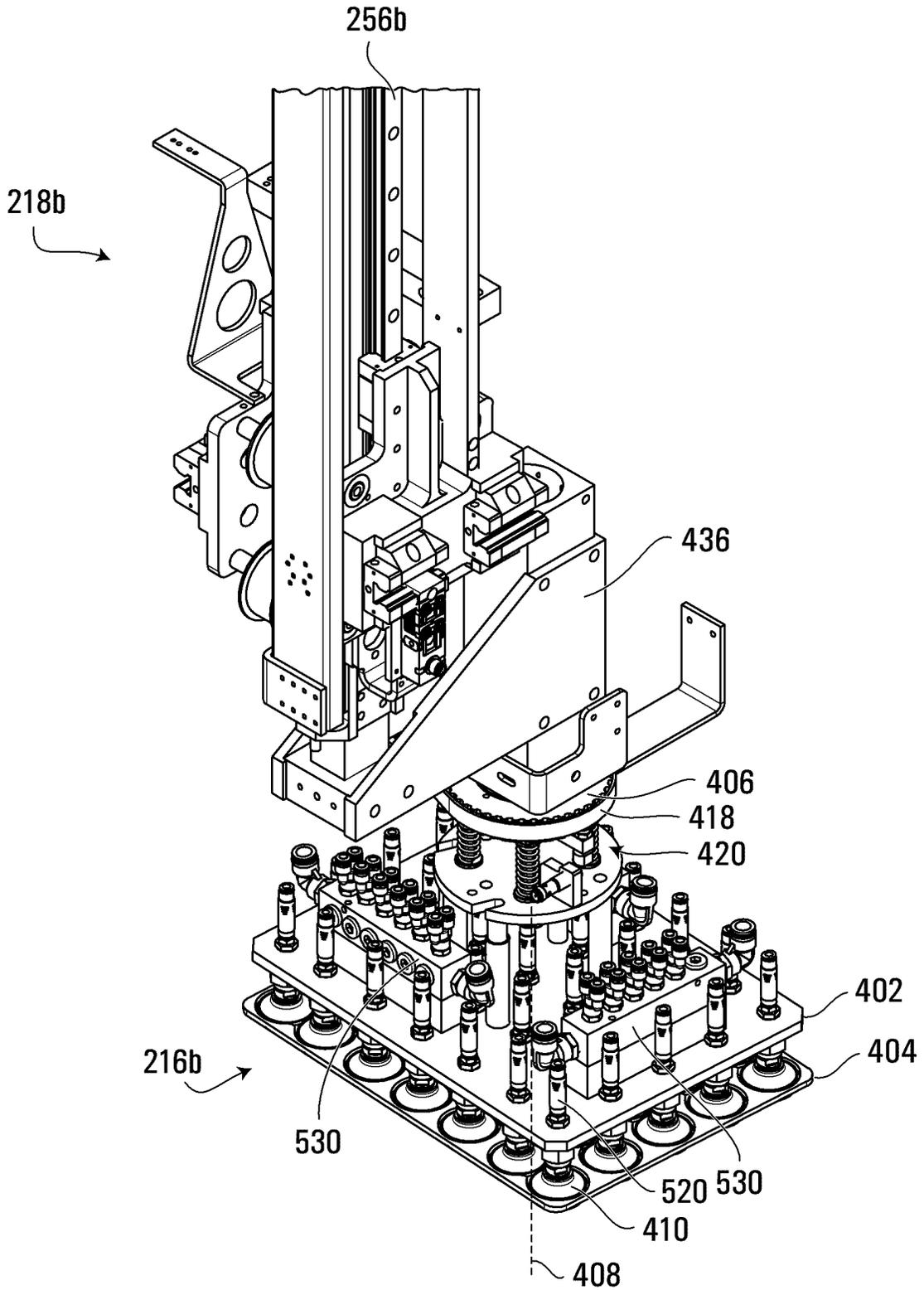


FIG. 15A

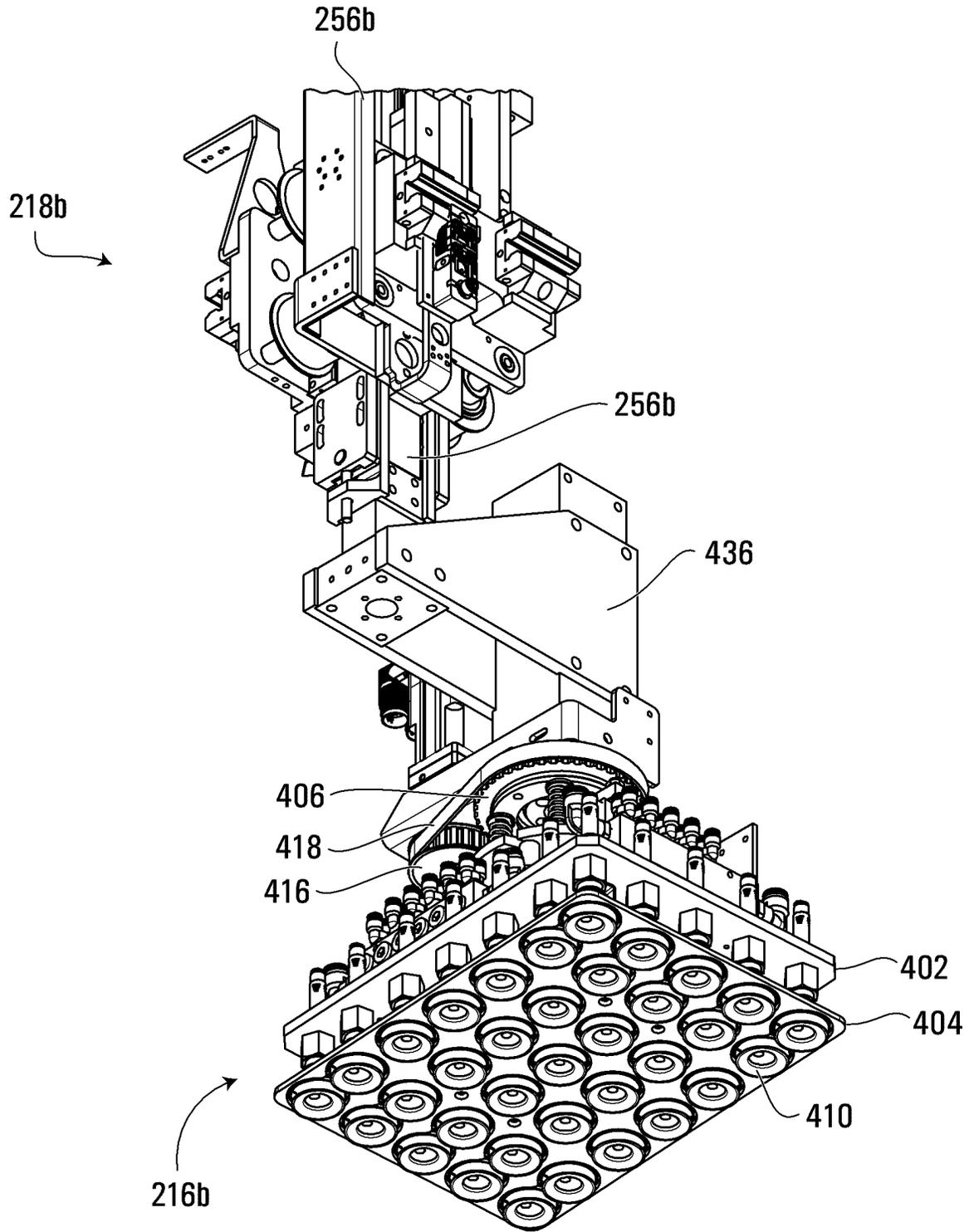


FIG. 15B

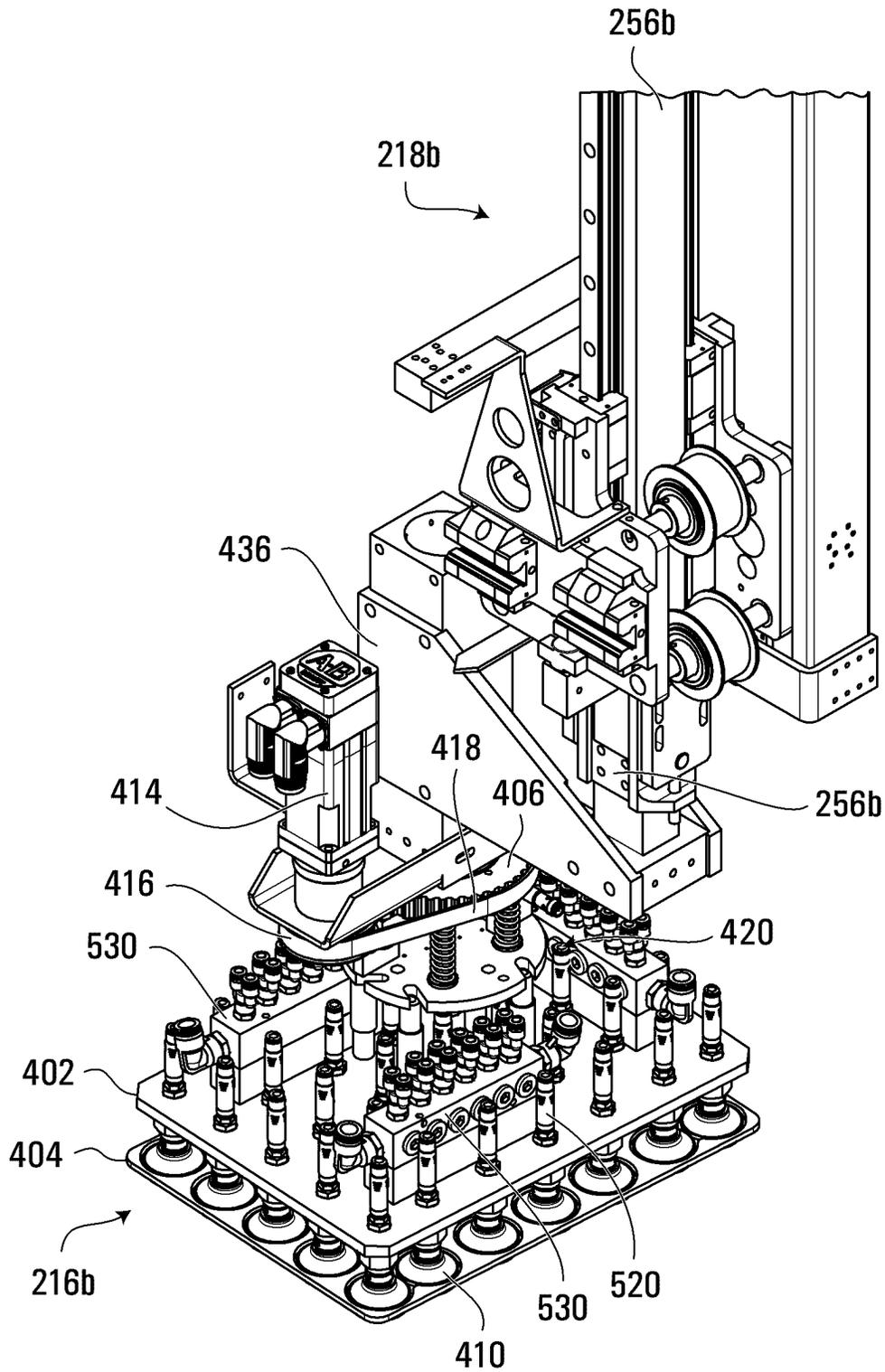


FIG. 15C

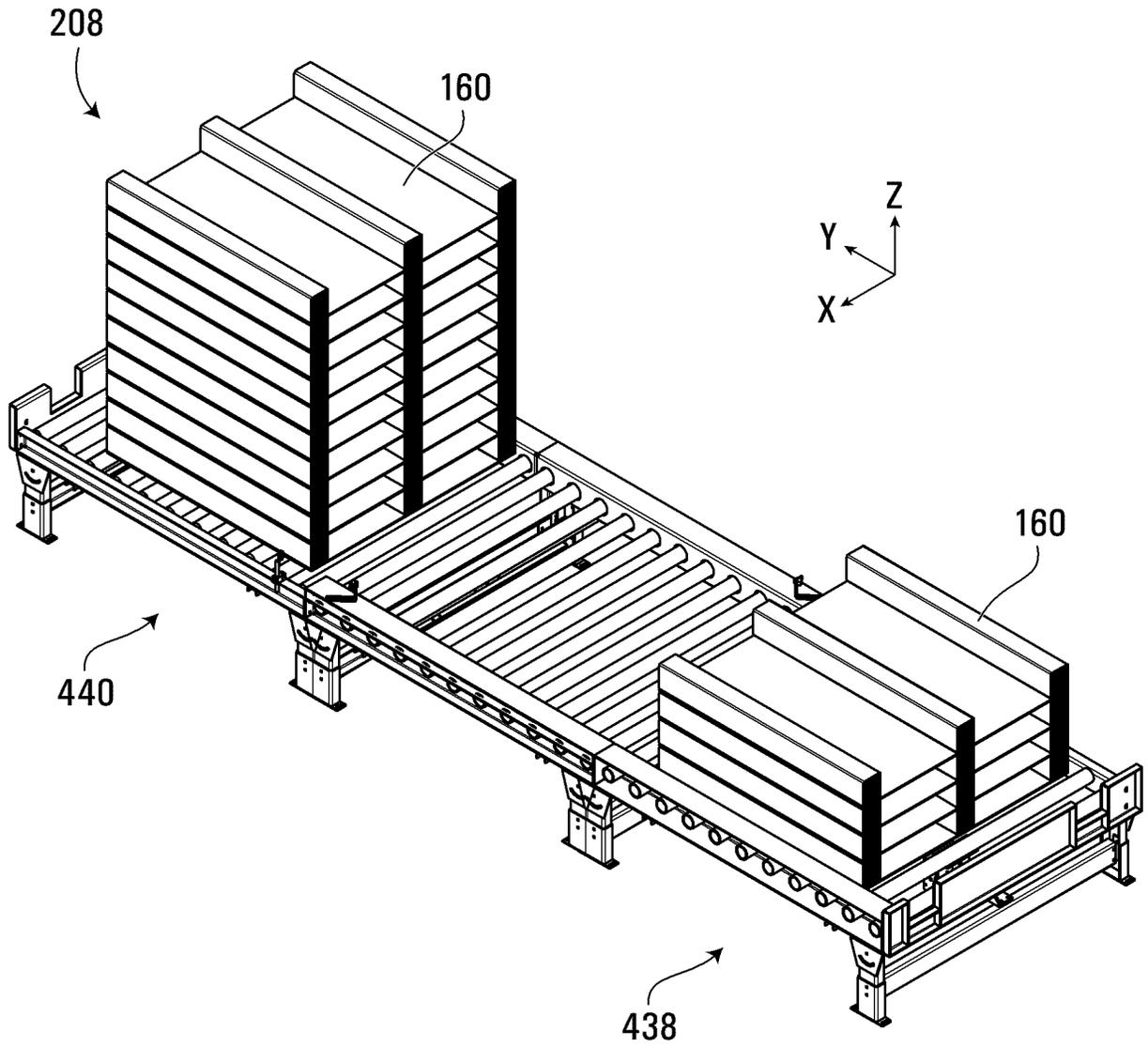
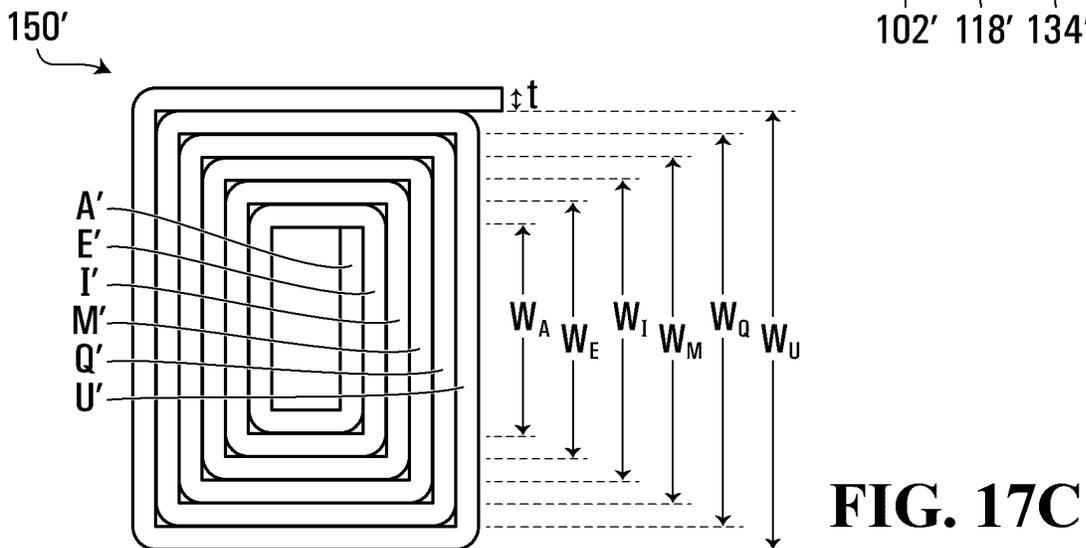
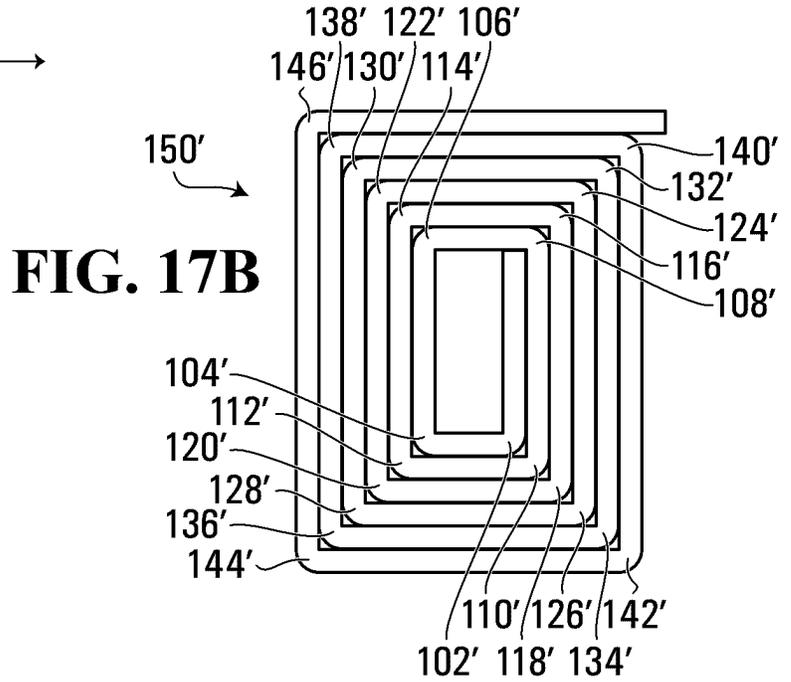
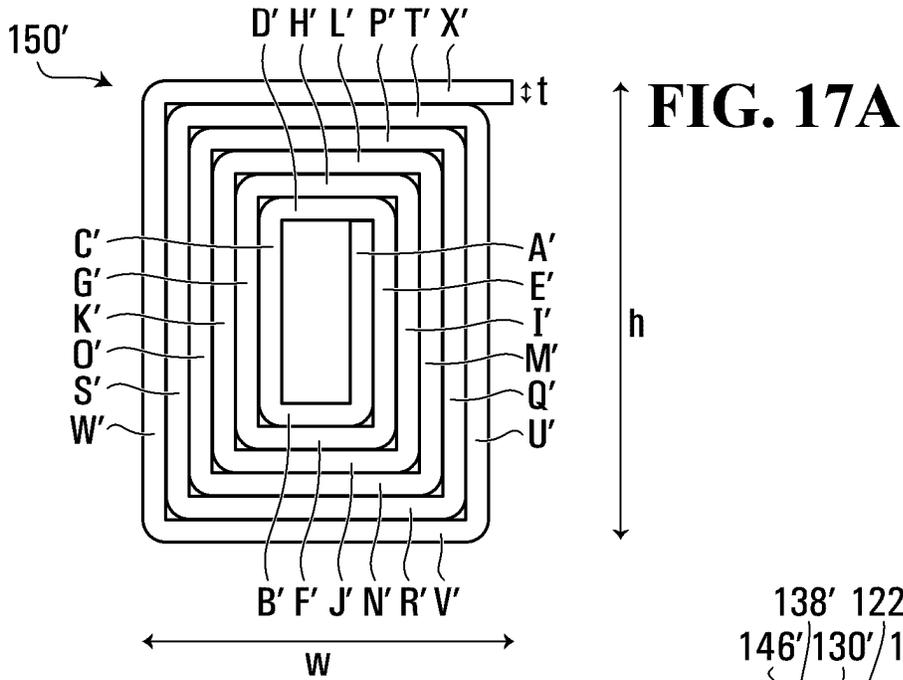


FIG. 16



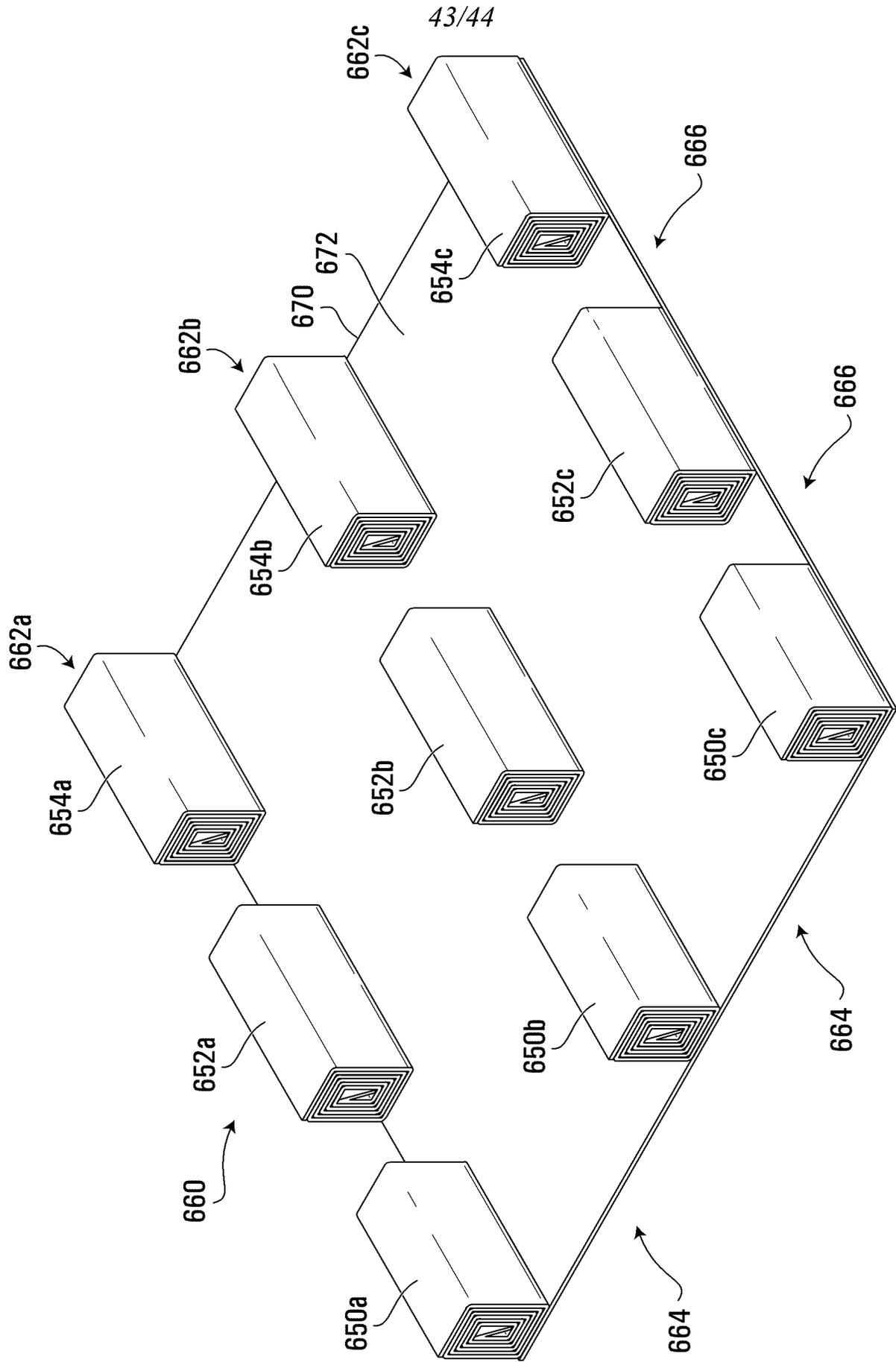


FIG. 18

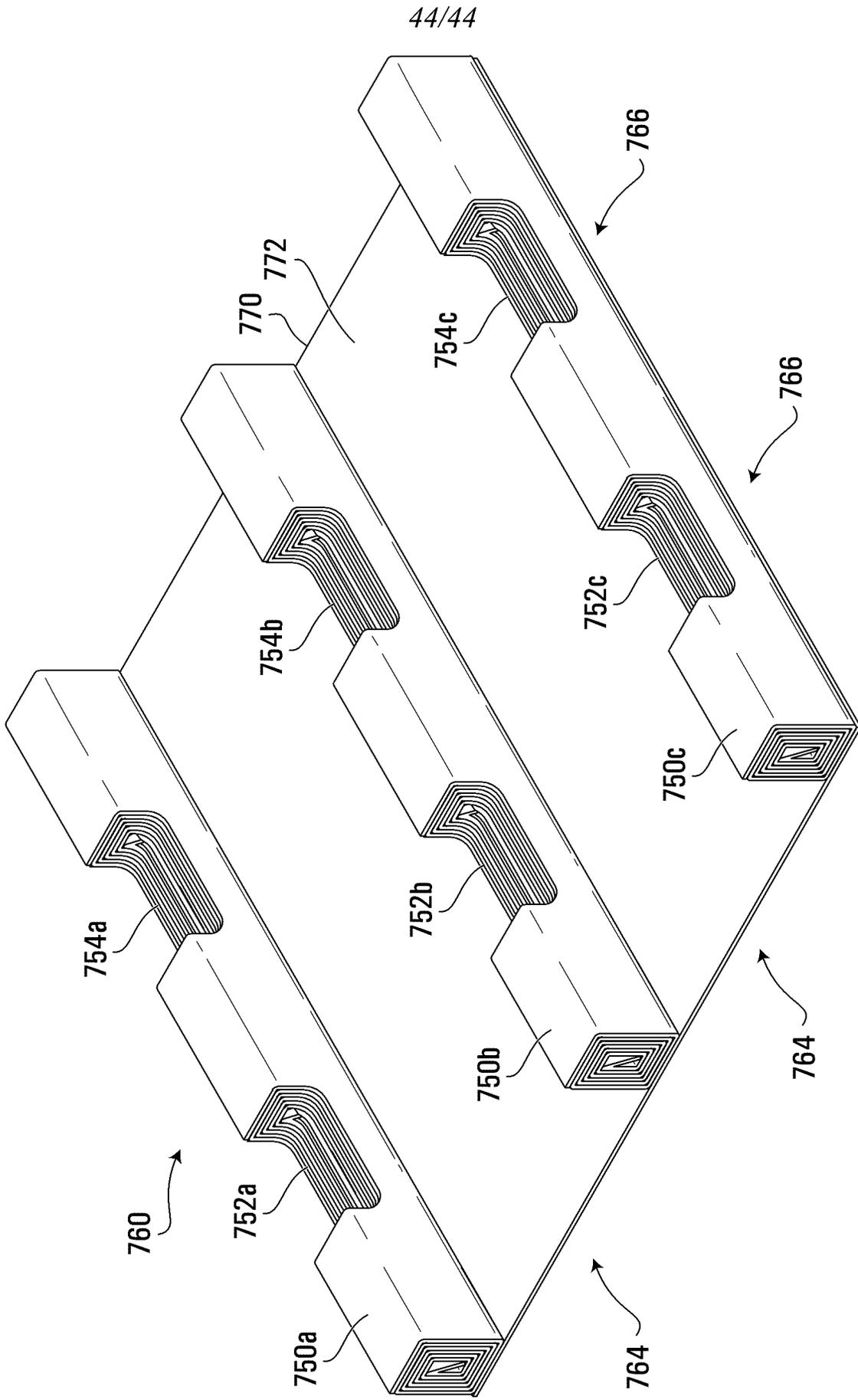


FIG. 19

CLAIMS:

1. An elongate pallet runner comprising:
 - a plurality of panels, each panel bent relative to an adjacent panel to form a continuous spiral structure having a cross-sectional profile that is nested, each panel having a planar surface that abuts against a planar surface of another panel.
2. The elongate pallet runner of claim 1, wherein the cross-sectional profile comprises nested layers of bent panels, each nested layer having a same geometric shape.
3. The elongate pallet runner of claim 1, wherein each panel is orientated perpendicular to its adjacent panel.
4. The elongate pallet runner of claim 1, wherein each panel is separated from its adjacent panel by a respective fold line.
5. The elongate pallet runner of claim 4, wherein each panel is folded relative to its adjacent panel about the respective fold line.
6. The elongate pallet runner of claim 1, wherein at least some of the abutting panels are adhered to each other by an adhesive.
7. The elongate pallet runner of claim 1, wherein the plurality of adjacent panels are integrally formed.
8. The elongate pallet runner of claim 1, wherein the elongate pallet runner has a rectangular cross-sectional profile.
9. The elongate pallet runner of claim 1, wherein the elongate pallet runner is formed of corrugated cardboard.
10. The elongate pallet runner of claim 1, wherein an innermost panel of the spiral structure includes a diagonal portion that does not abut against the planar surface of another panel.
11. A pallet comprising a deck having a top side and a bottom side and a plurality of elongate pallet runners secured to the bottom side of the deck, wherein each of the plurality of elongate pallet runners comprises:

- a plurality of panels, each panel bent relative to an adjacent panel to form a continuous spiral structure having a cross-sectional profile that is nested, each panel having a planar surface that abuts against a planar surface of another panel.

12. The pallet of claim 11, wherein the cross-sectional profile comprises nested layers of bent
5 panels, each nested layer having a same geometric shape.

13. The pallet of claim 11, wherein each panel is orientated perpendicular to its adjacent panel.

14. The pallet of claim 11, wherein each panel is separated from its adjacent panel by a
respective fold line.

15. The pallet of claim 14, wherein each panel is folded relative to its adjacent panel about
10 the respective fold line.

16. The pallet of claim 11, wherein at least some of the abutting panels are adhered to each
other by an adhesive.

17. The pallet of claim 11, wherein the plurality of adjacent panels are integrally formed.

18. The pallet of claim 11, wherein each elongate pallet runner has a rectangular cross-
15 sectional profile.

19. The pallet of claim 11, wherein each elongate pallet runner is formed of corrugated
cardboard.

20. The pallet of claim 11, wherein the pallet comprises three elongate pallet runners.

21. The pallet of claim 11, wherein the deck and plurality of elongate pallet runners are made
20 from corrugated carboard.

22. The corrugated pallet of claim 11, wherein the deck is a first deck and wherein the
corrugated pallet further comprises a second deck having a top side and bottom side, wherein
the plurality of elongate pallet runners are secured to the top side of the second deck.

23. A method of forming a corrugated pallet, the method comprising affixing a plurality of
25 elongate pallet runners to the same side of a deck, wherein each of the plurality of elongate
pallet runners comprises:

- a plurality of panels, each panel bent relative to an adjacent panel to form a continuous spiral structure having a cross-sectional profile that is nested, each panel having a planar surface that abuts against a planar surface of another panel.