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(54) **PALLET AND PALLET FORMING SYSTEM AND METHOD**

(71) Applicant: **AFA SYSTEMS LTD.**, BRAMPTON (CA)

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

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Publication Classification

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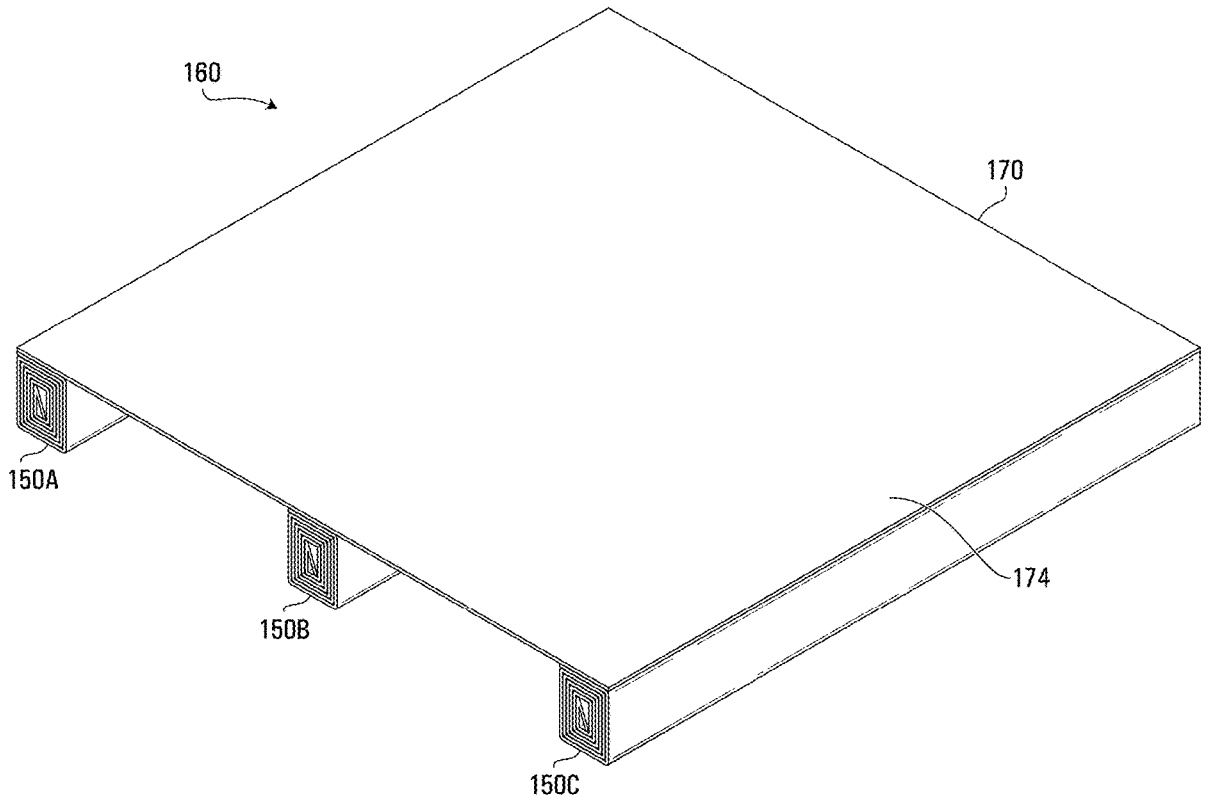
(52) **U.S. Cl.**
CPC ***B65D 19/0026*** (2013.01); *B65D 2519/00273* (2013.01); *B65D 2519/00288* (2013.01); *B65D 2519/00333* (2013.01); *B65D 2519/00417* (2013.01); *B65D 2519/00562* (2013.01); *B65D 2519/00796* (2013.01)

(57) **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 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.



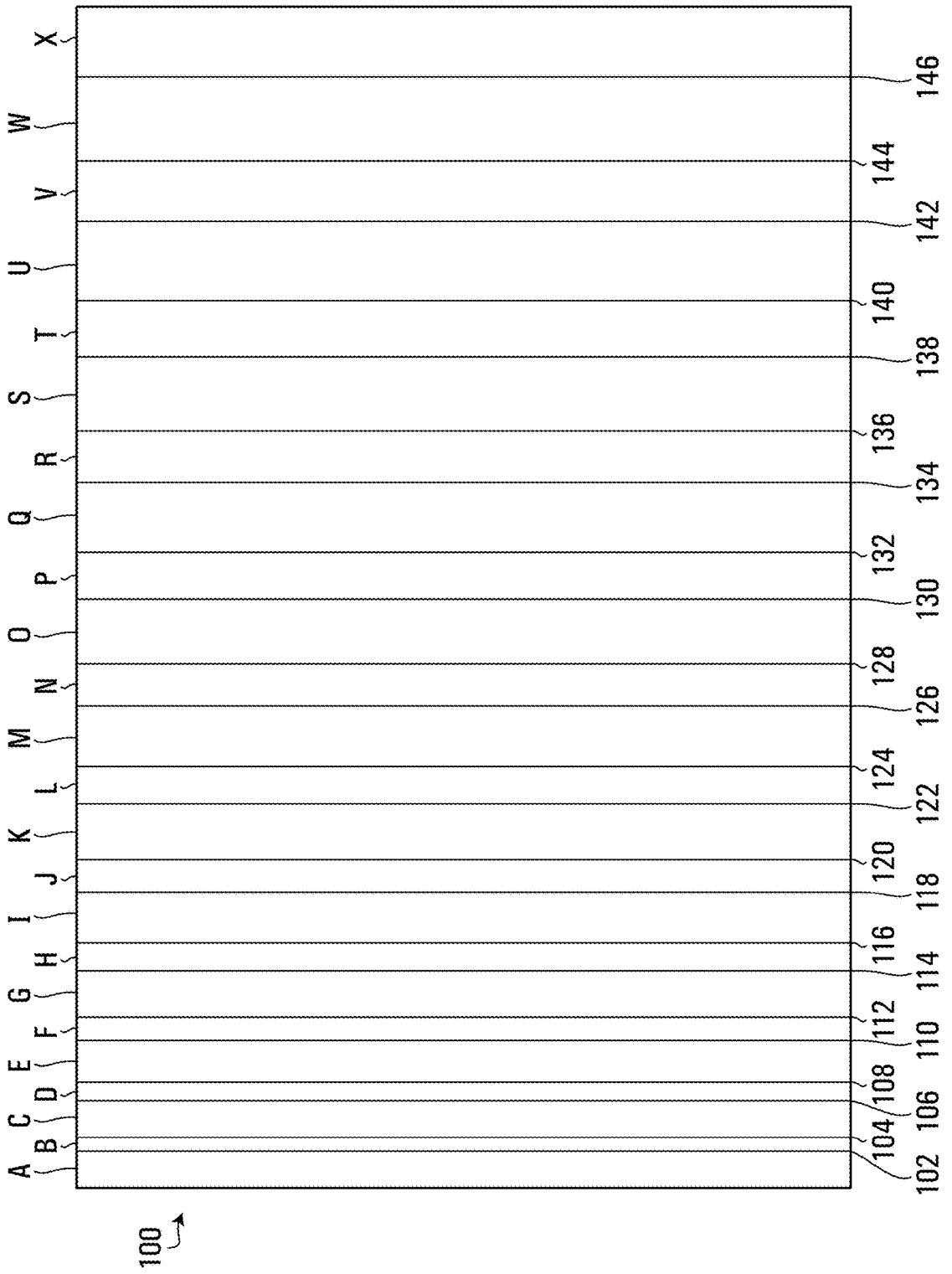

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FIG. 1

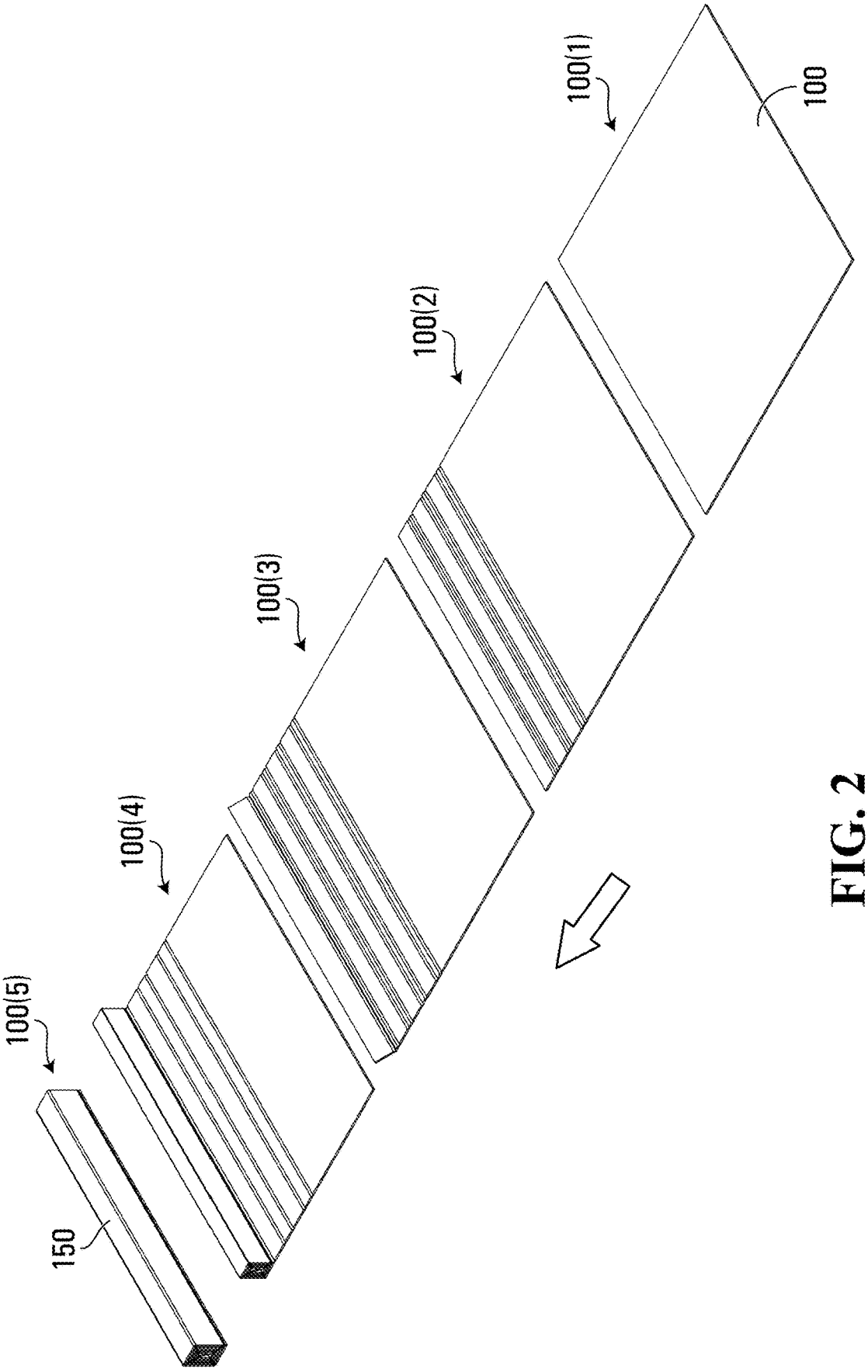

FIG. 2

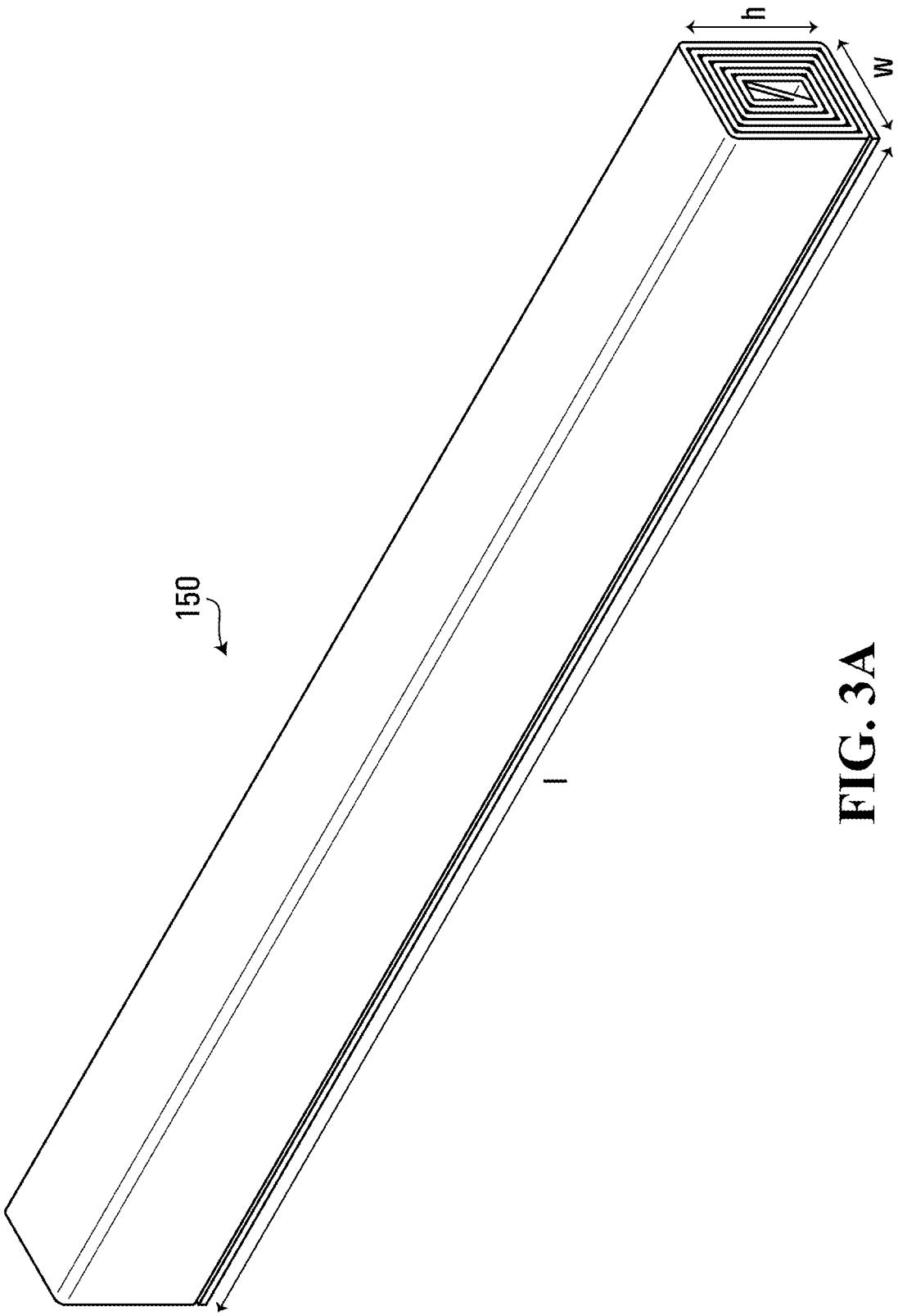

FIG. 3A

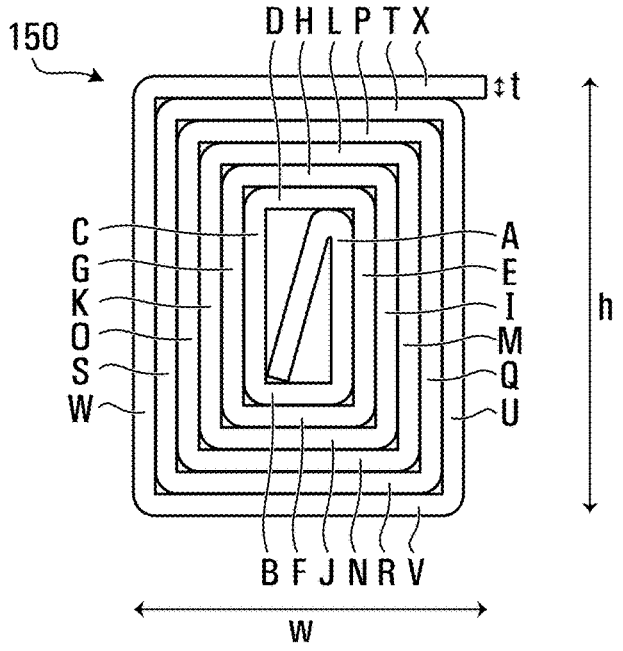

FIG. 3B

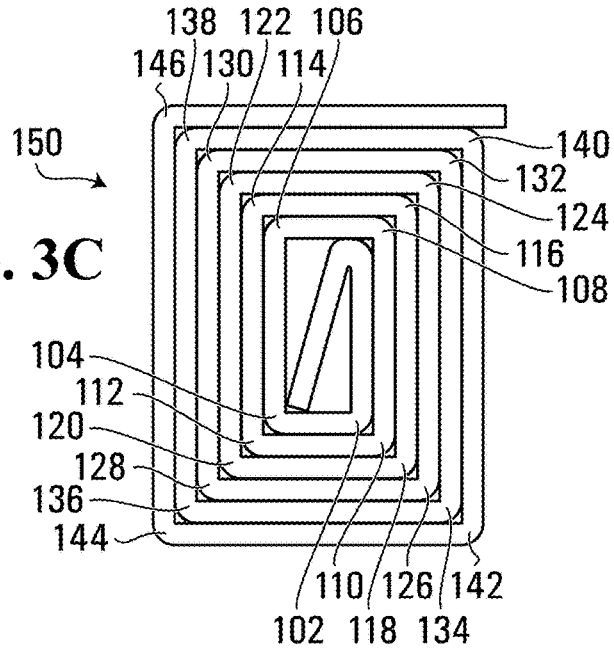

FIG. 3C

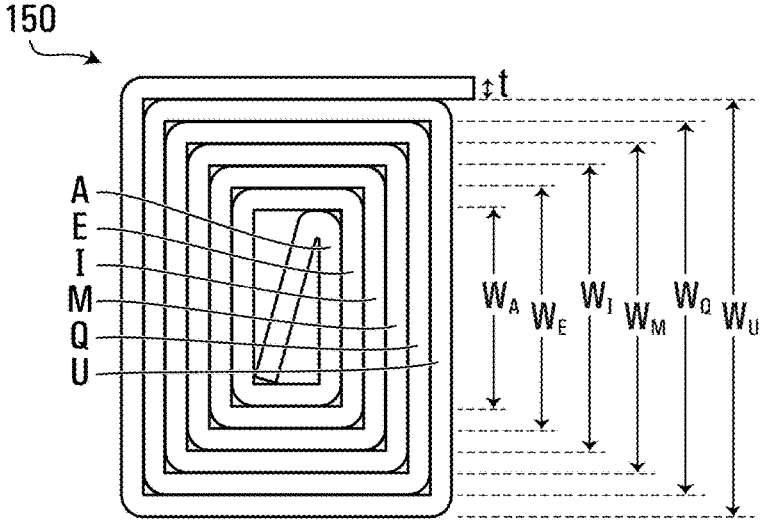

FIG. 3D

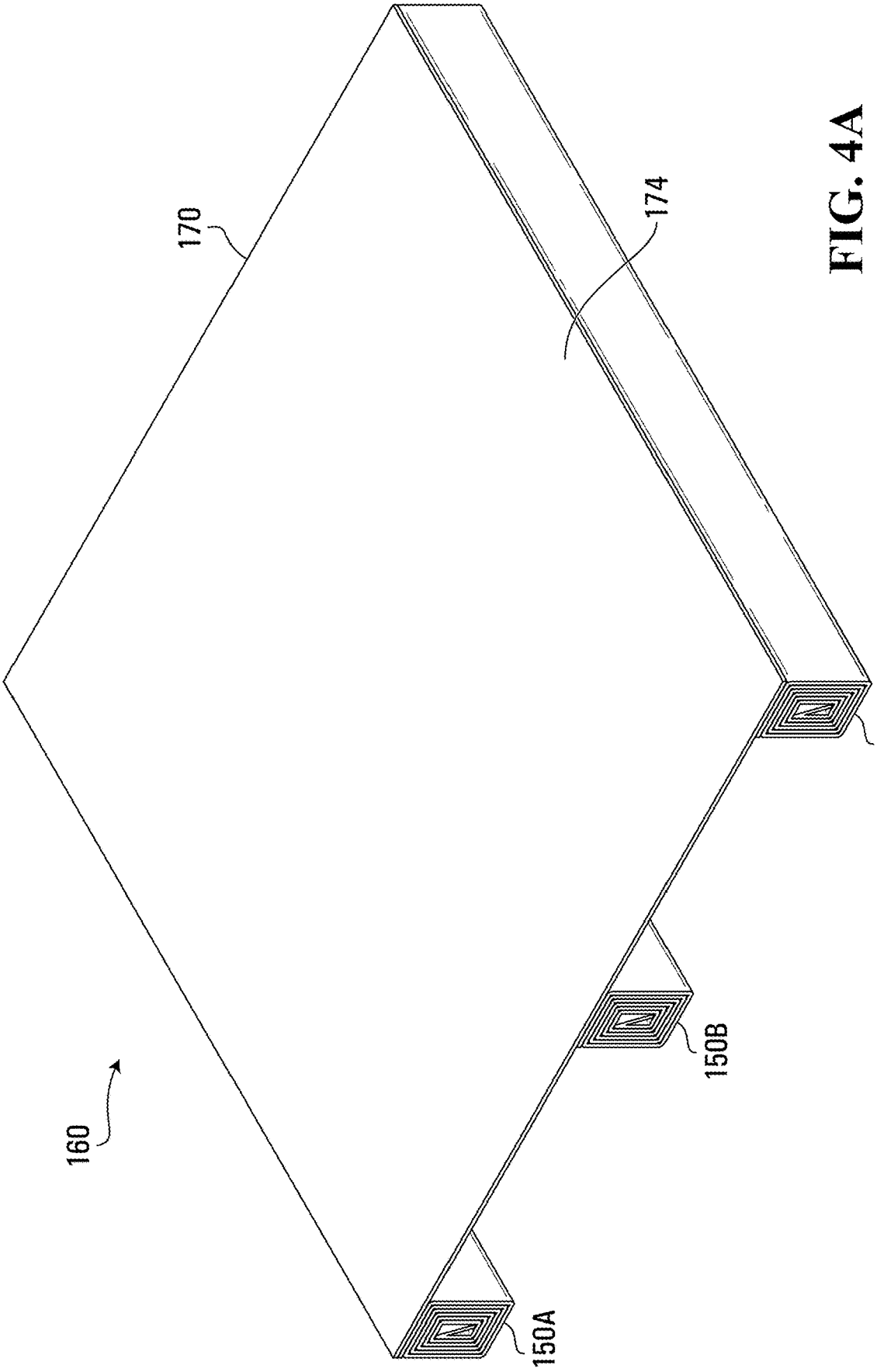

FIG. 4A

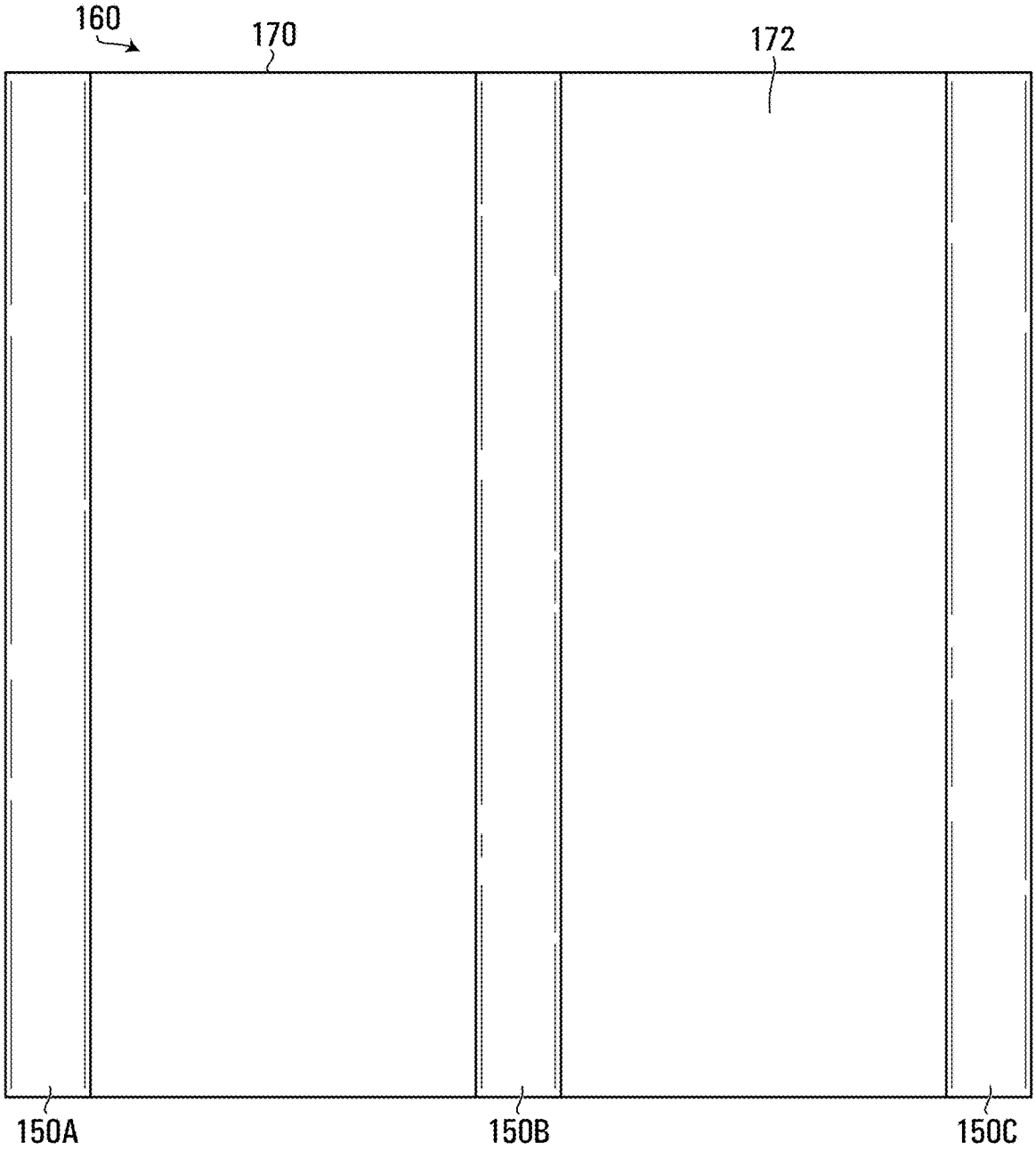

FIG. 4B

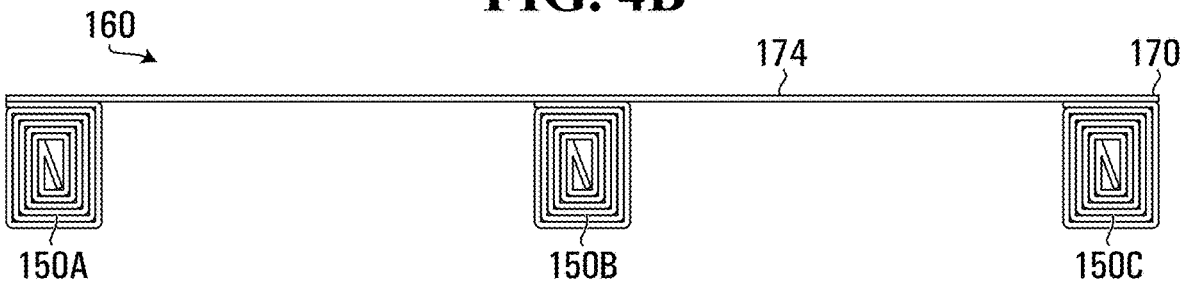

FIG. 4C

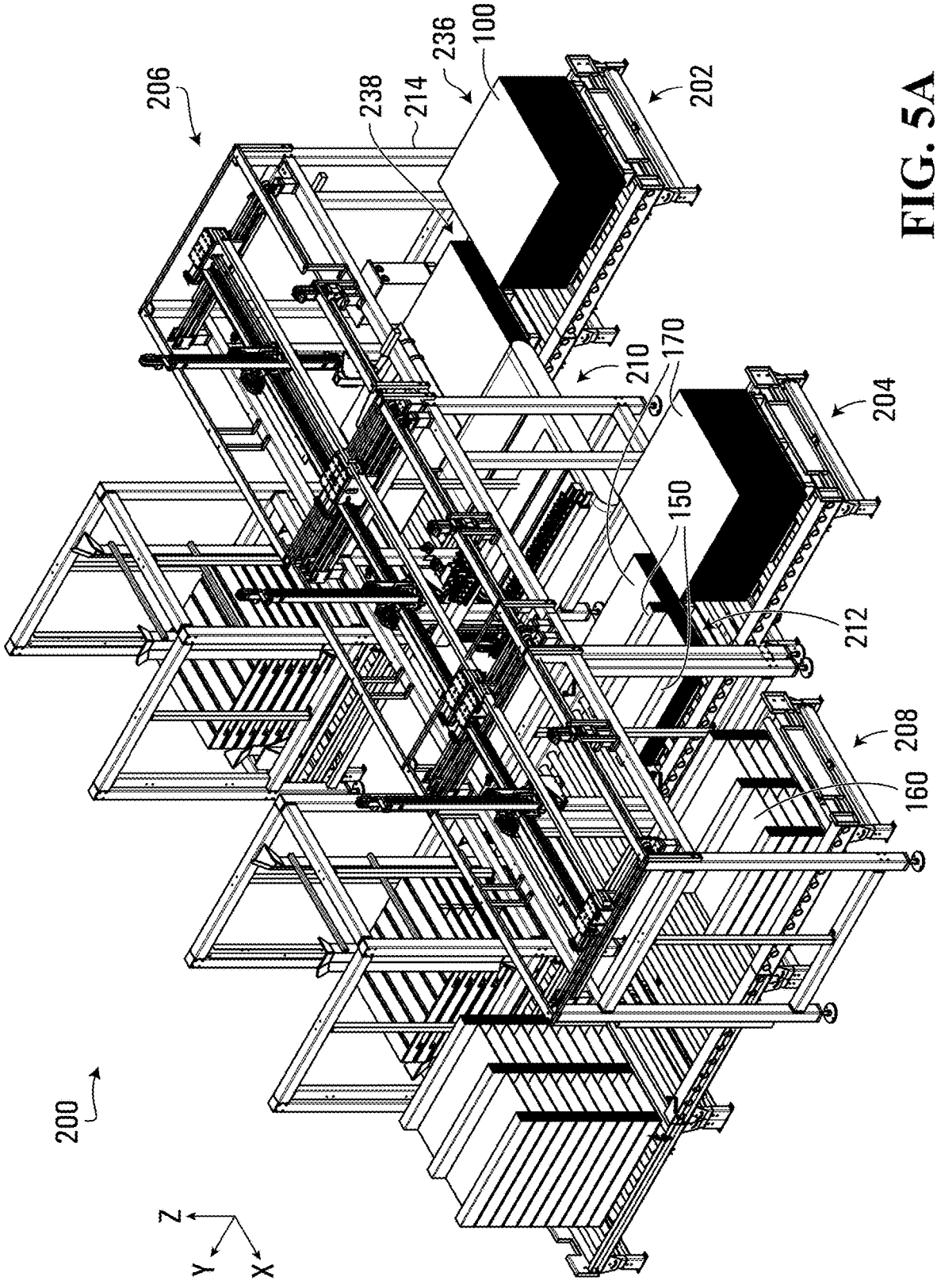

FIG. 5A

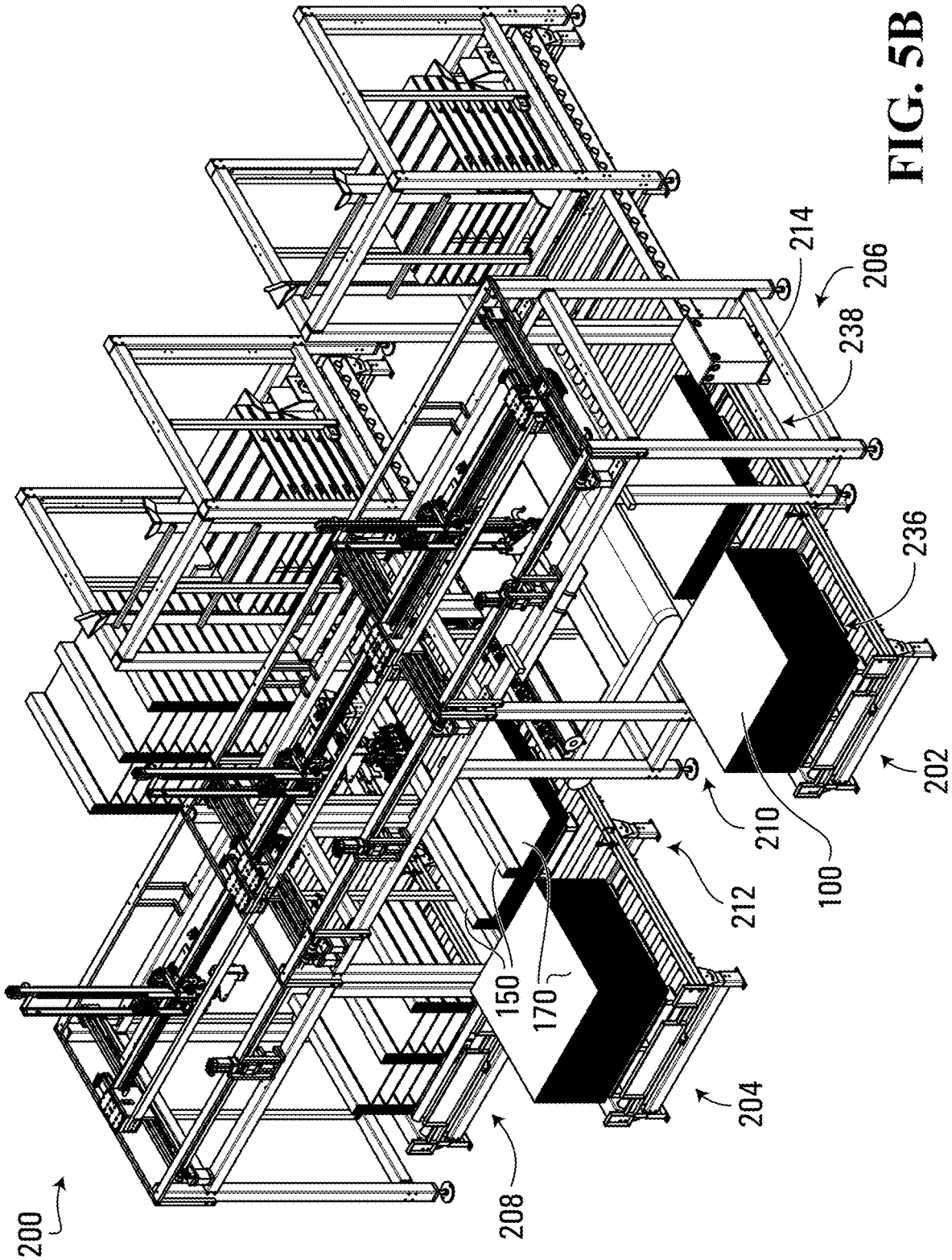

FIG. 5B

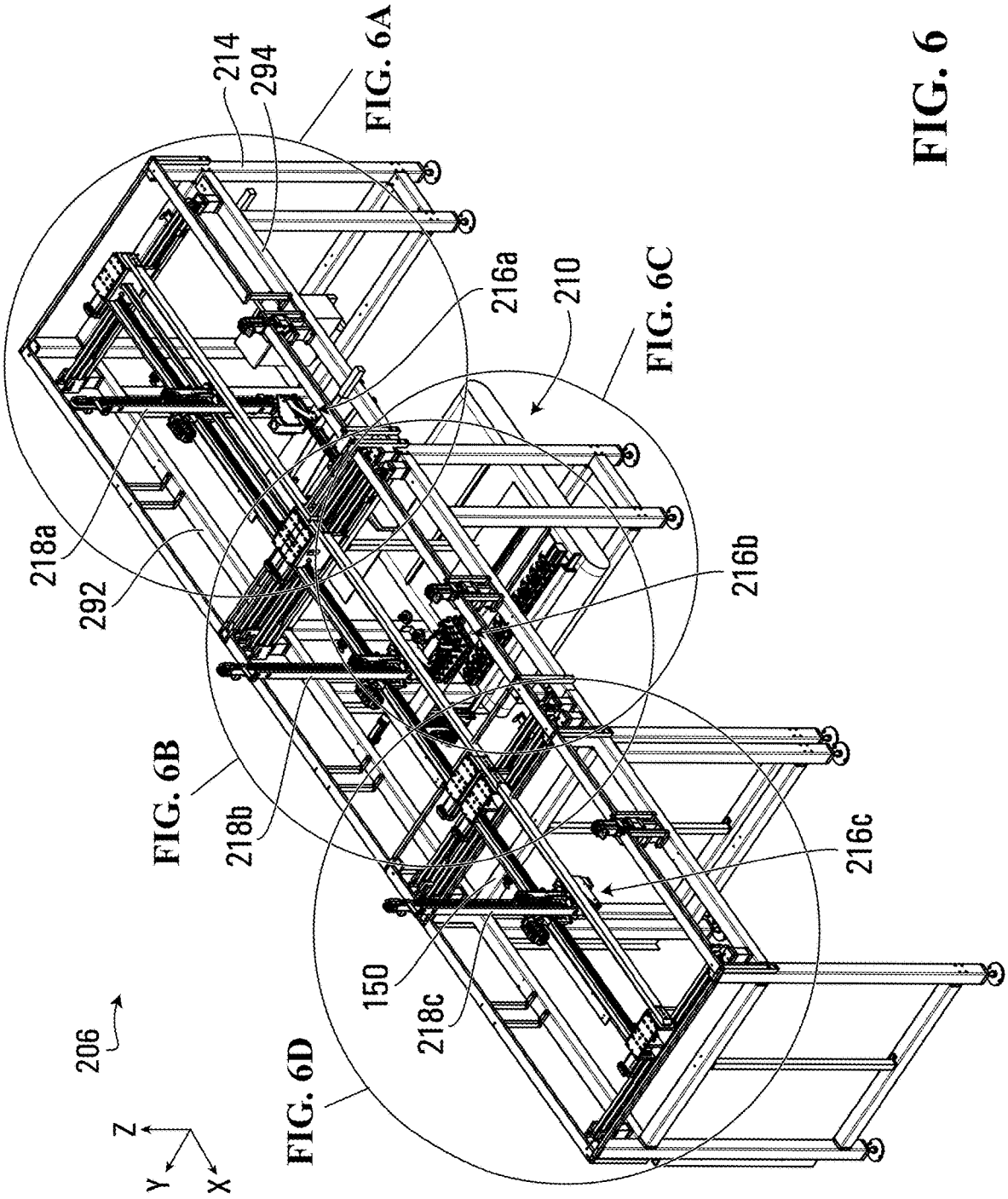
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FIG. 6A
216a
210
FIG. 6C
218a
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216b
FIG. 6B
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216c
150
218c
206
Z
Y
X
FIG. 6D

FIG. 6

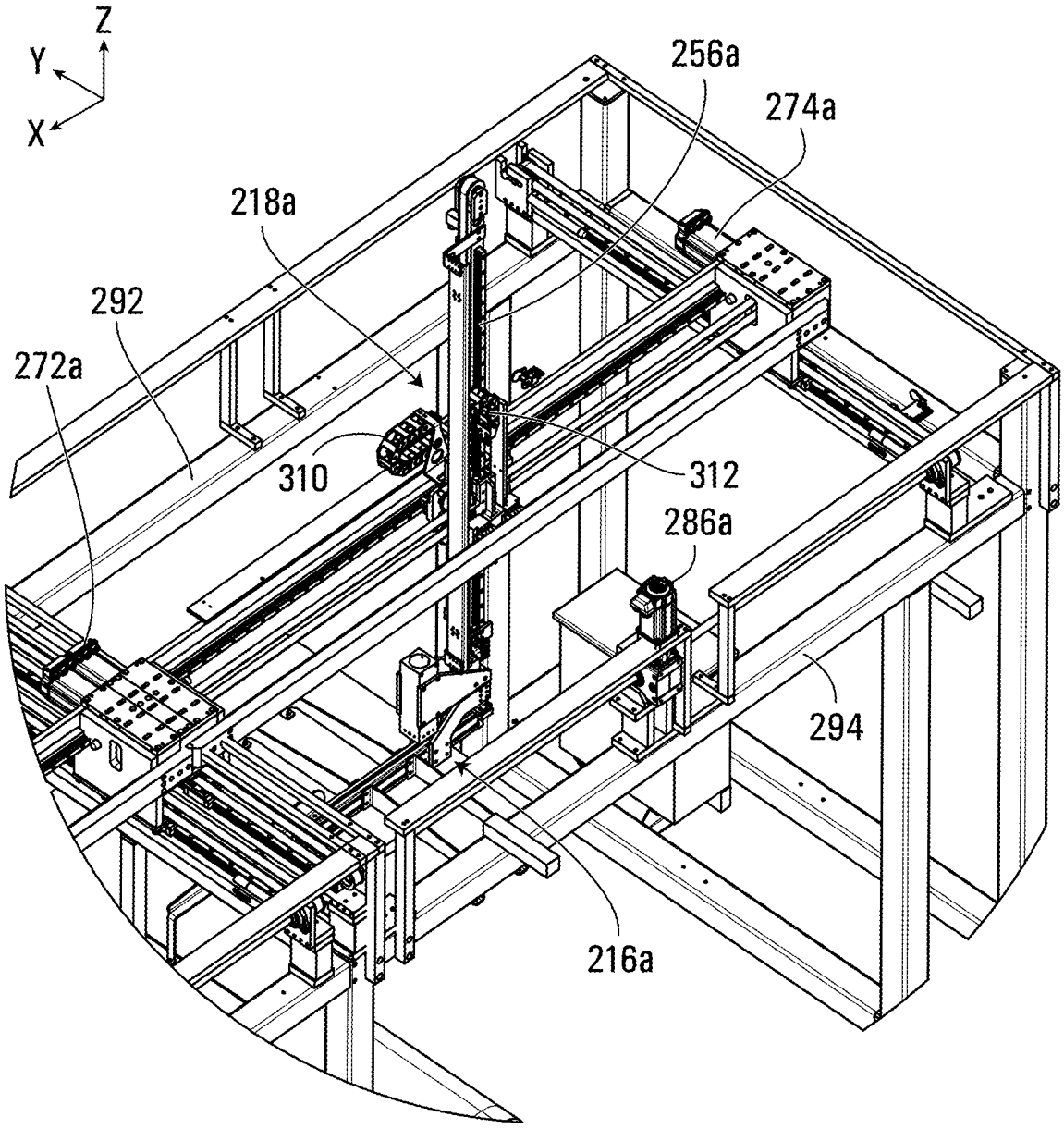


FIG. 6A

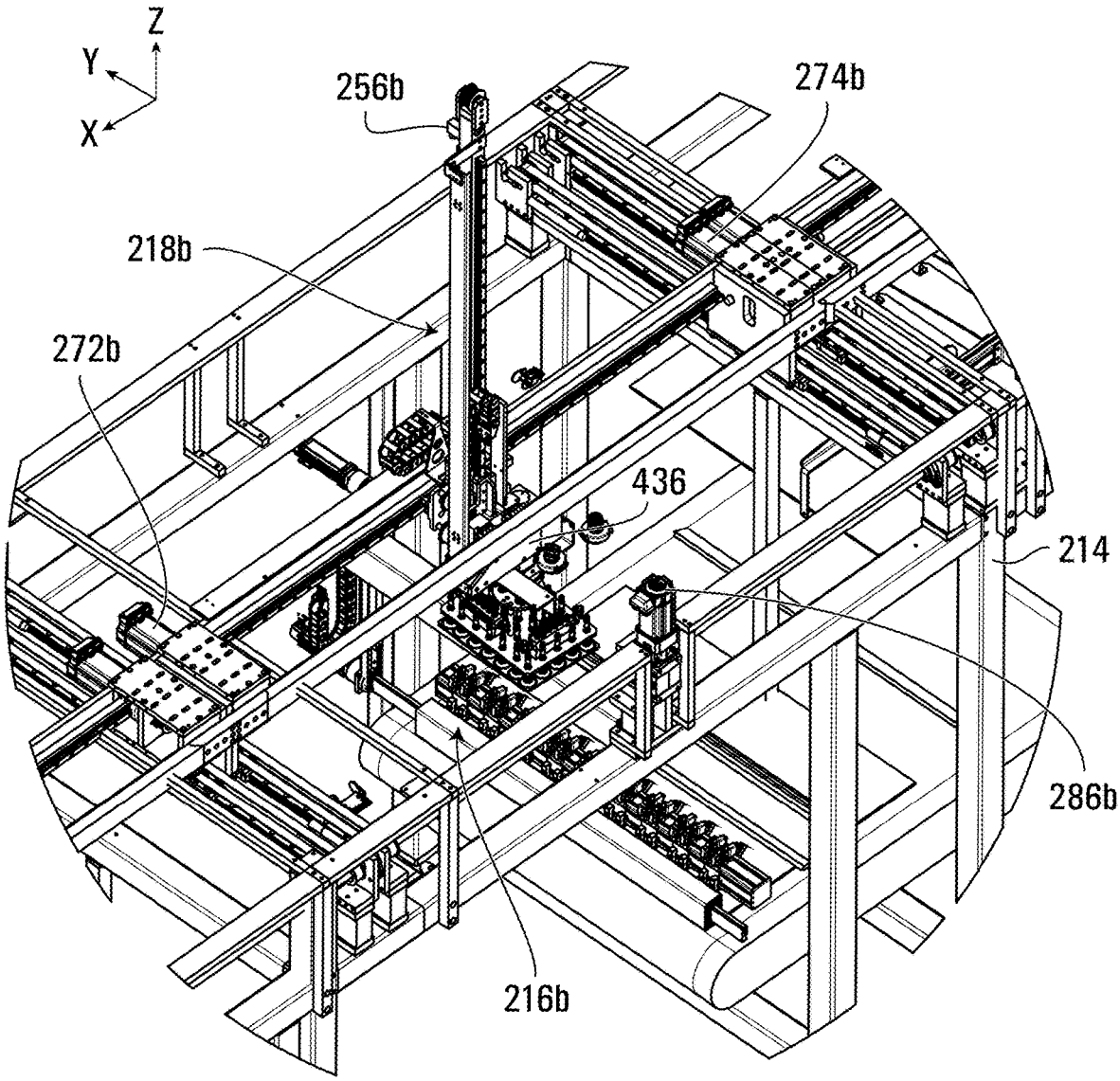


FIG. 6B

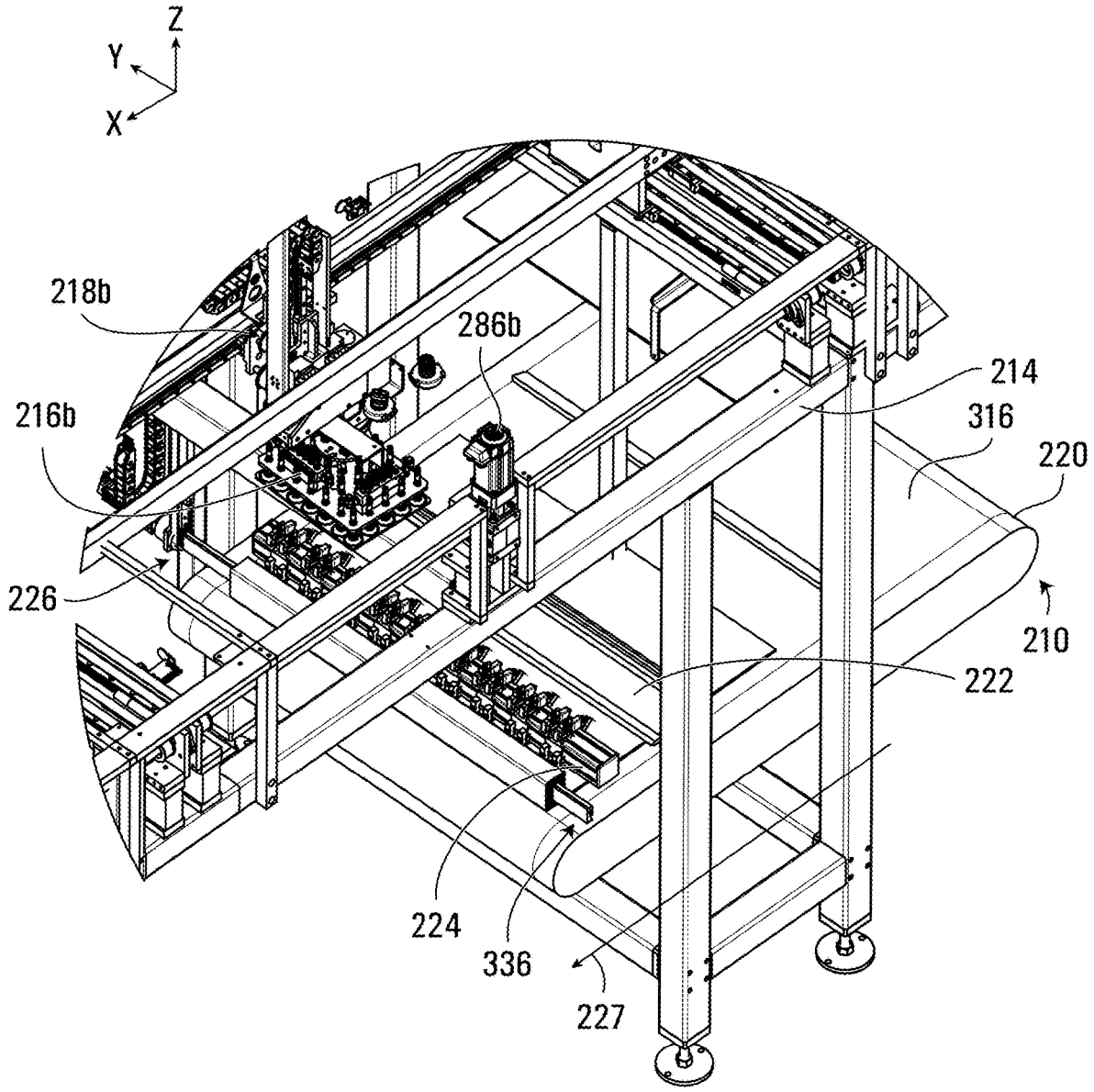


FIG. 6C

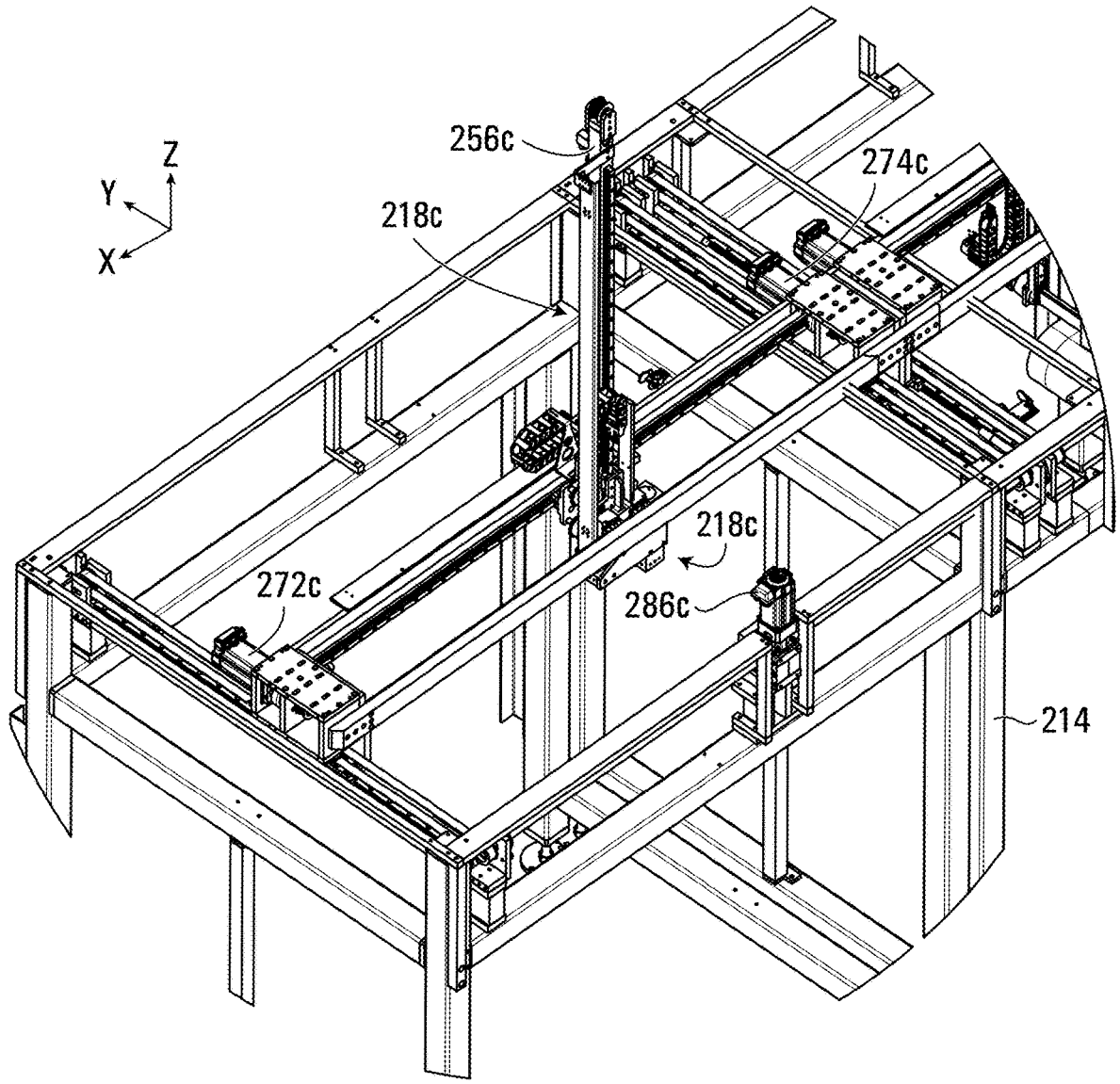
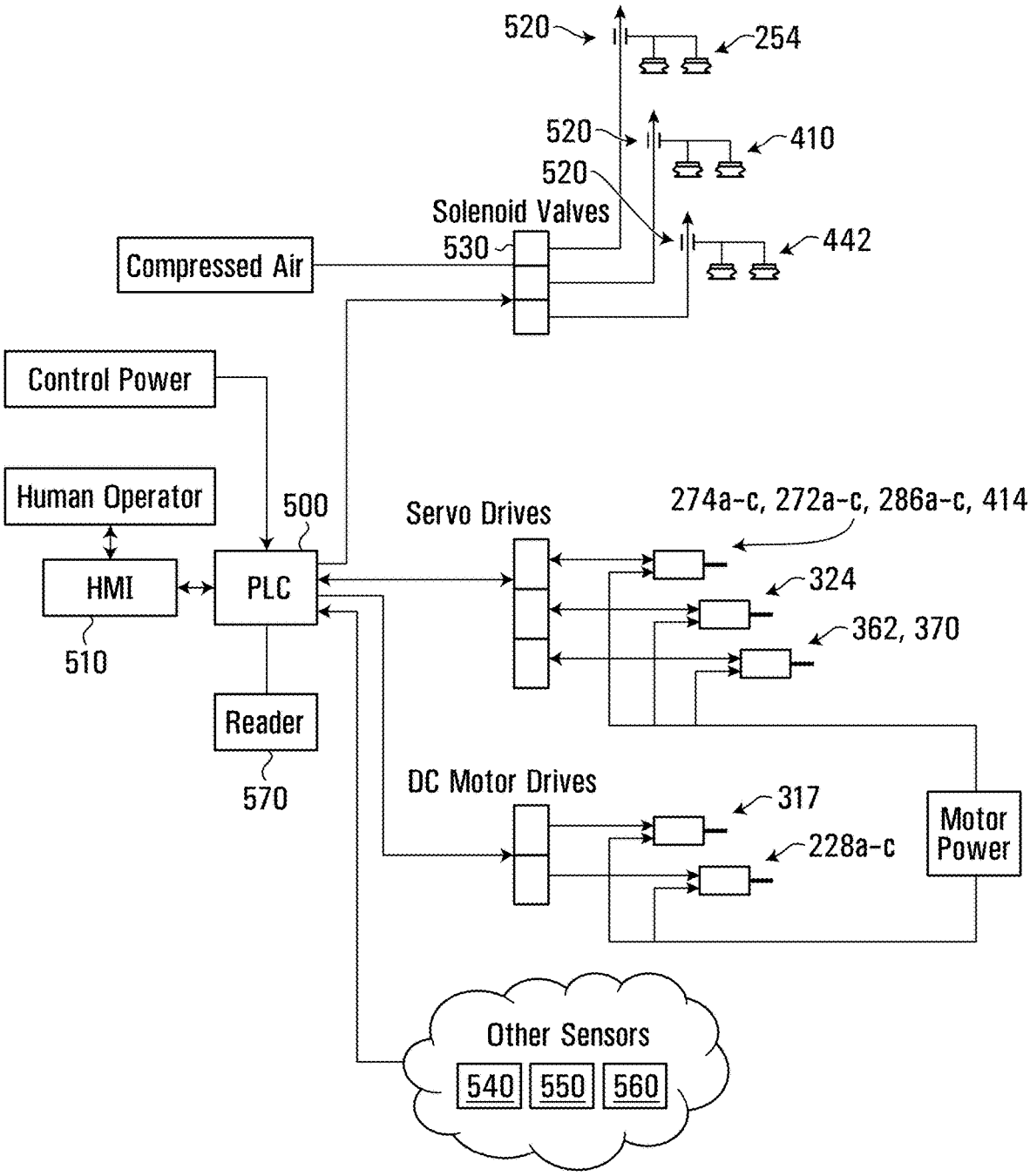


FIG. 6D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Solenoid Valves
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Compressed Air
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Human Operator
500
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HMI
PLC
324
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510
Reader
570
DC Motor Drives
317
228a-c
Motor Power
Other Sensors
540
550
560

FIG. 7

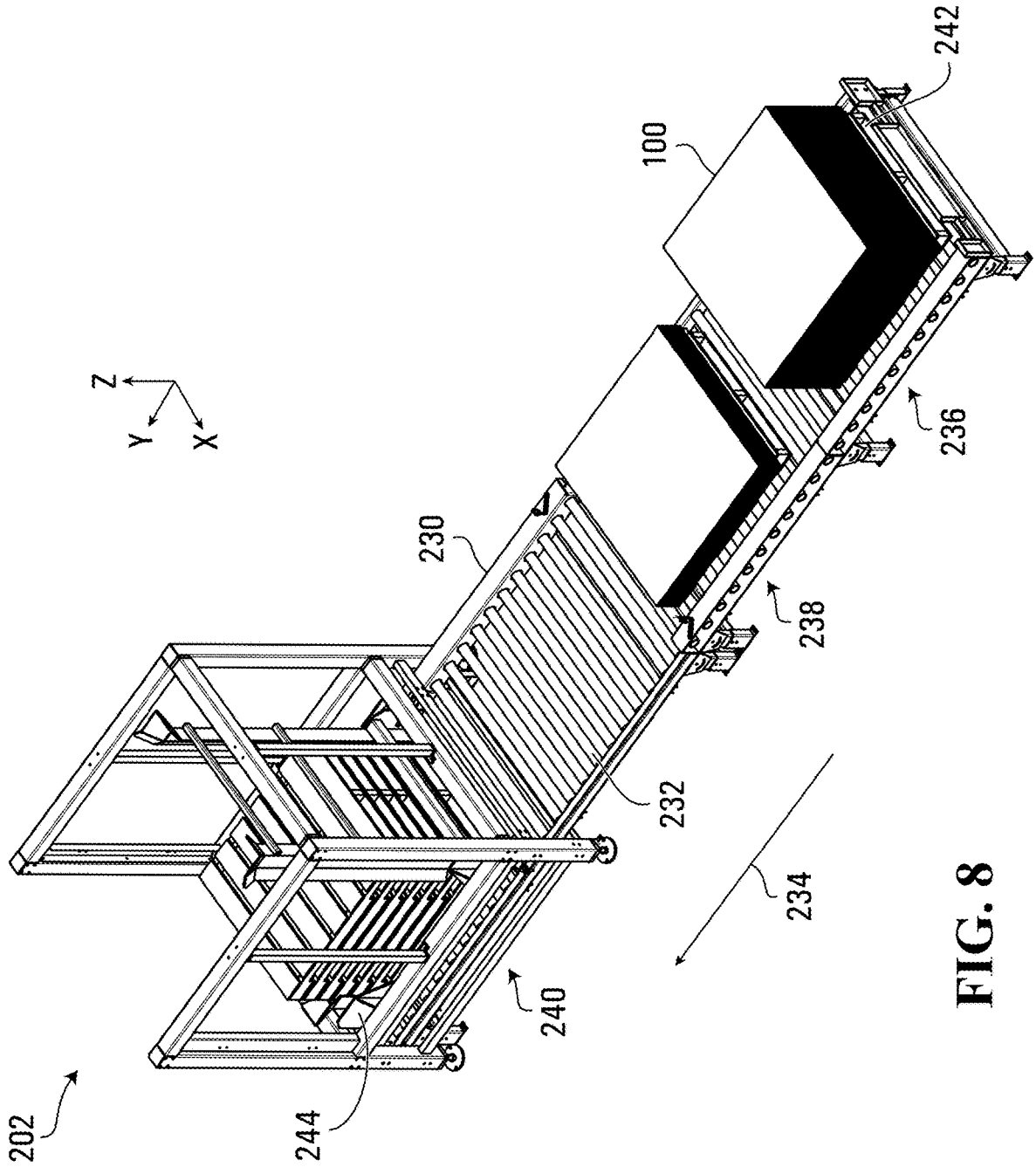

FIG. 8

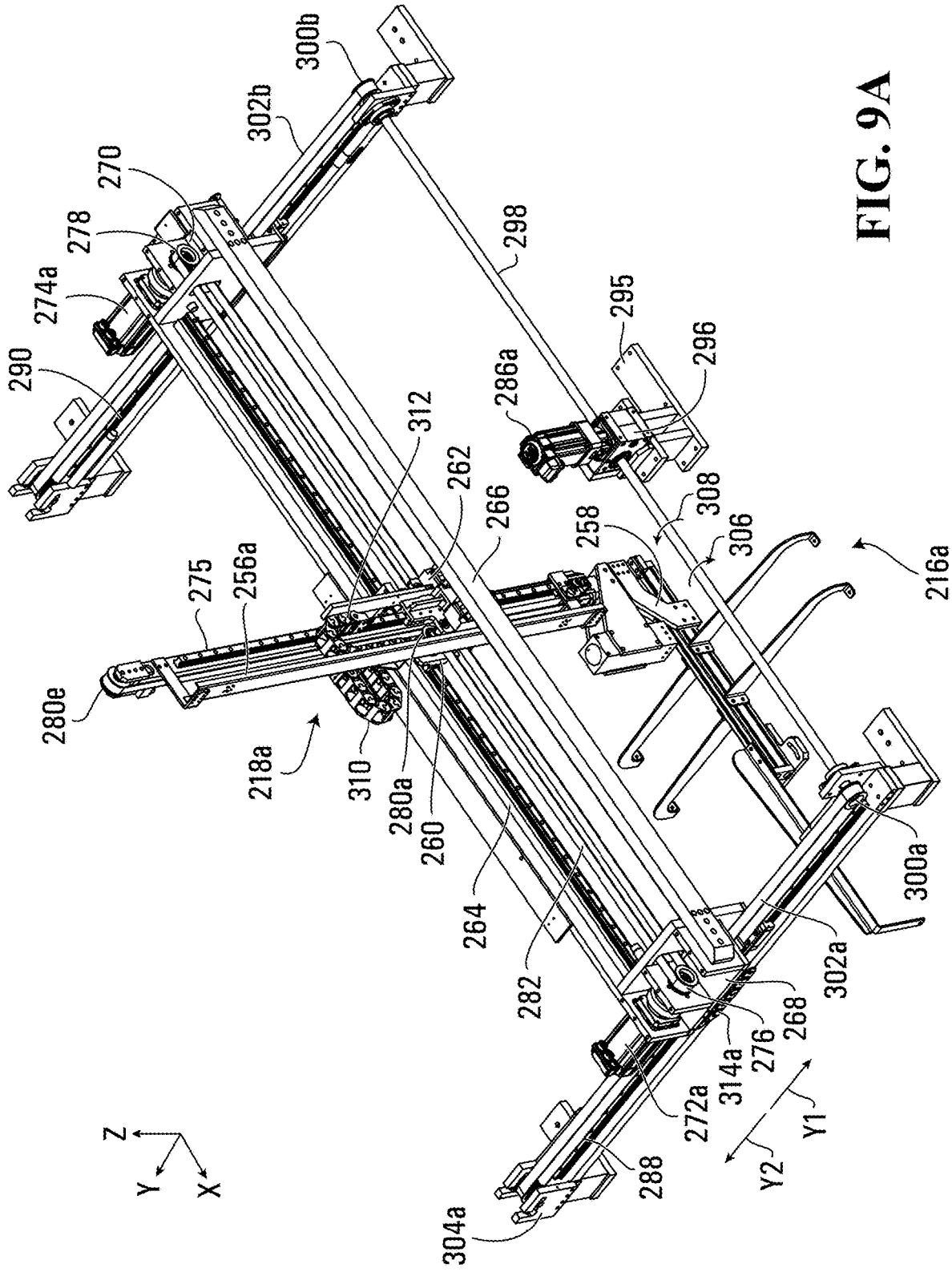
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FIG. 9A

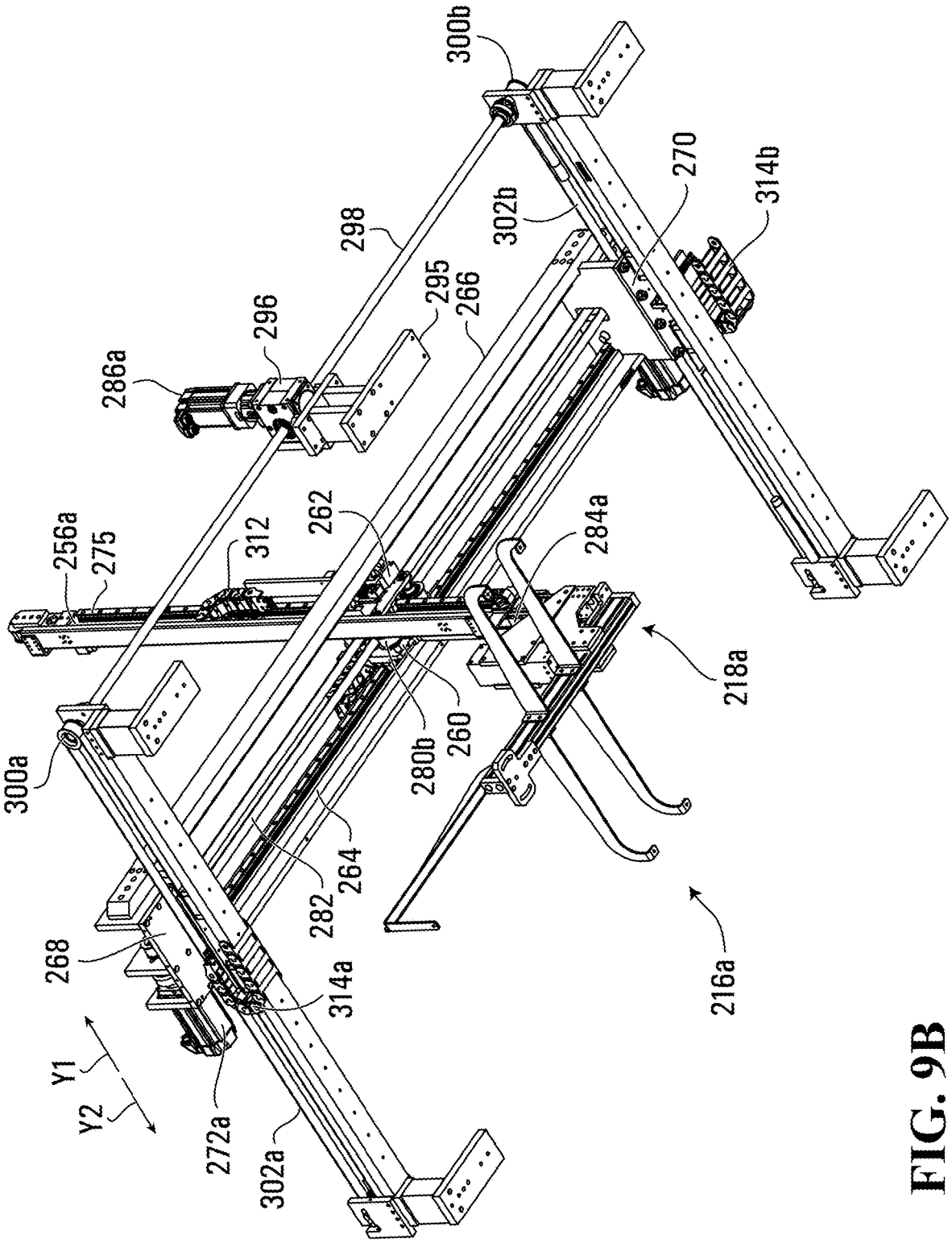
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FIG. 9B

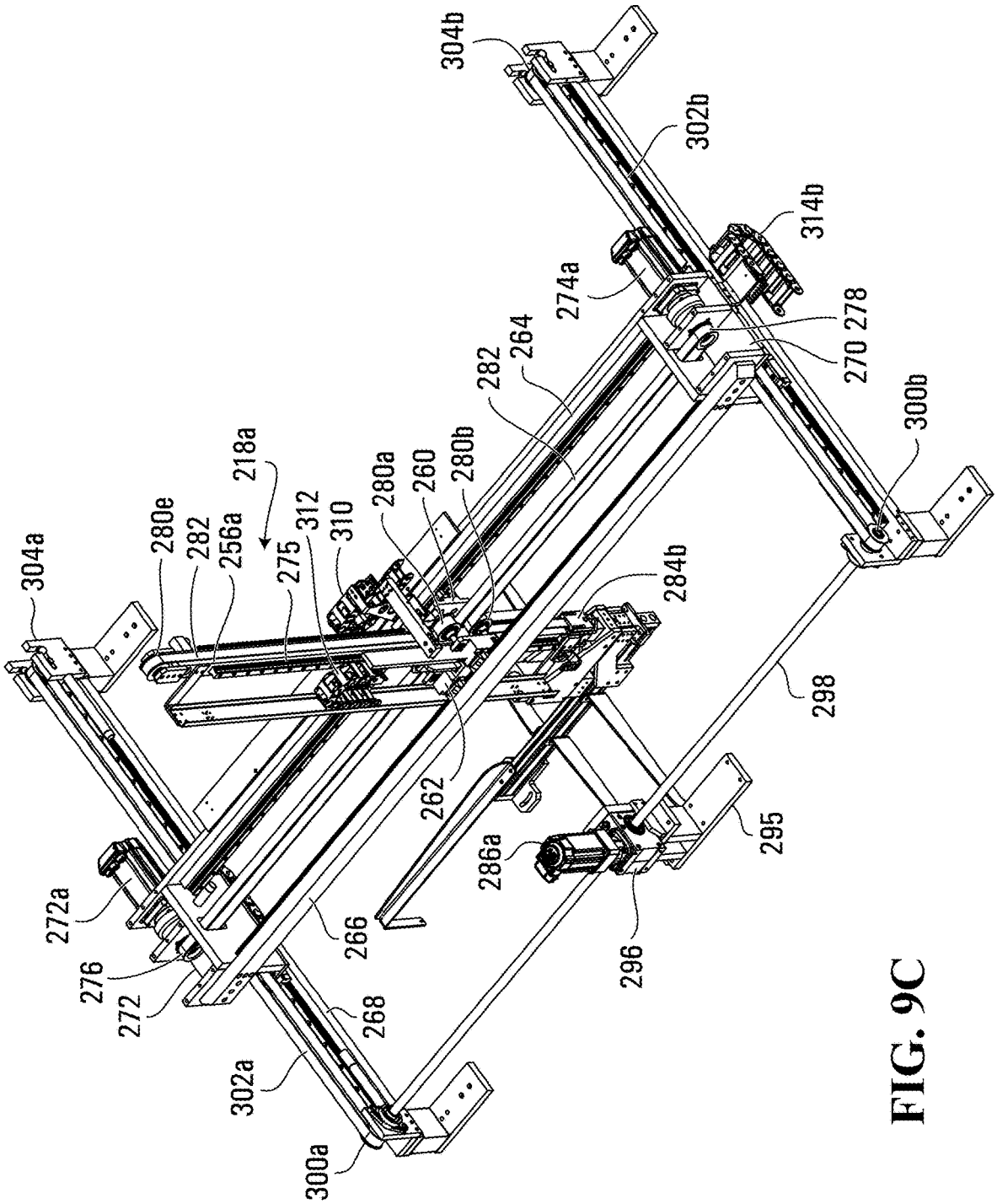
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FIG. 9C

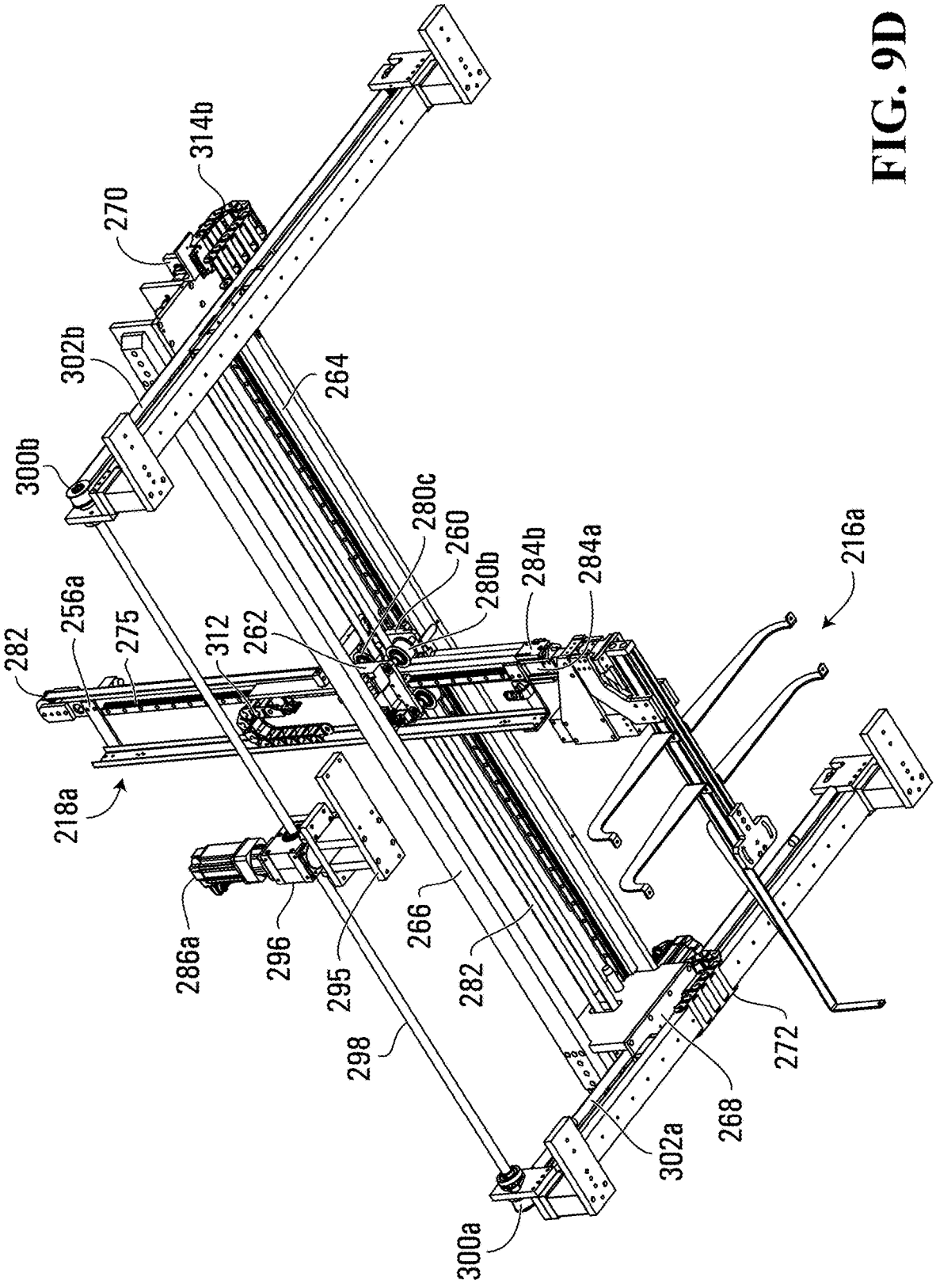
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FIG. 9D

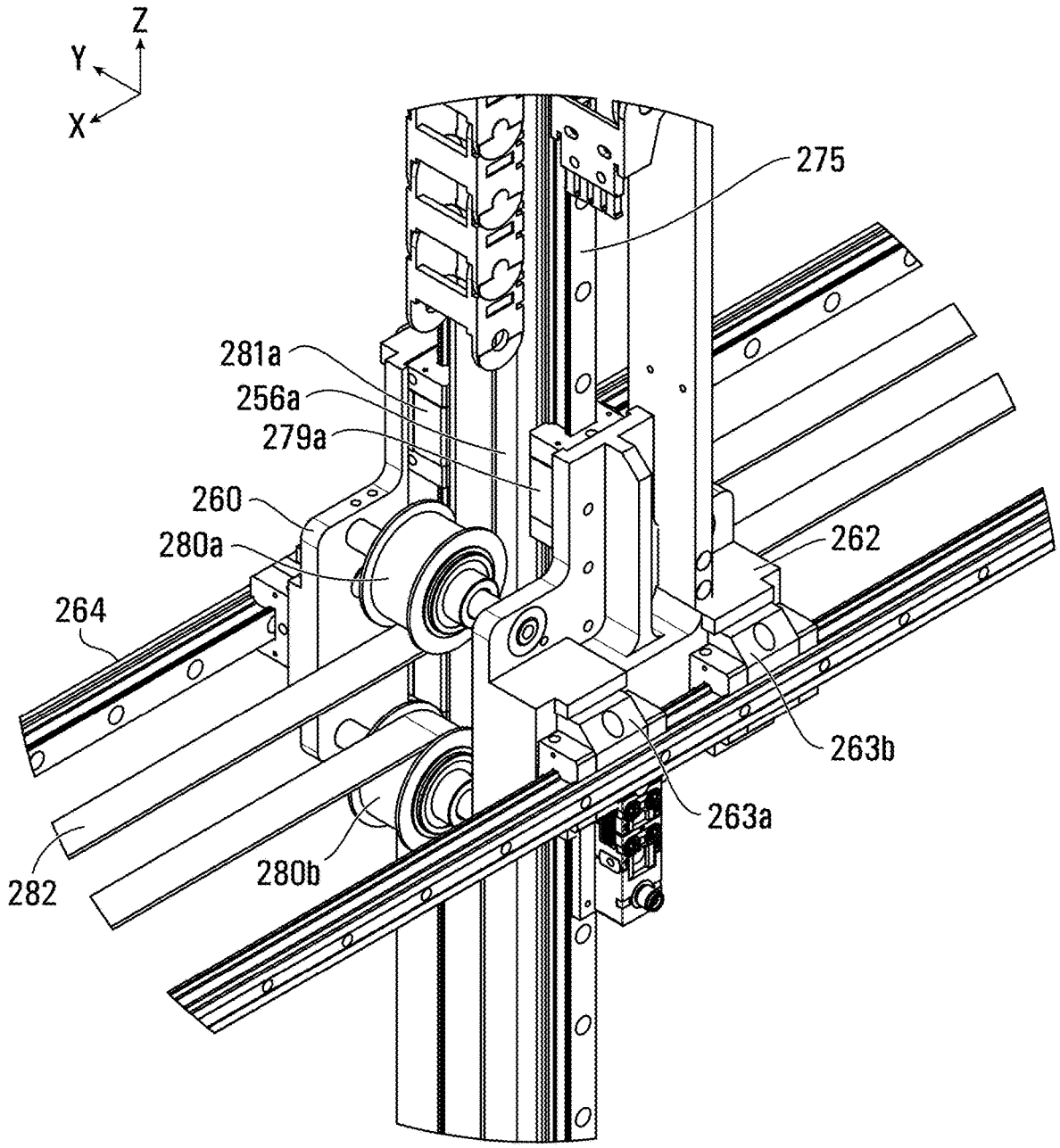

FIG. 9E

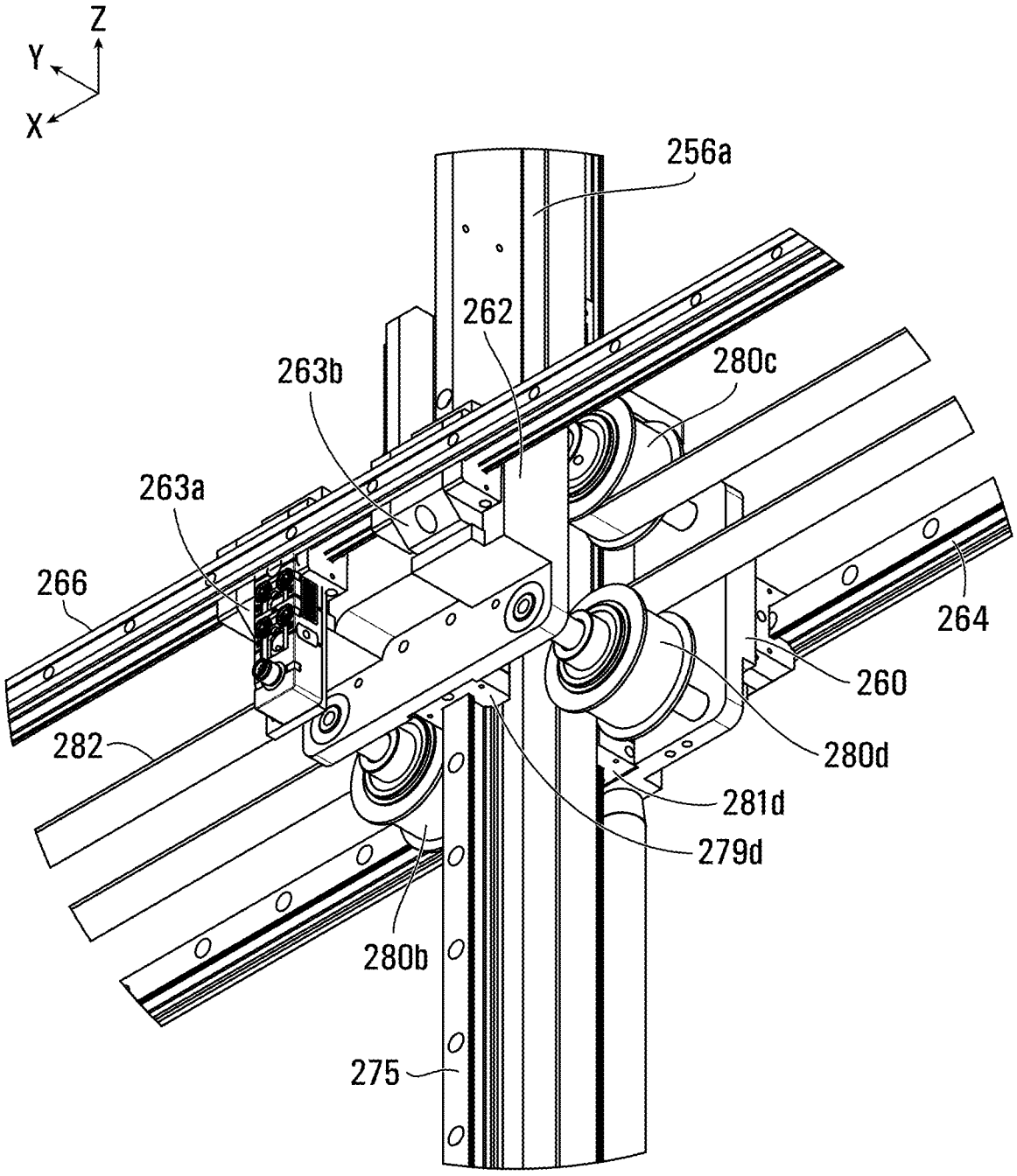
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FIG. 9F

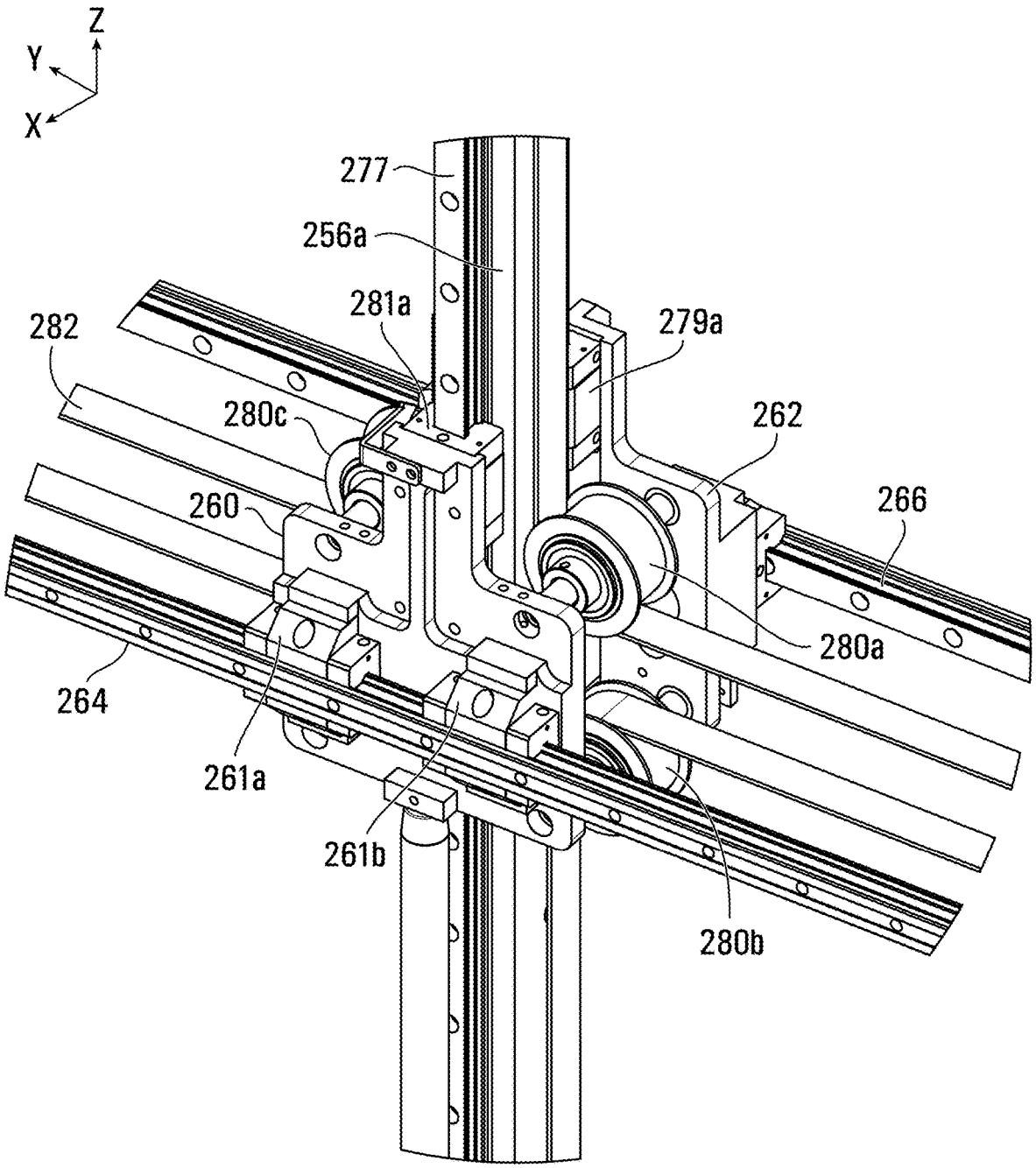
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FIG. 9G

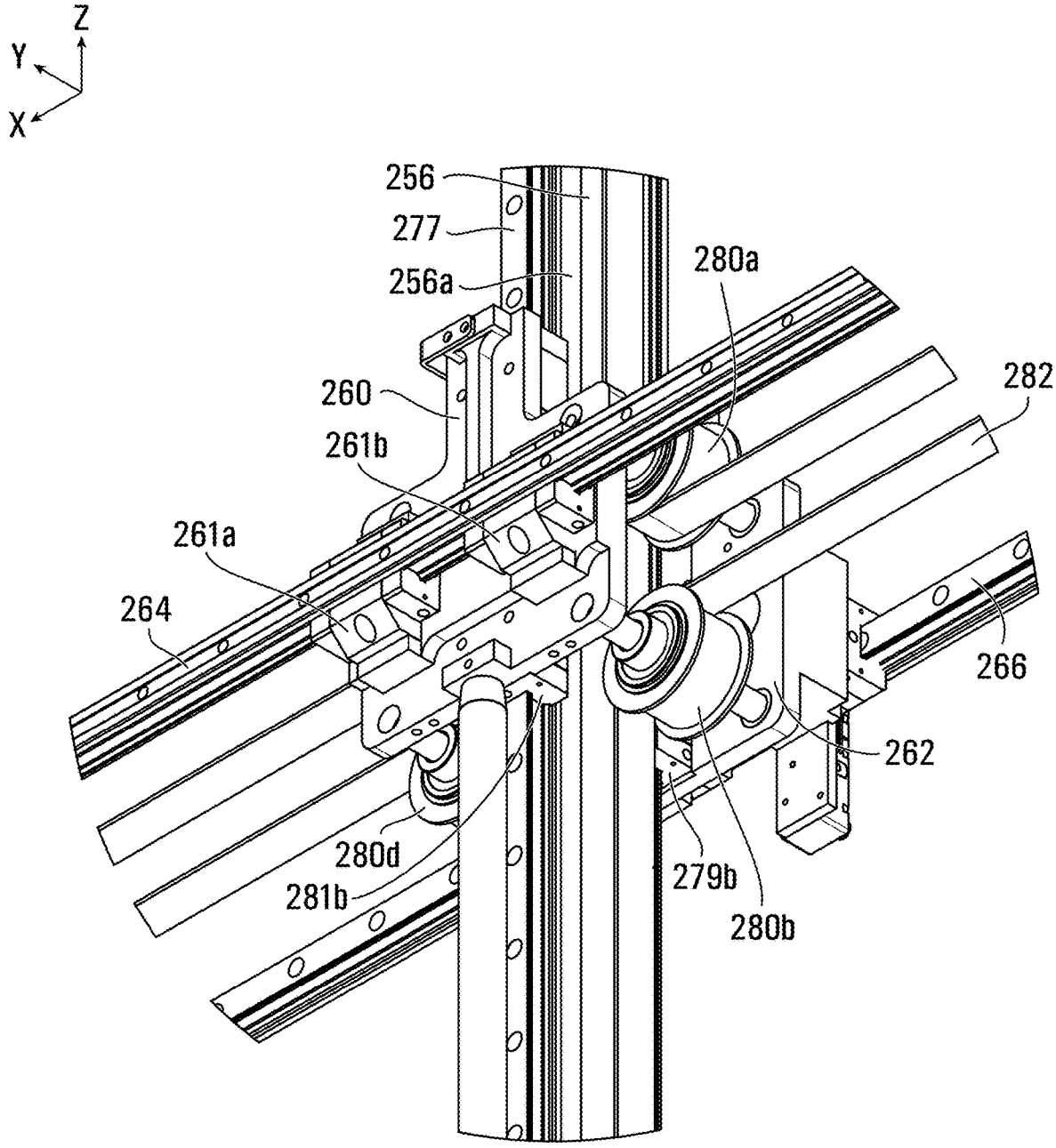
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FIG. 9H

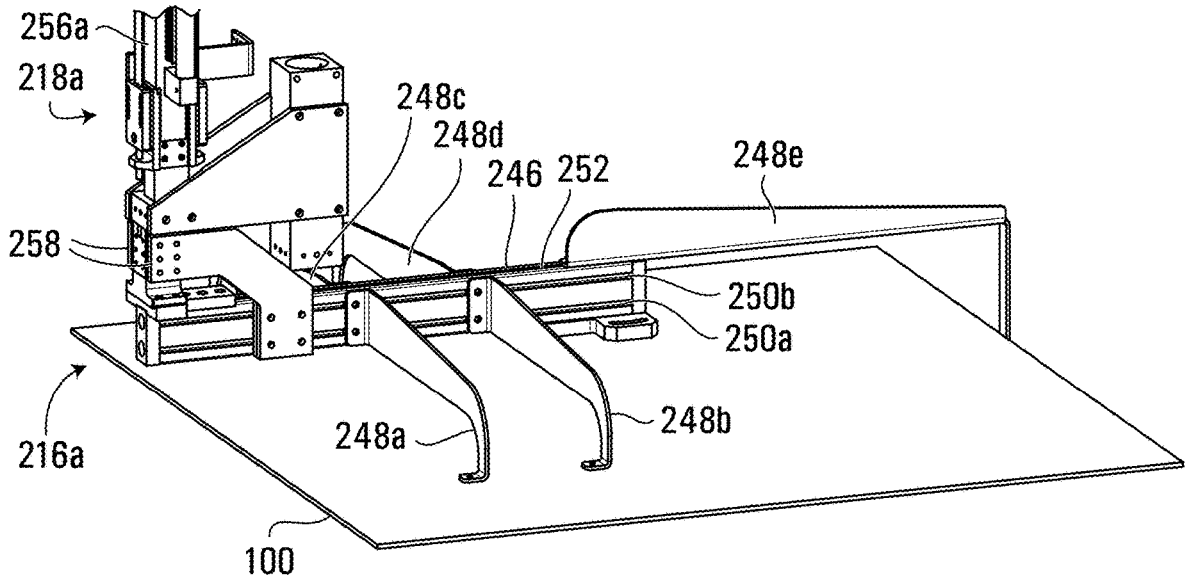
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FIG. 9I

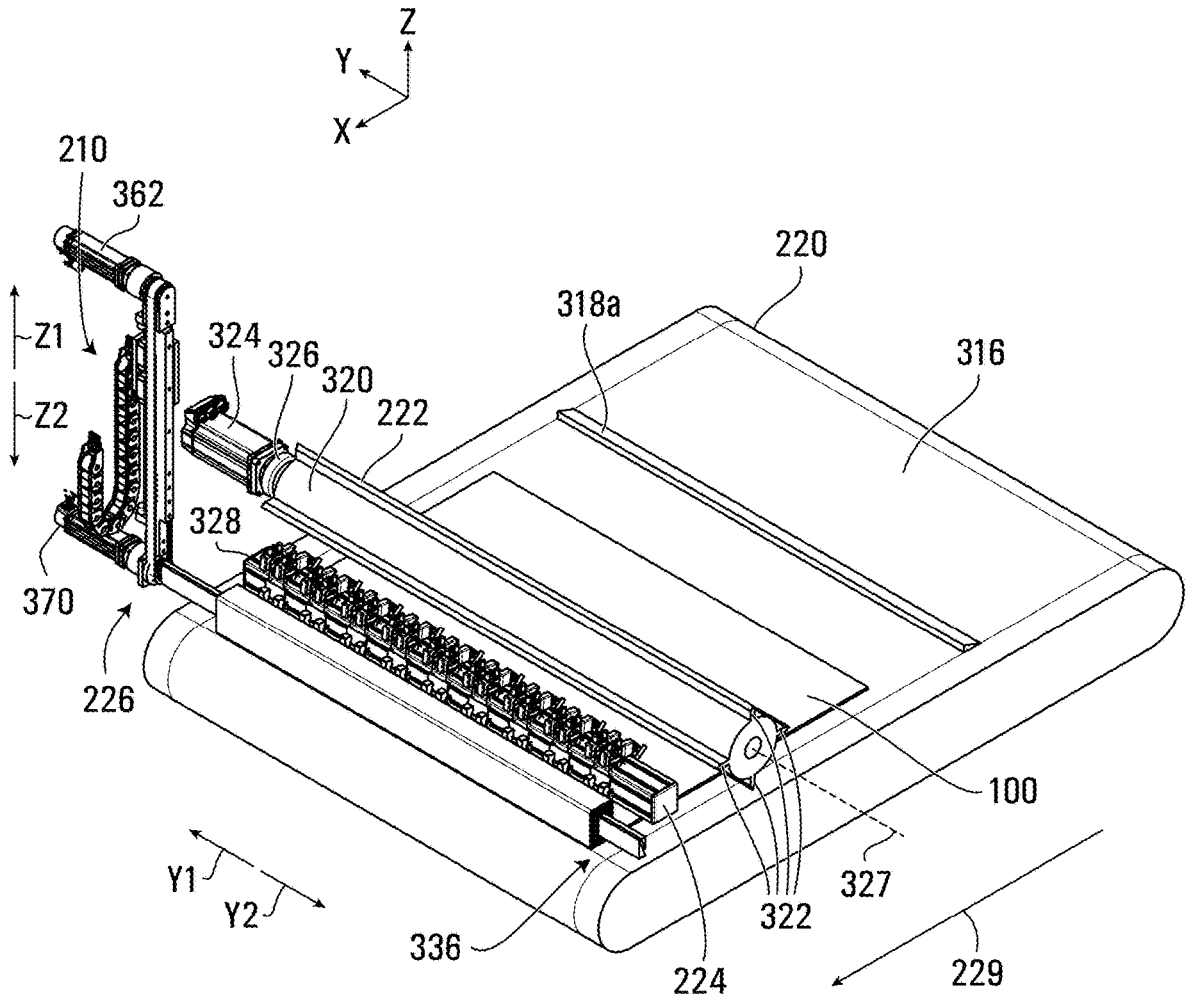
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FIG. 10A

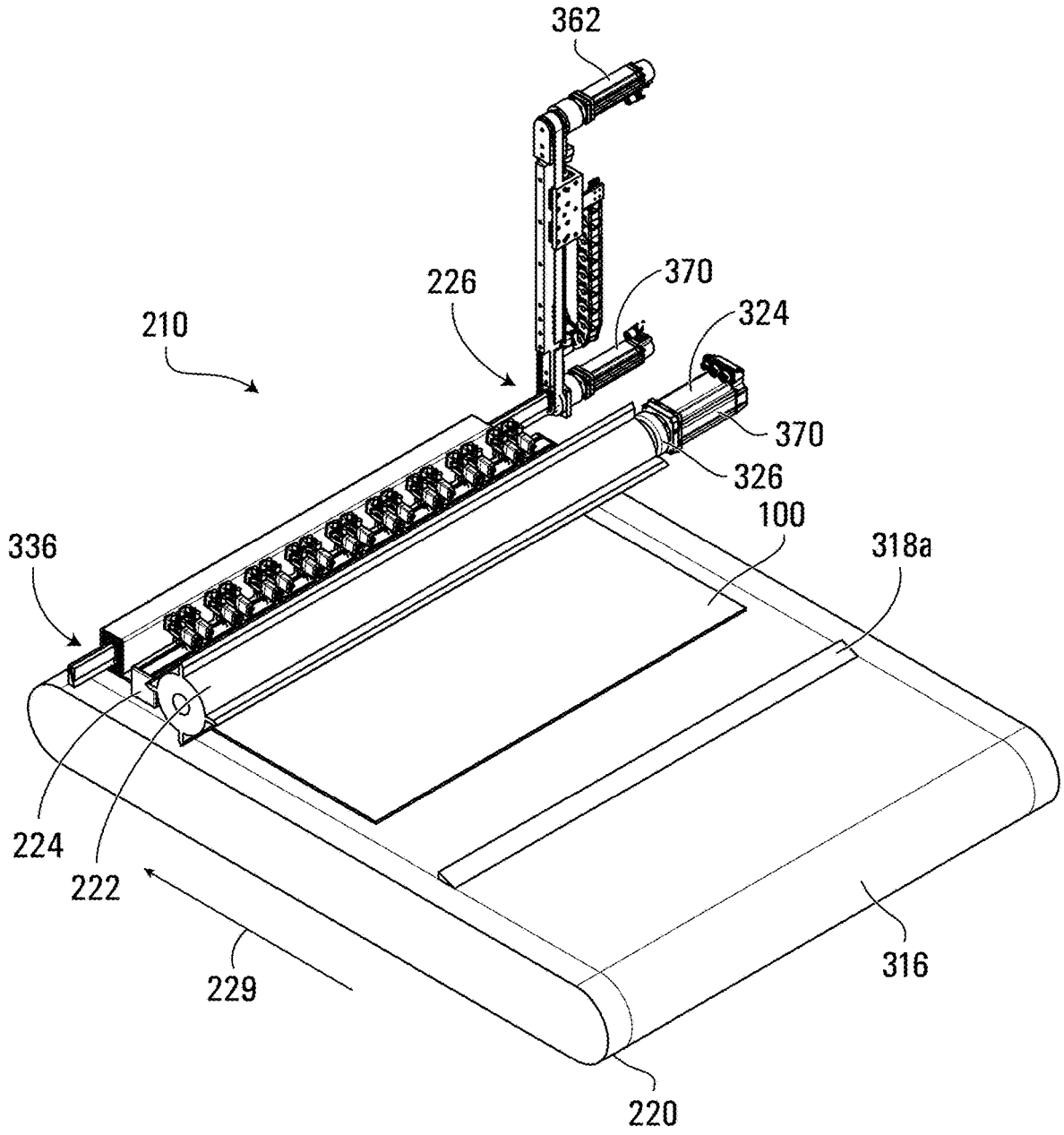

FIG. 10B

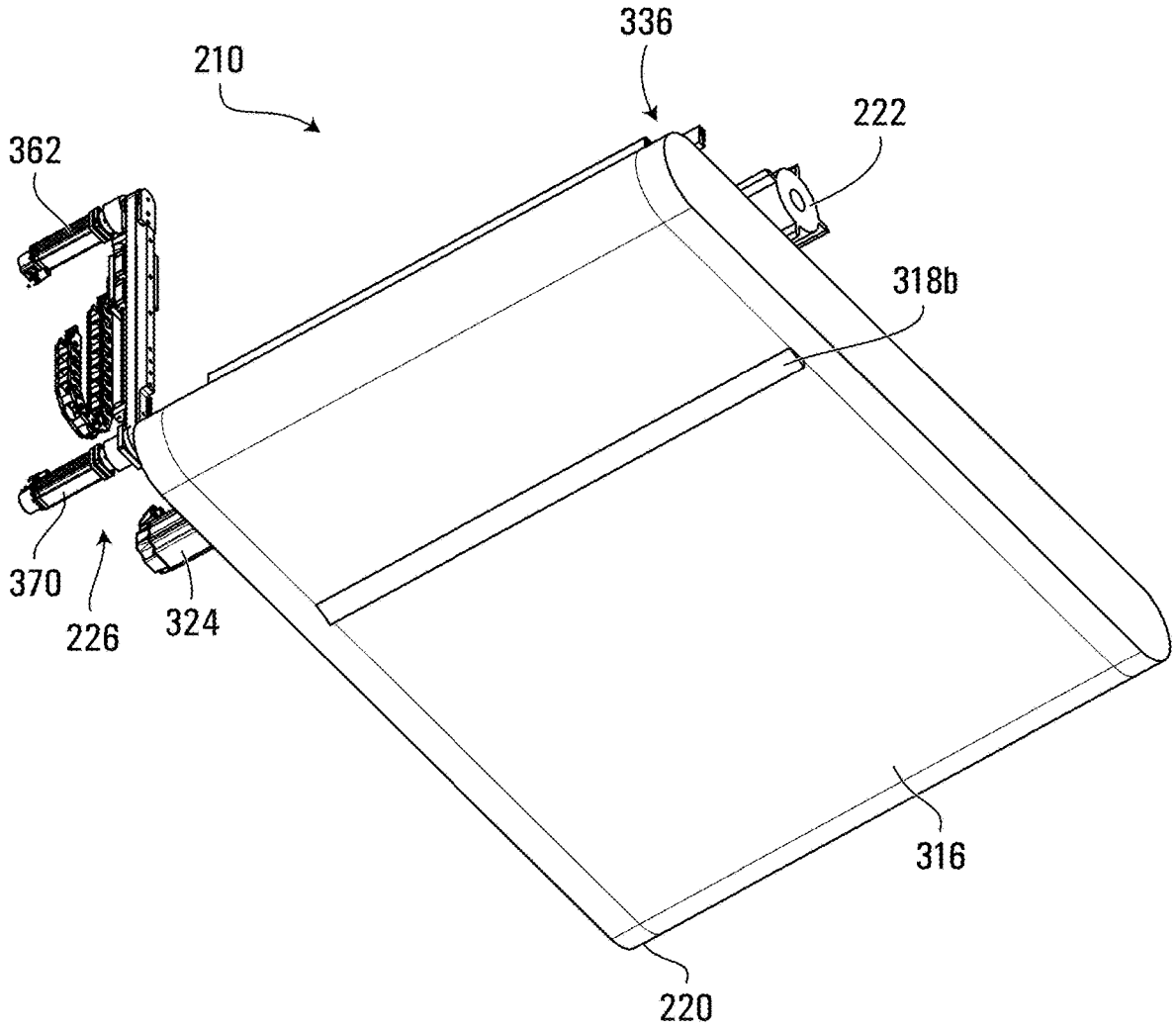

FIG. 10C

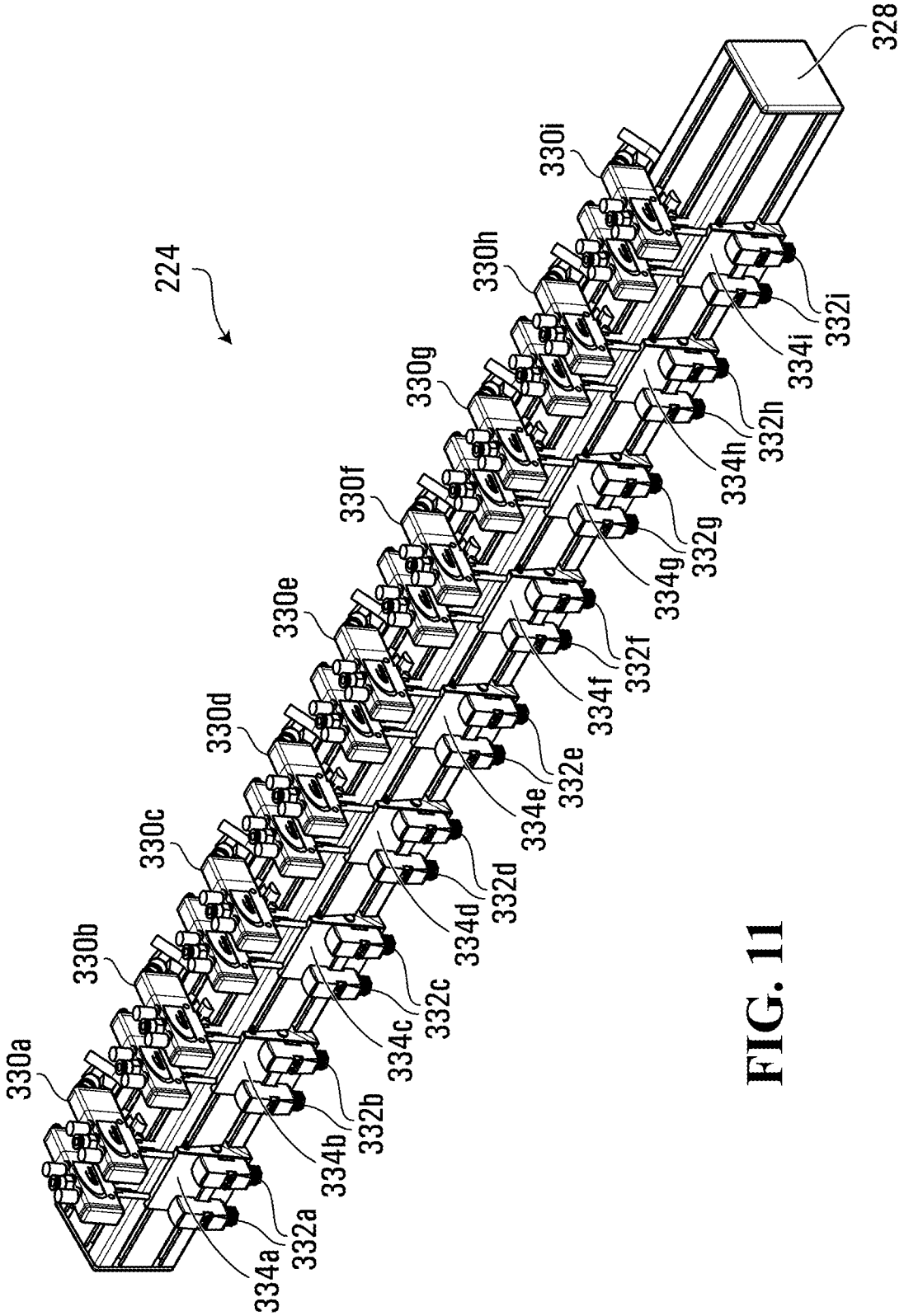
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FIG. 11

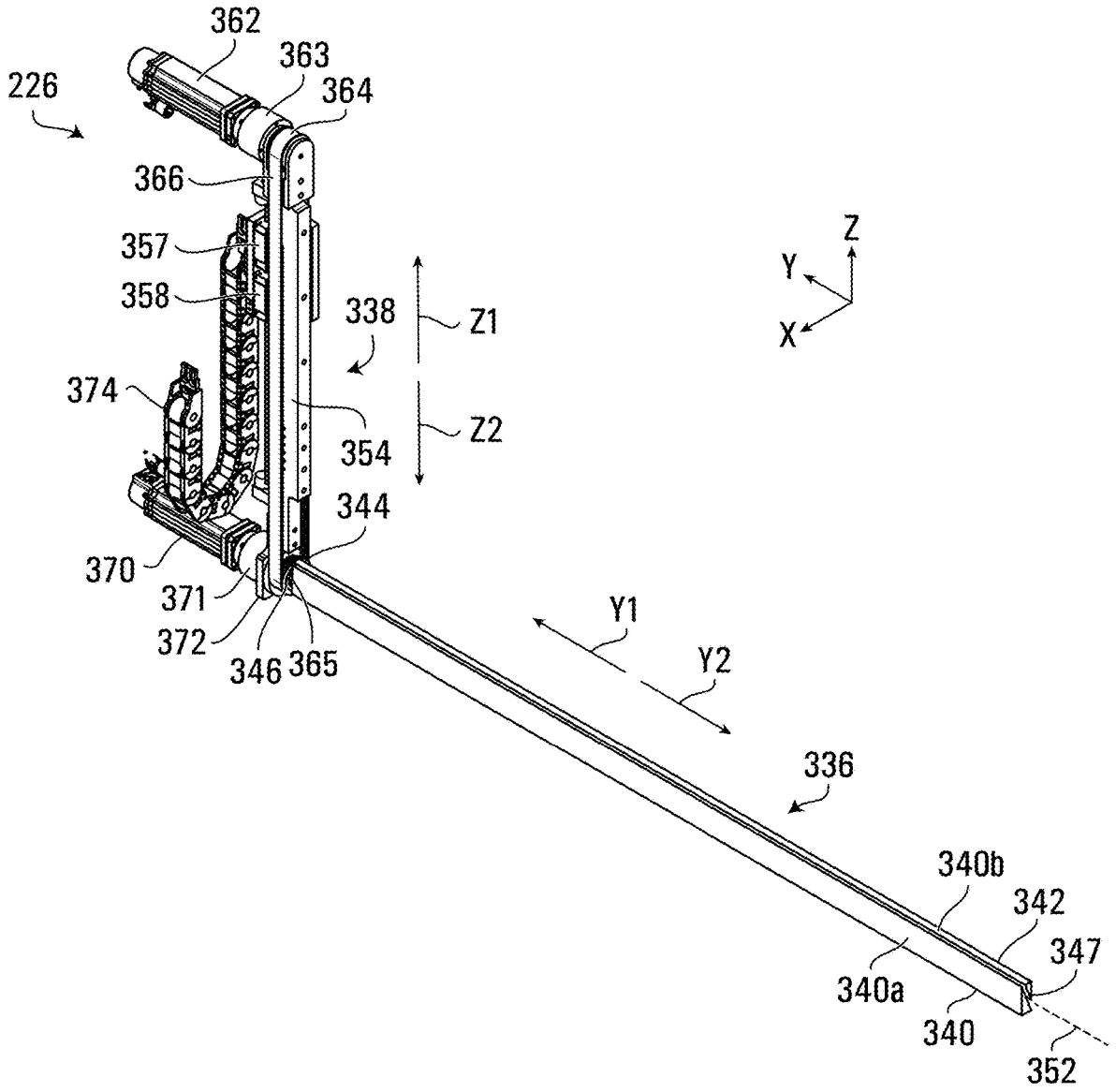
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FIG. 12

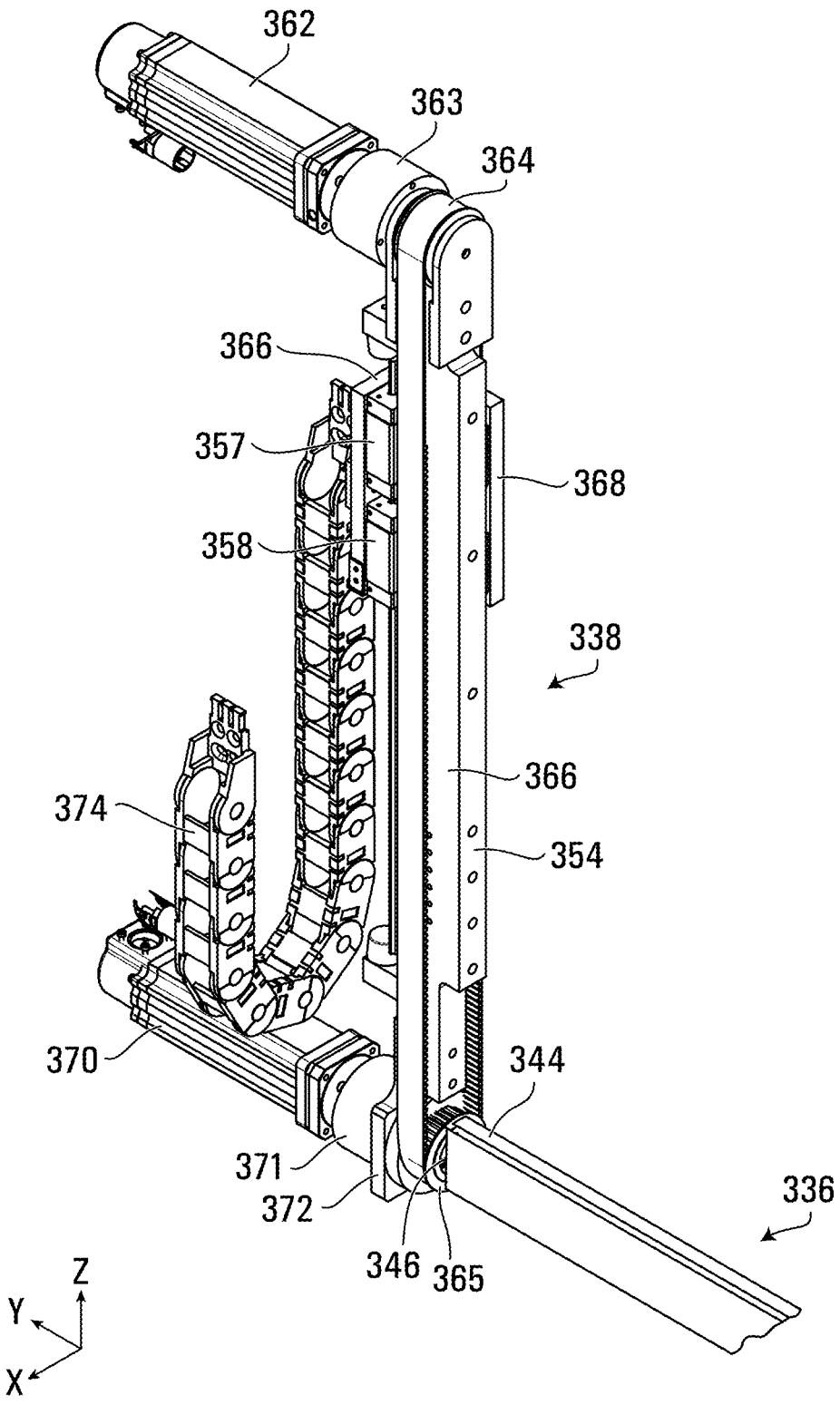
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FIG. 12A

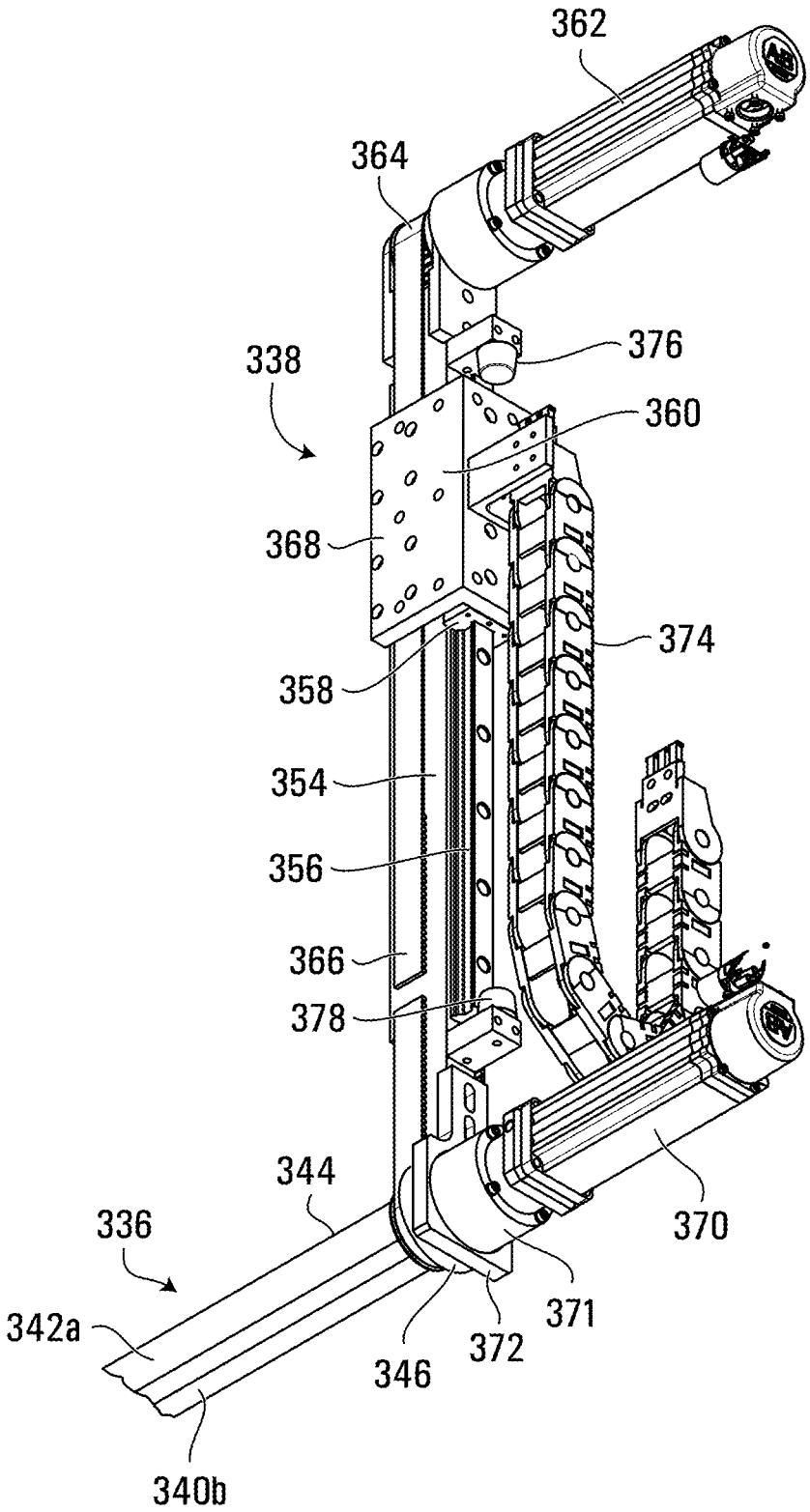
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FIG. 12B

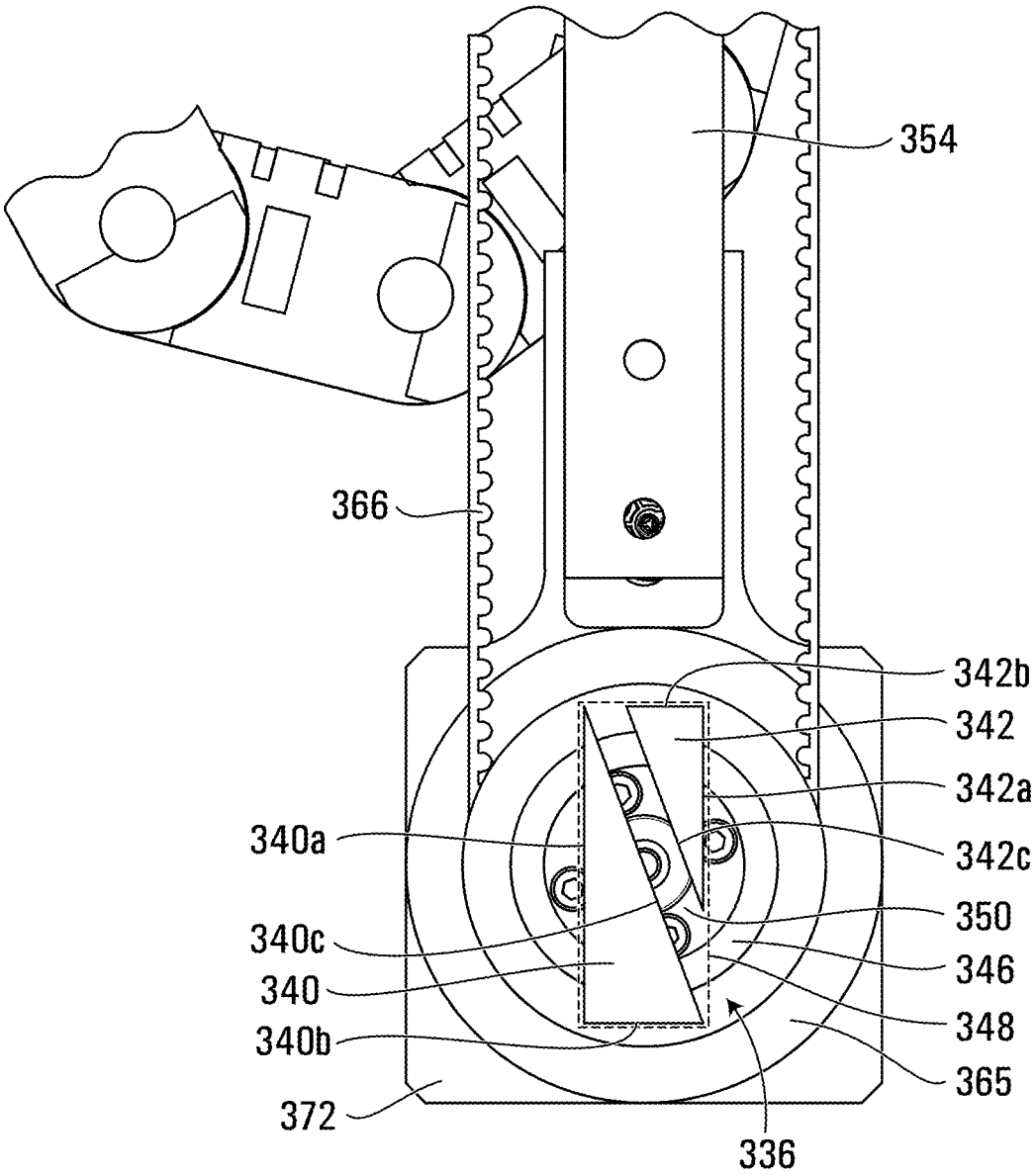
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FIG. 12C

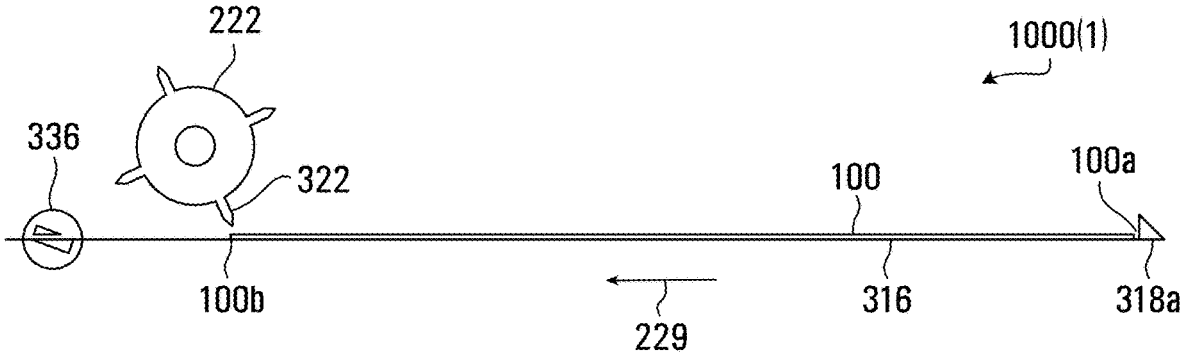

FIG. 13A

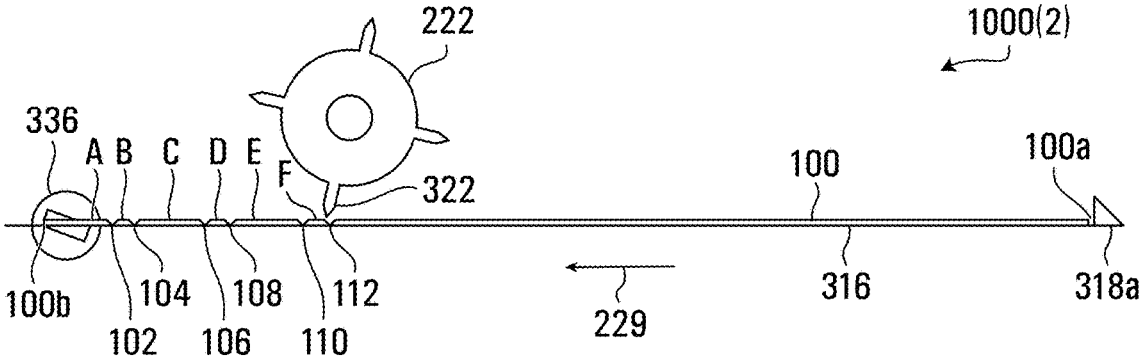

FIG. 13B

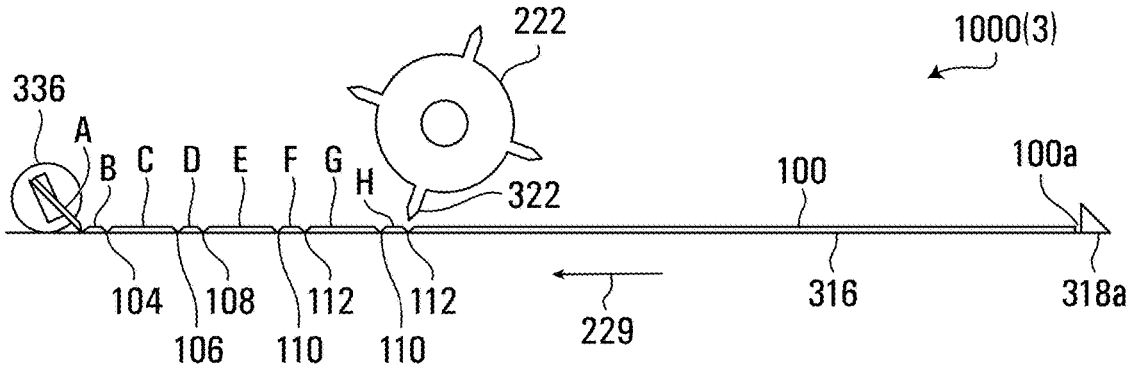

FIG. 13C

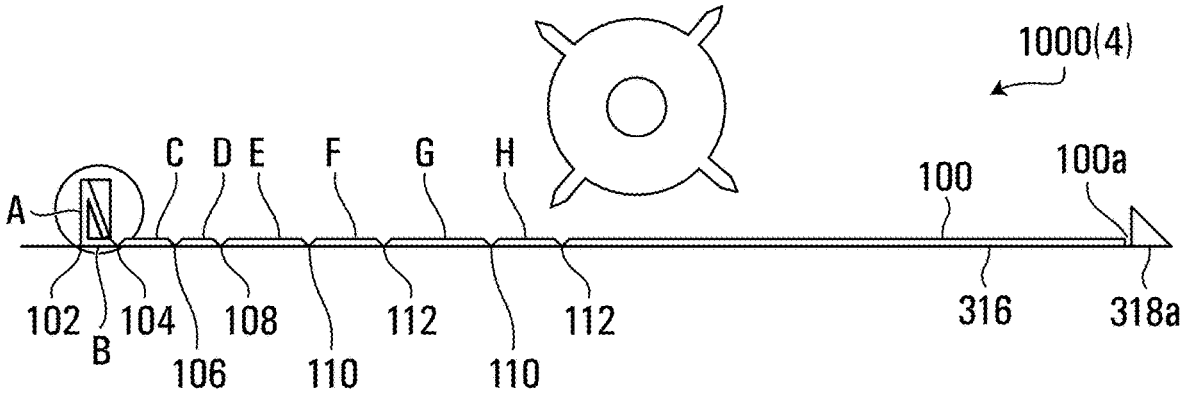

FIG. 13D

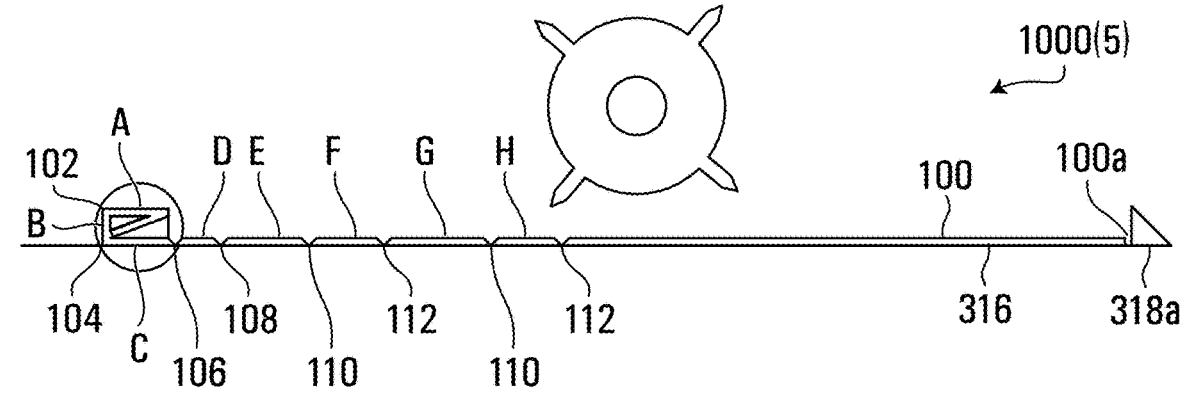

FIG. 13E

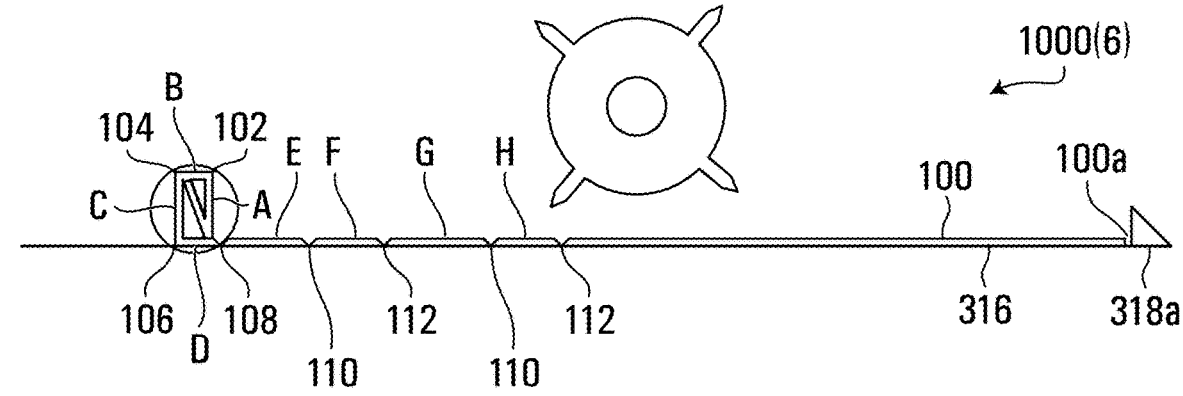

FIG. 13F

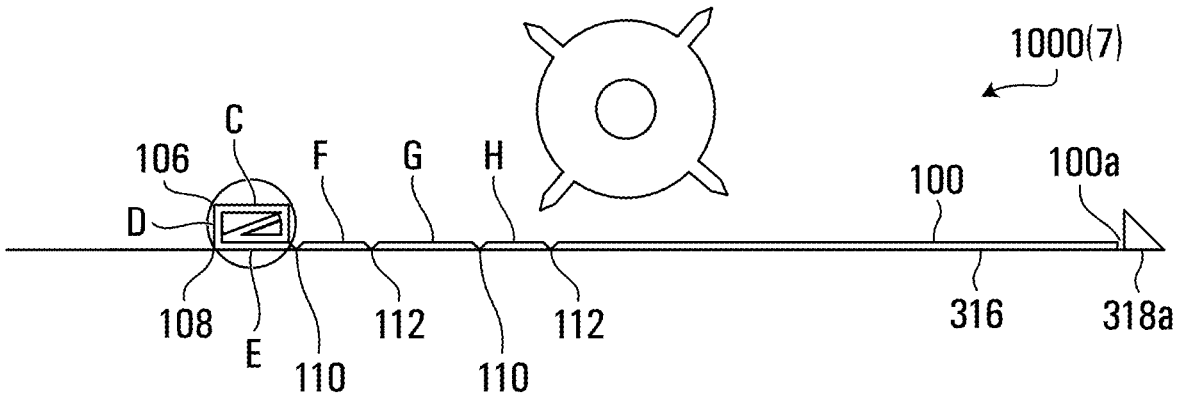

FIG. 13G

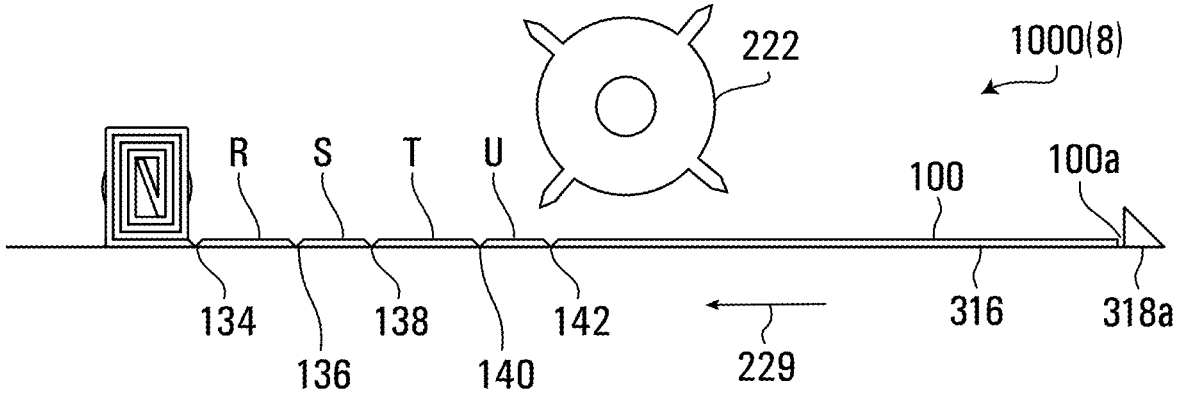

FIG. 13H

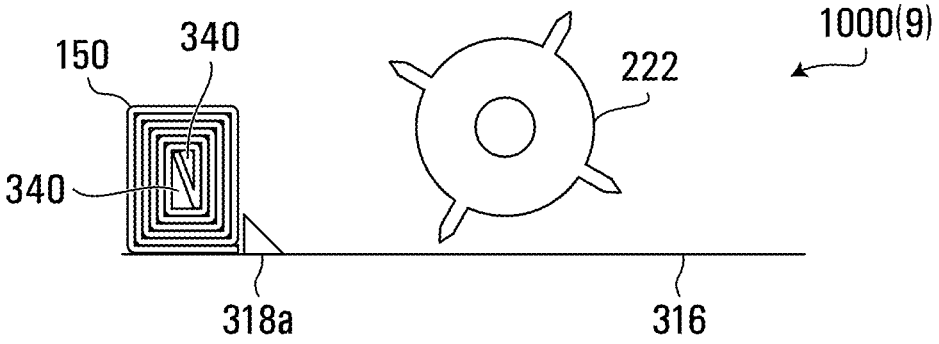

FIG. 13I

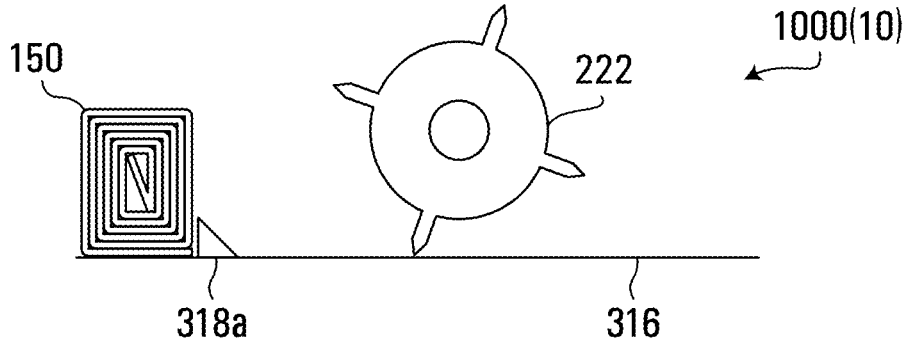

FIG. 13J

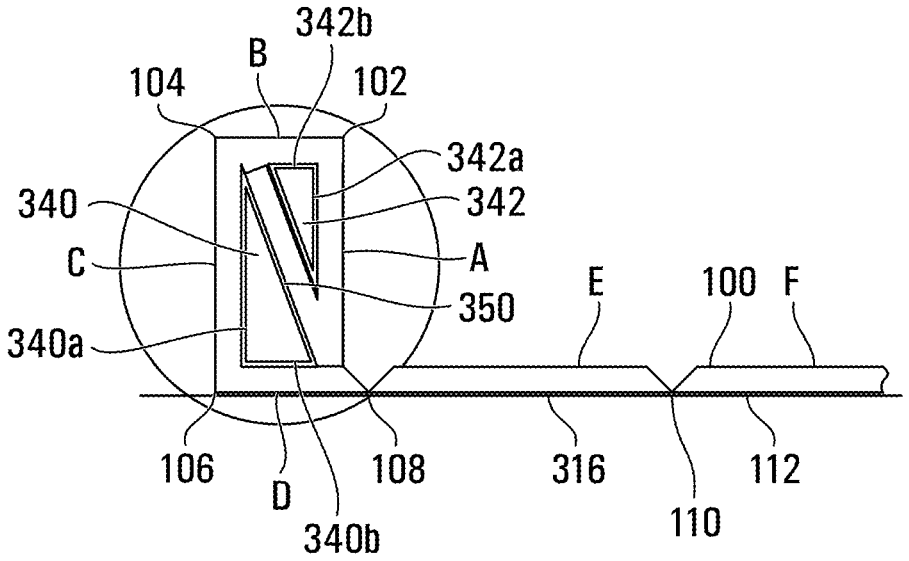

FIG. 13K

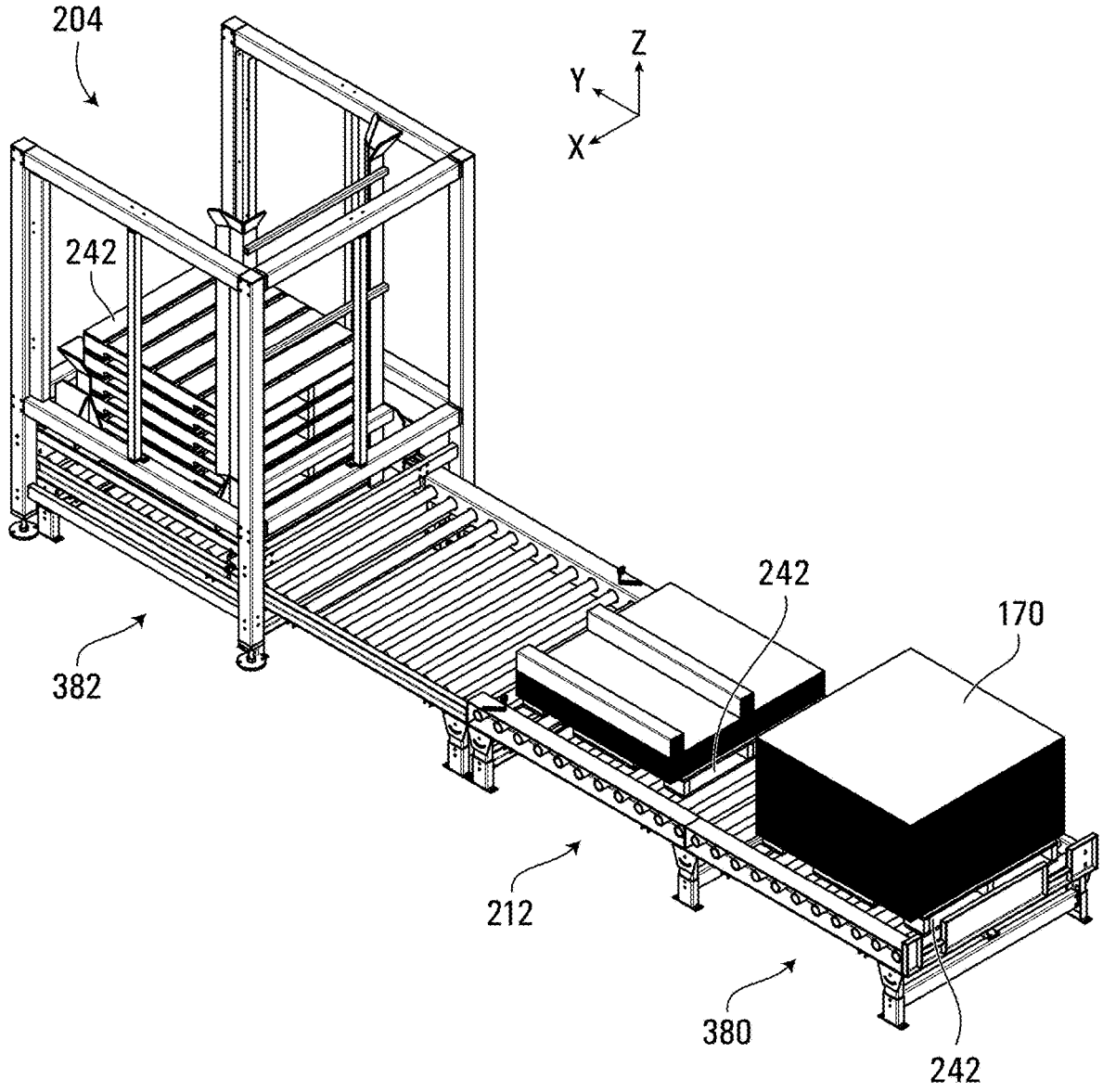

FIG. 14

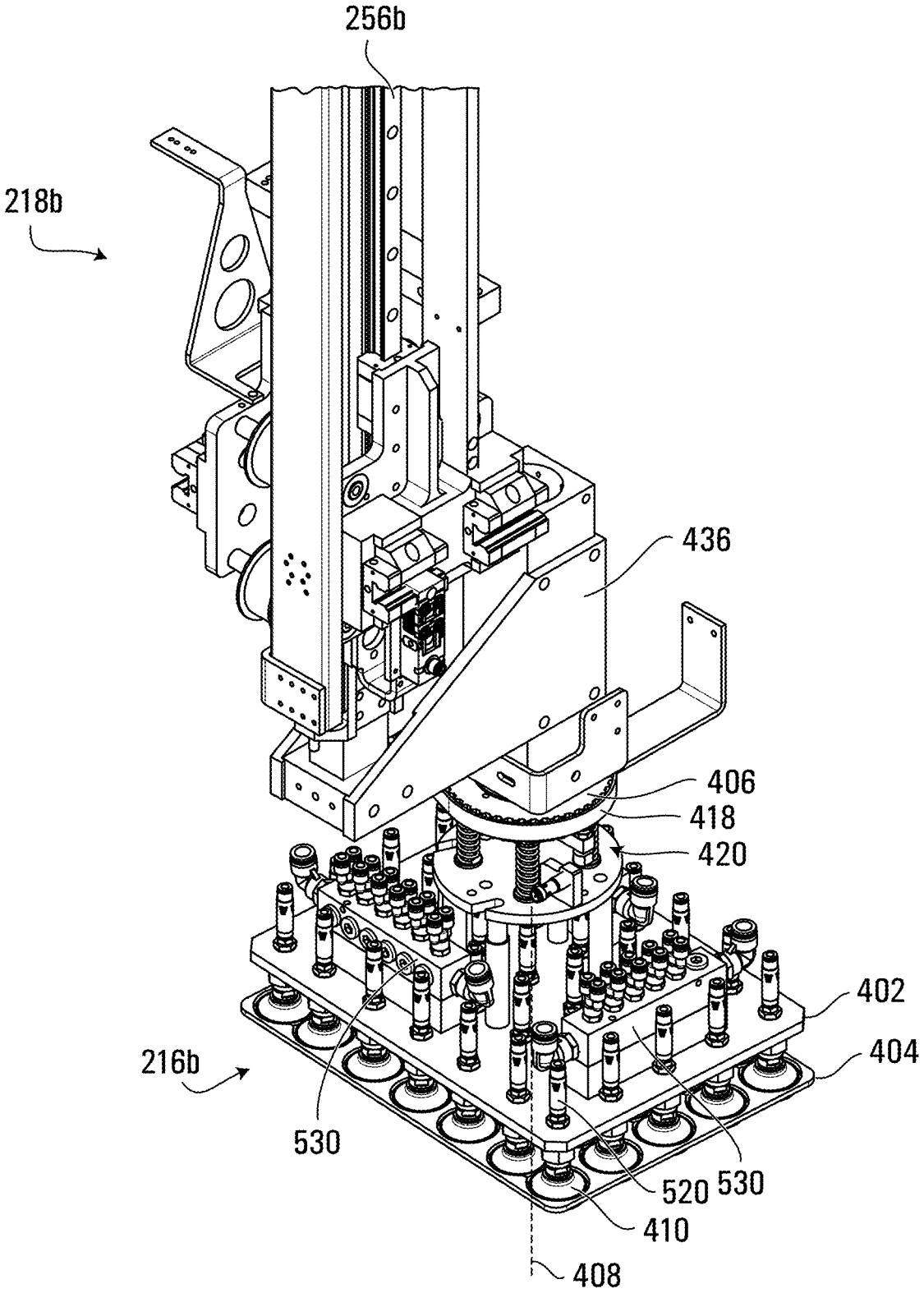

FIG. 15A

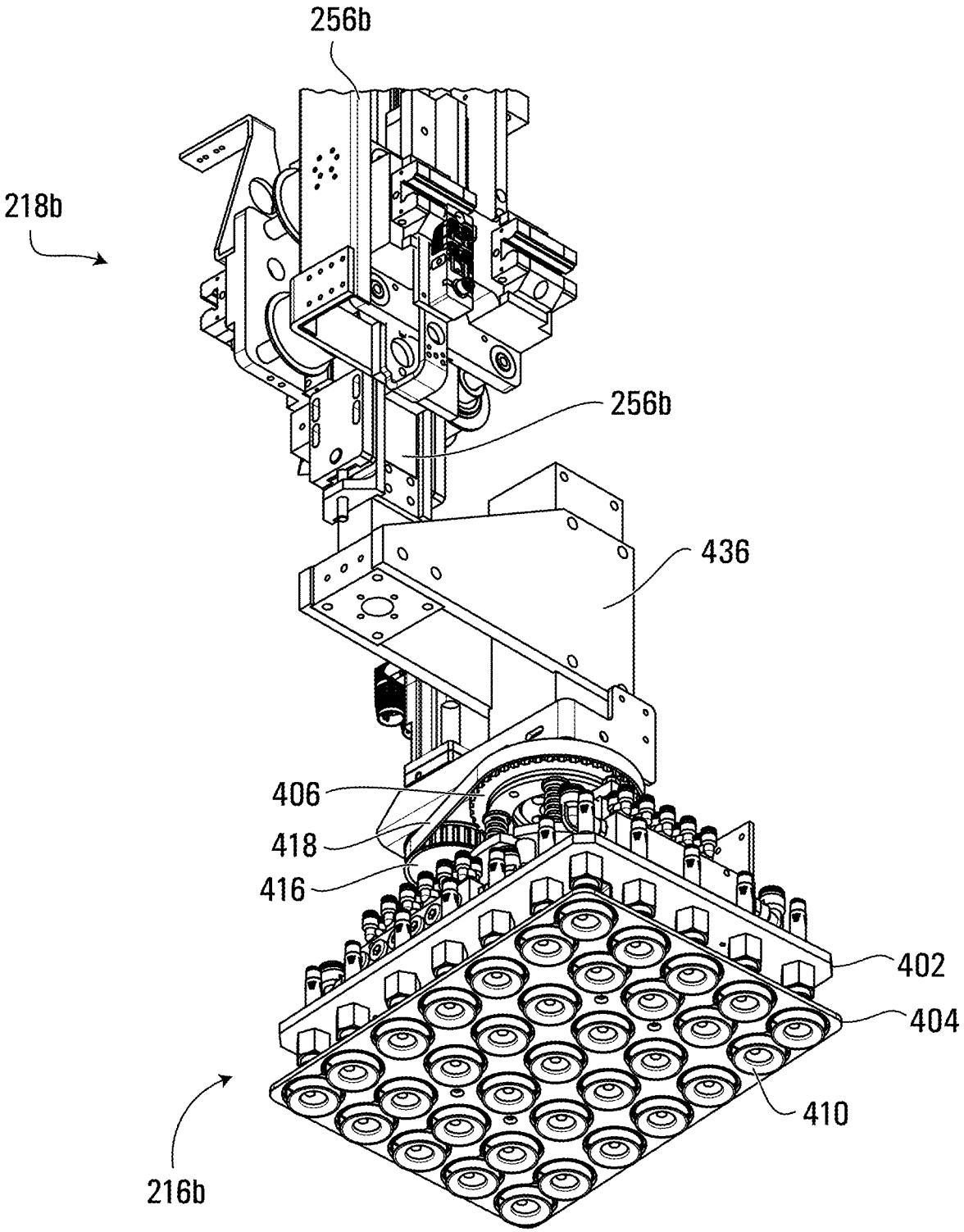

FIG. 15B

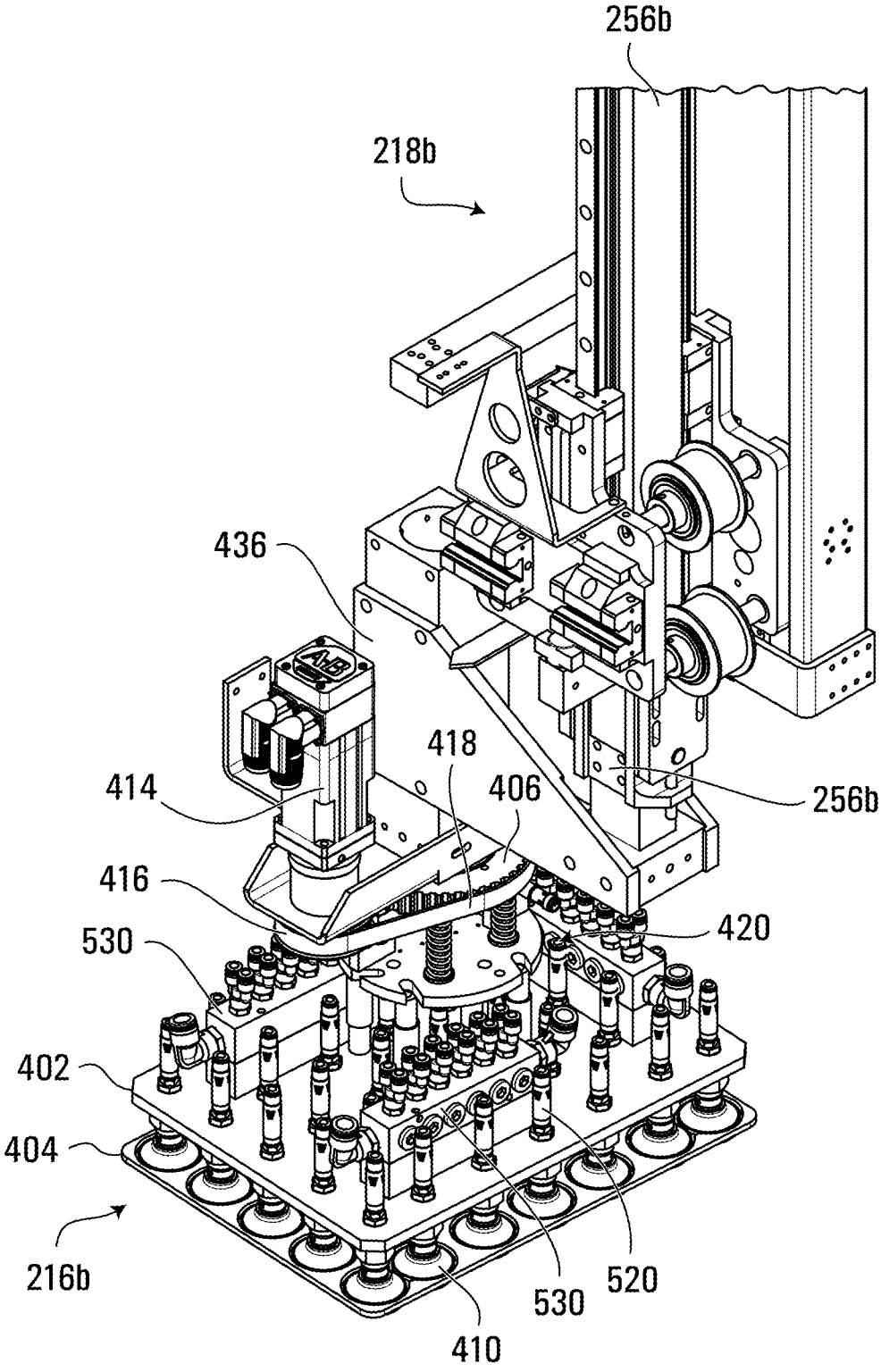
256b
218b
436
418
414
406
256b
416
420
530
402
404
216b
530
520
410

FIG. 15C

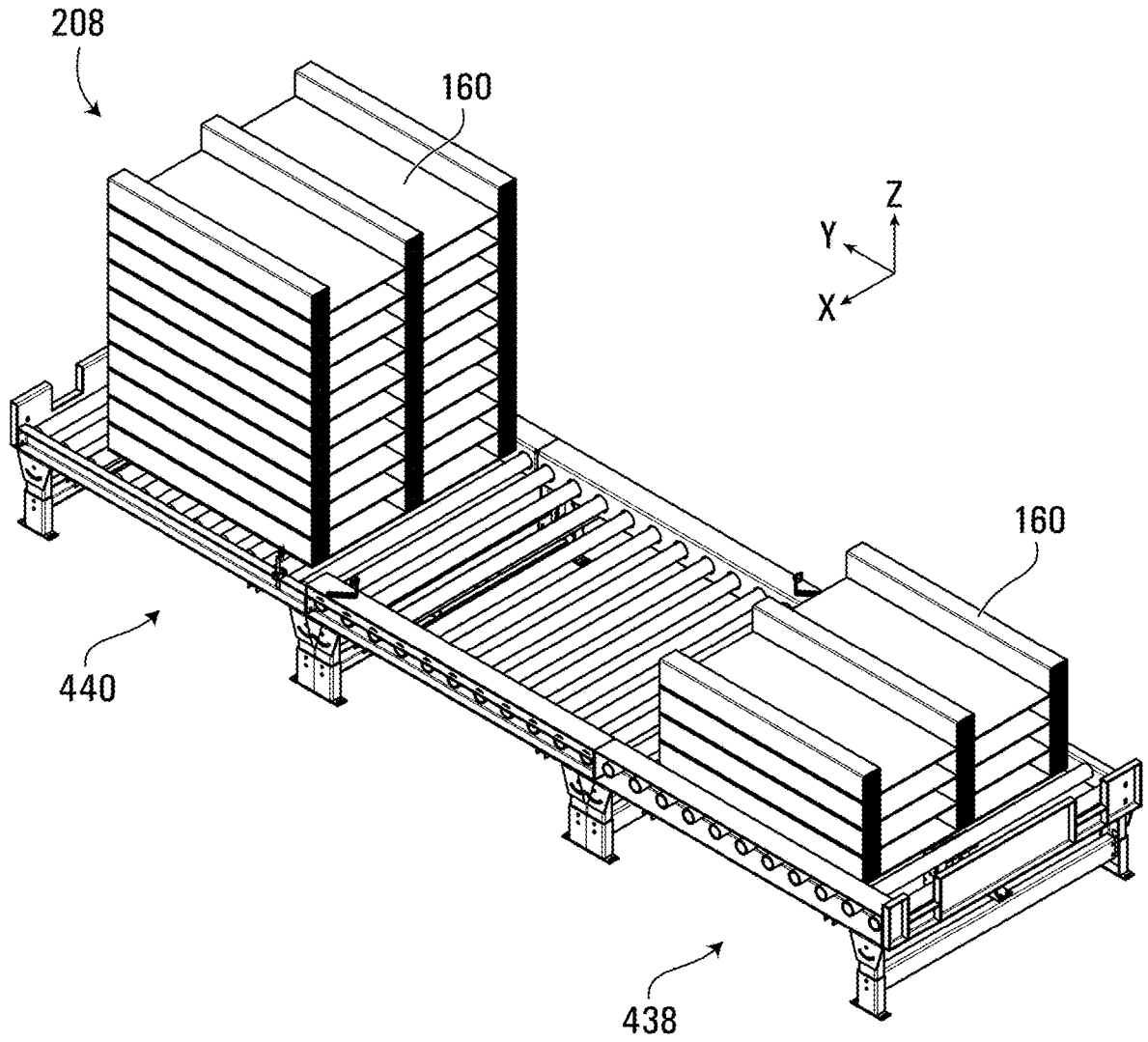

FIG. 16

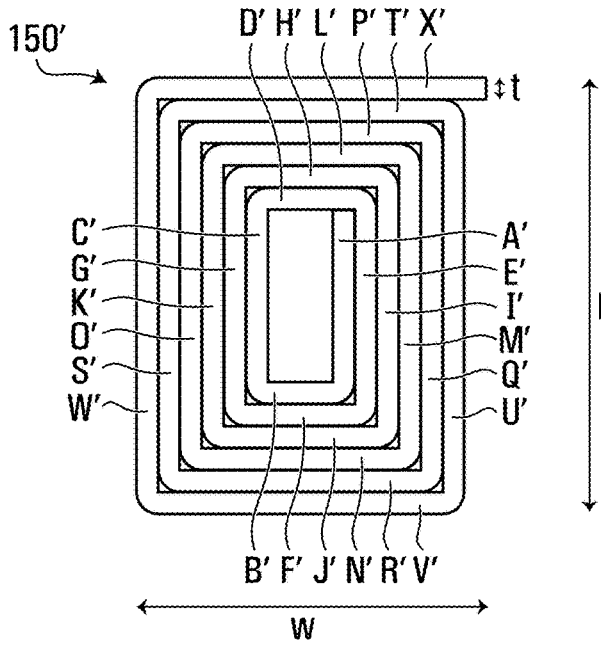

FIG. 17A

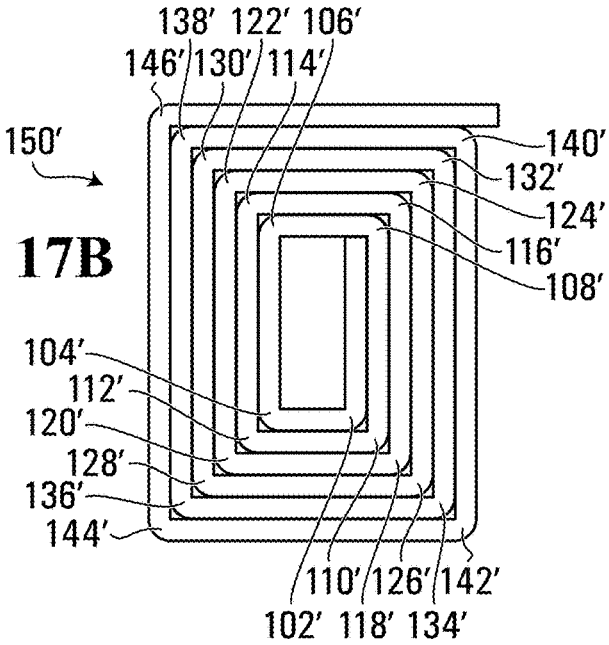

FIG. 17B

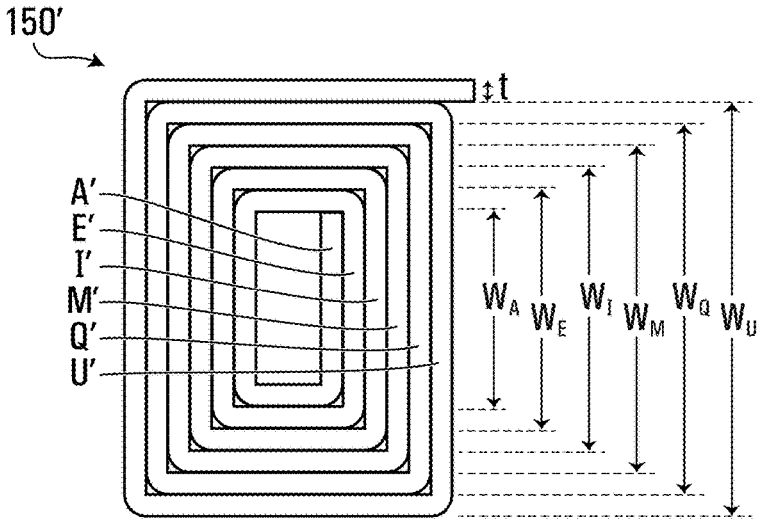

FIG. 17C

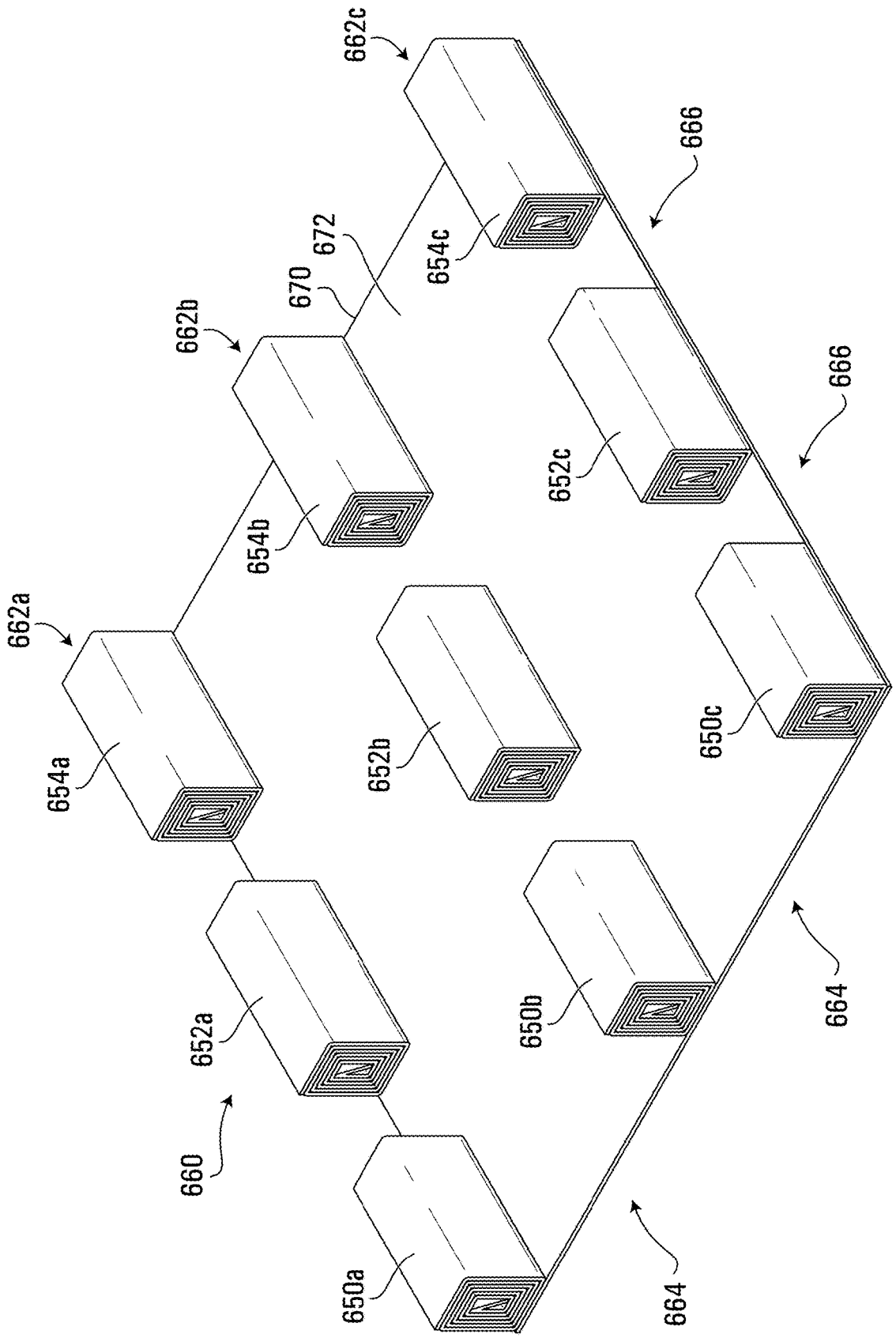
662c
666
672
670
654c
662b
652c
666
654b
662a
652b
650c
654a
652a
650b
664
660
650a
664

FIG. 18

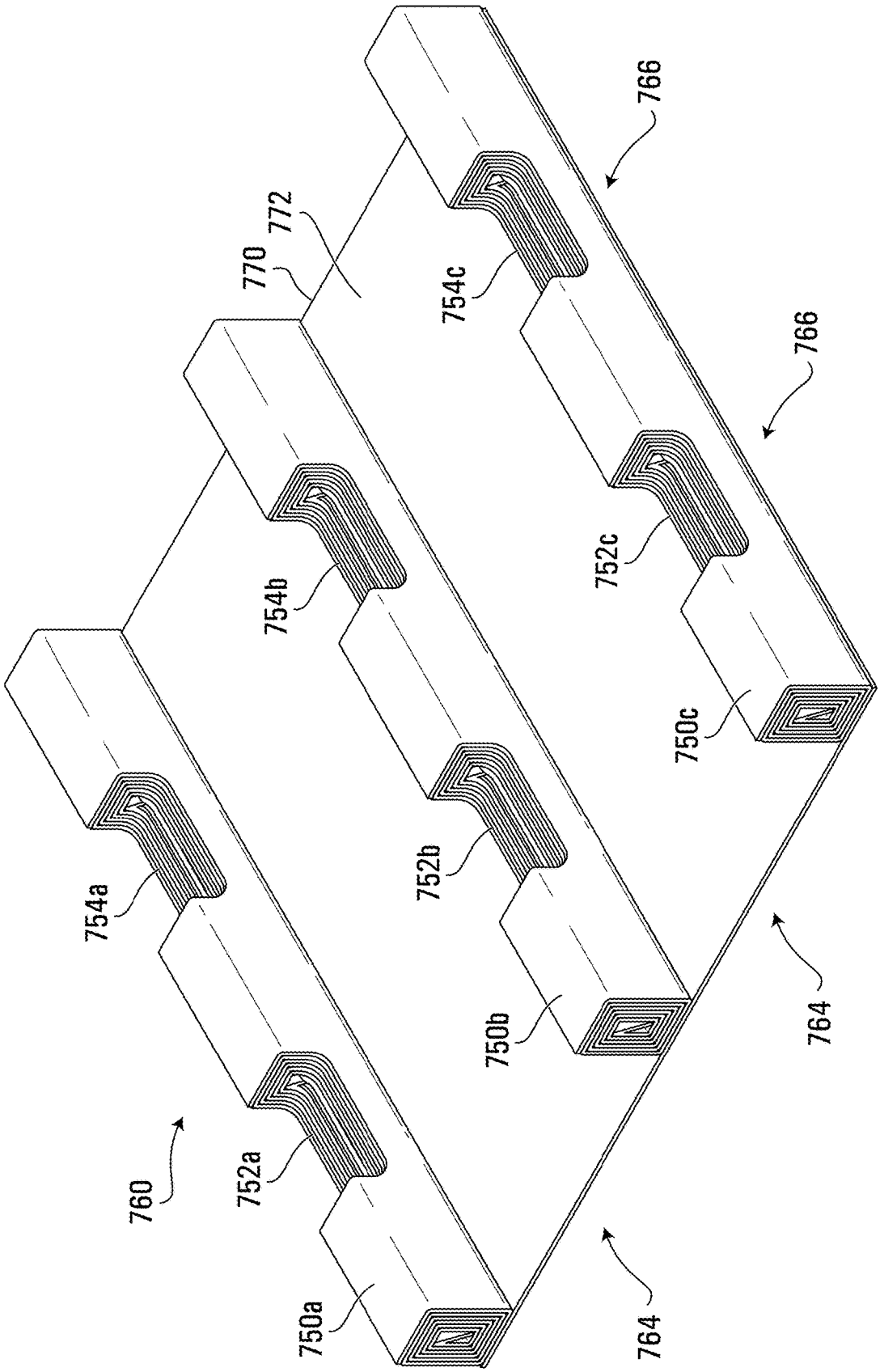
766
772
770
754c
766
754b
752c
754a
752b
750c
750b
764
760
752a
750a
764

FIG. 19

PALLET AND PALLET FORMING SYSTEM AND METHOD

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application is a continuation of U.S. patent application Ser. No. 18/099,812 filed on Jan. 20, 2023, the contents of which are incorporated by reference herein.

TECHNICAL FIELD

[0002] This invention relates generally to methods and systems for forming pallets and in particular to methods and systems for forming corrugated pallets.

BACKGROUND

[0003] 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 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.

[0004] 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 pallets has several drawbacks. Firstly, the nails or other fasters 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 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.

[0005] 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 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.

[0006] Accordingly, it is desirable to provide improved pallets and pallet runners, and methods and apparatuses for forming the same.

SUMMARY

[0007] 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.

[0008] In some embodiments, the cross-sectional profile comprises nested layers of bent panels, each nested layer having a same geometric shape.

[0009] In some embodiments, each panel is orientated perpendicular to its adjacent panel.

[0010] 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.

[0011] In some embodiments, at least some of the abutting panels are adhered to each other by an adhesive.

[0012] In some embodiments, the plurality of adjacent panels are integrally formed.

[0013] In some embodiments, the elongate pallet runner has a rectangular cross-sectional profile.

[0014] In some embodiments, the elongate pallet runner is formed of corrugated cardboard.

[0015] 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.

[0016] 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.

[0017] In some embodiments, the cross-sectional profile comprises nested layers of bent panels, each nested layer having a same geometric shape.

[0018] In some embodiments, each panel is orientated perpendicular to its adjacent panel.

[0019] 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.

[0020] In some embodiments, at least some of the abutting panels are adhered to each other by an adhesive.

[0021] In some embodiments, the plurality of adjacent panels are integrally formed.

[0022] In some embodiments, each elongate pallet runner has a rectangular cross-sectional profile.

[0023] In some embodiments, each elongate pallet runner is formed of corrugated cardboard.

[0024] In some embodiments, the pallet comprises three elongate pallet runners.

[0025] In some embodiments, the deck and plurality of elongate pallet runners are made from corrugated cardboard.

[0026] 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.

[0027] 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.

BRIEF DESCRIPTION OF THE DRAWINGS

[0028] In drawings which illustrate embodiments of the invention,

[0029] FIG. **1** is a top plan view of a runner blank according to an embodiment of the present disclosure;

[0030] 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**;

[0031] FIGS. **3**A-D are top right perspective and end views of a pallet runner formed from the runner blank of FIG. **1**;

[0032] FIGS. **4**A-C are top left perspective, bottom plan and end views of a corrugated pallet according to an embodiment of the present disclosure;

[0033] FIGS. **5**A and **5**B are top right and top left front perspective views of a pallet forming system according to an embodiment of the present disclosure;

[0034] FIG. **6** is a top right front perspective view of the pallet formation subsystem of the pallet forming system of FIGS. **5**A and **5**B;

[0035] FIGS. **6**A-D are enlarged perspective views of portions of the pallet formation subsystem of FIG. **6**;

[0036] FIG. **7** is a schematic diagram of a control system of the pallet forming system of FIGS. **5**A and **5**B;

[0037] FIG. **8** is a top right front perspective view of the runner blank conveyor of the pallet forming system of FIGS. **5**A and **5**B;

[0038] FIG. **9**A is a top right front perspective view of a movement apparatus and engagement head of the pallet formation subsystem of FIG. **6**;

[0039] FIG. **9**B is a bottom right front perspective view of the movement apparatus and engagement head of FIG. **9**A;

[0040] FIG. **9**C is a top left front perspective view of the movement apparatus and engagement head of FIG. **9**A;

[0041] FIG. **9**D is a bottom left front perspective view of the movement apparatus and engagement head of FIG. **9**A;

[0042] FIG. **9**E is a top right front perspective view of a portion of the movement apparatus of FIG. **9**A, with some components omitted;

[0043] FIG. **9**F is a bottom left front perspective view of a portion of the movement apparatus of FIG. **9**A, with some components omitted;

[0044] FIG. **9**G is a top right rear perspective view of a portion of the movement apparatus of FIG. **9**A, with some components omitted;

[0045] FIG. **9**H is a bottom right rear perspective view of a portion of the movement apparatus of FIG. **9**A, with some components omitted;

[0046] FIG. **9**I is a top right front perspective view of the engagement head of FIG. **9**A;

[0047] FIG. **10**A is a top right front perspective view of a runner forming station of the pallet formation subsystem of FIG. **6**;

[0048] FIG. **10**B is a top left front perspective view of the runner forming station of FIG. **10**A;

[0049] FIG. **10**C is a bottom right front perspective view of the runner forming station of FIG. **10**A;

[0050] FIG. **11** is a top right front perspective view of an adhesive applicator apparatus;

[0051] FIG. **12** is a top right front perspective view of a panel rotating apparatus of the runner forming station of FIG. **10**A;

[0052] FIG. **12**A is an enlarged top right front perspective view of the panel rotating apparatus of FIG. **12**;

[0053] FIG. **12**B is an enlarged bottom left rear perspective view of the panel rotating apparatus of FIG. **12**;

[0054] FIG. **12**C is an front end view of the panel rotating apparatus of FIG. **12**;

[0055] FIGS. **13**A-**13**K are schematic views showing a runner forming station in various stages of forming a pallet runner from a runner blank;

[0056] FIG. **14** is a top right front perspective view of the deck conveyor of the pallet forming system of FIGS. **5**A and **5**B;

[0057] FIG. **15**A is a top right front perspective view of an engagement head of the pallet forming system of FIGS. **5**A and **5**B;

[0058] FIGS. **15**B and **15**C are bottom right front and top left front perspective views of the engagement head of FIG. **15**A;

[0059] FIG. **16** is a top right front perspective view of the takeaway conveyor of the pallet forming system of FIGS. **5**A and **5**B;

[0060] FIGS. **17**A-C are top right perspective and end views of a pallet runner according to another embodiment;

[0061] FIG. **18** is a bottom perspective view of a corrugated pallet according to another embodiment; and

[0062] FIG. **19** is a bottom perspective view of a corrugated pallet according to another embodiment.

DETAILED DESCRIPTION

[0063] 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.

[0064] 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.

[0065] 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.

[0066] 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.

[0067] 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**).

[0068] 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**.

[0069] Runner **150** is depicted in greater detail in FIGS. **3**A-D and may have a generally rectangular cross section with a length I, 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. **3**A-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. **3**B, 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. **3**B, 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.

[0070] 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 the accommodate the increasing sizer of runner **150**. The progression of the increase in width between adjacent parallel panels in an outwards direction as viewed in FIG. **3**B may be equivalent to about double the thickness of blank **100**.

[0071] 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. **3**D, 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)).

[0072] 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 about 3 inches and about 4.5 inches and may preferably have a height of about 3.75 inches.

[0073] In the embodiment shown in FIGS. **3**A-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.

[0074] With particular reference to FIGS. **4**A-C in various embodiments, a number of runners may thereinafter be combined to form a corrugated pallet, such as corrugated pallet **160**. Pallet **160** may include a deck **170** combined with three runners **150***a*, **150***b* and **150***b*, 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 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 **150***a*, **150***b*, **150***c* 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 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.

[0075] Runners **150***a*, **150***b*, **150***c* 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 **170** may be any suitable shape, such the square configuration shown in FIGS. **4**A-C and may be made from any suitable material such as cardboard 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 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.

[0076] With reference to FIGS. **5**A-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**.

[0077] As shown in FIGS. **6**-**6**D 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 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.

[0078] 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 head **216***a* for retrieving a runner blank **100** from runner blank conveyor **202** and moving blank **100** to runner forming station **210**, a second engagement head **216***b* for retrieving a formed runner **150** from runner forming station **210** and moving runner **150** to pallet assembly station **212** and third engagement head **216***c* for retrieving corrugated pallets **160** from pallet assembly station **212** and moving to takeaway conveyor **208**.

[0079] Engagement heads **216***a-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 **216***a* may be mounted to and moved by a first movement apparatus **218***a*. Second engagement head **216***b* may be mounted to and moved by a second movement apparatus **218***b*. Third engagement head **216***c* may be mounted to and moved by a third movement apparatus **218***c*. Movement apparatuses **218***a-c* may be any suitable apparatus configured to move their respective engagement head in one or more directions.

[0080] An example of a scheme for the power and data/communication configuration for 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™/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**.

[0081] 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**. 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**

[0082] 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 FIG. 8.

[0083] 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 a second (or pickup) position 238, where a blank 100 may be engaged by first engagement head 216*a* of pallet formation subsystem 206 and moved by first movement apparatus 218*a* 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.

[0084] 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 228*a*. 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 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 242 to the third position 240. An encoder may be provided to monitor and control the position of the conveyor belt.

[0085] 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 signalling that a stack is at the pickup position 238.

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[0086] 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 retrieved from the stack of blanks 100 by engagement of first engagement head 216*a* with the upper surface of the upper most blank in the stack followed by movement of the engaged blank and first engagement head 216*a* by first movement apparatus 218*a* from pick up position 238 to runner forming station 210.

First Engagement Head 216*a*

[0087] First engagement head 216*a* is shown in greater detail in FIG. 9I and may be mounted to and moved by first movement apparatus 218*a*. First engagement head 216*a* may include a longitudinally extending member 246 affixed at a first end to the lower end of first movement apparatus 218*a*. Member 246 may be configured to connect to a series of transversely extending arms 248*a*, 248*b*, 248*c*, 248*d* and a longitudinally extending arm 248*e*. Arms 248*a-d* may be operable to slidably move along pairs of spaced apart tracks in the surface or member 246. For example, arms 248*a* and 248*b* may be slidably movable along tracks 250*a*, 250*b*. Similarly, longitudinally extending arm 248*e* may be slidably movable along a single track 252 in the upper surface of member 246. When in the desired position, arms 248*a-e* may be fixed in position, such as by bolts (not shown in FIGS). This adjustable positioning of 248*a*, 248*b*, 248*c*, 248*d* 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.

[0088] In other embodiments arms 248*a-e* may be permanently affixed to or formed as an integral part of member 246.

[0089] At the distal end of each of arms 248*a-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 216*a* to pick up bank 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 218*a*.

[0090] 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-M1 BH-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.

[0091] In other embodiments, a vacuum pump mounted externally may generate vacuum externally and then vacuum can be supplied through the aforementioned air channels.

[0092] Returning to FIG. 9I, the arms 248*a-e* may be positioned to provide adequate support of blank 100 and prevent any deformation/damage during engagement with first movement apparatus 218*a*. Through providing a degree of adjustability of the position of longitudinal positions of arms 248*a-e* relative to member 246, first engagement head 216*a* may be easily adjusted to accommodate different sizes of blank 100.

[0093] In other embodiments, first movement apparatus 218*a* may be configured with any suitable number and configurations of arms similar to arms 248*a-e* as required to engage a blank.

First Movement Apparatus **218***a*

[0094] First engagement head **216***a* and first movement apparatus **218***a* are shown in isolation in FIGS. **9**A to **91**. First engagement head **216***a* may have a dedicated movement apparatus, first movement apparatus **218***a* that allows first engagement head **216***a* to move in both the vertical Z and horizontal X/Y directions (i.e., directions parallel to axes Z, X and Y in FIG. **9**A).

[0095] First movement apparatus **218***a* includes a vertically orientated support tube **256***a* that may be generally rectangular in cross section to which first engagement head **216***a* is mounted by mounting brackets **258** (FIG. **9**A) such that first engagement head **216***a* moves in space with support tube **256***a*.

[0096] Support tube **256***a* is slidably mounted to a pair of slide blocks **260**, **262**, each mounted on opposing sides of support tube **256***a* (FIG. **9**B). 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. **9**E and **9**F, slide block **262** is secured to rail **266** by inner blocks **263***a* and **263***b*. Similarly, with reference to FIGS. **9**G and **9**H, slide block **260** is secured to rail **264** by inner blocks **261***a* and **261***b*. An example of a suitable rails system is the Bosch Rexroth^{T}M 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. **9**B). 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**).

[0097] Support tube **256***a* has a generally vertically orientated rail system to allow support tube **256***a* to be connected slide blocks **260**, **262** such that support tube **256***a* may move vertically relative to slide blocks **260**, **262**. More specifically, rails **275**, **277** extend vertically along opposed sides of tube **256***a*. Rail **275** is secured to slide block **262** by inner blocks **279***a*, **279***b* (FIGS. **9**E and **9**F). Similarly, with reference to FIGS. **9**G and **9**H, rail **277** is secured to slide block **260** by inner blocks **281***a*, **281***b* (FIGS. **9**G and **9**H). Again, a suitable rail system is the Bosch Rexroth™ ball rail system referenced above. Thus, support tube **256***a* can slide vertically relative to slide blocks **260**, **262** and will move horizontally with slide blocks **260**, **262** (relative to rails **264**, **266**).

[0098] In order to drive first movement apparatus **218***a* horizontally (in the X-direction in FIG. **9**A) and vertically (in the Y-direction in FIG. **9**A), a drive apparatus is provided which includes a left side drive motor **272***a* and a right side drive motor **274***a* (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 **272***a* has a drive wheel **276** and drive motor **274***a* has a drive wheel **278**. Both servo motors **272***a* and **274***a* 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 **272***a* and **274***a* 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 **272***a*, **274***a* 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.

[0099] Four freely rotatable pulley wheels **280***a*, **280***b*, **280***c* and **280***d* are secured between the inner vertical faces of slide blocks **260**, **262** and a further freely rotatable pulley wheel **280***e* is attached to the upper end of support tube **256***a*.

[0100] 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 **256***a* by a belt block **284***a* (FIG. **9**B). From there the belt extends upwardly to pulley wheel **280***b*, around the upper side of pulley wheel **280***b* and then horizontally to drive wheel **276** of drive motor **272***a* (FIG. **9**A). Belt **282** loops around the drive wheel **276** and extends around the underside of pulley wheel **280***a* and then upwards to pulley **280***e*. From there belt **282** extends around pulley **280***e*, downwards to block pulley **280***c*, around pulley wheel **280** and then to drive wheel **278** of drive motor **274***a* (FIG. **9**C). After passing around drive wheel **278**, belt **282** extends to the upper side of pulley wheel **280***d*. From pulley wheel **280***d*, belt **282** then extends vertically downwards to the bottom of the support tube **256***a* where it attached to the support tube by a belt block **284***b* (FIG. **9**D).

[0101] With this arrangement, by adjusting the relative rotations of drive wheels **276** and **278** through the operation of motors **272***a* and **274***a*, the vertical position of support tube **256***a* 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 **256***a* and first engagement head **216***a*. 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 **256***a* 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 **256***a*. The following will be appreciated in particular:

[0102] If drive wheels **276** and **278** both remain stationary then the position of support tube **256***a* will not be altered;

[0103] 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 **256***a* (and thus first engagement head **216***a*) will move horizontally from left to right (as viewed in FIG. **9**A);

[0104] 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 **256***a* (and thus first engagement head **216***a*) will move horizontally from right to left (as viewed in FIG. **9**A);

[0105] 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 **256***a*, and first engagement head **216***a*, will move vertically downwardly;

[0106] 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 **256***a*, and first engagement head **216***a*, will move vertically upwardly.

[0107] In some embodiments, first movement apparatus **218***a* may also be configured such that first engagement head **216***a* may also move in the Y-direction (i.e., directions parallel to the Y axis in FIG. **9**A). In order to drive first movement apparatus **218***a* horizontally in the Y-direction, a drive apparatus is provided which includes a central drive motor **286***a* (which may be 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. **9**A). Servo motor **286***a* can be driven in both directions at varying speeds by PLC **500** (FIG. **7**) through servo drives.

[0108] As described above, at either end rails **264**, **266** may be affixed to and supported by support plates **268**, **270** (FIG. **9**A). 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 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.

[0109] Servo motor **286***a* 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 **300***a*, **300***b*, which each drive continuous belts **302***a*, **302***b*.

[0110] Belt **302***a* may extend in a transverse direction from the lower side of pulley **300***a*, generally following rail **288** to the lower side of a pulley **304***a*, mounted above the opposite end of rail **288** to pulley **300***a*. From there belt **302***a* extends to the upper side of pulley **304***a* and in a transverse direction to the upper side of pulley **300***a*. Belt **302***a* is also connected to support plate **268**, such movement of belt **302***a* will drive movement of support plate **268** along rail **288**.

[0111] Similarly, belt **302***b* may extend in a transverse direction from the lower side of pulley **300***b*, generally following rail **290** to the lower side of a pulley **304***b*, mounted above the opposite end of rail **290** to pulley **300***b*. From there belt **302***b* extends to the upper side of pulley **304***b* and in a transverse direction to the upper side of pulley **300***b*. Belt **302***b* is also connected to support plate **268**, such movement of belt **302***b* will drive movement of support plate **270** along rail **290**.

[0112] With this arrangement, through operation of servo motor **286***a* the horizontal position in the Y-direction of support plates **268**, **270** and thus rails **264**, **266**, support tube **256***a* and first engagement apparatus **216***a* 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 **216***a*) 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 **216***a* can successfully engage and transfer the blank to the correct position on conveyor **220**.

[0113] The following will be appreciated in particular:

[0114] If servo motor **286***a* is not operated then driveshaft **298** will not rotate the position of rails **264**, **266** and interconnected support tube **256***a*/first engagement apparatus **216***a* in the Y1/Y2 directions (FIG. **9**A) will not be altered;

[0115] If servo motor **286***a* is operated such that driveshaft **298** rotates in the clockwise direction (as indicated by arrow **306** in FIG. **9**A), then pulleys **300***a*, **300***b* 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 **256***a*/first engagement apparatus **216***a* in the Y1 direction (as shown in FIG. **9**A) through slidable movement on rails **288**, **290**.

[0116] If servo motor **286***a* is operated such that driveshaft **298** rotates in the counter clockwise direction (as indicated by arrow **308** in FIG. **9**A), then pulleys **300***a*, **300***b* will also both 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 **256***a*/first engagement apparatus **216***a* in the Y2 direction (as shown in FIG. **9**A) through slidable movement on rails **288**, **290**.

[0117] It will be appreciated that if the speeds and directions of the motors **272***a*, **274***a*, **278** are varied in different manner, then the motion of the support tube **256***a* (and thus first engagement head **216***a*) 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 **256***a*—and thus for first engagement head **216***a* (such as a path having curved portions). Thus, by controlling the rotational direction and speed of the motors **272***a*, **274***a*, **278** independently of each other, PLC **500** can cause support tube **256***a* (and thus first engagement head **216***a*) 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 **280***e*, and the bottom of support tube **256***a* in the Z direction and the spacing between pulleys **300***a*, **300***b* and pulleys **304***a*, **304***b* in the Y direction.

[0118] An encoder may be provided for each of the servo drive motors **272***a*, **274***a* 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 and thus will determine and know the position of the first engagement head **216***a* in space at any given time.

[0119] 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**. Thus PLC

500 can in real time know/determine/monitor the belts **302***a*, **302***b* in space and thus will determine and know the position of the first engagement head **216***a* in the Y direction.

[0120] 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 **272***a*, **274***a*, **286***a* 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**.

[0121] Also associated with first movement apparatus **218***a* is a first, generally horizontally oriented caterpillar device **310** and a second generally vertically oriented caterpillar device **312** (FIG. **9**B). 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 **256***a* and first engagement head **216***a* are moved longitudinally. Caterpillar **312** allows such hoses and wires to move vertically as the support tube **256***a* and first engagement head **216***a* are moved vertically.

[0122] Also associated with first movement apparatus **218***a* are third and fourth, generally horizontally orientated caterpillar devices **314***a*, **314***b* (FIG. **9**B). Each of the caterpillars **314***a* and **314***b* have a hollow cavity housing hoses and wires carrying pressurized air/vacuum and electrical/communication wires. Caterpillars **314***a*, **314***b* allows such hoses and wires to move longitudinally as rails **264**, **266** and interconnected support tube **256***a*/first engagement apparatus **216***a* are moved longitudinally.

[0123] The caterpillars allow hoses and wires to supply first engagement head **216***a*. 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 **216***a*. 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 **216***a* could in other embodiments be accomplished using wireless technologies that are commercially available.

[0124] Through operation of first movement apparatus **218***a* as described above, first engagement head **216***a* may be moved towards a stack of blanks at second (or pick up) position **238** on runner blank conveyor **202** (FIG. **5**A). 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 **248***a-e* of first engagement head **216***a*. 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 **218***a* moves first engagement head **216***a* 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**

[0125] Runner forming station **210** is depicted in isolation in FIGS. **10**A to **10**C 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. **13**A to **13**J, 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**

[0126] 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.

[0127] Belt **316** may include a first engagement feature, such as first outwardly projecting ridge **318***a* configured to engage an edge **100***a* of a blank **100** that is placed on conveyor **220** by first movement apparatus **218***a*, as depicted schematically in FIG. **13**A. Ridge **318***a* is configured to prevent movement of blank **100** from left to right (as viewed in FIG. **10**A) 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 **318***b* (FIG. **10**C) on the opposite side of belt **316** to first ridge **318***a*. Second ridge **318***b* substantially performs the same function as first ridge **318***a* when ridge **316***b* is positioned on the upper side of runner forming station **210** due to movement of belt **316**

[0128] With reference to FIG. **13**A, at step **1000**(**1**) runner forming station **210** and blank **100** are shown in an initial configuration. In this configuration, first movement apparatus **218***a* has placed a blank **100** on conveyor **220** such that edge **100***a* abuts ridge **318***a* (or ridge **318***b* 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 **318***a* or **318***b* is positioned such that when first movement apparatus **218***a* moves first engagement head **216***a* with an engaged blank **100** to conveyor **220** of runner forming station **210**, edge **100***a* of the engaged blank **100** will be placed adjacent to ridge **318***a* or **318***b*.

Scoring Roller **222**

[0129] With reference to FIG. **13**B, 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 **100***a* of blank **100** may be in abutment with ridge **318***a* 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**.

[0130] 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. **10**A to **10**C and **13**A to **13**E, 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**.

[0131] 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**.

[0132] 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.

[0133] 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. **10**A) 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.

[0134] 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. **10**A). 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.

[0135] 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.

[0136] 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**).

[0137] 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.

[0138] 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 forming station **210** based on the signal(s) received from one or more of these sensors.

[0139] 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**.

Adhesive Applicator **224**

[0140] 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**.

[0141] 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 **330***a* to **330***i*. Adhesive applicators **330***a-i* may each be provided with nozzles **332***a-i* respectively. Individual adhesive applicators **330***a* to **330***i* can be appropriately positioned transversely along support beam **328** such that adhesive applicators **330***a-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 **330***a-i* may be controlled by PLC **500** by for example suitable wire connections that pass through frame **214**. Applicators **330***a-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.

[0142] In other embodiments, adhesive applicator apparatus may have any suitable number or arrangement of nozzles.

[0143] 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.

[0144] 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 **330***a-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 **330***a-i*, to form adhesive lines such as adhesive lines extending transversely across blank **100**.

[0145] 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.

[0146] 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.

[0147] In other embodiments, the adhesive applicator apparatus **224** may be pressurized cold seal glue system such as those manufactured by Nordson™ Inc.

[0148] 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. 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 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 U.S. Pat. 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.

[0149] Adhesive applicators **330***a-i* may be individually secured and adjusted by use of releasable adjustment mechanisms **334***a-i* which releasably secures the applicators **330***a-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 **330***a-i* 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.

[0150] 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.

[0151] 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**

[0152] Referring back to FIG. **13**B, as conveyor **220** advances blank **220**, at step **1000**(**2**), the edge **100***b* of blank **100** (which is the opposite edge of edge **100***a* described above) is engaged by panel rotating apparatus **226**.

[0153] Panel rotating apparatus **226** is depicted in isolation in FIGS. **12**-**12**C 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**.

[0154] 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 **340***a* and **340***b* and an inner facing side (or hypotenuse) **340***c*. Similarly, second portion **342** has a cross-sectional shape in the form of a right angle triangle, with outer facing sides **342***a* and **342***b* and an inner facing side (or hypotenuse) **342***c*. 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 **340***a* to side **340***b* to side **320***c* is the same as the ratio of the length of side **342***a* to side **342***b* to side **324***c*.

[0155] 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.

[0156] As depicted in FIG. **12**C, the outer facing sides **340***a* and **340***b* of first portion **340** and the outer facing sides **342***a* and **342***b* 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**.

[0157] Further, the respective inner sides **340***c*, **342***c* 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 **340***c* and inner facing side **342***c* (FIG. **12**C) is decreased, i.e. blank receiving slot **350** is narrowed such that inner facing sides **340***c*, **342***c* 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 **340***c*, **342** configured to realisably engage a portion of blank **100**.

[0158] With reference to FIG. **12**A, 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. **10**A and **12**A) and to allow mandrel to rotate about a generally horizontally orientated axis of rotation **352** shown in FIG. **12**.

[0159] 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. **12**A) such that mandrel **336** moves in space with support tube **354**.

[0160] Affixed to the rear of support tube **354** is a vertically extending rail **356** (FIG. **12**B), to which a pair of slide blocks **357**, **358** (FIG. **12**A) are mounted to rail **356**. Slide blocks **357**, **358** are each affixed to support bracket **360** (FIG. **12**B), 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.

[0161] 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**.

[0162] With reference to FIG. **12**C, 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**.

[0163] 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 can be adjusted relative to frame **214**.

[0164] The following will be appreciated in particular:

[0165] 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;

[0166] 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**.

[0167] 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**.

[0168] 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.

[0169] 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 form 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 Igus™ 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.

[0170] 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.

[0171] 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 **218***a*, **218***b*, **218***c* described above, which are operable to move mandrel **336** in the X, Y and Z directions.

[0172] 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. **12**B) 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.

[0173] 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 **286***a*. 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**.

[0174] The sequence of steps **1000**(**1**) to **1000**(**10**) in FIGS. **13**A to **13**J, will now be described whereby runner forming station **210** forms a pallet runner **150** from a runner blank **100**.

[0175] 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.

[0176] At step **1000**(**2**), as blank **100** in advanced on belt **316** direction **229**, edge **100***b* 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 **100**.

[0177] With reference to FIG. **13**C-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 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 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.

[0178] First, through steps **1000**(**2**) to **1000**(**4**) (FIGS. **13**B to **13**D), 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 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 **342***a* and **342***c* of second portion **342** of mandrel **336** to yield the configuration shown at **1000**(**4**).

[0179] At step **1000**(**4**) (FIG. **13**D), mandrel **336** is positioned such that side **342***b* (FIG. **12**C) of second portion **342** is in contact with panel B. Mandrel **336** may then rotate 90 degrees 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 **340***a* of first portion **340** is in contact with panel C.

[0180] 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) may be rotated 90 degrees relative to panel D about the fold line **106** between adjacent panels C and D such that side **340***b* of first portion **340** is in contact with panel D.

[0181] The configuration in **1000**(**6**) is shown in more detail in FIG. **13**K where panel A is partially located in blank receiving slot **350**, wraps around second portion **342** and is contact with side **342***a* of second portion **342**, the now inwardly facing side of panel B is in contact with side **342***b* of second portion **342**, the now inwardly facing side of panel C is in contact with side **340***a* of first portion **340** and the now inwardly facing side of panel D is in contact with side **340***b* 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. **13**A).

[0182] 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. **13**G, 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**.

[0183] 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.

[0184] 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. **10**A) in order to accommodate the increasing size of the partially formed runner.

[0185] 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.

[0186] Through steps **1000**(**7**) to **1000**(**9**) (FIGS. **13**G to **131**), 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. **13**J.

[0187] 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 **216***b* and moved by second movement apparatus **218***b* to pallet assembly station **212**.

[0188] 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 **318***b* is in the position shown at step **1000**(**1**). Another blank **100** may then be positioned on conveyor **210** by first movement apparatus **218***a* and the steps **1000**(**1**) to **1000**(**10**) may be repeated in order to form another pallet runner **150**.

[0189] 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.

[0190] 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**.

[0191] 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.

[0192] 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. **10**A). This may remove the requirement for mandrel **336** to be moveable in the Y1 and Y2 directions as described above.

[0193] 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.

[0194] 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 temple 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.

[0195] 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. **17**A-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. **17**A-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. **3**B), 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.

[0196] 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 and 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**

[0197] 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**

[0198] Deck conveyor **204** is shown in isolation in FIG. **14** and may 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 **228***b* (not shown in FIGS.) such as a DC motor or a variable frequency drive motor, which may be similar to motor **228***a* 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**.

[0199] 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**.

Second Engagement Head **216***b*

[0200] Second engagement head **216***b* may be configured to engage a complete runner **150** from runner forming station **210** and, through second movement apparatus **218***b* transfer runner **150** to pallet assembly station **212**.

[0201] With reference to FIG. **6**C, second engagement head **216***b* may be mounted to and moved by second movement apparatus **218***b* that allows second engagement head **216***a* to move in both the vertical Z and horizontal X/Y directions (i.e., directions parallel to axes Z, X and Y in FIG. **6**C).

[0202] Second engagement head **216***b* is shown in greater detail in FIGS. **15**A-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**.

[0203] 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 the supply of vacuum force to the suction cups **410**.

[0204] 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. **15**A). 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 **218***b* 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. **15**C, 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.

[0205] In some embodiments, second engagement head **216***b* 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 **216***b*, second movement apparatus **218***b* and any items engaged by second engagement head **216***b* during operation. Shock absorbing mechanism **420** may be any suitable mechanism operable to perform these functions, such as a spring mechanism.

Second Movement Apparatus **218***b*

[0206] Similar to first engagement head **216***a*, second engagement head **216***b* may also have a dedicated movement apparatus, second movement apparatus **218***b*. Second movement apparatus **218***b* may generally be configured similarly to first movement apparatus **218***a* described above such that second engagement head **216***b* may move in both the vertical Z and horizontal X/Y directions (i.e., directions parallel to axes Z, X and Y in FIG. **6**C), controlled by PLC **500**. With reference to FIG. **6**B, second movement apparatus **218***b* includes a vertically orientated support tube **256***b*, which may generally be similar to support tube **256***a* described above. Second engagement head **216***b* is mounted to support tube **256***b* by mounting brackets **436** (FIG. **6**C) such that second engagement head **216***b* moves in space with support tube **256***b*.

[0207] In order to drive second movement apparatus **218***b* horizontally (in the X-direction in FIG. **6**C) a drive apparatus is provided which includes a left side drive motor **272***b* and a right side drive motor **274***b*, which may be similar to motors **272***a*, **274***a* described above. In order to drive second movement apparatus **218***b* horizontally in the Y-direction, a drive apparatus is also provided which includes a central drive motor **286***b*, which may be similar to motor **286***a* described above.

Pallet Assembly Station **212**

[0208] With reference to FIGS. **5**A and **5**B, 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 **216***b* in the foregoing may be affected by second movement apparatus **218***b* and controlled by PLC **500**.

[0209] Through operation of second movement apparatus **218***b*, second engagement head **216***b* may be moved towards a completed pallet runner **150** at runner forming station **210** (FIG. **6**B), 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 **218***b* moves second engagement head **216***b* with an engaged pallet runner **150** from the runner forming station **210** to pallet assembly station **212**. Pallet runner **150** may then be bought into contact with deck **170**.

[0210] 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.

[0211] As runner **150** is bought into contact with deck **170**, downwards pressure may be applied to pallet runner **150**, through second engagement head **216***b* by downwards movement of support **256***b* of second movement apparatus **218***b* in order to ensure that the later of adhesive contacts both of the surfaces being bought into contact. This may be desirable when the later of adhesive comprises a pressure sensitive HMA. At this stage, second movement apparatus **218***b* 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.

[0212] Suction cups **410** will then disengage and release the engaged pallet runner **150** from engagement with second engagement head **216***b*. The steps described above, where second engagement head **216***b* 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 **216***b* may move to a home or idle position so as not to interfere with the subsequent movement of corrugated pallet **160**.

[0213] Whilst as shown in FIG. **5**A, 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.

[0214] Whist 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 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 **216***b*), moved by a suitable movement apparatus (which may be similar to second movement apparatus **218***b*) 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.

Takeaway Conveyor **208**

[0215] 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 **228***c* such as a DC motor or a variable frequency drive motor, which may be similar to motor **228***a* 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**.

[0216] 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 **228***c* of takeaway conveyor **208** to move the stack to second position **440**.

[0217] In some embodiments, completed corrugated pallets **160** may be transferred by takeaway conveyor **208** for the loading/packaging of items onto each pallet **160**.

[0218] 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 **216***c*/Third Movement Apparatus **218***c*

[0219] 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 **216***c* and third movement apparatus **218***c*.

[0220] With reference to FIG. **6**D, third engagement head **216***c* may be any apparatus configured to releasably engage a completed corrugated pallet **160**. In some embodiments, third engagement head **216***c* is generally similar to second engagement head **216***b* described above. Third engagement head **216***c* 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**).

[0221] Similar to first and second engagement heads **216***a*, **216***b*, third engagement head **216***c* may also have a dedicated movement apparatus, third movement apparatus **218***c*. With reference to FIG. **6**D, third movement apparatus **218***c* includes a vertically orientated support tube **256***c*, which may generally be similar to support tube **256***a* described above and to which third engagement head **216***c* is mounted to such that third engagement head **216***c* moves in space with support tube **256***c*.

[0222] Third movement apparatus **218***c* may generally be configured similarly to first and second movement apparatuses **218***a*, **218***b* described above such that third engagement head **216***c* may move in both the vertical Z and horizontal X/Y directions (i.e., directions parallel to axes Z, X and Y in FIG. **6**D), controlled by PLC **500** (FIG. **7**). In order to drive third movement apparatus **218***c* horizontally (in the X-direction in FIG. **6**D) a drive apparatus is provided which includes a left side drive motor **272***c* and a right side drive motor **274***c*, which may be similar to motors **272***a*, **274***a* described above. In order to drive third movement apparatus **218***c* horizontally in the Y-direction, a drive apparatus is provided which includes a central drive motor **286***c*, which may be similar to motor **286***a* described above.

[0223] In operation, through operation of third movement apparatus **218***c*, third engagement head **216***c* 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 **218***c* moves third engagement head **216***c* 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 position **438** to the second position **440**.

[0224] 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 first position **380** on deck conveyor **204** (FIG. **14**).

[0225] 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 **218***a* is activated to move first engagement head **216***a* 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 **216***a* engages and holds a blank **100**. First movement apparatus **218***a* 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 **216***a* can disengage from blank **100**. First movement apparatus **218***a* may then move first engagement head **216***a* away from runner forming station **210** and may return to pick up another blank **100** from second position **238**.

[0226] At this stage, runner forming station **210** may be configured as shown in FIG. **13**A. 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**.

[0227] 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**.

[0228] Next, under control of PLC **500**, second movement apparatus **218***b* is activated to move second engagement head **216***b* to the completed runner **150** at runner forming station **210**. PLC **500** then activates suction cups **410** such that second engagement head **216***b* engages runner **150**. Second movement apparatus **218***b* 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**.

[0229] As second movement apparatus **218***b* 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.

[0230] Further, as second movement apparatus **218***b* moves an engaged runner to pallet assembly station **212**, under control of PLC **500** second movement apparatus **218***b* may rotate second engagement head **216***b* and the engaged runner about axis **408** (FIG. **15**A) 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**.

[0231] Once runner **150** is placed on deck **170**, second engagement head **216***b* may remain engaged to runner **150** and second movement apparatus **218***b* 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 **218***b* 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**.

[0232] Next, PLC **500** then deactivates suction cups **410** such that second engagement head **216***b* can disengage from runner **150**. Second movement apparatus **218***b* may then move second engagement head **216***b* away from runner forming station **210** and may return to pick up another runner **150** from runner forming station **210**.

[0233] 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.

[0234] Next, under control of PLC **500**, third movement apparatus **218***c* is activated to move third engagement head **216***c* to the completed corrugated pallet **160** at pallet assembly station **212**. PLC **500** then activates suction cups **442** such that third engagement head **216***c* engages corrugated pallet **160**. Third movement apparatus **218***c* then moves the engaged pallet to the first position **438** of takeaway conveyor **208** and places corrugated pallet **160** at first position **438**.

[0235] Next, PLC **500** then deactivates suction cups **442** such that third engagement head **216***c* can disengage from corrugated pallet **160**. Third movement apparatus **218***b* may then move third engagement head **216***c* away from first position **438** of takeaway conveyor **208** and may return to pallet assembly station **212** to pick up another corrugated pallet **160**.

[0236] 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.

[0237] 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**.

[0238] 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**.

[0239] 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.

[0240] 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.

[0241] 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.

[0242] 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 **216***a* is in position to engage the completed runner, through coordination of runner forming station **210** and second movement apparatus **218***b*. At the same time, first movement apparatus **218***a* may position first engagement head **216***a*, 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.

[0243] 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 or reasons, for example to increase the strength of the corrugated pallet or to accommodate different forks of lifting equipment. For example, when a pallet is required to support a heavier load, a greater number of runners may be used.

[0244] Furthermore, in some embodiments the thickness of runner blank **100** and/or deck **170** may 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 **500** may be preprogrammed 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**.

[0245] 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 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.

[0246] 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 apart rows of pallet runner blocks **662***a*, **662***b*, **662***c* secured to lower surface **672** of deck **670**. Row **662***a* may include pallet runner blocks **650***a*, **652***a*, **652***a*, row **662***b* may include pallet runner blocks **650***b*, **652***b*, **652***b* and row **662***c* may include pallet runner blocks **650***c*, **652***c*, **652***c*.

[0247] 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 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.

[0248] In various embodiments, the spacing and length of pallet runner blocks **650***a-c*, **652***a-c* and **654***a-c* may be varied.

[0249] Each of the pallet runner blocks **650***a-c*, **652***a-c* and **654***a-c* may be constructed and formed in a similar manner to pallet runner **150** described above. In an embodiment, pallet runner blocks **650***a-c*, **652***a-c* and **654***a-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 **650***a-c*, **652***a-c* and **654***a-c* may be formed individually on a pallet forming system, such as pallet forming system **200** described above from a suitably sized blank.

[0250] 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 **750***a*, **750***b* and **750***b*, spaced apart in a parallel arrangement and secured to lower surface **772** of deck **770**. Runners **750***a*, **750***b* and **750***b* 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 **750***a* includes cut out portions **752***a*, **754***a*, runner **750***b* includes cut out portions **752***b*, **754***b* and runner **750***c* includes cut out portions **752***c*, **754***c*. Cut out portions **752***a-c*, **754***a-c* may be formed by cutting removing a section from a formed pallet runner **150**, such as by die cutting. Alternatively, the blank used to form pallet runners **750***a-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 **750***a-c* (such as on pallet forming system **200**), the runner is formed with cut-out portions **752***a-c*, **754***a-c*.

[0251] In various embodiments, the spacing and depth of cut out portions **752***a-c*, **754***a-c* may be varied.

[0252] 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 pallet and its supported load may be lifted and moved.

[0253] Pallets **660**, **670** may be manufactured from planar blanks on a pallet forming system, such as a modified version of pallet forming system **200**.

[0254] 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**.

[0255] In some embodiments, runner blank **100** may be a different material to deck **170**.

[0256] 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.

[0257] 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.

[0258] 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.

[0259] 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.

[0260] 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.

[0261] 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 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.

[0262] 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**.

[0263] 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 **216***a-c*, movement apparatuses **218***a-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.

[0264] 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.

[0265] 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.

[0266] In some embodiments, the method further comprises applying an adhesive to a surface of at least one of the plurality of adjacent panels.

[0267] In some embodiments, the gripper comprises a mandrel.

[0268] 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.

[0269] 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.

[0270] 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.

[0271] 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.

[0272] 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.

[0273] 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

[0274] 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 define a blank receiving slot configured to receive a portion of the first panel.

[0275] 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.

[0276] An embodiment as disclosed herein relates to a system for forming a pallet. 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 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 to place the engaged pallet runner on a surface of the deck.

[0277] 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 of planar blanks to the runner forming station.

[0278] 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 corrugated pallets.

[0279] 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.

[0280] 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.

[0281] When introducing elements of the present invention or the embodiments thereof, the articles "a," "an," "the," and "said" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements.

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 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 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-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 from corrugated cardboard.

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 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.

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