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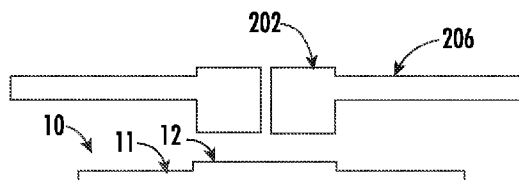


FIG. 6B

(57) Abstract: A glass ribbon processing apparatus including a plurality of rollers configured to translate a glass ribbon including a first portion having a first thickness adjacent to a second portion having a second thickness thinner than the first thickness, a thermal containment enclosing the plurality of rollers including an upper chamber having one or more heating elements configured to control a rate of cooling of the glass ribbon, and a lower chamber, and a modularly designed localized temperature control unit that includes a thermal element configured to cool the first portion or heat the second portion of the glass ribbon, a control arm configured to move the thermal element vertically or horizontally relative to the plurality of rollers, and a movable seal configured support the control arm and to maintain a thermal boundary between the upper chamber and the lower chamber.



MODULAR THERMAL CONTROL UNITS FOR VARIABLE THICKNESS GLASS RIBBON

Cross-Reference To Related Application

[0001] This application claims the benefit of priority under 35 U.S.C. § 119 of U.S. Provisional Application Serial No. 63/402628 filed on August 31, 2022, the content of which is relied upon and incorporated herein by reference in its entirety.

Field of the Disclosure

[0002] The present disclosure relates to devices and methods providing preferential cooling or heating of precise regions within a continuous glass ribbon. The devices and methods disclosed may provide control of the glass ribbon temperature to ensure the temperature difference between thick and thin regions remains at or near zero.

BACKGROUND

[0003] Back covers for certain smartphones and mobile devices or any glass body for an electronic component or enclosure design that have a non-uniform thickness, the non-uniform thickness being thicker in the camera region than the other portions, allow for improved camera lens designs (see, for example U.S. PG Pub. 2019/0364179 A1). As an example, the glass thickness may be 1.5-3.0 millimeters (mm) in thicker portions and <0.8 mm elsewhere. To fabricate the thicker portion for the device back-cover or enclosure, a relatively thick glass sheet may be ground, lapped, and polished to define a thicker area and a thinner area. In such a case, to make a glass article with a 1.6 mm thickness in the thicker portion and a 0.6 mm nominal thickness elsewhere, a glass sheet with a 1.9 mm thickness may be used. That is, 0.3 mm of material would be removed from the thicker portion and 1.3 mm of material from the thinner portion everywhere else. This approach has poor glass utilization, is time consuming, costly, inefficient, and not environmentally friendly.

[0004] In an alternative method of forming glass articles with non-uniform thickness, two glass substrates can be fused together (see, for example U.S. PG Pub. 2017/0210111A1). For example, a 25 mm x 25 mm x 1.0 mm glass piece may be fused to a larger glass piece of 70 mm x 150 mm x 0.6 mm by bonding or pressing together under high temperatures. This method improves glass utilization but is energy intensive, may result in bubble formation at the fused interface, and may be costly and more time consuming than the grinding process.

[0005] When the grinding process is not cost effective and produces too much waste, and when fusing two glass pieces together is not a viable option, another solution is to define a continuous glass ribbon having the desired thickness differences. Producing a glass ribbon with a variation in thickness may require generating a significant difference in temperatures between the thicker portion and the thinner portion.

SUMMARY

[0006] In some example embodiments, an ability to preferentially cool the thicker portion of a glass ribbon with a variation in thickness at a prescribed rate that is different from the cooling rate of the base ribbon (or the thinner portion of the glass ribbon) may enable manufacture of the glass ribbon with low stress and warp. It may also be desired to preferentially heat the base ribbon (or thin portion) to slow down its normal rate of cooling with respect to that of the thick portion.

[0007] Embodiments of the present disclosure provide apparatus and methods that minimize stress and warp in variable thickness glass sheets by cooling a thicker portion of a glass ribbon at a higher rate than cooling a thinner portion of the glass ribbon by managing thick-to-thin and top-to-bottom temperature gradients. The cooling may be performed through convection and/or radiation, and from the top and/or the bottom of the glass ribbon. Optionally, localized heating may be used along with preferential cooling to control the desired temperature parameters within the glass.

[0008] The embodiments described may be applied to a hot glass ribbon that is traveling in a lehr and/or controlled cooling apparatus (CCA). The CCA may be a modified lehr, or a roller hearth lehr, or a roller kiln that produces glass ribbons.

[0009] Without the thermal management methods presently described, stresses generated in glass ribbons with variable thicknesses may be undesirably high. Additional processes may be needed to remove or condition the glass ribbons including scoring glass ribbons, cutting high-stress portions out of glass ribbon, or providing extra finishing processes to produce glass to the desired size, shape, and thicknesses. Alternative methods to reduce stresses in glass ribbons would be to significantly increase the lehr length or adding an annealing step. Both of these methods involve significant cost and space requirements.

[0010] According to an embodiment of the present disclosure, a glass ribbon processing apparatus produces a glass ribbon having a first portion with a first thickness immediately

adjacent to a second portion with a second thickness, the apparatus comprising one or both of a localized temperature control unit and a modular thermal control unit, as described herein.

[0011] Additional features and advantages of the invention will be set forth in the detailed description which follows, and in part will be readily apparent to those skilled in the art from that description or recognized by practicing the invention as described herein, including the detailed description that follows, the claims, as well as the appended drawings.

[0012] It is to be understood that both the foregoing general description and the following detailed description present embodiments of the invention, and are intended to provide an overview or framework for understanding the nature and character of the invention as it is claimed. The accompanying drawings are included to provide a further understanding of the invention, and are incorporated into and constitute a part of this specification. The drawings illustrate various embodiments of the invention, and together with the description serve to explain the principles and operation of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] While the specification concludes with claims particularly pointing out and distinctly claiming the subject matter of the written description, it is believed that the specification will be better understood from the following written description when taken in conjunction with the accompanying drawings, wherein:

[0014] FIGs. 1A and 1B show perspective views of glass ribbons including thinner portions and thicker portions in accordance with an example embodiment;

[0015] FIG. 2 shows across-sectional view of a Lehr including a localized temperature control unit according to an example embodiment;

[0016] FIG. 3 shows a cross-sectional view of a liftable labyrinth seal spacer disposed in a Lehr according to an example embodiment;

[0017] FIGs. 4A and 4B show cross-sectional views of flexible fiber spacer in closed and lifted positions, respectively, according to an example embodiment;

[0018] FIGs. 5A and 5B show cross-sectional views of a Lehr with localized temperature control units in a working position and a parked position, respectively, in accordance with an example embodiment;

[0019] FIGs. 6A-6D show cross-sectional views of different sizes and positions of the thermal elements and control arms to accommodate the desired cooling of a glass ribbon with different thicker portion and thinner portion configurations according to an example embodiment;

[0020] FIG. 7 shows a perspective view of a Lehr having a plurality of localized temperature control units and mechanical linkages for moving control arms associated with the localized temperature control units according to an example embodiment;

[0021] FIG. 8 shows a cross-sectional view of a Lehr including a modular thermal control unit according to an example embodiment;

[0022] FIG. 9 shows a cross-sectional view of the modular thermal control unit according to an example embodiment; and

[0023] Figs 10A and 10B show perspective views of the modular thermal control unit with heating elements and cooling elements in different positions according to an example embodiment.

DETAILED DESCRIPTION

[0024] Glass ribbon geometries including thinner portions and thicker portions are made possible by devices and methods described in the present disclosure. Drawn glass ribbon geometries may include a certain width where a portion of the width is thicker than other portions. For example, the thicker portion may be in the center of the glass ribbon. Optionally, there may be more than one thicker portion spaced across the width of a glass ribbon. The geometry is usually designed for specific products.

[0025] Conventional thermal management inside the Lehr and/or CCA led to the thicker portion being consistently hotter than the thinner base glass throughout the controlled cooling section. This persistent thermal gradient between the thicker and thinner portions present during ribbon cooling, though reasonably well managed by controlling the Lehr, may cause high stress and warp in the as-formed products. This stress and warp may cause a pressing need for preferential thermal management tools used with the Lehr to lower the thermal gradient and reduce resulting stress.

[0026] In an example embodiment, with no or minimum damaging and/or changing of an existing Lehr, adding modular designed thermal control tools to realize extra cooling is provided via preferential thermal tools. As a result, the glass ribbon may achieve near identical temperatures in the thicker and thinner portions to maintain the thick-to-thin temperature difference (ΔT or DT) close to zero. In some example embodiments, preferential cooling of the thicker portion of the glass ribbon may be combined with preferential heating of the thinner portion. Heating of the thinner portions may be accomplished either by local heating tools or by keeping the overall Lehr temperature higher

than the temperature of thinner portions (while the cooling tools preferentially cool the thinner portions).

[0027] Cooling flow, stress, and warp data illustrate that as the thicker portion is cooled such that the temperature difference between the thicker and thinner portions is reduced, the stress in the glass ribbon is also reduced. Further, cooling device features may be optimized based on the particular application and desired results.

[0028] Providing cooling may be done using any combination of techniques including forced air (convection), radiation, and conduction. Cooling system design includes consideration of factors including emissivity, the ideal gas law and expansion of the heated air, removal of the heated air from the manufacturing building, and occupant safety.

[0029] Any type of cooling (convection, radiation, conduction, and combinations thereof), heating, or heating and cooling may be provided such that each device providing the treatment may be independently moveable and positioned to align with any portion of the glass ribbon. Any device may be placed in the center of the glass ribbon to cover a wider thicker portion or devices may be spread apart toward the edges of the glass ribbon to cover a narrower edge-strip configuration. Any of the devices may be independently located above, below, to the side, or parked out of the way when not in use with respect to the glass ribbon and be placed in position manually or by an automated electro-mechanical positioning system. Optionally, any number of positions of any number of devices that heat and/or cool may be located by automation and preprogrammed so that different configurations of processes of glass ribbons may be repeatable.

[0030] FIGs. 1A and 1B show perspective views of glass ribbons 10 including thinner portions 11 and thicker portions 12 in accordance with an example embodiment. The glass ribbon 10 may include one or more thicker portions 12 disposed directly adjacent to one or more thinner portions 11. In the example depicted in FIG. 1A, two thicker portions 12 are disposed longitudinally on the glass ribbon 10 with thinner portions 11 disposed on either side of each of the thicker portions 12. In the example depicted in FIG. 1B, one thicker portion 12 is disposed longitudinally on a center of the glass ribbon 10 with thinner portions 11 disposed on either side of the thicker portion 12. The thicker portions 12 and thinner portions 11 of the glass ribbon 10 may be generated by the geometry of forming rollers, for example, forming rollers having reduced profiles in one or more locations corresponding to the thicker portions 12. As an example, the thicker portions 12 may be 1.5-3.0 mm in thickness and the thinner portions 11 may be <0.8 mm, although other thicknesses for the thicker portions 12 and thinner portions 11 are contemplated.

[0031] FIG. 2 shows a cross-sectional view of a Lehr 100 including a localized temperature control unit 200 according to an example embodiment. The Lehr 100 comprises a thermal containment including an upper chamber 102 and lower chamber 104. Heaters 106, such as electric winding heaters, are located in the upper chamber 102 above silicon carbide (SiC) plates 108. A plurality of rollers 110 are disposed in lower chamber 104. During normal operation, the glass ribbon 10 (FIG. 1) is continuously passed, longitudinally, through the Lehr 100 on the rollers 110, and power applied to heater 106 may be regulated to maintain desired temperatures on each of the SiC plates 108 along the length of the Lehr 100.

[0032] The localized temperature control unit(s) 200, here a spacer-type airbox cooling unit device, is disposed between upper chamber 102 and lower chamber 104. The localized temperature control unit 200 provides cooling effects from the top side, e.g., “upper side” or “A-side” of the glass ribbon 10 translated on rollers 110.

[0033] The localized temperature control unit 200 may include one or more thermal elements 202, a movable seal or spacer 204, and a control arm 206. The localized temperature control unit 200 may be a modular assembly that can be installed in an existing Lehr 100 without significant modification. For example, the localized temperature control unit 200 may be installed into the Lehr 100 by raising the upper chamber 102 of the Lehr 100 and installing the spacer 204 in the space between the upper chamber 102 and the lower chamber 104. Additionally, the localized temperature control unit 200 may be removed from the Lehr 100 by reversing the process, without damage or significant modification to the Lehr 100.

[0034] The thermal elements 202 may include one or more heating elements or cooling elements, such as an electrical heating winding, an airbox, or the like. The thermal elements 202 provide convection or radiation preferential cooling effects to the top surface of a thicker portion 12 of the glass ribbon 10 and/or preferential heating effects to the top surface of the thinner portion 11 of the glass ribbon 10. The thermal elements 202 may include a top wall and two side walls, which may be insulated by thin refractory materials. Further, the thermal elements 202 may include a temperature conditioning face, such as airbox nozzles, which may face the glass ribbon 10.

[0035] As discussed above, the movable seal or spacer 204 may be disposed between a sidewall of the upper chamber 102 and a sidewall of the lower chamber 104. The spacer 204 enables the selective addition or removal of the localized temperature control unit from the Lehr 100. The spacer 204 provides vertical space or clearance for localized temperature control units 200 and seals the Lehr 100 during normal operation and/or when upper chamber

102 is lifted during threading operation of the glass ribbon 10. Example spacers 204 are discussed in further detail in reference to FIGs. 3, 4A, and 4B. The spacers 204 may be affixed to the upper chamber 102, the lower chamber 104, or both, such as by fasteners, adhesive, interference fit, clamping elements or the like. Advantageously, the spacers 204 may be removed from the Lehr 100 by disconnecting the spacer 204 from the upper chamber 102, the lower chamber 104 or both, by non-destructive means. Since the spacers 204 support the localized temperature control unit 200, the localized temperature control unit 200 is removed with the removal of the spacer 204.

[0036] Control arms 206 may be provided to support the thermal elements 202 and move the thermal elements 202 vertically or horizontally relative to the rollers 110. The control arms 206 extend through the spacer 204 to outside of Lehr 100. The control arms 206 may also be supported, at least partially, by the spacers 204. The control arms 206 may enable passage of coolant such as air, water, or the like, or electrical cabling to power electrical heater windings. Additionally or alternatively, the control arms 206 may include or be coupled to moving mechanisms to move the thermal elements to the desired position inside Lehr 100 relative to the rollers 110 and/or glass ribbon 10.

[0037] Movement of the thermal elements 202 horizontally may include extension or retraction of the control arm 206, such that the localized temperature control unit 200 is moved toward or away from a longitudinal centerline of the glass ribbon 10. For example, cooling thermal elements 202 may be positioned near either edge of the glass ribbon depicted in FIG. 1A to provide cooling to the thicker portions 12. For the glass ribbon depicted in FIG. 1B, the thermal elements may be positioned proximate to each other near a centerline of the glass ribbon 10, such that both thermal elements 202 provide cooling to the large thicker portion 12.

[0038] The spacers 204 enable changes of the vertical position of the thermal elements 202, as driven by the requirements of the ribbon geometry and process requirements. For example, the thermal elements 202 may be positioned close to the rollers 110 or glass ribbon 10, e.g., a working position, during operation for effective cooling of the thicker portion 12 and/or heating of the thinner portion 11, as depicted in FIG. 5A. Additionally, during initial threading of the glass ribbon 10, the thermal elements 202 may be positioned sufficiently high, e.g., a parked position, to allow a highly warped early portion of the glass ribbon 10 to pass thereunder, as depicted in FIG. 5B.

[0039] The spacers 204 may be liftable type spacers enabling the upper chamber 102 to be lifted during threading or used to adjust the height of the thermal elements 202 during

normal operation. The spacers 204 are well sealed to avoid external air entering lehr 100. In an alternative embodiment, the spacer 204 may be a solid type of spacer formed from solid refractory material, and the upper chamber 102 may be stationary during both threading and normal operation.

[0040] FIG. 3 shows a cross-sectional view of a Lifiable Labyrinth Seal Spacer (LLSS) 204 disposed in a lehr 100 according to an example embodiment. The liftable labyrinth seal spacer (LLSS) includes a plurality of interlocking refractory labyrinth fingers, which maintain an air seal as the upper chamber 102 is lifted during the threading process and/or lowered during normal processing operations. In some embodiments, a deformable material may be disposed between the interlocking refractory labyrinth fingers to provide additional clearance between upper and lower interlocking refractory labyrinth fingers during positioning and to provide the air seal, for example refractory fiber cloth, such as Zicar or Nextel.

[0041] FIGs. 4A and 4B show cross-sectional views of flexible fiber spacer 204 in closed and lifted positions, respectively, according to an example embodiment. A flexible refractory fiber cloth 224, such as Zicar or Nextel, is fastened, by fasteners 226, between an upper refractory block 220 of the upper chamber 102 and a lower refractory block 222 of the lower chamber 104 to limit or prevent air passage when the upper refractory block 120 is lifted with the upper chamber 102.

[0042] The spacer 204 could be of the labyrinth type as described above, or of the solid type. FIGs. 5A and 5B show cross-sectional views of a lehr 100 with localized temperature control units 200 with solid spacers 204 in a working position and a parked position, respectively, in accordance with an example embodiment. The localized temperature control units 200 may be moved between the working position of FIG. 5A and the parked position of FIG. 5B manually, such as by manual operation of the control arms 206 from the outside of lehr 100. In some example embodiments, the control arms 206 may be coupled to an actuator, such as a motor or mechanical linkage 130, as shown in FIG. 6.

[0043] In some example embodiments, the thermal elements 202 of the temperature control unit 200 may be replaceable prior to operation. For example, the size or thermal effect, e.g., cooling or heating, may be changed for the desired heating or cooling effect and/or the configuration of the glass ribbon 10. FIGs. 6A-6D show cross-sectional views of different size and positions of the thermal elements 202 and control arms 206 to accommodate the desired cooling of a glass ribbon 10 with different thicker portion 12 and thinner portion 11 configurations.

[0044] FIG. 7 shows a perspective view of a lehr 100 having a plurality of localized temperature control units 200 and mechanical linkages 130 for moving control arms 206 associated with each of the thermal elements 202 according to an example embodiment. The motor or mechanical linkage may automatically move the control arms 206 between the working position and the parked position. The thermal elements 202 may be coupled to the control arms 206 directly or indirectly. In an instance in which the thermal elements 202 are directly coupled to the control arm 206, the thermal elements 202 may rotate with the control arms 206 from the working position to the parked position. Alternatively, the thermal elements 202 may be coupled to the control arm 206 indirectly via a drive unit, such as a gear, linkage, or the like, such that when the control arm 206 rotates, the control arm 206 actuates the drive unit to move the thermal elements 202 vertically between the working and parked positions. In some embodiments, if the spacer 204 is of the labyrinth type, vertical movement of the localized temperature control unit 200 is a function of lifting the upper chamber 102. The control arms 206 may be coupled to the spacer 204, such that when the upper chamber 102 is lifted the control arm 206 is lifted with the upper portion of the spacer 204.

[0045] FIG. 8 shows a cross-sectional view of a lehr 100 including a modular thermal control unit 300. In an example embodiment, the modular thermal control unit 300 is installed at the bottom of the cavity of lower chamber 104 of the lehr 100. Refractory boards in the lower chamber 104 may be removed and the modular thermal control unit 300 may be disposed on the bed of the lehr 100, without significant modification to the lehr 100. The modular thermal control unit 300 occupies the cavity space between bottoms of the rollers 110 and the bottom of the lehr 100. The bottom of the modular thermal control unit 300 may extend out of the bottom of the lehr 100 to ensure that connecting mechanisms and moving mechanisms are placed outside of the lehr 100, and thereby outside the thermal effects of the lehr 100.

[0046] The modular thermal control unit 300 may include one or more cooling elements 302 and/or one or more heating elements 304. In the present example, the modular thermal control unit 300 is integrated with two cooling airboxes and two electrical heaters. As described below in reference to FIG. 9, the modular thermal control unit 300 may include one or more drive mechanisms configured to move the cooling elements 302 and/or heating elements 304 closer to, or farther from, the plurality of rollers 110 and the bottom side of glass ribbon 10. Additionally, the modular thermal control unit 300 may also be configured to move the cooling elements 302 and/or heating elements 304 horizontally to align the cooling

elements 302 and/or the heating elements 304 with the desired portion of the glass ribbon 10. For example, the cooling elements 302 may be moved beneath the thicker portion 12 of glass ribbon 10, and heating elements 304 may be moved beneath the thinner portion 11 of glass ribbon 10. Although only one modular thermal control unit 300 is depicted, a modular thermal control unit 300 may be installed in each zone of the lehr 100. Typically, each module of the lehr 100 contains two or more zones.

[0047] FIG. 9 shows a cross-sectional view of the modular thermal control unit 300 according to an example embodiment. The modular thermal control unit 300 may include one or more drive mechanisms configured to position the cooling elements 302 and/or the heating elements 304 vertically and/or horizontally relative to the plurality of rollers 110 and the glass ribbon 10. The drive mechanisms may include one or more motors 306, 308, such as electric motors, hydraulic motors, or the like, configured to rotate a drive assembly to position the cooling elements 302 and/or the heating elements 304 vertically or horizontally. The motors 306, 308 may be disposed at, or near, the bottom of the modular thermal control unit outside of lehr 100 to limit thermal stress subjected to the motors 306, 308.

[0048] A first motor 306 may be configured to move the cooling elements 302 and/or heating elements 304 horizontally. The first motor 306 may drive a screw gear having left- and right-hand threads. The left- and right-handed threading enables movement of both cooling elements 302 and/or heating elements 304 on rails simultaneously. Although a single horizontal motor 306 is depicted, additional motors may be utilized to enable independent movement of each cooling element 302 and/or heating element 304.

[0049] A second motor 308 may be configured to move the cooling elements 302 and/or heating elements 304 vertically. For example, the cooling elements 302 and/or heating elements 304s may be raised closer to the bottom side of the plurality of rollers 110 and the glass ribbon 10 in a working position, as depicted in FIG. 10B, and lowered to the parking position when not in use, as depicted in FIG. 10A. FIGs. 10A and 10B also depict the cooling elements 302 and heating elements 304 in different horizontal positions for illustrative purposes. The motors 306, 308 may be automatically controlled through a control logic to maximize the combined cooling and/or heating of the respective portions of the glass ribbon 10, thus, enabling a uniform temperature distribution of variable thickness glass. Further, automatic control of the motors 306, 308 may also enable positioning of the cooling elements 302 and/or heating elements 304 at an optimal distance from the glass ribbon 10 under different working conditions and glass material properties. The thermal characteristics of the modular thermal control unit 300, including but not limited to the positions of heaters

and coolers, the airflow through the cooling elements 302, and the power supplied to the heating elements 304, may be automatically controlled based on the real-time performance measurement of preferential thermal treatments for variable thickness glass ribbon 10.

[0050] In some example embodiments, the modular thermal control unit 300 may also include one or more drop doors 310, 312. The drop doors 310, 312 may be closed during normal operation, thereby limiting or eliminating air leaks into an upper hot tunnel of lehr 100 due to vacuum pressure. The drop doors 310, 312 may be configured to not interfere with the movement of the cooling elements 302 and/or the heating elements 304.

[0051] The upper drop doors 310 may be designed to work in a high temperature environment using ceramic-type refractory materials. The refractory material may limit or prevent the passage of heat, especially radiation heat, and to avoid overheating of the motors 306, 308, lower door 312, drive mechanisms, or the like. The upper door 310 may open periodically, such as when a predetermined amount of shattered glass builds up, a predetermined interval, or the like. The drop doors 310, 312 should not be opened at the same time to avoid ambient air being sucked directly into lehr 100 resulting in a drop in the set temperature in that location.

[0052] The lower door 312 may be formed from metal, such as steel, and be configured to work in a lower temperature environment than the inside of the thermal containment. The lower door 312 may be located at the bottom side of the modular thermal control unit 300. The lower door 312 may include a seal to limit or prevent air leakage into the lehr 100. The lower door 312 may be configured to open only when the upper door 310 is closed. For example, once the upper door 310 has opened and dumped shattered glass to the lower door and the upper door 310 has subsequently closed, the lower door 312 may open to dump shattered glass out of lehr 100 and reclose to maintain an air seal. As such, the lower door 312 may be referred to as a thermal interlock door. The doors 310, 312, including the thermal interlock feature may be automatically controlled via a control system.

[0053] In an example embodiment, the modular thermal control unit 300 may be disconnected and detached from the lehr 100 for maintenance or replacement. When the modular thermal control unit 300 is removed from the lehr 100, a manual door on the bottom side of lehr 100 may be closed to minimize air intake. Additionally, the modular thermal control unit 300 may be removed from the lehr 100 if the process no longer requires it. The space formally occupied by the modular thermal control unit 300 may be filled with refractory boards. As such, installation of the modular thermal control unit 300 is fully reversible to enable restoration of the lehr 100 to the original functionalities.

[0054] In an example embodiment, a glass ribbon processing apparatus is provided including a plurality of rollers configured to translate a glass ribbon longitudinally thereon. The glass ribbon includes a first portion having a first thickness adjacent to a second portion having a second thickness less than the first thickness. The glass processing apparatus also includes a thermal containment at least partially enclosing the plurality of rollers. The thermal containment includes an upper chamber having one or more heating elements configured to control a cooling rate of the glass ribbon, and a lower chamber. The glass processing apparatus may further include a localized temperature control unit including a thermal element configured to cool the first portion or heat the second portion of the glass ribbon, a control arm configured to move the thermal element vertically or horizontally relative to the plurality of rollers, and a movable seal configured to support the control arm and to maintain a thermal boundary between the upper chamber and the lower chamber as one of the upper chamber or the lower chamber moves toward or away from the other of the lower chamber or the upper chamber.

[0055] In an example embodiment, the localized temperature control unit is configured to be selectively installed and removed from the thermal containment. In some example embodiments, the movable seal may include a flexible fiber spacer, the flexible fiber spacer affixed to the upper chamber and the lower chamber. In an example embodiment, the thermal element is configured to convectively or radiatively heat or cool the glass ribbon. In some example embodiments, the thermal element may be a plurality of air nozzles directed toward the plurality of rollers. In an example embodiment, the control arm may be further configured to enable passage of a coolant or electrical cable through the control arm. In some example embodiments, the movement of the thermal element horizontally includes extension or retraction of the control arm, such that the thermal element is moved toward or away from a longitudinal centerline of the glass ribbon. In an example embodiment, the thermal element may be transitioned between a parked position and a working position. In some example embodiments, the glass ribbon processing apparatus may also include a modular thermal control unit including at least one cooling element and at least one heating element, the at least one cooling element configured to cool the first portion and the heating element configured to heat the second portion. In an example embodiment, the modular thermal control unit also includes at least one motor configured to position the at least one cooling element or the at least one heating element vertically or horizontally relative to the plurality of rollers. In some example embodiments, the at least one motor includes a plurality of motors configured to position the at least one heating element and the at least one cooling

element independently. In an example embodiment, the modular thermal control unit may also include a drop door configured to open periodically to release a build-up of glass particles. In some example embodiments, the modular thermal control unit may also include a thermal interlock door configured to be in a shut position when the drop door is in an open position to resist entrance of ambient air into the glass ribbon processing apparatus.

[0056] In another example embodiment, a glass ribbon processing apparatus is provided including a plurality of rollers configured to translate a glass ribbon longitudinally thereon, the glass ribbon comprises a first portion having a first thickness adjacent to a second portion having a second thickness less than the first thickness. The glass ribbon processing apparatus also includes a thermal containment at least partially enclosing the plurality of rollers, the thermal containment comprising an upper chamber having one or more heating elements configured to control a cooling rate of the glass ribbon, and a lower chamber, and a modular thermal control unit disposed at least partially in the lower chamber, the modular thermal control unit including at least one cooling element and at least one heating element, the at least one cooling element configured to cool the first portion and the heating element configured to heat the second portion.

[0057] In some example embodiments, the modular thermal control unit may also include at least one motor configured to position the at least one cooling element or the at least one heating element vertically or horizontally relative to the plurality of rollers. In an example embodiment, the at least one motor may include a plurality of motors configured to position the at least one heating element and the at least one cooling element independently. In some example embodiments, the modular thermal control unit may also include a drop door configured to open periodically to release a build-up of glass particles. In an example embodiment, the modular thermal control unit may also include a thermal interlock door configured to be in a shut position when the drop door is in an open position to resist entrance of ambient air into the glass ribbon processing apparatus.

[0058] In a further example embodiment, a glass ribbon processing apparatus is provided including a plurality of rollers configured to translate a glass ribbon longitudinally thereon, the glass ribbon includes a first portion having a first thickness adjacent to a second portion having a second thickness less than the first thickness. The glass processing apparatus may also include a thermal containment at least partially enclosing the plurality of rollers, the thermal containment including an upper chamber having one or more heating elements configured to control the cooling rate of the glass ribbon and a lower chamber, a localized temperature control unit including a thermal element configured to cool the first portion or

heat the second portion of the glass ribbon, a control arm configured to move the thermal element vertically or horizontally relative to the plurality of rollers, and a movable seal configured support the control arm and to maintain a thermal boundary between the upper chamber and the lower chamber as one of the upper chamber or the lower chamber moves toward or away from the other of the lower chamber or the upper chamber. The glass ribbon processing apparatus may also include a modular thermal control unit disposed at least partially in the lower chamber, the modular thermal control unit including at least one cooling element and at least one heating element, the at least one cooling element configured to cool the first portion and the at least one heating element configured to heat to the second portion.

[0059] In an example embodiment, the thermal element may be replaceable prior to operation to accommodate glass ribbon including different widths or locations of the thicker portion.

[0060] Many modifications and other embodiments of the invention set forth herein will come to mind to one skilled in the art to which the disclosure pertains having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. These modifications include, but are not limited to, number or type of fiber optic modules, use of a fiber optic equipment tray, fiber optic connection type, number of fiber optic adapters, density, etc.

[0061] Therefore, it is to be understood that the disclosure is not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. It is intended that the present disclosure cover modifications and variations such embodiments provided they come within the scope of the appended claims and their equivalents. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

WHAT IS CLAIMED IS:

1. A glass ribbon processing apparatus comprising:

a plurality of rollers configured to translate a glass ribbon longitudinally thereon, wherein the glass ribbon comprises a first portion having a first thickness adjacent to a second portion having a second thickness, wherein the first thickness is thicker than the second thickness;

a thermal containment at least partially enclosing the plurality of rollers, the thermal containment comprising an upper chamber having one or more heating elements configured to control a rate of cooling of the glass ribbon, and a lower chamber; and

a localized temperature control unit comprising:

a thermal element configured to cool the first portion or heat the second portion of the glass ribbon;

a control arm configured to move the thermal element vertically or horizontally relative to the plurality of rollers; and

a movable seal configured to support the control arm and to maintain a thermal boundary between the upper chamber and the lower chamber as one of the upper chamber or the lower chamber moves toward or away from the other of the lower chamber or the upper chamber.

2. The glass ribbon processing apparatus of claim 1, wherein the localized temperature control unit is configured to be selectively and non-destructively installed and removed from the thermal containment.

3. The glass ribbon processing apparatus of claim 2, wherein the movable seal comprises a liftable labyrinth seal spacer.

4. The glass ribbon processing apparatus of claim 2, wherein the movable seal comprises a flexible fiber spacer,

wherein the flexible fiber spacer is affixed to the upper chamber and the lower chamber.

5. The glass ribbon processing apparatus of any of claims 1-4, wherein the thermal element is configured to for convectively or radiatively heat or cool the glass ribbon.

6. The glass ribbon processing apparatus of any of claims 1-5, wherein the thermal element comprises a plurality of air nozzles directed toward the plurality of rollers.
7. The glass ribbon processing apparatus of any of claims 1-6, wherein the control arm is further configured to enable passage of a coolant or electrical cable through the control arm.
8. The glass ribbon processing apparatus of any of claims 1-7, wherein movement of the thermal element horizontally comprises extension or retraction of the control arm, such that the thermal element is moved toward or away from a longitudinal centerline of the glass ribbon.
9. The glass ribbon processing apparatus of any of claims 1-8, wherein the thermal element is transitioned between a parked position and a working position.
10. The glass ribbon processing apparatus of any of claims 1-9 further comprising:
 - a modular thermal control unit comprising:
 - at least one cooling element and at least one heating element, wherein the at least one cooling element is configured to cool the first portion and the at least one heating element is configured to heat the second portion.
11. The glass ribbon processing apparatus of claim 10, wherein the modular thermal control unit further comprises:
 - at least one motor configured to position the at least one cooling element or the at least one heating element vertically or horizontally relative to the plurality of rollers.
12. The glass ribbon processing apparatus of claim 11, wherein the at least one motor comprises a plurality of motors configured to position the at least one heating element and the at least one cooling element independently.
13. The glass ribbon processing apparatus of any of claims 10-12, wherein the modular thermal control unit further comprises:
 - a drop door configured to open periodically to release glass build up.

14. The glass ribbon processing apparatus of claim 13, wherein the modular thermal control unit further comprises:

a thermal interlock door configured to be in a shut position when the drop door is in an open position to resist entrance of ambient air into the glass ribbon processing apparatus.

15. A glass ribbon processing apparatus comprising:

a plurality of rollers configured to translate a glass ribbon longitudinally thereon, wherein the glass ribbon comprises a first portion having a first thickness adjacent to a second portion having a second thickness, wherein the first thickness is thicker than the second thickness;

a thermal containment at least partially enclosing the plurality of rollers, the thermal containment comprising an upper chamber having one or more heating elements configured to control a rate of cooling of the glass ribbon, and a lower chamber; and

a modular thermal control unit disposed at least partially in the lower chamber, the modular thermal control unit comprising:

at least one cooling element and at least one heating element, wherein the at least one cooling element is configured to cool the first portion and the at least one heating element is configured to heat the second portion.

16. The glass ribbon processing apparatus of claim 15, wherein the modular thermal control unit further comprises:

at least one motor configured to position the at least one cooling element or the at least one heating element vertically or horizontally relative to the plurality of rollers.

17. The glass ribbon processing apparatus of claim 16, wherein the at least one motor comprises a plurality of motors configured to position the at least one heating element and the at least one cooling element independently.

18. The glass ribbon processing apparatus of any of claims 15-17, wherein the modular thermal control unit further comprises:

a drop door configured to open periodically to release glass build up.

19. The glass ribbon processing apparatus of claim 18, wherein the modular thermal control unit further comprises:

a thermal interlock door configured to be in a shut position when the drop door is in an open position to resist entrance of ambient air into the glass ribbon processing apparatus.

20. A glass ribbon processing apparatus comprising:

a plurality of rollers configured to translate a glass ribbon longitudinally thereon, wherein the glass ribbon comprises a first portion having a first thickness adjacent to a second portion having a second thickness, wherein the first thickness is thicker than the second thickness;

a thermal containment at least partially enclosing the plurality of rollers, the thermal containment comprising an upper chamber having one or more heating elements configured to control a rate of cooling of the glass ribbon and a lower chamber;

a localized temperature control unit comprising:

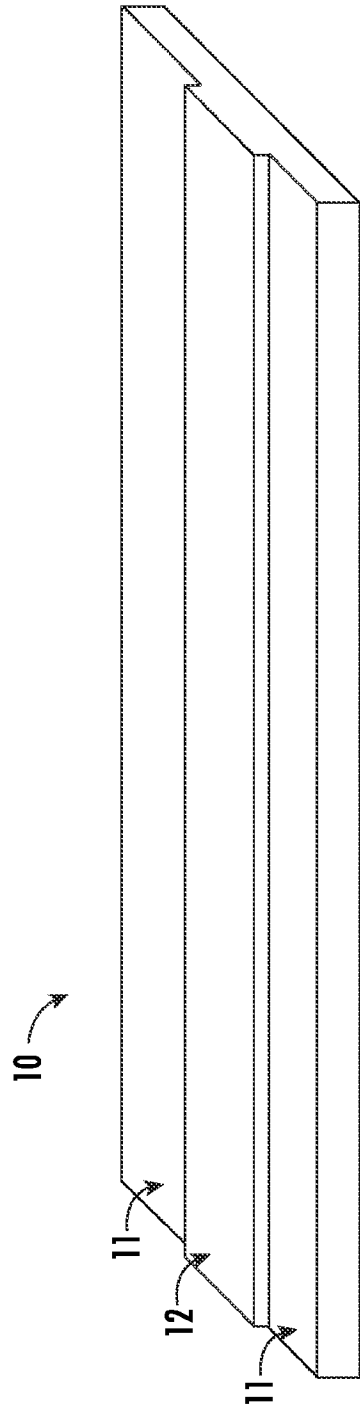
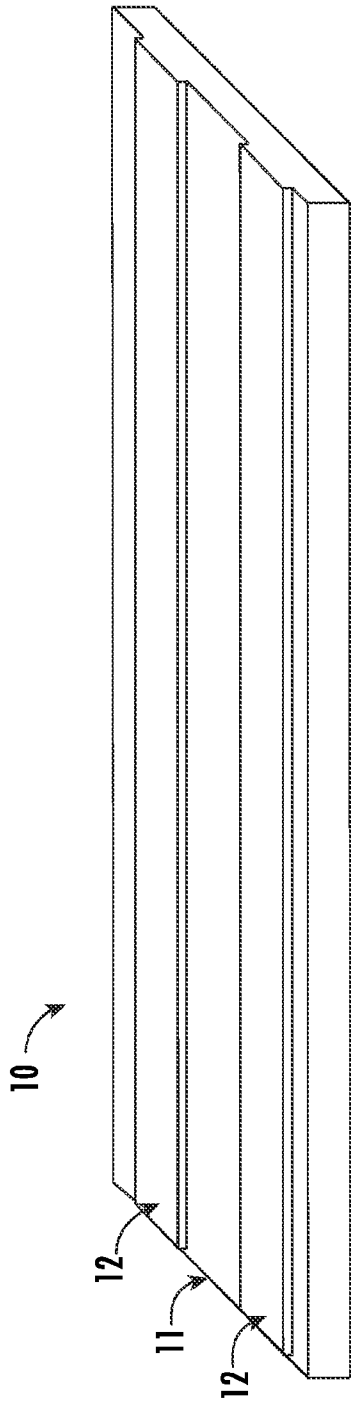
a thermal element configured to cool the first portion or heat the second portion of the glass ribbon;

a control arm configured to move the thermal element vertically or horizontally relative to the plurality of rollers; and

a movable seal configured to support the control arm and to maintain a thermal boundary between the upper chamber and the lower chamber as one of the upper chamber or the lower chamber moves toward or away from the other of the lower chamber or the upper chamber; and

a modular thermal control unit disposed at least partially in the lower chamber, the modular thermal control unit comprising:

at least one cooling element and at least one heating element, wherein the at least one cooling element is configured to cool the first portion and the at least one heating element is configured to heat the second portion.



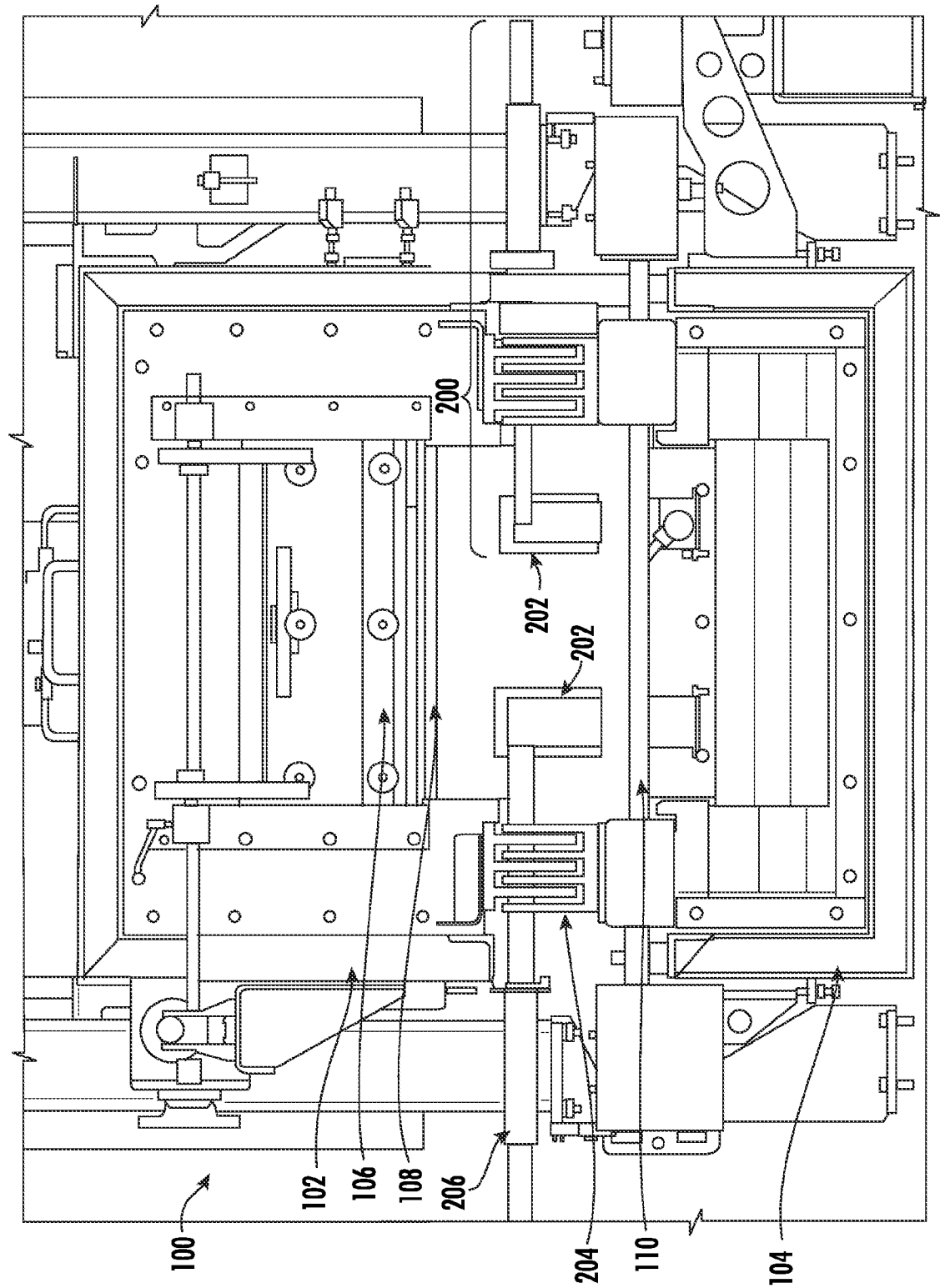


FIG. 2

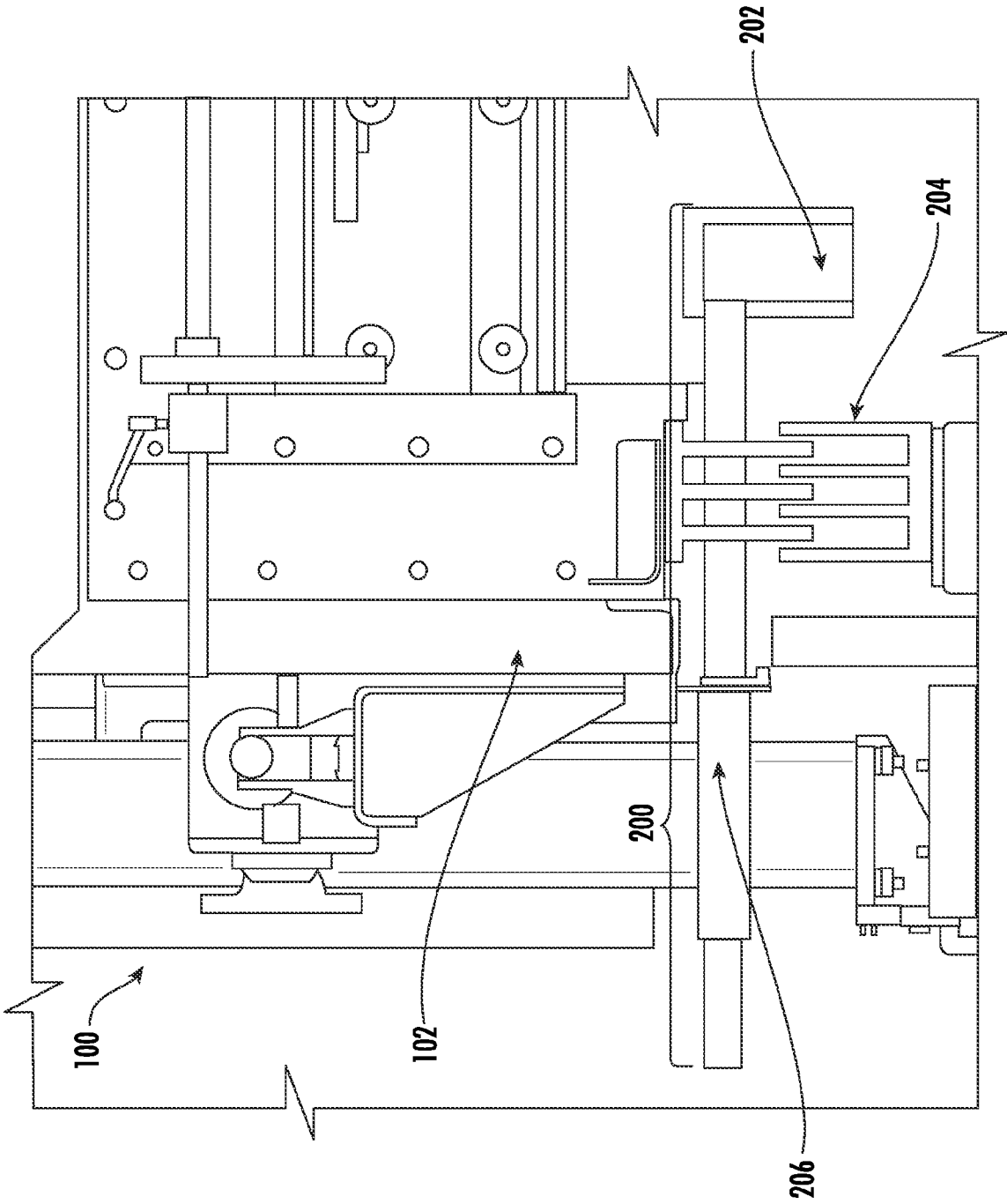


FIG. 3

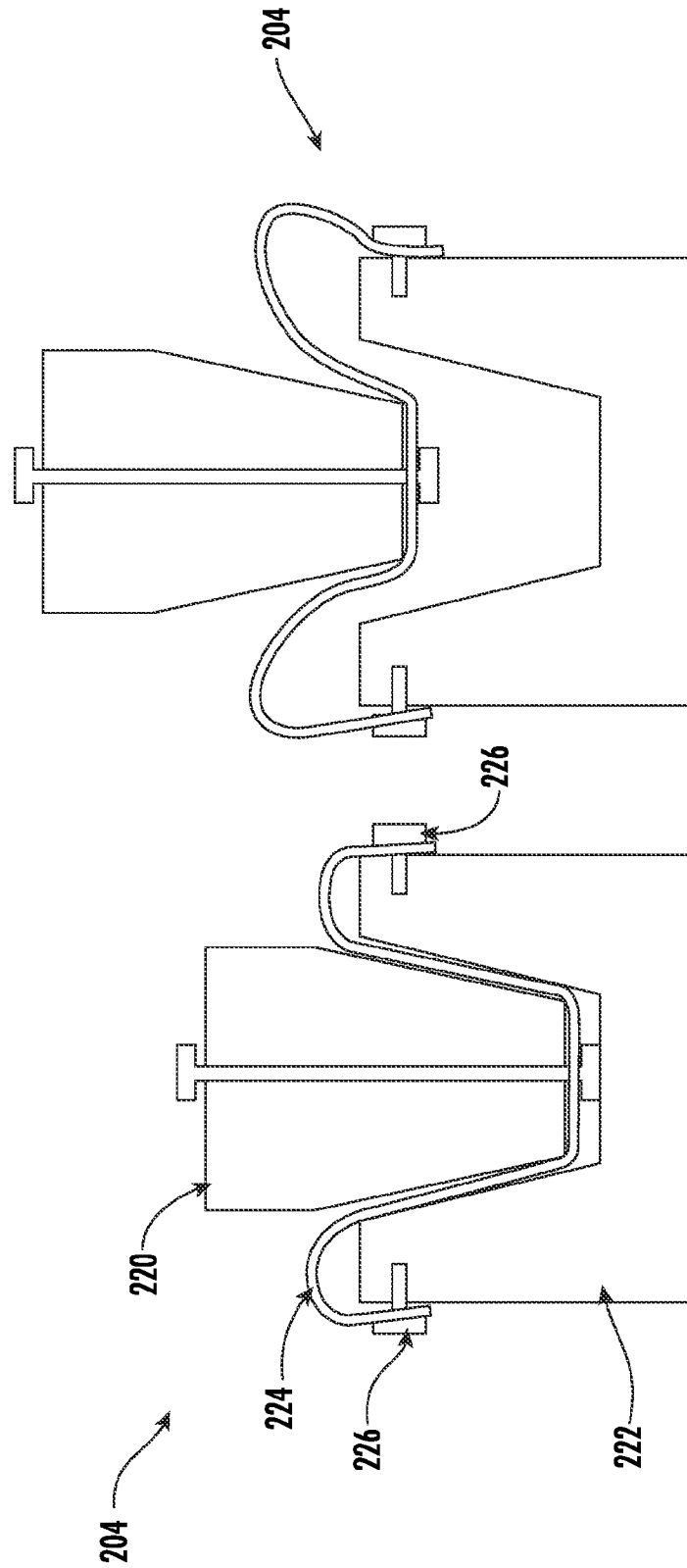


Fig. 43

Fig. 4A

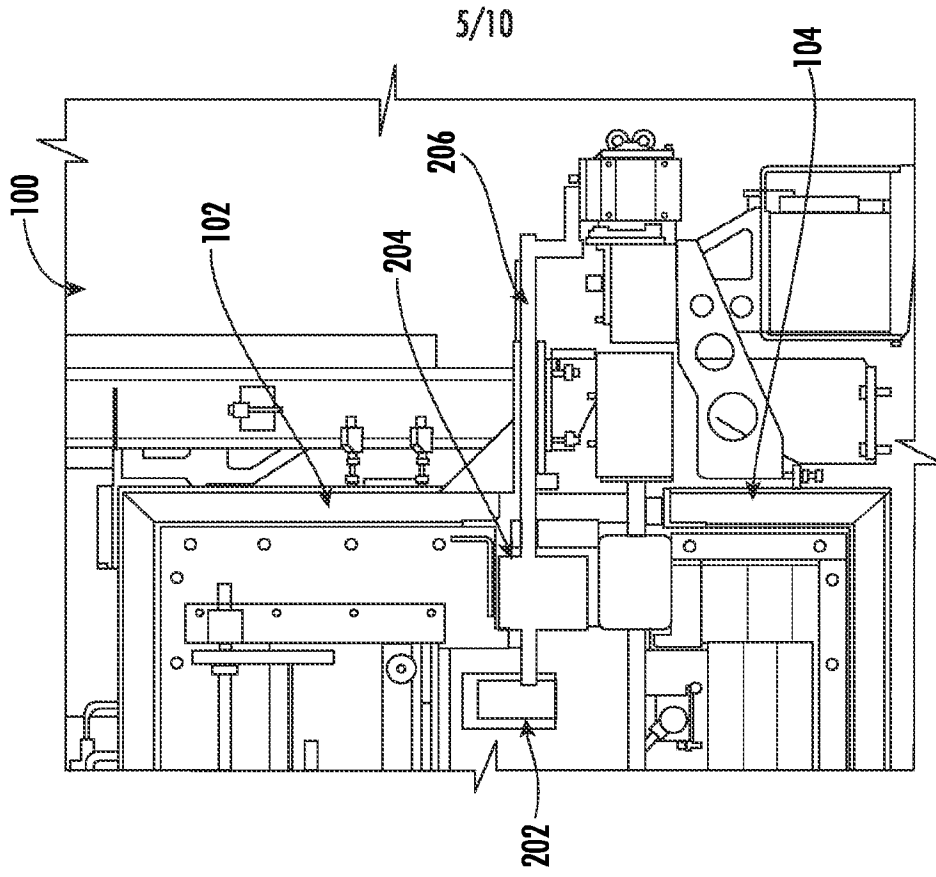


FIG. 5B

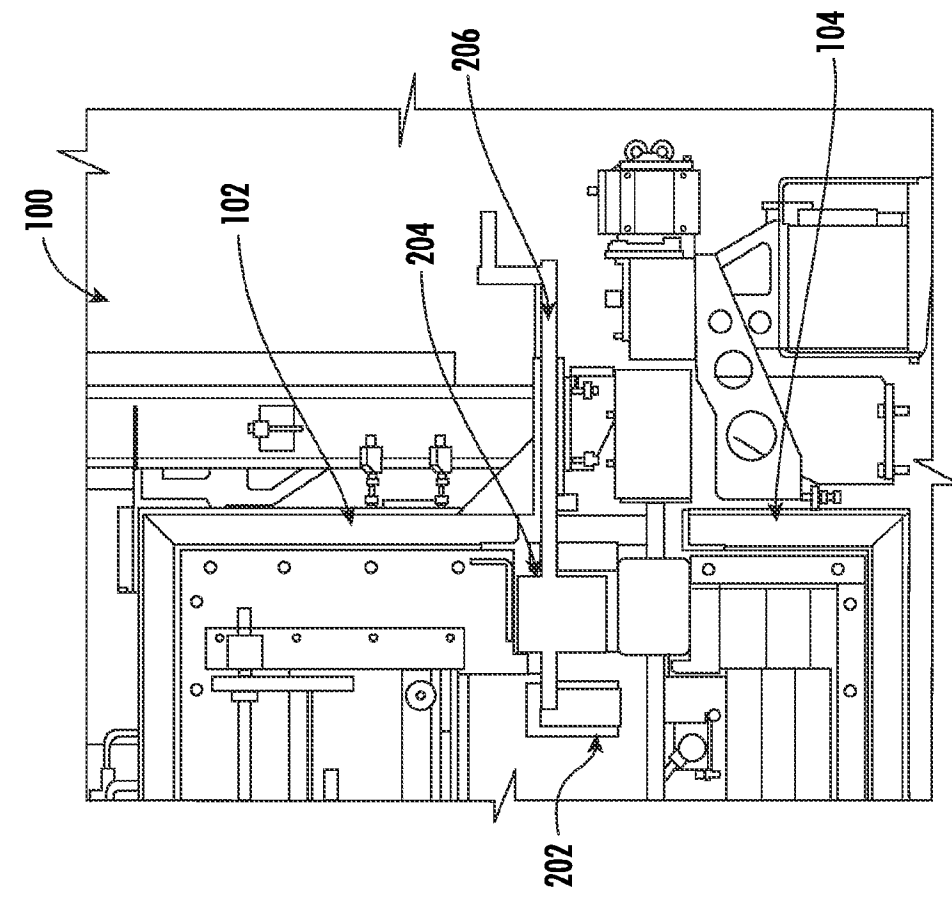


FIG. 5A

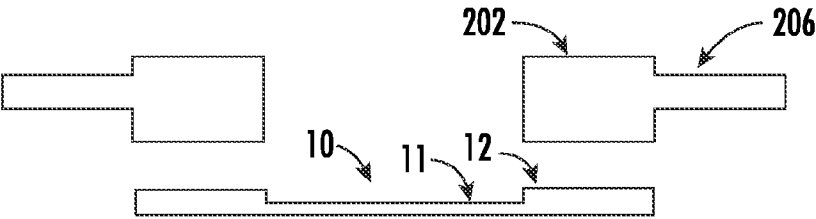


FIG. 6A

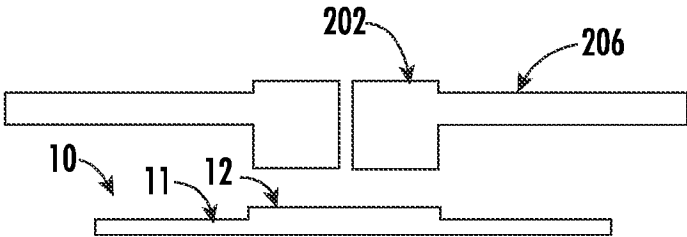


FIG. 6B

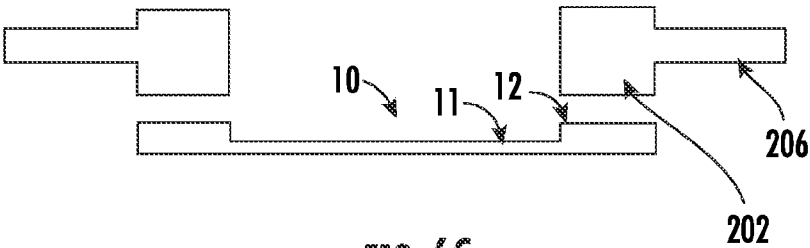


FIG. 6C

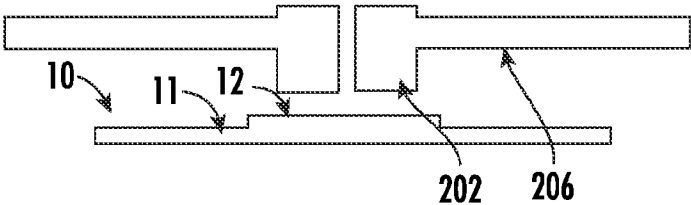


FIG. 6D

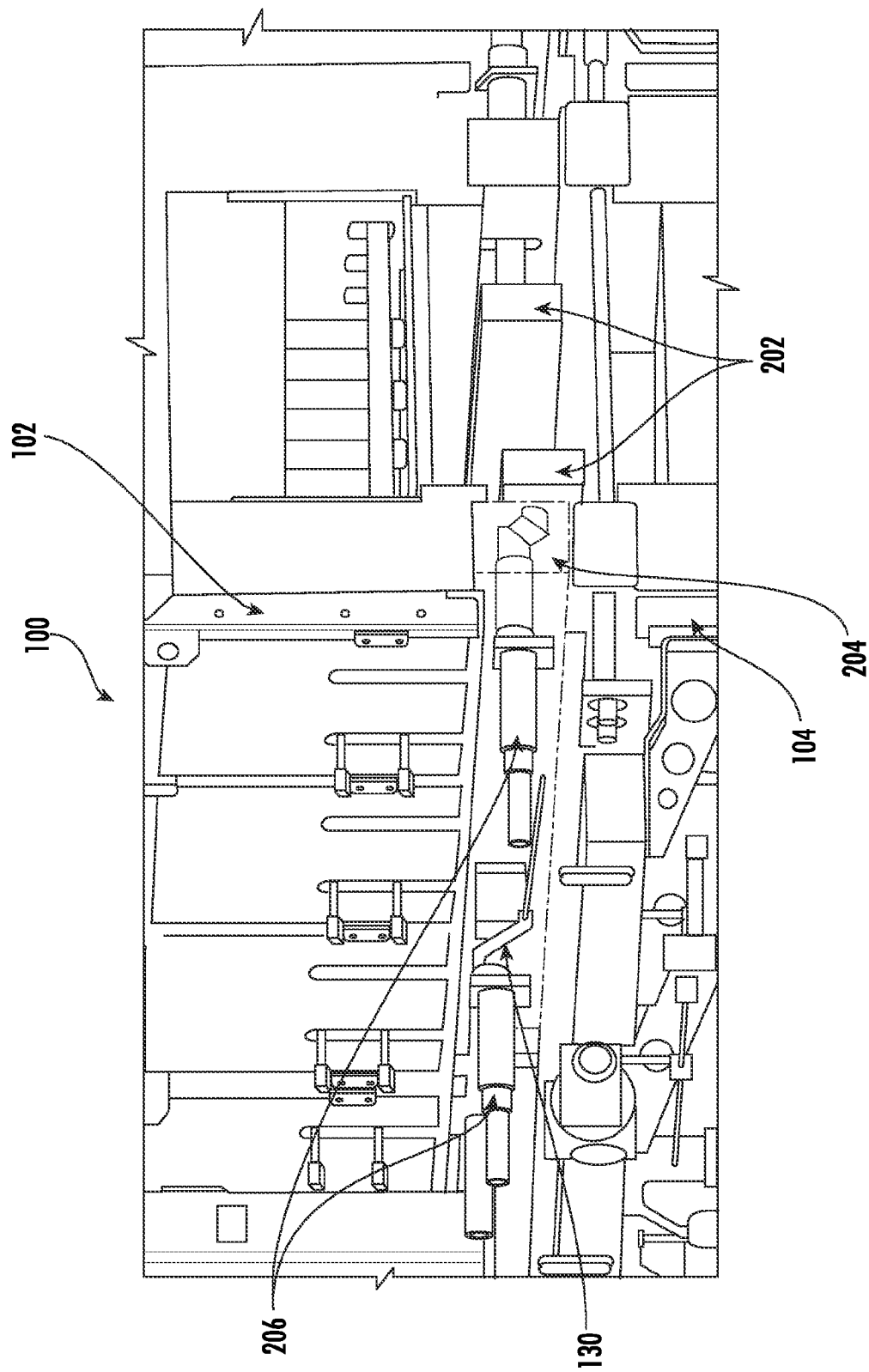


FIG. 7

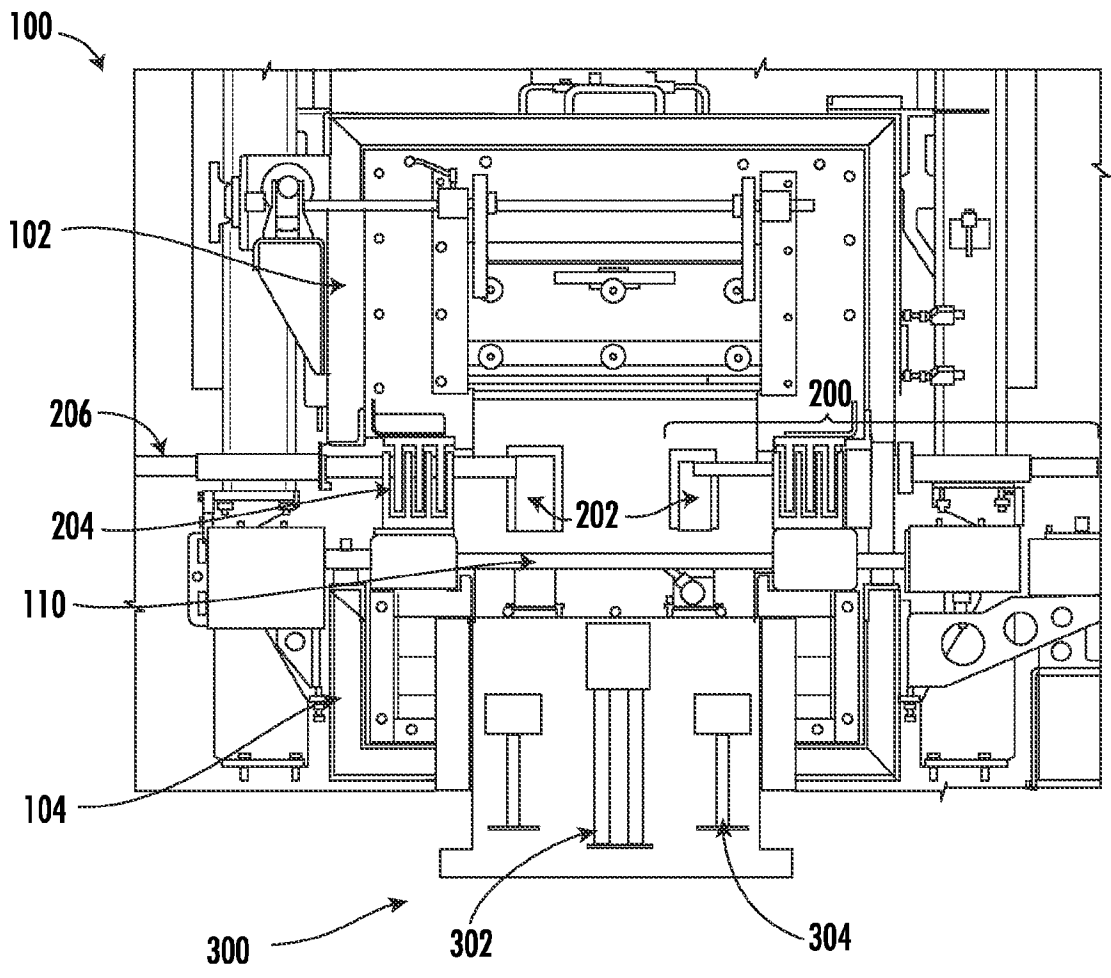
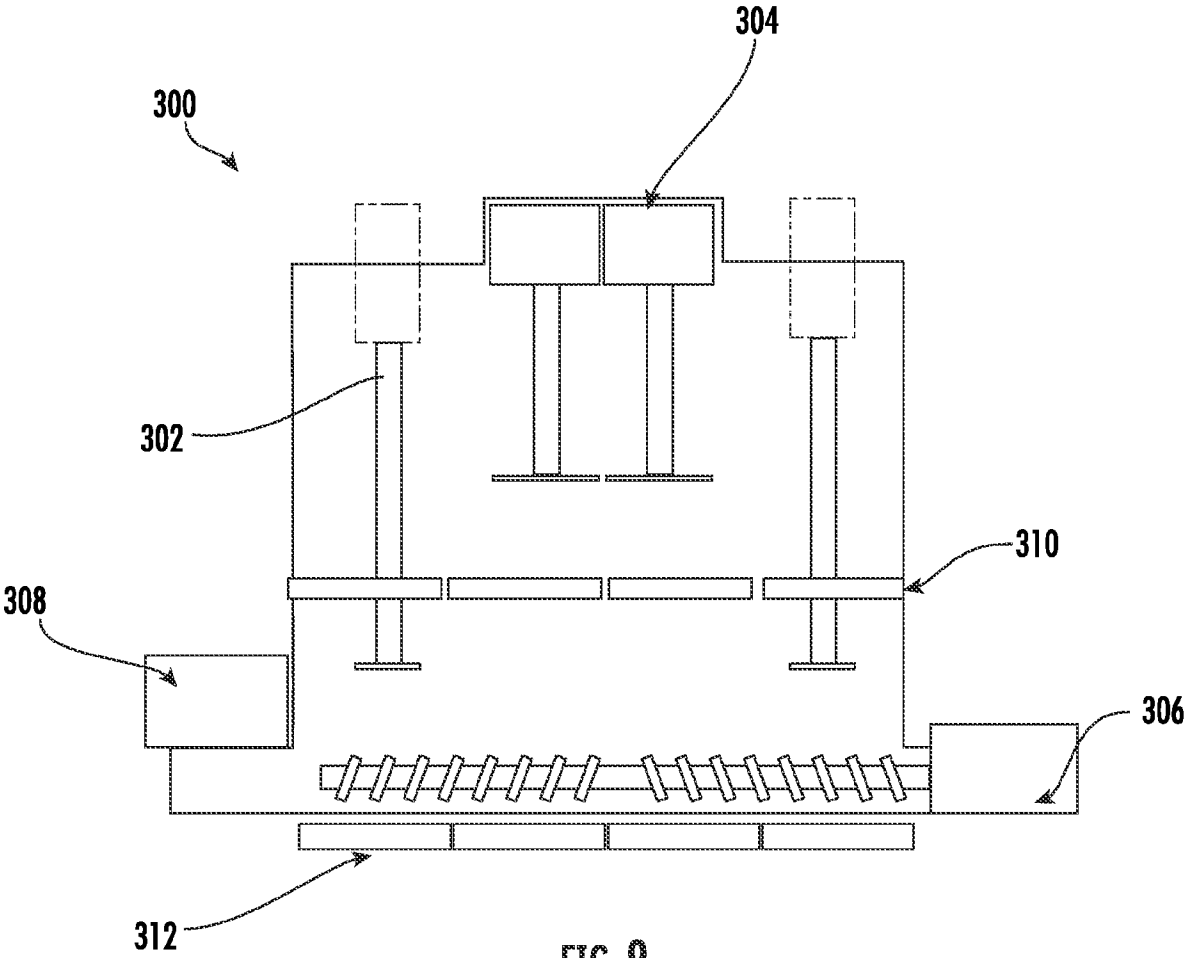


FIG. 8



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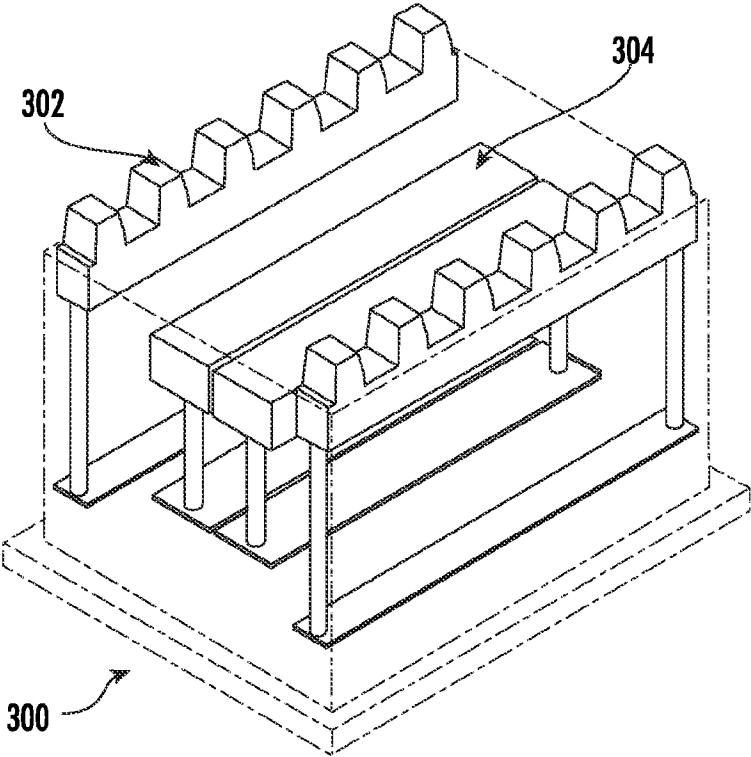


FIG. 10A

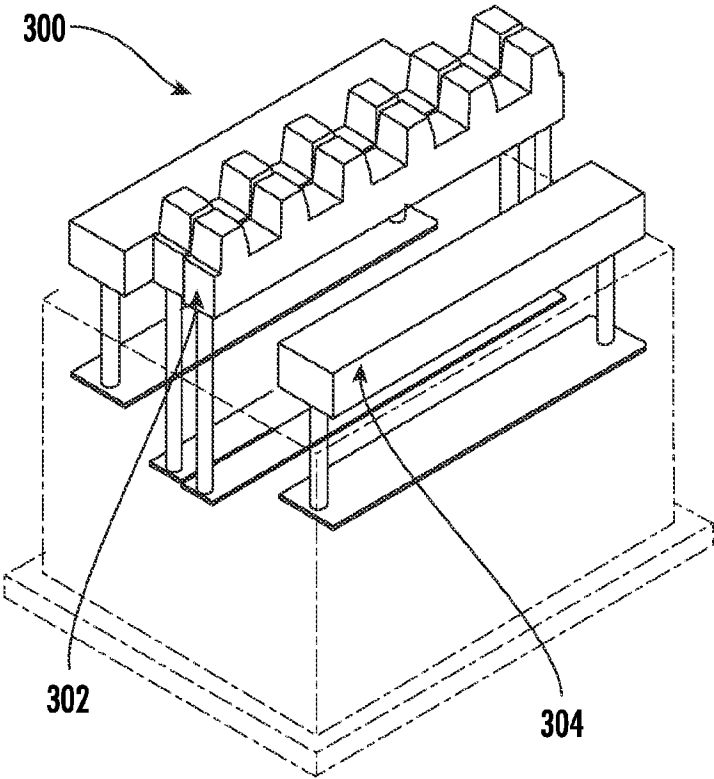


FIG. 10B

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2023/031003

A. CLASSIFICATION OF SUBJECT MATTER INV. C03B17/06 C03B25/06 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) C03B		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5 679 123 A (BENNETT COLIN MICHAEL [GB]	1-3, 5-9
A	ET AL) 21 October 1997 (1997-10-21) items 108, 106, 11, 12, 122, 123; column 6, lines 43-49 and column 9, line 61-column 10, line 2; figures; figures 3, 6	4, 10-14
Y	US 6 279 349 B1 (SCHNABEL JR JAMES P [US])	1-3, 5-9
A	28 August 2001 (2001-08-28) items 46, 42, 50; figures 3, 2, 7	4, 10-20
A	US 9 790 119 B2 (CORNING INC [US])	15-20
	17 October 2017 (2017-10-17) column 9, line 45-column 10, line 4	
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☒ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search		Date of mailing of the international search report
30 November 2023		13/12/2023
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Gkerou, Elisavet

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2023/031003

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
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A	column 15	4, 10-14, 20
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Information on patent family members

International application No

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