



- (51) **International Patent Classification:**
C03B 18/02 (2006.01)
- (21) **International Application Number:**
PCT/US2014/043567
- (22) **International Filing Date:**
23 June 2014 (23.06.2014)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
- (30) **Priority Data:**
61/839,106 25 June 2013 (25.06.2013) US
- (71) **Applicant:** CORNING INCORPORATED [US/US]; 1 Riverfront Plaza, Corning, New York 14831 (US).
- (72) **Inventors:** MCCREARY, Jeffrey Clinton; 210 Que Vista Drive, Horseheads, New York 14845 (US). SAKONA, Dean George; 233 Pine St., Corning, New York 14830 (US). WANG, Liming; 3545 Conhocton Road, Painted Post, New York 14870 (US). ZHOU, Naiyue; 52 S. Oakwood Drive, Painted Post, New York 14870 (US).
- (74) **Agents:** ABLE, Kevin M et al.; Corning Incorporated, Intellectual Property Department, SP-Ti-03-01, Corning, New York 14831 (US).
- (81) **Designated States** (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.
- (84) **Designated States** (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,

[Continued on next page]

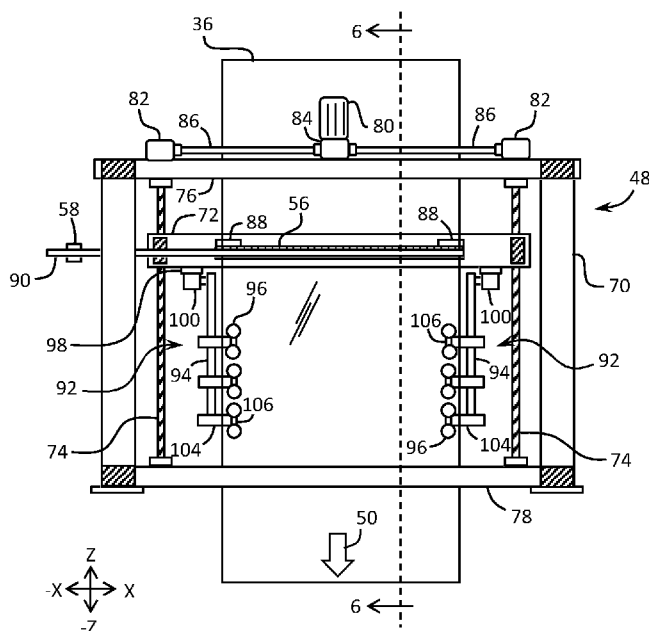
(54) **Title:** METHOD AND APPARATUS FOR SEPARATING A GLASS SHEET FROM A MOVING RIBBON OF GLASS

FIG. 5

(57) **Abstract:** A method of separating a glass sheet from a moving glass ribbon comprising engaging the moving glass ribbon with a traveling anvil machine comprising a separation device. The separation device applies a tension in a lateral (width-wise) direction and in a longitudinal direction (length-wise) relative to the glass ribbon, and a scoring device scores the glass ribbon across at least a portion of the width of the glass ribbon after the lateral and longitudinal tensioning. The separator device then applies a bending moment to the scored glass ribbon that causes the glass ribbon to separate along the score, thereby producing a glass sheet. The separator device reorients the glass sheet and transfers the glass sheet to a robot that conveys the glass sheet to a downstream process.



TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, —
KM, ML, MR, NE, SN, TD, TG).

*before the expiration of the time limit for amending the
claims and to be republished in the event of receipt of
amendments (Rule 48.2(h))*

Published:

— *with international search report (Art. 21(3))*

**METHOD AND APPARATUS FOR SEPARATING A GLASS SHEET FROM A MOVING
RIBBON OF GLASS**

PRIORITY

[0001] This application claims the benefit of priority under 35 U.S.C. § 119 of U.S. Provisional Application Serial No. 61/839106 filed on June 25, 2013, the content of which is relied upon and incorporated herein by reference in its entirety.

BACKGROUND

Field

[0002] The present invention relates generally to an apparatus and method of making a sheet of glass, and particularly to a method of separating a sheet of glass from a continuously moving ribbon of glass.

Technical Background

[0003] Recent trends in the Liquid Crystal Display (LCD) glass business have been toward progressively wider and thinner glass sheets (e.g. glass sheets having an average thickness of less than about 0.5 mm). Several years ago a typical thickness for glass sheet, such as glass for the flat panel display industry, was on average about 0.7 mm. One commercially successful method for producing high quality glass sheet is by the fusion downdraw process wherein a ribbon of glass is produced by flowing molten glass over a forming body, then cutting individual glass sheets from the continuously moving glass ribbon produced therefrom. This process requires that the glass ribbon exhibit a certain degree of stiffness. As the width and thickness of the glass ribbon decreases, the glass ribbon stiffness can be significantly decreased. As the ribbon stiffness decreases, both the forming process and the process parameters at the bottom of the draw area narrow. This results in reduced draw stability and an increased frequency of process upsets. For example, during the draw process the glass ribbon often exhibits a curvature across the ribbon width (transverse to a draw direction). This curvature increases the ribbon stiffness. However, a consistent process requires that the curvature also be consistent (e.g. that the curvature remains oriented in a consistent direction). Decreased stiffness of the glass ribbon owing to other factors, such as a decrease in thickness, can result in a reversal in the direction of curvature, sometimes suddenly, thereby upsetting the forming process. Another fault that can occur as a result of a

decrease in ribbon thickness and/or an increase in ribbon width is uncontrolled cracking of the glass ribbon, for example during the cutting process.

[0004] Glass thickness reduction, coupled with flow increase, produces more glass sheets or square footage. The fusion draw machine (FDM) delivers the glass ribbon at a much faster rate, which means a device involved in scoring the glass ribbon, the traveling anvil machine (TAM), must cycle faster to score the glass sheet, and the robot tooling used to perform the separation must track the ribbon and transfer the sheet at a faster rate.

[0005] The demand for thin sheet glass continues to increase, and to fully utilize draw equipment the flow of molten glass through a manufacturing apparatus has increased to keep pace. As a result, the allowable cycle time for the sheet separation cycle has been significantly reduced as well. However, the cycle time is limited by how fast the sheet can be separated and the vertical space (height) in which the separation process takes place. Current equipment is reaching design limits such that further reduction of the separation cycle time can produce an unstable draw process. Continuously increasing the speed of the equipment can negatively impact the glass cutting process stability and equipment life.

SUMMARY

[0006] The present disclosure relates to traveling anvil machine and robot function cycle time reduction at the bottom of the draw by adding mechanical devices and controls to the traveling carriage assembly portion of the traveling anvil machine without sacrificing process stability. These augmentations transfer the function of bending and separating sheets of glass at the scored line from the continuously forming ribbon of glass from the robot to the traveling anvil machine. Consequently, a multi-axis robot that typically performed these tasks can be relieved of these duties and act only as a material handling device to transfer the separated sheets to a downstream process station. Such a transfer of tasks can reduce the overall separation cycle time since bending of the glass ribbon and separation of a glass sheet from the ribbon can be performed by the traveling anvil machine before the robot has returned from transferring the previous sheet to a downstream process. That portion of the total separation cycle time the robot must spend at the traveling anvil machine position can therefore be reduced (e.g. in some cases a reduction of as much as from about 20% to about 50%). Moreover, as new glass sheet products become thinner, ribbon linear speeds will increase and separation cycle time can be reduced. The time required for the robot to cycle for current sheet separation and material handling functions can limit production speeds and may result in less than a optimum separation process. Employing separation apparatus and

methods described herein can serve to reduce overall separation cycle time and accommodate increased process speeds. In other aspects, employing separation apparatus and methods described herein can improve the separation process stability, especially for thin sheet (e.g. for ribbon having a thickness equal to or less than about 0.3 mm) by a) eliminating variations in tracking speed between the traveling anvil machine carriage assembly and the bending separation device, b) mechanically align the bending axis of rotation with the elevation of score line so that off-axis bending does not occur, c) provide for two axes of controlled horizontal sheet motion, d) provide for greater process optimization by using two axes of controlled rotational sheet motion wherein independently rotating separator arms can be used to impart a twist in glass ribbon and/or separated sheet, e) enable automated separation and cullet disposal in spite of a disruption to the robot, f) eliminate robot design limitations based on robot weight limits or robot clearance restrictions, thereby providing precision down force control independent of the bending angle and robot weight, g) enable symmetrical ribbon side tension to flatten the ribbon without twisting prior to scoring, h) significantly reduce separation cycle time by eliminating the need for the robot to track the glass ribbon movement, and i) allow suction cup and nosing alignment through a common equipment reference rather than coordinating multiple pieces of machinery. In summary, separation of a glass sheet from a moving ribbon of glass as a function of the traveling anvil machine eliminates the robot as a ribbon tracking, side tensioning, down force, and sheet bending separation device. The robot becomes a sheet transferring tool to transfer separated sheet from the area at the bottom of the draw to a downstream conveyor to reduce cycle time. Separation of a glass sheet from a moving ribbon of glass as a function of the traveling anvil machine sheet separation means the glass sheet separation process can be integrated with a servo driven nosing member. The robot waits at a predetermined position to capture the separated sheet and complete the hand-off with a separation device integrated with the traveling anvil machine.

[0007] Accordingly, in one embodiment disclosed herein, a method of separating a glass sheet from a moving ribbon of glass is described comprising drawing molten glass from a forming body in a draw direction at a speed S to form a glass ribbon; moving a carriage assembly in the draw direction at the speed S , the carriage assembly including a separator device comprising separator arms and suction devices coupled thereto; engaging the glass ribbon with the separator device; applying a tension to the glass ribbon in a width direction of the glass ribbon with the separator device; applying a tension to the glass ribbon in a length

direction of the glass ribbon with the separator device; producing a score in the glass ribbon with a scoring device; applying a bending moment to the glass ribbon with the separator device to separate a glass sheet from the glass ribbon at the score; engaging the glass sheet with a robot; and disengaging the separator device from the glass sheet.

[0008] Engaging the glass ribbon with the separator device may comprise movement of the separator device in a direction orthogonal to the draw direction. Engaging the glass ribbon with the separator device may comprise gripping the glass ribbon with the suction devices coupled to the separator arms.

[0009] Applying a tension to the glass ribbon in the width direction can comprise applying a lateral force with linear slides coupled to the suction devices.

[0010] Applying a tension to the glass ribbon in the length direction comprises applying a force to the glass ribbon in a length direction of the glass ribbon with linear slides coupled to the suction devices.

[0011] Applying a bending moment to the glass ribbon may comprise rotating the separator arms about a rotational axis.

[0012] Embodiments described herein may further comprise moving the separator arms in a direction toward the robot to a hand-off position after the glass sheet is separated from the glass ribbon.

[0013] Embodiments described herein may further comprise rotating the separator arms about an axis of rotation after separating the glass sheet from the glass ribbon but before the robot engages the glass sheet.

[0014] After applying a bending moment to the glass ribbon with the separator device that separates the glass sheet from the glass ribbon, the glass sheet can be moved in the draw direction away from the glass ribbon. This movement can occur quite rapidly owing to the tension applied by the separation device in the longitudinal device prior to scoring.

[0015] The suction devices coupled to the robot can engage the glass sheet on a side of the glass sheet opposite a side of the glass sheet engaged by the robot, or, in other embodiments the robot and the separation device can engage the glass sheet and/or ribbon on the same side.

[0016] In another aspect, an apparatus for separating a glass sheet from a glass ribbon moving in a draw direction is disclosed comprising: a traveling anvil machine comprising: a carriage assembly configured to move in the draw direction; a first nosing member coupled to the carriage assembly and configured to move in a direction orthogonal to the draw direction; and a separator device for engaging the glass ribbon coupled to the carriage assembly and

configured to move in a direction orthogonal to the draw direction and also to rotate about an axis of rotation. The apparatus may further comprise a scoring device coupled to the carriage assembly. The separator device may comprise separator arms, the separator arms further comprising suction devices coupled thereto and configured to move in at least two orthogonal directions relative to the separator arms. For example, the suction devices may be coupled to the separator arms with linear slides.

[0017] Additional features and advantages of the present disclosure 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 embodiments described herein, including the detailed description which follows, the claims, as well as the appended drawings.

[0018] It is to be understood that both the foregoing general description and the following detailed description present embodiments of the disclosure, 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 disclosure, and together with the description serve to explain the principles and operations of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] FIG. 1 is an elevational view of an exemplary fusion downdraw glass making apparatus;

[0020] FIG. 2 is a cross-sectional end view of a forming body from the glass making apparatus of FIG. 1;

[0021] FIG. 3 is a front view of the forming body of FIG. 2 showing a traveling anvil machine disposed below the forming body;

[0022] FIG. 4 is a cross sectional end view of the forming body and traveling anvil machine of FIG. 3;

[0023] FIG. 5 is a front view of an exemplary traveling anvil machine according to an embodiment disclosed herein;

[0024] FIG. 6 is a side view of the traveling anvil machine of FIG. 5, the traveling anvil machine including a carriage assembly comprising a nosing member, a separator device and a scoring device;

[0025] FIG. 7 is a side view of the traveling anvil machine of FIG. 6 illustrating the nosing member engaged with a glass ribbon;

[0026] FIG. 8 is a side view of the traveling anvil machine of FIG. 6 illustrating the separating device engaged with the glass ribbon;

[0027] FIG. 9 is a side view of the traveling anvil machine of FIG. 6 illustrating the scoring device engaged with a glass ribbon;

[0028] FIG. 10 is a side view of the traveling anvil machine of FIG. 6 illustrating the separator device applying a bending moment to the glass ribbon that separates a glass sheet from the glass ribbon;

[0029] FIG. 11 is a side view of the traveling anvil machine of FIG. 6 illustrating the separator device moving the glass ribbon to a hand-off position and re-orienting the glass sheet;

[0030] FIG. 12 is a side view of the traveling anvil machine of FIG. 6 illustrating the carriage assembly, the separator device and the nosing member returned to their respective start positions.

DETAILED DESCRIPTION

[0031] Reference will now be made in detail to embodiments of the present disclosure, examples of which are illustrated in the accompanying drawings. Whenever possible, the same reference numerals will be used throughout the drawings to refer to the same or like parts.

[0032] In an exemplary glass manufacturing apparatus 10 illustrated in FIG. 1, batch material, represented by arrow 12 is fed into a melting furnace 14, and melted to form molten glass 16 at a first temperature T_1 . First temperature T_1 is dependent on the particular glass composition, but for liquid crystal display-capable glasses, as a non-limiting example, T_1 can be in excess of 1500°C. The molten glass flows from melting furnace 14 through connecting conduit 18 to finer conduit (or “finer”) 20. From finer 20 the molten glass flows to stirring vessel 22 through connecting conduit 24 to be mixed and homogenized, and from stirring vessel 22 through connecting conduit 26 to delivery vessel 28 and thereafter to downcomer 30. The molten glass can then be directed from downcomer 30 to forming body 32 through inlet 34. As best seen in FIG. 2, forming body 32 comprises a trough 36 that receives the flow of molten glass from inlet 34, and exterior converging forming surfaces 38 that meet along a line, root 40, at the bottom of the forming body. In the case of the fusion downdraw process depicted in FIG. 1, the molten glass delivered to trough 36 overflows the trough and

flows over converging forming surfaces 38 of forming body 32 as separate streams that join together, or fuse, at root 40 to form ribbon of glass 42. The ribbon of glass is drawn downward from root 40 by gravity and pulling rolls 44. The ribbon may then be cooled and separated to form individual glass sheets 46 as will be described in more detail below.

[0033] FIG. 3 shows the forming body 32 of FIGS. 1 and 2, and includes also a depiction of pulling rolls 44 and a traveling anvil machine 48. Pulling rolls 44 are arranged in opposing pairs and are counter-rotating. That is, an individual pulling roll positions adjacent to a first side of the glass ribbon is rotating in a direction opposite a pulling roll positioned across from the first pulling roll and adjacent the second side of the glass ribbon. The glass ribbon is positioned between the opposing pairs of pulling rolls so that the pulling rolls contact and pinch the glass ribbon at the edge portions of the glass ribbon. The counter-rotating pulling rolls are driven by motors and apply a downward force on the glass ribbon, thereby drawing the glass ribbon from the forming body in a draw direction 50. They also help support a weight of the glass ribbon, since during at least a portion of the separation cycle that portion of the glass ribbon below the pulling rolls may be unsupported. Without a suitable pinching force, the pulling rolls may be unable to apply a sufficient downward pulling force, or be unable to support that portion of the glass ribbon below the pulling rolls against the force of gravity.

[0034] As the glass ribbon descends from the forming body, traveling anvil machine 48 periodically engages the ribbon and forms a score line 52 across at least a portion of the glass ribbon. To ensure maximum utilization of the sheets of glass separated from the glass ribbon, it is desirable to produce a score 55 that is substantially perpendicular to the laterally positioned edge portions 54 of the glass ribbon. Edge portions 54 can include bead portions that are thicker than the interior portions of the glass ribbon. For example, the bead portions may form as a result of surface tension effects. As the glass ribbon is moving continuously in draw direction 50, and the scoring device travels across the width of the glass ribbon at a finite speed, it should be apparent that to produce a score that is perpendicular to the edge portions of the glass ribbon the scoring device must move such that there is no relative motion between the scoring device and the glass ribbon in a direction parallel with the draw direction during the scoring process. Accordingly, during a scoring cycle traveling anvil machine 48 first moves from an initial start position in the draw direction and attains a velocity that matches that of the moving glass ribbon. That is, the glass ribbon is continuously moving with a velocity vector V_r comprising a direction in the draw direction

50 and a predetermined speed S . The traveling anvil machine acquires a velocity vector V_t that matches the velocity vector of the glass ribbon.

[0035] In reference to FIG. 4, At a predetermined time during the downward travel of traveling anvil machine 48, a first nosing member 56 coupled to the traveling anvil machine engages a first side of the glass ribbon that is opposite a second side of the glass ribbon that is contacted by a scoring device 58. For clarity, the side of the glass ribbon contacted by the scoring device 58 (e.g. a score wheel) will be designated as the “A” side of the glass ribbon, whereas the opposing side of the glass ribbon that is contacted by first nosing member 56 will be designated the “B” side (for simplicity, the same designation will be carried through to the glass sheet separated from the glass ribbon such that the side of the glass sheet that was formally contacted by the scoring device or the nosing member will be designated the “A” side and the “B” side of the glass sheet, respectively). First nosing member 56 can be used to flatten the glass sheet and to provide a force counter to the force applied by the scoring device. That is, first nosing member 56 functions as an anvil against which the scoring device presses glass ribbon 46 during the scoring process. Although not shown, in some embodiments, additional nosing members may be used, either on the “A” side of the glass ribbon, on the “B” side of the glass ribbon, or both the “A” side and the “B” side to aid in flattening the ribbon or reducing vibration that would otherwise travel upward along a length of the ribbon into a portion of the ribbon that is visco-elastic. Vibration in the visco-elastic portion of glass ribbon 42, where the ribbon is transitioning from a viscous state to an elastic state, can induce unwanted stress in the glass ribbon that can result in warping of glass sheet 46 removed from the glass ribbon.

[0036] In some scoring processes, a robot 60 engages with the end of the glass ribbon prior to the scoring process. Robot 60 includes a robot arm 62 comprising a platform 64 positioned at a distal end thereof and suction devices 66 (e.g. suction cups) arranged on the platform that engage with edge portions of the “B” side of the glass ribbon. Robot arm 62 moves platform 64 at a velocity vector V_{ra} that matches velocity vector V_r such that the glass ribbon, the traveling anvil machine (including scoring device 58 and first nosing member 56) and the platform 64 are all moving in tandem and there is no relative motion between them. In other words, robot 60 through robot arm 62 causes platform 64 to track with the ribbon. When platform 64 is tracking with glass ribbon 42 so that no relative motion in the draw direction between the platform and the glass ribbon is occurring, robot arm moves platform 64 such that suction devices 66 engage with the glass ribbon below score 55 (or in a location that will

be below the score once formed). Once scoring of the glass ribbon has been completed, robot arm 62, now coupled to glass ribbon 46, imparts a bending moment to the glass ribbon against first nosing member 56, creating tension across score 55 so that the vent crack formed in the glass ribbon as a result of the scoring propagates through the thickness of the glass ribbon and separates glass sheet 46 from glass ribbon 42. Robot arm remains coupled to glass sheet 46 and moves the glass ribbon to a receiving station. Robot 60 can, for example, deposit the glass sheet onto a conveyor assembly that moves the glass ribbon for downstream processing (such as removal of the edge portions of the glass sheet, edge finishing, washing, etc.). Once the glass sheet has been deposited at the next process, the robot arm is returned to a start position, prepared to separate and convey another glass sheet.

[0037] It should be apparent from the preceding description that such a process relies on well-choreographed movement and operation of traveling anvil machine 48 and robot 60. These movements and operations can add precious time to the overall separation cycle. As used herein, the term separation cycle time refers to a period of time beginning at when the traveling anvil machine starts traveling from a start position in the draw direction, and ends when the traveling anvil machine and the robot have returned to their respective start positions. In particular, relying on robot 60 to perform multiple functions, (e.g. attaining motion in the draw direction at the draw speed, engaging the glass ribbon, applying a bending motion and conveying the glass sheet to a downstream process) unnecessarily increases the separation cycle time. For example, separation of a second glass sheet after a first glass sheet has been separated must necessarily wait until the robot has disposed of the first glass sheet and returned to engage the glass ribbon). Accordingly, a reduction in separation cycle time can be obtained by eliminating and/or moving certain functions and movements from robot 60 to traveling anvil machine 48.

[0038] An exemplary traveling anvil machine that functions not only to engage and score the glass ribbon, but also to produce bending of the glass ribbon resulting in separation of a glass sheet from the ribbon, is shown in FIG. 5. In accordance with the present embodiment, robot 60 engages the glass ribbon at a predetermined location below root 40 of forming body 32 such that after glass sheet 46 is separated from glass ribbon 42 by traveling anvil machine 48, the glass sheet is handed off to robot 60 (i.e. robot arm 62). Robot 60 then passes glass sheet 42 to the next process station (e.g. conveying apparatus, receiving fixture, etc.). Accordingly, functions such as ribbon tracking, side tensioning, down force application, and sheet bending for separation are performed by traveling anvil machine 48. Robot 60 serves simply as a

sheet transfer tool arranged and configured to engage and transfer separated glass sheet from the bottom of the draw to a downstream process.

[0039] Referring now to FIG. 5, traveling anvil machine 48 according to the present embodiment comprises a frame 70 and a carriage assembly 72 coupled thereto. Frame 70 may be rigidly coupled to structural components of the facility in which the glass making apparatus is housed. For example, frame 70 may be rigidly coupled to the structural steel or concrete of a factory building. Travel screws 74 are rotatably mounted on frame 70 and extend between an upper frame member 76 and a lower frame member 78. Travel screws 74 may be coupled to at least one motor configured to turn the travel screws. For example, FIG. 5 depicts a single motor 80 driving two travel screws 74 through gear boxes 82, a transmission 84 and drive axles 86. Other arrangements are possible.

[0040] Carriage assembly 72 includes at least one follower nut (not shown) coupled thereto and through which a travel screw 74 passes. As a travel screw 74 turns, the follower nut travels along the screw in a direction dependent on the direction of rotation of the screw, therefore driving the carriage assembly in the direction of the follower nut. As previously described, first nosing member 56 is coupled to carriage assembly 72. For example, first nosing member 56 may be coupled to carriage assembly 72 by one or more linear slides 88 configured to extend or retract the first nosing member toward or away from glass ribbon, respectively, in a direction orthogonal to draw direction 50. In the extended position, first nosing member 56 is engaged with (e.g. contacting) glass ribbon 42. In the retracted position first nosing member 56 is disengaged from glass ribbon 42.

[0041] Carriage assembly 72 may further comprise scoring device 58 which can be coupled to carriage assembly 72 through rail 90. Scoring device 58 is driven along rail 90 by any drive mechanism capable of traversing scoring device 58 in a suitably precise path. For example, scoring device 58 may be driven along rail 90 by a travel screw and follower nut in a manner similar to the arrangement for carriage assembly 72. Pneumatic operation of the scoring device may also be used. Scoring device 58 may also include one or more pneumatic or stepper motor-activated linear slides configured to extend or retract the scoring device, or a portion thereof, toward the glass ribbon or away from the glass ribbon, respectively, in a direction orthogonal to draw direction 50. In the extended position, scoring device 58 is engaged with (e.g. contacting) glass ribbon 42. In the retracted position scoring device 58 is disengaged from glass ribbon 42. In some embodiments, scoring may be accomplished in a

non-contact manner, wherein scoring is accomplished by way of a laser beam. In such cases, extension and retraction of the scoring device may not be necessary.

[0042] Carriage assembly 72 may further comprise one or more separator devices 92 coupled thereto. Each of the one or more separator devices comprises a separator arm 94 and one or more suction devices 96 coupled to the separator arms. Each of the one or more separator arms 94 are configured to extend or retract toward or away from glass ribbon 42, respectively, in a direction orthogonal to draw direction 50 and generally parallel with a width-wise dimension of the glass ribbon. That is to say, parallel with the X-direction shown in FIG. 5. Additionally, each separator arm is configured to be rotated relative to an axis of rotation. For example, in the embodiment shown in FIG. 5, two separator arms 94 are shown comprising two separator devices. Each separator arm is coupled to carriage assembly 72 by a linear slide 98 and a rotary gear box 100, linear slide 98 being arranged to extend or retract the separator in a direction orthogonal to draw direction 50 and parallel with the Y-direction (See FIG. 6), and rotary gear box 100 being configured to rotate the separator arm about an axis of rotation 102 (see FIG. 6) positioned proximate a first end of the separator arm. Rotary gear box 100 may be driven, for example, by a stepper motor (not shown). Each separator arm may be independently controlled. For example, in some embodiments either the rate of rotation may be different between the separator arms, or the timing of the rotation may be different so the suction devices of the separator arms do not form a plane (that is, the separator arms can be used to impart a twist in the glass ribbon and/or the glass sheet so that one side edge of the glass ribbon is not parallel with the opposite side edge). Moreover, suction devices 96 may be coupled to the separator arms by first linear slides 104 configured to move (extend or retract) the suction devices in a direction parallel with draw direction 50, i.e. parallel with the Z-direction. For example, FIG. 6 illustrates a plurality of paired suction devices coupled to each separator arm with first linear slides 104 coupling each pair of suction devices to each coupling arm. In addition, suction devices 96 are further coupled to separator arm 94 by second linear slides 106 configured to move (extend or retract) suction devices 96 in a direction orthogonal to draw direction 50, i.e. parallel with the X-direction. It should be apparent that other configurations can be arranged. Linear slides 104 and 106 may be, for example, pneumatically operated slide devices, although alternative driving mechanisms include stepper motor-driven slide devices. Additionally, while FIG. 6 illustrates paired suction devices 96, suction devices 96 could be coupled singularly to separator arms 94.

[0043] The following is an overview of the process steps undertaken by traveling anvil machine 48 during a separation cycle and referring to FIGS. 7 – 12.

[0044] In a first step 200, carriage assembly 72 starts downward from a start position at the top of the traveling anvil machine stroke and attains a speed in draw direction 50 equal to or substantially equal to the glass ribbon speed (i.e. $V_r \cong V_t$). As used herein, the “stroke” of the carriage assembly encompasses the total extent of the movement of the carriage assembly in directions parallel with draw direction 50. The start position represents the upper-most extent of the carriage assembly travel during a glass separation cycle, and is the point from which the carriage assembly begins movement in the draw direction 50.

[0045] In a next step 202, and after carriage assembly 72 has attained a speed equal to or substantially equal to the speed of the glass ribbon in the draw direction 50, separator arms 94 traverse in a first direction (Y direction) orthogonal to draw direction 50 along linear slide 98, wherein suction devices 96 engage with glass ribbon 42 along edge portions 54 and a vacuum is applied to the suction devices such that the glass ribbon is held (e.g. gripped) by the suction devices.

[0046] At step 204, with carriage assembly 72 continuing to travel in the draw direction at a speed equal to or substantially equal to the speed S of the glass ribbon, second linear slides 106 are actuated so as to provide a lateral tension across a width of the glass ribbon parallel with the X-direction. To apply lateral tension parallel with the X-direction (i.e. a width direction) of the glass ribbon, second linear slides 106 are actuated to move the second linear slides outward (X and –X directions, respectively), in a direction away from the glass ribbon. As the suction devices 96 are fully engaged with the glass sheet however, attempted movement of the suction devices in an outward X and/or –X directions results in a force being applied to the glass ribbon in directions parallel with the width direction without significant actual movement of the suction devices. That is, a first set of second linear slides 106 located along one edge portion 54 of glass ribbon 42 are actuated to move in the X direction, and a second set of second linear slides 106 located along the opposite edge portion 54 of glass ribbon 42 are actuated to move in the –X direction. According, opposing forces are applied to glass ribbon 42 across a width portion of the glass ribbon that tension the glass ribbon in a width direction.

[0047] At step 206, scoring device 58 is moved into position on rail 90 and the scoring tool is extended to contact glass ribbon 42, whereupon scoring device 58 is moved across at least a portion of glass ribbon 42 in the X (or –X direction, depending on arrangement) to produce a

score 55 across the at least a portion of the width of the glass ribbon. It should be noted that the beads located within the edge portions 54 make scoring in this region difficult.

Accordingly, score 55 may be formed between the beads.

[0048] At step 208, first linear slides 104 are activated such that suction devices 96 apply a force to the glass ribbon in the draw direction (-Z direction) so that a tension is applied longitudinally (in a length direction) to glass ribbon 42.

[0049] At step 210, separator arms 94 are rotated about axis of rotation 102 so that glass ribbon 42 is pressed against first nosing member 56, thereby applying tension across the score until a failure stress is imparted across the score and a crack propagates at the score to separate glass sheet 46 from glass ribbon 42. At the moment of separation, the longitudinal force applied by actuation of first linear slides 104 causes an immediate displacement δ of glass sheet 46 downward and away from glass ribbon 42. This displacement prevents any inadvertent contact between the separated glass sheet and the newly-formed free end of the glass ribbon, thereby eliminating a source of potential damage to the glass sheet or the glass ribbon.

[0050] At step 212, linear slides 98 move separator arms 94 farther in the Y direction to a hand-off position. At step 214, separator arms 94 are rotated by rotary gear box 100 so that glass sheet 46 is vertical or substantially vertical, and movement of carriage assembly 72 in draw direction 50 stops. Meanwhile, robot 60 moves robot arm 62 so that suction devices 66 engage with the "A" side of glass sheet 46 and a vacuum is applied to suction devices 66 so that glass sheet 46 is held against (gripped by) the suction devices. At step 216, suction devices 96 are disengaged from the "B" side of the glass sheet, and are moved in a direction orthogonal to the draw direction (X and -X directions, respectively) to provide room for the descending glass ribbon 42, and the separator arms are moved in a second direction parallel with and orthogonal to the draw direction (-Y direction) until the separator arms are positioned in a start position awaiting the next separation cycle. At step 218, robot 60 transfers glass sheet 46 to a next downstream process. At step 220, carriage assembly 72 begins movement in a direction parallel to but opposite from draw direction 50 (Z direction). At step 222, suction devices 96 are moved inward in a direction (X and -X directions, respectively) orthogonal to the draw direction in preparation for re-engagement with the glass ribbon during a next separation cycle. At step 224, carriage assembly 72 is returned to the start position in preparation for the beginning of another separation cycle.

[0051] It should be apparent that in keeping with the intended goal of reducing the separation cycle time, many of the foregoing steps, while presented in a sequential manner for ease in understanding, can actually be performed simultaneously. For example, linear and rotational movement of the separator arms can occur simultaneously. Nor should it be interpreted that the specific order delineated above is required. Again, as an example, and assuming for the sake of argument that rotation and linear movement of the separator arms occurs sequentially, rotation may occur prior to linear traverse, or vice versa.

[0052] In accordance with embodiments described herein, glass sheet bending and separation may be performed by separator device 92 before robot 60 has returned from transferring the previous sheet. The portion of cycle time the robot must spend at the traveling anvil machine position is therefore greatly reduced, and the traveling anvil machine need not wait for the robot to perform actions other than engagement with and transfer of the glass sheet.

[0053] It should be apparent from the foregoing embodiment and description of operation that other embodiments are also possible. For example, in the context of FIGS. 5 and 6, separator device 92 is positioned so that suction devices 96 contact the edge portions 54 of glass ribbon 42 on the “B” side of the glass ribbon, and “pull” the glass ribbon in a direction toward first nosing member 56 by rotating in a counter-clockwise (in reference to FIG. 6). Separator device could easily be reconfigured so while separator device 92 is positioned on the “B” side of the glass ribbon, the suction devices engage the glass ribbon on the “A” side of the glass sheet (wherein the suction device mounting wraps around the edge of the glass ribbon. Even though robot 60 would therefore engage the glass sheet on the same side (“A” side), the suction devices could be moved laterally via linear second slides 106 so that the suction devices did not present an obstacle through which robot 60 would need to guide the glass sheet.

[0054] Alternatively, the position of separator device 92 could be rearranged on carriage assembly 72 so that the separator device is located on the “A” side of the glass ribbon, and robot 60 thereby positioned to be on the “B” side of the glass ribbon. In this embodiment, rather than “pulling” the glass ribbon in a direction toward first nosing member 56 by undergoing a counterclockwise rotation (in reference to FIG. 6), separator arms 94 would undergo a clockwise rotation and “push” the glass ribbon against first nosing member 56. However, while various equipment configurations are possible, they have in common the general steps outlines above: movement of a separator device coupled to the traveling anvil machine to bring the suction devices coupled thereon into engagement with the glass ribbon;

lateral tensioning of the glass ribbon by the separator device; longitudinal tensioning of the glass ribbon by the separator device; rotation of the separator device to apply a bending moment to the glass ribbon that separates a glass sheet from the glass ribbon; hand-off of the glass sheet to a robot, and a return of the traveling anvil machine (e.g. carriage assembly, separator arms, scoring device) to their start positions, ready for the beginning of another separation cycle.

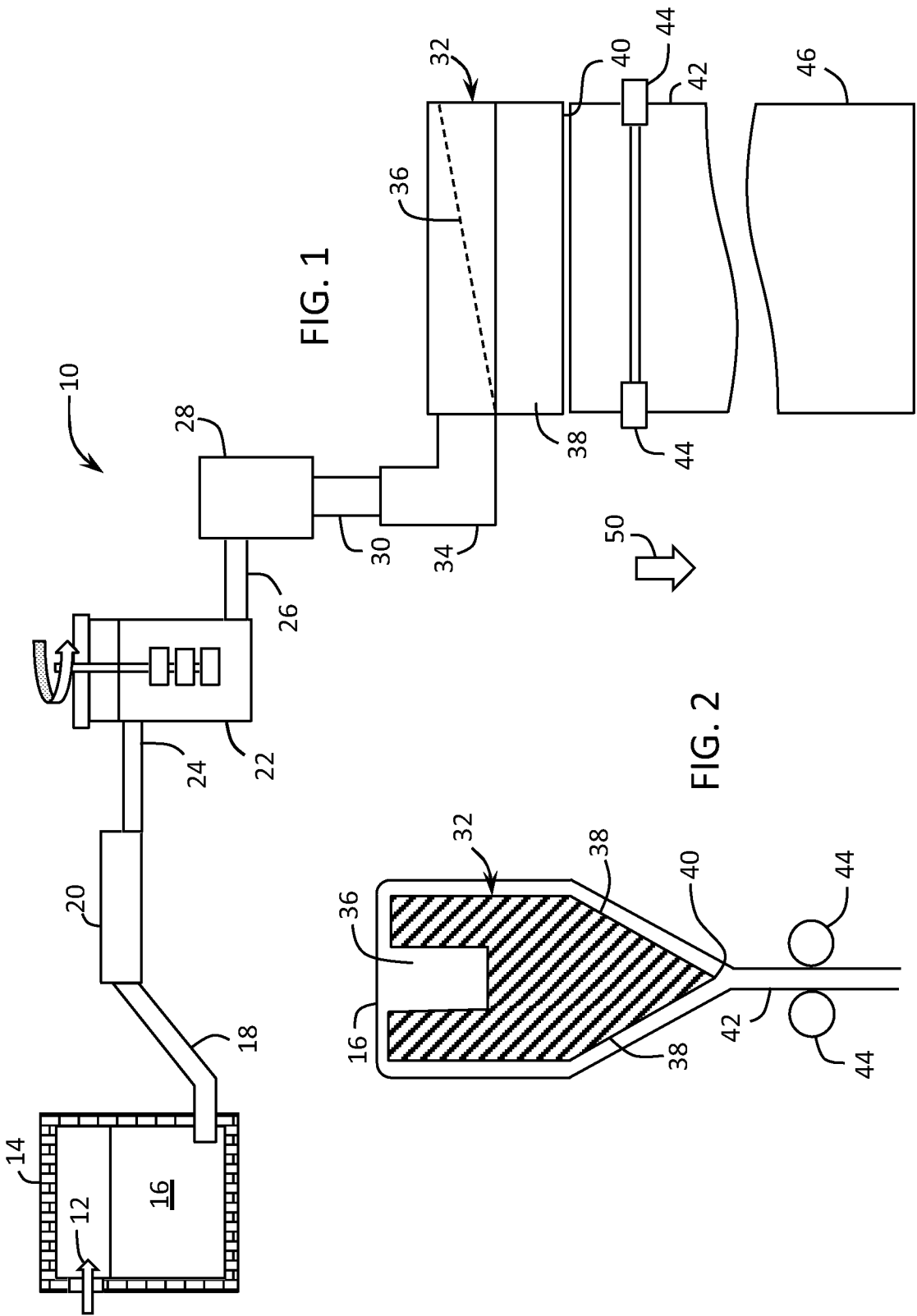
[0055] It will be apparent to those skilled in the art that various modifications and variations can be made to the present invention without departing from the spirit and scope of the present disclosure. Thus it is intended that the present disclosure cover the modifications and variations of embodiments disclosed herein provided they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. A method of separating a glass sheet from a moving ribbon of glass comprising:
 - drawing molten glass from a forming body in a draw direction at a speed S to form a glass ribbon;
 - moving a carriage assembly in the draw direction at the speed S , the carriage assembly including a separator device comprising separator arms and suction devices coupled thereto;
 - engaging the glass ribbon with the separator device;
 - tensioning the glass ribbon in a width direction of the glass ribbon with the separator device;
 - tensioning the glass ribbon in a length direction of the glass ribbon with the separator device;
 - producing a score in the glass ribbon with a scoring device;
 - applying a bending moment to the glass ribbon with the separator device to separate a glass sheet from the glass ribbon at the score;
 - engaging the glass sheet with a robot; and
 - disengaging the separator device from the glass sheet.
2. The method according to claim 1, wherein engaging the glass ribbon with the separator device comprises movement of the separator device in a direction orthogonal to the draw direction.
3. The method according to claim 1, wherein engaging the glass ribbon with the separator device comprises gripping the glass ribbon with the suction devices coupled to the separator arms.
4. The method according to claim 1, wherein tensioning the glass ribbon in the width direction comprises applying a lateral force with linear slides coupled to the suction devices.
5. The method according to claim 1, wherein tensioning the glass ribbon in the length direction comprises applying a force to the glass ribbon in a length direction of the glass ribbon with linear slides coupled to the suction devices.

6. The method according to claim 1, wherein applying a bending moment to the glass ribbon comprises rotating the separator arms about a rotational axis.
7. The method according to claim 1, further comprising moving the separator arms in a direction toward the robot to a hand-off position after the glass sheet is separated from the glass ribbon.
8. The method according to claim 1, further comprising rotating the separator arms about an axis of rotation after separating the glass sheet from the glass ribbon but before the robot engages the glass sheet.
9. The method according to claim 1, wherein after applying a bending moment to the glass ribbon with the separator device that separates the glass sheet from the glass ribbon, the glass sheet is moved in the draw direction away from the glass ribbon
10. The method according to claim 1, wherein the suction devices coupled to the robot engage the glass sheet on a side of the glass sheet opposite a side of the glass sheet engaged by the robot
11. An apparatus for separating a glass sheet from a glass ribbon moving in a draw direction, comprising:
 - a traveling anvil machine comprising:
 - a carriage assembly configured to move in the draw direction;
 - a first nosing member coupled to the carriage assembly and configured to move in a direction orthogonal to the draw direction; and
 - a separator device for engaging the glass ribbon coupled to the carriage assembly and configured to move in a direction orthogonal to the draw direction and also to rotate about an axis of rotation;

12. The apparatus according to claim 11, further comprising a scoring device coupled to the carriage assembly.
13. The apparatus according to claim 11, wherein the separator device comprises separator arms, the separator arms further comprising suction devices coupled thereto.
14. The apparatus according to claim 13, wherein the suction devices are configured to move in at least two orthogonal directions relative to the separator arms.
15. The apparatus according to claim 13, wherein the suction devices are coupled to the separator arms with linear slides.



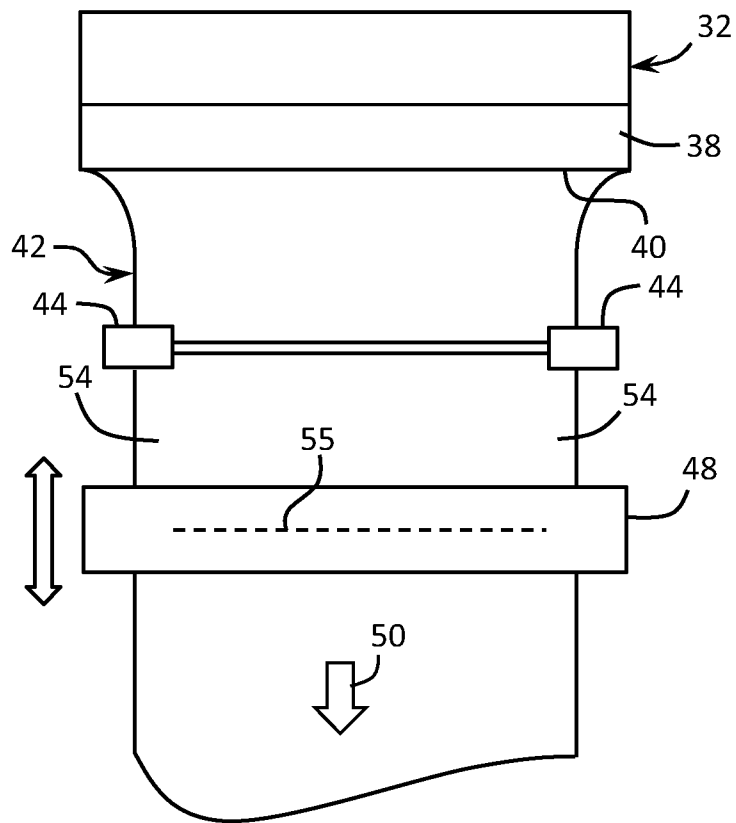
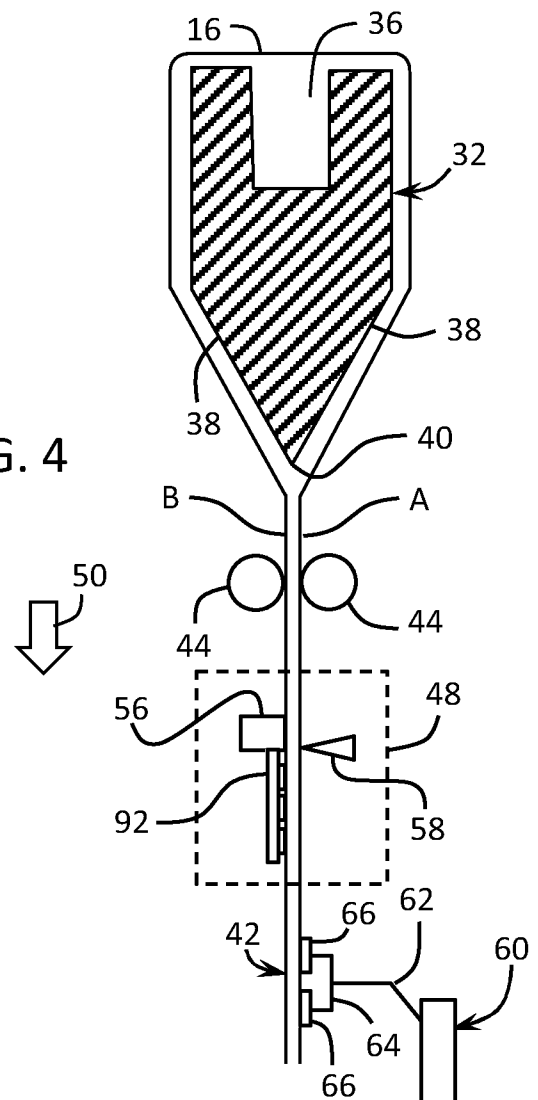


FIG. 3

FIG. 4



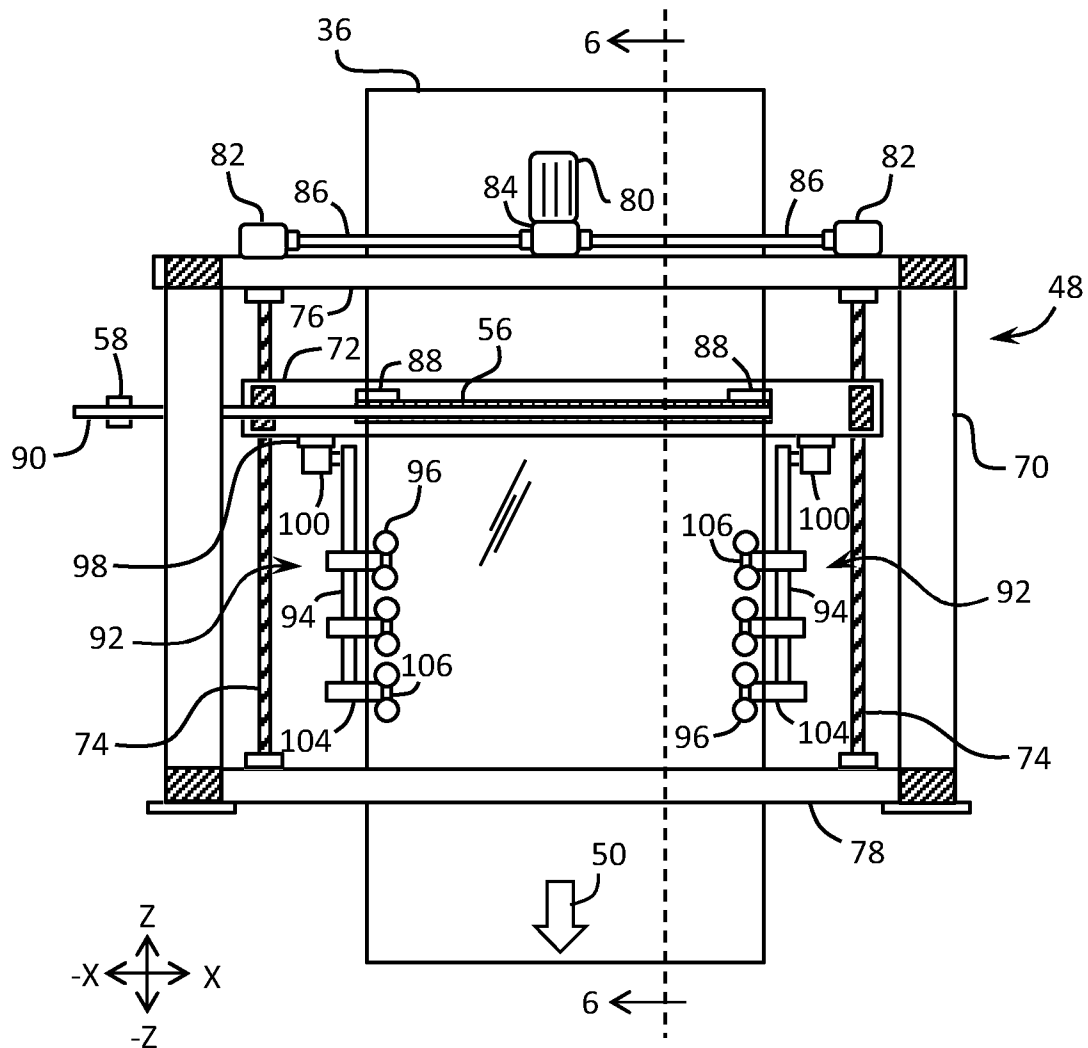


FIG. 5

4/10

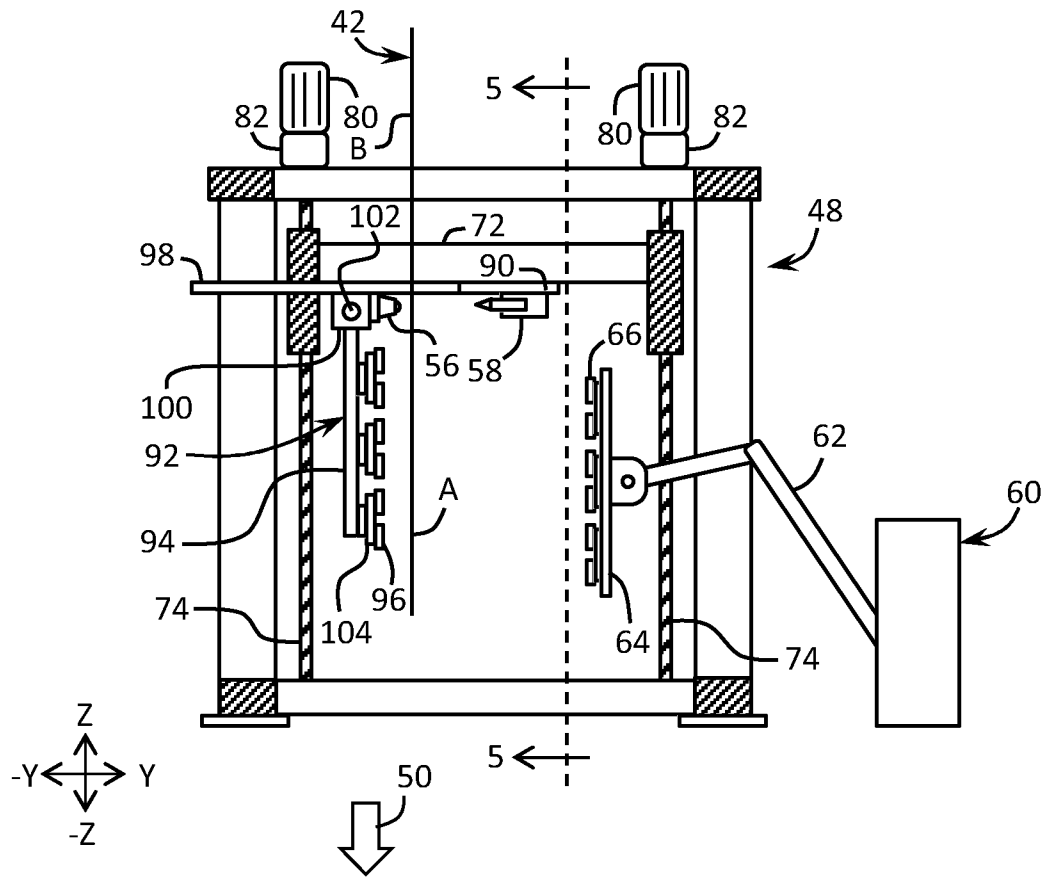


FIG. 6

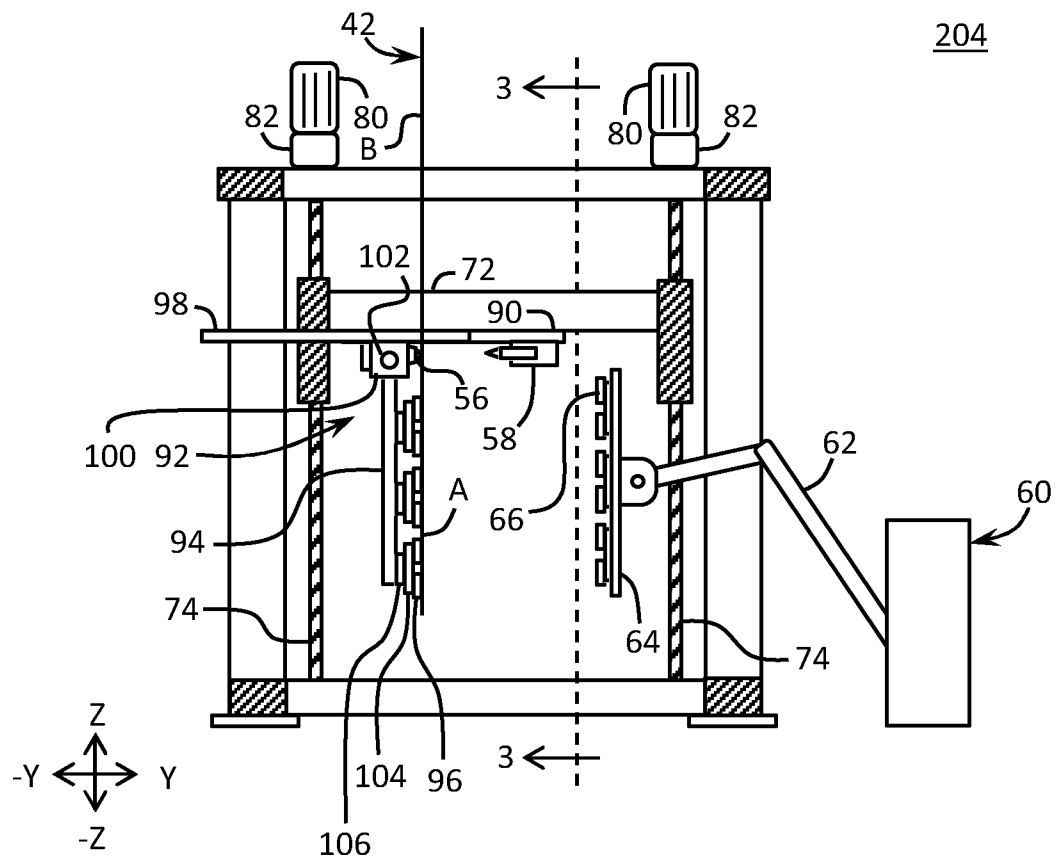


FIG. 8

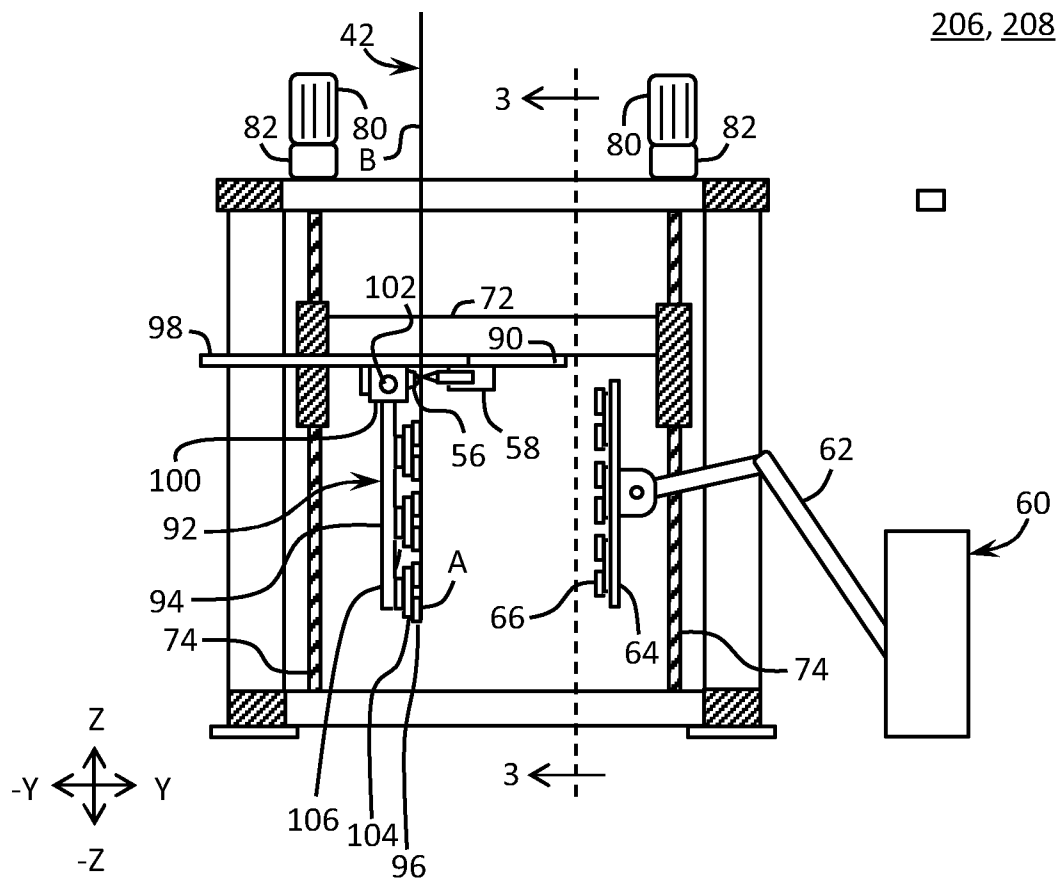


FIG. 9

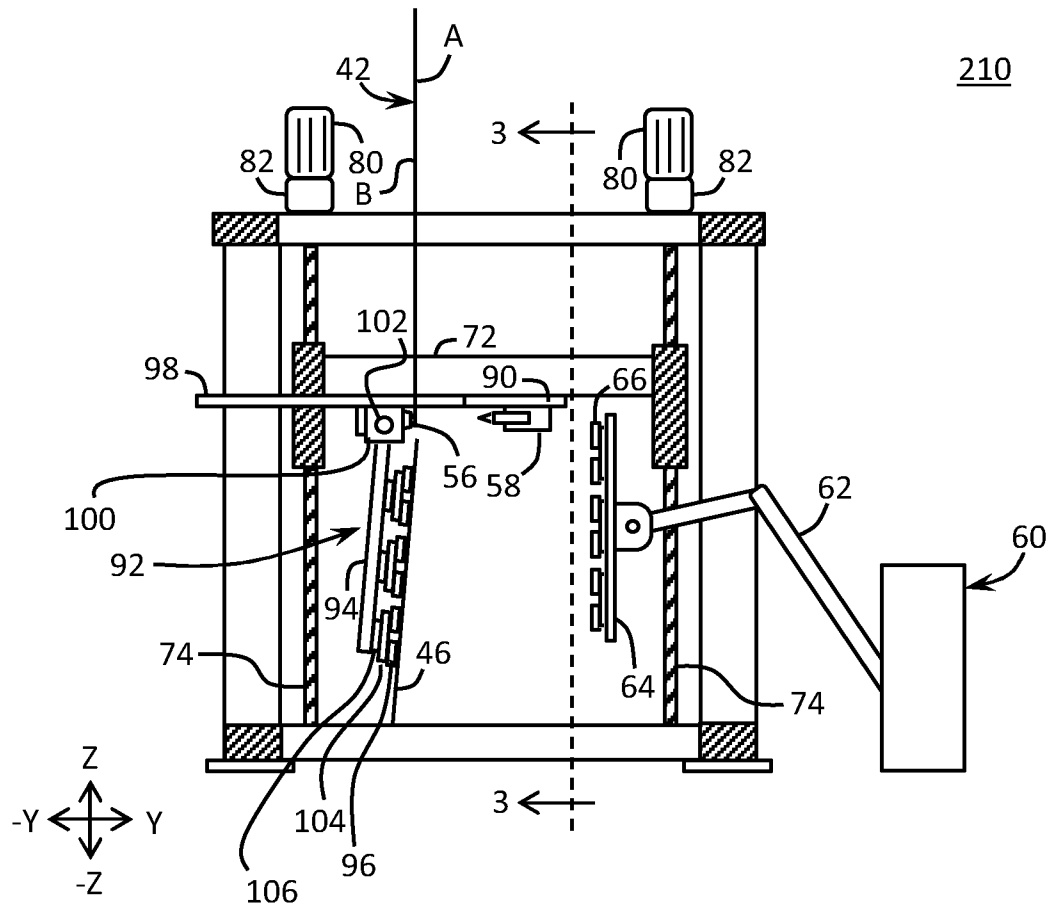


FIG. 10

212, 214

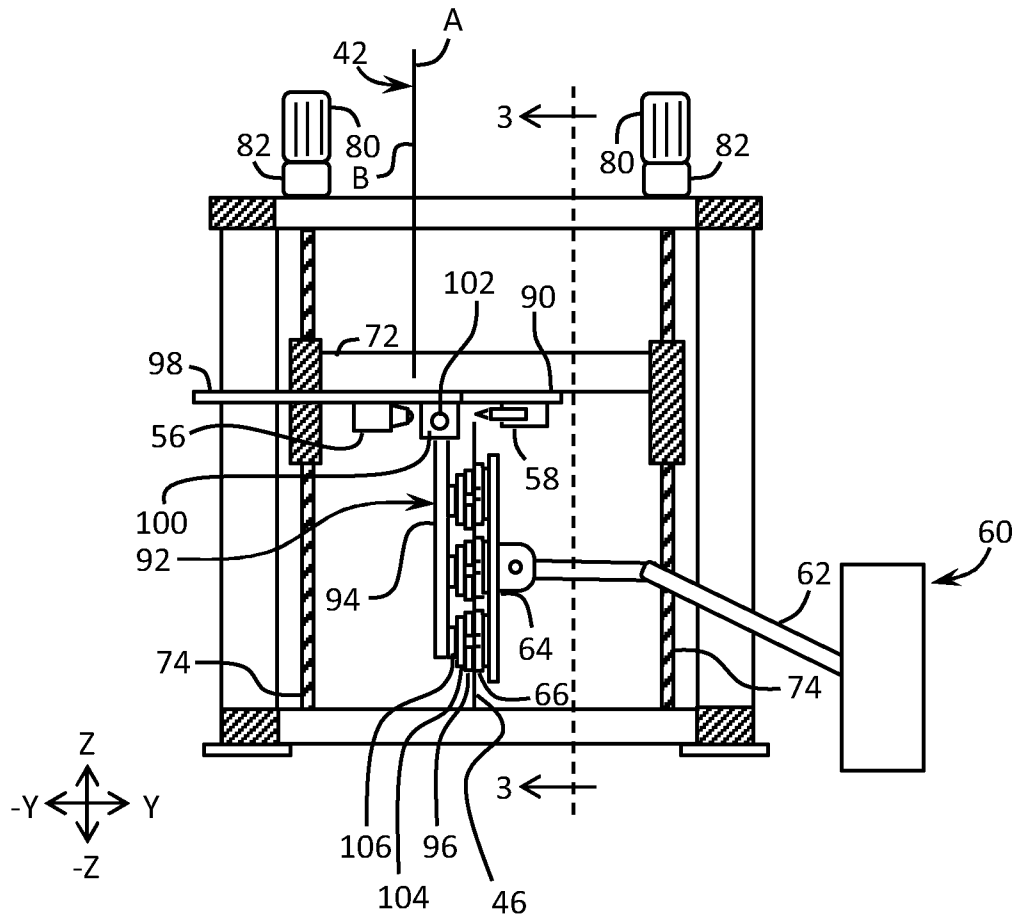


FIG. 11

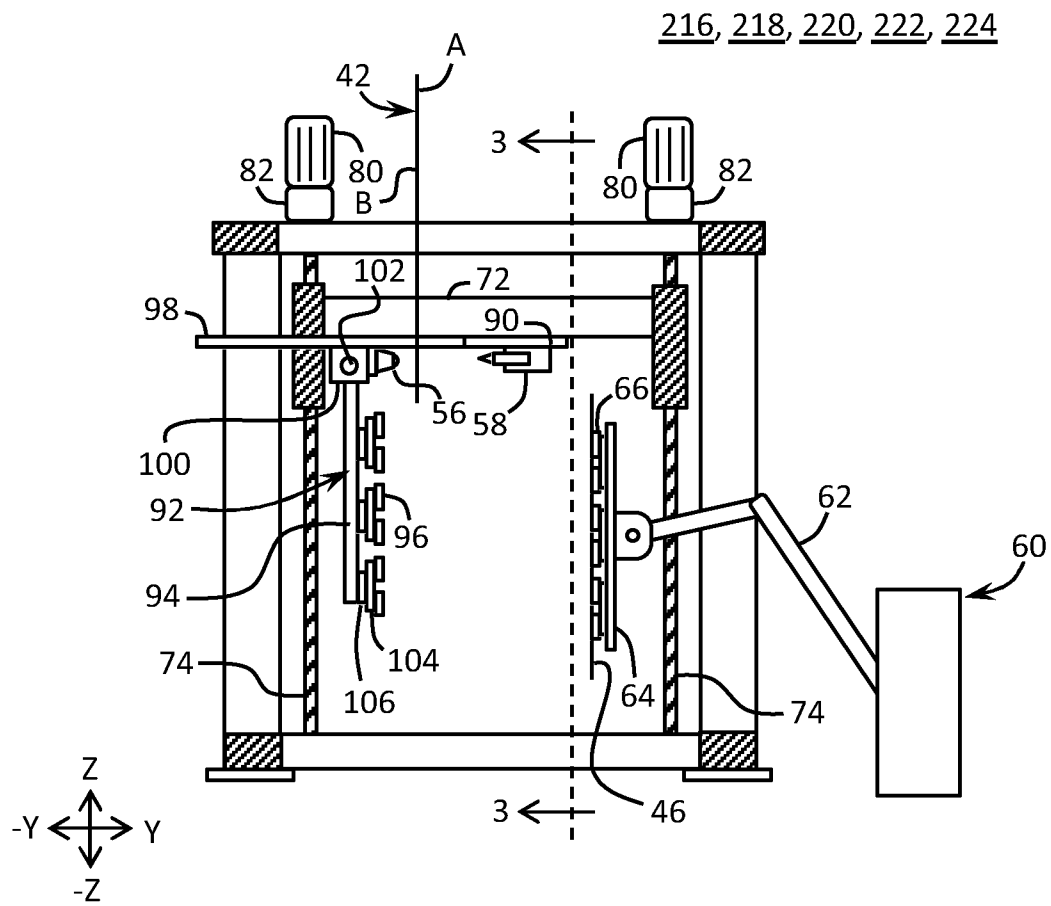


FIG. 12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/043567**A. CLASSIFICATION OF SUBJECT MATTER****C03B 18/02(2006.01)i**

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 18/02; C03B 5/26; C03B 33/02; B26D 3/08; C03B 33/033; C03B 33/023; B26F 3/00; C03B 3/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & keywords: glass, ribbon, separate, suction, arm, tension, width, length, score, bend, robot, speed

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013-0047674 A1 (MARKHAM, S. R. et al.) 28 February 2013 See paragraphs [0029]-[0031], [0036]-[0040] and [0042]-[0050]; figs. 2-6F.	11-15
A		1-10
A	US 2013-0047674 A1 (MARKHAM, S. R. et al.) 28 February 2013 See paragraphs [0029]-[0031], [0036]-[0040] and [0042]-[0050]; figs. 2-6F.	1-15
A	US 4140258 A (GRAY, MARTIN E.) 20 February 1979 See abstract; column 3, line 45-column 5, line 48; figs. 1-6.	1-15
A	US 2008-0276785 A1 (DAHROUG, M. et al.) 13 November 2008 See paragraphs [0013]-[0023]; figs. 1-6.	1-15
A	US 2008-0066498 A1 (MARKHAM, S. R. et al.) 20 March 2008 See abstract; paragraphs [0067]-[0089].	1-15



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

27 October 2014 (27.10.2014)

Date of mailing of the international search report

27 October 2014 (27.10.2014)

Name and mailing address of the ISA/KR

International Application Division
Korean Intellectual Property Office
189 Cheongsu-ro, Seo-gu, Daejeon Metropolitan City, 302-701,
Republic of Korea

Facsimile No. +82-42-472-7140

Authorized officer

HONG, Sung Ran

Telephone No. +82-42-481-5405



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2014/043567

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013-0047674 A1	28/02/2013	CN 102951783 A CN 202808572 U JP 2013-043828 A KR 10-2013-0023128 A TW 201313628 A US 8794036 B2	06/03/2013 20/03/2013 04/03/2013 07/03/2013 01/04/2013 05/08/2014
KR 10-2011-0051183 A	17/05/2011	CN 102099306 A CN 102099306 B JP 5267957 B2 TW 201008886 A TW I385135 B WO 2010-007953 A1	15/06/2011 28/08/2013 21/08/2013 01/03/2010 11/02/2013 21/01/2010
US 4140258 A	20/02/1979	JP 51-112822 A	05/10/1976
US 2008-0276785 A1	13/11/2008	CN 101679100 A CN 101679100 B JP 2010-526751 A JP 5165750 B2 KR 10-1439577 B1 KR 10-2010-0029754 A TW 200914386 A TW I406829 B US 2012-006058 A1 US 8051681 B2 US 8146386 B2 WO 2008-140678 A1	24/03/2010 28/08/2013 05/08/2010 21/03/2013 11/09/2014 17/03/2010 01/04/2009 01/09/2013 12/01/2012 08/11/2011 03/04/2012 20/11/2008
US 2008-0066498 A1	20/03/2008	CN 101595069 A CN 101595069 B EP 2064157 A1 JP 2010-504273 A JP 2013-253017 A JP 5330245 B2 KR 10-2009-0082359 A TW 200838814 A TW I329622 B US 7984625 B2 WO 2008-036227 A1	02/12/2009 15/08/2012 03/06/2009 12/02/2010 19/12/2013 30/10/2013 30/07/2009 01/10/2008 01/09/2010 26/07/2011 27/03/2008