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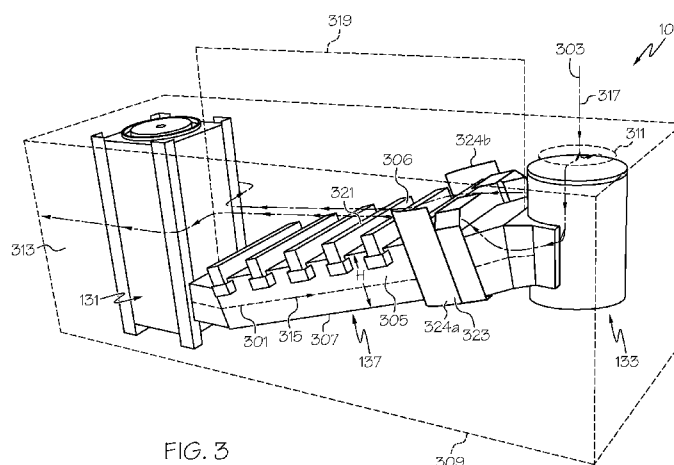


FIG. 3

(57) Abstract: Methods of processing molten material comprising the step (I) of flowing molten material through an interior of a conduit (137) from a first station (131) to a second station (133) of a glass manufacturing apparatus and the step (II) of cooling the molten material within the interior of the conduit by passing a cooling fluid along an exterior of the conduit. The method further includes the step (III) of directing a travel path of the cooling fluid toward a vertical plane (319) passing through the conduit. In further examples, a glass manufacturing apparatus comprises a first station, a second station, and a conduit (137) configured to provide a travel path for molten material traveling from the first station to the second station. The glass manufacturing apparatus further comprises at least one baffle (323) configured to direct a travel path of cooling fluid toward a vertical plane (319) passing through the conduit.

APPARATUS AND METHODS FOR COOLING MOLTEN GLASS MATERIAL

[0001] This application claims the benefit of priority under 35 U.S.C. § 120 of U.S. Application Serial No. 14/684,924, filed on April 13, 2015, the content of which is relied upon and incorporated herein by reference in its entirety.

FIELD

[0002] The present disclosure relates generally to apparatus and methods of processing molten material and, more particularly, to apparatus and methods of processing molten material flowing through an interior of a conduit.

BACKGROUND

[0003] It is known to manufacture glass ribbon from molten material. Typically, molten material is processed with a glass manufacturing apparatus including several stations arranged in series. In some examples, a pair of stations are joined with a conduit providing a travel path for molten material traveling from a first station to a second station.

SUMMARY

[0004] The following presents a simplified summary of the disclosure in order to provide a basic understanding of some example aspects described in the detailed description.

[0005] In accordance with a first aspect, a method of processing molten material comprises the step (I) of flowing molten material through an interior of a conduit from a first station to a second station of a glass manufacturing apparatus. The method further includes the step (II) of cooling the molten material within the interior of the conduit by passing a cooling fluid along an exterior of the conduit. The method still further includes the step (III) of directing a travel path of the cooling fluid toward a vertical plane passing through the conduit.

[0006] In one example of the first aspect at least one baffle directs the travel path of the cooling fluid during step (III).

[0007] In another example of the first aspect, the at least one baffle includes a first baffle, and step (III) includes directing a first portion of the travel path of the cooling fluid from a first lateral side portion of the conduit toward the vertical plane with the first baffle. In another example, the at least one baffle further includes a second baffle, and step (III) further includes directing a second portion of the travel path of the cooling fluid from a second lateral side portion of the conduit toward the vertical plane with the second baffle.

[0008] In yet another example of the first aspect, the at least one baffle includes a deflection panel extending at an angle relative to a travel path of the molten material flowing through the interior of the conduit, and step (III) includes directing the travel path of the cooling fluid with the deflection panel of the baffle. In another example, the at least one baffle further includes a shroud at least partially extending over a top portion of the conduit, and step (III) includes routing the travel path of the cooling fluid with the shroud to be directed by the deflection panel.

[0009] In another example of the first aspect, step (III) further directs the travel path of the cooling fluid over a top portion of the conduit.

[0010] In still another example of the first aspect, the vertical plane bisects the conduit.

[0011] In yet another example of the first aspect, the cooling fluid travels in a direction from the second station toward the first station.

[0012] In a further example of the first aspect, the cooling fluid may be substantially free from oxygen. In one example, the cooling fluid comprises nitrogen.

[0013] The first aspect can be provided alone or in combination with one or any combination of the examples of the first aspect discussed above.

[0014] In accordance with a second aspect, a glass manufacturing apparatus comprises a first station, a second station, and a conduit configured to provide a travel path for molten material traveling from the first station to the second station. The glass manufacturing apparatus further comprises at least one baffle configured to direct a travel path of cooling fluid toward a vertical plane passing through the conduit.

[0015] In one example of the second aspect, the first station comprises a mixing chamber.

[0016] In another example of the second aspect, the second station comprises a delivery vessel.

[0017] In still another example of the second aspect, the at least one baffle includes a deflection panel extending at an angle relative to the travel path provided by the conduit. In one example, an outer end of the deflection panel may be laterally positioned outside the travel path for the molten material. In another example, the deflection panel includes a concave inner surface facing toward the vertical plane.

[0018] In another example of the second aspect, the at least one baffle includes a shroud at least partially extending over a top portion of the conduit. In one example, the at least one baffle further includes a deflection panel extending away from the shroud at an angle relative to the travel path of the conduit.

[0019] In still another example of the second aspect, the at least one baffle includes a first baffle including a first deflection panel extending at a first angle relative to the travel path provided by the conduit and a second baffle including a second deflection panel extending at a second angle relative to the travel path provided by the conduit, wherein the first deflection panel and the second deflection panel converge toward one another.

[0020] The second aspect can be provided alone or in combination with one or any combination of examples of the second aspect discussed above.

[0021] It is to be understood that both the foregoing general description and the following detailed description present embodiments of the present disclosure, and are intended to provide an overview or framework for understanding the nature and character of the embodiments as they are described and claimed. The accompanying drawings are included to provide a further understanding of the embodiments, 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 thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] These and other features, aspects and advantages of the present disclosure are better understood when the following detailed description is read with reference to the accompanying drawings, in which:

[0023] **FIG. 1** schematically illustrates an example glass manufacturing apparatus;

[0024] **FIG. 2** illustrates a cross-sectional perspective view of the glass manufacturing apparatus along line **2-2** of **FIG. 1**;

[0025] **FIG. 3** is a schematic perspective view illustrating a travel path of cooling fluid being directed toward a vertical plane through a conduit;

[0026] **FIG. 4** schematically illustrates a top view of **FIG. 3**; and

[0027] **FIG. 5** illustrates an example baffle configured to direct the travel path of the cooling fluid.

DETAILED DESCRIPTION

[0028] Apparatus and methods will now be described more fully hereinafter with reference to the accompanying drawings in which example embodiments of the disclosure are shown. Whenever possible, the same reference numerals are used throughout the drawings to refer to the same or like parts. However, the claims may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein.

[0029] Glass sheets produced by apparatus and methods of the present disclosure are commonly used, for example, in display applications, for example liquid crystal displays (LCDs), electrophoretic displays (EPD), organic light emitting diode displays (OLEDs), plasma display panels (PDPs), or the like. In some examples, glass sheets may be separated from a glass ribbon produced by a glass manufacturing apparatus.

[0030] In some embodiments, the glass manufacturing apparatus can comprise a slot draw apparatus, float bath apparatus, down-draw apparatus, up-draw apparatus, press-rolling apparatus or other glass manufacturing apparatus as are generally known in the art. By way of example, **FIG. 1** schematically illustrates a glass manufacturing apparatus **101** for processing a quantity of molten material for fusion drawing a glass ribbon **103** for subsequent processing into glass sheets **104**. The glass manufacturing apparatus **101** can include one or more features shown in **FIG. 1**. For instance, the glass manufacturing apparatus **101** (e.g., the illustrated fusion down-draw apparatus) can include one or any plurality of the illustrated stations (e.g., a melting vessel **105**, a fining vessel **127**, a mixing chamber **131**, a delivery vessel **133** and a forming vessel **143**)

and/or features associated with the stations. For example, as shown in **FIG. 1**, the glass manufacturing apparatus **101** can include all of the illustrated stations arranged in series wherein molten material may sequentially travel through the stations to produce the glass ribbon **103** from the molten material **121**.

[0031] The melting vessel **105** may be configured to receive batch material **107** from a storage bin **109**. The batch material **107** can be introduced by a batch delivery device **111** powered by a motor **113** to introduce a desired amount of batch material **107** into the melting vessel **105**, as indicated by arrow **117**. The melting vessel **105** may then melt the batch material **107** into the molten material **121**.

[0032] The fusion draw apparatus **101** can also include the fining vessel **127** that can be located downstream from the melting vessel **105** and coupled to the melting vessel **105** by way of a first conduit **129**. In some examples, the molten material **121** may be gravity fed from the melting vessel **105** to the fining vessel **127** by way of the first conduit **129**. For instance, gravity may act to drive the molten material **121** to pass through an interior of the first conduit **129** from the melting vessel **105** to the fining vessel **127**. Within the fining vessel **127**, bubbles may be removed from the molten material **121** by various techniques.

[0033] The fusion draw apparatus can further include the mixing chamber **131** that may be located downstream from the fining vessel **127**. The mixing chamber **131** can be used to provide a homogenous molten material composition, thereby reducing or eliminating cords of inhomogeneity that may otherwise exist within the fined molten material exiting the fining vessel. As shown, the fining vessel **127** may be coupled to the mixing chamber **131** by way of a second conduit **135**. In some examples, the molten material **121** may be gravity fed from the fining vessel **127** to the mixing chamber **131** by way of the second conduit **135**. For instance, gravity may act to drive the molten material **121** to pass through an interior of the second conduit **135** from the fining vessel **127** to the mixing chamber **131**.

[0034] The fusion draw apparatus can further include the delivery vessel **133** that may be located downstream from the mixing chamber **131**. The delivery vessel **133** may condition the molten material **121** to be fed into a forming device. For instance, the delivery vessel **133** can act as an accumulator and/or flow controller to adjust and provide

a consistent flow of molten material **121** to the forming vessel **143**. As shown, the mixing chamber **131** may be coupled to the delivery vessel **133** by way of a third conduit **137**. In some examples, molten material **121** may be gravity fed from the mixing chamber **131** to the delivery vessel **133** by way of the third conduit **137**. For instance, gravity may act to drive the molten material **121** to pass through an interior of the third conduit **137** from the mixing chamber **131** to the delivery vessel **133**.

[0035] As further illustrated, a downcomer **139** can be positioned to deliver the molten material **121** from the delivery vessel **133** to an inlet **141** of the forming vessel **143** of a fusion draw machine **140**. As discussed more fully below, the fusion draw machine **140** may be configured to draw the molten material **121** into a glass ribbon **103**.

[0036] The conduits (e.g., the first conduit **129**, the second conduit **135**, and the third conduit **137**) of the glass manufacturing apparatus **101** can include an interior surface comprising a wide variety of shapes. For instance, a cross-sectional profile shape of the interior surface taken perpendicular to a travel path provided for the molten material can comprise a circular shape or a non-circular shape (e.g., an oblong shape, an elliptical shape or other shape configuration). In some examples, the same or geometrically similar cross-sectional profile shape may exist along a length of the conduit. In other examples, geometrically different cross-sectional profile shapes may exist along a length of the conduit. Providing the conduit with a cross-sectional profile shape that is non-circular can increase the efficiency of transferring heat from the molten glass in the conduit by providing a greater surface area to the conduit.

[0037] The melting vessel **105** and the forming vessel **143** are typically made from a refractory material, for example refractory (e.g. ceramic) brick. The glass manufacturing apparatus **101** may further include components that are typically made from platinum or platinum-containing metals for example platinum-rhodium, platinum-iridium and combinations thereof, but which may also comprise such refractory metals for example molybdenum, palladium, rhenium, tantalum, titanium, tungsten, ruthenium, osmium, zirconium, and alloys thereof and/or zirconium dioxide. The platinum-containing components can include one or more of the first conduit **129**, the fining vessel **127**, the second conduit **135**, the mixing chamber **131**, the third conduit **137**, the delivery vessel **133**, the downcomer **139** and the inlet **141**.

[0038] **FIG. 2** is a cross-sectional perspective view of the glass manufacturing apparatus **101** along line **2-2** of **FIG. 1**. As shown, the forming vessel **143** includes a forming wedge **201** comprising a pair of downwardly inclined forming surface portions **203**, **205** extending between opposed ends of the forming wedge **201**. The pair of downwardly inclined forming surface portions **203**, **205** converge along a draw direction **207** to form a root **209**. A draw plane **211** extends through the root **209** wherein the glass ribbon **103** may be drawn in the draw direction **207** along the draw plane **211**. As shown, the draw plane **211** can bisect the root **209** although the draw plane **211** may extend at other orientations with respect to the root **209**.

[0039] Referring to **FIG. 2**, in one example, the molten material **121** can flow into a trough **200** of the forming vessel **143**. The molten material **121** can then simultaneously flow over corresponding weirs **202a**, **202b** and downward over the outer surfaces **204a**, **204b** of the corresponding weirs **202a**, **202b**. Respective streams of molten material then flow along the downwardly inclined forming surface portions **203**, **205** to the root **209** of the forming vessel **143**, where the flows converge and fuse into the glass ribbon **103**. The glass ribbon **103** may then be drawn off the root **209** in the draw plane **211** along draw direction **207**.

[0040] As shown in **FIG. 2**, the glass ribbon **103** can be drawn from the root **209** with a first major surface **213** and a second major surface **215**. As shown, the first major surface **213** and the second major surface **215** face opposite directions with a thickness **217** defined between the first major surface **213** and the second major surface **215**. Although aspects of the disclosure may be beneficial to produce many alternative thicknesses (e.g., including thicknesses of greater than 1 mm or less than 50 μm , including all ranges and sub-ranges therebetween), in some examples, the thickness **217**, for example a thickness at a central portion of glass ribbon **103**, can be less than or equal to about 1 mm, for example, from about 50 μm to about 750 μm , for example from about 100 μm to about 700 μm , for example from about 200 μm to about 600 μm , for example from about 300 μm to about 500 μm .

[0041] In one example, glass ribbon **103** drawn off the root **209** may be separated into individual glass sheets **104** with a glass separation apparatus **145**. Alternatively, although not shown, the glass ribbon may be passed through further processing stations

and/or may be stored as a roll of glass ribbon rather than being immediately separated into individual glass sheets **104**.

[0042] In some examples, there may be a desire to cool molten material traveling within one or more of the conduits (e.g., the first conduit **129**, second conduit **135**, third conduit **137**, etc.) between adjacent stations (e.g., the melting vessel **105**, the fining vessel **127**, the mixing chamber **131**, the delivery vessel **133** and the forming vessel **143**) of the glass manufacturing apparatus **101**. Discussion of cooling will be described with respect to the third conduit **137** extending between a first station (e.g., the mixing chamber **131**) and a second station (e.g., the delivery vessel **133**) of the glass manufacturing apparatus **101**. Although not shown, the concepts of the disclosure may be applied to any of the other illustrated conduits (e.g., the first conduit **129**, the second conduit **135**) or any other conduit in other example glass manufacturing apparatus. Moreover, the illustrated stations are only one example configuration wherein the stations are arranged in series with the fining vessel **127** positioned downstream from the melting vessel **105**, the mixing chamber **131** positioned downstream from the fining vessel **127**, the delivery vessel **133** positioned downstream from the mixing chamber **131**, and the forming vessel **143** positioned downstream from the delivery vessel **133**. In some examples, more or less stations may be provided and/or the stations may be arranged in a different order wherein concepts of the disclosure may be applied to cool molten glass within a conduit providing a travel path for molten material traveling between stations in the series of stations.

[0043] Turning to **FIG. 3**, by way of example, the glass manufacturing apparatus **101** includes a first station that may comprise the illustrated mixing chamber **131**. The glass manufacturing apparatus **101** may further include a second station that may comprise the illustrated delivery vessel **133**. The glass manufacturing apparatus still further includes the third conduit **137**. As illustrated schematically in **FIG. 3**, the third conduit **137** can be configured to provide a travel path **301** for the molten material **121** traveling in a direction **315** from the first station to the second station.

[0044] There may be a desire to lower the temperature of the molten material **121** from a relatively high temperature in the mixing chamber **131** to a relatively low temperature in the delivery vessel **133**. Lowering the temperature of the molten material

121 can be desirable to provide a desired molten material property (e.g., viscosity) for processing the molten material **121** into the glass ribbon **103** with the fusion draw machine **140**.

[0045] In one example, cooling fluid **303**, such as gas, may be passed along an exterior **305** of the conduit **137** to achieve an increased cooling rate of the molten material within the conduit **137**. Indeed, a relatively cool fluid may pass along the conduit **137** to provide convective heat transfer, thereby removing heat from the conduit **137** that consequently reduces the temperature of the molten material **121** within the interior of the conduit **137**. The conduit **137** may include a core **307** fabricated from refractory metals (e.g., platinum or platinum-containing metals) that defines the interior of the conduit defining the travel path **301**. The conduit **137** can include other features such as coverings, coatings, or support structures in addition to the core **307**. For instance, as partially schematically illustrated, the conduit may include support structures **306** that may facilitate support of a core **307** of the conduit **137**. The cooling fluid **303** may be passed along the exterior **305** of the conduit **137** such as the exterior of the core **307**, the support structures **306** or other features of the conduit **137**.

[0046] As shown in **FIG. 3**, the conduit **137** may optionally be placed within a containment area **309**. As further shown in **FIG. 3**, the first station (e.g., the mixing chamber **131**) and the second station (e.g., the delivery vessel **133**) may also be placed in the containment area **309**. Placing the conduit **137**, the first station and the second station within the containment area **309** can help guide a controlled quantity of fluid to travel along a travel path from an upstream portion **311** of the containment area **309** to a downstream portion **313** of the containment area **309**. Moreover, the containment area **309** can be designed to place the conduit **137**, first station and second station within an atmosphere that may be substantially free from oxygen. As such, oxidation of portions of the glass manufacturing apparatus **101** can be minimized, such as prevented, to avoid contaminating the molten material being processed by the glass manufacturing apparatus **101**. In some examples, the cooling fluid may be substantially free from oxygen and comprise an inert gas, such as nitrogen, although the cooling fluid may comprise other chemical elements in further examples.

[0047] In operation, molten material **121** may travel along the travel path **301** of the conduit **137** in the direction **315** from the first station (e.g., the mixing chamber **131**) toward the second station (e.g., the delivery vessel **133**). Optionally, the cooling fluid may travel along a path in a direction from the second station toward the first station. Providing a cooling fluid that flows in the general opposite direction of the flow of molten material can provide enhanced convective heat transfer near the second station since the temperature difference between the cooling fluid and the conduit **137** will be higher near the second station than near the first station.

[0048] There is a desire to quickly and efficiently reduce the temperature of the molten material **121** within the interior of the conduit **137** to provide the desired temperature in the second station (e.g., delivery vessel **133**). Providing increased heat transfer can allow for increased flow of molten material within the conduit, thereby allowing for an increase rate of glass ribbon production. Moreover, providing increased heat transfer can reduce the length of the conduit that needs to be provided. Indeed, a relatively long conduit used to cool with a less efficient technique may be significantly shortened with more efficient heat transfer. Providing a relatively short conduit can be beneficial to reduce the quantity of expensive refractory metals used to produce the conduit.

[0049] As can be appreciated by **FIGS. 3 and 4**, the conduit **137** may include a height “**H**” that may be less than the width “**W**”. Such designs may be beneficial to provide an oblong or elliptical shape that can provide enhanced heat transfer of the molten material traveling within the conduit. In order to increase heat transfer, the glass manufacturing apparatus **101** may include at least one baffle configured to direct a travel path **317** of the cooling fluid **303** toward a vertical plane **319** passing through the conduit **137**. As shown, the vertical plane **319** passes through the top and bottom of the conduit **137** transverse to the width “**W**” of the conduit **137**. Moreover, as shown in **FIG. 4**, in some examples, the vertical plane **319** bisects the conduit **137**. Directing the cooling fluid **303** toward the vertical plane **319** can encourage the cooling fluid to travel along the relatively greater width “**W**” of the conduit **137** to enhance heat transfer.

[0050] As shown in **FIGS. 4 and 5** the baffle **323** can include a deflection panel **501** that may extend at an angle “**A**” relative to the travel path **301** provided by the

conduit **137**. The angle “**A**” can be measured by a surface extending from the deflection panel **501**. For instance, in the illustrated example, the angle “**A**” can be measured from a surface that extends tangent to a curved surface of the deflection panel **501**. As illustrated, the angle “**A**” can be an acute angle that permits gradual diversion of the cooling fluid **303** toward the vertical plane **319**. Moreover, as shown, the deflection panel **501** can include a concave inner surface **503** facing toward the vertical plane **319**. The concave inner surface **503** can further provide a gradual diversion of the cooling fluid **303** to reduce an undesired restriction of fluid flow. In other embodiments, the deflection panel **501** and inner surface **503** can be substantially straight.

[0051] As further illustrated, the baffle can include an optional shroud **505** that may at least partially extend over the top portion **321** of the conduit **137**. The shroud **505** may route the travel path of the cooling fluid into the deflection panel **501**. As shown in **FIG. 4**, the deflection panel **501** can extend away from the shroud **505** at the angle “**A**” relative to the travel path of the conduit. Furthermore, an outer end **401** of the deflection panel **501** may be laterally positioned outside the travel path for the molten material. Indeed, in one example, the deflection panel **501** may extend away from the shroud at an angle with the outer end **401** actually abutting a lateral side **403** of the conduit **137**. Positioning the outer end **401** to be laterally positioned outside the travel path, such as abutting the lateral side **403** of the conduit **137**, can help direct a significant portion, such as all, of the corresponding cooling fluid toward the vertical plane **319**. As such, the baffle can direct the cooling fluid to travel along the top portion **321** (or bottom portion) of the conduit rather than the lateral sides **403** that has a greater surface area than the lateral sides of the conduit, thereby providing increased convective heat transfer.

[0052] Although a single deflection panel may be provided, as shown in **FIGS. 3 and 4**, the at least one baffle can include a first baffle **324a** and a second baffle **324b**. As shown in **FIG. 4**, the first baffle **324a** can be associated with a first lateral side portion **403a** of the conduit **137** and the second baffle **324b** can be associated with a second lateral side portion **403b** of the conduit **137**. As shown, the first baffle **324a** can be identical or similar to the baffle **323** illustrated in **FIG. 5**. Likewise, the second baffle **324b** can be similar or identical to a mirror image of the baffle **323** illustrated in **FIG. 5**. As shown in **FIG. 4**, the first baffle **324a** includes a first deflection panel extending at a

first angle (e.g., angle “A”) relative to the travel path provided by the conduit **137** and the second baffle **324b** likewise includes a second deflection panel **501** extending at a second angle (e.g., angle “A”) relative to the travel path provided by the conduit **137**. As shown, the first deflection panel and the second deflection panel may converge toward one another.

[0053] Methods of processing molten material will now be discussed. The method can include the step of flowing molten material **121** through an interior of a conduit from a first station to a second station of the glass manufacturing apparatus. The first station can comprise the melting vessel **105**, the fining vessel **127**, the mixing chamber **131**, the delivery vessel **133**, or other station of the glass manufacturing apparatus. The second station can comprise the fining vessel **127**, the mixing chamber **131**, the delivery vessel **133**, the forming vessel **143**, or other station of the glass manufacturing apparatus. For example, as shown in **FIGS. 1, 3 and 4**, the first station can comprise the mixing chamber **131** and the second station can comprise the delivery vessel **133** positioned downstream from the mixing chamber **131**. Referring to **FIG. 3**, molten material flows through the interior of the conduit **137** along the travel path **301** from the first station (e.g., the mixing chamber **131**) to the second station (e.g., the delivery vessel **133**) of the glass manufacturing apparatus **101**.

[0054] The method further includes the step of cooling the molten material **121** within the interior of the conduit **137** by passing the cooling fluid **303** along the exterior **305** of the conduit **137**. Optionally, the cooling fluid may be substantially free from oxygen. In some particular examples, the cooling fluid may comprise nitrogen although other chemical elements may be used that inhibit, such as prevent, oxidation of the conduit **137**. As shown in **FIG. 3**, the cooling fluid may optionally travel in a direction from the second station (e.g., the delivery vessel **133**) to the first station (e.g., the mixing chamber **131**). As mentioned previously, providing opposite flow directions of the cooling fluid and the molten material may enhance the temperature differential, and consequently the heat transfer rate, at the portion of the conduit adjacent the delivery vessel **133**.

[0055] The method can further include the step of directing the travel path **317** of the cooling fluid **303** toward the vertical plane **319** passing through the conduit **137**. In

one example, the at least one baffle **324a**, **324b** directs the travel path **317** of the cooling fluid **303**. For instance, as shown in **FIGS. 3 and 4**, the at least one baffle can include the first baffle **324a** that directs at least a first portion **317a** of the travel path **317** of the cooling fluid **303** from the first lateral side portion **403a** of the conduit **137** toward the vertical plane **319**. In another example, as further illustrated in **FIGS. 3 and 4**, the at least one baffle can further include the second baffle **324b** that similarly directs a second portion **317b** of the travel path **317** of the cooling fluid **303** from the second lateral side portion **403b** of the conduit **137** toward the vertical plane **319**. As shown in **FIG. 4**, the first portion **317a** and the second portion **317b** of the travel path **317** may converge together towards the vertical plane **319** passing through the conduit **137**. Indeed, first and second portions **317a**, **317b** of the travel path may be directed away from a lateral location outside the vertical footprint of the conduit **137** shown in **FIG. 4** (i.e., laterally outside the first and second lateral side portions **403a**, **403b**) toward the vertical plane **319** passing through the conduit **137**. Consequently, portions of the cooling fluid traveling along the first and second portions **317a**, **317b** of the travel path can be redirected to travel along the top portion **321** (or bottom portion) of the conduit to increase the rate of heat transfer. For example, as mentioned previously, the top portion **321** and/or the bottom portion may have a larger surface area when compared to the first and second lateral side portions **403a**, **403b**. Consequently increased heat transfer rates can be achieved by directing the cooling fluid to travel along the top portion and/or the bottom portion of the conduit rather than traveling along one or both of the lateral side portions.

[0056] Still further, directing cooling fluid to travel along the top and/or bottom portions may reduce or prevent formation of stagnant areas with little or no flow of cooling fluid. Indeed, the redirected cooling fluid will provide increased cooling fluid flow across the otherwise stagnant areas to further increase the rate of convective heat transfer.

[0057] In examples, with a concave inner surface **503**, the deflection panels **501** may provide a relatively smooth transition to avoid eddies, turbulence and/or pressure drops that may otherwise occur with an abrupt change in direction by other panel

configurations. Although not shown, the deflection panel may comprise a substantially flat panel although other configurations may be provided in further examples.

[0058] In further examples, the baffle can include the shroud **505** discussed above. If provided, the shroud can route the travel path of the cooling fluid into the deflection panel, wherein the deflection panel subsequently directs the travel path toward the vertical plane **219** passing through the conduit **137**.

[0059] It will be apparent to those skilled in the art that various modifications and variations can be made to the present disclosure without departing from the spirit and scope of the invention. Thus, it is intended that the present invention cover the modifications and variations of this disclosure provided they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. A method of processing molten material comprising the steps of:
 - (I) flowing molten material through an interior of a conduit from a first station to a second station of a glass manufacturing apparatus;
 - (II) cooling the molten material within the interior of the conduit by passing a cooling fluid along an exterior of the conduit; and
 - (III) directing a travel path of the cooling fluid toward a vertical plane passing through the conduit.
2. The method of claim 1, wherein at least one baffle directs the travel path of the cooling fluid during step (III).
3. The method of claim 2, wherein the at least one baffle includes a first baffle, and step (III) includes directing a first portion of the travel path of the cooling fluid from a first lateral side portion of the conduit toward the vertical plane with the first baffle.
4. The method of claim 3, wherein the at least one baffle further includes a second baffle, and step (III) further includes directing a second portion of the travel path of the cooling fluid from a second lateral side portion of the conduit toward the vertical plane with the second baffle.
5. The method of claim 2, wherein the at least one baffle includes a deflection panel extending at an angle relative to a travel path of the molten material flowing through the interior of the conduit, and step (III) includes directing the travel path of the cooling fluid with the deflection panel of the baffle.
6. The method of claim 5, wherein the at least one baffle further includes a shroud at least partially extending over a top portion of the conduit, and step (III) includes routing the travel path of the cooling fluid with the shroud to be directed by the deflection panel.

7. The method of claim 1, wherein step (III) further comprises directing the travel path of the cooling fluid over a top portion of the conduit.
8. The method of claim 1, wherein the vertical plane bisects the conduit.
9. The method of claim 1, wherein the cooling fluid travels in a direction from the second station toward the first station.
10. The method of claim 1, wherein the cooling fluid is substantially free from oxygen.
11. The method of claim 10, wherein the cooling fluid comprises nitrogen.
12. A glass manufacturing apparatus comprising:
 - a first station;
 - a second station;
 - a conduit configured to provide a travel path for molten material traveling from the first station to the second station; and
 - at least one baffle configured to direct a travel path of cooling fluid toward a vertical plane passing through the conduit.
13. The glass manufacturing apparatus of claim 12, wherein the first station comprises a mixing chamber.
14. The glass manufacturing apparatus of claim 12, wherein the second station comprises a delivery vessel.
15. The glass manufacturing apparatus of claim 12, wherein the at least one baffle includes a deflection panel extending at an angle relative to the travel path provided by the conduit.

16. The glass manufacturing apparatus of claim 15, wherein an outer end of the deflection panel is laterally positioned outside the travel path for the molten material.
17. The glass manufacturing apparatus of claim 15, wherein the deflection panel includes a concave inner surface facing toward the vertical plane.
18. The glass manufacturing apparatus of claim 12, wherein the at least one baffle includes a shroud at least partially extending over a top portion of the conduit.
19. The glass manufacturing apparatus of claim 18, wherein the at least one baffle further includes a deflection panel extending away from the shroud at an angle relative to the travel path of the conduit.
20. The glass manufacturing apparatus of claim 12, wherein the at least one baffle includes a first baffle including a first deflection panel extending at a first angle relative to the travel path provided by the conduit and a second baffle including a second deflection panel extending at a second angle relative to the travel path provided by the conduit, wherein the first deflection panel and the second deflection panel converge toward one another.

1 / 5

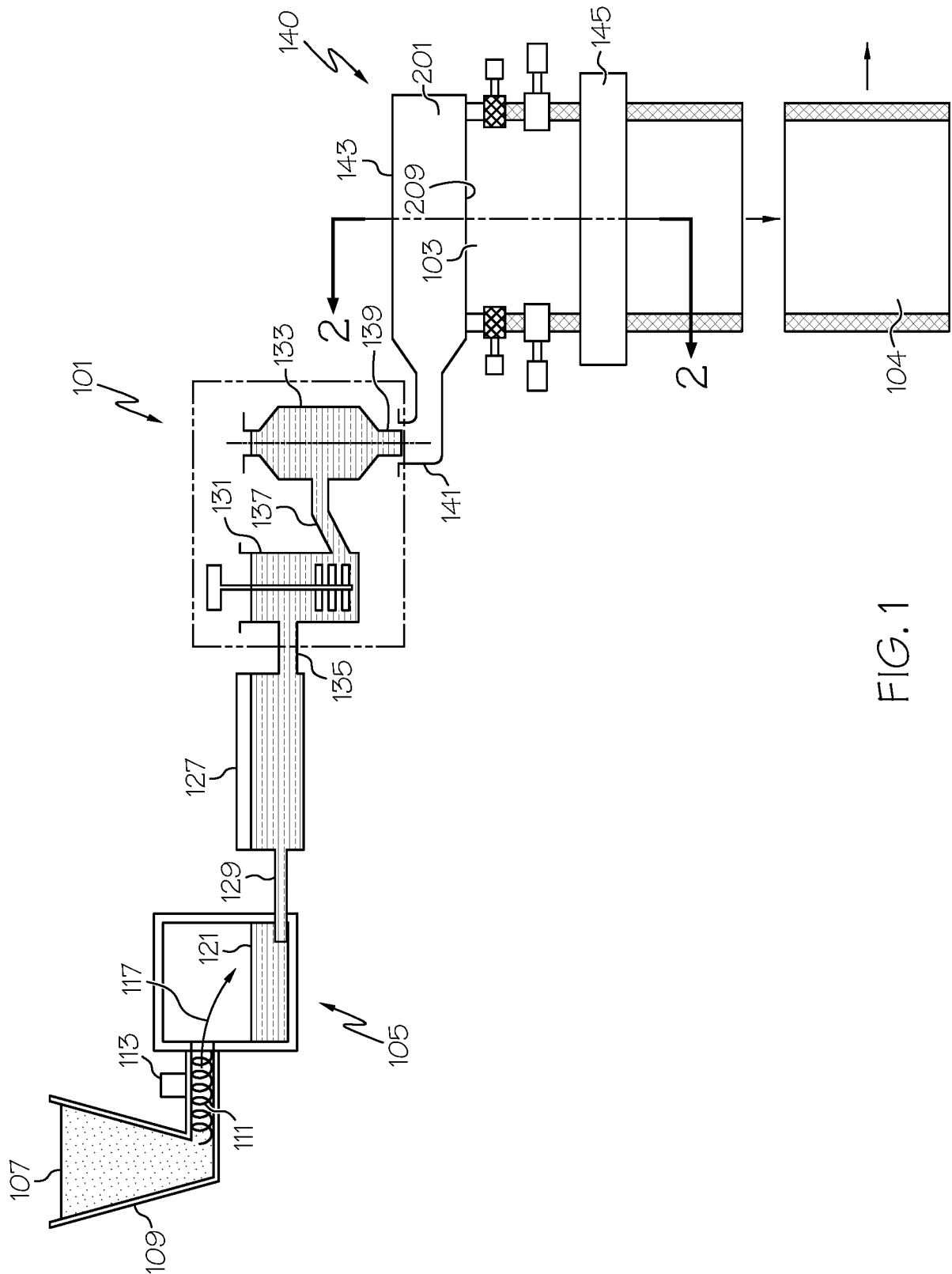


FIG. 1

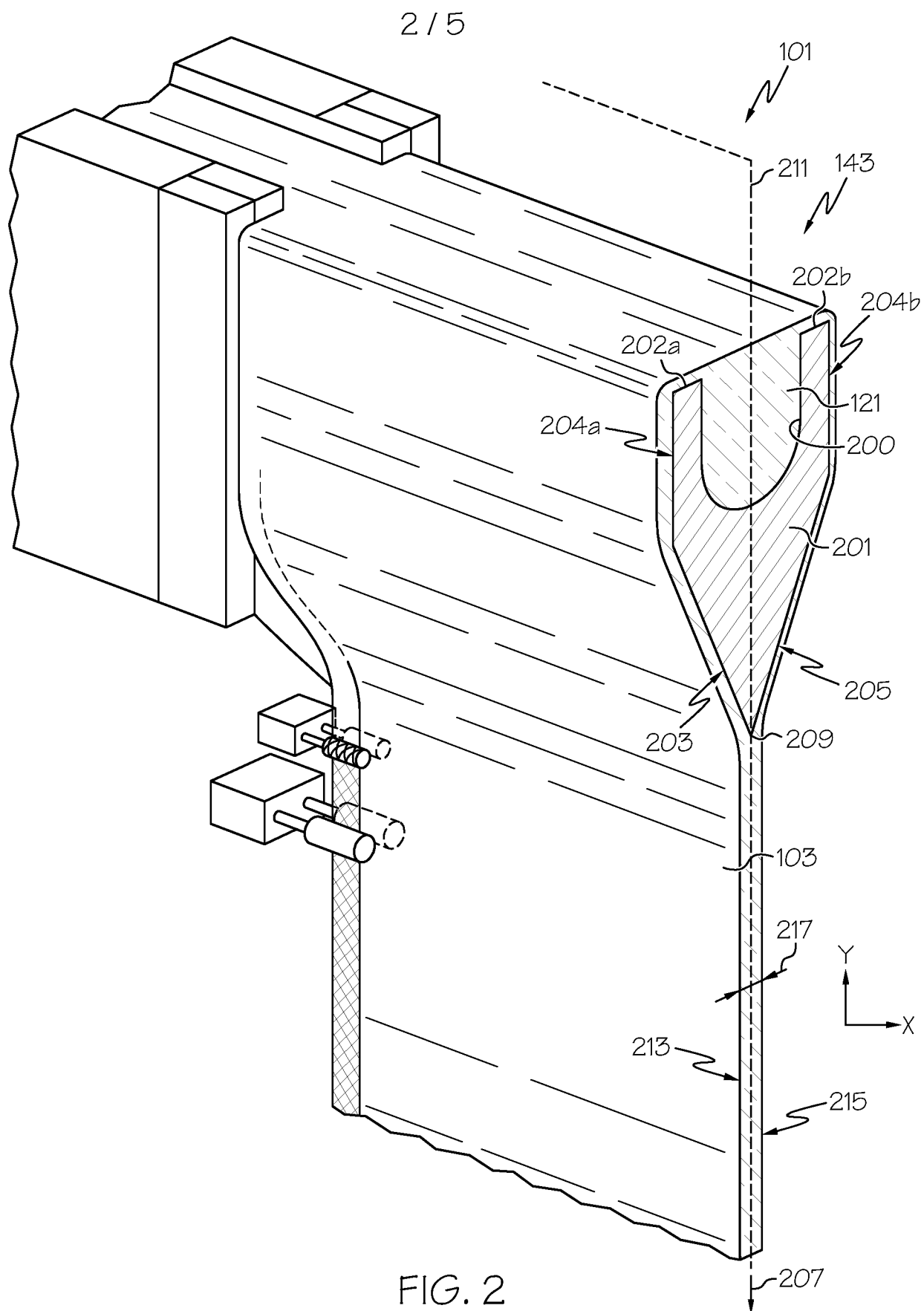
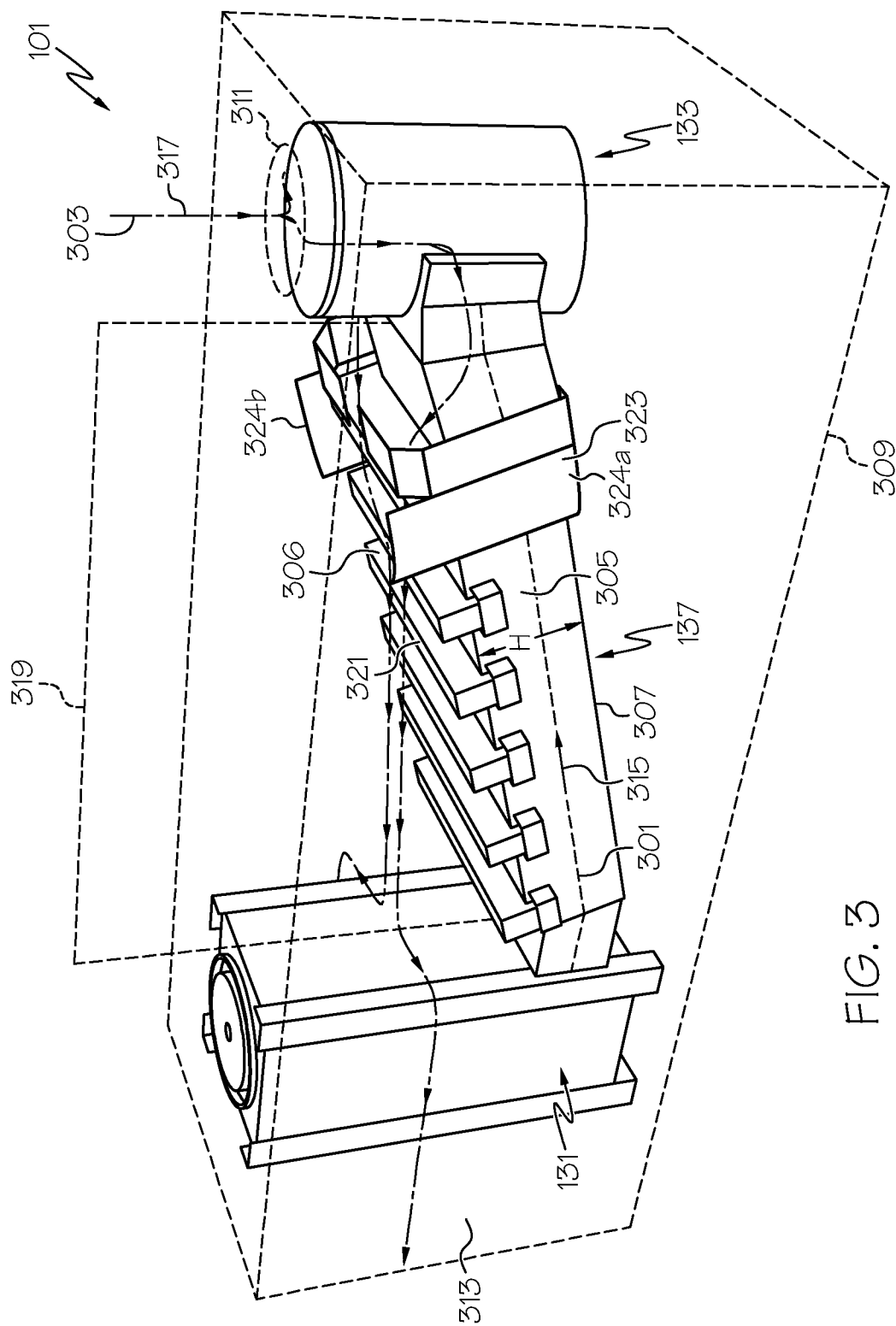


FIG. 2



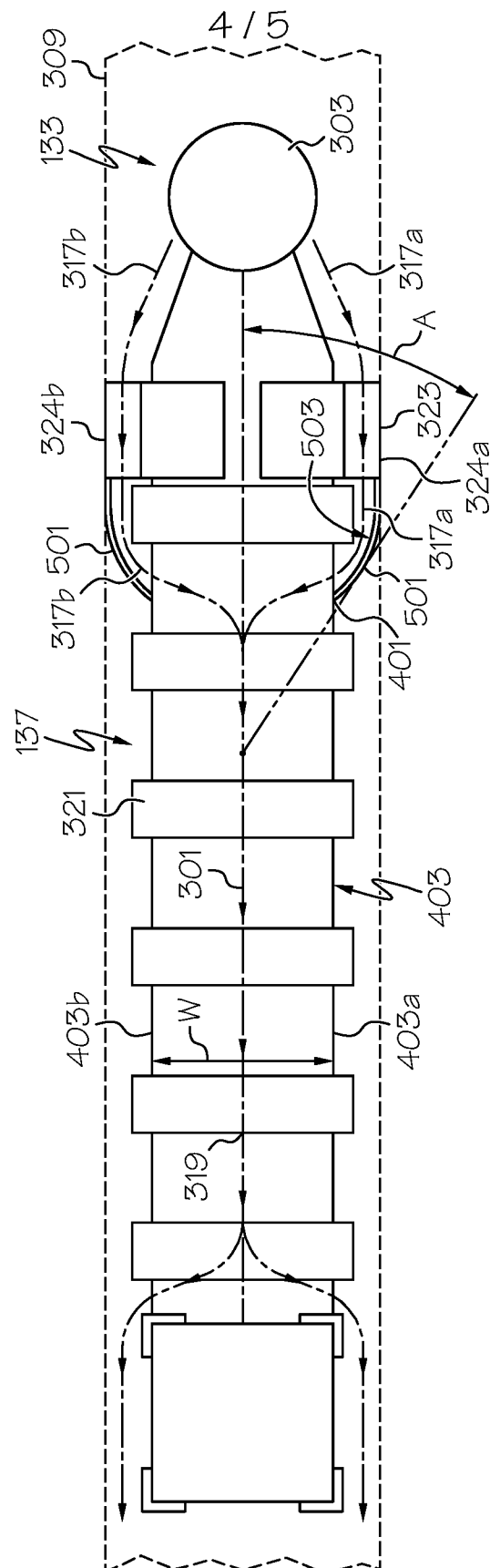


FIG. 4

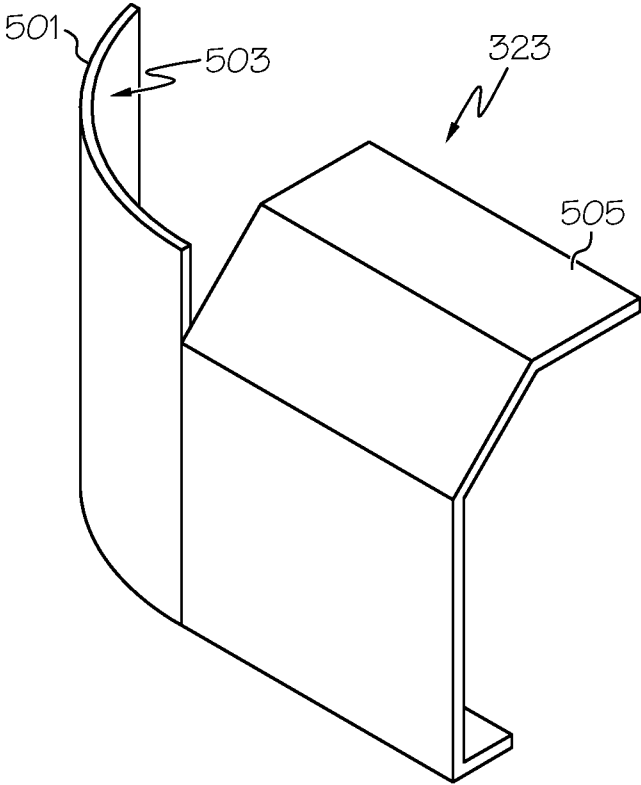


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/026901

A. CLASSIFICATION OF SUBJECT MATTER		
INV. C03B5/16	C03B5/167	C03B5/23 C03B7/06 C03B5/04
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, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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X	US 2014/144183 A1 (DEMIRBAS MEMDUH [US] ET AL) 29 May 2014 (2014-05-29) paragraph [0035]; figures 1,2 -----	12
X	US 2014/123710 A1 (LINEMAN DAVID MYRON [US] ET AL) 8 May 2014 (2014-05-08) figures 1,4,6 -----	12
X	WO 2006/115972 A1 (CORNING INC [US]; DEANGELIS GILBERT [US]; FRALEY RAYMOND E [US]; GIRT0) 2 November 2006 (2006-11-02) page 15, line 3 - page 16, line 25; claims 3,12,21; figure 1 page 19, lines 12-33 ----- -/-	1-20
☒ 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 28 June 2016		Date of mailing of the international search report 11/07/2016
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 Creux, Sophie

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2016/026901

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