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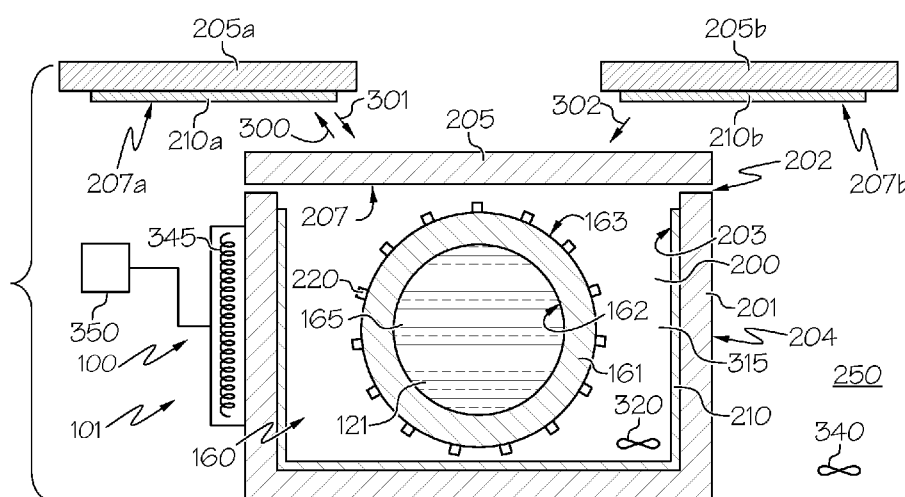


FIG. 3

(57) Abstract: A glass processing apparatus can include a vessel including a vessel wall with an inner surface defining a molten glass containment area. The glass processing apparatus can also include a housing including a housing wall with an inner surface spaced a distance from an outer surface of the vessel wall. The inner surface of the housing wall can face the outer surface of the vessel wall, and the inner surface of the housing wall can include an emissivity within a range of from about 0.75 to about 0.95. Methods of processing glass with a glass processing apparatus and methods of retrofitting a glass processing apparatus are also provided.



GLASS PROCESSING APPARATUS AND METHODS

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of priority of U.S. Provisional Application Serial No. 62/364,418 filed on July 20, 2016 the contents of which are relied upon and incorporated herein by reference in their entirety as if fully set forth below.

FIELD

[0002] The present disclosure relates generally to methods and apparatus for processing glass and, more particularly, to methods and apparatus for processing glass with a glass processing apparatus that includes a vessel including a vessel wall and a housing including a housing wall, where an inner surface of the housing wall is spaced a distance from an outer surface of the vessel wall.

BACKGROUND

[0003] It is known to process glass. It is further known to process molten glass in a molten glass containment area of a vessel.

SUMMARY

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

[0005] In some embodiments, a glass processing apparatus can include a vessel including a vessel wall with an inner surface defining a molten glass containment area. The glass processing apparatus can also include a housing including a housing wall with an inner surface spaced a distance from an outer surface of the vessel wall. The inner surface of the housing wall can face the outer surface of the vessel wall, and the inner surface of the housing wall can include an emissivity within a range of from about 0.75 to about 0.95.

[0006] In some embodiments, the inner surface of the housing wall can include black oxide.

[0007] In some embodiments, the housing wall can include stainless steel and the inner surface of the housing wall can include a layer of black oxide on the stainless steel.

[0008] In some embodiments, the layer of black oxide can include an emissivity within a range of from about 0.75 to about 0.95.

[0009] In some embodiments, a fluid circulation area can be defined between the inner surface of the housing wall and the outer surface of the vessel wall.

[0010] In some embodiments, the glass processing apparatus can include a fluid pressure source in fluid communication with the fluid circulation area.

[0011] In some embodiments, the vessel can include a plurality of protrusions extending from the outer surface of the vessel wall toward the inner surface of the housing wall.

[0012] In some embodiments, the plurality of protrusions can include a finned structure.

[0013] In some embodiments, the housing can be positioned within an environment, and the glass processing apparatus can include a fluid pressure source in fluid communication with the environment.

[0014] In some embodiments, the glass processing apparatus can include a cooling coil positioned on at least one of an outer surface or the inner surface of the housing wall, and the cooling coil can be in fluid communication with a cooling fluid source.

[0015] In some embodiments, a method of processing glass with a glass processing apparatus can include flowing molten glass through the molten glass containment area of the vessel, and cooling the vessel with radiation heat transfer by radiating heat from the outer surface of the vessel wall to the inner surface of the housing wall.

[0016] In some embodiments, the method can include cooling the housing with at least one of radiation heat transfer and convection heat transfer by transferring heat from an outer surface of the housing wall to an environment in which the housing is positioned.

[0017] In some embodiments, the method can include cooling the vessel with convection heat transfer by forcing cooling fluid through a fluid circulation area

defined between the inner surface of the housing wall and the outer surface of the vessel wall.

[0018] In some embodiments, the method can include mixing the molten glass as the molten glass flows through the molten glass containment area of the vessel.

[0019] In some embodiments, a temperature of the molten glass flowing into the molten glass containment area can be greater than a temperature of the molten glass flowing out of the molten glass containment area.

[0020] In some embodiments, a method of retrofitting a glass processing apparatus including a vessel including a vessel wall with an inner surface defining a molten glass containment area, and a housing including a first housing wall with an inner surface spaced a distance from an outer surface of the vessel wall, where the inner surface of the first housing wall faces the outer surface of the vessel wall, can include removing the first housing wall from a mounting location of the housing, and mounting a second housing wall at the mounting location, where an inner surface of the second housing wall has a higher emissivity than the inner surface of the first housing wall.

[0021] In some embodiments, the emissivity of the inner surface of the second housing wall can be within a range of from about 0.75 to about 0.95.

[0022] In some embodiments, the method can include modifying the first housing wall to provide the second housing wall.

[0023] In some embodiments, modifying the first housing wall can include increasing an emissivity of the inner surface of the first housing wall.

[0024] In some embodiments, increasing the emissivity can include forming black oxide on the inner surface of the first housing wall.

[0025] The above embodiments are exemplary and can be provided alone or in any combination with any one or more embodiments provided herein without departing from the scope of the disclosure. Moreover, 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

[0026] These and other features, embodiments, and advantages of the present disclosure can be further understood when read with reference to the accompanying drawings:

[0027] **FIG. 1** illustrates a schematic view of an exemplary glass processing apparatus in accordance with embodiments disclosed herein;

[0028] **FIG. 2** shows a schematic view of the region identified by numeral **2** of **FIG. 1** illustrating a vessel and a housing; and

[0029] **FIG. 3** shows a cross-sectional view of an exemplary vessel and housing along line **3-3** of **FIG. 2**.

DETAILED DESCRIPTION

[0030] Methods will now be described more fully hereinafter with reference to the accompanying drawings in which exemplary 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, this disclosure may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein.

[0031] Glass sheets are commonly fabricated by flowing molten glass to a forming body whereby a glass ribbon may be formed by a variety of ribbon forming processes including, float, slot draw, down-draw, fusion down-draw, up-draw, press roll or any other forming processes. The glass ribbon from any of these processes may then be subsequently divided to provide one or more glass sheets suitable for further processing into a desired application, including but not limited to, a display application. For example, the one or more glass sheets can be used in a variety of display applications, including liquid crystal displays (LCDs), electrophoretic displays

(EPD), organic light emitting diode displays (OLEDs), plasma display panels (PDPs), or the like.

[0032] **FIG. 1** schematically illustrates an exemplary glass processing apparatus **101** to process, manufacture, and form a glass ribbon **103**. The glass processing apparatus **101** can operate to provide a method of processing glass (represented by numeral **100**) that can, in some embodiments, include any one or more of the features of the glass processing apparatus **101** disclosed herein. For illustration purposes, the glass processing apparatus **101** is illustrated as a fusion down-draw apparatus, although other glass processing apparatus for up-draw, float, press rolling, slot draw, etc. may be provided in further embodiments. As illustrated, the glass processing apparatus **101** can include a melting vessel **105** oriented 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**. An optional controller **115** can be operated to activate the motor **113** such that the batch delivery device **111** can introduce a desired amount of batch material **107** into the melting vessel **105**, as indicated by arrow **117**. A glass melt probe **119** can be used to measure a level of molten material **121** within a standpipe **123** and communicate the measured information to the controller **115** by way of a communication line **125**.

[0033] The glass processing apparatus **101** can also include a fining vessel **127** located downstream from the melting vessel **105** and coupled to the melting vessel **105** by way of a first connecting conduit **129**. In some embodiments, molten material **121** may be gravity fed from the melting vessel **105** to the fining vessel **127** by way of the first connecting conduit **129**. For example, gravity may drive the molten material **121** through an interior pathway of the first connecting 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.

[0034] The glass processing apparatus **101** can further include a mixing chamber **131** that may be located downstream from the fining vessel **127**. In some embodiments, the mixing chamber **131** can include a stir shaft **150** including stir blades **151** to mix molten material **121** within the mixing chamber **131**. The mixing chamber **131** can be used to provide a homogenous composition of molten material **121**, thereby reducing or eliminating inhomogeneity that may otherwise exist within

the molten material **121** exiting the fining vessel **127**. As shown, the fining vessel **127** may be coupled to the mixing chamber **131** by way of a second connecting conduit **135**. In some embodiments, molten material **121** may be gravity fed from the fining vessel **127** to the mixing chamber **131** by way of the second connecting conduit **135**. For instance, gravity may drive the molten material **121** through an interior pathway of the second connecting conduit **135** from the fining vessel **127** to the mixing chamber **131**.

[0035] The glass processing apparatus **101** can further include a delivery vessel **133** that may be located downstream from the mixing chamber **131**. The delivery vessel **133** can condition the molten material **121** to be fed into a glass former **140**. For example, the delivery vessel **133** can function as an accumulator and/or flow controller to adjust and provide a consistent flow of molten material **121** to the glass former **140**. As shown, the mixing chamber **131** may be coupled to the delivery vessel **133** by way of a third connecting conduit **137**. In some embodiments, molten material **121** may be gravity fed from the mixing chamber **131** to the delivery vessel **133** by way of the third connecting conduit **137**. For instance, gravity may drive the molten material **121** through an interior pathway of the third connecting conduit **137** from the mixing chamber **131** to the delivery vessel **133**.

[0036] As further illustrated, a delivery pipe **139** can be positioned to deliver molten material **121** to the glass former **140** of the glass processing apparatus **101**. The glass former **140** may draw the molten material **121** into the glass ribbon **103** off of a root **145** of a forming vessel **143**. In the illustrated embodiment, the forming vessel **143** can be provided with an inlet **141** oriented to receive molten material **121** from the delivery pipe **139** of the delivery vessel **133**. In some embodiments, the forming vessel **143** can include a trough oriented to receive the molten material **121** from the inlet **141**. The forming vessel **143** can further include a forming wedge including a pair of downwardly inclined converging surface portions extending between opposed ends of the forming wedge. In some embodiments, the molten material **121** can flow from the inlet **141** into the trough of the forming vessel **143**. The molten material **121** can then overflow from the trough by simultaneously flowing over corresponding weirs and downward over the outer surfaces of the corresponding weirs. Respective streams of molten material **121** then flow along the

downwardly inclined converging surface portions of the forming wedge to be drawn off the root **145** of the forming vessel **143**, where the flows converge and fuse into the glass ribbon **103**. The glass ribbon **103** may then be fusion drawn off the root **145** with a width “**W**” of the glass ribbon **103** extending between a first vertical edge **147a** of the glass ribbon **103** and a second vertical edge **147b** of the glass ribbon **103**.

[0037] In some embodiments, a thickness of the glass ribbon **103** defined between a first major surface and a second major surface of the glass ribbon **103** can be, for example, from about 40 micrometers (μm) to about 1 millimeter (mm), for example, from about 40 micrometers to about 0.5 millimeters, for example, from about 40 micrometers to about 400 micrometers, for example, from about 40 micrometers to about 300 micrometers, for example, from about 40 micrometers to about 200 micrometers, for example, from about 40 micrometers to about 100 micrometers, or, for example, about 40 micrometers, although other thicknesses may be provided in further embodiments. In addition, the glass ribbon **103** can include a variety of compositions including but not limited to glass, ceramic, glass-ceramic, soda-lime glass, borosilicate glass, alumino-borosilicate glass, an alkali-containing glass, an alkali-free glass, or any combination thereof.

[0038] As shown in **FIG. 2**, which schematically illustrates a region of the glass processing apparatus **101** identified by numeral **2** in **FIG. 1**, the glass processing apparatus **101** can include a vessel **160** including a vessel wall **161** with a vessel wall inner surface **162** defining a molten glass containment area **165**. Although not shown, the top of the molten glass containment area **165** may be capped with a lid to seal the molten glass containment area **165**. In addition, the glass processing apparatus **101** can include a housing **200** including a housing wall **201** with a housing wall inner surface **203** spaced a distance from an outer surface **163** of the vessel wall **161**. In some embodiments, the vessel **160** can include any one or more features of the second connecting conduit **135**, the mixing chamber **131**, and the third connecting conduit **137**. Similarly, the housing **200** can provide an enclosure and a corresponding controlled atmosphere within the enclosure that can extend around the vessel **160** at a spaced distance and protect the vessel **160** from external disturbances. Accordingly, the vessel **160** and the housing **200** are shown to provide an exemplary, non-limiting embodiment of methods and apparatus in accordance with embodiments of the

disclosure, and it is to be understood that the methods and apparatus of the disclosure can be implemented alone or in combination with any one or more vessels and housings employed in methods of processing glass **100** with the glass processing apparatus **101**, as well as with any one or more vessels and housings not specifically disclosed herein.

[0039] In some embodiments, the method of processing glass **100** with the glass processing apparatus **101** can include flowing molten glass (e.g., molten material **121**) through the molten glass containment area **165** of the vessel **160**, and cooling the vessel **160** with radiation heat transfer by radiating heat from the vessel wall outer surface **163** to the housing wall inner surface **203**. In some embodiments, the method can include mixing the molten material **121** as the molten material **121** flows through the molten glass containment area **165** of the vessel **160**. For example, the stir shaft **150** and the stir blades **151** can move (e.g., rotate) within the molten glass containment area **165** of the vessel **160** to mix the molten material **121**. In some embodiments, the molten glass containment area **165** can define any one or more of a container in which molten material **121** can be held in either a stationary or non-stationary state, a passage through which molten material **121** can flow (e.g., without additional processing of the molten material **121**), and a container or passage in which additional processing of and interaction with the molten material **121** can occur (e.g., mixing, heating, cooling, etc.). In some embodiments, the molten glass containment area **165** of the vessel **160** can include a free surface of molten material **121** where a portion of an interior region of the vessel **160** may not be occupied by the molten material **121**. Alternatively, the interior region of the vessel **160** can be entirely occupied with molten material **121**, in some embodiments, and the molten glass containment area **165** can abut molten material **121** around an entire periphery of the molten glass containment area **165**.

[0040] In some embodiments, the method of processing glass **100** with the glass processing apparatus **101** can include cooling (e.g., conditioning) molten material **121** to provide molten glass with at least one of a temperature and a viscosity that is suitable for forming glass (e.g., glass ribbon **103**). In some embodiments, the molten material **121** can cool as the molten material **121** flows through the molten glass containment area **165** of the vessel **160**. For example, in some embodiments, a

first temperature “T1” of the molten glass flowing into the molten glass containment area 165 can be greater than a second temperature “T2” of the molten glass flowing out of the molten glass containment area 165. Accordingly, the first temperature “T1” being greater than the second temperature “T2” can indicate that heat has been removed from the molten material 121 between a time when the molten material 121 flowed into the molten glass containment area 165 and a time when the molten material 121 flowed out of the molten glass containment area 165. Likewise, the first temperature “T1” being greater than the second temperature “T2” can indicate that heat has been removed from the molten material 121 between a location where the molten material 121 flowed into the molten glass containment area 165 and a location where the molten material 121 flowed out of the molten glass containment area 165.

[0041] Any one or more of conduction heat transfer, convection heat transfer, and radiation heat transfer can define the cooling of the molten material 121 as heat transfers from the molten material 121 to the vessel 160 (e.g., the vessel wall inner surface 162), through the vessel wall 161 (e.g., from the vessel wall inner surface 162 to the vessel wall outer surface 163), from the vessel 160 (e.g., the vessel wall outer surface 163) to the housing 200 (e.g., the housing wall inner surface 203), through the housing wall 201 (e.g., from the housing wall inner surface 203 to the housing wall outer surface 204), and from the housing 200 (e.g., the housing wall outer surface 204) to the environment 250. In some embodiments, the environment 250 can include a room in which the housing 200 can be positioned as well as any one or more objects that are at least one of positioned within the room and surrounding the housing 200.

[0042] Accordingly, an amount of heat that can be transferred (e.g., removed) from the molten material 121 to cool the molten material 121 can be based at least in part on a rate at which heat can transfer from the molten material 121, through the vessel wall 161, through the housing wall 201, and to the environment 250. In some embodiments, it may be desirable to increase throughput and output of the method of processing glass 100 with the glass processing apparatus 101 to, for example, increase a rate at which the glass ribbon 103 is produced. In some embodiments, increased throughput and output of the method of processing glass 100 with the glass processing apparatus 101 can correspond to increased flow rates of the molten material 121 through the glass processing apparatus 101. When operating the glass processing

apparatus **101** with increased flow rates of molten material **121**, a corresponding increase in the rate of heat transfer from the molten material **121** to the environment **250** can be provided to at least one of maintain and increase a rate of cooling of the molten material **121** (e.g., to provide the molten material **121** with at least one of a temperature and a viscosity that is suitable for forming glass). The methods and apparatus of the disclosure can therefore provide cooling rates of the molten material **121** that cannot be obtained from existing glass processing apparatus and methods of processing glass. Additionally, the methods and apparatus of the disclosure can provide increased cooling rates of the molten material **121** within the glass processing apparatus **101** without significant modification of the methods of processing glass **100** and without significant modification of the glass processing apparatus **101**.

[0043] For example, as shown in **FIG. 3**, the housing wall inner surface **203** can face the vessel wall outer surface **163**. In addition, in some embodiments, the housing wall inner surface **203** can circumscribe the vessel wall outer surface **163**. In some embodiments, the housing wall inner surface **203** can include an emissivity within a range of from about 0.75 to about 0.95, for example, from about 0.8 to about 0.95, for example, from about 0.85 to about 0.95, for example, from about 0.9 to about 0.95, for example, about 0.95, including any ranges and subranges therebetween. The emissivity coefficient of an object can be defined between 0 and 1, where 0 indicates that the object reflects all radiation that radiates to its surface and 1 indicates that the object absorbs all radiation that radiates to its surface (e.g., a black body). Providing a housing wall inner surface **203** with an emissivity within a range of from about 0.75 to about 0.95, for example, from about 0.8 to about 0.95, for example, from about 0.85 to about 0.95, for example, from about 0.9 to about 0.95, for example, about 0.95, including any ranges and subranges therebetween, can define at least in part the radiation heat transfer characteristics of the housing wall **201** relative to the vessel wall **161**.

[0044] In some embodiments, the housing wall inner surface **203** can therefore absorb more and reflect less of the radiation that radiates from the vessel **160**. By absorbing more radiation, the housing **200** can remove more heat from the vessel **160**, and the vessel **160** can therefore remove more heat from the molten material **121**. Thus, in some embodiments, increasing the emissivity of the housing

wall inner surface **203** can increase radiation heat transfer between the vessel wall outer surface **163** and the housing wall inner surface **203**. Providing a housing wall inner surface **203** with an emissivity that permits radiation heat transfer from the vessel **160** to the housing **200** can, in some embodiments, increase the rate at which heat can likewise be transferred from the molten material **121** to the environment **250**, thus increasing the rate at which the molten material **121** can be cooled within the molten glass containment area **165** of the vessel **160**.

[0045] In some embodiments, the housing wall inner surface **203** can include a material that increases the emissivity. For example, in some embodiments, the housing wall inner surface **203** can include any one or more of a paint, a coating, a treatment, and any other surface or surface covering that includes an emissivity with a range of from about 0.75 to about 0.95, for example, from about 0.8 to about 0.95, for example, from about 0.85 to about 0.95, for example, from about 0.9 to about 0.95, for example, about 0.95, including any ranges and subranges therebetween. In some embodiments, black oxide **210** can be provided to provide the housing wall inner surface **203** with an emissivity within a range of from about 0.75 to about 0.95, for example, from about 0.8 to about 0.95, for example, from about 0.85 to about 0.95, for example, from about 0.9 to about 0.95, for example, about 0.95, including any ranges and subranges therebetween. In some embodiments, unless otherwise noted, any one or more materials, processes, and surfaces including materials, processes, and surfaces not explicitly disclosed herein can be provided to provide the housing wall inner surface **203** with an emissivity within a range of from about 0.75 to about 0.95, for example, from about 0.8 to about 0.95, for example, from about 0.85 to about 0.95, for example, from about 0.9 to about 0.95, for example, about 0.95, including any ranges and subranges therebetween, without departing from the scope of the disclosure.

[0046] In some embodiments, the housing wall inner surface **203** can include black oxide **210**, which, in embodiments described herein, is to be understood as a material that can decrease the thermal radiation reflective qualities of a surface and increase the thermal radiation absorption qualities of a surface and can be provided by a black oxide generating process, including, for example, at least one process as described herein. For example, in some embodiments, the black oxide **210** can be

provided as a coating on the housing wall inner surface **203** that is formed by a chemical reaction between the housing wall inner surface **203** and a solution (e.g., bath). In some embodiments, black oxide **210** can be provided as a conversion coating where the housing wall inner surface **203** can be converted into the black oxide **210** with a chemical or electro-chemical process. Accordingly, in some embodiments, the conversion coating can have little to no dimensional impact on the housing wall **201** by providing a coating layer that is about one micrometer thick or less. In some embodiments, the black oxide **210** can conform to any one or more military specifications including but not limited to MIL-DTL-13924D (MIL-C-13924C) Class 1, 2, 3, and 4.

[0047] In some embodiments, a hot black oxide process can be employed including a solution of at least one of sodium hydroxide, nitrates, and nitrites at about 285° F to about 300° F. In some embodiments, black oxide **210** can be provided using an oxidation process with a solution including at least one of a caustic, oxidizing, sulfur salt (e.g., an alkaline aqueous salt solution) at high temperature, for example a temperature of between about 285° F to about 300° F, for example about 300° F. In some embodiments, the solution can convert the housing wall inner surface **203** to the black oxide **210**. In some embodiments, a mid-temperature black oxide process can be employed that includes a solution at a temperature of about 220° F to 245° F that converts the housing wall inner surface **203** to the black oxide **210**. In some embodiments, a cold black oxide process can be employed that includes a solution at about room temperature (e.g., about 70° F). For example, in some embodiments, rather than converting the housing wall inner surface **203** to the black oxide **210**, the cold black oxide process can provide a deposited layer of black oxide **210** on the housing wall inner surface **203**.

[0048] In some embodiments, the housing wall **201** can include stainless steel, and the housing wall inner surface **203** can include at least one of a deposited layer of black oxide **210** on the stainless steel and a converted layer of black oxide **210**. For example, in some embodiments, a hot black oxide process can include a chemical reaction between iron or ferrous alloys of the housing wall inner surface **203** and the solution (e.g., bath) that can at least one of produce magnetite (Fe_3O_4) on the housing wall inner surface **203** and convert the housing wall inner surface **203** to magnetite.

In some embodiments, a cold black oxide process can include an auto-catalytic reaction of copper-selenide depositing on the stainless steel of the housing wall inner surface **203**. In some embodiments, the stainless steel can be a 300 series or a 400 series stainless steel. In some embodiments a 304 stainless steel (304-SS) with an emissivity (e.g., prior to blackening) of about 0.6 can be provided. In some embodiments, after blackening, the 304 stainless steel with the black oxide **210** can conform to military specification MIL-DTL-13924D (MIL-C-13924C) Class 4. In some embodiments, other metals, including but not limited to, ferrous materials, non-ferrous materials, steel, copper, zinc, ferrous alloys, non-ferrous alloys, copper based alloys, brass, bronze, and powdered metals can be provided. In some embodiments, the layer of black oxide **210** can include an emissivity within a range of from about 0.75 to about 0.95, for example, from about 0.8 to about 0.95, for example, from about 0.85 to about 0.95, for example, from about 0.9 to about 0.95, for example, about 0.95, including any ranges and subranges therebetween, to provide the housing wall inner surface **203** with beneficial characteristics including good absorption of thermal radiation. Moreover, in some embodiments, the layer of black oxide **210** can provide the housing wall inner surface **203** with abrasion resistance as well as protection against corrosion.

[0049] In some embodiments, a process of increasing an emissivity of the housing wall **201** can include dipping (e.g., submerging) the housing wall **201** in a solution (e.g., bath), including but not limited to any one or more of the solutions provided in the present disclosure, that blackens both the housing wall inner surface **203** and the housing wall outer surface **204**. Accordingly, in some embodiments, at least one of the housing wall inner surface **203** and the housing wall outer surface **204** can include an emissivity within a range of from about 0.75 to about 0.95, for example, from about 0.8 to about 0.95, for example, from about 0.85 to about 0.95, for example, from about 0.9 to about 0.95, for example, about 0.95, including any ranges and subranges therebetween, without departing from the scope of the disclosure.

[0050] In some embodiments, a fluid circulation area **315** can be defined between the housing wall inner surface **203** and the vessel wall outer surface **163** and can include a fluid (e.g., liquid, gas). Natural convection heat transfer can occur

within the fluid circulation area **315** with heat transferring from the vessel **160** to fluid within the fluid circulation area **315** and from the fluid to the housing **200** based at least in part on movement of the fluid from buoyancy forces created by density differences from thermal variations within the fluid in the fluid circulation area **315**. In some embodiments, the glass processing apparatus **101** can include a first fluid pressure source **320** (e.g., fan, blower, vacuum, pump, etc.) in fluid communication with the fluid circulation area **315**. The first fluid pressure source **320** can provide movement (e.g., forced flow) of the fluid within the fluid circulation area **315** to cause forced convection heat transfer from the vessel **160** to fluid within the fluid circulation area **315** and from the fluid to the housing **200**. Accordingly, in some embodiments, the method can include cooling the vessel **160** with convection heat transfer by forcing cooling fluid through the fluid circulation area **315** defined between the housing wall inner surface **203** and the vessel wall outer surface **163**.

[0051] In some embodiments, the vessel **160** can include a plurality of protrusions **220** extending from the vessel wall outer surface **163** toward the housing wall inner surface **203**. In some embodiments, as shown, the plurality of protrusions **220** can include a finned structure including a plurality of fins. The plurality of protrusions **220** can increase heat transfer from the vessel wall **161** and therefore increase the rate at which heat can be removed from the molten material **121** within the molten glass containment area **165** of the vessel **160**. For example, the plurality of protrusions **220** can increase at least one of convection heat transfer and radiation heat transfer by providing a greater surface area of the vessel wall outer surface **163** that can increase the rate at which heat can transfer from the vessel wall outer surface **163** to the housing **200**.

[0052] In some embodiments, the plurality of protrusions **220** can be employed together with the first fluid pressure source **320** and the corresponding movement of the fluid within the fluid circulation area **315** from the first fluid pressure source **320** to remove heat from the vessel **160** by increasing the rate of heat transfer from the vessel **160** to the fluid within the fluid circulation area **315** and from the fluid to the housing **200**. For example, in some embodiments, any one or more protrusions **220** can include a dimension defining at least in part a distance from the vessel wall outer surface **163** which the any one or more protrusions **220** extends. In

some embodiments, the distance which the protrusions **220** extend can correspond to the additional surface area provided on the vessel wall outer surface **163**, with a larger distance providing greater additional surface area relative to the additional surface area provided by a comparatively smaller distance. In some embodiments, the larger the additional surface area provided on the vessel wall outer surface **163**, the greater the rate of heat transfer from the vessel **160**. However, in some embodiments, for example, when movement of the fluid within the fluid circulation area **315** from the first fluid pressure source **320** is not provided, additional surface area provided on the vessel wall outer surface **163** may not provide greater heat transfer from the vessel **160**. For example, in some embodiments, the plurality of protrusions **220** may create isolated cavities in which fluid can stagnant, trapping heat, and thus slowing the rate of heat transfer from the vessel **160**. Accordingly, in some embodiments, the first fluid pressure source **320** can provide the corresponding movement of the fluid within the fluid circulation area **315** to circulate the stagnated air, thus removing heat from the vessel **160** by increasing the rate of heat transfer from the vessel **160** to the fluid within the fluid circulation area **315** and from the fluid to the housing **200**.

[0053] In some embodiments, a second fluid pressure source **340** (e.g., fan, blower, vacuum, pump, etc.) in fluid communication with the environment **250** can be positioned outside the housing **200** to provide movement (e.g., forced flow) of fluid within the environment **250**. The second fluid pressure source **340** can cause forced convection heat transfer from the housing **200** (e.g., housing wall outer surface **204**) to the environment **250**. In addition to forced convection heat transfer, natural convection heat transfer can occur within the environment **250** with heat transferring from the housing **200** to fluid within the environment **250** based at least in part on movement of the fluid from buoyancy forces created by density differences from thermal variations within the fluid in the environment **250**. Accordingly, in some embodiments, the method can include cooling the housing **200** with convection heat transfer by forcing cooling fluid over the housing wall outer surface **204**. In some embodiments, a cooling coil **345** can be positioned adjacent to or in contact with the housing wall outer surface **204**, although in further embodiments the cooling coil **345** may be positioned on the inner surface **203**. If positioned on the inner surface, the cooling coil may be treated with a black oxide material to increase the emissivity of

the cooling coil. Cooling fluid can be provided from a cooling fluid source **350** (e.g., pump, vacuum, etc.) in fluid communication with the cooling coil **345** to circulate cooling fluid through the cooling coil **345**. The circulating fluid can remove heat from the housing **200** by increasing a rate of heat transfer from the housing wall outer surface **204** and/or the inner surface **203**. Accordingly, in some embodiments, the method can include cooling the housing **200** by forcing cooling fluid through the cooling coil **345** positioned adjacent to or in contact with the housing wall outer surface **204** and/or the inner surface **203**.

[0054] In some embodiments, as illustrated schematically in **FIG. 3**, a method of retrofitting the glass processing apparatus **101** can include removing a first housing wall **205** from a mounting location **202** of the housing **200** (as illustrated by arrow **300**), and mounting a second housing wall **205a**, **205b** at the mounting location **202** (as shown by arrow **301** and arrow **302**). The method of retrofitting can provide a second housing wall inner surface **207a**, **207b** with a higher emissivity than the emissivity of the first housing wall inner surface **207**. In some embodiments, the emissivity of the second housing wall inner surface **207a**, **207b** can be within a range of from about 0.75 to about 0.95, for example, from about 0.8 to about 0.95, for example, from about 0.85 to about 0.95, for example, from about 0.9 to about 0.95, for example, about 0.95, including any ranges and subranges therebetween. In some embodiments, the higher emissivity of the second housing wall inner surface **207a**, **207b** can include the same or similar features as the emissivity including the black oxide **210** discussed herein with respect to the housing wall inner surface **203**. Therefore, in some embodiments, the higher emissivity of the second housing wall inner surface **207a**, **207b** can increase radiation heat transfer between the vessel wall outer surface **163** and the second housing wall inner surface **207a**, **207b**. Providing the second housing wall inner surface **207a**, **207b** with the higher emissivity can increase radiation heat transfer from the vessel **160** to the housing **200** and increase the rate at which heat can likewise be transferred from the molten material **121** to the environment **250**. The method of retrofitting can therefore increase the rate at which the molten material **121** can be cooled within the molten glass containment area **165** of the vessel **160**.

[0055] Additionally, retrofitting can be beneficial in applications where a vessel **160** and housing **200** are already employed and it may be desirable to modify at least one of the vessel **160** and the housing **200** rather than to replace that at least one of the vessel **160** and the housing **200**. For example, retrofitting a component can be less expensive than replacing or constructing the component anew. In addition, in some embodiments, retrofitting can reuse a particular component of the glass processing apparatus **101** that may have already been designed (e.g., fabricated, machined) to serve a specified purpose within the method of processing glass **100** with which modification of that component does not interfere. For example, in some embodiments, the method of retrofitting can include providing black oxide **210a**, **210b** on the second housing wall inner surface **207a**, **207b**. In some embodiments, the layer of black oxide **210a**, **210b** can be provided on the second housing wall inner surface **207a**, **207b** without impacting the dimensions of the housing wall **201**. Thus, for purposes of positioning and constructing the housing **200** as well as positioning other components in relation to the housing **200**, the method of retrofitting the glass processing apparatus **101** can be performed without making significant structural changes to the glass processing apparatus **101**. Accordingly, the methods of retrofitting the glass processing apparatus **101** in accordance with the disclosure can provide several advantages not obtainable with other methods or apparatus.

[0056] As illustrated by arrow **301**, in some embodiments, the method of retrofitting can include modifying the first housing wall **205** to provide the second housing wall **205a**. For example, in some embodiments, modifying the first housing wall **205** can include increasing an emissivity of the first housing wall inner surface **207** to provide the second housing wall **205a** with the second housing wall inner surface **207a** that includes the higher emissivity than the emissivity of the first housing wall inner surface **207**. In some embodiments, modifying the first housing wall **205** can include providing the layer of black oxide **210a** on the first housing wall inner surface **207** to provide the second housing wall **205a** including the second housing wall inner surface **207a** with the corresponding layer of black oxide **210a**. The second housing wall **205a** can then be mounted (e.g., remounted) at the mounting location **202** with the second housing wall inner surface **207a** facing the vessel wall outer surface **163**.

[0057] Alternatively, as illustrated by arrow **302**, in some embodiments, a different second housing wall **205b** that includes a corresponding different layer of black oxide **210b** can be mounted at the mounting location **202** with a different second housing wall inner surface **207b** facing the vessel wall outer surface **163**. For example, in some embodiments, the first housing wall **205** can be removed (as illustrated by arrow **300**) and the different second housing wall **205b** can be mounted at the mounting location **202** (as illustrated by arrow **302**) to replace the first housing wall **205** and provide the different second housing wall inner surface **207b** with the higher emissivity than the emissivity of the first housing wall inner surface **207**. Replacing the first housing wall **205** with the different second housing wall **205b** can be employed in embodiments where, for example, the first housing wall **205** is damaged and replacing the first housing wall **205** can provide a less expensive option than, for example, repairing the first housing wall **205**.

[0058] It will be appreciated that the various disclosed embodiments may involve particular features, elements or steps that are described in connection with that particular embodiment. It will also be appreciated that a particular feature, element or step, although described in relation to one particular embodiment, may be interchanged or combined with alternate embodiments in various non-illustrated combinations or permutations.

[0059] It is to be understood that, as used herein the terms "the," "a," or "an," mean "at least one," and should not be limited to "only one" unless explicitly indicated to the contrary. Thus, for example, reference to "a component" includes embodiments having two or more such components unless the context clearly indicates otherwise.

[0060] Ranges can be expressed herein as from "about" one particular value, and/or to "about" another particular value. When such a range is expressed, embodiments include from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by use of the antecedent "about," it will be understood that the particular value forms another aspect. It will be further understood that the endpoints of each of the ranges are significant both in relation to the other endpoint, and independently of the other endpoint.

[0061] Unless otherwise expressly stated, it is in no way intended that any method set forth herein be construed as requiring that its steps be performed in a specific order. Accordingly, where a method claim does not actually recite an order to be followed by its steps or it is not otherwise specifically stated in the claims or descriptions that the steps are to be limited to a specific order, it is no way intended that any particular order be inferred.

[0062] While various features, elements or steps of particular embodiments may be disclosed using the transitional phrase "comprising," it is to be understood that alternative embodiments, including those that may be described using the transitional phrases "consisting" or "consisting essentially of," are implied. Thus, for example, implied alternative embodiments to an apparatus that comprises A+B+C include embodiments where an apparatus consists of A+B+C and embodiments where an apparatus consists essentially of A+B+C.

[0063] 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 disclosure. Thus, it is intended that the present disclosure cover the modifications and variations of this disclosure provided they come within the scope of the appended claims and their equivalents.

CLAIMS

What is claimed is:

1. A glass processing apparatus comprising:
 - a vessel comprising a vessel wall with an inner surface defining a molten glass containment area; and
 - a housing comprising a housing wall with an inner surface spaced a distance from an outer surface of the vessel wall, wherein the inner surface of the housing wall faces the outer surface of the vessel wall, and wherein the inner surface of the housing wall comprises an emissivity within a range of from about 0.75 to about 0.95.
2. The glass processing apparatus of claim 1, wherein the inner surface of the housing wall comprises black oxide.
3. The glass processing apparatus of claim 1, wherein the housing wall comprises stainless steel, and wherein the inner surface of the housing wall comprises a layer of black oxide on the stainless steel.
4. The glass processing apparatus of claim 3, wherein the layer of black oxide comprises an emissivity within a range of from about 0.75 to about 0.95.
5. The glass processing apparatus of claim 1, wherein a fluid circulation area is defined between the inner surface of the housing wall and the outer surface of the vessel wall.
6. The glass processing apparatus of claim 5, further comprising a fluid pressure source in fluid communication with the fluid circulation area.
7. The glass processing apparatus of claim 1, wherein the vessel comprises a plurality of protrusions extending from the outer surface of the vessel wall toward the inner surface of the housing wall.

8. The glass processing apparatus of claim 7, wherein the plurality of protrusions comprise a finned structure.
9. The glass processing apparatus of claim 1, wherein the housing is positioned within an environment, and wherein the glass processing apparatus further comprises a fluid pressure source in fluid communication with the environment.
10. The glass processing apparatus of claim 1, further comprising a cooling coil positioned on at least one of an outer surface of the housing wall or the inner surface of the housing wall, and wherein the cooling coil is in fluid communication with a cooling fluid source.
11. A method of processing glass with the glass processing apparatus of claim 1, comprising:
 flowing molten glass through the molten glass containment area of the vessel;
 and
 cooling the vessel with radiation heat transfer by radiating heat from the outer surface of the vessel wall to the inner surface of the housing wall.
12. The method of claim 11, further comprising cooling the housing with at least one of radiation heat transfer and convection heat transfer by transferring heat from an outer surface of the housing wall to an environment in which the housing is positioned.
13. The method of claim 11, further comprising cooling the vessel with convection heat transfer by forcing cooling fluid through a fluid circulation area defined between the inner surface of the housing wall and the outer surface of the vessel wall.
14. The method of claim 11, further comprising mixing the molten glass as the molten glass flows through the molten glass containment area of the vessel.

15. The method of claim 11, wherein a temperature of the molten glass flowing into the molten glass containment area is greater than a temperature of the molten glass flowing out of the molten glass containment area.

16. A method of retrofitting a glass processing apparatus comprising a vessel comprising a vessel wall with an inner surface defining a molten glass containment area, and a housing comprising a first housing wall with an inner surface spaced a distance from an outer surface of the vessel wall, wherein the inner surface of the first housing wall faces the outer surface of the vessel wall, the method comprising:

removing the first housing wall from a mounting location of the housing; and
mounting a second housing wall at the mounting location, wherein an inner surface of the second housing wall has a higher emissivity than the inner surface of the first housing wall.

17. The method of claim 16, wherein the emissivity of the inner surface of the second housing wall is within a range of from about 0.75 to about 0.95.

18. The method of claim 16, comprising modifying the first housing wall to provide the second housing wall.

19. The method of claim 18, wherein modifying the first housing wall comprises increasing an emissivity of the inner surface of the first housing wall.

20. The method of claim 19, wherein increasing the emissivity comprises forming black oxide on the inner surface of the first housing wall.

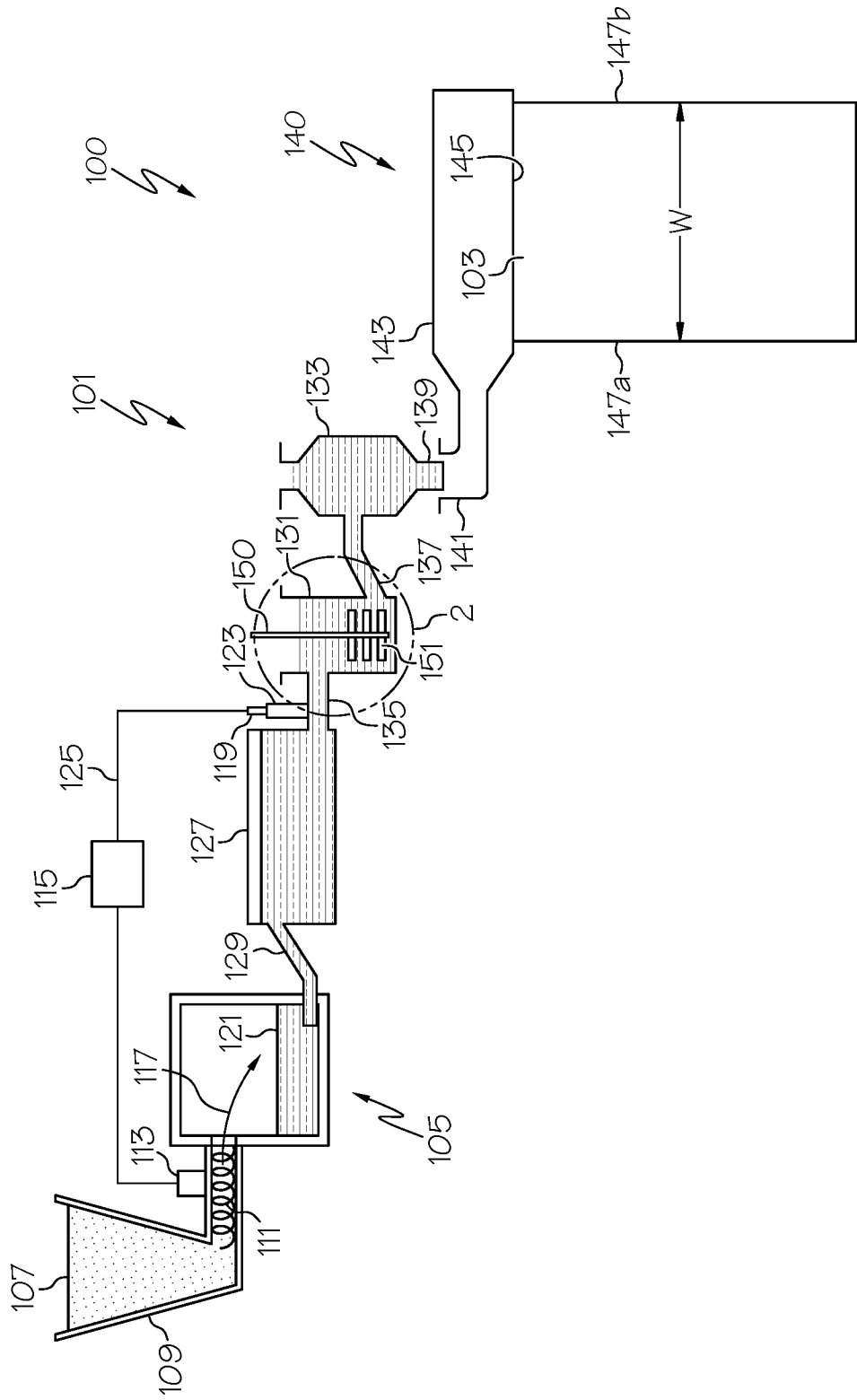


FIG. 1

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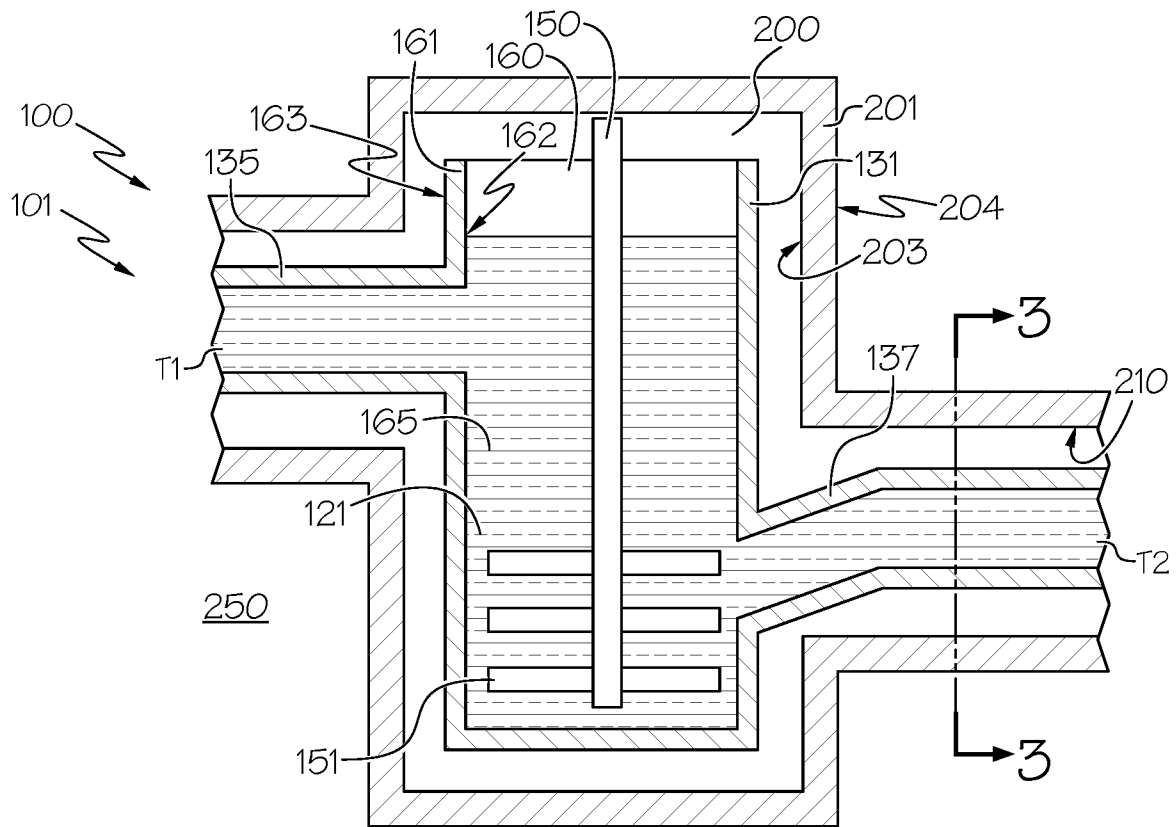


FIG. 2

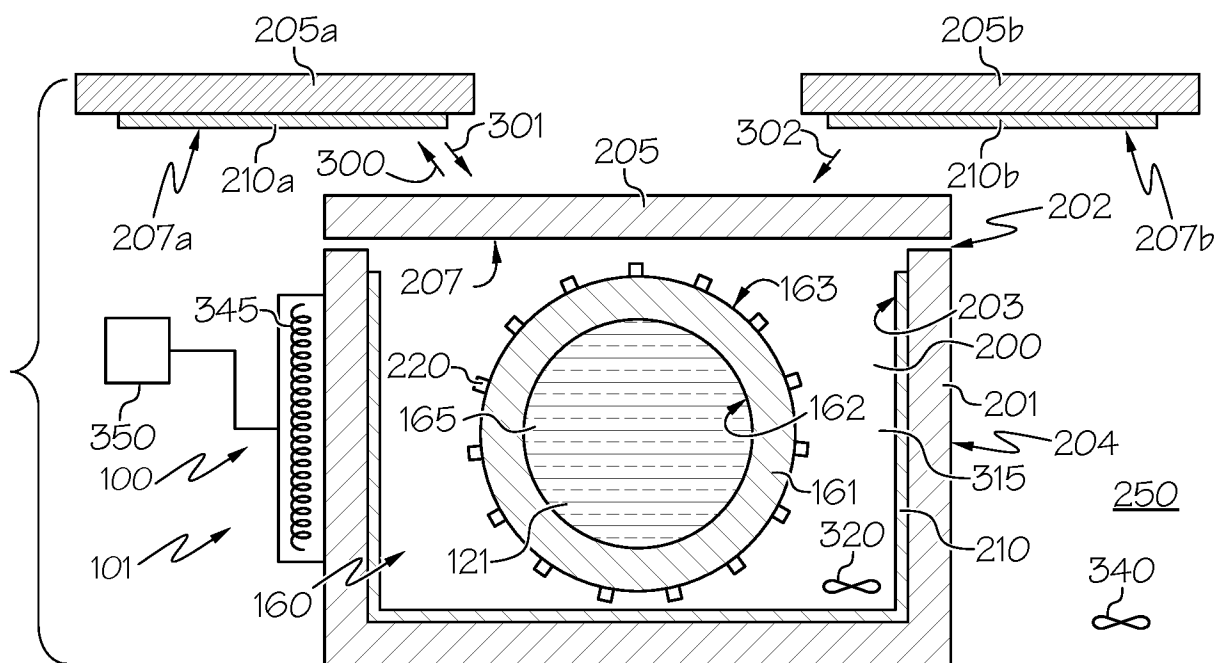


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2017/042030**A. CLASSIFICATION OF SUBJECT MATTER****C03B 5/43(2006.01)i, C03B 5/187(2006.01)i, C03B 5/44(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 5/43; C03B 37/01; C03B 17/06; C03B 23/02; F27D 7/06; C03B 37/018; C03B 18/00; C03B 5/187; C03B 5/44

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, vessel, molten glass, vessel wall, housing, housing wall, emissivity, black oxide, stainless steel**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 01-17919 A1 (CORNING INCORPORATED) 15 March 2001 See p.12, lines 14-16; p.13, line 1; figures 1, 3.	1-20
Y	"Emissivity values of common materials", 2007, Retrieved from the Internet: <URL: http://support.fluke.com/find-sales/Download/Asset/3038318_6251_ENG_A_W.PDF >. See left table, twenty fifth cell.	1-20
Y	US 2005-0013339 A1 (MILLER, D. J. et al.) 20 January 2005 See claim 15.	10
A	US 8484995 B2 (DELIA, R. et al.) 16 July 2013 See the whole document.	1-20
A	WO 01-96251 A1 (GLASSTECH, INC.) 20 December 2001 See the whole document.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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"E" earlier application or patent but published on or after the international filing date

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"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

24 October 2017 (24.10.2017)

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26 October 2017 (26.10.2017)

Name and mailing address of the ISA/KR

International Application Division

Korean Intellectual Property Office

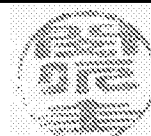
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Information on patent family members

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