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(71) Applicant: CORNING INCORPORATED [US/US]; 1

Riverfront Plaza, Corning, NY 14831 (US).

(72) Inventors: HEINE, David, Robert; 9906 Day Road, Ham-

mondsport, NY 14840 (US). QUIEL, Robert, Richard;

105 Saint Andrews Drive, Horseheads, NY 14845 (US).

(74) Agent: MCNUTT, Matthew, B.; Corning Incorporated,

Intellectual Property Department, SP-TI-03-1, Corning, NY

14831 (US).

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(54) Title: BATCH PILE DISTRIBUTOR FOR IMPROVED MELT UNIFORMITY

(57) Abstract: A material distributor including a top, a base including a distribution edge extending in at least two dimensions, and a distribution surface extending between the top and the base, the distribution surface sloped at an angle from the top to the base. The distribution surface is configured to outwardly distribute the feed material relative to the distribution edge. The material distributor is configured to extend below a material feed opening and above a material melt line of a melting vessel.

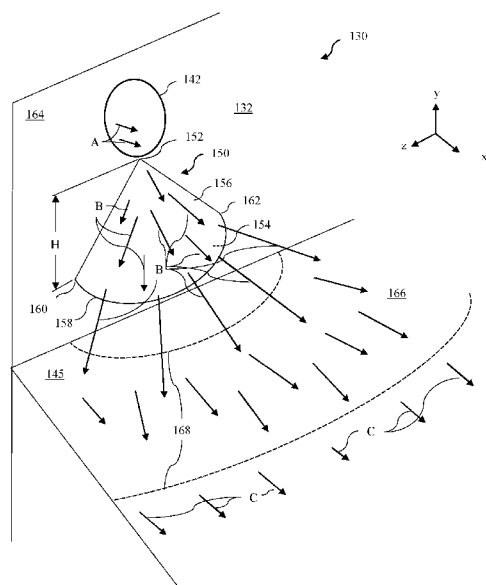


FIG. 2



BATCH PILE DISTRIBUTOR FOR IMPROVED MELT UNIFORMITY

BACKGROUND

Cross-Reference to Related Application

[0001] This application claims the benefit of priority under 35 U.S.C. § 119 of U.S. Provisional Application Serial No. 62/722507 filed on August 24, 2018, the content of which is relied upon and incorporated herein by reference in its entirety.

Field

[0002] The present disclosure generally relates to systems and methods for melting batch materials. More particularly, it relates to apparatuses and methods for loading batch materials into a furnace for melting.

Technical Background

[0003] Melting furnaces can be used to melt a wide variety of batch materials, such as glass and metal batch materials, to name a few. Batch materials can be fed into a melting furnace to form molten glass. Given the extreme environment within the melting furnace, conventional mixing is not used and convection and resident time are used to incorporate the raw materials into the melt and sufficiently mix them to create a homogeneous composition. The presence of a scum layer, formed by gases given off during the melting process, causes the added powder to sit on top of the pre-melt while slowly being incorporated. A batch pile, formed of unmelted batch materials atop the pre-melt and/or scum layer, can grow due to the continuous addition of raw materials deforming and extending across the tank, which can lead to batch material being fed downstream without sufficiently melting and mixing, possibly causing defects such as stones (i.e., unmelted batch particles, etc.) further downstream.

[0004] Accordingly, apparatuses and methods for distributing batch material in a melting furnace are disclosed herein.

SUMMARY

[0005] Some embodiments of the present disclosure relate to a material distributor including a top, a base including a distribution edge extending in at least two dimensions, and a distribution surface extending between the top and the base, the distribution surface sloped at an angle from

the top to the distribution edge. The distribution surface is non-planar. The distribution surface is configured to outwardly distribute a batch material relative to the distribution edge. The material distributor is configured to extend below a material feed opening and above a material melt line of a material melting vessel.

[0006] Other embodiments of the present disclosure relate to a melting vessel including a housing, a feed port, and a material distributor. The housing includes a top, a bottom, an inflow end wall, and an outflow end wall, and side walls extending between the inflow end wall and the outflow end wall and extending between the top and the bottom. The housing is configured to contain a material melt and has a material melt line disposed between the top and the bottom. The feed port includes an opening through the vessel housing. The feed port is disposed above the material melt line. The material distributor is disposed between the feed port opening and the material melt line. The material distributor includes a distribution surface extending between a top and a base. The base includes a non-linear distribution edge. The distribution surface is sloped between the top and the base. The distribution surface is configured to outwardly distribute the feed material relative to the distribution edge.

[0007] Yet other embodiments of the present disclosure relate to a method of distributing material within a melting vessel. The method includes delivering feed material from storage bin to a feed port of a melting vessel, dispensing the feed material from the feed port onto a distribution surface of a material distributor, sliding the raw material downward from a top of the material distributor and at an angle along the distribution surface to a bottom distribution edge of the material distributor, and dispersing the raw material tangentially outward from the bottom distribution edge of the material distributor across a melt surface within the melting vessel.

[0008] Additional features and advantages of the embodiments disclosed herein will be set forth in the detailed description that follows, and in part will be readily apparent to those skilled in the art from that description or recognized by practicing the embodiments as described herein, including the detailed description which follows, the claims, as well as the appended drawings.

[0009] It is to be understood that both the foregoing general description and the following detailed description present embodiments intended to provide an overview or framework for understanding the nature and character of the embodiments disclosed herein. The accompanying drawings are included to provide further understanding, 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

[0010] FIG. 1 is schematic illustration of a cross-sectional view of an example melting furnace system including a material distributor in accordance with principles of the present disclosure.

[0011] FIG. 2 is simplified perspective view of an example material distributor useful with the melting furnace system in accordance with principles of the present disclosure.

[0012] FIG. 3 is simplified front perspective view of another example material distributor useful with the melting furnace system in accordance with principles of the present disclosure.

[0013] FIG. 4 is schematic illustration of a cross-sectional view of a melting furnace system including another example material distributor in accordance with principles of the present disclosure.

[0014] FIG. 5A is a simplified cross-section view of an example material distributor assembly useful in the melting furnace system of FIG. 4 in accordance with principles of the present disclosure.

[0015] FIG. 5B is a simplified top view of the material distributor of FIG. 5A in accordance with principles of the present disclosure.

[0016] FIG. 6 is a simplified top view of a coolant system useful with a material distributor assembly in accordance with principles of the present disclosure.

[0017] FIG. 7 is a simplified cross-section view of another example material distributor assembly useful in the melting furnace system of FIG. 4 in accordance with principles of the present disclosure.

DETAILED DESCRIPTION

[0018] Reference will now be made in detail to embodiments of the present disclosure, examples of which are illustrated in the accompanying drawings. Whenever possible, the same reference numerals will be used throughout the drawings to refer to the same or like parts. However, this disclosure may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein.

[0019] Ranges can be expressed herein as from “about” one particular value, and/or to “about” another particular value. When such a range is expressed, another embodiment includes 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 embodiment. 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.

[0020] Directional terms as used herein - for example up, down, right, left, front, back, top, bottom - are made only with reference to the figures as drawn and are not intended to imply absolute orientation.

[0021] 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, nor that with any apparatus, specific orientations be required. Accordingly, where a method claim does not actually recite an order to be followed by its steps, or that any apparatus claim does not actually recite an order or orientation to individual components, or it is not otherwise specifically stated in the claims or description that the steps are to be limited to a specific order, or that a specific order or orientation to components of an apparatus is not recited, it is in no way intended that an order or orientation be inferred, in any respect. This holds for any possible non-express basis for interpretation, including: matters of logic with respect to arrangement of steps, operational flow, order of components, or orientation of components; plain meaning derived from grammatical organization or punctuation, and; the number or type of embodiments described in the specification.

[0022] As used herein, the singular forms "a," "an" and "the" include plural references unless the context clearly dictates otherwise. Thus, for example, reference to "a" component includes aspects having two or more such components, unless the context clearly indicates otherwise.

[0023] As used herein, "batch material" is used herein to denote a mixture of precursor components which, upon melting, react and/or combine to form the final desired material composition. Batch materials can, for example, comprise glass precursor materials, or metal alloy precursor materials, to name a few. Batch materials may be prepared and/or mixed by any known method for combining precursor materials. For example, in certain non-limiting embodiments, batch materials can include a dry or substantially dry mixture of precursor particles, e.g., without any solvent or liquid. In other embodiments, batch materials may be in the form of a slurry, for example, a mixture of precursor particles in the presence of a liquid or solvent. Batch materials can include metal oxides and one or more modifying agents, for example.

[0024] The batch materials may include glass precursor materials, such as silica, alumina, and various additional oxides, such as boron, magnesium, calcium, sodium, strontium, tin, or

titanium oxide. For instance, the glass batch materials may be a mixture of silica and/or alumina with one or more additional oxides. In various embodiments, the glass batch materials include from about 45 to about 95 weight percent (wt%) collectively of alumina and/or silica and from about 5 to about 55 wt% collectively of at least one oxide of boron, magnesium, calcium, sodium, strontium, tin, and/or titanium. Various materials can have various differing minimum angles that will result in flow of the material (i.e., angle of repose).

[0025] As used herein, “molten glass” shall be construed to mean a molten material which, upon cooling, can enter a glassy state. The term molten glass is used synonymously with the term “melt”. The molten glass may form, for example, a majority silicate glass, although the present disclosure is not so limited.

[0026] As used herein, the term “fluid” shall denote any gas, mixture of gasses, liquid, gas and liquid mixtures, vapor, or combinations thereof.

[0027] As used herein, the term “refractory”, or “refractory material” is used to denote non-metallic materials having chemical and physical properties that make them applicable for structures, or as components of systems, that are exposed to environments above about 538°C, for example equal to or greater than about 700°C, such as equal to or greater than about 800°C.

[0028] Embodiments of the disclosure will be discussed with reference to FIG. 1, which schematically depicts an exemplary melting furnace system 10 including a melting vessel 30. In general terms, melting vessel 30 can assume various forms, and generally includes or defines vessel housing having side walls 32, a ceiling or top 34, and a floor or bottom 36 that combine to define a chamber 38. Raw batch materials 40 can be introduced into the chamber 38 by way of one or more inlets or feed port 42. The feed port 42 includes an opening through the vessel housing. The raw batch materials 40 can then be heated and melted in the vessel 30 by any suitable method for their combination, e.g., conventional melting techniques such as by contact with the side walls 32 and/or the floor 36, which can be heated by combustion burners and/or by contact with electrodes (not shown). The melted batch materials form molten glass 44 which can flow out of the vessel chamber 38 by way of an outlet 46 for further processing.

[0029] Melting furnace system 10 can optionally include an upstream glass manufacturing apparatus 20 positioned upstream relative to melting vessel 30. In some examples, a portion of, or the entire upstream glass manufacturing apparatus 20, may be incorporated as part of the melting vessel 30. The upstream glass manufacturing apparatus 20 can include a raw material storage bin 22, a raw material delivery device 24, and a motor 26 connected to raw material delivery device 24. Storage bin 22 may be configured to store a quantity of raw material 40

that can be fed into melting vessel 30 of melting furnace system 10. The raw batch materials 40 can be introduced into the chamber by way of one or more feed ports 42, as discussed further below.

[0030] In some examples, raw material delivery device 24 can be powered by motor 26 such that raw material delivery device 24 delivers a predetermined amount of raw material 42 from the storage bin 22 to melting vessel 30. In further examples, motor 26 can power raw material delivery device 24 to introduce raw material 40 at a controlled rate based on a level of molten glass sensed downstream from melting vessel 30 relative to a flow direction, as indicated by arrow 48 of the molten glass 44. Raw material 40 within melting vessel 30 can thereafter be heated to form molten glass 44. Typically, in an initial melting step, raw material 40 is added to melting vessel 30 as particulate, for example as comprising various “sands”, onto a pre-melt surface 45 of the molten glass 44. Raw material 40 may also include scrap glass (i.e. cullet) from previous melting and/or forming operations. Combustion burners (not shown) are typically used to begin the melting process. The raw material is liquefied, or melted, to a molten state within melting vessel 30. The molten glass 44 can flow out of melting vessel 30 through outlet 46 for further processing in a flow direction indicated by arrow 48 of the molten glass 44.

[0031] The raw batch materials 40 can be melted according to any suitable method, e.g., conventional glass and/or metal melting techniques. For example, the batch materials 40 can be added to the chamber 38 and heated to a temperature ranging from about 1100 degrees Celsius (°C) to about 1700 °C, such as from about 1200 °C to about 1650 °C, from about 1250 °C to about 1600 °C, from about 1300 °C to about 1550 °C, from about 1350 °C to about 1500 °C, or from about 1400 °C to about 1450 °C, including all ranges and sub-ranges therebetween. The batch materials may, in certain embodiments, have a residence time in the vessel 30 ranging from several minutes to several hours to several days, or more, depending upon various variables, such as the operating temperature and the batch volume, and particle sizes of the constituents of the batch materials 32. For example, the residence time may range from about 30 minutes to about 3 days, from about 1 hour to about 2 days, from about 2 hours to about 1 day, from about 3 hours to about 12 hours, from about 4 hours to about 10 hours, or from about 6 hours to about 8 hours, including all ranges and sub-ranges therebetween.

[0032] In the case of glass processing, the molten glass materials can subsequently undergo various additional downstream processing steps, including fining to remove bubbles, and stirring to homogenize the glass melt, to name a few. In some examples, melting furnace system

10 may be incorporated as a component of a glass manufacturing system comprising a slot draw apparatus, a float bath apparatus, a down draw apparatus (e.g., a fusion down draw apparatus), an up draw apparatus, a pressing apparatus, a rolling apparatus, a tube drawing apparatus or any other glass manufacturing apparatus that would benefit from the present disclosure. The molten glass can then be processed, e.g., to produce a glass ribbon, using any known method, such as fusion draw, slot draw, and float techniques. Subsequently, in non-limiting embodiments, the glass ribbon can be formed into glass sheets, cut, polished, and/or otherwise processed.

[0033] The melting vessel 30 can be formed of any insulating or heat-resistant material suitable for use in a desired melting process, for example, refractory materials such as zircon, zirconia, alumina, magnesium oxide, silicon carbide, silicon nitride, and silicon oxynitride, precious metals such as platinum and platinum alloys, and combinations thereof. According to various embodiments, portions (e.g., the side walls 32, the ceiling 34, the floor 36, etc.) can include an outer layer with an interior lining of heat-resistant material such as a refractory material or precious metal. The melting vessel 30 can have any suitable shape or size for the desired application and can, in certain embodiments, have, for example, a circular, oval, square or polygonal cross-section. The dimensions of the melting vessel 30, including the length, height, width, and depth, to name a few, can vary depending upon the desired application. Dimensions can be selected as appropriate for a particular process or system. While FIG. 1 illustrates the melting vessel 30 as having the feed port 42 at the side wall 32 of melting vessel 30, one or more feed ports 42 may alternatively or additionally be disposed at the top 34 of melting vessel 30. A material distributor 50 is included in the melting vessel 30 below the feed port 42 for dispersing the raw batch material 40 into the chamber 38, such as across a surface of molten glass 44, as indicated by arrows 51 and as discussed further below.

[0034] The material distributor 50 can be useful to propagate batch material across the pre-melt surface 45 within melting furnace vessel 30. In some embodiments, the material distributor 50 can be included directly below, or proximally below, the feed port 42. The material distributor 50 can be useful to disperse raw batch material perpendicular, or at some other angle, relative to a discharge direction of the feed port 42. For example, the raw batch material can be moved horizontally to the feed port 42 via delivery device 24 to be discharged from the feed port 42 to fall vertically via gravity's force into the vessel 30. In accordance with aspects of the present disclosure, the batch material entering the chamber 38 from the feed port 42 falls onto the material distributor 50 and is redirected, as indicated by arrow 51, by the

material distributor 50 prior to the batch material contacting the pre-melt surface 45. The redirection by the material distributor 50 results in a batch pile that is then more widely and evenly distributed across the pre-melt surface within the melting vessel 30 than a batch pile that discharged directly onto the pre-melt surface from the feed port 42. The material distributor 50 has a three-dimensional non-planar distribution surface that extends or projects within the vessel 30 such that the batch material can slides downward at an angle from the feed port 42 instead of falling directly vertically onto the pre-melt surface 45.

[0035] The material distributor 50 can be suitably shaped to aid in distributing the batch material perpendicularly to the discharge direction and across a length and width of a pre-melt surface 45 within the vessel 30. The pre-melt surface 45 can be the bottom of the vessel 30 when the vessel 30 is otherwise empty, or can be a top surface of molten glass 44 within the vessel 30, for example. In some embodiments, a material melt line is defined by a pre-melt surface of molten glass within the melting vessel 30. A uniformly broad distribution of the batch material across the pre-melt surface 45 can assist with the melt process for rapid incorporation of the batch material into the molten glass. The distributed batch material spread perpendicularly places a majority of the batch material directly into the scum layer, given direct contact to heat, melt and incorporate the batch material into the molten glass within the vessel. The distributed batch material provides a more uniform coverage of the pre-melt surface, for example, covering more than 20 percent (%) of the pre-melt surface for a more uniform mixing and incorporation into the molten glass than available with more concentrated batch piles that may cover only 20 percent (%) or less of the pre-melt surface. With increased efficiency of incorporation of the batch material into the molten glass, a decrease in energy to melt the batch material may be realized.

[0036] FIG. 2 is a perspective simplified view of an example material distributor 150 useful in a melting furnace system as described above in accordance with aspects of the present disclosure. In this embodiment, the material distributor 150 is disposed at a side wall 132 of a melting vessel 130 within a chamber 138. The material distributor 150 includes a top 152, a base 154, and a distributing surface 156 extending between the top 152 and the base 154. In some embodiments, the top 152 can be pointed to be formed as an apex or point of intersection of the distribution surface 156. In some embodiments, the top 152 can be rounded. The top 152 can be vertically aligned with and below a feed port 142 to be exposed to the batch material as it enters the chamber 138 from the feed port 142. In some embodiments, the top 152 is directly

adjacent below the feed port 142. In other embodiments, the top 152 is spaced a predetermined distance below the feed port 142 along the y-axis.

[0037] The base 154 can be centered, or have a mid-line, aligned with the top 152 in the y-axial direction. The base 154 can extend generally perpendicularly from the side wall 132 into the chamber 138 to a distribution edge 158. The base 154 is formed a predetermined distance from the top 152 to define a height “H” of the material distributor 150. The base 154 is disposed or positioned above the pre-melt surface 145 a predetermined distance suitable to provide the desired distribution spread of the batch material onto the pre-melt surface 145. In some embodiments, the base 154 extends in a generally horizontal plane. In one embodiment, the base 154 of the material distributor is generally planar along the x and z axes. In other embodiments, the base 154 can be convex, concave, or other suitable shape. The base 154 of the material distributor 150 can have a perimeter or distribution edge 158 that is non-linear, extending in at least two dimensions. In some embodiments, the distribution edge 158 extends between a first end 160 to an opposing second end 162. The first end 160 and the second end 162 of the distribution edge 158 can each terminate at, or intersect with, the side wall 132 of the vessel 130. In other words, the distribution edge 158 extends from the side wall 132 between the first and second ends 160, 162. In some embodiments, the distribution edge 158 is curved. In one embodiment, the distribution edge 158 is curved to form a 180 degree arc. The distribution edge 158 can be semi-circular or semi-oval, for example. In other embodiments, the distribution edge 158 is defined by multiple segments in a polygonal or multifaceted configuration including segments of the same or varied lengths between the first end 160 and the second end 162. In some embodiments, the distribution edge 158 is at least slightly rounded from the distribution surface 156 to the base 154.

[0038] The distribution surface 156 extends between the top 152 and the distribution edge 158 of the base 154. The distribution surface 156 is a distribution surface for the batch material dispensed from the feed port 142 into the chamber 138. The distribution surface 156 is non-planar. In some embodiments, the distribution surface 156 can be conical or semi-conical, extending linearly from the top 152 to the bottom curved distribution edge 158. In other embodiments, the distribution surface 156 can be formed of polygonal or multifaceted sections (not shown).

[0039] The distribution surface 156 is formed at an angle relative to the x-z plane (i.e., horizontal), from the top 152 to the base 154. In general, the distribution surface 156 is disposed at an angle relative to the x-z plane that is suitable to result in the appropriate flow and

distribution of batch materials received from the feed port 142 onto the pre-melt surface. The angled distribution surface 156 is suitable to allow the batch material slide downward along the distribution surface 156 and can be equivalent to or exceed the angle of repose of the batch material to be used to form molten glass. In some embodiments, the distribution surface 156 may be angled at between 15 to 45 degrees (°) from the x-z plane, although other angles can also be suitable.

[0040] As indicated with arrows “A”, the raw batch material is fed into the vessel 130 via feed port 142 and redirected along the angled distribution surface 156 of the material distributor 150, as indicated by arrows “B” into a distribution zone 166 generally indicated between dashed lines 168 of pre-melt surface 145. The batch material continues to be moved across the vessel 130 toward the outlet as indicated by arrows “C” on the pre-melt surface 145 while being melted into the molten glass. The shape and size of the distribution zone 166 is generally shown for illustrative purposes and it is understood that the shape and size of distribution zone 166 can vary due to factors such as the shape, size and position of the material distributor 150 within the vessel 130 as well as the type of batch material used, for example.

[0041] Although the material distributor 150 is illustrated in FIG. 2 as extending from an inner surface 164 of the side wall 132, in some embodiments, the material distributor 150 can be fully or partially recessed within the side wall 132 of the melting vessel 130. The material distributor 150 can be formed in conjunction with the side wall 132 with additional attachment mechanisms to couple the material distributor 150 to the side wall 132 being unnecessary. In some embodiments, the material distributor 150 is formed of the same material as the melting vessel 130. The melting vessel 130 is typically formed from a refractory material, such as a refractory ceramic material, for example a refractory ceramic material comprising alumina or zirconia, although the refractory ceramic material may comprise other refractory materials, such as yttrium (e.g., yttria, yttria stabilized zirconia, yttrium phosphate), zircon (ZrSiO_4) or alumina-zirconia-silica or even chrome oxide, used either alternatively or in any combination. In some embodiments, melting vessel 130 may be constructed from refractory ceramic bricks. In some embodiments, the material distributor 150 is formed contiguously with, and of the same material, as the side wall 132 of the melting vessel 130. In other words, the material distributor 150 can be formed with the side wall 132 of the vessel 130. The material distributor 150 can include a coating, or layer, to cover the distribution surface 156 for improved resistance to wear. In one embodiment, the material distributor 150 is formed of refractory material coated with platinum.

[0042] FIG. 3 is simplified front perspective view of another example material distributor 250 useful with the melting furnace system of FIG. 1 in accordance with principles of the present disclosure. The material distributor 250 is disposed on and extending into a vessel 230 from a side wall 232 below a feed port 242. The material distributor 250 is similar to the material distributor 150 described above and can be spaced a predetermined distance from or disposed directly below a bottom edge of the feed port 242, for example. Other features described above with respect to the material distributor 150 are also applicable to the material distributor 250. In one embodiment, the material distributor 250 can have a parabolic or semi-parabolic shape. The material distributor 250 can include a distribution surface 256 extending curvilinearly between a top 252 and a base 254. In one embodiment, the distribution surface 256 is curved concavely from the top 252 to the bottom 254. In one embodiment, a distribution edge 258 is curved or semi-circular between a first end 260 and a second end 262. The first and second ends 260, 262 terminate at the side wall 232. In another embodiment, the distribution edge 258 includes polygonal or multifaceted segments (not shown) of the same or varied lengths between the first end 260 and the second end 262. The base 254 is disposed above the pre-melt surface 45. The direction of batch material flow from the feed port 242, along the distribution surface 256, and within a distribution zone 266 on the pre-melt surface 45 is indicated with arrows in FIG. 3. The distribution zone 266 is generally shown for illustrative purposes between the dashed lines 267 indicated on the pre-melt surface 45.

[0043] FIG. 4 is a schematic illustration of a melting furnace system 300 including another example material distributor 350 in accordance with principles of the present disclosure. The melting furnace system 300 is similar to the melting furnace system 100 described above with respect to FIG. 1. Similarly, a melting vessel 330 including side walls 332, a top or ceiling 334 and a bottom or floor 336 forming a chamber 338 can receive raw batch material 40 from an upstream glass manufacturing apparatus (see, e.g., upstream glass manufacturing apparatus 20 of FIG. 1) and can provide a flow of molten glass 44 to a downstream glass manufacturing apparatus through an outlet 346. The raw batch material 40 can be introduced into the melting vessel 330 from a feeder 372 via a feed port 342 in the top 334 of the melting vessel 330. In one embodiment, a slide gate or other flow control mechanism (not shown) can be included in the feeder 372, such as at the bottom, to start and stop the flow of batch material 40 from the feeder 372 into the melting vessel 330. The batch material entering the chamber 338 of the melting vessel 330 is deposited (e.g., falls via force of gravity) onto the material distributor 350

through the feed port 342 and is redirected, as indicated by arrows 351, by the material distributor 350 for distribution across the pre-melt surface 45 of the molten glass 44.

[0044] The material distributor 350 is included in a material distribution assembly 370. In addition to the material distributor 350, the material distribution assembly 370 includes the feeder 372 and a distributor support 374. In general terms, the material distributor 350 can be positioned within the chamber 338 of the melting vessel 330 below the feed port 342 as supported by or suspended from the distributor support 374. Details of embodiments disclosed herein can be further understood with reference to FIGS. 5A-5B, 6 and 7.

[0045] FIG. 5A is a simplified view of an example material distributor assembly 470 including a material distributor 450 useful in the melting furnace system 300 of FIG. 4 in accordance with principles of the present disclosure. With additional reference to FIG. 4, the material distributor assembly 470 can be mounted to the top 352 of the melting vessel 330. The material distributor 450 can be suspended into the melting vessel 330 via a distributor support 474 coupled to the feeder 472. The feeder 472 can be disposed above or extend at least partially through the feed port 472 in the top 352. The feeder 472 includes sides 476, a top 478, and a bottom, or throat, 480. In one embodiment, the sides 476 can be sloped at an angle greater than the angle of repose of the batch materials from the top 478 to the bottom 480 to channel, or funnel, the batch material (not shown) to the feed port 342 and assist in controlling a desired feed rate of batch material into the vessel. The feeder 472 can be sized and shaped as suitable to receive and provide some feed rate control of the raw batch material being introduced into the melting vessel 330. The top 478 can be fully or partially fluidly open to receive the batch material and for maintenance. In one embodiment, a flow control mechanism, such as a slide gate (not shown) can be included above the distributor support 474 additional flow control (e.g., start and stop of flow).

[0046] The bottom 480 can be sized and shaped to provide the desired flow of batch material into the vessel 330. The bottom 480 can be sized and aligned to correspond with the size and position of the feed port 342. The bottom 480 of the feeder 472 can be positioned directly above, at, or through the feed port 342. In one embodiment, the feed port 342 includes a single opening for passage of the batch material. In some embodiments, the feed port 342 can include multiple openings through which the batch material can pass through. In one embodiment, a valve (e.g., diaphragm flow control valve) indicated by dashed line 475 can be included at the bottom 480 of the feeder 472 for additional flow control. The valve, when included, should have an opening larger than the opening (e.g., diameter “d₂”) at the bottom 480 in order that

batch material would not be held up or built up on the valve as the batch material passes through the feeder 472.

[0047] In some instances, regular inspection and cleaning of the feeder sides 476 and bottom 480, as well as the bottom 454 and surface 456 of the material distributor 450 may be desirable. Due to temperature differences, condensation can occur on the sides 476 of the feeder 472 that can cause debris, including batch material, to adhere to the sides 476 of the feeder 472, particularly near the bottom, or throat, 480. The accumulation of debris adhered to the sides 476 of the feeder 472 can significantly reduce the flow rate of batch materials. In some embodiments, inspection and cleaning of accumulated debris can occur with access from the top 478.

[0048] With continued reference to FIG. 5A and FIG. 4, the material distributor 450 can be suspended within the interior chamber 338 of the melting vessel 330 via the distributor support 474. The distributor support 474 includes an extender 488 having a first end 490, a second end 492 opposite the first end 490, and an elongated body 494 extending between the first end 490 and the second end 492. The material distributor 450 can be assembled to the extender 488 at the first end 490. The extender 488 can be centered within the bottom 480 and with respect to the material distributor 450. In one embodiment, the first end 490 is coupled to the top 452 of the material distributor 450.

[0049] The distributor support 474 can include a brace 496. In one embodiment, the second end 492 is coupled to the brace 496 and the elongated body 494 extends vertically (i.e., along the y-axis) between the brace 496 and the material distributor 450. In one embodiment, the brace 496 extends across feeder 472 at or near the top 478. The brace 496 can extend horizontally across the feeder 472 perpendicular to the extender 488 and coupled to the side 476 so as to prevent rotation of brace 496, thus restricting movement of the material distributor 450 along the x or z axial directions within the vessel 330. More than one brace 496 can be included. The braces 496 are positioned and sized to allow the flow rate of batch materials to be greater than the flow rate provided by the throat of the feeder 472. In one embodiment, the braces 496 are positioned within the feeder 472 where the cross-sectional (along the x-z plane) opening is much greater than the throat opening to prevent the braces 496 from limiting the flow rate of batch materials. In one embodiment, two braces 496 are disposed perpendicular to one another and coupled to the extender 488. The braces 496 can assist with maintaining and restricting movement of the material distributor 450 along the x or z axial directions within the vessel 330.

[0050] The distributor support 474 can be formed of any suitable material to provide structural support for the material distributor 450 within the melting vessel and withstand the heat and moisture of the melting environment. In one embodiment, the brace 496 and the extender 488 can be formed as solid precious metal shaft or rods. The distributor support 474 can be sized and configured to minimally effect (e.g., reduce) a flow of batch material through the feeder 372 and to the material distributor 450. In one embodiment, the material distributor assembly 470 can be vertically adjusted relative to the top 334 or the bottom 336 of the melting vessel 330. In another embodiment, the distributor support 474 supporting the material distributor 450 can be adjustable in relation to the top 334 or the bottom 336 of the melting vessel 330. In some embodiments, it may be desirable to adjust the distance of the material distributor 450 from the top of the vessel 330 to adjust the spread distribution of the batch material across the surface of the melt. For example, the material distributor 450 can be adjusted upward to be closer to the top of the melting vessel 330 to provide a greater spread distribution of the batch material onto the pre-melt surface 45. In one embodiment, the distance “ d_1 ” between the bottom 480 of the feeder 472 and the top 452 of the material distributor 450 is at least equal to the width or diameter “ d_2 ” of the interior of the bottom 480. The distance “ d_1 ” can be adjusted to control the velocity of the batch material as the batch material contacts the material distributor 450. The velocity can impact the distance that the batch material travels laterally (e.g., x, z axial directions) within the vessel 330 and onto the pre-melt surface 45 in response to contact with the material distributor 450. In one embodiment, the distance “ d_1 ” can be adjusted to minimize fine materials in the batch material from becoming separated from the coarser materials in the batch material due to velocity and contact of the batch material onto a distribution surface 456 of the material distributor 450.

[0051] The material distributor 450 includes a top 452, a bottom 454, and a distribution surface 456 extending between the top 452 and a distribution edge 458 at the bottom 454. Similar to previous embodiments, the distribution surface 456 can extend linearly or curvilinearly between the top 452 and the bottom 454. In one embodiment, the base 454 is planar and extends horizontally along the x-axis within the vessel. Although illustrated as solid bodied between the top 452 and the bottom 454 in FIG. 5A, the material distributor 450 can be hollowed or partially hollowed. In one embodiment, the material distributor 450 can have a conical shape.

[0052] With additional reference to the top view of the material distributor 450 illustrated in FIG. 5B, the distribution edge 458 of the material distributor 450 can define a diameter “ d_3 ” or width of the base 454. In one embodiment, the diameter “ d_3 ” (or maximum dimension if not

circular) is less than the minimum dimension of the opening 342 to allow the distributor 450 to pass through the feed port 342 when installing or removing the material distributor 450, the distributor support 474, and the feeder 472 of the fully assembled distribution assembly 470. In one embodiment, the distribution edge 458 forms a diameter “ d_3 ” that is at least equal to the inside diameter “ d_2 ”, or throat diameter, at the bottom of the feeder 372 in order that the batch material contacts the distribution surface 456 prior to contacting the pre-melt surface 45. The distribution surface 456 can distribute the batch material fully around (i.e., 360 degrees) the material distributor 450 and onto the pre-melt surface. In one embodiment, the distribution edge 458 is circular. In one embodiment, the distribution edge 458 is elliptical. In one embodiment, the distribution edge 458 can form a regular polygonal shape (e.g., having multiple sides of equally length). Other two-dimensional shapes can also form the distribution edge 458. As with other embodiments, the distribution edge 458 can be at least slightly rounded to transition from the distribution surface 456 to the bottom 454.

[0053] Elements of the assembly should be formed of materials that are robust, chemically inert, and able to withstand high temperatures. Elements of the assembly may be formed from a precious metal that is machinable, for example. Suitable precious metals include platinum group metals selected from the group of metals consisting of platinum, iridium, rhodium, osmium, ruthenium and palladium, or alloys thereof. For example, components of the glass manufacturing apparatus may be formed from a platinum-rhodium alloy including from about 70% to about 90% by weight platinum and about 10% to about 30% by weight rhodium. However, other suitable metals can include molybdenum, rhenium, tantalum, titanium, tungsten and alloys thereof. In one embodiment, the material distributor 450 is formed of ceramic or refractory material.

[0054] With continued reference to FIG. 5A and additional reference to FIG. 6, the distribution assembly 470 can include thermal management devices (e.g., insulation components) that reduce heat transfer from the melting vessel 330. According to various embodiments, portions of the distribution assembly 470, such as the feeder 472, for example, subjected to extreme heat include an insulator 482, or insulative jacket, that can be useful to maintain the batch material within in flowable form (e.g., solid granules). Although the insulator 482 is discussed as being included at the feeder 472, it is understood the insulator 482 can be included to provide cooling to the other elements of the distribution assembly 470. The insulator 482 can provide cooling to the feeder 472 and the batch material contained within the feeder 472 from the hot melt environment of the melting furnace system.

[0055] FIG. 6 illustrates a simplified top view of the insulator 482 useful with a material distribution assembly 470 in accordance with principles of the present application. In one embodiment, the insulator 482 can be formed as a two-chamber insulative jacket including a first, or inner, chamber 484 disposed along the surfaces of the feeder 472 and a second, or outer, chamber 486 surrounding the first chamber 484. The insulative jacket 482 can include a flow path, indicated by dashed arrows 483a and 483b, for coolant. In one embodiment, the insulative jacket 482 can include an inner chamber 484 for coolant to enter (indicated with the flow path arrows 483a) from a coolant source (not shown) and provide cooling within the insulative jacket 482 to the feeder 472 and an outer chamber 486 for the coolant, to which heat transfer from the feeder 472 has occurred, to exit (indicated with the flow path arrows 483b) the insulative jacket 482. In one embodiment, the coolant flows cylindrically around the feeder 472 within the insulative jacket 482. With reference to FIG. 5A, coolant can be pumped into the top and flow downward (indicated with dashed arrows 483a) through the first chamber 484 to the bottom. At the bottom of the insulative jacket the coolant can then flow into the second chamber 486, flowing upward toward the top (indicated with dashed arrows 483b) within the second chamber 486 to exit the insulative jacket at port 487. The coolant flow pattern within the insulative jacket chambers 484, 486 minimizes potential areas of stagnant flow or trapped gases within the insulative jacket 482. In one embodiment, the coolant can be introduced into the inner annulus or chamber through a tangential port 489 at the top of the inner chamber 484 to facilitate a swirling flow pattern within both the inner and the outer chambers 484, 486 of the insulative jacket 482. The coolant can be any suitable coolant at a suitable flow rate to provide indirect cooling of the batch material in order to maintain the batch material in a solid granular form prior to entering the vessel 330.

[0056] The insulative jacket 482 can be disposed along at least the sides 476 of the feeder 472. The insulative jacket 482 can be disposed on an exterior surface of the feeder 472, on an interior surface of the feeder 472, or defined within the sides 476 of the feeder 472. The insulative jacket 482 can be formed of any suitable material to withstand and lessen heat transfer from the hot melt environment to the sides 476 of the feeder 472 and the batch material within the feeder 472. In one embodiment, the insulative jacket 482 is suitable for coolant to flow through.

[0057] FIG. 7 illustrates a simplified cross-sectional view of another material distributor assembly 570 including a material distributor 550 useful in the melting furnace system 300 of FIG. 4 in accordance with principles of the present disclosure. The material distributor assembly 570 is similar to the material distributor assembly 470 described above. In this

embodiment, the material distributor assembly 570 includes an elongation section 598 extending from a feeder 572. The feeder 572 includes sides 576 that are tapered inward from a top 578 to a bottom 580. The elongation section 598 extends from the bottom 580 of the feeder 572 along the y-axis. In one embodiment, the elongation section 598 can be formed of the same material as the feeder 572. The elongation section 598 can have an inner width and length (x and z axial directions) or diameter “ d_4 ” that is greater than the inner width and length (x and z axial directions) or diameter “ d_2 ” of the bottom 580. In one embodiment, an insulator 582 extends around exterior surfaces of both the feeder 572 and the elongation section 598. Coolant flows through inner and outer chambers 584, 586 of the insulator 582 as indicated by dashed arrows 583a, 583b.

[0058] The material distributor assembly 570 includes the material distributor 550 similar to the material distributor 450 described above. The material distributor 550 is coupled to an extender 588 of a distributor support 574. The material distributor 550 can be assembled to the elongation section 598 with a first end 590 of the extender 588 coupled to a top 552 of the material distributor 450. In one embodiment, a second end 592 of the extender 588 is coupled to a brace 596 and a body of the extender 588 extends vertically (i.e., along the y-axis) between the brace 596 and the material distributor 550. The brace 596 can extend across the width or diameter of the elongation section 598 perpendicular to the extender 588. In one embodiment, the distribution assembly 470 can be removed as a complete assembly from the vessel 330 through the opening, or feed port, 342 in the ceiling 378 of the vessel 330 for maintenance, replacement, or if no longer desired in the vessel 330. Removal can include closing a slide gate at the feed port 342 and detaching the distribution assembly 470 from the vessel 330.

[0059] The material distributors described above can be disposed an appropriate distance from the outlet 142, 342 of the melting vessel 130, 330 to provide sufficient melt time for the batch material as the batch material flows to the outlet 346. More than one material distributor can be included in the melting vessel. In accordance with principles of the present disclosure, a melting vessel can include a series of ceiling mounted material distributors (e.g., 350, 450, 550), a series of side wall mounted material distributors (e.g., 150, 250), or a combination of top mounted and side wall mounted distributors. In some embodiments, the material distributors will be aligned with one another along the x and y axes or the x and z axes. In one embodiment, more than one side wall mounted material distributor 150, 250 are aligned vertically along the side wall. In some embodiments, the more than one side wall mounted distributors 150, 250 can be evenly spaced from one another and/or the side walls extending

perpendicular to the side wall that they are mounted on. In some embodiments, more than one top mounted distributors are arranged in at least one row extending in the x and/or z axial directions. Other arrangements are also acceptable.

[0060] It will be apparent to those skilled in the art that various modifications and variations can be made to embodiments of the present disclosure without departing from the spirit and scope of the disclosure. Thus, it is intended that the present disclosure cover such modifications and variations provided they come within the scope of the appended claims and their equivalents.

What is claimed is:

1. A material distributor, comprising:
 - a top;
 - a base including a distribution edge extending in at least two dimensions; and
 - a distribution surface extending between the top and the base, the distribution surface sloped at an angle from the top to the distribution edge, the distribution surface being non-planar, the distribution surface configured to outwardly distribute a batch material relative to the distribution edge,wherein the material distributor is configured to extend below a material feed opening and above a material melt line of a melting vessel.
2. The material distributor of claim 1, wherein a bottom surface of the base is planar.
3. The material distributor of either one of claims 1-2, wherein the distribution edge is multifaceted.
4. The material distributor of claim 1, wherein the distribution edge is at least semi-circular and the distribution surface extends linearly from the top to the base, the distribution surface forming an at least semi-conical shape.
5. The material distributor of claim 1, wherein the distribution edge is at least semi-circular and the distribution surface extends curvilinearly from the top to the base, the distribution surface forming an at least semi-parabolic conical shape.
6. A melting vessel, comprising:
 - a housing including a ceiling, a bottom, an inflow end wall, and an outflow end wall, and side walls extending between the inflow end wall and the outflow end wall and extending between the top and the bottom, the housing configured to contain a material melt and comprising a material melt line disposed between the top and the bottom;
 - a feed port comprising an opening through the vessel housing, the feed port disposed above the material melt line; and

- a material distributor disposed between the feed port and the material melt line, the material distributor comprising a distribution surface extending between a top and a base, the base comprising a non-linear distribution edge, the distribution surface sloped between the top and the base, the distribution surface configured to outwardly distribute the feed material relative to the distribution edge.
7. The melting vessel of claim 6, wherein the material distributor extends from the inlet end wall.
 8. The melting vessel of either one of claims 6-7, wherein the material distributor is formed of a refractory material.
 9. The melting vessel of claim 6, wherein the opening comprising multiple openings disposed directly above the material distributor.
 10. The melting vessel of claim 9, wherein multiple openings are disposed within a portion of the ceiling above the material distributor, the portion comprising a surface area less than a surface area of the base.
 11. The melting vessel of claim 6, further comprising:
an extender comprising a first end, a second end below the first end, and an elongated body extending between the first end and the second end, wherein the material distributor is disposed at the first end, and wherein the material distributor is suspended within an interior of the vessel housing by the extender.
 12. The melting vessel of claim 11, further comprising:
an elongation section extending between the opening and the material distributor, the opening formed in the top of the vessel housing.
 13. The melting vessel of claim 12, wherein the extender extends into the housing from the elongation section.
 14. The melting vessel of claim 12, further comprising:

an insulator disposed along the elongation section, the insulator configured to cool the elongation section.

15. The melting vessel of claim 12, wherein the elongation section extends from an inverted conical shaped feeder at the opening.
16. A method of distributing material within a melting vessel, comprising:
 - delivering feed material through a feed port of a melting vessel;
 - dispensing the feed material onto a distribution surface of a material distributor;
 - sliding the raw material downward from a top of the material distributor along the distribution surface to a bottom distribution edge of the material distributor; and
 - dispersing the raw material laterally outward from the bottom distribution edge of the material distributor across a melt surface within the melting vessel.
17. The method of claim 16, wherein the delivery of the raw material is via gravity.
18. The method of claim 16, further comprising:
 - cooling a feeder disposed at the feed port with an insulator.
19. The method of claim 16, wherein the dispersing is at 360 degrees around a bottom perimeter.
20. The method of claim 16, wherein the dispersing is at 180 degrees around the bottom perimeter.

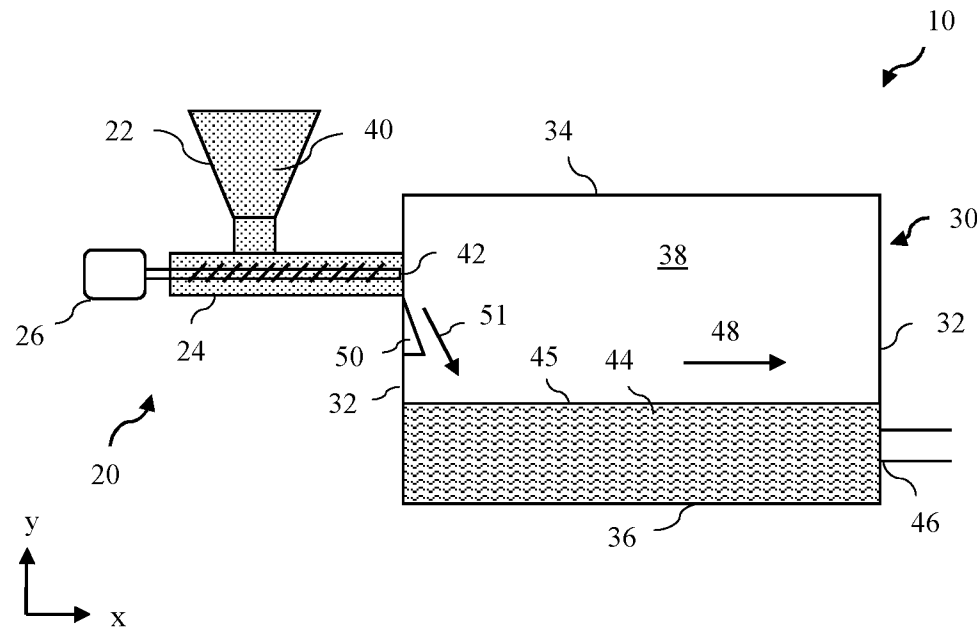


FIG. 1

2 of 6

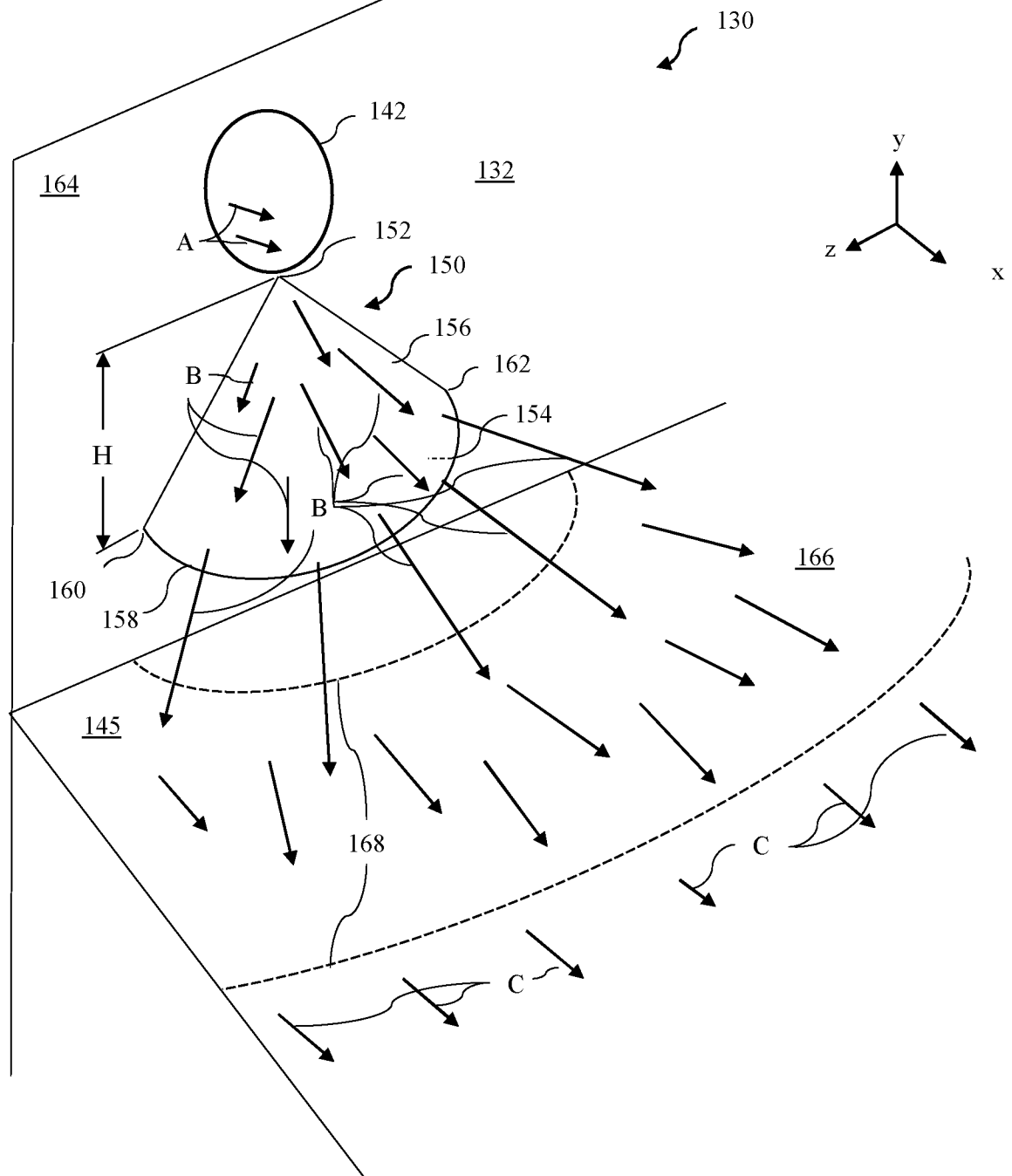


FIG. 2

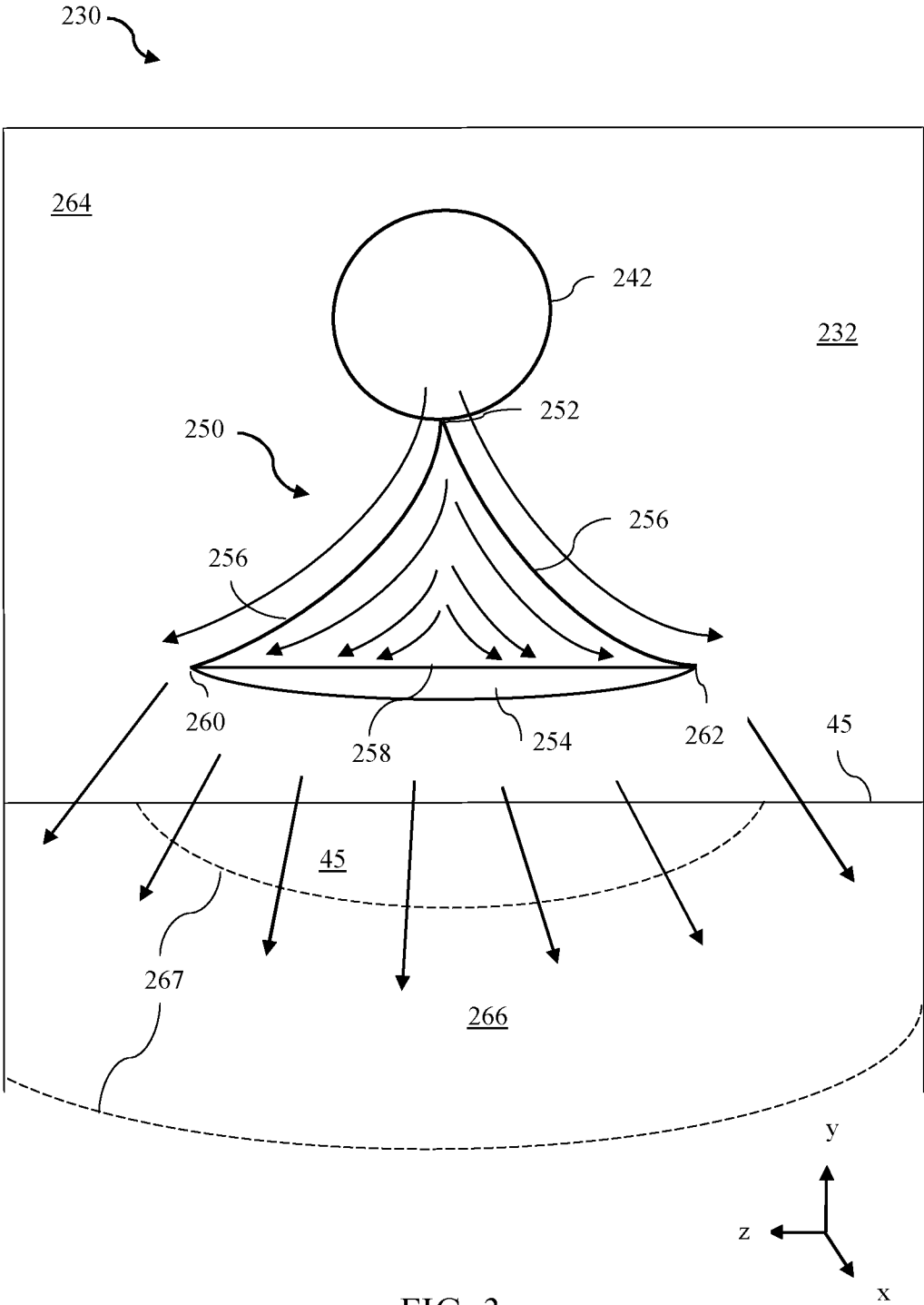


FIG. 3

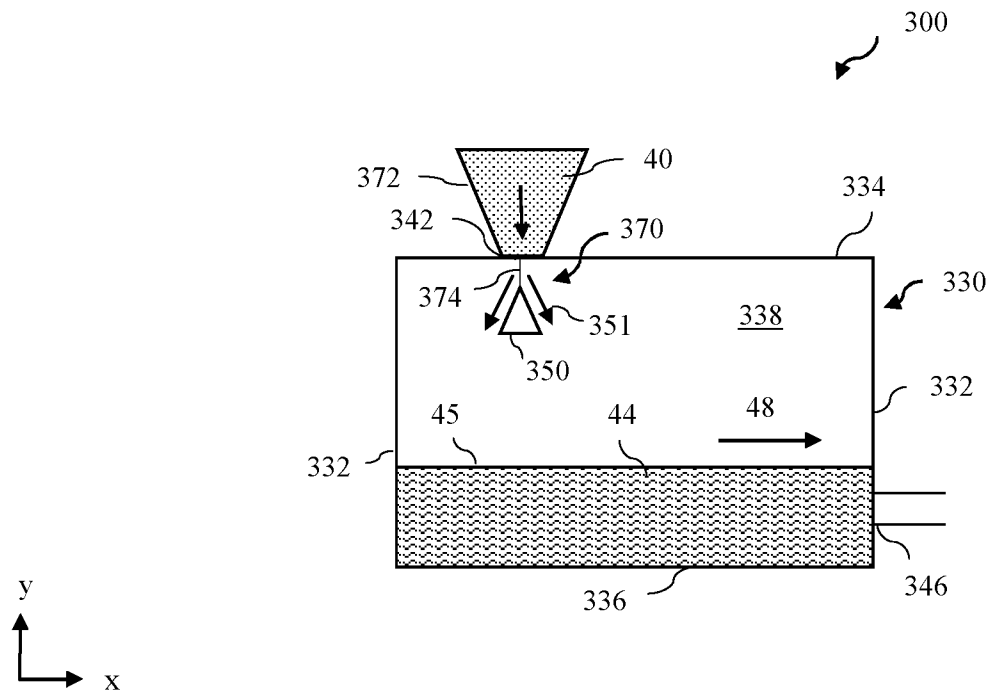


FIG. 4

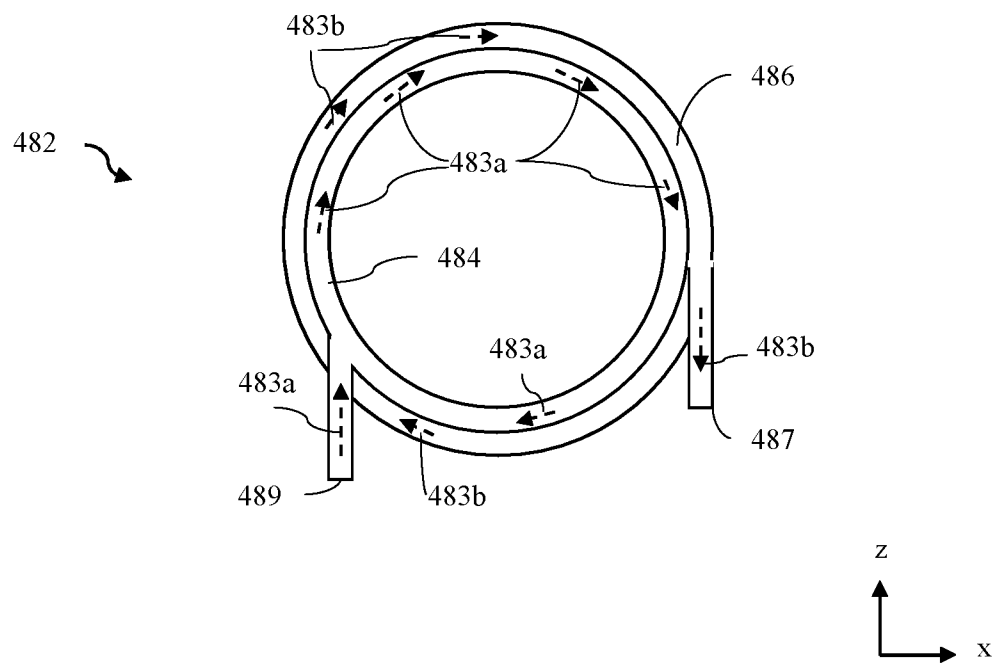
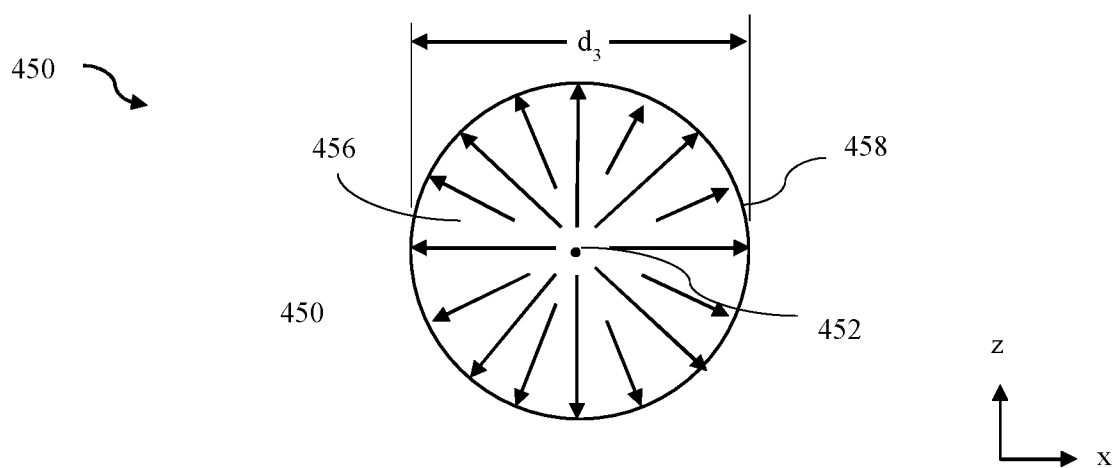
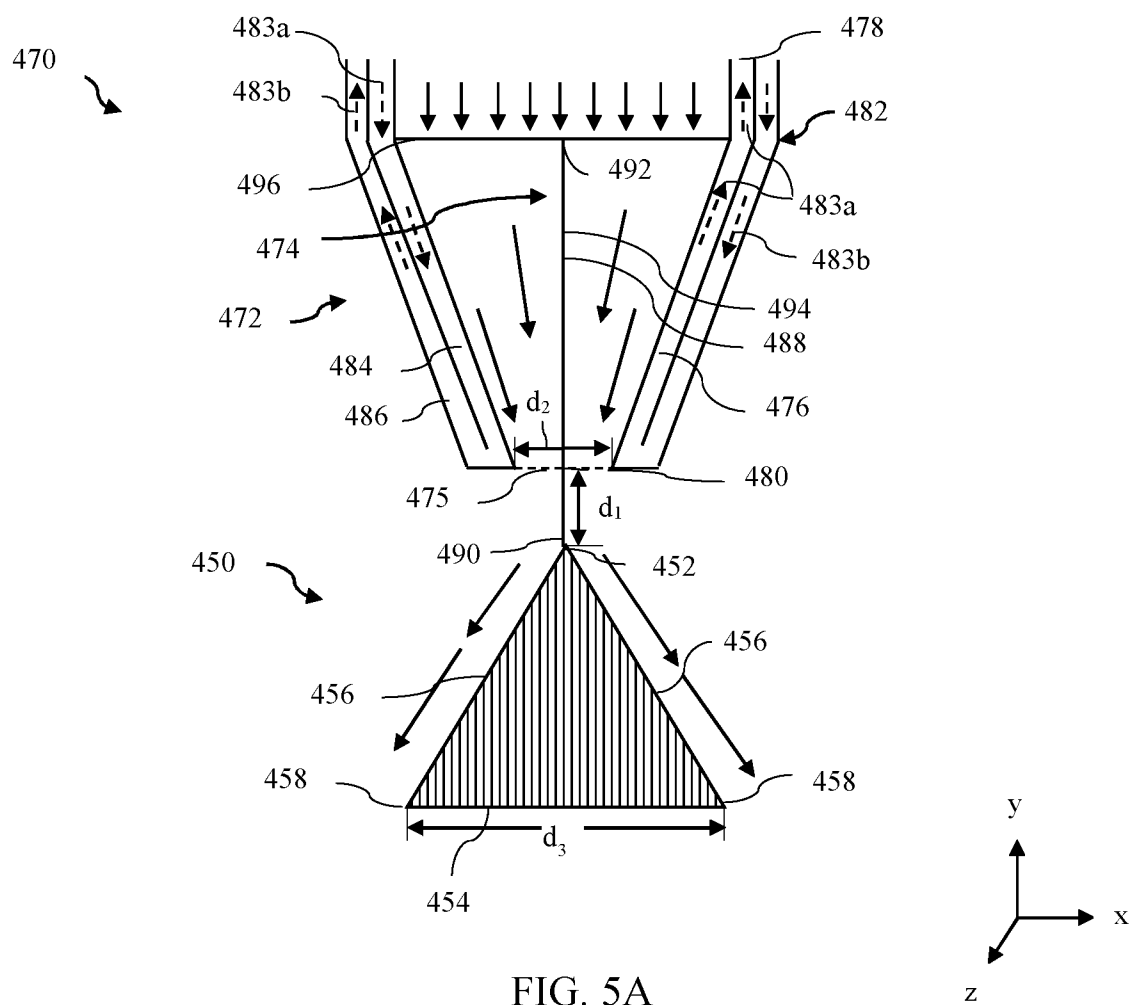


FIG. 6

5 of 6



6 of 6

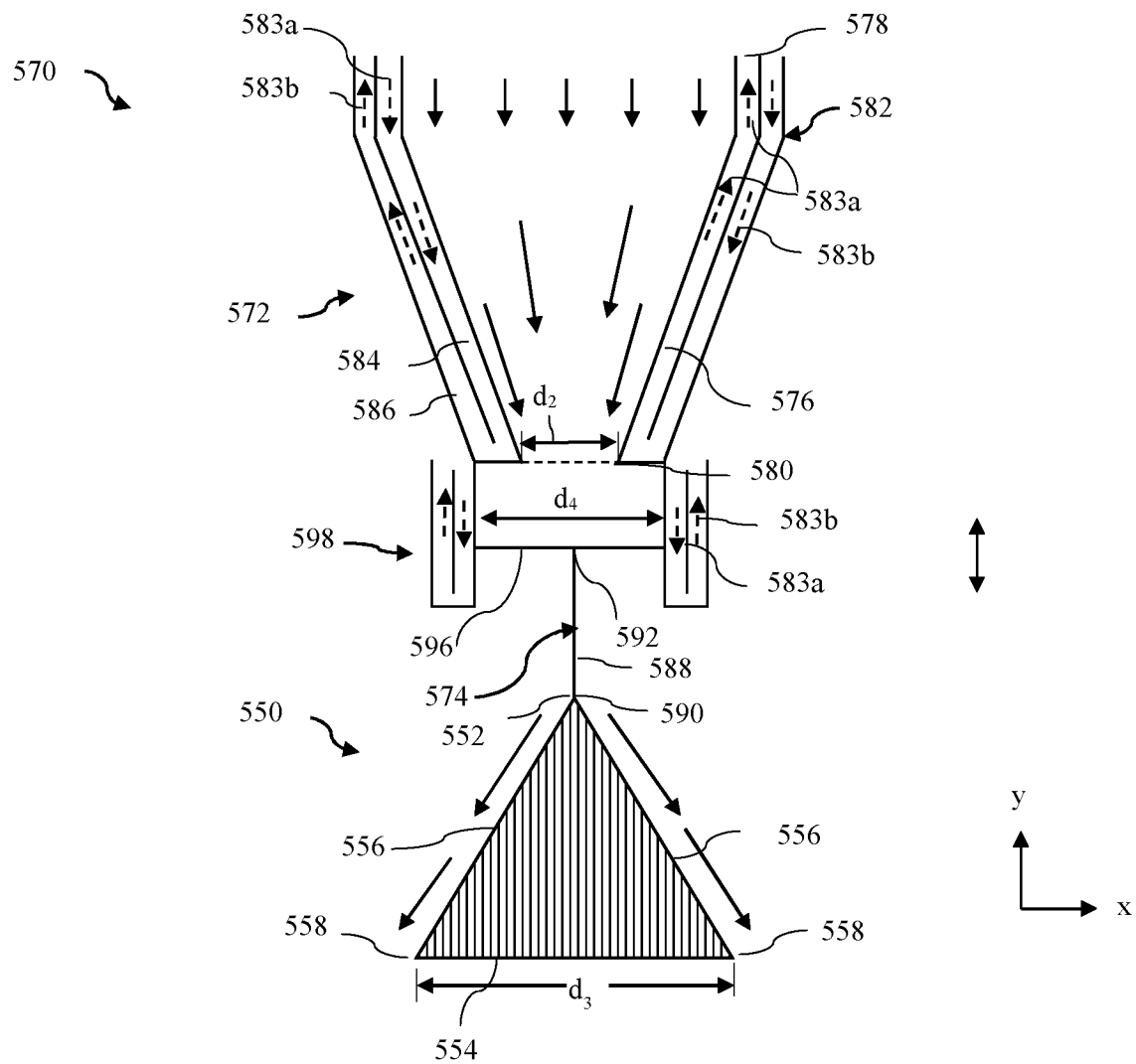


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2019/046451

A. CLASSIFICATION OF SUBJECT MATTER
INV. C03B3/00
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

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Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

13 November 2019

Date of mailing of the international search report

20/11/2019

Name and mailing address of the ISA/

European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040,
Fax: (+31-70) 340-3016

Authorized officer

Gkerou, Elisavet

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2019/046451

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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