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(71) Applicant: **CORNING INCORPORATED** [US/US]; 1 Riverfront Plaza, Corning, New York 14831 (US).(72) Inventors: **CHEN, Peng**; 3573 Conhocton Road, Painted Post, New York 14870 (US). **RAJESHIRKE, Pravin Anant**; Sawant Garden, Flat no 22C, Pune, Katraj 411046 (IN). **SELOKAR, Mayur Vitthal**; B2-604, Akshar Elementa Wakad, Pune, Maharashtra 411033 (IN).(74) Agent: **HOMA, Joseph M.**; Corning Incorporated, Intellectual Property Department, SP-TI-03-1, Corning, New York 14831 (US).(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

(54) Title: SHUTTLE KILN WITH ENHANCED RADIANT HEAT RETENTION

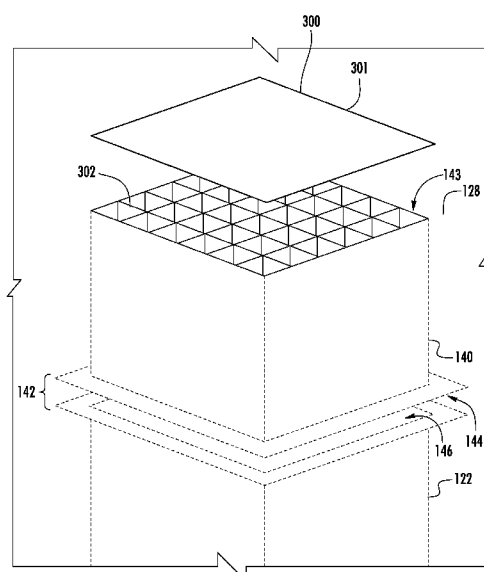


FIG. 3A

(57) Abstract: A shuttle kiln according to certain aspects includes at least one flue channel and multiple flue risers in fluid communication with the flue channel, and at least one shuttle defining multiple exhaust shafts arranged above the multiple flue risers, wherein at least one radiation blockers is arranged above outlet ports of the at least one shuttle. Such a configuration blocks line-of-sight radiant heat transfer between (i) heated surfaces above the shuttle within the kiln housing and (ii) outlet ports of the exhaust shafts, thereby enhancing radiant heat retention and reducing temperature variability within a kiln cavity of the shuttle kiln.

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SHUTTLE KILN WITH ENHANCED RADIANT HEAT RETENTION

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of priority under 35 U.S.C §120 of U.S. Provisional Application Serial No. 62/870,236 filed on July 3, 2019, the content of which is relied upon and incorporated herein by reference in its entirety.

BACKGROUND

[0002] The disclosure relates to shuttle kilns for producing fired bodies, and more particularly to shuttle kilns that exhibit reduced radiation heat loss, thereby enhancing radiant heat retention and enhancing temperature uniformity.

[0003] Shuttle kilns are typically used for batch processing of products (e.g., ceramics) at elevated temperatures. A shuttle kiln may include a kiln housing and one or more shuttles that in combination form a kiln cavity. Temperature variations in a kiln cavity (e.g., from a center an edge of the kiln cavity) can produce significant differences in the specifications and quality of fired products, depending on where a fired product was located within the kiln cavity during a firing process. Batch processing for sensitive applications may require increased temperature control and uniformity within the kiln cavity to provide consistent results and higher yields. For example, in certain applications, fired products (e.g., porous ceramic products containing organic matter) within a batch may exhibit different significant dimensional variation due to experience non-uniform part shrinkages in the firing process, based on exposure of the products to different maximum temperatures depending on where the products were located within a kiln cavity.

[0004] One such potential source of temperature variation within a kiln cavity is cold regions at exhaust shafts of shuttles due to radiation heat loss. Flue gas dilution creates cold regions below the shuttle that provide radiation heat transfer interaction with the hotter regions above the shuttle, resulting in radiation heat loss. Need therefore exists in the art for shuttle kiln exhaust systems that address limitations associated with conventional systems.

SUMMARY

[0005] A shuttle kiln according to certain aspects includes at least one flue channel and multiple flue risers in fluid communication with the flue channel, and at least one shuttle defining multiple exhaust shafts arranged above the multiple flue risers, wherein at least one radiation blocker is arranged above outlet ports of the at least one shuttle. Such a configuration blocks line-of-sight radiant heat transfer between (i) heated surfaces above the shuttle within the kiln housing and (ii) outlet ports of the exhaust shafts, thereby reducing temperature variability within a kiln cavity of the shuttle kiln.

[0006] In one aspect, the present disclosure relates to a shuttle kiln including a shuttle and a radiation blocker. The shuttle is configured to be removably positioned within an interior of the kiln housing. The shuttle includes at least one exhaust shaft having an inlet port and an outlet port arranged below the inlet port. The at least one exhaust shaft is configured to be positioned above and in fluid communication with at least one flue riser of the kiln housing, with the at least one exhaust shaft configured to be separated from the at least one flue riser to define an entrainment gap therebetween. The radiation blocker is positioned above the outlet port of the at least one exhaust shaft to block line-of-sight radiant heat transfer between (i) any heated surface above the shuttle within the kiln housing and (ii) the outlet port of the at least one exhaust shaft.

[0007] In certain embodiments, the shuttle kiln further includes the kiln housing, which includes at least one flue channel and the at least one flue riser in fluid communication with the at least one flue channel. In certain embodiments, the kiln housing includes a floor, a door, sidewalls, and a ceiling bounding the interior. The at least one flue channel is arranged below a top surface of the floor. The at least one flue riser extends above the top surface of the floor. In certain embodiments, at least a portion of the at least one exhaust shaft is vertically aligned with the at least one flue riser.

[0008] In certain embodiments, the shuttle kiln further includes furniture positioned on the shuttle and defining a plurality of support surfaces configured to support a plurality of unfired bodies to be fired within the shuttle kiln. In certain embodiments, the

shuttle kiln further includes at least one radiation shielding grid arranged within the at least one exhaust shaft. In certain embodiments, the at least one radiation shielding grid extends between the inlet port and the outlet port of the at least one exhaust shaft. In certain embodiments, at least a portion of the at least one exhaust shaft includes a tapered sidewall proximate to the inlet port.

[0009] In certain embodiments, the radiation blocker includes a shielding wall portion of the at least one exhaust shaft, with the shielding wall portion being non-perpendicular to an upper surface of the shuttle. In certain embodiments, the shielding wall portion defines a bend in the at least one exhaust shaft. In certain embodiments, the outlet port of the at least one exhaust shaft is laterally offset relative to the inlet port.

[0010] In certain embodiments, the radiation blocker includes at least one radiation shield positioned above the inlet port of the at least one exhaust shaft of the shuttle. In certain embodiments, the radiation blocker further includes at least one support to elevate the at least one radiation shield above the inlet port of the at least one exhaust shaft of the shuttle. In certain embodiments, the radiation blocker further includes the at least one support attached to furniture positioned on the shuttle to suspend the at least one radiation shield above the inlet port of the at least one exhaust shaft of the shuttle. In certain embodiments, a projected top area of the at least one radiation shield is at least as large as a cross-sectional area of the inlet port of the at least one exhaust shaft of the shuttle. In certain embodiments, the projected top area of the at least one radiation shield is in a range of from 0.09 m^2 to 0.21 m^2 , and a cross-sectional area of the inlet port of the at least one exhaust shaft of the shuttle in a range of from 0.09 m^2 to 0.21 m^2 . In certain embodiments, the at least one radiation shield includes a tapered bottom surface. In certain embodiments, the at least one radiation shield includes a conical or trapezoidal bottom surface.

[0011] In another aspect, the present disclosure relates to a method of fabricating at least one fired body. The method includes moving at least one shuttle carrying at least one unfired body into a kiln housing of a shuttle kiln. The method further includes arranging at least one exhaust shaft of the at least one shuttle above at least one flue riser

in the kiln housing. The method further includes heating a kiln cavity bounded by the at least one shuttle and the kiln housing to alter the at least one unfired body. The method further includes shielding radiation using a radiation blocker positioned above an outlet port of the at least one exhaust shaft to block line-of-sight radiant heat transfer between (i) any heated surface above the at least one shuttle within the kiln housing and (ii) the outlet port of the at least one exhaust shaft of the shuttle. The method further includes exhausting gas from the kiln cavity through the at least one exhaust shaft of the shuttle.

[0012] In certain embodiments, the radiation blocker includes a shielding wall portion of the at least one exhaust shaft, with the shielding wall portion being non-perpendicular to an upper surface of the shuttle. In certain embodiments, the radiation blocker includes at least one radiation shield positioned above an inlet port of the at least one exhaust shaft of the shuttle. In certain embodiments, the present disclosure relates to a fired body produced by the foregoing method.

[0013] Additional features and advantages will be set forth in the detailed description which follows, and in part will be readily apparent to those skilled in the art from that description or recognized by practicing the embodiments as described herein, including the detailed description which follows, the claims, as well as the appended drawings.

[0014] It is to be understood that both the foregoing general description and the following detailed description are merely exemplary, and are intended to provide an overview or framework to understanding the nature and character of the claims. The accompanying drawings are included to provide a further understanding, and are incorporated in and constitute a part of this specification. The drawings illustrate one or more embodiment(s), and together with the description serve to explain principles and operation of the various embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] **FIG. 1A** is a perspective view of a shuttle kiln including a kiln housing and multiple shuttles positioned therein;

[0016] **FIG. 1B** is a perspective view of an interior of the kiln housing of **FIG. 1A**;

[0017] **FIG. 1C** is a schematic top view of an exhaust system of the shuttle kiln of **FIG. 1A** including flue channels and an exhaust fan;

[0018] **FIG. 1D** is a schematic side view of the shuttle kiln of **FIG. 1A** including exhaust ports of the shuttle in fluid communication with flue risers of the kiln housing;

[0019] **FIG. 2A** is a perspective view illustrating radiation heat loss of a shuttle kiln without a radiation blocker;

[0020] **FIG. 2B** is a chart illustrating maximum temperature experienced within the shuttle kiln of **FIG. 2A** at a top of the shuttle kiln;

[0021] **FIG. 2C** is a chart illustrating maximum temperature experienced within the shuttle kiln of **FIG. 2A** at a middle of the shuttle kiln;

[0022] **FIG. 2D** is a chart illustrating maximum temperature experienced within the shuttle kiln of **FIG. 2A** at a bottom of the shuttle kiln;

[0023] **FIG. 3A** is a perspective view illustration of a radiation shield of the radiation blocker positioned above an exhaust shaft and a radiation shielding grid of the shuttle kiln of **FIG. 1A**;

[0024] **FIG. 3B** is a top view of the radiation blocker of **FIG. 3A**;

[0025] **FIG. 3C** is a schematic side view of the radiation blocker of **FIG. 3A**;

[0026] **FIG. 4A** is a side view illustrating radiation heat loss through the exhaust shaft of the shuttle with and without the radiation shielding grid and/or the radiation blocker;

[0027] **FIG. 4B** is a top view illustrating radiation heat loss through the exhaust shaft of the shuttle with and without the radiation shielding grid and/or the radiation blocker;

[0028] **FIG. 4C** is a chart illustrating maximum temperature uniformity at the exhaust shaft of the shuttle with and without the radiation shielding grid and/or the radiation blocker;

[0029] **FIG. 5** is a schematic side cross-sectional view of the radiation shield with a tapered bottom surface and the exhaust shaft of the shuttle with a tapered sidewall;

[0030] **FIG. 6A** is a schematic side cross-sectional view of a radiation blocker including a shielding wall portion having a bend in the exhaust shaft of the shuttle;

[0031] **FIG. 6B** is a schematic side cross-sectional view of a radiation blocker including the shielding wall portion having an offset between an inlet port and an outlet port of the exhaust shaft of the shuttle; and

[0032] **FIG. 7** is a flowchart illustrating of a method of fabricating at least one fired body.

DETAILED DESCRIPTION

[0033] The embodiments set forth below represent the necessary information to enable those skilled in the art to practice the embodiments and illustrate the best mode of practicing the embodiments. Upon reading the following description in light of the accompanying drawing figures, those skilled in the art will understand the concepts of the disclosure and will recognize applications of these concepts not particularly addressed herein. It should be understood that these concepts and applications fall within the scope of the disclosure and the accompanying claims.

[0034] It will be understood that, although the terms first, second, etc. may be used herein to describe various elements, these elements should not be limited by these terms. These terms are only used to distinguish one element from another. For example, a first element could be termed a second element, and, similarly, a second element could be termed a first element, without departing from the scope of the present disclosure. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0035] Relative terms such as "below" or "above" or "upper" or "lower" or "horizontal" or "vertical" may be used herein to describe a relationship of one element, layer, or region to another element, layer, or region as illustrated in the drawing figures. It will be understood that these terms and those discussed above are intended to encompass different orientations of the device in addition to the orientation depicted in the drawing figures.

[0036] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the disclosure. As used herein,

the singular forms "a," "an," and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises," "comprising," "includes," and/or "including" when used herein specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[0037] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs. It will be further understood that terms used herein should be interpreted as having a meaning that is consistent with their meaning in the context of this specification and the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0038] **FIGS. 1A-1D** are views of a shuttle kiln **100** including a kiln housing **102** and a first shuttle **104A**, a second shuttle **104B**, and a third shuttle **104C** (referred to generally herein as shuttles **104**) positioned therein. In certain embodiments, more or fewer shuttles **104** (may also be referred to herein as shuttle cars, kiln cars, kiln carts, etc.) may be used. A shuttle kiln **100** is a type of periodic kiln configured to uniformly heat a kiln cavity **138** bounded in part by the kiln housing **102** to a kiln peak temperature (may also be referred to as a maximum temperature, peak temperature, etc.). The features described herein and below may be applied to other types of periodic kilns.

[0039] Referring to **FIGS. 1A** and **1B**, the kiln housing **102** includes a floor **106**, a front door **108**, a left sidewall **110A**, a right sidewall **110B** (opposite the left sidewall **110A**), a back sidewall **110C** (wherein the foregoing left, right, and back sidewalls **110A-110C** may be referred to generally herein as sidewalls **110**), and a ceiling **112**, which bound and define an interior **114** of the kiln housing **102**. As shown in **FIG. 1A**, each shuttle **104A-104C** includes a top **128** and a bottom **130** (opposite the top **128**). When the shuttles **104** are positioned within the kiln housing **102** and the front door **108** is in the closed position, a kiln cavity **138** is defined between the front door **108**, the sidewalls **110**, and the ceiling **112** of the kiln housing **102** as well as the top **128** of the shuttle **104**.

The top **128** of the shuttle **104** serves as a moveable refractory floor that is used as a hearth of the shuttle kiln **100**.

[0040] The front door **108** of the kiln housing **102** is moveable from a closed position enclosing the interior **114** to an open position allowing insertion of shuttles **104** into, and/or removal of the shuttles **104** from, the interior **114** of the kiln housing **102**. The shuttles **104** are configured to carry unfired bodies into the interior **114** of the kiln housing **102** and carry fired bodies out of the interior **114** of the kiln housing **102** (e.g., through the front door **108**). In certain embodiments, the kiln housing **102** includes a back door (as well as a front door **108**).

[0041] The shuttle kiln **100** includes a firing system **116** to heat the kiln cavity **138**. The firing system **116** includes a plurality of burners **118** that extend through the left sidewall **110A** and right sidewall **110B** to heat the kiln cavity **138**. In certain embodiments, the plurality of burners **118** may additionally, or alternatively, extend through the ceiling **112**. The front door **108**, sidewalls **110**, and ceiling **112** each include refractory interior surfaces to retain heat produced by the plurality of burners **118** within the kiln cavity **138**. The plurality of burners **118** produce hot gas (which may also be referred to herein as flue gas) in the kiln cavity **138**.

[0042] Referring to **FIGS. 1B** and **1C**, the shuttle kiln **100** includes an exhaust system **120** to exhaust the hot gas (e.g., flue gas) from the kiln cavity **138**. The exhaust system **120** includes a plurality of flue risers **122** extending upward from a top surface of the floor **106** of the kiln housing **102**, with the plurality of flue risers **122** being in fluid communication with a plurality of flue channels **124** arranged below a top surface of the floor **106**. The flue risers **122** include a first plurality of flue risers **122A** in fluid communication with a first flue channel **124A** (proximate to the left sidewall **110A**), a second plurality of flue risers **122B** in fluid communication with a second flue channel **124B**, and a third plurality of flue risers **122C** in fluid communication with a third flue channel **124C** (proximate to the right sidewall **110B**). The second plurality of flue risers **122B** and the second flue channel **124B** are laterally positioned between the first and third plurality of flue risers **122A**, **122C** and the first and third flue channels **124A**, **124C**.

In certain embodiments, fewer or more flue risers **122** and/or flue channels **124** may be used. As shown in **FIG. 1C**, the flue channels **124** each lead to a header duct **127** that is arranged to collect fluid gas and supply the flue gas to a fan inlet duct **125**.

[0043] An exhaust fan **126** associated with the kiln housing **102** receives flue gas supplied from the flue channels **124** to the fan inlet duct **125**. The exhaust fan **126** pulls flue gas from the kiln cavity **138** through the flue risers **122**, the flue channels **124**, the header duct **127**, and the fan inlet duct **125**. As illustrated, the exhaust fan **126** may be positioned proximate to the second flue channel **124B** and proximate to the back sidewall **110C**. In certain embodiments, additional exhaust fans **126** may be used. Further, in certain embodiments, one or more exhaust fans may be positioned proximate to the first flue channel **124A** and/or the third flue channel **124C**. In each flue channel **124A-124C**, individual flue risers **122** are arranged at different distances relative to the exhaust fan **126**. For example, in each flue channel **124A-124C** the respective first flue riser **122A-1**, **122B-1**, **122C-1** is closer to the exhaust fan **126** than the respective second flue riser **122A-2**, **122B-2**, **122C-2**, etc.

[0044] Referring to **FIGS. 1A** and **1D**, each shuttle **104** is configured to carry furniture **132** positioned on the shuttle **104**. In certain embodiments, the first shuttle **104A** carries first furniture **132A**, the second shuttle **104B** carries second furniture **132B**, and the third shuttle **104C** carries third furniture **132C**. The furniture **132** defines a plurality of support surfaces **134** configured to support a plurality of bodies **136** (e.g., unfired bodies prior to firing, fired bodies after firing, etc.). In certain embodiments, the furniture **132** may resemble shelving units, with upstanding columns or posts supporting multiple shelf-like support surfaces **134** arranged at different heights.

[0045] Each shuttle **104** includes a plurality of exhaust shafts **140** (which may also be referred to herein as offtakes) that extend from the top **128** to the bottom **130** of the shuttles **104**. The exhaust shafts **140** extend through the shuttle **104** to exhaust hot gas from the kiln cavity **138** above the shuttle **104** to the flue risers **122** below the shuttle **104**. When the shuttle **104** is positioned within the interior **114** of the kiln housing **102**, each exhaust shaft **140** is arranged above and in fluid communication with a respective one of

the plurality of flue risers **122**, and each exhaust shaft **140** is vertically aligned with at least a portion of one of the plurality of flue risers **122**. In other words, when the shuttle **104** is positioned within the interior **114** of the kiln housing **102**, at least a portion of each flue riser **122** is arranged below a respective exhaust shaft of the shuttle **104**. In certain embodiments, the first shuttle **104A** includes a first plurality of exhaust shafts **140** that align with the first plurality of flue risers **122A** (which are in fluid communication with the first flue channel **124A**), the second shuttle **104B** includes a second plurality of exhaust shafts **140** that align with the second plurality of flue risers **122B** (which are in fluid communication with the second flue channel **124B**), and the third shuttle **104C** includes a third plurality of exhaust shafts **140** that align with the third plurality of flue risers **122C** (which are in fluid communication with the third flue channel **124C**). In certain embodiments, exhaust shafts of multiple shuttles **104** (with the shuttles arranged front to back) may be aligned with flue risers **122** associated with one flue channel **124**. For example, in certain embodiments, an exhaust shaft **140** of a first shuttle **104** may be aligned with a first flue riser **122A-1** of the first flue channel **124A** and an exhaust shaft **140** of a second shuttle **104** may be aligned with a seventh flue riser **122A-7** of the first flue channel **124A**.

[0046] The exhaust shafts **140** are vertically aligned with at least portions of the flue risers **122** to place the exhaust shafts **140** in fluid communication with the flue risers **122**. Restated, at least a portion of each exhaust shaft **140** may be vertically aligned with a respective one of the flue risers **122**. As the shuttle **104** is movable relative to the floor **106** of the kiln housing **102** (and relative to the flue risers **122**), the exhaust shafts **140** are not directly attached to the flue risers **122**. The exhaust shafts **140** each include an inlet port **143** at the top **128** of the shuttle **104**, and an outlet port **144** at the bottom **130** of the shuttle **104**. In each instance, the outlet port **144** is arranged below the inlet port **143**. Entrainment gaps **142** are defined between outlet ports **144** of the exhaust shafts **140** (at a bottom of each exhaust shaft **140**) and inlet ports **146** of the flue risers **122** (at a top of each flue riser **122**). In other words, each exhaust shaft **140** is configured to be separated from a corresponding flue riser **122** with an entrainment gap **142** arranged therebetween.

As the top **128** of the shuttle **104** has a refractory surface configured to reflect heat upward, cooler gas (e.g., undercar gas or undercar air) in the undercar space **148** beneath the shuttle **104** and above the floor **106** is cooler than the hot gas in the kiln cavity **138** above the shuttle **104**. As flue gas exhausts from the exhaust shaft **140** to the flue riser **122**, cooler gas is drawn through the entrainment gap **142** into the flue riser **122**, due to suction generated by the exhaust fan **126**. The cooler gas in the undercar space **148** mixes with and cools the hot gas entering the flue channel **124**. In certain embodiments, the exhaust fan **126** is configured to handle gas at a maximum operating temperature, and the cooler gas pulled through the entrainment gap **142** is used to cool the hot gas from the exhaust shaft **140** to a temperature below the maximum operating temperature. The temperature of the gas inside the flue channel **124** is lower than the temperature of the hot gas in the exhaust shafts **140** due to the addition of cooler gas through the entrainment gap **142**.

[0047] As the cooler gas beneath the shuttle **104** is colder than the hot gas above the shuttle **104**, this can cause a radiation heat transfer interaction, which can create non-uniform temperatures within the kiln cavity **138**.

[0048] FIGS. 2A-2D illustrate radiation heat loss of the shuttle kiln **100** without a radiation blocker. FIG. 2A is a partial perspective view illustrating radiation heat loss of the shuttle kiln **100** without a radiation blocker. The heat map shows the peak temperatures experienced by the plurality of support surfaces **134** of furniture **132** within the shuttle kiln **100**. The heat map illustrates that the center of the kiln cavity **138** experiences higher peak temperatures, and that there are cold spots produced by the exhaust shafts **140A-140C** due to radiation heat loss therethrough. Other sources of heat loss may include air leakages through seals, and/or convective heat loss through sidewalls **110**, etc. This temperature non-uniformity can result in non-uniform part shrinkages, as there is a correlation between peak temperature experienced by an unfired body and body shrinkage during the firing process.

[0049] FIGS. 2B-2C are charts illustrating maximum temperature experienced within the shuttle kiln **100** at each of a top, middle, and lower level, between the left sidewall

110A and the right sidewall **110B**. **FIG. 2B** is a chart illustrating maximum temperature experienced within the shuttle kiln **100** of **FIG. 2A** at a top of the shuttle kiln **100** (i.e., proximate to the ceiling **112**), and comparing experimental results and model calculations. **FIG. 2C** is a chart illustrating maximum temperature experienced within the shuttle kiln **100** of **FIG. 2A** at a middle of the shuttle kiln **100** (i.e., midway between the ceiling **112** of the kiln housing **102** and the top **128** of the shuttle **104**), and comparing experimental results and model calculations. **FIG. 2D** is a chart illustrating maximum temperature experienced within the shuttle kiln **100** of **FIG. 2A** at a bottom of the shuttle kiln **100** (i.e., proximate to the top **128** of the shuttle **104**), and comparing experimental results and model calculations. It is noted that for each of these charts, the experimental results were consistent with the model calculations.

[0050] **FIG. 2B** illustrates a relatively uniform peak temperature across a top of the shuttle kiln **100**, but with some temperature drop at the left sidewall **110A** and right sidewall **110B**. Comparatively, **FIG. 2D** illustrates dips in peak temperature (partly due to temperature drops proximate to the left sidewall **110A** and right sidewall **110B**) mainly due to the radiation heat loss at each of the exhaust shafts **140A-140C**. The radiation heat loss is one of the reasons why the temperature was less uniform at the bottom than the top of the shuttle kiln **100**. In certain instances, temperature non-uniformity could be as high as 25°C.

[0051] **FIGS. 3A-3C** are views of a radiation blocker **300** positioned above an exhaust shaft **140** and a radiation shielding grid **302** of the shuttle kiln **100** of **FIG. 1A**. The radiation blocker **300** (in this embodiment and other embodiments discussed herein) reduces radiation heat transfer through the exhaust shaft **140**, thereby increasing energy efficiency (by reducing heat loss by radiation heat transfer through the exhaust shafts **140**), and/or increasing temperature uniformity in the shuttle kiln **100** (particularly at the inlet port **143** of the exhaust shaft **140**). In certain embodiments, the radiation blocker **300** (with or without radiation shielding grid **302**) may result in temperature non-uniformity within ± 5 °C. Further, the radiation blocker **300** can be easily retrofitted into existing shuttle kilns **100**.

[0052] In certain embodiments, the radiation blocker **300** includes a radiation shield **301** (may also be referred to herein as a radiation shielding plate, radiation blocking plate, etc.) positioned above the inlet port **143** and/or the outlet port **144** of the exhaust shaft **140** to block line-of-sight radiant heat transfer between (i) any heated surface above the shuttle **104** within the kiln housing **102** and (ii) the outlet port **144** of the exhaust shaft **140**. The radiation shielding grid **302** is arranged within the exhaust shaft **140** and extends at least a portion of a length of the exhaust shaft **140** between the inlet port **143** and the outlet port **144**. In certain embodiments, the radiation shielding grid **302** extends a distance (e.g., substantially an entire distance) between the inlet port **143** and the outlet port **144** of the exhaust shaft **140**. The radiation shielding grid **302** reduces radiant heat transfer between the hot gas in the kiln cavity **138** and the cooler gas in the flue channel **124**. In certain embodiments, the radiation shielding grid **302** could be made with a finer grid mesh, with thicker grid lines, and/or with increased height; however, such modifications would tend to increase the pressure drop between the kiln cavity **138** and the flue channel **124** (which can reduce flow through the exhaust shaft **140**). Further, any such modifications would still not prevent line-of-sight radiation heat transfer perpendicular to the outlet port **144** of the exhaust shaft **140**.

[0053] Providing the radiation shield **301** above and offset from the inlet port **143** prevents line-of-sight radiation heat transfer to the outlet port **144** of the exhaust shaft **140** while also avoiding interference with gas flow through the exhaust shaft **140** (without increasing the pressure drop). This increases temperature uniformity within the shuttle kiln **100**. As provided below, Equation 1 is directed to the heat transfer between two parallel plates without use of the radiation shield **301**, and Equation 2 is directed to the heat transfer between two parallel plates with use of the radiation shield **301**.

$$Q_{12, \text{ no shield}} = \frac{E_{b1} - E_{b2}}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1}$$

Equation 1

$$Q_{12, \text{new shield}} = \frac{E_{b1} - E_{b2}}{\frac{1 - \epsilon_1}{A_1 \epsilon_1} + \frac{1}{A_1 F_{12}} + \frac{1 - \epsilon_{3,1}}{A_3 \epsilon_{3,1}} + \frac{1 - \epsilon_{3,2}}{A_3 \epsilon_{3,2}} + \frac{1}{A_3 F_{32}} + \frac{1 - \epsilon_2}{A_2 \epsilon_2}}$$

Equation 2

where F_{ij} is a view factor, E_b is a blackbody emissive power, ϵ is emissivity, and A is an area.

[0054] Referring to **FIG. 3C**, the radiation shield **301** includes a projected top area, which is a two-dimensional area of a vertical projection of the radiation shield **301** on a horizontal plane. In certain embodiments, the projected top area is defined by L1 and L2. The projected top area is configured to be at least as large as (and in certain embodiments larger than) a cross-sectional area of the inlet port **143** defined by L3 and L4. In combination with the radiation shielding grid **302**, such a configuration prevents any line-of-sight radiation heat transfer between any heated surface above the shuttle **104** within the kiln housing **102** (e.g., support surface **134**) and the outlet port **144** of the exhaust shaft **140**. It is noted that if the radiation shielding grid **302** were removed, to completely block line-of-sight radiation heat transfer, the projected top area of the radiation shield **301** may have to be increased and/or the offset H1 between the radiation shield **301** and the top **128** of the shuttle **104** may need to be decreased.

[0055] To offset the radiation shield **301** from the top **128** of the shuttle **104**, the radiation shield **301** may be elevated and/or suspended. For example, in certain embodiments, the radiation shield **301** includes at least one support to elevate the radiation shield **301** above the inlet port **143** of the exhaust shaft **140** of the shuttle **104**. In certain embodiments, the radiation shield **301** includes the at least one support attached to the furniture **132** (e.g., support surface **134**) on the shuttle **104** to suspend the radiation shield **301** above the inlet port **143** of the exhaust shaft **140** of the shuttle **104**.

[0056] **FIG. 4A** is a side view illustrating radiation heat loss through the exhaust shaft **140** of the shuttle **104** with and without the radiation shielding grid **302** and/or the radiation blocker **300**. Model **400A** illustrates temperature variation without a radiation shield **301** and without the radiation shielding grid **302**. Model **402A** illustrates temperature variation without the radiation shield **301** and with the radiation shielding grid **302**. Model **404A** illustrates temperature variation with the radiation shield **301** and without the radiation shielding grid **302**. Model **406A** illustrates temperature variation with the radiation shield **301** and the radiation shielding grid **302**.

[0057] As shown, model **400A** shows the greatest amount of heat loss. Model **404A** shows that the radiation shield **301** by itself reduces the amount of heat loss. Further, model **406A** shows the greatest temperature uniformity and the least amount of temperature variation at the support surface **134** of the furniture **132** (which holds the bodies **136**).

[0058] **FIG. 4B** is a top view illustrating radiation heat loss through the exhaust shaft **140** of the shuttle **104** with and without the radiation shielding grid **302** and/or the radiation blocker **300**. Model **400B** illustrates temperature variation without the radiation shield **301** and without the radiation shielding grid **302**. Model **400B** has an average temperature of 1388°C and a temperature difference of 40°C between the center and the edge of the support surface **134** of the furniture **132**. Model **402B** illustrates temperature variation without the radiation shield **301** and with the radiation shielding grid **302**. Model **402B** has an average temperature of 1394°C and a temperature difference of 18 °C between the center and the edge of the support surface **134** of the furniture **132**. Model **404B** illustrates temperature variation with the radiation shield **301** and without the radiation shielding grid **302**. Model **400B** has an average temperature of 1390°C and a temperature difference of 18°C between the center and the edge of the support surface **134** of the furniture **132**. Model **406B** illustrates temperature variation with the radiation shield **301** and the radiation shielding grid **302**. Model **406B** has an average temperature of 1396°C and a temperature difference of 12°C between the center and the edge of the support surface **134** of the furniture **132**.

[0059] Similar to **FIG. 4A** discussed above, model **400B** shows the greatest amount of heat loss. Model **404B** shows that the radiation shield **301** by itself reduces the amount of heat loss in the exhaust shaft **140**. Model **406B** shows the greatest temperature uniformity and the least amount of temperature variation in the exhaust shaft **140**.

[0060] **FIG. 4C** is a chart illustrating maximum temperature uniformity at the exhaust shaft **140** of the shuttle **104** with and without the radiation shielding grid **302** and/or the radiation blocker **300**. The lines illustrate the temperature variation on the support surface **134** of furniture **132** relative to a distance from a center of the outlet port **144** of the exhaust shaft **140**. Line **400C** illustrates temperature variation without the radiation shield **301** and without the radiation shielding grid **302**. Line **402C** illustrates temperature variation without the radiation shield **301** and with the radiation shielding grid **302**. Model **404C** illustrates temperature variation with the radiation shield **301** and without the radiation shielding grid **302**. Model **406C** illustrates temperature variation with the radiation shield **301** and the radiation shielding grid **302**.

[0061] **FIG. 5** is a schematic side cross-sectional view of the radiation shield **301'** with a tapered bottom surface **500** and the exhaust shaft **140** of the shuttle **104** with a tapered sidewall **502**. In certain embodiments, the tapered bottom surface **500** directs the airflow of hot gas downward into the exhaust shaft **140**. In certain embodiments, the tapered bottom surface **500** includes a conical or trapezoidal bottom surface. In certain embodiments, the exhaust shaft **140** includes the tapered sidewall **502** and a straight sidewall **504**. The tapered sidewall **502** is proximate to the inlet port **143** of the exhaust shaft **140**, and the straight sidewall **504** is proximate to the outlet port **144** of the exhaust shaft **140**. The tapered sidewall **502** includes a larger diameter **X1** proximate to the inlet port **143** and a smaller diameter **X2** proximate to the outlet port **144**. In certain embodiments, the tapered sidewall **502** includes a conical or trapezoidal sidewall. The tapered bottom surface **500** and/or the tapered sidewall **502** directs the airflow downward and/or reduces the pressure drop from the inlet port **143** to the outlet port **144** of the exhaust shaft **140**.

[0062] **FIG. 6A** is a schematic side cross-sectional view of a radiation blocker **300'** including a shielding wall portion **600** having a bend **601** in the exhaust shaft **140** of the shuttle **104**. In other words, the shielding wall portion **600** defines the bend **601** in the at least one exhaust shaft **140**. The exhaust shaft **140** includes an upper straight sidewall **602** (proximate to the inlet port **143**), lower straight sidewall **604** (proximate to the outlet port **144**), and the bend **601** therebetween. The shielding wall portion **600** is non-perpendicular to a top **128** (i.e., an upper surface) of the shuttle **104**. Further, the shielding wall portion **600** is angled relative to the upper straight sidewall **602** and/or the lower straight sidewall **604**. However, it is noted that in certain embodiments, the exhaust shaft **140** may include only the bend **601** without including the upper straight sidewall **602** and/or the lower straight sidewall **604**.

[0063] The upper straight sidewall **602** defines a center axis A, and the lower straight sidewall **604** defines a center axis B aligned with the center axis A. The outermost portion of the bend **601** defines a center axis C that is offset from the center axis A and the center axis B by a distance X3. This offset prevents line-of-sight radiation heat transfer between the inlet port **143** and the outlet port **144** of the exhaust shaft **140**.

[0064] **FIG. 6B** is a schematic side cross-sectional view of a radiation blocker **300''** including an offset between the inlet port **143** and the outlet port **144** of the exhaust shaft **140** of the shuttle **104**. In other words, the shielding wall portion **600'** defines an angled sidewall **601'** in the at least one exhaust shaft **140** to cause the outlet port **144** to be offset relative to the inlet port **143**. The exhaust shaft **140** includes an upper straight sidewall **602** (proximate to the inlet port **143**), lower straight sidewall **604** (proximate to the outlet port **144**), and an angled sidewall **601'** therebetween. The shielding wall portion **600'** is non-perpendicular to a top **128** (i.e., an upper surface) of the shuttle **104**. The shielding wall portion **600'** is also angled relative to the upper straight sidewall **602** and/or the lower straight sidewall **604**. However, in certain embodiments, the exhaust shaft **140** may include only the angled sidewall **601'** without including the upper straight sidewall **602** and/or the lower straight sidewall **604**.

[0065] The upper straight sidewall **602** defines a center axis A, and the lower straight sidewall **604** defines a center axis B that is not aligned with the center axis A and offset therefrom by a distance X4. The outlet port **144** is laterally offset relative to the inlet port **143**. This lateral offset prevents line-of-sight radiation heat transfer between the inlet port **143** and the outlet port **144** of the exhaust shaft **140**.

[0066] **FIG. 7** is a flowchart illustrating steps of a method for fabricating at least one fired body **136**. According to step **700**, at least one shuttle **104** carrying at least one unfired body **136** is moved into the kiln housing **102** of a shuttle kiln **100**. According to step **702**, at least one exhaust shaft **140** of the at least one shuttle **104** is arranged above at least one flue riser **122** in the kiln housing **102**. According to step **704**, the kiln cavity **138** bounded by the at least one shuttle **104** and the kiln housing **102** is heated to alter the at least one unfired body **136**. According to step **706**, radiation is shielded using the radiation blocker **300** positioned above the outlet port **144** of the at least one exhaust shaft **140** to block line-of-sight radiant heat transfer between (i) any heated surface above the at least one shuttle **104** within the kiln housing **102** and (ii) the outlet port **144** of the at least one exhaust shaft **140** of the shuttle **104**. According to step **708**, gas is exhausted from the kiln cavity **138** through the at least one exhaust shaft **140** of the shuttle **104**.

[0067] It will be apparent to those skilled in the art that various modifications and variations can be made without departing from the spirit or scope of the invention.

[0068] Many modifications and other embodiments of the embodiments set forth herein will come to mind to one skilled in the art to which the embodiments pertain having the benefit of the teachings presented in the foregoing descriptions and the associated drawings. Therefore, it is to be understood that the description and claims are not to be limited to the specific embodiments disclosed and that modifications and other embodiments are intended to be included within the scope of the appended claims. It is intended that the embodiments cover the modifications and variations of the embodiments provided they come within the scope of the appended claims and their equivalents. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation.

What is claimed is:

1. A shuttle kiln, comprising:
 - a shuttle configured to be removably positioned within an interior of a kiln housing and comprising at least one exhaust shaft having an inlet port and an outlet port arranged below the inlet port, wherein the at least one exhaust shaft is configured to be positioned above and in fluid communication with at least one flue riser of the kiln housing, with the at least one exhaust shaft configured to be separated from the at least one flue riser to define an entrainment gap therebetween; and
 - a radiation blocker positioned above the outlet port of the at least one exhaust shaft to block line-of-sight radiant heat transfer between (i) any heated surface above the shuttle within the kiln housing and (ii) the outlet port of the at least one exhaust shaft.
2. The shuttle kiln of claim 1, further comprising the kiln housing, wherein the kiln housing comprises at least one flue channel and the at least one flue riser is in fluid communication with the at least one flue channel.
3. The shuttle kiln of claim 2, wherein:
 - the kiln housing comprises a floor, a door, sidewalls, and a ceiling bounding the interior;
 - the at least one flue channel is arranged below a top surface of the floor; and
 - the at least one flue riser extends above the top surface of the floor.
4. The shuttle kiln of claim 2, wherein at least a portion of the at least one exhaust shaft is vertically aligned with the at least one flue riser.

5. The shuttle kiln of claim 1, further comprising furniture positioned on the shuttle and defining a plurality of support surfaces configured to support a plurality of unfired bodies to be fired within the shuttle kiln.
6. The shuttle kiln of claim 1, further comprising at least one radiation shielding grid arranged within the at least one exhaust shaft.
7. The shuttle kiln of claim 6, wherein the at least one radiation shielding grid extends between the inlet port and the outlet port of the at least one exhaust shaft.
8. The shuttle kiln of claim 1, wherein at least a portion of the at least one exhaust shaft comprises a tapered sidewall proximate to the inlet port.
9. The shuttle kiln of claim 1, wherein the radiation blocker comprises a shielding wall portion of the at least one exhaust shaft, with the shielding wall portion being non-perpendicular to an upper surface of the shuttle.
10. The shuttle kiln of claim 9, wherein the shielding wall portion defines a bend in the at least one exhaust shaft.
11. The shuttle kiln of claim 9, wherein the outlet port of the at least one exhaust shaft is laterally offset relative to the inlet port.
12. The shuttle kiln of claim 1, wherein the radiation blocker comprises at least one radiation shield positioned above the inlet port of the at least one exhaust shaft of the shuttle.
13. The shuttle kiln of claim 12, wherein the radiation blocker further comprises at least one support to elevate the at least one radiation shield above the inlet port of the at least one exhaust shaft of the shuttle.

14. The shuttle kiln of claim 12, wherein the radiation blocker further comprises at least one support attached to furniture positioned on the shuttle to suspend the at least one radiation shield above the inlet port of the at least one exhaust shaft of the shuttle.
15. The shuttle kiln of claim 12, wherein a projected top area of the at least one radiation shield is at least as large as a cross-sectional area of the inlet port of the at least one exhaust shaft of the shuttle.
16. The shuttle kiln of claim 12,
wherein a projected top area of the at least one radiation shield is in a range of from 0.09 m² to 0.21 m²; and
wherein a cross-sectional area of the inlet port of the at least one exhaust shaft of the shuttle in a range of from 0.09 m² to 0.21 m².
17. The shuttle kiln of claim 12, wherein the at least one radiation shield comprises a tapered bottom surface.
18. The shuttle kiln of claim 12, wherein the at least one radiation shield comprises a conical or trapezoidal bottom surface.
19. A method of fabricating at least one fired body, the method comprising:
moving at least one shuttle carrying at least one unfired body into a kiln housing of a shuttle kiln;
arranging at least one exhaust shaft of the at least one shuttle above at least one flue riser in the kiln housing;
heating a kiln cavity bounded by the at least one shuttle and the kiln housing to alter the at least one unfired body;

shielding radiation using a radiation blocker positioned above an outlet port of the at least one exhaust shaft to block line-of-sight radiant heat transfer between (i) any heated surface above the at least one shuttle within the kiln housing and (ii) the outlet port of the at least one exhaust shaft of the at least one shuttle;

exhausting gas from the kiln cavity through the at least one exhaust shaft of the at least one shuttle.

20. The method of claim 19, wherein the radiation blocker comprises a shielding wall portion of the at least one exhaust shaft, with the shielding wall portion being non-perpendicular to an upper surface of the at least one shuttle.

21. The method of claim 19, wherein the radiation blocker comprises at least one radiation shield positioned above an inlet port of the at least one exhaust shaft of the at least one shuttle.

22. A fired body produced by the method of claim 19.

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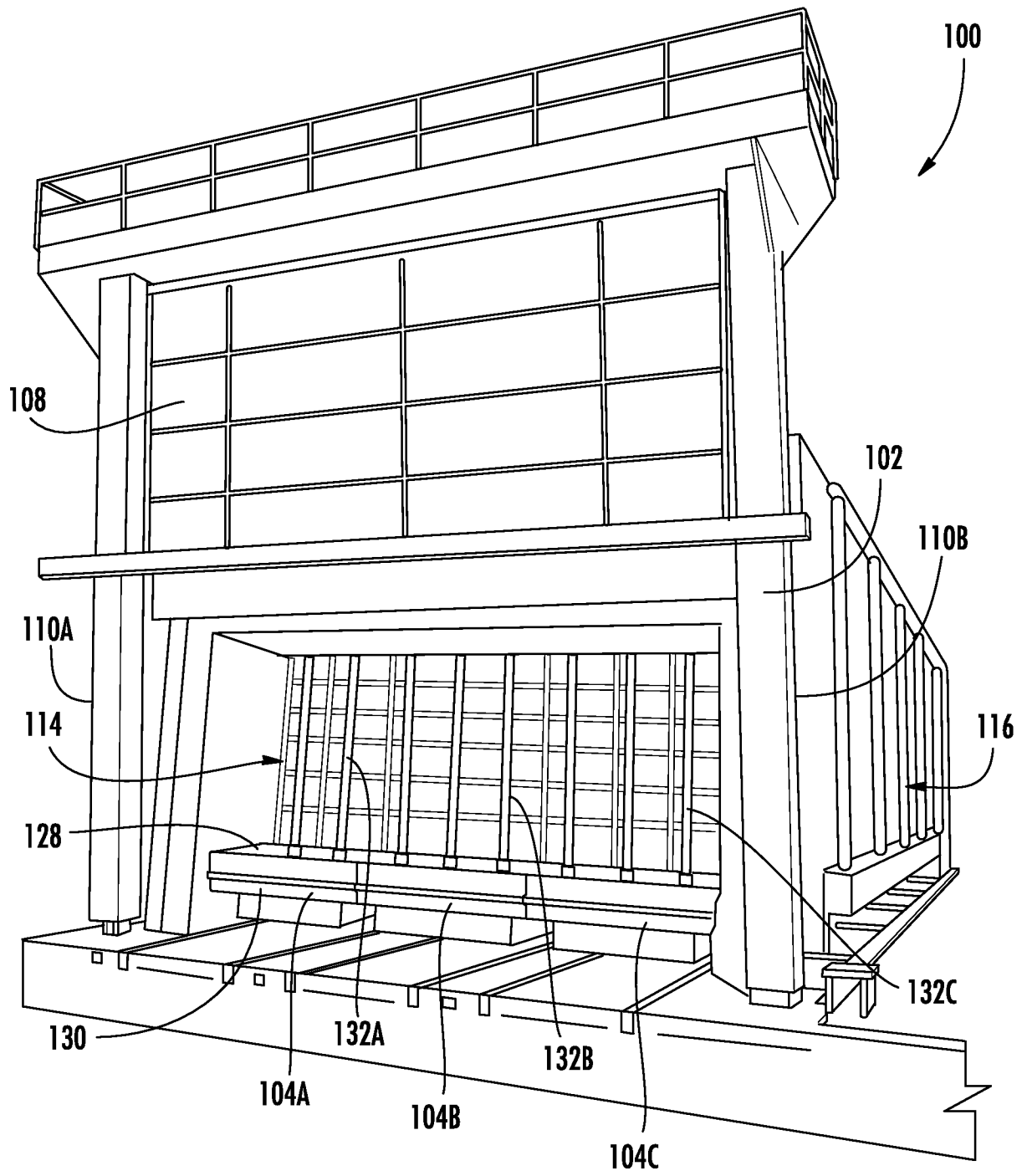


FIG. 1A

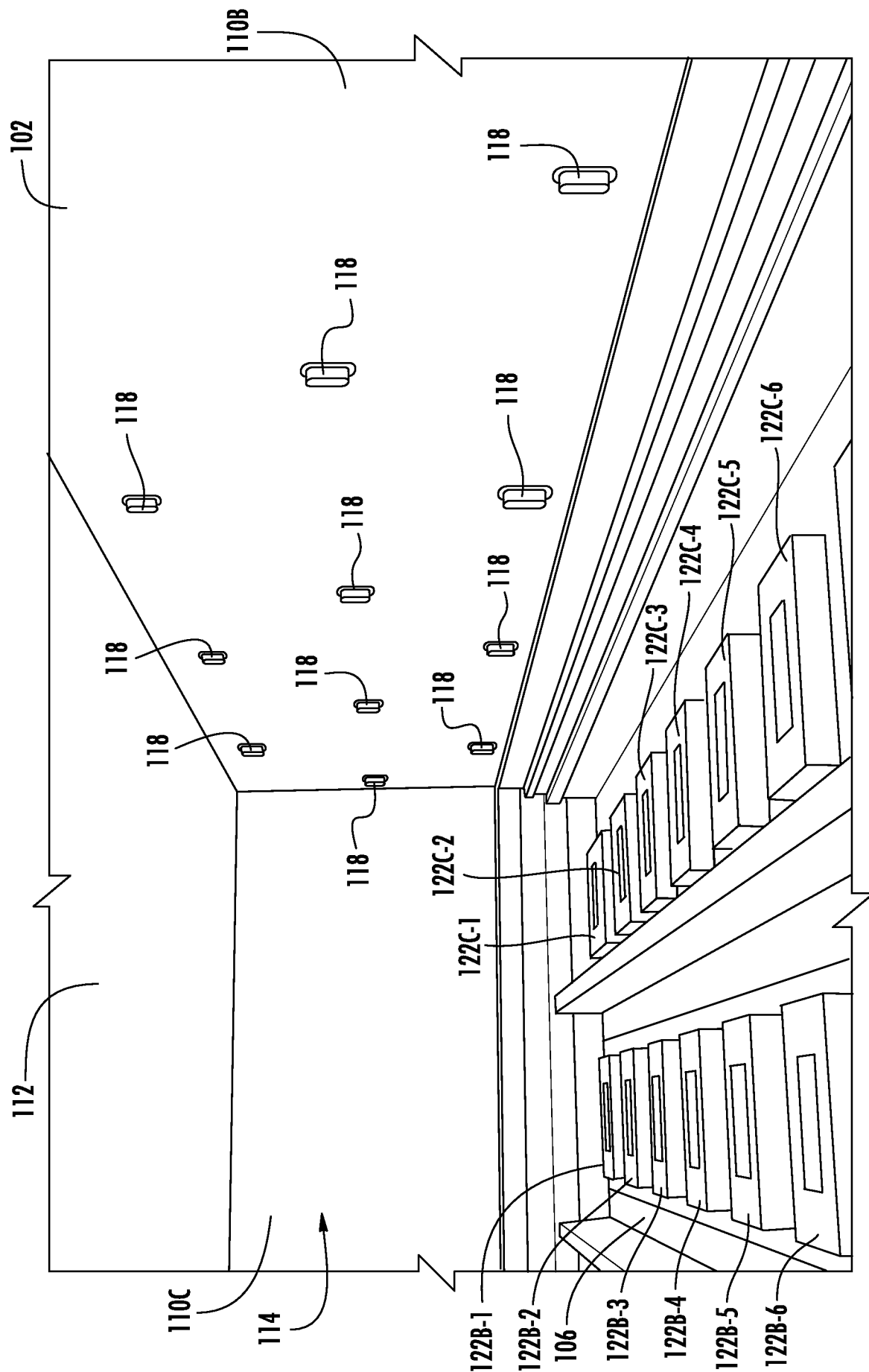
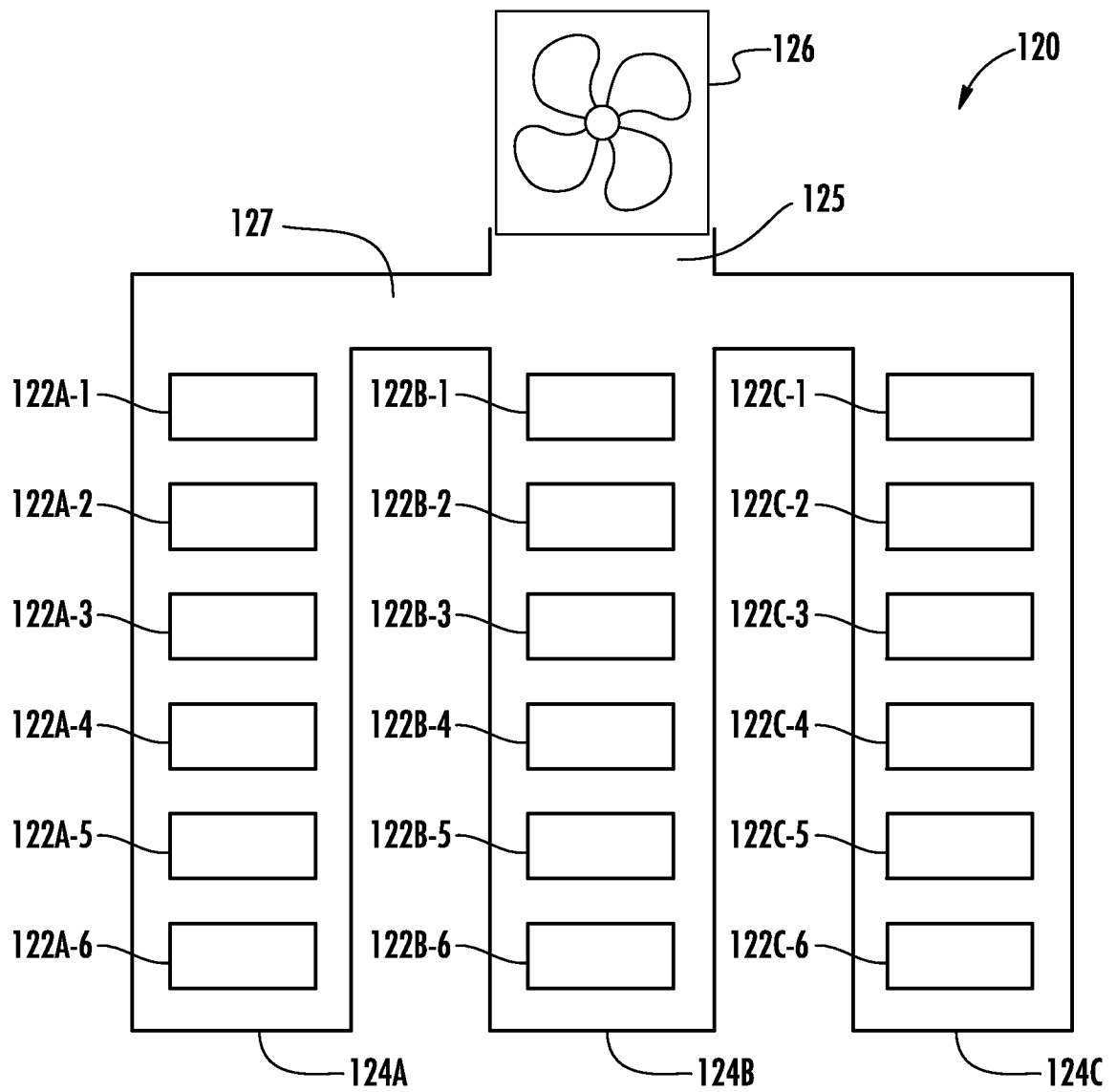


FIG. 1B

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**FIG. 1C**

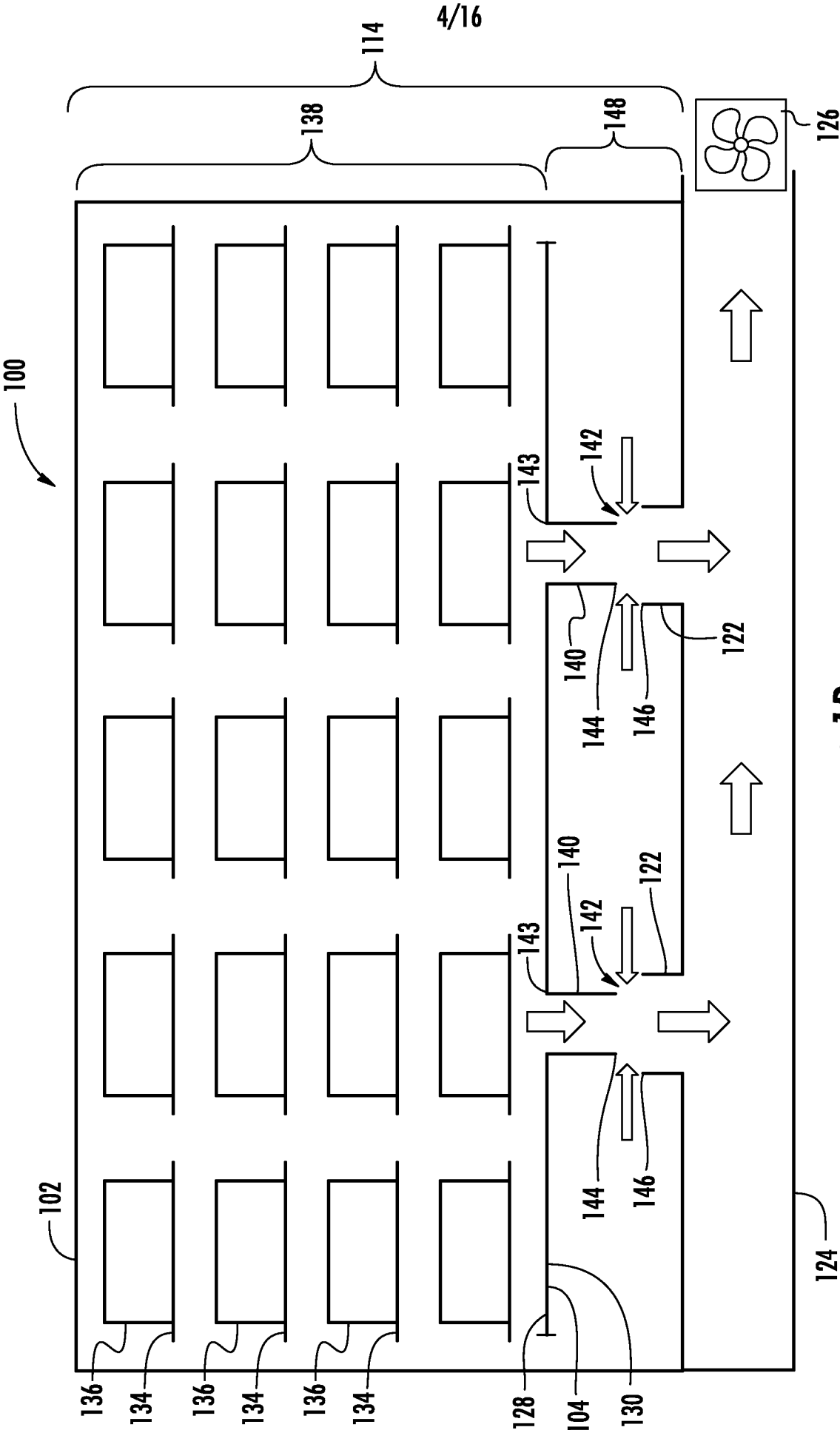


FIG. 1D

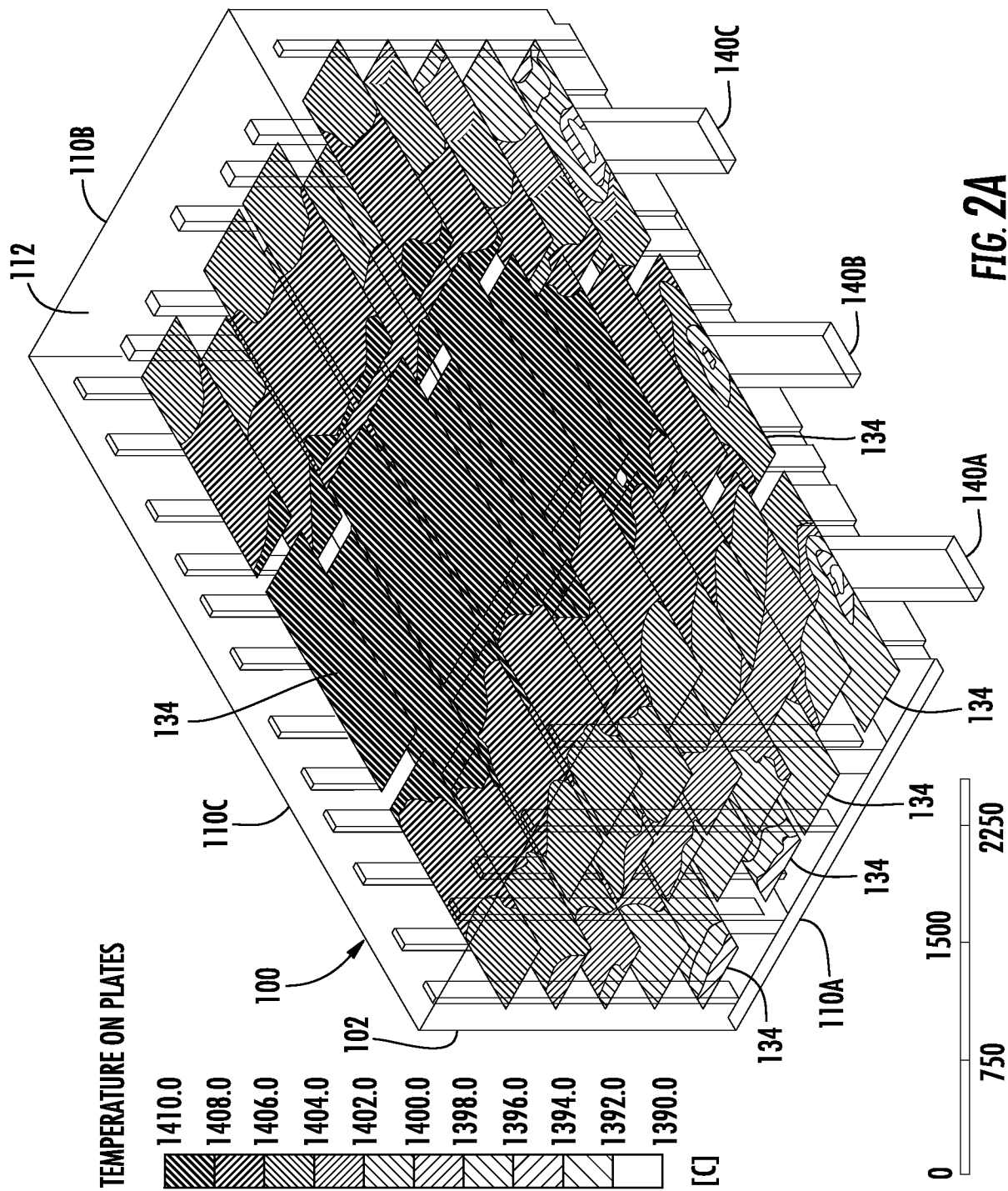
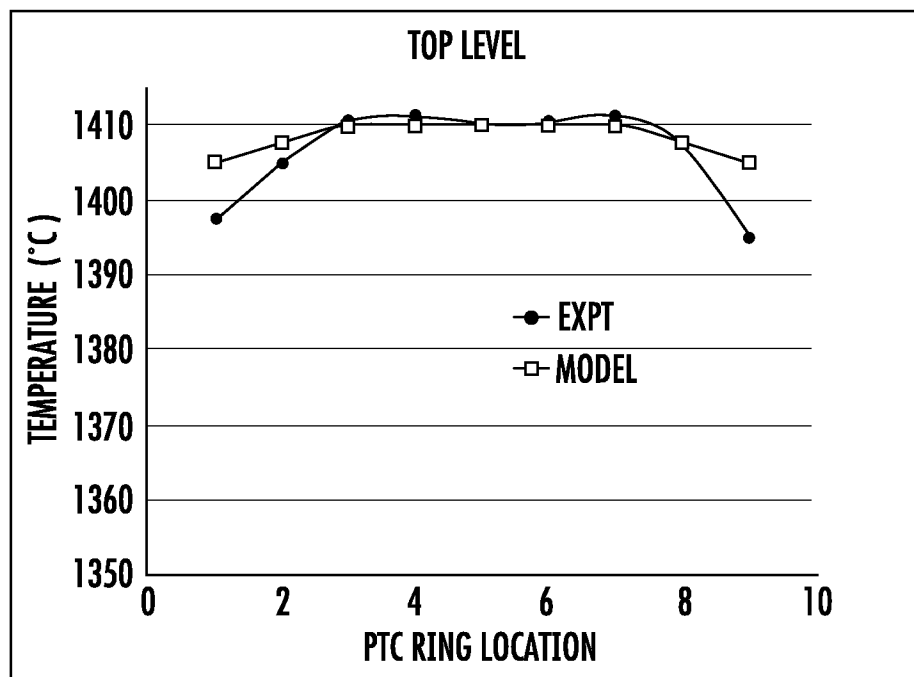
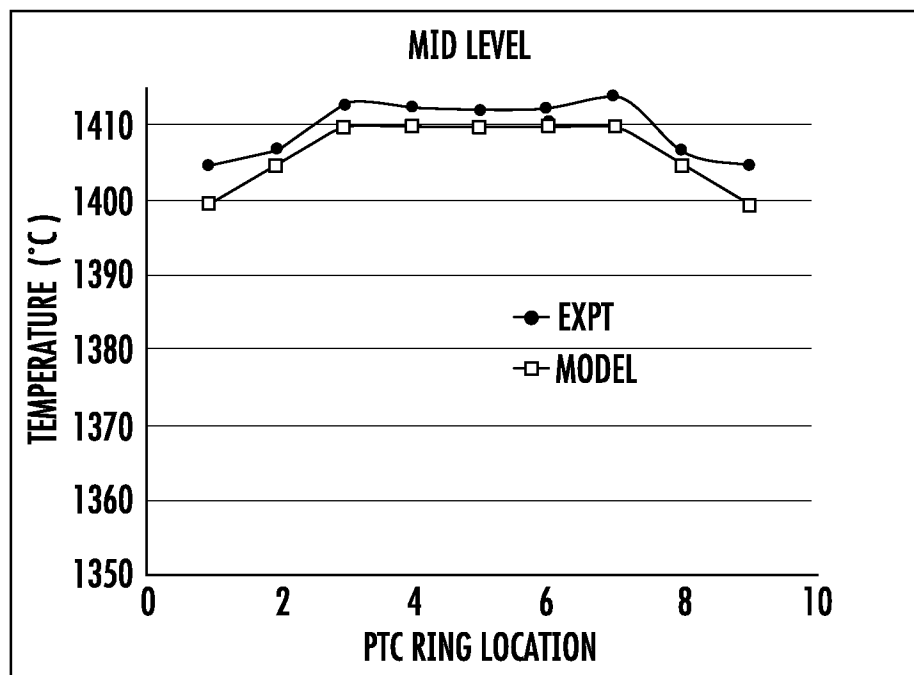


FIG. 2A

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**FIG. 2B****FIG. 2C**

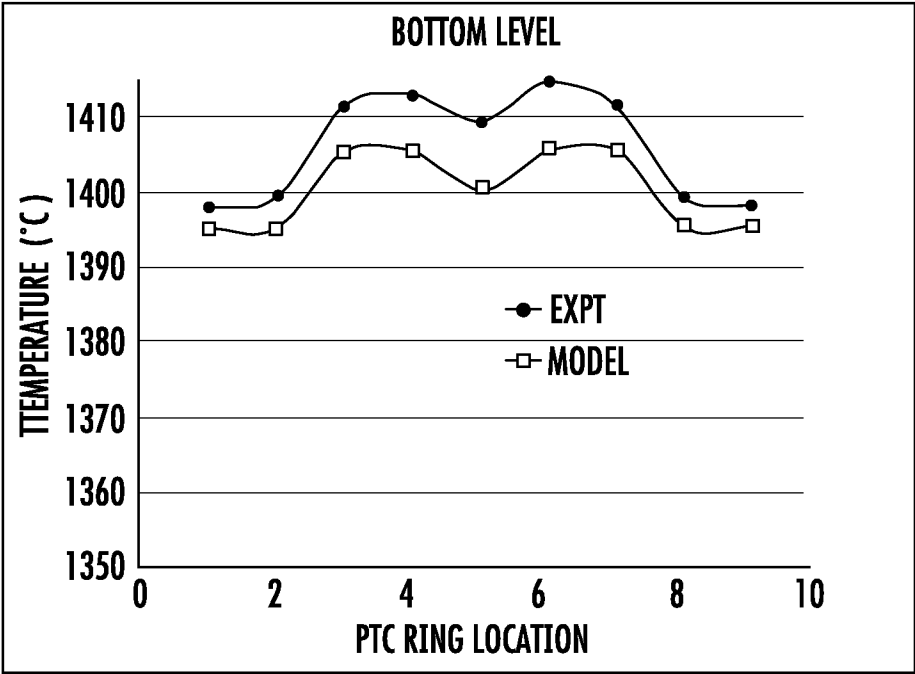


FIG. 2D

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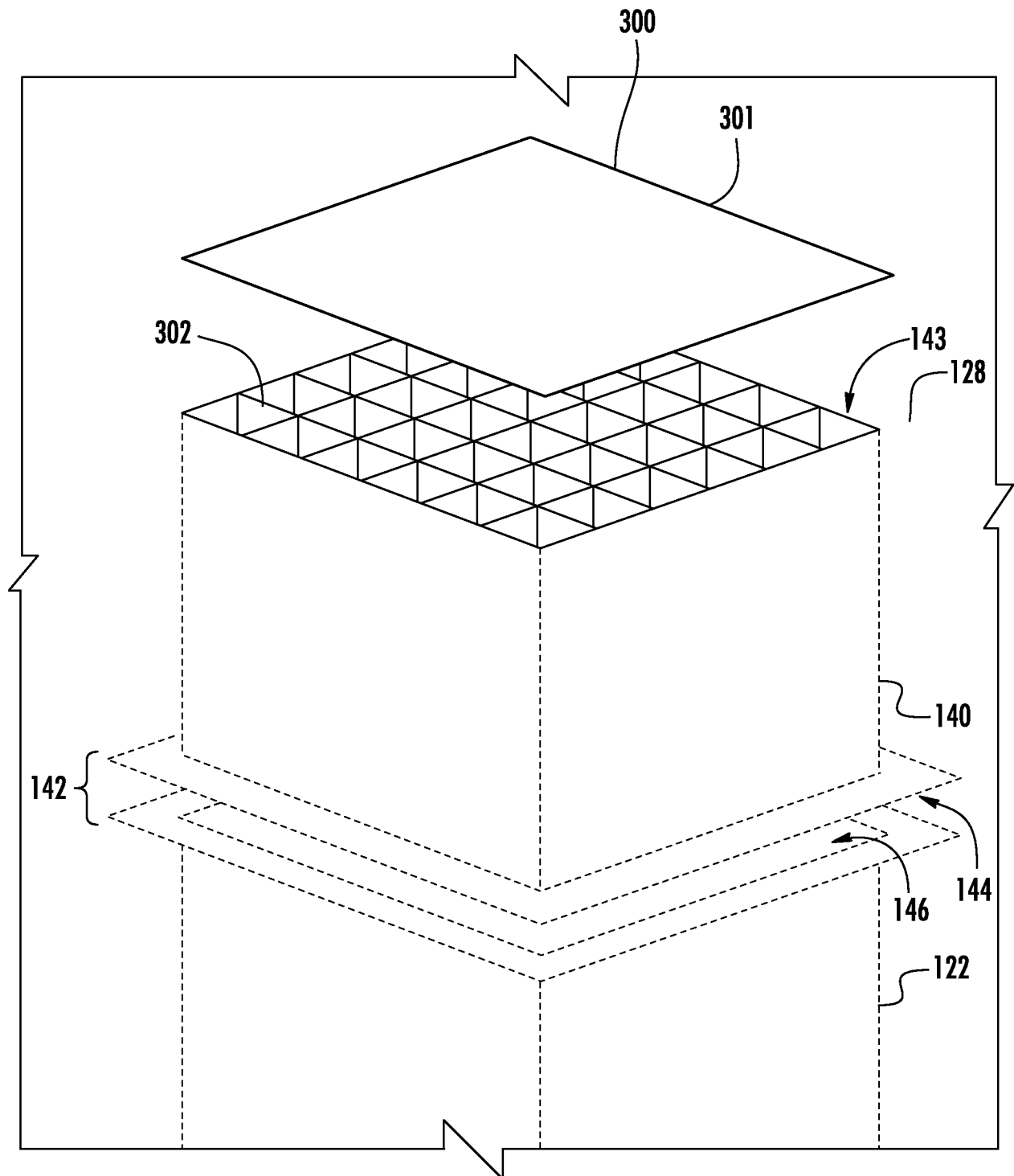


FIG. 3A

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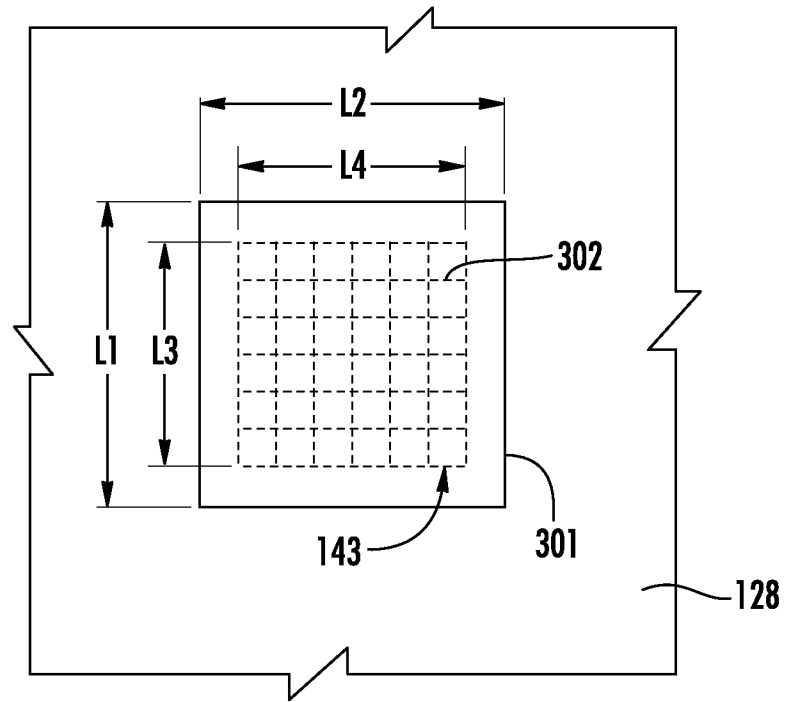


FIG. 3C

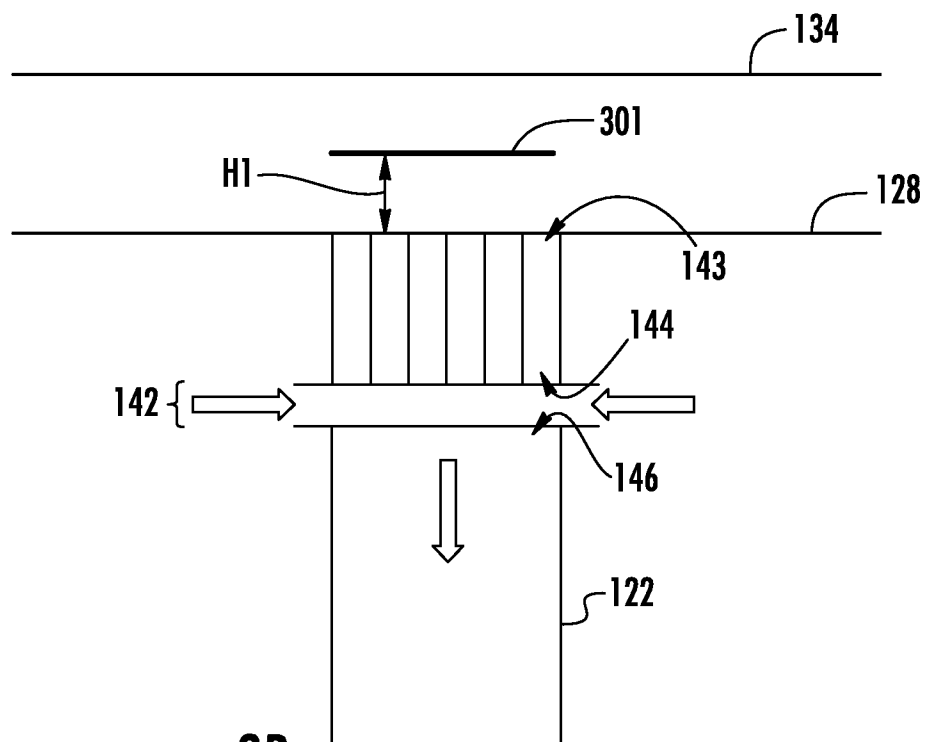


FIG. 3B

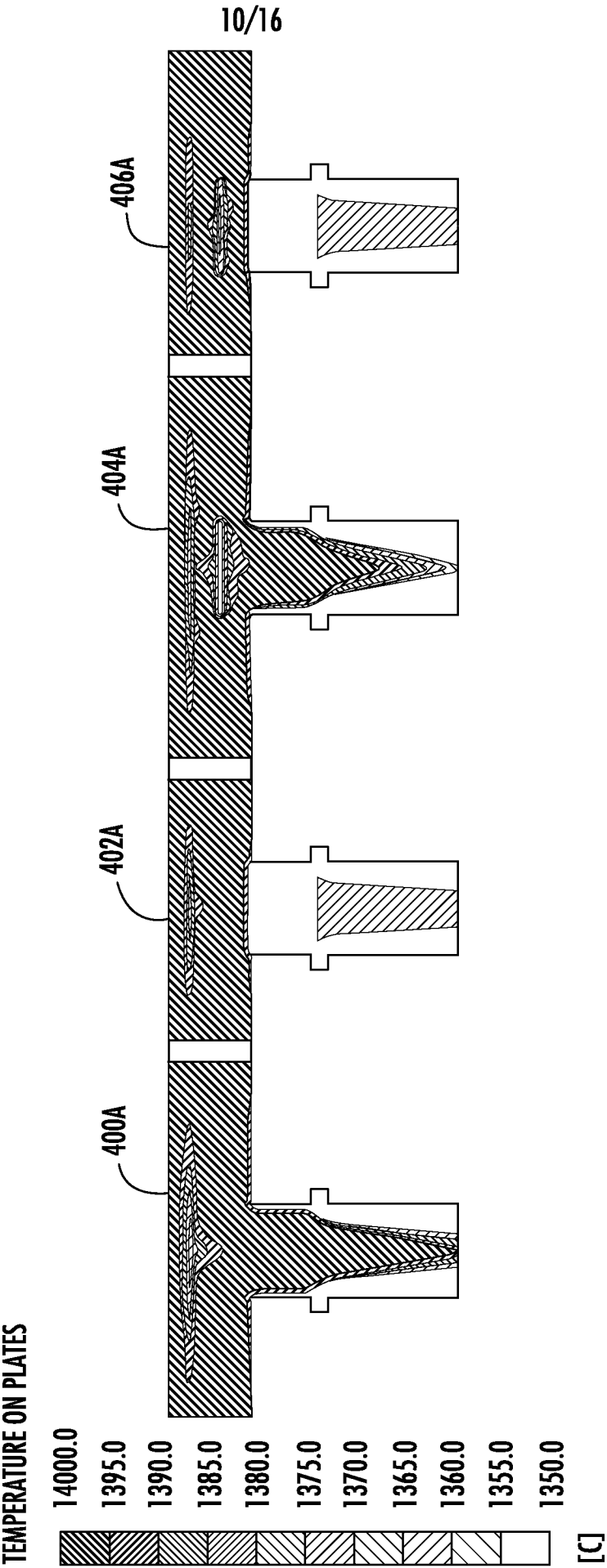
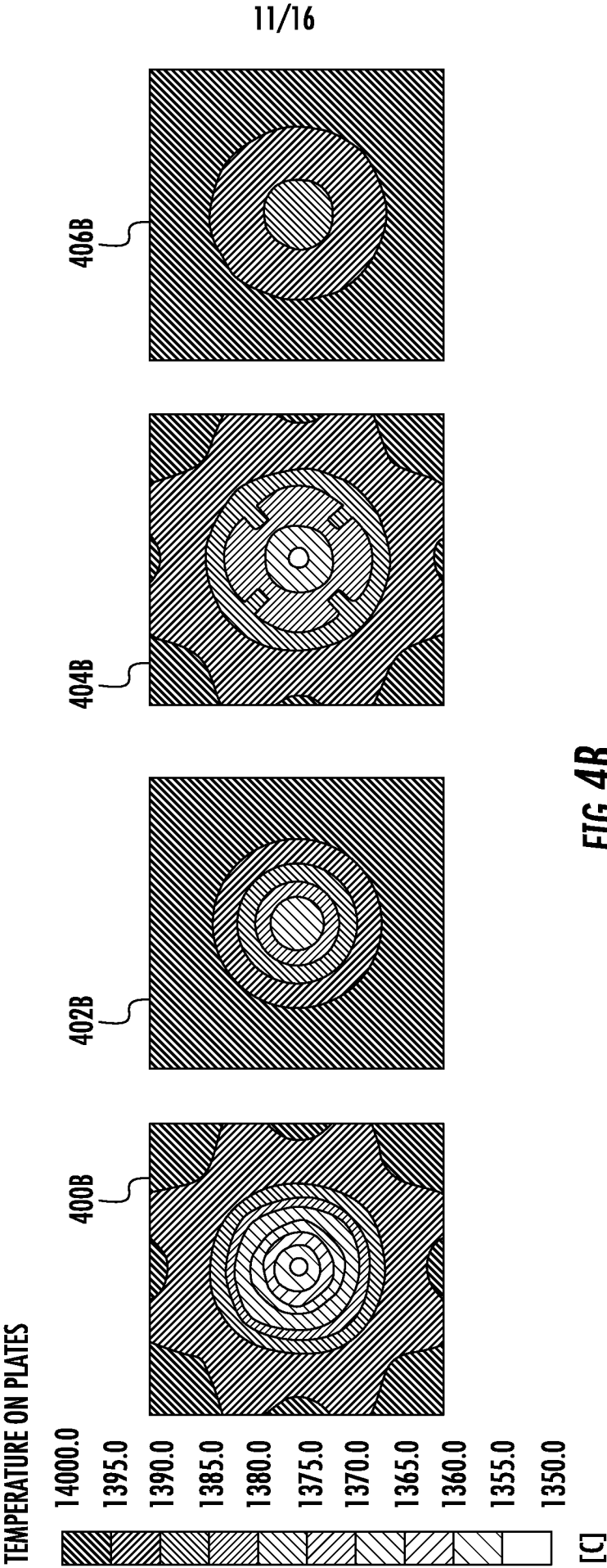


FIG. 4A



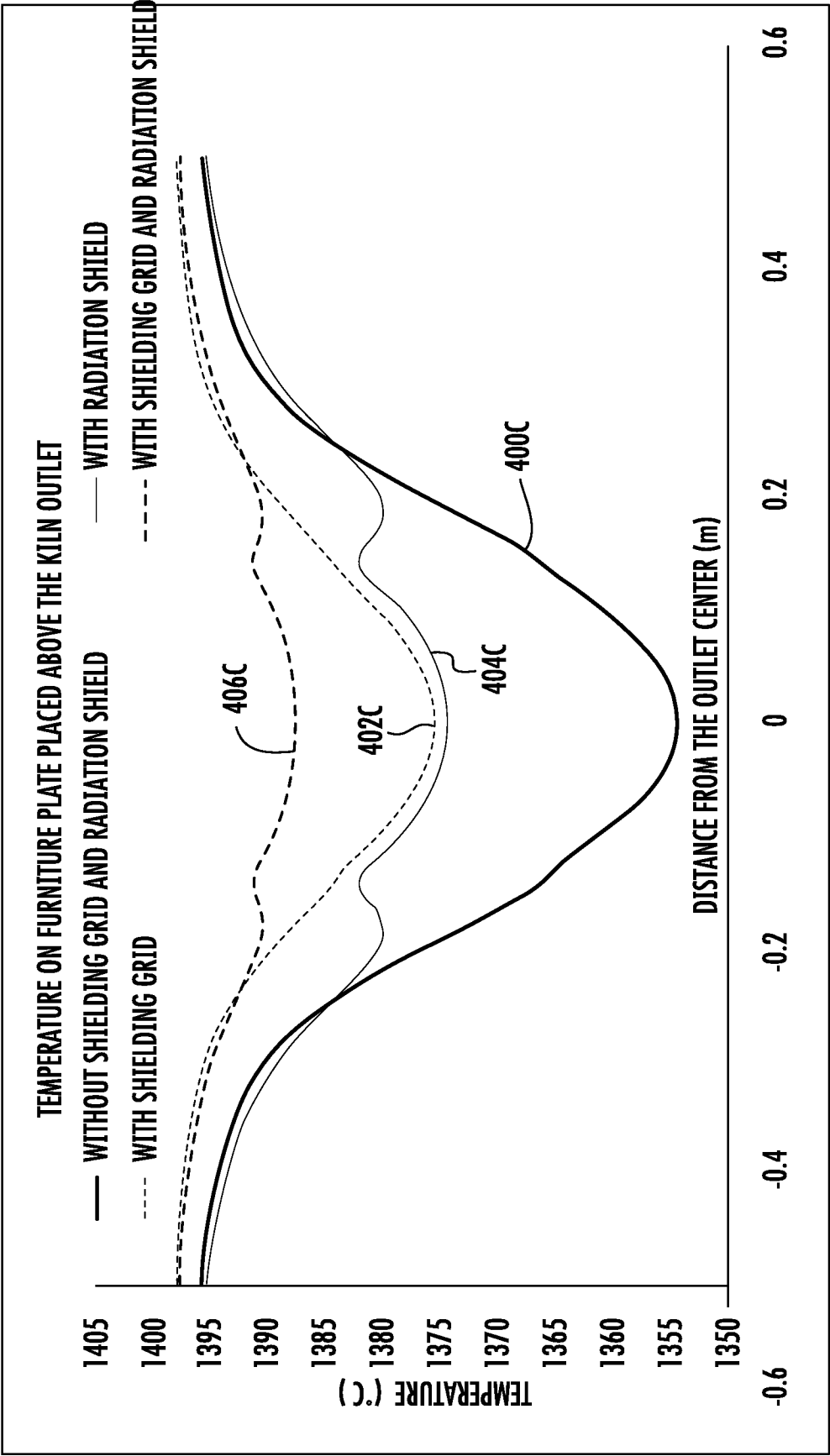


FIG. 4C

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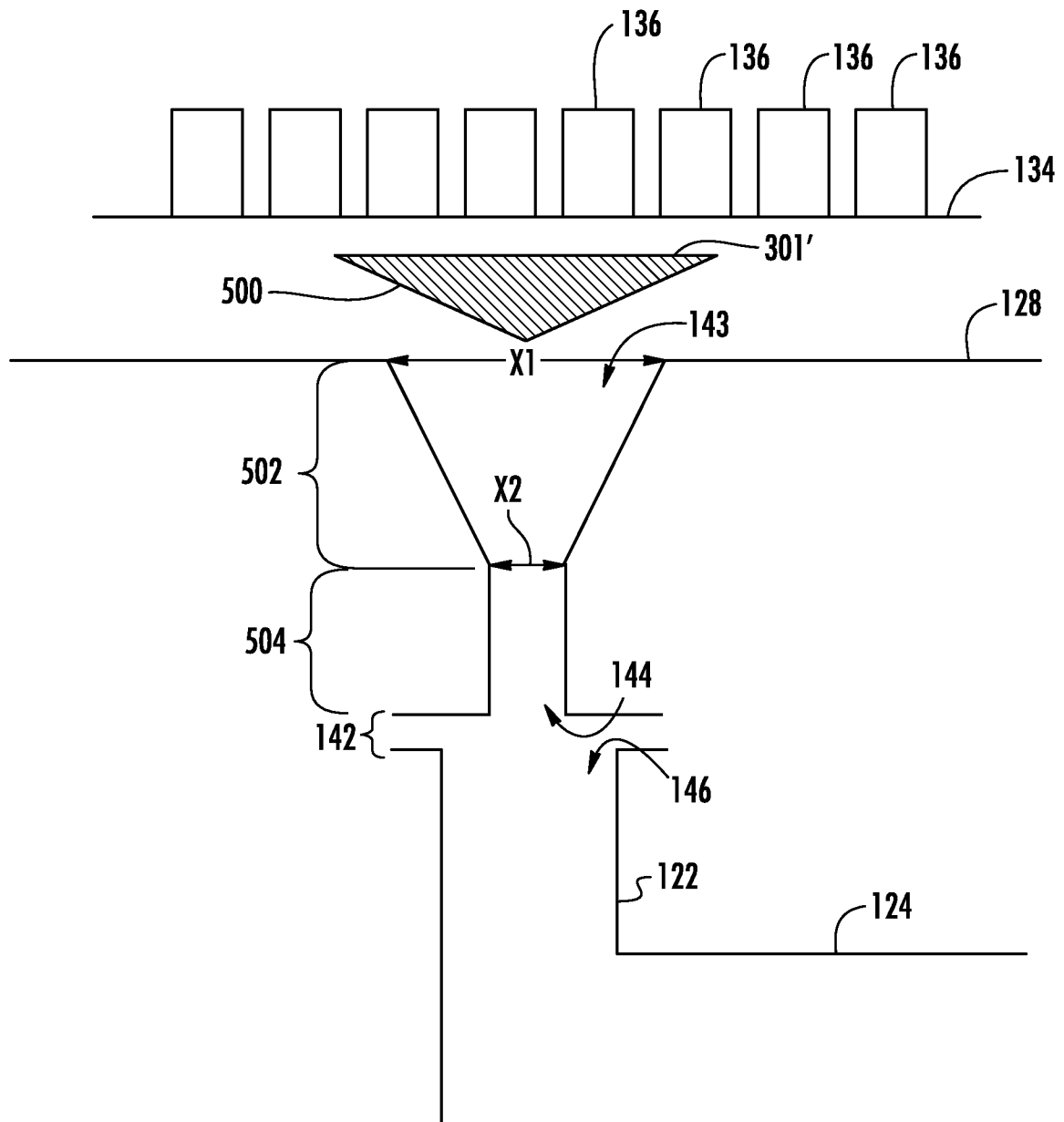


FIG. 5

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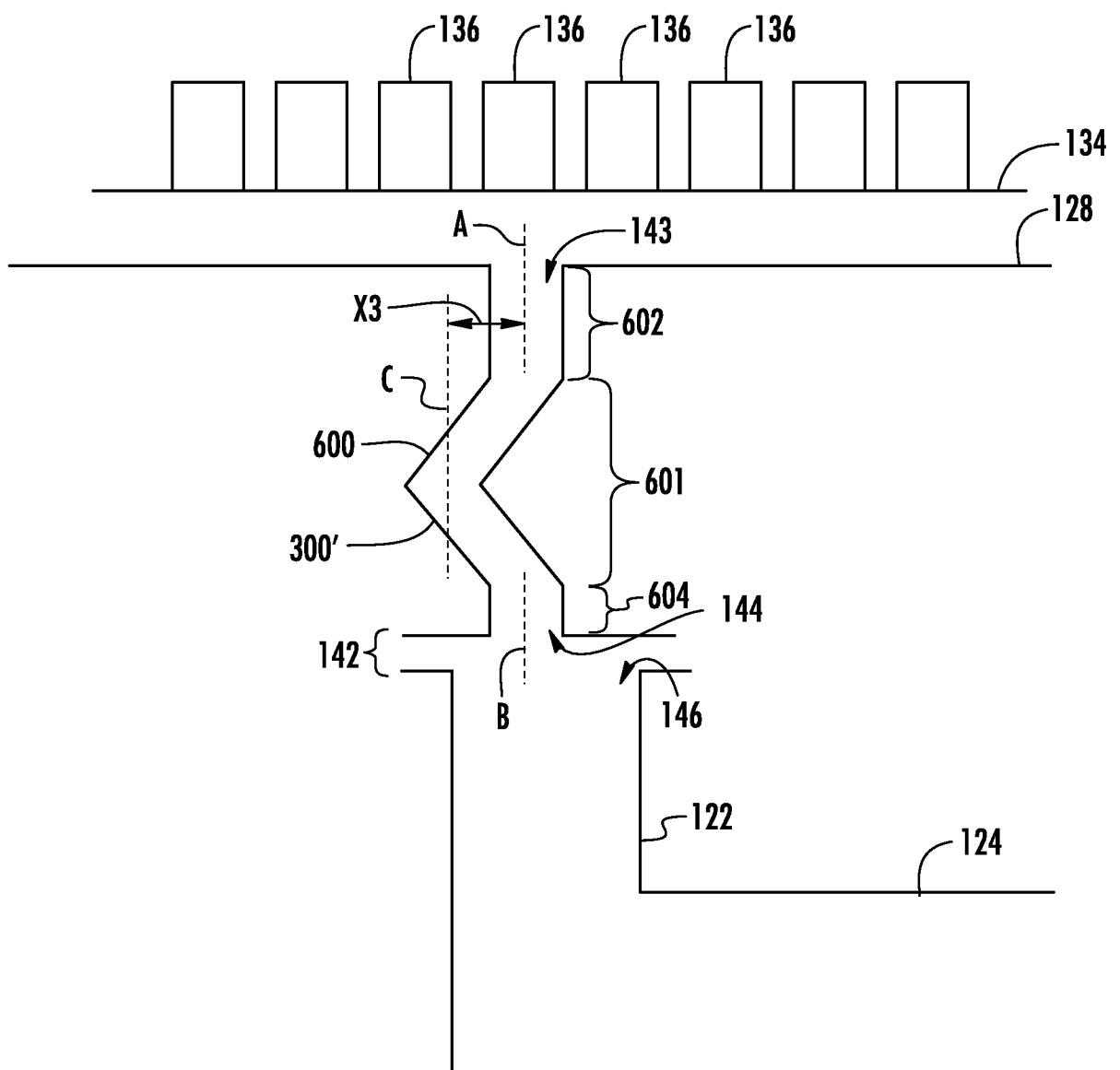
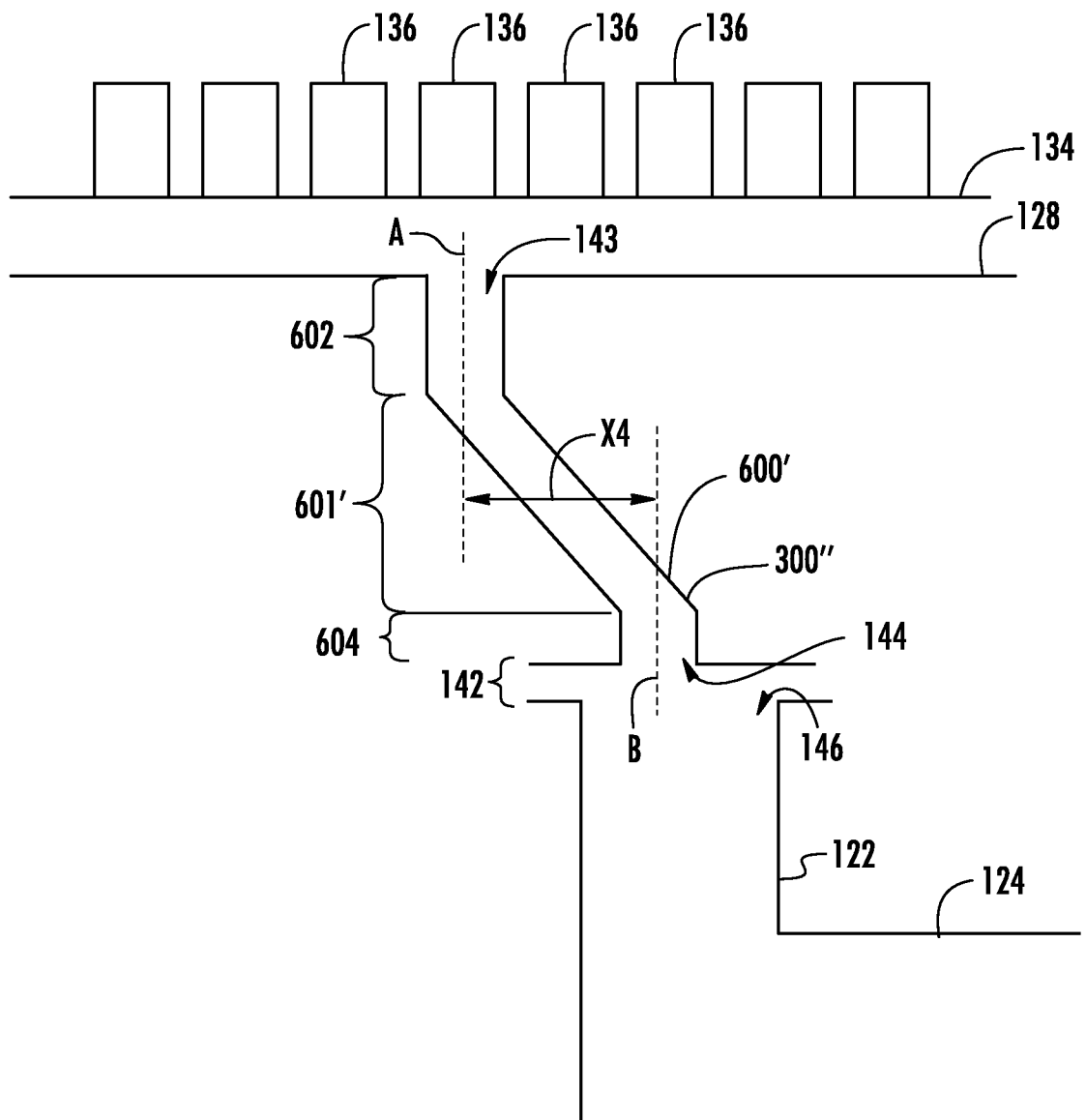
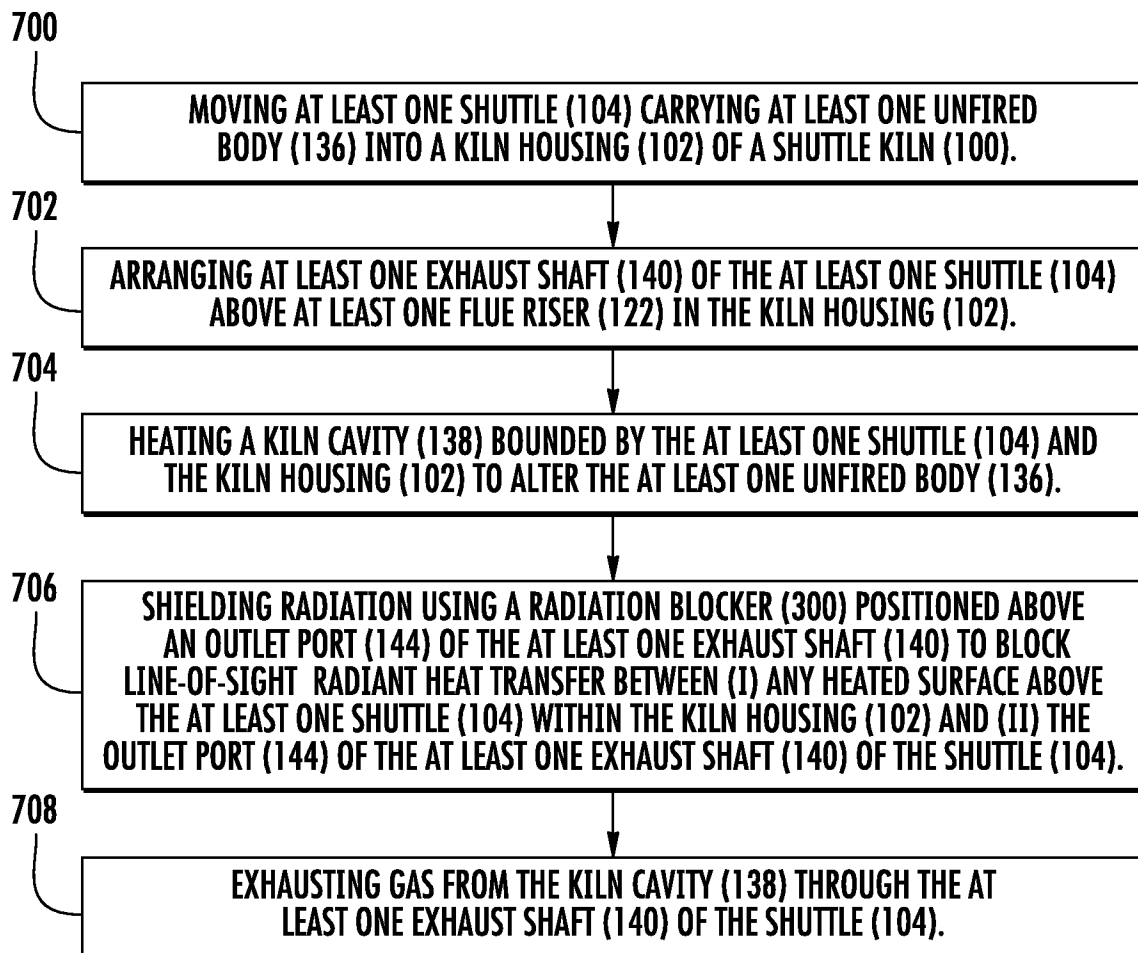


FIG. 6A

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**FIG. 6B**

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**FIG. 7**

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2020/039254

A. CLASSIFICATION OF SUBJECT MATTER INV. F27B9/10 F27B9/26 F27B9/30 F27B17/00 F27D7/02 F27D7/04 F27D17/00 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) F27B F27D Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data																				
C. DOCUMENTS CONSIDERED TO BE RELEVANT <table border="1"> <thead> <tr> <th>Category*</th> <th>Citation of document, with indication, where appropriate, of the relevant passages</th> <th>Relevant to claim No.</th> </tr> </thead> <tbody> <tr> <td>X</td> <td>GB 908 606 A (HOUILLERES BASSIN DU NORD) 24 October 1962 (1962-10-24) figures 1, 2 -----</td> <td>1-22</td> </tr> <tr> <td>X</td> <td>US 2012/240424 A1 (SUGIHARA TAKASHI [JP] ET AL) 27 September 2012 (2012-09-27) figure 18 -----</td> <td>1-22</td> </tr> <tr> <td>X</td> <td>US 2015/050610 A1 (ERNST EBERHARD [DE] ET AL) 19 February 2015 (2015-02-19) figures 3c - 6 -----</td> <td>1-4,6,10</td> </tr> <tr> <td>A</td> <td>US 4 616 997 A (ROSS ROBERT H [US]) 14 October 1986 (1986-10-14) figures 1, 2 -----</td> <td>3,13,14</td> </tr> <tr> <td>A</td> <td>US 6 107 614 A (LINN HORST [DE] ET AL) 22 August 2000 (2000-08-22) figure 4 -----</td> <td>17,18</td> </tr> </tbody> </table>			Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.	X	GB 908 606 A (HOUILLERES BASSIN DU NORD) 24 October 1962 (1962-10-24) figures 1, 2 -----	1-22	X	US 2012/240424 A1 (SUGIHARA TAKASHI [JP] ET AL) 27 September 2012 (2012-09-27) figure 18 -----	1-22	X	US 2015/050610 A1 (ERNST EBERHARD [DE] ET AL) 19 February 2015 (2015-02-19) figures 3c - 6 -----	1-4,6,10	A	US 4 616 997 A (ROSS ROBERT H [US]) 14 October 1986 (1986-10-14) figures 1, 2 -----	3,13,14	A	US 6 107 614 A (LINN HORST [DE] ET AL) 22 August 2000 (2000-08-22) figure 4 -----	17,18
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A	US 4 616 997 A (ROSS ROBERT H [US]) 14 October 1986 (1986-10-14) figures 1, 2 -----	3,13,14																		
A	US 6 107 614 A (LINN HORST [DE] ET AL) 22 August 2000 (2000-08-22) figure 4 -----	17,18																		
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.																				
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Date of the actual completion of the international search 29 July 2020		Date of mailing of the international search report 06/08/2020																		
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 Porté, Olivier																		

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2020/039254

Patent document cited in search report		Publication date	Patent family member(s)		Publication date
GB 908606	A	24-10-1962	DE	1262219 B	07-03-1968
			FR	77922 E	11-05-1962
			GB	908606 A	24-10-1962
			LU	39107 A1	25-10-1960

US 2012240424	A1	27-09-2012	CN	102652044 A	29-08-2012
			EP	2511036 A1	17-10-2012
			HU	E039943 T2	28-02-2019
			KR	20120093345 A	22-08-2012
			MY	158726 A	15-11-2016
			PL	2511036 T3	31-01-2019
			TW	201139031 A	16-11-2011
			US	2012240424 A1	27-09-2012
			WO	2011071041 A1	16-06-2011

US 2015050610	A1	19-02-2015	CN	104321605 A	28-01-2015
			DE	102012005180 A1	19-09-2013
			EP	2825830 A1	21-01-2015
			JP	2015513659 A	14-05-2015
			US	2015050610 A1	19-02-2015
			WO	2013135373 A1	19-09-2013

US 4616997	A	14-10-1986	NONE		

US 6107614	A	22-08-2000	NONE		
