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(54) MEMBRANE SUPPORT ASSEMBLY FOR AN ENERGY EXCHANGER

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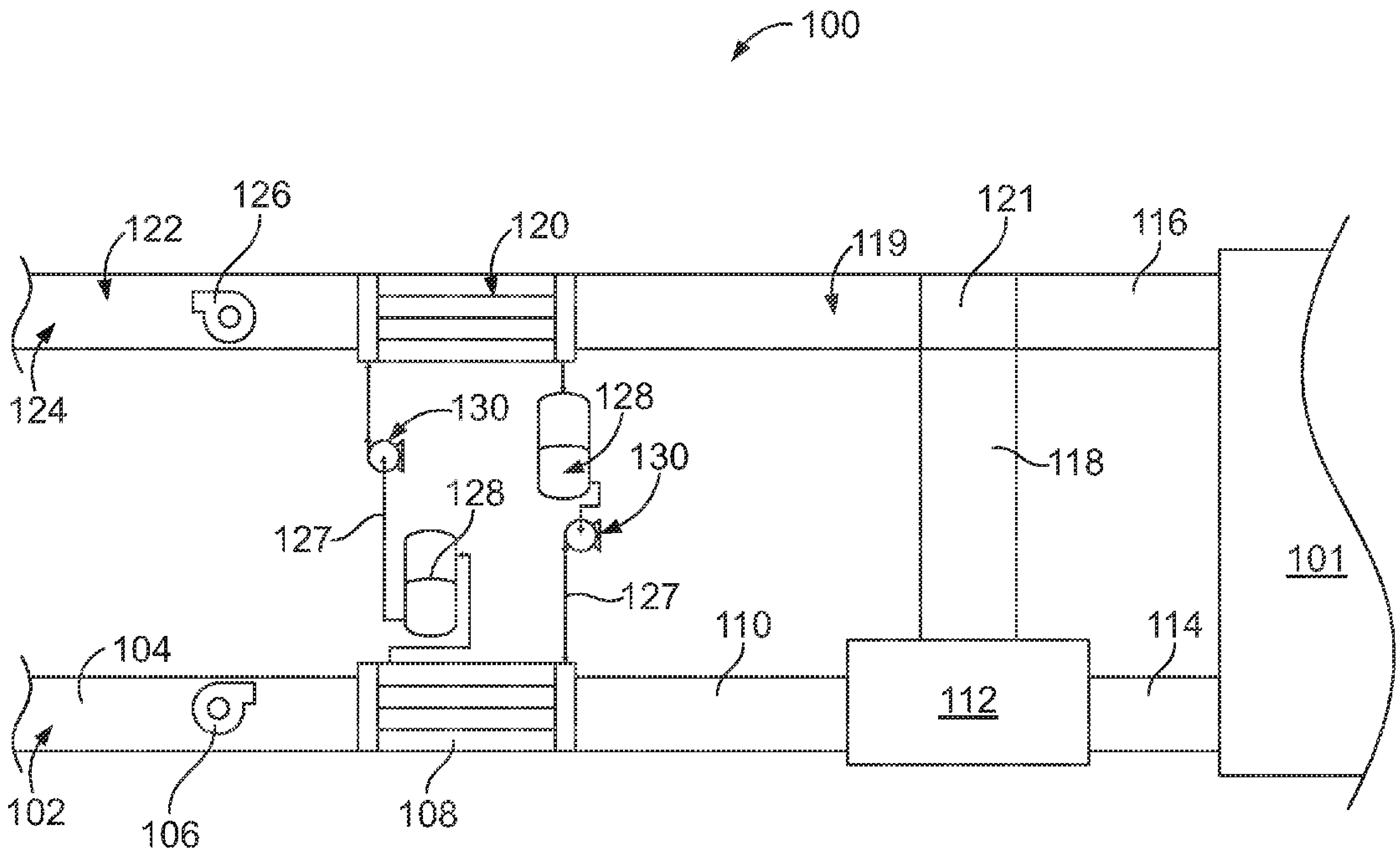
(57) **ABSTRACT**

A membrane support assembly is configured to be used with an energy exchanger, and is configured to be positioned within a fluid channel between first and second membranes. The assembly may include at least one support member configured to span between the first and second membranes, wherein the support member(s) is configured to support the fluid channel, and at least one turbulence promoter connected to the support member(s). The turbulence promoter(s) is configured to promote fluid turbulence within the fluid channel. The fluid turbulence within the fluid channel enhances energy transfer between the fluid channel and the first and second membranes.



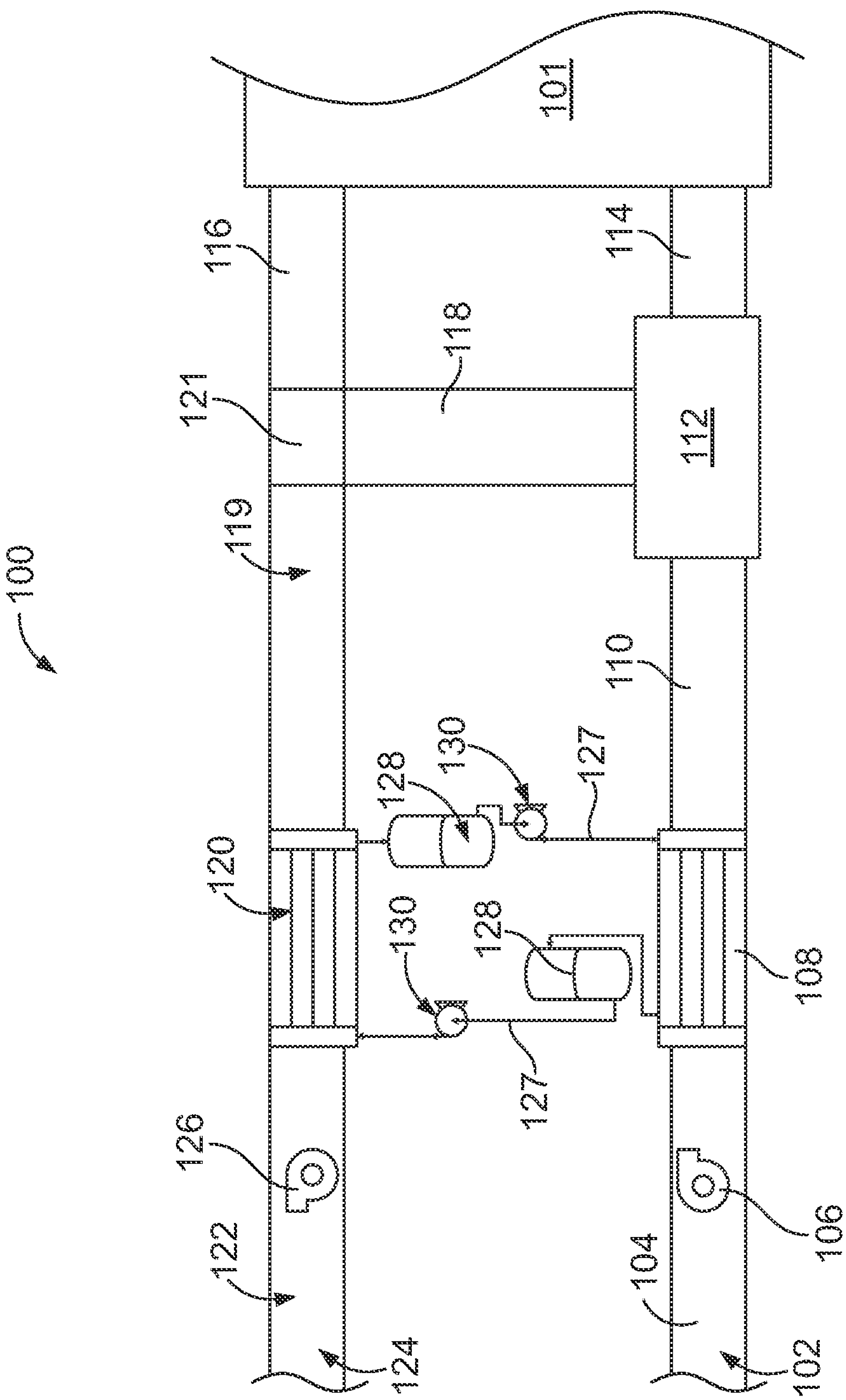

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FIG. 1

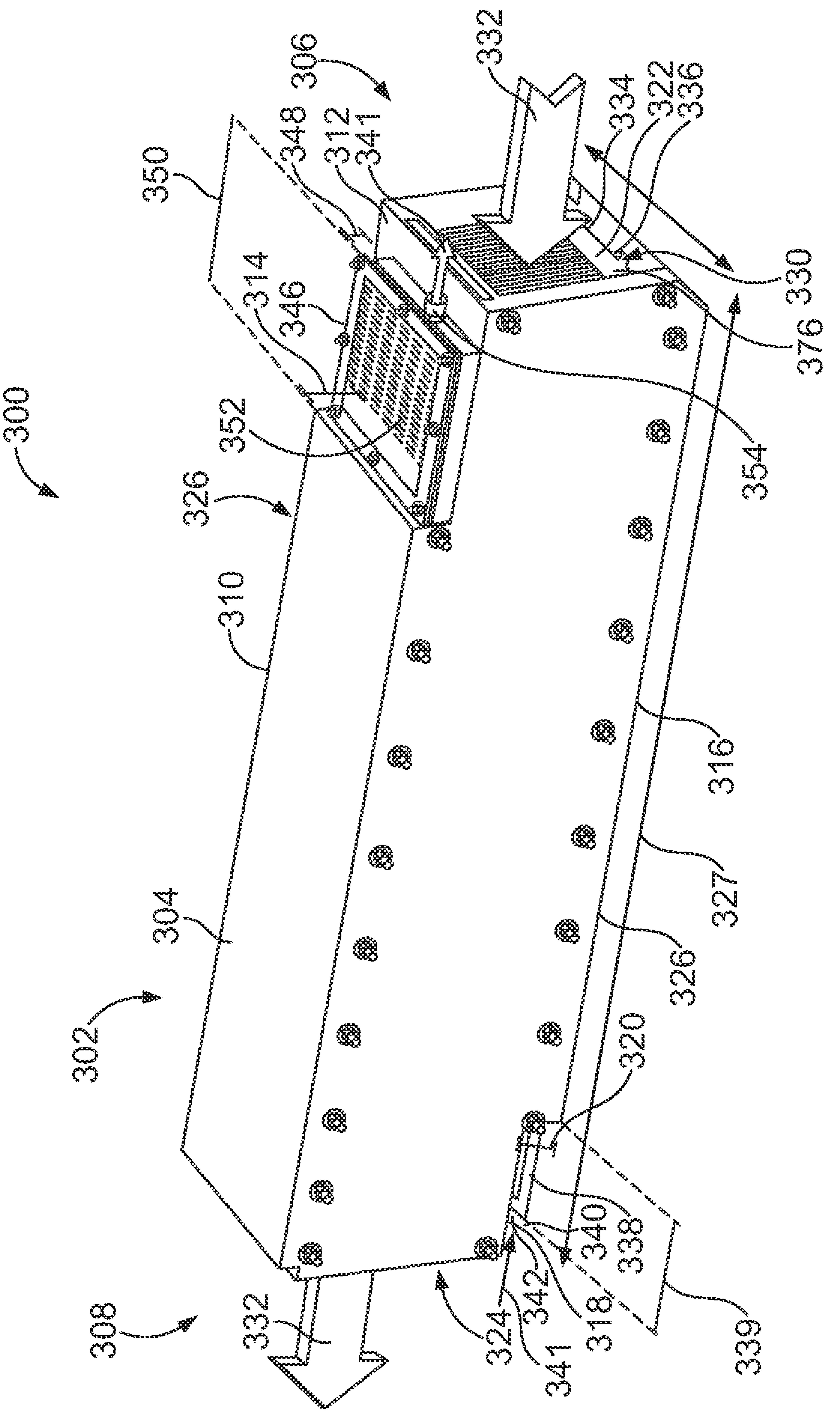
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FIG. 2

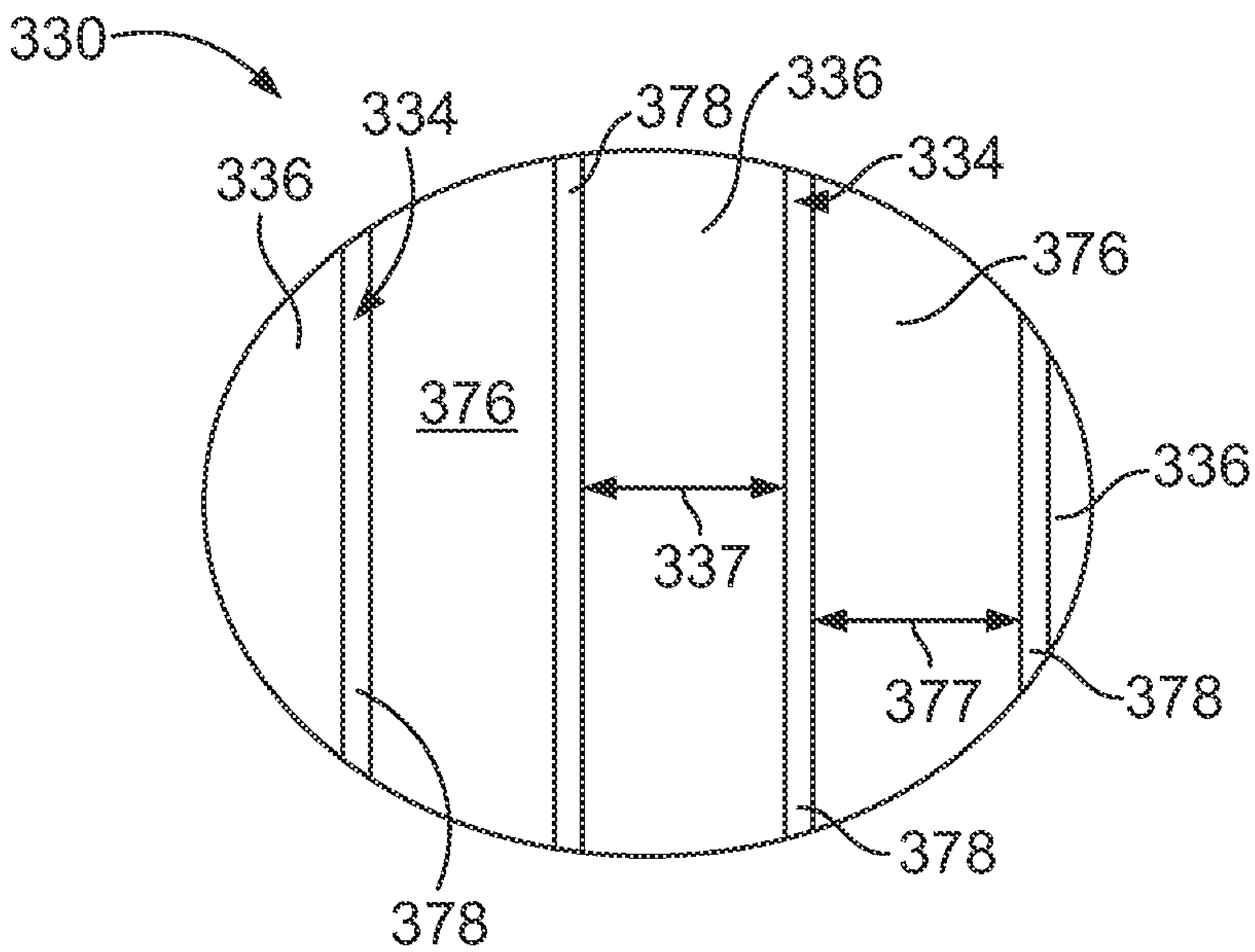
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FIG. 3

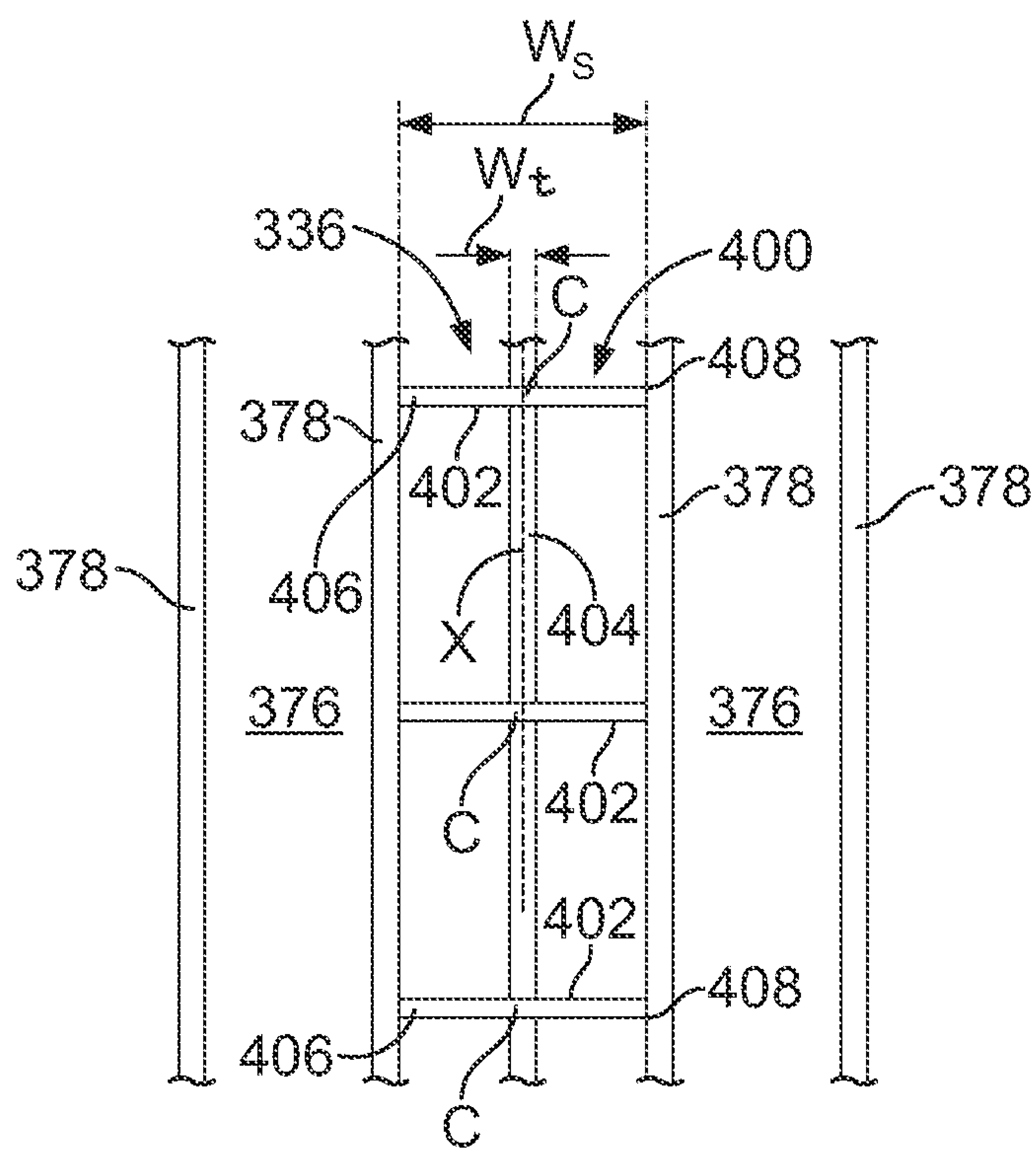
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FIG. 4

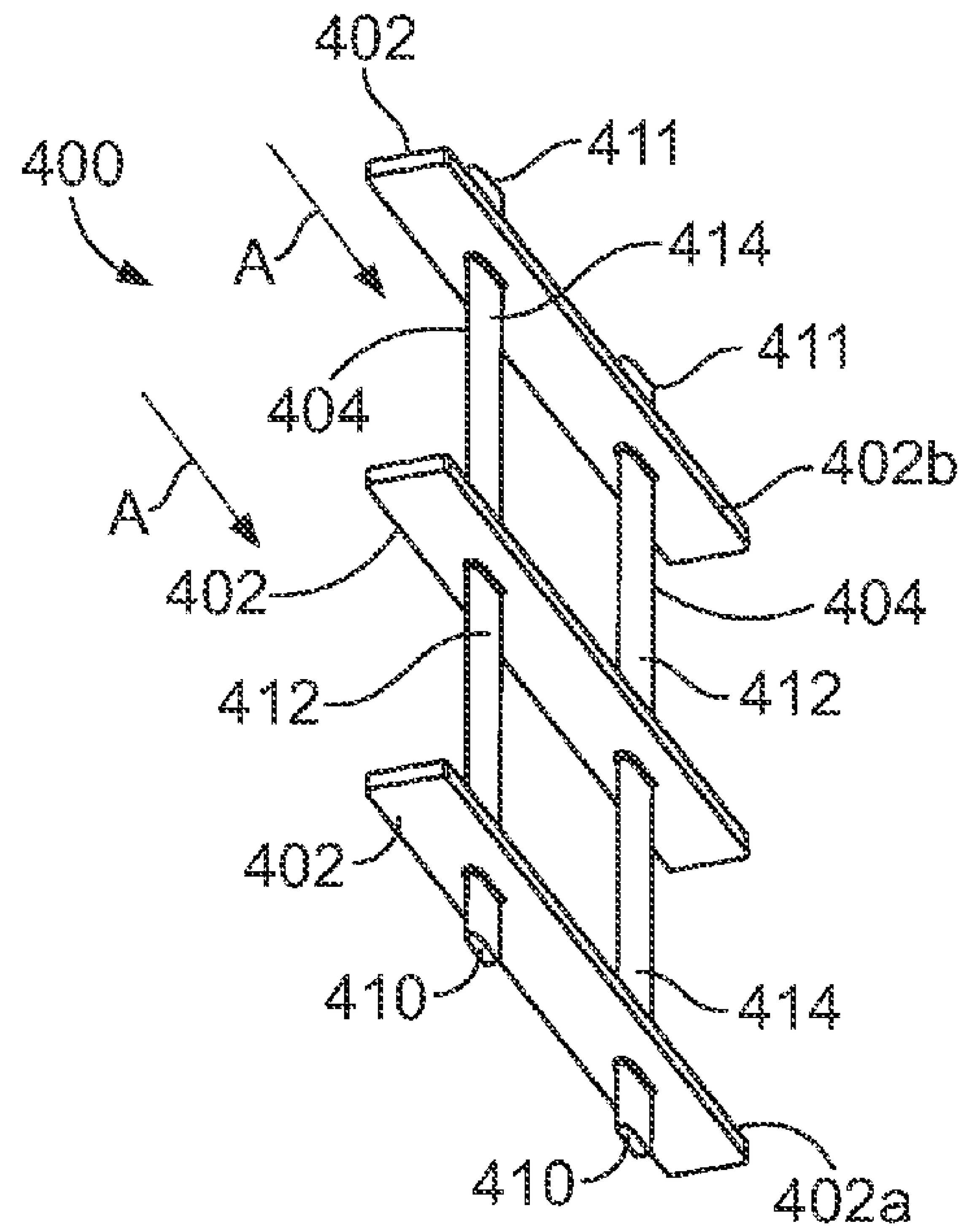

FIG. 5

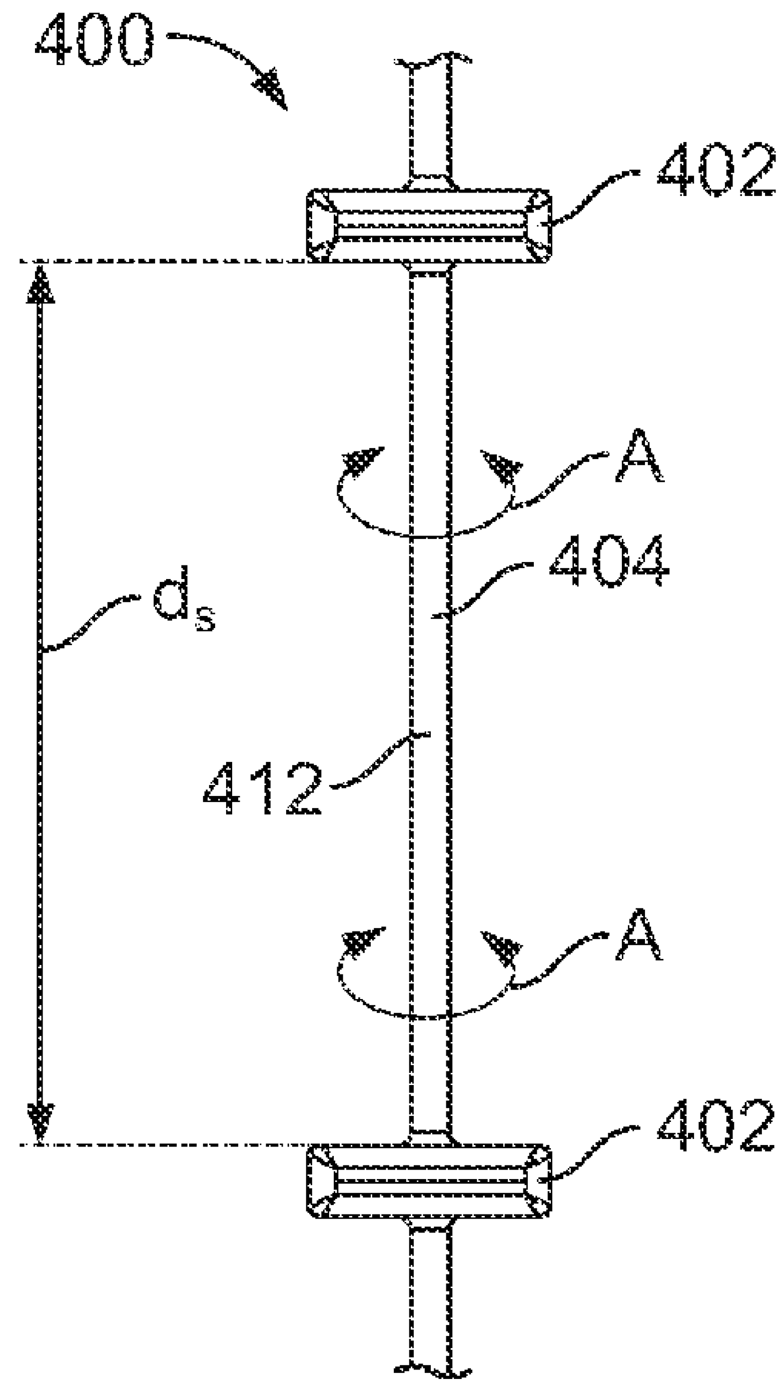

FIG. 6

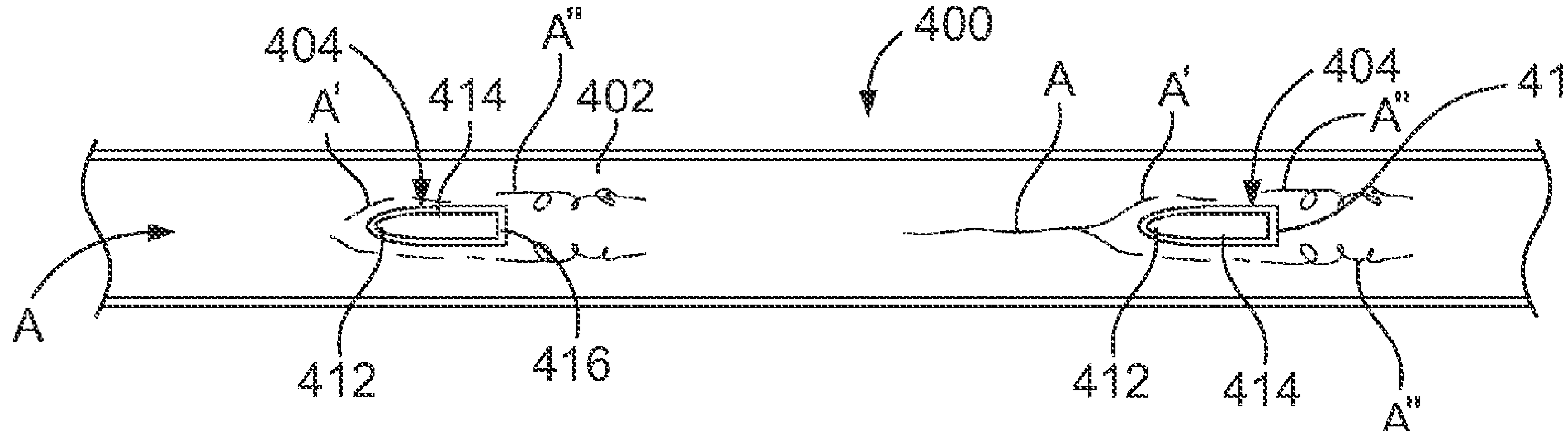

FIG. 7

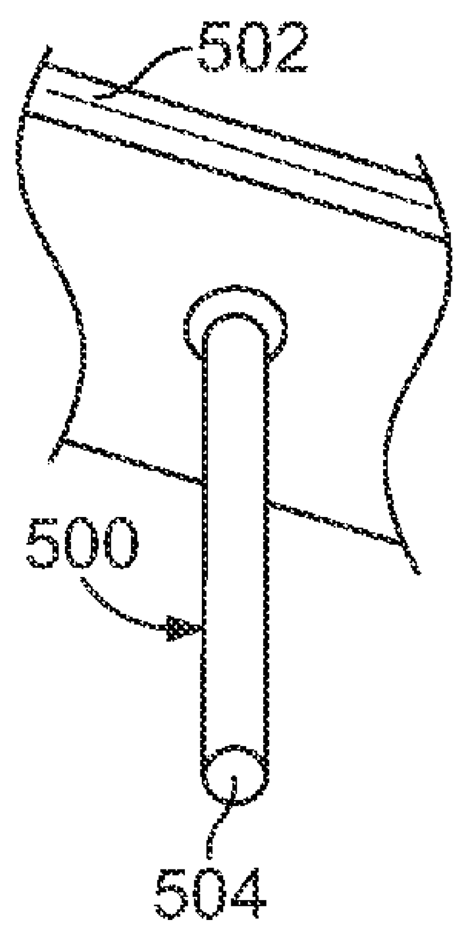

FIG. 8

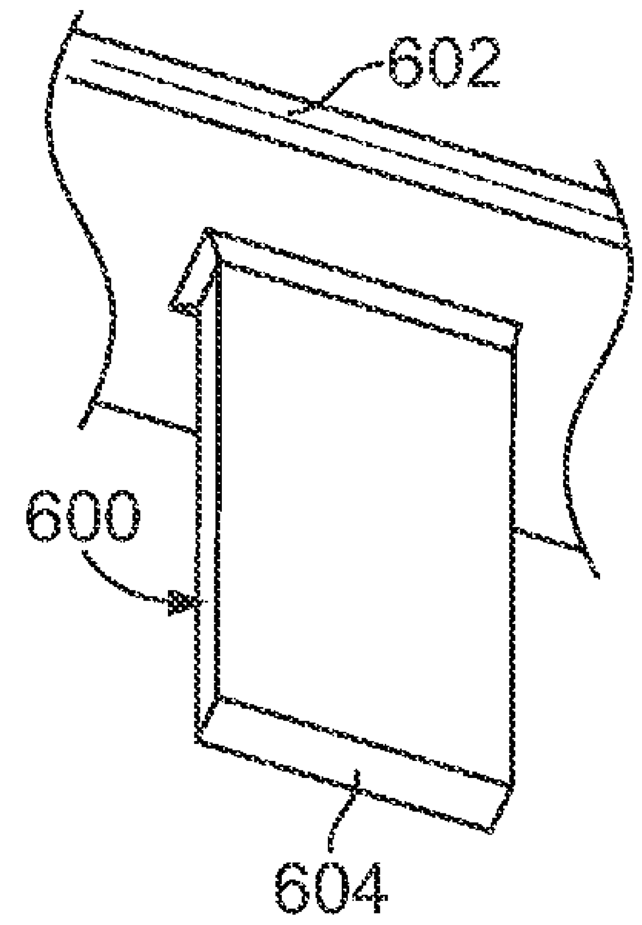

FIG. 9

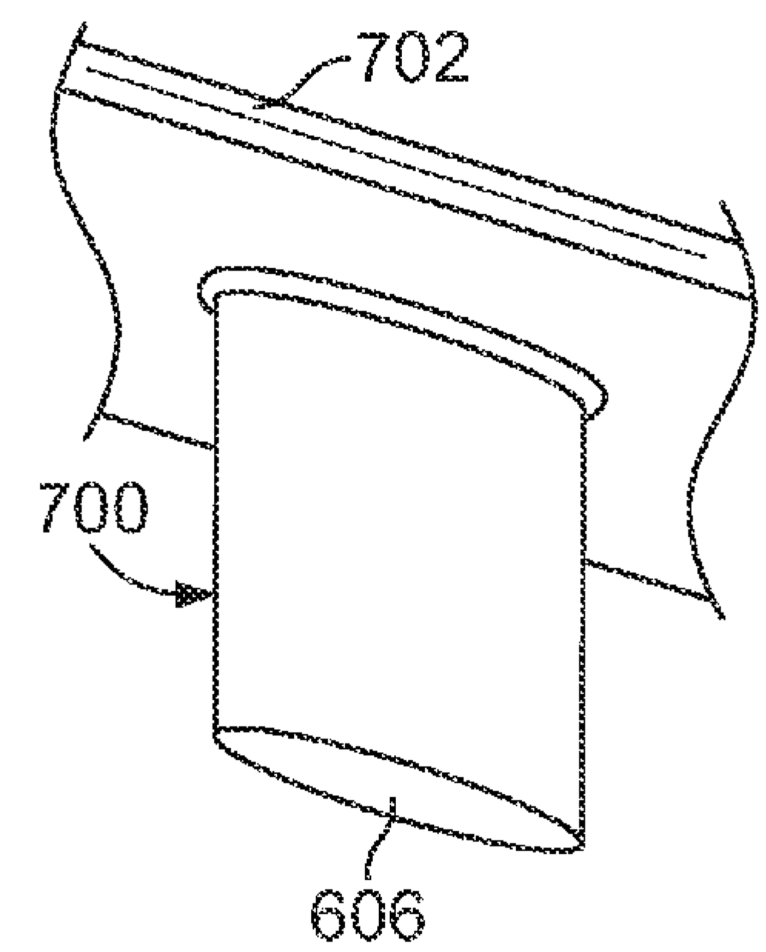

FIG. 10

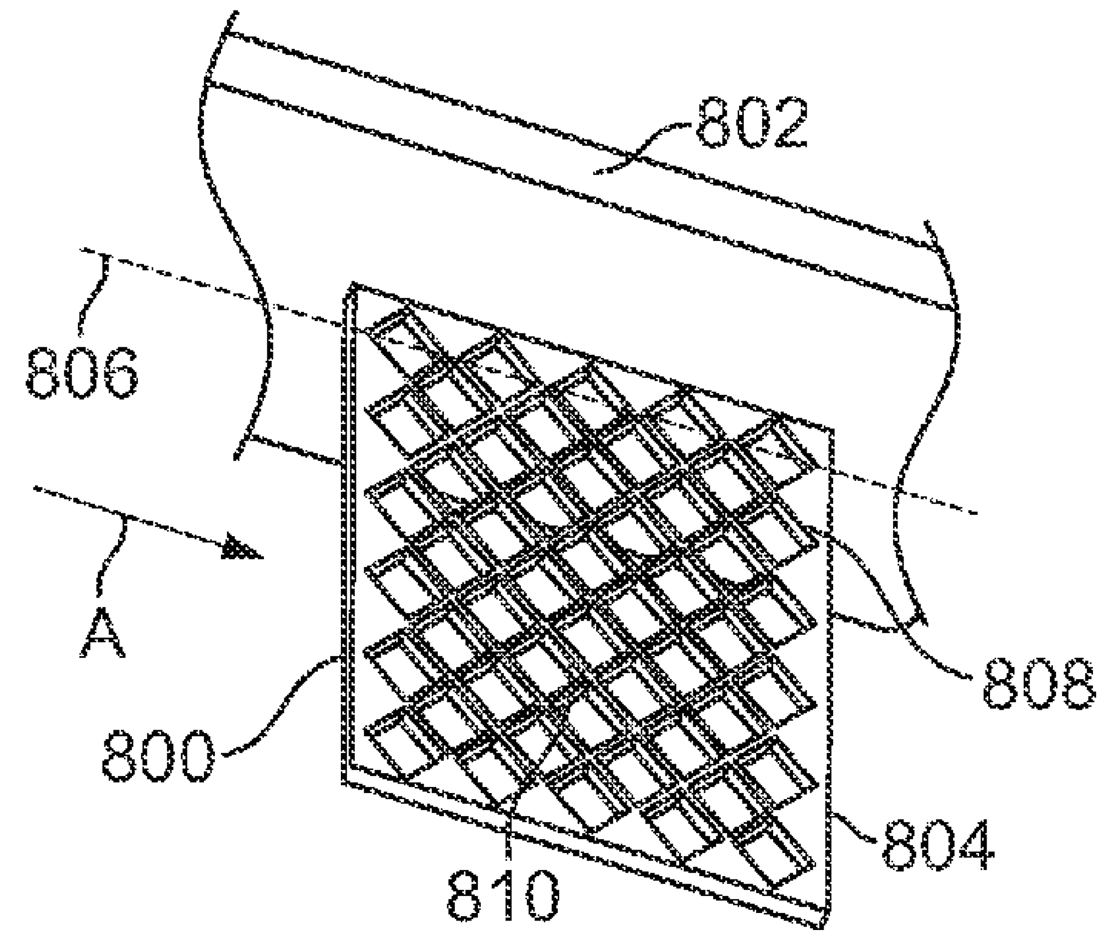

FIG. 11

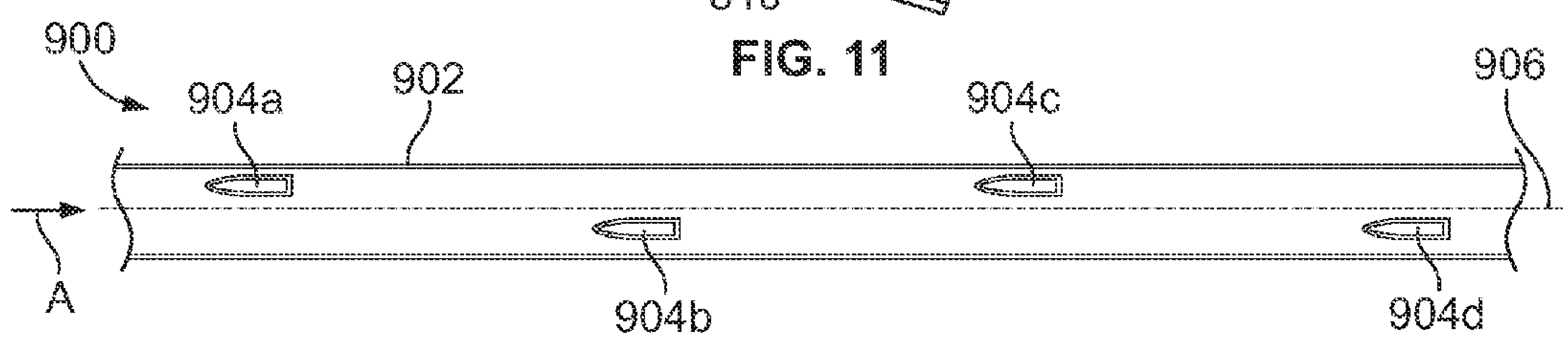

FIG. 12

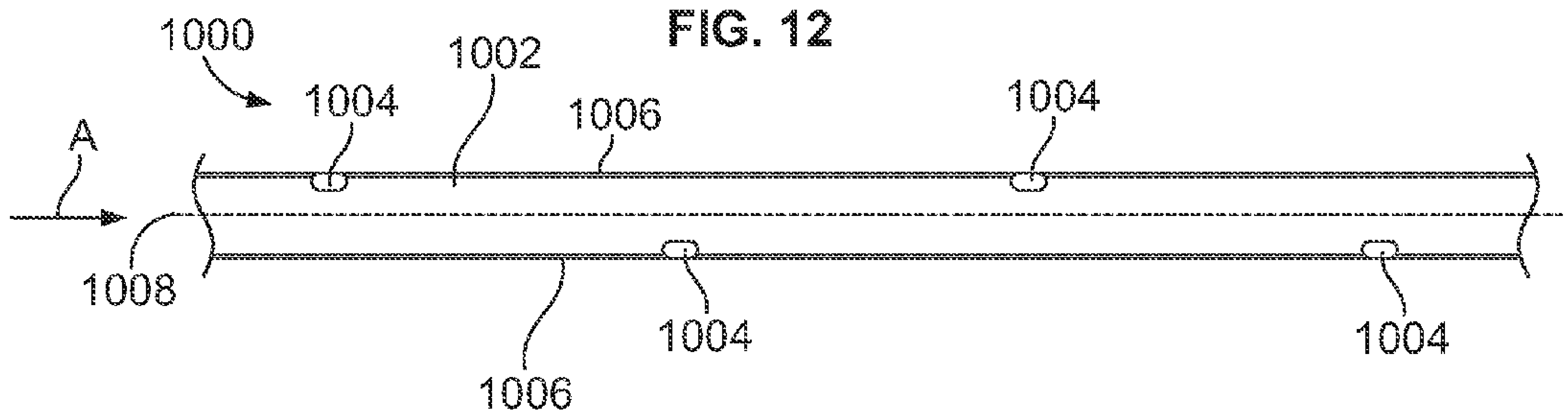

FIG. 13

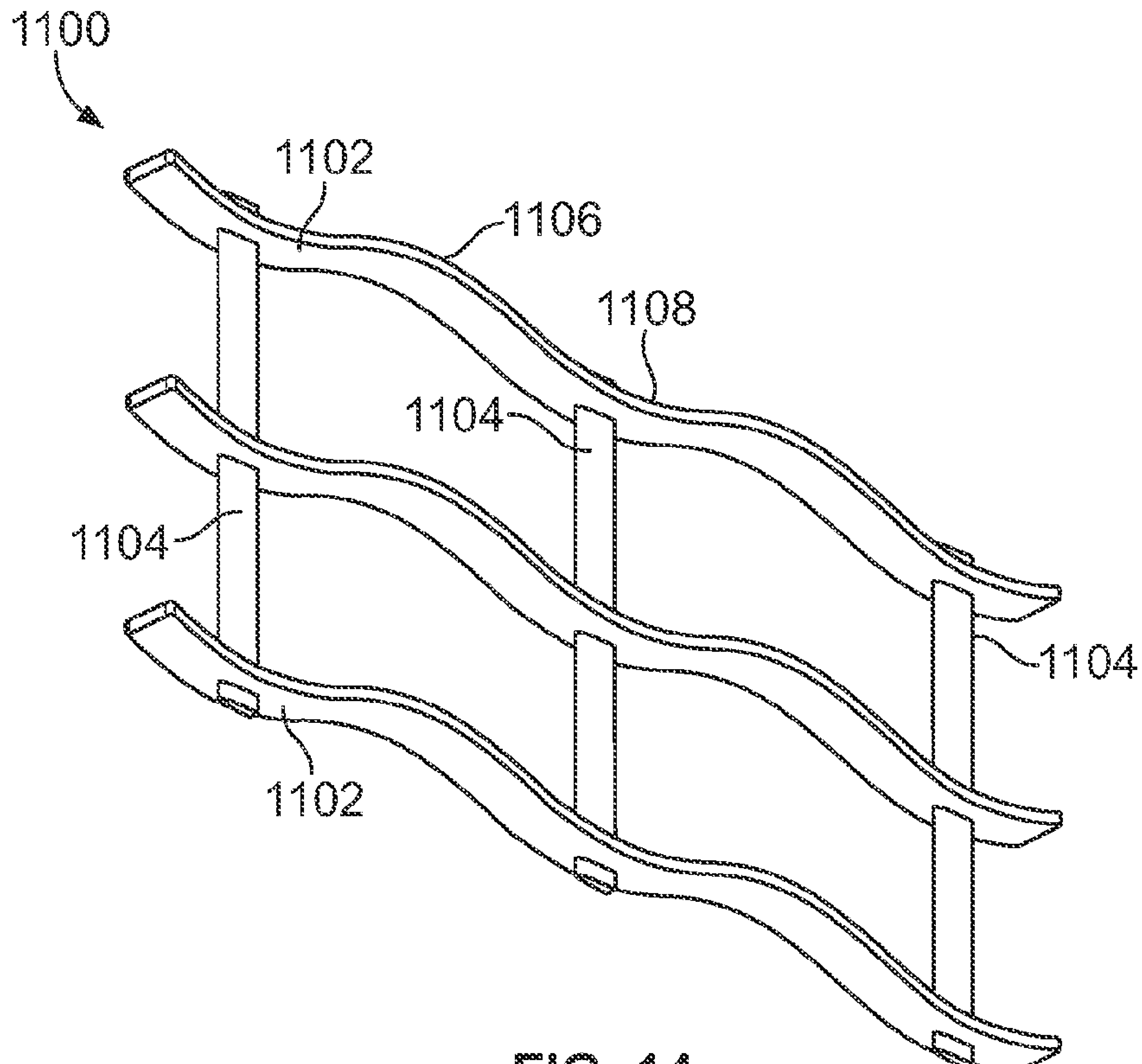
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FIG. 14

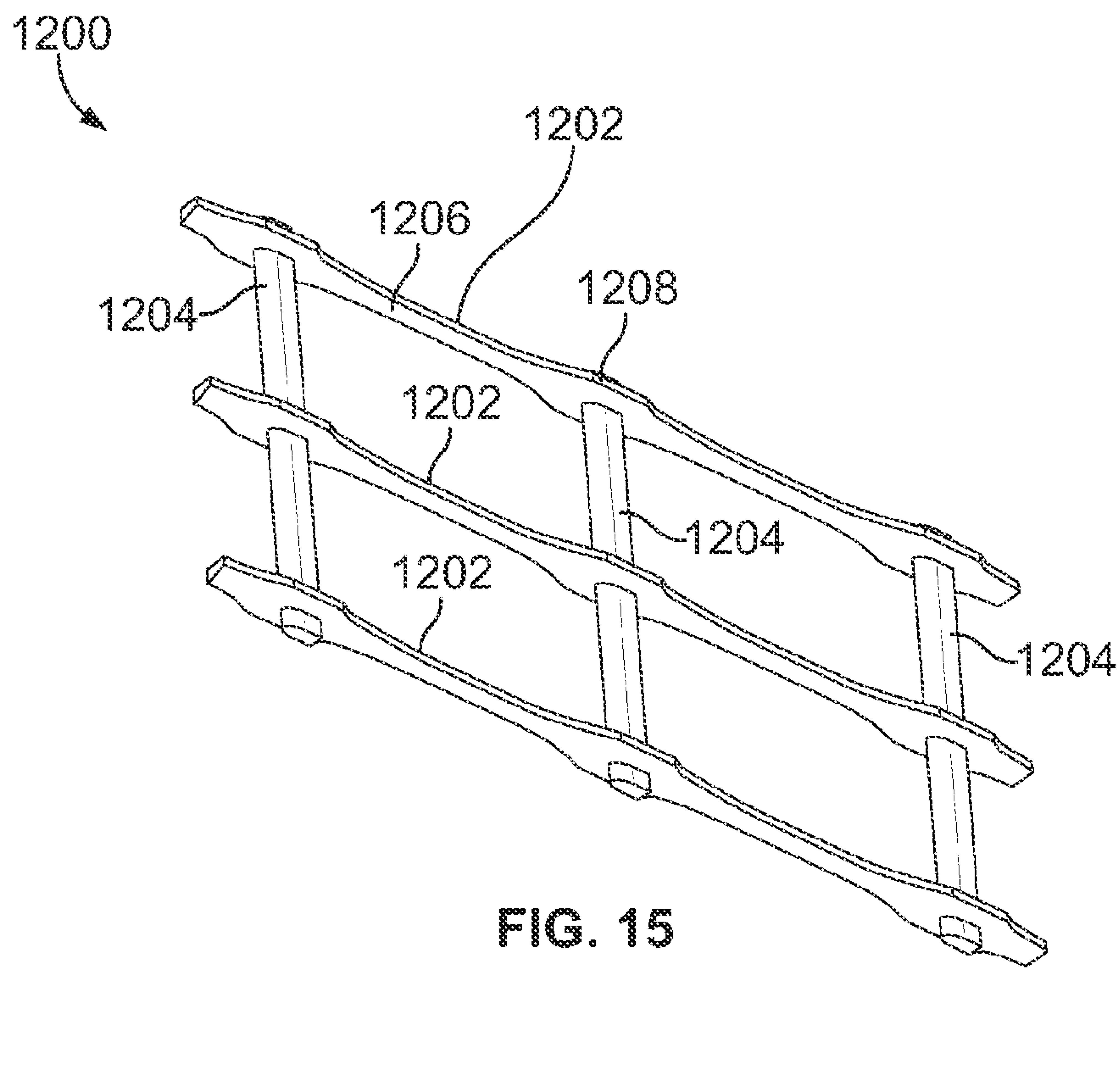
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FIG. 15

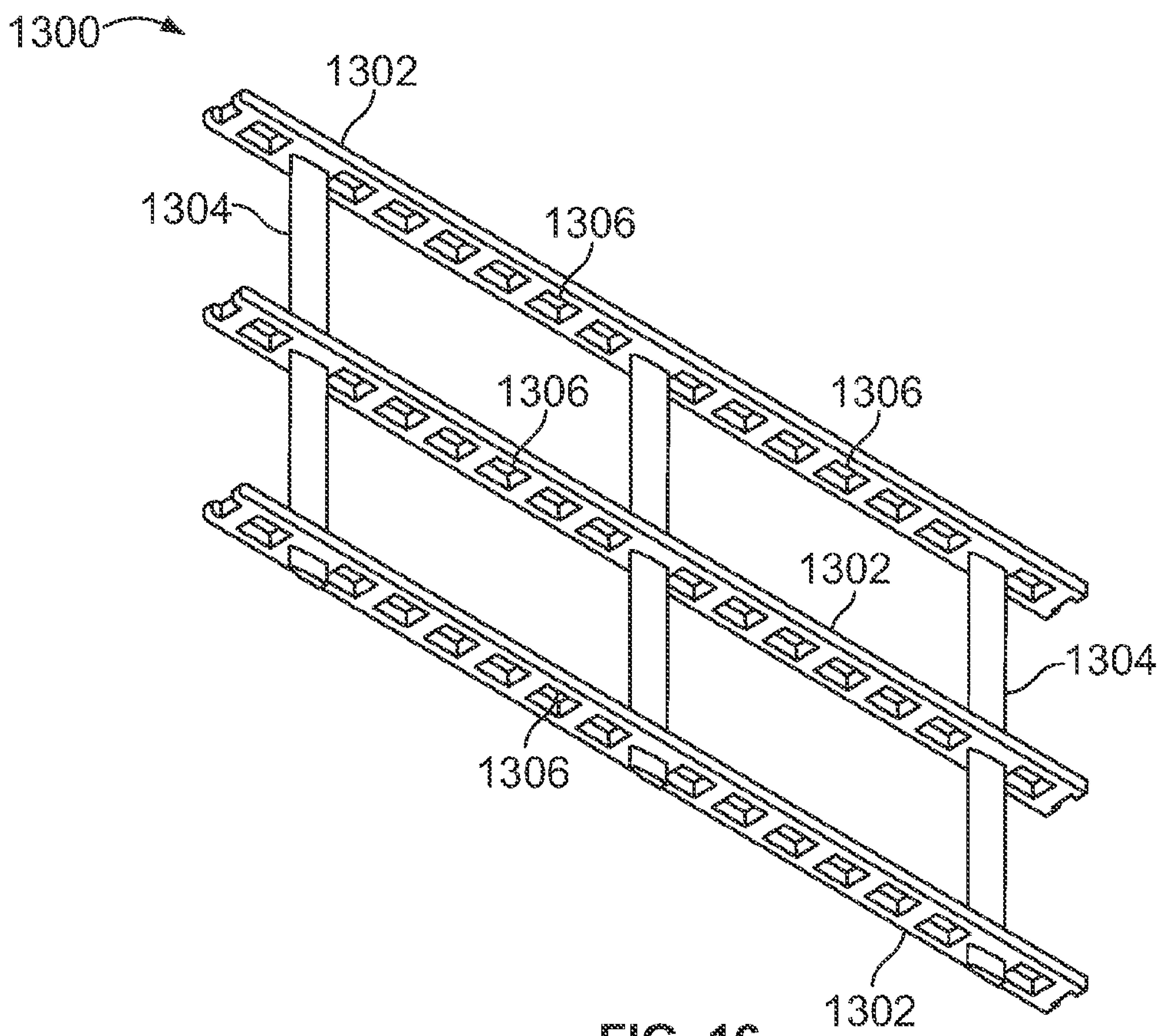
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FIG. 16

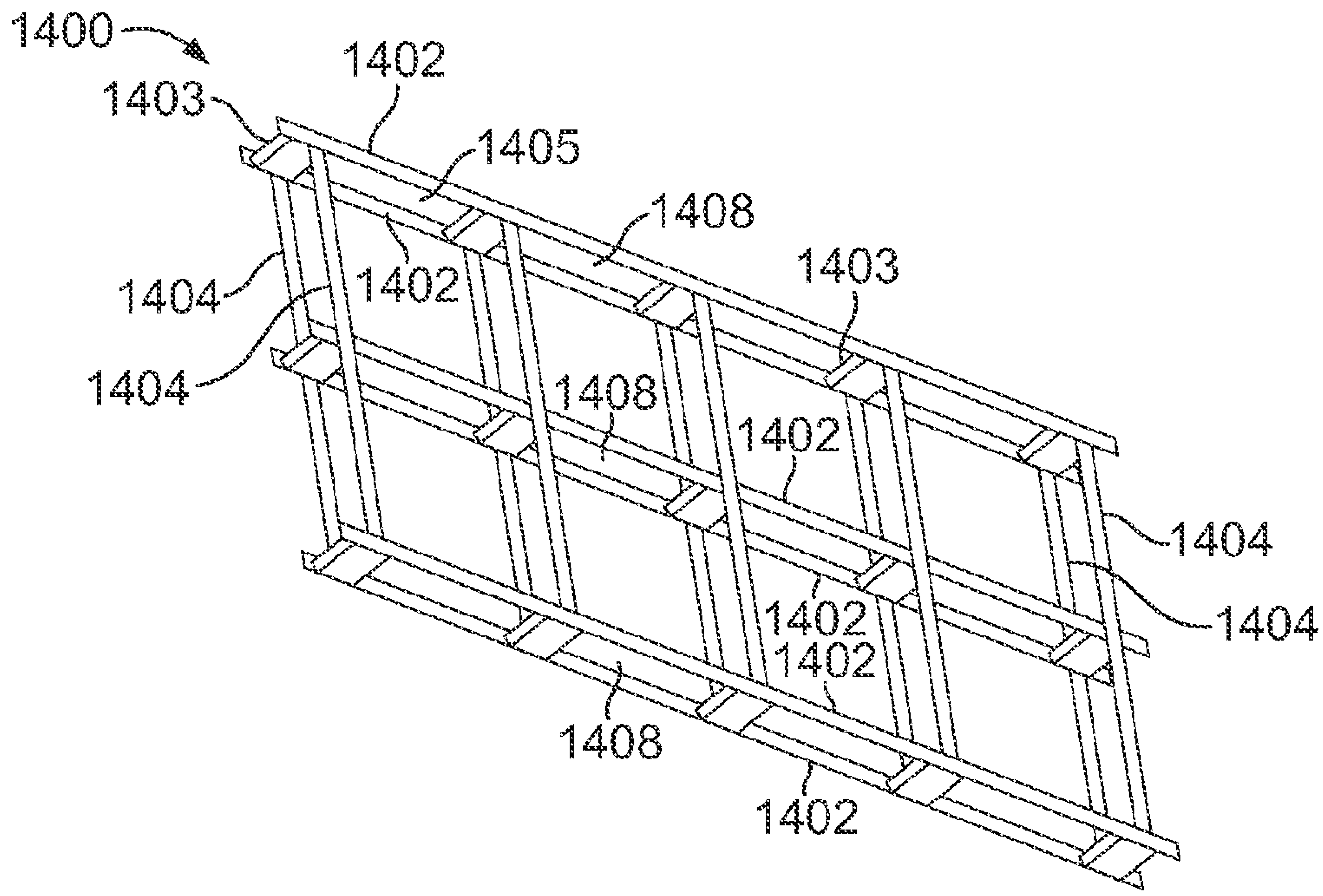
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FIG. 17

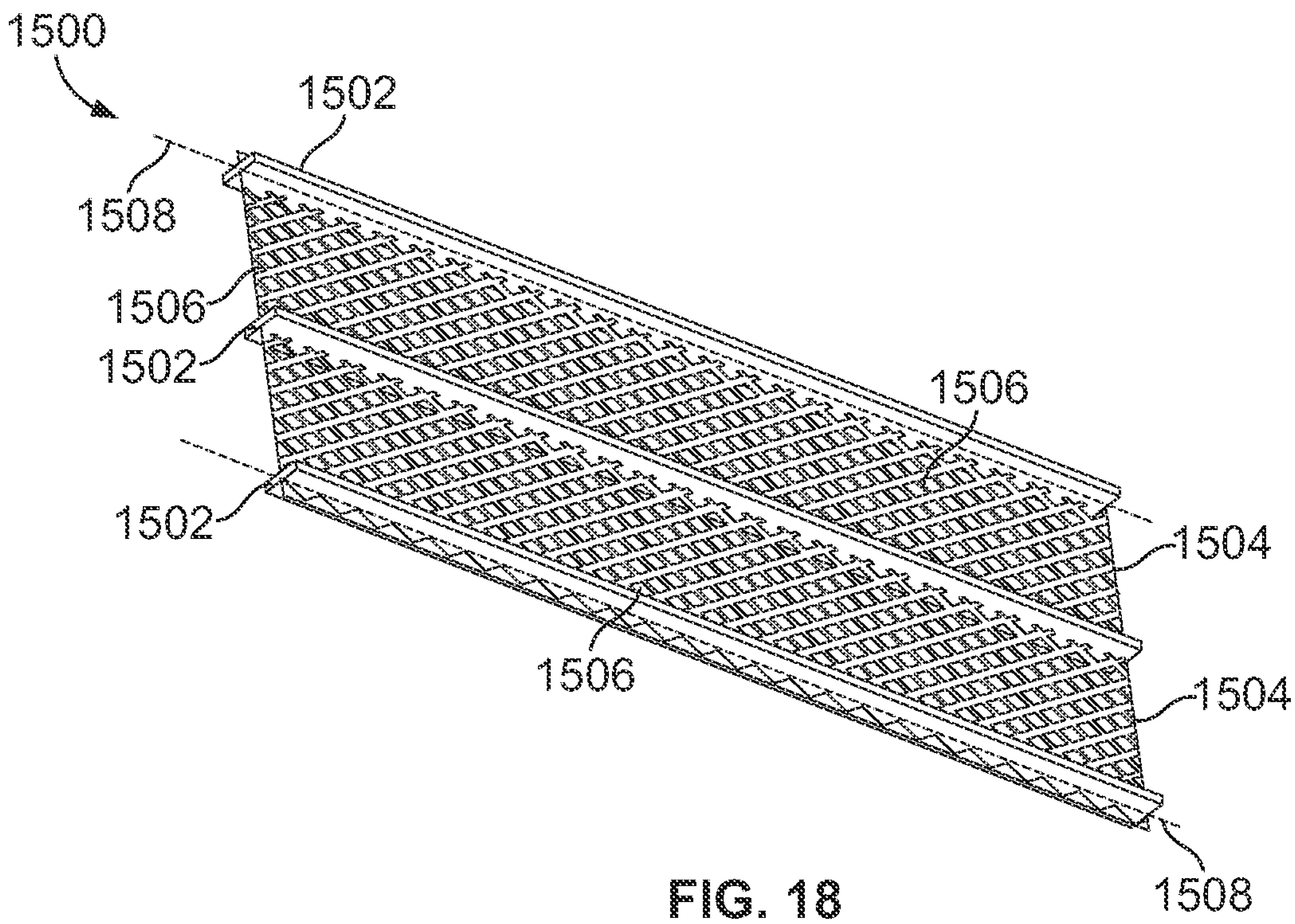
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FIG. 18

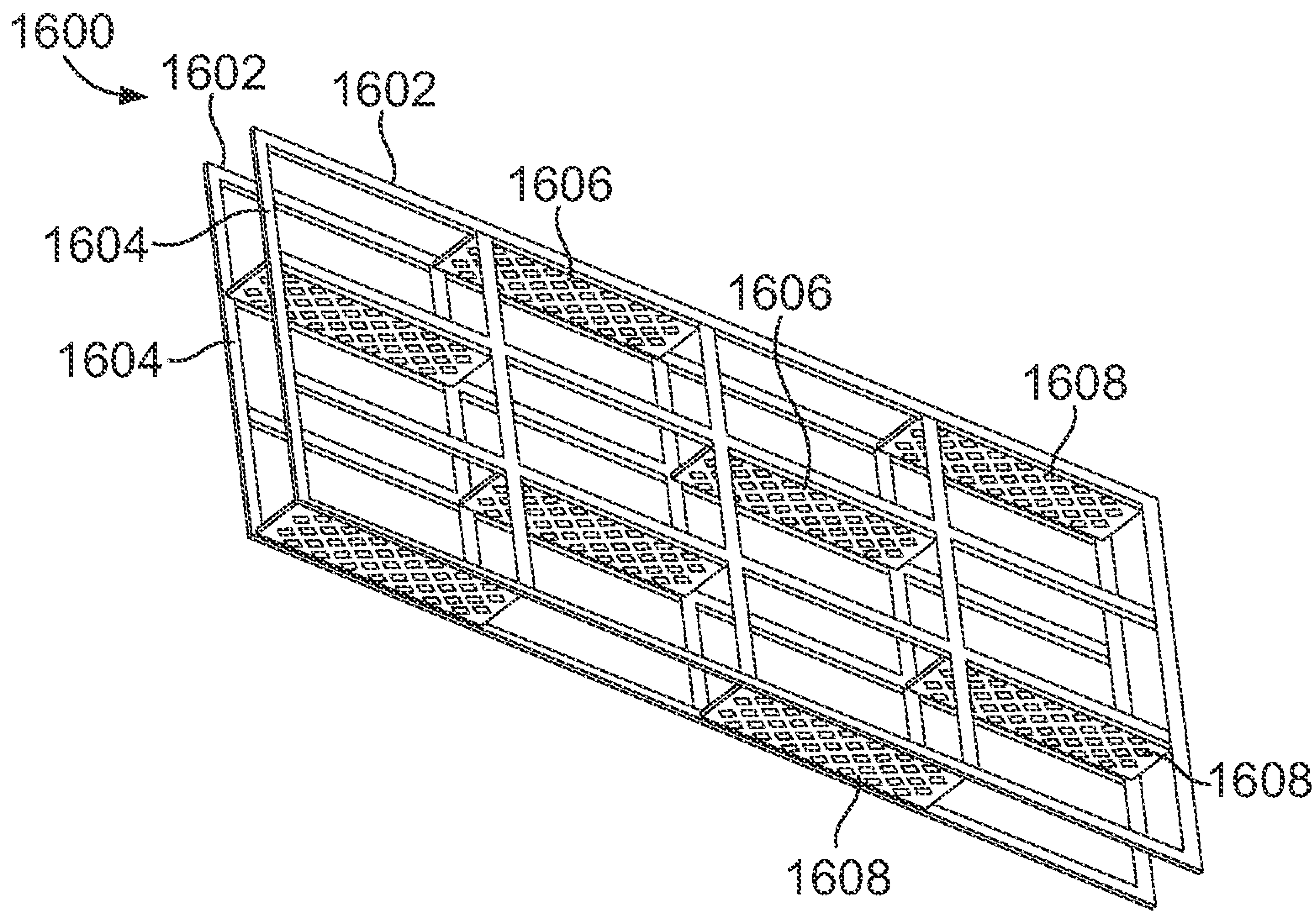
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FIG. 19

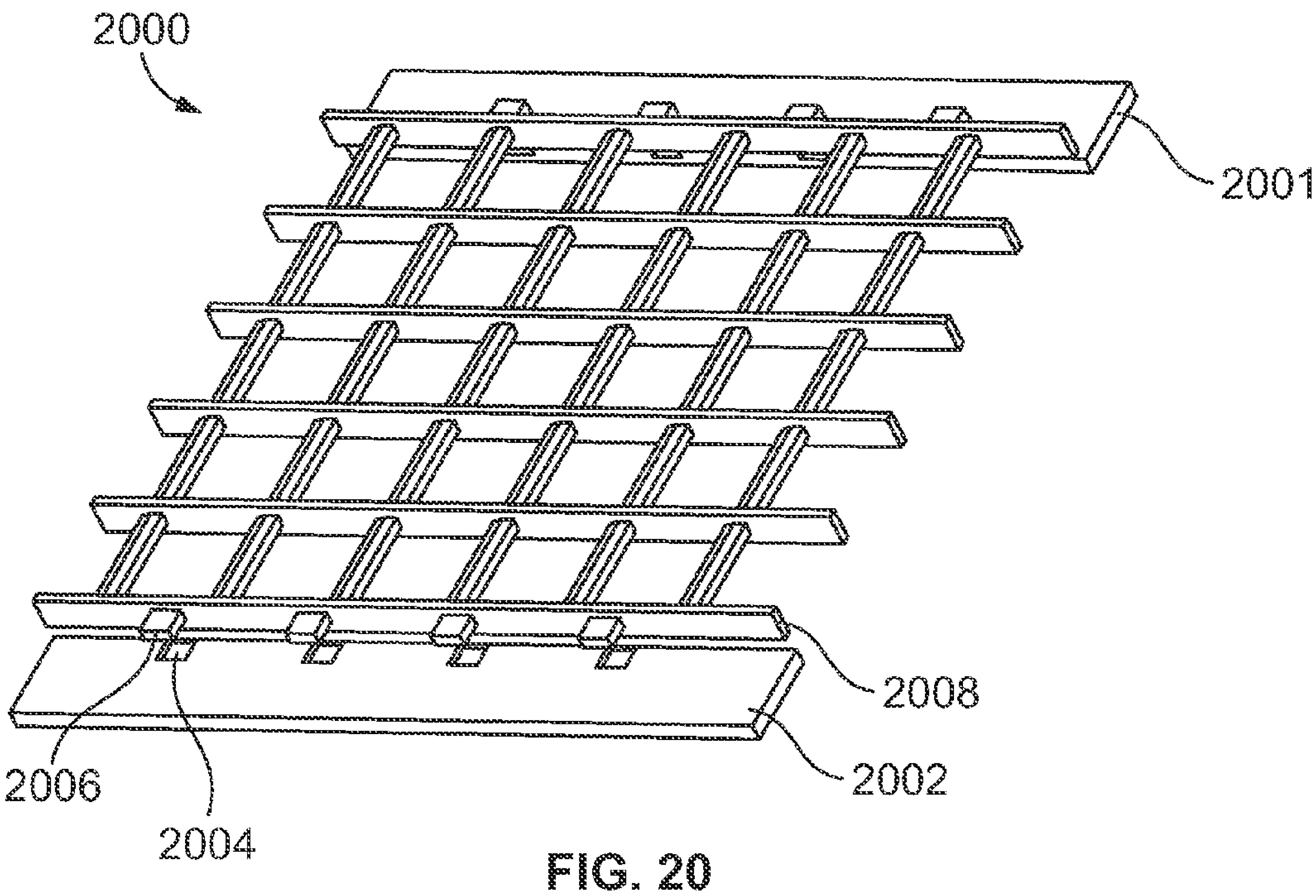
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FIG. 20

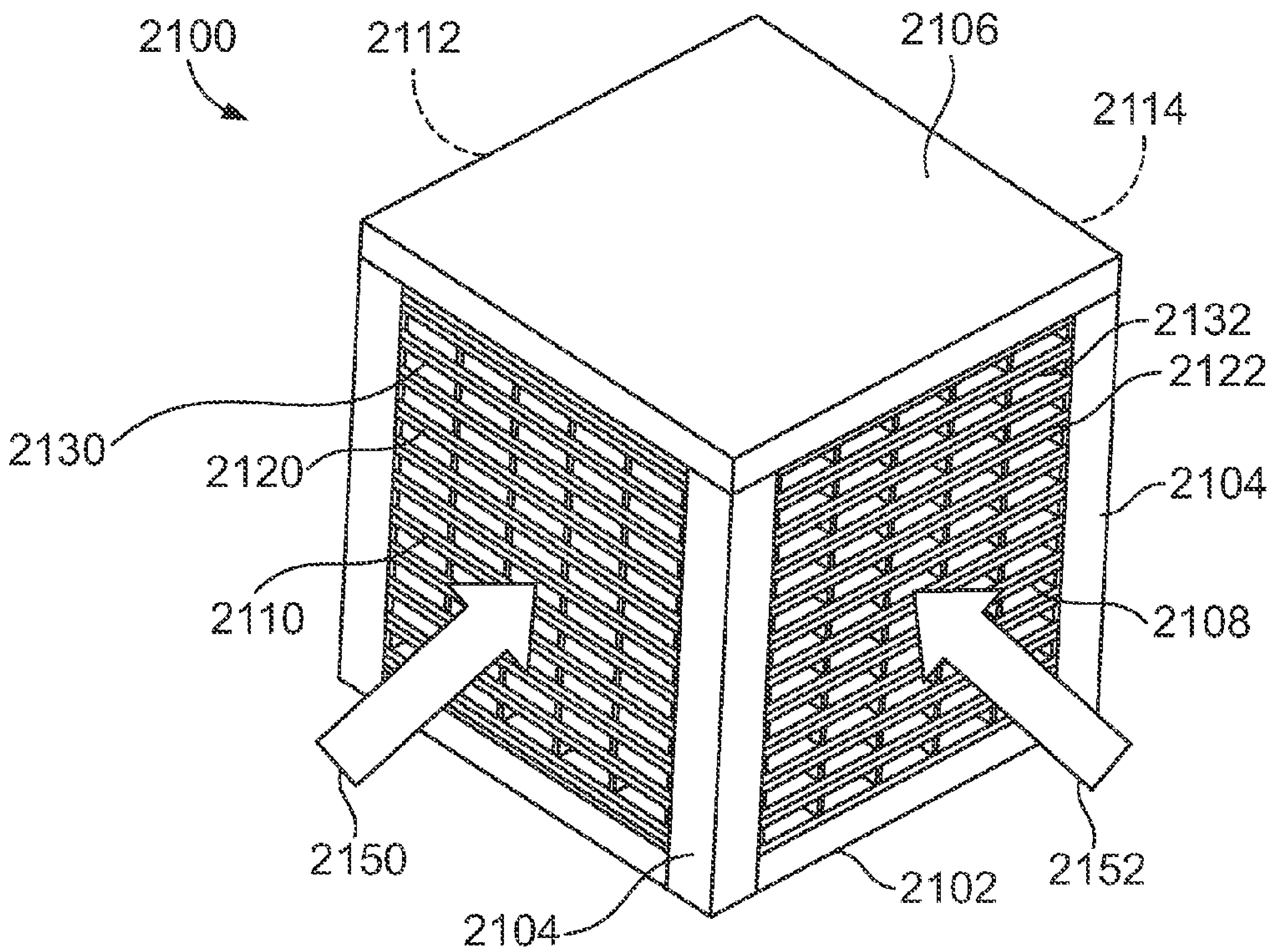
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FIG. 21

MEMBRANE SUPPORT ASSEMBLY FOR AN ENERGY EXCHANGER

CROSS REFERENCE TO RELATED APPLICATION

[0001] The present application is a Non-Provisional and claims priority from U.S. Provisional Application Ser. No. 61/774,184 filed Mar. 7, 2013, entitled "Membrane Support Assembly for an Energy Exchanger, which related and claims priority from U.S. Provisional Application Ser. No. 61/692,793 filed Aug. 24, 2012, entitled "Membrane Support Assembly for an Energy Exchanger," which is hereby expressly incorporated by reference in its entirety.

BACKGROUND OF THE DISCLOSURE

[0002] Embodiments of the present disclosure generally relate to an energy exchange system for conditioning air in an enclosed structure, and more particularly, to a membrane support assembly for an energy exchanger.

[0003] Enclosed structures, such as occupied buildings, factories and the like, generally include a heating/ventilation/air conditioning (HVAC) system for conditioning outdoor ventilated and/or recirculated air. The HVAC system typically includes a supply air flow path and an exhaust air flow path. The supply air flow path receives pre-conditioned air, for example outside air or outside air mixed with re-circulated air, and channels and distributes the pre-conditioned air into the enclosed structure. The pre-conditioned air is conditioned by the HVAC system to provide a desired temperature and humidity of supply air discharged into the enclosed structure. The exhaust air flow path discharges air back to the environment outside the structure. Without energy recovery, conditioning the supply air typically requires a significant amount of auxiliary energy, particularly in environments having extreme outside air conditions that are much different than the required supply air temperature and humidity. Accordingly, energy exchange or recovery systems are used to recover energy from the exhaust air flow path. Energy recovered from air in the exhaust flow path is utilized to reduce the energy required to condition the supply air.

[0004] Conventional energy exchange systems may utilize energy recovery devices (for example, energy wheels and permeable plate exchangers) or heat exchange devices (for example, heat wheels, plate exchangers, heat-pipe exchangers and run-around heat exchangers) positioned in both the supply air flow path and the return air flow path. Liquid-to-air membrane energy exchangers (LAMEEs) may be fluidly coupled so that a desiccant liquid flows between the LAMEEs in a run-around loop, similar to run-around heat exchangers that typically use aqueous glycol as a coupling fluid.

[0005] In general, a LAMEE transfers heat and moisture between a liquid desiccant solution and air through a thin flexible membrane. A flat plate LAMEE includes a series of alternating liquid desiccant and air channels separated by the membrane. Typically, the pressure of the liquid within a liquid channel between membranes is higher than that of the air pressure outside of the membranes. As such, the flexible membranes tend to outwardly bow or bulge into the air channel(s).

[0006] In order to avoid excessive restriction of the air flow due to membrane bulge, air channels of a LAMEE are relatively wide compared to the liquid channels. Moreover, a support structure is generally provided between membranes to limit the amount of membrane bulge. However, the relatively wide air channels and support structures typically diminish the performance of the LAMEE. In short, resistance to heat and moisture transfer in the air channel is relatively high due to the large air channel width, and the support structure may block a significant amount of membrane transfer area. Accordingly, a large amount of membrane area is needed to meet performance objectives, which adds costs and results in a larger LAMEE. Moreover, the support structure within an air channel may produce an excessive pressure drop, which also adversely affects operating performance and efficiency of the LAMEE.

[0007] The transfer of heat from an air channel to membranes within a parallel plate LAMME is described by the following:

$$q_s=h(T_s-T_m)$$

where q_s is the heat flux at the membrane per unit area, h is the local heat transfer coefficient, T_s is the local membrane temperature, and T_m is the local bulk mean temperature of the air. For a given temperature difference, (T_s-T_m), the rate at which heat is transferred to the membrane depends on the transfer coefficient h, which is related to the air channel width and air flow properties. The transfer of mass (for example, moisture) is governed by an analogous relationship. That is, the mass flux depends on a mass transfer coefficient h_m, and the difference in concentration (for example, humidity) between the bulk air flow and the air at the surface. The coefficients h and h_m are related to one another through the heat and mass transfer analogy for a given channel geometry and flow condition. The transfer coefficient is described by a dimensionless parameter referred to as the Nusselt number:

$$Nu=hD_h/k$$

where D_h is the hydraulic diameter of the air channel, which is equal to twice the air channel width for parallel plates, and k is the thermal conductivity of the air. A typical LAMEE creates laminar flow (that is, smooth, steady air flow with no turbulence) in the air channels

[0008] A known LAMEE includes metal, glass, or plastic rods placed in the air channels to maintain the width of the air channel. Additionally metal screens are used as extra support structures between the membranes and the rods. The metal rods may be sandwiched within an air channel between metal screens, which, in turn, are sandwiched between the rods and the membranes. In general, the longitudinal axes of the rods are parallel to the air flow. Air flow through the air channel is typically laminar. However, the rods typically take up considerable space in the air channel. Additionally, it has been found that laminar air flow through the air channels produces relatively low heat and moisture transfer rates between the air channel and the membrane.

SUMMARY OF THE DISCLOSURE

[0009] Certain embodiments of the present disclosure provide a membrane support assembly configured to be used with an energy exchanger, such as a liquid-to-air membrane energy exchanger, an air-to-air membrane exchanger, a liquid-to-liquid membrane energy exchanger, or even a non-membrane heat exchanger. The membrane support system is configured to be positioned within a fluid channel, such as an air or liquid channel, between first and second membranes. The membrane support assembly may include at least one support member configured to span between the first and second membranes. The support member(s) is configured to maintain the spacing of the fluid channel. The membrane support assembly may also include at least one turbulence promoter connected to the support structure(s). The turbulence promoter(s) is configured to promote fluid turbulence within the fluid channel. The fluid turbulence within the fluid channel enhances energy transfer between the fluid channel and the first and second membranes.

[0010] The turbulence promoter(s) may be perpendicular to the support member(s). The turbulence promoter(s) may be centered about a longitudinal axis of the support member(s). The turbulence promoter(s) may be offset with respect to a longitudinal axis of the support member(s). The turbulence promoter(s) may connect to the support member(s) proximate a lateral edge of the support member(s). The support member (s) may include at least one planar support strut.

[0011] The turbulence promoter(s) may include a rounded leading end (such as a semi-elliptical shape) connected to a blunted end through an intermediate portion. Alternatively, the turbulence promoter(s) may include a cylindrical post, a block-shaped post, an elliptical-shaped post, a triangular-shaped post, and/or a perforated screen. The perforated screen may be parallel with a longitudinal axis of the support member(s).

[0012] The support member(s) may include a waved support member having rounded peaks and valleys. The support member(s) may include a scalloped support member having connection beams connected to connection joints that are wider than the connection beams. The support member(s) may include a plurality of openings formed therethrough.

[0013] The turbulence promoter(s) may include at least one turbulence-promoting connection joint. The support member (s) may include parallel support beams connected to the turbulence-promoting connection joint(s).

[0014] The turbulence promoter may include a perforated screen. The perforated screen may be parallel to a longitudinal axis of the support member(s). Further, the support member(s) may include a perforated screen positioned along at least a portion of the support member(s).

[0015] Certain embodiments provide an energy exchange system configured to exchange energy between a first fluid, such as an air stream or liquid stream, and a second fluid, such as an air stream or a liquid stream. The energy exchange system may include first and second membranes defining first and second liquid channels, an air channel defined between the first and second membranes, wherein the air channel is configured to allow air to pass therethrough, and wherein the air contacts the membranes to exchange energy between the air and liquid within the first and second liquid channels, and a membrane support assembly positioned within the air channel between the first and second membranes.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. **1** illustrates a schematic view of an energy exchange system, according to an embodiment of the present disclosure.

[0017] FIG. **2** illustrates a side perspective view of a liquid-to-air membrane energy exchanger, according to an embodiment of the present disclosure.

[0018] FIG. **3** illustrates a front view of panels within an energy exchange cavity of a liquid-to-air membrane energy exchanger, according to an embodiment of the present disclosure.

[0019] FIG. **4** illustrates a front view of a membrane support assembly between membranes of a liquid-to-air membrane energy exchanger, according to an embodiment of the present disclosure.

[0020] FIG. **5** illustrates an isometric view of a membrane support assembly, according to an embodiment of the present disclosure.

[0021] FIG. **6** illustrates a front end view of a membrane support assembly, according to an embodiment of the present disclosure.

[0022] FIG. **7** illustrates a top view of a membrane support assembly, according to an embodiment of the present disclosure.

[0023] FIG. **8** illustrates a turbulence promoter, according to an embodiment of the present disclosure.

[0024] FIG. **9** illustrates a turbulence promoter, according to an embodiment of the present disclosure.

[0025] FIG. **10** illustrates a turbulence promoter, according to an embodiment of the present disclosure.

[0026] FIG. **11** illustrates a turbulence promoter, according to an embodiment of the present disclosure.

[0027] FIG. **12** illustrates a top view of a membrane support assembly, according to an embodiment of the present disclosure.

[0028] FIG. **13** illustrates a top view of a membrane support assembly, according to an embodiment of the present disclosure.

[0029] FIG. **14** illustrates an isometric view of a membrane support assembly, according to an embodiment of the present disclosure.

[0030] FIG. **15** illustrates an isometric view of a membrane support assembly, according to an embodiment of the present disclosure.

[0031] FIG. **16** illustrates an isometric view of a membrane support assembly, according to an embodiment of the present disclosure.

[0032] FIG. **17** illustrates an isometric view of a membrane support assembly, according to an embodiment of the present disclosure.

[0033] FIG. **18** illustrates an isometric view of a membrane support assembly, according to an embodiment of the present disclosure.

[0034] FIG. **19** illustrates an isometric view of a membrane support assembly, according to an embodiment of the present disclosure.

[0035] FIG. **20** illustrates an isometric view of a membrane support assembly, according to an embodiment of the present disclosure.

[0036] FIG. **21** illustrates an isometric view of a fluid-to-fluid membrane energy exchanger, according to an embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE DRAWINGS

[0037] The foregoing summary, as well as the following detailed description of certain embodiments will be better understood when read in conjunction with the appended drawings. As used herein, an element or step recited in the singular and proceeded with the word "a" or "an" should be understood as not excluding plural of said elements or steps, unless such exclusion is explicitly stated. Furthermore, references to "one embodiment" are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features. Moreover, unless explicitly stated to the contrary, embodiments "comprising" or "having" an element or a plurality of elements having a particular property may include additional such elements not having that property.

[0038] It has been found that heat and mass transfer coefficients can be substantially increased by using a transfer enhancement device, such as a turbulence promoter, within a fluid channel, such as an air channel, of an energy exchange system, such as a LAMEE, or various other fluid-to-fluid energy exchangers, such as an air-to-air energy exchanger, or liquid-to-liquid energy exchanger. In a LAMEE, for example, transfer enhancement can be accomplished through the creation of unsteady flow patterns, such as eddies, vortices, or other such turbulence, in the air flow. The production of turbulence in the air flow increases the transfer potential because eddies, vortices, and other such turbulence vigorously mix the air within an air channel toward a membrane of the LAMEE. A wide variety of solid shapes placed in the air channel can produce eddies and generate mixing in the air flow. An efficient and high performance transfer enhancement device produces a significant enhancement in transfer rates without creating an excessive pressure drop in the air flow. Excessive pressure drop may be detrimental to operating performance and efficiency because a greater amount of fan power may be needed to move air through the air channel.

[0039] FIG. **1** illustrates a schematic view of an energy exchange system **100**, according to an embodiment of the present disclosure. The system **100** is configured to partly or fully condition air supplied to a structure **101**. The system **100** may include an inlet **102** for a pre-conditioned air flow path **104**. The pre-conditioned air flow path **104** may include outside air, air from a building adjacent to the enclosed structure **101**, or air from a room within the enclosed structure **101**. Airflow in the pre-conditioned air flow path **104** may be moved through the pre-conditioned air flow path **104** by a fan **106**. The fan **106** directs the pre-conditioned air flow through path **104** to a supply air liquid-to-air membrane energy exchanger (LAMEE) **108**. The supply air LAMEE **108** conditions the pre-conditioned air flow in path **104** to generate a change in air temperature and humidity (for example, to partly or fully pre-condition the air) for a supply air flow condition to be discharged into the enclosed space **101**. During a winter mode operation, the supply air LAMEE **108** may condition the pre-conditioned air flow path **104** by adding heat and moisture to the pre-conditioned air in flow path **104**. In a summer mode operation, the supply air LAMEE **108** may condition the pre-conditioned air flow path **104** by removing heat and moisture from the pre-conditioned air in flow path **104**. The pre-conditioned air **110** may be channeled to an HVAC system **112** of the enclosed structure **101**. The HVAC system **112** may further condition the pre-conditioned air **110** to generate the desired temperature and humidity for the supply air **114** that is supplied to the enclosed structure **101**.

[0040] As shown in FIG. **1**, one fan **106** may be located upstream of the LAMEE **108**. Optionally, the pre-conditioned air flow path **104** may be moved by a down-stream fan and/or by multiple fans or a fan array or before and after each LAMEE in the system.

[0041] Return air **116** is channeled out of the enclosed structure **101**. A mass flow rate portion **118** of the return air **116** may be returned to the HVAC system **112**. Another mass flow rate portion **119** of the return air **116** may be channeled to a return air or regeneration LAMEE **120**. The portions **118** and **119** may be separated with a damper **121** or the like. For example, 80% of the return air **116** may be channeled to the HVAC system **112** and 20% of the return air **116** may be channeled to the return air LAMEE **120**. The return air LAMEE **120** exchanges energy between the portion **119** of the return air **116** and the preconditioned air **110** in the supply air LAMEE **108**. During a winter mode operation, the return air LAMEE **120** collects heat and moisture from the portion **119** of the return air **116**. During a summer mode operation, the return air LAMEE **120** discharges heat and moisture into the portion **119** of the return air **116**. The return air LAMEE **120** generates exhaust air **122**. The exhaust air **122** is discharged from the structure **101** through an outlet **124**. A fan **126** may be provided to move the exhaust air **122** from the return air LAMEE **120**. The system **100** may include multiple fans **126** or one or more fan arrays located either up-stream or down-stream (as in FIG. **1**) of the return air LAMEE **120**.

[0042] A desiccant fluid **127** flows between the supply air LAMEE **108** and the return air LAMEE **120**. The desiccant fluid **127** transfers the heat and moisture between the supply air LAMEE **108** and the return air LAMEE **120**. The system **100** may include desiccant storage tanks **128** in fluid communication between the supply air LAMEE **108** and the return air LAMEE **120**. The storage tanks **128** store the desiccant fluid **127** as it is channeled between the supply air LAMEE **108** and the return air LAMEE **120**. Optionally, the system **100** may not include both storage tanks **128** or may have more than two storage tanks. Pumps **130** are provided to move the desiccant fluid **127** from the storage tanks **128** to one of the supply air LAMEE **108** or the return air LAMEE **120**. The illustrated embodiment includes two pumps **130**. Optionally, the system **100** may be configured with as few as one pump **130** or more than two pumps **130**. The desiccant fluid **127** flows between the supply air LAMEE **108** and the return air LAMEE **120** to transfer heat and moisture between the conditioned air **110** and the portion **118** of the return air **116**.

[0043] Turbulent flow conditions are induced in the air and liquid flow channels of the LAMEEs by selecting a distribution and geometric shape for the air and liquid flow channel spacers in the LAMEE. The turbulence is used to enhance the heat and mass transfer convection coefficients in the air flow channels which may be used to increase the effectiveness and/or decrease the LAMEE size. In certain embodiments, turbulence in the liquid flow channels is facilitated to enhance the bulk mean flow distribution (and eliminate laminar flow fingering and mal-distributions) and increase the convective heat and moisture transfer coefficients (for example, decrease mal-distributions in the liquid flows) because the physical effect increases the effectiveness of a given LAMEE.

[0044] FIG. **2** illustrates a side perspective view of a LAMEE **300**, according to an embodiment of the present disclosure. The LAMEE **300** may be used as the supply air LAMEE **108** and/or the return or exhaust air LAMEE **120** (shown in FIG. **1**). The LAMEE **300** includes a housing **302** having a body **304**. The body **304** includes an air inlet end **306** and an air outlet end **308**. A top **310** extends between the air inlet end **306** and the air outlet end **308**. A stepped-down top **312** may be positioned at the air inlet end **306**. The stepped-down top **312** may be stepped a distance **314** from the top **310**. A bottom **316** extends between the air inlet end **306** and the air outlet end **308**. A stepped-up bottom **318** may be positioned at the air outlet end **308**. The stepped-up bottom **318** may be stepped a distance **320** from the bottom **316**. In certain embodiments, the stepped-up bottom **318** or stepped-down top **312** sections may have different sizes of steps or no step at all. Alternatively, a stepped-up top may be positioned at the air inlet end or a stepped-down bottom may be positioned at the air outlet end.

[0045] An air inlet **322** is positioned at the air inlet end **306**. An air outlet **324** is positioned at the air outlet end **308**. Sides **326** extend between the air inlet **322** and the air outlet **324**.

[0046] An energy exchange cavity **330** extends through the housing **302** of the LAMEE **300**. The energy exchange cavity **330** extends from the air inlet end **306** to the air outlet end **308**. An air stream **332** is received in the air inlet **322** and flows through the energy exchange cavity **330**. The air stream **332** is discharged from the energy exchange cavity **330** at the air outlet **324**. The energy exchange cavity **330** includes a plurality of panels **334**.

[0047] A desiccant inlet reservoir **338** may be positioned on the stepped-up bottom **318**. The desiccant inlet reservoir **338** may have a height **340** equal to the distance **320** between the bottom **316** and the stepped-up bottom **318**. Alternatively, the liquid desiccant inlet reservoir **338** may have any height that meets a desired performance of the LAMEE **300**. The desiccant inlet reservoir **338** extends a length **339** of the LAMEE body **304**. The length **339** that is configured to meet a desired performance of the LAMEE **300**. In an embodiment, the desiccant inlet reservoir **338** may extend no more than one fourth of the length **327** of the LAMEE body **304**. Alternatively, the desiccant inlet reservoir **338** may extend along one fifth, for example, of the length **327** of the LAMEE body **304**.

[0048] The liquid desiccant inlet reservoir **338** is configured to receive desiccant **341** from a storage tank **128** (shown in FIG. **1**). The desiccant inlet reservoir **338** includes an inlet **342** in flow communication with the storage tank **128**. The desiccant **341** is received through the inlet **342**. The desiccant inlet reservoir **338** includes an outlet that is in fluid communication with desiccant channels **376** in the energy exchange cavity **330**. The liquid desiccant **341** flows through the outlet into the desiccant channels **376**. The desiccant **341** flows along the panels **334** through the desiccant channels **376** to a desiccant outlet reservoir **346**.

[0049] The desiccant outlet reservoir **346** may be positioned on the stepped-down top **312** of the housing **302**. Alternatively, the desiccant outlet reservoir **346** may be positioned at any location along the top **312** of the LAMEE housing **302** or alternatively on the side of the reservoir with a flow path connected to all the panels. The desiccant outlet reservoir **346** has a height **348** that may be equal to the distance **314** between the top **310** and the stepped-down top **312**. The desiccant outlet reservoir **346** extends along the top **312** of the LAMEE housing **302** for a length **350**. In an embodiment, the length **350** may be no more than one fourth the length **327** of the flow panel exchange area length **302**. In another embodiment, the length **350** may be one fifth, for example, the length **327** of the panel exchange area length **302**.

[0050] The desiccant outlet reservoir **346** is configured to receive desiccant **341** from the desiccant channels **376** in the energy exchange cavity **330**. The desiccant outlet reservoir **346** includes an inlet **352** in flow communication with the desiccant channels **376**. The desiccant **341** is received from the desiccant channels **376** through the inlet **352**. The desiccant outlet reservoir **346** includes an outlet **354** that is in fluid communication with a storage tank **128**. The desiccant **341** flows through the outlet **354** to the storage tank **128** where the desiccant **341** is stored for use in another LAMEE **300**. In an alternative embodiment, the desiccant outlet reservoir **346** may be positioned along the bottom **318** of the LAMEE housing **302** and the desiccant inlet reservoir **338** may be positioned along the top **310** of the housing **302**.

[0051] As shown in FIG. **2**, the LAMEE **300** includes one liquid desiccant outlet reservoir **346** and one liquid desiccant inlet reservoir **338**. Alternatively, the LAMEE **300** may include liquid desiccant outlet reservoirs **346** and liquid desiccant inlet reservoirs **338** on the top and bottom of each of each end of a LAMEE **300**. A liquid flow controller may direct the liquid flow to either the top or bottom.

[0052] FIG. **3** illustrates a front view of the panels **334** within the energy exchange cavity **300** of the LAMEE **300**, according to an embodiment of the present disclosure. The liquid flow panels **334** form a liquid desiccant channel **376** that may be confined by semi-permeable membranes **378** on either side and is configured to carry desiccant **341** therethrough. The semi-permeable membranes **378** are arranged in parallel to form air channels **336** with an average flow channel width of **337** and liquid desiccant channels **376** with an average flow channel width of **377**. In an embodiment, the semi-permeable membranes **378** are spaced to form uniform air channels **336** and liquid desiccant channels **376**. The air stream **332** (shown in FIG. **2**) travels through the air channels **336** between the semi-permeable membranes **378**. The desiccant **341** in each desiccant channel **376** exchanges heat and moisture with the air stream **332** in the air channels **336** through the semi-permeable membranes **378**. The air channels **336** alternate with the liquid desiccant channels **376**. Except for the two side panels of the energy exchange cavity, each air channel **336** may be positioned between adjacent liquid desiccant channels **376**.

[0053] In order to minimize or otherwise eliminate the liquid desiccant channels **376** from outwardly bulging or bowing, membrane support assemblies may be positioned within the air channels **336**. The membrane support assemblies are configured to support the membranes, as well as promote turbulent air flow between the air channels **336** and the membranes **378**.

[0054] The LAMEE **300** may be a LAMEE as described in WO 2011/161547, entitled "Liquid-To-Air Membrane Energy Exchanger," filed Jun. 22, 2011, which is hereby incorporated by reference in its entirety. Liquid panel assemblies that may be used in the LAMEE **300** are described and shown in U.S. application Ser. No. ______ entitled "Liquid Panel Assembly," filed ______, which claims priority to U.S. Provisional Application No. 61/692,798, entitled "Liquid Panel Assembly," filed Aug. 24, 2012, both of which are also incorporated by reference in their entireties.

[0055] It is to be understood that the embodiments shown and described with respect FIG. **2** (and the entire application, in general) may also be used with respect to various types of fluid-to-fluid energy exchangers, such as gas-to-gas, liquid-to-liquid, or liquid-to-gas energy exchangers. For example, air channels may be used in place of desiccant channels.

[0056] FIG. **4** illustrates a front view of a membrane support assembly **400** between membranes **378** of a LAMEE, according to an embodiment. Optionally, the membrane support assembly **400** may be positioned between membranes in an air-to-air membrane energy exchanger, or a liquid-to-liquid energy exchanger. For example, the membranes **378** may separate air channels, or liquid channels. While the membrane support assembly **400** is shown between membranes of a LAMEE, such as the LAMEE **300**, the membrane support assembly **400** may be used with respect to any type of

LAMEE or energy exchange system that uses membranes. The LAMEE **300** shown and described with respect to FIG. **3** is merely exemplary. Embodiments, such as the membrane support assembly **400** and other membrane support assemblies described in the present application are in no way limited to use with the LAMEE **300**.

[0057] The membrane support assembly **400** is positioned within an air channel **336** between neighboring membranes **378** of liquid desiccant channels **376**. The membrane support assembly **400** includes support members, such as struts **402** connected to turbulence promoters **404**. The turbulence promoters **404** may be perpendicular to the support struts **402**. As shown in FIG. **4**, the support struts **402** may be horizontally oriented, while the eddy turbulence promoters **404** may be vertically oriented.

[0058] Each support strut **402** includes terminal ends **406** and **408** that abut into a membrane **378**. In general, the support struts **402** span the width w_s of the air channel **336**.

[0059] Each turbulence promoter **404** may pass through a central plane C of each support strut **402**. The widths w_t of the turbulence promoters **404** are less than the widths w_s of the support struts **402**. The turbulence promoters **404** may be located about a central vertical plane X of the air channel **336**. Further, the width w_t of the turbulence promoters **404** may extend a short distance on either side of the central plane x.

[0060] The membrane support assembly **400** may be integrally molded and formed as a single piece. For example, the membrane support assembly **400** may be integrally molded and formed of injection molded plastic. Optionally, the membrane support assembly **400** may be formed of metal. Alternatively, the support struts **402** and the turbulence promoters **404** may be separately formed and connected to one another. In an embodiment, the support struts **402** may be formed of metal, while the turbulence promoters **404** may be formed of plastic, or vice versa.

[0061] In operation, the support struts **402** provide bracing support between neighboring membranes **378**, while the turbulence promoters **404** cause turbulence in the airflow within the air channel **336**. Heat and mass transfer coefficients are substantially increased through the membrane support assembly **400** within the air channel **336**. The turbulence promoters **404** generate turbulence, such as unsteady flow patterns, in the air flow, which enhances energy exchange between the air within the air channel **336** and the desiccant within the liquid desiccant channels **376**. The turbulence in the air flow increases the transfer potential because eddy and vertical structures vigorously mix the air from the center x of the air channel **336** toward the membranes **378**. The turbulence promoters **404** may be a wide variety of solid shapes, as explained below.

[0062] FIG. **5** illustrates an isometric view of the membrane support assembly **400**, according to an embodiment of the present disclosure. The membrane support assembly **400** may include three parallel support struts **402** and two spaced-apart turbulence promoters **404** that are perpendicular to the support struts **402**. However, more or less support struts **402** and turbulence promoters **404** may be used. For example, the membrane support assembly **400** may include two support struts **402** and one turbulence promoter **404**. Also, for example, the membrane support assembly **400** may include four support struts **402** and four turbulence promoters **404**.

[0063] As shown in FIG. **5**, bottom ends **410** of the turbulence promoters **410** may extend downwardly past the lower support strut **402***a*. Similarly, upper ends **411** of the turbulence promoters **410** may extend upwardly past the upper support strut **402***b*. The lower and upper ends **410** and **411**, respectively, of the turbulence promoters **410** may abut against a base and upper wall, respectively, of a housing that defines an energy exchange cavity of a LAMEE. As such, the lower and upper ends **410** and **411** may stabilize and orient the membrane support assembly **400** within the energy exchange cavity of the LAMEE. Optionally, the lower and upper ends **410** and **411** of the turbulence promoters **404** may terminate at an interface with the lower and upper support struts **402***a* and **402***b*, respectively. In such an embodiment, the lower and upper support struts **402***a* and **402***b* stabilize and orient the membrane support assembly **400** within the energy exchange cavity of the LAMEE.

[0064] The membrane support assembly **400** is positioned and oriented within an air channel between membranes of a LAMEE so that air flow denoted by arrows A flows over and/or across the turbulence promoters **404**. Air flow A encounters a leading, rounded (such as a semi-elliptical shape) end **412** of each turbulence promoter **404** and passes around an intermediate portion **414**, and creates turbulence, such as eddies and/or vortices, as it passes around a straight-edge blunted end **416** (as shown in FIG. **7**, in particular). The support struts **402** provide structural support for the air channel, as shown in FIG. **4**, for example. The support struts **402** prevent neighboring membranes from outwardly bulging or bowing. The support struts **402** maintain the width of the air channel, and also provide support to the flexible membranes.

[0065] The turbulence promoters **404** generate unsteady airflow, eddies, vortices, and other such turbulence in the air stream, which enhances heat and moisture transfer rates between the air and the membranes that define the liquid desiccant channels. The turbulence promoters **404** generate vortex shedding, and the mixing of air (as opposed to laminar flow) increases the heat and moisture transfer rates to the membranes.

[0066] FIG. **6** illustrates a front end view of the membrane support assembly **400**, according to an embodiment of the present disclosure. The number of support struts **402**, and the width distance d_s between the support struts **402** may vary depending on a desired level of membrane and air channel support. As shown in FIG. **6**, as air flow A encounters the leading, rounded end **412** of the turbulence promoter **404**, the air flow A separates around the turbulence promoter **404**, and creates turbulence as it passes around and past the turbulence promoter **404**.

[0067] FIG. **7** illustrates a top view of the membrane support assembly **400**, according to an embodiment of the present disclosure. As noted above, each turbulence promoter **404** includes a leading, rounded end **412** integrally connected to an intermediate portion **414**, which, in turn, connects to a straight-edge blunted end **416**. As the air flow A encounters the leading end **412**, the air flow separates around the turbulence promoter **404** at area A'. As separated airflow passes around the intermediate portion **414** and the blunted end **416**, the air flow mixes and creates vortices, eddies, and other such turbulence at area A".

[0068] The leading, rounded end **412** and the straight-edge blunted end **416** provide an efficient shape for turbulence generation. Alternatively, the turbulence promoters **400** may be various other shapes configured to promote turbulence in airflow.

[0069] FIG. **8** illustrates a turbulence promoter **500**, according to an embodiment of the present disclosure. The turbulence promoter **500** may be connected to one or more support struts **502**, as explained above. The turbulence promoter **500** may be a cylindrical post **504**. The cylindrical turbulence promoter **500** may be used in place of any of the turbulence promoters described above. The cylindrical shape of the turbulence promoter **500** is a ubiquitous shape, and easy to manufacture.

[0070] FIG. **9** illustrates a turbulence promoter **600**, according to an embodiment of the present disclosure. The turbulence promoter **600** may be connected to one or more support struts **602**, as explained above. The turbulence promoter **600** may be shaped as a square or rectangular member **604**, such as a plate, panel, post, or the like. The turbulence promoter **600** may be used in place of any of the turbulence promoters described above. The turbulence promoter **600** may be efficiently formed through extrusion and punching operations.

[0071] FIG. **10** illustrates a turbulence promoter **700**, according to an embodiment of the present disclosure. The turbulence promoter **700** may be connected to one or more support struts **702**, as explained above. The turbulence promoter **700** may be shaped as an elliptical member **704**, such as a panel, plate, post, or the like. The turbulence promoter **600** may be used in place of any of the turbulence promoters described above. The elliptical turbulence promoter **700** is configured for low drag and low pressure drop with respect to the airflow.

[0072] Referring to FIGS. **8-10**, the turbulence promoters may be various shapes and sizes that are not shown. The turbulence promoters are shaped and sized to promote turbulent, as opposed to laminar, airflow.

[0073] FIG. **11** illustrates a turbulence promoter **800**, according to an embodiment of the present disclosure. The turbulence promoter **800** may be connected to one or more support struts **802**, as explained above. The turbulence promoter **800** includes a planar fin **804**, such as a mesh screen, that is perpendicular to the support strut **802**, and is aligned parallel to the longitudinal axis **806** of the support strut **802**. The planar fin **804** may be formed of a metal, such as aluminum. The planar fin **804** may include multiple openings **808**, such as holes, perforations, channels, cavities, or the like, formed therethrough. As airflow A passes into and around the turbulence promoter **800**, the openings **808** cause the airflow A to swirl, mix, or otherwise pass therethrough, causing turbulence, such as eddies or vortices.

[0074] The openings **808** may be formed through a lattice **810**. Alternatively, the openings **808** may be formed at various points in the planar fin **804**. Additionally, alternatively, the planar fin **804** may not be parallel with the longitudinal axis **806**. Instead, the planar fin **804** may be angled with respect to the longitudinal axis **806**. For example, the planar fin **804** may be perpendicular to the longitudinal axis **806**. In such an embodiment, the planar fin **804** may or may not span between neighboring membranes within a LAMEE.

[0075] The turbulence promoter **800** is configured to create shear layer destabilization. The turbulence promoter **800** may be used in place of any of the turbulence promoters described above.

[0076] FIG. **12** illustrates a top view of a membrane support assembly **900**, according to an embodiment of the present disclosure. The membrane support assembly **900** includes support struts **902** connected to turbulence promoters **904**. The membrane support assembly **900** is similar to the membrane support assembly shown in FIGS. **4-7**, except that the turbulence promoters **904** may be offset with respect to a longitudinal axis **906** of each support strut **902**. As shown, the turbulence promoters **904** alternately offset with respect to the longitudinal axis **906**, such that the turbulence promoters **904***a* and **904***c* are above the longitudinal axis **906**, while the turbulence promoters **904***b* and **904***d* are below the longitudinal axis **906**. Alternatively, the turbulence promoters **904** may be offset in a non-alternating pattern. For example, the turbulence promoters **904***a* and **904***b* may both be above or below the longitudinal axis **906**, while the turbulence promoters **904***c* and **904***d* may also both be above or below the longitudinal axis **906**. Moreover, three of the four turbulence promoters **904** may be offset to one side of the longitudinal axis **906**. When the turbulence promoters **904** are offset from the longitudinal axis **906**, such that they are closer to a membrane, heat and moisture transfer between the air stream and the membranes may be increased (as compared to when the turbulence promoters are aligned along the longitudinal axis).

[0077] More or less turbulence promoters **904** than those shown may be used. The turbulence promoters **904** may be replaced with any of the turbulence promoters shown in FIGS. **8-10**.

[0078] FIG. **13** illustrates a top view of a membrane support assembly **1000**, according to an embodiment of the present disclosure. The membrane support assembly **1000** includes support struts **1002** connected to turbulence promoters **1004**. The turbulence promoters **1004** may be square posts, as shown. The turbulence promoters **1004** may be proximate lateral edges **1006** of the support struts **1002**. In this manner, each turbulence promoters **1004** may directly abut into a membrane, thereby providing additional support to the membrane.

[0079] Neighboring turbulence promoters **1004** may be offset with respect to the longitudinal axis **1008** in an alternating fashion, as shown. Optionally, the turbulence promoters **1002** may not alternate in a regular repeating fashion. More or less turbulence promoters **1004** than those shown may be used. The turbulence promoters **1004** may be replaced with any of the turbulence promoters shown in FIGS. **4-10**.

[0080] FIG. **14** illustrates an isometric view of a membrane support assembly **1100**, according to an embodiment of the present disclosure. The membrane support assembly **1100** includes support struts **1102** connected to turbulence promoters **1104**. The membrane support assembly **1100** is similar to the membrane support assembly shown in FIGS. **4-7**, except that the support struts **1102** may have a wave shape, with undulating, rounded peaks **1106** and valleys **1108**. The waved support struts **1102** provide support to the membranes of a LAMEE over greater distances, as the effective support distance ranges from a peak **1106** to a valley **1108** of an individual support strut **1102**. The waved support struts **1102** contact the membranes over a greater distance.

[0081] Any of the turbulence promoters shown in FIGS. **8-11** may be used in place of the turbulence promoters **1104**.

[0082] FIG. **15** illustrates an isometric view of a membrane support assembly **1200**, according to an embodiment of the present disclosure. The membrane support assembly **1200** includes support struts **1202** connected to turbulence promoters **1204**. The membrane support assembly **1200** is similar to the membrane support assembly shown in FIGS. **4-7**, except that the support struts **1202** may be scalloped, with thin connection beams **1206** connected to wider connection joints **1208**. The scalloped support struts **1202** are slimmer and lighter than the support struts shown in FIGS. **4-7**, for example. Additionally, the thin connection beams **1206** provide space between the membranes, thereby providing additional space for turbulent airflow to impact the membranes.

[0083] Any of the turbulence promoters shown in FIGS. **8-11** may be used in place of the turbulence promoters **1204**.

[0084] FIG. **16** illustrates an isometric view of a membrane support assembly **1300**, according to an embodiment of the present disclosure. The membrane support assembly **1300** includes support struts **1302** connected to turbulence promoters **1304**. The membrane support assembly **1300** is similar to the membrane support assembly shown in FIGS. **4-7**, except that the support struts **1302** may have openings **1306**, such as perforations, holes, channels, cavities, or the like formed therethrough. The openings **1306** promote additional heat and moisture transfer enhancement.

[0085] Openings, such as the openings **1306**, may be formed in any of the support struts shown and described with respect to FIGS. **4-7** and **12-15**. Further, any of the turbulence promoters shown in FIGS. **8-11** may be used in place of the turbulence promoters **1304**.

[0086] FIG. **17** illustrates an isometric view of a membrane support assembly **1400**, according to an embodiment of the present disclosure. Instead of support struts, the membrane support assembly **1400** includes support members, such as horizontal beams **1402** and vertical beams **1404**, which provide support to the assembly **1400**, connected together and spaced apart through turbulence-promoting connection joints **1403**, which may securely connect the support beams **1402** and **1404** together through a snap fit, latch members, or the like.

[0087] The connection joints **1403** and/or the beams **1402** and/or **1404** may promote turbulence. As such, the connection joints **1403**, the beams **1402**, and the beams **1404** may also be turbulence promoters. The connection joints **1403** and/or the beams **1402** and/or **1404** may be shaped similar to any of the turbulence promoters shown and described with respect to FIGS. **5-16**, for example. The beams **1404** are located at either side of the turbulence-promoting connection joints **1403**, and, along with the support beams **1402**, may provide support to membranes of a LAMEE. Turbulent airflow may pass between and around the beams **1404**, as well as between and around the turbulence-promoting connection joints **1403** and the support beams **1402**. Because the support beams **1402** are separated from one another, air gaps **1408** exist between parallel support beams **1402**. Air is able to pass into the air gaps **1408**, thereby providing increased heat and moisture transfer between the air stream and the membranes.

[0088] The turbulence-promoting connection joints **1403** may be separate and distinct from the support beams **1402** and the support beams **1404**. Alternatively, the connection joints **1403** may be integrally formed with either parallel support beams **1402**, and/or parallel support beams **1404**. Also, alternatively, the entire membrane support assembly **1400** may be molded and formed as an integral unit.

[0089] Any of the turbulence promoters shown in FIGS. **8-11** may be used in place of the turbulence promoters, such as the support beams **1402** and **1404** and/or the turbulence-promoting connection joints **1403**.

[0090] FIG. **18** illustrates an isometric view of a membrane support assembly **1500**, according to an embodiment of the present disclosure. The membrane support assembly **1500** includes parallel support struts **1502** connected to turbulence promoters **1504**. The turbulence promoters **1504** may be perforated screens having openings **1506** formed therethrough. The turbulence promoters **1504** may be perpendicular to the support struts **1502**, and may be generally parallel to longitudinal axes **1508** of the support struts **1502**. Alternatively, the turbulence promoters **1504** may be waved or angled with respect to the longitudinal axes **1508**. Additionally, any of the turbulence promoters discussed above may be used in addition to the turbulence promoters **1504**.

[0091] The turbulence promoters **1504**, as perforated screens, create thin wakes or shear layers in the airflow, which may lead to flow instability and an early transition to turbulence. The turbulence promoters **1504** may be formed from rolled expanded screens.

[0092] The membrane support assembly **1500** may be formed of metal. Optionally, the membrane support assembly **1500** may be formed of plastic. Alternatively, the support struts **1502** may be metal or plastic, while the turbulence promoters **1504** may be formed of the other of metal or plastic.

[0093] FIG. **19** illustrates an isometric view of a membrane support assembly **1600**, according to an embodiment of the present disclosure. The membrane support assembly **1600** includes support beams **1602** and **1604**, such as shown in FIG. **17** (but without connection joints), connected to turbulence promoters **1606**, which may include perforated screens. The support beams **1602**, **1604** and the turbulence promoters **1606** may be integrally molded and formed as a unit.

[0094] The perforated screens **1606** may span portions of parallel support beams **1602**. The perforated screens **1606** have openings **1608** that promote turbulent airflow therethrough. The perforated screens **1606** may span an entire length of parallel support beams **1602**. The perforated screens **1606** may be regularly spaced between portions of the parallel support beams **1602**, as shown in FIG. **19**. The perforated screens may be integrally formed with parallel support struts **1602**, thereby connecting the support struts **1602** together.

[0095] The perforated screens **1606** may be used in addition to, or in place of, any of the support struts shown in FIGS. **4-7** and **12-18**. Additionally, any of the turbulence promoters shown in FIGS. **8-11** may be used with the assembly **1600**.

[0096] FIG. **20** illustrates an isometric view of a membrane support assembly **2000**, according to an embodiment of the present disclosure. The membrane support assembly **2000** includes opposed brackets **2002** and **2004**. Each bracket **2002** may be a planar member, such as a fin, plate, sheet, or the like, that includes one or more recesses **2004**. Each recess **2004** is configured to receive and retain a securing member **2006**, such as a tab, stud, post, column, or other such protuberance, extending from a membrane support **2008**. The recesses **2004** are configured to securely lock onto the securing members **2006**, thereby securely locking the membrane support **2008** between the opposed brackets **2002** and **2004**. The opposed brackets **2002** and **2004** may be configured to be quickly and easily urged into a housing of an energy exchanger, such as a LAMEE, an air-to-air exchanger, or the like. The recesses **2004** and securing members **2006** cooperate to provide interlocking features that securely locks the membrane support **2008** in place. Alternatively, the membrane support **2008** may include the recesses, while the brackets **2002** and **2004** include the securing members. Also, alternatively, one of the brackets **2002** and **2004** may be integrally formed and molded with the membrane support **2008**, while the other is removably secured to the membrane support **2008** through the interlocking features. The interlocking features shown and described with respect to FIG. **20** may be used with any of the membrane support assemblies shown and described in the present application.

[0097] FIG. **21** illustrates an isometric view of a fluid-to-fluid membrane energy exchanger **2100**, according to an embodiment of the present disclosure. The energy exchanger **2100** may include a housing **2102** having a base **2102** connected to upstanding supports **2104**, which, in turn, connect to an upper wall **2106**. Fluid inlets **2108** and **2110** and fluid outlets **2112** and **2114** are defined between the upstanding supports **2104**. As shown in FIG. **21**, the housing **2102** is formed as a cube, but may be formed as various other shapes.

[0098] A plurality of membranes **2120** are longitudinally aligned from the fluid inlet **2110** to the fluid outlet **2114**, while a plurality of membranes **2122** are longitudinally aligned from the fluid inlet **2108** to the fluid outlet **2112**. The membranes **2110** define fluid passages **2130** therebetween, while the membranes **2122** define fluid passages **2132** therebetween. The fluid passages **2130** are generally perpendicular to the fluid passages **2132**. A fluid **2150**, such as a gas (for example, air), passes through the fluid passages **2130** and exchanges sensible and latent energy with fluid **2152**, such as a gas (for example, air), that passes through the fluid passages **2132** through the membranes **2120** and **2122**. The membranes **2120** and **2122** may be supported with membrane support assemblies, such as any of the membrane support assemblies described above. The energy exchanger **2100** may be an air-to-air membrane energy exchanger, for example.

[0099] As shown and described with respect to FIGS. **1-21**, embodiments of the present disclosure provide membrane support assemblies that create a pathway for air to flow over a surface of a membrane. The membrane support assemblies enhance heat and mass transfer rates within the air channels. The membrane support assemblies ensure that the air channels prevent the membranes from compressing the air channels, constrain the amount of membrane bulge, and support membrane seals to reduce the risk of leaks.

[0100] Embodiments may be used with various types of energy exchangers, such as liquid-to-air, air-to-air, or liquid-to-liquid membrane energy exchangers. For example, the membrane support assemblies described above may be positioned within an air or liquid channel between membranes, or within a membrane.

[0101] The membrane support assemblies described above allow for less membrane surface area within a LAMEE, for example, as the membrane support assemblies provide turbulent airflow that enhances heat and mass transfer between the air channels and the membranes. Consequently, because the membranes may be smaller, a cost savings is realized in that less material is used. Further, smaller membranes lead to more compact energy exchangers, thereby leading to less packaging volume, and greater system configuration and layout flexibility.

[0102] As explained above, embodiments provide membrane support assemblies that promote turbulent airflow through air channels between membranes. As such, embodiments provide increased heat and moisture transfer rates between the air channels and membranes, as compared to previously-known systems.

[0103] While various spatial and directional terms, such as top, bottom, lower, mid, lateral, horizontal, vertical, front and the like may be used to describe embodiments of the present disclosure, it is understood that such terms are merely used with respect to the orientations shown in the drawings. The orientations may be inverted, rotated, or otherwise changed, such that an upper portion is a lower portion, and vice versa, horizontal becomes vertical, and the like.

[0104] It is to be understood that the above description is intended to be illustrative, and not restrictive. For example, the above-described embodiments (and/or aspects thereof) may be used in combination with each other. In addition, many modifications may be made to adapt a particular situation or material to the teachings of the various embodiments of the disclosure without departing from their scope. While the dimensions and types of materials described herein are intended to define the parameters of the various embodiments of the disclosure, the embodiments are by no means limiting and are exemplary embodiments. Many other embodiments will be apparent to those of skill in the art upon reviewing the above description. The scope of the various embodiments of the disclosure should, therefore, be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. In the appended claims, the terms "including" and "in which" are used as the plain-English equivalents of the respective terms "comprising" and "wherein." Moreover, in the following claims, the terms "first," "second," and "third," etc. are used merely as labels, and are not intended to impose numerical requirements on their objects. Further, the limitations of the following claims are not written in means-plus-function format and are not intended to be interpreted based on 35 U.S.C. §112, sixth paragraph, unless and until such claim limitations expressly use the phrase "means for" followed by a statement of function void of further structure.

[0105] This written description uses examples to disclose the various embodiments of the disclosure, including the best mode, and also to enable any person skilled in the art to practice the various embodiments of the disclosure, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the various embodiments of the disclosure is defined by the claims, and may include other examples that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if the examples have structural elements that do not differ from the literal language of the claims, or if the examples include equivalent structural elements with insubstantial differences from the literal languages of the claims.

What is claimed is:

1. A membrane support assembly configured to be used with an energy exchanger, wherein the membrane support system is configured to be positioned within a fluid channel between first and second membranes, the membrane support assembly comprising:

at least one support member configured to span between the first and second membranes, wherein the at least one support member is configured to support the fluid channel; and

at least one turbulence promoter connected to the at least one support member, wherein the at least one turbulence promoter is configured to promote fluid turbulence within the fluid channel, and wherein the fluid turbulence within the fluid channel enhances energy transfer between the fluid channel and the first and second membranes.

2. The membrane support assembly of claim **1**, wherein the at least one turbulence promoter is perpendicular to the at least one support member.

3. The membrane support assembly **1**, wherein the at least one turbulence promoter is centered about a longitudinal axis of the at least one support member.

4. The membrane support assembly of claim **1**, wherein the at least one turbulence promoter is offset with respect to a longitudinal axis of the at least one support member.

5. The membrane support assembly of claim **1**, wherein the at least one turbulence promoter connects to the at least one support member proximate a lateral edge of the at least one support member.

6. The membrane support assembly of claim **1**, wherein the at least one support member comprises at least one planar support strut.

7. The membrane support assembly of claim **1**, wherein the at least one turbulence promoter comprises a rounded leading end connected to a blunted end through an intermediate portion.

8. The membrane support assembly of claim **1**, wherein the at least one turbulence promoter comprises a cylindrical post.

9. The membrane support assembly of claim **1**, wherein the at least one turbulence promoter comprises a block-shaped post.

10. The membrane support assembly of claim **1**, wherein the at least one turbulence promoter comprises an elliptical-shaped post.

11. The membrane support assembly of claim **1**, wherein the at least one turbulence promoter comprises a triangular-shaped post.

12. The membrane support assembly of claim **1**, wherein the at least one turbulence promoter comprises a perforated screen.

13. The membrane support assembly of claim **11**, wherein the perforated screen is parallel with a longitudinal axis of the at least one support member.

14. The membrane support assembly of claim **1**, wherein the at least one support member comprises a waved support member having rounded peaks and valleys.

15. The membrane support assembly of claim **1**, wherein the at least one support member comprises a scalloped support member having connection beams connected to connection joints that are wider than the connection beams.

16. The membrane support assembly of claim **1**, wherein the at least one support member comprises a plurality of openings formed therethrough.

17. The membrane support assembly of claim **1**, wherein the at least one turbulence promoter comprises at least one turbulence-promoting connection joint, wherein the at least one support member comprises parallel support beams connected to the at least one turbulence-promoting connection joint.

18. The membrane support assembly of claim **1**, wherein the at least one turbulence promoter comprises a perforated screen.

19. The membrane support assembly of claim **18**, wherein the perforated screen is parallel to a longitudinal axis of the at least one support member.

20. The membrane support assembly of claim **1**, wherein the at least one support member comprises a perforated screen positioned along at least a portion of the at least one support member.

21. The membrane support assembly of claim **1**, wherein the energy exchanger is a liquid-to-gas membrane energy exchanger.

22. The membrane support assembly of claim **1**, wherein the energy exchanger is an air-to-air membrane energy exchanger.

23. The membrane support assembly of claim **1**, wherein the energy exchanger is a liquid-to-liquid energy exchanger.

24. An energy exchange system configured to exchange energy between an air stream and a liquid, the energy exchange system comprising:

first and second membranes defining first and second liquid channels;

an air channel defined between the first and second membranes, wherein the air channel is configured to allow air to pass therethrough, and wherein the air contacts the membranes to exchange energy between the air and liquid within the first and second liquid channels; and

a membrane support assembly positioned within the air channel between the first and second membranes, the membrane support assembly comprising:

at least one support member configured to span between the first and second membranes, wherein the at least one support member is configured to support the air channel; and

at least one turbulence promoter connected to the at least one support member, wherein the at least one turbulence promoter is configured to promote airflow turbulence within the air channel, and wherein the airflow turbulence within the air channel enhances energy transfer between the air channel and the first and second membranes.

25. The energy exchange system of claim **24**, wherein the at least one turbulence promoter is perpendicular to the at least one support member.

26. The energy exchange system of claim **24**, wherein the at least one turbulence promoter is centered about a longitudinal axis of the at least one support member.

27. The energy exchange system of claim **24**, wherein the at least one turbulence promoter is offset with respect to a longitudinal axis of the at least one support member.

28. The energy exchange system of claim **24**, wherein the at least one turbulence promoter connects to the at least one support member proximate a lateral edge of the at least one support member.

29. The energy exchange system of claim **24**, wherein the at least one support member comprises at least one planar support strut.

30. The energy exchange system of claim **24**, wherein the at least one turbulence promoter comprises a rounded leading end connected to a blunted end through an intermediate portion.

31. The energy exchange system of claim **24**, wherein the at least one turbulence promoter comprises a cylindrical post.

32. The energy exchange system of claim **24**, wherein the at least one turbulence promoter comprises a block-shaped post.

33. The energy exchange system of claim **24**, wherein the at least one turbulence promoter comprises an elliptical-shaped post.

34. The energy exchange system of claim **24**, wherein the at least one turbulence promoter comprises a perforated screen.

35. The energy exchange system of claim **34**, wherein the perforated screen is parallel with a longitudinal axis of the at least one support member.

36. The energy exchange system of claim **24**, wherein the at least one support member comprises a waved support member having rounded peaks and valleys.

37. The energy exchange system of claim **24**, wherein the at least one support member comprises a scalloped support member having connection beams connected to connection joints that are wider than the connection beams.

38. The energy exchange system of claim **24**, wherein the at least one support member comprises a plurality of openings formed therethrough.

39. The energy exchange system of claim **24**, wherein the at least one turbulence promoter comprises a turbulence-promoting connection joint, and wherein at least one support member comprises parallel support beams connected to the at least one turbulence-promoting connection joint.

40. The energy exchange system of claim **24**, wherein the at least one turbulence promoter comprises a perforated screen.

41. The energy exchange system of claim **40**, wherein the perforated screen is parallel to a longitudinal axis of the at least one support member.

42. The energy exchange system of claim **24**, wherein the at least one support member comprises a perforated screen positioned along at least a portion of the at least one support member.

43. The energy exchange system of claim **24**, wherein the membrane support assembly includes at least one interlocking member configured to securely interlock with at least a portion of the energy exchange system.

44. An energy exchange system configured to exchange energy between first and second fluids, the energy exchange system comprising:

first and second membranes defining first and second first fluid channels;

a second fluid channel defined between the first and second membranes, wherein the second fluid channel is configured to allow the second fluid to pass therethrough, and wherein the second fluid contacts the membranes to exchange energy between the second fluid and the first fluid within the first and second first fluid channels; and

a membrane support assembly positioned within the second fluid channel between the first and second membranes, the membrane support assembly comprising:

at least one support member configured to span between the first and second membranes, wherein the at least one support member is configured to support the second fluid channel; and

at least one turbulence promoter connected to the at least one support member, wherein the at least one turbulence promoter is configured to promote fluid turbulence within the second fluid channel, and wherein the fluid turbulence within the second channel enhances energy transfer between the second channel and the first and second membranes.

45. The energy exchanger system of claim **44**, wherein the first fluid includes a gas or liquid, and wherein the second fluid includes the gas or the liquid.

46. The energy exchanger system of claim **44**, wherein the first fluid includes a first gas or a first liquid, and where the second fluid includes a second gas or a second liquid.

47. The energy exchanger system of claim **44**, wherein the first and second fluids include air.

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