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(54) **CLAMSHELL HEAT EXCHANGERS**

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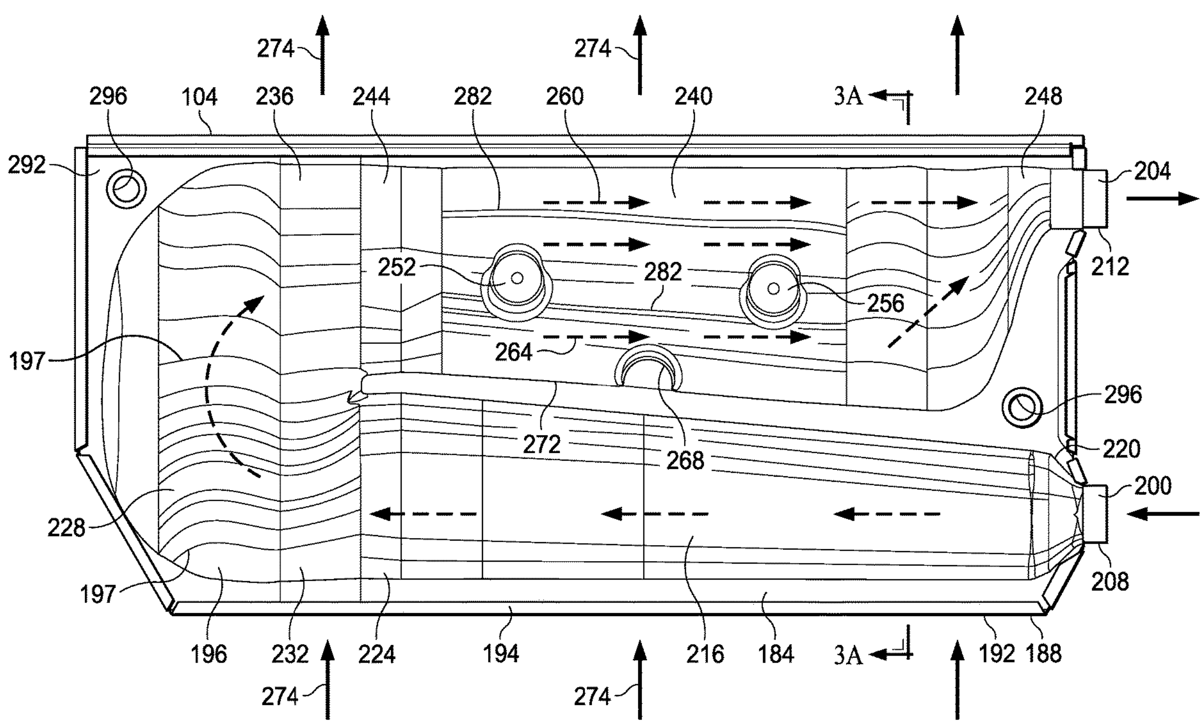
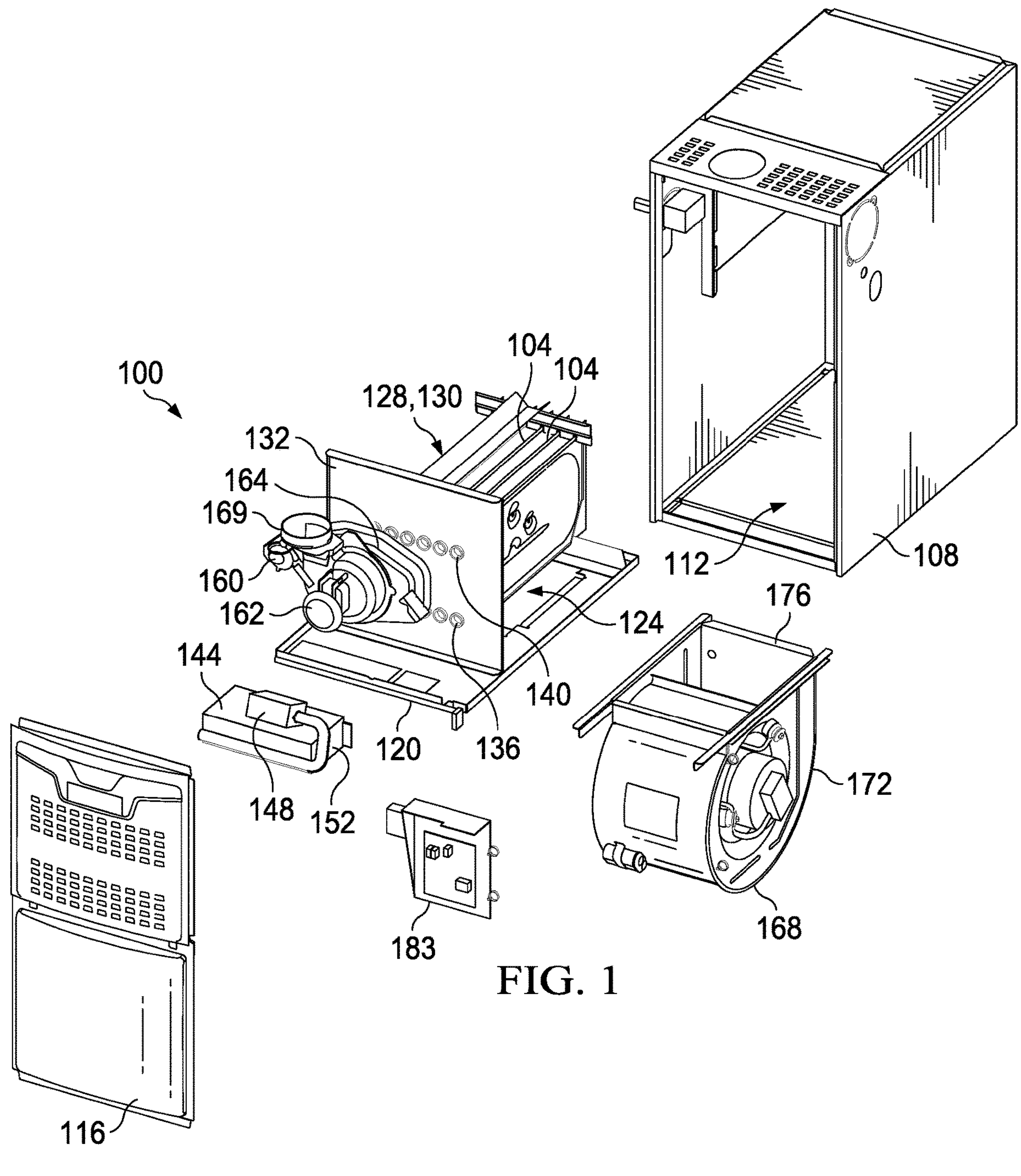
CPC ***F24H 3/105*** (2013.01); ***F28D 9/0031*** (2013.01); ***F28F 3/044*** (2013.01); *F28F 2250/102* (2013.01)

(57) **ABSTRACT**

A clamshell heat exchanger for use in a combustion furnace of an HVAC system is presented that includes in one instance two passageways coupled by a turnaround passageway. The first passageway that receives the combustion products diverges. A cross section of the first passageway resembles a tear drop or air foil with the widest portion closest to the second passageway. The second passageway also diverges from the turnaround portion towards the outlet. The second passageway may include a baffle that forms two flow streams. Other embodiments are presented.

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128,130
132
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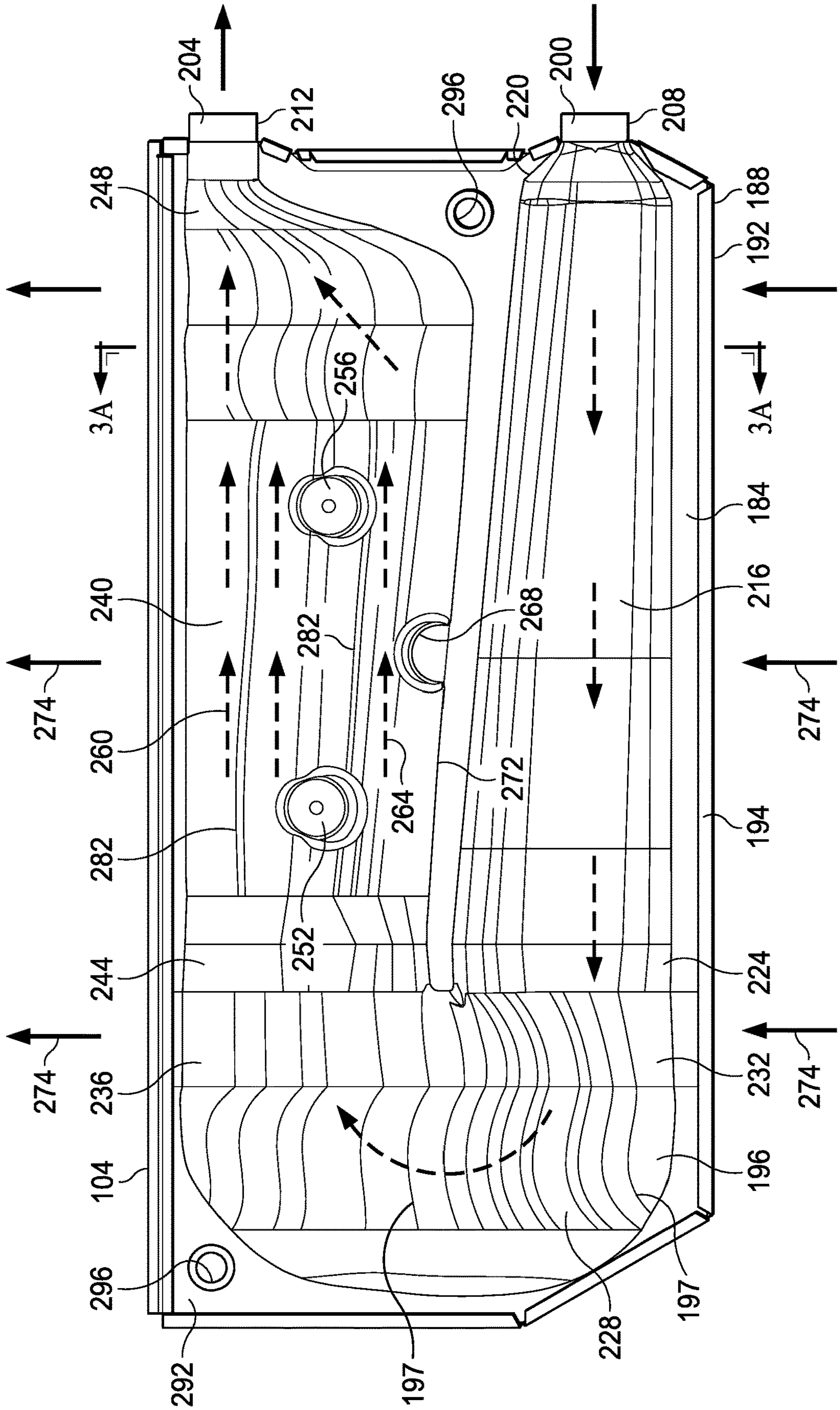
116

FIG. 1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274
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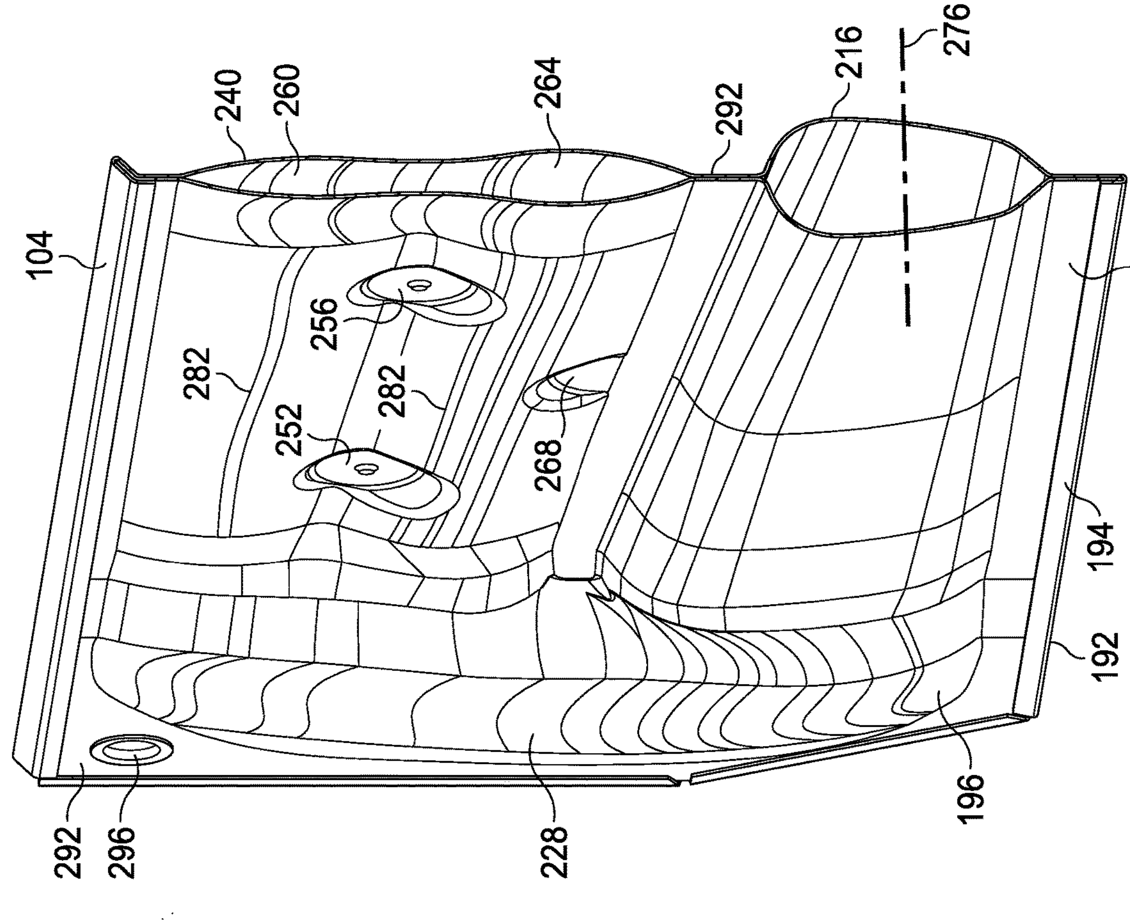
FIG. 2


104
240
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296

FIG. 3A

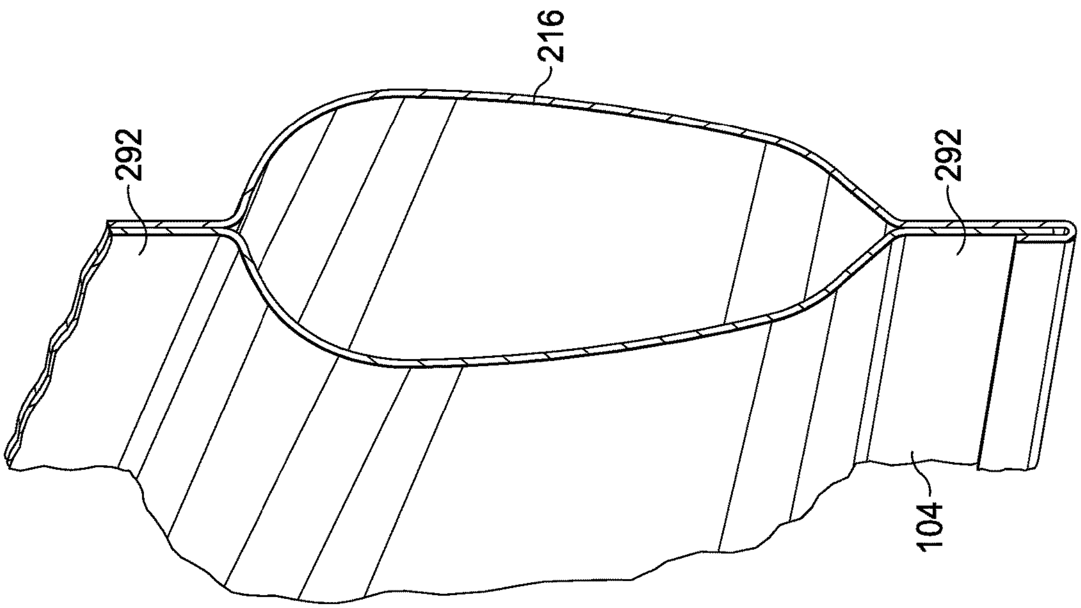
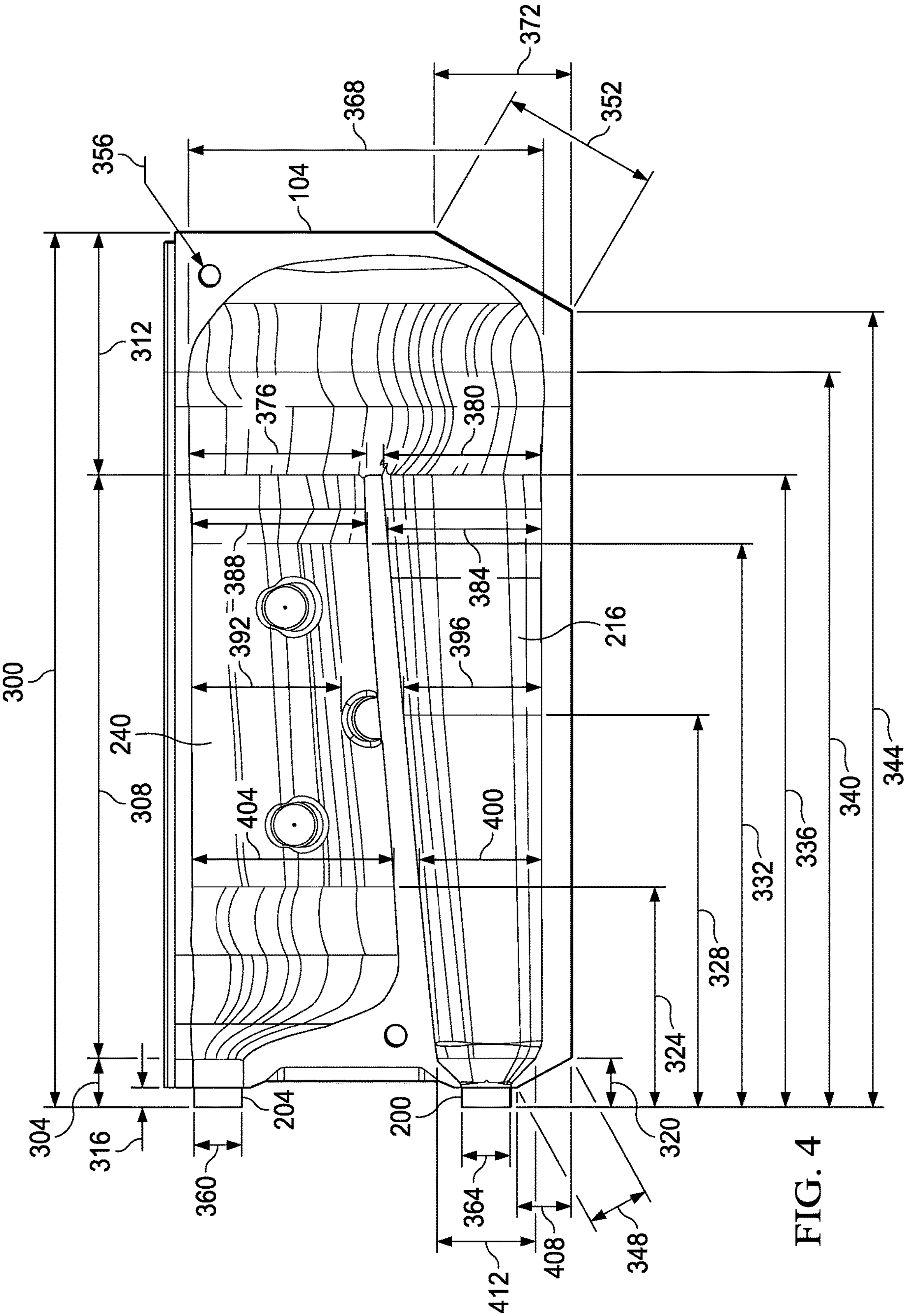

216
292
292
104

FIG. 3B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356
104
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348
412

FIG. 4

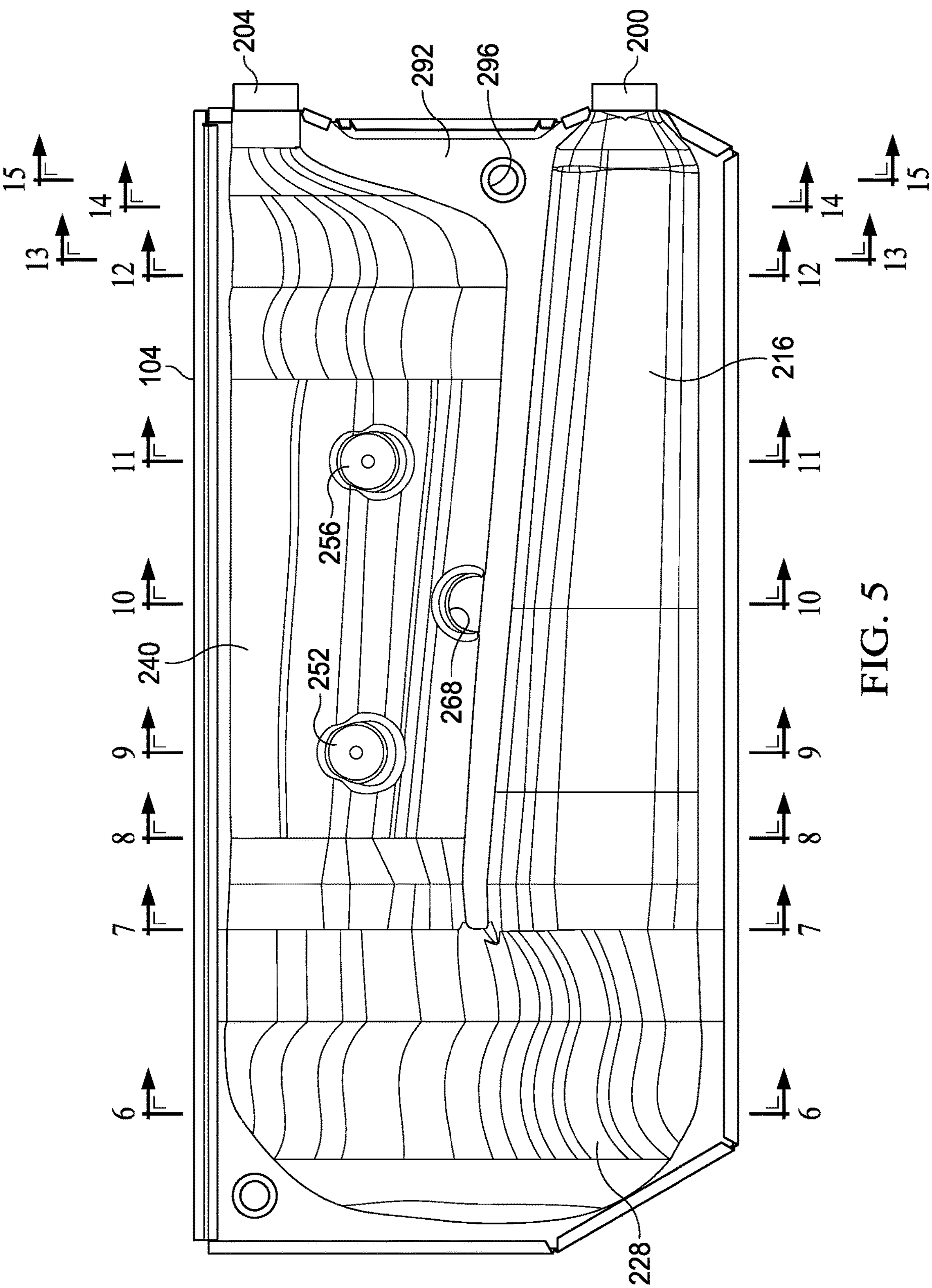


FIG. 5

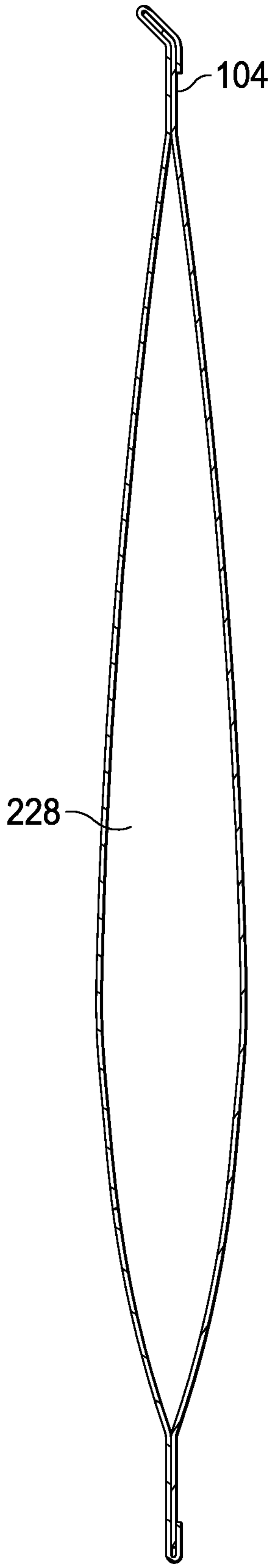


FIG. 6

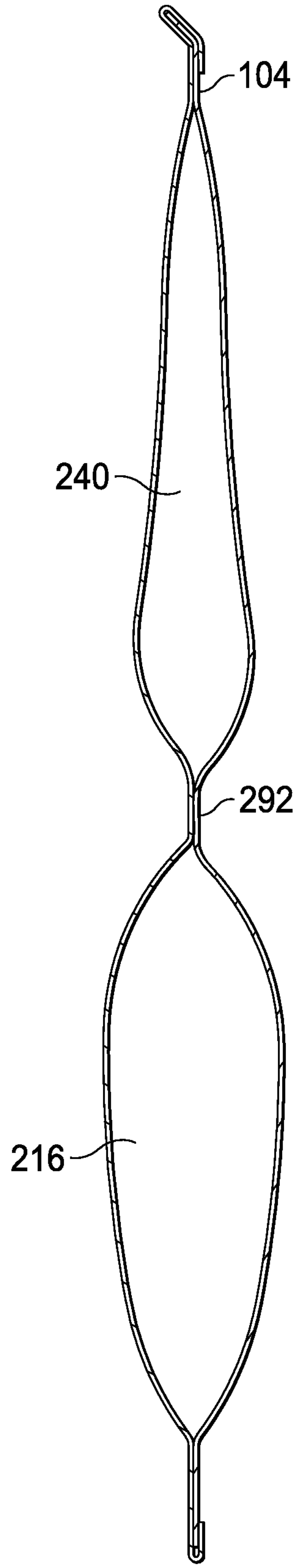


FIG. 7

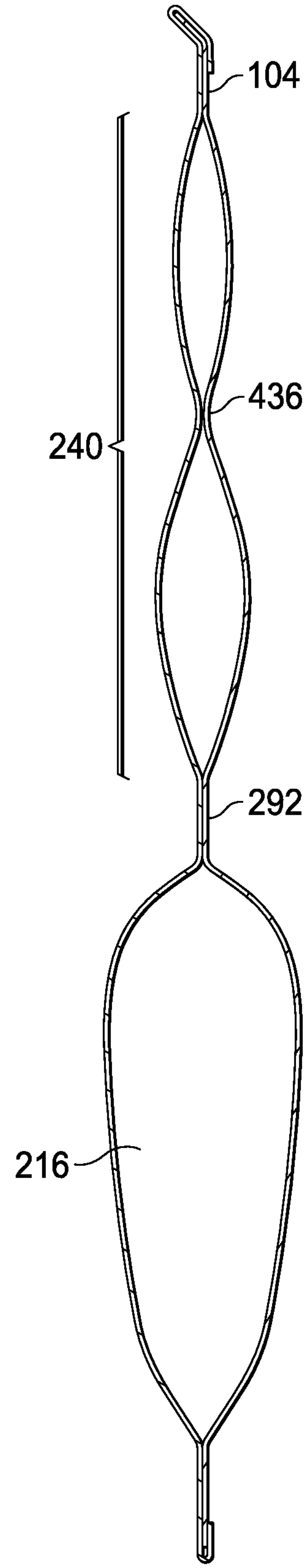


FIG. 8

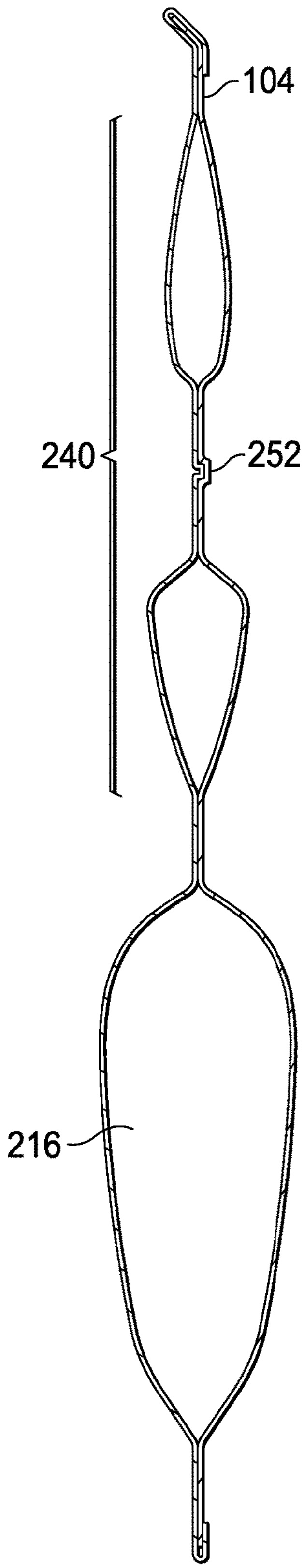


FIG. 9

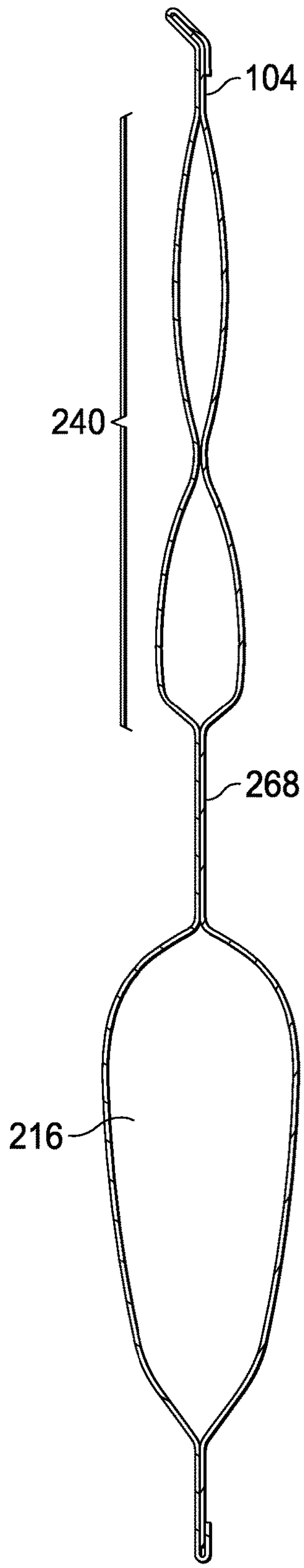


FIG. 10

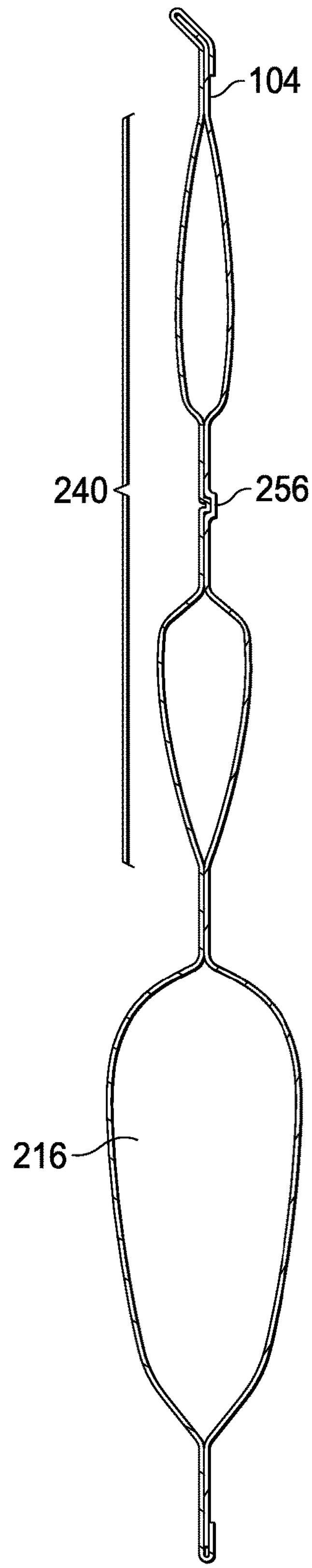


FIG. 11

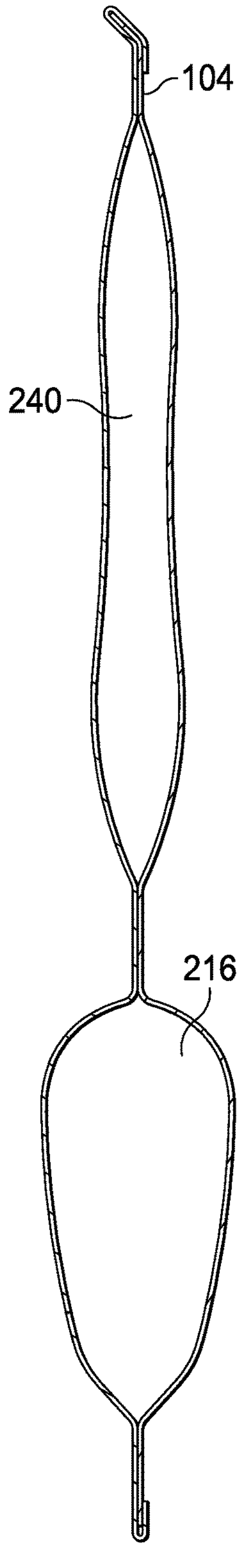


FIG. 12

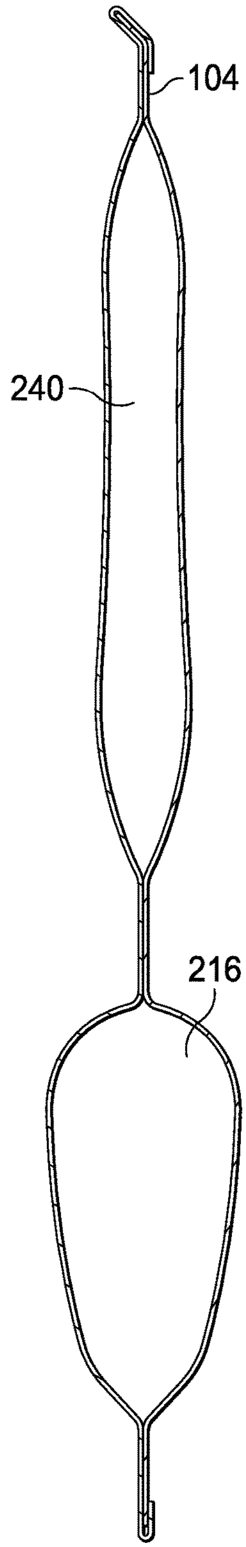


FIG. 13

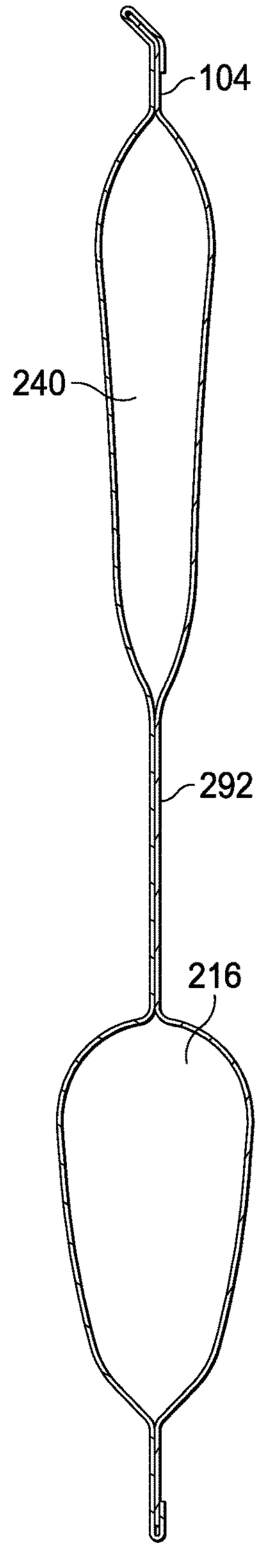


FIG. 14

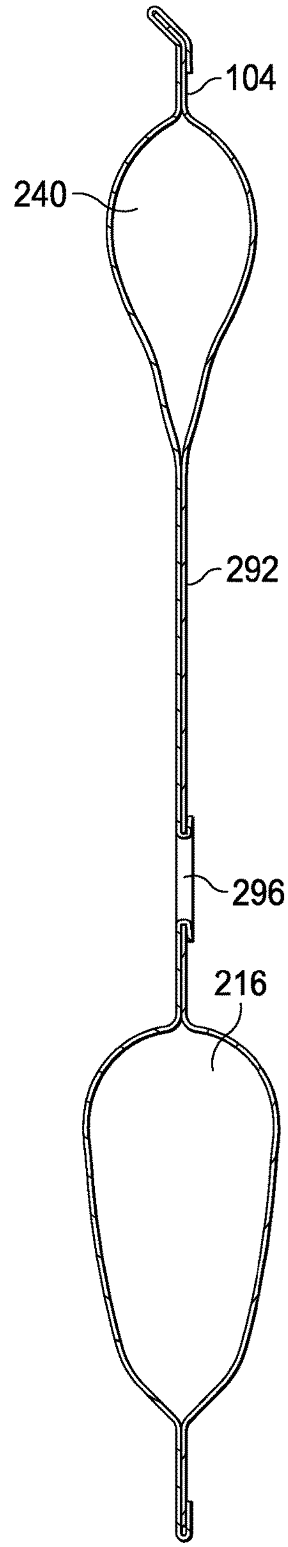


FIG. 15

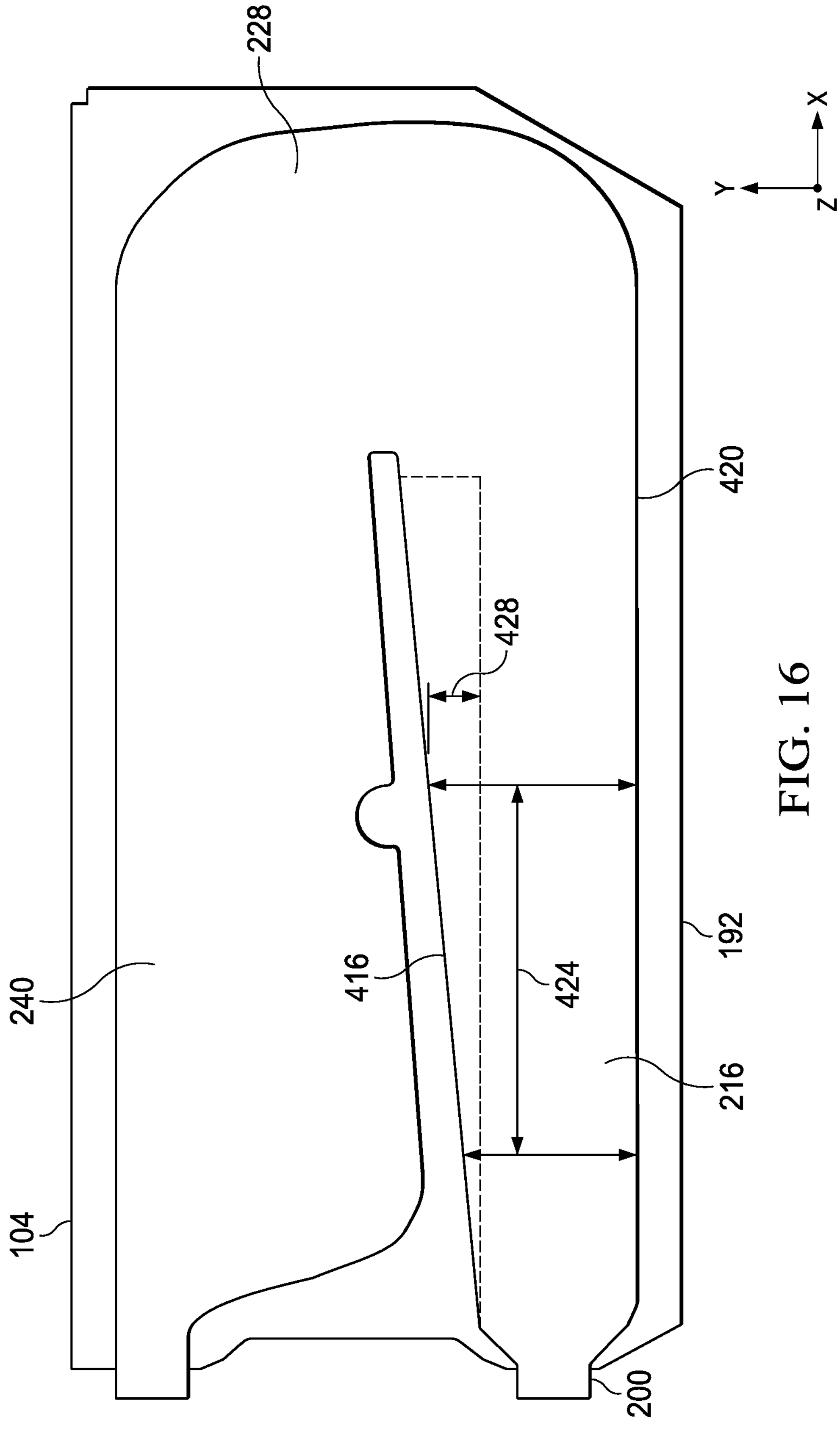


FIG. 16

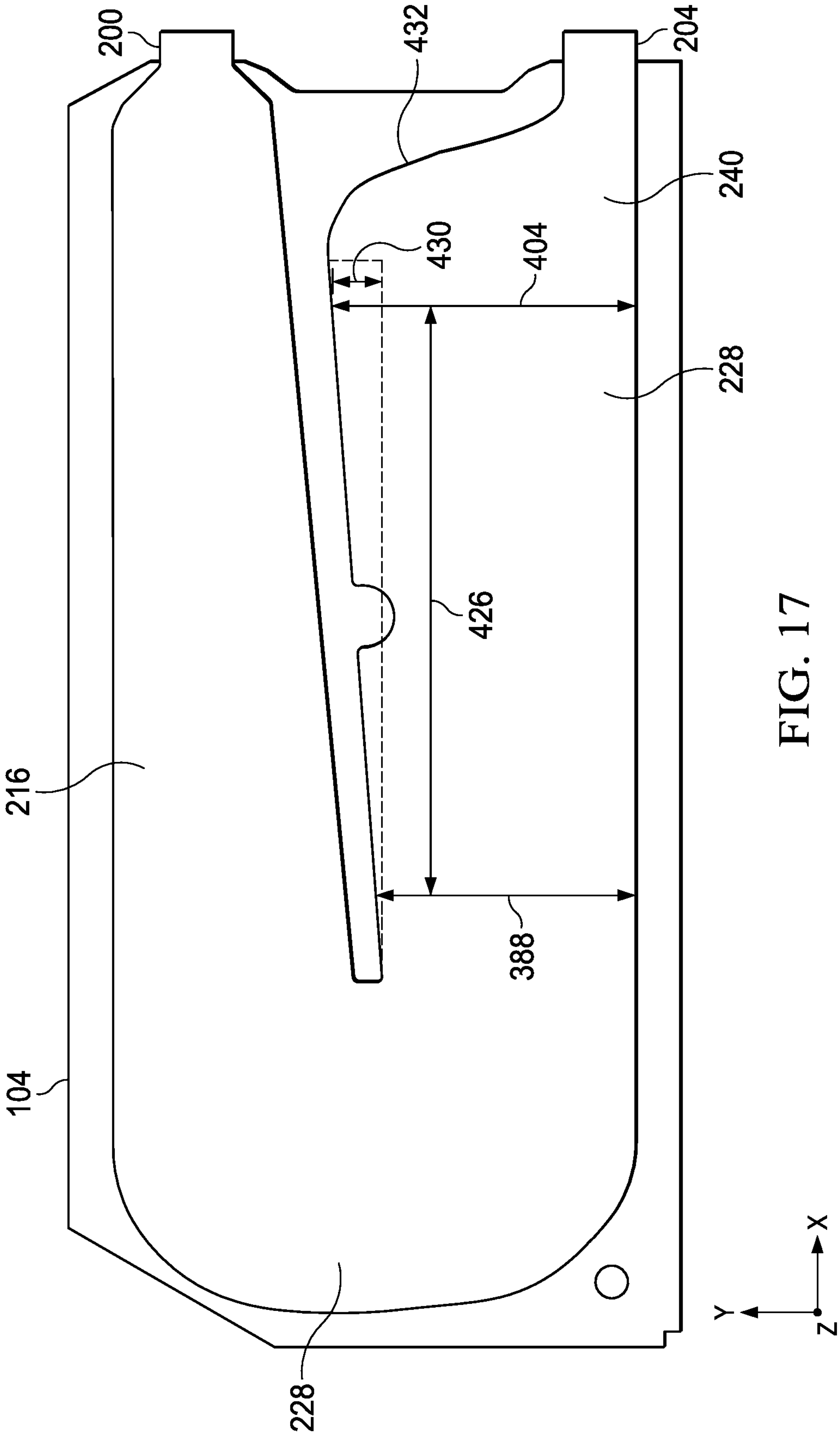
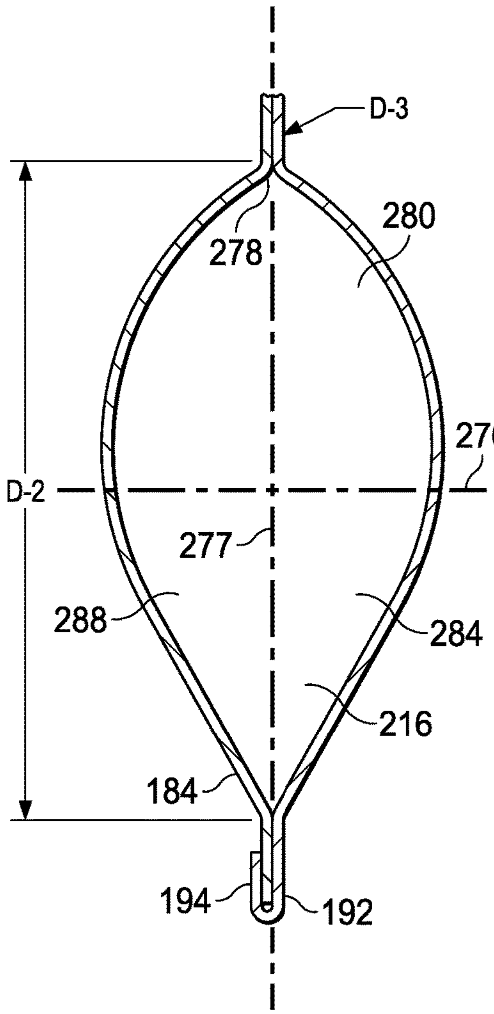


FIG. 17



D-3
280
278
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D-2
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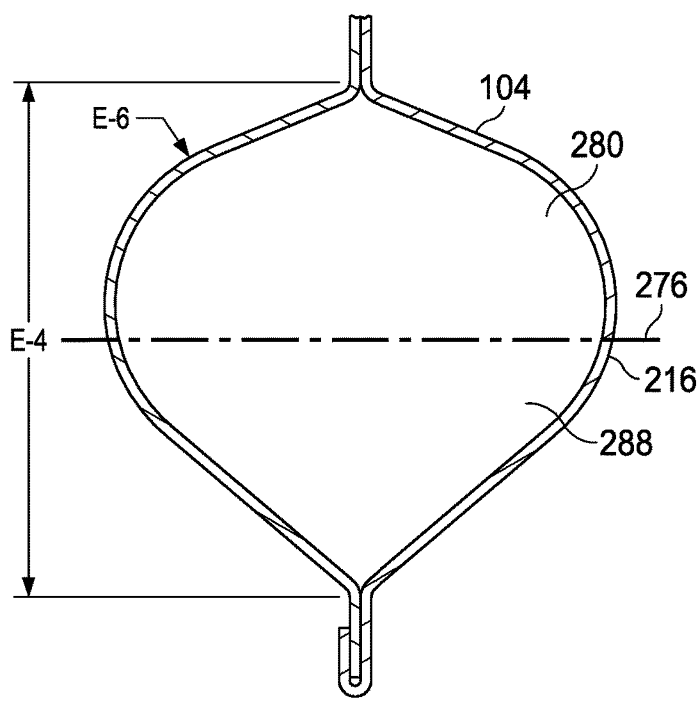
284
216
184
194
192

FIG. 18



104
E-6
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276
E-4
216
288

FIG. 19

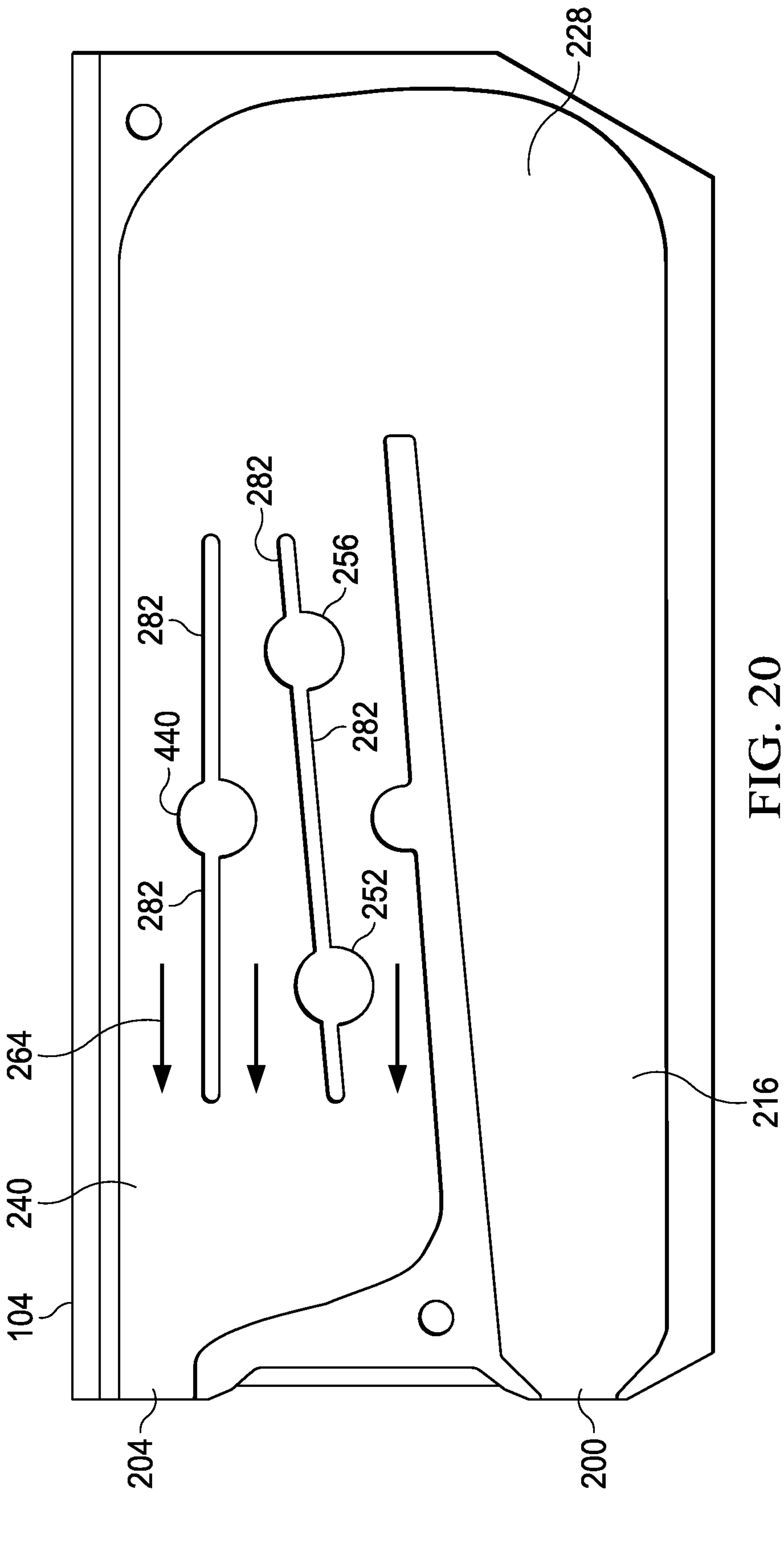

FIG. 20

CLAMSHELL HEAT EXCHANGERS

TECHNICAL FIELD

[0001] This application is directed, in general, to combustion furnaces for HVAC systems, and more specifically, to clamshell heat exchangers.

BACKGROUND

[0002] In gas furnaces used as an aspect of heating ventilating air conditioning (HVAC) systems, a number of heat exchangers are utilized. The heat exchangers may be used in a heating area of the furnace to heat an airstream that passes through the heating area of the furnace. One type of heat exchanger that is used is a "clamshell" heat exchanger. A "clamshell" heat exchanger typically includes two concave halves that are joined either by welding or folding to form a passageway or opening with an inlet and an outlet. To form such a clamshell heat exchanger, individual panel halves, typically formed by stamping mirror images of the combustion chambers into corresponding metal sheets, are coupled together to form the passageway. Clamshell heat exchangers have been used extensively, and yet still, improvements are desired.

[0003] The preceding discussion of the background is intended to facilitate an understanding of the present disclosure only. It should be appreciated that the discussion is not an acknowledgement or admission that any of the material referred to was part of the common general knowledge at the priority date of the application.

SUMMARY

[0004] According to an illustrative embodiment, a clamshell heat exchanger for use in a direct combustion furnace of an HVAC system includes a first clamshell half and a second clamshell half. When the first clamshell half is coupled to the second clamshell half, it forms an assembled clamshell heat exchanger. The clamshell heat exchanger further includes an inlet and an outlet, and a first passageway, which is a combustion passageway, having a first end and a second end. The inlet is proximate the first end. The clamshell heat exchanger also includes a turnaround passageway having a first end and second end, wherein the second end of the first passageway is fluidly coupled to the first end of the turnaround passageway, and includes a second passageway, which is an exhaust passageway, having a first end and a second end, wherein the first end is fluidly coupled to the second end of the turnaround passageway and wherein the outlet is proximate the second end of the second passageway. The first passageway is fluidly coupled to the turnaround passageway and the second passageway is fluidly coupled to the turnaround passageway to form a flow pathway for combustion products. A lateral cross section of the first passageway has more area above a lateral centerline than below the lateral centerline. In one illustrative embodiment, the lateral cross section of the first passageway is shaped like an upside down tear drop or like an airfoil with a leading edge facing upward.

[0005] According to another illustrative embodiment, a clamshell heat exchanger for use in a combustion furnace includes a first clamshell half and a second clamshell half. When coupled, the first clamshell half and the second clamshell half form the clamshell heat exchanger. The clamshell heat exchanger further includes a first passageway coupled to an inlet for receiving combustion products from a burner assembly. The first passageway has a longitudinal length in a first direction and forms a first portion of a flow pathway. The clamshell heat exchanger also includes a turnaround passageway coupled to the first passageway and forming a second portion of a flow pathway that receives fluids going in a first direction and turns the fluids at least 120 degrees. The clamshell heat exchanger further includes a second passageway coupled to the turnround passageway and having a longitudinal length in the first direction and forming a third flow pathway that is opposite in direction to the first flow pathway and that comprises two flow streams. The first passageway has a lateral cross section resembling an airfoil with its leading edge closest to the second passageway.

[0006] According to still another illustrative embodiment, a clamshell heat exchanger for a combustion furnace includes a heat exchanger body formed with an inlet and an outlet; a first passageway, turnaround passageway, and a second passageway formed in the heat exchanger body that together define a flow pathway from the inlet through the first passageway, then the turnaround passageway, then the second passageway, and finally to the outlet. An outer wall portion and an inner wall portion of the first passageway diverge from one another. The first passageway is not symmetric about a lateral centerline. In one embodiment, a lateral cross section of the first passageway is shaped like a teardrop having a widest portion closest to the second passageway. Other embodiments and teachings are disclosed herein.

DESCRIPTION OF THE DRAWINGS

[0007] Illustrative embodiments of the present invention are described in detail below with reference to the attached drawing figures, which are incorporated by reference herein and wherein:

[0008] FIG. **1** is an exploded, schematic, perspective view of a portion of a combustion furnace showing one illustrative deployment of an illustrative embodiment of a clamshell heat exchanger according to the disclosure;

[0009] FIG. **2** is a schematic, elevation view of an illustrative embodiment of a clamshell heat exchanger for use in a combustion furnace;

[0010] FIG. **3**A is a schematic, perspective view of the clamshell heat exchanger of FIG. **2** with a cross section cut made at line **3**A-**3**A;

[0011] FIG. **3**B is a detail of the cross section cut of the first passageway of the clamshell heat exchanger of FIGS. **2** and **3**A;

[0012] FIG. **4** is a schematic, elevation view of an illustrative embodiment of a clamshell heat exchanger for use in a combustion furnace;

[0013] FIG. **5** is a schematic, elevation view of an illustrative embodiment of a clamshell heat exchanger for use in a combustion furnace;

[0014] FIG. **6** is a schematic, cross section of the clamshell heat exchanger of FIG. **5** taken along line **6**-**6**;

[0015] FIG. **7** is a schematic, cross section of the clamshell heat exchanger of FIG. **5** taken along line **7**-**7**;

[0016] FIG. **8** is a schematic, cross section of the clamshell heat exchanger of FIG. **5** taken along line **8**-**8**;

[0017] FIG. **9** is a schematic, cross section of the clamshell heat exchanger of FIG. **5** taken along line **9**-**9**;

[0018] FIG. **10** is a schematic, cross section of the clamshell heat exchanger of FIG. **5** taken along line **10-10**;

[0019] FIG. **11** is a schematic, cross section of the clamshell heat exchanger of FIG. **5** taken along line **11-11**;

[0020] FIG. **12** is a schematic, cross section of the clamshell heat exchanger of FIG. **5** taken along line **12-12**;

[0021] FIG. **13** is a schematic, cross section of the clamshell heat exchanger of FIG. **5** taken along line **13-13**;

[0022] FIG. **14** is a schematic, cross section of the clamshell heat exchanger of FIG. **5** taken along line **14-14**;

[0023] FIG. **15** is a schematic, cross section of the clamshell heat exchanger of FIG. **5** taken along line **15-15**;

[0024] FIG. **16** is a schematic, elevation view of an illustrative embodiment of a clamshell heat exchanger for use in a combustion furnace showing determination of a slope of the first passageway;

[0025] FIG. **17** is a schematic, elevation view of an illustrative embodiment of a clamshell heat exchanger for use in a combustion furnace showing determination of a slope of the second passageway;

[0026] FIG. **18** is a schematic, cross section of an illustrative embodiment of a clamshell heat exchanger for use in a combustion furnace taken along a portion of the first passageway such as at line **3A-3A** of FIG. **2**;

[0027] FIG. **19** is a schematic, cross section of an illustrative embodiment of a clamshell heat exchanger for use in a combustion furnace taken along a portion of the first passageway such as at line **3A-3A** of FIG. **2**; and

[0028] FIG. **20** is a schematic, elevation view of an illustrative embodiment of a clamshell heat exchanger for use in a combustion furnace.

DETAILED DESCRIPTION

[0029] In the following detailed description of the preferred embodiments, reference is made to the accompanying drawings that form a part hereof, and in which is shown, by way of illustration, specific embodiments in which the invention may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the invention, and it is understood that other embodiments may be utilized and that logical structural, mechanical, electrical, and chemical changes may be made without departing from the spirit or scope of the invention. To avoid detail not necessary to enable those skilled in the art to practice the invention, the description may omit certain information known to those skilled in the art. The following detailed description is, therefore, not to be taken in a limiting sense, and the scope of the present invention is defined only by the claims.

[0030] In gas furnaces used as an aspect of heating ventilating air conditioning (HVAC) systems, a number of heat exchangers are utilized, such as a "clamshell" heat exchanger. A "clamshell" heat exchanger typically includes two concave halves that are coupled either by welding or folding to form a passageway or opening with an inlet and an outlet. To form such a clamshell heat exchanger, individual panel halves, typically formed by stamping mirror images of the combustion chambers into corresponding metal sheets, are coupled together to form the passageway. The metal sheet may be made with various materials and thickness. In one illustrative embodiment, the clamshell halves are made from 0.74 mm (29 mil) T1-40 EDDS aluminized steel. In other embodiments, the material may be 0.74 mm (29 mil) T1-25 EDDS aluminized steel or DDS aluminized steel, or 409 stainless steel.

[0031] With these types of furnaces using clamshell exchangers, air passes through the heating zone from a blower or fan and is heated. The furnaces of this type experience high operating temperatures, which can cause failure within the heating chamber. In this context, the illustrative embodiments of the clamshell heat exchangers, systems, and methods herein may lead to a reduction in thermo-mechanical stress of the clamshell heat exchangers while maintaining combustion, heat transfer, and flue and air-side pressure drops as desired. Moreover, the heat exchangers, systems, and methods may provide improved reliability compared to existing systems and, in some embodiments, allow for lower-cost materials to be used.

[0032] One type of furnace that is used in HVAC systems at times is referred to as an "80% gas furnace." Such a furnace may be one in which approximately 80% of the energy put into the furnace is converted into heat for the purposes of heating a targeted space. Such furnaces may have high operating temperatures, e.g., >1000° Fahrenheit. Other furnaces may be used as well that involve higher efficiencies. Two commercial examples are the LENNOX ML 180 furnace and the LENNOX EL296V gas furnace. The illustrative embodiments herein may be well suited for such furnaces. Unless otherwise indicated, as used throughout this document, "or" does not require mutual exclusivity.

[0033] Referring now to the figures and initially to FIG. **1**, an illustrative embodiment of a gas furnace **100**, which is an "80% gas furnace," that includes a plurality of clamshell heat exchangers **104**. Those skilled in the art will understand that the clamshell heat exchangers described herein may be used with many different types and sizes of furnaces. While the term "clamshell" is used herein, it should be understood that the same may be formed as integral piece as well.

[0034] The illustrative gas furnace **100** includes a housing **108** having an opening **112** that in an assembled position is covered by covering **116**. A mounting shelf **120**, which is formed with opening **124**, is positioned within the housing **108** when assembled. A heating zone **128** is formed in a heat exchanger assembly **130**, which includes the plurality of clamshell heat exchangers **104**.

[0035] The clamshell heat exchangers **104** have a configuration to provide a number of potential benefits over previously known clamshell heat exchangers. The plurality of clamshell heat exchangers **104** are coupled to an inlet panel **132**, or vest panel. A plurality of combustion inlets **136** on the inlet panel **132** provide combustion products into inlets of each of the plurality of clamshell heat exchangers **104** and a plurality of combustion outlets **140** on a upper portion of the inlet panel **132** receive the combustion products after they have traveled through the plurality of clamshell heat exchangers **104**. While a specific number of clamshell heat exchangers **104** are shown in the figure, those skilled in the art will understand that other embodiments may include fewer or more of the clamshell heat exchangers **104**. The flow pathway through each clamshell heat exchanger **104** is generally serpentine with a **180** turn as will be described herein. The inlets **136** and outlets **140** may be coplanar on the inlet panel **132**, or vest panel.

[0036] The furnace **100** further includes a burner assembly **144**. The burner assembly **144** may include a thermostatically-controlled solenoid valve **148** or other valve and one more gas inlets (not explicitly shown). Gas orifices (not explicitly shown) are coupled to a manifold **152**. Burners within the burner assembly **144** may correspond in a one-to-one fashion with the plurality of inlets **136** although other illustrative embodiments may have more or fewer burners. When assembled, the burner assembly **144** lines up with the heat exchanger assembly **130** such that burners of the burner assembly **144** align with the plurality of inlets **136** to provide combustion products thereto.

[0037] The illustrative furnace **100** also includes a draft-inducer assembly **160**. The draft-inducer assembly **160** includes a draft-inducing fan **162** fluidly coupled to a manifold **164**, which fluidly couples with the outlets **140** on the inlet panel **132**, and further includes a flue **169**. The flue **169** is coupled to an outlet of the draft-inducing exhaust fan **162**. Burned gases (i.e., products of combustion) may be delivered into flue **169** that vents the gases. In an assembled position, the draft-inducer assembly **160** is positioned relative to the heat exchanger assembly **130** such that manifold **164** at least substantially aligns with the outlets **140** and the flue **169** aligns with an opening in housing **108** to exhaust burned gases.

[0038] To move the air that is to be heated for the controlled space, a blower assembly **168** is suspended from the shelf **120**. The blower assembly **168** includes a blower **172** with the blower outlet **176** that aligns with the opening **124** in the mounting shelf **120**. When assembled and operating, air is pulled into sides of the blower **172** and then forced air exits the blower outlet **176** and goes through the opening **124** in the shelf **120** before going as an airstream over an exterior of the plurality of clamshell heat exchangers **104** before exiting the furnace **100** through a heated-air outlet of the housing **108**.

[0039] A controller **183** is shown associated with the blower **172**. The controller **183** may be operable to turn on the draft-inducing fan **162** to initiate a draft in the heat exchangers **104** in the heating zone **128** and purge potentially harmful unburned gases or gaseous combustion products. The controller **183** activates an igniter to warm up over a set period of time. Then the controller **183** opens the valve **148** to admit gas into the manifold **152** and the one or more gas orifices. The gas exits the orifice(s) and begins to mix with primary air to form a rich gas-air mixture inside the burner(s). Assuming ignition by the igniter (protocols are provided in case that is not the situation), the controller **183** then activates the blower **172**, which forces the airstream upward through the opening **124** and across the heat exchangers **104**. As the airstream passes over the surfaces of the heat exchangers **104**, the air is warmed, whereupon it may be delivered or distributed as needed to provide heating in the space to be conditioned.

[0040] Referring now primarily to FIGS. **2-18**, and initially to FIG. **2**, an illustrative embodiment of a clamshell heat exchanger **104** is presented. The clamshell heat exchanger **104** has a first clamshell half **184** and a second clamshell half **188**. The clamshell halves **184**, **188** may be formed by shaping a sheet metal blank to form the two halves. The halves may be placed with the concave portions facing each other and joined by edge crimping or clamping along a peripheral edge **192** or fastening or welding. This may be done by having a lip portion **194** of one of the clamshell halves, e.g., clamshell half **188**, extend further and be bent and crimped on the other clamshell half **184**.

[0041] The joining of the two clamshell halves **184**, **188** forms a clamshell body **196**. The claimshell body **196** is shown with contour lines **197** for illustration purposes. The clamshell heat exchanger **104** includes an inlet **200** and an outlet **204**. The inlet **200** receives combustion products from a burner assembly, e.g., burner assembly **144** (FIG. **1**). The inlet **200** has an inlet collar **208** that slides through the vest panel, e.g., **132** in FIG. **1**, and is rolled over to form an attachment. Similarly, the outlet **204** is formed with an outlet collar **212** that also slides through the vest panel and is rolled over for attachment.

[0042] The clamshell heat exchanger **104** in the assembled position includes a first passageway **216** having a first end **220** and a second end **224**. The first passageway **216** is a combustion passageway that receives combustion products from the burner assembly as introduced through the inlet **200**. The second end **224** of the first passageway is fluidly coupled with another portion of the clamshell heat exchanger **104**, namely, a turnaround passageway **228**.

[0043] The turnaround passageway **228** has a first end **232** and a second end **236**. The first end **232** is coupled to the second end **224** of the first passageway **216**. The turnaround passageway **228** is configured to change the direction of fluid flow received from the first passageway **216** by at least about 120 degrees and in some embodiments by 150 degrees or 180 degrees as shown. The second end **236** of the turnaround passageway **228** is coupled to a second passageway **240**.

[0044] The second passageway **240** has a first end **244** and a second end **248**. The first end **244** of the second passageway **240** is coupled to the second end **236** of the turnaround passageway **228**. The outlet **204** is coupled to the second passageway **240** proximate the second end **248** of the second passageway **240**. The second passageway **240** may include a first dimple **252** and a second dimple **256** that create a restriction and direct the gas flow around the dimples **252**, **256** to cover a broader area of the second passageway **240**. The second passageway **240** creates a plurality of flow streams, e.g., flow streams **260** and **264** in portions. A half dimple **268** may be formed on an inboard edge **272** of the second passageway **240**. A plurality of veins **282** in the second passageway **240** create a number of flow streams **260**, **264**, e.g., two or three or more. The veins **282** direct flue gas flow to maximize heat transfer and efficiency while minimizing flow restriction (ie pressure drop) through passageway **240**.

[0045] The first passageway **216** is fluidly coupled to the inlet **200** on the first end **220** and to the turnaround passageway **228** at the second end **224**. The first end **244** of the second passageway **240** is fluidly coupled to the second end **236** of the turnaround passageway **228** and to the outlet **204** at the second end **248**. Together, the first passageway **216**, turnaround passageway **228**, and second passageway **240** form a flow pathway for combustion products through the clamshell heat exchanger **104**. The combustion products enter the inlet **200**, travel through the first passageway **216**, turn at the turnaround passageway **228**, go through the second passageway **240**, and exit at the outlet **204** from where the flow may go to a draft inducer. Meanwhile, a blower assembly, e.g., blower assembly **168**, moves an airstream **274** across an exterior of the clamshell heat exchanger **104** to transfer heat thereto. The heated airstream **274** may then be delivered to a space that is to be conditioned or controlled.

[0046] The first passageway **216** has a lateral cross section that has more area above a lateral center line **276**, than below the lateral center line. This is seen clearly in FIGS. **3**A, **3**B, and **18** a cross section of the first passageway **216** has more area in an upper portion than a lower portion. With reference to FIG. **18**, a lateral centerline (horizontal midline) **276** (directions for orientation shown) defines a first area **280** above the lateral centerline **276** and a second area **284** below the lateral centerline **276**. Note also while the first passageway **216** is symmetric about a vertical midline **277**, the first passageway is not symmetric about the lateral centerline **276**. The overall shape of a lateral cross section or combined cross sectional area **288** is that of an upside down tear drop or an airfoil with the leading edge on top **278** for the orientation shown, which is also saying the wider portion is closest to the second passageway **240** as is clear in FIG. **3**A. The shape may help to reduce fatigue stress and increase the life of the heat exchanger. FIG. **19** shows a portion of another embodiment of a clamshell heat exchanger **104** with a cross section of the first passageway **216** that has more cross section area above the lateral centerline **276** than below the lateral centerline **276**.

[0047] The clamshell heat exchanger **104** includes one or more seal portions or flanges **292** with one or more eyelets **296**. The two clamshell halves **184**, **188** are attached to each other to avoid leaks from within the passageways **216**, **228**, **240**.

[0048] In the illustrative embodiment of FIG. **2**, there are only two passes of the heated gases and not three or some other number. The passes are straight.

[0049] Referring now primarily to FIGS. **4-15**, details of one illustrative embodiment are presented. It will be appreciated by one skilled in the art that the dimensions may vary in different applications and with different cabinet sizes. The illustrative dimensions for FIG. **4** are in Table I below.

TABLE I

Numeral	Description or Name	Dimension (inches)
300	Length (Longitudinal)	19.97
304	Length	1.12
308	Length	13.39
312	Length	5.47
316	Length	0.46
320	Length	1.12
324	Length	5.06
328	Length	9.00
332	Length	12.93
336	Length	14.51
340	Length	16.87
344	Length	18.22
348	Length of angled portion	1.42
352	Length of angled portion	3.50
356	Outer Diameter	0.559
360	Outer Diameter	1.10
364	Outer Diameter	1.10
368	Height	8.13
372	Height	3.02
376	Height	4.10
380	Height	3.5
384	Height	3.56
388	Height	4.01
392	Height	3.47
396	Height	3.19
400	Height	2.84
404	Height	4.62
408	Height	1.25
412	Height	2.29

[0050] It will be apparent that the first passageway **216** diverges in the direction of the fluid flow along the flow pathway. For example, at approximately 25% of the distance from just beyond the inlet **200** to the far end of the turnaround passageway **228**, the height **400** is 2.84 inches and at approximately 50% the height **396** is 3.19 inches, which is a 12% greater in height. At approximately the 75% point, the height **384** is 3.56 inches, which is about 25% greater than the height at the 25% point. The first passageway **216** diverges along a majority of the flow pathway from the inlet **200** to the turnaround passageway **228**. In one illustrative embodiment, the first passageway **216** has a first end **220** proximate the inlet **200** and a second end **224** opposite the first end **220**, and the first passageway **216** diverges from proximate the first end **220** to the second end **224** by at least 35%.

[0051] With reference now primarily to FIG. **16**, a slope of the diverging walls in the first passageway **216** may be determined. In this embodiment, with respect to the inner wall **416** (closest to the second passageway **240**) and outer wall **420** (closest to the peripheral edge **192**) of the first passageway **216**, the outer wall **420** is substantially straight in elevation view and the other wall, inner wall **416**, is angled. The inner wall **416** expands with a slope between the outer wall **420** and the inner wall **416** of the first passageway **216** of approximately 0.08 for at least a majority of a longitudinal length of the first passageway **216**. For example, the length between a 25% point and a 50% point of the horizontal (for orientation shown) length of the first passageway **216** is 3.94 inches (see numeral **424**) and the rise is 0.35 inches (see numeral **428**), and accordingly, the slope is 0.35/3.94, which is 0.088. The slope of the first passageway **216** generally will have a range of about 0.07 to 0.09.

[0052] Referring again primarily to FIG. **4**, the second passageway **240** (I don't see **240** shown in FIG. **4**) also diverges in the direction of flow along the flow pathway for most of its longitudinal length. So, with reference from a distance just beyond the outlet **204** to the back of the turnaround passageway **228**, the dimensions are as follows: at approximately the 75% point the height **388** is 4.01; and at approximately the 25% point the height **404** is 4.62. So that is an increase of about 15%; in some embodiments the range is 13% to 18%. In one illustrative embodiment, the second passageway **240** diverges from proximate the first end **244** of the second passageway **240** to the widest portion of the second passageway **240** by at least 14%. A slope for the diverging walls in the second passageway **240** can also be calculated.

[0053] With reference now primarily to FIG. **17**, the horizontal difference between the locations where heights **388** and **404** are taken is 7.87 inches (see numeral **426**) and the difference in the heights are 0.61 inches (see numeral **430**). So, the slope is 0.61/7.87 which is 0.077. In other embodiments, the range may be 0.07 to 0.12.

[0054] The final portion **432** of the second passageway **240** that is about 10% to 18% of the longitudinal length of the second passageway **240** has a steep slope back to the outlet **204**; in some embodiments, the slope is in the range of −1.25 to −2.5, and in the embodiment shown is approximately −2.3. The negative sign is for the orientation shown in FIG. **17** but may be left off in some representations here, but the reader will understand the direction.

[0055] In some embodiments, the first passageway **216** diverges along the flow path only. In others, both the first passageway **216** and the second passageway **240** diverge along a majority of the flow path for each. The first passageway **216** diverges along a majority of the flow pathway from the first end **220** to the second end **224** of the first passageway **216** and the second passageway **240** diverges along a portion of the flow pathway from the first end **244** to the second end **248** of the second passageway **240**. In one embodiment, the two passages **216**, **240** both diverge with a slope of 0.08 (orientation of FIGS. **16** and **17**, respectively) over a majority of their respect longitudinal lengths.

[0056] Referring now primarily to FIGS. **5-15**, an illustrative embodiment of the clamshell heat exchanger **104** is shown with lateral cross sections (FIGS. **6-15**) taken at the various locations shown in FIG. **5** going from the left to the right in that figure. FIG. **6** is near a far end of the turnaround passageway **228**. FIG. **7** is the interface of the first passageway **216**, the second passageway **240** and the turnaround passageway **228**. FIG. **8** shows a portion just to the right of FIG. **7** in FIG. **5** and shows a baffle **436** that creates two channels having two flow streams. The flow steams are accentuated further downstream as shown in FIG. **9** by the dimple **252**. The two flow streams help keep the flue-side pressure losses within a desired range while maintaining heat transfer at a desired level. FIG. **10** is taken at the half dimple **268**. FIG. **11** is at the next dimple **256**. FIGS. **12-15** are at the final downstream portion of the flow pathway.

[0057] Referring now primarily to FIG. **20**, another illustrative embodiment of a clamshell heat exchanger **104** is shown. This embodiment includes three dimples **252**, **256**, and **440** in the second passageway **240** to create additional flow streams **264**. The embodiment shown has three flow streams.

[0058] In some embodiments, the clamshell heat exchangers **104** shown above may include additional features. For example, a folding pattern of the lip **194** over the other clamshell half may be used. "W" shaped stamping may be the pattern between the first passageway and the second passageway to prevent short circuiting of the combustion gases and resultant loss in efficiency. Of course, perimeter profiles of the heat exchanger may be modified to fit into particular furnace applications.

[0059] Although the present invention and its advantages have been disclosed in the context of certain illustrative, non-limiting embodiments, it should be understood that various changes, substitutions, permutations, and alterations can be made without departing from the scope of the invention as defined by the claims. It will be appreciated that any feature that is described in a connection to any one embodiment may also be applicable to any other embodiment.

What is claimed:

1. A clamshell heat exchanger for use in a direct combustion furnace of an HVAC system, the clamshell heat exchanger comprising:

a first clamshell half;

a second clamshell half;

wherein coupling the first clamshell half to the second clamshell half forms an assembled clamshell heat exchanger comprising:

an inlet and an outlet,

a first passageway, which is a combustion passageway, having a first end and a second end, wherein the inlet is proximate the first end,

a turnaround passageway having a first end and second end, wherein the second end of the first passageway is fluidly coupled to the first end of the turnaround passageway,

a second passageway, which is an exhaust passageway, having a first end and a second end, wherein the first end is fluidly coupled to the second end of the turnaround passageway and wherein the outlet is proximate the second end of the second passageway,

wherein the first passageway is fluidly coupled to the turnaround passageway and the second passageway is fluidly coupled to the turnaround passageway to form a flow pathway for combustion products, and

wherein a lateral cross section of the first passageway has more area above a lateral centerline than below the lateral centerline.

2. The clamshell heat exchanger of claim **1**, wherein the lateral cross section of the first passageway is shaped like an upside down tear drop.

3. The clamshell heat exchanger of claim **1**, wherein the lateral cross section of the first passageway is shaped like an airfoil with a leading edge facing upward.

4. The clamshell heat exchanger of claim **1**, wherein the first passageway diverges along a majority of the flow pathway from the inlet to the turnaround passageway.

5. The clamshell heat exchanger of claim **1**, wherein the first passageway diverges along a majority of the flow pathway from the first end to the second end of the first passageway and wherein the second passageway diverges along a portion of the flow pathway from the first end to the second end of the second passageway.

6. The clamshell heat exchanger of claim **1**,

wherein the first passageway diverges along a majority of a flow pathway from the first end to the second end with a slope of at least 0.08; and

wherein the second passageway diverges along a majority of a flow pathway from the first end to the second end with a slope of at least 0.08.

7. The clamshell heat exchanger of claim **1**, further comprising a baffle formed on an inboard portion of the second passageway forming two flow streams.

8. The clamshell heat exchanger of claim **1**, further comprising a first dimple and a second dimple on an inboard portion of the second passageway.

9. The clamshell heat exchanger of claim **1**, wherein the flow pathway increases in height along a majority of a length of the flow pathway.

10. The clamshell heat exchanger of claim **1**, wherein the second passageway has a outer wall and an inner wall that converge at least within a final ten percent of the flow pathway proximate the outlet with a slope of at least 1.25 towards the outlet.

11. The clamshell heat exchanger of claim **1**,

wherein the lateral cross section of the first passageway is shaped like an upside down teardrop;

wherein the first passageway diverges along a flow pathway from the first end to the second end with a slope of at least 0.08 for a majority of the flow pathway in the first passageway;

wherein the second passageway diverges along the flow pathway from the first end to the second end with a slope of at least 0.08 for a majority of the flow pathway in the second passageway;

further comprising a baffle formed on an inboard portion of the second passageway forming two flow streams; and

wherein the second passageway has a top wall and a bottom wall that converge within a final ten percent of the flow pathway proximate the outlet with a slope of at least 1.25.

12. A clamshell heat exchanger for use in a combustion furnace, the clamshell heat exchanger comprising:

a first clamshell half;

a second clamshell half;

wherein, when coupled, the first clamshell half and the second clamshell half form the clamshell heat exchanger;

a first passageway coupled to an inlet for receiving combustion products from a burner assembly, the first passageway having a longitudinal length in a first direction and comprising a first portion of a flow pathway;

a turnaround passageway coupled to the first passageway and comprising a second portion of a flow pathway that receives fluids going in a first direction and turns the fluids at least 120 degrees;

a second passageway coupled to the turnround passageway and having a longitudinal length in the first direction and comprising a third flow pathway that is opposite in direction to the first flow pathway and that comprises two flow streams; and

wherein the first passageway has a lateral cross section resembling an airfoil with its leading edge closest to the second passageway.

13. The clamshell heat exchanger of claim **12**, wherein the lateral cross section of the first passageway has a first area to one side of a lateral centerline, wherein the first area is closest to the second passageway with respect to the lateral centerline, and wherein the first area is greater than a second area that is on an opposite side of the lateral centerline.

14. The clamshell heat exchanger of claim **12**, further comprising a baffle formed on an inboard portion of the second passageway forming two flow streams.

15. A clamshell heat exchanger for a combustion furnace, the clamshell heat exchanger comprising:

a heat exchanger body formed with an inlet and an outlet;

a first passageway, turnaround passageway, and a second passageway formed in the heat exchanger body that together define a flow pathway from the inlet through the first passageway, then the turnaround passageway, then the second passageway, and finally to the outlet;

wherein an outer wall portion and an inner wall portion of the first passageway diverge from one another; and

wherein the first passageway is not symmetric about a lateral centerline.

16. The clamshell heat exchanger of claim **15**, wherein a lateral cross section of the first passageway is shaped like a teardrop having a widest portion closest to the second passageway.

17. The clamshell heat exchanger of claim **15**, with respect to the inner and outer wall of the first passageway, one wall is substantially straight in elevation view and the other is angled, and wherein a slope between the outer wall and the inner wall of the first passageway is greater than or equal to 0.08 for at least a majority of a longitudinal length of the first passageway.

18. The clamshell heat exchanger of claim **15**, wherein for at least a majority of a longitudinal length of the second passageway, an outer wall and an inner wall of the second passageway diverge from one another.

19. The clamshell heat exchanger of claim **15**, wherein the clamshell body comprises a first clamshell half and a second clamshell half coupled at least along a peripheral edge.

20. The clamshell heat exchanger of claim **15**, further comprising a baffle formed on the clamshell body in the second passageway to form two flow streams.

21. The clamshell heat exchanger of claim **15**, wherein the first passageway has a first end proximate the inlet and a second end opposite the first end, and the first passageway diverges from proximate the first end to the second end by at least 35%.

22. The clamshell heat exchanger of claim **15**, wherein the second passageway has a first end proximate the turnaround passageway and a second end proximate the outlet, and the second passageway diverges from proximate the first end of the second passageway to a widest portion of the second passageway by at least 14%.

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