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(54) **Reflare tool and process**

(57) A flaring body (220) has first (235) and second (240) opposing ends. A perimeter surface (242) intersects the first end, and a flaring surface (245) is located between the perimeter surface and the second end. The perimeter surface has a first cross-sectional profile (250) with a first area, and the flaring surface having a second cross-sectional profile (255) with a second area less than the first area. The perimeter surface and the flaring surface are joined by an inside, rounded corner (246). A crimping body (230) has a top surface (232) and an opposing bottom surface (285), and an interior surface (260) that defines a passageway (270) that connects said top and bottom surfaces (232,285). The interior surface has a third cross-sectional profile with a third area larger than the first area. The flaring body (220) is slidably captureable in the passageway (270). The interior surface further has a crimping channel (280) that extends along at least a portion thereof and terminates at the bottom surface (285).

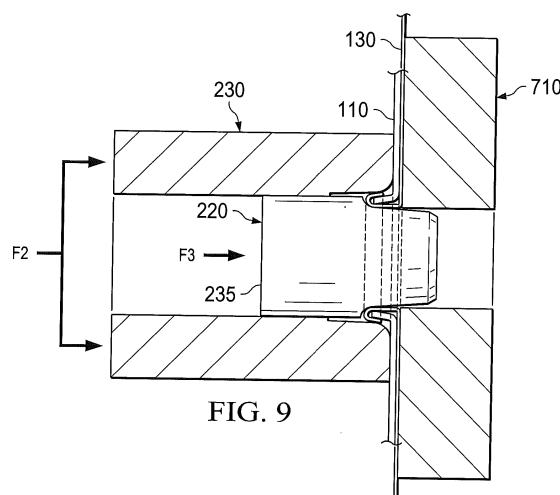


FIG. 9

Description

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Application Serial No. 61/295,501, filed by Shailesh S. Manohar, et al., on January 15, 2010, entitled "An Improved Heating Furnace for a HVAC System", and incorporated herein by reference in its entirety. This application is related to U.S. Application Serial No. 12/834,547 (attorney docket number P070075), filed by Donald N. Zimmer, et al. on July 12, 2010, entitled "Heat Exchanger Expanded Overlap Joint", commonly assigned with this application and incorporated herein by reference.

TECHNICAL FIELD

[0002] The present disclosure is directed in general to metal working, and more specifically, to metal joining.

BACKGROUND

[0003] In some metal joining applications, a sheet metal flange is fastened to a port located in a panel or bulkhead. In some of these applications, the flange is formed of two halves, e.g. a clamshell, that have been formed separately and then joined. One flange half is typically abutted against the other flange half. If the flange is fastened to the port by flaring the flange, a gap typically forms between the flange halves. In some applications the resulting gap must be sealed to prevent leakage at the joint. The sealed gap may fail to prevent leakage when a sealant ages.

SUMMARY

[0004] In one aspect, the disclosure provides a reflare tool that includes a flaring body and a crimping body. The flaring body has a first end and a second opposing end. A perimeter surface intersects the first end, and a flaring surface is located between the perimeter surface and the second end. The perimeter surface has a first cross-sectional profile with a first area. The flaring surface has a second cross-sectional profile with a second area less than the first area. The perimeter surface and the flaring surface are joined by an inside, rounded corner. The crimping body has a top surface and an opposing bottom surface. An interior surface defines a passageway that connects the top and bottom surfaces, and has a third cross-sectional profile with a third area larger than the first area such that the flaring body is slidably captureable in the passageway. The interior surface further has a crimping channel extending along at least a portion thereof and terminating at the bottom surface.

[0005] In another aspect, a method is provided for forming a reflare tool. A flaring body is formed that has a first end and a second opposing end. A perimeter sur-

face intersects the first end, and a flaring surface is located between the perimeter surface and the second end. The perimeter surface has a first cross-sectional profile with a first area. The flaring surface has a second cross-sectional profile with a second area less than the first area. An inside, rounded corner is formed between the perimeter surface and the flaring surface. A crimping body is formed that has a top surface and an opposing bottom surface. The crimping body includes an interior surface that defines a passageway that connects the top and bottom surfaces. The passageway has a third cross-sectional profile with a third area larger than the first area such that the flaring body is slidably captureable in the passageway. A crimping channel is formed that extends along at least a portion of the interior surface of the crimping body. The crimping channel terminates at the bottom surface of the crimping body.

[0006] In yet another aspect, a method of operating a reflare tool is provided. The method includes providing a port ring and a joint flange located within the port ring. The joint flange is flared by applying a first force to a first end of a flaring body having a second end opposing the first end. The flaring body includes a perimeter surface that intersects the first end, and a flaring surface located between the perimeter surface and the second end. The perimeter surface has a first cross-sectional profile with a first area. The flaring surface has a second cross-sectional profile with a second area less than the first area. The perimeter surface and the flaring surface are joined by an inside, rounded corner. The joint flange is crimped to the port ring by applying a second force to a top surface of a crimping body that has an opposing bottom surface. An interior surface defines a passageway connecting the top surface to the bottom surface. The interior surface has a third cross-sectional profile with a third area larger than the first area such that the flaring body is slidably captureable in the passageway. The interior surface also has a crimping channel extending along at least a portion thereof and terminating at the bottom surface.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Reference is now made to the following descriptions taken in conjunction with the accompanying drawings, in which:

FIGs. 1A-1D illustrates a panel port, a flange and a flare-crimp seal of the disclosure;

FIGs. 2A and 2B illustrate various aspects of a reflare tool of the disclosure, where FIG. 2A illustrates a flaring body and FIG. 2B illustrates a crimping body; FIGs 2C, 2D-1, 2D-2, 2E-1 and 2E-2 illustrate various alternate embodiments of the reflare tool of FIGs. 2A and 2B;

FIG. 3 presents a detail view of an inside rounded corner of the flaring body of FIG. 2A;

FIG. 4 illustrates a detail view of a crimping channel of the crimping body of FIG. 2B;

FIGs. 5 and 6 respectively present a method of forming and using a reflare tool, such as the reflare tool of FIGs. 2A and 2B;

FIGs. 7-9 illustrate operation of the flaring body and the crimping body of FIGs. 2A and 2B;

FIG. 10 illustrates a detail view of a flare-crimp joint during formation thereof; and

FIGs. 11-16 illustrate various aspects of an illustrative an embodiment in which a flare-crimp joint attaches a heat exchanger to a furnace vest panel according to various aspects of the disclosure.

DETAILED DESCRIPTION

[0008] Conventional fastening of crimped flange joints suffers from several significant deficiencies. Conventional crimping processes typically use several moving parts, adding complexity to the tooling and cost to the joining operation, and increasing the possibility of future failure of the joint. In some cases, such as when the crimped flange is a portion of a heat exchanger for a furnace or similar applications, exhaust gases produced by combustion of heating fuel may leak from a compromised conventional joint, creating a health or other risk to occupants of a heated building, e.g. For at least these reasons, a joint and joint crimping process is needed that reduces cost and increases reliability of the joint.

[0009] To address such deficiencies of conventional practice, the present disclosure describes novel and innovative embodiments of a flare-crimp joint between a flange and a panel port, a re-flare tool to form the flare-crimp joint, and a method of forming the flare-crimp joint. Embodiments of the disclosure overcome the deficiencies of conventional practice in part by flaring and crimping the flange in a two-step operation that provides a metal-on-metal seal that remains leak-free. In some embodiments the seal flange includes overlapping flange halves that form a seam when flared and crimped by the disclosed flare and crimp tool. Such embodiments result in lower cost, greater manufacturing efficiency, and increased reliability and safety of flange seals.

[0010] Referring initially to FIGs. 1A-1D, illustrated is a panel 110 (FIG. 1A) having a port 120, and a conduit 130 (FIG. 1B) having a port flange 140. The conduit 130 may channel, e.g., a gas or a liquid to or from the port 120. In one embodiment the conduit is a furnace heat exchanger, as briefly described below and described in greater detail in co-pending U.S. Patent Application No. 12/834,547 (attorney docket P070075) (the '547 application).

[0011] FIG. 1A presents a sectional and a plan view of the panel 110. The port 120 includes a port ring 150 having a height H_R . FIG. 1B presents a sectional and a plan view of the conduit 130. The port flange 140 has a height H_F greater than H_R . The port 120 has an inside diameter larger than an outside diameter of the port flange 140 so that the port flange 140 is receivable within the port 120. FIG. 1C illustrates the port flange 140 located within the

port 120. An extending portion 160 of the port flange 140, having a height $H_F - H_R$, extends beyond the port 120. The extending portion 160 is formed into a flare-crimp seal 170 (FIG. 1D) with the port ring 150 according to embodiments described below.

[0012] Turning to FIGs. 2A and 2B, illustrated is a reflare tool 210 of the disclosure that may be used to form the flare-crimp seal 170. The reflare tool 210 includes a flaring body 220 (FIG. 2A) and a crimping body 230 (FIG. 2B). The flaring body 220 and the crimping body 230 may each be formed of any material having sufficient mechanical strength to perform flare and crimp operations described below. In a non-limiting example, the flaring body 220 and the crimping body 230 are formed of tool steel.

[0013] Referring to FIG. 2A, an axis 225 defines an axis of travel during operation of the flaring body 220 relative to the crimping body 230. The flaring body 220 has a first end 235, a second opposing end 240, and a perimeter surface 242 therebetween that intersects the first end 235. By "intersects", it is meant that the first end 235 and the perimeter surface 242 meet via a corner that may be sharp, rounded or chamfered, or the equivalent of such a corner. A flaring surface 245 is located between and joins the perimeter surface 242 to the second end 240. The perimeter surface has a first cross-sectional profile 250 that has a first area. The second end 240 has a second cross-sectional profile 255 that is about circular and has a second area less than the first area. The profile 255 may include on or more notches, as described below, and still be regarded as about circular. An inside, rounded corner 246 joins the flaring surface 245 to the perimeter surface 242. Optionally, the corner formed by the second end 240 and the flaring surface 245 may be broken by a chamfer 247.

[0014] The crimping body 230 (FIG. 2B) has a top surface 232, an opposing bottom surface 285 and an interior surface 260 that defines a passageway 270 that connects the top and bottom surfaces 232, 285. The passageway 270 has an axis 275 parallel to the direction of travel of the flaring body 220 therein, and a cross-sectional profile 277 that is the same shape as the first cross-sectional profile 250, but larger by a clearance for the flaring body 220, e.g. about 50-100 μm . The flaring body 220 is thereby slidably captureable in the passageway 270. The interior surface 260 has a crimping channel 280 with a channel sidewall 282 extending along at least a portion thereof that terminates at the bottom surface 285 of the crimping body 230. The crimping channel 280 typically has a cross-sectional profile with the same shape as the profile 255. However, the crimping channel 280 profile is larger than the profile 255 to create a space between the flaring surface 245 and the channel sidewall 282 when these surfaces are brought adjacent to each other. Thus, in the illustrated embodiment the cross-sectional profile of the passageway 270 at the crimping channel 280 is also about round. Optionally, the crimping channel 280 widens into an outside rounded corner 290 at the bottom surface 285.

[0015] It is noted that while the profiles 250, 277 are circular in the illustrated embodiment, these profiles may in general be arbitrary as long as the flaring body 220 is slidably captureable within the passageway 270. For example, the passageway 270 may include a keyed portion, or the profiles 255, 277 may be elliptical. FIG. 2C illustrates an example of a cross-section of the crimping body 230 with the passageway 270 having a keyed profile 292. The profile 292 is but one of many shapes that may be used in a keyed portion. When the passageway 270 includes a keyed portion, the flaring body 220 will typically have a complementary profile to the keyed portion.

[0016] While the port 120 and the port flange 140 are illustrated as being about circular, other shapes are within the scope of the disclosure, including oval, elliptical, square, triangular, etc. In some cases, it may be desirable to form the flare-crimp seal 170 without any gaps or breaks in the seal to ensure no leakage to or from the conduit 130. Such a seal is described in the 'XXX application (docket number P070075). In such cases, it is expected that a round or elliptical port 120 and port flange 140 will be more able than an opening with sharp corners to accommodate the stresses produced by the flare-crimp operation without compromising the seal formed by the port flange 140.

[0017] The cross-sectional profile of the flaring body 220 taken at the flaring surface 245 will typically be the same shape as the port 120 and the port flange 140. For example, FIG. 2D-1 illustrates an elliptical profile 294 of the flaring body 220 at the flaring surface 245, which would be advantageous when the port 120 and the port flange 140 are elliptical. Similarly, FIG. 2D-2 illustrates a profile 295 of the passageway 270 taken through the channel sidewall 282 may be elliptical when the port 120 and the port flange 140 are elliptical. Of course, other shapes may be used for the port 120 and the port flange 140, with the flaring body 220 and the passageway 270 being configured accordingly at the crimping channel 280.

[0018] FIG. 3 illustrates aspects of the flaring body 220. In the illustrated embodiment, the curvature of the inside rounded corner 246 is approximated by a circle with radius 310. As described further below, the radius 310 is selected to smoothly deform the extending portion 160 away from the port 120 during a flare-crimp operation. In general, the radius 310 may be selected taking into account mechanical and material factors related to the port flange 140, such as stiffness and malleability. In a non-limiting embodiment, a radius of about 3.2 mm ($\approx 0.125"$) may be used when the flange is formed of aluminized type 1 steel sheet with a thickness in a range of about 0.6 mm to about 0.8 mm (≈ 20 -22 ga or ≈ 0.024 -0.032"). Also illustrated in FIG. 3 is an angle θ_1 between the axis 225 and the flaring surface 245. The flaring surface 245 optionally may be sloped ($\theta_1 > 0$) to provide some flaring of the extending portion 160 as the flaring body 220 enters the port flange 140, as described further below. In a nonlimiting embodiment, θ_1 ranges from about 0° to

about 5°, with about 2.5° being preferred.

[0019] FIG. 4 illustrates aspects of the crimping channel 280. The channel sidewall 282 is characterized by an angle θ_2 relative to the axis 275. Optionally θ_2 may have a value greater than zero. For example, the θ_2 may be selected to reduce binding between the channel sidewall 282 and the flange 140, and/or to produce a desired pressure on the flare-crimp seal 170 during the flare-crimp operation, as described further below. In a nonlimiting embodiment, θ_2 ranges a value in a range from about 1° to about 10°. In some cases, a value in a range from about 5° to about 8° is preferred, and a value of about 7.5° is more preferred.

[0020] FIG. 5 presents a method generally designated 500 of forming a reflare tool. The method 500 is described with reference to the reflare tool 210, without limitation to the illustrated embodiment thereof. The method 500 begins in a step 510, in which the flaring body 220 is formed. The flaring body 220 may be formed using conventional tool-forming techniques, including, e.g., lathing, milling, heating and quenching. The flaring body 220 may be formed, e.g., from a conventional material such as W-1 tool steel. The previously described features of the flaring body 230 are formed, including the first end 235, the second opposing end 240, and the perimeter surface 242 located therebetween. In a step 520, the inside, rounded corner 246 is formed between the perimeter surface 242 and the second opposing end 240.

[0021] In a step 530, the crimping body 230 is formed. Again, the crimping body 230 may be formed using conventional tool materials and methods. The previously described features of the crimping body 230 are formed, including the passageway 270 in which the flaring body 220 is slideably capturable. In a step 540, the crimping channel 280 is formed. Optionally, the outside rounded corner 290 is formed.

[0022] FIG. 6 presents a method generally designated 600 of operating a reflare tool, such as the reflare tool 210 including the flaring body 220 and the crimping body 230. The method 600 is described with concurrent reference to FIGs. 7-10, which illustrate operation of the reflare tool 210 in one nonlimiting embodiment of the disclosure. The method 600 is described with reference to elements of FIGs. 1A-1D, 2A-2B, 3 and 4 without limitation to the embodiments illustrated therein. Those of ordinary skill in the pertinent art will recognize that the reflare tool 210 may be operated to join any parts that include features functionally similar to the port ring 150 and the port flange 140.

[0023] Referring to FIG. 6 initially, in a first step 610 the port ring 150 is provided with the port flange 140 located therein. As used herein and in the claims, "provided" means that an item being provided may be manufactured by the individual or business entity performing the disclosed methods, or obtained thereby from a source other than the individual or entity, including another individual or business entity.

[0024] In a step 620, the flaring body 220 flares the

port flange 140. FIG. 7 illustrates an initial configuration of the flaring body 220, the crimping body 230, the port flange 140 and the port ring 150. The flaring body 220 may be initially located as illustrated such that the port flange 140 contacts the inside rounded corner 246. A backing plate 710 may provide support to the panel 110 and the conduit 130 during crimping and flaring. The crimping body 230 may be located such that the bottom surface 285 does not obstruct the port flange 140 as the port flange 140 is flared. (See FIG. 8, e.g.) To ensure no obstruction occurs, in the illustrated embodiment the bottom surface 285 is placed at a distance D from the port flange 140 that may be, e.g., a few millimeters. In FIG. 8, a force F_1 from a force-producing source (e.g., a hydraulic piston) is applied to the flaring body 220, causing the port inside rounded corner 246 to deform the flange 140 away from the flaring body 220. The inside rounded corner 246 eases the deformation of the port flange 140 by, e.g., distributing the deformation forces over a greater time and distance.

[0025] In a step 630, the crimping body 230 crimps the port flange 140 to the port ring 150. Referring to FIG. 9, a force F_2 is applied to the crimping body 230. The crimping body 230 moves in response to the force F_2 to capture the flared portion of the port flange 140 in the crimping channel 280. The force F_2 may be applied independently of the force F_1 .

[0026] Referring to FIG. 10, the channel sidewall 282, the flaring surface 245 and the inside rounded corner 246 cooperate to constrain the volume of the port ring 150 and the port flange 140 in a high-pressure zone 1010. In the zone 1010, a distance W between the channel sidewall 282 and the flaring surface 245 is less than the sum of the original thicknesses of the metal layers therein. Thus, when the crimping body 230 is forced over the port ring 150, the resulting pressure on the port flange 140 and the port ring 150 may cause a metallurgical bond to form therebetween. The metallurgical bond is expected to provide a robust seal to prevent leakage into or out of the conduit 130 at the location of the flare-crimp seal 170.

[0027] Referring back to FIGs. 6 and 9, in an optional step 640 a third force F_3 that may be different from F_2 is maintained on the flaring body 220 while the force F_2 is applied to the crimping body 230. In this manner, the pressure within the zone 1010 may be controlled to a greater extent than would otherwise be the case, providing an additional means to determine the characteristics of the flare-crimp seal 170.

[0028] Turning now to FIGs. 11-16, illustrated are aspects of an example embodiment of forming a flare-crimp seal using a reflare tool of the disclosure, such as the reflare tool 210. Those of ordinary skill in the pertinent art will recognize that the demonstrated principles may be applied to other embodiments within the scope of the disclosure.

[0029] Referring initially to FIG. 11, in the illustrated embodiment a furnace heat exchanger 1110 includes flanges 1120 at ends of a serpentine conduit 1130 that

carries hot gases produced by combustion of a heating fuel. In other embodiments the heat exchanger 1110 may not be serpentine, such as a "U" shaped heat exchanger. The heat exchanger 1110 may be formed, e.g., by joining two halves of a stamped-metal clamshell assembly by a crimping process that forms crimp seals 1140. A crimp-flare seal may be formed to join the heat exchanger 1110 to a furnace vest panel or a collector box panel, e.g.

[0030] FIG. 12 illustrates a sectional view of a first heat exchanger half 1210 (FIG. 12A) and a second heat exchanger half 1220 (FIG. 12B) taken through respective flange halves 1230, 1240. The two halves 1210, 1220 are joined to form the heat exchanger 1110 and the flange 1120. FIG. 12C illustrates a section taken through the flange 1120, illustrating overlap of the flange half 1230 by the flange half 1240.

[0031] FIG. 13 illustrates aspects of the flange 1120 in greater detail. The flange 1120 includes overlap regions 1310 in which capturing tabs 1320 overlap terminating portions 1330. FIG. 14 shows a panel port 1410 in a panel 1420 configured to receive the flange 1120. The port 1410 includes a port ring 1430, and notches 1440 configured to receive the overlap regions 1310.

[0032] Conventionally, a joint formed between a furnace heat exchanger and a panel port may present a risk of leakage of exhaust gases from the joint. Typically, two heat exchanger halves are joined such that two flange halves form butt joints where they meet. When the assembled flange is fastened to the panel port, the butt joints typically spread to form a gap. To ensure that exhaust does not leak from the joint, a sealant is typically used, adding to assembly cost and reducing reliability of the joint.

[0033] In embodiments represented by the flange 1120 and the port 1410, the overlap region 1310 forms a robust seal when the flange 1120 is joined to the port ring 1430 using a reflare tool of the disclosure, e.g. the reflare tool 210. Using an assembly method of the disclosure, e.g. the method 600, the flange 1120 is first flared by the flaring body 220, and then crimped to the port ring 1430 by the crimping body 230. The length of the overlap region 1310 may be determined to provide sufficient overlap between the flange halves 1230, 1240 in the overlap region such that no gap forms therebetween when the flange 1120 is flared and crimped. Pressure in the zone 1010 produced by the force F_1 acting on the flaring surface 245 (FIG. 2A) and the channel sidewall 282 (FIG. 2B) is thought to increase friction between the flange halves 1230, 1240, further reducing relative movement of the capturing tabs 1320 and the terminating portions 1330 that might otherwise cause a gap to form. The pressure is further thought to form a metallurgical bond between the flange halves 1230, 1240 that ensures no leakage to or from the conduit 1130. Additional details are described in the 'XXX application (docket number P070075).

[0034] In some cases, it may be advantageous to limit the pressure formed at the overlap regions 1310 during

the flaring and crimping operations. In such cases the flaring body 220 and the crimping body 230 may include notches at positions corresponding to the location of the overlap regions 1310. Referring to FIG. 2E-1, a cross-sectional profile 296 of the flaring body 220 taken through the flaring surface 245 (FIG. 2A) may include one or more notches 297 corresponding to each overlap region 1310. Similarly, FIG. 2E-2 illustrates a cross-sectional profile 298 of the crimping body 230 taken through the channel sidewall 282 (FIG. 2B) may include one or more notches 299 to accommodate the overlap regions 1310.

[0035] FIGs. 15A and 15B illustrate two sections as indicated in FIG. 14 through a flare-crimp joint 1510 formed from the flange 1120. In FIG. 15A, the joint 1510 includes, in addition to the port ring 1430, the capturing tabs 1320 of the outer flange half 1240 and the terminating portions 1330 of the inner flange half 1230. Thus, the joint 1510 includes two metal layers over the port ring 1430 in this sectional view. In FIG. 15B, the flare-crimp joint 1510 includes, in addition to the port ring 1430, only the inner flange half 1230 and the outer flange half 1240. To accommodate the extra thickness of the metal layers in the view of FIG. 15A, the flaring body 220 and/or the crimping body 230 respectively include the notches 297, 299 as previously described. The flare-crimp joint 1510 may be sealant-free, meaning that no sealant is needed to prevent leakage of gases to or from the conduit 1130.

[0036] FIG. 16 illustrates a photograph of a nonlimiting embodiment of a vest panel 1605 to which a heat exchanger is joined by a flare-crimp joint 1610 as formed using a method within the scope of the disclosure. The port flange 1120 has an outside diameter of about 2.5 cm (~1"), and a height H_F of about 10 mm (~0.4"). The port ring 1430 has a height H_R of about 5 mm (~0.2") and a thickness of about 0.75 mm (~0.029"). Under the conditions of this example, the flare-crimp joint 1610 may be formed using the reflare tool 210, wherein the force F_1 is about 1.56E4 N (about 3500 lbs), and the force F_2 is about 7.56E3 N (about 1700 lbs).

[0037] Notably, the flare-crimp joint 1610 smoothly transitions from single-layer portions 1620, 1630 to double-layer portions (seams) 1640, 1650 that include two metal layers, e.g., the capturing tab 1320 and the terminating portion 1330. Advantageously, and in contrast to conventional practice, the flare-crimp joint 1610 does not include any sealant, and none is necessary. The flare-crimp joint 1610 forms a tight seal with the vest panel 1605, preventing leakage of exhaust gases, and obviating the need for any sealant.

[0038] Those skilled in the art to which this application relates will appreciate that other and further additions, deletions, substitutions and modifications may be made to the described embodiments.

Claims

1. A reflare tool comprising:

a flaring body having a first end, a second opposing end, a perimeter surface that intersects said first end, and a flaring surface located between said perimeter surface and said second end, said perimeter surface having a first cross-sectional profile with a first area, and said flaring surface having a second cross-sectional profile with a second area less than said first area, said perimeter surface and said flaring surface being joined by an inside, rounded corner; and a crimping body having a top surface, an opposing bottom surface, and an interior surface that defines a passageway that connects said top and bottom surfaces and has a third cross-sectional profile with a third area larger than said first area such that said flaring body is slidably captureable in said passageway, said interior surface further having a crimping channel extending along at least a portion thereof and terminating at said bottom surface.

2. The reflare tool as recited in Claim 1, wherein said second cross-sectional profile includes one or more notches.

3. The reflare tool as recited in Claim 1, wherein said crimping channel includes a sloped channel sidewall.

4. A method of forming a reflare tool, comprising:

forming a flaring body having a first end, a second opposing end, a perimeter surface that intersects said first end, and a flaring surface located between said perimeter surface and said second end, said perimeter surface having a first cross-sectional profile with a first area, and said flaring surface having a second cross-sectional profile with a second area less than said first area;

forming an inside, rounded corner between said perimeter surface and said flaring surface;

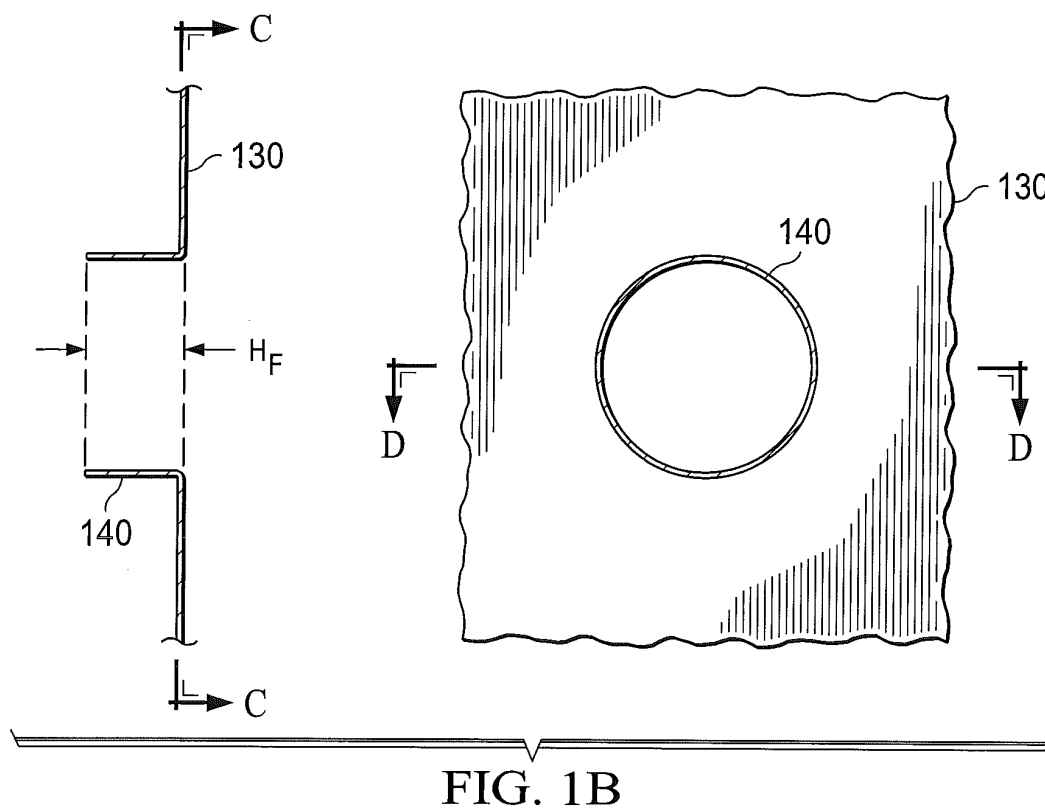
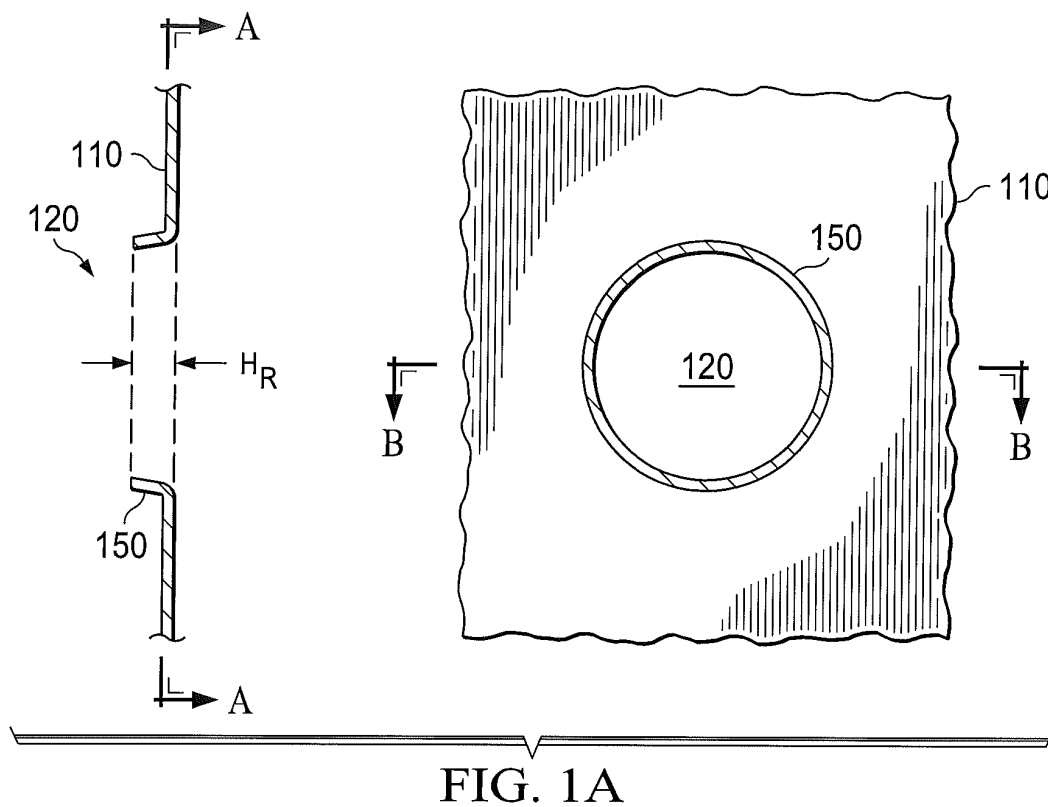
forming a crimping body having a top surface, an opposing bottom surface, and an interior surface that defines a passageway that connects said top and bottom surfaces and has a third cross-sectional profile with a third area larger than said first area such that said flaring body is slidably captureable in said passageway; and forming a crimping channel extending along at least a portion of said interior surface of said crimping body, and terminating at said bottom surface of said crimping body.

5. The method as recited in Claim 4, wherein said crimping channel has a cross-sectional profile that is about circular.

6. The method as recited in Claim 4, further comprising forming said crimping channel with a sloped sidewall.
7. A method of operating a reflare tool, comprising:
- 5 providing a port ring and a joint flange located within said port ring;
 - flaring said joint flange by applying a first force to a first end of a flaring body having a second end opposing said first end, a perimeter surface that intersects said first end, and a flaring surface located between said perimeter surface and said second end, said perimeter surface having a first cross-sectional profile with a first area, and said flaring surface having a second cross-sectional profile with a second area less than said first area, said perimeter surface and said flaring surface being joined by an inside, rounded corner; and
 - 10 crimping said joint flange to said port ring by applying a second force to a top surface of a crimping body having an interior surface that defines a passageway connecting said top surface to an opposing bottom surface, said interior surface having a third cross-sectional profile with a third area larger than said first area such that said flaring body is slidably captureable in said passageway, said interior surface further having a crimping channel extending along at least a portion thereof and terminating at said bottom surface.
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 - 20
 - 25
 - 30
8. The method as recited in Claim 7, further comprising compressing said joint flange and said port ring between said flaring surface and a channel sidewall of said crimping channel.
- 35
9. The method as recited in Claim 7, further comprising applying a first value of said first force to said flaring body during said flaring and a different second value of said first force to said flaring body during said crimping.
- 40
10. The method as recited in Claim 7, wherein said joint flange is a portion of a furnace heat exchanger.
- 45

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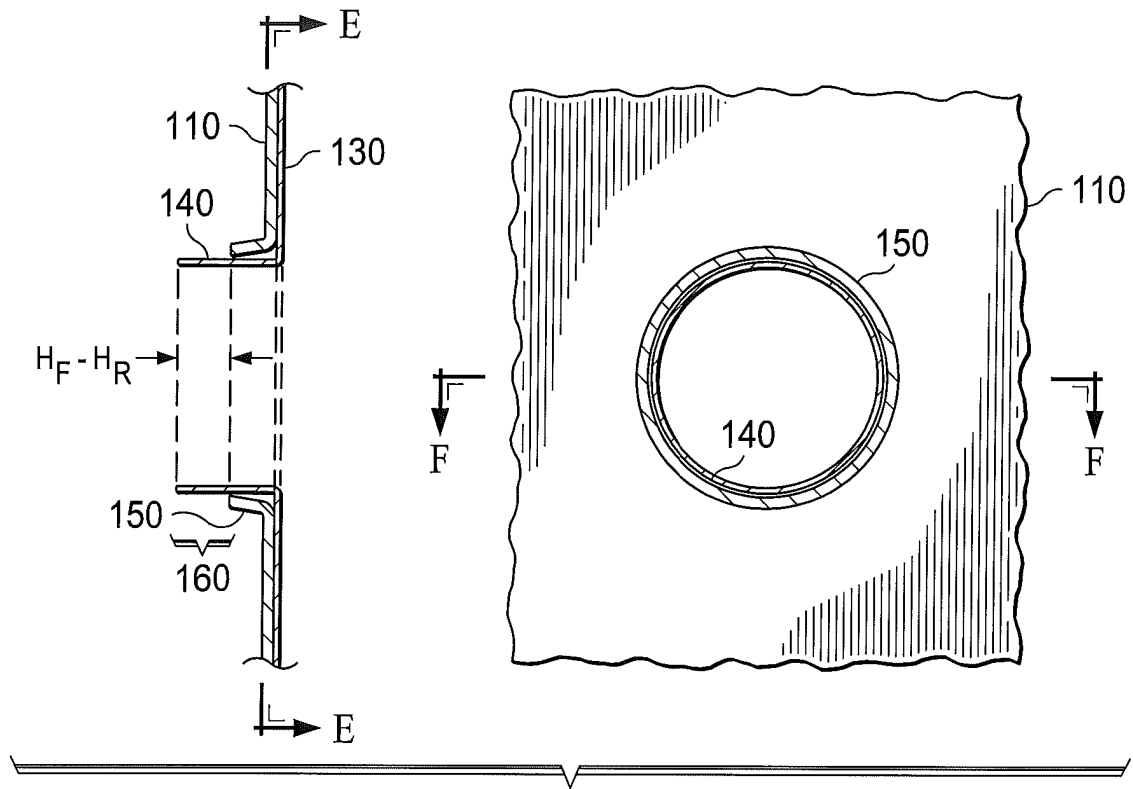


FIG. 1C

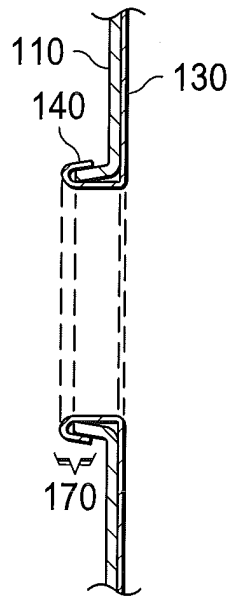


FIG. 1D

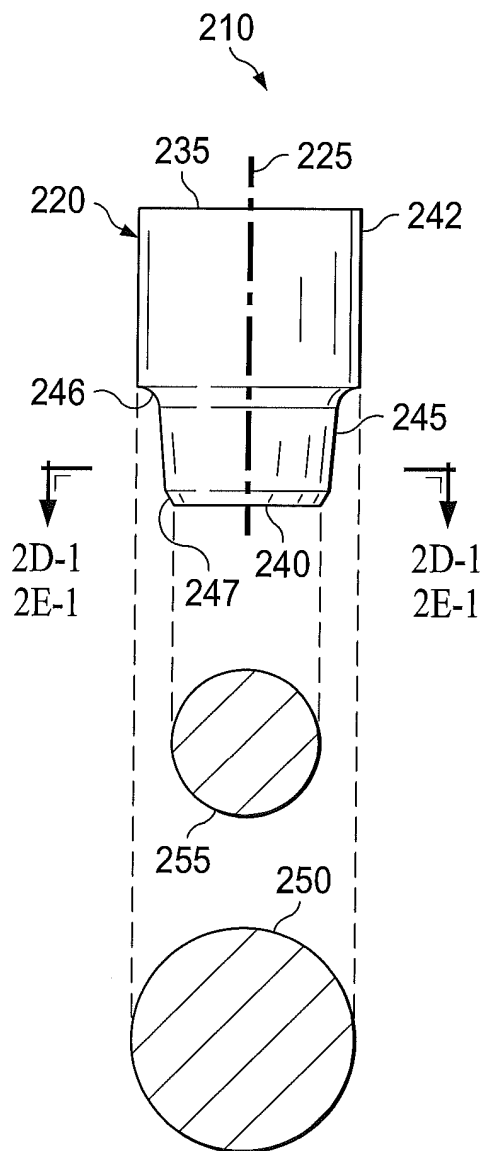


FIG. 2A

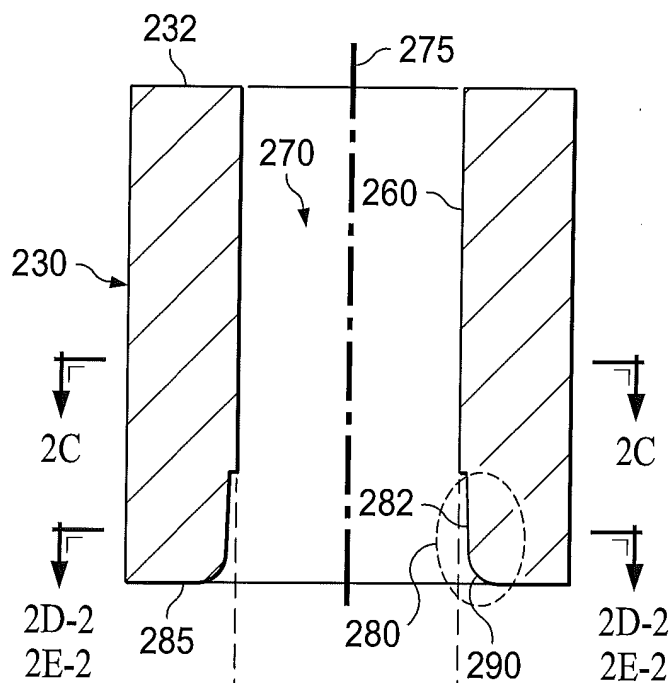


FIG. 2B

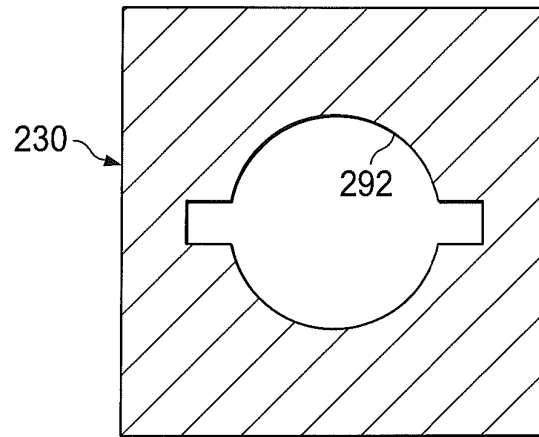


FIG. 2C



FIG. 2D-1

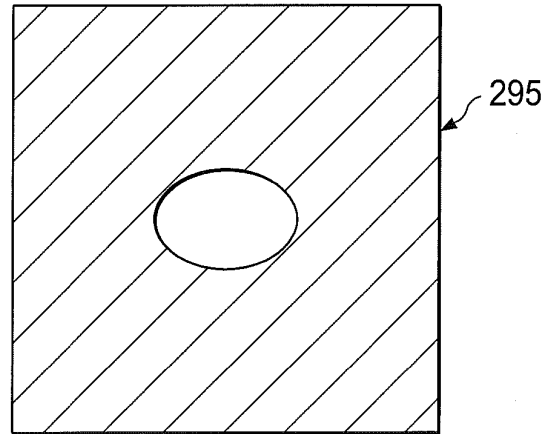


FIG. 2D-2

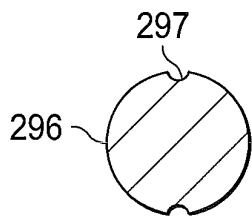


FIG. 2E-1

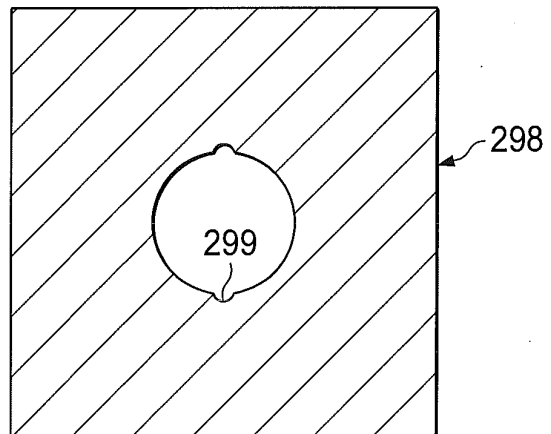


FIG. 2E-2

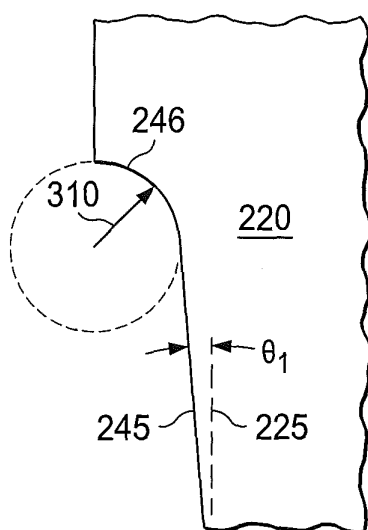


FIG. 3

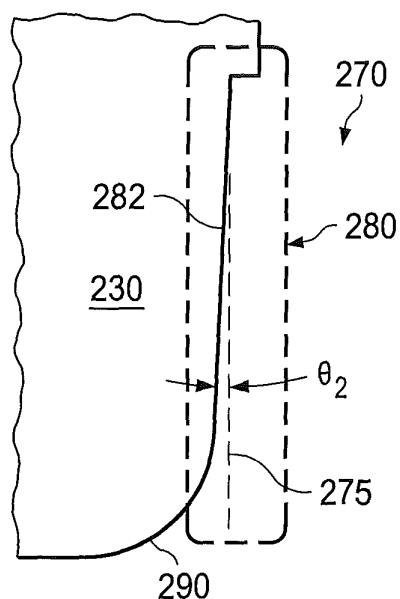


FIG. 4

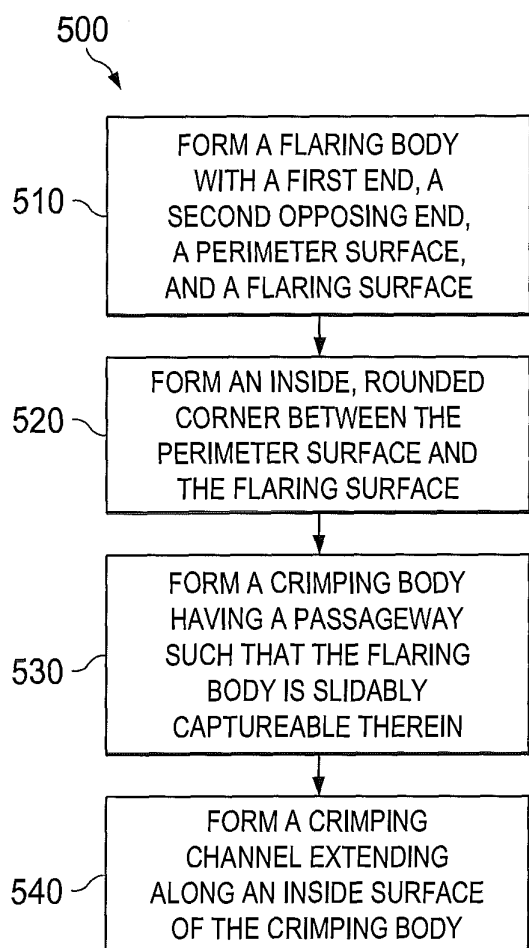


FIG. 5

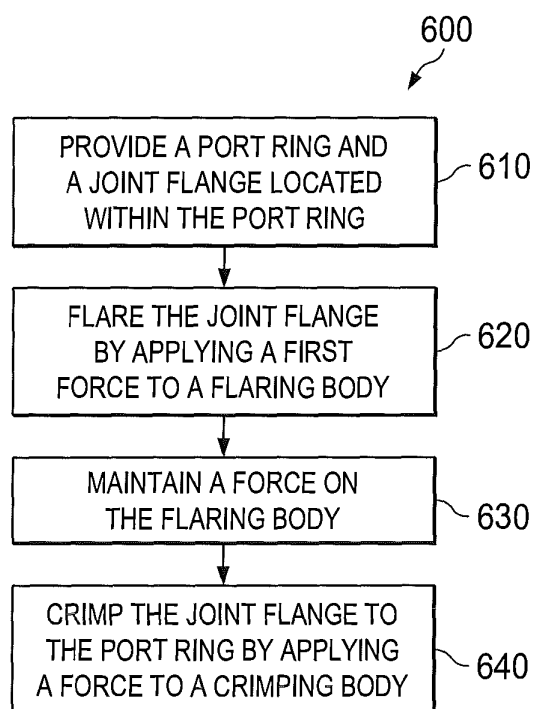
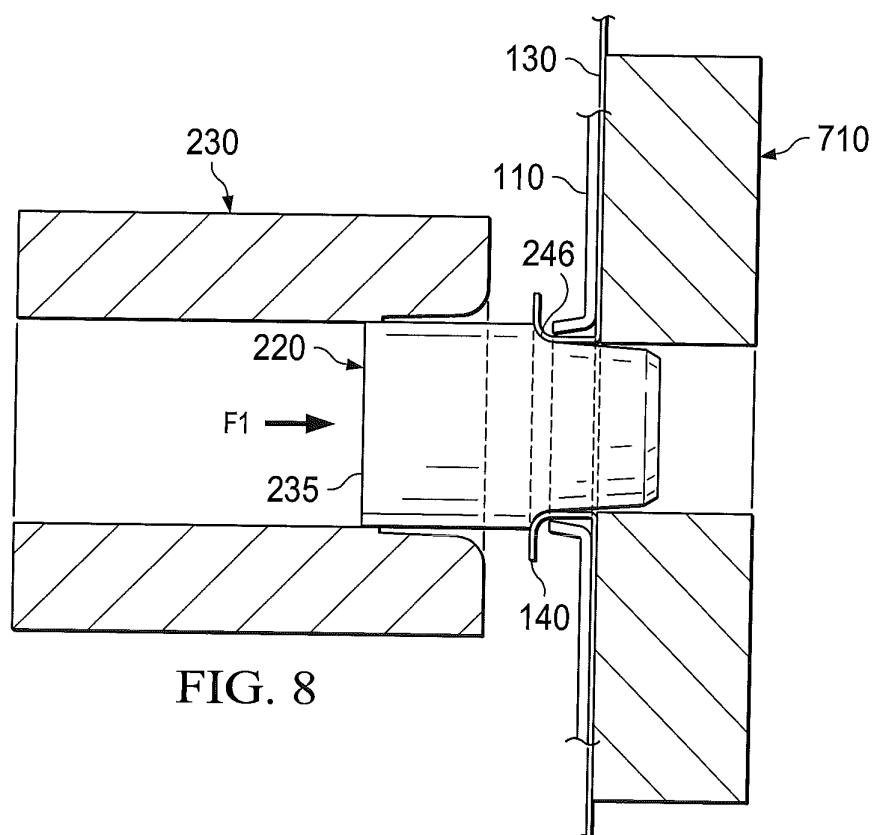
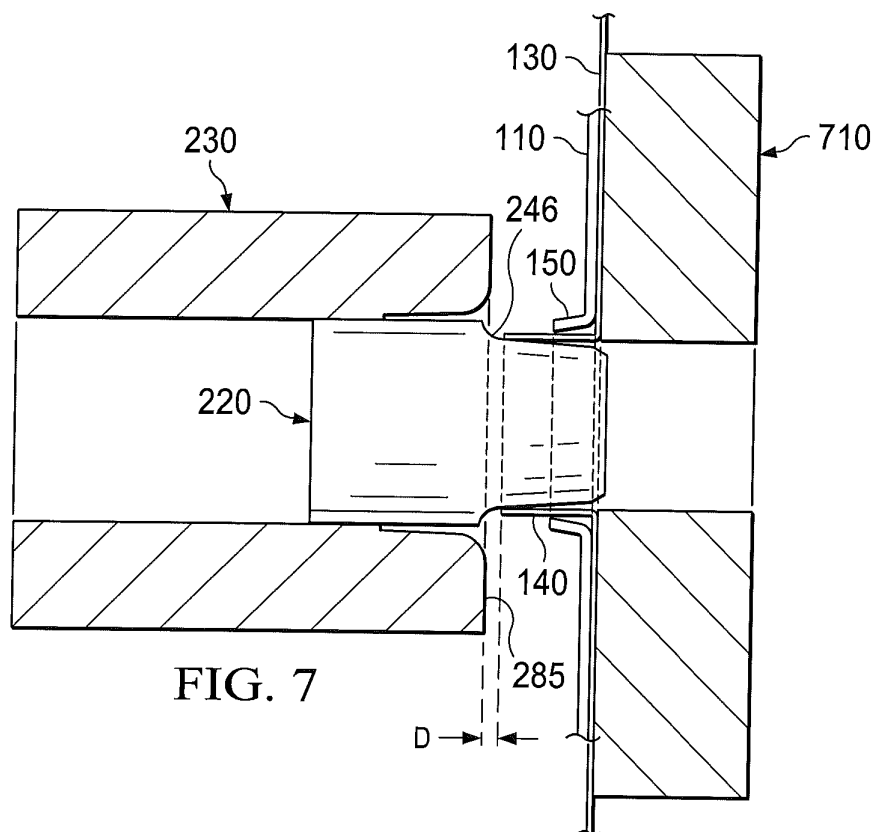
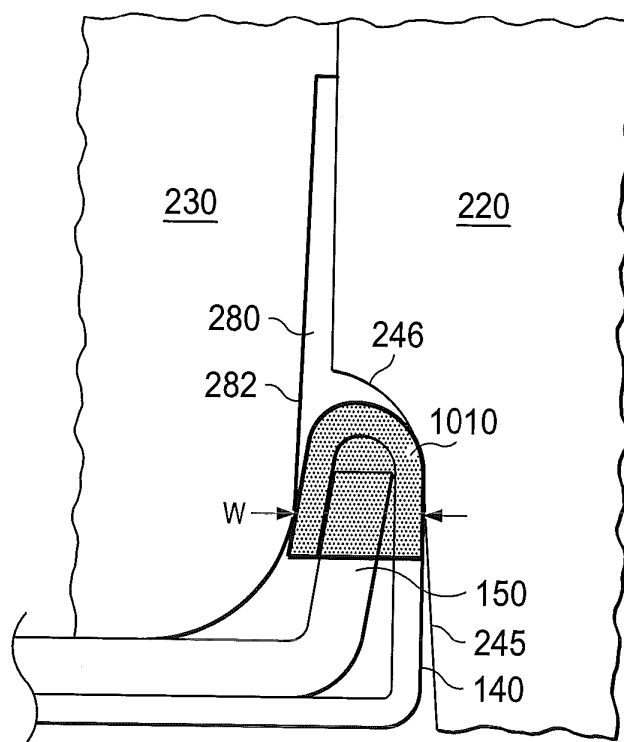
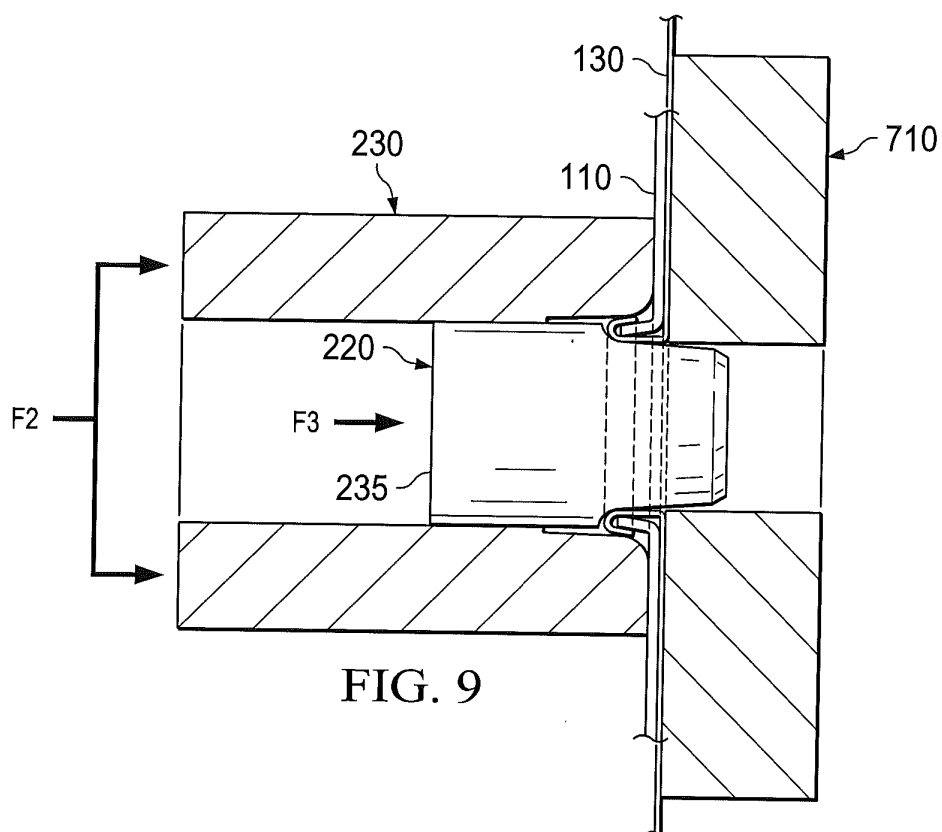


FIG. 6





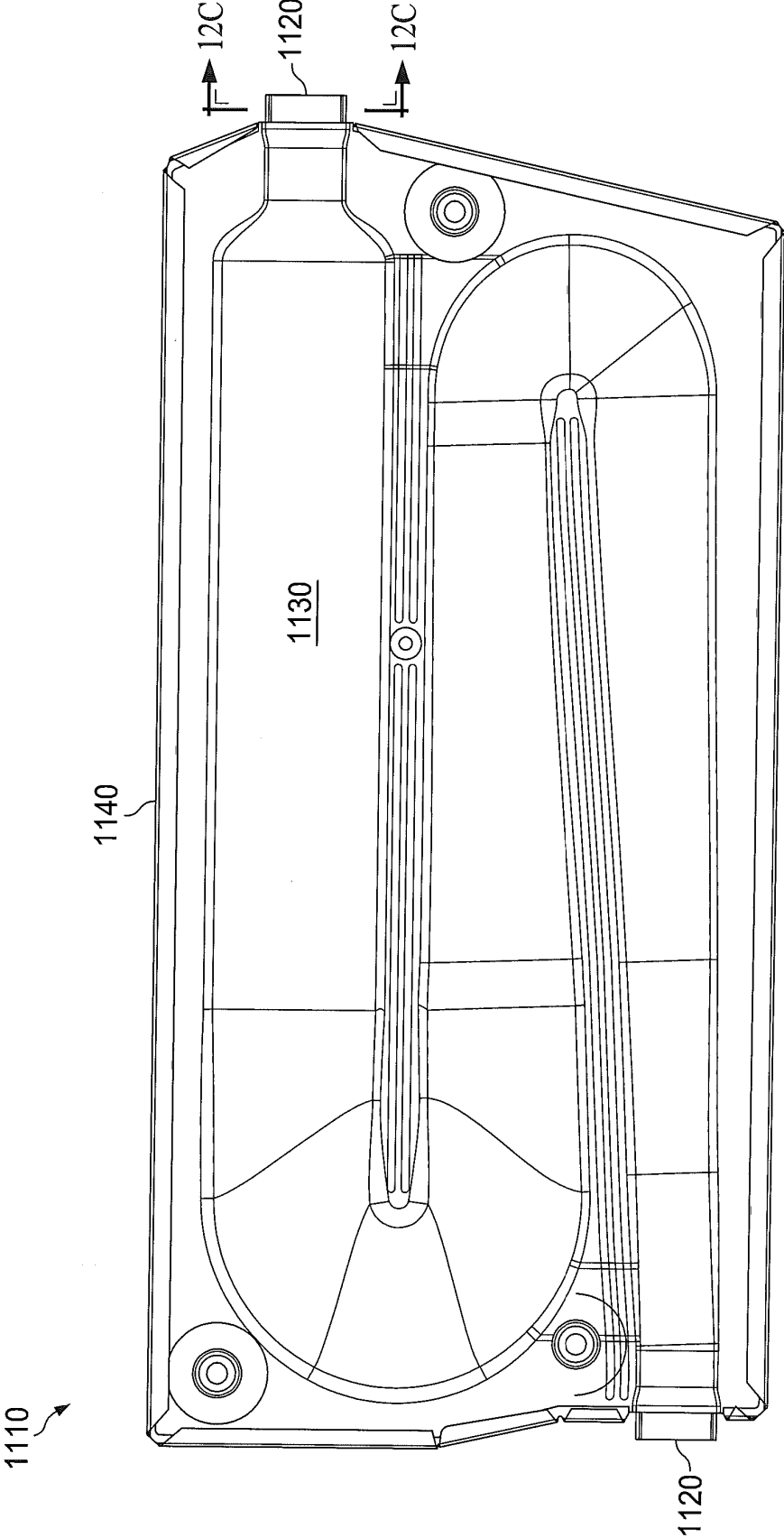


FIG. 11

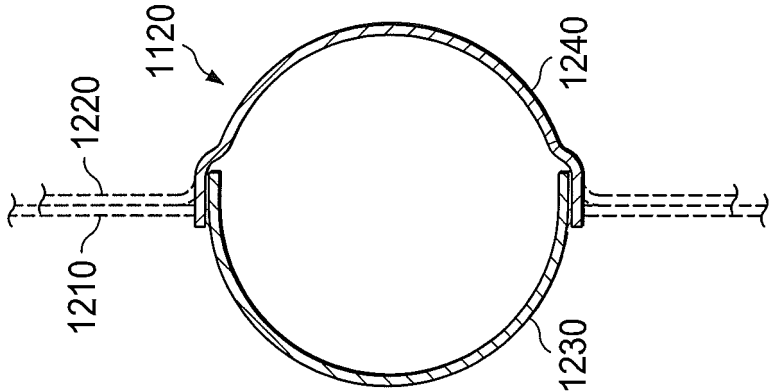


FIG. 12C

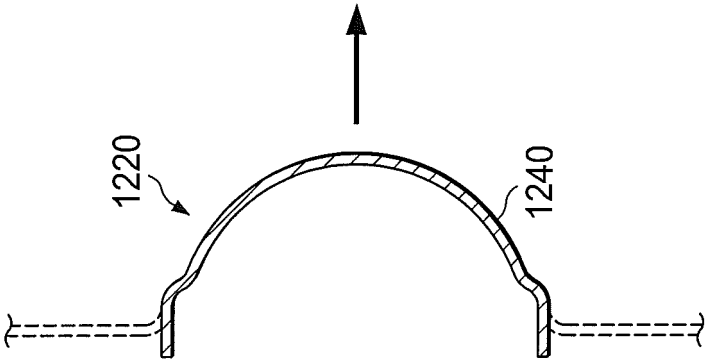


FIG. 12B

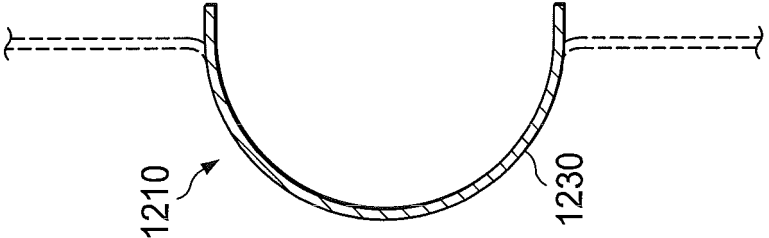


FIG. 12A

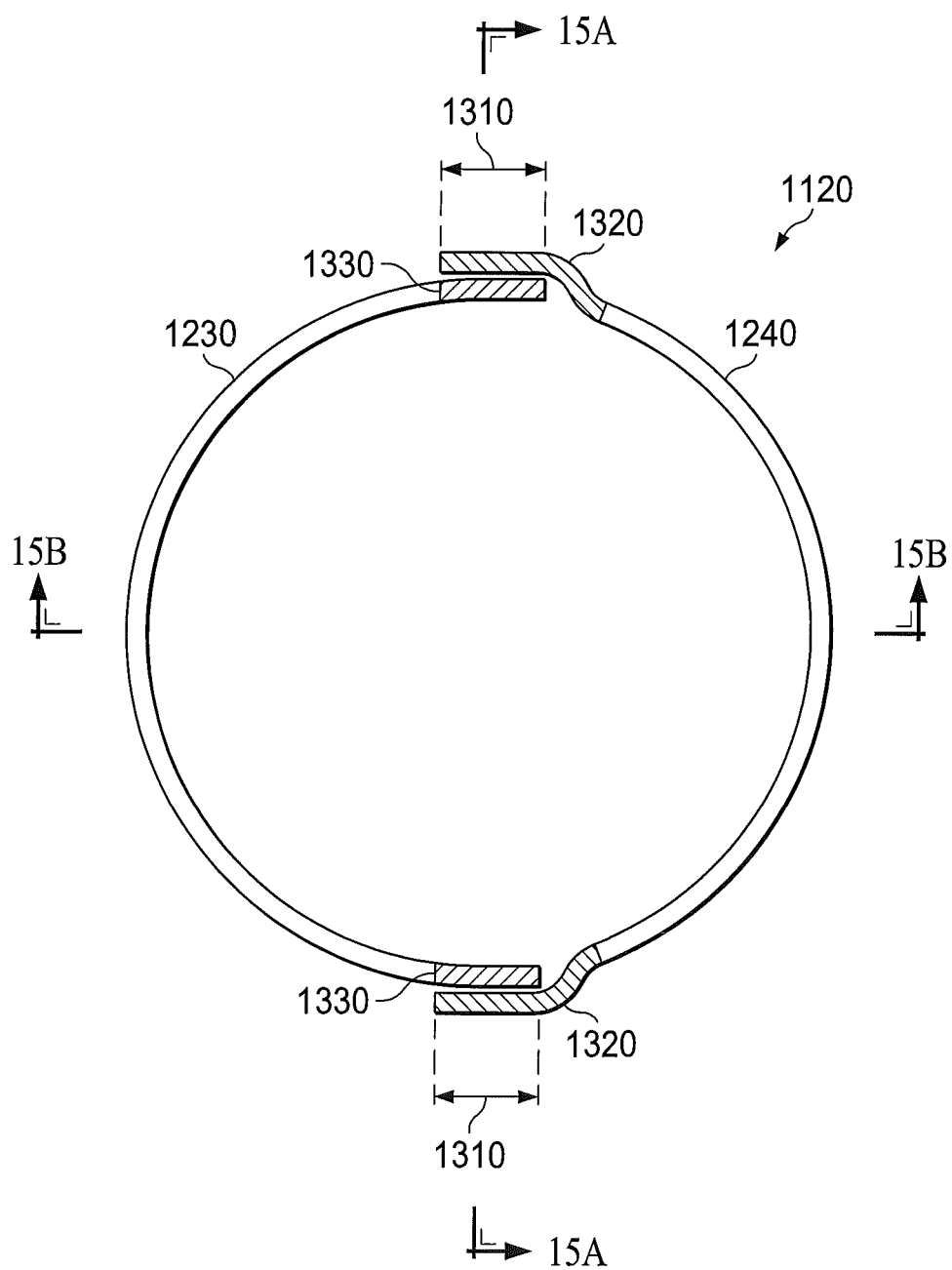


FIG. 13

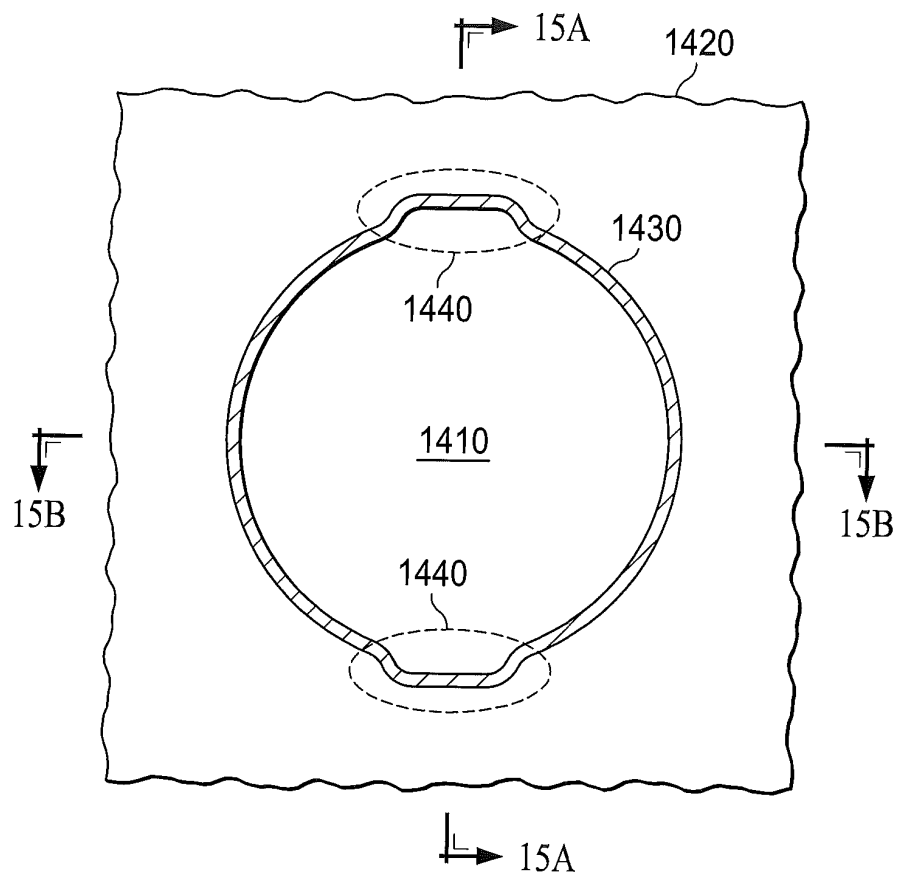


FIG. 14

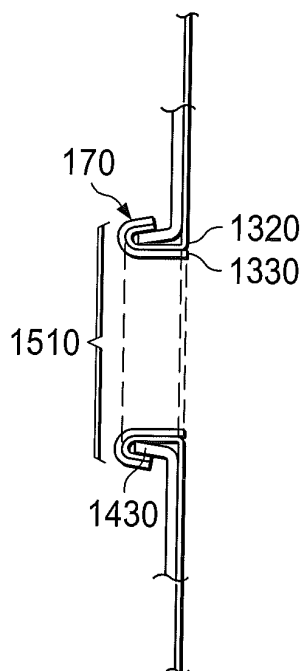


FIG. 15A

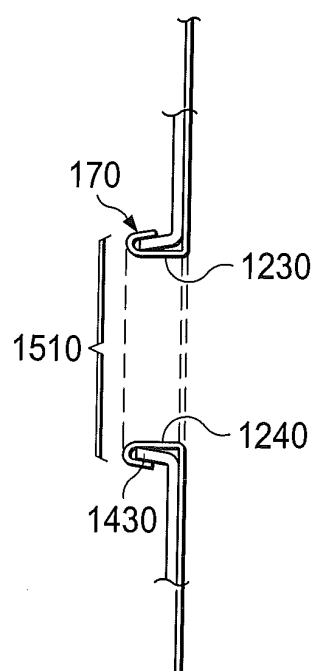


FIG. 15B

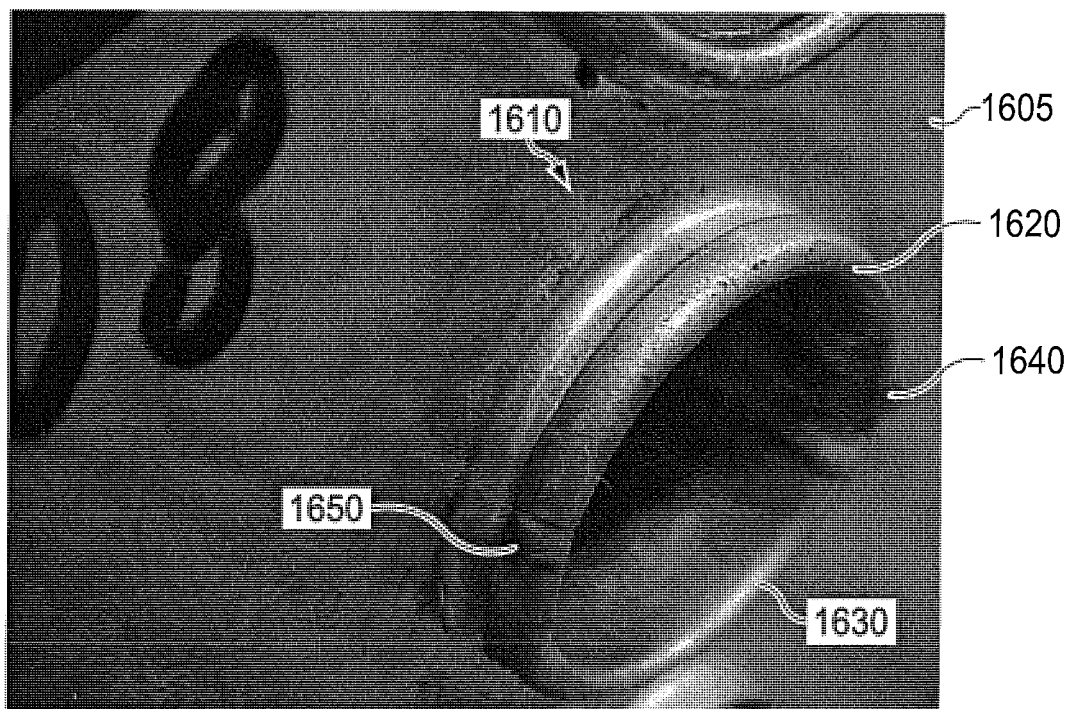


FIG. 16

REFERENCES CITED IN THE DESCRIPTION

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