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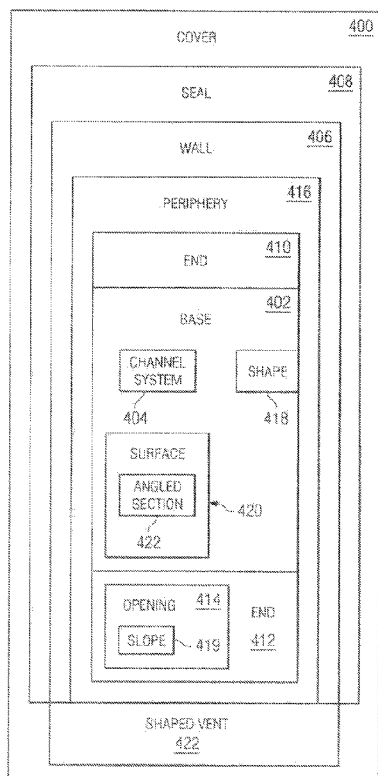


FIG. 4

(57) Abstract: An apparatus for laser welding comprises a base (402), a wall (406), and an opening (414) in the wall. The base (402) has a first end (410), a second end (412), and a channel system (404). The channel system (404) is located closer to the first end (410) than the second end (412) of the base. The wall (406) extends from a side of the base (402) to partially enclose the channel system (404). The opening (414) in the wall (406) is located closer to the second end (412) than the first end (410). The shape of the wall (406) is capable of retaining a gas introduced through the channel system (404) in a welding location and causing the gas to move away from the channel system (404) and through the opening (414) in the wall (406).



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INERT GAS COVER SYSTEM FOR LASER WELDING WITH A BASE AND WALL HAVING AN OPENING

BACKGROUND

The present disclosure relates generally to manufacturing and, in particular, to a method and apparatus for laser welding.

5 Laser welding is a technique that may be used to join multiple pieces of metal through the use of a laser. A laser beam may provide a concentrated heat source to weld different metallic parts to each other. Laser welding may be performed using various types of lasers including solid state and gas lasers. The use of a laser allows for narrow and/or deep welds. Further, the use of a laser also may provide for high welding rates. Laser welding is typically
10 used in high-volume applications such as in the aircraft and/or automotive industry.

 Laser welding may be used to weld metal components such as those comprised of carbon steel, stainless steel, aluminum, and titanium. One advantage of laser welding may be the capability to join metal components such as scrap pieces of metal for the purpose of “scrap reduction” and formation of parts rather than machining these parts from larger pieces of raw
15 materials.

 The use of laser welding for manufacturing aircraft parts and aircraft may be useful in reducing the weight of aircraft. Laser welding may be used in place of riveting when joining large metal fuselage parts to each other. These parts include, for example, stringers used in metal fuselages. Using laser welding provides an advantage over rivets, because laser welding
20 results in less weight when manufacturing aircraft.

 For example, in addition to eliminating the use of rivets, the use of a filler metal between rivet parts also may be eliminated. As a result, the structure of an aircraft may be reduced by around five percent using laser welding instead of rivets. Further, a welded joint formed using laser welding may provide greater compressive and shared strength even though
25 this type of joint is lighter. In addition, laser welding also may have a lower cost than the use of rivets. A further advantage of using laser welding to join parts to each other is that laser welded parts are less susceptible to corrosion.

 Typically, the speed of welding is proportional to the amount of power supplied to the laser as well as the type and thickness of the parts being welded. Further, the speed at which
30 laser welding may occur also may be limited by a number of different factors. For example, when welding titanium, it is desirable to prevent air from contacting molten titanium.

Unwanted gases in the air may attack the metal and cause contamination in the molten titanium during a welding process. This type of contamination may occur if the hot metal is not kept away from air until the titanium is cool enough. This type of discoloration is undesirable for aesthetic purposes.

Further, the contamination may be identified by discoloration, which may indicate a presence of adverse effects to metal properties in the titanium. Contamination of the titanium with air during welding can cause significant reduction in ductility and fracture toughness. This condition may lead to premature cracks and early fatigue failures.

One manner in which air may be prevented from contacting the molten titanium is to perform the laser welding in a vacuum. Although this type of process may be suitable for preventing discoloration, vacuum environments may be impractical based on the size of the part. Another technique involves introducing an inert gas to prevent air from contacting the titanium until the titanium is cool enough. This type of process, however, may slow down the speed at which welding can occur for titanium.

Therefore, it would be advantageous to have a method and apparatus that overcomes the problems described above.

SUMMARY

In one advantageous embodiment, an apparatus comprises a base, a wall, and an opening in the wall. The base has a first end, a second end, and a channel system. The channel system is located closer to the first end than the second end of the base. The wall extends from a side of the base to partially enclose the channel system. The opening in the wall is located closer to the second end than the first end. The shape of the wall is capable of retaining a gas introduced through the channel system in a welding location and causing the gas to move away from the channel system and through the opening in the wall.

In another advantageous embodiment, a cover for laser welding comprises a base, a wall, an opening in the wall, and a seal attached to the wall. The base has a first side, a second side, and a channel extending from the first side to the second side. The channel is capable of receiving a laser beam and an inert gas. The wall extends from the first side of the base, with the wall enclosing an area having an elongate shape. The elongate shape has a largest area around the channel and tapers away from the channel. The wall partially surrounds the channel and has a tapered end. The opening in the wall is located around the tapered end of the wall. The

elongate shape is capable of causing the inert gas to move from the channel to the opening. The seal attached to the wall is capable of conforming to a surface of a structure.

In yet another advantageous embodiment, a method is present for laser welding. A cover is positioned over a structure. The cover has a base with a first end, a second end, and a channel, in which the channel is located closer to the first end than the second end of the base. The cover also has a wall extending from a side of the base to partially enclose the channel. The cover further has an opening in the wall that is located closer to the second end than the first end. An inert gas is supplied through the channel. The shape of the wall retains a portion of the inert gas introduced through the channel in a welding location and causes a flow of the inert gas to move away from the channel and through the opening in the wall. A laser beam is sent through the channel onto a surface of the structure at the welding location. The laser beam is moved with the cover over the structure to weld the structure.

The features, functions, and advantages can be achieved independently in various embodiments of the present disclosure or may be combined in yet other embodiments in which further details can be seen with reference to the following description and drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a diagram illustrating an aircraft manufacturing and service method in accordance with an advantageous embodiment;

FIG. 2 is a diagram of an aircraft in which an advantageous embodiment may be implemented;

FIG. 3 is a diagram of a welding environment in accordance with an advantageous embodiment;

FIG. 4 is a diagram of a cover in accordance with an advantageous embodiment;

FIG. 5 is a diagram of a cover in accordance with an advantageous embodiment;

FIG. 6 is another view of a cover in accordance with an advantageous embodiment;

FIG. 7 is a top view of a cover in accordance with an advantageous embodiment;

FIG. 8 is a diagram of a portion of a cover in accordance with an advantageous embodiment;

FIG. 9 is a side view of a portion of a cover in accordance with an advantageous embodiment;

FIG. 10 is a bottom view of a portion of a cover in accordance with an advantageous embodiment;

FIG. 11 is a side view of a seal in accordance with an advantageous embodiment;
FIG. 12 is a top view of a seal in accordance with an advantageous embodiment;
FIG. 13 is a diagram of a cover on a structure in accordance with an advantageous embodiment; and

5 FIG. 14 is a flowchart of a process for performing a laser welding operation in accordance with an advantageous embodiment.

DETAILED DESCRIPTION

Referring more particularly to the drawings, embodiments of the disclosure may be described in the context of aircraft manufacturing and service method **100** as shown in **FIG. 1**
10 and aircraft **200** as shown in **FIG. 2**. Turning first to **FIG. 1**, a diagram illustrating an aircraft manufacturing and service method is depicted in accordance with an advantageous embodiment. During pre-production, exemplary aircraft manufacturing and service method **100** may include specification and design **102** of aircraft **200** in **FIG. 2** and material procurement **104**.

During production, component and subassembly manufacturing **106** and system
15 integration **108** of aircraft **200** in **FIG. 2** takes place. Thereafter, aircraft **200** in **FIG. 2** may go through certification and delivery **110** in order to be placed in service **112**. While in service by a customer, aircraft **200** in **FIG. 2** is scheduled for routine maintenance and service **114**, which may include modification, reconfiguration, refurbishment, and other maintenance or service.

Each of the processes of aircraft manufacturing and service method **100** may be
20 performed or carried out by a system integrator, a third party, and/or an operator. In these examples, the operator may be a customer. For the purposes of this description, a system integrator may include, without limitation, any number of aircraft manufacturers and major-system subcontractors; a third party may include, without limitation, any number of vendors, subcontractors, and suppliers; and an operator may be an airline, leasing company, military
25 entity, service organization, and so on.

With reference now to **FIG. 2**, a diagram of an aircraft is depicted in which an advantageous embodiment may be implemented. In this example, aircraft **200** is produced by aircraft manufacturing and service method **100** in **FIG. 1** and may include airframe **202** with a plurality of systems **204** and interior **206**. Examples of systems **204** include one or more of
30 propulsion system **208**, electrical system **210**, hydraulic system **212**, and environmental system **214**. Any number of other systems may be included. Although an aerospace example is shown,

different advantageous embodiments may be applied to other industries, such as the automotive industry.

Apparatus and methods embodied herein may be employed during any one or more of the stages of aircraft manufacturing and service method **100** in FIG. **1**. For example,

5 components or subassemblies produced in component and subassembly manufacturing **106** in FIG. **1** may be fabricated or manufactured in a manner similar to components or subassemblies produced while aircraft **200** is in service **112** in FIG. **1**.

Also, one or more apparatus embodiments, method embodiments, or a combination thereof may be utilized during production stages, such as component and subassembly
10 manufacturing **106** and system integration **108** in FIG. **1**, for example, without limitation, by substantially expediting the assembly of or reducing the cost of aircraft **200**. Similarly, one or more of apparatus embodiments, method embodiments, or a combination thereof may be utilized while aircraft **200** is in service **112** or during maintenance and service **114** in FIG. **1**. As one example, the different advantageous embodiments may be used to perform laser welding during at
15 least one of component and subassembly manufacturing **106** and maintenance and service **114**.

The different advantageous embodiments provide an apparatus that is capable of controlling the flow of gas and/or maintaining a gas environment adjacent to molten metal in a manner that reduces and/or prevents contamination during a welding process. The different advantageous embodiments provide a containment system for an inert gas to maintain the inert
20 gas around the molten metal in a manner that seals the hot metal from contamination. Further, gas may be channeled and vented away from the molten metal. The shape of the containment system is such that the gas introduced into the air moves away from the area in which molten metal is present. This movement of gas may reduce soot or other contaminants that may be generated during the welding process.

25 In one advantageous embodiment, an apparatus has a base having a first end, a second end, and a channel system. The channel system is located closer to the first end than the second end of the base. A wall extends from the base to partially enclose the channel system. An opening is present in the wall that is located closer to the second end than the first end. A shape of the wall is capable of causing a gas introduced through the channel system to move away from
30 the channel system and through the opening in the wall. In these examples, soot may be any type of particulate, gas, or other matter generated when applying a laser beam to a structure.

This type of movement of the gas is capable of moving soot away from the location at which the welding is occurring on a structure. More particularly, the gas may move away from

the channel system towards the opening in the wall and carry soot that may be generated during welding away from the welding location and/or locations of heated metal. By moving soot away from these locations, contaminants may be moved away from molten metal.

Further, the shape of the wall is capable of containing or sealing gas to prevent air from contacting the metal that has been heated and/or welded until the metal has sufficiently cooled in a manner that reduces and/or prevents contamination resulting from contact to air. The movement of the soot away from the molten metal and source of the laser beam also prevents the soot from blocking the laser light from reaching the metal.

With reference now to FIG. 3, a diagram of a welding environment is depicted in accordance with an advantageous embodiment. Welding environment **300** in this example is a laser welding environment. Welding environment **300** includes laser **302**, gas supply **304**, cooling unit **306**, robotic unit **308**, computer **310**, and vision system **312**.

Laser **302** may take various forms. For example, without limitation, laser **302** may be a solid state laser and/or a gas laser. Solid state lasers may include, for example, a neodymium laser or some other suitable type of solid state laser. A gas laser may be, for example, a carbon dioxide laser, a nitrogen laser, a helium laser, or some other suitable type of gas laser. Laser energy may be supplied to robotic unit **308** through fiber optic cable **314**. A laser beam may be emitted from fiber optic cable **314** through welding head **316** on robotic unit **308**.

Robotic unit **308** may take various forms. For example, without limitation, robotic unit **308** may be a servo controlled, multi-access mechanical arm with welding head **316** being attached to the mechanical arm. Of course, in other advantageous embodiments, other types of mechanical structures may be used for robotic unit **308**.

Gas supply **304** in these examples may supply an inert gas to robotic unit **308** through gas line **318**. Gas line **318** may carry an inert gas to welding head **316**. Gas supply **304** may take various forms. For example, gas supply **304** may supply an inert gas in the form of nitrogen, helium, argon, or some other suitable inert gas.

Of course, the particular gas selected may depend on the material being welded. For example, with titanium, nitrogen may cause contamination. As a result, if titanium is being welded, nitrogen is not used. Of course, a combination of gases may be supplied through gas supply **304** depending on the particular implementation.

Cooling unit **306** provides coolant to robotic unit **308** through coolant line **320**. In these examples, the different advantageous embodiments include cover **322**, which may be attached to welding head **316**.

Vision system **312** provides information about the area in which welding is being performed by robotic unit **308**. This information is used by computer **310** to control welding operations within welding environment **300**. For example, vision system **312** may be used to guide robotic unit **308** in performing the welding operations.

5 In these illustrative examples, computer **310** may control laser **302**, gas supply **304**, cooling unit **306**, robotic unit **308**, and vision system **312**. Robotic unit **308** may be controlled to direct laser energy from laser **302** onto welding location **324** of structure **326**. Welding location **324** is a location at which a laser beam is applied or directed onto structure **326**. Structure **326** may be one or more objects in these examples. In particular, structure **326** is a metal structure in
10 the depicted examples.

As welding operations are performed, welding location **324** changes and prior welding locations on structure **326** are heated metal locations **328**. Heated metal locations **328** are any locations in which welding has occurred and/or other locations in which heating of the metal in structure **326** has occurred such that contamination may occur with contact to air.

15 Contamination of welding location **324** and/or heated metal locations **328** upon contact with air may occur until heated metal locations **328** cool sufficiently. In the different advantageous embodiments, cover **322** has a shape capable of maintaining inert gas **330** around welding location **324** and heated metal locations **328**. Cover **322** is capable of maintaining an environment of inert gas around welding location **324** and heated metal locations **328** in a
20 manner that reduces and/or prevents contamination of these locations.

Additionally, cover **322** has a shape that channels or causes inert gas **330** to move away from welding location **324** and heated metal locations **328**. This type of movement moves soot **332** or other contaminants generated during welding away from these areas. Further, cooling unit **306** may provide cooling for cover **322** in addition to welding head **316**.

25 The illustration of welding environment **300** in FIG. 3 is not meant to imply physical or architectural limitations to the manner in which different welding environments may be implemented. Other welding environments may include other components in addition to or in place of the ones illustrated. In still other welding environments, some of the components illustrated in welding environment **300** may be unnecessary. For example, in some welding
30 environments, a laser, in addition to laser **302**, may be present.

In yet other advantageous embodiments, welding environment **300** may be a laser-hybrid welding environment in which another type of welding process is used in addition to laser welding. For example, in addition to laser **302**, an arc welding unit also may be used in

conjunction with laser **302** to perform welding on structure **326**. In still other advantageous embodiments, vision system **312** may be unnecessary. In yet other advantageous embodiments, instead of using robotic unit **308**, the movement of welding head **316** and cover **322** may be performed manually by a human operator.

5 With reference now to FIG. **4**, a diagram of a cover is depicted in accordance with an advantageous embodiment. In this example, cover **400** is an example of cover **322** in FIG. **3**. In this illustrative example, cover **400** includes base **402**, channel system **404**, wall **406**, and seal **408**. Base **402** has end **410** and end **412**. End **410** may be a first end and end **412** may be a second end of base **402**.

10 In these examples, channel system **404** is a number of channels. A number as used herein refers to one or more items. For example, a number of channels is one or more channels.

 In this example, channel system **404** is capable of receiving a laser beam and an inert gas. Depending on the particular implementation, the laser beam and inert gas may be received through a single channel. In other advantageous embodiments, the laser beam may be received
15 through one channel in channel system **404**, and the inert gas may be introduced using another channel within channel system **404**.

 Wall **406** extends from periphery **416** of base **402** and has opening **414**. Base **402** and wall **406** have shape **418**. Opening **414** is present around end **412** in wall **406**. Wall **406** partially encloses channel system **404**. Channel system **404** is closer to end **410** than to end **412**
20 in these examples.

 Base **402** also may contribute to shape **418**. In these examples, surface **420** of base **402** has angled section **422**. In these examples, surface **420** is closer to an opposite surface on base **402** at around end **412** as compared to end **410**.

 Shape **418** is capable of maintaining an inert gas introduced through channel system **404**
25 in a welding location and/or heated metal locations such that contamination of these locations is reduced and/or eliminated. Further, shape **418** is such that an inert gas introduced through channel system **404** is capable of being channeled or moved from channel system **404** through opening **414** at around end **412**. When base **402** and wall **406** are placed over a structure, a volume or other three-dimensional region is defined containing shape **418**.

30 Shape **418**, in this example, is an elongate shape that has a larger area around channel system **404** than opening **414**. Wall **406** is a contoured wall such that shape **418** reduces in size from end **410** to end **412**. In these different illustrative embodiments, shape **418** may be a tear drop shape. Of course, other shapes may be used as long as the shapes are capable of

maintaining inert gas around a welding location and/or heated metal locations that may be contaminated in a manner that reduces and/or prevents contamination.

Further, shape **418** also may have a shape that allows for moving the inert gas through channel system **404** through opening **414** as the inert gas expands or is introduced. Movement of the inert gas from channel system **404** to opening **414** may aid in moving soot away from welding locations and/or heated metal locations to reduce and/or prevent contamination. Further, moving soot away from these locations also prevents or reduces a reduction in energy provided by a laser beam that can be caused by soot.

Opening **414** has slope **419** and is a nozzle and/or vent that allows for channeling the venting of gas away from a welding location and/or heated metal locations.

Seal **408** is attached to wall **406**. In some advantageous embodiments, seal **408** may be part of wall **406** or may be comprised of wall **406**. Seal **408** provides a capability to maintain an inert gas within the area of base **402** partially enclosed by wall **406**. Seal **408** does not need to maintain an airtight seal in which an inert gas cannot escape through portions of seal **408**.

Seal **408** provides enough of a barrier to prevent turbulence from introducing air into the area enclosed by wall **406**. Seal **408** is capable of maintaining this type of environment when moving over contoured surfaces in these examples. Seal **408** may pivot about wall **406** in some examples.

Additionally, shaped vent **422** may be placed over opening **414** to change the shape and/or size of opening **414**. Shaped vent **422** may be used to reduce the size of opening **414** in these examples. A reduction in the size of opening **414** may be appropriate depending on the rate of welding and/or type of material being welded. The change in the shape of opening **414** may be performed to insure that inert gas is maintained around the welding location and/or heated metal locations in which contamination may occur.

Seal **408** may take various forms. For example, seal **408** may be comprised of a material such as steel, a ceramic fabric, aluminum, copper, or some other suitable material. In these examples, base **402** and wall **406** may be comprised of a metal or other material that is capable of being used in laser welding without introducing contaminants. For example, base **402** and wall **406** may be made from a material such as, for example, aluminum, steel, titanium, or some other suitable material.

The illustration of cover **400** in FIG. 4 is not meant to imply physical or architectural limitations to the manner in which different covers may be implemented in different advantageous embodiments. For example, in some advantageous embodiments, wall **406** and

base **402** may be made from a single piece. In other advantageous embodiments, wall **406** may be a separate part attached to base **402**.

In yet other advantageous embodiments, wall **406** also may function as a seal itself in place of seal **408**. In these examples, shape **418** may vary depending on the particular implementation. Other shapes may be used as long as these shapes provide for a capability to maintain inert gases in a location around welding locations and molten materials that may still be contaminated to prevent or minimize contact with air in a manner that reduces and/or prevents contamination.

Further, shape **418** may vary in a manner that allows for movement of inert gas from the channel towards opening **414** to move soot away from a welding location and heated metal locations.

With reference now to FIG. **5**, a diagram of a cover is depicted in accordance with an advantageous embodiment. Cover **500** is an example of one implementation for cover **400** in FIG. **4**. In this illustrative example, cover **500** has base **502** with wall **504** extending from periphery **506** of base **502**. Base **502** has channel **508**, which provides an opening for a gas and a laser beam to enter. In this example, seal **512** is movably attached to wall **504**.

Seal **512** may pivot about arrow **514** in these examples. Movement of seal **512** may be provided through screws or other fasteners used to attach seal **512** to wall **504**. As can be seen in this view, a screw may be placed into hole **518** of seal **512** to attach seal **512** to wall **504**.

Another screw and opening may be located on side **520** but not seen in this view. In this particular example, wall **504** is a contour of a wall and partially encloses channel **508** with opening **510**.

As can be seen in this illustrative example, base **502** and wall **504** of cover **500** partially enclose area **522**. Area **522** has a shape that tapers and/or lessens in size from end **524** to end **526**. End **524** may be a first end, while end **526** may be a second end. In this example, area **522** is an elongate shape that is around the shape of a tear drop. Gas may be introduced through channel **508** when cover **500** is placed over a structure for laser welding.

The introduction of the gas through channel **508** may form an environment in which inert gas is present and prevents air from touching areas in which laser welding is occurring and heated metal areas that still need to be cooled without contact to air to minimize and/or avoid contamination.

The shape of area **522** with wall **504** forms partially enclosed volume **528** when seal **512** is placed onto a structure. The shape of partially enclosed volume **528** is such that inert gas

entering through channel **508** may move towards end **526** and exit through opening **510** in a manner such that any soot generated during laser welding may be moved with the inert gas through opening **510**. Thus, the movement of the soot may prevent the soot from resulting in a reduction in the energy of a laser beam sent through channel **508** to perform laser welding.

5 The shape of area **522** is such that gas moves towards end **526**. In these examples, a higher pressure of gas is present closer to end **524** where channel **508** is present as opposed to end **526** where opening **510** is present. In these examples, the length and width of cover **500** may vary depending on the particular implementation. The target speed of welding may influence both the length and width of cover **500**.

10 For example, as the welding speed increases, a longer length and/or wider width may be needed. The width of cover **500** may insure that inert gas is present over any of the locations having a temperature that will cause contamination from air. For example, as the heat input increases, the width of the hot metal will increase requiring a wider width of coverage. Reducing the speed while maintaining a constant power will increase the heat input. As speed increases
15 with constant power, the heat input decreases.

 Further, the shape and size of cover **500** also may be influenced depending on whether the welding operation is being performed in a straight line or not in a straight line. If a straight line is used for welding, the width from side **520** to side **530** may be narrower. Curved weld paths may require the width of the cover to be increased for various curve radii.

20 In these illustrative examples, hole **532** and hole **534** on wall **504** provide a place to mount a plate or vent to change the size of opening **510**. A smaller size for opening **510** may be desirable depending on the gas flow rate, type of gas, and/or speed at which laser welding occurs. These and other factors may affect the amount of soot that is generated during welding operations.

25 In these examples, seal **512** may be made from a material such as, for example, without limitation, aluminum, steel, or some other suitable metal. In other advantageous embodiments, a ceramic fabric may be used for seal **512** depending on the particular implementation. In these examples, cover **500** is attached to mounting plate **536**. Mounting plate **536** may, in turn, be attached to another structure such as, for example, a welding head or assembly. Mounting plate
30 **536** may be cooled depending on the particular implementation. By cooling mounting plate **536**, heat may be channeled away from cover **500**.

 With reference now to FIG. **6**, another view of a cover is depicted in accordance with an advantageous embodiment. In this example, cover **500** may be seen from another perspective

view. In this particular view, hole **600** may be seen in seal **512** on side **520** of cover **500**. A screw may be placed through hole **600** to movably mount seal **512** to wall **504**.

With reference now to FIG. 7, a top view of a cover is depicted in accordance with an advantageous embodiment. In this example, a portion of cover **500** is illustrated. Base **502** and wall **504** without seal **512** is depicted in this example. In this example, a top view of cover **500** is illustrated. In this particular view, channel **508** may be seen having diameter **700** on surface **702** with diameter **704** on a surface opposite to surface **702**. In other words, channel **508** has a cone shape.

In this illustrative example, base **502** has length **706**, which may be around 4.4 inches. Base **502** may have width **708**, which tapers down to width **710**. In these illustrative examples, width **708** may be around 2.25 inches, while width **710** may be around 1.123 inches.

With reference now to FIG. 8, a diagram of a portion of cover **500** is depicted. In this example, a rear view of base **502** and wall **504** is illustrated. Further, channel **508** is shown in phantom to better illustrate the cone shape of channel **508** in this particular view.

With reference now to FIG. 9, a side view of a portion of a cover is depicted in accordance with an advantageous embodiment. In this illustrative example, a side view of base **502** with wall **504** is depicted in accordance with an advantageous embodiment. As can be seen in this side view, base **502** has angled surface **900**, which becomes closer to top **702** as angled surface **900** extends from end **524** to end **526**. In this example, angled surface **900** may have angle **902**. Additionally, wall **506** also may be angled at angle **904**.

With reference now to FIG. 10, a bottom view of a portion of a cover is depicted in accordance with an advantageous embodiment. In this example, a bottom view of base **502** with wall **504** is illustrated. Angled surface **900** is on the opposite side of base **502** from surface **702**.

With reference now to FIG. 11, a diagram illustrating a seal is depicted in accordance with an advantageous embodiment. In this example, a side view of seal **512** is depicted. In this example, edge **1100** is substantially planar, while edge **1102** has angled section **1104** that has angle **1106**. In this advantageous embodiment, seal **512** may have length **1108**. Length **1108** may be around 4.68 inches in this example. Seal **512** may have height **1110** at end **1112** which tapers down to height **1114** at end **1116**. This tapering occurs in these examples through angled section **1104**.

With reference now to FIG. 12, a top view of a seal is depicted in accordance with an advantageous embodiment. In this illustration of seal **512**, seal **512** may have width **1200**, which may taper to width **1202**. Width **1200** may be around 2.71 inches, while width **1202** may be

around 1.4 inches. In these examples, seal **512** may have thickness **1204** which may be around 0.2 inches.

With reference now to FIG. **13**, a diagram of a cover on a structure is depicted in accordance with an advantageous embodiment. In this example, cover **1300** is an example of cover **500** in FIG. **5** on structure **1302**. In this example, structure **1302** may be titanium parts being welded to each other through a laser welding process. Also in this example, cover **1300** may include base **1303** and seal **1304**.

In this illustrative example, seal **1304** contacts surface **1306** of structure **1302**. Laser beam **1308** and gas **1310** are introduced through channel **1312** through laser welding head **1313** and into the interior of cover **1300** in the direction of arrow **1314**. Welding may occur around location **1316** on surface **1306** of structure **1302**. During welding of structure **1302**, the gas introduced through channel **1312** forms an environment within cover **1300** in which air may be prevented from contacting location **1316** and causing contamination. Further, gas **1310** may travel in as gas and soot exhaust **1318** along the direction of arrows **1320** to exit cover **1300** at opening **1322**. In this welding process, cover **1300** may move in the direction of arrow **1324**.

The movement of gas and soot exhaust **1318** along the direction of arrows **1320** may move the soot in gas and soot exhaust **1318** away from location **1316** and out of cover **1300** through opening **1322**. This movement of soot away from location **1316** may not only prevent air from contaminating location **1316** but also may minimize and/or prevent reduction in the laser power applied to location **1316** that may be due to the soot in gas and soot exhaust **1318**.

With reference now to FIG. **14**, a flowchart of a process for performing a laser welding operation is depicted in accordance with an advantageous embodiment. The process illustrated in FIG. **14** may be implemented using a welding environment such as, for example, welding environment **300** in FIG. **3**.

The process begins by positioning a cover over a structure (operation **1400**). In this example, the cover has a base with a first end, a second end, and a channel system in which the channel system is located closer to the first end than the second end of the base. A wall extends from the side of the base to partially enclose the channel system. An opening in the wall is located closer to the second end than the first end. The shape of the wall is capable of retaining an inert gas introduced through the channel systems in a welding location and capable of causing the inert gas to move away through the channel system through the opening in the wall.

The process supplies inert gas through the channel system (operation **1402**). The process also sends a laser beam through the channel system onto the surface of the structure at a

welding location (operation **1404**). The process then moves the laser beam with the cover over the structure to weld the structure (operation **1406**), with the process terminating thereafter.

In this example, operation **1402** continues to be performed while operations **1404** and **1406** are performed. In other advantageous embodiments, other operations such as, for example, halting application of the laser beam through the channel system and moving the cover to another structure may be performed. In these examples, the structure may be, for example, without limitation, two aircraft parts being welded together.

The flowchart and block diagrams in the different depicted embodiments illustrate the architecture, functionality, and operation of some possible implementations of apparatus, methods, and computer program products. In this regard, each block in the flowchart or block diagrams may represent a module, segment, or portion of computer usable or readable program code, which comprises one or more executable instructions for implementing the specified function or functions.

In some alternative implementations, the function or functions noted in the block may occur out of the order noted in the FIGS.. For example, in some cases, two blocks shown in succession may be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved.

Thus, the different advantageous embodiments provide a method and apparatus for welding structures. In the different advantageous embodiments, a cover having a base with a first end, a second end, and a channel system is present. A wall extends from the base to partially enclose the channel system. An opening is present in the wall that is closer to a second end than the first end of the base.

The shape of the wall is capable of retaining a gas introduced through the channel system in a welding location and causing the gas to move away from the channel system and through the opening in the wall. One or more of the different advantageous embodiments provide a capability to seal a welding location and hot metal from contamination until the hot metal is capable of cooling sufficiently to minimize or prevent contamination.

Further, the different advantageous embodiments also provide a capability to channel gas from a channel system through an opening. This channeling of the gas may occur in a manner that helps move soot away from the laser beam to prevent soot from blocking the laser beam during welding operations. Also, a seal that is movable may provide a capability to move over contoured surfaces while still providing adequate gas pressure to prevent contamination from air.

The description of the different advantageous embodiments has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the embodiments in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. Further, different advantageous embodiments may provide different

5 advantages as compared to other advantageous embodiments.

The embodiment or embodiments selected are chosen and described in order to best explain the principles of the embodiments, the practical application, and to enable others of ordinary skill in the art to understand the disclosure for various embodiments with various modifications as are suited to the particular use contemplated.

CLAIMS

What is claimed is:

1. An apparatus comprising:

a base having a first end, a second end, and a channel system, wherein the channel
5 system is located closer to the first end than the second end of the base;

a wall extending from a side of the base to partially enclose the channel system; and

an opening in the wall that is located closer to the second end than the first end, wherein
a shape of the wall is capable of retaining a gas introduced through the channel system in a
welding location and causing the gas to move away from the channel system and through the
10 opening in the wall.

2. The apparatus of claim 1 further comprising a seal attached to a surface of the wall
wherein the seal is capable of conforming to the surface.

3. The apparatus of claim 2, wherein the seal is moveably attached to the surface of the
wall, wherein the seal is capable of moving the seal on the surface to conform to the surface.

4. The apparatus of claim 3 further comprising a pair of screws that moveably attach the
15 seal to the surface of the wall.

5. The apparatus of claim 1, wherein the channel system comprises a number of holes in
the base, wherein the number of holes is capable of receiving a laser beam and an inert gas.

6. The apparatus of claim 1, wherein the shape of the wall reduces in size from the first
20 end to the second end.

7. The apparatus of claim 1, wherein the shape of the wall is a tear drop shape.

8. The apparatus of claim 1, wherein the side of the base is a first side, the base has a
second side opposite the first side, and the first side of the base has a slope that slopes toward the
second side and the opening.

9. The apparatus of claim 1, wherein the side is a first side, the base has a second side
25 opposite the first side, and the channel system comprises a channel having a first diameter at the
first side and a second diameter at the second side.

10. The apparatus of claim 1 further comprising a shaped vent attached to the opening, wherein the shaped vent reduces a size of the opening.

11. The apparatus of claim 2 wherein the seal is comprised of a material selected from steel, a ceramic fabric, aluminum, and copper.

5 12. The apparatus of claim 1 wherein the base and the wall extending from the base are comprised of a material selected from one of steel, aluminum, and copper.

13. The apparatus of claim 1 further comprising a welding head, wherein the base is capable of being secured to the welding head;

10 14. The apparatus of claim 13 further comprising a laser coupled to the welding head, and a gas supply connected to the welding head.

15. The apparatus of claim 14 further comprising a cooling unit connected to the welding head and capable of cooling the base and the wall.

16. The apparatus of claim 15 further comprising:

15 a robotic unit, wherein the welding head is attached to the robotic unit and wherein the robotic unit is capable of moving the welding head during a laser welding operation; and
a computer connected to the robotic unit, wherein the computer is capable of controlling the robotic unit to move the welding head to perform the laser welding operation.

17. A cover for laser welding, the cover comprising:

20 a base having a first side, a second side, and a channel extending from the first side to the second side, wherein the channel is capable of receiving a laser beam and an inert gas;

a wall extending from the first side of the base, wherein the wall encloses an area having an elongate shape that has a largest area around the channel, wherein the elongate shape tapers away from the channel, wherein the wall partially surrounds the channel, and wherein the wall has a tapered end;

25 an opening in the wall located around the tapered end of the wall, wherein the elongate shape is capable of causing the inert gas to move from the channel to the opening; and

a seal attached to the wall, wherein the seal is capable of conforming to a surface of a structure.

18. The cover of claim 17, wherein the seal is comprised of a material selected from one of aluminum, steel, and a ceramic fabric.

19. A method for laser welding, the method comprising:

positioning a cover over a structure, wherein the cover has a base with a first end, a
5 second end, and a channel, in which the channel is located closer to the first end than the second end of the base; a wall extending from a side of the base to partially enclose the channel; and an opening in the wall that is located closer to the second end than the first end;

supplying an inert gas through the channel, wherein a shape of the wall retains a portion
of the inert gas introduced through the channel in a welding location and causes a flow of the
10 inert gas to move away from the channel and through the opening in the wall;

sending a laser beam through the channel onto a surface of the structure at the welding
location; and

moving the laser beam with the cover over the structure to weld the structure.

20. The method of claim 10 wherein the positioning step and the moving step are
15 performed using a robotic unit.

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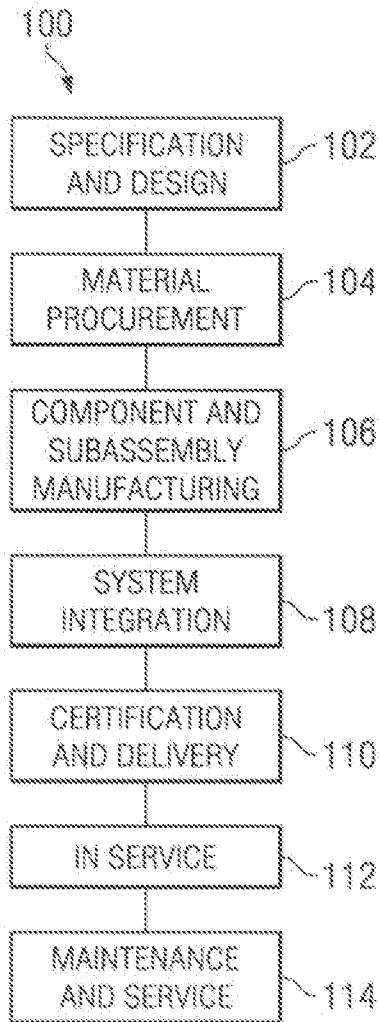


FIG. 1

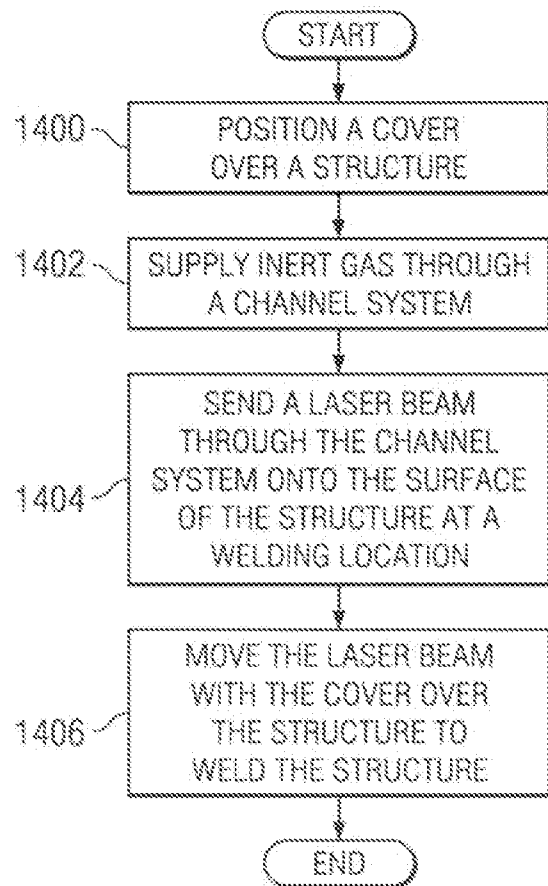


FIG. 14

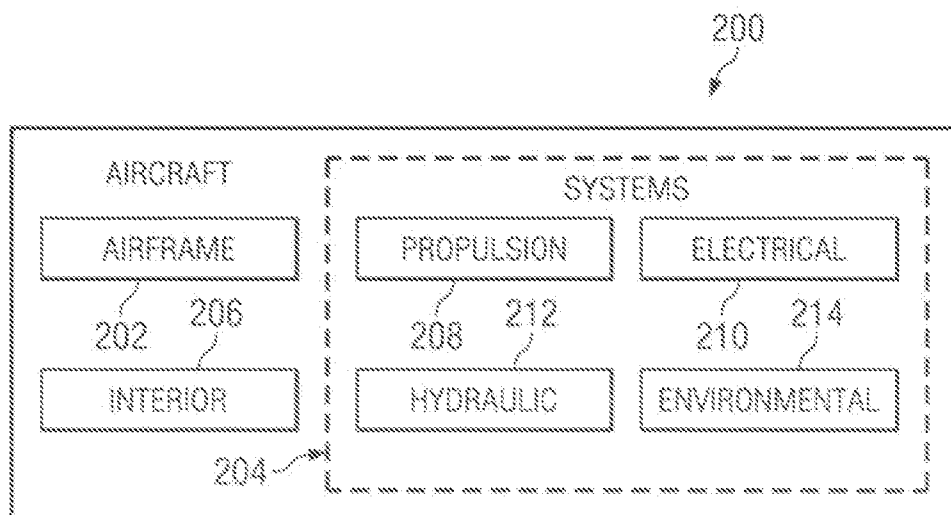


FIG. 2

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WELDING
ENVIRONMENT
300

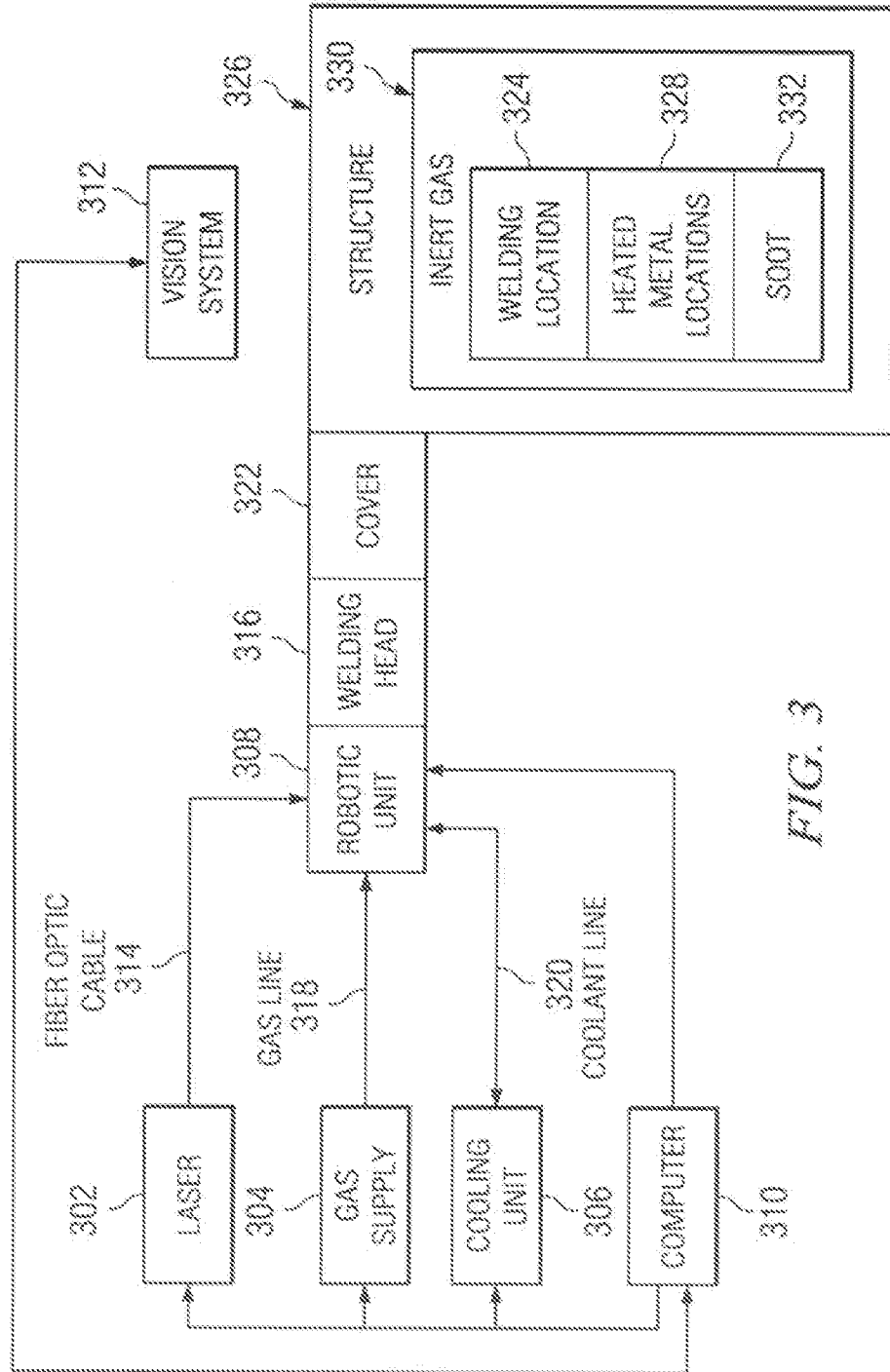


FIG. 3

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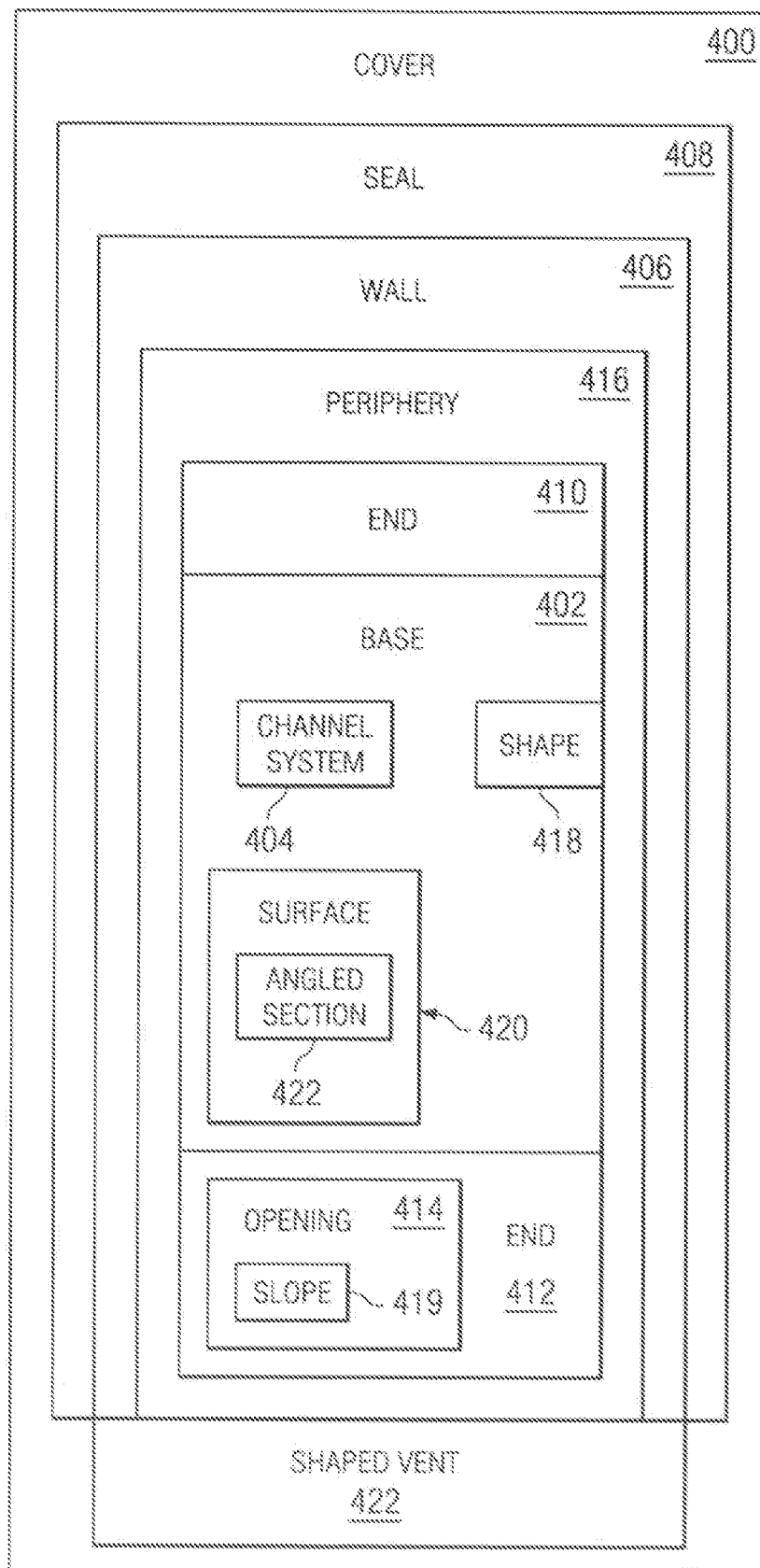
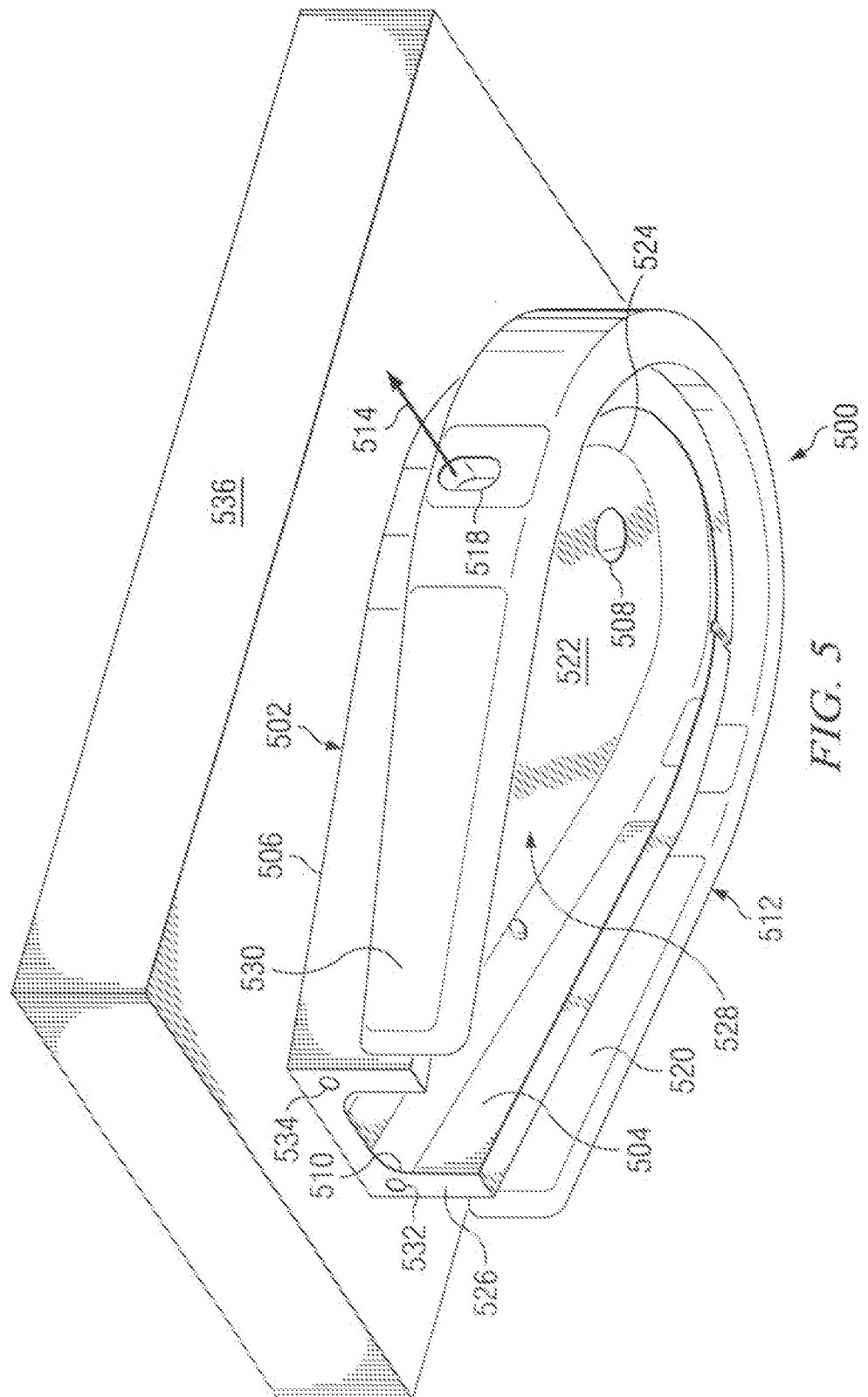
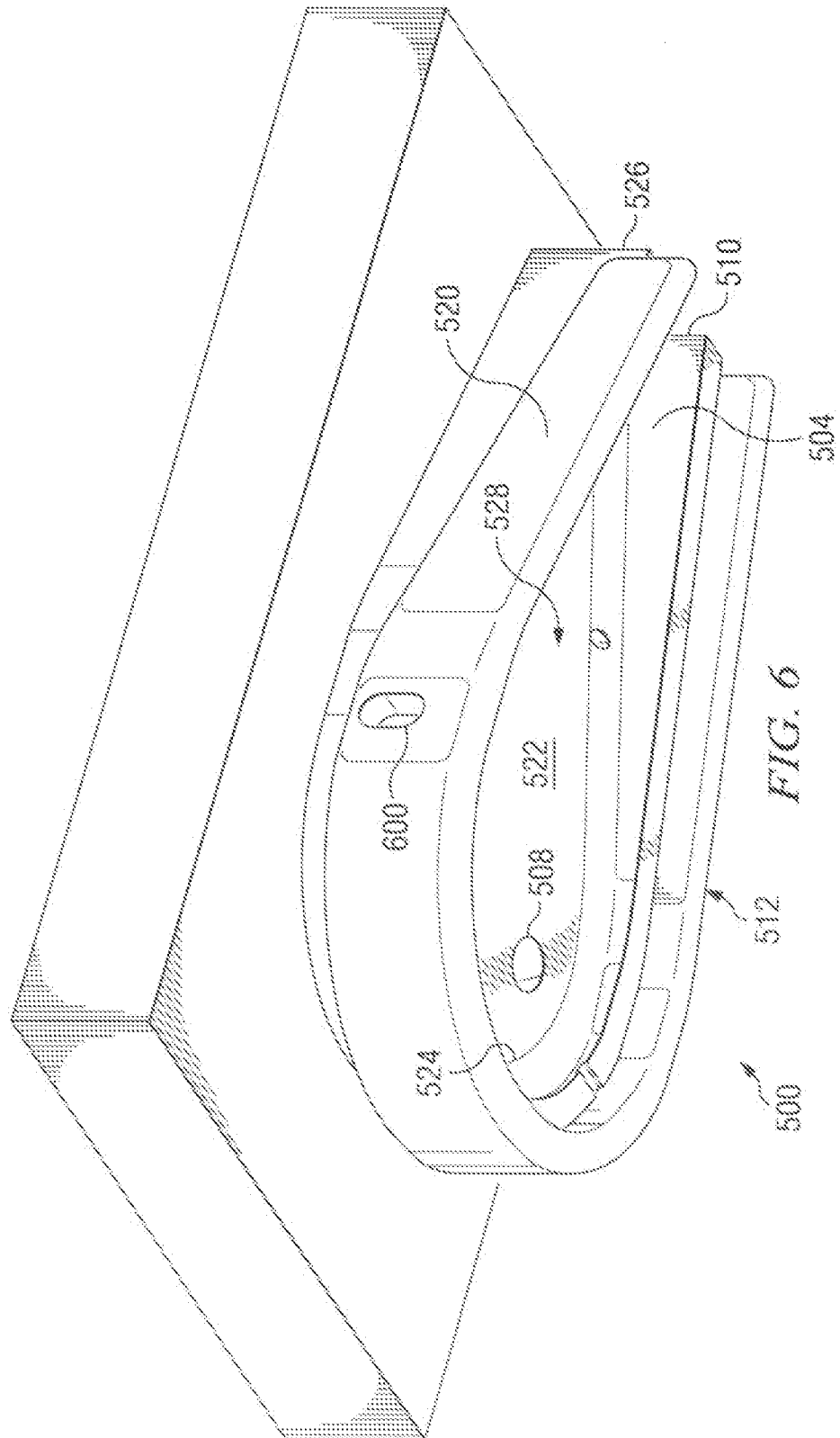


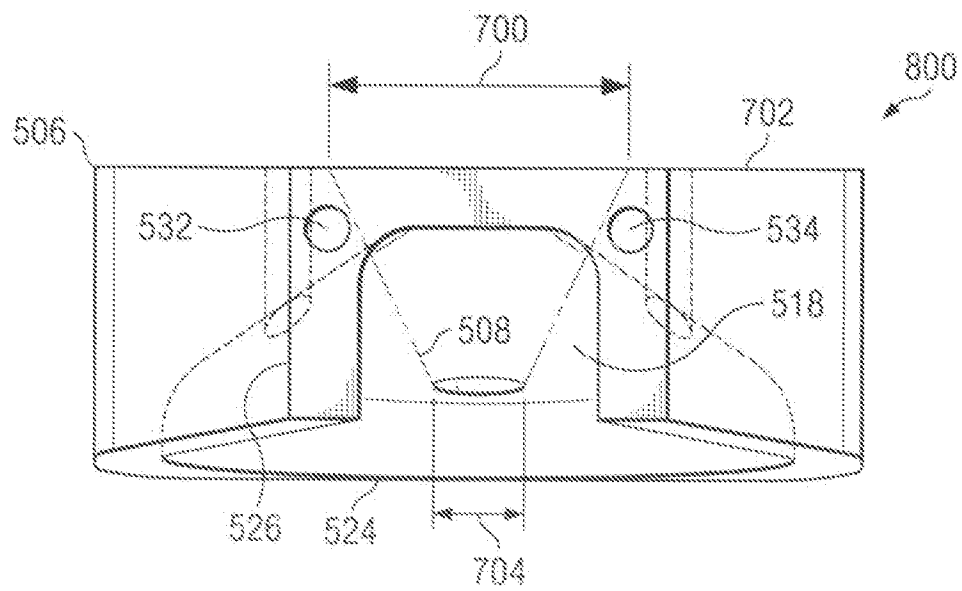
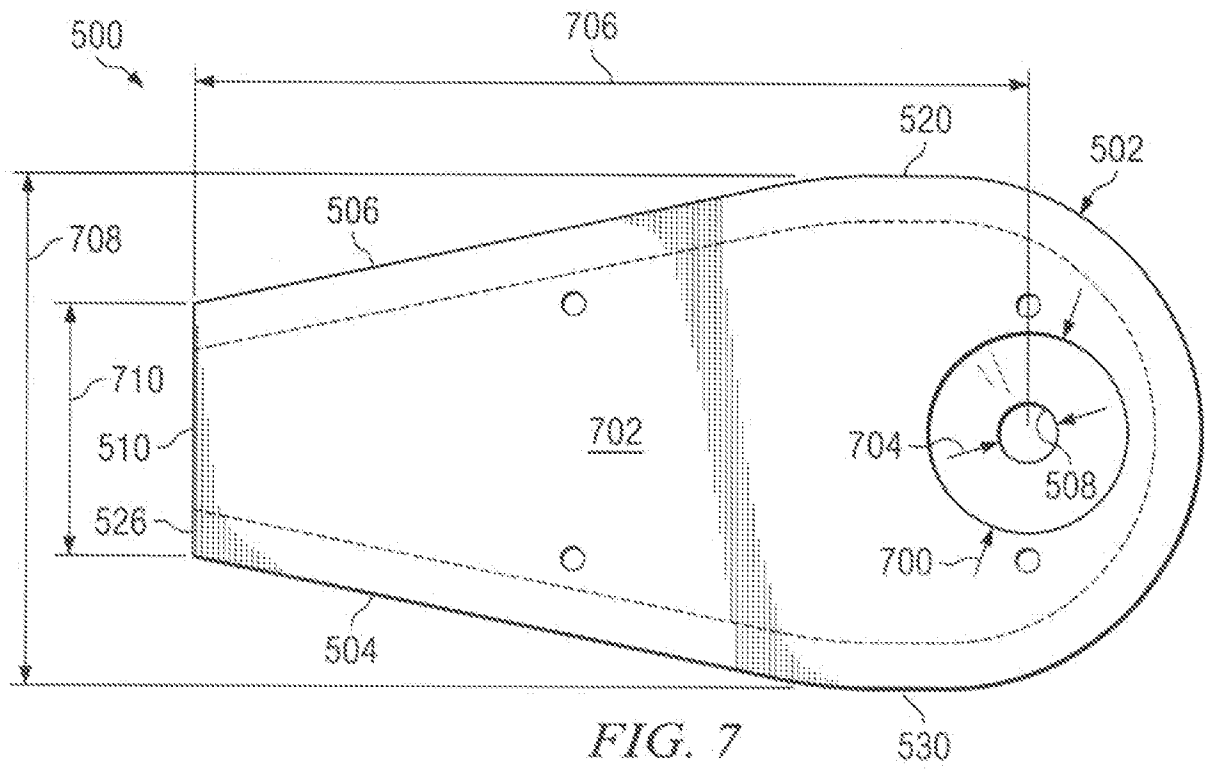
FIG. 4



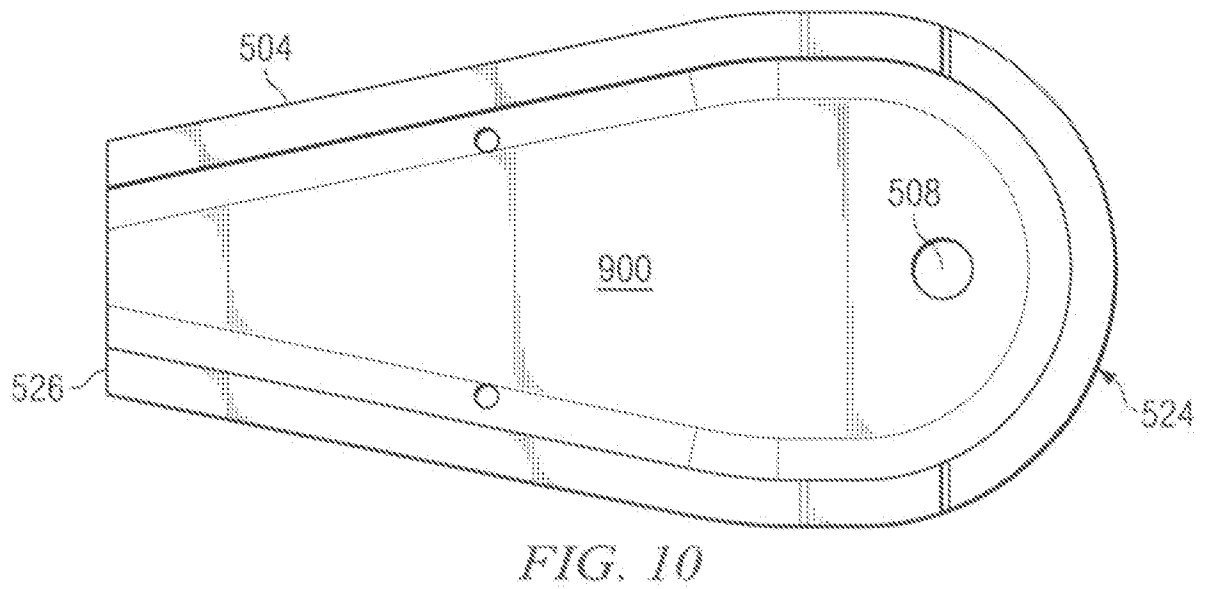
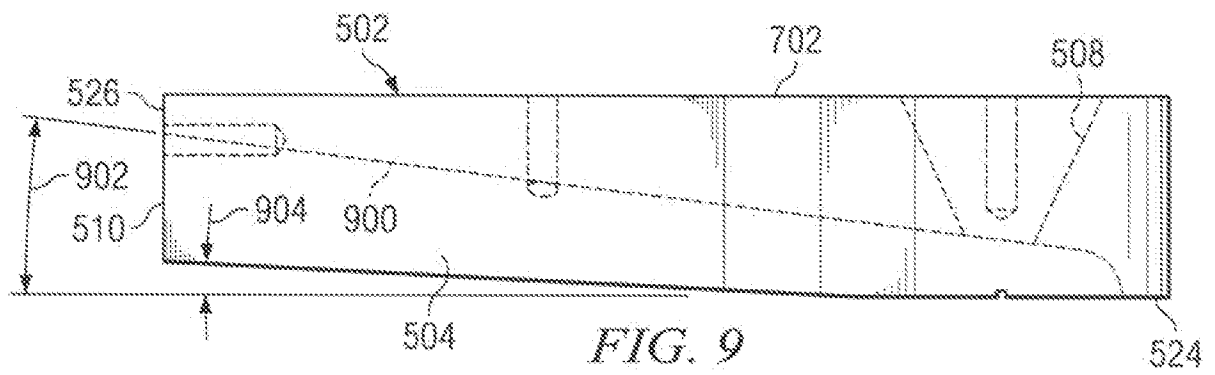
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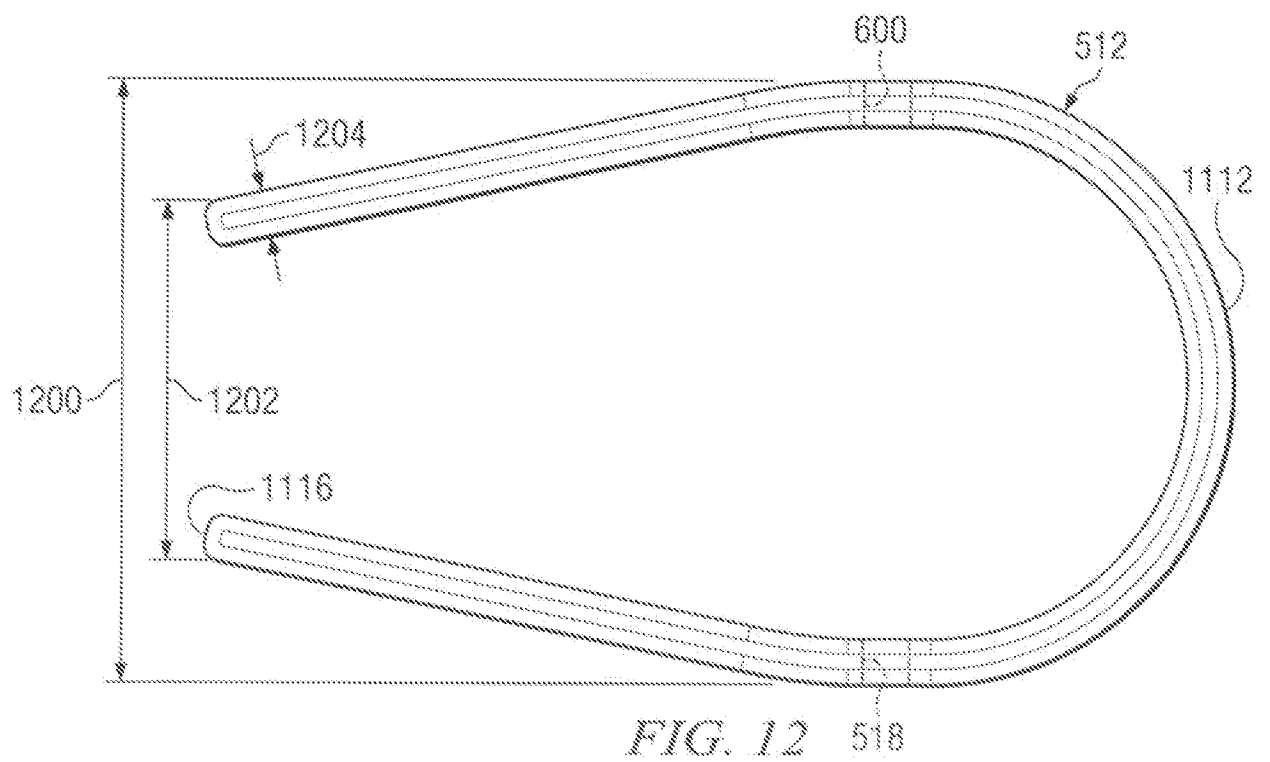
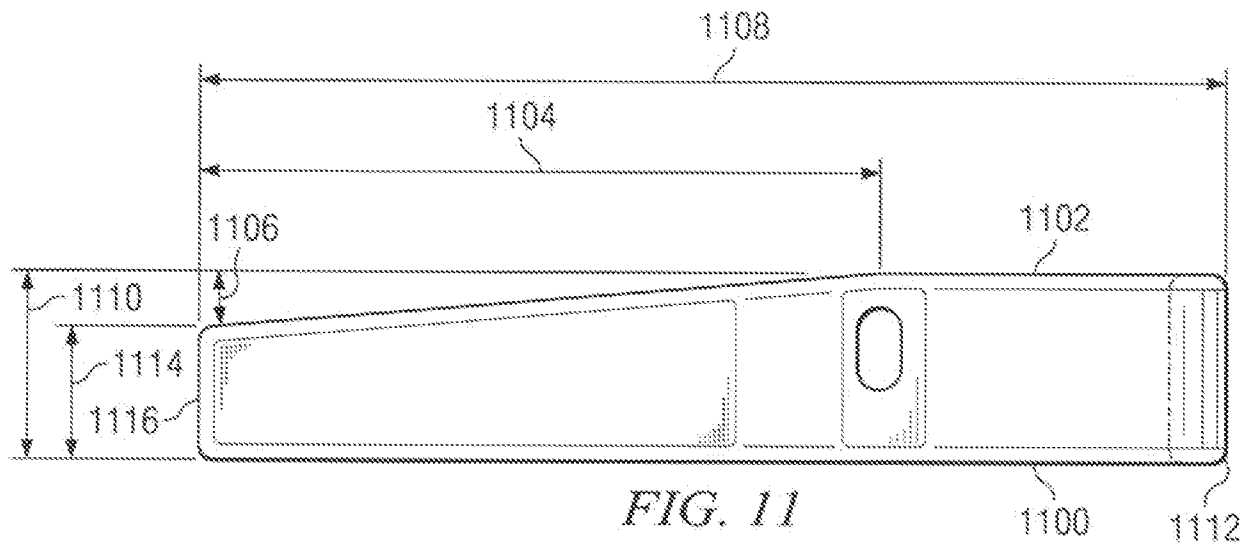
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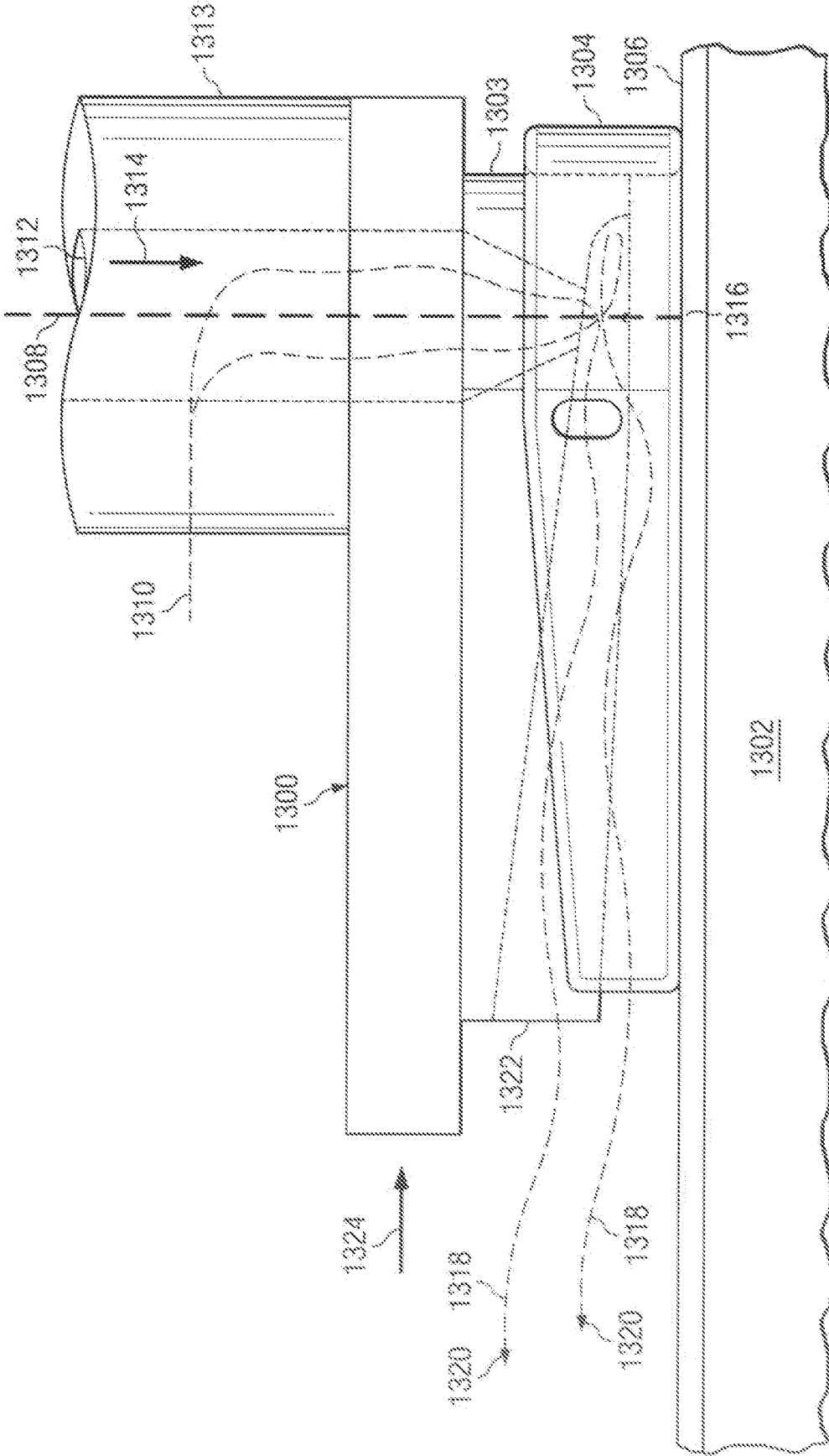


FIG. 13

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2009/062434

A. CLASSIFICATION OF SUBJECT MATTER

INV. B23K26/12 B23K26/20 B23K26/14 F23D14/54 B23K26/16
B23K28/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B23K F23D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	column 4, line 15 - column 6, line 10; figures 4-7	2-3, 16-17, 19-20
Y	EP 1 669 159 A1 (BYSTRONIC LASER AG) 14 June 2006 (2006-06-14) paragraphs [0024] - [0026]; figure 3	2-3,17
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Further documents are listed in the continuation of Box C.



See patent family annex.

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search

2 February 2010

Date of mailing of the international search report

10/02/2010

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INTERNATIONAL SEARCH REPORT

International application No

PCT/US2009/062434

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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