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### HIGH-FREQUENCY WELDING FOR HEADGEAR

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#### Abstract

Welded headgear sections can be produced by using a weld tool having pins protruding from a weld region contact surface to deliver high-frequency electromagnetic energy to a weld region defined by overlapping top and bottom headgear straps. The pins fully penetrate the top strap and at least partially penetrate the bottom strap. The pins concentrate the electromagnetic energy to achieve a weld joint of acceptable weld strength and aesthetic appeal.

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## Background/Summary

### INCORPORATION BY REFERENCE OF PRIORITY APPLICATIONS

[0001] The entireties of any and all priority applications are hereby incorporated by reference herein and made a part of the present disclosure.

### BACKGROUND

#### Technical Field

[0002] The present disclosure generally relates to headgear for patient interfaces.

#### Description of the Related Art

[0003] In patients suffering from obstructive sleep apnea (OSA), muscles that normally keep the upper airway open relax during slumber to the extent that the airway is constrained or completely closed off, a phenomenon often manifesting itself in the form of snoring. When this occurs for a period of time, the patient's brain typically recognizes a threat of hypoxia and partially wakes the patient in order to open the airway so that normal breathing may resume. The patient may be unaware of these waking episodes, which may occur as many as several hundred times per session of sleep. This partial awakening may significantly reduce the quality of the patient's sleep, over time potentially leading to a variety of symptoms, including excessive daytime sleepiness, chronic fatigue, elevated heart rate, elevated blood pressure, weight gain, headaches, irritability, depression and anxiety.

[0004] Obstructive sleep apnea is commonly treated with the application of positive airway pressure (PAP) therapy. PAP therapy involves delivering a flow of gas to a patient at a therapeutic pressure above atmospheric pressure that will reduce the frequency and/or duration of apneas, hypopneas, and/or flow limitations. The therapy is often implemented by using a positive airway pressure device to deliver a pressurized stream of air through a conduit to a patient through a patient interface or mask positioned on the face of the patient.

### SUMMARY

[0005] A patient interface for use with PAP therapy or other respiratory therapies involving the administration of gas can comprise headgear that helps to retain the patient interface on the face of a patient. The headgear generally interfaces with a frame that serves as a channel through which gas is delivered to the patient and the headgear comprises one or more straps that pass around the patient's head. To reduce the material waste and cost of producing headgear, instead of producing the entire headgear from a single blank of material, it is desirable to cut headgear straps from the material and join them via stitching, adhesives, or welding processes, e.g., high-frequency welding processes. In high-frequency welding, the straps can be overlapped to define an overlap weld region. The straps can be forced together (e.g., placed under pressure) through the use of a weld tool adapted to deliver high-frequency energy to the weld region. High-frequency welding is useful for joining straps quickly and in a sterile manner. However, in some cases, the welded joints can have visible markings, burns or bulges that reduce the aesthetic appeal and/or comfort of the headgear.

[0006] Certain features, aspects and advantages of at least one of the configurations disclosed herein include the realization that overlapping headgear straps or other materials can be joined through the use of a weld tool adapted to deliver high-frequency energy, wherein the weld tool

comprises pins extending from a contact surface of the weld tool that at least partially penetrate each of the overlapping headgear straps. To diffuse the heat and/or energy generated at the contact surface of the weld tool near the pins, portions of the surface of the weld tool surrounding the pins can be inwardly chamfered. The contact surface of the weld tool can have beveled or rounded edges to further reduce the undesired concentration of energy along parts of the surfaces of headgear straps. One or both of the headgear straps can be specially formed to reduce potential distortions in shape encountered in the welding process. More aesthetically pleasing and/or comfortable headgear may thus be formed.

[0007] Thus, in accordance with certain features, aspects and advantages of at least one of the embodiments disclosed herein, a method of producing headgear for a patient interface is disclosed. The method comprises using a weld tool to apply high-frequency energy to a weld region defined by overlapping top and bottom straps. The weld tool comprises pins that at least partially penetrate both the top and bottom straps. In some configurations, the pins may extend from a contact surface of the weld tool. In some configurations, the material comprised in at least one of the straps may be at least in part polar or may comprise polar molecules, moieties or sections.

[0008] In some configurations, the top and bottom headgear straps are positioned on a weld base and the weld tool is forced against the weld region to apply pressure to the headgear straps.

[0009] In some configurations, the pins fully penetrate the top headgear strap and partially penetrate the bottom headgear strap. In some such configurations, the pins penetrate 20% or about 20% of the depth of the bottom headgear strap. In other configurations, the pins penetrate 1% to 99% or about 1% to about 99% of the depth of the bottom headgear strap, or about 10% to about 90%, or about 20% to about 80%, or about 30% to about 70%, or about 40% to about 60%, or about 50% of the depth of the bottom headgear strap.

[0010] In some configurations, the surface of the weld tool that faces the weld region (e.g., the contact surface of the weld tool) comprises beveled or rounded edges.

[0011] In some configurations, portions of the surface of the weld tool surrounding the pins are inwardly chamfered. In some such configurations, the chamfered portions are substantially arcuate or rounded. In some such configurations, the substantially arcuate chamfered portions are defined by crater-like recesses present in the surface of the weld tool. In some such configurations, the curvatures of the sides of the crater-like recesses are defined by substantially circular cross-sections of the weld tool having radii  $x$  that are proportional to the average distance between pins  $y$  according to the range of ratios  $x:y=0.3$  to  $0.4$  or about  $0.3$  to about  $0.4$ .

[0012] In some configurations, the pins are arranged in a plurality of rows. In some such configurations, the rows are offset such that pins are present in a honeycomb arrangement.

[0013] In some configurations, the pins are arranged such that each pin is substantially equidistant from adjacent pins.

[0014] In some configurations, either of top or bottom headgear straps comprises an edge section and a body section, the edge section having a smaller width than the body section. In some such configurations, the width of the edge section is in the range of 80% to 90% or about 80% to about 90% of the width of the body section. A substantially curved transition region can lie between the body section and the edge section.

[0015] In some configurations, the average distance between adjacent pins is in the range of about 1.5 mm to about 2.0 mm.

[0016] In some configurations, the average distance between adjacent pins is in the range of about 3 to about 4 times the average width of the pins.

[0017] Additionally, in accordance with certain features, aspects and advantages of at least one of the embodiments disclosed herein, a method of welding two straps of material together is disclosed. The method comprises using a weld tool to apply high-frequency energy to a weld region defined by overlapping top and bottom straps. The weld tool comprises pins that fully penetrate the top strap and penetrate 20% or about 20% of the depth of the bottom strap. In other

configurations, the pins penetrate 1%-99% or about 1%-about 99% of the depth of the bottom strap, or about 10% to about 90%, or about 20% to about 80%, or about 30% to about 70%, or about 40% to about 60%, or about 50% of the depth of the bottom strap. The material comprised in at least one of the straps is at least in part polar or comprises polar molecules, moieties or sections. [0018] In some configurations, the top and bottom straps are positioned on a weld base and the weld tool is forced against the weld region to apply pressure to the straps.

[0019] In some configurations, the surface of the weld tool that faces the weld region (e.g., the contact surface of the weld tool) comprises beveled or rounded edges.

[0020] In some configurations, portions of the surface of the weld tool surrounding the pins are inwardly chamfered. In some such configurations, the chamfered portions are substantially arcuate. In some such configurations, the substantially arcuate chamfered portions are defined by crater-like recesses present in the surface of the weld tool. In some such configurations, the curvatures of the sides of the crater-like recesses are defined by substantially circular cross-sections of the weld tool having radii  $x$  that are proportional to the average distance between pins  $y$  according to the range of ratios  $x:y=0.3$  to  $0.4$  or about  $0.3$  to about  $0.4$ .

[0021] In some configurations, the pins are arranged in a plurality of rows. In some such configurations, the rows are offset such that the pins are present in a honeycomb arrangement.

[0022] In some configurations, the pins are arranged such that each pin is substantially equidistant from adjacent pins.

[0023] In some configurations, either the top or bottom straps comprises an edge section and a body section, the edge section having a smaller width than the body section. In some such configurations, the width of the edge section is in the range of 80% to 90% or about 80% to about 90% of the width of the body section. A substantially curved transition region can lie between the body section and the edge section.

[0024] In some configurations, the average distance between adjacent pins is in the range of 1.5 mm to 2.0 mm or about 1.5 mm to about 2.0 mm.

[0025] In some configurations, the average distance between adjacent pins is in the range of 3 to 4 or about 3 to about 4 times the average width of the pins.

[0026] Additionally, in accordance with certain features, aspects and advantages of at least one of the embodiments disclosed herein, a method of welding two straps of material together is disclosed. The method comprises using a weld tool to apply high-frequency energy to a weld region defined by overlapping top and bottom straps, wherein either the top or bottom straps comprises an edge section and a body section, the edge section having a smaller width than the body section. The material comprised in at least one of the straps is at least in part polar or comprises polar molecules, moieties or sections.

[0027] In some configurations, the weld tool comprises pins that at least partially penetrate both the top and bottom straps. In some such configurations, pins fully penetrate the top strap and partially penetrate the bottom strap. The pins can be arranged in a plurality of rows. In some such configurations, the rows are offset such that the pins are present in a honeycomb arrangement. The pins can be arranged such that each pin is substantially equidistant from adjacent pins.

[0028] In some configurations, portions of the surface of the weld tool surrounding the pins are inwardly chamfered. In some such configurations, the chamfered portions are substantially arcuate. In some such configurations, the substantially arcuate chamfered portions are defined by crater-like recesses present in the surface of the weld tool. In some such configurations, the curvatures of the sides of the crater-like recesses are defined by substantially circular cross-sections of the weld tool having radii  $x$  that are proportional to the average distance between pins  $y$  according to the ratio  $x:y=\text{about } 0.3$  to about  $0.4$ .

[0029] In some configurations, the top and bottom straps are positioned on a weld base and the weld tool is forced against the weld region to apply pressure to the straps.

[0030] In some configurations, the surface of the weld tool that faces the weld region (e.g., the

contact surface of the weld tool) comprises beveled or rounded edges.

[0031] Additionally, in accordance with certain features, aspects and advantages of at least one of the embodiments disclosed herein, a method of welding two straps of material together is disclosed. The method comprises using a weld tool to apply high-frequency energy to a weld region defined by overlapping top and bottom straps, the weld tool comprising pins that at least partially penetrate both the top and bottom straps, wherein the portions of the surface of the weld tool surrounding the pins are inwardly chamfered. The material is at least in part polar or comprises polar molecules.

[0032] In some configurations, the chamfered portions are substantially arcuate. In some such configurations, the substantially arcuate chamfered portions are defined by crater-like recesses present in the surface of the weld tool. In some such configurations, the curvatures of the sides of the crater-like recesses are defined by substantially circular cross-sections of the weld tool having radii  $x$  that are proportional to the average distance between pins  $y$  according to the ratio  $x:y$ =about 0.3 to about 0.4.

[0033] Additionally, in accordance with certain features, aspects and advantages of at least one of the embodiments disclosed herein, a method of welding two straps of material together is disclosed. The method comprises forcing a weld tool against a weld region defined by overlapping top and bottom straps positioned on a weld base and applying high-frequency energy using the weld tool, the weld tool comprising pins that at least partially penetrate both the top and bottom straps, wherein a surface of the weld tool that contacts the weld region comprises beveled or rounded edges.

[0034] Additionally, in accordance with certain features, aspects and advantages of at least one of the embodiments disclosed herein, headgear is disclosed. The headgear is produced at least in part using one or more of the methods described above or elsewhere in this disclosure.

[0035] Additionally, in accordance with certain features, aspects and advantages of at least one of the embodiments disclosed herein, a patient interface is disclosed. The patient interface comprises headgear produced at least in part using one or more of the methods described above or elsewhere in this disclosure. In some configurations, the patient interface further comprises a cushion module adapted to be positioned over the face of a patient and a frame removably secured to the cushion module, the frame adapted to receive a gases flow from a flow generator.

[0036] Additionally, in accordance with certain features, aspects and advantages of at least one of the embodiments disclosed herein, a respiratory therapy system is disclosed. The respiratory therapy system comprises a flow generator (e.g. PAP device), a patient interface and a conduit extending between the flow generator and the patient interface. In some configurations, the respiratory therapy system also comprises a humidifier in-line between the flow generator and the patient interface. The patient interface comprises headgear produced at least in part using one or more of the methods described above or elsewhere in this disclosure.

[0037] Additionally, in accordance with certain features, aspects and advantages of at least one of the embodiments disclosed herein, a weld tool is disclosed. The weld tool is adapted to be used in a high-frequency welding process. The weld tool comprises a plurality of pins extending from a contact surface of the weld tool, wherein portions of the contact surface surrounding the pins are inwardly chamfered.

[0038] In some configurations, the chamfered portions are substantially arcuate. In some such configurations, the substantially arcuate chamfered portions are defined by crater-like recesses present in the surface of the weld tool. In some such configurations, the curvatures of the sides of the crater-like recesses are defined by substantially circular cross-sections of the weld tool having radii  $x$  that are proportional to the average distance between pins  $y$  according to the ratio  $x:y$ =about 0.3 to about 0.4.

[0039] In some configurations, the pins are arranged in a plurality of rows. In some configurations, the rows are offset such that the pins are present in a honeycomb arrangement. The pins can be

arranged such that each pin is substantially equidistant from adjacent pins.

[0040] Additionally, in accordance with certain features, aspects and advantages of at least one of the embodiments disclosed herein, a weld tool is disclosed. The weld tool is adapted to be used in a high-frequency welding process. The weld tool comprises a plurality of pins extending from a contact surface of the weld tool. The contact surface comprises beveled or rounded edges.

[0041] In some configurations, the pins are arranged in a plurality of rows. In some such configurations, the rows are offset such that the pins are present in a honeycomb arrangement. The pins can be arranged such that each pin is substantially equidistant from adjacent pins.

[0042] Additionally, in accordance with certain features, aspects and advantages of at least one of the embodiments disclosed herein, a welding system is disclosed. The welding system comprises a weld tool adapted to be used in a high-frequency welding process. The weld tool comprises a plurality of pins extending from a contact surface of the weld tool. At least portions of the contact surface of the weld tool surrounding the pins are inwardly chamfered. The welding system additionally comprises a weld base. The weld base is adapted to support material to be welded. In use, the weld tool is forced against the material supported by the base.

[0043] In some configurations, the welding system additionally comprises a stop adapted to limit the range of axial motion between the weld tool and the weld base. In some such configurations, the stop extends outwardly from the weld tool and rests upon a raised portion of the weld base.

[0044] In some configurations, the chamfered portions are substantially arcuate. In some such configurations, the substantially arcuate chamfered portions are defined by crater-like recesses present in the surface of the weld tool. In some such configurations, the curvatures of the sides of the crater-like recesses are defined by substantially circular cross-sections of the weld tool having radii  $x$  that are proportional to the average distance between pins  $y$  according to the ratio  $x:y$ =about 0.3 to about 0.4.

[0045] In some configurations, the pins are arranged in a plurality of rows. In some such configurations, the rows are offset such that the pins are present in a honeycomb arrangement. The pins can be arranged such that each pin is substantially equidistant from adjacent pins.

[0046] Additionally, in accordance with certain features, aspects and advantages of at least one of the embodiments disclosed herein, a welding system is disclosed. The welding system comprises a weld tool adapted to be used in a high-frequency welding process. The weld tool comprises a plurality of pins extending from a contact surface of the weld tool. The contact surface comprises beveled or rounded edges. The welding system additionally comprises a weld base. The weld base is adapted to support material to be welded. In use, the weld tool is forced against the material supported by the base.

[0047] In some configurations, the welding system further comprises a stop adapted to limit the range of axial motion between the weld tool and the weld base. In some such configurations, the stop extends outwardly from the weld tool and rests upon a raised portion of the weld base.

[0048] Additionally, in accordance with certain features, aspects and advantages of at least one of the embodiments disclosed herein, a welding system for welding together top and bottom sheets of fabric is disclosed. The welding system comprises a weld tool adapted to be used in a high-frequency welding process. The weld tool comprises a plurality of pins extending from a contact surface of the weld tool. The welding system additionally comprises a weld base. The weld base has a cavity to support the top and bottom sheets in an overlapping relationship. The weld tool and the cavity have a corresponding shape such that the weld tool engages the cavity and the contact surface applies pressure to the top and bottom sheets.

[0049] In some configurations, the pins are arranged in a single-file row along an outer edge of the weld tool.

[0050] In some configurations, the pins are arranged in a double-file row along an outer edge of the weld tool.

[0051] In some configurations, the pins are arranged in a staggered row along an outer edge of the

weld tool.

[0052] In some configurations, the pins have a diameter within a range of 0.3 mm to 1.0 mm.

[0053] In some configurations, centers of the pins are spaced apart a distance of 2.5 mm to 6.0 mm.

[0054] In some configurations, the weld tool is formed from a thermally insulating material.

[0055] In some configurations, the contact surface of the weld tool has a thermally insulating coating.

[0056] In some configurations, the pins are arranged in a plurality of rows. In some such configurations, the rows are offset such that the pins are present in a honeycomb arrangement. The pins can be arranged such that each pin is substantially equidistant from adjacent pins.

[0057] In some configurations, the pins in the honeycomb arrangement are arranged in a hexagonal shape around a center pin.

[0058] In some configurations, the pins arranged in the hexagonal shape are enclosed within a hexagonal-shaped area that surrounds the pins. Outer segments that define the hexagonal-shaped area are tangent to outer edges of outermost adjacent pins. A pin density ratio is defined as a ratio between a total area of the pins versus an area of the hexagonal-shaped area.

[0059] In some configurations, the pin density ratio is equal to 33.85%.

[0060] In some configurations, each pin has a diameter of 0.5 mm, and wherein a distance between each pin is 1.0 mm.

[0061] In some configurations, the pins in the honeycomb arrangement are arranged in concentric hexagons around a center pin.

[0062] In some configurations, the pins arranged in concentric hexagons are enclosed within a hexagonal-shaped area that surrounds the pins. Outer segments that define the hexagonal-shaped area are tangent to outer edges of outermost adjacent pins. A pin density ratio is defined as a ratio between a total area of the pins versus an area of the hexagonal-shaped area.

[0063] In some configurations, the pin density ratio is equal to 28.37%.

[0064] In some configurations, each pin has a diameter of 0.5 mm and a distance between each pin is 1.0 mm. The honeycomb arrangement can have two concentric hexagons, and a radial distance between centers of adjacent pins is 1.0 mm.

[0065] In some configurations, the pins are arranged in a concentric circular arrangement having pins arranged in at least one concentric circle around a center pin.

[0066] In some configurations, the pins arranged in at least one concentric circle are enclosed within a circular-shaped area that surrounds the pins. An outermost circle that defines the circular area is defined by radially outermost points of the outermost pins. A pin density ratio is defined as a ratio between a total area of the pins versus an area of the circular-shaped area.

[0067] In some configurations, the pin density ratio is equal to 18.34%.

[0068] In some configurations, each pin has a diameter of 0.5 mm. The concentric circular arrangement includes three concentric circles, and a radial distance between centers of adjacent pins is 1.0 mm.

[0069] In some configurations, the pins are arranged in a square grid arrangement having each row squarely aligned with an adjacent row and each row having a quantity of pins that is equal to a quantity of rows.

[0070] In some configurations, the pins are arranged such that each pin is spaced equidistant to an adjacent pin.

[0071] In some configurations, an orthogonal distance between an outer edge of each pin is equal a diameter of each pin. The pins arranged in the square grid arrangement are enclosed within a square-shaped area that surrounds the pins. Outer segments that define the square-shaped area are tangent to outer edges of outermost adjacent pins. A pin density ratio is defined as a ratio between a total area of the pins versus an area of the square-shaped area.

[0072] In some configurations, the pin density ratio is equal to 21.71%.

[0073] In some configurations, the diameter of each pin is equal to 0.5 mm.

[0074] In some configurations, the pins have either a first diameter or a second diameter, and the pins alternate between the first diameter and the second diameter along a length of each row.

[0075] In some configurations, the pins arranged in the square grid arrangement are enclosed within a square-shaped area that surrounds the pins. Outer segments that define the square-shaped area are tangent to outer edges of outermost alternating pins. A pin density ratio is defined as a ratio between a total area of the pins versus an area of the square-shaped area.

[0076] In some configurations, the pin density ratio is equal to 13.59%

[0077] In some configurations, the first diameter is equal to 0.5 mm and the second diameter is equal to 0.25 mm. An orthogonal distance between an outer edge of each pin is equal 0.625 mm.

[0078] In some configurations, the pins are arranged such that each pin is spaced equidistant to an adjacent pin along a length of the row.

[0079] In some configurations, the pins are enclosed within a square-shaped area that surrounds the pins. Outer segments that define the square-shaped area are tangent to outer edges of outermost pins. A pin density ratio is defined as a ratio between a total area of the pins versus an area of the square-shaped area.

[0080] In some configurations, the pin density ratio is equal to 19.63%.

[0081] In some configurations, the diameter of each pin is equal to 0.5 mm and a distance between centers of pins of adjacent rows in a direction perpendicular to a length of the row is 1.0 mm.

[0082] In some configurations, the pins have identical diameters along a length of the row and the pins in each row alternate between a first diameter and a second diameter.

[0083] In some configurations, the pins are enclosed within a square-shaped area that surrounds the pins. Outer segments that define the square-shaped area are tangent to outer edges of outermost pins. A pin density ratio is defined as a ratio between a total area of the pins versus an area of the square-shaped area.

[0084] In some configurations, the pin density ratio is equal to 14.09%.

[0085] In some configurations, the first diameter is equal to 0.5 mm and the second diameter is equal to 0.25 mm. A distance between centers of adjacent pins along a length of the row is equal to 1.0 mm, and a distance between centers of pins of adjacent rows in a direction perpendicular to a length of the row is 1.0 mm.

[0086] In some configurations, the pin densities are within a range of 10-50%.

[0087] In some configurations, the pin densities are within a range of 15-35%.

[0088] In some configurations, the pin densities are within a range of 15-25%.

[0089] In some configurations, the pins have a pointed tip.

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## Description

### BRIEF DESCRIPTION OF THE DRAWINGS

[0090] Specific embodiments and modifications thereof will become apparent to those skilled in the art from the detailed description herein having reference to the figures that follow, of which:

[0091] FIG. 1 shows a schematic diagram of a respiratory therapy system.

[0092] FIGS. 2A and 2B show rear perspective and front views, respectively, of a patient wearing a patient interface.

[0093] FIG. 3 shows a view of respiratory headgear that is shown in FIGS. 2A and 2B.

[0094] FIG. 4 shows a high-frequency welding system.

[0095] FIG. 5 shows a weld tool for use in high-frequency welding.

[0096] FIGS. 6A-6D show a top-down diagram detailing the positioning of various components during a high-frequency welding process.

[0097] FIGS. 7A-7D show a side view of a process of high-frequency welding a pair of overlapping straps together.



[0098] FIGS. **8A-8L** show various views of weld tools for use in high-frequency welding.

[0099] FIGS. **9A** and **9B** show a cross-section of a diagram of a high-frequency welding system and a close-up view of the cross-section of the diagram, respectively.

[0100] FIG. **10** shows a cross-section of a diagram of a high-frequency welding system.

[0101] FIG. **11** shows a close-up cross-sectional view of a pair of welded straps.

[0102] FIG. **12** shows a close-up view of a cross-section of straps and a pin having pointed tip.

[0103] FIG. **13** shows a plan view of a high-frequency welding system.

[0104] FIG. **14** shows a side view illustrating the weld tool inserted into the weld base of the high-frequency welding system.

[0105] FIG. **15** shows a side view illustrating the weld tool partially inserted into the weld base of the high-frequency welding system.

[0106] FIGS. **16A-16D** show a headgear strap welded by the high-frequency welding system.

[0107] FIGS. **17A** and **17B** show alternative pin arrangements for the high-frequency welding system.

#### DETAILED DESCRIPTION

[0108] With reference to the non-limiting exemplary embodiment illustrated in FIG. **1**, a respiratory therapy system **100** is shown. The respiratory therapy system **100** comprises a flow generator **102**. The flow generator **102** comprises a PAP device. The flow generator **102** receives gases from a gases inlet **104** and propels them to a humidifier **106**. The flow generator **102** and the humidifier **106** may be part of an integrated flow delivery system or may share a housing **108**. The humidifier **106** heats and humidifies the gases. Heated and humidified gases are passed from a humidifier outlet to a gases conduit **112**. The gases conduit **112** comprises a heater **114**. The heater **114** reduces or prevents the condensation of moisture along the walls of the gases conduit **112**. Gases are passed from the gases conduit **112** to a patient interface **200** through which they are delivered to a patient. The respiratory therapy system **100** comprises a controller **111** that controls the operation of the flow generator **102**. The controller **111** also controls the operation of the humidifier **106**. The respiratory therapy system **100** comprises an input/output (I/O) module **110**. The I/O module **110** comprises a way for a user to interact with and set parameters for the flow generator **102** and/or humidifier **106** as well as receive information regarding the operation of the respiratory therapy system **100** and/or its components. The I/O module **110** may comprise, for example, buttons, knobs, dials, switches, levers, touch screens, speakers, displays and/or other input or output elements. In some configurations, the humidifier **106** may not be present. In some configurations, the gas conduit **112** may not have a heater **114**. In some configurations, the flow generator **102** may comprise elements other than PAP devices, including but not limited to high flow therapy devices or ventilation devices.

[0109] FIGS. **2A** and **2B** demonstrate a non-limiting patient interface **200** that can be used with the respiratory therapy system **100** shown in FIG. **1**. As illustrated, the patient interface **200** comprises a nasal mask. In some configurations, the patient interface **200** may comprise a sealing or non-sealing interface. For example, the patient interface **200** may comprise an oral mask, an oro-nasal mask, a full face mask, a nasal pillows mask, an endotracheal tube, a combination of the above, or some other gas conveying system or apparatus.

[0110] The patient interface **200** shown comprises a frame **202** adapted to receive gases from a gases source (for example, the flow generator **102** described elsewhere in this disclosure with reference to FIG. **1**) and channel them to the patient. An aperture **204** in the frame **202** is adapted to receive an elbow component **206** configured to interface with a gases delivery conduit (for example, the gases conduit **112** described elsewhere in this disclosure with reference to FIG. **1**). The elbow component **206** may be adapted to swivel or rotate (through, for example, a ball-joint connection). The elbow component **206** comprises vent holes **207** that permit a leak flow to escape the patient interface **200**. The vent holes **207** can help to mitigate the build-up of carbon dioxide in the patient interface **200** and/or gas delivery conduit. The frame **202** interfaces with a cushion

module **220**. The cushion module **220** comprises a relatively rigid or hard cushion housing adapted to interface with the frame **202** and a relatively flexible or soft cushion adapted to sealingly engage with the patient's face to provide a substantially sealed gas passageway between the patient and the gases delivery conduit. The frame **202** comprises a neck **208** that substantially extends along the head of the patient across, for example, the nasalis muscles and the procerus muscles. The neck **208** ends in a forehead support **210** comprising first and second hooked legs **212**, **213**. Openings **214**, **215** are defined between the hooked legs **212**, **213** and the forehead support **210**. The frame **202** also comprises apertures **216**, **218**.

[0111] Headgear **300** interfaces with the frame **202** to provide a way for retaining the patient interface **200** on the face. A four-point connection with the frame **202** is made available using the openings **214**, **215** present near the forehead support **210** and using the apertures **216**, **218** present on the frame **202**. The headgear **300** comprises left and right top straps **304**, **302** and left and right bottom straps **308**, **306**. The top and bottom straps **302**, **304**, **306**, **308** join at a back section **316**. The back section **316** comprises a top back strap **318** and a bottom back strap **320**. The headgear **300** additionally comprises a crown strap **314** that extends between the left and right top straps **304**, **302**. To interface with the frame **202**, the left and right bottom straps **308**, **306** are looped through openings **223**, **221** present in hook connectors **217**, **219** that are retained in the apertures **216**, **218** present on the frame **202**. The left and right bottom straps **308**, **306** comprise loop patches **316**, **314** that allow the straps **308**, **306** to be loosened or tightened and fixed into place (for example, using corresponding hooked regions on the straps **308**, **306** to facilitate a hook-and-loop fastening arrangement) after they are looped through the openings **223**, **221**. The left and right top straps **304**, **302** are looped at the ends. The looped ends are placed over the hooked legs **212**, **213** such that they are retained between the forehead support **210** and the hooked legs **212**, **213**. Similarly, the left and right top straps **304**, **302** comprise loop patches **312**, **310** that allow straps **304**, **302** to be loosened or tightened and fixed into place (for example, using corresponding hooked regions on the straps **304**, **302** to facilitate a hook-and-loop fastening arrangement) after they are positioned on the hooked legs **212**, **213**.

[0112] FIG. **3** shows another view of the headgear **300** illustrated in FIGS. **2A** and **2B**. As shown, the headgear **300** comprises a plurality of strap sections **S** joined at joints **J**. In particular, the left and right top straps **304**, **302** form strap sections **S1**, **S2** and are joined at **J5** to form the top back strap **318** of the back section **316**. The left and right top straps **304**, **302** are also joined at joints **J7**, **J6** via the crown strap **314**, which forms strap section **S3**. The bottom back strap **320**, which forms strap section **S4** is joined to the top back strap **318** through joints **J4**, **J3**, and interfaces with left and right bottom straps **308**, **306** (sections **S5**, **S6**) through joints **J2**, **J1**. In the illustrated configuration, the joints **J** are formed through the use of high-frequency welding. The strap sections **S** can be formed from any material appropriate for use with respiratory headgear, including but not limited to fabrics, fabric/foam composites or Breath-O-Prene™.

[0113] FIG. **4** illustrates a high-frequency welding system **400** adapted to manufacture headgear from sections (e.g. strap sections) **S** of headgear (for example, but not limited to, the headgear described elsewhere in this disclosure with reference to FIG. **3**). High-frequency welding as described in this disclosure refers to a method of joining sections of material (e.g., straps, sheets, films, etc.) (the material comprised in at least one of the sections at least in part being polar or comprising polar molecules, moieties or sections) together using a rapidly alternating electric field (including, but not necessarily limited to, electric fields having alternation frequencies in the range of 13 to 100 or about 13 to about 100 megahertz, or, for example, 27.12 or about 27.12 megahertz). The welding system **400** comprises a weld base (e.g., anvil) **402** comprising a relatively elevated section **403** and a relatively depressed section **404** adapted to hold overlapping straps of headgear. A stop plate **406** rests on the relatively elevated section **403** of the weld base **402**. The stop plate **406** comprises apertures through which weld tools (e.g. horn) **408** protrude. In use, the weld tools **408** may be energized with electromagnetic energy (using an energy source, not shown), causing

the weld tools **408** to generate alternating electric fields that cause polar molecules in the straps of material to oscillate and orient themselves with respect to the field. This movement of the polar molecules generates heat, causing a temperature increase that results in the melting of the sheets. The weld tools **408** are forced (using a press, not shown) against weld regions defined by overlapping top and bottom sheets to apply pressure to the sheets. It should be understood that 'top' and 'bottom' as used in this disclosure can be interpreted as referring to positioning with respect to a weld tool **408** rather than with respect to gravity. The top sheet can refer to the sheet closest to the weld tool **408** and the bottom sheet can refer to the sheet furthest from the weld tool **408**. The combination of melting and pressure promotes the formation of a welded joint between the sheets. The weld tools **408** further comprise rows of pin heads **410** that are further described below with reference to the accompanying figures. Although the weld tools **408** shown are rectangular or hexagonal, it should be understood that the weld tools **408** could have other shapes, including, but not limited to, triangular or circular shapes. In some configurations, the stop plate **406** could be integrally formed with or be in the form of a single piece with one or more of the weld tools **408**. [0114] FIG. 5 illustrates a weld tool **408** configured to be used with the high frequency welding system **400**. The weld tool **408** comprises a top section **412** that rests on the stop plate **406** (see FIG. 4) in use and cooperates with the stop plate **406** to limit the range of axial motion between the weld tool **408** and the weld base **402**. The weld tool **408** comprises a bottom section **414**. The bottom section **414** comprises a lower average cross-sectional area than the cross-sectional area of the top section **412**. The bottom section **414** is adapted to protrude through apertures in the stop plate **406** as described elsewhere in this disclosure with reference to FIG. 4. The bottom section **414** comprises a contact surface **416** that is forced against straps of material to apply pressure. The weld tool **408** comprises a plurality of pins **413** (see also FIGS. 7A-7D and the accompanying disclosure), the pins comprising pin heads **410** and ends **418**. The pins **413** enter the weld tool **408** through apertures in the top section **412**, extend through the body of the weld tool **408** and protrude (e.g., via ends **418**) through the bottom section **414**. In alternative configurations, the weld tool **408** could comprise only a single pin. In some configurations, the pins **413** could be permanently positioned in the weld tool **408** (for example, via the use of adhesives or frictional fits or couplings). In some configurations, and particularly if the weld tool **408** is integrally formed with the stop plate **406**, the weld tool may only comprise a single section. Usage of the weld tool **408** is further described below with reference to the accompanying figures.

[0115] FIGS. 6A-6D show non-limiting exemplary diagrams for the positioning of various components during a high-frequency welding method. The illustrated straps are headgear straps. However, straps of materials for forming other articles (including, but not limited to, articles of clothing) could be used. FIG. 6A shows a bottom strap **500**. As used above or elsewhere in this disclosure, it should be understood that the words 'top' and 'bottom' do not refer to the relative positions of the straps with respect to the force of gravity but, instead, refer to the relative positions of the straps with respect to the weld tool **408**. The bottom strap **500** comprises a body section **500A** of a first width and an edge section **500B** of a second width. The edge section **500B** is inwardly stepped relative to the body region **500A**. In other words, the edge section **500B** is of a smaller width than the body section **500A**. In the illustrated configuration, the body section **500A** has a width  $L_{sub.1}$  of 17 mm or about 17 mm. The edge section **500B** has a width  $L_{sub.2}$  of 15 mm or about 15 mm with insteps  $L_{sub.3}$ ,  $L_{sub.4}$  of 1 mm on either side of the edge section **500B**. In some configurations, the width of the edge section **500B** may be in the range of about 60% to about 97% of the width of the body section **500A**, or about 65% to about 95%, or about 70% to about 93%, or about 80% to about 90% of the width of the body section **500A**. Maintaining the desired width of the body section **500A** relative to the width of the edge section **500B** helps to mitigate the tendency of molten material to flow too far outwardly from the weld region **504** (see FIG. 6B), which can cause undesired bulging at the sides of the finished weld joint formed at the weld region **504**. If two rectangular straps are welded together, a weld joint with bulging edges

along the sides of the joint is more likely to be formed. Using a strap with inset portions can create cavities in which excess molten material can reside. A substantially curved transition region TR lies between the body section **500A** and the edge section **500B**. The transition region TR promotes adequate distribution of energy during welding, allowing for the formation of an aesthetically acceptable weld joint. In alternative configurations, the transition region TR may not be present. In FIG. **6B**, a portion of a substantially rectangular top strap **502** is laid over the bottom strap **500**. A weld region **504** is defined by the overlapping top and bottom straps **502**, **504**. However, in other configurations, both of the straps **502**, **500** could have substantially rectangular shapes. In still other configurations, either or both of the straps could have other shapes, including, but not limited to, circular or triangular shapes.

[0116] FIG. **6C** shows the position of the bottom section **414** of the weld tool **408** over the weld region **504**. As shown, at least the contact surface **416** of the bottom section **414** (i.e., on the underside of the bottom section **414**) comprises a stepped shape similar to shape of the bottom strap **500**. Using a contact surface **416** with a stepped shape promotes the distribution of energy along the contact surface **416**, further mitigating undesired bulging at the sides of the weld joint formed at the weld region **504**. However, in other configurations the contact surface **416** could have other shapes, including, but not limited to, rectangular, circular or triangular shapes. Additionally, as shown, the bottom section **414** extends outwardly past the weld region **504** and/or contact surface **416**. In some configurations, the edges of the bottom section **414** may extend, for example, 1 mm or about 1 mm past the edges of the weld region **504**. The larger footprint of the bottom section **414** helps to improve the tolerance of errors in proper placement of the weld tool **408**. FIG. **6D** shows the position of the top section **412**. As shown, the top section **412** is substantially rectangular with rounded edges. However, in other configurations, the top section **412** may have other shapes, including, but not limited to, triangular or circular shapes.

[0117] FIGS. **7A-7D** illustrate a non-limiting exemplary high-frequency welding method. FIG. **7A** demonstrates again a weld region **504** defined by overlapping top and bottom straps **502**, **500**. The straps **502**, **500** can lie in the depressed section **404** of the base plate **402**. As described elsewhere in this disclosure, the weld tool **408** comprises a top section **412** and a bottom section **414** comprising a contact surface **416**. The weld tool **408** comprises pins **413** that pass through the weld tool **408**, extending from pin heads **410** positioned on the top section **412** to ends **418** projecting from the contact surface **416** of the bottom section **414**. The top section **412** can cooperate with the stop plate **406** and the elevated section **403** of the weld base **402** to limit axial movement of the weld tool **408** relative to the weld base **402** (see FIG. **7B**). As the weld tool **408** is moved into the weld region **504**, the contact surface **416** is forced against the weld region **504**. The urging of the contact surface **416** against the weld region **504** provides pressure to the straps **502**, **500**. The ends **418** of the pins **413** that project outwardly from the contact surface **416** penetrate the entire depth of the top strap **502** and partially penetrate the bottom strap **500**.

[0118] In the illustrated configuration, the stop plate **406** and the elevated portion **403** of the weld base **402** are positioned such that a clearance L.sub.2 of 2.5 mm or about 2.5 mm is present between the contact surface **416** and the recessed portion **404** of the weld base **402**. The ends **418** of the pins **413** project a length L.sub.3 of about 1.5 mm from the contact surface **416**. About 1 mm of clearance L.sub.1 is present between the ends **418** of the pins **413** and the recessed portion **404**. The ratio L.sub.2:L.sub.1 in the illustrated configuration, then, is about 2.5:1. In other configurations, the ratio L.sub.2:L.sub.1 can comprise other values. For example, the ratio L.sub.2:L.sub.1 can be in the range of 2:1 to 3:1 or about 2:1 to about 3:1. In other configurations, the straps **502**, **500** are each 1.25 mm or about 1.25 mm thick when compressed by the weld tool **408**. The ends **418**, then, penetrate the full 1.25 mm thickness of the top strap **502** and 0.25 mm or about 0.25 mm of the depth of the bottom strap **500**. In other words, the pins **413** penetrate 20% or about 20% of the depth of the bottom strap **500**. In other configurations, the pins **413** can penetrate about 5% to about 50% of the depth of the bottom strap **500**, or about 10% to about 40%, or about

15% to about 30%. In still other configurations, the pins **413** can penetrate 1% to 99% or about 1% to about 99% of the depth of the bottom strap **500**, or about 10% to about 90%, or about 20% to about 80%, or about 30% to about 70%, or about 40% to about 60%, or about 50% of the depth of the bottom strap **500**.

[0119] It has been discovered that the depth of penetration of the bottom strap **500** can factor into the weld strength and aesthetic appeal of the weld joint formed at the weld region **504**. If the penetration depth is too high, in some cases the ends **418** may not deliver enough energy to the interface between the top and bottom straps **502**, **500**. Additionally, too much energy may be delivered to the bottom strap **500**, which can promote excessive melting or burning of the bottom strap **500**. If the penetration depth is too low, in some cases the ends **418** may not project far enough into the bottom strap **500**, or the ends **418** may not project at all into the bottom strap **500**. Too much energy may be delivered to the top strap **502**, which can promote excessive melting or burning of the top strap **502**.

[0120] Additionally, it has been discovered that it is desirable to minimize the clearance L.sub.1 to decrease the chance of electrical arcing from the contact surface **416** and/or ends **418** to the weld base **404**. Undesired electrical arcing can cause excessive melting and/or burns in one or both of the straps **502**, **500**, which can lead to aesthetically unappealing welded joints. In some configurations, the clearance L.sub.1 can be about 80% of the pin length L.sub.3 (ratio L.sub.1:L.sub.3=about 0.8). In other configurations, the ratio L.sub.1:L.sub.3 can be in the range of, for example, about 0.7 to about 0.9.

[0121] As shown in FIG. 7C, electromagnetic energy applied to the weld tool **408** is concentrated at the ends **418** of the pins **413**, resulting in the generation of high-frequency alternating electric fields (represented using arcs W on either side of the contact surface **416**). The electric fields cause polar molecules in the straps **502**, **500** to oscillate and orient themselves with respect to the fields, which generates heat in the straps **502**, **500** causing them to melt and fuse. Pressure applied using the contact surface **416** of the weld tool **408** (together with the press described elsewhere in this disclosure with reference to FIG. 4) promotes the formation of a weld joint J at the weld region **504**. The weld tool **408** is then pulled away from the finished weld joint J (see FIG. 7D).

[0122] FIGS. 8A-8C show bottom, side, and bottom close-up views of a non-limiting exemplary weld tool **408**. As shown in FIG. 8C, the contact surface **416** comprises apertures **420** adapted to hold the pins **413**. The apertures **420** are defined by recesses **422** present in the contact surface **416**. The recesses **422** can be crater-like, or can have substantially hemi-spherical or frustoconical geometry. The recesses **422** lie on portions of the contact surface **416** surrounding the pins **413** (particularly near the ends **418**) in use. In the illustrated contact surface **416**, the apertures **420** (and pins **413** in use) are arranged in rows such that consecutive or touching recesses **422** are present. The rows may be offset by about half of the distance between the centers of two adjacent apertures **420** of a given row. The offset is such that the rows are arranged in a honeycomb-like shape.

[0123] FIG. 8D illustrates a weld tool **408** having a similar aperture arrangement (recesses **422** not illustrated) as FIG. 8C. The apertures **420**, which hold the pins **413** (not shown), are offset and spaced apart such that each aperture **420** is substantially equidistant from each adjacent aperture **420**. As illustrated, six apertures **420** are arranged around a center aperture **420** in a hexagonal arrangement or honeycomb-like shape and spaced apart from each adjacent aperture **420** by a distance X. Each aperture **420** has a diameter D. Maintaining proper spacing of the apertures **420** (and ends **418** in use) can promote an even or balanced weld joint. Further, the hexagonal arrangement of the apertures **420** provides uniform weld strength and flex characteristics across the weld joint. Preferably, the distance X may be 1.0 mm and the diameter D may be 0.5 mm. However, the distance X and diameter D can, for example, be larger or smaller than shown and described with reference to the illustrated embodiment. In the illustrated configuration, the hexagonal arrangement has an overall height H of 2.232 mm and an overall width W of 2.5 mm. The apertures **420** are enclosed within a hexagonal-shaped area that surrounds the apertures **420**.

That is, the welding area of the weld tool **408** may be defined as a hexagonal-shaped area that surrounds the apertures **420**. As illustrated, outer segments S that define the hexagonal-shaped area are tangent to outer edges of outermost adjacent pins **420**. The segments S may have a length of 1.25 mm such that the total area of the hexagonal-shaped area is 4.06 mm.<sup>sup.2</sup>. As such, seven apertures **420** having a diameter D of 0.5 mm provide a total aperture area of 1.374 mm.<sup>sup.2</sup>. As each aperture **420** accommodates a pin **413** having a substantially identical diameter and area, a pin density percentage may be defined as a ratio percentage of pin area versus total welding area (i.e., hexagonal-shaped area). Therefore, a weld tool **408** having seven apertures **420** with diameters D of 0.5 mm, spaced apart by a distance X of 1.0 mm and arranged in a hexagonal arrangement having a total area of 4.06 mm.<sup>sup.2</sup>, has a pin density percentage of 33.8%. Accordingly, a strap or material welded by the weld tool **408** with the illustrated hexagonal arrangement can have a weld joint that approximates the pin density. In the instant example, the pin density is 33.8%, which may result in the weld joint having approximately 33.8% melted welded material within the weld area or pin area. The actual portion of melted material within the weld or pin area can vary based on relevant factors of the welding process (e.g., weld power, weld time, materials being welded, etc.). Thus, the actual portion of melted material may differ from the pin density, but will likely fall within a range the approximates the pin density (e.g., within 5%, 10%, 20% or 25% of the pin density). A weld joint having a higher pin density percentage provides a less flexible weld joint than a weld joint having a lower pin density percentage. This is because more of the weld joint will include melted welded material which is relatively rigid and inflexible. As a result, there will be less fabric between each of the weld points that has not been melted and is still able to be flexed or stretched, thereby, allowing the strap or material to stretch. In alternative configurations, the apertures **420** may have a diameter D between 0.1 to 1.0 mm. As such, decreasing the diameter D of the aperture **420** (and the pin **413**) will decrease the pin density percentage and result in a weld joint with more flexibility and/or stretch while larger diameters will provide less flexibility and/or stretch. Accordingly, the diameter D and/or distance X may be varied according to the amount of flex or stretch desired by the weld joint.

[0124] FIG. **8E** illustrates a similar hexagonal arrangement as FIG. **8D** with identical aperture diameters D and distance X between apertures **420**. FIG. **8E** differs by having nineteen total apertures **420** with the apertures **420** arranged in two concentric hexagons around a center aperture **420**. As such, due to the increased number of apertures **420**, the hexagonal arrangement has segments S with a length of 2.25 mm such that the total area of the hexagonal-shaped area 13.15 mm.<sup>sup.2</sup>. Therefore, a weld tool **408** having nineteen apertures **420** with diameters D of 0.5 mm and that are arranged in a hexagonal arrangement, has a pin density percentage of 28%. Thus, compared to the pin density percentage of 33.8% provided by the seven apertures **420** in the hexagonal arrangement in FIG. **8D**, the pin density percentage decreases as the number of apertures **420** and the overall hexagonal-shaped area increases.

[0125] FIG. **8F** illustrates a weld tool **408** having a radial arrangement with thirty-one apertures **420** arranged in three concentric circles around a center aperture **420**. Each aperture **420** has a diameter D of 0.5 mm. The distance X between each aperture **420** in the radial direction is 0.5 mm. The total radial distance R from the center aperture **420** to a radially-outermost point of the outermost apertures **420** is 3.25 mm, which defines a circular-shaped area with a total area of 33.18 mm.<sup>sup.2</sup>. Therefore, a weld tool **408** having thirty-one apertures **420** arranged in three concentric circles, spaced apart a distance X of 0.5 mm and having a diameter D of 0.5 mm, has a pin density percentage of 18%. Further, as illustrated, the circumferential distance between adjacent apertures **420** increases as the distance from the center of the weld joint increases. Accordingly, the flexibility of the weld joint will be greater in regions further away from the center of the weld joint. Therefore, the radial aperture arrangement in FIG. **8F** provides different strength and flexibility characteristics compared to the hexagonal aperture arrangements in FIG. **8A-8E**. In other configurations, the outermost apertures **420** may have an ovular or elongated shape to reduce the

circumferential distance between adjacent apertures **420** and provide additional strength to the regions further from the center of the weld joint.

[0126] FIG. **8G** illustrates a weld tool **408** having a square grid aperture arrangement with one hundred apertures **420** aligned in ten rows having ten apertures **420** per row. Each aperture **420** is spaced apart from each adjacent aperture **420** by distances X, Y of 0.5 mm. Each aperture **420** has a diameter D of 0.5 mm. As such, the diameter D and distances X, Y of the apertures **420** have a 1:1 relationship. The square grid arrangement has a height H and width W of 9.5 mm. Therefore, a weld tool **408** having one hundred apertures **420** with a diameter D of 0.5 mm and arranged in the square grid arrangement illustrated in FIG. **8G**, has a pin density percentage of 21.71%. In alternative configurations, the diameter D may have a value of 0.1 to 1.0 mm and distance X may have a value different than the distance Y with values between 0.1 to 5.0 mm.

[0127] FIG. **8H** also illustrates a weld tool **408** having a square grid arrangement with one hundred apertures **420A**, **420B** aligned in ten rows having ten apertures **420A**, **420B** per row. However, in contrast to FIG. **8G**, the square grid arrangement includes large apertures **420A** and small apertures **420B** which are alternately disposed along the length of each row. The large apertures **420A** have a diameter D.sub.1 of 0.5 mm and the small apertures **420B** have a diameter D.sub.2 of 0.25 mm. Each aperture **420A**, **420B** is spaced apart from each adjacent aperture **420A**, **420B** by distances X, Y of 0.625 mm. The square grid arrangement has a height H and width W of 9.5 mm. Therefore, a weld tool **408** having fifty large apertures **420A** and fifty small apertures **420B** arranged in a square grid arrangement as illustrated in FIG. **8H**, has a pin density percentage of 13.59%. Thus, compared to the pin density percentage of 21.71% provided by the square grid aperture arrangement in FIG. **8G**, the square grid arrangement having apertures **420A**, **420B** with large and small diameters D.sub.1, D.sub.2 may provide a weld joint with greater flexibility. In alternative configurations, the diameter D may have a value of 0.1 to 1.0 mm and the distance X may have a value different than the distance Y with values between 0.2 to 5.0 mm.

[0128] FIG. **8I** also illustrates a weld tool **408** having a grid arrangement with apertures **420** arranged in rows having five apertures **420** per row. However, in contrast to FIGS. **8G** and **8H**, each row is offset by a distance O from each adjacent row. Preferably, the offset distance O is 0.5 mm. Each aperture **420** is spaced apart from each adjacent aperture **420** by distances X, Y of 0.5 mm and each aperture **420** has a diameter D of 0.5 mm. As such, the diameter D and the distances X, Y of the apertures **420** have a 1:1 relationship. The square grid arrangement has a height H and width W of 5.0 mm. Therefore, a weld tool **408** having twenty-five apertures **420** with a diameter D of 0.5 mm and arranged in a grid arrangement with offset rows, has a pin density percentage of 20%. Put another way, the grid arrangement has one aperture **420** for every 1 mm.sup.2. In alternative configurations, the diameter D may have a value of 0.1 to 1.0 mm and the distance X may have a different value than the distance Y with values ranging between 0.2 to 5.0 mm. Further, in some configurations, the offset distance O may be determined by the following equation:  $O=(X+D)/2$ .

[0129] FIG. **8J** also illustrates a weld tool **408** having a grid arrangement with offset rows. However, in contrast to FIG. **8I** but similar to FIG. **8H**, the grid arrangement includes large apertures **420A** and small apertures **420B** which are disposed in alternating rows. The large apertures **420A** have a diameter D.sub.1 of 0.5 mm and the small apertures have a diameter D.sub.2 of 0.25 mm. Each large apertures **420A** is spaced apart a distance X.sub.1 of 0.5 mm from each adjacent large apertures **420A**. Each small aperture **420B** is spaced apart a distance X.sub.2 of 0.75 mm from each adjacent small aperture **420B**. Each row is offset by a distance O of 0.5 mm from each adjacent row. The grid arrangement has a height H of 5.0 mm and a width W of 4.875 mm. Therefore, a weld tool **408** having a bottom section **414** with twenty-five apertures **420** with diameters D.sub.1, D.sub.2 and arranged in a grid arrangement with offset rows, has a pin density percentage of 14%. Thus, compared to the pin density percentage of 20% provided by the aperture arrangement in FIG. **8I**, the aperture arrangement having apertures **420A**, **420B** with large and small diameters D.sub.1, D.sub.2 may provide a weld joint with greater flexibility.

[0130] For the aperture arrangements disclosed, the pin density percentage can be within a range of 10-50%. The pin density percentage may depend upon the region of the headgear where straps are joined since consideration must be given to the desired strength and flexibility for that region of the headgear. In some configurations, the pin density percentage can be within the range of 15-35%. Preferably, the pin density percentage is between 15-25%.

[0131] In other configurations, the apertures **420** (and pins **413** in use) may be arranged according to other shapes or patterns, including, but not limited to, sine wave, square wave, or zig-zag shapes. In other configurations, the distance of each aperture **420** from adjacent apertures **420** can be irregular or inconsistent over the contact surface **416**. For example, and as illustrated in FIG. **8K**, the apertures **420** may be randomly scattered over the contact surface **416**. In other configurations, the apertures **420** can be arranged in rows. For example, and as illustrated in FIG. **8L**, the apertures **420** may be arranged in vertical rows along the contact surface **416**. Arranging the apertures **420** in rows can allow for a relatively strong weld at the finished weld joint while allowing for flexing or bending at the weld joint in one or more axes (e.g. preferential bending).

[0132] As shown in FIG. **8C**, the contact surface **416** comprises beveled edges **424**. In some configurations, the edges **424** could be rounded or arcuate. Beveling or rounding the edges of the contact surface **416** lessens concentrations of energy on the edges of the weld region **504**. This can promote a more even or balanced weld joint and lessen chances of excessive melting or burning in undesired places. In other configurations, the contact surface **416** may comprise straight edges.

[0133] FIGS. **9A-9B** show a cross-section of a non-limiting exemplary recess **422** in more detail. The recess **422** is inwardly chamfered (in contrast with the straight edge **421** shown in FIG. **10**). The inwardly chamfered recess **422** is curved or substantially arcuate. The arcuate recess **422** can help prevent undesired concentrations of electromagnetic energy along portions of the contact surface **416**, which can minimize the chance of excessive melting or burning of the top strap **502** in use. In other configurations, the recess **422** can have straight edges. In other configurations, and as described elsewhere in this disclosure, beveled recesses **422** may also be used. The illustrated recess **422** is substantially crater-like. The curvatures of the sides of the crater-like recess **422** are defined by substantially circular cross-sections of the weld tool **408** (as shown by circle c in the close-up shown in FIG. **9B**). In the illustrated configuration, the circle c comprises a radius  $r=0.6$  mm or about 0.6 mm. In other configurations, the radius may, for example, be in the range of about 0.2 mm to about 1.0 mm, or about 0.3 mm to about 0.9 mm, or about 0.4 mm to about 0.8 mm, or about 0.5 mm or about 0.7 mm. In some configurations, the circle c has a radius  $r$  selected to give the contact surface **416** of the weld tool **408** a shape that allows for energy to be efficiently transferred to the weld region **504**. In some configurations, the curvatures of the sides of the crater-like recesses are defined by substantially circular cross-sections of the weld tool having radii  $x$  that are proportional to the average distance between pins  $y$  according to the ratio  $x:y$ . In some such configurations, the ratio  $x:y$  can be in the range of 0.3 to 0.4, or about 0.3 to about 0.4. In other configurations, the ratio  $x:y$  can be in the range of about 0.2 to about 0.5, or about 0.25 to about 0.45.

[0134] FIG. **11** shows a close up cross-sectional view of straps welded at a pair of weld points W.sub.1, W.sub.2 using a pin **413** as a reference. The pin **413** has a width of 0.5 mm or about 0.5 mm. As can be seen, the illustrated non-limiting exemplary top and bottom straps **502**, **500** each comprise several layers. The top strap **502** comprises cloth or fabric layers **502A**, **502C** (hereinafter generally referred to as cloth layers) comprising hairs **502D** that project outwardly from the layers **502A**, **502C**. The hairs **502D** may act as a hooked surface that can engage with, for example, the loop patches **316**, **314**, **312**, **310** described elsewhere in this disclosure with reference to FIGS. **2A-2B**. The cloth layers **502A**, **502C** sandwich a foam layer **502B**. Similarly, the bottom strap **500** comprises cloth layers **500A**, **500C** sandwiching a foam layer **500B**. Hairs extending from the bottom fabric layer **502C** of the top strap **502** and hairs extending from the top fabric layer **500A** of the bottom strap **500** to at least some extent interweave and compress against one another when the



straps are overlaid to form the weld region **504**, facilitating the formation of a weld joint. As can be seen, use of the disclosed welding methods, tools, apparatus and systems can promote a weld while mitigating the presence of visible bulges or burns. Additionally, the use of a weld tool **408** comprising pins **413** that protrude into the straps **502**, **500** can reduce or eliminate the formation of witness marks (e.g., marks created by detailing on the contact surface **416** of the weld tool **408**, including, but not limited to, ridges or recesses) on the finished weld joints. Witness marks may be caused when the fabric is melted and the straps **502**, **500** are fused together to become a solid plastic region that includes a portion of a visible surface of the fabric. It may be undesirable in some headgear for there to be regions of reduced flexibility and/or elasticity on or near a visible surface of the fabric (e.g., aesthetic appeal, user comfort, etc.).

[0135] Although the illustrated embodiments show that the weld tool **408** comprises pins **413** that are positioned over the weld base **402**, in some configurations, the weld base **402** may comprise the pins **413** and the weld tool **408** may primarily serve to exert pressure against the weld region **504**. In some configurations, both the weld tool **408** and the weld base **402** may comprise pins **413**. For example, pins extending from the weld tool **408** may penetrate the straps **502**, **500** on one half of the weld region **504** and pins extending from the weld base **402** may penetrate the straps **502**, **500** on the other half of the weld region **504**. In some configurations, the weld tool **408** can be secured to the weld base **402** and the weld press alone (described elsewhere in this disclosure with reference to FIG. 4) can be used to apply pressure to the straps **502**, **500**.

[0136] Although the illustrated embodiments show that two overlapping sections of material (e.g. straps) can be welded, in some configurations, a greater number of sections can be welded. For example, in some configurations **3**, **4** or **5** straps can be welded together using the methods, apparatus, tools and systems disclosed. In some configurations, the weld tool **408** can comprise pins **413** that penetrate all of the sections of material. For example, three overlapping headgear straps (being called top, middle and bottom straps) may be welded using a weld tool **408** having pins **413** that penetrate the entire depth of the top and middle straps and a portion of the bottom strap. In other configurations, the pins **413** may be of variable length to promote adequate weld strength between straps along each strap interface. For example, if three overlapping headgear straps are used, a weld tool **408** having pins **413**, a portion of which penetrate the full depth of the top strap and a portion of the middle strap, another portion of which penetrate the full depth of the top and middle straps and a portion of the bottom strap, may be used.

[0137] FIG. **12** is a close-up cross-sectional view of a pin configuration which reduces or eliminates the formation of witness marks on the finished weld joints. The pin **413** has an elongate portion **417** that extends in a direction away from the weld tool (not shown) toward a pin end **418** that is opposite the weld tool (not shown). As illustrated, the elongate portion **417** narrows at the pin end **418** to form a pointed tip **419**. To weld the straps **502**, **500** together, the pointed tip **419** pierces an outer surface **512A** and penetrates entirely through the top strap **502**. As opposed to applying pressure directly to the outer surface **512A**, piercing the outer surface **512A** causes the outer surface **512A** to remain substantially undeflected (i.e., the outer surface **512A** is not pressed closer to the inner surfaces **512B**, **510B**). As illustrated, while penetrating through the top strap **502**, the pin **413** presses the inner surface **512B** of the top strap **502** against the inner surface **510B** of the bottom strap **500**. While the inner surfaces **510B**, **512B** are compressed, electromagnetic energy is applied to the pin **413** which generates heat that causes the straps **502**, **500** to melt around the weld point **506**, thereby, fusing the straps **502**, **500** together. However, since the outer surface **512A** remains undeflected, the outer surface **512A** will not be joined in the weld. Accordingly, a visible witness mark will not be formed on the outer surface **512A**. In other configurations, it is possible that a portion of the pointed tip **419** may exit and extend through the inner surface **512B** of the top strap **502**. However, despite the pin end **418** penetrating through the inner surface **512B**, the pointed tip **419** may still press the inner surface **512B** of the top strap **502** against the inner surface **510B** of the bottom strap **500**. It should be understood that the shape and geometry of the elongate

portion **417** and pointed tip **419** may vary according to the thickness and type of strap material, quantity and geometry of the pins, desired weld strength, etc.

[0138] FIGS. **13-15** illustrate a high frequency welding system **600** that may further reduce or eliminate the formation of a witness mark and form a weld joint that does not significantly effect or that preserves a substantial amount of the flexibility and/or elasticity of the fabric. The welding system **600** comprises a weld base (e.g., anvil) **610** and a weld tool **620**. The weld base **610** includes a top surface **612** and a positioning cavity **614** that is recessed below the top surface **612** and adapted to hold the top and bottom sheets of material **702**, **704** in overlapping alignment prior to forming the strap **700** of the headgear. The weld tool **620** includes a top plate **622**, pins **624** and an insert portion **626**. The pins **624** are positioned within and extend through both the top plate **622** and the insert portion **626** such that the top plate **622** is connected to the insert portion **626** via the pins **624**. The weld tool **620** may also have bosses **638** positioned between the top plate **622** and the insert portion **626** to connect the top plate **622** to the insert portion **626**. In some configurations, the insert portion **626** may slide axially along the lengths of the pins **624** and the bosses **638**.

[0139] The pins **624** are substantially straight and include a head portion **632**, an elongate portion **634** and a tip portion **636**. The head portion **632** is positioned within the top plate **622** and extends entirely through the top plate **622**. An upper region of the head portion **632** may protrude from the top plate **622** to provide a connection with an energy source (not shown). The elongate portion **634** is connected to the head portion **632** and extends perpendicularly outward from the top plate **622** in a direction that is parallel to the insertion direction of the insert portion **626** into the positioning cavity **614**, as will be discussed in greater detail below. The elongate portion **634** extends entirely through the insert portion **626** such that elongate portion **634** protrudes outward from a surface **628** of the insert portion **626** that is opposite the top plate **622** and that faces the positioning cavity **614**. The tip portion **636** is positioned at the end of the elongate portion **634** that protrudes outwardly from the insert portion **626**. The elongate portion **634** and the tip portion **636** may protrude a distance from the surface **628** of the insert portion **626** according to the desired depth of penetration of the bottom sheet **704** (if any) and clearance, as previously disclosed. The elongate portion **634** of the pins **624** may have a diameter of 0.3 mm to 1 mm and the tip portion **636** may narrow to a point. The pins **624** may be spaced apart by a distance of 2.5 mm to 6 mm (i.e., between the centers of the pins **624**) arranged in a single-file row along an outer edge of the surface **628** of the insert portion **626**. The pins **624** may be arranged in single-file rows that are aligned according to the direction of stretch of the finished product, which will be discussed in greater detail below. It should be noted that the welding system **600** is not limited to pins **624** arranged in single file rows and may be arranged according to any of the aperture/pin arrangements previously disclosed.

[0140] As illustrated in FIGS. **14** and **15**, the top plate **622** may be joined with the weld base **602** such that the top plate **622** rests on top of the weld base **602** and the insert portion **626** is able to be inserted into the positioning cavity **614**. The insert portion **626** has a size and shape that corresponds with the shape of the positioning cavity **614**. Spacers **616** may be attached to the weld base **610** and/or the weld tool **620** to limit axial motion (i.e., the direction parallel to the insertion direction) between the weld base **610** and the weld tool **620** when the insert portion **626** is inserted into the positioning cavity **614**. The spacers **616** may be arranged to provide the desired clearance and depth of penetration (if any) into the bottom sheet **704**, as previously disclosed.

[0141] The weld base **610**, the top plate **622** and/or the insert portion **626** may be a non-conductive tool and/or formed from an insulating material, such as plastic, to reduce or minimize heat or energy transferred from the surface **628** of the insert portion **626** to the top and bottom sheets of material **702**, **704**, thereby, further reducing or preventing the formation of a witness mark. Preferably, at least the weld base **610** and insert portion **626** (or other portions that contact the sheets **702**, **704**) are constructed from or comprise an insulating material. Therefore, the only heat or energy transferred to the top and bottom sheets **702**, **704** are substantially provided by the pins **624**. In some configurations, any one or all of the top plate **622**, the pins **624** or the insert portion

**626** may be formed from a non-insulating material, such as metal. However, with such a configuration, a thermally insulating material or coating may be applied to the surface **628** to reduce or minimize heat transferred from the surface **628** of the insert portion **626** to the top and bottom sheets **702**, **704**. The non-conductive or insulating material can be selected in view of the type or particulars of the weld process. For example, the tool can be configured to reduce thermal conductivity or reduce electrical or electromagnetic conduction. The tool may be formed from a material that prevents or reduces thermal conductivity, electrical conductivity, or electromagnetic conductivity.

[0142] In operation, the strap **700** may be formed by inserting the top and bottom sheets **702**, **704** into the positioning cavity **614**. The top and bottom sheets of material **702**, **704** may be inserted and arranged in an overlapping relationship. It should be understood that ‘top’ and ‘bottom’ as used in this disclosure can be interpreted as referring to positioning with respect to the high frequency welding system **600** rather than with respect to gravity. The weld tool **620** is positioned onto the weld base **610** such that the insert portion **626** is inserted into the position cavity **614**. A compressive force is applied to the top plate **622** of the weld tool **620**. Accordingly, the pins **624** and the insert portion **626** contact and apply pressure to the top and bottom sheets **702**, **704**. The tip portion **626** of the pins **624** penetrate the entire depth of the top sheet **702** and partially penetrate the bottom sheet **704**. The weld tool **620** is energized with electromagnetic energy (using an energy source, not shown), causing the pins **624** to generate alternating electric fields that cause polar molecules in the straps of material to oscillate and orient themselves with respect to the field. This movement of the polar molecules generates heat, causing a temperature increase that result in the melting of the sheets. Although the positioning cavity **614** and the insert portion **626** shown are rectangular, it should be understood that the positioning cavity **614** and the insert portion **626** could be formed in other shapes, for example, shapes which correspond to geometries of the straps to be welded. Further, the pins **624** are illustrated as having an elongate cylindrical shape. However, it should be understood that the pins could be formed in shapes (e.g., rectangular, ovular, etc. in cross-section) according to the desired strength and flexibility provided by the strap.

[0143] FIGS. **16A-16D** illustrate the strap **700** after the sheets **702**, **704** have been welded together by the high frequency welding system **600**. As shown in FIG. **16A**, the strap **700** has linearly spaced weld points **710** that are equidistantly spaced apart along the length of the strap **700**. In contrast to a strap having a continuous seam weld, the weld points **710** are spaced apart such that the weld region formed by a single pin does not merge with a weld region from another pin. The weld points **710** provide a discontinuous weld such that the strap **700** can be stretched in a direction parallel to the direction of the linearly spaced weld points **710**. Each of the weld points **710** may be spaced apart from an adjacent weld point **710** by a distance of 3.5 mm (i.e., in a neutral unstretched position of the strap **700**), which also corresponds to the spacing between the pins **624**. Depending upon the amount of desired stretch and flexibility by the strap **700**, the distance between weld points **710** (i.e., distance between the centers of each weld points **710**) may be within a range of 2.5 mm to 6.0 mm. Accordingly, a greater distance between weld points **710** will provide a greater amount of stretch and flexibility. However, significantly larger distances between weld points **710** may be undesirable because the edges of the strap **700** may split or bow outward (i.e., the sheets **702**, **704** may separate) between the weld points **710** when the strap **700** is either bent or turned inside out.

[0144] As shown in FIG. **16B**, the weld points **710** may be visible when viewing the top sheet **702** of the strap **700** from a top-down view. However, as shown in FIG. **16C**, the weld points **710** are concealed within the strap **700** and not visible when viewing the bottom sheet **704** of the strap **700** from a top-down view. FIG. **16D** illustrates a cross-sectional view of the strap **700**. As the pins **624** are arranged in single file rows along the outer edges of the top and bottom sheets **702**, **704**, the weld points **710** are positioned along the outer edges of the top and bottom sheets **702**, **704** such that a central opening **706** is provided at a center of the strap **700**. As illustrated in FIG. **16D**, the

top sheet **702** and the outer edges of the top sheet **702** may be slightly more curved and deformed relative to the bottom sheet **704**. The downward pressure provided by the pins **624** may press and hold the outer edges of the top sheet **702** to the outer edges of the bottom sheet **704**. When the weld points **710** are formed, the top sheet **702** may retain a slight curvature due to the downward pressure provided by the pins **624**. The existence or amount of curvature may depend on the width and flexibility of the top and bottom sheets, the depth, geometry and position of the weld points, etc. In some configurations, the welding system **600** may be configured such that the top sheet is not more curved or deformed than the bottom sheet such that both the top and bottom straps are substantially identical.

[0145] FIGS. **17A** and **17B** illustrate straps **800** welded together using alternative pin arrangements provided by the welding system **600**. FIGS. **17A-B** illustrate welded straps **800** having equidistantly spaced weld points **810** that are located along the outer edges of the strap **800**. In contrast to the strap **700** in FIGS. **16A-D**, the strap **800** in FIG. **17A** has double-file rows of linearly spaced weld points **810** along the length of the strap **800**. In FIG. **17B**, the strap **800** has weld points **810** arranged in a staggered row (i.e., each aperture **810** is offset from an adjacent aperture **810**) along the length of the strap **800**. The alternative pin arrangements in FIG. **17A-B** provide different strength and flexibility characteristics than the single-file pin arrangement of the strap **700** in FIGS. **16A-D**. For example, the double-file row of weld points **810** may provide greater weld strength but lower flexibility compared to the single-file row of weld points **710** in FIGS. **16A-D**. Conversely, the staggered row of weld points **810** may provide lower weld strength but greater flexibility compared to the single-file row of weld points **710** in FIGS. **16A-D**. However, similar to the single-file row of weld points **710** of strap **700**, both the double-file and staggered rows of weld points **810** may allow the strap **800** to stretch in a direction parallel to the lengthwise of the strap **800**, as indicated by the arrow in FIGS. **17A** and **17B**. It should be understood that the welding system **600** is not limited to single-file, double-file or staggered pin arrangements and may utilize the pin arrangements disclosed herein according to the desired strength and flexibility characteristics of the strap. Further, although the illustrated embodiments show the top and bottom sheets in a fully overlapping relationship, the top and bottom sheets may still be welded despite only a portion of the top and bottom sheets overlapping.

[0146] Certain features, aspects and advantages of some configurations of the present disclosure have been described with reference to high-frequency welding of overlapping headgear straps. However, certain features, aspects and advantages of the methods, apparatus, tools and systems described may be advantageously used on other materials, including but not limited to sheets, plates and films, for the purpose of producing other products, including but not limited to articles of clothing. In addition, certain features, aspects and advantages of the use of methods, apparatus, tools and systems may be equally applied to other welding technologies, including but not limited to ultrasonic welding.

[0147] Unless the context clearly requires otherwise, throughout the description and the claims, the words “comprise”, “comprising”, and the like, are to be construed in an inclusive sense as opposed to an exclusive or exhaustive sense, that is to say, in the sense of “including, but not limited to.”

[0148] Where, in the foregoing description reference has been made to integers or components having known equivalents thereof, those integers or components are herein incorporated as if individually set forth.

[0149] The disclosed methods, apparatus and systems may also be said broadly to comprise the parts, elements and features referred to or indicated in the disclosure, individually or collectively, in any or all combinations of two or more of said parts, elements or features.

[0150] Recitation of ranges herein is merely intended to serve as a shorthand method of referring individually to each separate sub-range or value falling within the range, unless otherwise indicated herein, and each separate sub-range or value is incorporated into the specification as if it were individually recited herein. Moreover, the term “about,” when used in combination with a number

or a range of numbers, shall be inclusive of standard manufacturing tolerances of the number recited as well as a rounding to the next significant figure represented by the number under standard rounding rules. Moreover, any dimensions or other values provided herein, including the number of decimal places or significant figures provided in such dimensions or values, are merely exemplary, unless otherwise indicated, and include the dimensions or values as rounded to any desired decimal place.

[0151] Reference to any prior art in this specification is not, and should not be taken as, an acknowledgement or any form of suggestion that that prior art forms part of the common general knowledge in the field of endeavour in any country in the world.

[0152] Although the present disclosure has been described in terms of certain embodiments, other embodiments apparent to those of ordinary skill in the art also are within the scope of this disclosure. Thus, various changes and modifications may be made without departing from the spirit and scope of the disclosure. For instance, various components may be repositioned as desired. Moreover, not all of the features, aspects and advantages are necessarily required to practice the present disclosure. Accordingly, the scope of the present disclosure is intended to be defined only by the claims that follow.

## Claims

1. A method of producing headgear for a patient interface, comprising: applying pressure to a weld region defined by overlapping top and bottom headgear straps with a contact surface of a weld tool, wherein the contact surface is separate from a plurality of pins of the weld tool, wherein the plurality of pins conducts electrical or electromagnetic energy, and wherein portions of the contact surface of the weld tool surrounding the pins are inwardly chamfered; at least partially penetrating both the top and bottom headgear straps with the plurality of pins; and applying high-frequency energy to the weld region through the plurality of pins.
2. The method of claim 1, wherein the plurality of pins fully penetrates the top headgear strap and partially penetrates the bottom headgear strap.
3. The method of claim 2, wherein the plurality of pins penetrates about 20% of the depth of the bottom headgear strap.
4. The method of claim 1, wherein the contact surface of the weld tool that faces the weld region comprises beveled or rounded edges.
5. The method of claim 1, wherein the chamfered portions are substantially arcuate.
6. The method of claim 5, wherein the substantially arcuate chamfered portions are defined by crater-shaped recesses present in the contact surface of the weld tool.
7. The method of claim 6, wherein the curvatures of the sides of the crater-shaped recesses are defined by substantially circular cross-sections of the weld tool having radii  $x$  that are proportional to the average distance between each of the plurality of pins  $y$  according to the ratio  $x:y$ =about 0.3 to about 0.4.
8. The method of claim 1, wherein the plurality of pins is arranged in a plurality of rows.
9. The method of claim 8, wherein the rows are offset such that the plurality of pins is present in a honeycomb arrangement.
10. The method of claim 1, wherein the plurality of pins is arranged such that each pin is substantially equidistant from adjacent pins.
11. The method of claim 1, wherein either the top or bottom headgear straps comprises an edge section and a body section, the edge section having a smaller width than the body section.
12. The method of claim 11, wherein the width of the edge section is in the range of about 80% to about 90% of the width of the body section.
13. The method of claim 11, wherein a substantially curved transition region lies between the body section and the edge section.

- 14.** The method of claim 1, wherein the average distance between adjacent pins of the plurality of pins is in the range of about 1.5 mm to about 2.0 mm.
- 15.** The method of claim 1, wherein the average distance between adjacent pins of the plurality of pins is in the range of about 3 to about 4 times the average width of the pins.
- 16.** The method of claim 1, wherein each of the plurality of pins has an exposed pin head at one end of the weld tool and a protruding pin tip opposite the pin head.
- 17.** The method of claim 1, wherein the inwardly chamfered surfaces define a discrete cavity for each pin.
- 18.** The method of claim 1, wherein each of the plurality of pins has a pointed tip that pierces an outer surface of the top headgear strap.
- 19.** The method of claim 18, wherein each of the plurality of pins penetrates entirely through the top headgear strap and at least partially through the bottom headgear strap.
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