FINE AIR STREAM SOLAR CELL SOLDERING ASSEMBLY PROVIDING UNIFORM OUTPUT AIR TEMPERATURE DISTRIBUTION

Technical Field

The present disclosure relates generally to a soldering device. More particularly, the present disclosure describes various embodiments of a soldering device and associated techniques that can be used for establishing electrical couplings to a set of photovoltaic (PV) cells in a solar module in a manner that enhances heat distribution uniformity and which can effectively achieve high soldering quality and extend the functional life of electrical connections to PV cells.

Background

As a response to rising fuel costs, global warming concerns, and an increasing demand for electricity, substantial efforts have been made to promote renewable or alternative energy. Solar energy is one of the earliest forms of alternative energy. Solar energy is typically generated from a device called a solar or photovoltaic (PV) cell that converts sunlight into electrical energy by way of the photovoltaic effect. Assemblies of multiple PV cells or the like are used to manufacture solar panels, solar modules, or PV modules. PV modules generally have a sheet of transparent material(s) (e.g. glass, plastic, etc.) on a front side, permitting light to pass while protecting the internal PV materials from damage arising from environmental objects (e.g. rain, hail, etc…). In modules, individual PV cells are electrically connected either in series to create additive voltage or in parallel to yield a higher current. Modules are subsequently interconnected, in series and/or parallel in accordance with design objectives to form an array for supplying predetermined peak DC voltage and current.

In industry practice, one important step during the manufacture of PV modules involves electrically connecting a plurality of individual PV cells to form a module. A typical approach involves positioning an electrically conductive material (e.g., copper or aluminum) in the form of strips, hereinafter referred to as “ribbons,” upon frontside or backside electrical contact(s) of adjacent PV cells, followed by soldering each ribbon to the

electrical contact(s) along a portion or segment of its length. The soldering is generally performed at a temperature of approximately 350 to 400 ^{o}C.

Because the PV module is a sealed unit with a typically thin and fragile internal structure, any degradation, damage, or failure of one or more soldered connections between individual PV cells can lead to a malfunction of an overall module. Consequently, a PV module may require replacement prior to its expected functional life, which PV module manufacturers usually guarantee for up to 25 years. Such undesirable failure can have a significant adverse economic impact on PV module manufacturers and solar cell users, and hence undesirably affect users' overall interest in purchasing or installing solar power modules.

Although automated production machines capable of soldering PV cells presently exist, soldering quality and thus solar module reliability remains a concern. One particular problem associated with present PV cell soldering devices and techniques is inadequate soldering heating uniformity. Currently available soldering processes used in interconnecting ribbons employ contact heaters, optical heaters, or hot air flow as soldering heat sources. Existing PV cell soldering devices may fail to provide sufficient heating uniformity to reduce or largely eliminate electrical interconnection reliability problems. Moreover, previous efforts to sufficiently control soldering temperature uniformity have given rise to soldering device designs that are undesirably complex, structurally redundant, and/or cost inefficient. Accordingly, a need exists for soldering devices or techniques that overcome one or more of the foregoing problems.

Summary

In accordance with an aspect of the disclosure, a solar cell soldering head assembly includes a set of hot air generators coupled to a source of incoming air, and a heat distribution block coupled to the set of hot air generators. The heat distribution block includes an insertion surface having a set of insertion openings dimensioned to matingly receive the set of hot air generators, and an outlet surface having a set of hot air outlets, each hot air outlet having an area smaller than a cross sectional area of an insertion opening within the set of insertion openings. The heat distribution block further includes a set of channels exposed to the

insertion openings and the set of hot air outlets. The heat distribution block includes a thermally conductive material, such as a material having a thermal conductivity of at least approximately 80 Watts per meter-Kelvin. In an embodiment, the heat distribution block can be a single machined piece of material.

In accordance with an aspect of the disclosure, at least one hot air outlet, and in one embodiment each hot air outlet, within the set of hot air outlets, has a height of approximately 0.1 to approximately 2.5 millimeters, for instance, approximately 0.5 millimeters. In accordance with particular aspects of the disclosure, a plurality of hot air outlets are laterally coupled to each other by a bridge, which in an embodiment has a width of approximately 0.5 millimeters – 5.0 millimeters (e.g., about 2.0 millimeters).

In accordance with another aspect of the disclosure, the heat distribution block includes a set of recesses, each recess within the set of recesses extending from an insertion opening within the set of insertion openings to a predetermined recess depth in the heat distribution block. An aspect of the disclosure includes a set of air channels that extends between at least the recess depth and the set of hot air outlets. The set of air channels can include at least one individual air channel having a width that exceeds a width of a corresponding individual recess within the set of recesses. In one aspect of the disclosure, the heat distribution block includes a set of transition features that define the recess depth.

According to an aspect of the disclosure, the solar cell soldering head assembly includes a thermal sensor coupled to the heat distribution block, which in an embodiment includes a thermocouple. According to another aspect of the disclosure, the solar cell soldering head assembly includes a support structure, which in one embodiment substantially carries the weight of the heat distribution block. In another aspect of the disclosure, the solar cell soldering head assembly includes at least one heat reduction, heat shielding, or insulating panel or plate, which in an embodiment can be coupled to at least the heat distribution block and possibly the support structure.

In accordance with an aspect of the disclosure, a process for generating a hot air stream having a heat distribution profile that is suitable for facilitating enhanced reliability solar cell soldering processes includes providing an incoming air stream to a plurality of hot air generators; heating the incoming air stream within each hot air generator; emitting heated air from an output portion of each hot air generator; receiving the heated air emitted from each hot air generator within a heat distribution block; and providing a set of air channels within the heat distribution block through which heated air emitted from each hot air generator can flow to a set of hot air outlets, each air channel within the set of air channels having a separation distance that is smaller than a separation distance between hot air generators. In one aspect of the disclosure, the process can include providing a heat distribution block having a thermal conductivity of greater than approximately 80 Watts per meter-Kelvin. In one aspect, the process can include emitting hot air at the set of hot air outlets, and applying the hot air emitted at the set of hot air outlets to a portion of a solar cell assembly (e.g., a wire or ribbon) to facilitate a soldering operation.

In accordance with an aspect of the disclosure, a hot air temperature variation across the set of hot air outlets is approximately 25% - approximately 75% (e.g., approximately 50%) less than a hot air temperature variation across the plurality of hot air generators output segments. In an embodiment, a temperature variation of hot air emitted by the set of hot air outlets is approximately 10 ^{o}C.

Brief Description of the Drawings

Particular embodiments of the disclosure are described herein with reference to the following drawings, in which:

FIG. 1A is a schematic illustration of a solar cell soldering head assembly according to an embodiment of the disclosure;

FIG. 1B is a schematic illustration of a portion of a support structure according to an embodiment of the disclosure;

FIG. 1C is a schematic illustration of another portion of a support structure according to an embodiment of the disclosure;

FIG. 2A is a perspective view of a heat distribution block according to an embodiment of the disclosure;

FIG. 2B is a cross sectional top view of a heat distribution block according to an embodiment of the disclosure;

FIG. 2C is a first cross sectional side view of a heat distribution block according to an embodiment of the disclosure;

FIG. 2D is a second cross sectional side view of a heat distribution block according to an embodiment of the disclosure; and

FIG. 3 is a flow diagram of a process for generating at least one hot air stream having a temperature distribution or heat distribution profile that is desirable or suitable for facilitating enhanced reliability solar cell soldering processes according to an embodiment of the disclosure.

Detailed Description

The present disclosure is directed generally toward a solar cell soldering head assembly for generating and outputting a hot air stream having a balanced, uniform heat distribution that facilitates high reliability soldering of cell coupling ribbons during PV cell manufacturing processes. In particular embodiments, a high degree of heat uniformity is achieved by way of a heat distribution block that is coupled to receive hot air produced by a set of hot air generators. The heat distribution block is configured to direct incoming hot air into, along, or through one or more pathways or channels that are shaped and dimensioned in a manner that facilitates uniform heat distribution, as further described below. A solar cell soldering head system can include a solar cell soldering head assembly in accordance with the present

disclosure, and a control system that receives temperature signals from a thermal sensor assembly that is carried by a heat distribution block.

FIGs. 1A, 1B, and 1C are schematic illustrations of portions of a solar cell soldering head assembly 10 according to an embodiment of the disclosure. In one embodiment, the solar cell soldering head assembly 10 includes of a set of incoming air ports 20; a set of hot air generators 30 coupled to the set of incoming air ports 20; and a heat distribution block 100 coupled to the set of hot air generators 30. The solar cell soldering head assembly 10 can additionally include a support member 40 that carries, supports, braces, or holds particular portions of the soldering head assembly 10 in a manner that facilitates carrying or moving the soldering head assembly 10 as a unified structure. In some embodiments, the solar cell soldering head assembly 10 further includes a heat reduction, heat shielding, or insulating panel or plate 60, which can be coupled to the heat distribution block 100 by way of a first set of attachment members 202, and further coupled to the support member 40 by way of a second set of attachment members (not shown). The solar cell soldering head assembly 10 can also include a thermal or temperature sensor assembly 70 that is coupled to the heat distribution block 100.

The set of incoming air ports 20 includes a number of individual incoming air ports or pathways 20a-h, and the set of hot air generators 30 includes a number of individual hot air generators 30a-h. In several embodiments, the set of incoming air ports 20 and the set of hot air generators 30 each include an identical number of individual air transfer or handling elements. While FIG. 1 depicts eight individual incoming air ports 20a-h and eight individual hot air generators 30a-h, the number of individual incoming air ports 20a-h and/or individual hot air generators 30a-h can vary depending upon embodiment details or an industrial application under consideration.

The set of incoming air ports 20 is coupled to an air source (not shown), which provides or supplies an incoming air stream at a given pressure. An incoming air pressure can be selected by way of, for instance, a pressure regulator (not shown). The incoming air stream flows into and through the set of incoming air ports 20 and into the set of hot air generators

30. An individual incoming air port 20a-h can include a coupling structure, member, or assembly 24 that can be coupled, secured, mated, or attached to a receiving portion of an individual hot air generator 30a-h, for instance, by way of one or more fitting and/or securing elements (e.g., a nut and a threaded assembly).

In various embodiments, an individual hot air generator 30a-h includes an outer portion, casing, housing, or tube 32 that carries, encloses, or surrounds a heating element. An individual hot air generator 30a-h can be a type of sheathed heater. In a representative implementation, an individual hot air generator 30a has a cylindrical shape and a diameter of approximately 5 - 20 millimeters, or approximately 8 - 18 millimeters, or about 13 millimeters. An individual hot air generator's housing 32 can include an input portion or segment 34 and an output portion or segment 36. Air is introduced into an individual hot air generator 30a-h proximate to its input segment 34, and heated air is emitted by an individual hot air generator 30a-h proximate to its output segment 36. An individual hot air generator's input segment 34 can carry a mating element 33 such as a set of threads to facilitate coupling to an individual incoming air port's coupling structure 24. An individual hot air generator's input segment 34 can additionally include a flange, seat, or stop member 35, which can define or approximately define a coupling depth for an individual air port's coupling structure 24. A flange or seat member 35 can have a dimension or span that is larger than the dimension or span of an individual hot air generator's housing 32.

A heating element can be coupled by way of a set of wires 38 to receive a heating signal (e.g., an electrical signal having a particular voltage or current level) from a temperature controller (not shown) to facilitate an adjustment of the heating element's thermal output, in a manner understood by one of ordinary skill in the relevant art. Individual hot air generators 30a-h can be separated from each other by a gap *g*, as further detailed below. In a representative implementation, an individual hot air generator 30a can be a portion of a commercially available device, such as a body portion of a MiSUMI MAHZC 2 hot air generator (MiSUMI Group, Tokyo, JP).

As further illustrated in FIGs. 1B and 1C, the assembly 10 can include a support structure 40 that facilitates assembly transport. Such transport can occur by way of an automated, semi-automated, or manual assembly positioning device, for instance, a gantry robot or a robotic device (not shown) that can position the assembly 10 relative to a set of solar cells or other devices. In several embodiments the support structure 40 includes a first or upper member 42, and in some embodiments includes a second or lower member 50. The upper member 42 can include a plate having a set of openings 46 formed therein for receiving and supporting or carrying the set of hot air generators 30. In one embodiment, the set of openings 46 includes a first opening 46a that is dimensioned to receive a first through a fourth hot air generator 30a-d, and a second opening 46b that is dimensioned to receive a fifth through an eighth hot air generator 30e-h. A given individual hot air generator 30a-h can be inserted into a plate opening 46a, 46b such that the hot air generator's flange or seat member 35 rests upon and is supported by the plate. Following the insertion of an individual hot air generator 30a-b into a plate opening 46a, 46b, a portion of the hot air generator 30a-h (e.g., proximate to its input segment 34, and lengthwise toward its output segment 36) extends beneath or below the plate.

The upper member 42 can further include a coupling segment 48 that extends away from the plate, which can be coupled or secured to or carried or held by a portion of an assembly positioning device. In some embodiments, the coupling segment 48 and the plate are perpendicular or approximately perpendicular to each other, and together form a T-shaped or L-shaped structure. Depending upon embodiment details, the coupling segment 48 and the plate can be formed from a single piece of material (e.g., a single machined piece of metal) or separate pieces of material. In a representative implementation, the plate includes a machined piece of metal (e.g., steel, such as #1045 steel) having two generally elliptical openings 46a, 46b, which are configured to carry two sets of four individual hot air generators 30a-d, 30e-h in a side-by-side configuration.

The support structure's lower member 50 can include a set of openings 56 that can positionally align relative to the upper member's set of openings 46, such that a number of individual openings 56a-h in the lower member 50 can be aligned or matched with

particular openings 46a, 46b in the upper member 42. An given hot air generator 30a-h can thus be inserted through a particular upper member opening 46a, 46b and a corresponding lower member individual opening 56a-h. The lower member 50 can be secured, attached, or mounted to the upper member 40, for instance, by way of a set of screws or pins. The lower member 50 can additionally include a set of guides 58 for carrying and routing a given length of the assembly's set of wires 38. In a representative embodiment, the lower member 50 includes a machined piece of metal (e.g., stainless steel) configured to carry, retain, or hold eight individual hot air generators 30a-h. Each of the lower member's individual openings 56a-h can have a dimension or span that is slightly larger than that of an individual hot air generator 30a-h.

As indicated above, each individual hot air generator 30a includes an output segment 36 at or proximate to a terminal end of its housing 32. The output segment 36 supplies heated air from the hot air generator 30a to the heat distribution block 100. The heat distribution block 100 includes particular structural features and/or elements that facilitate heat balancing and uniform hot air output, as described in detail hereafter with reference to FIGs. 2A – 2D and continued reference to FIGs. 1A – 1C.

FIG. 2A is a perspective view, FIG. 2B is a cross sectional top view, FIG. 2C is a first cross side sectional view, and FIG. 2D is a second cross sectional side view of a heat distribution block 100 according to an embodiment of the disclosure. In one embodiment, the heat distribution block 100 includes a block or piece of material having an interface portion 110 and an air distribution or output portion 180. Depending upon embodiment details, the interface portion 110 and the air distribution portion 180 can be made from a single (e.g., machined) piece of material, or separate pieces of material. The heat distribution block 100 also includes an insertion surface 120; a front or first face 130; a rear or second face 132; a first side 134; and a second side 138. Additionally, the heat distribution block 100 includes an air outlet surface 138 that is carried by the heat distribution block's output portion 180.

The heat distribution block 100 includes at least one material having a high thermal conductivity. In some embodiments, the heat distribution block 100 includes a material

having a target or acceptable or generally acceptable minimum thermal conductivity, for instance, greater than approximately 70 – 80 Watts per meter-Kelvin (e.g., greater than approximately 75 Watts per meter-Kelvin, or about 100 Watts per meter-Kelvin). Depending upon embodiment details and design, the heat distribution block 100 can include one or more pieces, layers, particles, or alloys of a metal (e.g., brass, Aluminum, Copper, Iron, Silver, Molybdenum, Tungsten, or another metal), a polymer composite, and/or another material. In a representative implementation, the heat distribution block 100 includes brass. In another representative implementation, the heat distribution block 100 is formed or substantially formed from a single piece of brass.

The heat distribution block's insertion surface 120 includes a set of openings 122 that forms or provides access to a set of recesses, slots, or sockets 140 carried by or formed in the heat distribution block 100. In various embodiments, each opening 122a-h within the set of openings 122 corresponds to a recess 140a-h within the set of recesses 140, and each opening 122a-h is shaped and dimensioned to accommodate or matingly receive an individual hot air generator 30a-h. In multiple embodiments, an opening 122a-h can be defined as an access aperture for a corresponding recess 140a-h; an opening 122a-h can alternatively be defined as forming a corresponding recess 140a-h.

Each opening 122a-h can have a cross sectional shape configured to receive the cross sectional shape of the output segment 36 of an individual hot air generator 30. Thus, each opening 122a-h can have a width w or a cross sectional area A that corresponds to or is slightly larger than a width or a cross sectional area of an individual hot air generator 30a-h. In a representative implementation, an insertion surface opening 122a-h can have a diameter of approximately 5.25 – 20.25 millimeters, or approximately 8.1 – 18.1 millimeters, or about 13.1 millimeters. In addition to the foregoing, a border or boundary 124 exists between an edge or periphery of an opening 122a-h and the front and rear faces 130, 132 of the heat distribution block 100. In a representative implementation, the border or boundary 124 can be approximately 1 – 4 millimeters, or about 2 millimeters, wide.

Each opening 122a-h can be spaced apart by a separation distance *s* that matches a gap *g* between individual hot air generators 30a-h. A separation distance s between the interface portion's openings 122a-h and/or a gap *g* between individual hot air generators 30a-h can be selected to satisfy one or more thermal performance characteristics or heating uniformity constraints. For instance, a separation distance *s* and/or a gap *g* can be selected to enhance a likelihood of facilitating a predictable or a maximum allowable temperature deviation along one or more portions of the heat distribution block 100 in view of a target hot air application temperature or temperature range. In a representative implementation, a separation distance *s* between the interface portion openings 122a-h and/or a gap *g* between the individual hot air generators 30a-g can be approximately 2 – 12 millimeters, or approximately 4 – 10 millimeters, or about 7 millimeters.

In various embodiments, a given recess 140a-h can have a crosswise or cross sectional dimension that is identical to the width *w* or the area *A* of a corresponding opening 122a-h in the heat distribution block's insertion surface 120. That is, a recess 140a-h and its corresponding opening 122a-h can each have the same width *w* or a cross sectional area *A*. In certain embodiments, a recess 140a-h can include a wider or narrower dimension or a larger cross sectional area than its corresponding opening 122a-h.

Each recess 140a-h is shaped and dimensioned to receive a portion of an individual hot air generator 30a-h. More particularly, each recess 140a-h has a depth *d* that is sufficient to receive or accommodate at least part of an individual hot air generator's terminal portion 38 (e.g., toward or up to a hot air generator insertion depth). In various embodiments, a recess 140a-h includes a transition region, portion, or structural aspect, feature, or element 142 such as a bottom surface that defines or facilitates the definition of the recess' depth. The size, orientation, shape, and/or contour of a transition feature 142 can vary depending upon embodiment details. For instance, a transition feature 142 can include one or more planar or generally planar surfaces or one or more curved surfaces that occupy a portion or form a boundary of a recess 140a-h at depth *d*. In a representative implementation, a recess 140a-h can have a depth of approximately 5 – 25 millimeters, or approximately 10 – 20 millimeters, or about 16 millimeters; and a hot air generator's terminal portion 36 can reside

approximately 1 – 25 millimeters, or approximately 2 – 15 millimeters, or about 5 millimeters deep in a recess 140a-h. Additionally, in one implementation, a recess 140a-h includes a planar or generally planar bottom surface 142, which can be generally circular.

The heat distribution block 100 provides, delivers, or applies hot air by way of a set of hot air outlets 170 that are carried by the heat distribution block's air outlet surface 138. A set of air passages, channels, or ducts 160 is at least partially exposed or accessible to the insertion surface's set of openings 122 and the set of hot air outlets 170. In various embodiments, the set of air channels 160 extends between the set of recesses 140 and the set of hot air outlets 170 to facilitate such hot air delivery. More particularly, in several embodiments, an air channel 160a-h extends between the depth *d* of a recess 140a-h and a hot air outlet 170a-h. Still more particularly, in some embodiments, an air channel 160a-h extends from one or more openings 144 in a transition feature or bottom surface 142 of a recess 140a-h to a hot air outlet 170a-h. The portion or region of the heating block assembly 100 through which an air channel 170a-h extends can define the heating block's output portion 180.

In multiple embodiments, an air channel 160a-h can be a passage having a generally uniform cross sectional area A_c, or a generally uniform channel width w_c and/or channel height h_c, along a channel length l_c. In other embodiments, an air channel 160a-h can be tapered, contoured, or nonuniform along one or more air channel dimensions. An air channel 160a-h can extend at an angle relative to a particular heating block assembly reference axis or surface. For instance, an air channel 160a-h can extend along its channel length l_c at a predetermined channel angle θ_c relative to an axis extending through a center point of a recess 140a-h along the recess depth *d*. Depending upon embodiment details, θ_c can be nonzero or zero, and may be selected or defined to facilitate the delivery of hot air in a target direction or toward a target soldering site. The heating block's insertion surface 120 and the heating block's air outlet surface 138 can reside in parallel or non-parallel planes relative to each other, in a manner that depends upon the value of θ_c. In a representative implementation, θ_c is between approximately 45 – 75 degrees, or about 70

degrees. In another representative implementation, θ_c is less than approximately 15 degrees, or about zero degrees.

An air channel dimension such as its width w_c can be approximately identical to, larger than, or smaller than a dimension, diameter, or width of a recess 140a-h. In some embodiments, an air channel's width w_c is larger than the diameter of a recess 140a-h. In several embodiments, a terminal end of a given air channel 160a-h can form a corresponding hot air outlet 170a-h. Depending upon embodiment details, a given air channel 160a-h and a corresponding hot air outlet 170a-h can have identical, approximately identical, or different cross sectional areas, widths, or heights. Hot air outlets 170a-h can be separated from each other by a bridge member 172 having a particular bridge width w_b. In embodiments in which air channels 160a-h and hot air outlets 170a-h have an identical cross sectional area, air channels 160a-h can also be separated from each other by a bridge member 172 having bridge width w_b. In such embodiments, the bridge member 172 can be a continuous structure or structural feature along the length l_c of the hot air channel 160a-h.

In a representative implementation, an air channel 160a-h has a width w_c of approximately 15 – 20 millimeters, or about 18 millimeters; a height h_c of approximately 0.1 – 2.0 millimeters, or about 0.5 millimeters; and a length l_c of approximately 20 - 25 millimeters, or about 23 millimeters. In such an implementation, a hot air outlet 170a-h can have a width and a height that is identical or essentially identical to an air channel's width w_c and height h_c. Additionally, a bridge width w_b is approximately 0.2 – 5.0 millimeters, or about 2 millimeters.

In various embodiments, the solar cell soldering head assembly 10 further includes one or more insulating plates 60 that provide an insulation layer or envelope for the set of hot air generators 30. Insulating plates 60 can prevent the set of hot air generators 30 from an undesirable amount of exposure to an external cooler environment, thereby reducing or minimizing heat loss and saving energy. FIG. 1A depicts a single insulating plate 60 for purpose of illustration and to aid understanding. In some embodiments, two insulating plates 60 can form an enclosed or partially enclosed box around the set of hot air generators

30. Insulating plates 60 can be made from a single piece of material, or separate pieces of material to cover one, two, or more sections or sides of the set of hot air generators 30.

An insulating plate 60 can additionally serve as 1) a bridge or spanning member that couples the heat distribution block 100 to the assembly's support structure 40, such that the support structure 40 substantially bears the heat distribution block's weight; and 2) a positioning member that situates or orients the heat distribution block 100 relative to the hot air generators' output segments 36. In a representative implementation, an insulating plate 60 can be made of stainless steel, quartz, a ceramic, and/or other material.

One or more insulating plates 60 can be coupled to the heat distribution block 100 by way of a first set of attachment members 202, and/or coupled to the assembly's support structure 40 by way of a second set of attachment members (not shown). In a representative implementation, the first set 202 and second set of attachment members can include individual attachment elements such as pins or screws, and possibly a set of ceramic or other type of washers. An individual attachment element can secure an insulating plate 60 to the assembly's support structure 40 or the heat distribution block 100 by way of a set of support structure openings (not shown) or a set of heat distribution block openings 212, respectively. An individual support structure opening or an individual heat distribution block opening 212a-c is appropriately shaped and dimensioned to receive an attachment element.

In various embodiments, an opening that is configured to receive a given attachment element can have a width w_o or a cross sectional area A_o that corresponds to or is slightly larger than a width or a cross sectional area of the attachment element. For the heat distribution block 100, three attachment members 202a-c and three corresponding openings 212a-c are depicted in FIG. 1 and FIG. 2A. Similar considerations can apply to the support structure 40 and any attachment elements by which a heat insulating plate 60 is coupled thereto. However, the number of attachment elements and/or corresponding openings (e.g., heat distribution block openings 212a-c) configured to receive such attachment elements can vary depending on embodiment details and design.

For example, while FIG. 1 depicts an embodiment in which three attachment members 202a-c can couple the heat distribution block 100 to one insulating plate 60 through three openings 212a-c, in another embodiment, a solar cell soldering head assembly 10 can include three attachment members 202a-c that couple two insulating plates 60 to the heat distribution block 100 by way of three openings 212a-c; or six attachment members that couple two insulating plates 60 to the heat distribution block 100 by way of six openings. The positions of and/or distances between the individual openings 212a-c (e.g., as measured from an opening edge or center point) on the heat distribution block 100 can vary depending upon embodiment details (e.g. a number of openings 212a-c or the length of the heat distribution block 100). In a representative implementation, the distances between the center lines of individual openings 212a-c on the heat distribution block's first side 134 is 26.5 mm, 86.5 mm, and 146.5 mm, respectively. The gaps or distances between each such openings 212a-c can be identical or different. In one implementation, the gap between each opening 212 a-c is approximately 70 mm. Similar considerations to those described above can also apply to support structure openings and corresponding attachment members.

The apparatus 10 and/or a system in which the apparatus 10 resides can include one or more thermal sensing elements, for instance, a thermocouple, a thermistor, a resistance temperature detector (RTD), or an optical (e.g., infrared) sensor. Such devices can facilitate temperature monitoring and regulation by way of a closed loop temperature control subsystem, which can include, for instance, a Proportional Integral Derivative (PID) controller. Depending upon embodiment details, particular thermal sensing elements can be carried by or separate from the heat distribution block 100. In several embodiments, a thermal sensor or thermal sensor assembly 70 is carried by or coupled to the heat distribution block 100. The thermal sensor assembly 70 can include one or more types of thermal sensors, such as a thermocouple that can reside upon and/or within particular portions of the heat distribution block 100. The thermal sensor assembly 70 can further include one or more mounting elements (e.g., a screw or pin) for securing a portion of the thermal assembly 70 to the heat distribution block 100.

In one embodiment, the thermal sensor assembly 70 includes a ring type thermocouple (RTT), which is mounted to the heat distribution block 100 by way of a screw or pin that can be inserted into a mounting opening 218 in the heat distribution block. While FIG. 1 illustrates a single thermal sensor assembly 70, the number and/or type of thermal sensor assemblies 70 or mounting elements can vary depending upon embodiment details or design. In a representative implementation, a distance between a the center line of the mounting opening 218 with respect to the first side 134 and the rear face 132 is approximately 3.5 mm and approximately 10 mm, respectively.

As indicated above, one or more thermal sensing elements can be coupled to a control system, subsystem, or device, or more particularly, a temperature controller (not shown). A given thermal sensing assembly 70 can generate a temperature signal that the temperature controller utilizes (e.g., based upon a sensed or computed temperature and a target temperature or temperature range) to generate a temperature control signal. The temperature control signal can drive a current control device to regulate an amount of electric current provided to one or more individual hot air generators 30a-h in order to achieve or maintain the target temperature or temperature range. In a representative implementation, a current control device can include an SCR (Semiconductor Controlled Rectifier) or an SSR (Solid State Relay).

In various embodiments, the temperature of air that enters or is input to the set of incoming air ports 20 can range from approximately 10 - 40 ^{o}C, or approximately 20 – 30 ^{o}C, or about 25 ^{o}C. Incoming air flowing into individual hot air generators 30a-h is heated to reach a target or required soldering process temperature, which can be any specific temperature or narrower range within a temperature span of approximately 360 – 400 ^{o}C.

In general, across the set of hot air generators 30, a maximum or generally expected maximum temperature variation of hot air that is output by individual hot air generators 30a-h (e.g., at the individual hot air generators' output segments 36) prior to or upon entering the heat distribution block 100 can be plus or minus approximately 20 ^{o}C or larger. In a representative situation, the temperature of hot air that is output by the most exterior or

most environmentally exposed individual hot air generators 30a, 30h can be approximately 20 ^{o}C or more cooler than that of hot air output by the most interior or least environmentally exposed individual hot air generators 30d, 30e as a result of environmental heat loss.

At or proximate to the heat distribution block's set of hot air outlets 170, the hot air that is output or emitted by the heat distribution block 100 can exhibit a temperature variation across the set of hot air outlets 170 of plus or minus approximately 5 – 15 ^{o}C, or approximately 10 ^{o}C. Thus, the heat distribution block 100 can provide a reduction in temperature variation of approximately 25% - 75%, or approximately 50%, relative to an emitted hot air temperature variation across the set of hot air generators 20.

Particular structural aspects of the heat distribution block 100 provide a thermal balancing effect, such that a temperature variation or a temperature extreme exhibited by hot air that is output by or across individual hot air generators 30a-h is reduced or minimized to an extent that is suitable for enhanced or high reliability solar cell soldering processes. Such structural aspects can include one or more of a separation distance s between interface portion openings 122a-h; a dimension (e.g., a depth) of the set of set of recesses 140; a shape, location, and/or orientation of one or more transition features 142; a shape, dimension, and/or length of the set of channels 160; a shape or dimension of the set of hot air outlets 170; and a shape or dimension of and/or a spacing between bridge members 172. Such structural aspects can further include the material(s) from which the heat distribution block 100 is formed or constructed, for instance, one or more materials having a suitable thermal conductivity (e.g., a target or acceptable minimum thermal conductivity, which can be defined relative to one or more temperatures such as a target soldering process temperature).

FIG. 3 is a flow diagram of a process 300 for generating at least one hot air stream having a temperature distribution or heat distribution profile that is desirable or suitable for facilitating enhanced reliability solar cell soldering processes. Relative to FIGs. 1 – 2D previously described herein, like reference numbers indicate like or analogous elements. In one embodiment, the process 300 includes a first process portion 310 that involves

providing an incoming air stream to one or more hot air generators 20a-h, and a second process portion 320 that involves heating the incoming air stream within the set of hot air generators 20. A third process portion 330 involves emitting heated air from the output portion of at least one hot air generator 20a-h, and a fourth process portion 340 involves receiving the heated air emitted from the hot air generator(s) 20a-h at a location upon or within a heat distribution block 100. The fourth process portion 340 can include providing a heat distribution block 100 that includes one or more materials having a thermal conductivity of at least approximately 70 – 80 Watts per meter-Kelvin. A fifth process portion 350 involves directing the heated air that has been emitted from each hot air generator 20a-g to a set of hot air outlets 170 by way of a set of air channels 160 within the heat distribution block 100. Individual air channels 160a-h can be separated by a distance that is less than a separation distance or gap between individual hot air generators 20a-h. For instance, individual air channels 160a-h can be separated by the width of a bridge member 172.

The above described embodiments of the present disclosure are intended for illustrative purposes and do not restrict the scope of the present disclosure. While aspects of particular components, design, and system associated with certain embodiments have been described herein, it will be appreciated that several of the above disclosed and other structural features and functions, or alternatives thereof, may be desirably combined into various other different embodiment, implementations, systems, or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations, or improvements therein can be made to the above described embodiments without departing from the scope of the present disclosure.

Claims

1. A solar cell soldering head assembly comprising:

a set of hot air generators coupled to a source of incoming air;

a heat distribution block coupled to the set of hot air generators, the heat distribution block comprising:

an insertion surface having a set of insertion openings dimensioned to matingly receive the set of hot air generators, each insertion opening within the set of insertion openings having a cross sectional area;

an outlet surface having set of hot air outlets, each hot air outlet within the set of hot air outlets having an area smaller than a cross sectional area of an insertion opening within the set of insertion openings; and

a set of channels exposed to the set of insertion openings and the set of hot air outlets.

2. The apparatus of claim 1, wherein the heat distribution block comprises a thermally conductive material.

3. The apparatus of claim 1, wherein the heat distribution block comprises a thermally conductive material having a thermal conductivity of at least approximately 80 Watts per meter-Kelvin.

4. The apparatus of claim 1, wherein the heat distribution block is formed from a single machined piece of thermally conductive material.

5. The apparatus of claim 1, wherein at least one hot air outlet within the set of hot air outlets has a height of approximately 0.1 to approximately 2.5 millimeters.

6. The apparatus of claim 1, wherein at least one hot air outlet within the set of hot air outlets has a height of approximately 0.5 millimeters.

7. The apparatus of claim 1, wherein each hot air outlet within the set of hot air outlets has a height of approximately 0.5 millimeters.

8. The apparatus of claim 1, wherein the set of hot air outlets includes a plurality of individual hot air outlets, the apparatus further comprising a connecting bridge between each individual hot air outlet.

9. The apparatus of claim 8, wherein a connecting bridge has a width of approximately 0.5 millimeters to approximately 5.0 millimeters.

10. The apparatus of claim 8, wherein a connecting bridge has a width of approximately 2.0 millimeters.

11. The apparatus of claim 1, wherein the set of hot air generators includes a plurality of individual hot air generators, the set of insertion openings includes a plurality of insertion openings, and the set of hot air outlets includes a plurality of hot air outlets, the apparatus further comprising a connecting bridge between each hot air outlet.

12. The apparatus of claim 11, wherein a connecting bridge has a width of approximately 0.5 millimeters to approximately 5.0 millimeters.

13. The apparatus of claim 11, wherein each connecting bridge has a width of approximately 2.0 millimeters.

14. The apparatus of claim 1, wherein the heat distribution block further comprises a set of recesses defined therein, each recess within the set of recesses extending from an insertion opening within the set of insertion openings to a predetermined recess depth in the heat distribution block.

15. The apparatus of claim 14, wherein the set of air channels extends between the recess depth and the set of hot air outlets.

16. The apparatus of claim 14, wherein the heat distribution block further comprises a set of transition features that defines the recess depth.

17. The apparatus of claim 14, wherein the set of air channels includes at least one individual air channel having a width that exceeds a width of at least one corresponding individual recess within the set of recesses.

18. The apparatus of claim 1, further comprising a thermal sensor coupled to the heat distribution block.

19. The apparatus of claim 1, further comprising a thermocouple coupled to the heat distribution block.

20. The apparatus of claim 1, further comprising a support structure coupled to the set of hot air generators.

21. The apparatus of claim 20, wherein the support structure comprises:

a plate having a set of openings defined therein for matingly receiving a portion of the set of hot air generators; and

a coupling segment extending away from the plate.

22. The apparatus of claim 21, further comprising at least one heat insulating plate coupled to each of the support structure and the heat distribution block.

23. The apparatus of claim 22, wherein the support structure substantially carries the weight of the heat distribution block.

24. A method for generating a hot air stream having a heat distribution profile that is suitable for facilitating enhanced reliability solar cell soldering processes, the method comprising:

providing an incoming air stream to a plurality of hot air generators, each hot air generator separated from another hot air generator by a separation distance, each hot air generator including an air travel pathway having a cross sectional area, each hot air generator including an output segment from which heated air is emitted;

heating the incoming air stream within each hot air generator;

emitting heated air from the output portion of each hot air generator;

receiving the heated air emitted from each hot air generator within a heat distribution block; and

providing a set of air channels within the heat distribution block through which heated air emitted from each hot air generator can flow to a set of hot air outlets, each air channel within the set of air channels having a separation distance that is smaller than the separation distance between hot air generators.

25. The method of claim 24, wherein a hot air temperature variation across the set of hot air outlets is approximately 25% - 75% less than a hot air temperature variation across the plurality of hot air generators' output segments.

26. The method of claim 24, wherein a hot air temperature variation across the set of hot air outlets is approximately 50% less than a hot air temperature variation across the plurality of hot air generators' output segments.

27. The method of claim 24, further comprising providing a heat distribution block material having a thermal conductivity of at least approximately 80 Watts per meter-Kelvin.

28. The method of claim 24, further comprising:

emitting hot air at the set of hot air outlets; and

applying the hot air emitted at the set of hot air outlets to a portion of a solar cell assembly to facilitate a soldering operation.

29. The method of claim 28, wherein a temperature variation of hot air emitted by the set of hot air outlets is approximately 10 ^{o}C.