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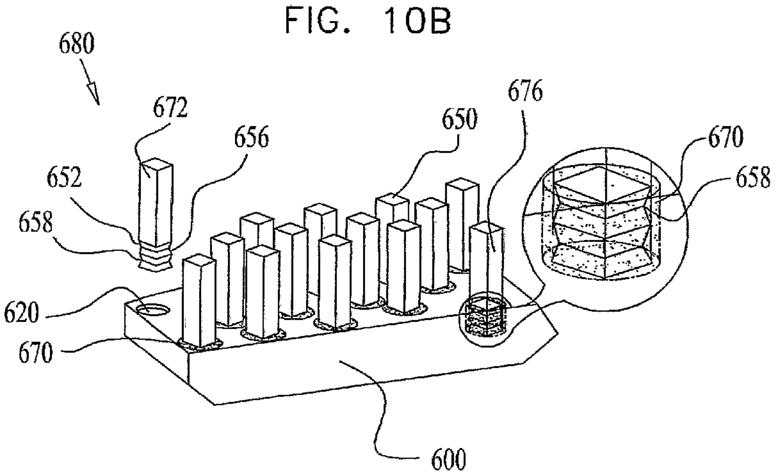
FIG. 10B



(57) Abstract: A method for manufacturing a solar absorber element forming a solar absorber of a solar receiver including providing a substrate, placing at least one projection within the substrate, and attaching the projection to the substrate with an attachment functionality operative to attach the projection to the substrate, thus defining the solar absorber element, the solar absorber being configured to allow a fluid to flow therein and be heated by solar radiation penetrating the projection of the solar absorber element.

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A METHOD FOR MANUFACTURING A SOLAR RADIATION ABSORBER

REFERENCE TO CO-PENDING APPLICATIONS

Applicant hereby claims priority of U.S. Provisional Patent Application Serial No. 61/152,241, filed on February 12, 2009, entitled "A Method for Manufacturing a Solar Radiation Absorber"; U. S. Provisional Patent Application Serial No. 61/153,656, filed on February 19, 2009, entitled "A Method for Manufacturing a Solar Radiation Absorber"; and U. S. Provisional Patent Application Serial No. 61/164,474, filed on March 30, 2009, entitled "A Method for Manufacturing a Solar Radiation Absorber", all applications are incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates to a method for manufacturing a solar radiation absorber.

BACKGROUND

Turbines are commonly used to produce electrical power. Typically, a fluid, such as air, steam or any other gas, is compressed and heated before being supplied to the turbine, wherein the fluid is expanded and some of the energy content of hot, compressed fluid is converted to mechanical motion which is then converted to electricity by use of a generator.

In solar energy systems one device known in the art for heating the fluid prior to entering the turbine is a solar receiver. Such a receiver utilizes solar radiation which impinges upon a solar radiation absorber within the solar receiver. The fluid is heated by the absorber, and thereafter the fluid transfers the heat via the turbine for producing electrical power therefrom. Additionally, the heated fluid may be introduced into any heat consuming system for utilizing the thermal energy of the heated fluid.

SUMMARY OF THE INVENTION

There is thus provided in accordance with an embodiment of the present invention a method for manufacturing a solar absorber element forming a solar absorber of a solar receiver including providing a substrate, placing at least one projection within the substrate, and attaching the projection to the substrate with an attachment functionality operative to attach the projection to the substrate, thus defining the solar absorber element, the solar absorber being configured to allow a fluid to flow therein and be heated by solar radiation penetrating the projection of the solar absorber element. Additionally, the attachment functionality includes an indentation formed in the projection and an attachment means designated to engage the projection with the substrate. Accordingly, the attachment means includes an adhesive. Alternatively, the attachment means includes a clip.

In accordance with an embodiment of the invention the indentation is defined by perforations formed within the projection. Additionally, the indentation is defined by a jagged portion of the projection. Accordingly, the substrate is formed of a thermal insulating material. Furthermore, the projection is formed with perforations therein.

There is thus provided in accordance with another embodiment of the present invention a solar radiation absorber including at least one solar radiation absorber element defining the solar radiation absorber, a substrate, at least one projection, and an attachment functionality operative to attach the projection to the substrate, thus defining the solar radiation absorber element, the solar absorber being configured to allow a fluid to flow therein and be heated by solar radiation penetrating the projection of the solar radiation absorber element. Accordingly, the attachment functionality includes an indentation formed in the projection and an attachment means designated to engage the projection with the substrate. Additionally, the attachment means includes an adhesive. Alternatively, the attachment means includes a clip.

In accordance with an embodiment of the present invention the indentation is defined by perforations formed within the projection. Accordingly, the indentation is defined by a jagged portion of the projection. Additionally, the substrate is formed of a thermal insulating material. Furthermore, the projection is formed with perforations therein.

There is thus provided in accordance with yet another embodiment of the present invention a solar receiver including the solar radiation absorber, an inlet for allowing the fluid to flow therein and to be heated within the solar radiation absorber, and an outlet for egress of the heated fluid therefrom.

There is thus provided in accordance with still another embodiment of the present invention a solar radiation absorber manufacturing assembly including a receptacle for receiving a substrate material therein, and a plurality of projections operative to be embedded within the substrate material wherein the substrate material is in an unsolidified state. Accordingly, the projections are partially embedded within the substrate material. Additionally, the assembly includes an aligning element. Furthermore, the assembly includes a cover. Accordingly, an aperture is provided for suction of the substrate material.

There is thus provided in accordance with a further embodiment of the present invention a solar receiver including a solar radiation absorber assembly manufactured in the solar radiation absorber manufacturing assembly, an inlet for allowing a fluid to flow therein and to be heated within the solar radiation absorber ~~assembly, and an outlet for egress of the heated fluid therefrom.~~

There is thus provided in accordance with yet a further embodiment of the present invention a method for manufacturing a solar absorber element forming a solar absorber of a solar receiver including providing a substrate wherein a substrate material is unsolidified, placing a plurality of projections within the unsolidified substrate material, and solidifying the substrate material thereby embedding the projections within the substrate and thus defining the solar absorber element. Accordingly, the solidifying is performed by heat. Additionally, the projections are formed of a perforated material. Furthermore, the substrate is formed of a thermal insulating material. Additionally, a solar receiver includes a solar radiation absorber formed of at least one projection placed in a substrate, the projection being formed of a perforated material for allowing solar radiation to penetrate therein and thereby heat the absorber, an inlet for allowing a fluid to flow therein and to be heated within the solar radiation absorber, and an outlet for egress of the heated fluid therefrom.

There is thus provided in accordance with still a further embodiment of the present invention a solar radiation absorber including at least one solar radiation absorber element including a substrate, and at least one projection projecting from the substrate, the projection being placed within the substrate wherein a material of the substrate is unsolidified and thereafter the projection being embedded within the substrate following solidification of the material of the substrate, the solar absorber element being configured to allow a fluid to flow therein and be heated by solar radiation penetrating the projection of the solar absorber element. Accordingly, the projection is formed of a perforated material. Additionally, a solar receiver includes the solar radiation absorber an inlet for allowing the fluid to flow therein and to be heated within the solar radiation absorber, and an outlet for egress of the heated fluid therefrom.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be understood and appreciated more fully from the following detailed description, taken in conjunction with the drawings in which:

Fig. 1 is a simplified partially pictorial, partially sectional illustration of a solar receiver constructed and operative in accordance with an embodiment of the present invention;

Figs. 2A – 2C are simplified pictorial illustrations of a solar radiation absorber manufacturing assembly at an initial manufacturing stage, an intermediate manufacturing stage and a final manufacturing stage, respectively, constructed and operative in accordance with an embodiment of the present invention;

Fig. 3 is a simplified exploded view pictorial illustration of a disassembled solar radiation absorber manufacturing assembly constructed and operative in accordance with another embodiment of the present invention;

Fig. 4 is a simplified pictorial illustration of the solar radiation absorber manufacturing assembly of Fig. 3 in a partially assembled state;

Fig. 5 is a simplified pictorial illustration of a solar radiation absorber manufacturing assembly of Figs. 3 and 4 at an initial manufacturing stage;

Figs. 6A & 6B are oppositely facing simplified pictorial illustrations of the solar radiation absorber manufacturing assembly of Figs. 3 - 5 in an intermediate manufacturing stage;

Fig. 7 is a simplified pictorial illustration of the solar radiation absorber manufacturing assembly of Figs. 3 – 6B at a final manufacturing stage, shown in the orientation of Fig. 6B;

Figs. 8A – 8C are simplified pictorial illustrations of a solar radiation absorber manufacturing assembly at an initial manufacturing stage, an intermediate manufacturing stage and a final manufacturing stage, respectively, constructed and operative in accordance with yet another embodiment of the present invention;

Figs. 9A and 9B are simplified pictorial illustrations of a solar radiation absorber manufacturing assembly at an initial manufacturing stage and a final manufacturing stage, respectively, constructed and operative in accordance with still another embodiment of the present invention;

Figs. 10A and 10B are simplified pictorial illustrations of a solar radiation absorber manufacturing assembly at an initial manufacturing stage and a final manufacturing stage, respectively, constructed and operative in accordance with a further embodiment of the present invention; and

Figs. 11A, 11B and 11C are simplified pictorial illustrations of a solar radiation absorber manufacturing assembly at an initial manufacturing stage, a final manufacturing stage and a bottom view of the assembly at the final manufacturing stage, respectively, constructed and operative in accordance with yet a further embodiment of the present invention.

DETAILED DESCRIPTION

In the following description, various aspects of the present invention will be described. For purposes of explanation, specific configurations and details are set forth in order to provide a thorough understanding of the present invention. However, it will also be apparent to one skilled in the art that the present invention may be practiced without the specific details presented herein. Furthermore, well known features may be omitted or simplified in order not to obscure the present invention.

Reference is now made to Fig. 1, which is a simplified pictorial illustration of a solar receiver constructed and operative in accordance with an embodiment of the present invention. As seen in Fig. 1, a solar receiver 100 comprises a solar radiation absorber 110 for absorbing solar radiation penetrating therein and thereby heating a fluid flowing therein. The fluid may flow into the solar radiation absorber 110 via an inlet 120 and heated fluid may egress the solar radiation absorber 110 via an outlet 124.

The solar radiation absorber 110 may comprise a plurality of solar absorber elements 130, which are pressed together so as to form solar radiation absorber 110. Each of the solar absorber elements 130 may be comprised of a substrate 140 supporting a multiplicity of projections 150 protruding therefrom.

The substrate 140 may be formed of any suitable material, preferably a thermal insulating material such as silicon oxide or aluminum silicon or a compound comprising silicon oxide and aluminum silicon, for example.

Projections 150 may be formed of any suitable material. Preferably, the projections 150 are formed of a material operative to allow solar radiation and the fluid to pass therethrough.

It is a particular feature of the present invention that the projections 150 are structured so as to allow the projections 150 to securely sit within substrate 140, as will be further described in reference to Figs. 2A-11C.

Reference is now made to Figs. 2A – 2C, which are simplified pictorial illustrations of a solar radiation absorber manufacturing assembly at an initial manufacturing stage, an intermediate manufacturing stage and a final manufacturing stage, respectively, constructed and operative in accordance with an embodiment of the present invention. As seen in Fig. 2A, a substrate 152 is placed in a receptacle such as a mold 180 at an initial stage of manufacturing wherein the substrate material is pliable and unsolidified.

Turning to Fig. 2B it is seen that projections 182 are placed within the unsolidified material of the substrate 152 in any suitable arrangement. Placement of the projections 182 within substrate 152 may be performed in any suitable manner, such as manually.

As seen in Fig. 2B, the projections 182 are preferably formed with indentations therein. For example, projections 182 may be formed of a perforated material thereby defining perforations 184 therein. The perforated material may be any suitable material, such as foam made of a ceramic material operative to withstand relatively high temperatures, for example. The ceramic material may be a silicon carbide foam or silicon infiltrated silicon carbide foam, for example. The projections 182 may be formed in any suitable configuration.

Perforations 184 allow the substrate material to penetrate therein. A jig (not shown) may be provided so as to prevent the dislocation of projections 182 within substrate 152.

It is noted that alternatively projections 182 may be formed of a solid material with apertures defined therein so as to allow the substrate material to penetrate therein.

The mold 180 may be introduced into a vacuum oven and thereafter into to a furnace, such as a high temperature furnace, for drying and solidifying the substrate material. In a non-limiting example the temperature of the furnace may be in the range of 1000-1500°C. Alternatively the substrate material may be solidified by any heat source or in any suitable manner.

Following removal of the mold 180 from the furnace, the mold 180 and the jig, if provided, are removed from the substrate 152. As seen in Fig. 2C, the substrate material is solidified with the projections 182 embedded therein thus forming an absorber element 190. Wherein the projections are formed of a perforated material it is noted that the substrate material is utilized as an attachment means when it solidifies within perforations 184, thereby providing attachment functionality for enhanced stability of the projections 182 embedded within the substrate 152.

It is appreciated that in accordance with an embodiment of the present invention projections 182 may be formed in any suitable manner allowing any suitable attachment functionality to facilitate securing projections 182 to substrate 152 thereby forming absorber element 190.

It is noted that substrate 152 of Figs. 2A-2C may be identical to substrate 140 of Fig. 1. Projections 182 of Figs. 2A-2C may be identical to projections 150 of Fig. 1. Absorber element 190 of Fig. 2C may be identical to absorber element 130 of Fig. 1.

Reference is now made to Figs. 3 and 4, which are a simplified exploded view pictorial illustration of a disassembled solar radiation absorber manufacturing assembly constructed and operative in accordance with an embodiment of the present invention and a simplified pictorial illustration of the solar radiation absorber manufacturing assembly of Fig. 3 in a partially assembled state, respectively. As seen in Fig. 3, a solar radiation absorber manufacturing assembly 200 comprises a base 202 formed of stainless steel or any other suitable material. Base 202 may comprise a top portion 206 defining an array of apertures 210 in a central location 212 thereof.

Underlying central location 212 is a bottom portion 214 protruding from top portion 206 and forming a support location for a plurality of projections 220 to be inserted within apertures 210 and placed within bottom portion 214.

An aligning element 230 is formed with a generally planar surface 232 defining an array of apertures 234 therein, which apertures 234 are arranged to overlie apertures 210. Apertures 234 are preferably shaped substancially similar to a shape of a bottom surface 236 of projections 220 so as to ensure projections 220 stand substancially erect within apertures 210 and bottom portion 214, wherein aligning element 230 is placed on base 202, as seen in Fig. 4. Aligning element 230 may be formed of any suitable material, such as stainless steal for example.

It is appreciated that aligning element 230 may be obviated.

A receptacle formed as an enclosure subassembly 250 comprises an external enclosure element 252 preferably configured as a rectangular-like shaped frame. A top peripheral recess 258 is defined on an upper surface 260 thereof and a bottom peripheral recess is defined on a bottom surface thereof (not shown) for allowing O-rings 262 to be placed therein. External enclosure element 252 may be formed of any suitable material, such as stainless steal for example.

An aperture 264 may be defined within a wall 268 forming external enclosure element 252. It is noted that aperture 264 may be defined within any suitable location within the absorber manufacturing assembly 200.

An internal enclosure element 270 of enclosure subassembly 250 may be formed in any suitable manner such as by placing inclined surfaces 272 of two opposite facing bars 274 on an inclined surface 276 of a wedge 278. Internal enclosure 270 is preferably placed within external enclosure 252 thereby defining a receiving volume 280 (Fig. 4) therein.

External enclosure element 252 and internal enclosure element 270 of enclosure subassembly 250 may be formed of any suitable material, such as stainless steel, for example.

A cover 284 is formed of a generally planer surface 286 and is arranged to be placed upon enclosure subassembly 250 and engaged with external enclosure element 252 of enclosure subassembly 250 and base 202 in any suitable manner, such as by threads 288 inserted within bores 292, 294 and 296 of cover 284, external enclosure element 252 and base 202, respectively. Cover 284 may be engaged with internal enclosure element 270 and base 202 in any suitable manner, such as by pins 298 inserted within bores 300, 302 and 304 of cover 284, internal enclosure element 270 and base 202, respectively. Cover 284 may be formed of any suitable material, such as stainless steel.

Each of projections 220 may be inserted within an aperture 210 of base 202 and partially placed within bottom portion 214. As seen in Fig. 3, a single projection, designated by reference numeral 318 is shown to be inserted within an aperture 210 and placed within bottom portion 214, thus defining a portion 320 thereof situated within bottom portion 214 and a remaining portion 322 protruding upwardly from aperture 210. A sealing material, such as wax or oil, may be introduced within apertures 210 so as to prevent displacement of projections 220 within apertures 210 and additionally to prevent other materials from penetrating projection portion 320, as will be further described hereinbelow. Insertion of the projections 220 within apertures 210 and introduction of the sealing material therein may be performed in any suitable manner, such as manually.

Projections 220 may be formed of any suitable material. Preferably, the projections 220 are formed of a material operative to allow solar radiation and the fluid to pass therethrough. The projections 220 are preferably formed with indentations therein. For example, projections 220 may be formed of a perforated material thereby defining perforations 330 therein. The perforated material may be any suitable material, such as foam made of a ceramic material operative to withstand relatively high temperatures, for example. The ceramic material may be silicon carbide foam or silicon infiltrated silicon carbide foam, for example. The projections 220 may be formed in any suitable configuration.

Aligning element 230 may be thereafter placed over base 202 and projections 220 so as to prevent displacement of projections 220 within apertures 210 and to ensure projections 220 stand erect therein. External enclosure element 252 of enclosure subassembly 250 may be placed upon base 202 and house two opposite facing bars 274 and wedge 278 of internal enclosure element 270 therein, thereby defining receiving volume 280 (Fig. 4) therein. O-rings 262 may be placed within top peripheral recess 258 and bottom peripheral recess so as to ensure that the manufacturing assembly 200, when closed, is a tight sealed enclosed assembly.

Reference is now made to Fig. 5, which is a simplified pictorial illustration of a solar radiation absorber manufacturing assembly of Figs. 3 and 4 at an initial manufacturing stage. As seen in Fig. 5, a substrate material 340 may be introduced into receiving volume 280 wherein the substrate material is pliable and unsolidified. The substrate material may be any suitable material, preferably a thermal insulating material such as silicon oxide or aluminum silicon or a compound comprising silicon oxide and aluminum silicon, for example.

Reference is now made to Figs. 6A – 7, which are oppositely facing simplified pictorial illustrations of the solar radiation absorber manufacturing assembly of Figs. 3 - 5 in an intermediate manufacturing stage and at a final manufacturing stage, respectively. As seen in Fig. 6A, cover 284 is placed upon enclosure subassembly 250 and the substrate material 340 and is threadably engaged thereto via threads 288 inserted within bores 292, 294 and 296 of cover 284, external enclosure element 252 and base 202, respectively and pins 298 inserted within bores 300, 302 and 304 of cover 284, internal enclosure element 270 and base 202, respectively. It is appreciated that cover 284 may be obviated and the enclosure subassembly 250 may be enclosed in any suitable manner.

The enclosed absorber manufacturing assembly 200 may be introduced into a vacuum oven and thereafter into to a furnace, such as a high temperature furnace, for drying and solidifying the substrate material 340. In a non-limiting example the temperature of the furnace may be in the range of 1000-1500°C. Alternatively, the substrate material may be solidified in any suitable manner.

Suction may be performed prior to introduction into the vacuum oven or furnace via aperture 264 (Figs 3&4) so as to minimize formation of air bubbles within the substrate material.

Turning to Fig. 7 it is seen that following removal of the absorber manufacturing assembly 200 from the furnace, the base 202, aligning element 230, enclosure assembly 250, cover 284 and sealing material are removed and thus a solar radiation absorber element 350 is formed. The substrate material 340 is solidified to form a substrate 360 with the projections 220 embedded therein thus forming the absorber element 350.

Wherein the projections are formed of a perforated material it is noted that the substrate material 340 is utilized as an attachment means when it solidifies within perforations 330 in portion 320 of projections 220, thereby providing attachment functionality for enhanced stability of the projections embedded within the substrate 360.

It is appreciated that in accordance with an embodiment of the present invention projections 220 may be formed in any suitable form allowing any suitable attachment functionality to facilitate securing projections 220 to substrate 360 thereby forming absorber element 350.

It is noted that substrate 360 of Fig. 7 may be identical to substrate 140 of Fig. 1. Projections 220 of Figs. 3-7 may be identical to projections 150 of Fig. 1. Absorber element 350 of Fig. 7 may be identical to absorber element 130 of Fig. 1.

Reference is now made to Figs. 8A – 8C, which are simplified pictorial illustrations of a solar radiation absorber manufacturing assembly at an initial manufacturing stage, an intermediate manufacturing stage and a final manufacturing stage, respectively, constructed and operative in accordance with yet another embodiment of the present invention. As seen in Fig. 8A, a substrate 400 is provided at an initial stage of manufacturing. Substrate 400 may be formed of any suitable material, preferably a thermal insulating material such as silicon oxide or aluminum silicon or a compound comprising silicon oxide and aluminum silicon, for example. As seen in Fig. 8A, the substrate material may be in an unsolidified state or in a solidified state. An array of apertures 420 may be defined within substrate 400 for allowing a plurality of projections 450 to be inserted therein, as seen in Fig. 8B.

Apertures 420 may be formed in any suitable shape, such as a rectangular-like shape or a circular-like shape, for example, or any suitable shape operative to accommodate projections 450 therein.

Projections are preferably formed of a material operative to allow solar radiation and fluid to pass therethrough. For example, projections 450 may be formed of a perforated material thereby defining perforations 460 therein (Figs. 8B & 8C). The perforated material may be any suitable material, such as foam made of a ceramic material operative to withstand relatively high temperatures, for example. The ceramic material may be a silicon carbide foam or silicon infiltrated silicon carbide foam, for example. The projections 450 may be formed in any suitable configuration. Apertures 420 may be formed in any suitable configuration.

Turning to Fig. 8B it is seen that the projections 450 are placed within the apertures 420 in any suitable arrangement. Placement of the projections 450 within apertures 420 may be performed in any suitable manner, such as manually. The projections 450 are preferably formed with the perforations 460 for allowing any suitable attachment means, such as an adhesive 470 to be introduced within apertures 420 and penetrate perforations 460 thereby adhering projections 450 to substrate 400. The adhesive 470 may be any suitable adhesive. A jig (not shown) may be provided so as to prevent the dislocation of projections 450 within substrate 400 during placement of projections 450 therein.

The adhesive 470 is typically introduced into apertures 420 in an unsolidified form and is thereafter solidified in any suitable manner, such as air-dried or by heat, for example

As seen in Fig. 8C, the adhesive 470 is solidified with the projections 450 placed in substrate 400 thus forming an absorber element 480.

It is appreciated that in accordance with an embodiment of the present invention projections 450 may be formed in any suitable manner allowing any suitable attachment functionality to facilitate securing projections 450 to substrate 400 thereby forming absorber element 480.

It is noted that substrate 400 of Figs. 8A-8C may be identical to substrate 140 of Fig. 1. Projections 450 of Figs. 8B&8C may be identical to projections 150 of Fig. 1. Absorber element 480 of Fig. 8C may be identical to absorber element 130 of Fig. 1.

Reference is now made to Figs. 9A and 9B, which are simplified pictorial illustrations of a solar radiation absorber manufacturing assembly at an initial manufacturing stage and a final manufacturing stage, respectively, constructed and operative in accordance with still another embodiment of the present invention. As seen in Fig. 9A, a substrate 500 is provided at an initial stage of manufacturing. Substrate 500 may be formed of any suitable material, preferably a thermal insulating material such as silicon oxide or aluminum silicon or a compound comprising silicon oxide and aluminum silicon, for example. As seen in Fig. 9A, the substrate material may be in an unsolidified state or in a solidified state. An array of apertures 520 may be defined within substrate 500 for allowing a plurality of projections 550 to be inserted therein, as seen in Fig. 9B.

Apertures 520 may be formed in any suitable shape, such as a rectangular-like shape or a circular-like shape, for example, or any suitable shape operative to accommodate projections 550 therein.

Projections 550 are preferably formed of a material operative to allow solar radiation and fluid to pass therethrough and may be formed in any suitable configuration. As seen in Fig. 9B projections 550 are formed without perforations.

Turning to Fig. 9B it is seen that the projections 550 are placed within the apertures 520 in any suitable arrangement. Placement of the projections 550 within apertures 520 may be performed in any suitable manner, such as manually. A single projection 552 is shown prior to insertion within aperture 520.

Projections 550 are engaged with substrate 500 by any suitable attachment means, such as an adhesive 570. Adhesive 570 is typically introduced into apertures 520 in an unsolidified form and is thereafter solidified in any suitable manner, such as air-dried or by heat, for example. A single projection 572 is shown inserted within aperture 520 with adhesive 570 surrounding projection 572, thereby securing projection 572 within substrate 500.

As seen in Fig. 9B, the projections 550 are secured in substrate 500 thus forming an absorber element 580.

It is appreciated that in accordance with an embodiment of the present invention projections 550 may be formed in any suitable manner allowing any suitable attachment functionality to facilitate securing projections 550 to substrate 500 thereby forming absorber element 580.

It is noted that substrate 500 of Figs. 9A&9B may be identical to substrate 140 of Fig. 1. Projections 550 of Figs. 9A&9B may be identical to projections 150 of Fig. 1. Absorber element 580 of Fig. 9B may be identical to absorber element 130 of Fig. 1.

Reference is now made to Figs. 10A and 10B, which are simplified pictorial illustrations of a solar radiation absorber manufacturing assembly at an initial manufacturing stage and a final manufacturing stage, respectively, constructed and operative in accordance with a further embodiment of the present invention.

As seen in Fig. 10A, a substrate 600 is provided at an initial stage of manufacturing. Substrate 600 may be formed of any suitable material, preferably a thermal insulating material such as silicon oxide or aluminum silicon or a compound comprising silicon oxide and aluminum silicon, for example. As seen in Fig. 10A, the substrate material may be in an unsolidified state or in a solidified state. An array of apertures 620 may be defined within substrate 600 for allowing a plurality of projections 650 to be inserted therein, as seen in Fig. 10B.

Apertures 620 may be formed in any suitable shape, such as a rectangular-like shape or a circular-like shape, for example, or any suitable shape operative to accommodate projections 650 therein.

Projections 650 are preferably formed of a material operative to allow solar radiation and fluid to pass therethrough and may be formed in any suitable configuration. On a lower portion 652 of projections 650 may be defined an indented structure 656. Indented structure 656 may be configured with any form of indentations 658 for allowing an attachment functionality comprising an attachment means, such as an adhesive 670, to engage with indentations 658 so as to secure lower portion 652 to substrate 600. As seen in Fig. 10B, indented structure 656 is formed with a jagged configuration with adhesive 670 inserted within indentations 658.

Projections 650 are placed within the apertures 620 in any suitable arrangement. Placement of the projections 650 within apertures 620 may be performed in any suitable manner, such as manually. A single projection 672 is shown prior to insertion within an aperture 620.

Adhesive 670 is typically introduced into apertures 620 in an unsolidified form and is thereafter solidified in any suitable manner, such as air-dried or by heat, for example. A single projection 676 is shown inserted within aperture 620 with adhesive

670 inserted within indentations 658, thereby securing projection 676 within substrate 600.

As seen in Fig. 10B, the projections 650 are secured in substrate 600 thus forming an absorber element 680.

It is appreciated that in accordance with an embodiment of the present invention projections 650 may be formed in any suitable manner allowing any suitable attachment functionality to facilitate securing projections 650 to substrate 600 thereby forming absorber element 680.

It is noted that substrate 600 of Figs. 10A&10B may be identical to substrate 140 of Fig. 1. Projections 650 of Figs. 10A&10B may be identical to projections 150 of Fig. 1. Absorber element 680 of Fig. 10B may be identical to absorber element 130 of Fig. 1.

Reference is now made to Figs. 11A, 11B and 11C, which are simplified pictorial illustrations of a solar radiation absorber manufacturing assembly at an initial manufacturing stage, a final manufacturing stage and a bottom view of the assembly at the final manufacturing stage, respectively, constructed and operative in accordance with yet a further embodiment of the present invention.

As seen in Fig. 11A, a substrate 700 is provided at an initial stage of manufacturing. Substrate 700 may be formed of any suitable material, preferably a thermal insulating material such as silicon oxide or aluminum silicon or a compound comprising silicon oxide and aluminum silicon, for example. As seen in Fig. 11A, the substrate material may be in an unsolidified state or in a solidified state. An array of apertures 720 may be defined within substrate 700 for allowing a plurality of projections 750 to be inserted therein, as seen in Figs. 11B and 11C.

Apertures 720 may be formed in any suitable shape, such as a rectangular-like shape or a circular-like shape, for example, or any suitable shape operative to accommodate projections 750 therein.

Projections 750 are preferably formed of a material operative to allow solar radiation and fluid to pass therethrough and may be formed in any suitable configuration. Along the projections 750 may be defined an indented portion 756 configured to receive any suitable attachment means, such as a clip 770, thereby forming an attachment functionality. Clip 770 may be formed in any suitable manner and may define a semi-annular portion 774 with a protrusion 776 protruding therefrom. Semi-annular portion 774 is shown in Fig. 11C to encircle indented portion 756 and to be attached thereto via protrusion 776 thus securing projections 750 to substrate 700 thus forming an absorber element 780.

Projections 750 are placed within the apertures 720 in any suitable arrangement. Placement of the projections 750 within apertures 720 may be performed in any suitable manner, such as manually. A single projection 790 is shown prior to insertion within aperture 720.

It is appreciated that in accordance with an embodiment of the present invention projections 750 may be formed in any suitable manner allowing any suitable attachment functionality to facilitate securing projections 750 to substrate 700 thereby forming absorber element 780.

It is noted that substrate 700 of Figs. 11A, 11B. and 11C may be identical to substrate 140 of Fig. 1. Projections 750 of Figs. 11A, 11B. and 11C may be identical to projections 150 of Fig. 1. Absorber element 780 of Fig. 11B and 11C may be identical to absorber element 130 of Fig. 1.

It is noted that the projections described with reference to Figs. 1-11C may be engaged with the substrate by any suitable means employing any suitable attachment functionality. For example, the projections may be engaged with the substrate by heating a portion of the projections so as to melt a portion of the projection into the substrate, thereby embedding the projections within said substrate.

It is appreciated that the substrates of Figs. 1-11C may be formed in any suitable manner so as to form the absorber element. For example, the absorber element may be configured in an annular shape or any configuration operative to allow a fluid flowing within the solar receiver 100 to be heated with the absorber element.

It will be appreciated by persons skilled in the art that the present invention is not limited by what has been particularly shown and described herein above. Rather the scope of the present invention includes both combinations and subcombinations of the various features described hereinabove as well as variations and modifications which would occur to persons skilled in the art upon reading the specifications and which are not in the prior art.

CLAIMS

1. A method for manufacturing a solar absorber element forming a solar absorber of a solar receiver comprising:

providing a substrate;

placing at least one projection within said substrate; and

attaching said projection to said substrate with an attachment functionality operative to attach said projection to said substrate, thus defining the solar absorber element,

said solar absorber being configured to allow a fluid to flow therein and be heated by solar radiation penetrating said projection of said solar absorber element.

2. A method according to claim 1 and wherein said attachment functionality comprises an indentation formed in said projection and an attachment means designated to engage said projection with said substrate.

3. A method according to claim 2 and wherein said attachment means comprises an adhesive.

4. A method according to claim 2 and wherein said attachment means comprises a clip.

5. A method according to claim 2 and wherein said indentation is defined by perforations formed within said projection.

6. A method according to claim 2 wherein said indentation is defined by a jagged portion of said projection.

7. A method according to any one of claims 1-6 wherein said substrate is formed of a thermal insulating material.

8. A method according to any one of claims 1-7 wherein said projection is formed with perforations therein.

9. A solar radiation absorber comprising:

at least one solar radiation absorber element defining said solar radiation absorber;

a substrate;

at least one projection; and

an attachment functionality operative to attach said projection to said substrate, thus defining said solar radiation absorber element,

said solar absorber being configured to allow a fluid to flow therein and be heated by solar radiation penetrating said projection of said solar radiation absorber element.

10. A solar radiation absorber according to claim 9 and wherein said attachment functionality comprises an indentation formed in said projection and an attachment means designated to engage said projection with said substrate.

11. A solar radiation absorber according to claim 10 and wherein said attachment means comprises an adhesive.

12. A solar radiation absorber according to claim 10 and wherein said attachment means comprises a clip.

13. A solar radiation absorber according to claim 10 and wherein said indentation is defined by perforations formed within said projection.

14. A solar radiation absorber according to claim 10 wherein said indentation is defined by a jagged portion of said projection.

15. A solar radiation absorber according to any one of claims 9-14 wherein said substrate is formed of a thermal insulating material.

16. A solar radiation absorber according to claim any one of claims 9-15 wherein said projection is formed with perforations therein.

17. A solar receiver comprising:

said solar radiation absorber according to any one of claims 9-16;

an inlet for allowing said fluid to flow therein and to be heated within said solar radiation absorber; and

an outlet for egress of heated said fluid therefrom.

18. A solar radiation absorber manufacturing assembly comprising:

a receptacle for receiving a substrate material therein; and

a plurality of projections operative to be embedded within said substrate material wherein said substrate material is in an unsolidified state.

19. An assembly according to claim 18 and wherein said projections are partially embedded within said substrate material.

20. An assembly according to claim 18 or 19 and comprising an aligning element.

21. An assembly according to any one of claims 18-20 and comprising a cover.

22. An assembly according to one of claims 18-21 and wherein an aperture is provided for suction of said substrate material.

23. A solar receiver comprising:

a solar radiation absorber assembly manufactured in said solar radiation absorber manufacturing assembly according to any one of claims 18-22;

an inlet for allowing a fluid to flow therein and to be heated within said solar radiation absorber assembly; and

an outlet for egress of heated said fluid therefrom.

24. A method for manufacturing a solar absorber element forming a solar absorber of a solar receiver comprising:

providing a substrate wherein a substrate material is unsolidified;

placing a plurality of projections within said unsolidified substrate material; and

solidifying said substrate material thereby embedding said projections within said substrate and thus defining the solar absorber element.

25. A method according to claim 24 wherein said solidifying is performed by heat.

26. A method according to claim 24 or 25 wherein said projections are formed of a perforated material.

27. A method according to any one of claims 24 – 26 wherein said substrate is formed of a thermal insulating material.

28. A solar receiver comprising:

a solar radiation absorber formed of at least one projection placed in a substrate, said projection being formed of a perforated material for allowing solar radiation to penetrate therein and thereby heat said absorber;

an inlet for allowing a fluid to flow therein and to be heated within said solar radiation absorber; and

an outlet for egress of heated said fluid therefrom.

29. A solar radiation absorber comprising:

at least one solar radiation absorber element including:

a substrate; and

at least one projection projecting from said substrate,

said projection being placed within said substrate wherein a material of said substrate is unsolidified and thereafter said projection being embedded within said substrate following solidification of said material of said substrate,

said solar absorber element being configured to allow a fluid to flow therein and be heated by solar radiation penetrating said projection of said solar absorber element.

30. A solar radiation absorber according to claim 29 and wherein said projection is formed of a perforated material.

31. A solar receiver comprising:

said solar radiation absorber according to claim 29 or 30;

an inlet for allowing said fluid to flow therein and to be heated within said solar radiation absorber; and

an outlet for egress of heated said fluid therefrom.

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FIG. 1

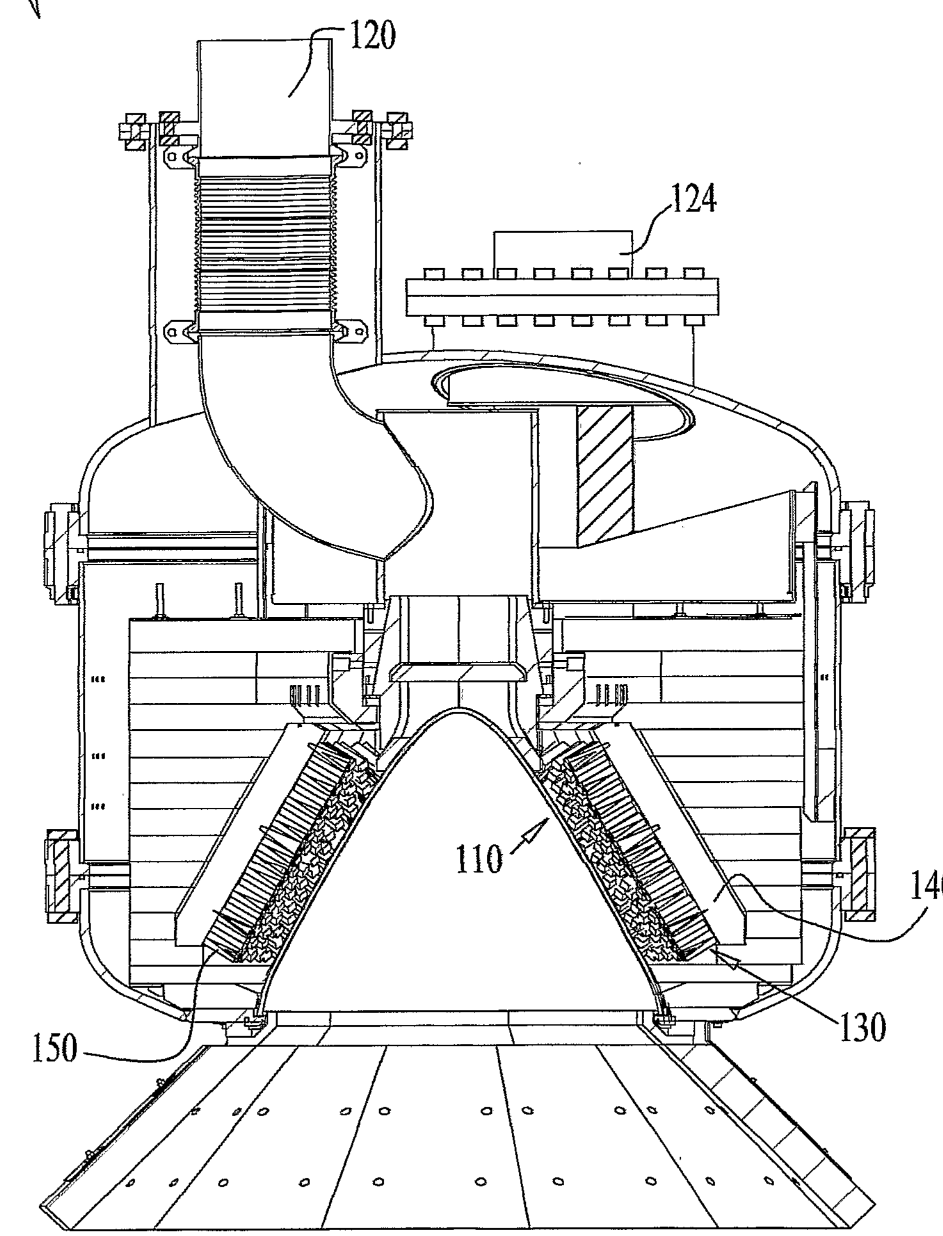

FIG. 2A

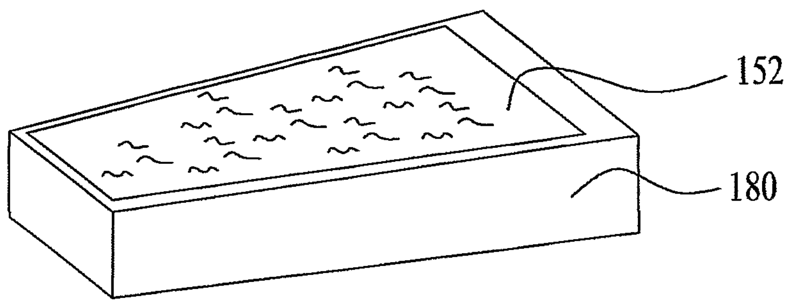

FIG. 2B

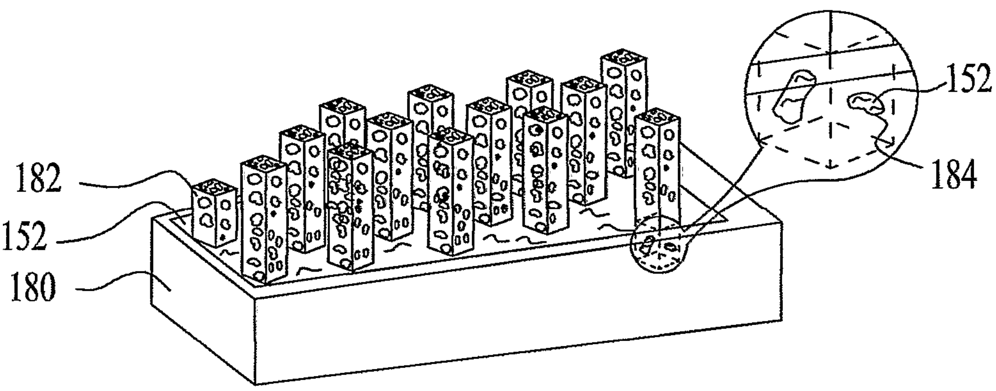

FIG. 2C

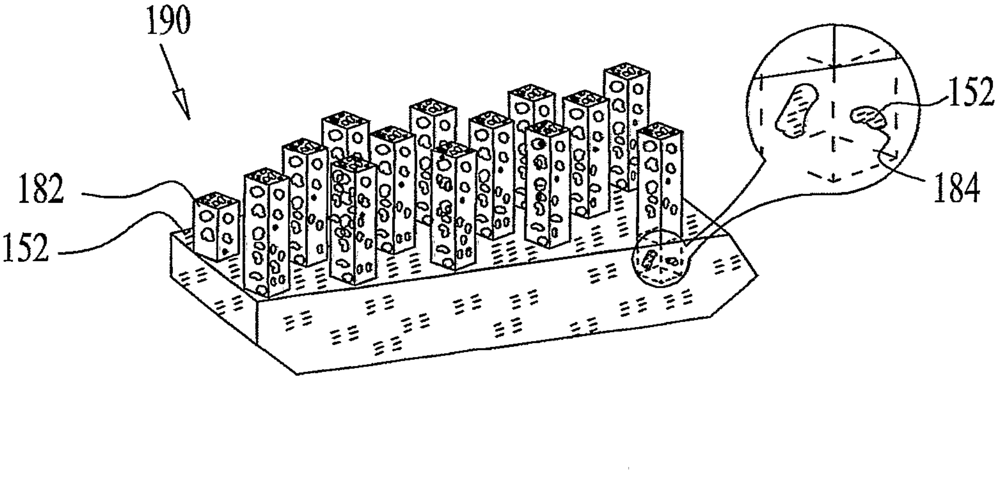

FIG. 3

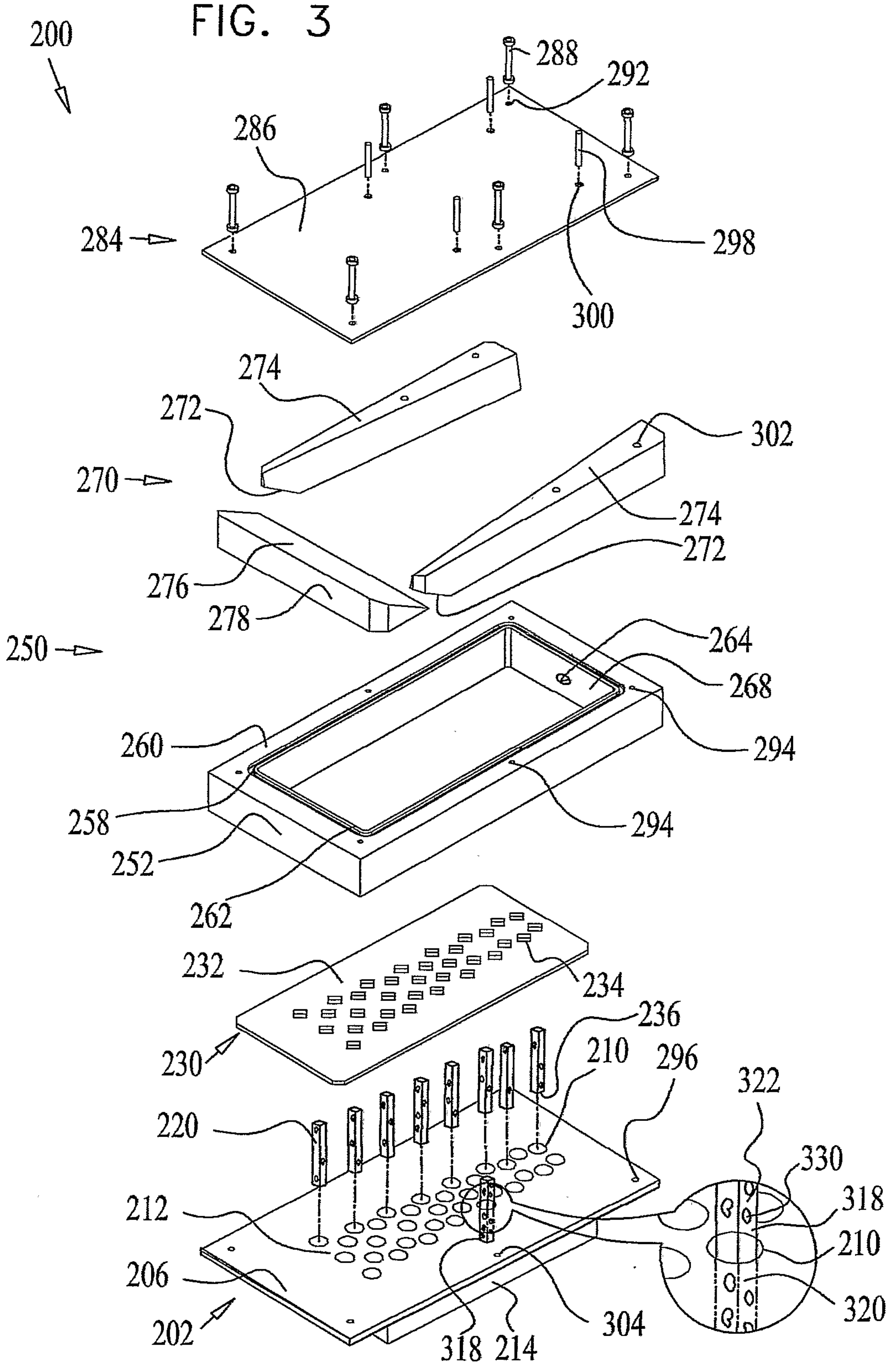
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FIG. 4

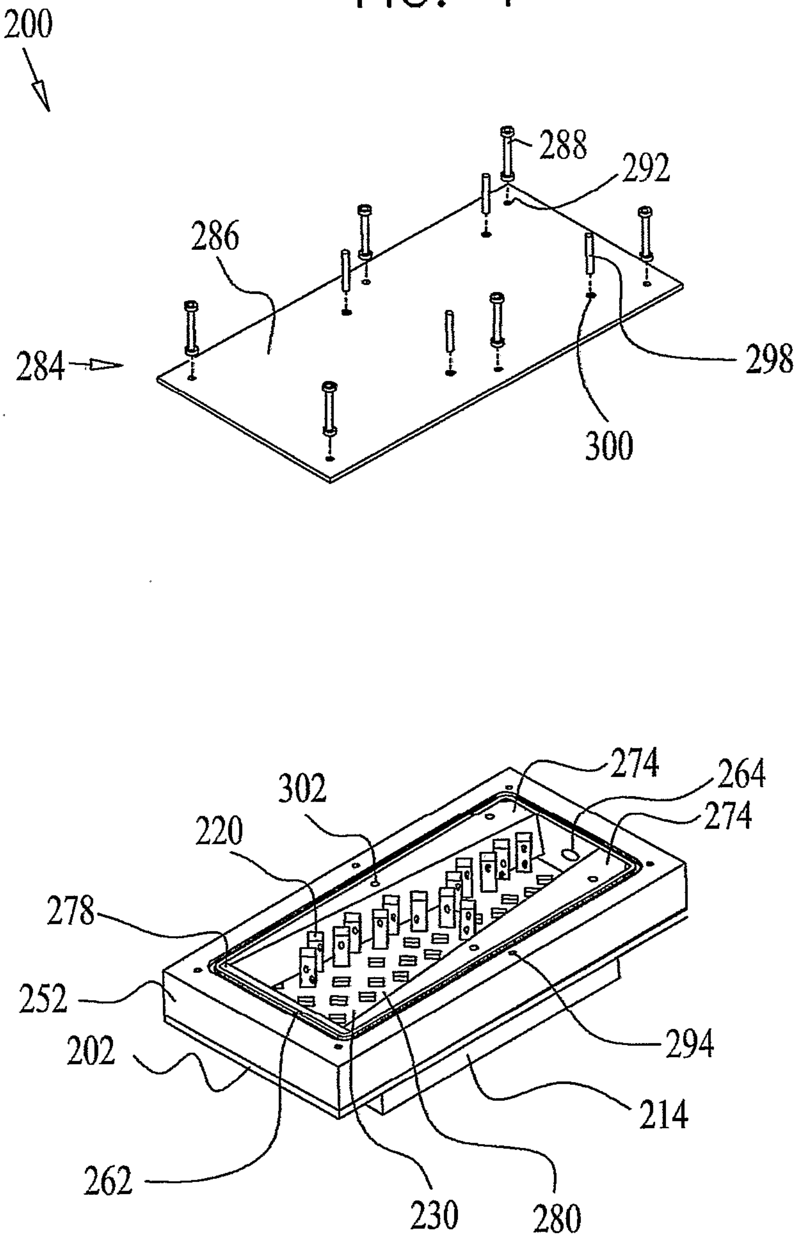
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FIG. 5

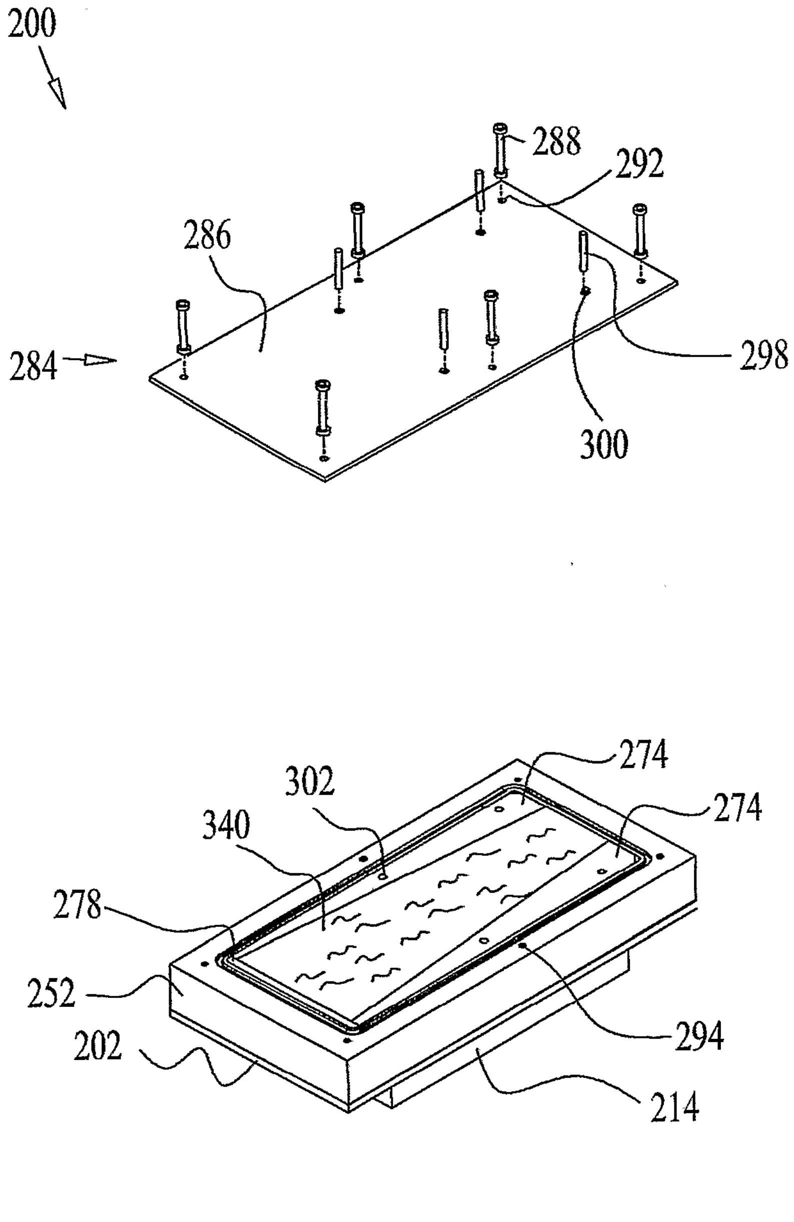


FIG. 6A

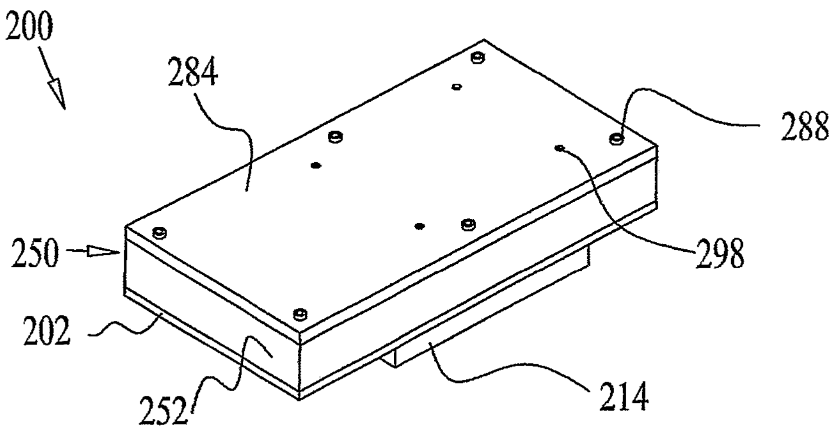


FIG. 6B

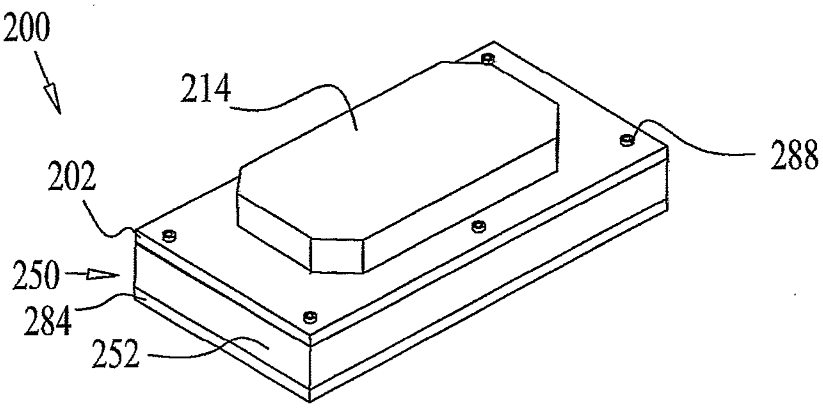


FIG. 7

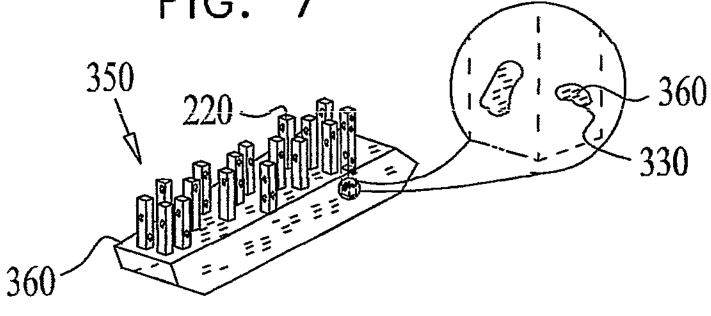


FIG. 8A

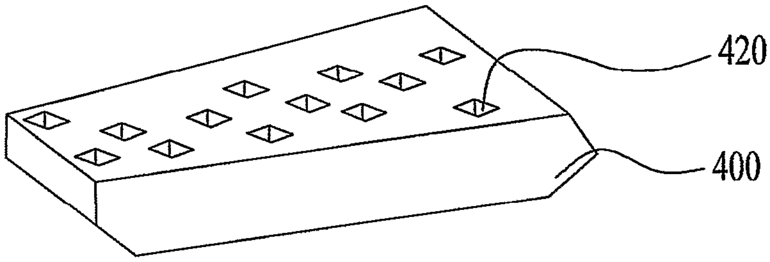


FIG. 8B

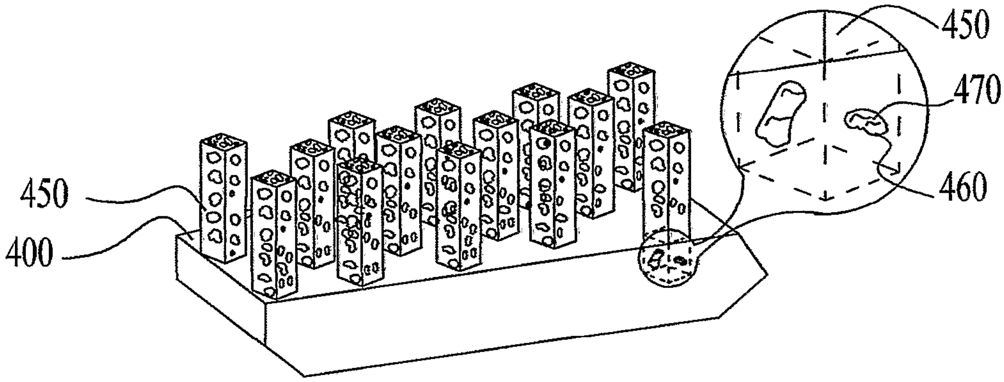


FIG. 8C

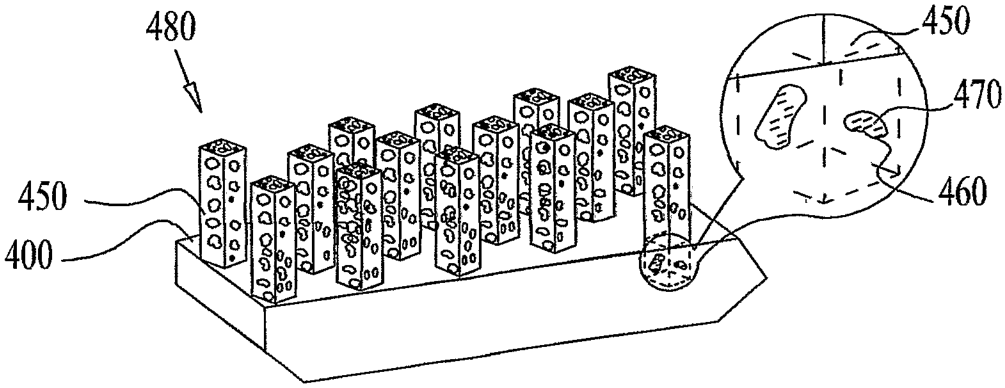


FIG. 9A

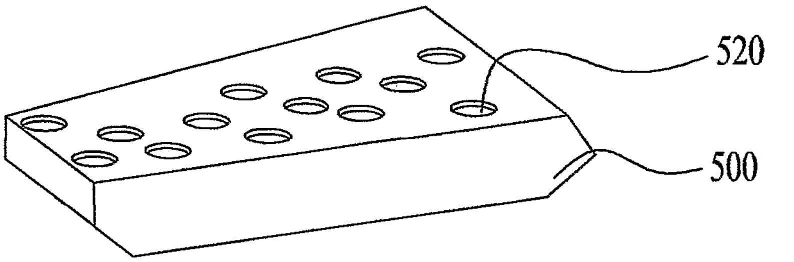


FIG. 9B

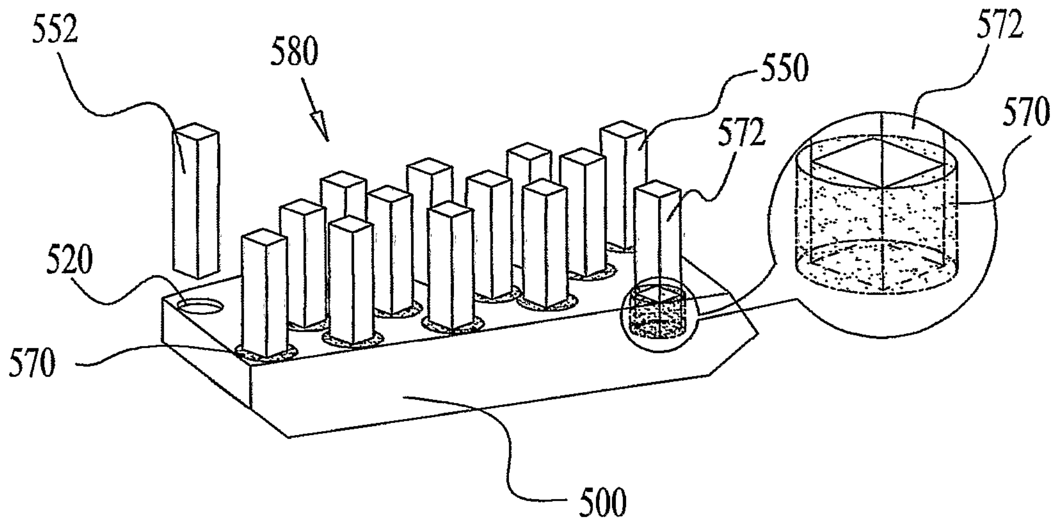


FIG. 10A

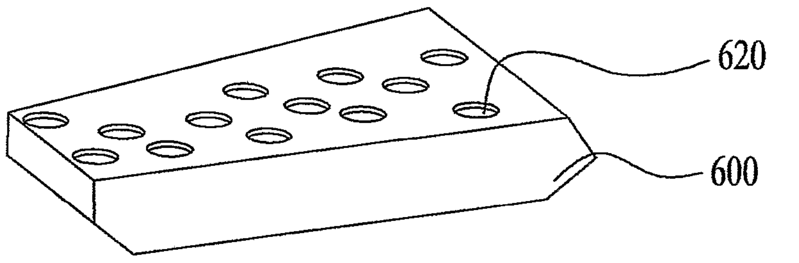


FIG. 10B

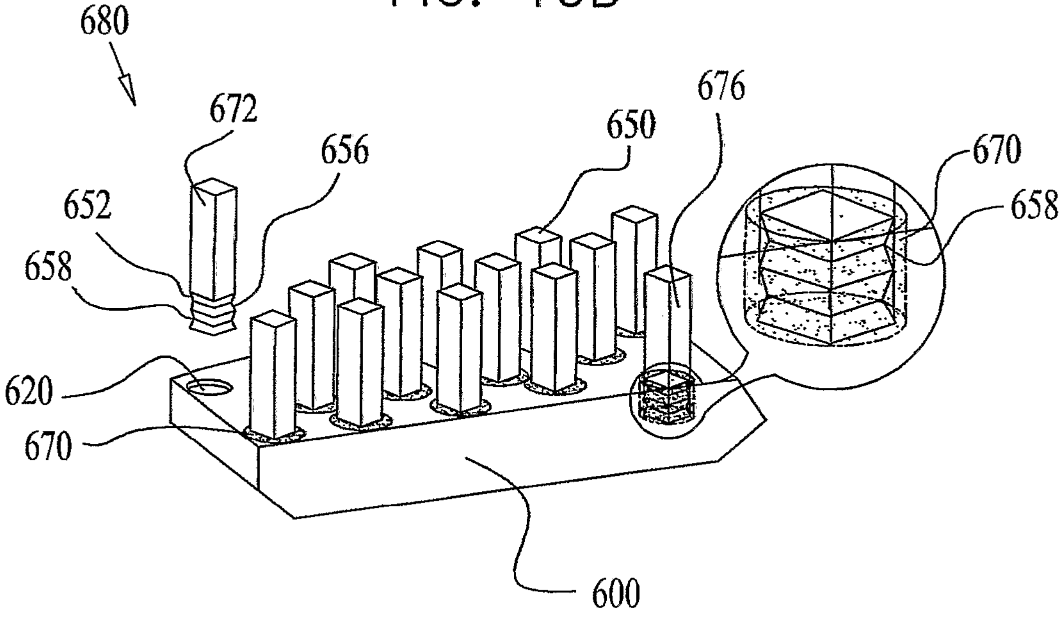


FIG. 11A

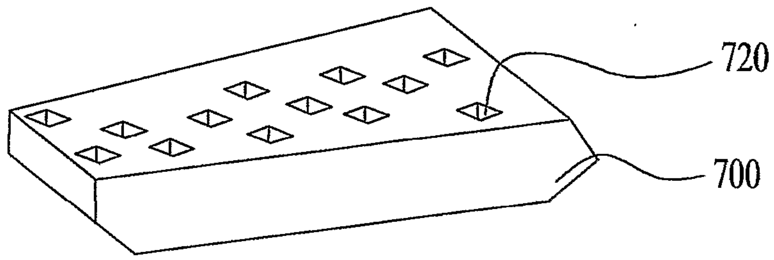


FIG. 11B

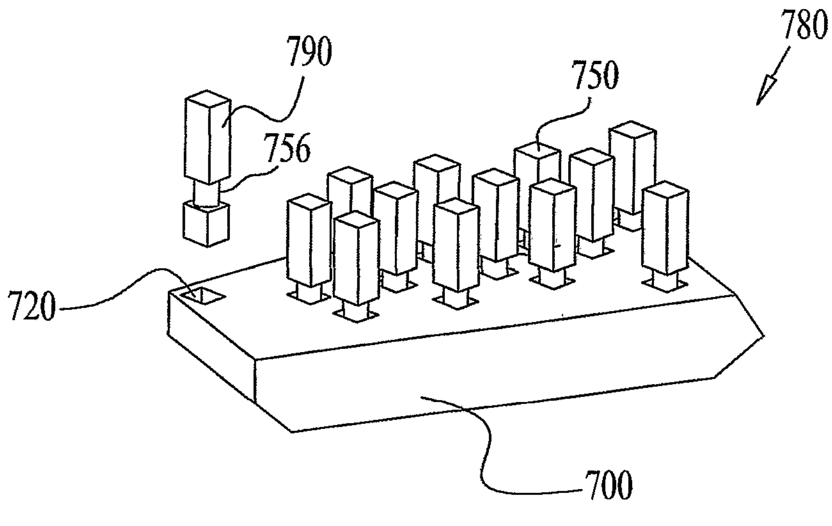
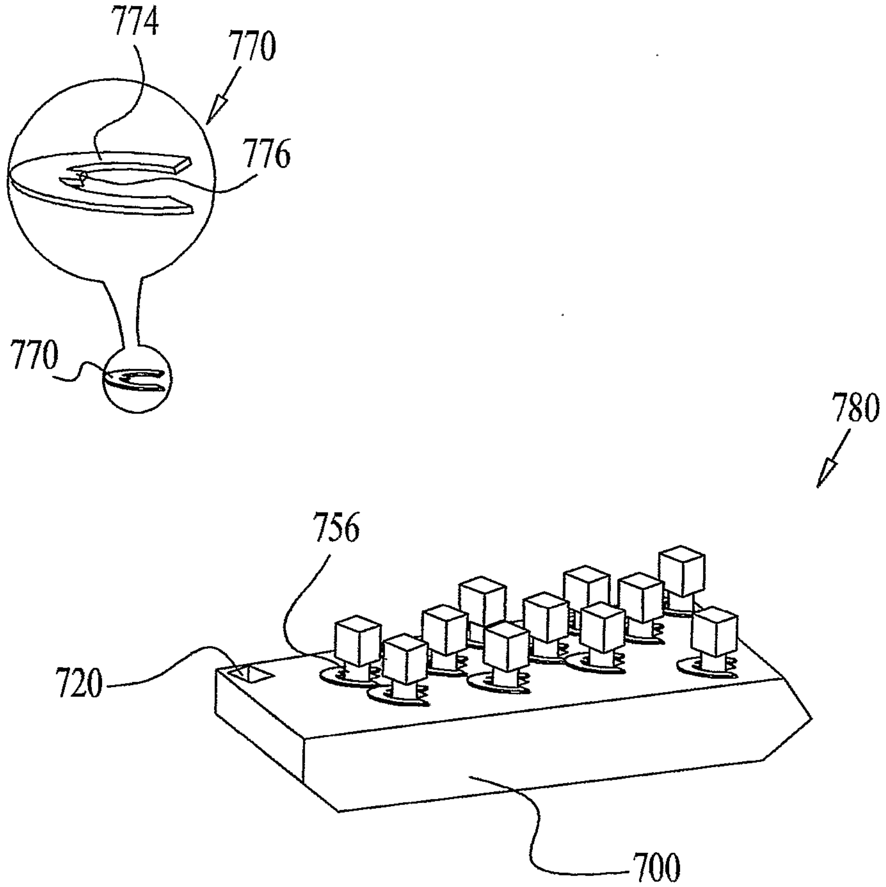


FIG. 11C



INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL 10/00083

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - F24J 2/22; F24J 2/00 (2010.01)
USPC - 126/674; 126/704; 165/170
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
USPC: 126/674; 126/704; 165/170

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
USPC: 126/569, 674, 704; 165/170 (text search - see terms below)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWEST(USPT,PGPB,EPAB,JPAB); Google
Search Terms used: solar, heat, absorber, substrate, fluid, flow, adhesive, epoxy, connected, embedded, perforated, porous, mold, projection, pillar, clip

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X -- Y	US 5,596,981 A (SOUCY) 28 January 1997 (28.01.1997), entire document especially the Abstract; Figs 1, 3, 11A; col 6, lns 1-13; col 6, lns 19-23; col 5, lns 32-34; col 10, lns 3-5	1-4, 6, 7/(1)-7(4), 7/(6), 9-12, 14, 15/(9)-15(12), 15/(14) -------- 5, 7/(5), 13, 15/(13), 29-31
X -- Y	US 4,065,593 A (PETERSEN) 27 December 1977 (27.12.1977), entire document especially the Abstract; Fig 1; col 3, lns 21-33; col 4, lns 17-41	18-20, 24, 25 -------- 26, 29-31
X	US 4,186,721 A (WHITMAN) 05 February 1980 (05.02.1980), entire document especially the Abstract; Fig 1; col 1, ln 68-col 2, ln 15	28
Y	US 2008/0146440 A1 (WESTIN et al.) 19 June 2008 (19.06.2008), entire document especially paras [0053], [0093], [0096]-[0097]	5, 7/(5), 13, 15/(13), 26
A	US 842,658 A (HASKEL) 29 January 1907 (29.01.1907), entire document	1-7, 9-15, 18-20, 24-26, 28-31
A	US 980,505 A (EMMET) 03 January 1911 (03.01.1911), entire document especially	1-7, 9-15, 18-20, 24-26, 28-31
A	US 4,007,728 A (GUBA) 15 February 1977 (15.02.1977), entire document especially	1-7, 9-15, 18-20, 24-26, 28-31

☐ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
18 May 2010 (18.05.2010)	03 JUN 2010

Name and mailing address of the ISA/US	Authorized officer:
Mail Stop PCT, Attn: ISA/US, Commissioner for Patents P.O. Box 1450, Alexandria, Virginia 22313-1450 Facsimile No. 571-273-3201	Lee W. Young PCT Helpdesk: 571-272-4300 PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL 10/00083

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 8, 16, 17, 21-23, 27
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL 10/00083

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4,299,205 A (GARFIELD) 10 November 1981 (10.11.1981), entire document	1-7, 9-15, 18-20, 24-26, 28-31