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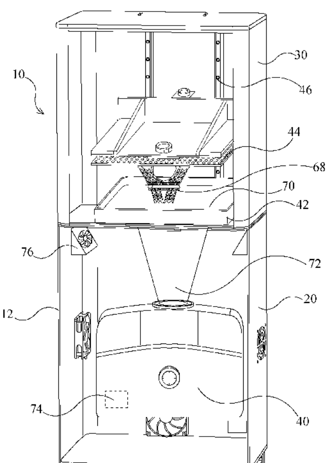

Fig. 7

(57) Abstract: ABSTRACT OF THE DISCLOSURE A stereolithography system comprises an emitting device and a tank disposed above the emitting device. The tank has an optically transparent bottom wall. There is a linear stage that extends away from the tank and a carrier platform is moveable along the linear stage away from the tank. There is also a wettable material at a bottom wall of the tank within the tank. The wettable material may be coated on the optically transparent bottom wall of the tank or the wettable material may overlay the optically transparent bottom wall of the tank.

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IMPROVED STEREOLITHOGRAPHY SYSTEM

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] The present invention relates to a stereolithography system and, in particular, to a stereolithography system including a tank with a wettable material at an optically transparent bottom thereof.

Description of the Related Art

[0002] PCT Application Publication Number WO 2014/126837 to DiSimone et al., the full disclosure of which is incorporated herein by reference, discloses a method of forming a three-dimensional object. The method comprises providing a carrier and an optically transparent member having a build surface. The carrier and the build surface define a build region therebetween. The build region is filled with a polymerizable liquid and the build region is irradiated through the optically transparent member to form a solid polymer from the polymerizable liquid while concurrently advancing the carrier away from the build surface to form the three-dimensional object from the solid polymer, while also concurrently: (i) continuously maintaining a dead zone of polymerizable liquid in contact with the build surface, and (ii) continuously maintaining a gradient of polymerization zone between the dead zone and the solid polymer and in contact with each thereof, the gradient of polymerization zone comprising the polymerizable liquid in partially cured form. An apparatus for carrying out the method is also disclosed.

SUMMARY OF THE INVENTION

[0003] It is an object of the present invention to provide an improved stereolithography system.

[0004] There is accordingly provided a stereolithography system comprising an emitting device and a tank disposed above the emitting device. The tank has an optically transparent bottom wall. There is a linear stage which extends away from the tank and a carrier platform which is moveable along the linear stage away from the tank. There is also a wettable material at the optically transparent bottom wall of the tank within the tank. The wettable material may be coated on the optically transparent bottom wall of the tank or the wettable material may be a membrane that overlays the optically transparent bottom wall of the tank. The optically transparent bottom wall of the tank may have a thermal conductivity of greater than 20 W/(m x K) at 300K. The optically transparent bottom wall of the tank may be sapphire glass or transparent ceramic spinel.

[0005] The wettable material may include a hydrogel and, in certain examples, may include a hydrogel and hydrogen peroxide. The wettable material may include a hydrogen donor and an oxygen scavenger. The wettable material may include glycerine. The wettable material may include a UV inhibitor. The wettable material may have a superhydrophobic surface. A nanostructure of the superhydrophobic surface of the wettable material may be a vertically aligned surface or a hierarchically structured surface, or a combination thereof. A nanostructure of the superhydrophobic surface of the wettable material may include a plurality of projections which have a top diameter of between 5 microns and 15 microns and which are spaced less than 10 microns apart. The wettable material may be adhered to the bottom of the tank using adhesive applied in a pattern having intersecting lines.

[0006] The tank may be in fluid communication with a resin recirculation system. The tank may be in fluid communication with a resin cooling system. There may be a cooling device which cools the tank and the cooling device may be an air knife. The bottom wall of the tank may include a UV OLED or an LCD monitor with a UV LED. The tank may further include a reservoir in fluid communication with the wettable material. In other examples, the optically transparent bottom wall of the tank and the emitting device may be integral. There may be a vibrator that vibrates the tank. The vibrator may vibrate at between 25 HZ and 60 HZ. The vibrator may be a piezo vibrator.

[0007] There is also provided a stereolithography system comprising an emitting device and a tank disposed above the emitting device. The tank has an optically transparent bottom wall. There is a linear stage which extends away from the tank and a carrier platform which is moveable along the linear stage away from the tank. There is also a silicon material at the optically transparent bottom wall of the tank within the tank. The silicon material may have a superhydrophobic surface. A nanostructure of the superhydrophobic surface of the silicon material may be a vertically aligned surface or a hierarchically structured surface, or a combination thereof. A nanostructure of the superhydrophobic surface of the silicon material may include a plurality of projections which have a top diameter of between 5 microns and 15 microns and which are spaced less than 10 microns apart. The silicon material may be adhered to the bottom of the tank using adhesive applied in a pattern having intersecting lines. There may be a vibrator that vibrates the tank. The vibrator may vibrate at between 25 HZ and 60 HZ. The vibrator may be a piezo vibrator.

BRIEF DESCRIPTIONS OF DRAWINGS

[0008] The invention will be more readily understood from the following description of the embodiments thereof given, by way of example only, with reference to the accompanying drawings, in which:

[0009] Figure 1 is a perspective view of an improved stereolithography system;

[0010] Figure 2 is a front elevation view of the stereolithography system of Figure 1;

[0011] Figure 3 is a front elevation, partially broken away view of the stereolithography system of Figure 1;

[0012] Figure 4A is a perspective, sectional view of a tank of the stereolithography system of Figure 1;

[0013] Figure 4B is an enlarged view of a surface area of a wettable material within the tank of the stereolithography system of Figure 1;

[0014] Figures 5A to 5D are enlarged views of alternative embodiments of a surface area of a wettable material that may be within the tank of the stereolithography system of Figure 1;

[0015] Figures 6A to 6C are top, plan views of the tank of the sterolithography system of Figure 1;

[0016] Figure 7 is a perspective, partially broken away view of the stereolithography system of Figure 1 showing an object being formed;

[0017] Figure 8 is a fragmentary view of the stereolithography system of Figure 1 showing a hollow portion of the object being formed by continuous curing of the resin;

[0018] Figure 9 is another fragmentary view of the stereolithography system of Figure 1 showing the hollow portion of the object being formed by continuous curing of the resin;

[0019] Figure 10 is a fragmentary view of the stereolithography system of Figure 1 showing a solid portion of the object with a relatively small cross-section being formed by continuous-layered curing of the resin;

[0020] Figure 11 is a fragmentary view of the stereolithography system of Figure 1 showing a solid portion of the object with a relatively small cross-section being formed by continuous-layered curing of the resin with the wettable material flexing as the object is being pulled away from a bottom of a tank;

[0021] Figure 12 is a fragmentary view of the stereolithography system of Figure 1 showing the solid portion of the object with a relatively small cross-section being formed by continuous-layered curing of the resin;

[0022] Figure 13 is another fragmentary view of the stereolithography system of Figure 1 showing the solid portion of the object with a relatively small cross-section being formed by continuous-layered curing of the resin;

[0023] Figure 14 is a fragmentary view of the stereolithography system of Figure 1 showing the solid portion of the object with a relatively small cross-section being formed by continuous-layered curing of the resin with a spacing between the object and the wettable material;

[0024] Figure 15 is a fragmentary view of the stereolithography system of Figure 1 showing the solid portion of the object with a relatively small cross-section being formed by continuous-layered curing of the resin with the resin partially filling a spacing between the object and the wettable material;

[0025] Figure 16 is a fragmentary view of the stereolithography system of Figure 1 showing the solid portion of the object with a relatively small cross-section being formed by continuous-layered curing of the resin with the resin partially filling a spacing between the object and the wettable material;

[0026] Figure 17 is a fragmentary view of the stereolithography system of Figure 1 showing the solid portion of the object with a relatively large cross-section being formed by layered curing of the resin;

[0027] Figure 18 is a fragmentary view of the stereolithography system of Figure 1 showing the solid portion of the object with a relatively large cross-section being formed by layered curing of the resin with the tank being tilted in a first direction;

[0028] Figure 19 is a fragmentary view of the stereolithography system of Figure 1 showing the solid portion of the object with a relatively large cross-section being formed by layered curing of the resin with the tank being tilted in a second direction;

[0029] Figure 20 is a fragmentary view of the stereolithography system of Figure 1 showing the solid portion of the object with a relatively large cross-section being formed by layered curing of the resin;

[0030] Figure 21 is another fragmentary view of the stereolithography system of Figure 1 showing the solid portion of the object with a relatively large cross-section being formed by layered curing of the resin;

[0031] Figure 22 is a perspective, sectional view of a second embodiment of a tank which may be used with the stereolithography system of Figure 1;

[0032] Figure 23 is a perspective, sectional view of a third embodiment of a tank which may be used with the stereolithography system of Figure 1;

[0033] Figure 24 is a perspective, sectional view of a fourth embodiment of a tank which may be used with the stereolithography system of Figure 1;

[0034] Figure 25 is a perspective, sectional view of a fifth embodiment of a tank which may be used in with the stereolithography system of Figure 1;

[0035] Figure 26 is a perspective view of another improved stereolithography system;

[0036] Figure 27 is a perspective, sectional view of a tank of the stereolithography system of Figure 26; and

[0037] Figure 28 is a perspective, sectional view of another tank which may be used with the stereolithography system of Figure 26.

DESCRIPTIONS OF THE PREFERRED EMBODIMENTS

[0038] Referring to the drawings and first to Figures 1 and 2, an improved stereolithography system 10 is shown. The stereolithography system 10 comprises a housing 12 which is mounted on a plurality of castors, for example castors 14 and 16, to allow the stereolithography system 10 to be easily moved to a desired location. The castors 14 and 16 are substantially identical in structure and function and each have a respective brake, for example, brake 18 which is called out for one of the castors 14. The brake 18 is a ground engaging brake and allows the stereolithography system 10 to be fixed at the desired location. The housing 12 has a lower portion 20 and an upper portion 30. The lower portion 20 of the housing 12 includes a door 22 provided with a handle 24 and a lock 26 to allow and restrict access to the lower portion 20 of the housing 12. The lower portion 20 of the housing 12 is also provided with a vent 28, shown only in Figure 1, to allow air to circulate in the lower portion 20 of the housing 12. Likewise, the upper portion 30 of the housing 12 includes a door 32 provided with a handle 34 and a lock 36 to allow and restrict access to the upper portion 30 of the housing 12. In this example, the door 32 of the upper portion 30 of the housing 12 is provided with an optically transparent pane 38.

[0039] Referring now to Figure 3, there is an emitting device 40 disposed within the lower portion 20 of the housing 12. The emitting device may be any suitable light-emitting device which may be used to cure or polymerize resin. There is a tank 42 disposed within the upper portion 30 of the housing 12 above the emitting device. There is also a liner stage 44 in the upper portion 30 of the housing 12. The linear stage 44 extends vertically away from the tank 42 and a carrier platform 46 is moveable along the linear stage 44. The stereolithography system 10, as thus far described, is a generally conventional stereolithography system used in a “top down” three-dimensional printing technique in which cross-sections of an object are formed at a bottom of the object being formed.

[0040] However, as best shown in Figure 4A, the tank 42 of the stereolithography system 10 has a novel structure. The tank 42 has a bottom wall 48 which is optically transparent. There is a plurality of side walls, for example, side walls 50, 52 and 54 which extend from the bottom wall 48 of the tank 42. There is an optically transparent wettable material 56 at the bottom wall 48 of the tank 42 within the tank 42. The wettable material 56 may be any material that is capable of being wetted, i.e. retaining water. In this example, the wettable material 56 is in the form of a membrane and overlays the bottom wall 48 of the tank 42. However, in other examples, the wettable material 56 may be coated or formed on the bottom wall 48 of the tank 42. The wettable material 56 may have a thickness of between 1 millimeter and 4 millimeters.

[0041] Figure 4B shows the nanostructure of a surface of the wettable material 56. The nanostructure of the surface of the wettable material 56 includes a plurality of projections in the form of truncated cones, for example projections 58a, 58b and 58c, which are spaced-apart along the surface of the wettable material 56. In this example, the projections 58a, 58b and 58c have a base diameter of between 10 microns and 20 microns and a top diameter of between 5 microns and 15 microns. The projections 58a, 58b and 58c are spaced-apart at less than 10 microns apart in this example. The nanostructure of the surface of the wettable material 56 renders the surface of the wettable material 56 a superhydrophobic surface and may take alternative suitable forms as shown in Figures 5A to 5D which are illustrative examples. In Figure 5B the nanostructure of the surface of the wettable material comprises a plurality of projections in the form of cylinders. In Figures 5C and 5D the nanostructure of the surface of the wettable material are replicas a nanostructure of a flower petal. The nanostructure of the surface of the wettable material 56 may be prepared by chemical treatment or laser sculpting or photolithography. The nanostructure of the surface of the wettable material 56 may be a vertically aligned surface, or a hierarchically structured surface, or a combination thereof. It may still alternatively be possible to coat the nanostructure of the surface of the wettable material 56 with, for example, Teflon® or another hydrophobic material. It will be understood by a person skilled in the art that the same or a similar process as described in this paragraph may be used to provide a silicon material (e.g. layer) in a conventional "top-down" stereolithography system with a superhydrophobic surface.

[0042] Referring now to Figures 6A to 6C, in this example, the wettable material 56 is secured to the bottom wall 48 (not shown in Figures 6A to 6C) of the tank 42 by an optically transparent adhesive 60 such as an adhesive primer or a cyanoacrylate adhesive. The wettable material 56 may be adhered to the bottom wall 48 of the tank 42 about its perimeter only as shown in Figure 6A. This allows the wettable material 56 to flex. The wettable material 56 may be adhered to the bottom wall 48 of the tank 42 in a grid pattern as shown in Figure 6B. This allows the wettable material 65 to flex only within defined areas. A similar result may be achieved by adhering the wettable material 56 in circular patterns as shown in Figure 6C or any other suitable pattern with intersecting lines. It will be understood by a person skilled in the art that the same or a similar process as described in this paragraph may be used to adhere a silicon material (e.g. layer) to a conventional "top-down" stereolithography system to allow the silicon material to flex only within defined areas.

[0043] The tank 42 is also provided with actuators which may be in the form of vibrators 62 and 64. In this example, the vibrators 62 and 64 are ultrasonic transducers and, in particular, piezo actuators or vibrators. However, any suitable vibrator may be used. The vibrators 62 and 64 are used in the vertical orientation in this example but may be used in the horizontal orientation in other examples. The vibrators 62 and 64 may vibrate at frequencies between 25 Hz and 60 Hz. The vibrators 62 and 64 function to tilt the tank 42 when required. However, any suitable actuators such as motor driven linear actuators disposed on either side of the tank may be used to tilt the tank in other examples.

[0044] Figure 7 shows an object 68 being formed from resin 70 in the tank 42 of the stereolithography system 10. The emitting device 40 emits a blast or emission of light 72 as the object 68 is being formed on the carrier platform 46. The carrier platform 46 moves upwardly away from the tank 42 as the emitting device 40 emits the blast or emission of light 72 and the object 68 is formed. A controller 74 may be used to control the duration and the intensity of the blast or emission of light depending on the object being formed or part of the object being formed. The object 68 may accordingly be formed using continuous, continuous-layered, or layered curing of the resin 70 in the tank 42. The stereolithography system 10 may also be provided with a cooling device such as a cooling fan 76 to cool the tank 42, and contents thereof, namely, the wettable material 56 and the resin 70 when the object 68 is being formed and high temperatures are generated. The cooling device may alternatively be an air knife or another suitable cooling device. High temperatures are generated during the operation of the stereolithography system 10 disclosed herein because of the relatively high speeds at which the object 68 is formed. It will be understood by a person skilled in the art that the resin is cured or polymerized by irradiation to form cross-sections of the object 68.

[0045] Since heat is created as the resin cures, it is desirable to dissipate as much heat as possible, in particular, when the object 68 is being formed continuously. By forming the bottom wall 48 of the tank 42 from a material with high thermal conductivity, the heat can be dissipated more quickly which allows the size of the cross-section and the height of the object 68 to be increased as a result of less heat being accumulated. Furthermore, if the bottom wall 48 of the tank 42 has a high thermal conductivity, then air bubbles are generally not formed in the wettable material and/or resin. The formation of air bubbles in the wettable material and/or resin may adversely affect the formation of the object 68.

[0046] It is accordingly desirable to form the bottom wall 48 of the tank 42 from an optically transparent material with high thermal conductivity. Sapphire glass, which has a thermal conductivity of 25 W/ (m x K) at 300K, may be used to form the bottom wall 48 of the tank 42. Transparent ceramic spinel, which has a thermal conductivity of 25 W/ (m x K) at 300K, may also be used to form the bottom wall 48 of the tank 42. Low-iron glasses with high thermal conductivity such as Starphire™ glass may also be used However, the bottom wall 48 of the tank 42 may also be formed from acrylic glass, which has a thermal conductivity of 0.20 W/ (m x K) at 25K, or soda-lime glass or soda-lime-silica glass which has a thermal conductivity of 0.95 W/ (m x K) at 25K.

[0047] During the formation of a hollow portion 78 of the object 68, as shown in Figures 8 and 9, the controller 74 may decrease the duration of the blast or emission of light 72 and increase the intensity of the blast or emission of light 72. The duration of the blast or emission of light 72 is decreased during the formation of the hollow portion 78 because less time is required for the resin to cure or polymerize due to the smaller surface area being cured. However, the intensity of the blast or emission of light 72 is increased during the formation of the hollow portion 78 to accelerate the formation of the object 68 though continuous formation of cross-sections of the object 68. Figures 8 and 9 show a gap 80 between the wettable material 56 at the bottom wall 48 of the tank 42 and the object 68 being formed from the resin 70 in the tank 42. The gap 80 allows the object 68 to be formed continuously because the object 68 is not formed directly on the bottom wall 48 of the tank 42 thereby generally doing away with the need for the object 68 to be peeled or pulled away from the bottom wall 48 of the tank 42 during the formation of the hollow portion 78 of the object 68.

[0048] During the formation of a solid portion 82 of the object 68 with a relatively small cross-section, as shown in Figures 10 to 13, the controller 74 may increase the duration of the blast or emission of light 72 and lower the intensity of the blast or emission of light 72 during the formation of the solid portion 82. The duration of the blast or emission of light 72 is increased during the formation of the solid portion 82 because additional time is required for the resin to cure or polymerize due to the larger surface area being cured. The intensity of the blast or emission of light 72 is lowered during the formation of the solid portion 82 to minimize excess heat which may dry the wettable material 56. Figures 10 and 13 also show a gap 80 between the wettable material 56 at the bottom wall 48 of the tank 42 and the object 68 being formed from the resin 70 in the tank 42. The gap 80 allows the object 68 to be formed by continuous-layered curing of the resin 70 because the object 68 is not formed directly on the bottom wall 48 of the tank 42 and the object 68 can be easily pulled away from the bottom wall 48 of the tank 42, as best shown in Figures 10 and 11, during the formation of at the solid portion 82 of the object 68. This is because the wettable material 56 is able to flex within defined areas, as shown at area 84 of the wettable material 56, thereby reducing the force required to pull the object 68 away. This reduces the time required to form cross-sections of the solid portion 82 of the object 68.

[0049] Referring now to Figures 14 to 17, the formation of air bubbles in the object 68 may also be prevented by not providing a blast or emission of light until resin fills a spacing 86 between a bottom 88 of the object 68 and the bottom wall 48 of the tank 42. During the formation of the object 68, and as best shown in Figure 14, there is momentarily a spacing 86 between the gap 80 and the bottom 88 of the object 68 as the carrier platform 46 moves away from the bottom wall 48 of the tank 42. The spacing 86 is nearly instanteously filled with the resin 70 as shown in Figures 15 and 16. However, if a cross-section of the object 68 is formed prior to the resin 70 completely filling the spacing 86, as shown in Figure 15, then the spacing 86 forms an air bubble in the object 68 as the resin around the spacing 86 is cured during the formation of a cross-section of the object 68. It is accordingly desirable to wait until spacing 86 is substantially filled with the resin 70, as shown in Figure 16, prior to forming a cross-section of the object 68. This may be achieved by programing a controller 74 to employ the following algorithm.

Step 1: START.

Step 2: Move the object 68 away from the bottom of the tank 48 as shown in Figure 14.

Step 3: Momentarily emit no light as resin flows into the spacing 86 between the bottom 88 of the object 68 being formed and the gap 80 as shown in Figures 15 and 16.

Step 4: Emit light to cure resin to form desired cross-section of the object 68 being formed as the resin 70 fills the spacing 86 between the bottom 88 of the object 68 being formed and the gap 80 as shown in Figure 17.

Step 5: Repeat Step 2.

[0050] During the formation of a solid portion 90 of the object 68 with a relatively large cross-section, as shown in Figures 18 to 21, it may be desirable to tilt the tank 42 to micro peel away the solid portion 90 of the object 68. The vibrators 62 and 64, shown in Figures 6A to 6C, vibrate alternately while the carrier platform 46 is moved away from the tank 42 as shown in Figures 18 and 19. This facilitates the flow of the resin 70 between the object 68 and the wettable material 56 as shown in Figure 20. Another cross-section of the object 68 area can then be formed as shown in Figure 21. The carrier platform 46 is repositioned and the process is repeated until the object 68 is fully formed.

[0051] The vibrators 62 and 64 may be actuated at any time light is not being emitted to cure or polymerize the resin 70. The vibrators 62 and 64 may also be used to aid the flow of the resin 70. The vibrators 62 and 64 may be positioned so that a vibrator on one side of the tank 42 vibrates upwardly while a vibrator on the opposite side of the tank vibrates downwardly. The vibrators 62 and 64 may be selectively actuated to produce a combination of vibrations that is most effective based on the cross-section of the object 68 being formed.

[0052] Figure 22 shows a second embodiment of a tank 110 that may be used with the stereolithography system 10 disclosed herein. The tank 110 is substantially similar to the tank 24 shown in Figure 4A. The tank 110 has an optically transparent bottom wall 112 with a wettable material 114 at the bottom wall 112 of the tank 110 within the tank 110. However, the tank 110 has an actuator 116 disposed at a first side thereof and a hinge mechanism 118 at a second side thereof. In this example, the actuator 116 is a motor driven linear actuator which pivots the tank 110 about the hinge mechanism 118 in order to tilt the tank 110.

[0053] Figure 23 shows a third embodiment of a tank 120 which may be used with the stereolithography system 10 disclosed herein. The tank 120 is substantially similar to the tank 42 shown in Figure 4A. The tank 120 has an optically transparent bottom wall 122 with a wettable material 124 at the bottom wall 122 of the tank 120 within the tank 120. However, the tank 120 further has a reservoir 126 in fluid communication with the wettable material 124. There may be water in the reservoir 126 which may be applied to the wettable material 124 to keep the wettable material wet.

[0054] Figure 24 shows a fourth embodiment of a tank 130 which may be used with the stereolithography system 10 disclosed herein. The tank 130 is substantially similar to the tank 42 shown in Figure 4A with the notable exception that the tank 140 has an optically transparent bottom wall 132 which is formed from a wettable material.

[0055] Figure 25 shows a fifth embodiment of a tank 140 which may be used with the stereolithography system 10 disclosed herein. The tank 140 is substantially similar to the tank 42 shown in Figure 4A. The tank 140 has an optically transparent bottom wall 142 with a wettable material 144 at the bottom wall 142 of the tank 140 within the tank 140. However, the tank 140 is further provided with a closed-loop resin recirculation and/or resin cooling system 150 which includes a pump 152 which is in fluid communication with an input conduit 154. The input conduit 154 has three input ports 156a, 156b and 156c which allow fluid communication between the input conduit 154 and the tank 140. The closed-loop resin cooling system 150 also includes an output port 158 which allows fluid communication between the tank 140 and an output conduit 160. There is a coil 162 disposed along the output conduit 160 between the output port 158 and the pump 152. In operation, the pump 152 draws resin from the tank 140 through the output port 158. The resin flows to the pump 152 through the output conduit 160 and may be cooled as it flows through the coil 162. The pump 152 then pumps the resin though the input conduit 154 and back into the tank 140 through the input ports 156a, 156b and 156c. The resin flows into the tank 140 at a flow rate of about 100mm per minute to minimize turbulence in the resin and flows into the tank 140 adjacent to the bottom wall 142 thereof. It will be understood by a person skilled in the art that a closed-loop resin recirculation and/or resin cooling system may also be used with a tank in a conventional “top-down” stereolithography system.

[0056] Figure 26 shows another improved sterolithography system 210, which is substantially identical to the sterolithography system 10 shown in Figure 7, with the notable exceptions that the light-emitting device 240 is integrated with the tank 220 and that the cooling device of the sterolithography system 210 is an air knife 250. The tank 220 is shown in greater detail in Figure 27 and is generally similar to the tank 42 shown in Figure 4A. The tank 220 has an optically transparent bottom wall 222 with a wettable material 224 at the bottom wall 222 of the tank 220 within the tank 220. However, the bottom wall 222 of the tank 220 further includes a plurality of light-emitting devices, for example, light-emitting devices 226 and 228, disposed along a peripheral edge thereof. The light-emitting devices provide a continuous emission of light to form an object. The bottom wall of the tank may be a modified LCD monitor in which white back lights of the LCD monitor are replaced with UV LED lights which function as light-emitting devices. This allows an image that would have previously been projected on the LCD monitor in white light to be continuously projected in a blast or emission of UV light to form an object in the shape of the image. It will be understood by a person skilled in the art that a modified LCD monitor in which white back lights of the LCD monitor are replaced with UV LED lights which function as light-emitting devices may also be used as a bottom wall of a tank in a conventional "top-down" stereolithography system.

[0057] Figure 28 shows another embodiment of a tank 230 which may be used with the stereolithography system disclosed herein. The tank 230 is substantially similar to the tank 42 shown in Figure 4A. The tank 230 has an optically transparent bottom wall 232 with a wettable material 234 at the bottom wall 232 of the tank 230 within the tank 230. However, there is a UV organic light-emitting diode (OLED) 236 at the bottom wall 232 of the tank 230. The UV OLED functions as the light-emitting device. It will be understood by a person skilled in the art that a UV OLED functioning as a light-emitting device may also be used with a tank in a conventional "top-down" stereolithography system.

[0058] The sterolithography system 210 is also provided with a controller 240 which controls the light-emitting devices integrated with the tank.

[0059] Figure 29 is a flow chart showing the logic of the controllers of the sterolithography system disclosed herein. When executing the best algorithm the controller determines whether the object should be formed by continuous, continuous-layered or layered curing of the resin.

Wettable Material

[0060] The wettable material 56 may be a hydrogel, e.g. silicone hydrogel, or any other suitable wettable material which results in the gap 80 or "dead zone" at the interface between the wettable material 56 and resin in the tank 42 as shown in Figures 21 to 29. The gap 80 may be a result of intermolecular forces of repulsion between the wettable material 56 and the resin in the tank 42 and/or the gap 80 may be the result of a layer of water which separates the wettable material 56 and the resin because the resin and water are immiscible. The separation between the wettable material 56 and the resin may be improved by adding glycerine to the wettable material 56 since glycerine is immiscible with the resin. The separation between the wettable material 56 and the resin may be further improved by adding a UV inhibitor and glycerine to the wettable material 56. Addition of the UV inhibitor and glycerine prevents the curing of a very thin layer of the resin at the interface between the wettable material 56.

[0061] The concentrations of glycerine and UV inhibitor in the wettable material 56 depend on the type of resin being used. The concentration of glycerine in the wettable material 56 may be as low as 1% by volume for a hydrogel-based wettable material and as high as 95% by volume for a glycerine gel-based wettable material. The concentration of UV inhibitor in the wettable material 56 may be between 0.5% by volume and 25% by volume. High reactive resins, which contain more photoinitiators, may require more glycerine and more UV inhibitor while low reactive resins, which contain less photoinitiators, may require less glyercine and less UV inhibitor.

Hydrogel-based Wettable Materials

[0062] The hydrogel used in the wettable material 56 may be prepared by any means with the following means being exemplary:

[0063] A poly(acrylic acid) hydrogel may be prepared in a solution of acrylic acid and/or salts thereof with a water soluble cross-linker, e.g. methylene bis-acrylamide, in an aqueous solution with a concentration of 10% to 70% and using methoxyhydroquinone (MHC) as an inhibitor. This may result in a gel-elastic product, crystalline, that can be dried and pulverized for storage.

[0064] A superabsorbent hydrogel may be prepared as a mixture of acrylamide as a monomer with bis-acrylamide as a cross-linker diluted in deionized water.

[0065] A polyethylene glycol hydrogel may be prepared by cross-linking a polyethylene glycol acrylate using a radical generator (UV initiator) then stabilizing the hydrogel using hydroquinone monomethyl ether (MEHQ) as an inhibitor.

[0066] A physically cross-linked hydrogel may be prepared by warming Kappa-Carrageenan in a solution until a helix shape in the molecule is formed. The additional use of a solution containing a salt (Na+, K+) will result in further helices aggregating to form a stable gel.

[0067] A sodium alginate hydrogel may be prepared as a mixture of wt.2% sodium alginate poured into a mixture of 1 wt.% of calcium chloride.

[0068] A patterned poly(ethylene glycol)-based hydrogel may be prepared by dissolving poly(ethylene glycol) in an aqueous solution with 2,2 dimethoxy-2-phenyl acetophenone as a photoinitiator. A photolithography technique is used during the UV curing process to obtain the desired pattern.

[0069] A PEGDA lyophilized gel may be prepared by mixing freeze-dried PEGDA with water and a photoinitiator and exposed to UV light (365nm) to form a hydrogel structure.

[0070] A polyvinyl pyrrolidone-based hydrogel may be prepared by mixing polyvinyl pyrrolidone with hydrogen peroxide as required for the specific application and using UV light (254nm) to cross-link to form gel structures.

[0071] Collagen/HEMA hydrogel may be prepared by using a collagen solution mixed with HEMA monomer, ammonium persulfate and sodium metabisulfate.

[0072] A polyhydroxyethylmethacrylate hydrogel may be prepared by mixing SucMA, hydroxyethylmethacrylate using tripropylene glycol diacrylate as a cross-linker and ammonium persulfate and sodium metabisulfate as radical initiators.

[0073] A polyhydroxyethylmethacrylate hydrogel may also be prepared by thermal polymerization. Hydroxymethlmethacrylate may be polymerized with trimetil propane trimethacrylate as a cross-linker and benzoil peroxide as a radical initiator. The mixture is then warmed to 75 degrees Celsius for a period of time according to the characterization of the gel.

[0074] The above mentioned hydrogels and 20% to 50% concentrated hydrogen peroxide may be used to prepare the wettable material using a mixture of between 40ml and 60ml hydrogel, and 60ml and 80ml hydrogen peroxide. The above mentioned hydrogels may also be used to prepare the wettable material using a mixture of hydrogel and perfluorocarbons. This may result in an oxygen rich wettable material with a surface layer which inhibits polymerization.

[0075] The above mentioned hydrogels may also be used to prepare the wettable material using a mixture of hydrogel together with a hydrogen donor and an oxygen scavenager.

Glycerine-based Wettable Materials

[0076] A glycerine-based gel may be prepared in an aqueous solution of glycerine with a wt.% of glycerine varying according to the thermal requirements of the application. The wettable material may be a glycerine gel which repels resin and is able to withstand high temperatures.

[0077] It will be understood by a person skilled in the art that many of the details provided above are by way of example only, and are not intended to limit the scope of the invention which is to be determined with reference to the following claims.

What is claimed is:

1. A stereolithography system comprising:

an emitting device;

a tank disposed above the emitting device, the tank having an optically transparent bottom wall;

a linear stage extending away from the tank and a carrier platform moveable along the linear stage away from the tank; and

a wettable material at the optically transparent bottom wall of the tank within the tank.

2. The stereolithography system as claimed in claim 1 wherein the wettable material is coated on the optically transparent bottom wall of the tank.

3. The stereolithography system as claimed in claim 1 wherein the wettable material is a membrane that overlays the optically transparent bottom wall of the tank.

4. The stereolithography system as claimed in claim 1 wherein the wettable material includes a hydrogel.

5. The stereolithography system as claimed in claim 1 wherein the wettable material includes a hydrogel and hydrogen peroxide.

6. The stereolithography system as claimed in any one of claims 1, 4 or 5 wherein the wettable material includes a hydrogen donor and an oxygen scavenger.

7. The stereolithography system as claimed in any one of claims 1, 4 or 5 wherein the wettable material includes glycerine.

8. The stereolithography system as claimed in any one of claims 1, 4 or 5 wherein the wettable material includes a UV inhibitor.

9. The stereolithography system as claimed in claim 1 wherein the wettable material has a superhydrophobic surface.

10. The stereolithography system as claimed in claim 9 wherein a nanostructure of the superhydrophobic surface is a vertically aligned surface or a hierarchically structured surface, or a combination thereof.

11. The stereolithography system as claimed in claim 9 wherein a nanostructure of the superhydrophobic surface includes a plurality of projections which have a top diameter of between 5 microns and 15 microns and are spaced less than 10 microns apart.

12. The stereolithography system as claimed in claim 1 wherein the optically transparent bottom wall of the tank has a thermal conductivity of greater than 20 W/(m x K) at 300K.

13. The stereolithography system as claimed in claim 1 wherein the optically transparent bottom wall of the tank is sapphire glass.

14. The stereolithography system as claimed in claim 1 wherein the optically transparent bottom wall of the tank is transparent ceramic spinel.

15. The stereolithography system as claimed in claim 1 wherein the wettable material is adhered to the bottom of the tank using adhesive applied in a pattern having intersecting lines.

16. The stereolithography system as claimed in claim 1 wherein the tank is in fluid communication with a resin recirculation system.

17. The stereolithography system as claimed in claim 1 wherein the tank is in fluid communication with a resin cooling system.

18. The stereolithography system as claimed in claim 1 further including a cooling device which cools the tank.

19. The stereolithography system as claimed in claim 18 wherein the cooling device is an air knife.

20. The stereolithography system as claimed in claim 1 wherein the bottom wall of the tank includes a UV OLED or an LCD monitor with a UV LED.

21. A stereolithography system comprising:

an emitting device;

a tank disposed above the emitting device, the tank having an optically transparent bottom wall;

a linear stage extending away from the tank and a carrier platform moveable along the linear stage away from the tank; and

a silicon material at the optically transparent bottom wall of the tank within the tank.

22. The stereolithography system as claimed in claim 21 wherein the silicon material has a superhydrophobic surface.

23. The stereolithography system as claimed in claim 22 wherein a nanostructure of the superhydrophobic surface is a vertically aligned surface or a hierarchically structured surface, or a combination thereof.

24. The stereolithography system as claimed in claim 22 wherein a nanostructure of the superhydrophobic surface includes a plurality of projections which have a top diameter of between 5 microns and 15 microns and are spaced less than 10 microns apart.

25. The stereolithography system as claimed in claim 21 wherein the optically transparent bottom wall of the tank has a thermal conductivity of greater than 20 W/(m x K) at 300K.

26. The stereolithography system as claimed in claim 21 wherein the optically transparent bottom wall of the tank is sapphire glass.

27. The stereolithography system as claimed in claim 21 wherein the optically transparent bottom wall of the tank is transparent ceramic spinel.

28. The stereolithography system as claimed in claim 21 wherein the silicon material is adhered to the bottom of the tank using adhesive applied in a pattern having intersecting lines.

29. The stereolithography system as claimed in claim 21 wherein the tank is in fluid communication with a resin recirculation system.

30. The stereolithography system as claimed in claim 21 wherein the tank is in fluid communication with a resin cooling system.

31. The stereolithography system as claimed in claim 21 further including a cooling device which cools the tank.

32. The stereolithography system as claimed in claim 31 wherein the cooling device is an air knife.

33. The stereolithography system as claimed in claim 21 wherein the bottom wall of the tank includes a UV OLED or an LCD monitor with a UV LED.

34. The stereolithography system as claimed in claim 1 or 21 further including a vibrator that vibrates the tank.

35. The stereolithography system as claimed in claim 34 wherein the vibrator vibrates at between 25 HZ and 60 HZ.

36. The stereolithography system as claimed in claim 34 wherein the vibrator is a piezo vibrator.

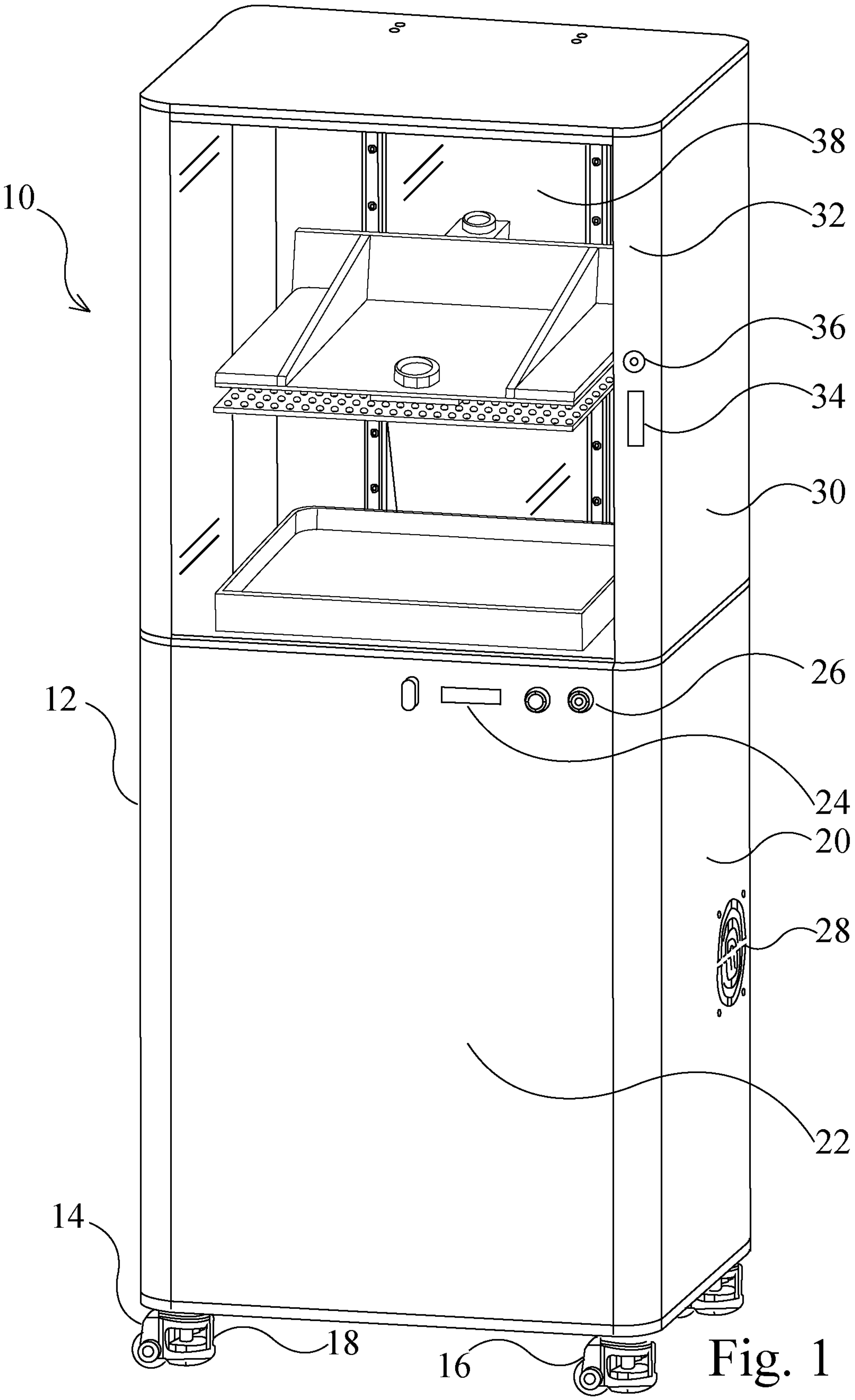


Fig. 1

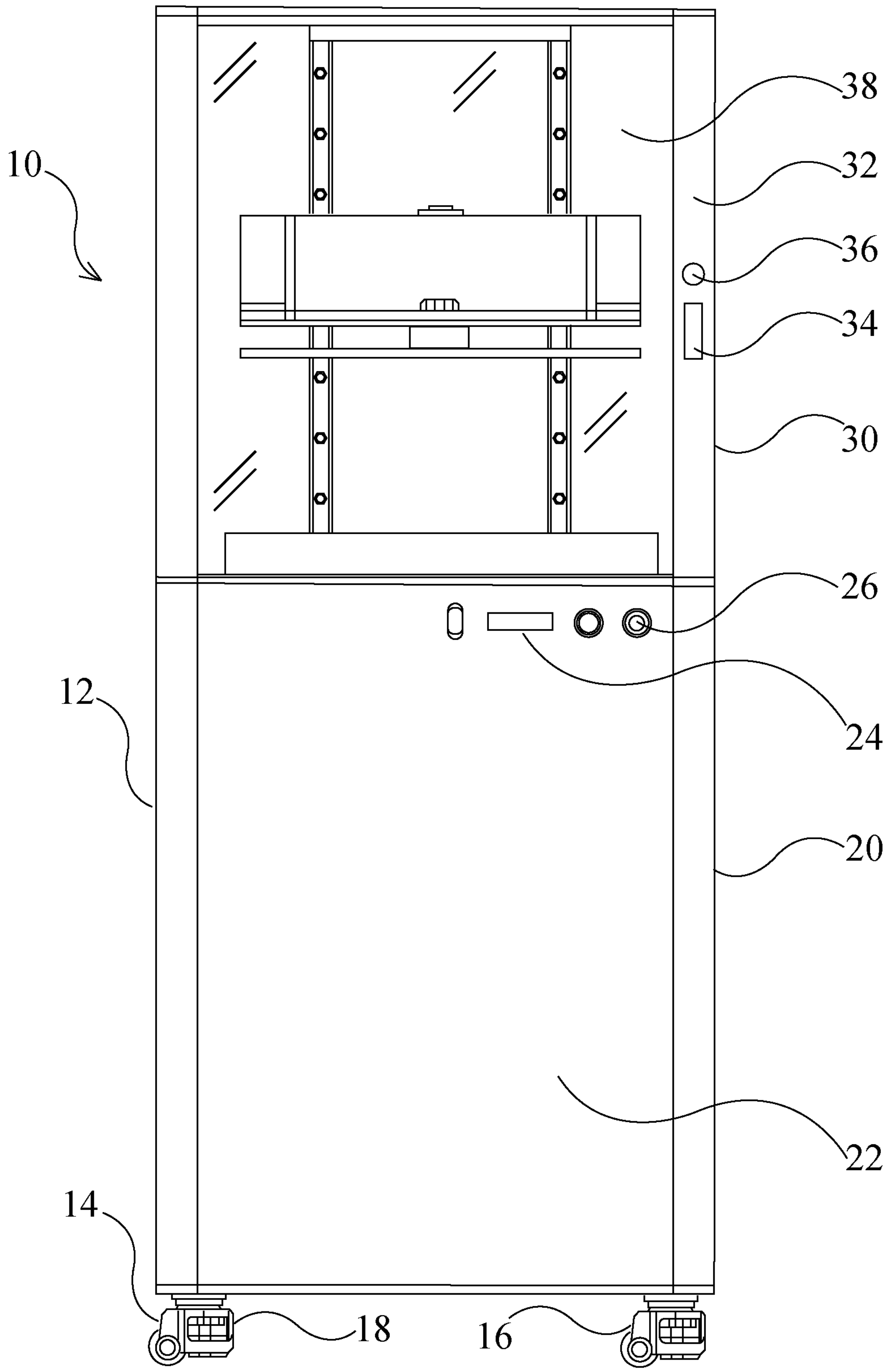
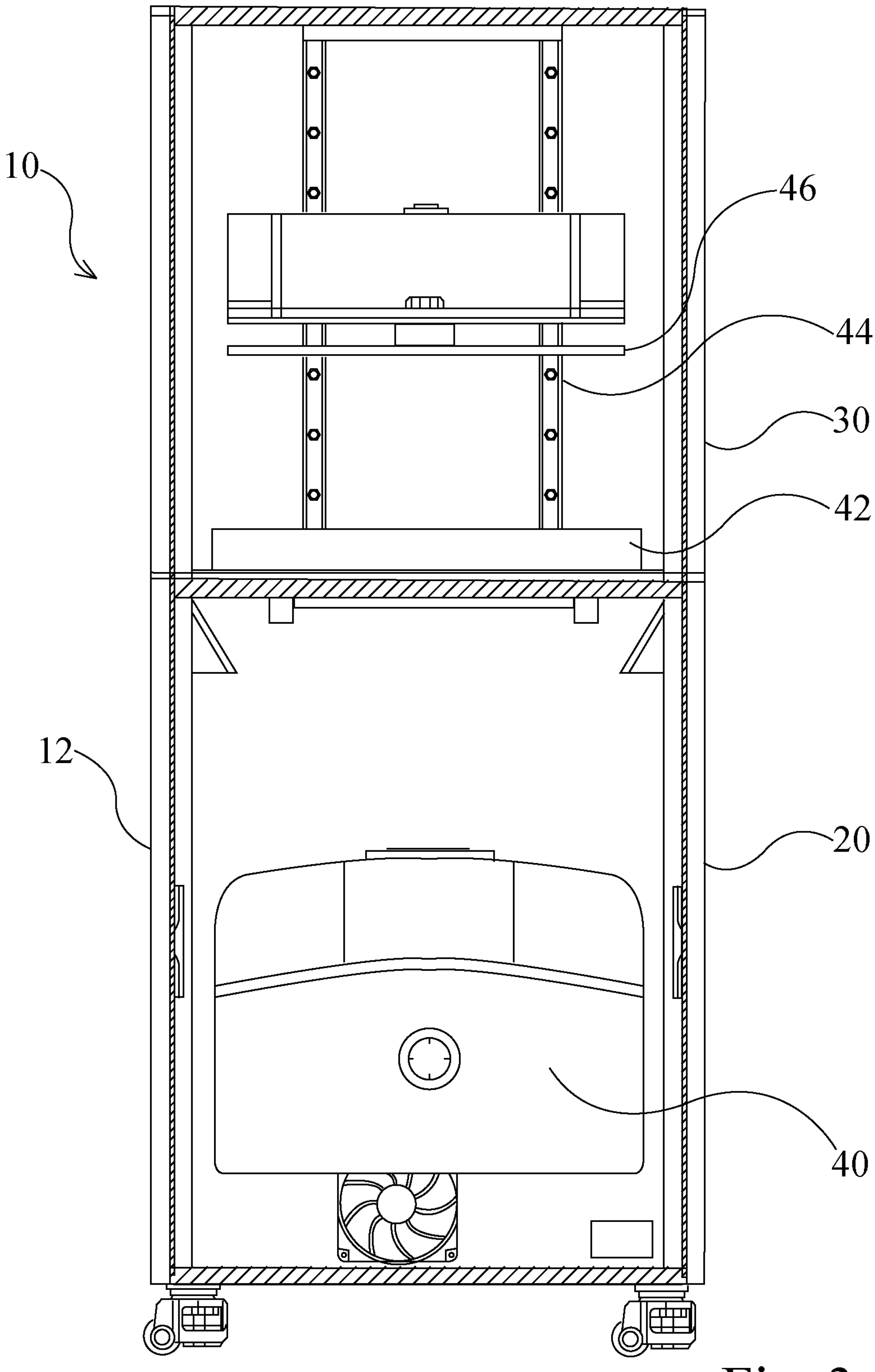


Fig. 2



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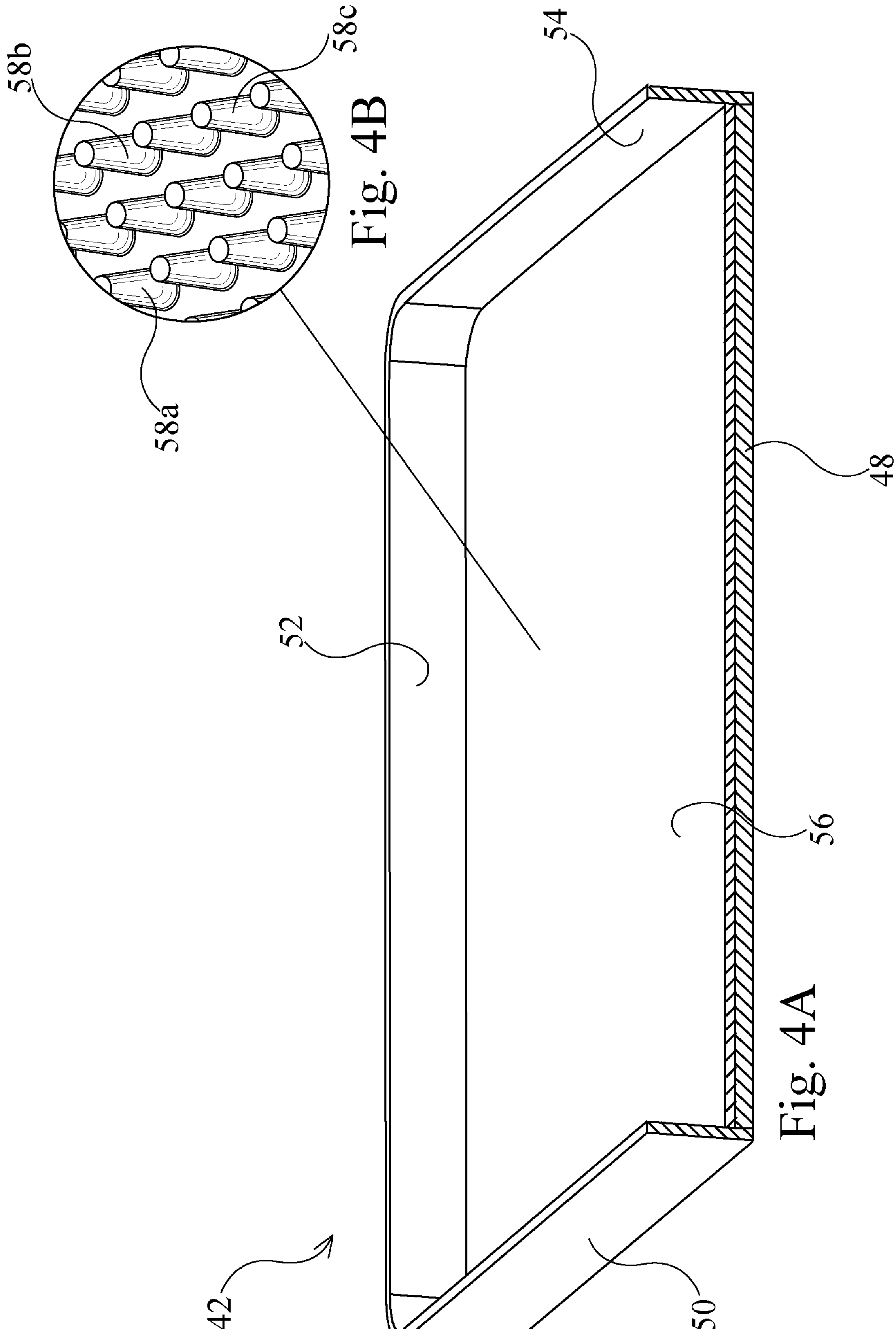


Fig. 4B

Fig. 4A

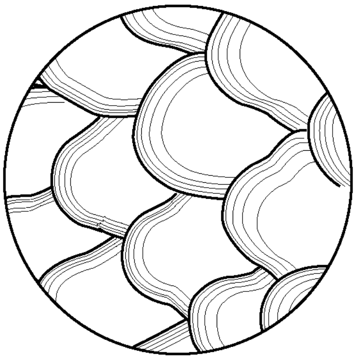


Fig. 5B

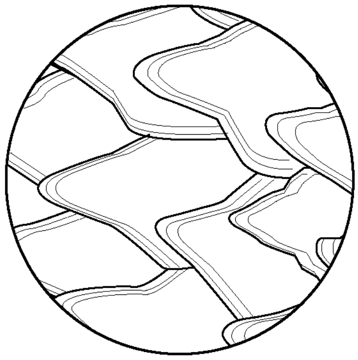


Fig. 5D

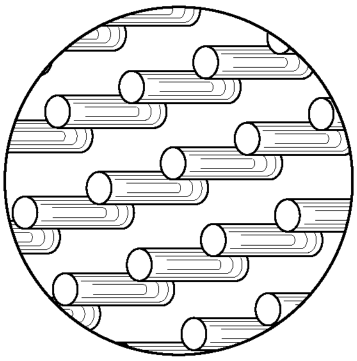


Fig. 5A

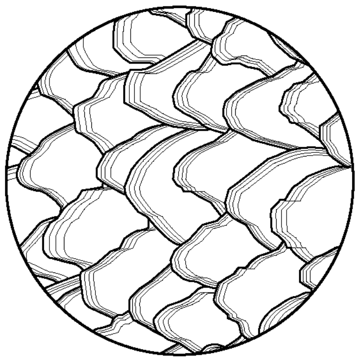


Fig. 5C

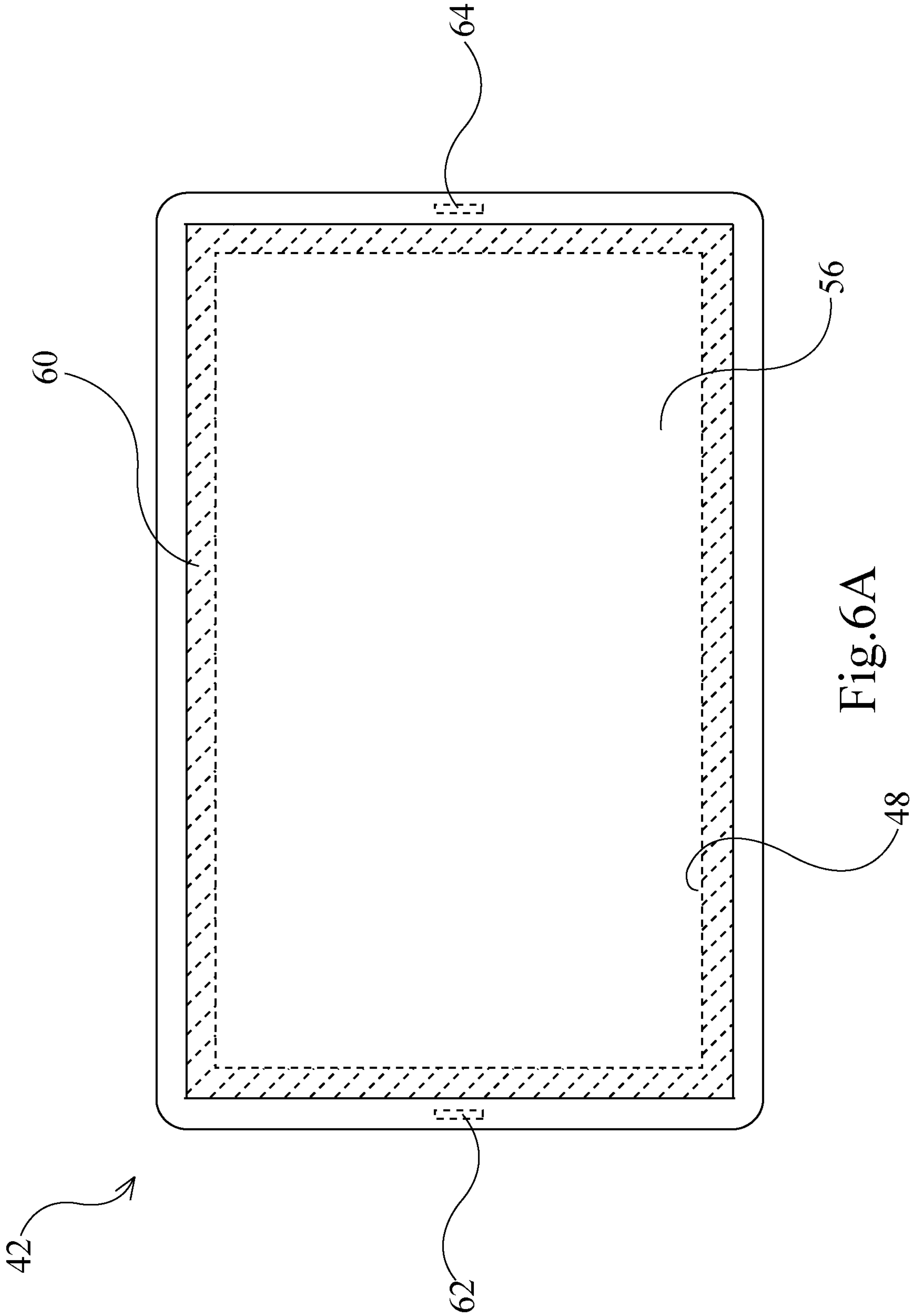


Fig.6A

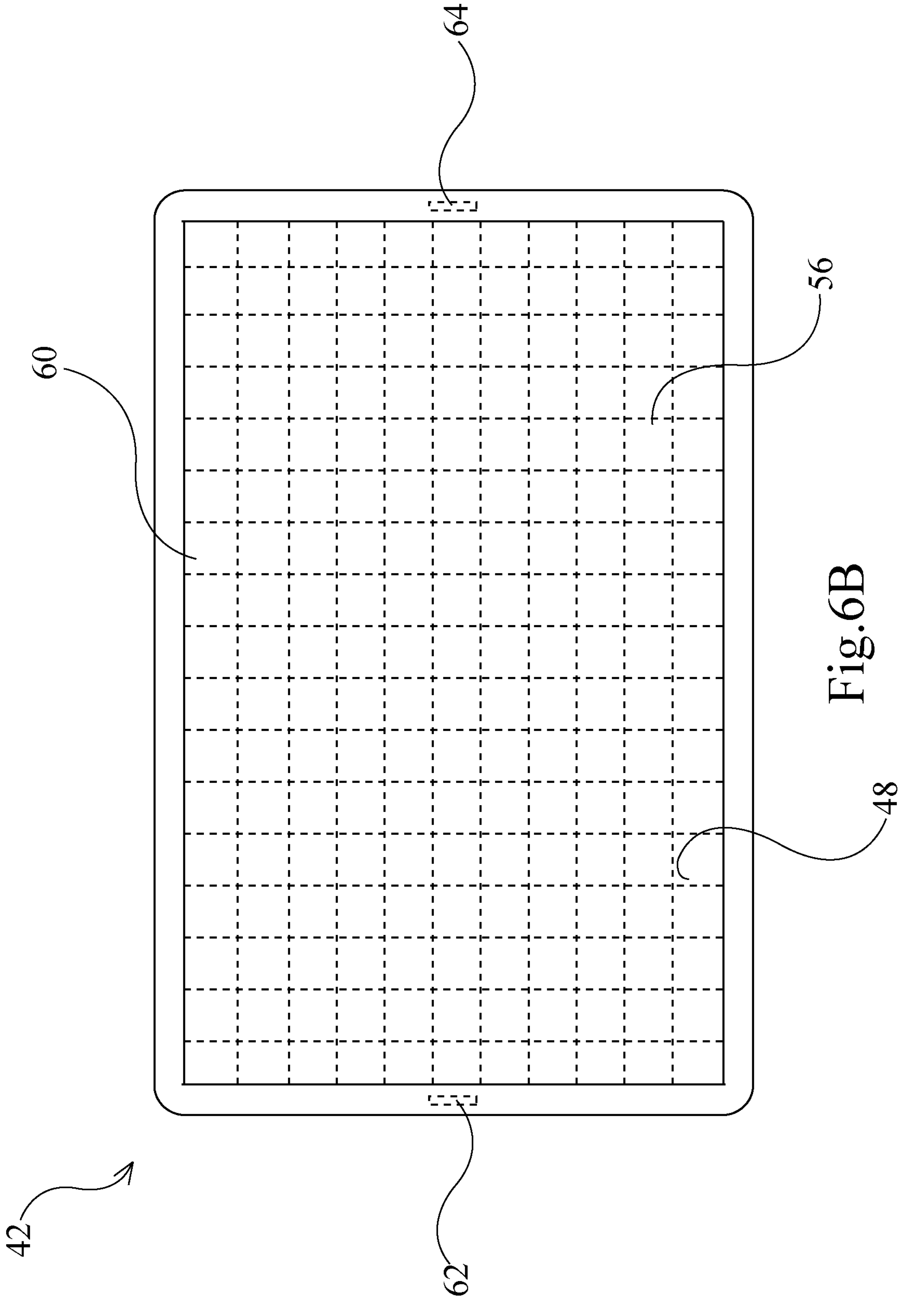


Fig.6B

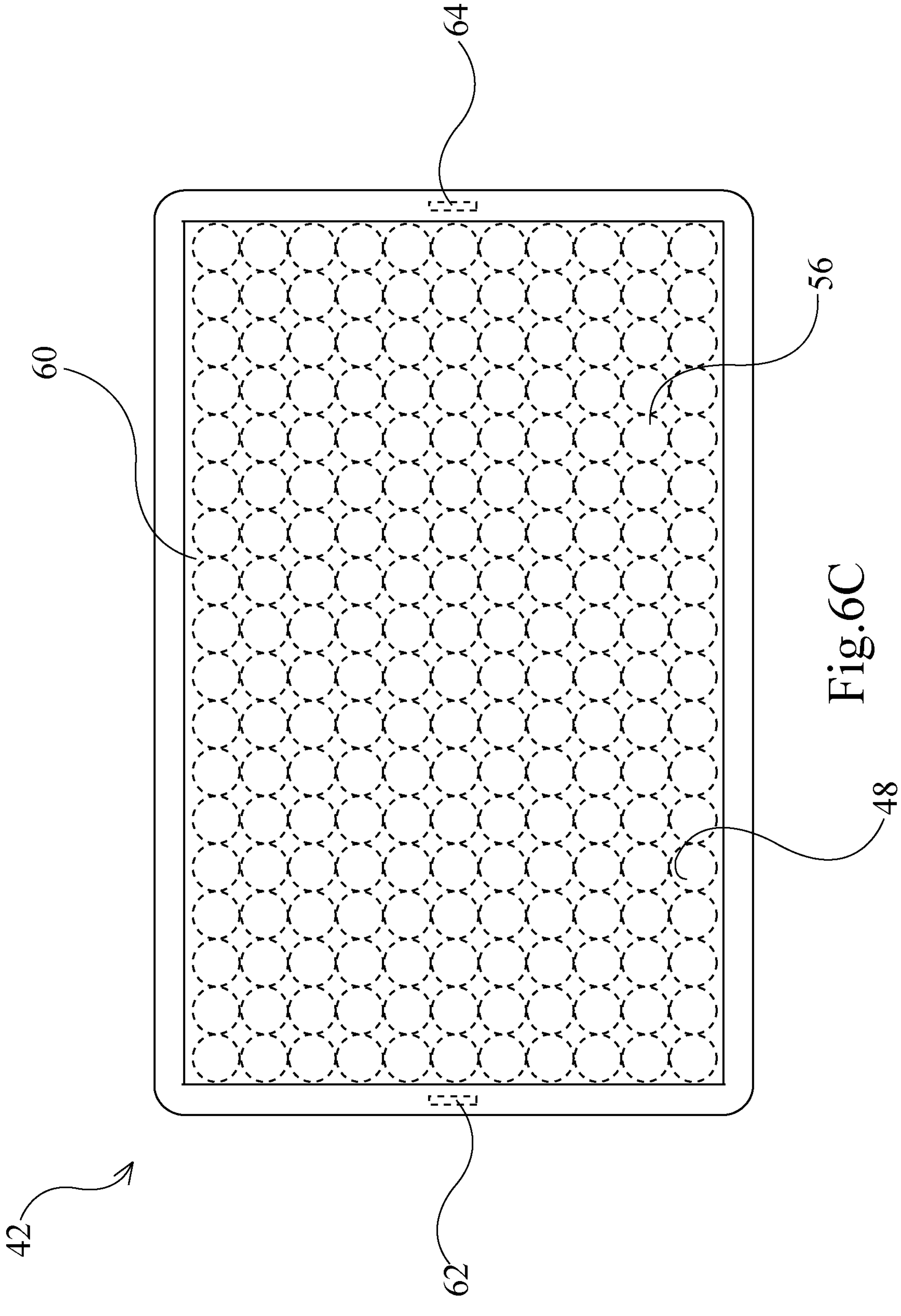
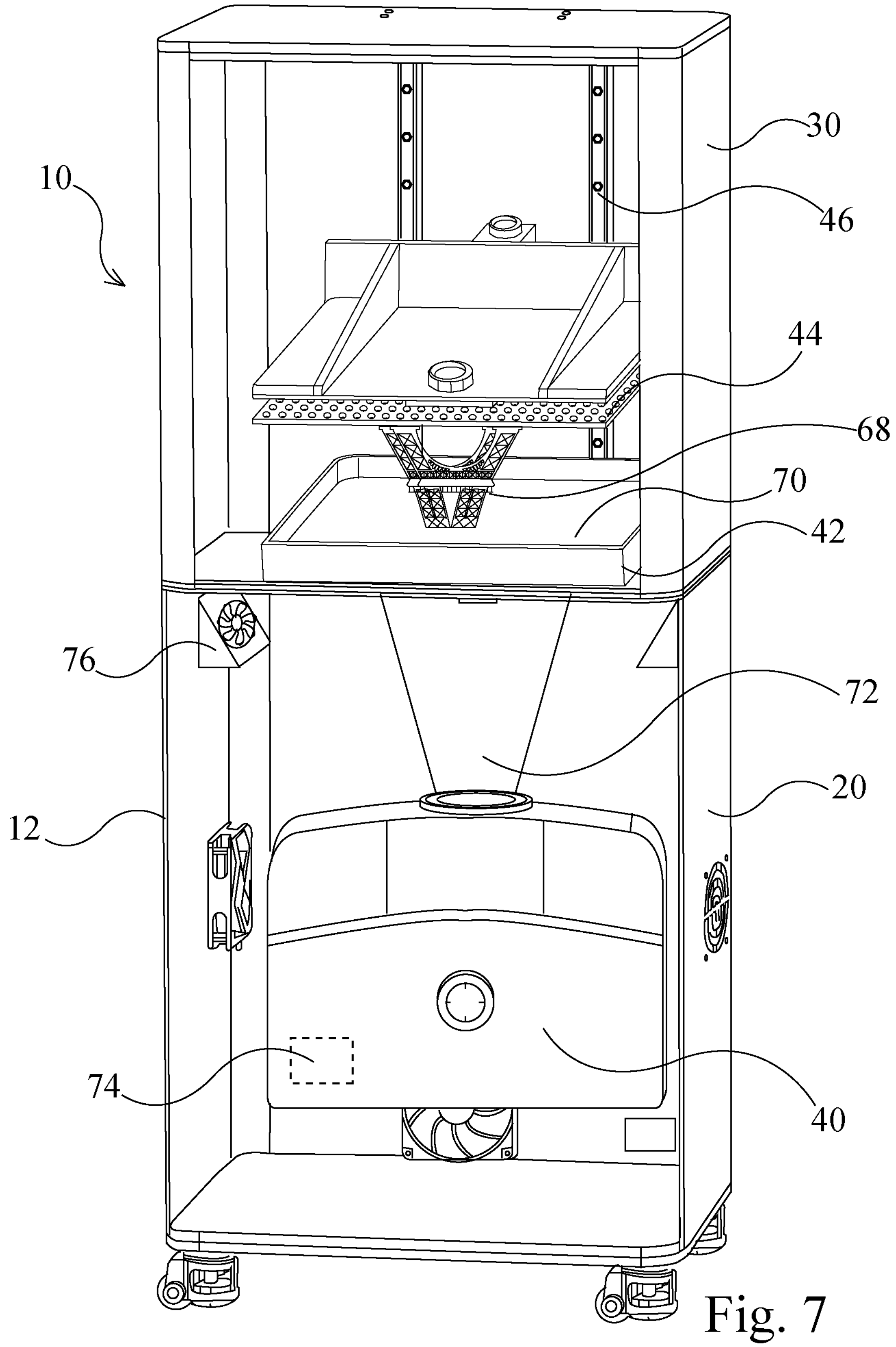


Fig.6C



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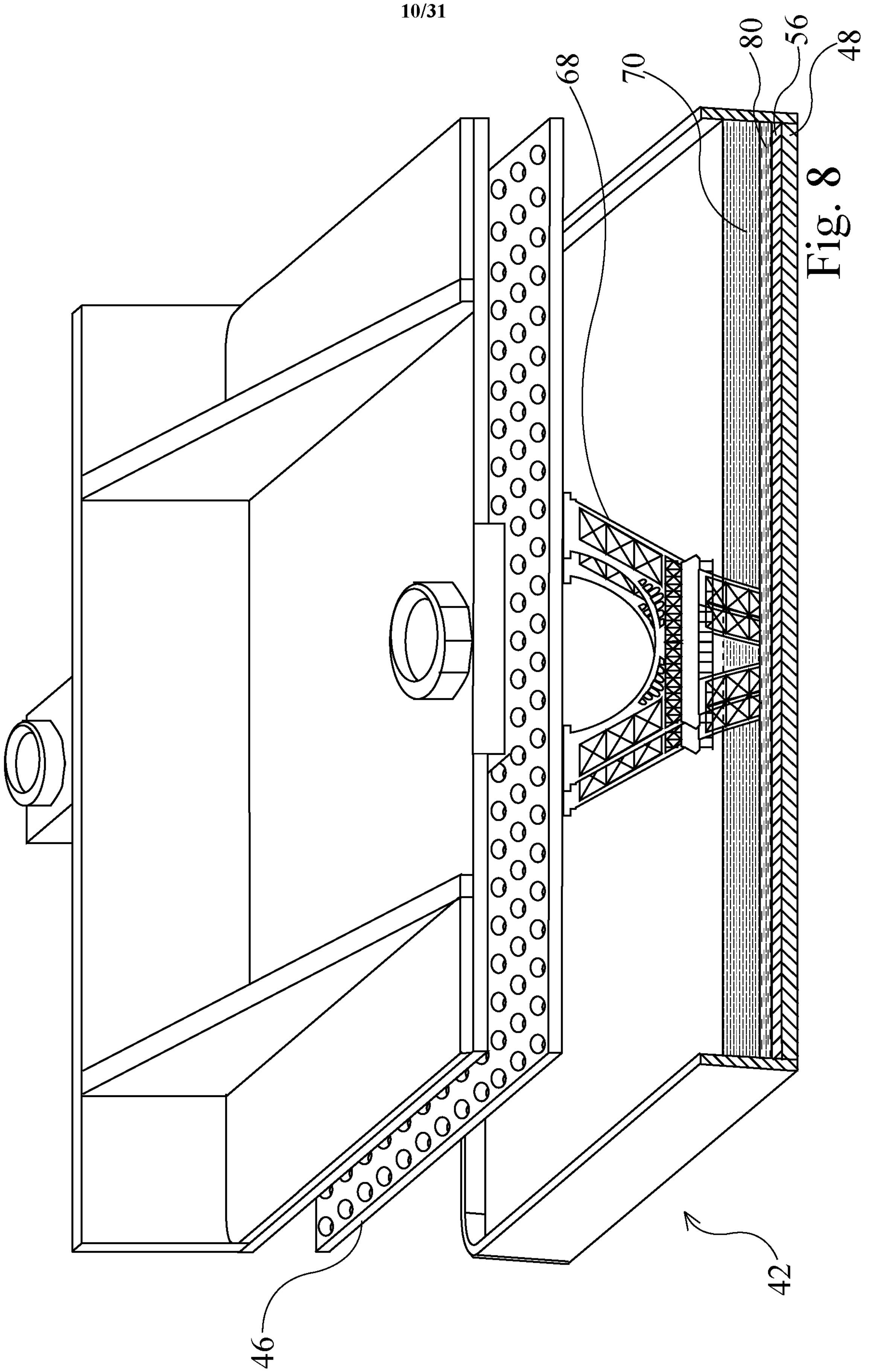


Fig. 8

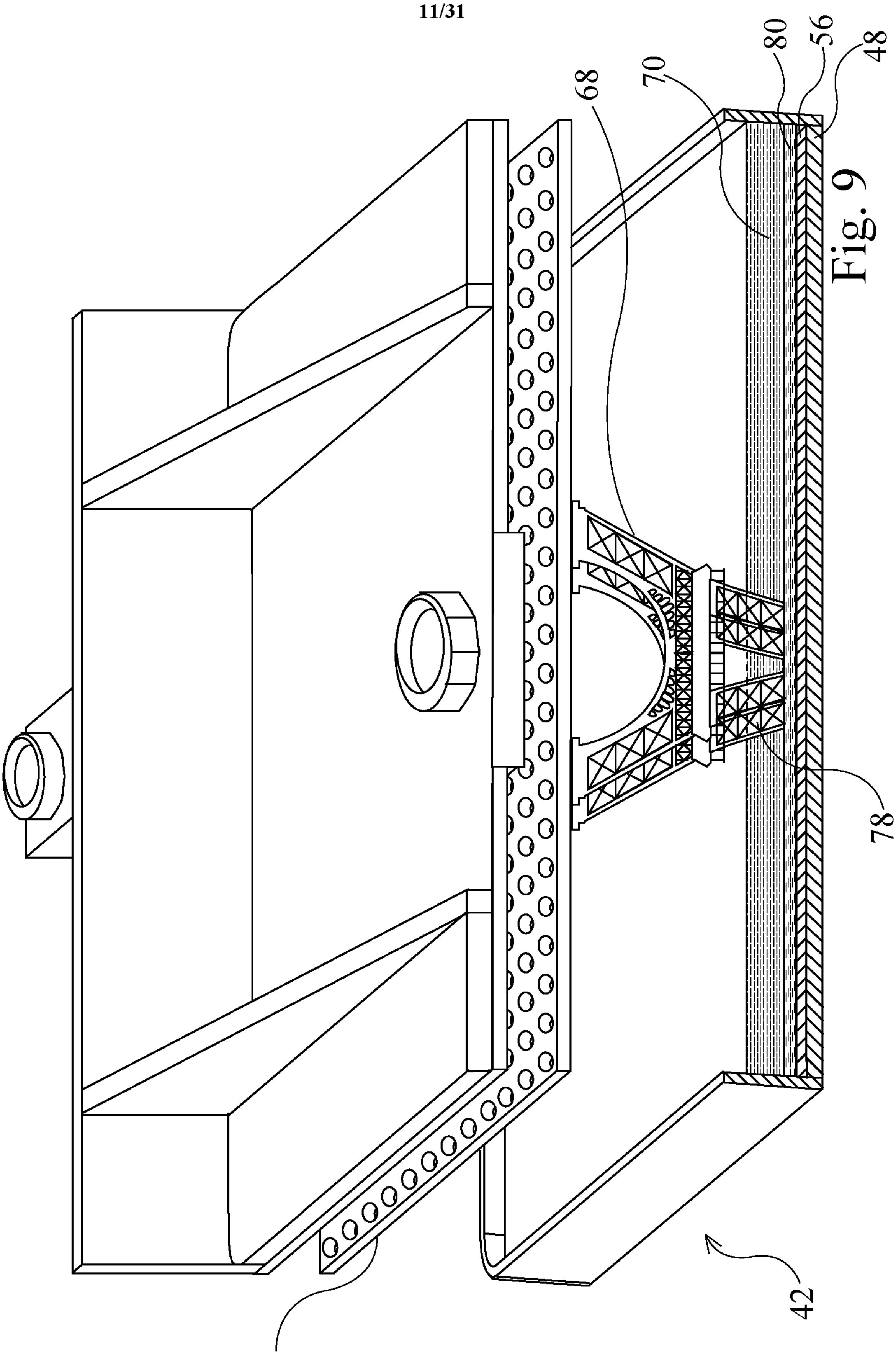


Fig. 9

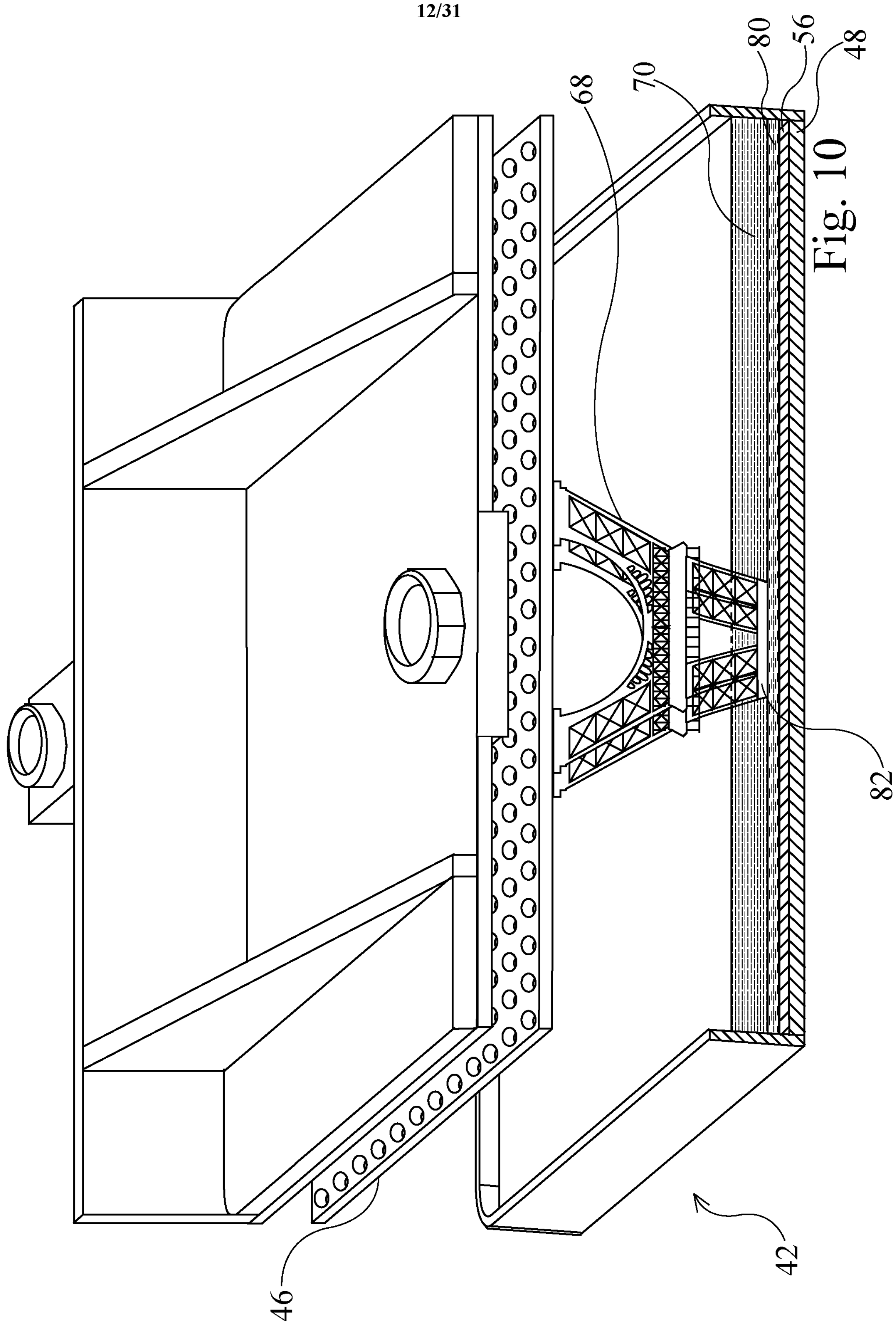


Fig. 10

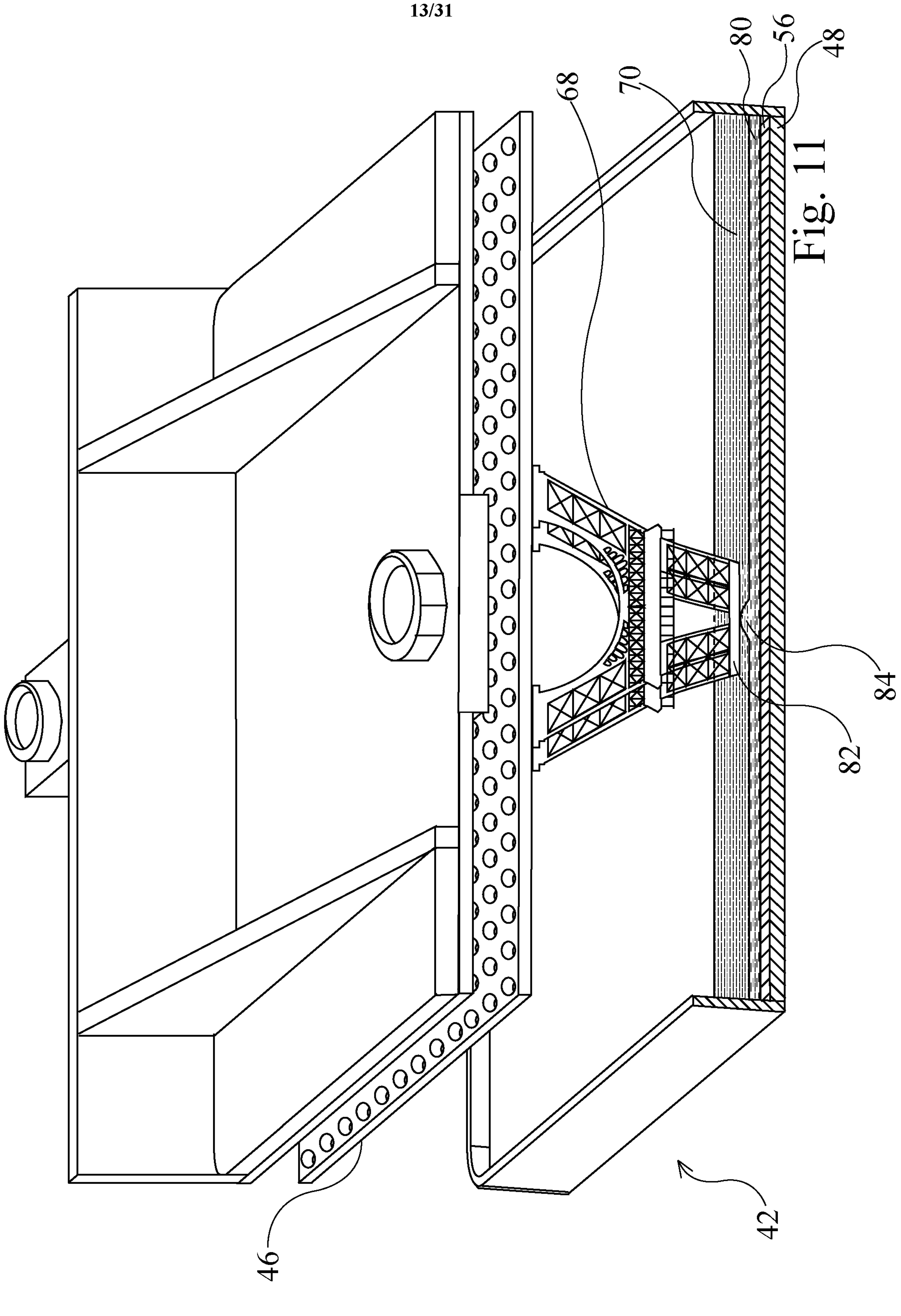


Fig. 11

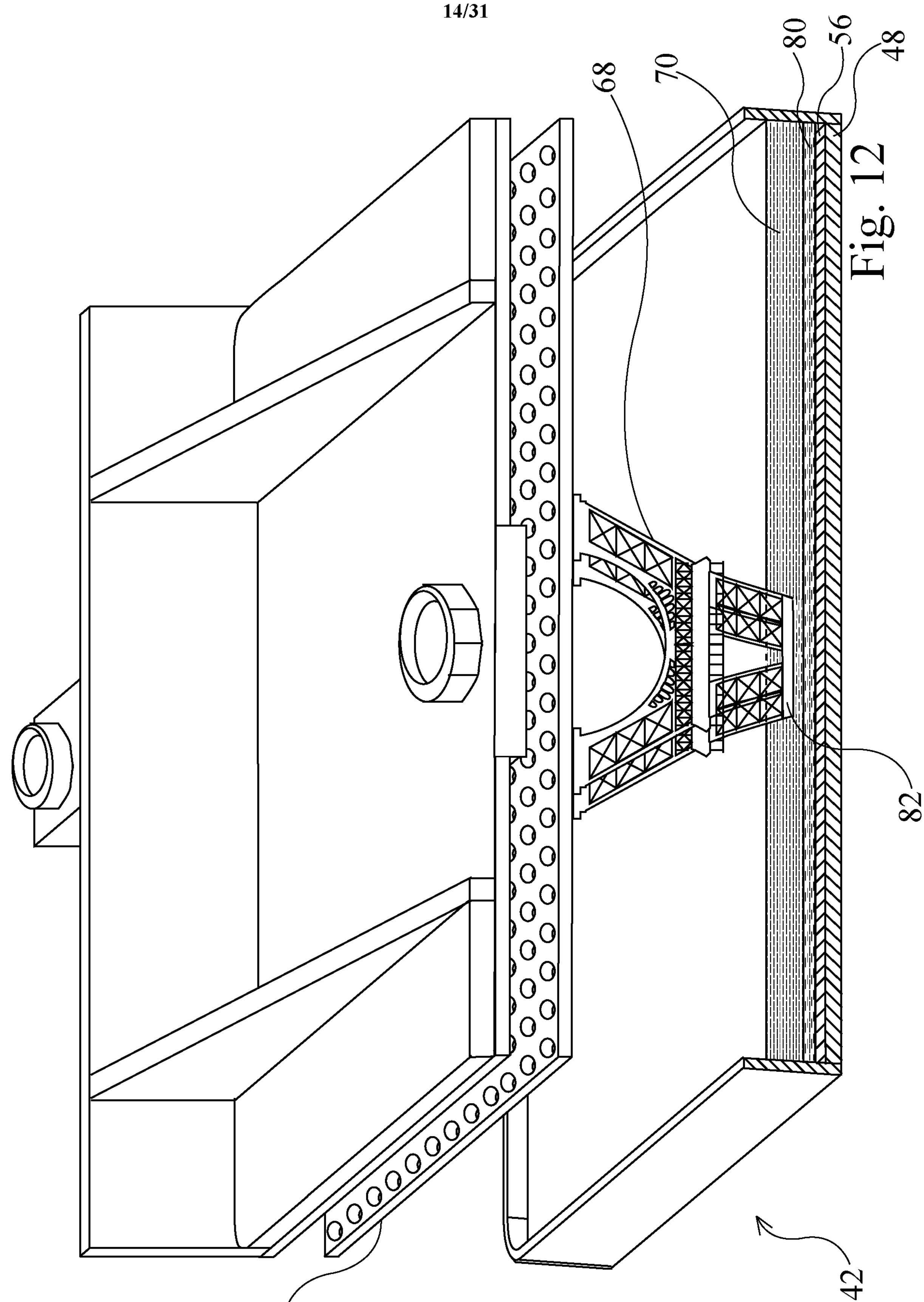


Fig. 12

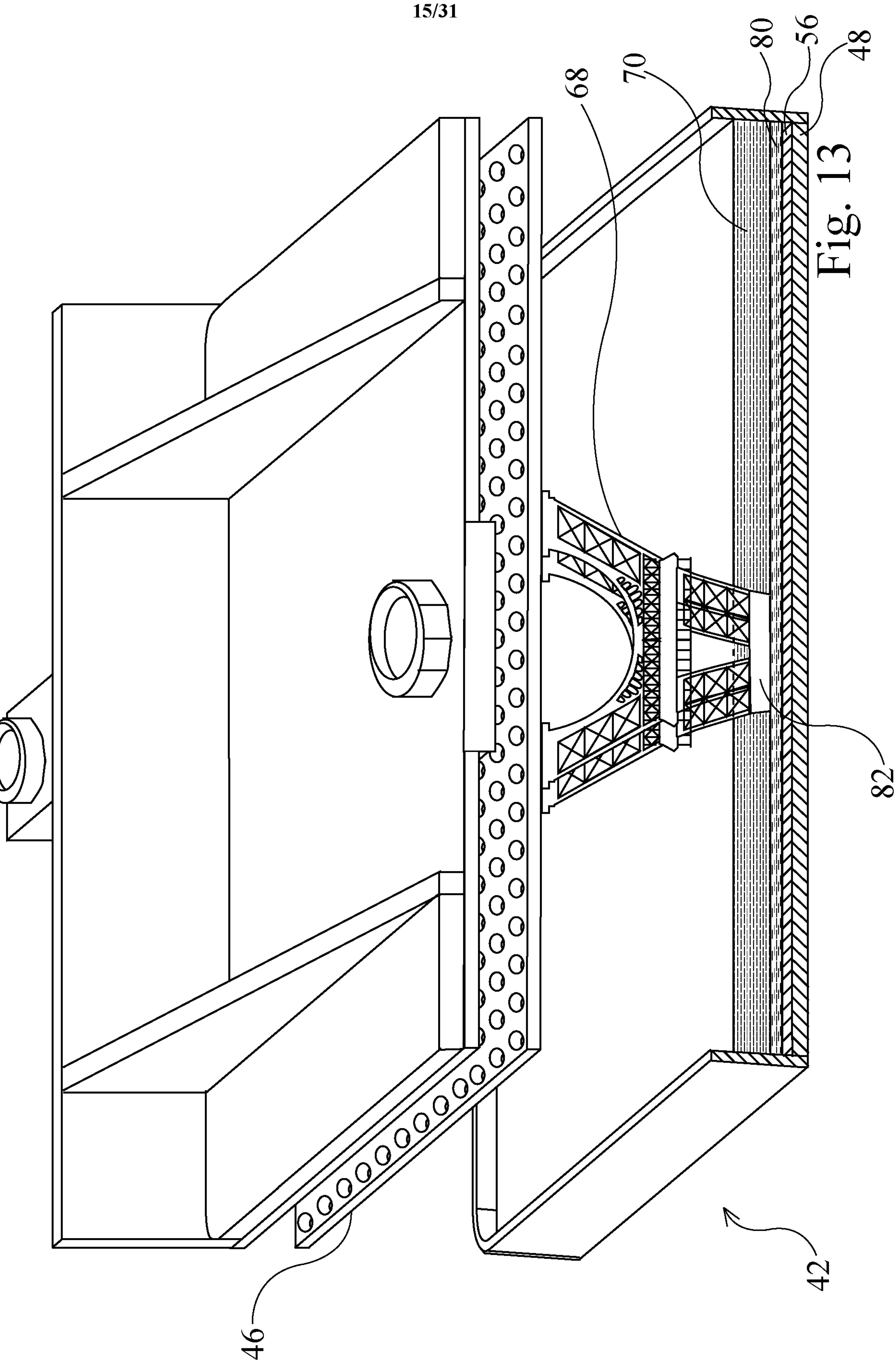


Fig. 13

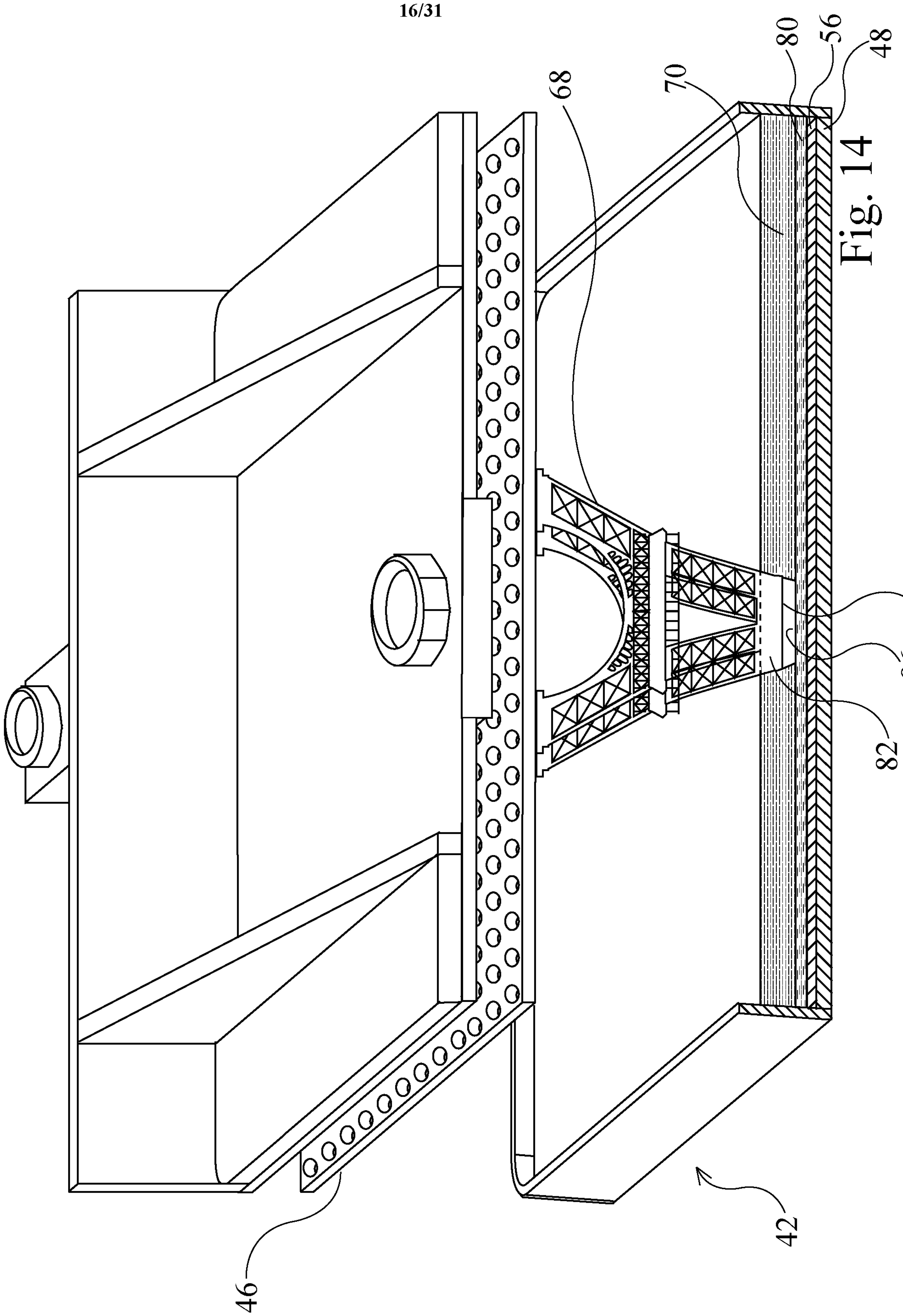


Fig. 14

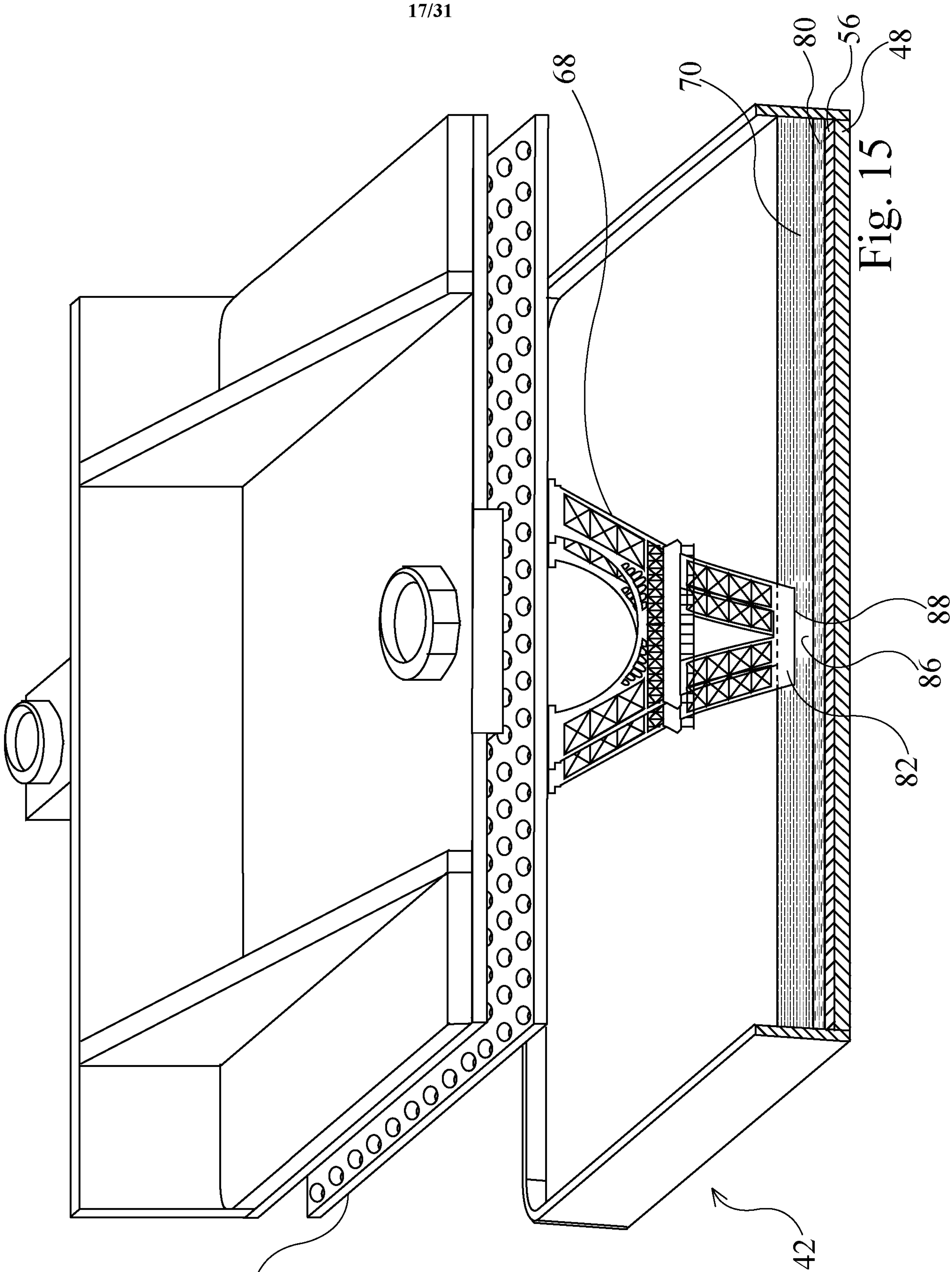


Fig. 15

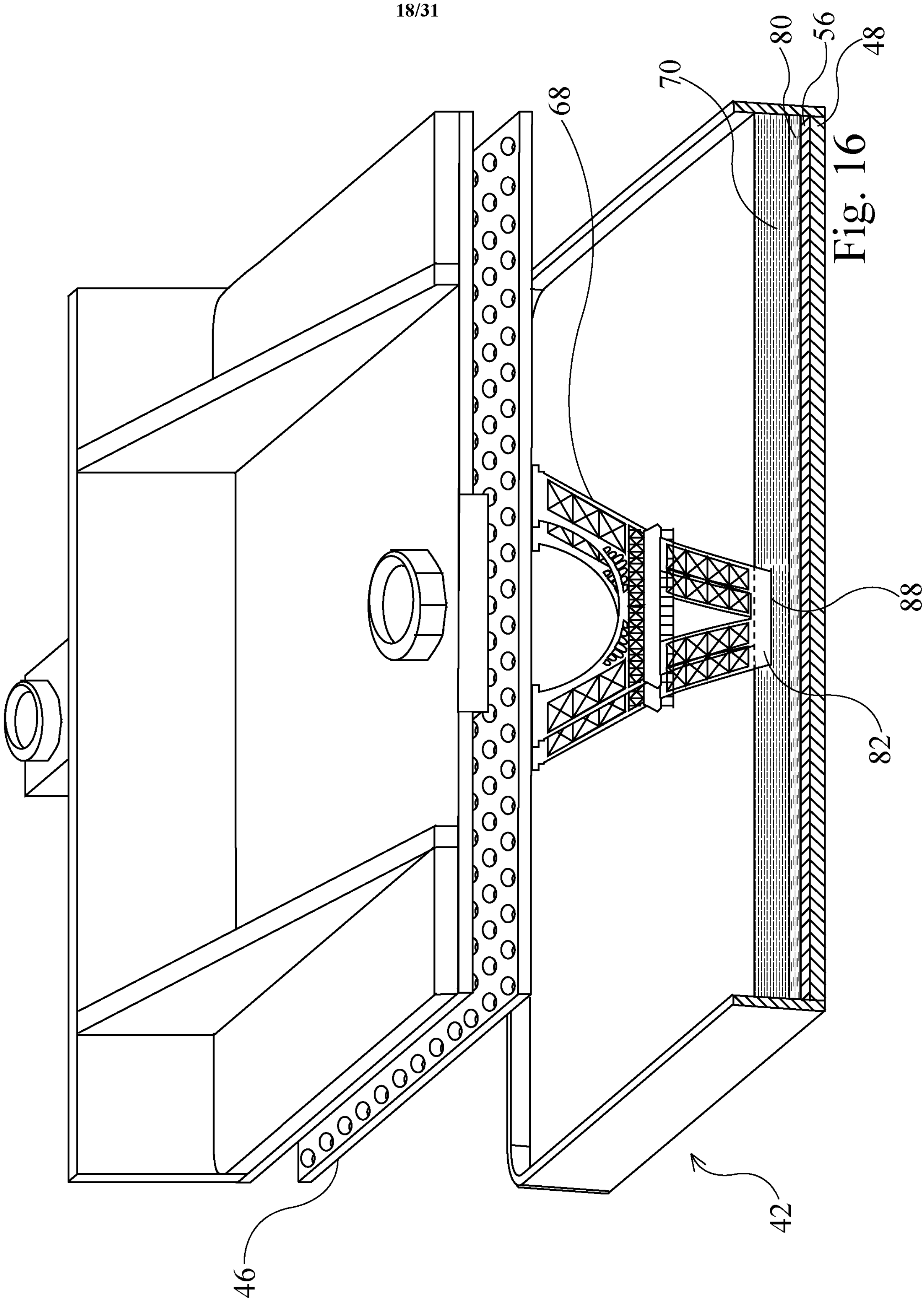


Fig. 16

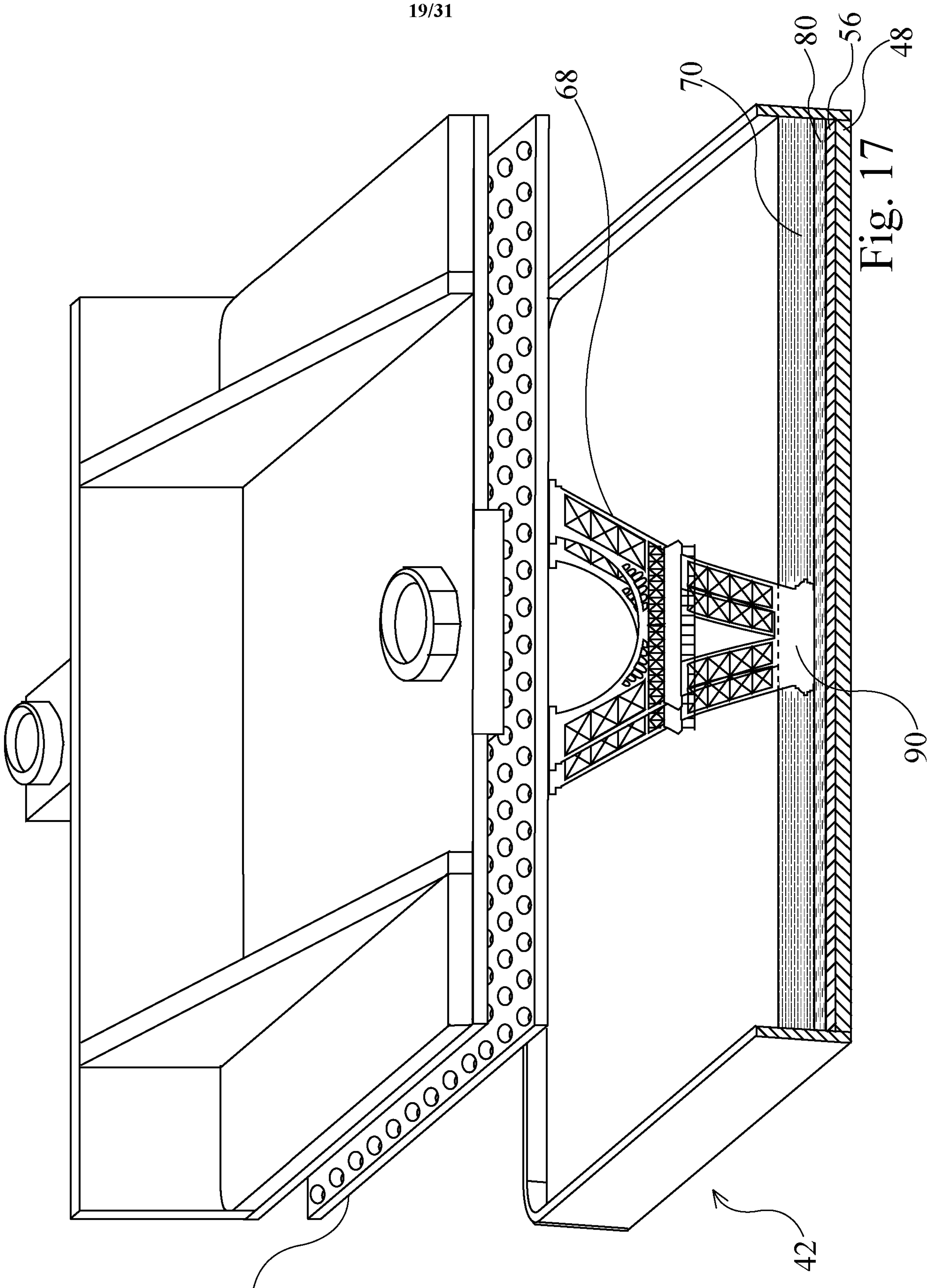


Fig. 17

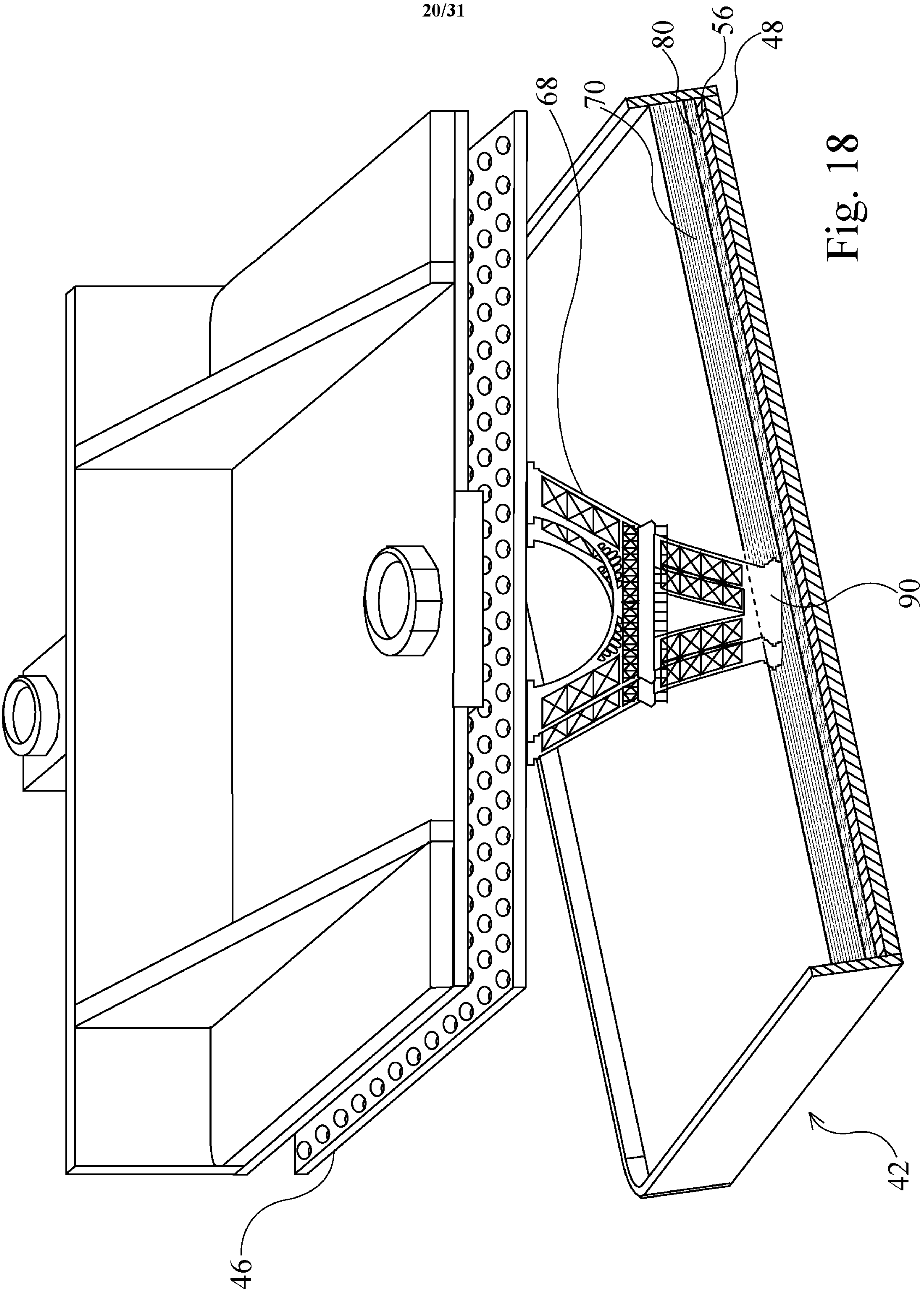


Fig. 18

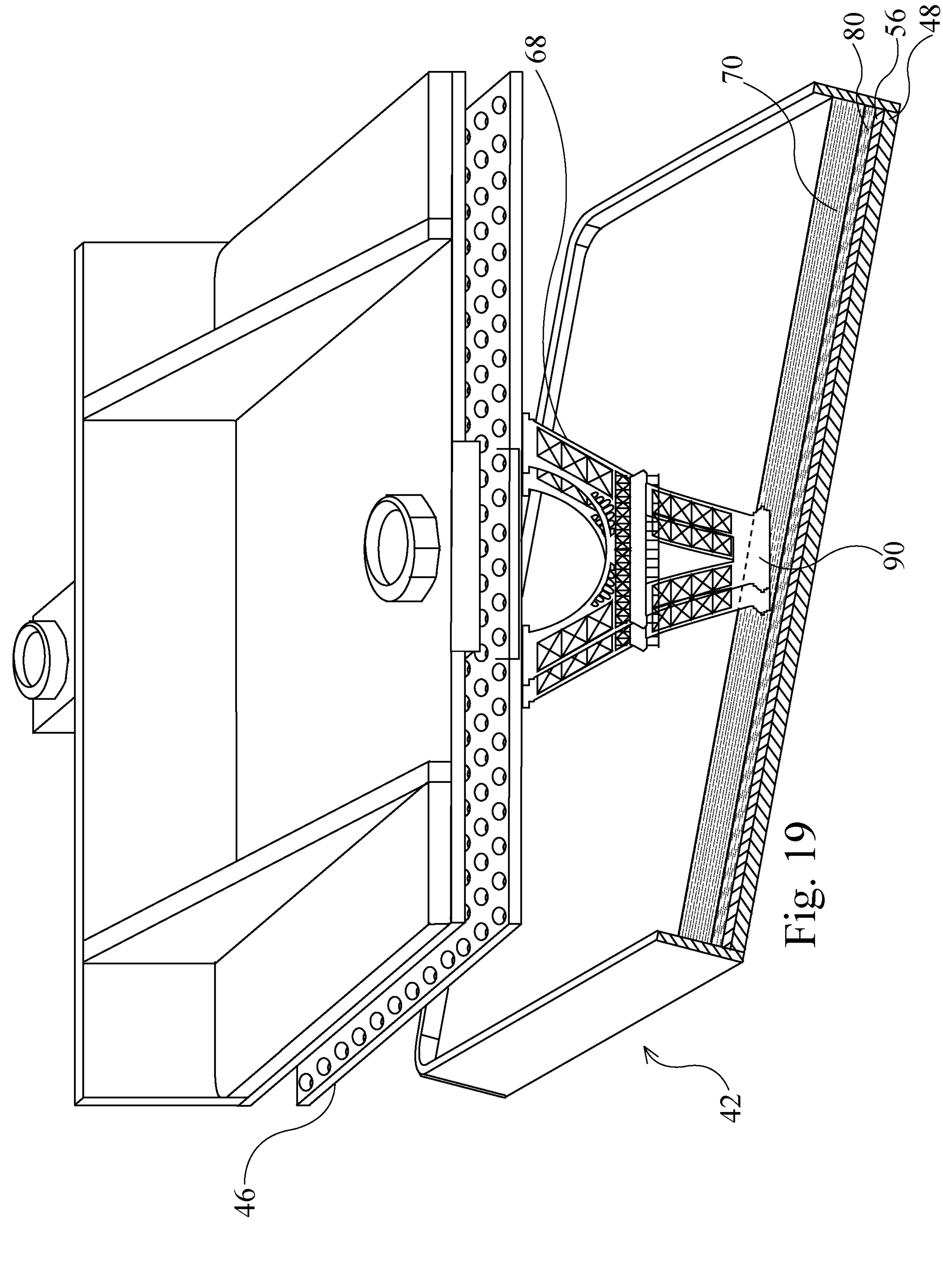


Fig. 19

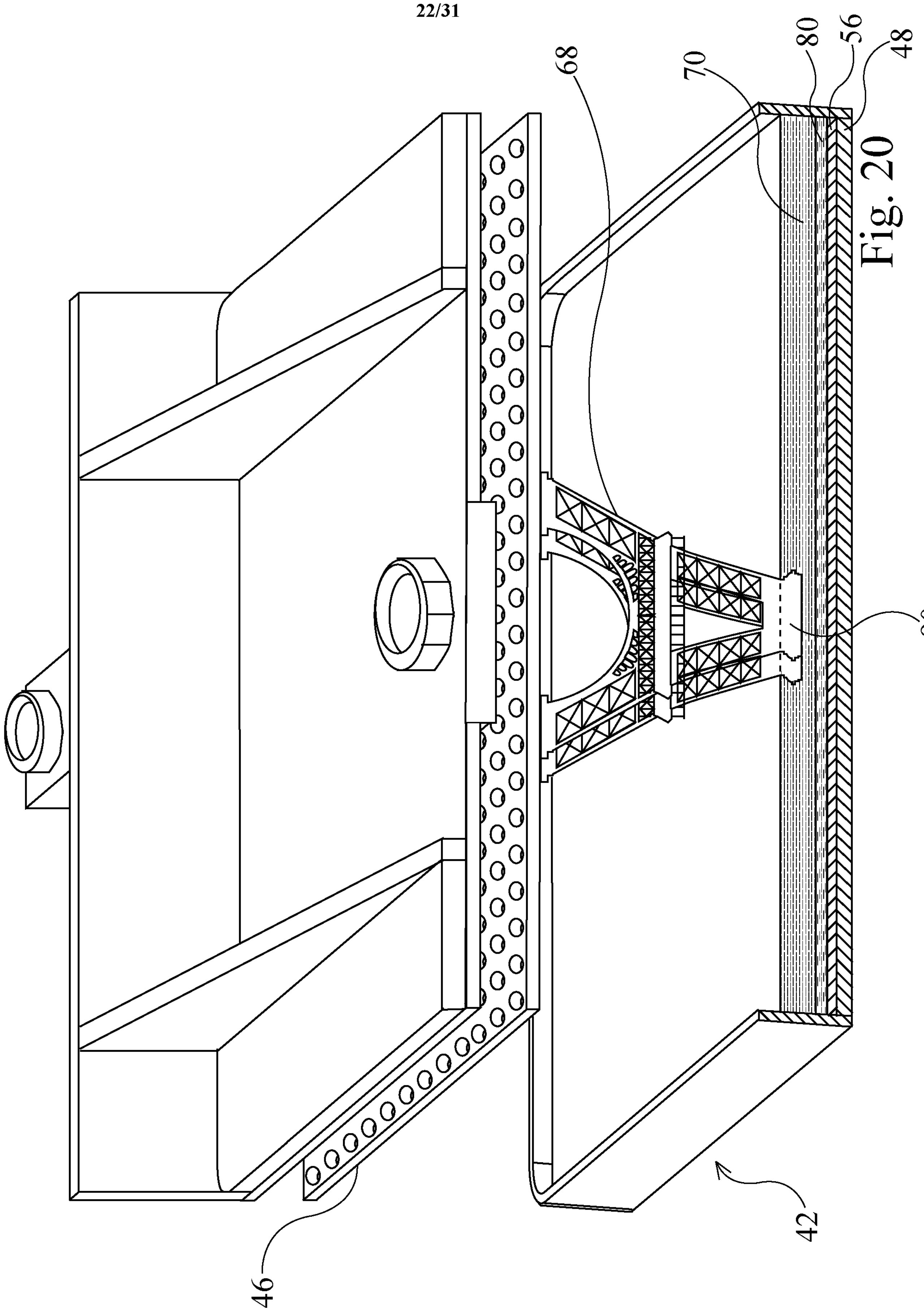


Fig. 20

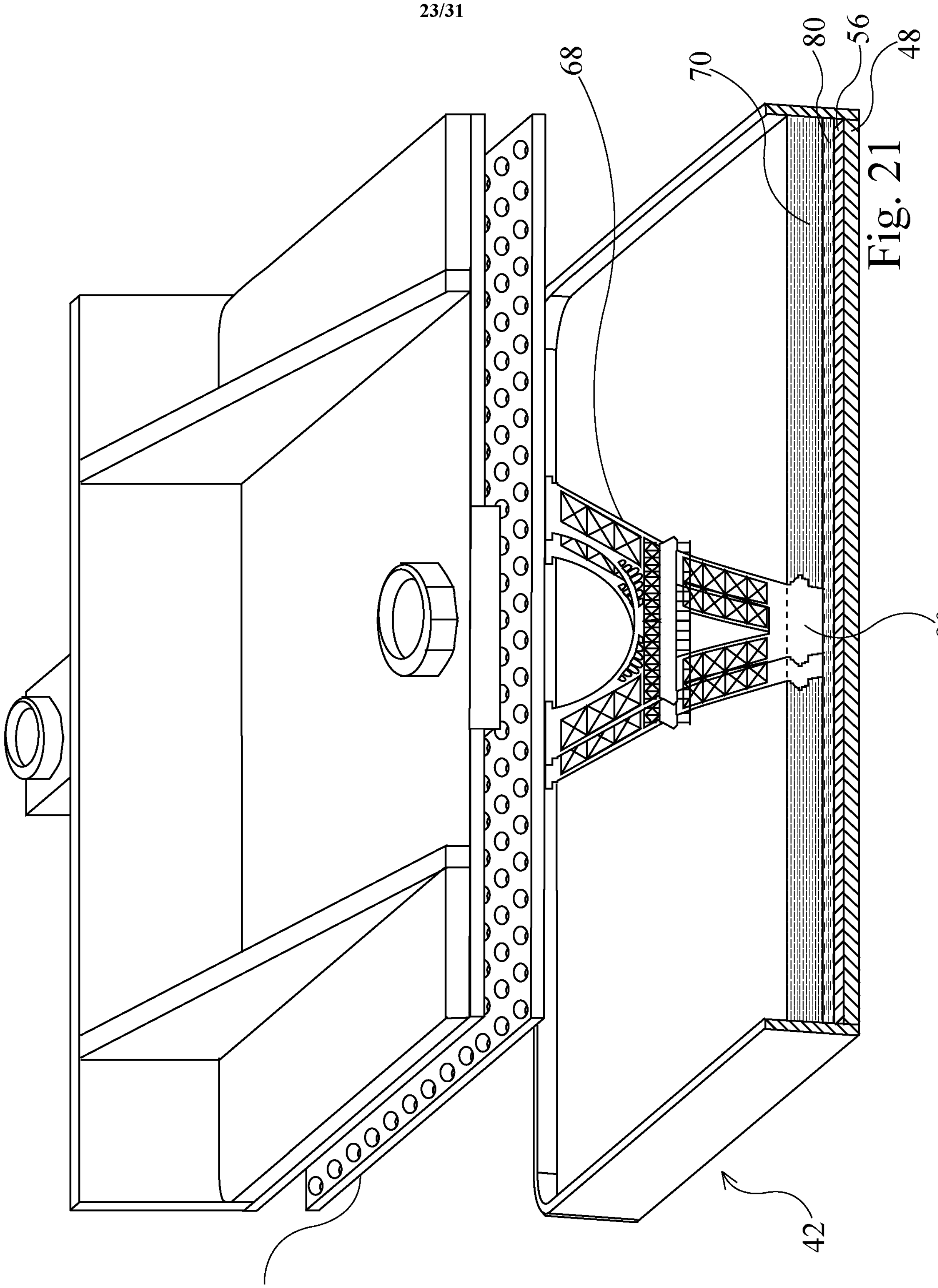


Fig. 21

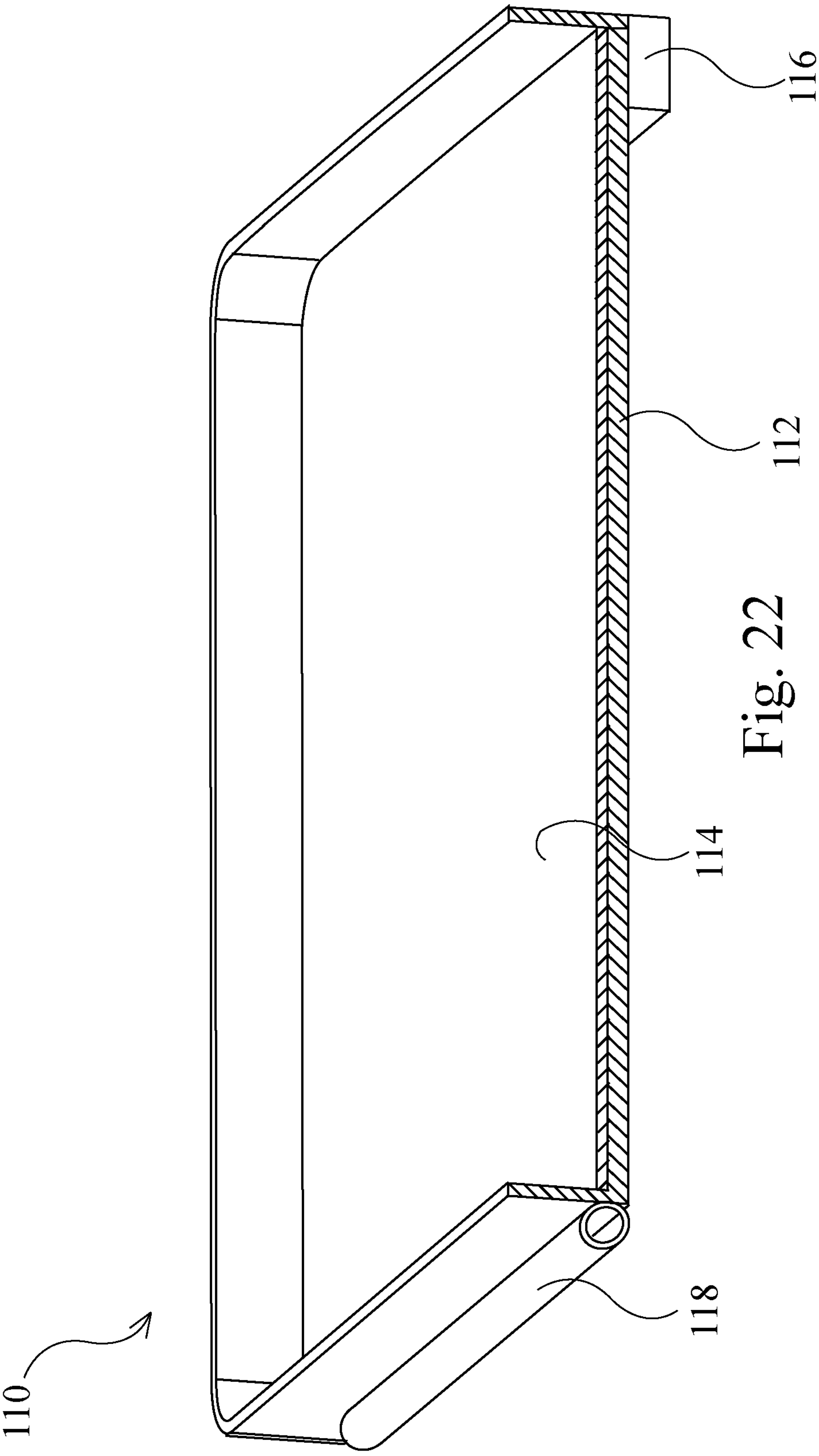


Fig. 22

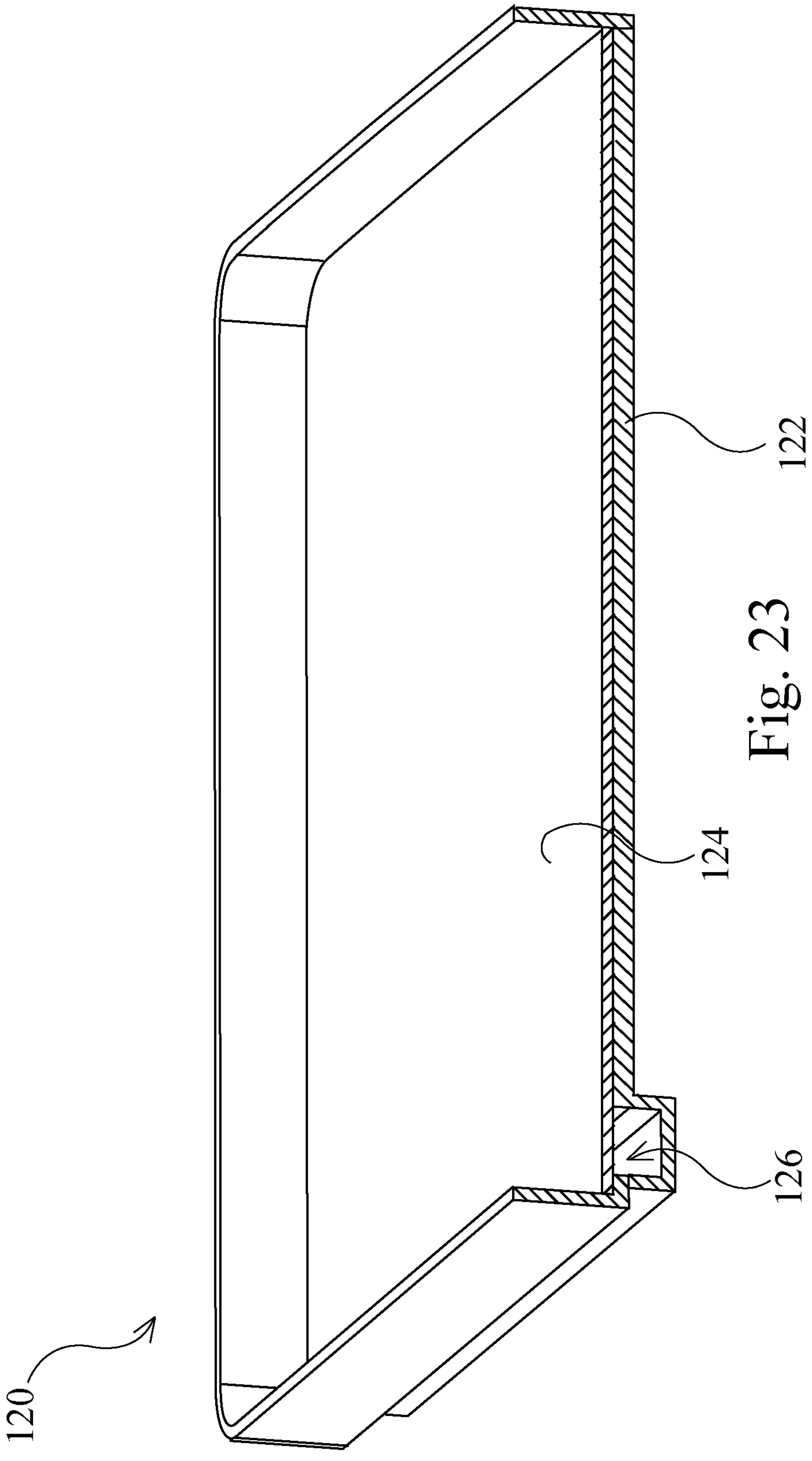


Fig. 23

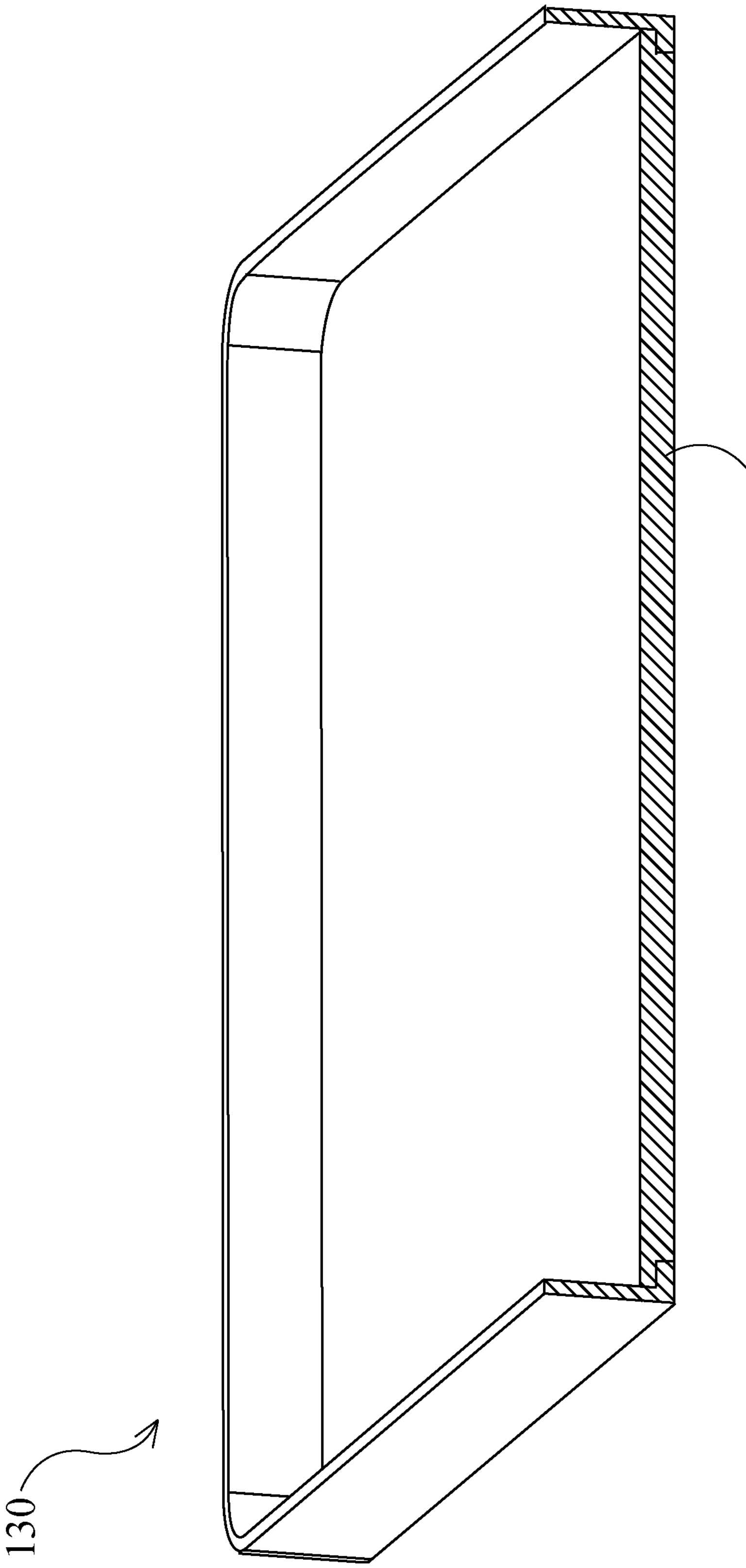


Fig. 24

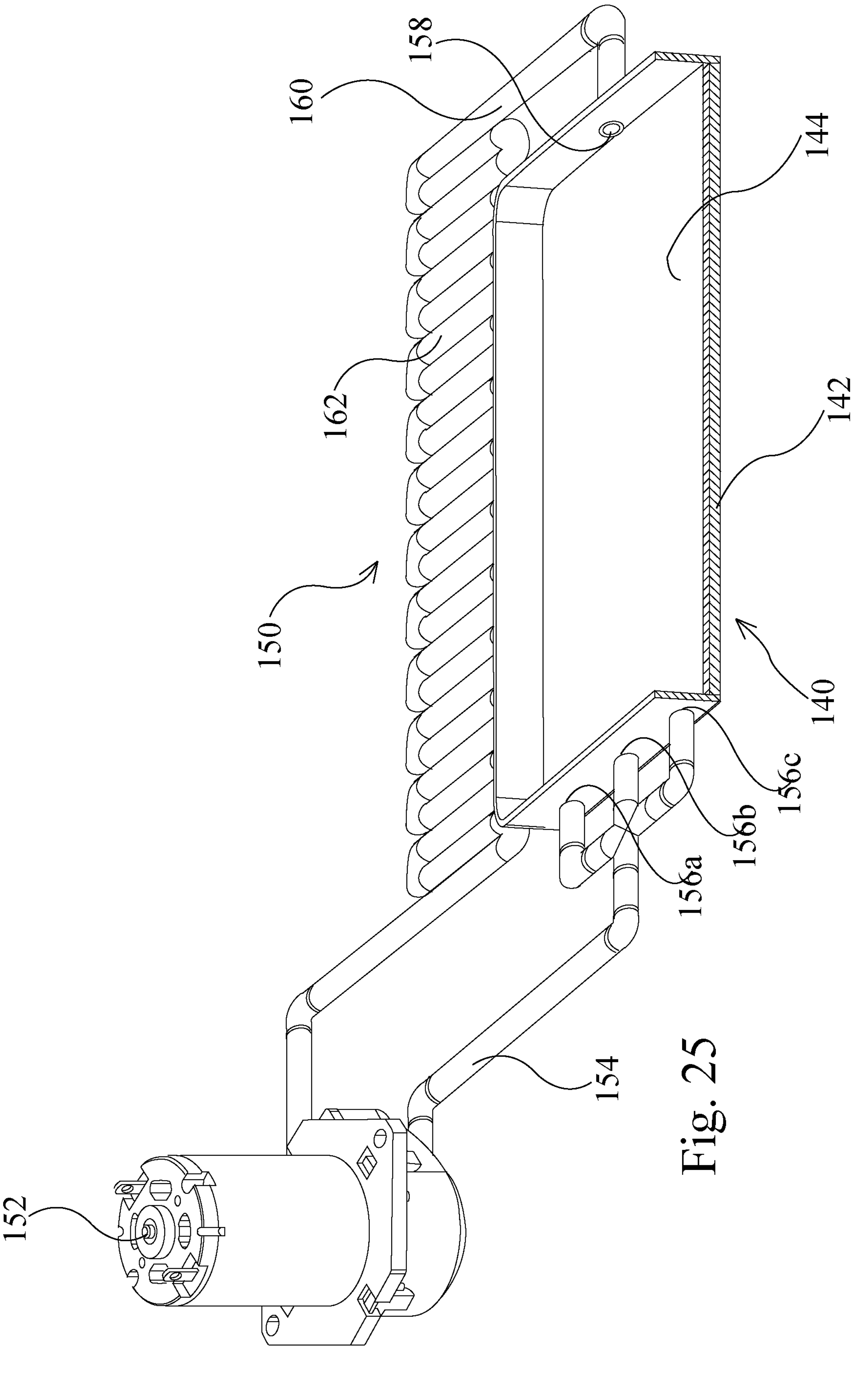


Fig. 25

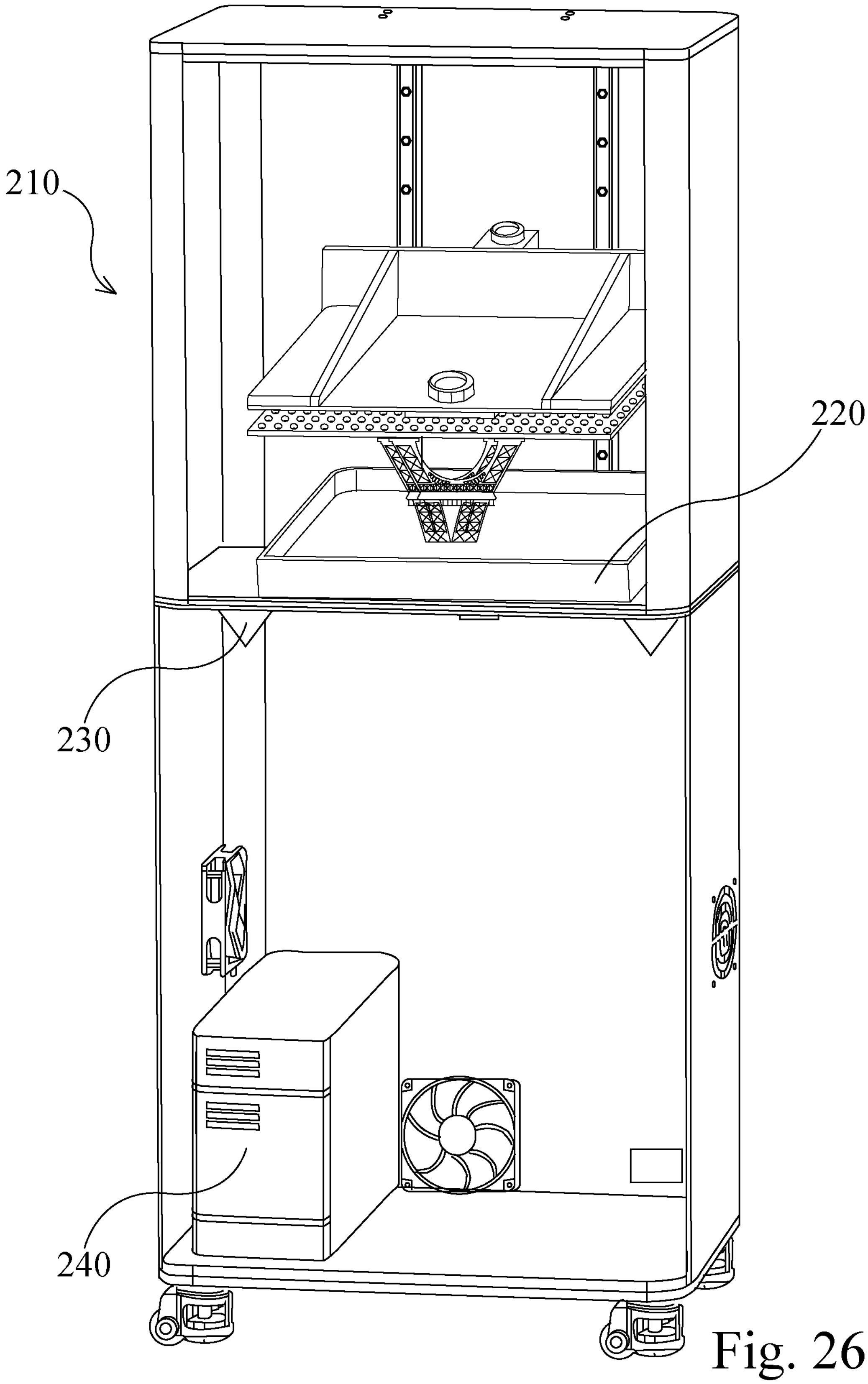


Fig. 26

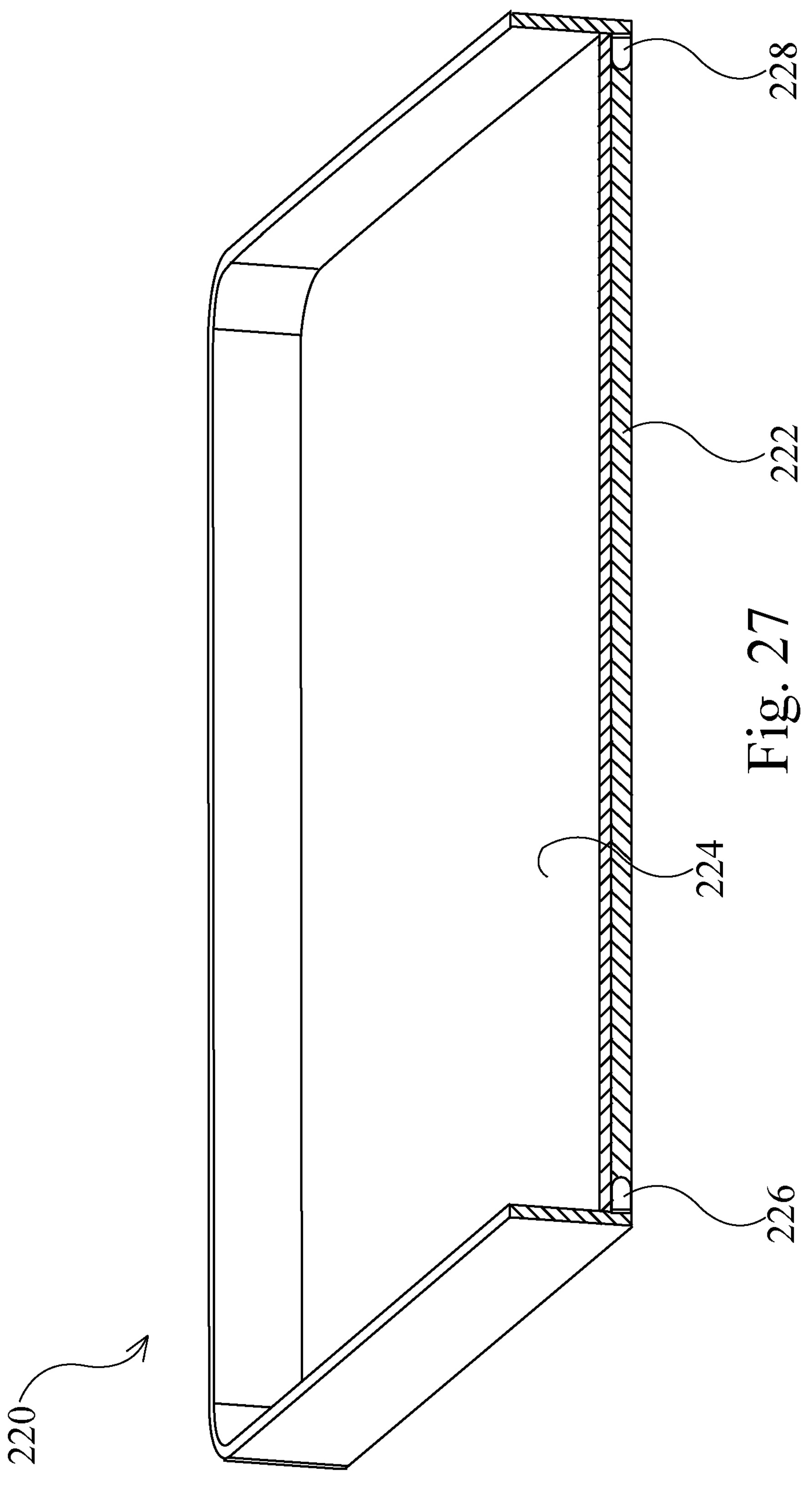


Fig. 27

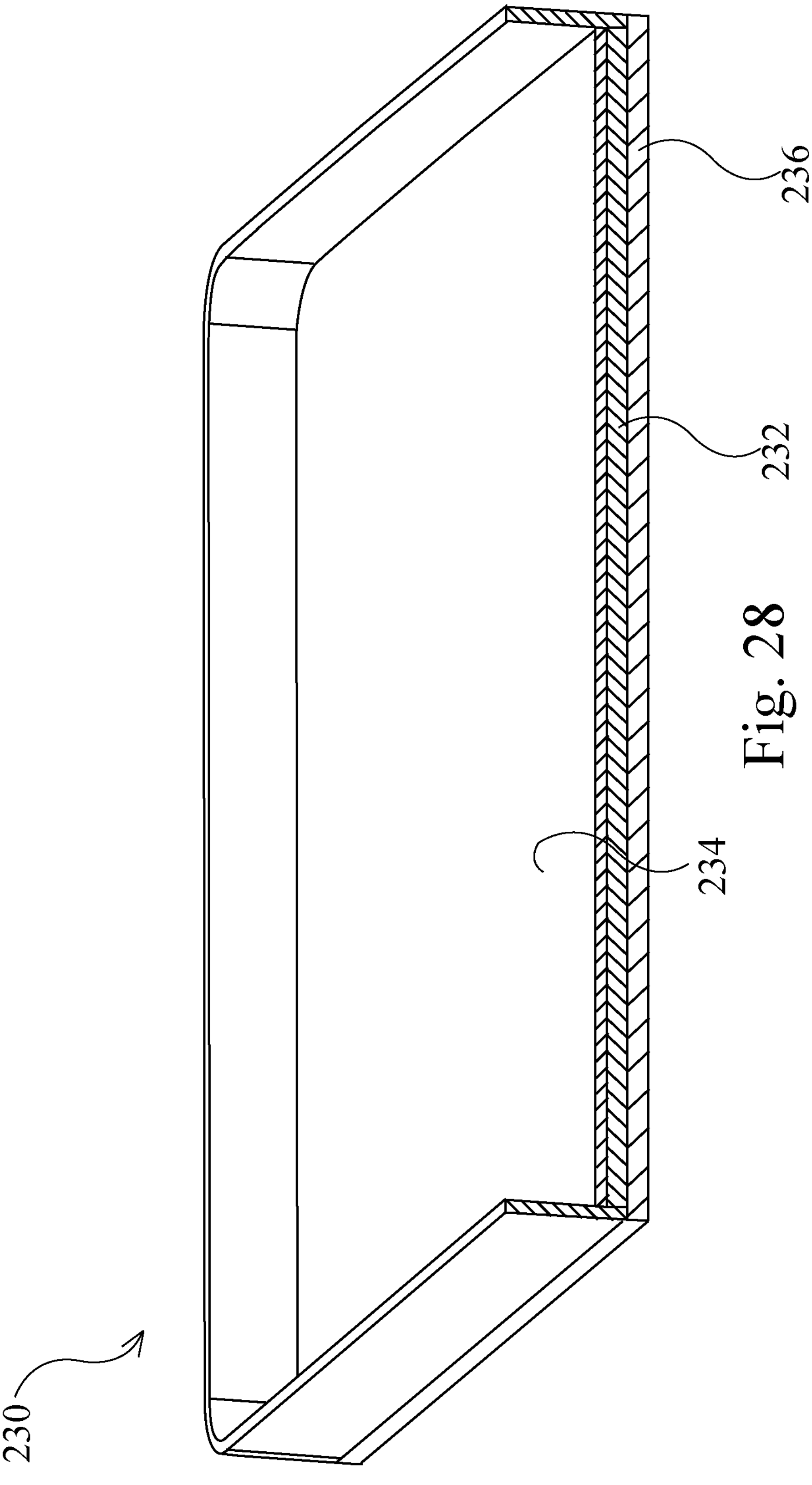
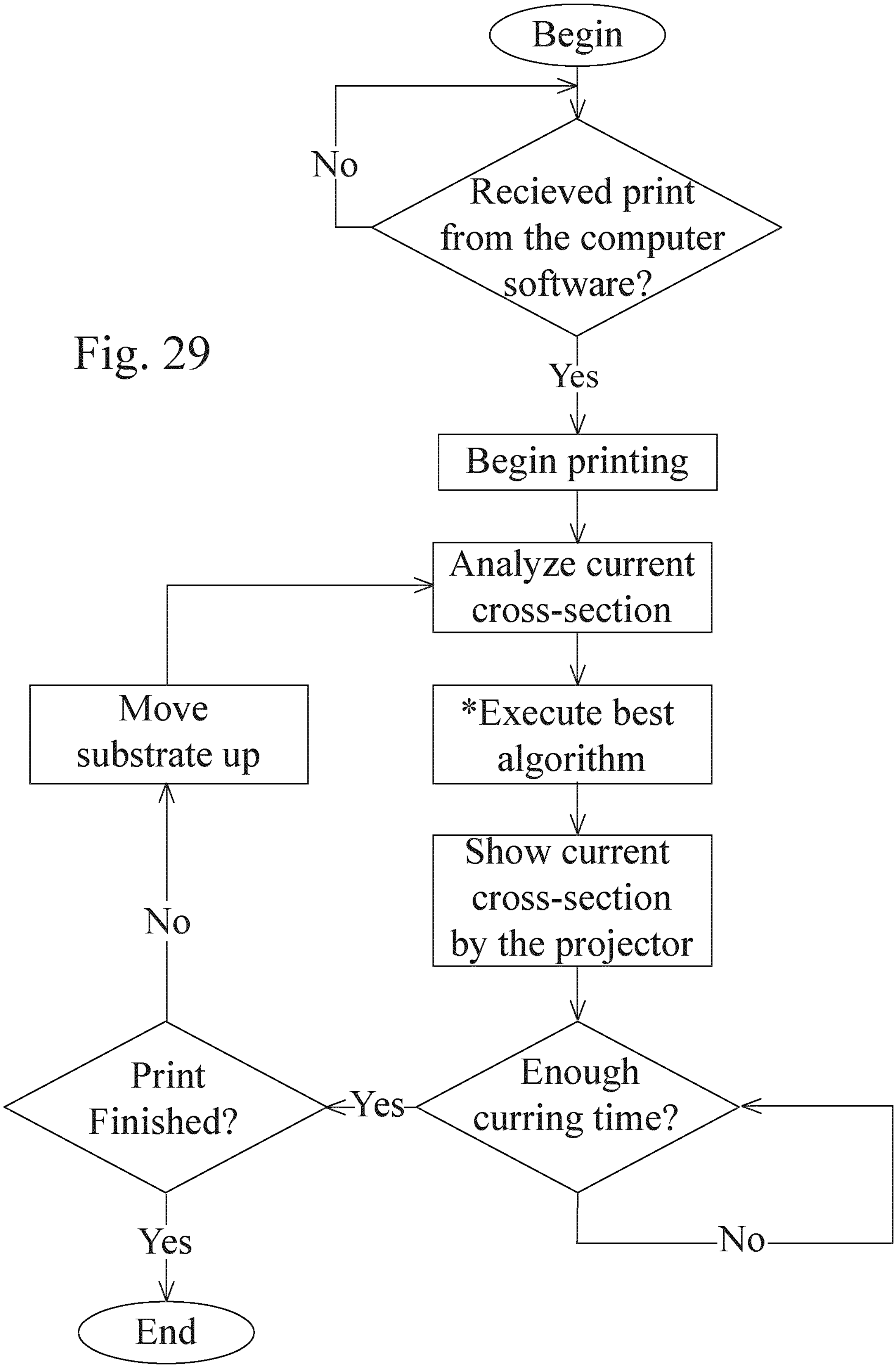


Fig. 28

Fig. 29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Analyze current cross-section
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Show current cross-section by the projector
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Enough curring time?
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Yes
Print Finished?
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INTERNATIONAL SEARCH REPORT

International application No.
PCT/CA2016/050299

A. CLASSIFICATION OF SUBJECT MATTER
IPC: ***G03F 7/00*** (2006.01) , ***B33Y 30/00*** (2015.01) , ***B82Y 30/00*** (2011.01)

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)
IPC: ***G03F 7/00*** (2006.01) , ***B33Y 30/00*** (2015.01) , ***B82Y 30/00*** (2011.01)

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

Electronic database(s) consulted during the international search (name of database(s) and, where practicable, search terms used)
Canadian Patent Database, QUESTEL-ORBIT (Keywords: stereolithography, transparent, lithograph*, optical*, apparatus, optical+, lithograph+)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CA 2 898 098 A1 (DeSimone et al.) 21 August 2014 (21-08-2014) *whole document*	1-36
X	CA 2 898 103 A1 (DeSimone et al.) 21 August 2014 (21-08-2014) *whole document*	1-36
X	CA 2 898 106 A1 (DeSimone et al.) 21 August 2014 (21-08-2014) *whole document*	1-36

☐ Further documents are listed in the continuation of Box C. ☑ See patent family annex.

* Special categories of cited documents:
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"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
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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"&" document member of the same patent family

Date of the actual completion of the international search
20 May 2016 (20-05-2016)

Date of mailing of the international search report
09 June 2016 (09-06-2016)

Name and mailing address of the ISA/CA
Canadian Intellectual Property Office
Place du Portage I, C114 - 1st Floor, Box PCT
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Gatineau, Quebec K1A 0C9
Facsimile No.: 819-953-2476

Authorized officer
Malcolm Downey (819) 934-2329

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