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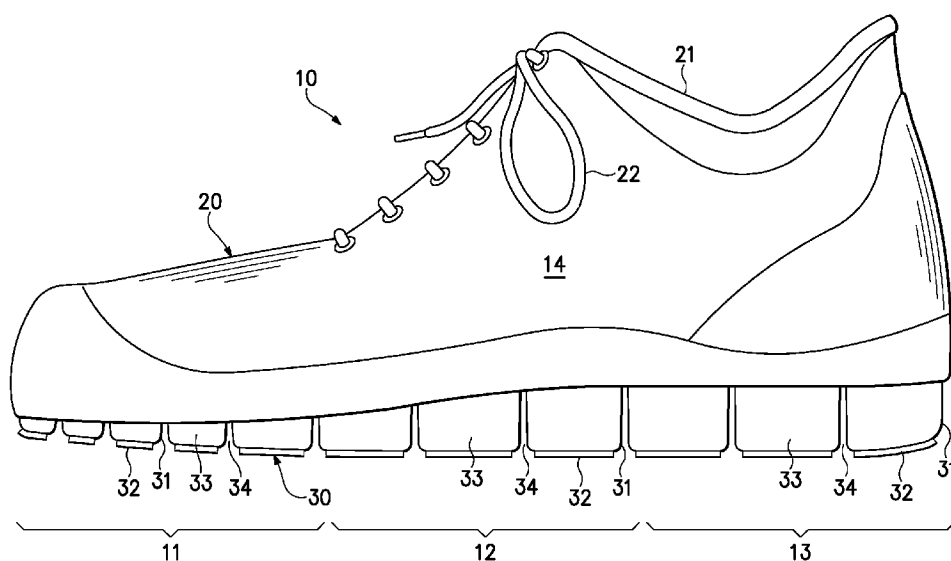


Figure 1

(57) Abstract: An article of footwear may have an upper and a sole structure secured to the upper. The sole structure has a plurality of support elements, and each of the support elements include a shell and a core. The shell defines an interior void and is formed from a polymer material that extends around substantially all of the void. The core has a shape of the void and is located within the void, with at least a portion of the core being a polymer foam material. The polymer foam material of at least two of the support elements may have different densities.

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AN ARTICLE OF FOOTWEAR INCORPORATING FOAM-FILLED ELEMENTS
AND METHODS FOR MANUFACTURING THE FOAM-FILLED ELEMENTS

BACKGROUND

- [01]** Conventional articles of athletic footwear include two primary elements, an upper and a sole structure. The upper provides a covering for the foot that comfortably receives and securely positions the foot with respect to the sole structure. The sole structure is secured to a lower portion of the upper and is generally positioned between the foot and the ground. In addition to attenuating ground reaction forces, the sole structure may provide traction, control foot motions (e.g., by resisting pronation), and impart stability, for example. Accordingly, the upper and the sole structure operate cooperatively to provide a comfortable structure that is suited for a wide variety of athletic activities.
- [02]** The sole structure generally incorporates multiple layers that are conventionally referred to as an insole, a midsole, and an outsole. The insole is a thin, compressible member located within the upper and adjacent to a plantar (i.e., lower) surface of the foot to enhance footwear comfort. The midsole is conventionally secured to a lower surface of the upper and forms a middle layer of the sole structure that is primarily responsible for attenuating ground reaction forces. The outsole forms the ground-contacting element of footwear and is usually fashioned from a durable, wear-resistant material that includes texturing to improve traction.
- [03]** The conventional midsole is primarily formed from a resilient, polymer foam material, such as polyurethane or ethylvinylacetate, that extends throughout the length of the footwear. The properties of the polymer foam material in the

midsole are primarily dependent upon factors that include the dimensional configuration of the midsole and the specific characteristics of the material selected for the polymer foam, including the density of the polymer foam material. By varying these factors throughout the midsole, the relative stiffness and degree of ground reaction force attenuation may be altered to meet the specific demands of the wearer or of the activity for which the footwear is intended to be used.

- [04]** In addition to polymer foam materials, conventional midsoles may include, for example, one or more fluid-filled chambers. In general, the fluid-filled chambers are formed from an elastomeric polymer material that is sealed and pressurized. The chambers are then encapsulated in the polymer foam of the midsole such that the combination of the chamber and the encapsulating polymer foam functions as the midsole of the sole structure. In some configurations, textile or foam tensile members may be located within the chamber or reinforcing structures may be bonded to an exterior or interior of the chamber to impart shape to the chamber.

SUMMARY

- [05]** One aspect relates to an article of footwear having an upper and a sole structure secured to the upper. The sole structure has a plurality of support elements, and each of the support elements include a shell and a core. The shell defines an interior void and is formed from a polymer material that extends around substantially all of the void. The core has a shape of the void and is located within the void, with at least a portion of the core being a polymer foam material. The polymer foam material of at least two of the support elements may have different densities.

- [06]** Another aspect relates to a method of manufacturing a sole structure for an article of footwear. The method includes defining a plurality of depressions in a first polymer layer and partially filling the depressions with different volumes of a substantially unexpanded polymer foam material. The polymer foam material is then expanded to substantially fill the depressions, and a second polymer layer is secured to the first polymer layer to seal the polymer foam material within the depressions.
- [07]** The advantages and features of novelty characterizing various aspects of the invention are pointed out with particularity in the appended claims. To gain an improved understanding of the advantages and features of novelty, however, reference may be made to the following descriptive matter and accompanying drawings that describe and illustrate various embodiments and concepts related to the aspects of the invention.

DESCRIPTION OF THE DRAWINGS

- [08]** The foregoing Summary, as well as the following Detailed Description, will be better understood when read in conjunction with the accompanying drawings.
- [09]** Figure 1 is a lateral side elevational view of an article of footwear.
- [10]** Figure 2 is a medial side elevational view of the article of footwear.
- [11]** Figure 3 is a top plan view of a first sole component of the article of footwear.
- [12]** Figures 4A and 4B are cross-sectional views of the first sole component, as defined by section lines 4A and 4B in Figure 3.
- [13]** Figure 5 is a lateral side elevational view of the first sole component.

- [14]** Figure 6 is a medial side elevational view of the first sole component.
- [15]** Figure 7 is a bottom plan view of the first sole component.
- [16]** Figure 8 is a perspective view of a portion of the first sole component.
- [17]** Figure 9 is a cross-sectional view of the portion of the first sole component, as defined by section line 9 in Figure 8.
- [18]** Figure 10 is an exploded perspective view of the portion of the first sole component.
- [19]** Figures 11A-11F are schematic side elevational views of a manufacturing process for forming the portion of the first sole component.
- [20]** Figure 12 is a side elevational view of an apparatus that may be utilized in the manufacturing process.
- [21]** Figure 13 is an exploded perspective view of the apparatus.
- [22]** Figure 14 is an exploded cross-sectional view of the apparatus, as defined by section line 14-14 in Figure 13.
- [23]** Figures 15A-15F are cross-sectional views of the apparatus that correspond to Figure 14 and depict another manufacturing process for forming the portion of the first sole component.
- [24]** Figure 15G is a cross-sectional view of the portion of the first sole component, as manufactured by the process depicted in Figures 15A-15F.
- [25]** Figures 16A-16E are cross-sectional views that correspond with Figure 9 and depict alternate configurations of the portion of the first sole component.

- [26]** Figure 17 is a cross-sectional view corresponding with Figure 14 and depicting another configuration of the apparatus.
- [27]** Figure 18 is a perspective view of a second sole component.
- [28]** Figure 19 is a top plan view of the second sole component.
- [29]** Figures 20A-20C are cross-sectional views of the second sole component, as defined by section lines 20A-20C in Figure 19.
- [30]** Figure 21 is a side elevational view of the second sole component.
- [31]** Figure 22 is a bottom plan view of the second sole component.
- [32]** Figures 23A and 23B are perspective views of a bonding apparatus.
- [33]** Figures 24A-24C are side elevational views of the bonding apparatus and depict a portion of a manufacturing process for forming the second sole component.

DETAILED DESCRIPTION

- [34]** The following discussion and accompanying figures disclose a sole component for an article of footwear and methods for manufacturing the sole component. Concepts related to the sole component are disclosed with reference to footwear having a configuration that is suitable for running. The sole component is not limited solely to footwear designed for running, however, and may be utilized with a wide range of athletic footwear styles, including basketball shoes, tennis shoes, football shoes, cross-training shoes, walking shoes, soccer shoes, and hiking boots, for example. The sole component may also be utilized with footwear styles that are generally considered to be non-athletic, including dress shoes, loafers, sandals, and boots. An individual skilled in the relevant art will

appreciate, therefore, that the concepts disclosed herein apply to a wide variety of footwear styles, in addition to the specific style discussed in the following material and depicted in the accompanying figures. The concepts disclosed herein may also be applied to products other than footwear, including seat cushions, gloves, and padding for helmets and other protective devices, for example.

Footwear Configuration

- [35]** An article of footwear 10 is depicted in Figures 1 and 2 as including an upper 20 and a sole structure 30. For reference purposes, footwear 10 may be divided into three general regions: a forefoot region 11, a midfoot region 12, and a heel region 13. Footwear 10 also includes a lateral side 14 and an opposite medial side 15. Forefoot region 11 generally includes portions of footwear 10 corresponding with the toes and the joints connecting the metatarsals with the phalanges. Midfoot region 12 generally includes portions of footwear 10 corresponding with the arch area of the foot, and heel region 13 corresponds with rear portions of the foot, including the calcaneus bone. Lateral side 14 and medial side 15 extend through each of regions 11-13 and correspond with opposite sides of footwear 10. Regions 11-13 and sides 14-15 are not intended to demarcate precise areas of footwear 10. Rather, regions 11-13 and sides 14-15 are intended to represent general areas of footwear 10 to aid in the following discussion. In addition to footwear 10, regions 11-13 and sides 14-15 may also be applied to upper 20, sole structure 30, and individual elements of either of upper 20 and sole structure 30.
- [36]** Upper 20 is depicted as having a substantially conventional configuration incorporating a plurality material elements (e.g., textiles, foam, leather, and synthetic leather) that are stitched or adhesively bonded together to form an

interior void for securely and comfortably receiving a foot. An ankle opening 21 in heel region 13 provides access to the interior void. In addition, upper 20 may include a lace 22 that is utilized in a conventional manner to modify the dimensions of the interior void, thereby securing the foot within the interior void and facilitating entry and removal of the foot from the interior void. Lace 22 may extend through apertures in upper 20, and a tongue portion of upper 20 may extend between the interior void and lace 22. Given that various aspects of the present application primarily relate to sole structure 30, upper 20 may exhibit the general configuration discussed above or the general configuration of practically any other conventional or non-conventional upper. Accordingly, the structure of upper 20 that is utilized with sole structure 30 or variants thereof may vary significantly.

- [37]** Sole structure 30 is secured to upper 20 and has a configuration that extends between upper 20 and the ground. The primary elements of sole structure 30 are a sole component 31 and a plurality of outsole sections 32. Sole component 31, which is depicted individually depicted in Figures 3-7, is secured to upper 20 and extends through each of regions 11-13 and between sides 14 and 15. As discussed in greater detail below, sole component 31 includes a plurality of downwardly-extending support elements 33 that are separated by various flexion indentations 34. Support elements 33 form independent portions of sole structure 30 that compress to attenuate ground reaction forces, and flexion indentations 34 extend between support elements 33 to permit sole structure 30 to flex or otherwise bend during walking, running, and other ambulatory activities. Outsole sections 32, which may be absent in some configurations, are secured to a lower surface of each of support elements 33 and are formed from a durable, wear-resistant material (e.g., rubber) that may include texturing to improve traction.

Sole Component Configuration

- [38]** Sole component 31 includes an outer shell 40 and a compressible foam material 50 located within shell 40. An upper portion of shell 40, which is adjacent to upper 20, is formed from a first layer 41 of a polymer material, and a lower portion of shell 40 is formed from a second layer 42 of the polymer material. Whereas first layer 41 has a relatively planar configuration and forms an upper surface of the various support elements 33, second layer 42 is contoured to form sidewalls and a lower surface of support elements 33. That is, second layer 42 defines voids or depressions for receiving foam material 50. In addition, layers 41 and 42 are bonded or otherwise joined to each other to seal the various support elements 33 in upper portions of flexion indentations 34.
- [39]** The contours of second layer 42 define support elements 33 and the various flexion indentations 34 that extend between support elements 33. In general, support elements 33 are discrete portions of sole component 31 that extend downward from upper 20. The shape of each support element 33 is partially determined by the positions of the various flexion indentations 34. As depicted in Figure 7, three of flexion indentations 34 extend in a longitudinal direction along sole structure 30, and a majority of flexion indentations 34 extend in a generally lateral direction. This positioning of flexion indentations 34 forms a majority of support elements 33 to exhibit a generally square, rectangular, or trapezoidal shape. The rearmost support elements 33 have a quarter-circular shape due to the curvature of sole structure 30 in heel region 13. Although the number and positions of flexion indentations 34 may vary considerably, in some configurations sole structure 30 has at least one flexion indentation 34 extending in the longitudinal direction along sole structure 30, and at least two flexion indentations 34 extending in the lateral direction.

- [40] The shape of each support element 33, as discussed above, is partially determined by the positions of the various flexion indentations 34, which are spaces that extend upward into sole component 31. As depicted, flexion indentations 34 extend through a majority of the thickness of sole component 31 (i.e., almost entirely between the lower and upper surfaces). In some configurations, flexion indentations 34 may only extend through one-half of a distance between the lower and upper surfaces if both layers 41 and 42 are contoured to form flexion indentations 34 in this manner.
- [41] Flexion indentations 34 increase the flexibility of sole structure 30 by forming an articulated configuration in sole component 31. Whereas the conventional footwear midsole is a unitary element of polymer foam, flexion indentations 34 form flexion lines in sole component 31 and, therefore, have an effect upon the directions of flex in sole structure 30. Lateral flexibility of sole structure 30 (i.e., flexibility in a direction that extends between lateral side 14 and medial side 15) is provided by the three longitudinal flexion indentations 34. Whereas one of the longitudinal flexion indentations 34 extends longitudinally through an entire length of sole component 31 (i.e., through all three of regions 11-13), the other two longitudinal flexion indentations 34 extend only through about half of a length of sole component 31. Although each of the longitudinal flexion indentations 34 may have a straight or linear configuration, the longitudinal flexion indentations 34 are depicted as having a generally curved or s-shaped configuration. In forefoot region 11 and midfoot region 12, the longitudinal flexion indentation 34 extending through the entire length of sole component 31 is adjacent to and spaced inward from lateral side 14, but is centrally-located in heel region 13. In further configurations of sole structure 30, each of the longitudinal flexion indentations 34 may extend through the entire length of sole component 31, or

none of the longitudinal flexion indentations 34 may extend through the entire length of sole component 31.

[42] Longitudinal flexibility of sole structure 30 (i.e., flexibility in a direction that extends between regions 11 and 13) is provided by ten lateral flexion indentations 34. Referring to Figure 7, the lateral flexion indentations 34 are generally parallel to each other and extend in a medial-lateral direction (i.e., between sides 14 and 15). Although the lateral flexion indentations 34 have a generally parallel configuration and extend in the medial-lateral direction, the lateral flexion indentations 34 in forefoot region 11 are somewhat angled with respect to the lateral flexion indentations 34 in heel region 13. Although each of the lateral flexion indentations 34 are depicted as extending entirely across sole component 31, some or all of the lateral flexion indentations 34 may extend only partially across sole component 31 in some configurations.

[43] The positions and orientations of flexion indentations 34 are selected to complement the natural motion of the foot during the running cycle. In general, the motion of the foot during running proceeds as follows: Initially, the heel strikes the ground, followed by the ball of the foot. As the heel leaves the ground, the foot rolls forward so that the toes make contact, and finally the entire foot leaves the ground to begin another cycle. During the time that the foot is in contact with the ground, the foot typically rolls from the outside or lateral side to the inside or medial side, a process called pronation. That is, normally, the outside of the heel strikes first and the toes on the inside of the foot leave the ground last. The longitudinal flexion indentations 34 provide lateral flexibility in order to permit the foot to pronate naturally during the running cycle. The lateral flexion indentations 34 ensure that the foot remains in a neutral foot-strike position and complement the forward roll of the foot as it is in contact with the ground. Similarly, the angled configuration of the lateral flexion indentations 34,

as discussed above, provides additional flexibility that further enhances the natural motion of the foot.

[44] In addition to flexing that complements the natural motion of the foot, sole component 31 compresses to attenuate ground reaction forces (i.e., to provide cushioning for the foot). As discussed above, each of support elements 33 form independent elements of sole structure 30 that incorporate foam material 50. As sole structure 30 is compressed between the foot and the ground, foam material 50 compresses to impart cushioning to the foot. As the foot leaves the ground, the compressive forces upon support elements 33 are reduced and foam material 50 expands to its original, uncompressed configuration. During walking, running, and other ambulatory activities, therefore, support elements 33 compress to attenuate ground reaction forces experienced by the foot. Depending upon the configuration, sole component 31 may also impart stability or limit various foot motions, such as pronation.

[45] The degree to which support elements 33 compress at least partially depends upon the density of foam material 50, which forms a core of the various support elements 33. In general, as the density of foam material 50 increases, the compressibility of foam material 50 decreases. That is, greater forces are required to deflect foam material 50 as the density of foam material 50 increases. By varying the density of foam material 50 in different portions of sole component 31, the compressive forces generated by the foot during various portions of the running cycle may be accounted for. As an example, the foam material 50 located in heel region 13 may have a lesser density than the foam material 50 located in each of midfoot region 12 and forefoot region 11 to account for differences between forces experienced by the sole component 31 during heel strike and as the foot rolls forward. As another example, the foam material 50 located adjacent to lateral side 14 may have a greater density than the foam

material 50 located adjacent to medial side 15 in order to reduce the rate of pronation as the foot rolls toward lateral side 14. In other examples, multiple densities of foam material 50 may be utilized in different areas of sole component 31. Accordingly, the density of foam material 50 may vary throughout sole component 31 to attenuate ground reaction forces, control foot motions, and impart stability, for example.

- [46]** A variety of polymer materials may be utilized for shell 40. In selecting a material for shell 40, consideration may be given to the engineering properties of the material (e.g., tensile strength, stretch properties, fatigue characteristics, dynamic modulus, and loss tangent). When formed of thermoplastic urethane, for example, the walls of shell 40 may have a thickness of approximately 1.0 millimeter (0.040 inches), but the thickness may range from 0.25 millimeter (0.010 inches) to 3.0 millimeters (0.120 inches) or more, for example. In addition to thermoplastic urethane, a variety of other thermoplastic or thermoset polymer materials may be utilized for shell 40, including polyurethane, polyester, polyester polyurethane, and polyether polyurethane. Additionally, any of the materials disclosed in U.S. Patent Numbers 5,713,141 and 5,952,065 to Mitchell, et al.; U.S. Patent Numbers 6,013,340, 6,082,025, 6,127,026, 6,203,868, and 6,321,465 to Bonk, et al.; and U.S. Patent Numbers 4,183,156, 4,219,945, 4,936,029, and 5,042,176 to Rudy may be utilized for shell 40. As with shell 40, a variety of thermoplastic and thermoset polymer foam materials may be utilized for foam material 50, including polyurethane and ethylvinylacetate, for example. Accordingly, a variety of materials may be suitable for each of shell 40 and foam material 50.

Manufacturing Process

- [47]** For purposes of discussing a manufacturing process for sole component 31, a portion 35 of sole component 31 is identified in Figures 3 and 7 and also depicted individually (i.e., separate from a remainder of sole component 31) in Figures 8-10. Portion 35 includes two support elements 33, which are separately identified as support elements 33a and 33b for purposes of reference. A portion of one of flexion indentations 34 extends between support elements 33a and 33b. As with the remainder of sole component 31, layers 41 and 42 of shell 40 are shaped to define support elements 33a and 33b, and foam material 50 is located within support elements 33a and 33b. As discussed above, the density of foam material 50 may vary throughout sole component 31. Through the manufacturing process discussed below, support element 33a is formed to have greater compressibility than support element 33b. More particularly, portion 35 is formed such that foam material 50 within support element 33a exhibits lesser density than foam material 50 within support element 33b.
- [48]** With reference to Figure 11A, a foam source 60 is schematically-depicted as having a pair of outlet conduits 61a and 61b that are respectively positioned above depressions in second layer 42 that form support elements 33a and 33b. Outlet conduits 61a and 61b are depicted as having different widths, with outlet conduit 61a having a narrower configuration than outlet conduit 61b. Once second layer 42 is properly positioned below outlet conduits 61a and 61b, foam material 50 is simultaneously ejected from outlet conduits 61a and 61b and pours into or otherwise enters the depressions in second layer 42, as depicted in Figure 11B. Due to differences in the widths of outlet conduits 61a and 61b, the quantity of foam material 50 entering the depressions is different. That is, a greater volume of foam material 50 is expelled from outlet conduit 61b than outlet conduit 61a.

- [49] Once the depressions in second layer 42 are filled with a pre-determined amount of foam material 50, foam source 60 ceases the supply of foam material 50 and a permeable block 62 is placed above the depressions, as depicted in Figure 11C. When expelled from outlet conduits 61a and 61b, foam material 50 may be in a pre-foamed state that expands after entering the depressions in second layer 42. Foam material 50 may also be in a partially-foamed state that continues expanding after entering the depressions in second layer 42. That is, foam material 50 may include a reactive material that forms gas-filled voids within foam material 50 after entering the depressions in second layer 42. Permeable block 62 permits air within the depressions in second layer 42 and gas that is produced from the reaction within foam material 50 to escape the depressions in second layer 42, but effectively blocks foam material 50 from expanding above the depressions in second layer 42. Accordingly, foam material 50 expands to fill the depressions in second layer 42, as depicted in Figure 11D, but foam material 50 substantially remains within the depressions due to the presence of permeable block 62.
- [50] Following the expansion of foam material 50, permeable block 62 is removed and first layer 41 is located relative to second layer 42 and foam material 50, as depicted in Figure 11E. First layer 41 is then bonded to second layer 42, as depicted in Figure 11F, to effectively complete the manufacture of portion 35. In some configurations, first layer 41 may also be bonded to an upper surface of foam material 50. In order to bond first layer 41 to second layer 42, a bonding apparatus having the features of a bonding apparatus 160, which is discussed below, may be utilized. Although the manufacturing process discussed above is described with reference to portion 35, one skilled in the relevant art will appreciate that concepts associated with the manufacturing process of portion 35 may be applied to the entirety of sole component 31. That is, the general

process discussed above may be utilized to form the entirety of sole component 31.

[51] As discussed above, different quantities of foam material 50 entered the depressions in second layer 42 due to differences in outlet conduits 61a and 61b. The different quantities have an effect upon the resulting densities of foam material 50 within each of support elements 33a and 33b. More particularly, support element 33a received a lesser quantity of foam material than support element 33b, and the density of foam material 50 within support element 33a is less than the density of foam material 50 within support element 33b. By varying the supply of foam material 50, therefore, the density within the support elements 33a and 33b also varies. Although physical differences (e.g., width, diameter, etc.) in outlet conduits 61a and 61b may be utilized to affect the relative quantities of foam material 50 entering the depressions in second layer 42, shut-off valves and other techniques may be utilized to provide each of the depressions with different quantities of foam material 50.

[52] Given that the volumes of support elements 33a and 33b are substantially similar, the different quantities of foam material 50 resulted in different densities. In configurations where support elements 33a and 33b have different volumes, the different quantities of foam material 50 may result in substantially similar densities. Referring to sole component 31, for example, many of the various support elements 33 are depicted as having different sizes. The various quantities of foam material 50 that are located within each of support elements 33 may result, therefore, in different densities, substantially similar densities, or a variety of density configurations. Accordingly, the physical differences (e.g., width, diameter, etc.) in outlet conduits 61a and 61b may be utilized to affect the relative quantities of foam material 50 entering the depressions in second layer

42, thereby resulting in the particular densities that are desired for different footwear styles.

- [53]** Permeable block 62 permits gas that is produced from the reaction within foam material 50 to escape the depressions in second layer 42, but effectively blocks foam material 50 from expanding above the depressions in second layer 42. An example of a material that may be utilized for permeable block 62 is a cellular structure metal material. As known in the art, a cellular structure metal material is primarily formed from a metal base member that includes various voids (e.g., cells or pores) formed therein. Like a polymer foam, which includes a base polymer with various cells or pores, a cellular structure metal material defines the various voids, which form fluid-filled (e.g., air, gas, liquid) cells that reduce the overall density of the cellular structure metal material in comparison with the base metal. Accordingly, the cellular structure metal material may also be referred to as a cellular foam or a cellular metal foam.
- [54]** The cellular structure metal material forming permeable block 62 may have a density that ranges between two percent and ninety-eight percent of the density of the base metal without the cellular structure. In comparison with a non-cellular metal, therefore, the density of the cellular structure metal material may be two percent, ten percent, twenty-five percent, fifty percent, seventy-five percent, or ninety-five percent, for example, of the density of the same metal material without a cellular structure. Despite the reduced amount of structural material due to the presence of voids, the resulting material of the cellular structure metal material maintains sufficient physical properties, such as strength, rigidity, and deformation resistance, for use in a mold for sole component 31.
- [55]** The cellular structure metal material forming permeable block 62 may have an open cellular structure. In the open cellular structure, voids may interconnect or

otherwise be in fluid communication. As an example, air may pass through the cellular structure metal material due to the interconnecting voids, thereby giving the cellular structure metal material a porous or air-permeable property. The voids may be generally formed throughout the three dimensional structure of permeable block 62. In addition, the porous structure of permeable block 62 is selected such that foam material 50 does not plug or otherwise disrupt the flow of air or other gasses that are passing through permeable block 62.

- [56]** While any desired type of metal or other material may be used for the cellular structure metal material, more specific examples of suitable metal materials include aluminum, titanium, nickel, copper, zinc, carbon, zirconium, tungsten, lead, molybdenum, and/or combinations and alloys thereof (such as nickel-aluminum alloys, pewter, brass, etc.). Also, any desired method of making the cellular structure material may be used without departing from the invention, including conventional ways that are known and used by commercial vendors of cellular structure metal materials, such as: ALM (Applied Lightweight Materials) GmbH of Saarbrücken, Germany; Alulight International GmbH of Ranshofen, Austria; Cymat Corporation of Mississauga, Ontario, Canada; ERG Materials and Aerospace Corporation of Oakland, California; Foamtech Co., Ltd. of Seoul, Korea; FiberNide Ltd. of Ontario, Canada; Gleich GmbH of Kaltenkirchen, Germany; Hütte Klein-Reichenbach Ges.m.b.H of Schwarzenau, Austria; Inco Ltd. of Toronto, Ontario, Canada; Korea Metalfoam of Choenan, Korea; Mitsubishi Materials Corporation of Okegawa-shi, Japan; M-Pore GmbH of Dresden, Germany; Porvair Advanced Materials of Hendersonville, NC; Recemat International B.V. of the Netherlands; Reade Advanced Materials of Providence, RI; Spectra-Mat, Inc. of Watsonville, CA; SAS Solea of Boussens, France; and Ultramet Corporation of Pacoima, CA. In addition, the various materials and methods of making them are described in U.S. Patent Numbers 6,932,146;

6,866,084; 6,840,301, 6,706,239; 6,592,787; 5,951,791; 5,700,363; and 4,957,543.

Manufacturing Apparatus

- [57]** Foam source 60 provides differing quantities of foam material 50 to each of support elements 33a and 33b. An alternative to foam source 60 is depicted in Figures 12-14 as a mold 70. The primary elements of mold 70 are an upper mold portion 71 and a lower mold portion 72. Upper mold portion 71 includes a depression 73, a pair of outlet conduits 74a and 74b, a sealing lid 75, and a permeable block 76. Lower mold portion 72 includes a pair of cavities 77 that are shaped to correspond with and receive the various depressions in second layer 42.
- [58]** In operation, upper mold portion 71 and lower mold portion 72 are separated so that second layer 42 may be located therebetween, as depicted in Figure 15A. In addition, sealing lid 75 is removed from a location within depression 73 and outlet conduits 74a and 74b. Once second layer 42 is properly positioned, mold portions 71 and 72 close and a pre-measured quantity of foam material 50 is poured into depression 73, as depicted in Figure 15B. Foam material 50 then flows due to gravitational forces through outlet conduits 74a and 74b to enter the depressions within second layer 42, as depicted in Figure 15C. In a manner that is similar to outlet conduits 61a and 61b, outlet conduits 74a and 74b are depicted as having different diameters, with outlet conduit 74a having a lesser diameter than outlet conduit 74b. Due to differences in the diameters of outlet conduits 74a and 74b, the quantity of foam material 50 passing through outlet conduits 74a and 74b and entering the depressions in second layer 42 is different. That is, a greater volume of foam material 50 is expelled from outlet conduit 74b than outlet conduit 74a.

- [59]** When substantially all of foam material 50 has flowed through outlet conduits 74a and 74b and into the depressions in second layer 42, sealing lid 75 is placed within depression 73 such that protrusions on sealing lid 75 extend into outlet conduits 74a and 74b, as depicted in Figure 15D, and are flush with a lower surface of permeable block 76. When poured into depression 73, foam material 50 may be in a pre-foamed state that expands after entering the depressions in second layer 42. That is, foam material 50 may include a reactive material that forms gas-filled voids within foam material 50 after entering the depressions in second layer 42. Sealing lid 75 prevents foam material 50 from expanding upward and into outlet conduits 74a and 74b, and permeable block 76 permits gas that is produced from the reaction within foam material 50 to escape the depressions in second layer 42, but effectively blocks foam material 50 from expanding above the depressions in second layer 42. Accordingly, foam material 50 expands to fill the depressions in second layer 42, as depicted in Figure 15E, but remains within the depressions due to the presence of sealing lid 75 and permeable block 76. As with permeable block 62, permeable block 76 may be formed from a cellular structure metal material. Although not depicted, various channels or conduits may extend through upper mold portion 71 to expel the air or gas that passes through permeable block 76.
- [60]** Following the expansion of foam material 50, second layer 42 and foam material 50 are removed from mold 70 and then first layer 41 is located relative to second layer 42 and foam material 50, as depicted in Figure 15F. Alternately, second layer 42 and foam material 50 may remain within lower mold portion 72. First layer 41 is then bonded to second layer 42, as depicted in Figure 15G, to effectively complete the manufacture of portion 35. In some configurations, first layer 41 may also be bonded to an upper surface of foam material 50 when compatible materials are utilized. In order to bond first layer 41 to second layer

42, a bonding apparatus having the features of a bonding apparatus 160, which is discussed below, may be utilized. Although the manufacturing process discussed above with mold 70 is described with reference to portion 35, one skilled in the relevant art will appreciate that concepts associated with the manufacturing process of portion 35 may be applied to the entirety of sole component 31. That is, the general process discussed above may be utilized to form the entirety of sole component 31. In further processes, different foam materials may be located within each of support elements 33a and 33b, or foam material 50 may be poured or otherwise located within support elements 33a and 33b at different times, rather than simultaneously.

- [61]** As discussed above, different quantities of foam material 50 entered the depressions in second layer 42 due to differences in outlet conduits 74a and 74b. The different quantities have an effect upon the resulting densities of foam material 50 within each of support elements 33a and 33b. More particularly, support element 33a received a lesser quantity of foam material than support element 33b, and the density of foam material 50 within support element 33a is less than the density of foam material 50 within support element 33b. By varying the supply of foam material 50, therefore, the density within the support elements 33a and 33b also varies.

Further Configurations

- [62]** In each of the configurations discussed above, foam material 50 entirely fills the various support elements 33. With reference to Figures 16A-16C, cross-sectional views of portion 35 depict configurations wherein fluid-filled or air-filled cavities 51 are formed in foam material 50. More particularly, Figure 16A depicts a configuration wherein foam material 50 forms trapezoidal-shaped cavities 51, and Figure 16B depicts a configuration wherein foam material 50 forms rounded

or generally semicircular-shaped cavities 51. In contrast with Figure 16A, cavities 51 in Figure 16B exhibit different sizes. As with the technique of pouring different quantities of foam material 50 into support elements 33a and 33b, forming cavities 51 to have different sizes also has an effect upon the relative compressibilities of support elements 33a and 33b. As depicted in Figure 16C, cavities 51 may also be fluid gaps between an upper surface of foam material 50 and first layer 41. Although cavities 51 are depicted as being adjacent to shell 40, cavities 51 may be located in a center of foam material 50 in some configurations of sole component 31. In addition, the gas within cavities 51 may be pressurized or unpressurized relative to the exterior of footwear 10.

[63] In manufacturing portion 35 to include cavities 51, mold 70 may be modified to incorporate protrusions 78, as depicted in Figure 17. Protrusions 78 extend into the depressions in second layer 42 during the manufacturing process of portion 35. During expansion, foam material 50 extends around protrusions 78 to form cavities 51 with the shape of protrusions 78. Protrusions 78 are depicted as having a generally trapezoidal shape and form, therefore, the configuration of cavities 51 depicted in Figure 16A. In other configurations, protrusions 78 may have rounded configurations or any other configuration to form cavities 51 to exhibit other shapes. Protrusions 78 may be formed from a cellular structure metal material or a variety of other materials.

[64] In the various configurations discussed above, one of flexion indentations 34 is depicted as extending between support elements 33a and 33b. More particularly, a variety of flexion indentations 34 are depicted as extending between the various support elements 33. In further configurations, support elements 33a and 33b may be joined such that flexion indentation 34 is absent, as depicted in Figure 16D. In other configurations, support elements 33a and

33b may also be separate portions of sole structure 30, as depicted in Figure 16E.

- [65]** Sole component 31 is depicted as extending throughout a length and a width of footwear 10. In some configurations, a similar sole component may be limited to particular areas of sole structure 30. For example, a sole component may be located within only heel region 13 or forefoot region 11, for example. Alternately, a sole component may only be located adjacent lateral side 14. Accordingly, the manner in which sole component 31 or similar structures are utilized within an article of footwear may vary significantly.
- [66]** Referring to Figures 18-22, another sole component 131 is depicted as including outer shell 140 and a compressible foam material 150 located within shell 140. Whereas sole component 31 has a configuration that extends along substantially all of the length of footwear 10, sole component 131 has a configuration that may be primarily located in a heel region of an article of footwear. Foam elements or other sole elements may, therefore, form the midfoot and forefoot portions of a sole structure incorporating sole component 131.
- [67]** An upper portion of shell 140 is formed from a first layer 141 of a polymer material, and a lower portion of shell 140 is formed from a second layer 142 of the polymer material. Each of layers 141 and 142 exhibit a contoured configuration. More particularly, first layer 141 is contoured to form a central depression, and second layer 142 is contoured to define six support elements 133 and various flexion indentations 134 that extend between support elements 133. As with sole component 30, support elements 133 may be discrete portions of sole component 131 that extend downward from a footwear upper. In the configurations of portion 35 depicted in Figures 16A-16C, foam material 50 formed various cavities 51 that provided an air or gas space within support

elements 33a and 33b. Foam material 150 also defines various cavities 151 that define air or gas spaces within support elements 133.

- [68]** In order to form cavities 151, protrusions similar to protrusions 78 may be incorporated into a mold that pours foam material 150 into the depressions formed by second layer 142. Once the foam has expanded, the mold may be opened to such that second layer 142 and foam material 150 may be removed. A bonding apparatus 160, which is depicted in Figures 23A and 23B, may then be utilized to join first layer 141 to second layer 142 or to join first layer 141 to second layer 142 and an upper surface of foam material 150.
- [69]** Bonding apparatus 160 includes an upper bonding portion 161 and a lower bonding portion 162. Bonding portion 161 has a contoured area that corresponds with the shape of first layer 141. More particularly, upper bonding portion 161 has an area with a shape that corresponds with the shape of the upper surface of sole component 131. Similarly, lower bonding portion 162 has a contoured area that corresponds with the shape second layer 142. More particularly, lower bonding portion 162 has an area with a shape that corresponds with the shape of the lower surface of sole component 131 and extends into the various flexion indentations 134.
- [70]** In order to bond first layer 141 to second layer 142, first layer 141 and the combination of second layer 142 and foam material 150 are located between upper bonding portion 161 and lower bonding portion 162, as depicted in Figure 24A. Bonding portions 161 and 162 then translate toward each other to compress layers 141 and 142 together, as depicted in Figure 24B. At this point, heat or radio frequency (RF) energy may be utilized to elevate the temperature of layers 141 and 142, thereby bonding or otherwise securing the layers together.

Bonding portions 161 and 162 then separate to permit removal of the completed sole component 131.

[71] In contrast with many radio frequency welding apparatuses for footwear applications, bonding apparatus 160 has contoured interfaces. As discussed above, first layer 141 is contoured to form a central depression. The bond that joins layers 141 and 142 follows, therefore, the contours of the central depression. Similarly, the areas of bonding portions 161 and 162 that form the bonds between layers 141 and 142 are also contoured to form the non-planar bond.

[72] The invention is disclosed above and in the accompanying drawings with reference to a variety of embodiments. The purpose served by the disclosure, however, is to provide an example of the various features and concepts related to aspects of the invention, not to limit the scope of aspects of the invention. One skilled in the relevant art will recognize that numerous variations and modifications may be made to the embodiments described above without departing from the scope of the invention, as defined by the appended claims.

CLAIMS

That which is claimed is:

1. An article of footwear having an upper and a sole structure secured to the upper, the sole structure comprising a plurality of support elements, each of the support elements including:

a shell that defines an interior void, the shell being formed from a polymer material that extends around substantially all of the void; and

a core having a shape of at least a portion of the void and located within the void, at least a portion of the core being a polymer foam material,

the polymer foam material of at least two of the support elements having different densities.

2. The article of footwear recited in claim 1, wherein the polymer foam material of the core defines a cavity.

3. The article of footwear recited in claim 2, wherein at least a portion of the cavity is adjacent to the shell.

4. The article of footwear recited in claim 2, wherein air is located within the cavity.

5. The article of footwear recited in claim 1, wherein the shell is formed from a first sheet and a second sheet of the polymer material, the first sheet forming a first surface of the support elements, and the second sheet forming a second surface and a sidewall of the support elements, the first surface being opposite the second surface.

6. An article of footwear having an upper and a sole structure secured to the upper, the sole structure comprising a first support element and a second support element, each of the support elements including:

a shell that define an interior void; and

a polymer foam material having a shape of at least a portion of the void and located within the void,

the first support element being located adjacent to and spaced from the second support element to define a flexion indentation extending upwardly into the sole structure.

7. The article of footwear recited in claim 6, wherein the polymer foam material of the first support element is less compressible than the polymer foam material of the second support element.

8. The article of footwear recited in claim 7, wherein the first support element is located closer to a medial side of the footwear than the second support element.

9. The article of footwear recited in claim 6, wherein the polymer foam material of the first support element has a greater density than the polymer foam material of the second support element.

10. The article of footwear recited in claim 6, wherein the polymer foam material of the first support element defines a cavity.

11. The article of footwear recited in claim 10, wherein at least a portion of the cavity is adjacent to the shell.

12. The article of footwear recited in claim 10, wherein air is located within the cavity.

13. The article of footwear recited in claim 6, wherein the shell is formed from a first sheet and a second sheet of a polymer material, the first sheet forming a first surface of the first support element and the second support element, and the second sheet

forming a second surface and a sidewall of the first support element and the second support element, the first surface being opposite the second surface.

14. An article of footwear having an upper and a sole structure secured to the upper, the sole structure comprising a plurality of support elements with an upper surface and an opposite lower surface, the support elements being separated by a plurality of flexion indentations that extend upward from the lower surface and into the sole structure, the flexion indentations including:

a first flexion indentation that extends longitudinally through at least a portion of a length of the sole structure; and

at least two second flexion indentations that extend through substantially all of a width of the sole structure,

the support elements including a shell that define an interior void and a polymer foam material located within the void.

15. The article of footwear recited in claim 14, wherein the polymer foam material of at least two of the support elements have different densities.

16. The article of footwear recited in claim 14, wherein the polymer foam material of at least one of the support elements defines a cavity.

17. The article of footwear recited in claim 16, wherein at least a portion of the cavity is adjacent to the shell.

18. The article of footwear recited in claim 16, wherein air is located within the cavity.

19. The article of footwear recited in claim 14, wherein the shell is formed from a first sheet and a second sheet of polymer material, the first sheet forming the upper surface, and the second sheet forming the lower surface and a sidewall of the support elements.

20. An article of footwear having an upper and a sole structure secured to the upper, the sole structure comprising a plurality of support elements with an upper surface and an opposite lower surface, the support elements being separated by a plurality of flexion indentations that extend upward from the lower surface and into the sole structure, the flexion indentations including:

- a first flexion indentation that extends through substantially all of a length of the sole structure;

- a second flexion indentation that extends through a portion of a length of the sole structure and is located in at least a forefoot region of the sole structure;
- and

- at least two third flexion indentations that extend through substantially all of a width of the sole structure,

each of the support elements including:

- a shell that define an interior void, the shell being formed from a polymer material that extends around substantially all of the void; and

- a core having a shape of the void and located within the void, at least a portion of the core being a polymer foam material,

the polymer foam material of at least two of the support elements having different densities.

21. The article of footwear recited in claim 20, wherein a plurality of outsole elements are secured to at least a portion of the support elements to form a ground-contacting surface.

22. The article of footwear recited in claim 21, wherein the outsole elements are secured to the lower surfaces of the support elements.
23. The article of footwear recited in claim 20, wherein the polymer foam material of at least one of the support elements defines a cavity.
24. The article of footwear recited in claim 23, wherein at least a portion of the cavity is adjacent to the shell.
25. The article of footwear recited in claim 23, wherein air is located within the cavity.
26. The article of footwear recited in claim 20, wherein the shell is formed from a first sheet and a second sheet of polymer material, the first sheet forming the upper surface, and the second sheet forming the lower surface and a sidewall of the support elements.
27. A method of manufacturing polymer foam-filled elements, the method comprising steps of:
- providing a first void and a second void;
 - simultaneously expelling a foam material from a first outlet to fill at least a portion of the first void and a second outlet to fill at least a portion of the second void, the first outlet having a greater size than the second outlet; and
 - expanding the foam material such that a density of the foam material in the first void is greater than a density of the foam material in the second void.
28. The method recited in claim 27, wherein the step of providing includes defining the first void and the second void as depressions in a polymer layer.

29. The method recited in claim 28, wherein the step of providing further includes spacing the first void from the second void.

30. The method recited in claim 28, further including a step of sealing the first void and the second void with another polymer layer.

31. The method recited in claim 27, wherein the step of simultaneously expelling includes dispensing a greater volume of the foam material from the first outlet than the second outlet.

32. The method recited in claim 27, further including a step of incorporating the foam-filled elements into an article of footwear.

33. A method of manufacturing a sole structure for an article of footwear, the method comprising steps of:

defining a plurality of depressions in a first polymer layer;

locating different volumes of a polymer foam material within the depressions to partially fill the depressions;

expanding the polymer foam material to substantially fill the depressions; and

securing a second polymer layer to the first polymer layer to seal the polymer foam material within the depressions.

34. The method recited in claim 33, further including a step of forming spaces between the depressions.

35. The method recited in claim 33, wherein the method of expanding the polymer foam material includes utilizing a permeable block to substantially prevent the polymer foam material from expanding out of the depressions.

36. The method recited in claim 35, wherein the method of expanding the polymer foam material further includes selecting the permeable block to be a cellular structure metal material.

37. A method of manufacturing a sole structure for an article of footwear, the method comprising steps of:

shaping a first polymer layer to define a plurality of depressions and spaces located between the depressions, the depressions being arranged to have a shape of an outline of the sole structure, and the spaces having:

a first space that extends through substantially all of a length of the sole structure, and

at least two second spaces that extend through substantially all of a width of the sole structure,

partially filling the depressions with different volumes of a polymer foam material; expanding the polymer foam material to substantially fill the depressions, the polymer foam material having different densities in at least two of the depressions; and

securing a second polymer layer to the first polymer layer to seal the polymer foam material within the depressions.

38. The method recited in claim 37, further including a step of securing outsole elements to lower surfaces of at least a portion of the depressions.

39. The method recited in claim 37, wherein the method of expanding the polymer foam material includes utilizing a permeable block to substantially prevent the polymer foam material from expanding out of the depressions.

40. The method recited in claim 39, wherein the method of expanding the polymer foam material further includes selecting the permeable block to be a cellular structure metal material.

41. An article of footwear having an upper and a sole structure secured to the upper, the sole structure comprising a plurality of support elements, each of the support elements including:

a shell that defines an interior void, the shell being formed from a polymer material that extends around substantially all of the void; and

a core having a shape of at least a portion of the void and located within the void, at least a portion of the core being a polymer foam material,

the interior voids of at least two of the support elements having different volumes, and the cores within the interior voids of the at least two of the support elements having substantially similar densities.

42. The article of footwear recited in claim 41, wherein the polymer foam material of the core defines a cavity.

43. The article of footwear recited in claim 42, wherein at least a portion of the cavity is adjacent to the shell.

44. The article of footwear recited in claim 42, wherein air is located within the cavity.

45. The article of footwear recited in claim 41, wherein the shell is formed from a first sheet and a second sheet of the polymer material, the first sheet forming a first surface of the support elements, and the second sheet forming a second surface and a sidewall of the support elements, the first surface being opposite the second surface.

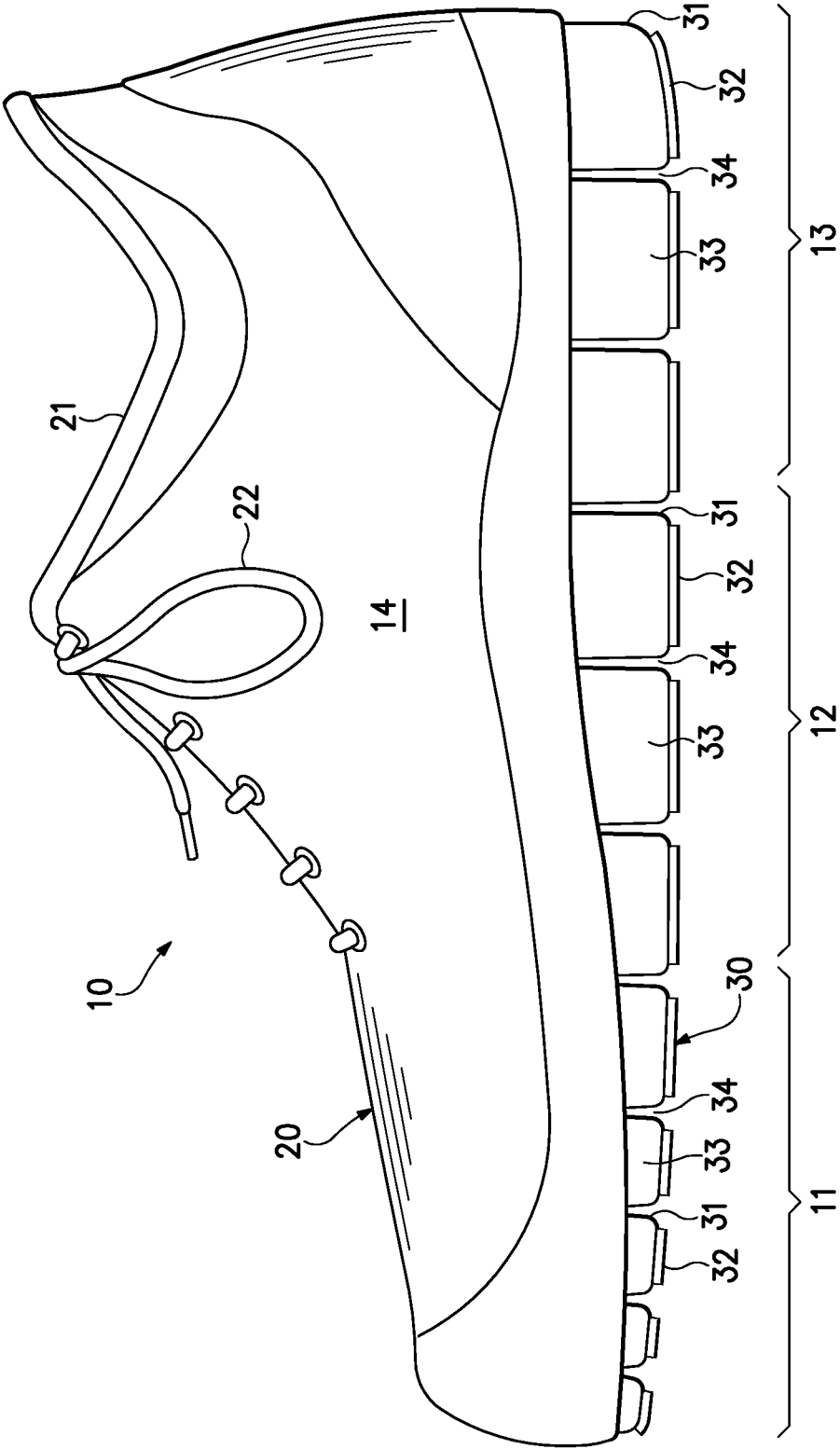


Figure 1

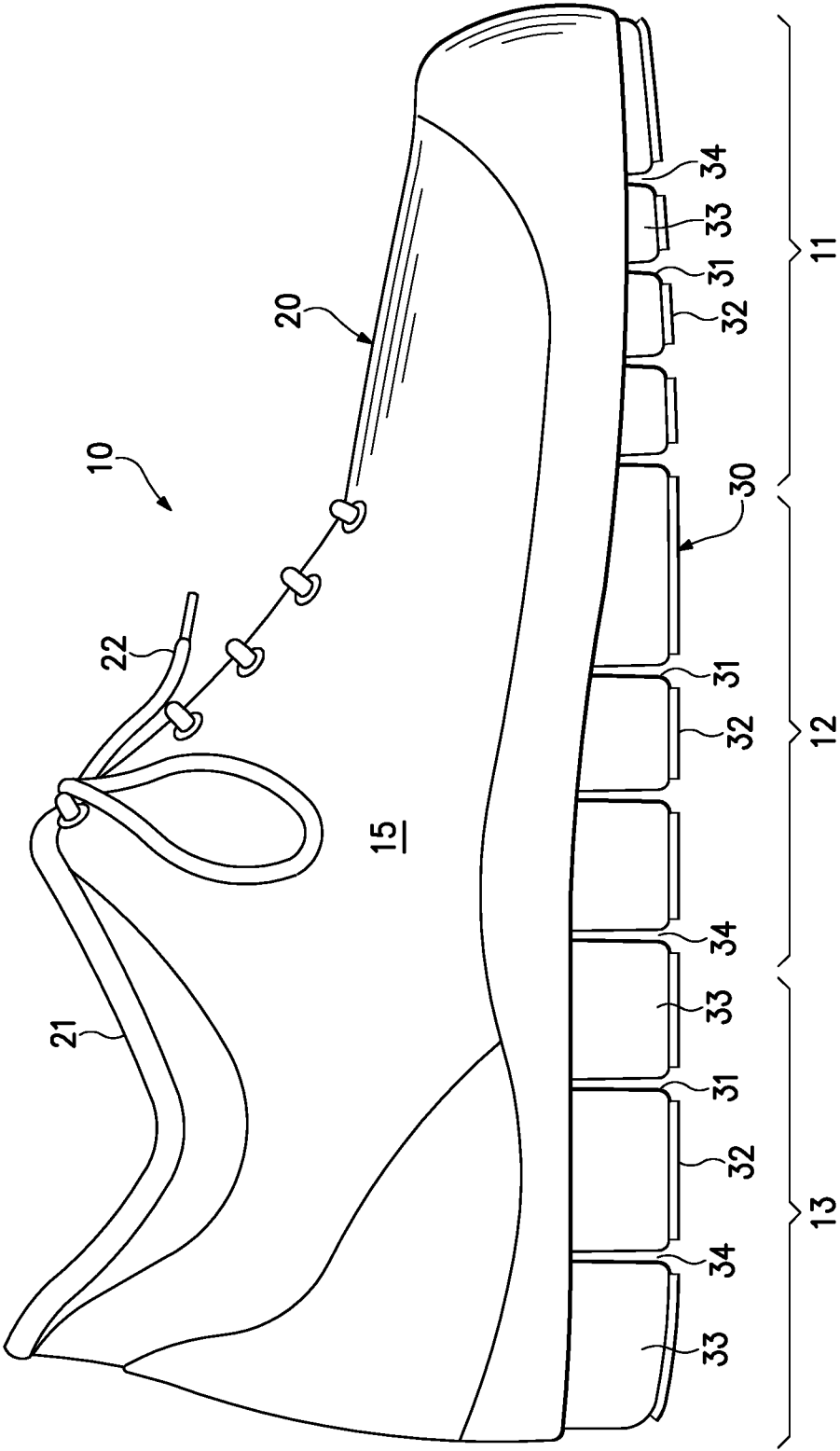


Figure 2

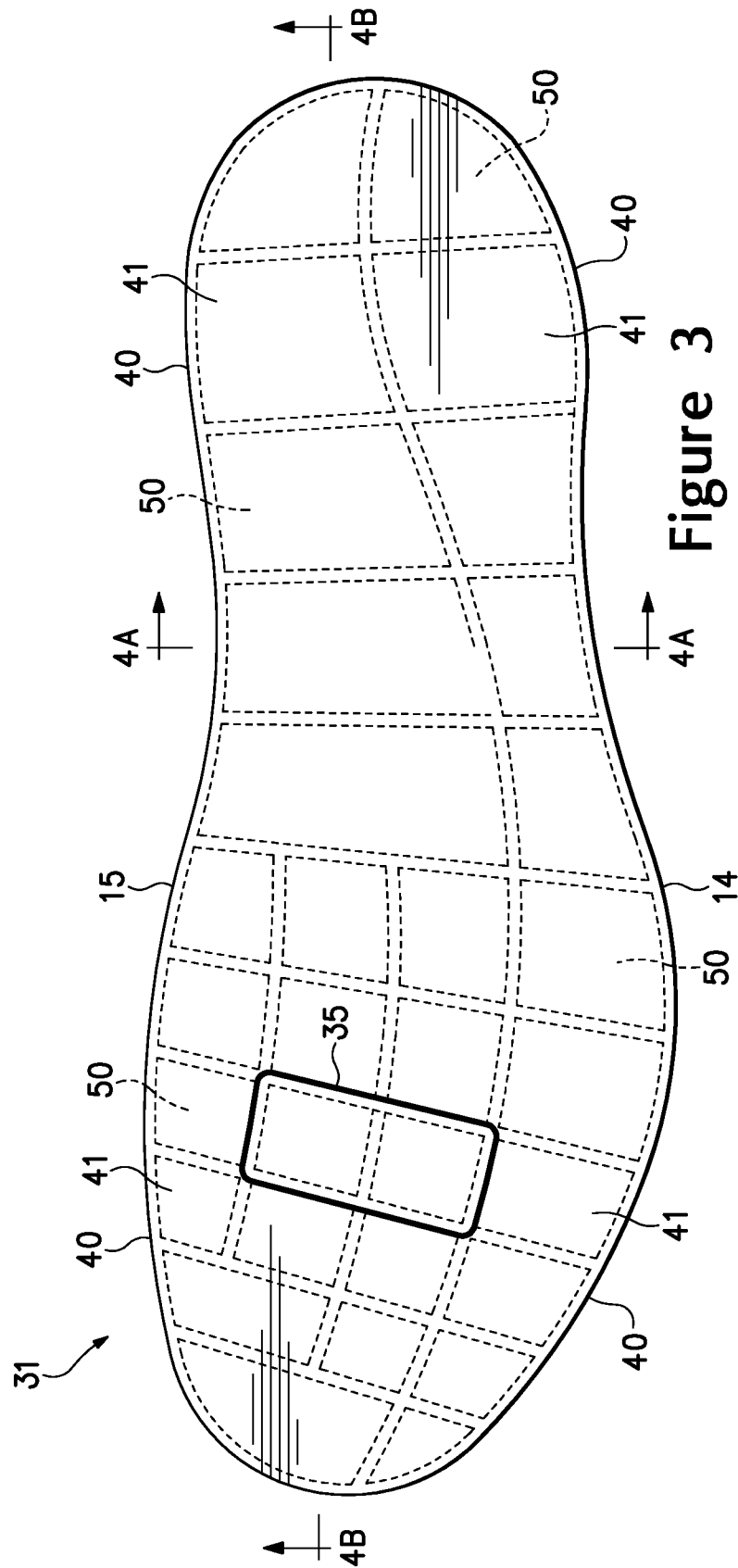


Figure 3

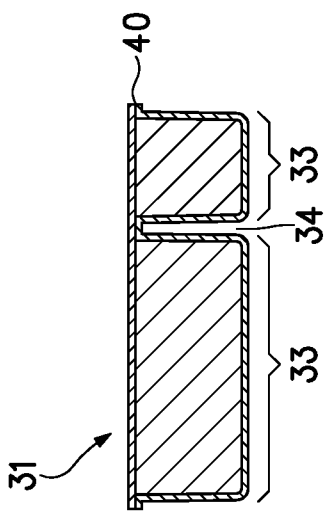


Figure 4A

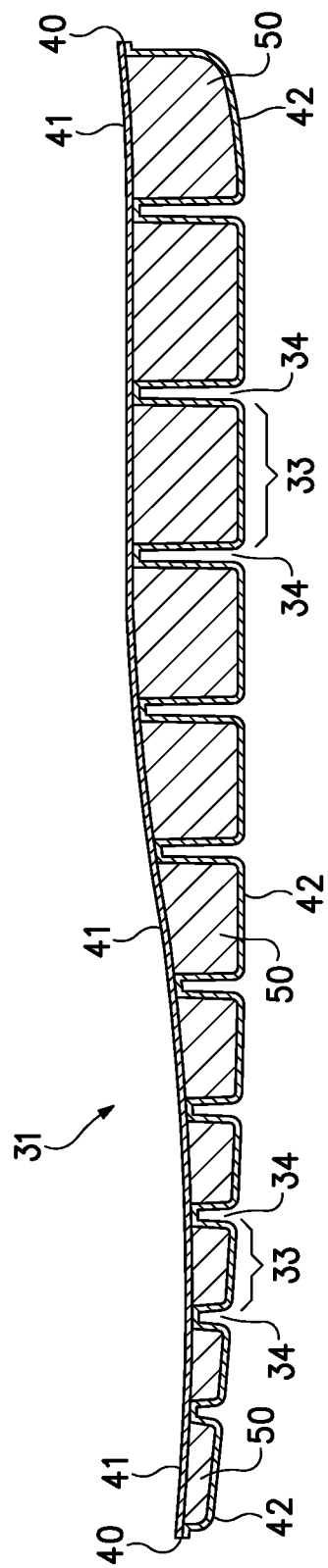
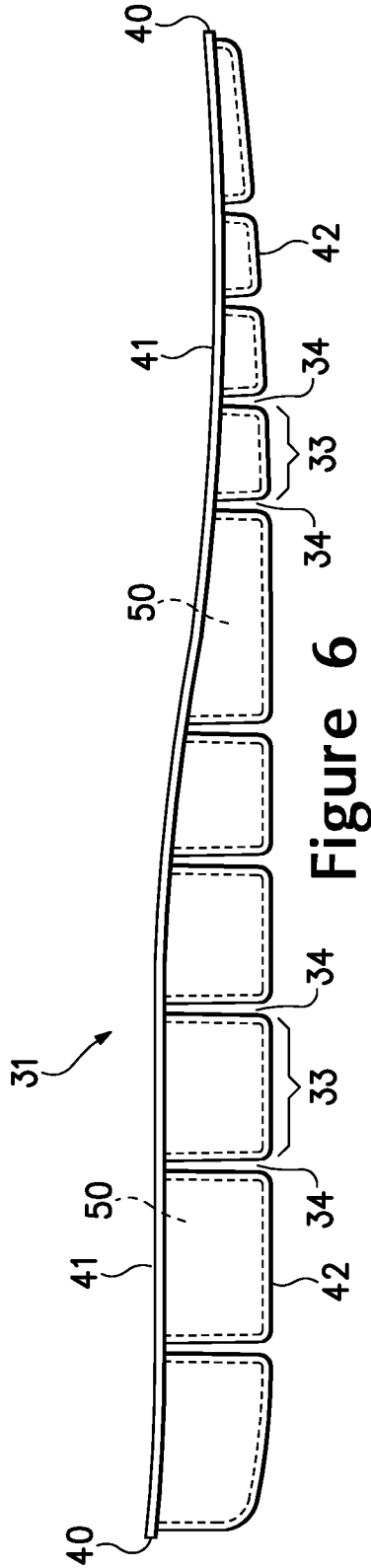
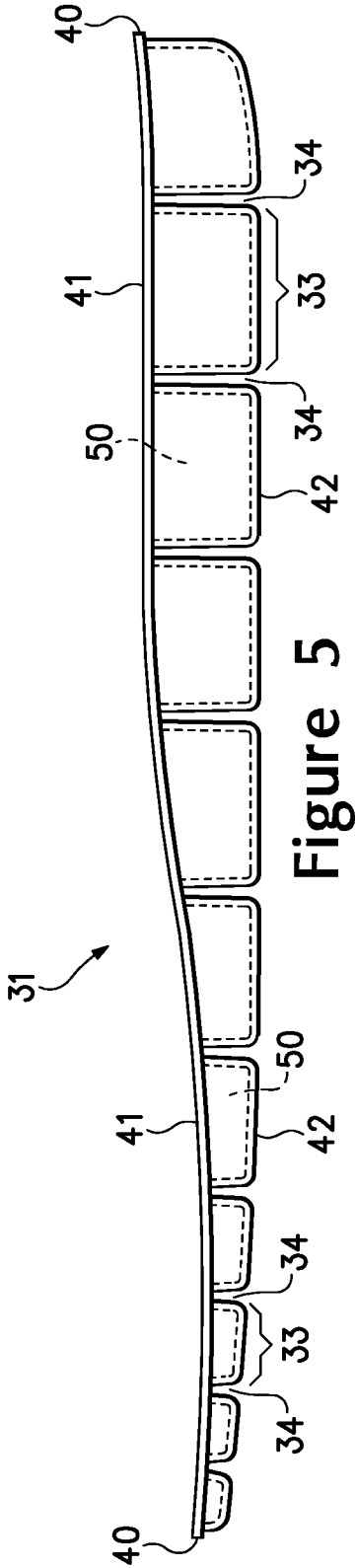
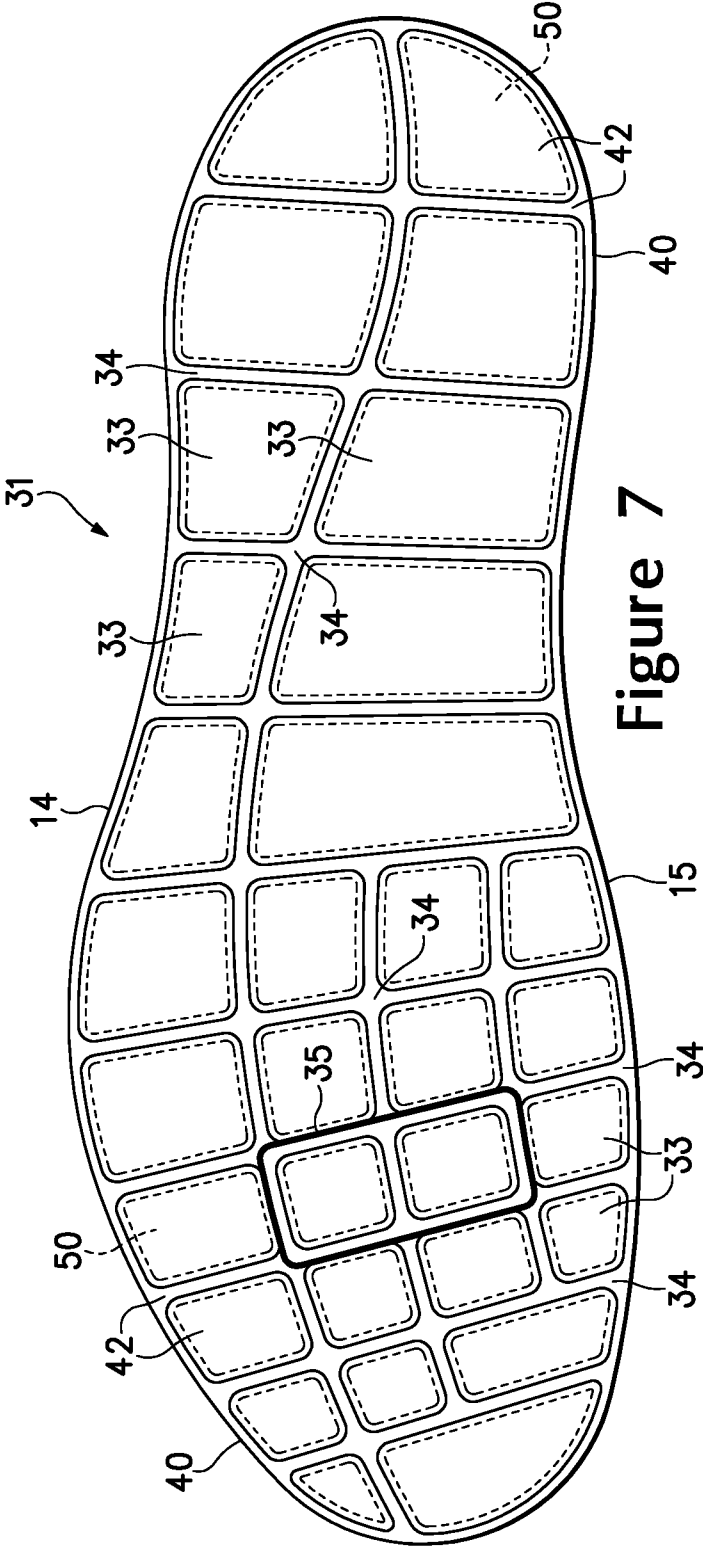
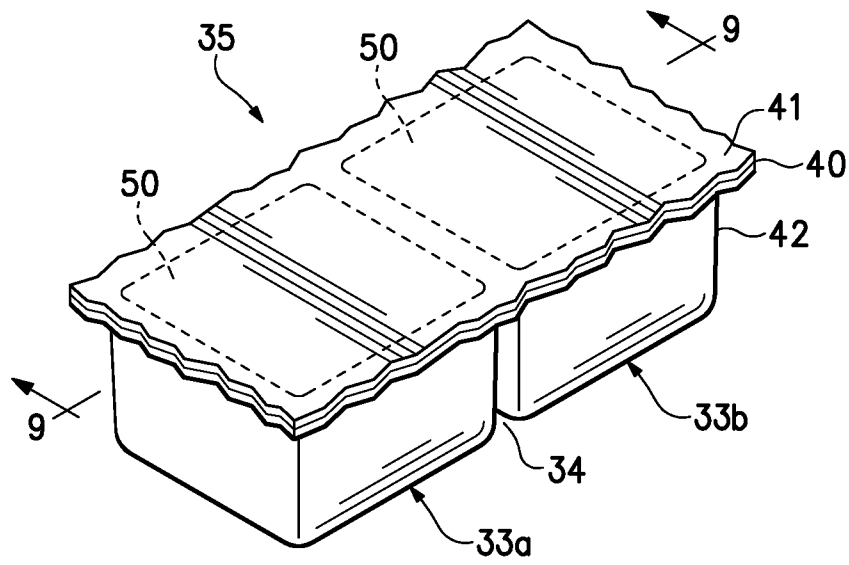
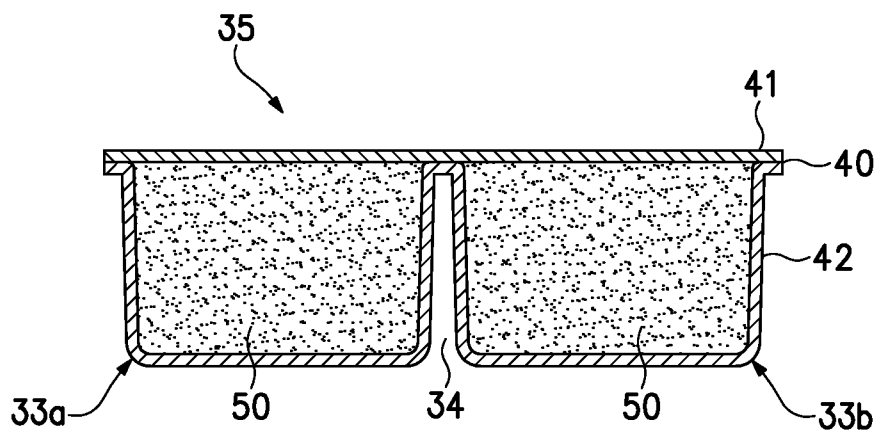


Figure 4B





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**Figure 8****Figure 9**

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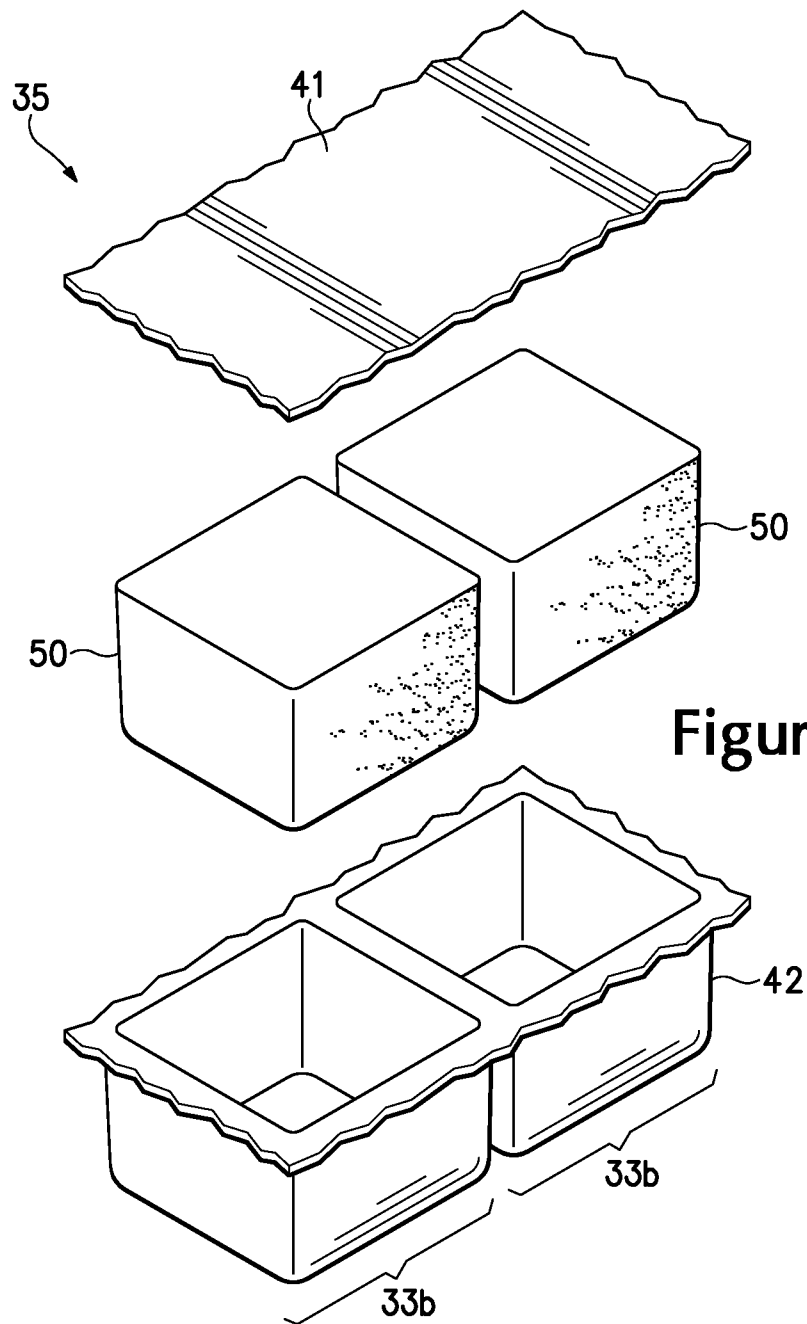
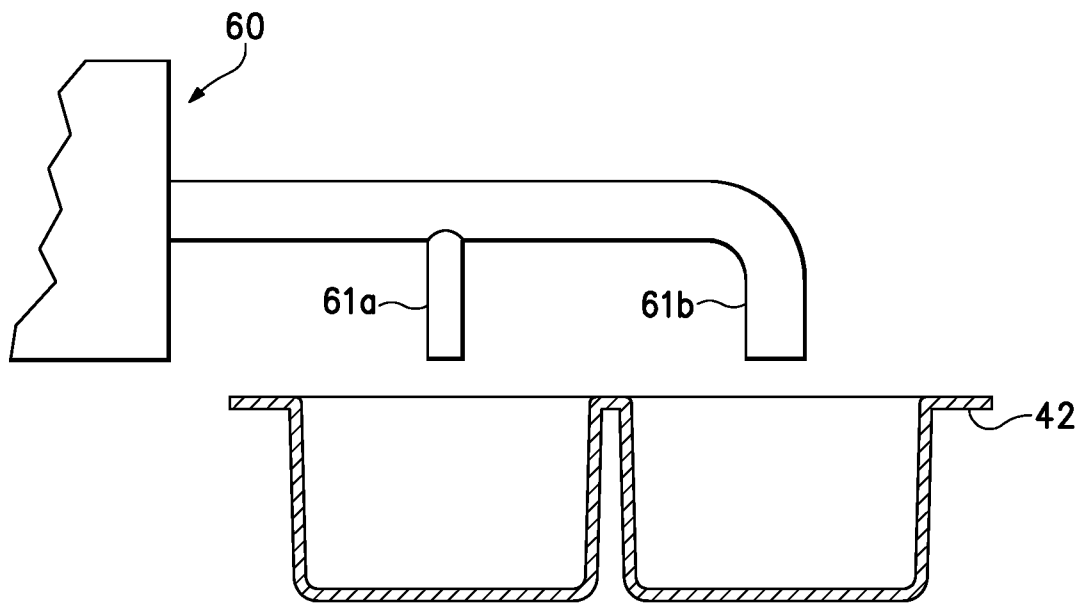
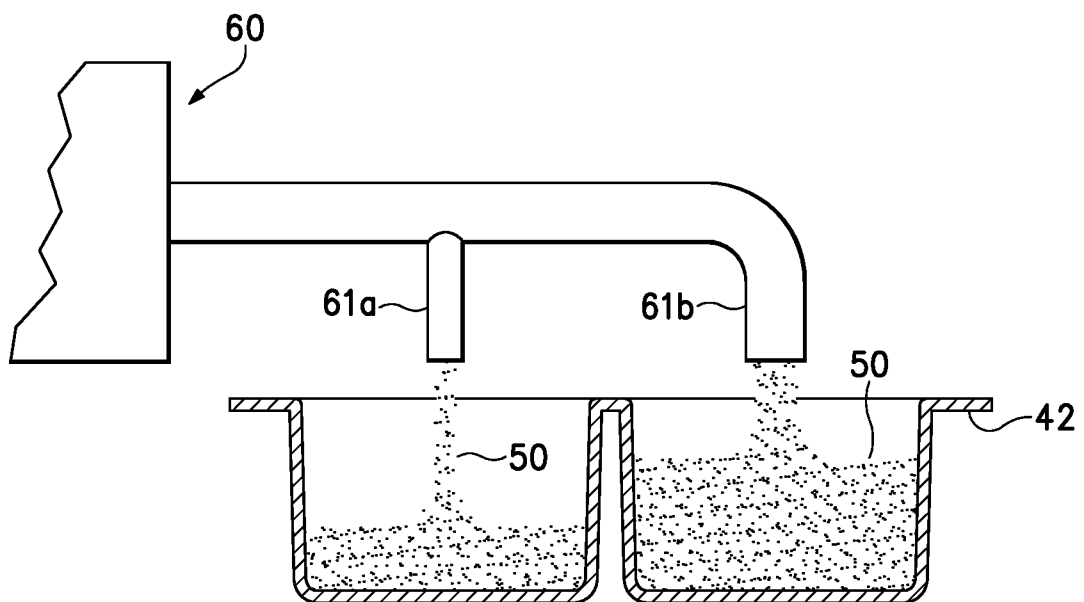


Figure 10

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**Figure 11A****Figure 11B**

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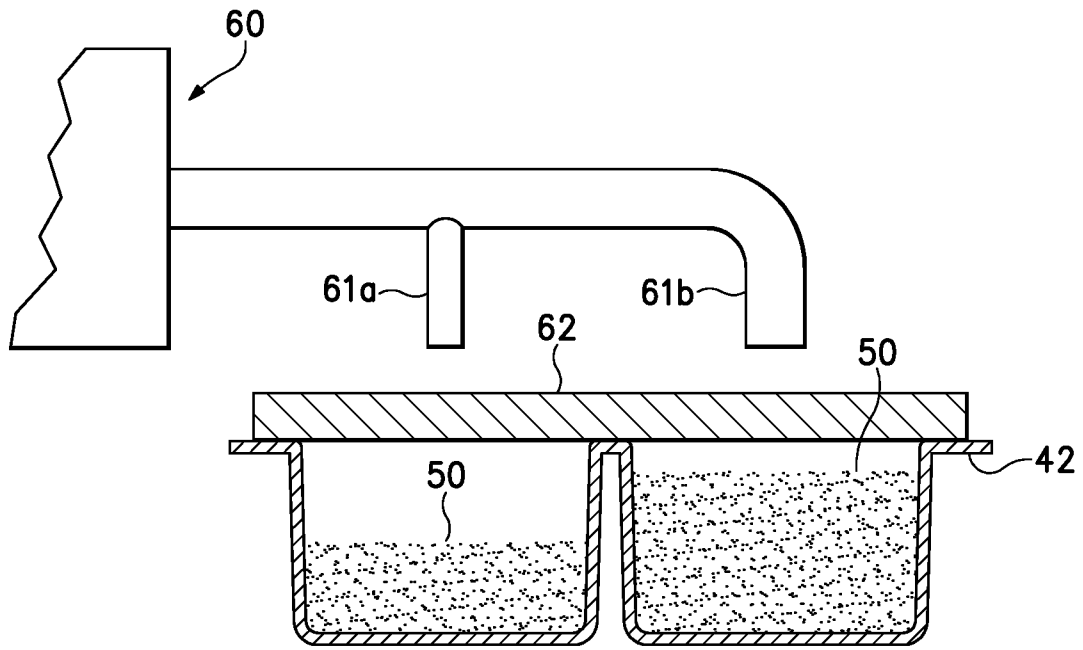


Figure 11C

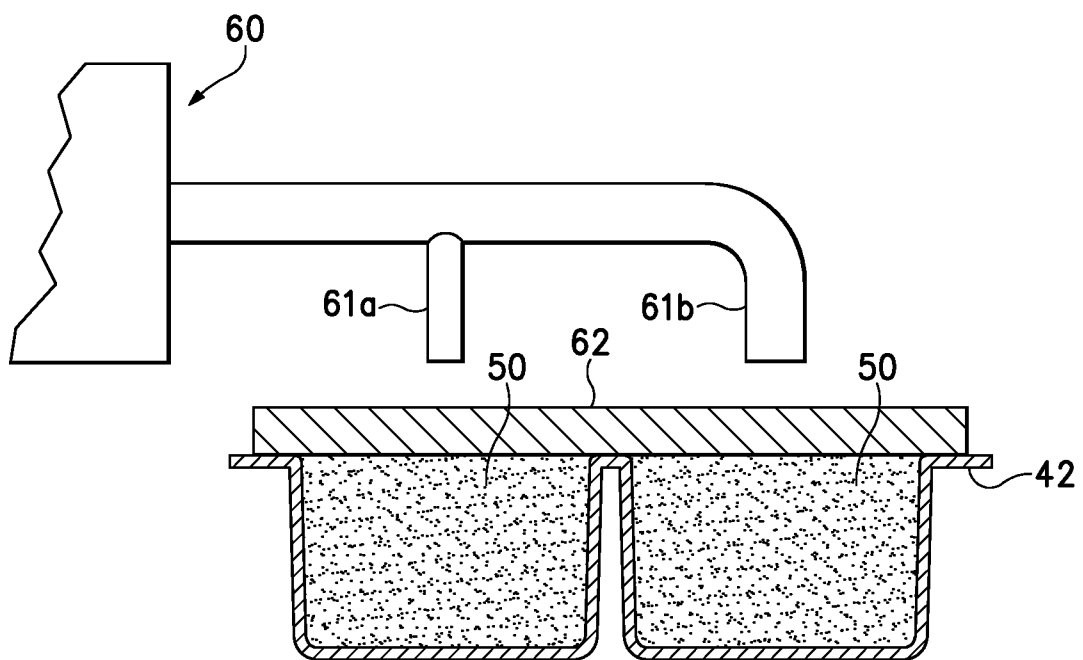


Figure 11D

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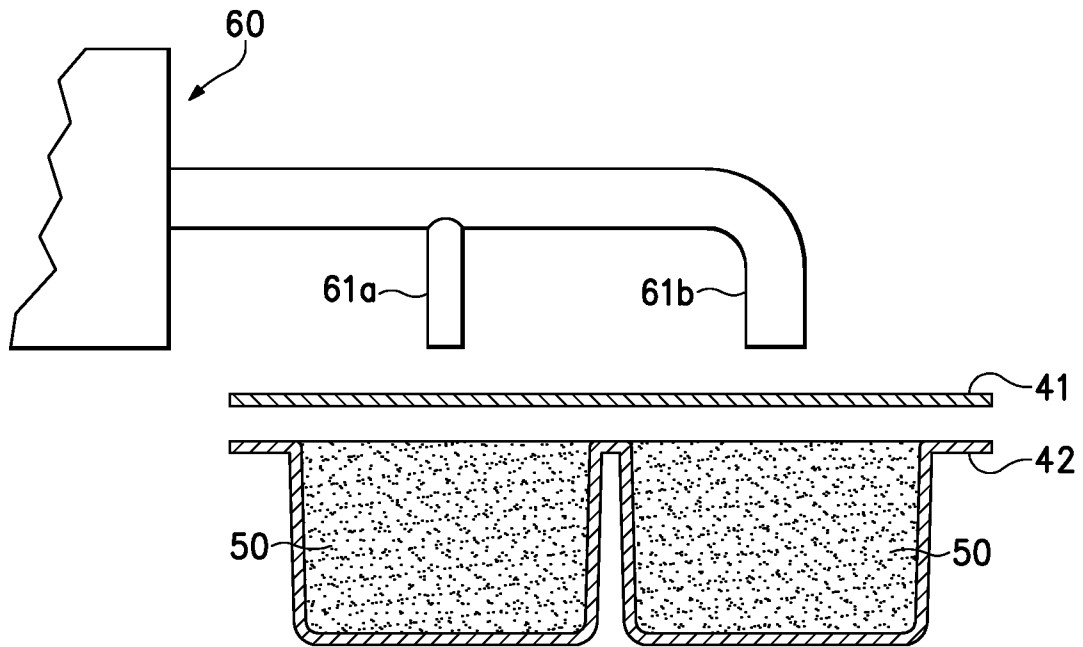


Figure 11E

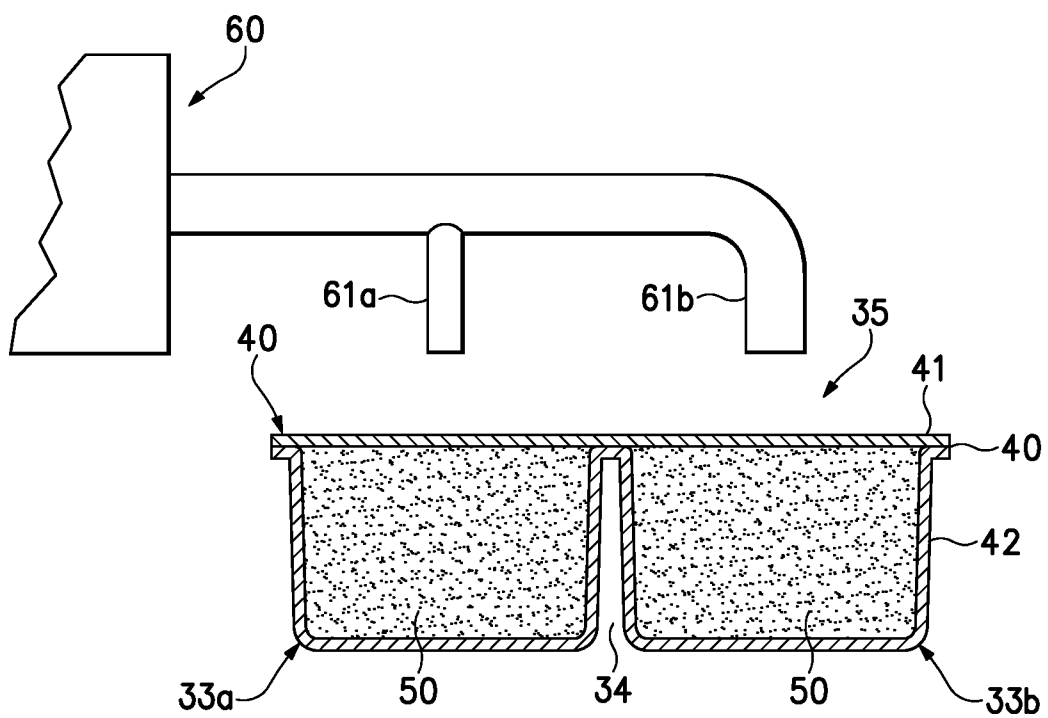
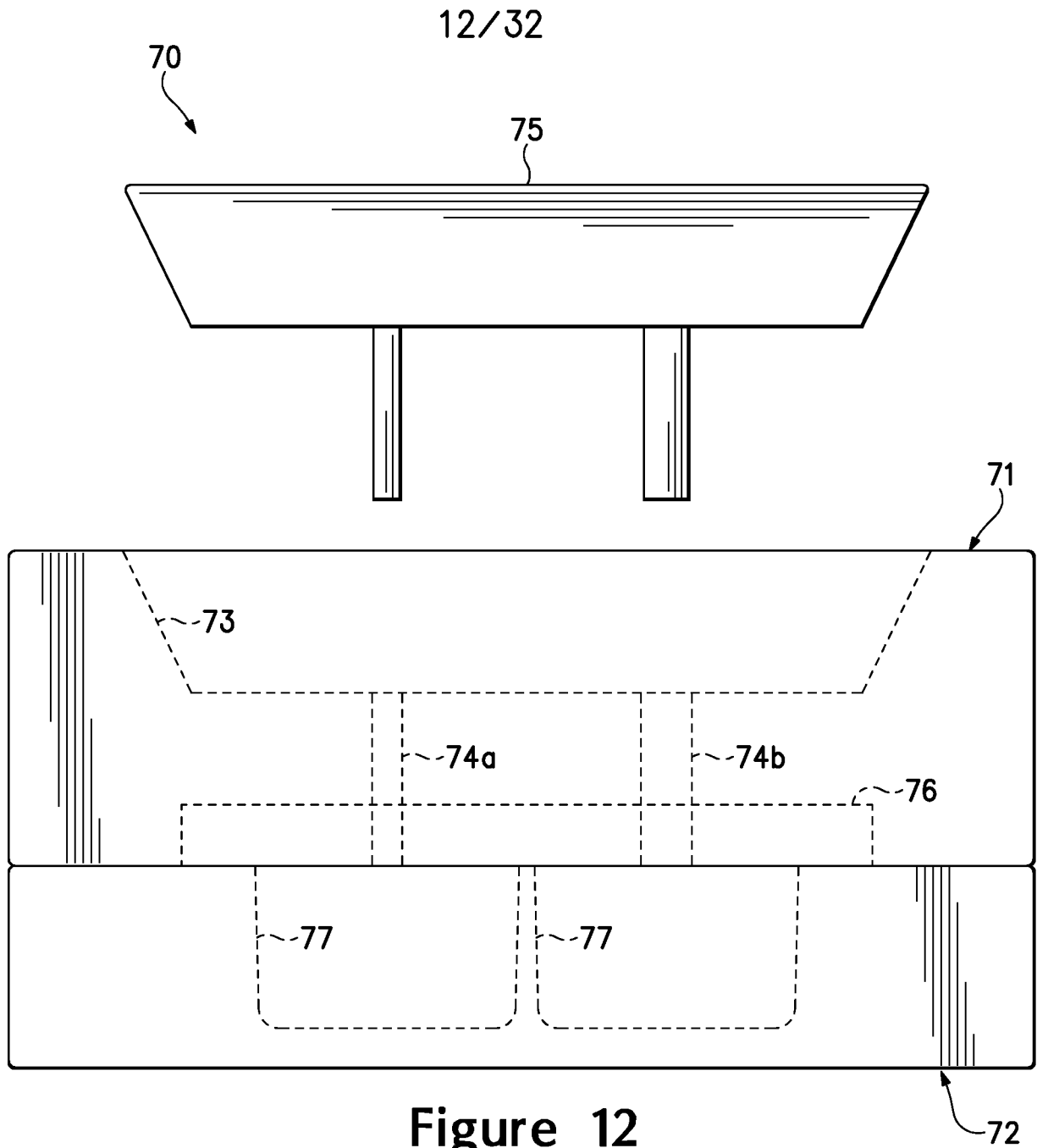


Figure 11F



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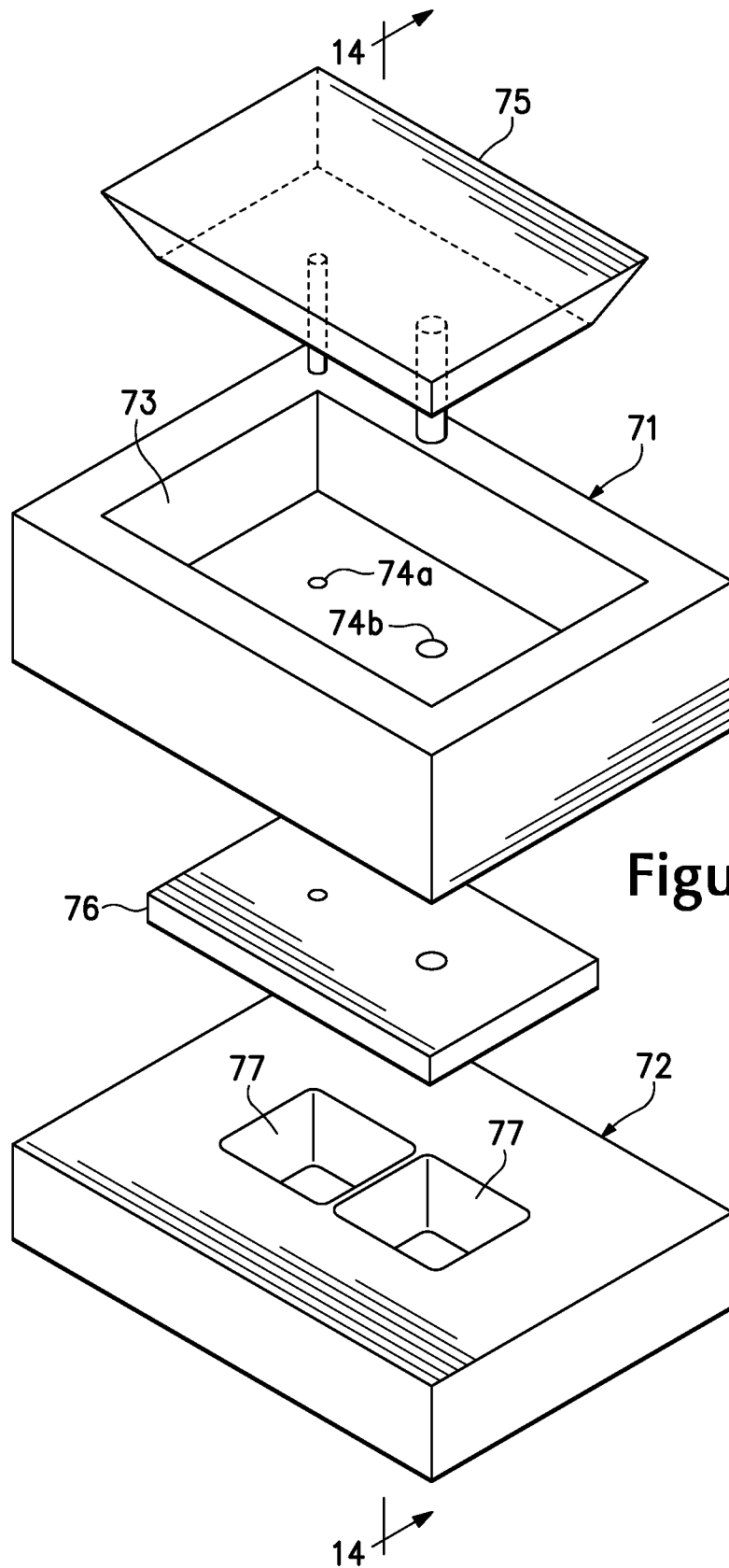


Figure 13

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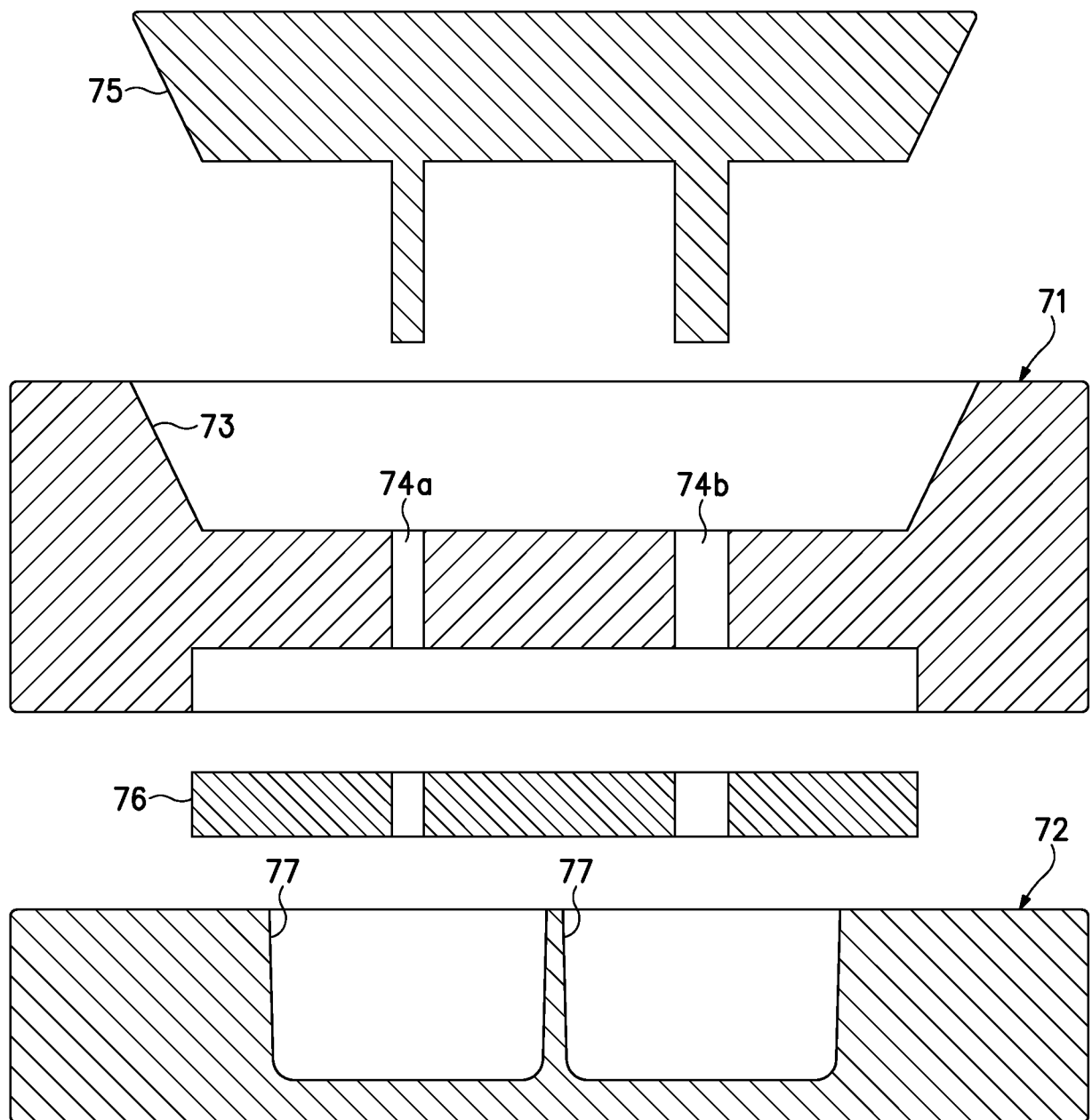


Figure 14

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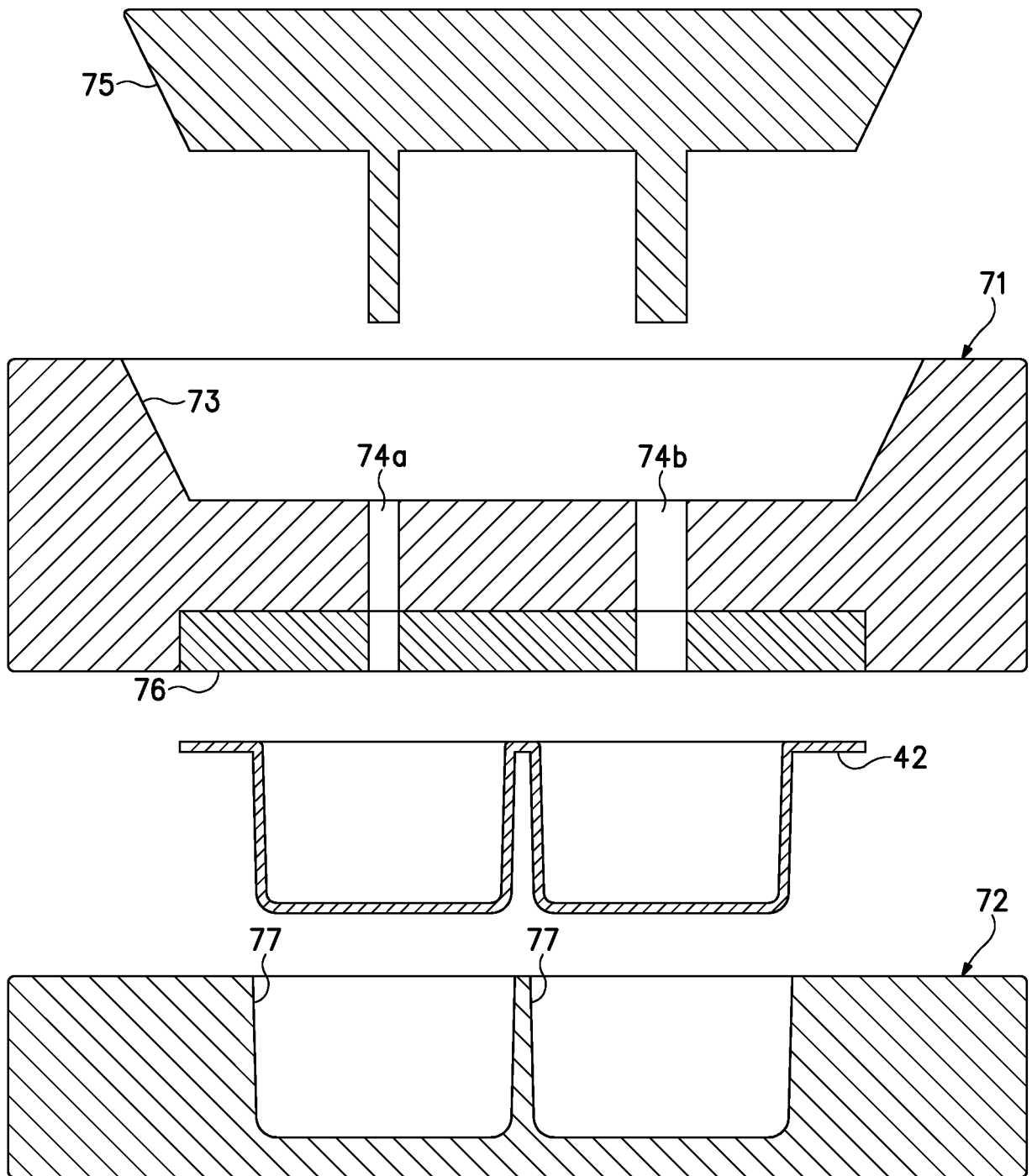


Figure 15A

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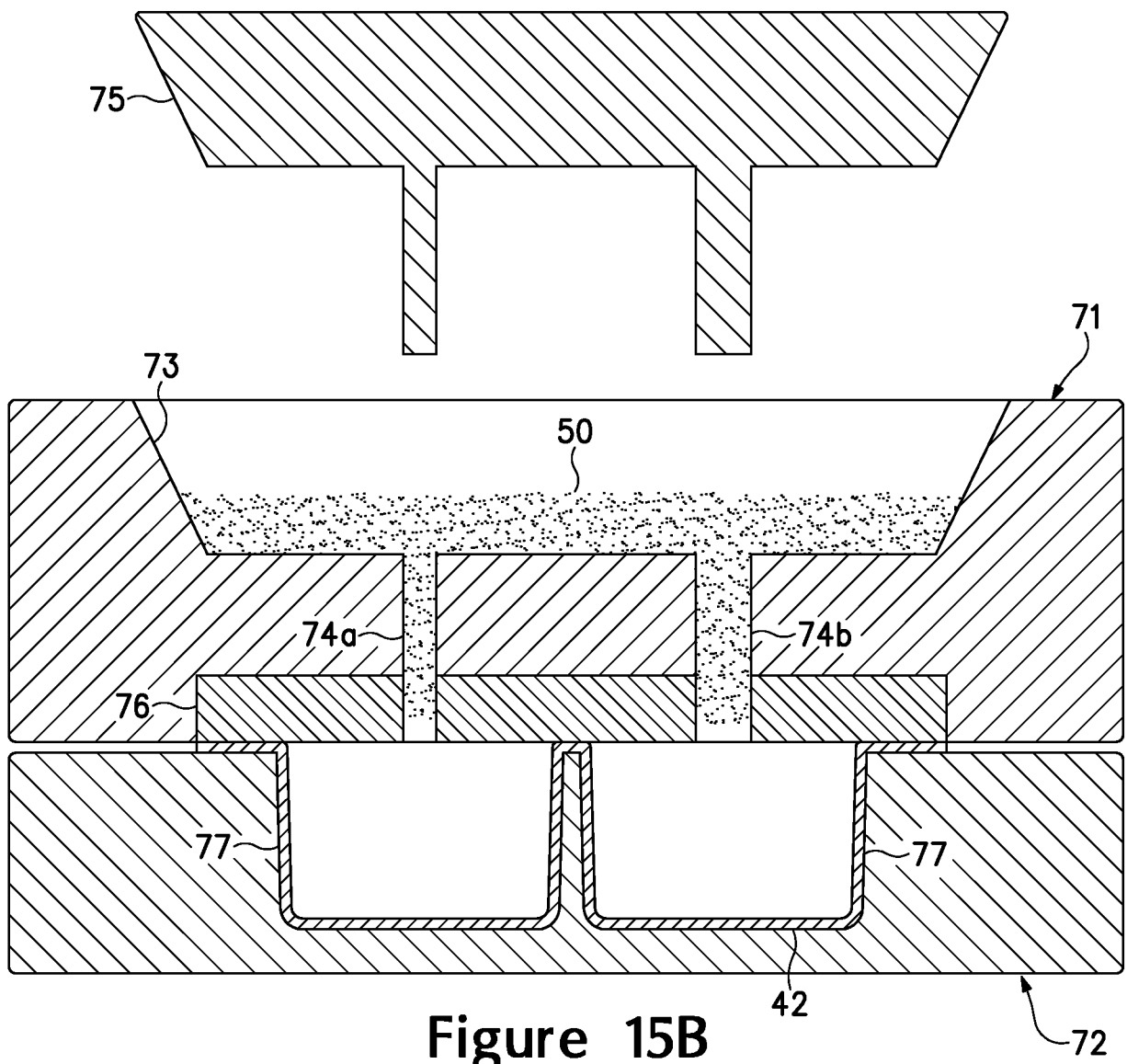


Figure 15B

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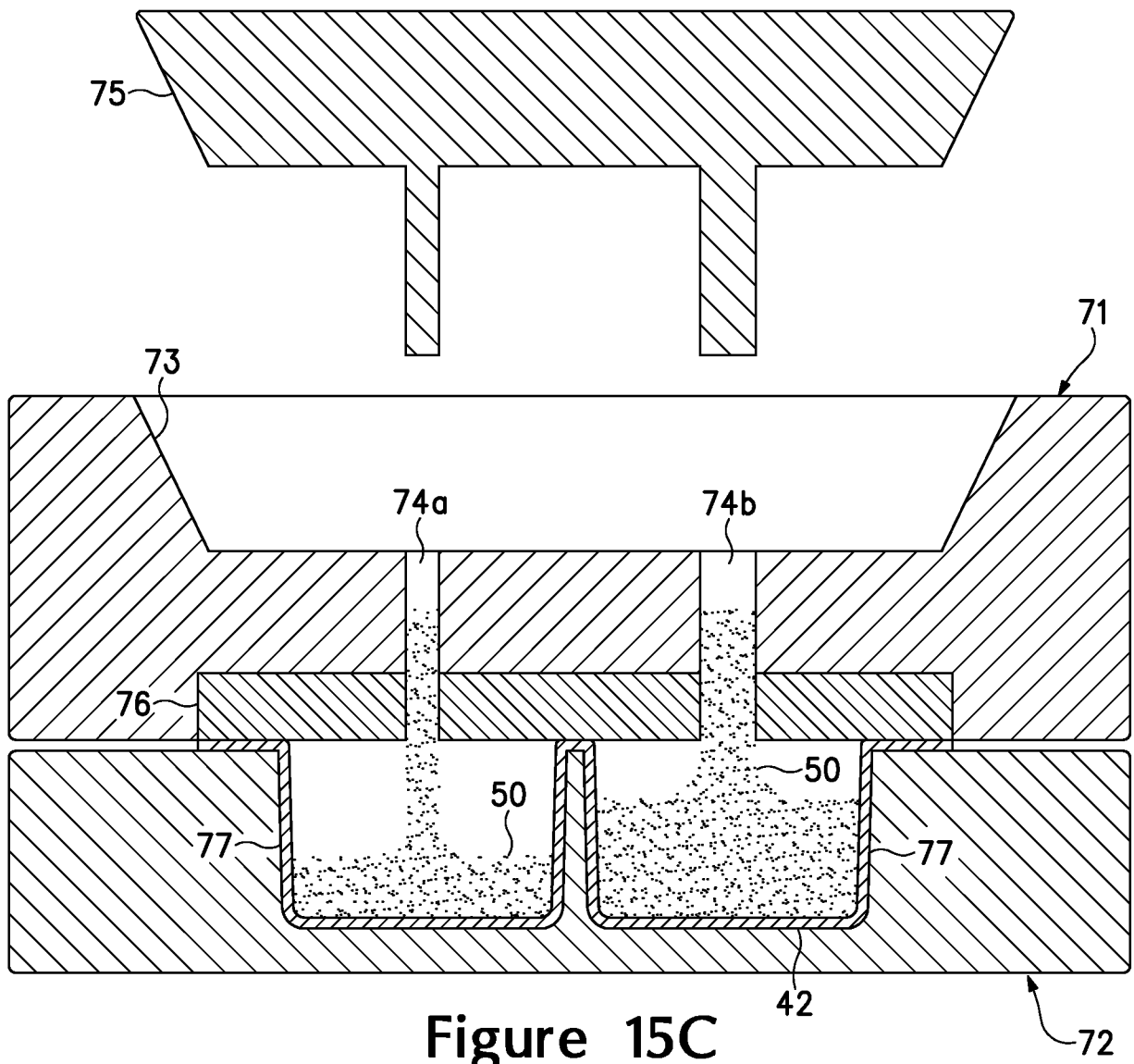
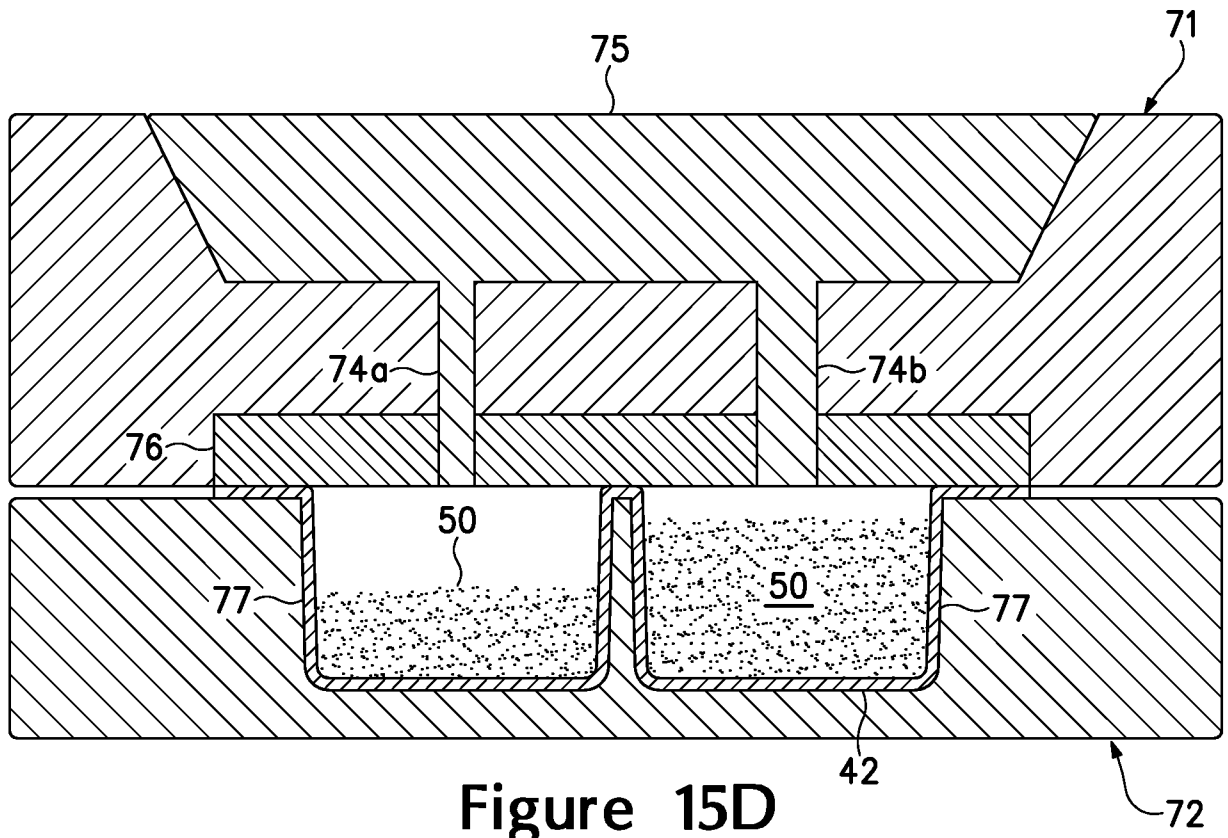
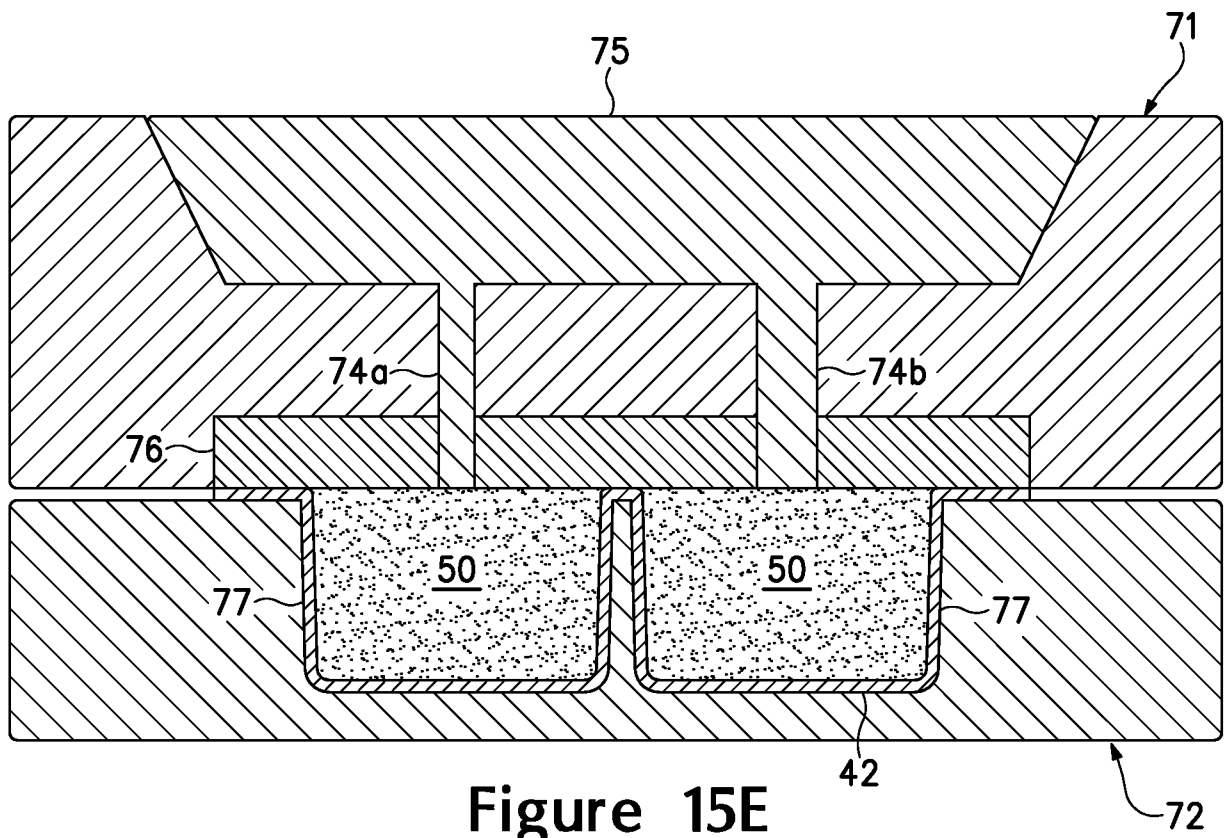


Figure 15C

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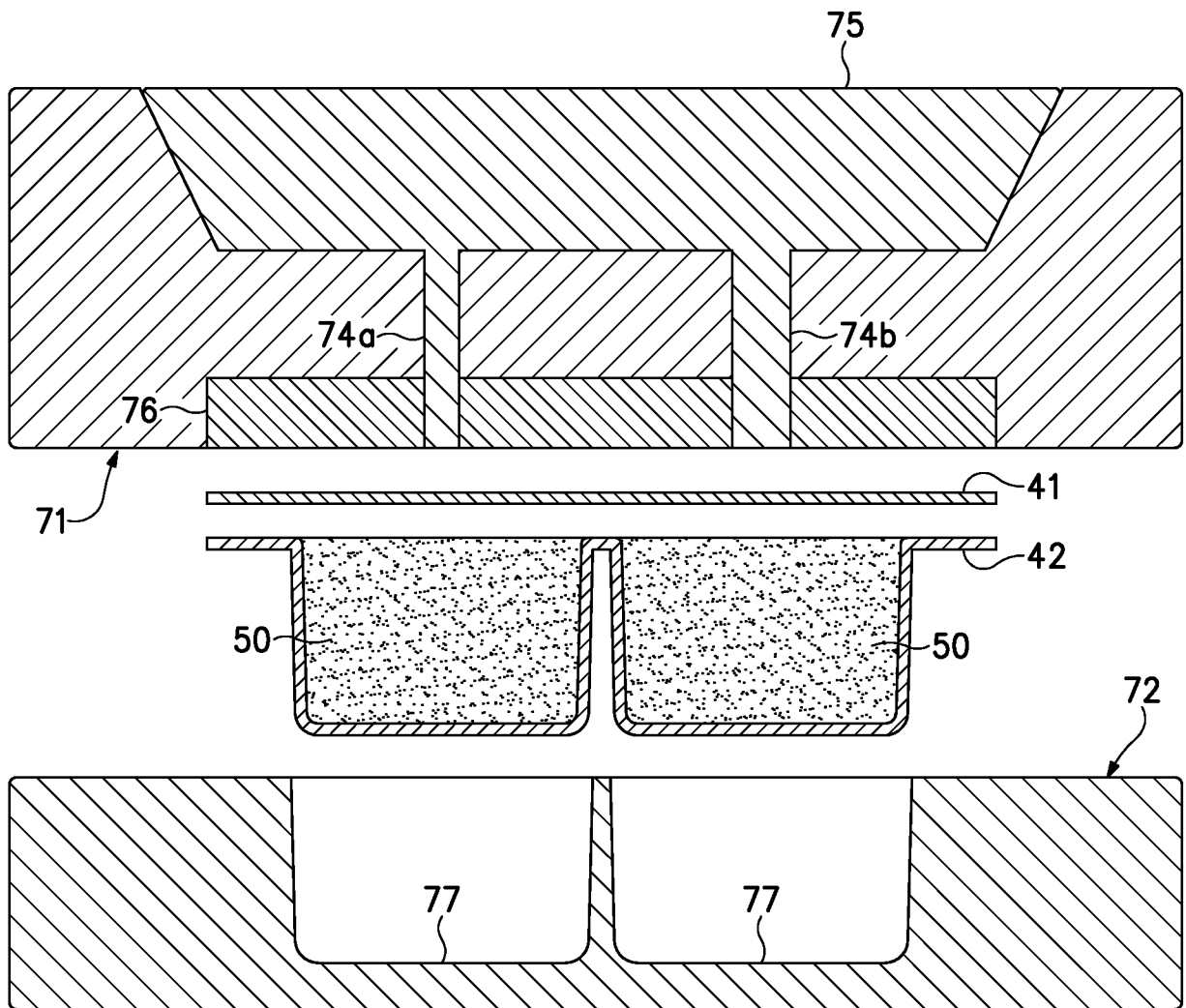


Figure 15F

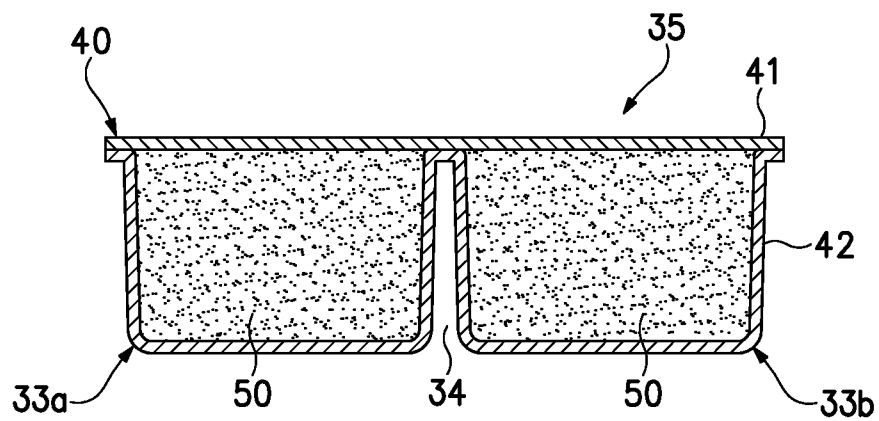
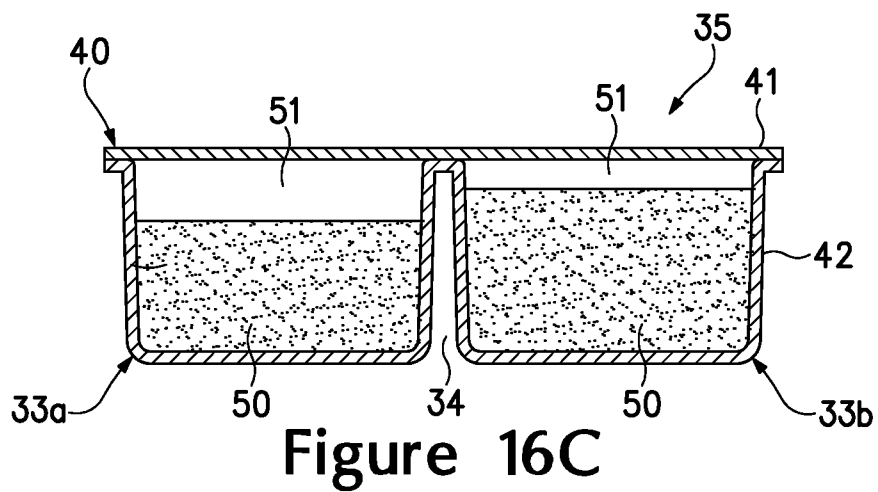
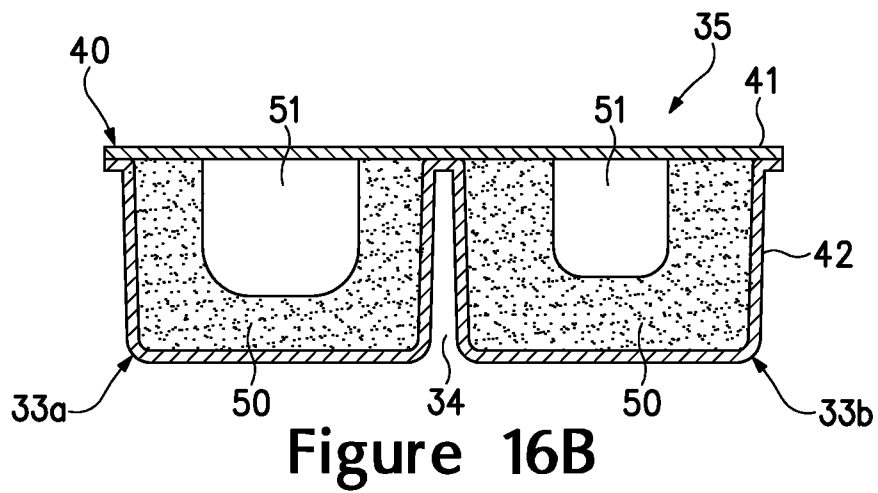
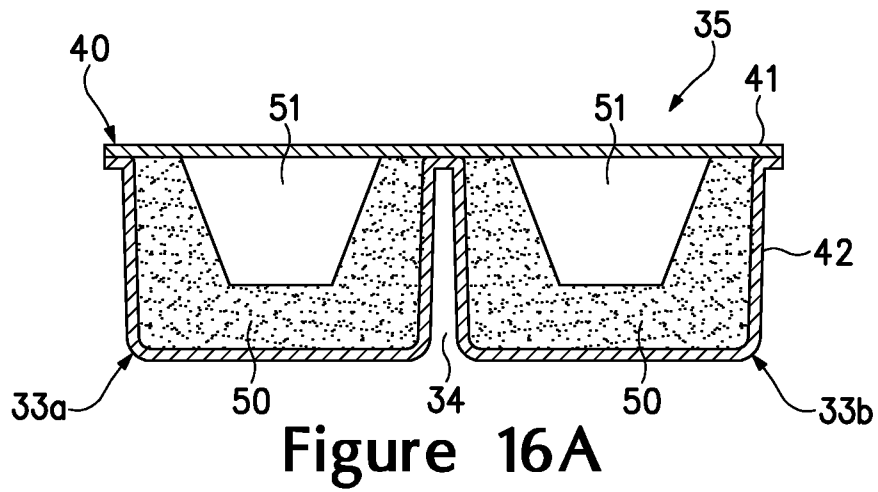


Figure 15G

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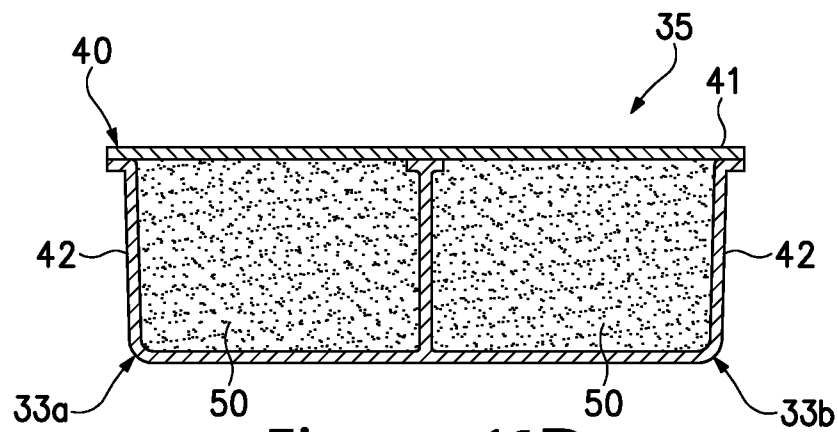


Figure 16D

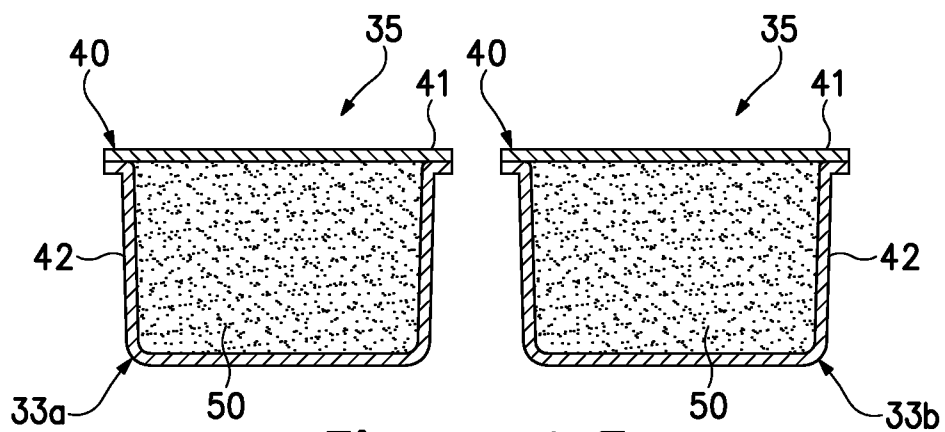


Figure 16E

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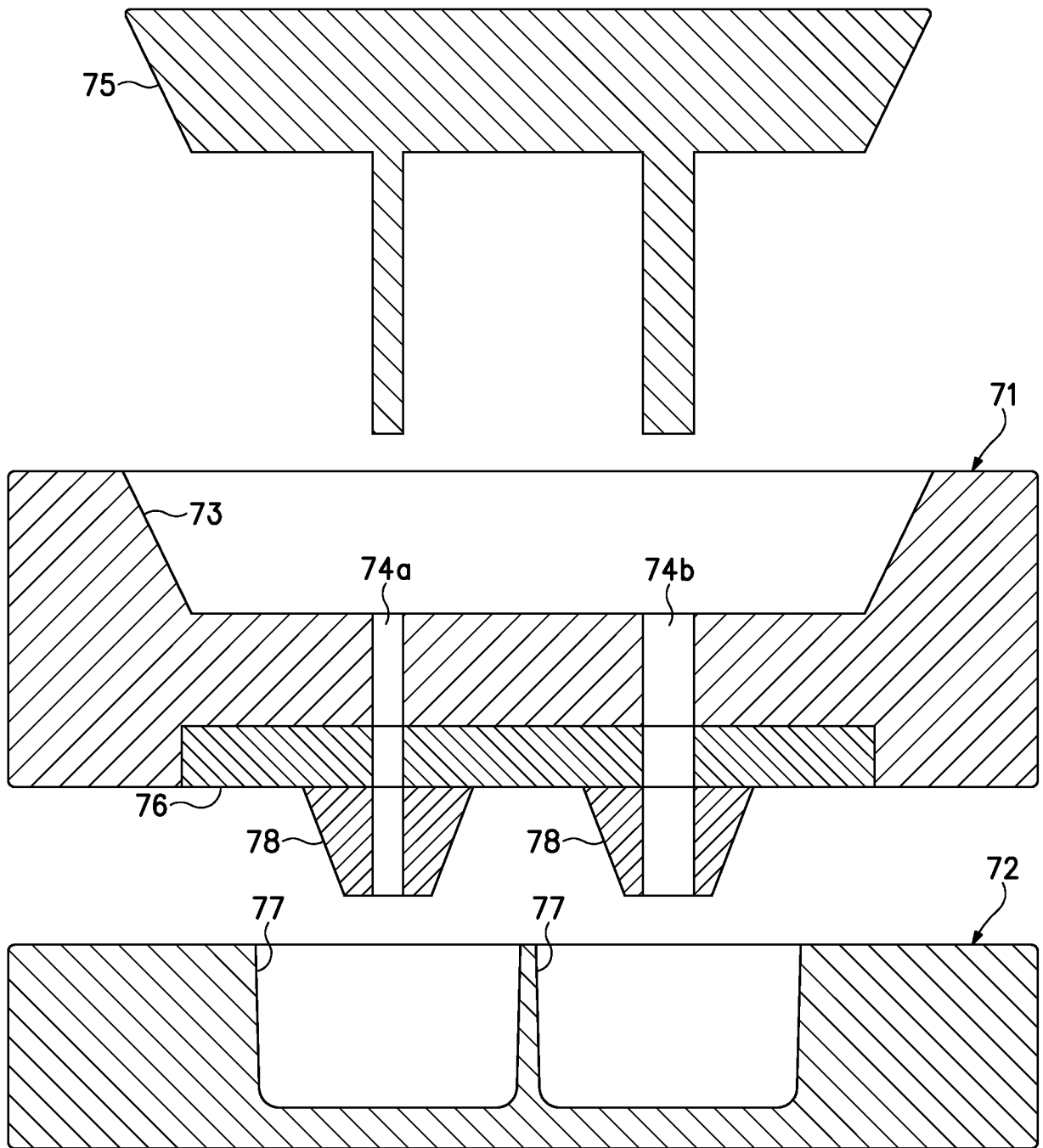
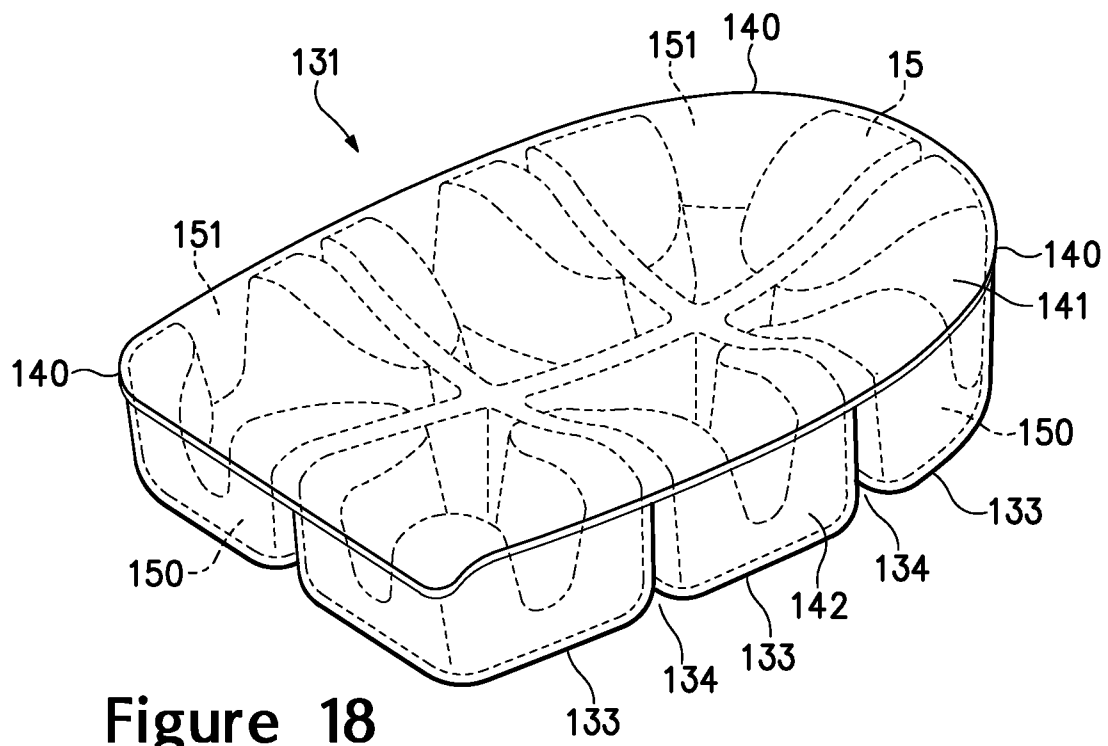


Figure 17

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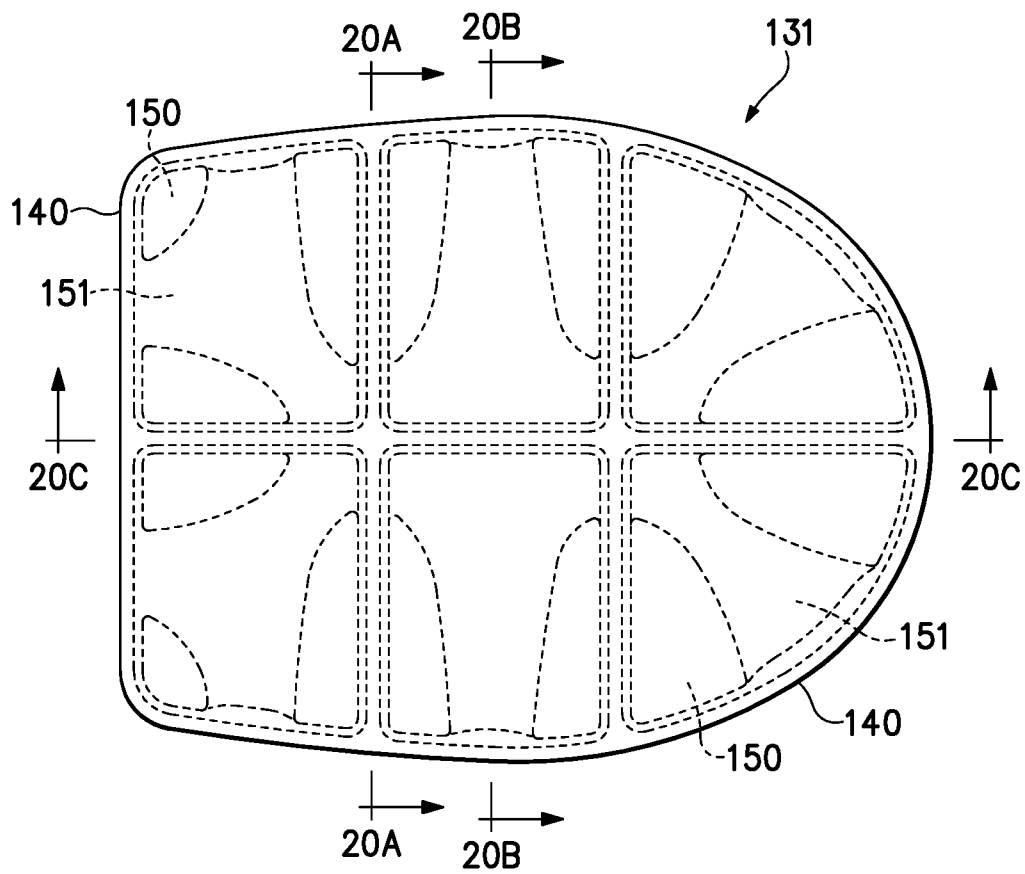
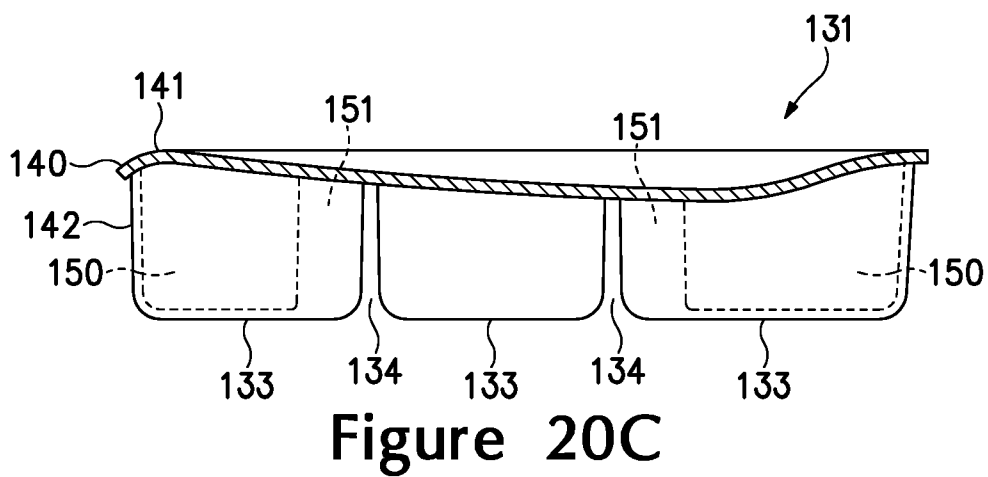
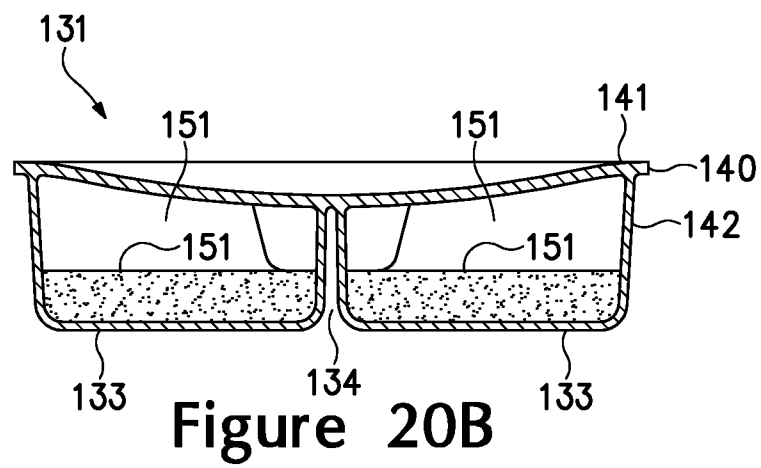
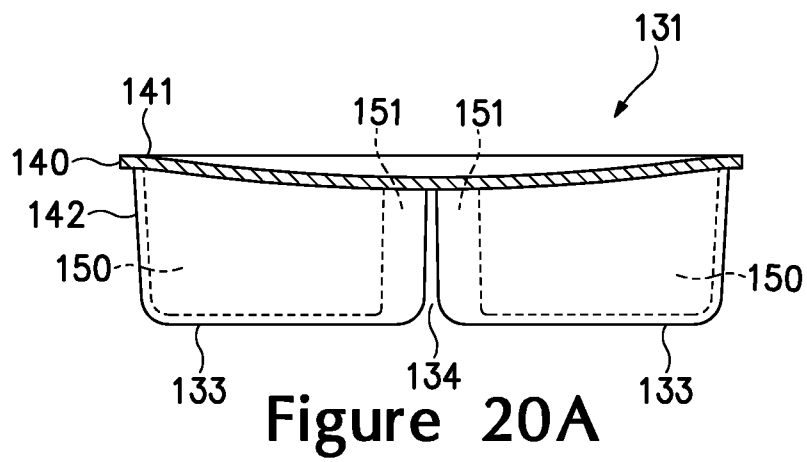


Figure 19

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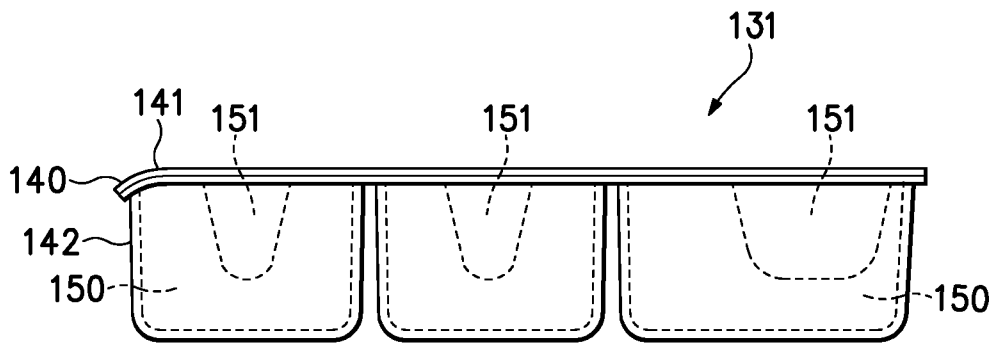


Figure 21

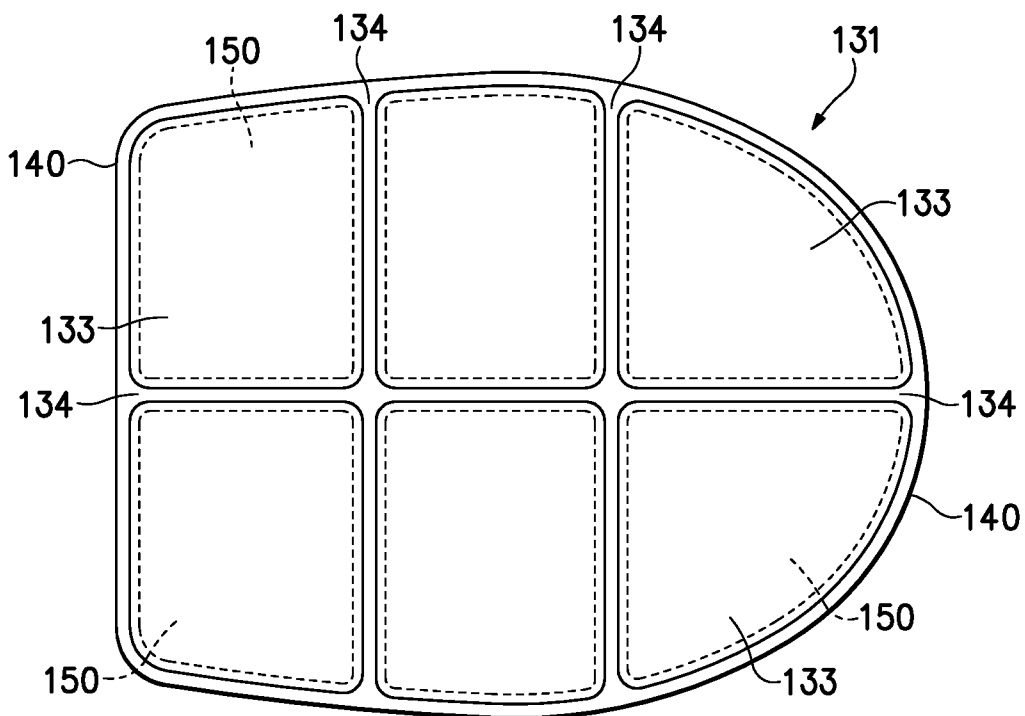


Figure 22

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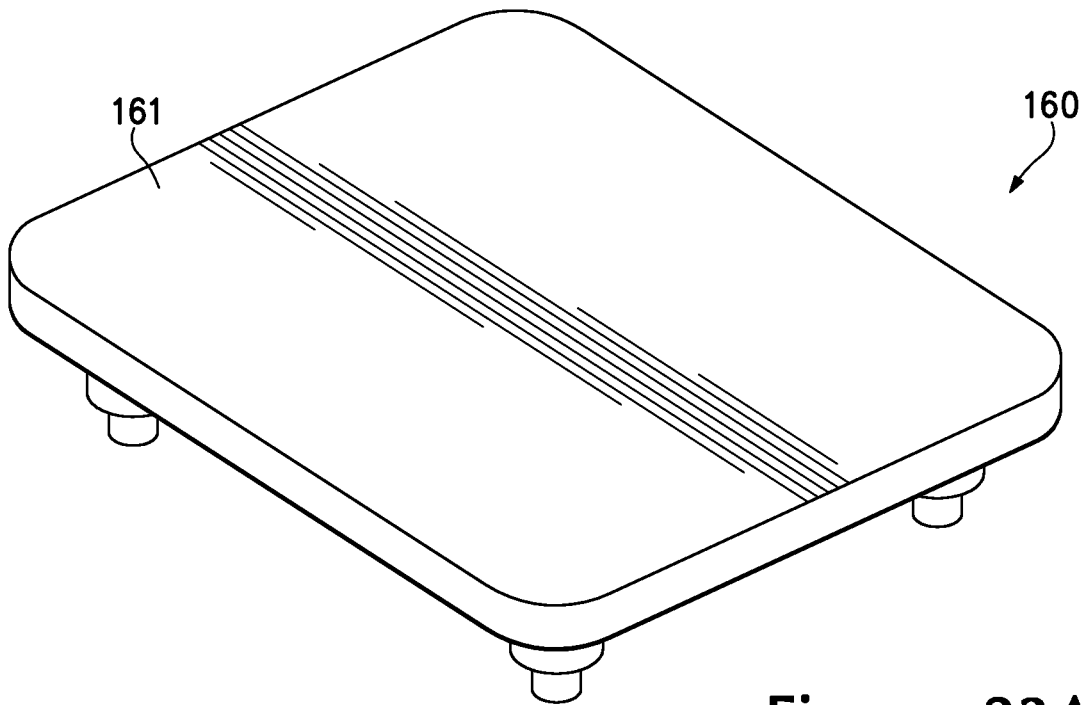
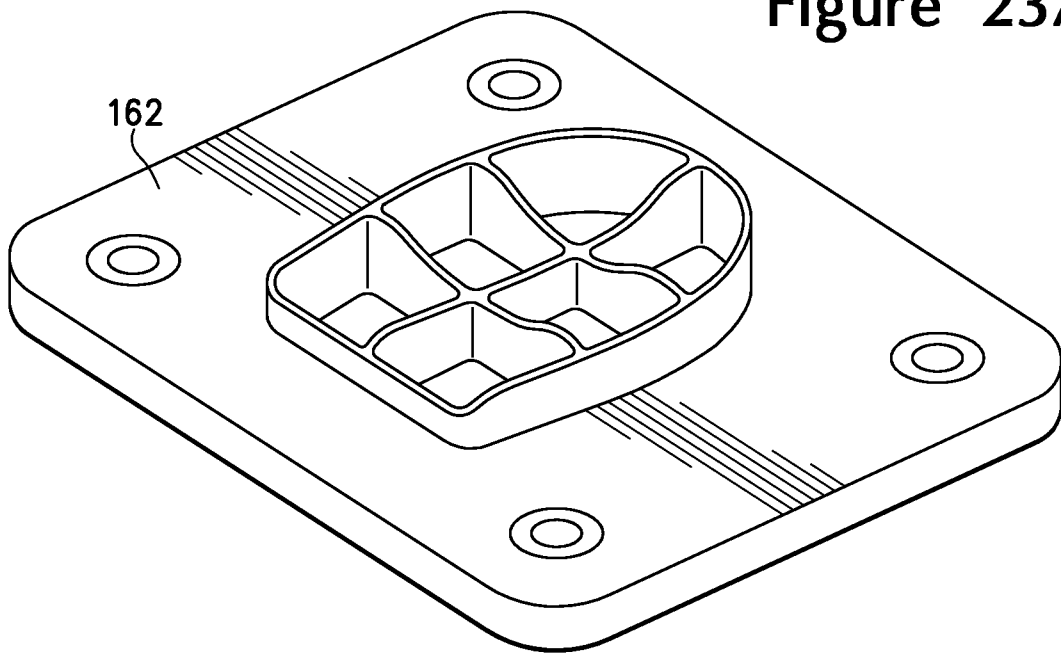


Figure 23A



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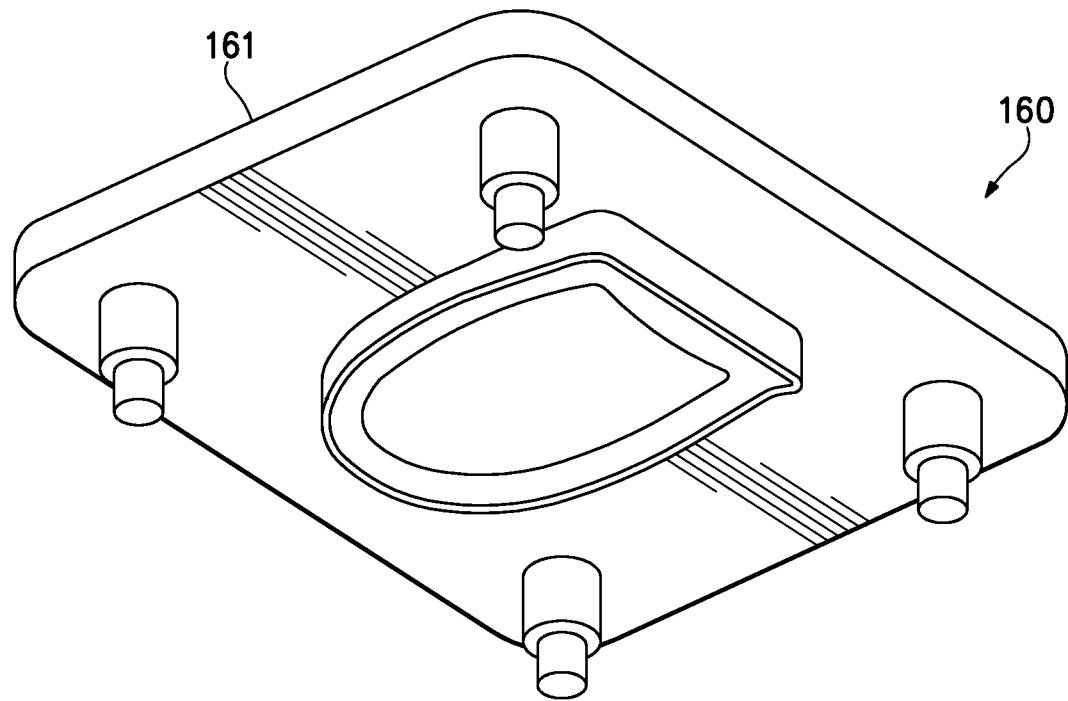
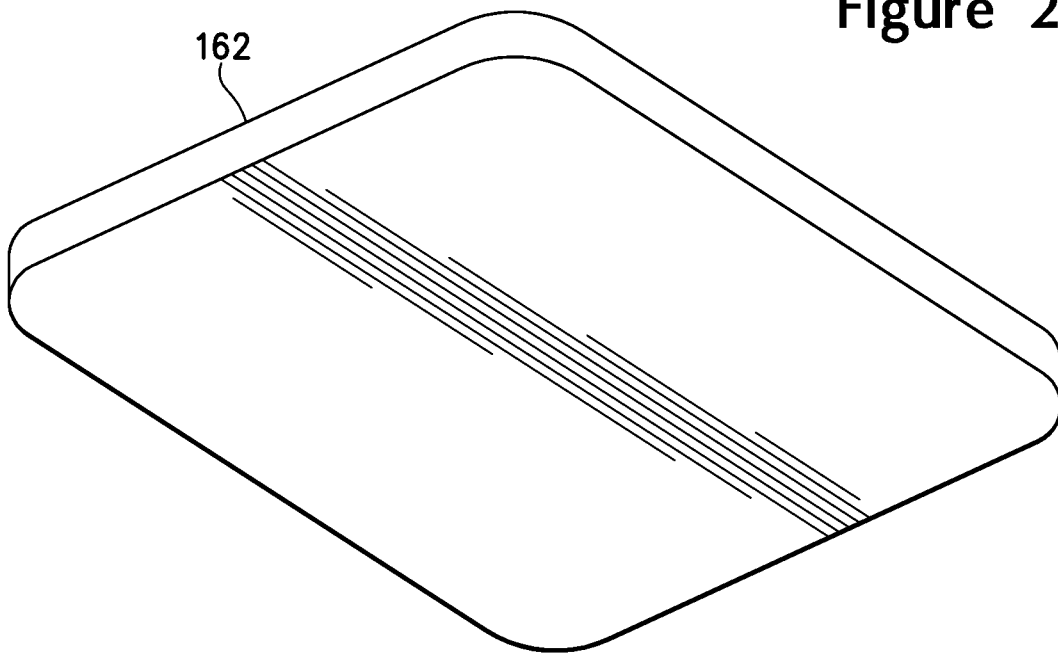


Figure 23B



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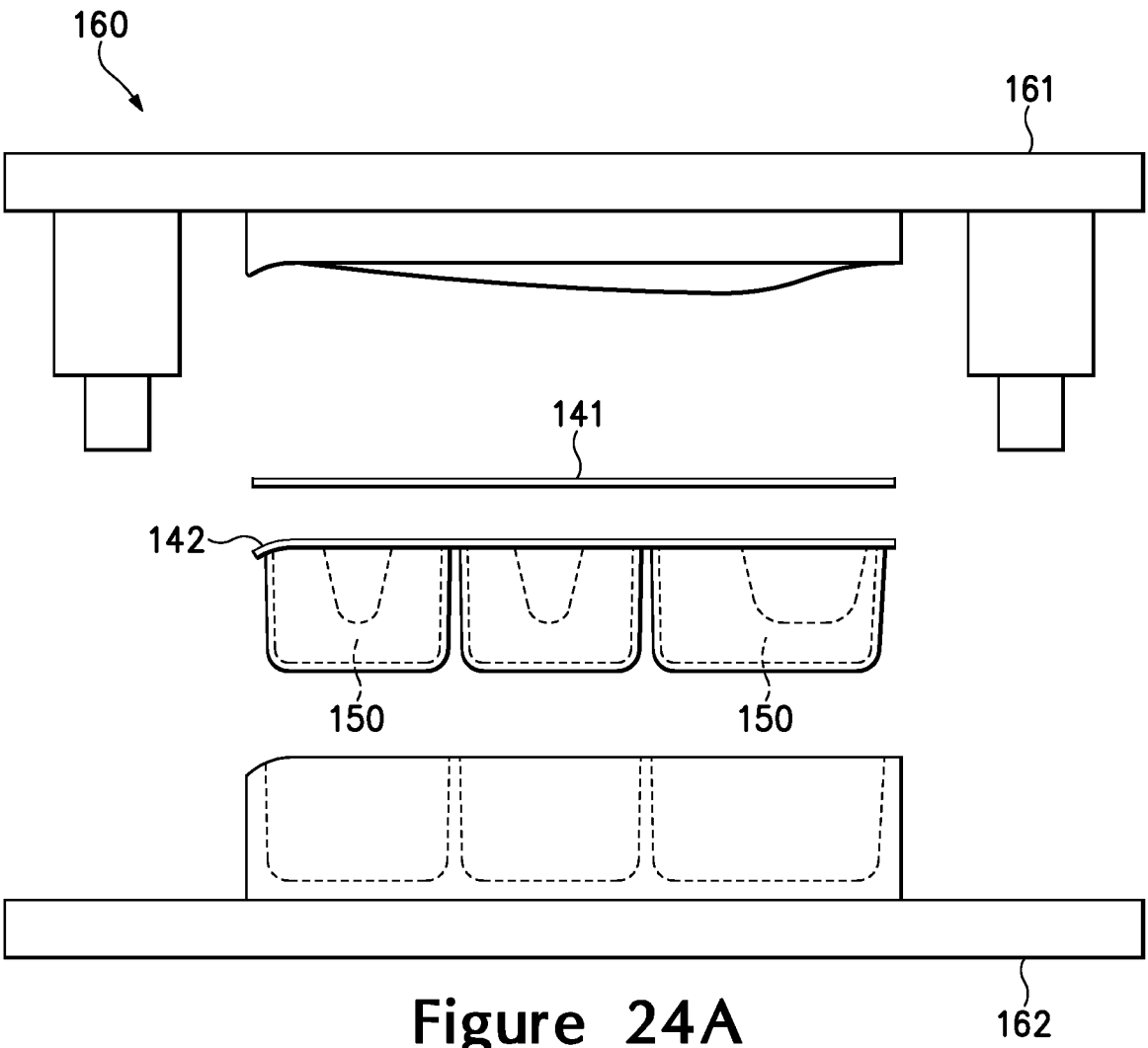
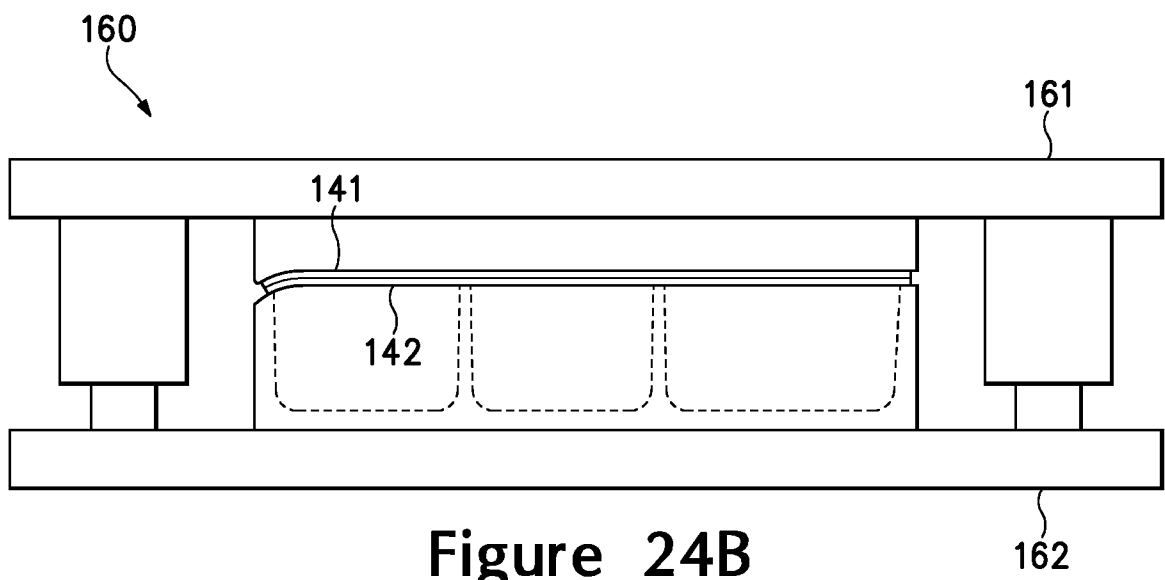


Figure 24A

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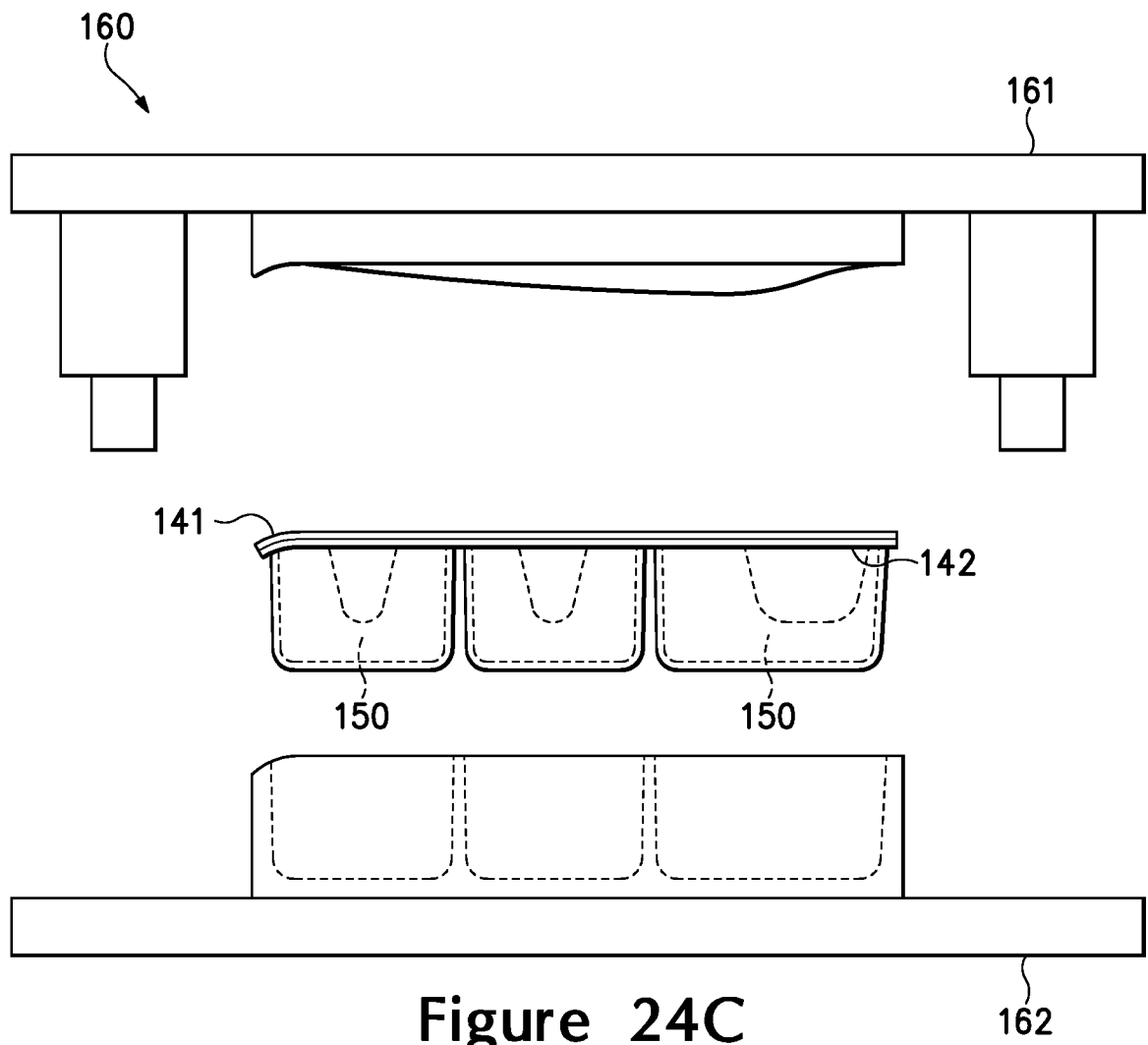


Figure 24C