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Structural member and composite panel including same

The advent of computers in recent years gave rise to the development of what is known as access flooring. Such flooring comprised a modular embodiment of rigid structural floor panels supported on pedestal columns and frequently requiring beam-like stringer members spanned between said columns for edge reinforcement. Typical assemblies were installed on top of a supporting subfloor, thus providing an adequate and secluded space to accommodate an array of power cables and the like beneath the readily accessible floor panels. This underfloor space or cavity also serves well as a distributions plenum for conditioned air. Change in location and frequent servicing of computerised equipment in an access floor environment requires repetitive physical handling of the interconnecting cables and is accomplished quite easily by the temporary removal of such modular panels. Subsequently, the underfloor cavity is exposed for complete freedom to perform any task within the maze of previously hidden wiring. When such work is finished, the modular panels fit quickly and easily back into their original position, thereby returning the area to a totally unobstructed and uniform top floor surface.

In view of the weight of computers and other equipment, it was essential that the modular floor panels be substantially rigid, such that when loaded they do not appreciably allow flexure or retain permanent set once flexed, so that the access floor is uniformly flat and all panels are in a common plane. To accomplish this, some of the earlier panels were made of substantially reinforced metal encased wood and heavy metallic castings but this has been appreciably abandoned in favour of lighter weight, high strength metal sandwich panels of which the panel comprising the subject matter of U.S. Patent No. 3 236 018, to *Graham et al.* dated February 22, 1966, is an example which is popular, is still being produced and is used extensively in the industry. An earlier example of light weight, metal constructional panels is to be found in U.S. Patent No. 1 417 664 to *Leslie H. Garlinghouse* dated May 30, 1922, which describes *inter alia* a reinforcing plate with a pattern of rows of staggered ribs or corrugations arranged so that no line can be drawn through the panel which does not cut the corrugations.

In recent years, the access flooring industry has expended in two ways. The first is in the field of high performance, heavy duty panels for specific heavy load areas above and beyond standard computer room criteria. Secondly, the access floor industry has been expanding more and more into office renovation and general office construction for new buildings and other typical lighter load applications. A dramatic shift in the performance requirements for this type of general construction floor has substantially taken place.

Current art has attempted to economically satisfy this need by means of altering panel designs by varying material thicknesses, but sometimes by discarding the standard stringer support provided at the panel edge. Although this readily achieves a lighter weight and more economical product, it inherently introduces an objectionable deficiency, namely, edge-to-edge movement, in the character of the system as viewed by architects and users who are foremost aesthetically minded. Another prominent objection is related to the feel of springiness within a light weight floor under normal foot traffic. Insecure feelings also arise due to the visible edge-to-edge movement between panels under light equipment use. Although the structural integrity, specifically the ultimate strength, more than satisfies the most stringent general office construction criteria, this objectionable panel-to-panel motion is a restricting factor to the growth and acceptance of the product in the general construction and renovation market.

The industry, to satisfy this need, has developed systems which reduce perimeter movement by adding secondary structures, such as perimeter stringers or complex panel-to-panel hard connecting devices. Although such structures tend to reduce edge-to-edge movement, they directly affect the accessibility and ease of handling the floor system as originally conceived.

Additionally, in renovations and, more importantly, in general office construction, it is desirable to hold the finished floor height of the access floor to a minimum while providing an adequate space or cavity for underfloor cables and to perform as an air distribution plenum. Thicker panels diminish vital underfloor clearance or floor-to-ceiling height. The thickness of the access floor panel is often as much as one-third of the total of this low finished floor height; therefore, an economical panel with needed structural properties, yet thinner in depth, is an advancement in the art and a savings in total building height and cost for new construction, and also provides the ability to maintain adequate minimum floor-to-ceiling height in renovations. To do this, the structural efficiency of the panel has to be dramatically increased over existing art, especially at the perimeter.

Since the development of the aforementioned patented panel, efforts have been made to simplify and also reduce the weight and the amount of metal required in said panels, without reducing, but instead, striving to increase the resistance of the panels to flexure and/or permanent set, especially at the panel perimeter when subjected to static or moving loads. This has resulted in explorations and development, especially in the design, of the structural member which is primarily the lower stress member in a metal sandwich-type floor panel in which it is able to perform integrally with the upper planar member upon which the load is usually imposed.

In such exploration, we have determined that a key factor to resistance to flexure is the reduction of clear straight lines of vision through said sandwich panel and, more importantly, the repeated blockage in all directions within the sandwich. It has been found that several patterns of projections with common strategic dimensional relationships can provide both necessary blockage of clear lines of vision and suitable support of the top sheet to resist localised indentation of the access floor panel. Projections were selected because they combined the benefits of a continuous bottom member with the support obtained from arch-shaped projections to prevent collapse thereof, together with an optimum depth which, combined with the structural and economic efficiency of the section, developed blockage of "see through", thereby providing sufficient section properties to resist deflection by the loads applied.

The strategic dimensional relationship is a combination of considerations of five major characteristics of the projections and their interrelation; namely (1) depth of projections for needed section modulus and moment of inertia; (2) diameter of projections to obtain their needed depth; (3) distance between the centre-lines of projections for sufficient top sheet support; (4) strategic positioning of projections to repeatedly block clear lines of vision throughout the member; and (5) remaining bottom surface material adequate to perform as a stress member and also develop necessary section modulus and moment of inertia. Prior art has failed to combine and/or incorporate one or more of these five structurally significant characteristics and has, therefore accomplished a less than optimum one-piece structural member which, when combined with a top sheet, does not provide an economical metal sandwich construction of desired comparable strength-to-weight ratio or structure efficiency.

It has been found that specific patterns of several different embodiments of projections, in which at least the major portions of the configuration of said projections are circular and details of which are described fully hereinafter, results in increased rigidity and resistance to flexure to a marked extent. Said projections are formed in sheets of planar industrial material of lighter gauge than now employed in the floor panel of the type shown in said aforementioned Patent No. 3 236 018 for improved performance under the same load conditions. The efficiency in performance of the developed core structure has thus been dramatically improved. Such characteristics and features are not found in the prior art, notwithstanding the disclosure of formed sheets having various types of projecting ribs and/or figures of a regular contour pressed from planar sheets and other means which block straight lines of sight across the formed sheet and through such ribs and figures, either because the configurations do not permit sufficient depth of section for strength purposes, are not sufficiently conducive to resist flexure under the required loads existing in access floor use, or are not economical to competitively market the same.

The prime object of this invention is to form, within a single sheet, a structurally efficient combination core and bottom stress member which when affixed to a planar top member surpasses the combined strength, rigidity, and economics of prior art.

One of the principal objects of the invention is to provide a structural member comprising a one-piece rigid member formed from a sheet of structural material having formed therefrom a plurality of elongated dome-like projections extending from the plane of the said sheet, being arranged in substantially perpendicular basket weave pattern having a strategic dimensional relationship between the dimensions of said projections and the distances therebetween such that the projections repeatedly block straight lines of vision laterally in all directions across said sheet, said one piece member being capable of resistance to flexure, said elongate projections each comprising two substantially hemispherical portions connected by a saddle portion forming a generally figure 8 configuration, and portions of said member which are intermediate said elongate projections comprising continuous structural ribbon-like stress sections of fluctuating width and being arcuate in plane view and capable of optimising stress-resisting integrity of said structural member. Further, said projections which form the pair which resemble a figure 8, are arranged in said sheet in a structurally strategic geometric pattern of which rows of pairs of dome-like projections are in a straight line in any direction and said rows are in a perpendicular basket weave pattern relative to each other. Said pattern repeatedly blocks straight lines of clear vision in all directions across said sheet and therefore, the occurrence of said projections in said sheet is such that the spaces between adjacent projections is inadequate to accommodate another similar projection. Said projections are spaced from each other a limited distance to provide therebetween intermediate continuous structural ribbon-like stress-sustaining sections of fluctuating width capable of optimising stress-resisting integrity with the same being arcuate in plan view and extending between the opposite edges of said sheet to sustain the stresses under load conditions. Such a structural member may be utilised in the manufacture of composite sections, such as access flooring, decking, or other structures which require economical high strength-to-weight ratios and structural efficiency. Additionally, they can provide structural components as in the construction of walls and other reinforcements where the individual sheet is utilised as an intermediate core member, or by itself, as a flexure-resisting component. Such one-piece structural members readily satisfy demands and applications in such marketable products as roofing, decks, wall constructions and a variety of other applications to provide structural efficiency.

An additional object of the invention is to maintain said arcuate structural ribbon-like stress

sections in their original shape under stress by the circular configuration of said projections converting load stresses, which would tend to straighten said sections, into hoop stresses around said projections, thereby resisting said tendency to straighten said sections.

5 A further object of the invention is to isolate any reduction in material thickness to substantially within the formed area of the configurations themselves. This leaves optimum material in the stress-sustaining sections located where maximum section properties can be developed.

A further object of the invention is to provide repeated blockage of clear lines of sight across said sheet in all directions. This is accomplished by several embodiments of patterns of projections, which are paired to form the elongated configuration, such as when the projections formed in a sheet of material are combined in groups of four and arranged in a rhombus pattern of a structurally strategic dimensional relationship between the diameter of said projections and the centre-to-centre distance therebetween, and adjacent rhomboidal patterns are positioned in a close perpendicular basket weave orientation. Said basket weave orientation in a structurally strategic geometric pattern also is produced by rows of pairs of equally-spaced in-line projections being interwoven perpendicularly with other such rows of pairs in a basket weave fashion, so that the portions of a centre line of a row of pairs of projections that lies between two aligned pairs bisects the pairs thereof in transverse rows, as shown by dotted lines in Figure 8 and also provides sufficient pattern density to block straight lines of clear vision repeatedly in all directions across said sheet to form a one-piece rigid structural member capable of resistance to flexure. Similarly, blocking is accomplished by arranging a plurality of configurations in close proximity to each other within the pattern in which certain of said configurations resembling a figure 8 are combined with others which are circular in cross-section, at least a major portion of the circumference of all projections are circular in plan view with the combinations of said configurations and projections in said sheet being such as to repeatedly block straight lines of clear vision across said sheet. Finally, blockage is accomplished by including at least one drawn section formed from the original planar sheet in the same direction as said configurations, said drawn section having an area larger than said configurations surrounding said pattern. The arrangements of said configurations, projections and drawn section are designed so as to repeatedly block clear lines of vision across said sheet. The blocking of clear lines of sight repeatedly across said sheet provide a structural member of increased resistance to flexure due to increased structural efficiency, and when combined with a planar top sheet becomes an economical composite structural unit of substantially greater strength than one in which lines of clear vision are present around which the structural unit can be flexed.

Still another object of the invention is to provide the location of said configurations and projections in such a manner that a composite unit which is resistant to flexure is substantially isotropic, whereby said unit when penetrated by an opening of limited cross-section located inward from the edges is resistant to flexure due to the resulting stresses in said unit when under load being redirected around said opening. This provides a unit which can be utilised as an access floor panel or other wall panel uses in which ready penetration can be made without significant reduction in the structural integrity of the unit in order to provide penetrations for cables, pipes, or other accesses as needed in the construction industry.

40 Other further important object of the invention is to combine any of the previously described patterns of configurations and projections in a structural member with a flat sheet of structural material of similar size and shape and fixedly connect the upper ends of said projections to said flat sheet to form a composite structural panel in which said sheet of said panel is disposed uppermost in use, thereby forming load-carrying composite structures usable in many industrial applications.

45 A still further object is utilisation of this composite structural member in the fabrication of access floor panels wherein the perimeter of said structural member has the outer edge portions formed at right angles to said member to provide a continuous bracing flange around the panel of a given finite size to provide a panel which can be selectively supported at the edges or corners thereof and which can accept substantial uniform or concentrated loads, such as those seen in access flooring applications.

50 A still further object of the invention is to provide an integral perimeter lip bent outward from said peripheral bracing flange to provide an additional connection between said member and said top sheet which is utilised as a stiffened lip by which the access floor panel can be selectively supported at the corners or along the perimeter to develop an access floor system in combination with pedestals and/or stringers.

55 A still further object of the invention is to provide said peripheral bracing flange with a greater transverse depth relative to said intermediate portion of said structural member between said projections, and in which said depth is greater than the height of said configurations and projections and a portion extending in the opposite direction from said configurations and projections and another portion extending in the same direction as said configurations and projections to provide a perimeter of increased strength and resistance to flexure, especially when utilised as an access floor panel without the use of secondary members, such as stringers or more complicated panel-to-panel hard connecting devices to prevent edge-to-edge movement.

60 Another object is to form said structural member in such manner that all surfaces of said configurations and projections and the junctures thereof with said intermediate structural stress

sections in the original plane of said sheet are free from sharp edges or bends whereby there are no areas or portions in said sheet which comprise corners or other shapes which normally tend to pucker or otherwise resist formation of smoothly stretched areas when formed from planar sheets and subjected to shaping by dies.

5 One further object of said invention is to provide a structural member which can be combined with a similar member and fixedly connected, end-to-end, to provide a composite core structure which can be utilised in industrial application, especially where high strength-to-weight ratio properties are desired and which do not necessarily require a flat planar sheet. Flat planar sheets may be added to this composite structure if desired.

10 Various other objects, features and attendant advantages of the present invention will be more fully appreciated as the same becomes better understood from the following detailed description when considered in connection with the accompanying drawings in which like reference characters designate like or corresponding parts throughout the several views, and wherein:—

Figure 1 is a plan view of a fragment of a structural member embodying the principles of the present invention in which one embodiment of dome-like pairs of projections combined with a saddle portion resembling a figure 8 in plan view are formed, said figure illustrating diagrammatically broken lines tracing arcuate structural stress sections of said member, which are ribbon-like.

Figure 2 is a fragmentary vertical sectional view of the structural member shown in Figure 1, as seen on the line 2—2 thereof.

20 Figure 3 is a fragmentary sections view similar to Figure 2 but showing the cross-section of the member shown in Figure 1, as seen on the line 3—3 thereof.

Figure 4 is a fragmentary sectional view of a panel embodying the structural member shown in Figures 1—3 but to which a fragmentarily illustrated section of a top planar sheet has been affixed and said illustration being on a larger scale than in the preceding figures.

25 Figure 5 is a fragmentary vertical sectional view similar to Figure 4 but illustrating another embodiment of reinforcing flange from that shown in Figure 4.

Figure 6 is a fragmentary bottom plan view of a corner of the panel illustrated in Figure 4 but shown on a smaller scale than employed in said Figure.

30 Figure 7 is a view similar to Figure 6 but showing a corner of the panel illustrated in Figure 5 and using a smaller scale than employed in Figure 5.

Figure 8 is a bottom plan view of one embodiment of structural panel and in which a pattern of the embodiment of configurations shown in Figure 1 combined with a plurality of projections circular in plan view is illustrated.

35 Figure 9 is a fragmentary vertical section illustrating a pair of the structural members of the embodiment illustrated in Figures 1—3 disposed in bottom-to-bottom relationship in which the outermost ends of the projections of said members abut and are connected together.

Figure 10 is a fragmentary diagrammatic plan view similar to Figure 1 and in which additional embossed ribs have been formed in the arcuate structural ribbon-like stress sections of the structural member in transverse relationship.

40 Figure 11 is a fragmentary vertical sectional view illustrating on a larger scale than in Figure 10 a sectional elevation of the embossed rib arrangement shown in Figure 10, as viewed from the line 11—11.

45 Figure 12 is a fragmentary exemplary plan view of still another embodiment of an arrangement of configurations formed in a structural member similar to the embodiments previously illustrated in Figure 1.

Figure 13 is a fragmentary vertical sectional view shown on a larger scale than in Figure 12 but illustrating a portion of the structural member shown in Figure 12, as seen on the line 13—13 thereof.

Figure 14 is a fragmentary sectional view of a structural unit similar to Figure 4 but in which the bracing flange is shown abutting the top sheet adaptable for direct connection thereto.

50 Figure 15 is a view similar to Figure 14 but in which the depth of the flange is greater than the height of the projections.

Figure 16 is a fragmentary plan view of a further embodiment similar to Figure 1 but in which additional protrusions are included within the stress sections.

Figure 17 is a fragmentary sectional view as seen on line 17—17 of Figure 16.

55 The most important part of the present invention comprises a one-piece structural member formed from a sheet of industrial material which preferably comprises metal, such as steel, for example, but for certain applications of the invention, other industrial material, such as certain plastics, may be employed. Particularly when made from metal, a sheet of such industrial materials is subjected to appropriate punches and dies respectively for forming a plurality of any one of a number of different shapes, kinds, and patterns of configurations and projections, details of which are described hereinafter, said configurations and projections preferably extending from one surface of the sheet of material and all the upper ends of said configurations and projections preferably being substantially within the same plane. Except for the integral edge construction which may be formed simultaneously from within said sheet, all surfaces of the major portion of the sheet are smoothly curved and are free from sharp angles
65 or bends which otherwise would comprise corners or other shapes which normally tend to pucker or

resist formation of smoothly stretched areas when formed from a planar sheet and subjected to shaping by such punches and dies. Except for the possibility of forming a limited number of holes or openings in the sheet, such as for the transmission of air in certain applications of the invention, the formed sheet is substantially imperforate.

5 To provide an understanding of certain terms used in the specification and claims of this application, the following definitions are set forth:—

1. Stress section—The portion of the structural member between the projections designed to withstand tensile and compressive stresses.

2. Structurally strategic geometric pattern—the dimensional relationship and orientation of
10 projections in which the following five major characteristics are strategically interrelated:—

- (1) depth of projection for needed section modulus and moment of inertia;
- (2) diameter of projections to obtain needed depth;
- (3) distance between the centrelines of projections for adequate top sheet support;
- 15 (4) strategic positioning of projections to repeatedly block clear lines of vision throughout the member;
- (5) remaining bottom surface material adequate to perform as a stress member and also provide necessary section modulus and moment of inertia.

3. Structural unit—a unit of two or more members, which when combined provide a substantial
20 increase in section modulus and strength-to-weight ratio over these same properties of the individual members.

4. Substantially hemispherical dome-like projections—projections having radiused contours in all directions of one or a combination of radii to provide arches for top sheet support and to develop optimum height for increased section modulus.

5. Fixedly secured—any means causing two members to work together as a composite unit, such
25 as welding, riveting, use of structural adhesives, direct fusion or other known methods.

6. Optimisation of support—providing specific density of projections in a base sheet of material, such that they prevent localised indentation of the top sheet when used as a composite unit, providing frequency of load transfer from the top sheet to the structural member and minimising top sheet
30 thickness while optimising strength-to-weight ratio of the unit.

7. Straight lines of vision—visible longitudinal openings providing direct open paths through a composite section around which the section can bend or flex and through a member around which the member can flex. Increased frequency of blockage is directly proportional to increased resistance to flexure.

8. Rhombus pattern—geometric pattern of an equilateral parallelogram having oblique angles
35 wherein the centres of the projections are located at corners of a rhombus.

9. Basket weave orientation—the combination of patterns of pairs of projections or elongated configurations interlaced or intermeshed and in which one pattern is perpendicular to an adjacent pattern so that a straight line of sight therebetween is intercepted, thus providing a unique pattern of
40 location and density for sufficient top sheet support and optimum strength-to-weight ratio.

10. Saddle portion—material unrestrained by the die during pressing, located between two dome-like projections in an elongated configuration, which is unrestricted at the original plane of the member, and is naturally stretched down between the projections usually to a depth less than, but may be equal to, the depth of the projections. When depth of the saddle portion is made equal to the depth
45 of projections as when formed with a die, the saddle portion provides additional top sheet support.

11. Elongated configuration—a combination of two or more projections with the saddle portion extending between said projections, and resembling at least a figure 8, peanut-like in shape.

12. Arcuate structural stress members—stress members between said projections of the sheet, sinuous in shape and held in their configuration when under stress by the circular ends of the
50 projections acting to resist deformation and tendency to straighten.

13. Continuous bracing flange—the edge termination of a member of finite size and perpendicular thereto which provides continuous built-in means of edge stiffening.

14. Peripheral lip—the return of the outermost edge portion of the continuous bracing flange to dispose it in the same plane as the terminal ends of said projections and when affixed to a top sheet
55 provides a means of selectively supporting a panel at the corners and/or edges thereof.

15. Greater transverse depth—additional depth provided at the edge termination of a member of finite size, said depth being deeper than said projections and providing added edge stiffness.

16. Isotropic—load-resisting properties of a composite unit having substantially the same values when measured along axes in all directions and which is substantially free from directional weakness
60 when the unit is penetrated by holes, cut-outs, and the like.

17. Structural efficiency—the efficient design and utilisation of structural components in such a way as to permit the use of shallower sections and thinner materials in lieu of deeper sections and heavier materials while developing equal or better moment of inertia and/or more balanced section modulus. Relative structural efficiencies of two units expressed as a percentage, said units under the
65 same load and support conditions is determined by the following formula:—

$$\frac{\text{Deflection Unit 1}}{\text{Deflection Unit 2}} \times \frac{\text{Mass weight Unit 1}}{\text{Mass weight Unit 2}} \times \left(\frac{\text{Section depth Unit 1}}{\text{Section depth Unit 2}} \right)^2 \times 100$$

5 18. Hoop stress—tensile or compressive stress in a circular member acting circumferentially. Because of symmetry of the member, there is no tendency for any part of the circumference to depart from the circular form under load as long as the hoop stress remains below the yield point of the material.

10 19. Directional weakness—appreciable loss of strength in a structural unit caused by planes of flexural weakness that are developed by penetration of said structural unit and around which planes the unit readily flexes relative to flexure in other directions.

20. Strength-to-weight ratio—ratio of the mathematical product of deflection times mass for one unit compared to the same ratio for a second unit. The strength-to-weight ratio is used to determine minimum weight consistent with the geometry of the unit required to maintain the integrity of the unit to resist flexure. Relative strength-to-weight ratios of two units expressed as a percentage, said units being under the same load and support conditions, is determined by the following formula:—

$$\frac{\text{Deflection Unit 1}}{\text{Deflection Unit 2}} \times \frac{\text{Mass weight Unit 1}}{\text{Mass weight Unit 2}} \times 100$$

Referring to Figure 1, there is shown therein a fragmentary section of a sheet 10 of structural material, which initially is planar and the same is subjected to a set of dies to form therein a plurality of projections 12 which, as will be seen from Figures 2 and 3, are dome-shaped, are substantially hemispherical in cross-section, arranged in pairs and connected by a saddle portion 38 which as shown in cross-section in Figures 2 and 3 does not usually project as far from the original plane of sheet 10 as the pair of projections 12. From Figure 1 it will be seen that the resulting elongated configuration 40 in plan view closely resembles a figure 8, peanut-like shape. This arrangement provides one embodiment of configurations which adapts itself to being disposed in patterns, such as shown in one exemplary manner in Figure 1, in which said configurations are in close relationship to each other, the end of one configuration 40 interfits with the adjacent configurations 40, thereby repeatedly blocking straight lines of vision laterally in all directions across sheet 10. Further, said projections which form the pairs which resemble a figure 8 are arranged in said sheet in a structurally strategic geometric pattern of which rows of pairs of equally-spaced in-line projections are interwoven perpendicularly in basket weave fashion, and as further illustrated diagrammatically by broken lines in Figure 8, the portions of a centreline of a row of pairs that lies between two aligned pairs bisecting the pairs thereof in rows transverse thereto. Said projections are spaced a limited distance from each other so as to provide therebetween sections of the original sheet which are arcuate as indicated by the exemplary somewhat sinuous diagrammatic line 14, which outlines the intermediate continuous planar structural ribbon-like stress sections 16 of the original sheet 10.

It will also be observed from Figure 1 that the projections 12 are arranged in said sheet in such manner that only a limited number, such as pairs of evenly-spaced projections, are disposed in what might be considered a straight line and, preferably, the projections are disposed in patterns in which a preferred arrangement, such as perpendicular basket weave configuration, shown diagrammatically in Figure 8, which also constitutes rhombus configurations denoted by the diagrammatic figures 18 as shown in Figure 16, which in turn, extend between the centres of the projections 12. It will also be seen that said patterns touch each other at points, whereby the illustration clearly shows the relatively saturated occurrence of the projections 12 within the sheet 10, while at the same time, permitting the occurrence of the intermediate stress sections 16 between the individual, adjacent projections 12. Most importantly, however, it will be seen that the patterns 18 of the projections 12 comprise a structurally strategic geometric pattern of a density which repeatedly blocks straight lines of clear vision in all directions across the sheet and thereby, in accordance with a major objective of the present invention, this feature provides maximum rigidity to the structural member comprising sheet 10 with the configurations 40 and projections 12 formed therein due to the inter-relationship of the diameter of the projections and the centre-to-centre distance between adjacent projections.

Another advantage of forming the projections 12 in dome-like configuration of a thickness no greater than that of the original sheet is that the same are readily capable of being formed to a substantial height from the original plane of the sheet 10 in which, for example, the intermediate stress sections 16 are disposed as shown in an exemplary manner in Figure 4 and also in Figure 5, whereby the uppermost portions of the projections 12 are thinner than the lower portions thereof, while the intermediate stress sections 16 preferably retain optimum material, thereby providing maximum stress-resisting capabilities. Further, the formed structural member comprising the sheet 10 with the configurations 40 formed therein may be produced by a simple form die arrangement. The shape of the projections 12 also is capable of being formed without rupture or shearing and, it desired, the resulting product may be imperforate. However, particularly when the structural member is employed in either a

structural unit or finished structural panel through which, for example, cable cut-outs or the like are desired, the structural member per se may be provided with suitable openings of limited diameter in appropriate locations through both the intermediate stress sections 16 or the outer ends, for example, of the projections 12, when desired, without detracting from the stress-resisting capabilities of the structural member, due to the isotropic properties of the unit.

In most applications of the invention, the structural member comprising the sheet 10 and the configurations 40 formed therein is combined with a second planar sheet 20. Due to the fact that the upper ends of the projections 12 are substantially within a common plane, when the sheet 20 is abutted commonly with said outer ends of the projections 12, it may be secured to said upper ends by any appropriate means, such as welding, rivets, industrial adhesives, direct fusion, or any other known means of suitable nature, by which the planar sheet 20 is fixedly connected to said projections 12. This results in producing a structural unit which finds a most useful application when formed into a composite panel, several preferred embodiments of which are illustrated fragmentarily respectively in Figures 4 and 5 in vertical section and, correspondingly, and respectively in Figures 6 and 7, in which fragmentary corners of a composite structural panel 22 of one embodiment, and a second embodiment 24 thereof, as shown in bottom plan view.

To form said composite panel, the edges of a finite shape and size of the sheet 10 with the configurations therein are bent upwardly at a right angle to form a reinforcing bracing flange 26 which has the same vertical dimension as the height of the projections 12 and, additionally, in the embodiments shown in Figures 4—8, the terminal edge portion of the bracing flange 26, which is continuous around all four sides of the composite panel, is bent outwardly at a right angle thereto to form preferably a continuous lip 28, the upper surface of which is in a plane common with that of the upper ends of the projections 12, whereby the second planar sheet 20 commonly abuts the upper surface of the lip 28 and the upper ends of all of the projections 12, it being understood that the planar sheet 20 also will be of substantially the same finite shape and size as that of the embodiment of structural member 30 to which it is fixedly connected.

As can be visualised from the illustration of the occurrence of the configurations 40 within the sheet 10 of the structural member 30, especially as seen from Figure 1, there is very frequent support afforded the second planar sheet 20, whereby a sheet of substantially reduced thickness may be utilised and still permit the same to afford resistance to indentation even by localised loads when applied to the planar sheet 20 of the composite structural panel 22 and the structurally strategic geometric pattern which embodies the unique relationship between the diameter of the projections and the centre-to-centre distance therebetween so as to provide increased resistance to deflection relative to strength-to-weight ratio and structural efficiency, even when subjected to substantial loads of either a uniform or concentrated nature.

Referring to Figures 5 and 7, the composite structural panel 24 shown therein is similar to the panel shown in Figures 4 and 6, except that the bracing flange 32 thereof is of a greater depth than the height of the projections 12 of the configurations 40 and is formed by means of depressing the peripheral sections 34 of the additional embodiment of structural member 36 from the remaining portions of the basic sheet 10 in a direction opposite to that from which the projections 12 extend, thereby producing a portion which extends oppositely to projections 12 and wherein said bracing flange 32 extends in the same direction as the projections 12 and is of greater vertical dimension than the flange 26 in the embodiment of Figure 4. The resulting composite structural panel 24, shown in Figures 5 and 7, particularly adapts this embodiment of structural panel to provide support, especially by the corners thereof. This eliminates the need for supporting stringers between suitable pedestals, which, for example, are required in an elevated floor such as a so-called access floor in which a plurality of such structural panels are employed as floor panels and, under which circumstances, many available structural panels presently in use do not have the required rigidity along the edges thereof.

Notwithstanding the fact that the intermediate stress sections 16 of the embodiments of the invention shown in the foregoing figures are arcuate and somewhat sinuous in plan view, said stress sections are maintained in said configuration and are capable of not being moved therefrom when subjected to stress due to the fact that the circular configuration of the projections 12 in cross-section converts load stress to hoop stress adjacent to the opposite sides of said stress section. It is well known that a circular hoop is the strongest configuration for resisting deformation from its original shape when forces are supplied radially around the circumference thereof. As can be seen, especially from Figure 1, the arcuate intermediate stress sections 16 extend substantially around all sides of the circular projections 12 and thereby utilise the hoop stress property of such projections advantageously for the stated purpose with respect to the stress sections 16.

Further, the major portion of the perimeters especially the perimeters of the opposite end portions of the configurations 40, are circular in plan view, thereby providing the aforementioned hoop stress which serves to maintain the intermediate stress sections 16. This is represented by the diagrammatic lines 14 in Figure 1 which illustrate the sinuous shape thereof even when the sheet 10 is subjected to loads.

A more comprehensive concept of the several embodiments of composite panels is represented and illustrated in the several embodiments shown in the preceding figures. Attention is directed to

Figure 8, in which the composite structural panels 22 and 24 are shown in bottom plan view, which correspond to the fragmentary vertical sections thereof, respectively, shown in Figures 4 and 5.

Referring now to Figure 10, in which a fragmentary portion of the structural sheet 10 is specifically shown with elongated configurations 40 formed therein, the arcuate intermediate stress sections 16 may have the effectiveness thereof increased by forming in at least certain of said sections 16 an additional embossed rib 56, several of which are illustrated in an exemplary manner in Figure 10, and also in cross-section in Figure 11, the latter figure being on a larger scale than that used in Figure 10. The embossed ribs 56 generally follow the shape of the arcuate, ribbon-like intermediate stress sections 16. Although only a pair of the ribs 56 are shown in outline pattern in Figure 10 in intersecting relationship, it is to be understood that any desired number of such additional reinforcing ribs may be employed, as desired, especially in relation to the rigidity required, commensurate with the thickness of the sheet 10 and the shape and spacings of the projections extending therefrom.

Still another embodiment of patterns of projections which may be employed in accordance with the principles of the invention is illustrated in Figures 12 and 13, in which a fragmentary section of a sheet of structural material 10 is shown, and this particular illustration embodies a mixture of different shapes of configurations and projections which are more extensively illustrated in certain of the preceding figures, and also the circular configurations 12, which similarly, are illustrated more extensively in certain of the preceding figures.

In addition to these previously described configurations and projections, however, the embodiment shown in Figures 12 and 13 also include a still further projection comprising a section 58, which is drawn from the original plane of the structural sheet 10, the drawn section 58 being of the same depth with respect to sheet 10, as the configurations 40 and the projections 12, the same being surrounded in a pattern of such projections and configurations but in a manner so that the entire pattern repeatedly blocks straight lines of clear vision between any of the sides of the structural member when viewed along a plane parallel to the intermediate stress sections 16.

Still another embodiment of the invention is illustrated in Figures 14 and 15 with regard both to structural members 30 and 34 and similar structural members 42 and 44, as well as to the composite structural panels 22 and 24 in which they respectively are included. This embodiment comprises terminating the bracing flanges 26 and 28 in these respective structural members and composite structural panels at the upper ends and omit the lips 28 thereon, thus butting the upper ends of the flanges directly against the adjacent surfaces of the top planar sheets 20 in said members and panels and connecting said upper ends of the flanges fixedly to the perimeters of said top planar sheets which also terminate at the vertical plane of the outside surfaces of said bracing flanges, as clearly shown in Figures 14 and 15. Under such circumstances, when the structural panels thus formed are used in an access floor, the outer surfaces of said bracing flanges of adjacent panels closely interfit in the overall access floor.

Still a further embodiment of the invention is illustrated in Figures 16 and 17, and similarly to the embodiment illustrated in Figures 10 and 11, increases the effectiveness of the arcuate intermediate stress sections 16. Specifically, additional protrusions 60 are formed in stress sections 16 between configurations 40 and of less height than projections 12. As previously discussed in reference to Figure 8, projections 12 are positioned in a manner that form rhombus configurations denoted by diagrammatic figures 18. The additional protrusions 60 are preferably positioned in the centre of the squared areas 62 between the rhombus patterns 18 and are sized so as to retain a planar portion of each stress section 16, said portions being located between protrusions 60 and projections 12 forming the corners of the squared areas 62. The acceptance of tension and compression stresses by stress sections 16 are, therefore, substantially unaffected by the inclusion of protrusions 60 since the stresses are resisted by being distributed around the protrusions 60. At the same time, the section modulus of the sheet can be increased with an attendant gain in rigidity.

The embodiment of Figures 16 and 17 can be advantageous in specialised applications requiring a small but, nevertheless increased rigidity of the embodiment of Figure 8, but could be undesirable if the application was such that an increased section depth was undesirable. By way of example and with reference to Figure 14, if protrusions 60 were formed in stress sections 16 and extended from the sheet in a direction opposite to the projections 12, the increased thickness of the sheet might render it undesirable in those installations requiring small clearance between sub-floor and panel.

From the foregoing, it will be seen that the present invention provides a plurality of embodiments of structural members and composite structural panels which include the same and in which such panels are relatively of light weight and embody optimisation of support by utilising the most effective strength-to-weight ratio and structural efficiency and embodying maximum resistance to deflection, as well as resistance to indentation of the planar top sheet of such panels due to the frequency of structural support therefor by projections in the structural members included therein. For maximum support of the planar sheets 20 by projections 12 in the sheet 10, it will be seen in the various illustrated embodiments that additional single projections not comprising parts of pairs thereof or of the basket weave patterns or rhombus configurations are included in the sheets 10 and are similar to the projections in the patterns thereof to occupy areas of sheet 10 which would otherwise not offer desired support to the planar sheets 20 of the composite structure and structural units of the invention.

To demonstrate the significantly improved characteristics and performance of the present invention, comparisons have been made with access floor panels disclosed in prior art and which are commercially available. Comparisons have been made on a "strength-to-weight" basis, and a "structural efficiency ratio" basis, both described more fully below. Of existing prior art panels, there are some which have comparable resistance to flexure when loaded either at the centre of the panel and/or at the midspan of the perimeter, but which require significantly greater material by weight and/or depth of section. For prior art panels to have comparable performance, they would require additional material and/or greater depth of section, through demonstrating lower structural efficiency which is needed to develop required moment of inertia. By combining material mass weight savings, thinner depth of section, and deflection performance, the panels of the present invention demonstrate a marked improvement in actual structural efficiency. In some instance, the improvement is in excess of 150%.

Strength-to-weight ratio, in the context of the present invention, is used to related deflection under a given load to the mass weight of the material. Expressed as the following formula:

$$\frac{\text{Deflection of Unit \#1}}{\text{Deflection of Unit \#2}} \times \frac{\text{Mass Weight Unit \#1}}{\text{Mass Weight Unit \#2}} \times 100$$

the result is a numerical performance ratio, expressed as a percentage of access floor unit #1 (prior art) to access floor unit #2 (present invention).

Data employed in the formula for the present invention is an average of 3 random samples taken from a test run, and data for panels of the prior art is derived from sample panels available on the market.

The "structural efficiency ratio" is a comparative ratio that relates deflection, mass weight, and section depth. In essence, it is a measure of the efficiency of the panel section in its utilisation of the mass of the material. Expressed as the following formula:

$$\frac{\text{Deflection Unit \#1}}{\text{Deflection Unit \#2}} \times \frac{\text{Mass Weight Unit \#1}}{\text{Mass Weight Unit \#2}} \times \left(\frac{\text{Section Depth Unit \#1}}{\text{Section Depth Unit \#2}} \right)^2 \times 100$$

the result is a numerical structural efficiency ratio, expressed as a percentage of access floor unit #1 (prior art) to access floor unit #2 (present invention). As before, the data employed in the formula for the present invention is an average of three sample panels taken from a test run and the data for the prior art panel is derived from sample panels available on the market.

The test method was identical for all panels tested. Three panels were selected at random from a test run of panels of the present invention and were tested along with commercially available sample panels available on the market. Each panel was placed on rigid pedestal supports without the use of edge stringers. Concentrated loads of identical magnitude were applied to the centre of the panel and at mid-span of the perimeter. Deflection readings were recorded from the bottom of the panel directly under the load. All panels were reloaded with deflection recorded again. On each loading sequence, the permanent set was also recorded.

The following chart expresses relative "strength-to-weight" and "structural efficiency" ratios. The differences in these parameters are stated as a percentage improvement of the performance of panels of the present invention. Note that the present invention had performances superior to prior art panels and/or panels presently available on the market. As a base, the average weight of the panels of the present invention was 9.2 kg.

As can be seen from the data, the present invention demonstrates a dramatic improvement in structural efficiency and strength-to-weight ratios over all available prior art panels and panels currently being marketed. The present invention offers a reduction in material usage over all panels to which it was compared. It provides improved resistance to flexure when loaded and utilised as an access floor panel.

The foregoing specification illustrates preferred embodiments of the invention. However, concepts employed may, based upon such specification, be employed in other embodiments without departing from the scope of the invention. Accordingly, the following claims are intended to protect the invention broadly, as well as in the specific forms shown herein.

Model or name	Ref. patent no.	Industry identification	Sample panel weight	Edge		Center	
				Strength-to-weight ratio	Structural efficiency ratio	Strength-to-weight ratio	Structural efficiency ratio
Mark 30	3,696,578 to Swenson Oct. 10, 1972	Liskey Architectural	11.7 Kg	30.1%	20.3%	2.3%	75.2%
Mark 40	3,696,578 believed to be to Swenson Oct. 10 1972	Liskey Architectural	9.87 Kg	8.6%	17.0%	56.8%	182.4%
Model 50	Non-determined	Donn Products	11.1 Kg	73.2%	57.8%	67.0%	193.8%
Mult-A Frame	Similar to 2,391,997 to Noble Jan. 1, 1946	Mult-A-Frame	11.1 Kg	69.1%	35.0%	49.0%	129.6%
Waco-Plate	3,258,892 to Rushton July 5, 1966	Washington Aluminium	14 Kg	183.6%	77.5%	109.8%	153.3%

Claims

1. A structural member comprising a one-piece rigid member formed from a sheet (10), of structural material having formed therefrom a plurality of similar, elongated dome-like projections (40) extending from the plane of the said sheet, being arranged in a substantially perpendicular basket weave pattern having a strategic dimensional relationship between the dimensions of said projections and the distances therebetween such that the projections repeatedly block straight lines of vision laterally in all directions across said sheet, said one-piece member being capable of resistance to flexure, characterised in that said elongate projections (40) each comprise two substantially hemispherical portions (12) connected by a saddle portion (38) forming a generally figure 8 configuration, and that portions of said member (10) which are intermediate said elongate projections (40) comprise continuous structural ribbon-like stress sections of fluctuating width and which are arcuate in plan view and capable of optimising stress-resisting integrity of said structural member.
2. A structural member according to Claim 1, characterised in that the elongate projections (40) are arranged in a structurally strategic geometric pattern, in which rows of equally spaced pairs of in-line projections (40) are interwoven perpendicularly with other such rows of pairs in a basket weave fashion so that the portion of a centreline of a row of pairs of projections (40) that lies between two aligned pairs bisects the pairs thereof in transverse rows and has sufficient pattern density to block straight lines of clear vision repeatedly in all directions across said sheet (10).
3. A structural member according to Claim 1, characterised in that at least a majority of said projections (40) in plan view are also combined in groups of four arranged in a rhombus pattern and adjacent rhombus patterns are positioned in a close perpendicular basket weave orientation, thereby locating said projections to repeatedly block said clear lines of vision as aforesaid.
4. A structural member according to Claim 1, characterised in that stiffening protrusions (60) are formed in said sheet within the areas between said rhombus patterns of projections to a depth less than the depth of said projections.
5. A structural member according to Claim 1, characterised in that said elongated projections (40) are in close proximity to each other within said pattern and in which additional projections (12'), circular in cross-section, are combined in said sheet so as to repeatedly block straight lines of clear vision across said sheet in all directions through said pattern of configurations and projections.
6. A structural member according to Claim 5, characterised by further including at least one section (58) drawn from the original planar sheet in the same direction as said elongate projections from said sheet, said sections having an area larger than said projections and surrounded in said pattern by additional projections, circular in plan view, and wherein the arrangements of said elongate and

circular projections and drawn section or sections of said entire pattern are designed so as to repeatedly block straight lines of clear vision across said sheet in all directions through said pattern.

7. A structural member according to Claim 1, characterised in that all surfaces of said elongate projections and the junctures thereof with said intermediate structural stress sections in said original plane of said sheet are free from sharp angles or bends, whereby there are no areas or portions in said sheet which comprise corners or other shapes which normally tend to pucker or otherwise resist formation of smoothly stretched areas when formed from a planar sheet and subject to shaping by dies.

8. A structural member according to Claim 1, characterised by further comprising a second structural member (20) wherein outer ends of said projections of each of said structural members are fixedly attached to form a composite structural unit capable of resistance to flexure with said projections serving as arches to resist flexure and the hemispherical shape of said projections providing resistance to collapse thereof.

9. A structural member according to Claim 1, characterised in that said structural material comprises steel.

10. A composite structural unit comprising a one-piece rigid structural member formed from a sheet (10) of structural material having formed therein a plurality of similar, elongated dome-like projections (40) of no greater thickness than said sheet and extending from the plane of said sheet, being arranged in a substantially perpendicular basket weave pattern having a strategic dimensional relationship between the dimensions of said projections and the distances therebetween and of which, in plan view, the end of one projection interfits with adjacent projections (40), combined with additional projections (12') circular in cross-section, thereby repeatedly blocking straight lines of vision laterally in all directions across said sheet to form said one-piece rigid structural member being capable of resistance to flexure, characterised in that said elongated projections each comprise two substantially hemispherical portions (40) connected by a saddle portion (38) forming a generally figure 8 configuration, and that portions of said member (10) which are intermediate said elongate projections (40) and said additional circular projections (12') comprise continuous structural ribbon-like stress sections of fluctuating width and which are arcuate in plan view and capable of optimising stress-resisting integrity of said structural member (10) such that sections extending between opposite edges of said sheet are capable of maintaining resistance to the load stresses throughout said structural member and also capable of being maintained in the stated shape thereof when under stress by the projections preventing movement thereof, and further characterised by having a planar sheet (20) fixedly secured to the outer terminal ends of said projections and connected to said structural member, thereby forming said composite structural unit in which the optimisation of support versus strength-to-weight ratio and structural efficiency is achieved, whereby when said planar sheet (10) is subject to loading, said projections (40, 12') serve as arches to resist flexure and the hemispherical shape of said projections (40, 12') providing resistance to collapse thereof.

11. A structural unit according to Claim 10, characterised in that the pattern of said projections (40, 12) and the formation thereof from said sheet produce a resistance to flexure in said structural unit which is substantially isotropic when said unit is penetrated by an opening of limited cross-section located inward from the edges thereof, thereby substantially retaining its resistance to flexure without directional weakness due to the resulting stresses in said unit when under load being redirected around said opening.

12. A structural unit according to Claim 10, characterised in that at least the majority of said elongated projections (40) in plan view are also combined in groups of four arranged in a rhombus pattern with adjacent rhombus patterns being positioned in close perpendicular basket weave orientation, thereby locating said projections (40) to repeatedly block said clear lines of vision as aforesaid.

13. A structural unit according to Claim 12, characterised in that it comprises stiffening protrusions (60) formed in said sheet within the areas between said rhombus patterns of projections (40) to a depth less than the depth of said projections.

14. A structural unit according to Claim 10, characterised in that it comprises at least one drawn section (58) formed from the original planar sheet in the same direction as said elongated projections (40) from said sheet, such drawn section (58) having an area larger than said projections (40) and surrounded in said pattern by additional projections (12), circular in plan view, the arrangement of said projections (40, 12) and drawn section (58) of said entire pattern being designed so as to repeatedly block straight lines of clear vision across said sheet in all directions through said pattern.

15. A structural unit according to Claim 10, characterised in that it comprises a rib (56) extending from within said arcuate members to further increase the rigidity of said structural unit to resist flexure under stress.

16. A structural unit according to Claim 10, characterised in that said structural unit is of a given finite size and further comprising portions of said original planar material including a peripheral edge extending at right angles to said planar material to form a continuous bracing flange (32) around the periphery of said structural unit, and means fixedly connecting said planar sheet to said bracing flange wherein upper surfaces of upper ends of said projections (40) form a rigid panel constructed to be

supported selectively at the edges or corners thereof which is capable of sustaining substantial uniform or concentrated loads without appreciable deflection or permanent set.

17. A structural unit according to Claim 16, characterised in that said peripheral bracing flange (32) has a greater transverse depth than the height of said projections (40) and provides a perimeter of increased strength, said perimeter having one portion (34) extending in the opposite direction to said projections (40) relative to the original plane of said sheet and further comprising an additional portion extending in the same direction as said projections (40) from said original plane of said sheet.

18. A structural unit according to Claim 17, characterised in that outer extremities of said edge portions of said formed bracing flange (32) are also bent outward at a right angle to said flange (32) to form a peripheral lip (28) parallel to the plane of said intermediate portions of said member between said projections (40), and further comprising means fixedly connecting said peripheral lip (28) to said planar top sheet (20).

19. A structural unit according to Claim 17, characterised in that said additional portion terminates in a flange bent outward at a right angle to said additional portion to form a peripheral lip (28) parallel to the plane of said intermediate portions of said member between said projections (40), and further comprising means fixedly connecting said peripheral lip (28) to said planar top sheet (20).

20. A structural unit according to Claim 10, characterised in that said structural material and said planar sheet (20) comprise steel.

21. A structural unit according to Claim 20, characterised in that said planar sheet (20) is secured to said outer terminal ends of said projections (40) by welding.

Revendications

1. Un élément structurel comprenant un élément rigide d'une seule pièce formé à partir d'une feuille (10) de matière structurelle dans laquelle sont formées une pluralité de protubérances analogues allongées (40) en forme de dôme, qui sont saillies sur le plan de ladite feuille, sont arrangées dans un dessin d'entrelacement de vannerie sensiblement perpendiculaire qui présente une relation dimensionnelle stratégique entre les dimensions desdites protubérances et les distances qui les séparent telle que les protubérances obstruent répétitivement les lignes de vision rectilignes latéralement dans toutes les directions d'un bord à l'autre de la feuille, ledit élément d'une seule pièce étant capable de résistance à la flexion, caractérisé en ce que lesdites protubérances allongées comprennent chacune deux portions (12) sensiblement hémisphériques reliées par une portion en ensellement (38) pour former une configuration de la forme générale du chiffre 8 et en ce que des portions dudit élément (10) qui sont intermédiaires entre lesdites protubérances allongées (40) constituent des sections de contrainte structurelles continues en forme de ruban, de largeur fluctuante et qui sont incurvées dans une vue en plan et capables d'optimiser l'intégrité de résistance à la contrainte dudit élément structurel.

2. Un élément structurel suivant la revendication 1, caractérisé en ce que les protubérances allongées (40) sont agencées dans un dessin géométrique structurellement stratégique dans lequel des rangées de paires également espacées de protubérances (40) en lignes sont entrelacées perpendiculairement avec d'autres rangées de paires dans un mode d'entrelacement de vannerie de sorte que la portion de l'axe d'une rangée de paires de protubérances (40) qui se trouve entre deux paires alignées bissecte les paires de protubérances des rangées transversales et en ce que les protubérances possèdent une densité de dessin suffisante pour obstruer répétitivement les lignes droites de vision dégagée dans toutes les directions d'un bord à l'autre de ladite feuille (10).

3. Un élément structurel suivant la revendication 1, caractérisé en ce qu'au moins la majorité des protubérances (40), considérées dans une vue en plan, sont également combinées en groupes de quatre agencés en un dessin en losange et en ce que les dessins en losange adjacents sont positionnés dans une orientation d'entrelacement de vannerie perpendiculaire serré, en positionnant ainsi lesdites protubérances de manière à obstruer répétitivement lesdites lignes de vision dégagée comme indiqué plus haut.

4. Un élément structurel suivant la revendication 1, caractérisé en ce que des protubérances raidisseuses (60) sont formées dans ladite feuille, dans les zones situées entre les dessins en losange de protubérances, à une profondeur inférieure à la profondeur desdites protubérances.

5. Un élément structurel suivant la revendication 1, caractérisé en ce que lesdites protubérances allongées (40) sont à proximité immédiate l'une de l'autre dans ledit dessin et en ce que des protubérances additionnelles (12') circulaires en section transversale sont combinées dans ladite feuille de façon à obstruer répétitivement les lignes droites de vision dégagée d'un bord à l'autre de la feuille dans toutes les directions à travers ledit dessin de configurations étirées de protubérances.

6. Un élément structurel suivant la revendication 5, caractérisé par le fait qu'il comprend en outre au moins une section (58) étirée à partir de la feuille plane d'origine dans le même sens que lesdites protubérances allongées sont tirées de ladite feuille, lesdites sections ayant une surface plus grande que lesdites protubérances et étant entourées dans ledit dessin par des protubérances additionnelles, circulaires dans une vue en plan et en ce que les arrangements desdites protubérances allongées et circulaires et de la section ou des sections étirée(s) dudit dessin complet sont conçus de manière à

obstruer répétitivement des lignes droites de vision dégagée d'un bord à l'autre de ladite feuille dans toutes les directions à travers ledit dessin.

7. Un élément structurel suivant la revendication 1, caractérisé en ce que toutes les surfaces desdites protubérances allongées ainsi que les jonctions entre ces protubérances et lesdites sections de contrainte structurelles intermédiaires contenues dans ledit plan d'origine de ladite feuille sont exemptes d'angles au plis vifs, de sorte qu'il n'y a pas dans ladite feuille de zones ou portions qui comprennent des angles ou autres formes qui tendraient normalement à plisser ou à résister d'une autre façon à la formation de surfaces tendues lisses lorsqu'elles sont formées à partir d'une feuille plane et soumises à une mise en forme au moyen d'outils.

8. Un élément structurel suivant la revendication 1, caractérisé par le fait qu'il comprend en outre un deuxième élément structurel (20) les extrémités extérieures desdites protubérances de chacun des éléments structurels étant réunies de façon fixe pour former une unité structurelle composite capable de résistance à la flexion, lesdites protubérances servant de voûtes pour résister à la flexion et la forme hémisphérique desdites protubérances donnant de la résistance à l'écrasement de celles-ci.

9. Un élément structurel suivant la revendication 1, caractérisé en ce que ladite matière structurelle est l'acier.

10. Une unité structurelle composite comprenant un élément structurel rigide d'une seule pièce formé à partir d'une feuille (10) de matière structurelle dans laquelle sont formées une pluralité de protubérances analogues allongées (40) en forme de dôme, d'épaisseur non supérieure à celle de ladite feuille et qui font saillie sur le plan de ladite feuille, sont agencées suivant un dessin d'entrelacement de vannerie sensiblement perpendiculaire qui présente une relation structurelle stratégique entre les dimensions desdites protubérances et les distances qui les séparent, l'extrémité d'une protubérance, considérée dans une vue en plan, s'ajustant avec les protubérances adjacentes (40) en combinaison avec des protubérances additionnelles (12') circulaires en direction transversale, en obstruant ainsi répétitivement les lignes droites de vision latéralement dans toutes les directions d'un bord à l'autre de ladite feuille, pour former ledit élément structurel rigide d'une seule pièce capable de résistance à la flexion, caractérisée en ce que lesdites protubérances allongées comprennent chacune deux portions sensiblement hémisphériques (40) reliées par une portion en ensellement (38) pour former une configuration de la forme générale du chiffre 8, et en ce que des portions dudit élément (10) qui sont intermédiaires entre lesdites protubérances allongées (40) et lesdites protubérances circulaires additionnelles (12') constituent des sections de contrainte structurelles continues en forme de ruban de largeur fluctuante et incurvées dans une vue en plan et capables d'optimiser l'intégrité de la résistance à la contrainte dudit élément structurel (10), de telle manière que des sections s'étendant entre des bords opposés de ladite feuille soient capables de conserver la résistance aux contraintes de charge sur toute l'étendue dudit élément structurel et également capables de rester maintenues dans leur forme indiquée lorsqu'elles sont sous contrainte, par les protubérances qui les empêchent de se déplacer, et caractérisée en outre par le fait qu'elles possèdent une feuille plane (20) réunie de façon fixe aux extrémités terminales extérieures desdites protubérances et assemblés audit élément structurel, pour fermer ladite unité structurelle composite dans laquelle on obtient l'optimisation du support relativement au rapport solidité-poids et à l'efficacité structurelle, de sorte que, lorsque ladite feuille plane (10) est soumise à une charge, lesdites protubérances (40, 12') servent de voûtes pour résister à la flexion et la forme hémisphérique desdites protubérances (40, 12') assure la résistance de celles-ci à l'effondrement.

11. Une unité structurelle suivant la revendication 10, caractérisée en ce que le dessin desdites protubérances (40, 12) et la formation de ces protubérances à partir de ladite feuille engendrent dans ladite unité structurelle une résistance à la flexion qui est sensiblement isotrope lorsque la dite unité est pénétrée par une ouverture de section transversale limitée située à l'intérieur par rapport à ses bords, cette unité conservant ainsi sensiblement sa résistance à la flexion sans faiblesse directionnelle grâce au fait que les contraintes résultantes engendrées dans ladite unité lorsqu'elle est sous charge sont redirigées autour de ladite ouverture.

12. Une unité structurelle suivant la revendication 10, caractérisée en ce qu'au moins la majorité des dites protubérances allongées (40), considérées dans une vue en plan, sont également combinées en groupes de quatre disposés dans un dessin en losange, les dessins en losanges adjacents étant positionnés dans une orientation d'entrelacement de vannerie perpendiculaire serré, en positionnant de cette façon lesdites protubérances (40) de manière à obstruer répétitivement lesdites lignes de vision dégagée comme indiqué plus haut.

13. Une unité structurelle suivant la revendication 12, caractérisée en ce qu'elle comprend des protubérances raidisseuses (60) formées dans ladite feuille dans les zones situées entre lesdits dessins en losange de protubérances (40) à une profondeur inférieure à la profondeur desdites protubérances.

14. Une unité structurelle suivant la revendication 10, caractérisée en ce qu'elle comprend au moins une section étirée (58) formée à partir de ladite feuille plane d'origine dans le même sens que lesdites protubérances allongées sont formées à partir de ladite feuille, ladite section étirée (58) ayant une plus grande surface que les protubérances (40) et étant entourée dans ledit dessin par des protubérances additionnelles (12) circulaires dans une vue en plan, l'agencement desdites protubérances (40, 12) et de la section étirée (58) dudit dessin complet étant conçu de manière à obstruer répétitive-

ment les lignes droites de vision dégagée d'un bord à l'autre de la feuille dans toutes les directions à travers ledit dessin.

15 15. Une unité structurelle suivant la revendication 10, caractérisée en ce qu'elle comprend une nervure (56) qui fait saillie sur lesdites éléments incurvés pour augmenter encore la rigidité de ladite
5 unité structurelle pour résister à la flexion sous contrainte.

16. Une unité structurelle suivant la revendication 10, caractérisée en ce que ladite unité
10 structurelle est d'une dimension finie donnée et, en outre, on ce que des portions de ladite matière plane d'origine comprennent un bord périphérique qui s'étend à angle droit par rapport à ladite matière plane pour former un rebord d'entretoisement continu (32) le long de la périphérie de ladite unité struc-
turelle, et des moyens qui assemblent de façon fixe ladite feuille plane audit rebord d'entretoisement, sur la face supérieure des extrémités supérieures desdites protubérances (40) formant un panneau rigide construit pour pouvoir être supporté sélectivement le long de ses bords ou à ses angles et qui est capable de supporter d'importantes charges réparties ou concentrées sans fléchissement appréciable ni déformation permanente.

15 17. Une unité structurelle suivant la revendication 16, caractérisée en ce que ledit rebord d'entre-
toisement périphérique (32) possède une profondeur transversale supérieure à la hauteur desdites pro-
tubérances (40) et donne un périmètre de plus grande résistance, ledit périmètre ayant une portion (34)
qui s'étend en sens inverse desdites protubérances (40) relativement au plan d'origine de ladite feuille
et ledit périmètre comprenant en outre une partie additionnelle qui s'étend dans le même sens que
20 lesdites protubérances (40) en partant dudit plan d'origine de ladite feuille.

18. Une unité structurelle suivant la revendication 17, caractérisée en ce que des extrémités exté-
rieures desdites portions de bord dudit rebord d'entretoisement (32) formé sont également pliées vers
l'extérieur à angle droit par rapport audit rebord (32) pour former une lèvre périphérique (38) parallèle
au plan desdites portions intermédiaires dudit élément comprises entre lesdites protubérances (40), et
25 l'unité comprenant en outre des moyens qui assemblent ladite lèvre périphérique (28) de façon fixe à
ladite feuille supérieure plane (20).

19. Une unité structurelle suivant la revendication 17, caractérisée en ce que ladite portion
additionnelle se termine dans un rebord replié vers l'extérieur à angle droit par rapport à ladite portion
additionnelle pour former une lèvre périphérique (28) parallèle au plan desdites portions intermédiaires
30 dudit élément comprises entre lesdites protubérances (40), et l'unité comprenant en outre des moyens
qui assemblent ladite lèvre périphérique (28) à ladite feuille supérieure plane (20).

20. Une unité structurelle suivant la revendication 10, caractérisée en ce que ladite matière
structurelle et ladite feuille plane (20) sont faites d'acier.

35 21. Une unité structurelle suivant la revendication 20, caractérisée en ce que ladite feuille plane
(20) est fixée auxdites extrémités terminales extérieures desdites protubérances (40) par soudage.

Patentansprüche

1. Struktureller Körper, mit einem einstückigen festen Körper, der aus einer Platte aus struk-
40 turellem Werkstoff gebildet ist, welche eine Anzahl von gleichen kuppelförmigen Vorsprüngen (40)
aufweist, die sich aus der Ebene dieser Platte erheben, im wesentlichen in einem senkrechten
Leinwandbindungsmuster angeordnet sind und eine operative Abmessungsbeziehung zwischen den
Abmessungen der Vorsprünge und deren Abständen derart aufweisen, daß die Vorsprünge von der
45 Seite aus gesehen gerade Sichtlinien in allen Richtungen quer über die Platte wiederholt blockieren,
wobei der einstückige feste Körper gegen Biegung widerstandsfähig ist, dadurch gekennzeichnet, daß
jeder dieser länglichen Vorsprünge (40) zwei im wesentlichen halbkugelförmige Teile (12) aufweist, die
durch einen Sattelteil (38) miteinander verbunden sind und im wesentlichen die Gestalt der Ziffer 8
bilden, und daß Teile der Platte, die zwischen den länglichen Vorsprüngen angeordnet sind, einen
50 fortlaufenden strukturellen bandförmigen Beanspruchungsteil veränderlicher Breite haben und in Drauf-
sicht gesehen gebogen ausgebildet und fähig sind, den der Belastung widerstehenden Zusammenhalt
des strukturellen Körpers zu optimieren.

2. Körper nach Anspruch 1, dadurch gekennzeichnet, daß die länglichen Vorsprünge (40) in einem
strukturellen operativen geometrischen Muster angeordnet sind, in welchem Reihen von in gleichen
Abständen angeordneten Paaren von in Reihe liegenden Vorsprüngen mit anderen solchen Reihen von
55 Paaren in einer Art Leinwandbindung senkrecht durchwoben sind, so daß der Teil einer Mittellinie einer
Reihe von Vorsprungspaaren, die zwischen zwei ausgerichteten Paaren liegen, die Paare davon in quer
angeordneten Reihen halbieren, und daß die Vorsprünge eine ausreichende Musterdichte aufweisen,
um gerade Sichtlinien in allen Richtungen quer über die Platte (10) wiederholt zu blockieren.

3. Körper nach Anspruch 1, dadurch gekennzeichnet, daß mindestens der größere Teil der
60 Vorsprünge (40) in Draufsicht auch in Gruppen zu vier kombiniert und in einem Rhombusmuster
angeordnet ist und daß die einander benachbarten Rhombusmuster in einer engen senkrechten
Leinwandbindung angeordnet sind, wobei diese Vorsprünge wiederholt gerade Sichtlinien blockieren.

4. Körper nach Anspruch 1, dadurch gekennzeichnet, daß Versteifungsvorsprünge (60) in der
Platte innerhalb der Bereiche zwischen den Rhombusmustern der Vorsprünge zu einer Tiefe geringer als
65 die Tiefe der Vorsprünge geformt sind.

5 5. Körper nach Anspruch 1, dadurch gekennzeichnet, daß die länglichen Vorsprünge (40) innerhalb eines vorbestimmten Musters nahe beieinander liegen, mit denen zusätzliche, im Querschnitt kreisförmige Vorsprünge (12') in der Platte kombiniert sind, um wiederholt gerade Sichtlinien quer über die Platte in allen Richtungen durch das Muster der länglichen Vorsprünge und der anderen Vorsprünge zu blockieren.

10 6. Körper nach Anspruch 5, dadurch gekennzeichnet, daß zusätzlich mindestens ein gezogener Teil (58) vorgesehen ist, der von der ursprünglichen Platte in der gleichen Richtung wie die länglichen Vorsprünge aus der Platte gezogen ist, daß mindestens dieser Teil einen Bereich hat, der größer ist als die länglichen Vorsprünge und in diesen Mustern durch zusätzliche, in Draufsicht kreisförmige Vorsprünge umgeben ist, wobei die Anordnung dieser länglichen Vorsprünge und des gezogenen Teiles des gesamten Musters so gewählt sind, daß sie die geraden Sichtlinien quer über diese Platte in allen Richtungen durch dieses Muster wiederholt blockieren.

15 7. Körper nach Anspruch 1, dadurch gekennzeichnet, daß alle Oberflächen der länglichen Vorsprünge und die Verbindungen davon mit den dazwischen liegenden strukturellen Beanspruchungsteilen in der ursprünglichen Ebene der Platte frei von scharfen Winkeln oder Biegungen sind, wodurch keine Bereiche oder Teile in dieser Platte vorhanden sind, welche Ecken oder andere scharfe Kanten aufweisen, welche üblicherweise zum Faltenziehen neigen oder in anderer Weise der Bildung glattgestreckter Bereiche widerstehen, wenn der Körper aus einer Platte gebildet und der Verformung durch einen Stempel und ein Gesenk unterworfen wird.

20 8. Körper nach Anspruch 1, dadurch gekennzeichnet, daß ein zweiter struktureller Körper (20) vorgesehen ist, an dem die äußeren Enden der Vorsprünge des ersten strukturellen Körpers zur Bildung einer zusammengesetzten strukturellen Einheit fest angebracht sind, die Biegung widersteht, wobei diese Vorsprünge als Gewölbe zur Verhinderung einer Biegung dienen und die halbkugelförmige Gestalt dieser Vorsprünge einen Widerstand gegen deren Zusammenbrechen bilden.

25 9. Körper nach Anspruch 1, dadurch gekennzeichnet, daß der strukturelle Werkstoff Stahl ist.

10. Zusammengesetzte strukturelle Einheit, mit einem einstückigen steifen strukturellen Körper, der aus einer Platte (10) aus strukturellem Werkstoff gebildet ist, in dem eine Anzahl gleicher länglicher kuppelförmiger Vorsprünge (40) von nicht größerer Dicke als die Platte geformt sind, die sich aus der Ebene der Platte erheben und die im wesentlichen in einem Muster einer senkrechten Leinwandbindung angeordnet sind, eine operative Abmessungsbeziehung zwischen den Abmessungen der Vorsprünge und den Abständen dazwischen aufweisen und bei denen in Draufsicht gesehen das Ende einer der länglichen Vorsprünge mit benachbarten Vorsprüngen (40) zusammenpaßt, die mit zusätzlichen, im Querschnitt kreisförmigen Vorsprüngen (12') kombiniert sind, wodurch wiederholt gerade Sichtlinien von der Seite her in allen Richtungen quer über die Platte wiederholt blockiert werden, wodurch ein einstückiger steifer struktureller Körper gebildet wird, der Biegebeanspruchungen widerstehen kann, dadurch gekennzeichnet, daß jeder dieser länglichen Vorsprünge (40) zwei im wesentlichen halbkugelförmige Teile (46) aufweist, die durch einen Sattelteil (38) miteinander verbunden sind und im wesentlichen die Gestalt der Ziffer 8 haben, und daß Teile seines Körpers (10), welche zwischen diesen länglichen Vorsprüngen (40) und den zusätzlichen kreisförmigen Vorsprüngen (12') liegen, fortlaufende strukturelle bandförmige Beanspruchungsteile veränderlicher Breite bilden, die in Draufsicht gebogen sind und fähig sind, den beanspruchungsverhindernden Zusammenhalt des strukturellen Körpers (10) derart zu optimieren, daß Teile, die sich zwischen den einander gegenüberliegenden Rändern der Platte befinden, in der Lage sind, einen Widerstand gegenüber Lastbeanspruchungen über den ganzen strukturellen Körper aufrechtzuerhalten, und auch durch die Vorsprünge in der Lage, die bestimmte Gestalt beizubehalten, wenn sie unter Belastung kommen, wodurch deren Bewegung verhindert wird, und daß eine ebene Platte (20) vorgesehen ist, welche an den äußeren Enden der Vorsprünge befestigt und mit dem strukturellen Körper verbunden ist, wodurch eine zusammengesetzte strukturelle Einheit gebildet ist, in welcher eine Optimierung der Unterstützung gegenüber dem Festigkeits-Gewichts-Verhältnis und eine strukturelle Qualität erreicht wird, wodurch, wenn diese ebene Platte (10) einer Belastung ausgesetzt wird, diese Vorsprünge (40, 12') als Gewölbe zur Verhinderung des Biegens dienen und die halbkugelförmige Gestalt der Vorsprünge einen Widerstand gegen deren Zusammenbrechen bildet.

55 11. Einheit nach Anspruch 10, dadurch gekennzeichnet, daß das Muster der Vorsprünge (40, 12) und deren Bildung aus der Platte einen Widerstand gegenüber Biegung in der strukturellen Einheit erzeugt, welche im wesentlichen isotropisch ist, wenn diese Einheit durch eine Öffnung von begrenztem Querschnitt durchdrungen wird, die innerhalb deren Rändern angeordnet ist, wobei im wesentlichen ihr Widerstand gegenüber Biegen ohne gerichtete Schwäche aufgrund der resultierenden Beanspruchung in dieser Einheit unter Last erhalten bleibt, wenn diese um diese Öffnung umgeleitet wird.

60 12. Einheit nach Anspruch 10, dadurch gekennzeichnet, daß mindestens die Mehrzahl der länglichen Vorsprünge (40) in Draufsicht auch in Gruppen zu vier kombiniert und in einem Rhombusmuster angeordnet ist und daß die einander benachbarten Rhombusmuster in einer engen senkrechten Leinwandbindung angeordnet sind, wobei diese Vorsprünge wiederholt die geraden Sichtlinien blockieren.

65 13. Einheit nach Anspruch 12, dadurch gekennzeichnet, daß Versteifungsvorsprünge (60) in der

Platte innerhalb der Bereiche zwischen den Rhombusmustern der Vorsprünge (40) zu einer Tiefe geringer als die Tiefe der Vorsprünge geformt sind.

14. Einheit nach Anspruch 10, dadurch gekennzeichnet, daß mindestens ein gezogener Teil (58) vorgesehen ist, der von der ursprünglichen ebenen Platte in der gleichen Richtung wie die länglichen Vorsprünge (40) aus der Platte gezogen ist, daß dieser Teil einen Bereich hat, der größer ist als die länglichen Vorsprünge und in diesen Mustern durch zusätzliche, in Draufsicht kreisförmige Vorsprünge (12) umgeben ist, wobei die Anordnung dieser länglichen Vorsprünge und des gezogenen Teiles (58) des gesamten Musters so gewählt sind, daß die geraden Sichtlinien quer über diese Platte in allen Richtungen durch dieses Muster wiederholt blockiert werden.

15. Einheit nach Anspruch 10, dadurch gekennzeichnet, daß sich eine zusätzliche Rippe (56) zwischen den gebogenen Körpern zur Vergrößerung der Festigkeit der strukturellen Einheit im Widerstand gegen Biegung unter Beanspruchung erstreckt.

16. Einheit nach Anspruch 10, dadurch gekennzeichnet, daß die strukturelle Einheit von einer vorgegebenen endlichen Größe ist und weiterhin Teile des ursprünglichen ebenen Werkstoffes aufweist, welcher einen Umfangsrand einschließt, der sich im rechten Winkel zu dieser Platte zur Bildung eines kontinuierlichen Versteifungsrandes (32) rund um den Umfang der Strukturellen Einheit erstreckt, und daß Mittel vorgesehen sind, die die ebene Platte mit dem Umfangsrand verbinden, worin die Oberflächen der oberen Enden der Vorsprünge (40) eine feste Platte bilden, die so ausgebildet ist, daß sie wahlweise an ihren Rändern oder Ecken abgestützt werden kann, und geeignet ist, im wesentlichen einheitliche oder konzentrierte Lasten ohne merkliche Durchbiegung oder dauerndes Setzen aufzunehmen.

17. Einheit nach Anspruch 16, dadurch gekennzeichnet, daß der ringsum laufende Versteifungsflansch (32) eine größere Tiefe in Querrichtung hat als die Vorsprünge (40) hoch sind und einen Umfang vergrößerter Festigkeit bildet, daß der Umfang einen Teil (34) hat, der sich in Gegenrichtung zu den Vorsprüngen gegenüber der ursprünglichen Ebene der Platte erstreckt, und weiterhin einen zusätzlichen Teil, der sich in der gleichen Richtung wie die Vorsprünge von der Originalebene der Platte erstreckt.

18. Einheit nach Anspruch 17, dadurch gekennzeichnet, daß äußere Enden der Randteile des gebildeten Versteifungsflansches (32) ebenfalls nach außen unter einem rechten Winkel zu dem Flansch abgebogen sind und eine Umfangsrippe (28) parallel zu der Ebene der dazwischen liegenden Teile des Körpers zwischen den Vorsprüngen (40) bilden und daß Mittel zum festen Verbinden der Umfangsrippe mit der Deckplatte (20) vorgesehen sind.

19. Einheit nach Anspruch 17, dadurch gekennzeichnet, daß der zusätzliche Teil in einem Flansch endet, der unter einem rechten Winkel zu dem zusätzlichen Teil zur Bildung einer Umfangsrippe (28) parallel zur Ebene der dazwischen liegenden Teile des Körpers zwischen diesen Vorsprüngen (40) abgekantet ist, und daß weiterhin Mittel vorgesehen sind, um die Umfangsrippen mit der oberen Deckplatte zu verbinden.

20. Einheit nach Anspruch 10, dadurch gekennzeichnet, daß der strukturelle Werkstoff und die ebene Platte (20) aus Stahl bestehen.

21. Einheit nach Anspruch 20, dadurch gekennzeichnet, daß die ebene Platte (20) mit den äußeren Enden der Vorsprünge (40) durch Schweißen verbunden ist.

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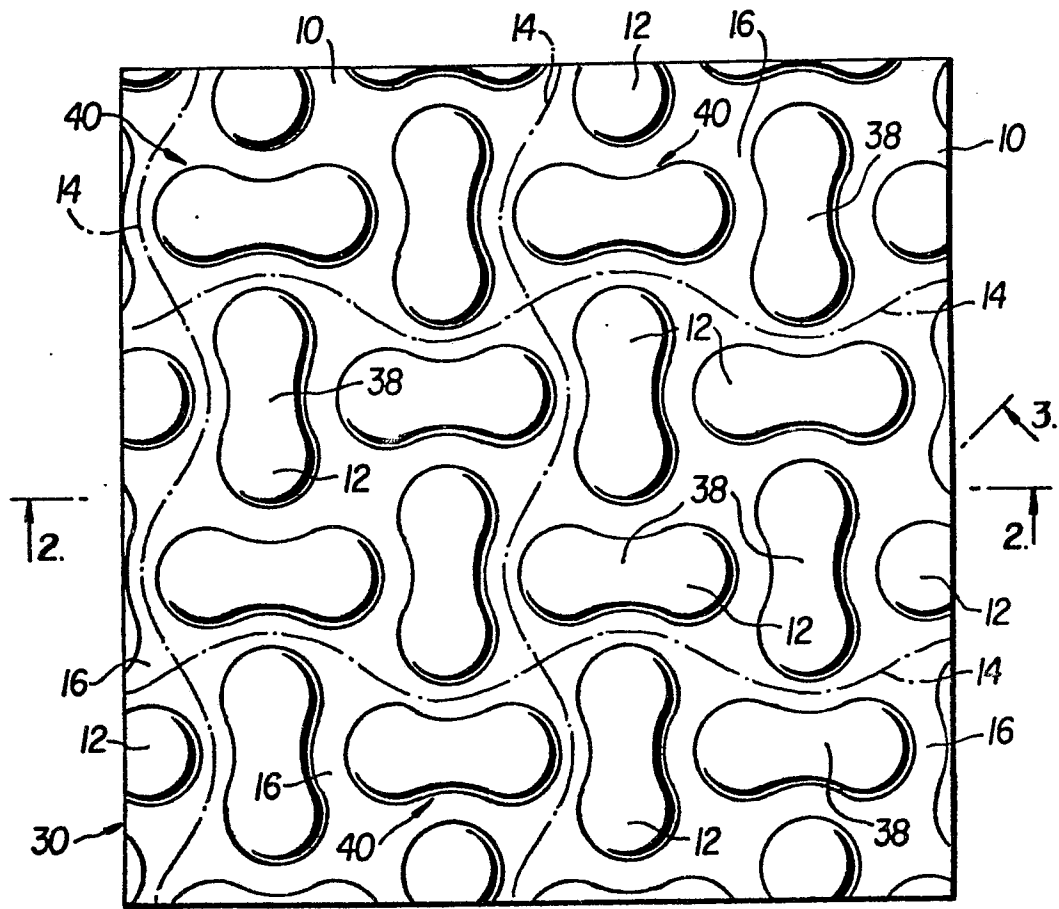


FIG. 1

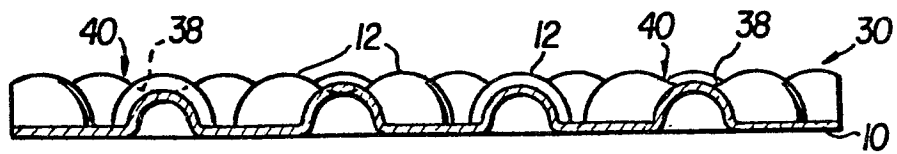


FIG. 2

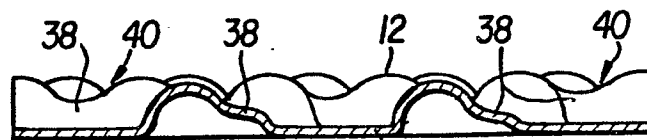


FIG. 3

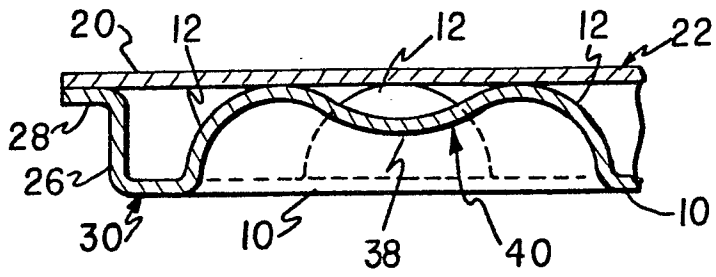


FIG. 4

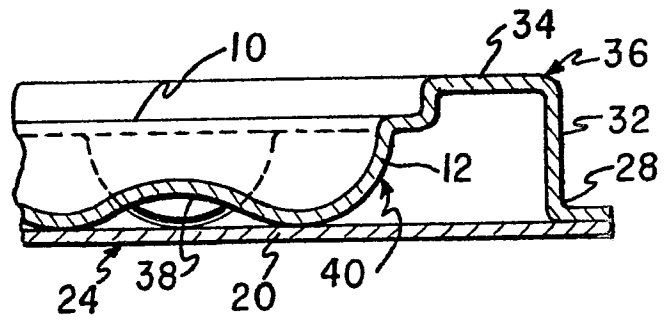


FIG. 5

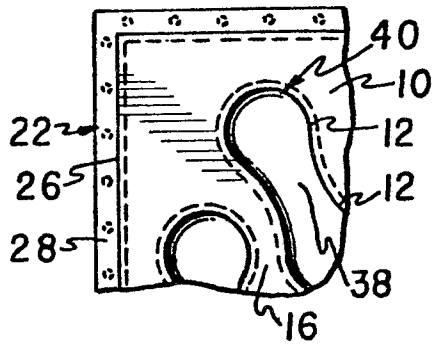


FIG. 6

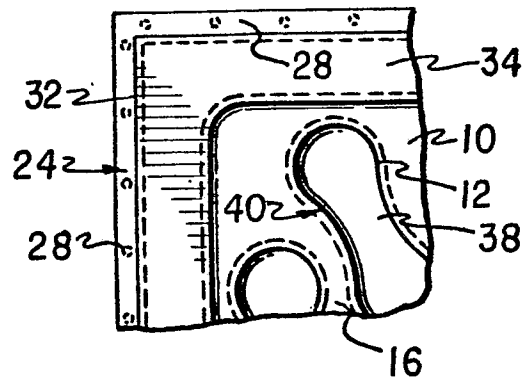


FIG. 7

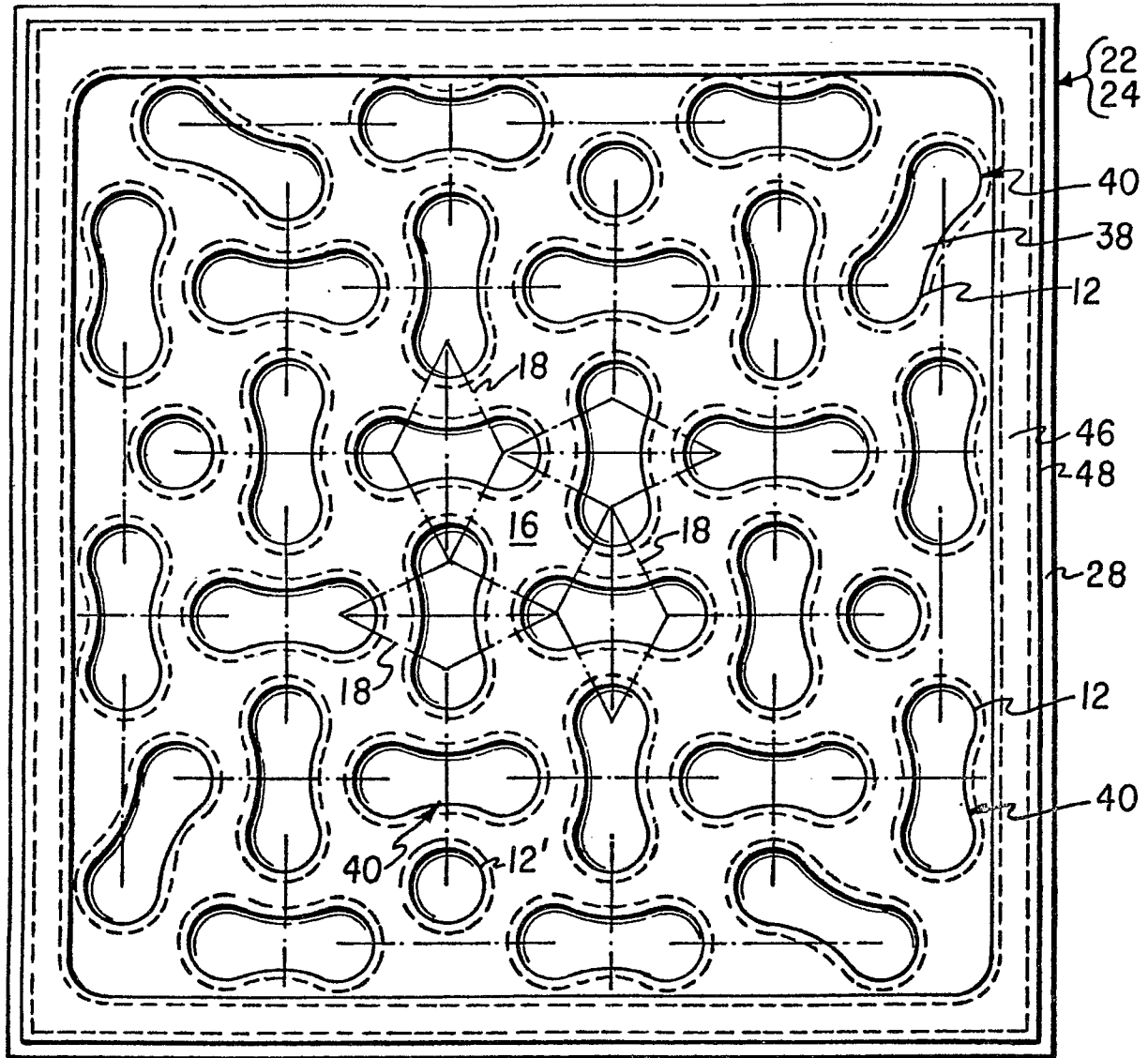


FIG. 8

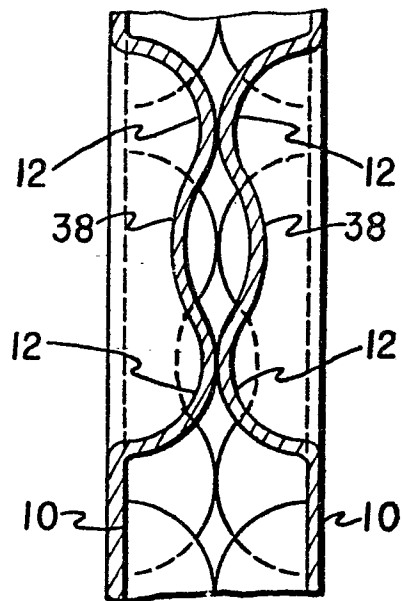


FIG. 9

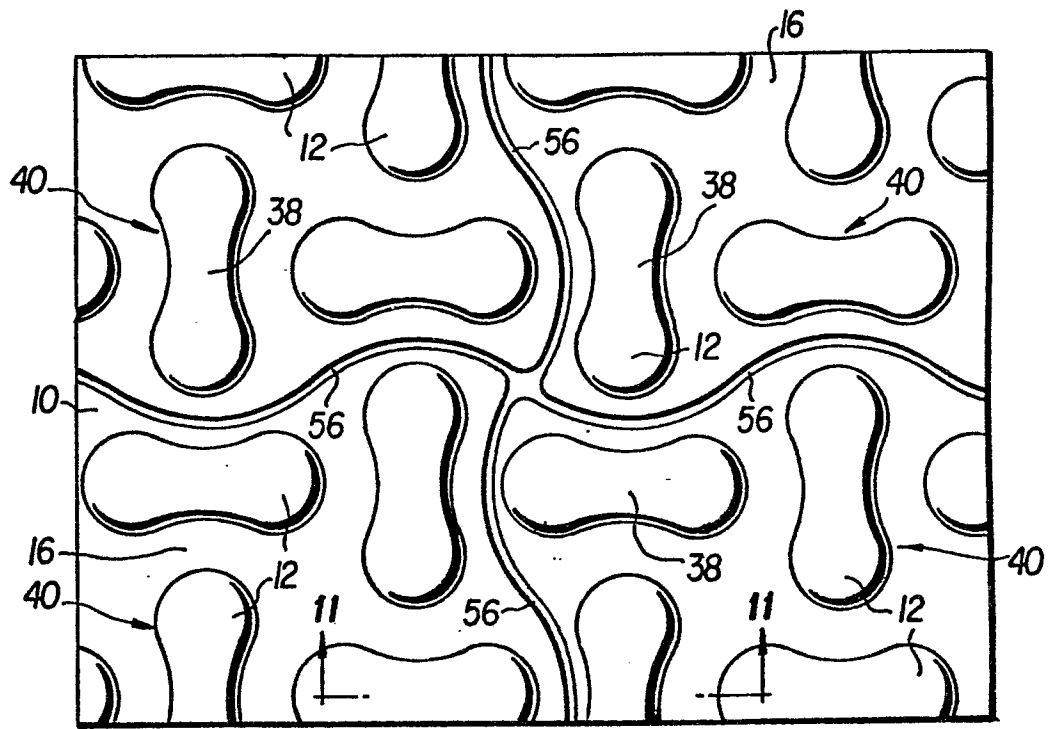


FIG. 10

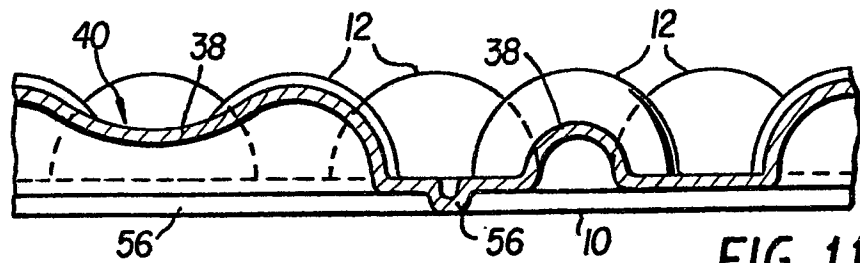


FIG. 11

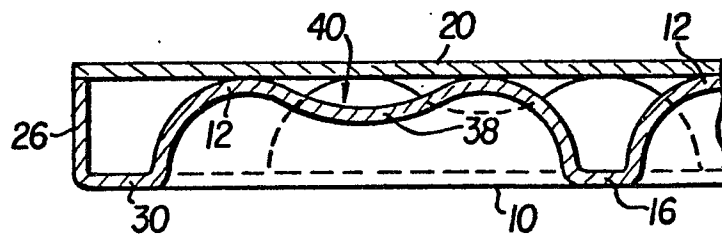


FIG. 14

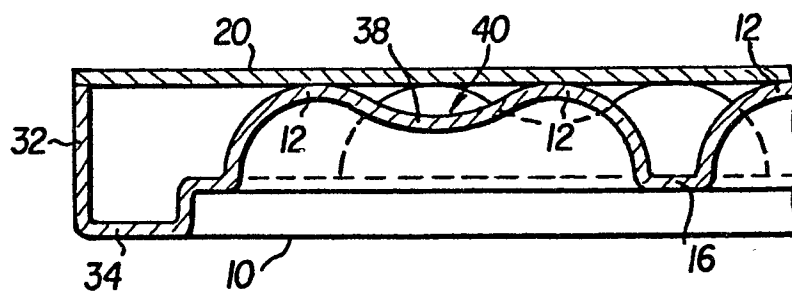


FIG. 15

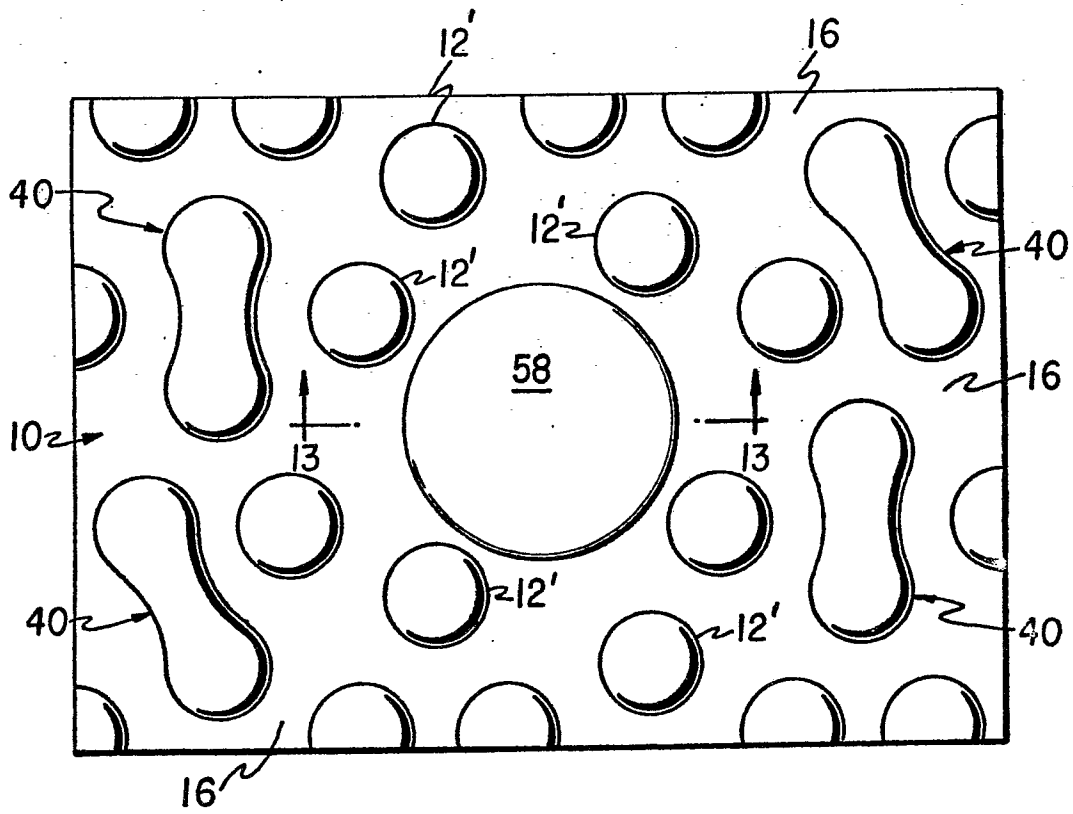


FIG. 12

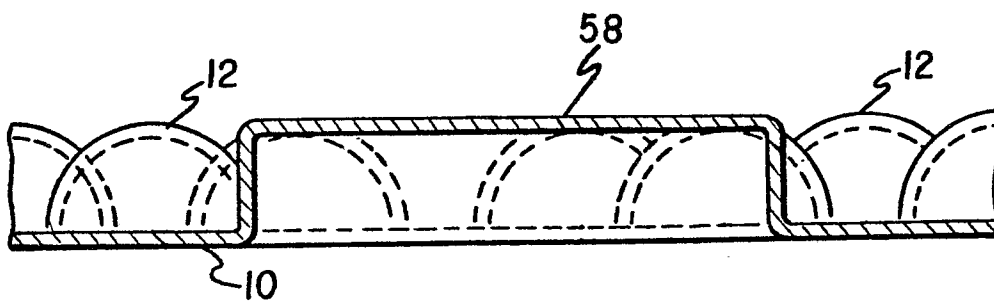


FIG. 13

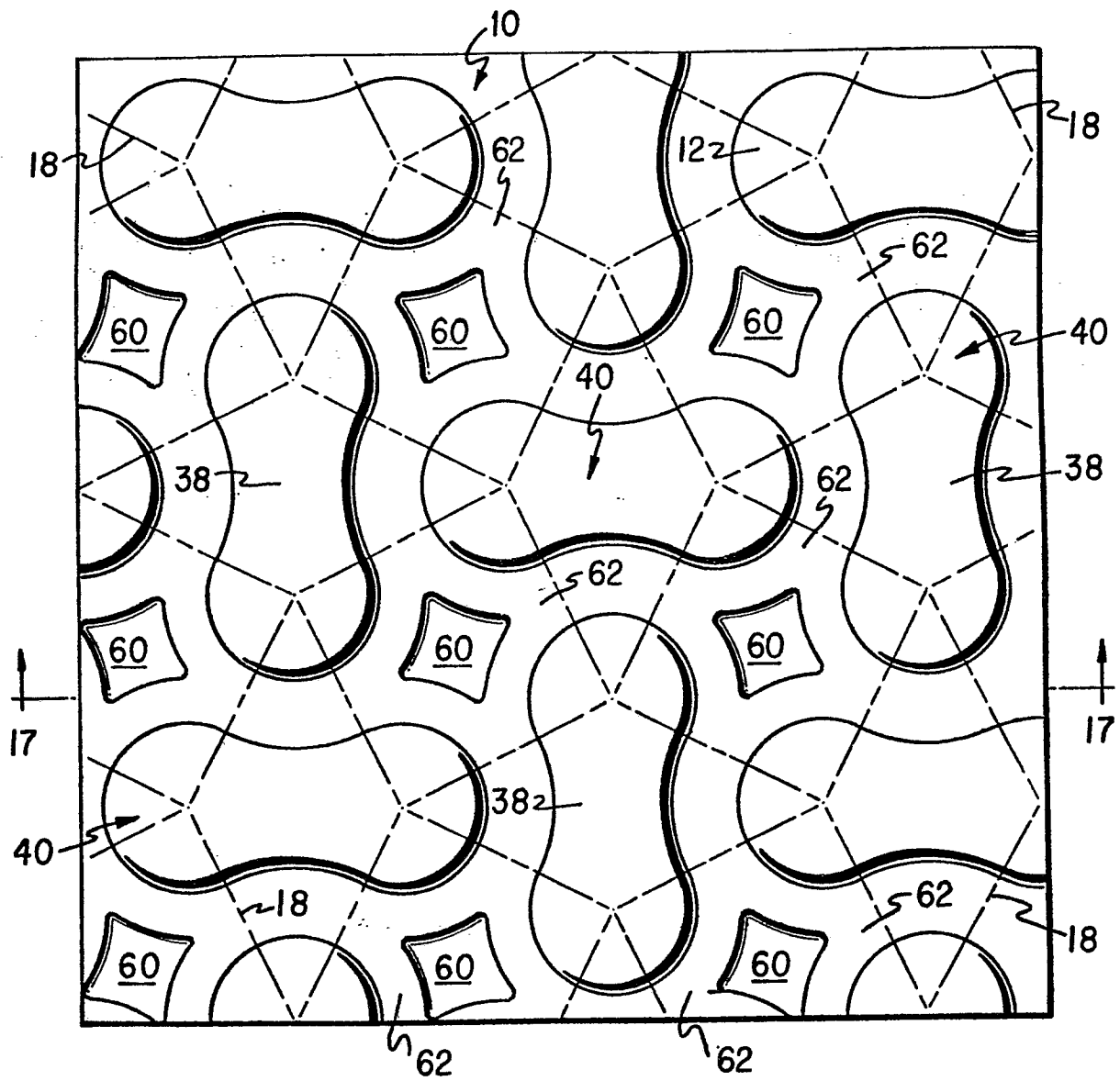


FIG. 16

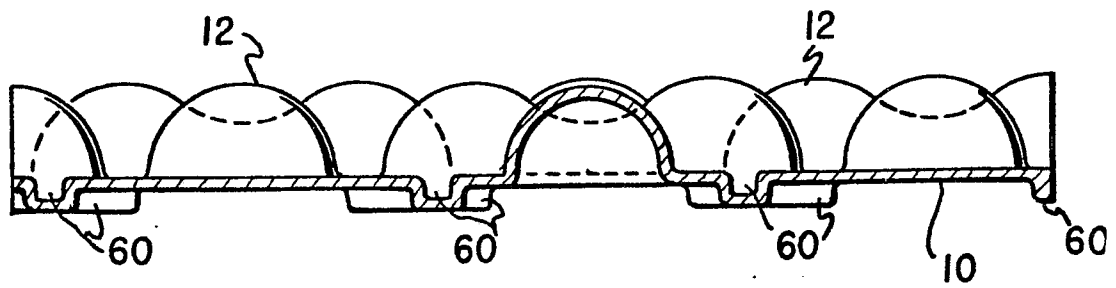


FIG. 17