

Sept. 6, 1949.

J. C. SCURLOCK

2,481,046

PANEL STRUCTURE

Filed Nov. 13, 1947

3 Sheets-Sheet 1

Fig. 1.

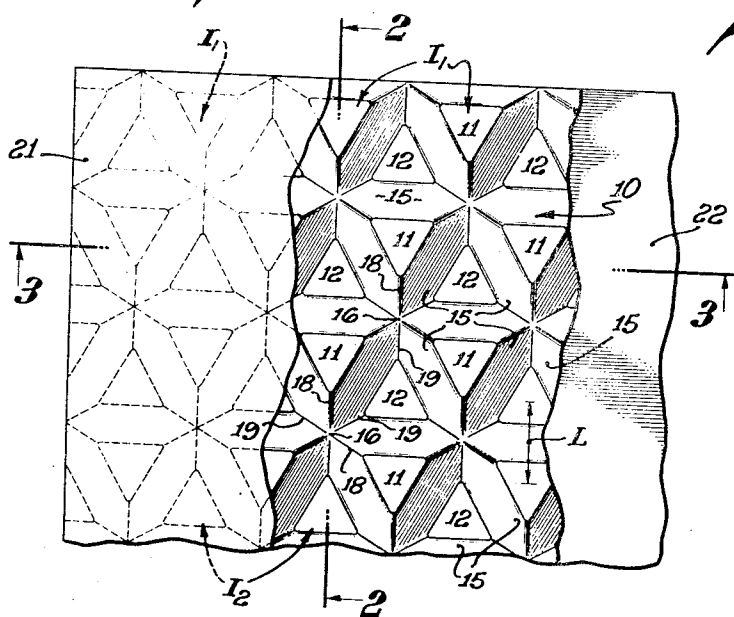


Fig. 2.

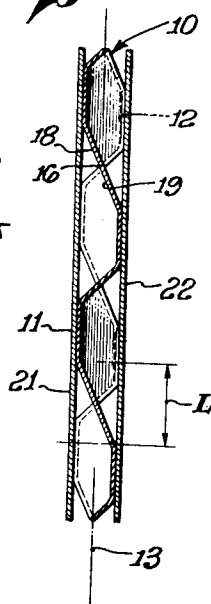


Fig. 3.

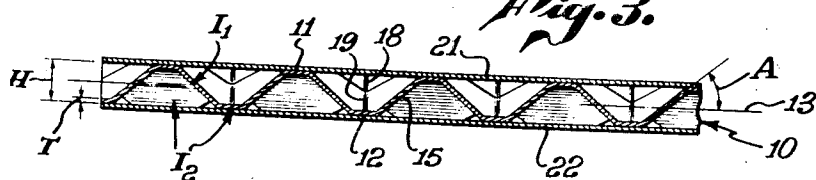
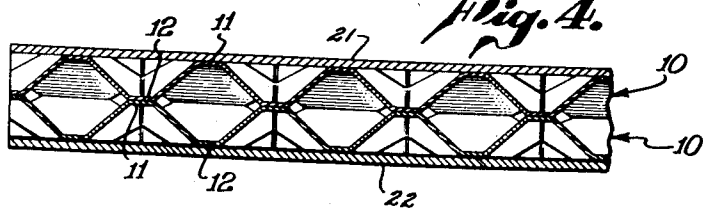


Fig. 4.



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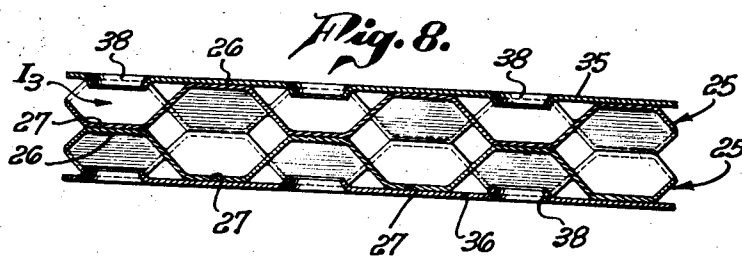
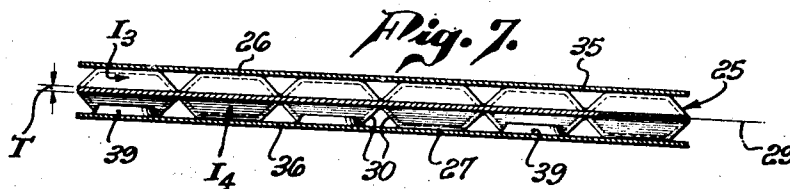
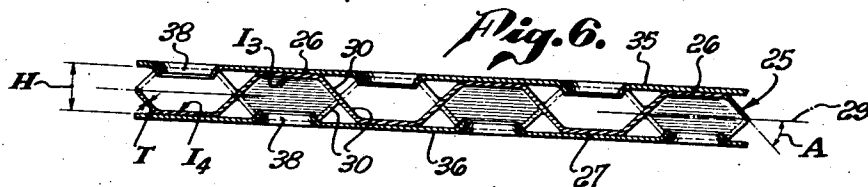
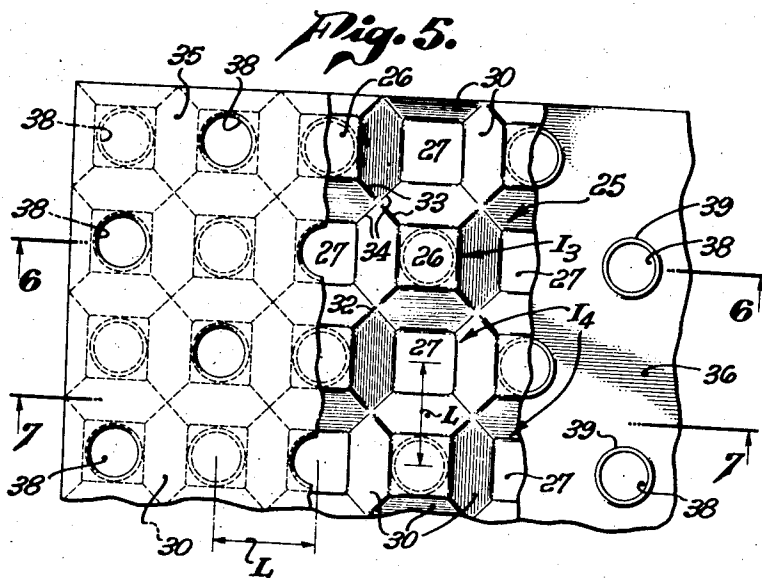
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Fig. 9.

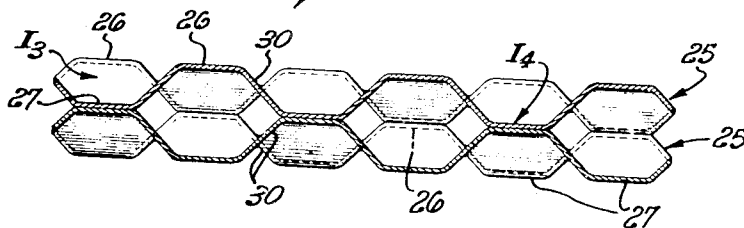


Fig. 10.

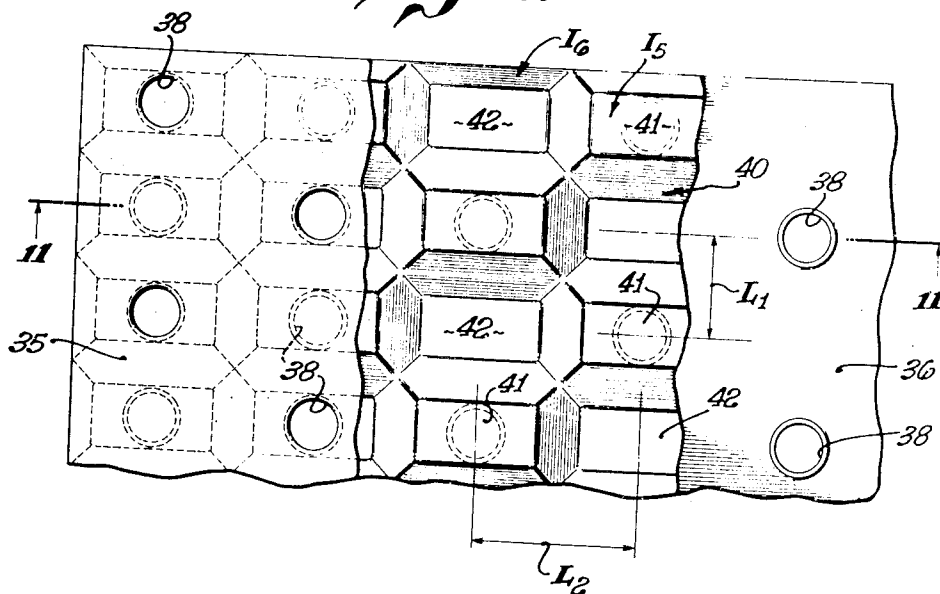
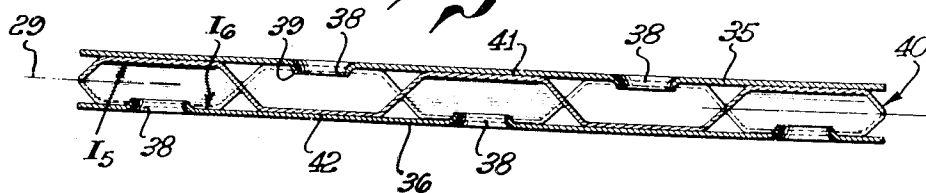


Fig. 11.



UNITED STATES PATENT OFFICE

2,481,046

PANEL STRUCTURE

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Application November 13, 1947, Serial No. 785,610

27 Claims. (Cl. 189—34)

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The present invention relates generally to panel structures, and more particularly to panels which comprise one or more relatively thin sheets which have been deformed or embossed in order to impart greatly increased rigidity and structural strength to the sheet. In this way, desired strength characteristics of the sheet are increased without adding to the weight of the sheet.

The present application is a continuation-in-part of my co-pending application on "Panel structure," serial No. 484,677, filed April 26, 1943, now abandoned, Ser. No. 572,874, filed January 15, 1945, now abandoned, and Serial No. 785,305, filed November 12, 1947 in which I have disclosed and claimed features of the invention disclosed herein.

Panels of this character can be put to many uses. For example, they can be used as part of wall or ceiling structures in buildings, in which case the surface of the panel may be utilized to provide ornamental effects in addition to the load-bearing qualities of the panel. Another typical use of such panels is in the walls, ceilings or floors of vehicles such as airplanes, trailers, freight trucks and the like, where a strong, lightweight member is desired. Under such conditions, the panels may be called upon to withstand a considerable variety of loads, so that a panel which is designed to be loaded in a single direction only is not satisfactory. Of course various substances may be used for the panel, but in general metal is the most satisfactory from all standpoints, and particularly so in structures, because of its high strength and great durability. The handicap of weight resulting from its relatively high density, can be overcome to a large extent by so disposing the metal as to obtain maximum strength for the quantity of metal used. It is also contemplated that certain of the synthetic resins or plastics may be used.

For uses of these kinds, many different types of panels have been devised previously; but usually these have been adapted to some particular use and so find only a limited commercial application. Another shortcoming of many known types of panels is that they have not always achieved the most efficient distribution of the metal used, so that they have not been as lightweight as possible for a given strength.

In view of these considerations, it is a general object of my invention to provide a panel structure made from thin sheet material in which a maximum of strength is obtained in proportion to the weight of the panel.

It is also a general object of my invention to devise a panel structure of the above character

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which is versatile in use and appearance, and easily capable of being built in different sizes and with different constructions in order to achieve the strength required under given conditions.

5 It is a further object of my invention to provide a panel structure of this character which may have a smooth outer sheet that particularly adapts the panel for use in aircraft structures, or other structures, in which a rough exterior is not desired.

10 A further object of my invention is to provide a panel structure of the character described which is simple and economical of manufacture, and is also easy to install and use in various different types of structures.

15 The above and other objects and advantages of my invention have been attained in a panel construction consisting basically of a sheet member which is provided with a plurality of indentations or embossments in the form of hollow polyhedrons with polygonal outer faces, the polyhedrons in some cases being hollow truncated pyramids. These indentations are arranged in two groups, one of which extends in one direction from a medial surface of the embossed sheet and the other of which extends in the opposite direction, the indentations of the two groups being symmetrically interspersed between each other. Inclined side wall portions of each indentation of one group are coplanar with similar side wall portions of the adjacent indentation of the other group, so that these coplanar side wall portions are substantially flat surfaces extending from one side of the sheet member to the other between the two truncated portions. These coplanar side wall portions of adjacent indentations intersect at a common point lying in said medial surface of the panel and define salient and re-entrant angle portions arranged alternately around this common point of intersection. A core sheet of this character may be used alone as a panel, or it may be reinforced by another similarly embossed sheet or by one or two flat surface sheets. In either case the added sheets are attached to the core sheet at certain of the outer wall portions or truncated portions of the indentations by suitable fastening means.

How the above objects and advantages of my invention, as well as others not particularly referred to herein, are attained will be more easily understood by reference to the following description and to the annexed drawings, in which:

Fig. 1 is a fragmentary plan view of a panel structure according to my invention composed of a core sheet having triangular indentations

and a surface sheet attached at each side of the core sheet, portions of the core and top sheets being broken away;

Fig. 2 is a fragmentary cross-section through the panel on line 2—2 of Fig. 1 showing both surface sheets fully;

Fig. 3 is a fragmentary cross-section through the panel on line 3—3 of Fig. 1 showing both surface sheets fully;

Fig. 4 is a fragmentary cross-section through a variational form of panel structure, viewed similarly to Fig. 3, showing a panel composed of two triangularly indented sheets attached together;

Fig. 5 is a fragmentary plan view of another form of panel structure composed of a core sheet having square indentations and a surface sheet with dimpled openings attached at each side of the core sheet, portions of the top surface sheet and core sheet being broken away;

Fig. 6 is a fragmentary cross-section through the panel of Fig. 5 on line 6—6 thereof, showing both surface sheets in place on the core sheet;

Fig. 7 is another fragmentary cross-section of the panel of Fig. 5 on line 7—7 thereof with both surface sheets in place;

Fig. 8 is a fragmentary cross-section of a modified form of panel structure composed of two core sheets having square indentations and two surface sheets having dimpled openings;

Fig. 9 is a fragmentary cross-section through a modified form of panel composed only of two core sheets having square indentations;

Fig. 10 is a fragmentary plan view of a variational panel structure composed of a core sheet having rectangular indentations and a surface sheet with dimpled openings attached at each side of the core sheet, portions of the core and top sheets being broken away; and

Fig. 11 is a fragmentary cross-section through the panel of Fig. 10 on line 11—11 thereof.

Referring now to the drawings, there is shown in Figs. 1 to 3 a composite panel having a core sheet 10 which is formed from a single flat sheet by embossing or indenting the sheet. Sheet member 10 has a plurality of triangular indentations in the form of hollow truncated triangular pyramids arranged in two groups. All of the indentations in one group are similarly oriented with respect to directions in a plane parallel to the medial plane of the sheet as defined below, while all of the indentations in the other group are oppositely oriented. One group of these indentations comprises the upwardly extending indentations I_1 that terminate in triangular outer walls or surfaces 11 which define truncated portions of the full pyramids. The other group of indentations comprises the oppositely or downwardly extending indentations I_2 that terminate in triangular outer walls or surfaces 12, which also define truncated portions of the full pyramidal indentations.

It is contemplated that the embossed sheet members will ordinarily be made from a flat sheet by a stamping operation in which the two groups of indentations I_1 and I_2 are formed by striking them up and down respectively from the flat sheet. For this reason, but without any limitation to this particular method of forming the panel to be inferred therefrom, it is easy to consider the panel as having two groups of pyramidal indentations of which one group is at one side of a surface located at the initial position of the original flat sheet, and the other group of indentations lies at the other side of such surface.

This surface then becomes medial surface 13 of the embossed sheet member. Walls 11 are uniformly spaced from surface 13 at one side thereof, and walls 12 are uniformly spaced from surface 13 at the other side thereof; and in the preferred form of my invention, surfaces 11 and 12 are equally spaced from the medial surface. But my invention is not necessarily so limited; and for this reason the term "medial" as used herein is used in a broad sense to include planes or surfaces either at or near the midpoint between outer surfaces 11 and 12.

The neutral plane of the panel shown in Figs. 1 to 3 coincides with the medial plane; and both are planes, the panel being flat. However, the panel may not always be flat but may be curved or cylindrical, in which case the neutral or medial surface is no longer a plane but a curved surface. Hence the expression "medial surface" is used herein as being a broader and, in some instances, more accurate term than "medial plane."

The triangular indentations of each group are of the same size and shape, i. e., are congruent, and are symmetrically interspersed between indentations of the other group. In the preferred form shown, in which the medial surface 13 coincides with the neutral surface of the panel, the indentations I_1 are the same size and shape as the indentations I_2 . Each indentation has three inclined side walls 15; and triangular surfaces 11 are connected with triangular surfaces 12 by these sloping side wall portions which extend divergently away from the three sides of outer faces 11 and 12. Since each indentation of one group has its side walls coplanar with the side wall portions of each adjacent indentation of the other group, these two coplanar side wall portions are substantially flat in continuous planes which extend from one side of the sheet to the other between triangular surfaces 11 and 12. The continuous character of these flat coplanar side walls 15 is shown clearly in the sectional views of Fig. 2 and Fig. 3.

The coplanar side walls of adjacent pyramids intersect at a common point 16 substantially at the medial surface 13. Because of the thickness of the metal sheet, intersection takes place in a zone rather than at a geometrical point; and the medial surface for this reason may well be considered as a zone rather than a plane in the strict geometrical sense. This zone has a thickness approximately equal to the thickness of the sheet; and it is within this zone that the side walls 15 intersect.

The formation of the panel at and around this point of intersection is shown to advantage in Fig. 1 in which it will be seen that the intersection of the six sides 15 defines a total of six angle portions, three of which are salient and three re-entrant. Three salient angles 18 alternate with three re-entrant angles 19, so that the six angle portions are alternately arranged about the common point of intersection 16. All three salient angles 18 are located above medial plane 13, while the re-entrant angles 19 are located below the medial plane. It will also be noted that each salient angle 18 formed by a linear intersection of two surfaces 15 is aligned across the point of intersection 16 with a re-entrant angle 19 formed by a linear intersection of two other surfaces 15 so that a straight line drawn along and through two opposed angle portions passes through the common point of intersection of all the coplanar side walls intersecting at a common point 16. Since each salient angle portion is directly in

line through the point of intersection with a re-entrant angle portion, the salient and re-entrant angle portions provide for direct transmission of tension and compression stresses along an interrupted straight line between opposite sides of the panel, that is between surfaces 11 and 12.

The composite panel is completed by adding to embossed core sheet 10, two surface sheets, one disposed at each side of the embossed sheet 10. These two surface sheets are flat and smooth, and are designated as 21 and 22. Sheet 21 lies over the top or one side of core sheet 10 and is in contact with indentations I_1 at surfaces 11. Flat sheet 22 extends over the bottom or other side of core sheet 10 and is in contact with indentations I_2 at surfaces 12. At certain of the truncated portions of the indentations, as represented by triangular surfaces 11 and 12 of the core sheet, there is provided means for attaching each surface sheet to the core sheet. This attachment may be by spot or projection welding the two sheets together, or by some added means, such as rivets. However it will be understood that it is within the scope of my invention to use any other suitable means of securing either or both of the surface sheets to the core sheet if desired.

The two sheets 21 and 22 with the core sheet 10 form a truss structure. Two angle portions 18 and 19 aligned with each other form a straight line path for the transmission of stresses from one surface sheet to the other and cooperate with the two sheets in making a strong rigid panel.

It will be obvious from a consideration of Figs. 1 to 3 inclusive, without further illustration, how the construction shown therein may be modified by omitting either one or both of surface sheets 21 or 22. Under some circumstances it may be both desirable and satisfactory to have a panel which is composed only of core sheet 10. Or it may be that a panel of sufficient strength is obtained by adding to the indented core sheet a single surface sheet, either 21 or 22. Hence, my invention includes a panel composed only of an indented core sheet, as well as a panel composed of a core sheet and a single surface sheet attached thereto.

In forming embossed panels of this character, I have found that certain dimensions or proportions are preferred for the embossed core sheet because they lead to the most favorable results. Thus the acute angles A which sides 15 of the pyramidal indentations make with the medial plane are uniform and should be not less than 20° , and preferably are greater than 30° , the angle chosen being dependent upon the type of material used and the purpose and loading for which the panel is intended. Thus in the figures I show sides 15 as making an acute angle A with the medial plane which is in the vicinity of 45° . With an angle A of less than 20° , the gain in structural strength and rigidity of the embossed sheet, as compared with the original flat sheet, is substantially less than the maximum possible; whereas when this angle is increased to more than 30° , or into the vicinity of 45° , the increase in strength approaches a maximum, all conditions being considered. This angle A of side walls 15 is the same when referred to either one of the two parallel planes in which lie surfaces 11 and 12, or surface sheets 21 and 22, since these two planes are parallel to medial surface 13.

Other dimensions or proportions which have been found to give improved results when adhered to, are the thickness T of the sheet, the thickness of the embossed panel H , the spacing

L between indentations, and their relative values. The dimension H is the overall thickness of the embossed panel, or the distance between outer surfaces 11 and 12 measured in a direction perpendicular to the medial plane. The dimension L is defined as the shortest distance between the centers of two adjoining and oppositely disposed triangular indentations, measured along a line lying in a plane parallel to the medial plane 13, as shown in Fig. 2. It will be evident from Fig. 1, that in the case of the triangular indentations I_1 and I_2 there is another and longer distance between two oppositely disposed indentations, if the measurement is taken along two aligned angle portions 18 and 19 through point 16; but this longer distance may be considered as being a function of the shorter distance L as indicated in the drawings and defined above as being measured across the intervening coplanar wall 15. The distance L is measured parallel to the medial surface, as shown in the drawings.

It is contemplated that my composite panel will ordinarily be made from relatively thin sheets, both the embossed core sheet and the attached surface sheets 21 and 22. For the core sheet, it is contemplated that it will have an original thickness T ranging from a few thousandths of an inch to a thickness of several hundredths in the case of panels formed by pressing or stamping; and in the case of cast or molded core members, the thickness will ordinarily be somewhat greater. It will be realized that the range of thicknesses here given is not limitative upon the invention but is mentioned solely for purpose of information and it would depend in any particular instance upon various practical considerations, among which are the nature and physical characteristics of the material used.

For a sheet of given thickness, the ratio of the distance L to both the sheet thickness T and the panel thickness H should preferably lie within certain ranges. Thus I find that the ratio of L/T may have a considerable range, satisfactory results being obtained within a range of 15:1 to 100:1. As typical of actual values using a sheet of duraluminum of 26 gauge or .018" thickness, very satisfactory results have been obtained in making a triangularly indented core sheet in which L equals .58" and H equals .33". Here the ratio of L/T equals 32. In this typical sheet the ratio of H/T equals 18, but it is believed that satisfactory results can be obtained within a range of 4:1 to 50:1 for this latter ratio.

It will be evident that the size of the triangular surfaces 11 and 12 can be increased by increasing the spacing L between them and without any change in the dimension H or in the inclination of side walls 15. Obviously such an undue extension of the dimension L in this manner with reference to the other dimensions deprives the panel of maximum gain in strength and rigidity. For this reason I find that the ratio L/H should not exceed a value of 30:1; and in the typical panel of which the dimensions are given above, this ratio has a value of 1.75 or 7:4.

Another form of composite panel structure is shown in Fig. 4, in which the panel includes two indented panels 10 placed in parallel relationship, back-to-back. The panels are in contact at their truncated portions 11 and 12, the upper wall portions 11 of the lower panel being in contact with the lower faces 12 of the upper panel. Means is provided at certain of the contacting portions of the two embossed sheet members to intersecure them. Such means may be spot welding, rivets,

or any other suitable means, as explained above. Surface sheets 21 and 22 may be added if desired to the outer faces of indented panels 10 to form the complete composite panel of Fig. 4. Sheets 21 and 22 are each attached to one of the indented panels 10 at a plurality of the outwardly facing wall portions, in the same manner as described in connection with Fig. 3. It will be readily apparent that a variational panel structure may also be formed without one or both of surface sheets 21 and 22.

Referring now to Figs. 5, 6 and 7, there is shown a composite panel in which the core sheet 25 has a plurality of square indentations in the form of hollow truncated pyramids arranged in two groups extending in opposite directions from a medial surface of the sheet, all of the indentations being similarly oriented with respect to directions in planes parallel to the medial plane. One group of these indentations comprises the upwardly extending indentations I_3 that terminate in square outer walls or surfaces 26 which define truncated portions of the full pyramids. The other group of indentations comprises the oppositely or downwardly extending indentations I_4 that terminate in square outer walls or surfaces 27 which also define truncated portions of the full pyramidal indentations.

In this form of core sheet, the medial plane is indicated at 29 and indicates the position of the original flat sheet from which the embossed sheet is made. As in the previously described form of embossed sheet, outer wall portions 26 are uniformly spaced from the medial surface at one side thereof, and outer wall portions 27 are likewise uniformly spaced from medial surface 29 at the other side thereof; and in the preferred form of core sheet illustrated in Figs. 5 to 7 inclusive, surfaces 26 and 27 are equally spaced from the medial surface. However, my invention is not necessarily so limited, but is considered as being broad enough to include an embossed sheet in which one set of indentations, for example wall portions 27, are spaced at a different distance from the medial plane than the other set, surfaces 26.

The indentations of each group are congruent or of the same size and shape, and are symmetrically interspersed between indentations of the other group. In the preferred form of my invention illustrated herein, in which the medial surface 29 coincides with the neutral surface of the panel, indentations I_3 are the same size and shape as indentations I_4 , that is, all the indentations of the sheet are congruent. Each indentation has four inclined side walls 30 which extend divergently away from the sides of outer wall portions 26 and 27 to medial surface 29. Square surfaces 26 are connected with square surfaces 27 by the sloping side wall portions 30 of the pyramidal indentations; and since each pyramidal indentation of one group has its side walls coplanar with the side wall portions of each adjacent indentation of the other group, side wall portions 30 are substantially flat and continuous planes which extend from one side of the sheet to the other between the two sets of square surfaces 26 and 27. The continuous character of these flat coplanar side walls 30 is shown clearly in the section of Fig. 6.

The coplanar side walls of adjacent rectangular pyramids intersect at a common point 32 substantially at medial surface 29. Two adjacent indentations of either group have a total of four walls which meet at this common point 32. The

meeting walls around this intersection define a total of four angle portions, two salient and two re-entrant. Two salient angles 33 alternate with two re-entrant angles 34, so that the four angle portions are alternately arranged around point 32. The salient angles 33 are located above medial plane 29, while the re-entrant angles 34 are located below the medial plane. Two salient angles are aligned with each other across point 32, as are two re-entrant angles.

The core sheet 25, as so far described, may be used alone as a panel. But the composite panel is completed by two sheets 35 and 36 attached one on either side of the embossed sheet 25. Surface sheet 35 lies over the top or one side of embossed sheet 25 and is in contact with indentations I_3 at outer wall portions 26; while surface sheet 36 extends over the bottom or other side of core sheet 25 and is in contact with indentations I_4 at outer wall portions 27. At certain of the contacting truncated portions 26 and 27, there is provided means for attaching each of the surface sheets to the core sheet. While this may be any one of a number of different means, as explained above, I have here shown sheets which are particularly adapted to attachment by spot welding, and for this purpose each surface sheet is provided with a plurality of openings 38 of a size to receive the welding electrodes. Each opening 38 is so located in a surface sheet as to be opposite the open side of an indentation, that is, each opening 38 in sheet 35 is located above the larger or open side of an indentation I_3 so that the welding electrode comes into contact with the upper or inner side of a wall portion 27.

Surface sheets 35 and 36 may be made flat, or they may be provided with a flange 39 around each opening 38. The nature of these flanges 39 around each opening 38 is shown clearly in Fig. 6; and it will be understood that these flanges are the same as parts of dimpled portions which may be applied to the sheet even though holes 38 are omitted. In this latter event, the dimpled portions take the form of shallow, inwardly indented bosses in the surface sheet which are continuous across the locations of openings 38. The advantage of dimpled portions is that the surface sheets are stiffened in the unsupported areas between successive contacting surfaces 26 or 27 of the core sheet.

In making embossed panels 25 with rectangular pyramids, I have found that the general ratios of dimensions mentioned above are productive of most favorable results. Walls 30 make an angle in excess of 20° with medial plane 29 and are preferably in excess of 30° with respect thereto. Where the materials and conditions permit, I find it advantageous to make this angle in the vicinity of 45° . The ratios of the other dimensions should be held within the limits above given. The dimension L, the distance between the centers of two adjoining and oppositely disposed indentations, is measured along a line lying in a plane parallel to the medial plane 29. This dimension for the square pattern is the same for any two adjoining and oppositely disposed indentations, rather than having two different values as with the triangular pattern.

As an example of actual values which have been found to be advantageous, I have formed a core sheet from 26 gauge duraluminum, or .018" in thickness, and have obtained satisfactory results when L equals .80" and H equals .33". In this case the ratio of L/T equals 44 and the ratio of 75 H/T equals 18. L/H for this example equals 2.4.

A modified form of composite panel construction is shown in Fig. 8 which differs from that shown in the preceding three figures in that the core member is composed of two indented sheets 25 placed parallel to each other in back-to-back relation and fastened to each other at the inwardly facing, contacting portions 26 and 27. Surface sheets 35 and 36 are fastened to the outwardly facing outer wall portions 26 and 27 of the upper and lower indented sheets 25 respectively. Fastening means of the character described are provided at certain of the inwardly and outwardly facing outer wall portions 26 and 27 to intersecure the several elements of the composite panel.

Just as one or both of the surface sheets may be omitted from the form shown in Figs. 6 and 7, so may one or both of the surface sheets be omitted from the composite panel shown in Fig. 8. Thus my invention contemplates a composite panel as illustrated in Fig. 9 which is composed of two embossed sheets 25 lying parallel to each other and fastened together at the inwardly facing outer wall portions 26 and 27 of the two embossed sheets; and it also contemplates a composite panel comprising two such embossed sheets with a surface sheet fastened at one side only. Likewise a composite panel consisting of more than two embossed sheets, intersecured as described above, may also be made within the scope of my invention.

I have described above two different patterns of indentations for my embossed panels in which the indentations are truncated pyramids of either triangular or square cross-section. Both of these patterns may also be described as comprising polyhedral indentations; and it will be apparent that polyhedral indentations other than truncated pyramids may also be utilized in embossing the panels of my invention. As an example of this, there is shown in Figs. 10 and 11 an embossed sheet 40 in which the indentations I_1 and I_2 have all characteristics the same as the indentations I_3 and I_4 respectively, except that the outer wall portions 41 and 42 are rectangular but oblong in outline rather than square as are walls 26 and 27.

The elongation of one dimension of polyhedrons I_1 and I_2 so that their outer surfaces 41 and 42, as well as other cross-sections, are correspondingly elongated but still in the form of parallelograms, makes only one change in the embossed sheet and composite panel as compared with the forms described in connection with Figs. 5 to 9 inclusive. This change is brought about by the fact that the spacing between centers of two adjoining and oppositely disposed indentations has two different values, measured at right angles to each other. Consequently there are two different values for the dimension L , and these have been designated as L_1 and L_2 in Fig. 10. In considering the various ratios between sheet and panel thickness and indentation spacing, the shorter of these two dimensions, L_1 , should be used and not the longer one. Undue extension of the indentations in one direction with a resultant relatively high value of L_2 should be avoided. The value of the ratio L_2/L_1 may range from 1:1, in which case the outer faces of the indentations are square as in Figs. 5 to 8 inclusive, to as high as 20:1. In the example shown in Fig. 10, the value of the ratio is approximately 13:8.

The unilateral elongation of indentations I_1 and I_2 prevents the four inclined sides 30 of any one indentation from intersecting, when projected, at a point, which is a characteristic

of a true pyramid. In the elongated indentation, the point is correspondingly elongated to a line, so that the elongated indentations are more properly defined as polyhedrons rather than truncated pyramids.

In building and testing composite panels of the character described above, certain unexpected and advantageous results have been found to be obtained by my invention. According to accepted engineering practice, it would be expected that where a composite panel structure is subjected to loading in simple bending (i. e., by loading normal to the plane of the panel), the same deflection per unit load would be obtained, independently of the width of the panel or beam, with uniform distribution of the load transversely to the length of the beam. For example, a panel structure of a given width and given length between the points of support, when loaded with a certain load per unit of width, should show a given deflection. If the width were doubled and the total load increased proportionately so that the same loading per unit of width is maintained, the deflection would be expected to be the same as before. From laboratory tests of panels constructed according to my invention, it has been found by observation that such a composite panel exhibits a marked decrease in the expected deflection when the width is increased and the loading per unit width is kept constant.

This novel characteristic of my invention may be more fully explained by giving a concrete example based upon observed measurements. The test sample in one case consisted of an embossed sheet 25 with a single surface sheet, such as surface sheet 21. The structure was subjected to simple bending, while supported on supports spaced apart a distance equivalent to a span of 30 rows of indentations. Panels of various widths were tested, with the same span between supports, and the same load per unit width. A panel having a width of five rows of indentations showed a deflection of .105" under a load of 288 grams per row. A ten row panel, also loaded at 288 grams per row, or a total load of 2,880, showed only .090" deflection. The same per unit load produced but 86% as much deflection. A twenty row panel, under load of 5,760 or a load of 288 grams per row, showed but a .075" deflection, or 71% of the deflection measured with the five row panel. A thirty row panel, loaded with 8,640 grams or 288 grams per row of width, showed only .065" deflection, a reduction to but 62% of the deflection of the first panel tested.

In another laboratory test, the test panel consisted of two embossed sheets 25, each having square embossments of the same size and shape, fastened together by welding at each of the contacting outer surfaces 26 and 27. This test specimen corresponded in construction to the showing of Fig. 5. The panel was subjected to simple bending while supported only on spaced supports, with a clear span of 36 rows of indentations. Panels of various widths were tested, with the same clear span between supports and the same loading per unit width, the several widths of panel being six, twelve, thirty-six and fifty-six rows of indentations. The panel six rows wide deflected .120" under a load of 3,762 grams or 627 grams per row. When the panel width was doubled to twelve rows, the maximum measured deflection at the center was .118" for the same unit loading. The expect-

ed deflection decreased 1.7%. The thirty-six row panel, under the same unit loading, showed a maximum deflection of .112" which was a decrease of 7% from the deflection of the six row panel. The widest panel tested had fifty-six rows and under the unit loading of 627 grams per row, showed a maximum deflection of .107". This deflection was only 89% of the deflection of the first panel tested, or a decrease in deflection of 11% from the normally predictable value. These tests were carried out under laboratory conditions with the several factors under sufficiently close control to insure that the results obtained would truly reflect the increased strength of the panel structure. The uniformity of the test results demonstrates the unexpected property of building up a resistance to bending in the case of wider panels at a greater rate than the increase in width, as compared with narrow panels.

In the various forms of my invention I have shown the outer surface portions 11, 12, 26, 27, 41, and 42 as being flat, or substantially so, and this has a definite advantage when a surface sheet is attached to the embossed sheet by welding, as the flat area provides a favorable location for the weld. On the other hand, my invention is not necessarily so limited, and the outer wall portions may have surfaces other than flat, that is, they may be rounded or curved. This may be desired to contribute to the appearance of the embossed sheet wherever a surface sheet is omitted. The polygonal outline of the outer wall portions is retained so that the surfaces are still of the same outline whether or not they are flat.

Having described various embodiments of my invention, it will be evident that changes in the arrangement and construction of the various elements of a panel constructed according to my invention may be made by persons skilled in the art, without departing from the spirit and scope of my invention; and consequently I wish it understood that the foregoing description is considered as being illustrative of, rather than limitative upon, the appended claims.

I claim:

1. In a light-weight, high-strength, metallic panel construction, a core sheet member of relatively thin sheet metal provided with a plurality of hollow polyhedral indentations extending in opposite directions from a medial surface of said sheet member, said indentations comprising one group of similarly oriented congruent indentations having polygonal outer wall portions located in uniformly spaced relation to and at one side of such medial surface, and a second group of similarly oriented congruent indentations having polygonal outer wall portions located in uniformly spaced relation to and at the other side of such medial surface, each indentation having a plurality of inclined substantially planar side wall portions extending divergently from the respective sides of its outer wall portion to said medial surface and each such inclined side wall portion of each indentation of one group being coplanar with a similar side wall portion of an adjacent indentation of the other group to define a substantially flat plane extending between polygonal outer wall portions of adjacent oppositely oriented indentations, and side wall portions of a set of adjacent indentations of each group meeting at a common point substantially at said medial surface; a surface sheet of relatively thin sheet metal extending over one side of said core

sheet member; and means at a plurality of said polygonal outer face portions of the indentations of the group at said one side of said core sheet member to intersecure said core sheet member and said surface sheet.

2. A panel construction as in claim 1 in which the ratio of L/H for the core sheet lies between approximately 1:1 and approximately 30:1, where L is the shortest distance between centers of two adjoining oppositely disposed indentations measured in a plane parallel to the medial surface, and H is the maximum thickness of the core sheet measured perpendicular to the medial surface.

3. A panel construction as in claim 1 in which the ratio of L/H for the core sheet is approximately 7:4, where L is the shortest distance between centers of two adjoining oppositely disposed indentations measured in a plane parallel to the medial surface, and H is the maximum thickness of the core sheet measured perpendicular to the medial surface.

4. A panel construction as in claim 1 in which the acute angle made by the coplanar side walls with the medial surface is over 20°, measured in a plane perpendicular to the side walls.

5. A panel construction as in claim 1 in which the acute angle made by the coplanar side walls with the medial surface is approximately 45°, measured in a plane perpendicular to the side walls.

6. A panel construction as in claim 1 in which the surface sheet has dimpled portions.

7. A panel construction as in claim 1, and comprising in addition: a second surface sheet of relatively thin sheet metal extending over the other side of said core sheet member; and means at a plurality of said polygonal face portions of the indentations of the group at said other side of the core sheet member to intersecure said core sheet member and said second surface sheet.

8. In a light-weight, high-strength, metallic panel construction, the combination comprising: a plurality of sheet members of relatively thin sheet metal attached to each other and each provided with a plurality of hollow polyhedral indentations extending in opposite directions from a medial surface of said sheet member, said indentations comprising one group of similarly oriented congruent indentations having polygonal outer wall portions located in uniformly spaced relation to and at one side of such medial surface, and a second group of similarly oriented congruent indentations having polygonal outer wall portions located in uniformly spaced relation to and at the other side of such medial surface, each indentation having a plurality of inclined substantially planar side wall portions extending divergently from the respective sides of its outer wall portion to said medial surface and each such inclined side wall portion of each indentation of one group being coplanar with a similar side wall portion of an adjacent indentation of the other group to define a substantially flat plane extending between polygonal outer wall portions of adjacent oppositely oriented indentations, and side wall portions of a set of adjacent indentations of each group meeting at a common point substantially at said medial surface, the sheet members being arranged with inwardly facing outer wall portions of adjoining sheet members in contact; and means at a plurality of said outer wall portions in contact for securing together said adjoining sheet members at their contacting outer wall portions.

9. In a panel construction, a relatively dense thin rigid sheet member provided with a plurality of indentations extending in opposite directions from a medial surface of said sheet member, said indentations comprising one group of similarly oriented hollow truncated pyramids having truncated portions located in uniformly spaced relation to and at one side of said medial surface, and a second group of similarly oriented hollow truncated pyramids having truncated portions located in uniformly spaced relation to and at the other side of such medial surface, the respective side wall portions of each pyramidal indentation of said one group being coplanar with similar side wall portions of the adjacent pyramidal indentations of the other group, such coplanar side wall portions defining substantially flat planes extending between the truncated portions of adjacent oppositely directed pyramidal indentations, and the meeting side wall portions of two adjacent pyramidal indentations of the same group intersecting at a point disposed substantially in said medial surface; a second relatively dense thin rigid sheet extending over one side of said sheet member; and means at a plurality of said truncated portions of the pyramidal indentations of the group at said one side of said sheet member to intersecure said sheet member and said second sheet.

10. A construction as set forth in claim 9, and comprising in addition: a third relatively dense thin rigid sheet extending over the other side of said sheet member; and means at certain of said truncated portions of the indentations at said other side of said sheet member attaching the same to said third sheet to intersecure said sheet member and said third sheet.

11. In a panel structure, the combination of: a plurality of relatively dense thin rigid reinforcing sheets secured together, each of said reinforcing sheets being provided with a plurality of indentations extending in opposite directions from a medial surface of said sheet, said indentations comprising one group of similarly oriented hollow truncated pyramids having truncated portions located in uniformly spaced relation to and at one side of said medial surface, and a second group of similarly oriented hollow truncated pyramids having truncated portions located in uniformly spaced relation to and at the other side of such medial surface, the respective side wall portions of each pyramidal indentation of said one group being coplanar with similar side wall portions of the adjacent pyramidal indentations of the other group, such coplanar side wall portions defining substantially flat flanges extending between the truncated portions of adjacent oppositely directed pyramidal indentations, and the meeting side wall portions of two adjacent pyramidal indentations of the same group intersecting at a point disposed substantially in said medial surface; and means at a plurality of said truncated portions of the pyramidal indentations of one sheet in contact with truncated portions of an adjoining sheet for securing together said adjoining sheets at their contacting truncated portions.

12. A panel structure as set out in claim 11, having a relatively dense thin rigid surface sheet in contact with and secured to certain of the truncated portions of the outer pyramidal indentations of one of said reinforcing sheets.

13. A panel structure as set out in claim 11, having a relatively dense thin rigid surface sheet in contact with and secured to certain of the

truncated portions of the outer pyramidal indentations of one of said reinforcing sheets, said surface sheet having dimpled portions.

14. A panel structure as set out in claim 11, having a first relatively dense thin rigid surface sheet in contact with and secured to certain ones of the truncated portions of the outer pyramidal indentations of one of said reinforcing sheets, and a second relatively dense thin rigid surface sheet in contact with and secured to certain of the truncated portions of the outer pyramidal indentations of a second one of said reinforcing sheets.

15. In a light weight, high-strength panel construction, a sheet member of relatively dense thin rigid material provided with a plurality of indentations extending in opposite directions from a medial surface of said sheet member, said indentations comprising one group of similarly oriented hollow truncated triangular pyramids having triangular truncated portions located in uniformly spaced relation to and at one side of such medial surface, and a second group of similarly oriented hollow truncated triangular pyramids having triangular truncated portions located in uniformly spaced relation to and at the other side of said medial surface, the indentations of said one group being oriented oppositely to and being symmetrically interspersed between the indentations of said second group, and the respective side wall portions of each pyramidal indentation of said one group being coplanar with similar side wall portions of the adjacent pyramidal indentations of the other group, such coplanar side wall portions defining substantially flat planes extending from one side of said sheet member to the other between the truncated portions of adjacent oppositely directed pyramidal indentations, and said coplanar side wall portions of a set of adjacent pyramidal indentations intersecting at a common point lying in said medial surface and thereby defining three salient angle portions and three re-entrant angle portions alternately arranged about said common point of intersection in opposing relation, the salient angle portions being disposed at one side of said medial surface and the re-entrant angle portions being disposed at the other side of said medial surface, and the intersection defined by each salient angle portion being aligned with the intersection defined by the opposing re-entrant angle portion along a substantially straight line extending through said common point.

16. In a light weight, high-strength, metallic panel construction, a sheet member of relatively thin sheet metal provided with a plurality of indentations in the form of hollow truncated triangular pyramids extending in opposite directions from a medial surface of said sheet member and each having three side wall portions inclined to said medial surface and a triangular wall portion meeting said side wall portions at the outer edges of the latter portions, said indentations comprising one group of similarly oriented hollow truncated triangular pyramids having their triangular wall portions located in uniformly spaced relation to and at one side of said medial surface and a second group of similarly oriented hollow truncated triangular pyramids having their triangular wall portions located in uniformly spaced relation to and at the other side of said medial surface, the indentations of said one group being oriented oppositely to and interspersed between the indentations of said second group and each inclined side wall portion

of each indentation of said one group being coplanar with an inclined side wall portion of an adjacent indentation of said second group, such coplanar side wall portions defining substantially flat planes extending between the triangular wall portions of adjacent oppositely directed indentations, and said coplanar side wall portions of a set of adjacent indentations intersecting at a common point lying in said medial surface and thereby defining three salient angle portions and three re-entrant angle portions alternately arranged about said common point of intersection in opposing relation, the salient angle portions being disposed at one side of said medial surface and the re-entrant angle portions being disposed at the other side of said medial surface, and the linear intersection defined by each salient angle portion being aligned with the linear intersection defined by an opposing re-entrant angle portion along a substantially straight line extending through said common point.

17. A panel construction as in claim 16 in which the ratio of L/H lies between approximately 1:1 and approximately 30:1, where L is the distance between centers of two adjoining oppositely disposed indentations measured in a plane parallel to the medial surface, and H is the maximum thickness of the panel measured perpendicular to the medial surface.

18. A panel construction as in claim 16 in which the ratio of L/H is approximately 7:4, where L is the distance between centers of two adjoining oppositely disposed indentations measured in a plane parallel to the medial surface, and H is the maximum thickness of the panel measured perpendicular to the medial surface.

19. A panel construction as in claim 16 in which the acute angle made by the coplanar side walls with the medial surface is over 20°, measured in a plane perpendicular to the side walls.

20. A panel construction as in claim 16 in which the acute angle made by the coplanar side walls with the medial surface is approximately 45°, measured in a plane perpendicular to the side walls.

21. A panel construction as in claim 16, and comprising in addition: a surface sheet of relatively thin sheet metal extending over one side of said indented sheet member; and means at a plurality of said triangular wall portions of the sheet member attaching it to the surface sheet to intersecure the indented sheet member and the surface sheet.

22. A panel construction as in claim 16, and comprising in addition: a second surface sheet of relatively thin sheet metal extending over the other side of said indented sheet member; and means at a plurality of others of said triangular wall portions of the sheet member attaching it to the second surface sheet to intersecure the indented sheet member and the second surface sheet.

23. In a light weight, high-strength, metallic panel construction the combination of: a plurality of sheet members of relatively thin sheet metal each of which is provided with a plurality of indentations in the form of hollow truncated triangular pyramids extending in opposite directions from a medial surface of said sheet member and each having three side wall portions inclined to said medial surface and a triangular wall portion meeting said side wall portions at the outer edges of the latter portions, said indentations

comprising one group of similarly oriented hollow truncated triangular pyramids having their triangular wall portions located in uniformly spaced relation to and at one side of said medial surface and a second group of similarly oriented

hollow truncated triangular pyramids having their triangular wall portions located in uniformly spaced relation to and at the other side of said medial surface, the indentations of said one group being oriented oppositely to and interspersed between the indentations of said second group and each inclined side wall portion of each indentation of said one group being coplanar with an inclined side wall portion of an adjacent indentation of said second group, such coplanar side wall portions defining substantially flat planes extending between the triangular wall portions of adjacent oppositely directed indentations, and said coplanar side wall portions of a set of adjacent indentations intersecting at a common point lying in said medial surface and thereby defining three salient angle portions and three re-entrant angle portions alternately arranged about said common point of intersection in opposing relation, the salient angle portions being disposed at one side of said medial surface and the re-entrant angle portions being disposed at the other side of said medial surface, and the linear intersection defined by each salient angle portion being aligned with the linear intersection defined by an opposing re-entrant angle portion along a substantially straight line extending through said common point, the indented sheet members extending parallel to each other with inwardly facing triangular wall portions of adjoining sheet members in mutual contact; and means at a plurality of the contacting triangular wall portions to intersecure adjoining indented sheet members.

24. A panel construction as in claim 23, and comprising in addition: a surface sheet of relatively thin sheet metal extending over one side of one of said indented sheet members; and means at a plurality of the outwardly facing triangular wall portions of said one indented sheet member attaching it to the surface sheet to intersecure the indented sheet member and the surface sheet.

25. A panel construction as in claim 24, and comprising in addition: a second sheet of relatively thin sheet metal extending over one side of another of said indented sheet members; and means at a plurality of the outwardly facing triangular wall portions of the other of the indented sheet members attaching it to the second surface sheet to intersecure the other indented sheet member and the second surface sheet.

26. In a light weight, high-strength, metallic panel construction, a sheet member of relatively thin sheet metal with a plurality of indentations extending in opposite directions from a medial surface of said sheet member, said indentations comprising one group of similarly oriented hollow truncated pyramids of square cross section having square truncated portions located in uniformly spaced relation to and at one side of said medial surface, and a second group of similarly oriented hollow truncated pyramids of square cross section having square truncated portions located in uniformly spaced relation to and at the other side of such medial surface, the respective side wall portions of each pyramid/indentation of said one group being coplanar with similar side wall portions of the adjacent pyramidal indentations of the other group, such

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coplanar side wall portions defining substantially flat planes extending between the truncated portions of adjacent oppositely directed pyramidal indentations, and the meeting side wall portions of a set of four adjacent pyramidal indentations intersecting at a point disposed substantially in said medial surface and defining two salient and two re-entrant angle portions alternately arranged around said point; a second sheet of relatively thin sheet metal extending over one side of said sheet member; and means at a plurality of said truncated portions of the pyramidal indentations of the group at said one side of said sheet member to inter-secure said sheet member and said second sheet.

27. In a light weight, high-strength, metallic panel construction, a sheet member of relatively thin sheet metal with a plurality of indentations extending in opposite directions from a medial surface of said sheet member, said indentations comprising one group of similarly oriented hollow truncated polyhedrons of oblong rectangular cross section having oblong rectangular truncated portions located in uniformly spaced relation to and at one side of said medial surface, and a second group of similarly oriented hollow truncated polyhedrons of oblong rectangular cross section having oblong rectangular truncated portions located in uniformly spaced relation to and at the other side of such medial surface, the respective side wall portions of each polyhedral indentation of said one group being coplanar with similar side wall portions of the adjacent polyhedral indentations of the other

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group, such coplanar side wall portions defining substantially flat planes extending between the truncated portions of adjacent oppositely directed polyhedral indentations, and the meeting side wall portions of a set of four adjacent polyhedral indentations intersecting at a point disposed substantially in said medial surface and defining two salient and two re-entrant angle portions alternately arranged around said point; a second sheet of relatively thin sheet metal extending over one side of said sheet member; and means at a plurality of said truncated portions of the polyhedral indentations of the group at said one side of said sheet member to inter-secure said sheet member and said second sheet.

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Patent No. 2,481,046

Certificate of Correction

September 6, 1949

JAMES C. SCURLOCK

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows:

Column 2, line 8, for "paned" read *panel*; column 6, line 47, for "satisfactory" read *satisfactory*; column 14, line 10, for the word "securely" read *secured*; column 15, line 56, for the claim reference numeral "16" read *21*; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 7th day of February, A. D. 1950.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.

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[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.