Nov. 20, 1956 J. C. SCURLOCK 2,771,164

WALL CONSTRUCTION

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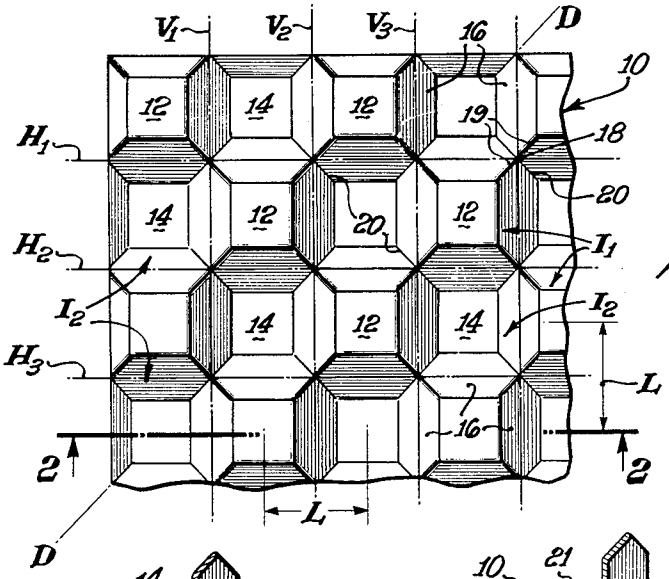


Fig. 1.

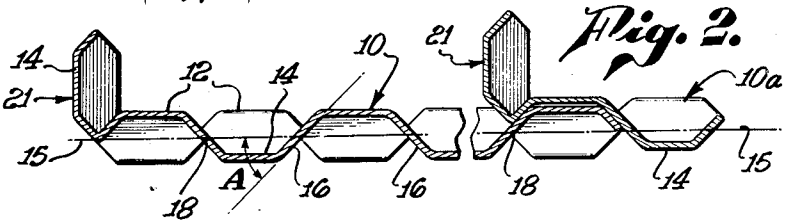


Fig. 2.

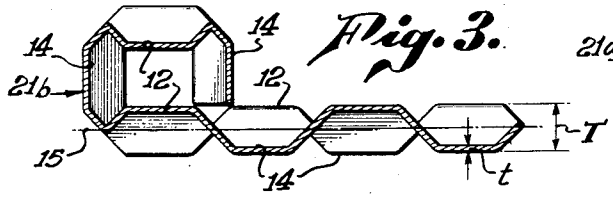


Fig. 3.

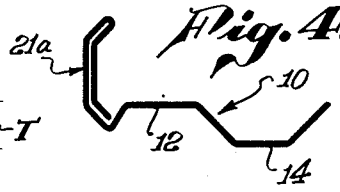


Fig. 4.

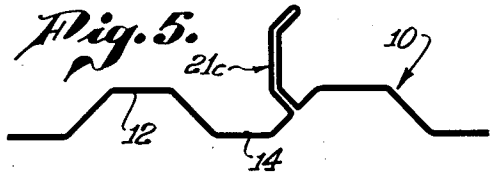


Fig. 5.

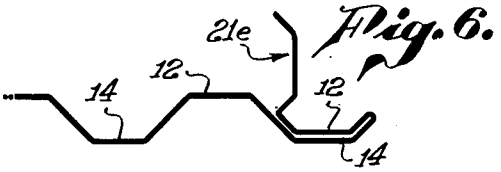


Fig. 6.

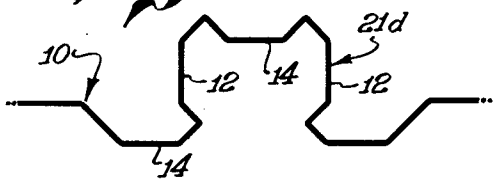


Fig. 7.

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Fig. 8.

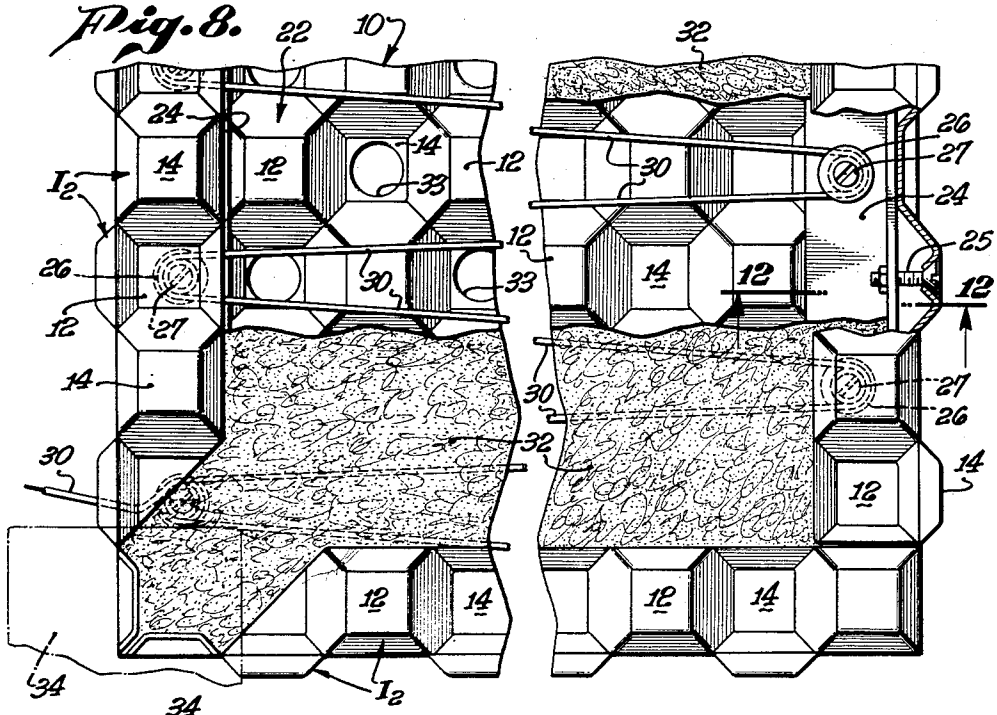


Fig. 10.

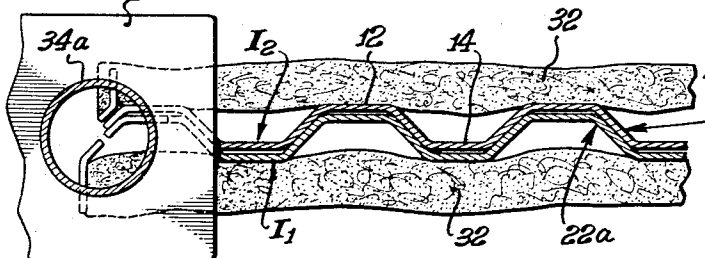


Fig. 9.

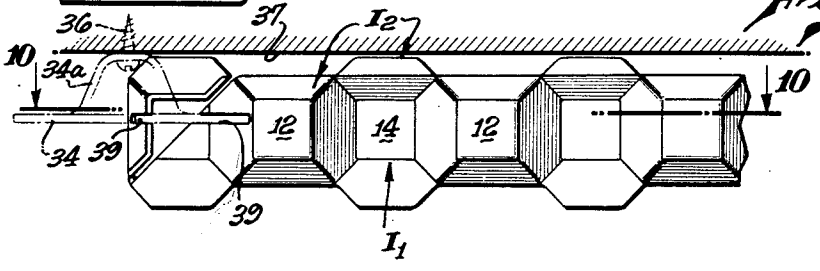


Fig. 11.



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Fig. 14.

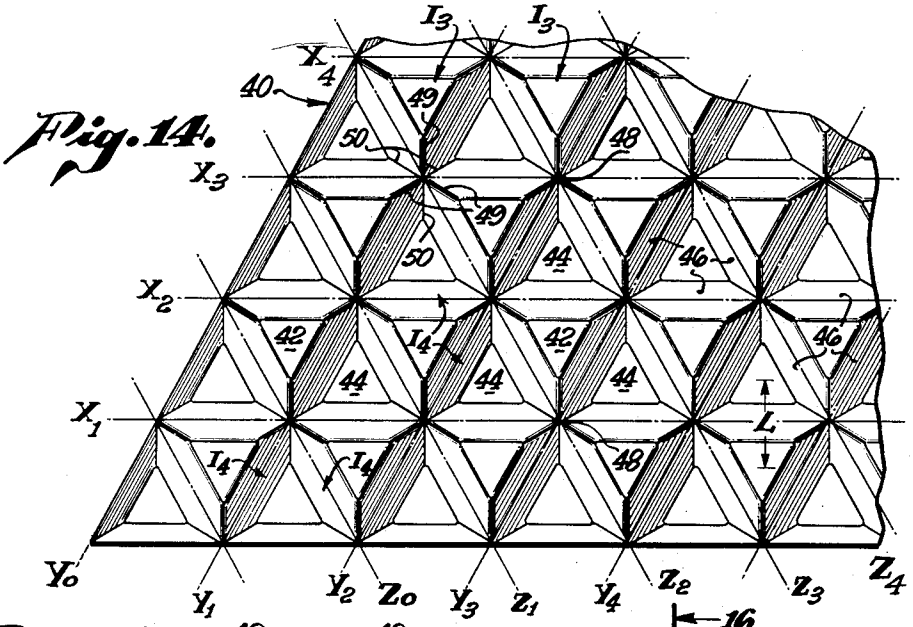


Fig. 15.

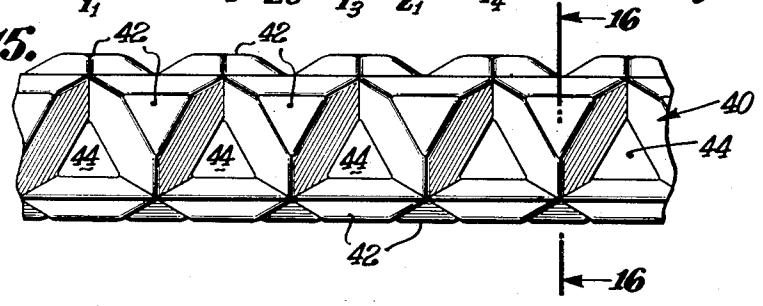


Fig. 13.

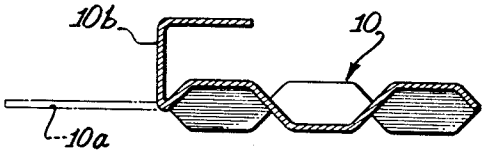


Fig. 16.

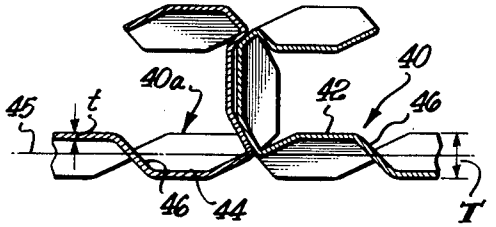
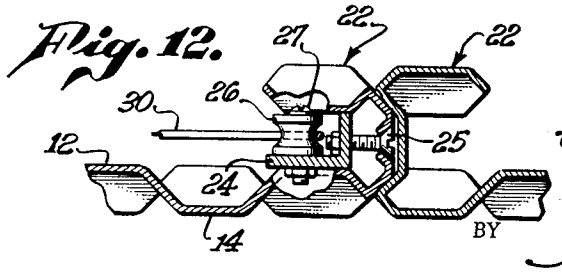


Fig. 12.



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2,771,164

WALL CONSTRUCTION

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Application January 27, 1949, Serial No. 73,147

8 Claims. (Cl. 189—34)

The present invention relates generally to wall constructions, and more particularly to relatively thin, lightweight surface members used to produce an ornamental or decorative finish on a wall as well as for other utilitarian purposes.

A flat sheet of relatively thin material is not suited for these purposes because the sheet is too limber or flexible. It is a matter of common observation that a piece of flat sheet metal of any substantial size buckles or deflects in its central portion very easily and so does not present a suitable appearance.

Except for these characteristics, relatively thin sheet materials can advantageously be used for many purposes. For example, they may be used as surfacing on side walls or ceilings in buildings, as free standing screens, or they may be incorporated in radiant heating elements attached to walls. Thin sheet materials, especially metal, have a relatively high strength, are light in weight and may be painted or otherwise finished in a variety of different ways that present a pleasing appearance. Such surface members may also be treated or combined with a layer of insulating material in such a manner as to provide not only thermal insulation but to render the surface members effective as sound deadening or sound insulating members.

Various substances may be used for such thin, lightweight surface members, but, in general, metal is the most satisfactory material because of its relatively high strength and durability. It can be polished or painted or otherwise attractively finished. On the other hand, various other sheet materials may be used, as for example synthetic resins, commonly termed "plastics," especially those having thermoplastic properties.

Hence, it becomes a general object of my invention to provide a surface member for wall construction that is made of relatively thin sheet material and is lightweight but is sufficiently rigid to retain a given shape under its own weight or light applied loads.

It is also an object of my invention to provide a surface member of the character described which is sufficiently versatile in use that it can be used not only as a wall surfacing member directly attached to a wall but can be incorporated in heating elements or the like which are subsequently attached to the walls.

It is also an object of my invention to provide a lightweight surface member made of thin sheet material that can be used by itself, or in combination with other materials to insulate against sound and heat.

The above and other objects and advantages of my invention have been attained by constructing a surface member from a sheet which is provided with a plurality of indentations or embossments in the form of hollow polyhedrons with polygonal outer faces that impart a high degree of rigidity to the sheet. The polyhedrons are in some cases hollow truncated pyramids of either square or triangular cross section. 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 reentrant angle portions arranged alternately around this common point of intersection.

In the embossed sheet, the inclined side walls of the indentations intersect the medial surface of the sheet along a plurality of straight lines which are arranged in a plurality of groups. In each group the lines are straight and parallel to each other, and intersect the lines of the other group or groups. Along any one of these lines, the sheet offers a minimum resistance to bending, and these lines are therefore termed "bend lines." By bending a portion of the sheet about one of these lines, there is formed a reinforcing element or flange which reinforces or strengthens the sheet against bending about any other bend lines which intersect the reinforcing element. In this way the sheet may be provided with an integrally formed reinforcement that adds substantially to its rigidity. Such reinforcing elements may be formed at one or more of the edges of a sheet, or they may be formed in central portions of the sheet removed from an edge. In a preferred embodiment, a reinforcing element of angular cross section is formed entirely around the periphery of the sheet to form a tray-like structure to which may be added heating elements and a layer of insulating material that is held in place by the marginal reinforcing element.

Reference may be also made to my co-pending patent application on "Panel Structure," Serial No. 785,610, filed on November 13, 1947, now Patent 2,481,046, issued September 6, 1949, wherein is disclosed more fully various details of the embossed sheet and I claim certain forms of panels including an embossed sheet.

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

Fig. 1 is a fragmentary plan view of a corner of an embossed sheet having square indentations, showing the sheet as it appears before bending;

Fig. 2 is a fragmentary transverse cross section of the sheet of Fig. 1, as on line 2—2 of that figure, but showing one marginal row of indentations bent up at an edge of the sheet, and also showing two sheets overlapping at their margins;

Fig. 3 is a fragmentary section similar to Fig. 2 but showing three successive rows of indentations at the edge of a sheet bent at 90° to each other to form a reinforcing column at the edge of the sheet;

Fig. 4 is a diagrammatic view of an embossed sheet in cross section showing two successive rows at the edge of a sheet bent relatively thereto, one row being bent through 180° and the other through 90°;

Fig. 5 is a diagrammatic view of an embossed sheet in cross section illustrating a stiffening web intermediate the sides of the sheet with two successive rows of indentations bent at 180° to each other, both rows being bent at 90° to the general extent of the sheet;

Fig. 6 is a diagrammatic view of an embossed sheet in cross section showing another manner of bending the sheet to reinforce the marginal portion;

Fig. 7 is a diagrammatic view of an embossed sheet in

cross section having three successive bends at 90° to each other to form a reinforcing column intermediate the sides of the sheet;

Fig. 8 is a fragmentary plan view of an embossed sheet with marginal portions bent up at all sides to form a tray holding electrical heating elements and thermal insulation;

Fig. 9 is a fragmentary end elevation of the tray of Fig. 8, also illustrating how the tray is held at a corner against a structural surface, as wall or ceiling;

Fig. 10 is a fragmentary horizontal section through the engaging sides of two abutting trays showing how they nest together;

Fig. 11 is a side view, partly in elevation and partly in section, of a hanger for attaching the tray of Fig. 8 to a wall;

Fig. 12 is a fragmentary transverse section on line **12—12** of Fig. 8 but showing how the sides of two similar trays nest with each other;

Fig. 13 is a fragmentary cross section similar to Fig. 2 of a partially embossed sheet, the marginal portion remaining flat;

Fig. 14 is a fragmentary plan view of an embossed sheet having triangular indentations, showing the sheet as it appears before it is bent;

Fig. 15 is a fragmentary side elevation of a tray formed from a sheet embossed with triangular indentations, the margins of the sheet being bent in the same manner as the tray of Fig. 8; and

Fig. 16 is a fragmentary section on line **16—16** of Fig. 15, but showing how the sides of two similar trays nest together.

Referring now to the drawings, there is shown in Fig. 1 a portion of a sheet **10** which is formed from a single plane sheet by embossing or indenting the sheet with a plurality of hollow polyhedral indentations. Sheet member **10** has a plurality of square indentations in the form of hollow truncated pyramids arranged in two groups extending in opposite directions from the medial surface of the sheet as defined below, 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_1 that terminate in square outer walls or surfaces **12** which define truncated portions of the full pyramids. The other group of indentations comprises oppositely or downwardly extending indentations I_2 that terminate in square outer walls or faces **14** which also define truncated portions of the full pyramidal indentations.

It is contemplated that the embossed sheet 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 sheet, it is easy to consider the panel as having two groups of polyhedral 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 the medial surface **15** of the embossed sheet member, as shown in Fig. 2. Walls **12** are uniformly spaced from surface **15** at one side thereof, and walls **14** are uniformly spaced from surface **15** at the other side thereof; and in the preferred form of my invention, surfaces **14** and **12** are equally spaced from medial surface **15**. 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 a planar surface either at or near the midpoint between outer surfaces **12** and **14**.

The neutral plane of the sheet as shown in Fig. 2 coincides with the medial plane; and both are planes, the embossed sheet as a whole being flat. However, the ultimate shape of the embossed sheet may not always be flat but can 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 indentations of each group I_1 and I_2 are congruent or the same size and shape, and are symmetrically interspersed between indentations of the other group. In a preferred form of embossed sheet illustrated herein, in which the medial surface **15** coincides with the neutral surface, indentations I_1 are of the same size and shape as indentations I_2, that is, all the indentations of the sheet are congruent. Each indentation has four inclined side walls **16** which extend divergently away from the sides of outer wall portions **12** and **14** to medial surface **15**. Square surfaces **12** are connected with square surfaces **14** by the sloping side wall portions **16** of the pyramidal indentations; and since each pyramidal indentation of one group has its side walls coplanar with the side wall portion of each adjacent indentation of the other group, side wall portions **16** are substantially flat and continuous planes which extend from one side of the sheet to the other between the two sets of square surfaces **12** and **14**. The continuous character of these flat coplanar side walls **16** is illustrated clearly when the sheet is viewed in section, as in Fig. 2.

The coplanar side walls of adjacent rectangular pyramids intersect at a common point **18** substantially at medial surface **15**. Two adjacent indentations of either group have a total of four walls which meet at this common point **18**. All the meeting walls around this intersection define a total of four angle portions, two salient and two reentrant. Two salient angles **19** alternate with two reentrant angles **20** so that these four angle portions are alternately arranged around point **18**. Salient angles **19** are located above medial plane **15**, while reentrant angles **20** are located below the medial plane. Two salient angles are aligned with each other across point **18**, as are also two reentrant angles.

Certain dimensions or proportions are preferred in embossing sheet **10** because they lead to the most favorable results, as explained in greater detail in my copending application referred to above. The acute angle A which sides **16** of the indentations make with the medial plane **15** is uniform and preferably greater than 30°, the exact angle chosen being dependent to some extent upon the type of material used and the purpose or loading for which the panel is intended. In the drawings, I show the inclined sides **16** of the indentations making an angle A with the medial plane of approximately 45°. When this angle is increased to more than 30°, or is in the vicinity of 45°, the increase in strength and rigidity of the embossed sheet is substantial and approaches a maximum, all conditions being considered. Of course, angle A is the same at both sides of the sheet.

Other dimensions or proportions which have been found to give improved results are the thickness *t* of the sheet, the thickness of the embossed panel T, the spacing L between identations, and their relative values. The dimension T is the overall thickness of the embossed sheet, or the distance between outer surfaces **12** and **14** measured in a direction perpendicular to the medial plane, as shown in Fig. 3. The dimension L is defined as the shortest center-to-center distance between two adjoining and oppositely disposed square indentations, measured parallel to medial plane **15**, as indicated in Fig. 1. The dimension L can be taken in either of two directions at right angles to each other, as shown in Fig. 1. When the embossments I_1 and I_2 are square, L is the same measured in either direction; but if the embossments are elongated rectangles, then the distance L is greater in one direction than in the other. For purposes of computing the ratios hereinafter mentioned,

the shorter of the two distances L is used, as discussed in greater detail in my co-pending application.

Ordinarily embossed sheet **10** will be made from a relatively thin sheet, especially when the material is metal, the thickness being determined by the material used an the loading to which the panel will be subjected. Typically, the original thickness of the sheet may range from a few thousandths of an inch to several hundredths; although a considerably greater thickness may be used in the case of cast or molded members. For a given thickness *t*, the ratio of the distance L both to the sheet thickness *t* and the panel thickness T should preferably lie within certain ranges. Satisfactory results have been obtained within a range of 15:1 to 100:1 for the ratio of *L/t*, while for the ratio of *T/t* a range of 4:1 to 50:1 gives satisfactory results. An undue increase in the spacing between successive indentations results in an undue weakening of the strength and rigidity of the embossed sheet, so that the ratio *L/T* should not exceed a value of 30:1.

In an embossed sheet having square or rectangular indentations of the character shown in Fig. 1, the sloping sides of indentations I_1 meet the coplander sides of the other group of indentations I_2 along straight lines which lie in or at medial plane **15**. These lines of intersection of the inclined side walls with the medial plane, because of the shape of the indentations are in two groups disposed at right angles to each other, the lines in each group being parallel to one aonther. Lines in each group have been indicated in Fig. 1 by the letter H or the letter V with subscripts to denote individual lines. Lines H are spaced apart equally by a distance equal to the center-to-center spacing between surfaces **12** and **14**. Lines V are equally spaced, as long as the indentations are of a square pattern. If a pattern of elongated rectangles is used, the spacing between lines H is different than the spacing between lines V. Since the body or substance of the sheet along these lines is at the medial plane, it offers a minimum resistance to bending about these lines, and lines H and V are referred to as the natural "bend lines" of the sheet. At all other positions, the material of the sheet is removed to a greater or lesser extent from the medial plane so that a correspondingly greater resistance is offered to bending.

Advantage may be taken of this fact to deliberately bend the sheet along one or more bend lines in varying combinations, as will be explained, in order to obtain a bent-up portion of the sheet which constitutes an integral reinforcing flange or element. There is shown in Fig. 2 a reinforcement formed by bending one row of indentations about the line V_1, the row being bent to a position at 90° with respect to the remainder of the sheet. The bent-up row of indentations forms a flange or element **21** which reinforces the sheet proper against any bending along any bend lines H, perpendicular thereto, which intersect the flange thus formed. This is a very elementary formation and involves bending a portion of the sheet along only one edge. It may be desirable to bend a similar portion of the sheet along a plurality of edges, as, for example, along each of two opposed, parallel edges, particularly if a sheet is to be used alone. But where a sheet is to be used in conjunction with adjoining sheets, as shown in Fig. 2, the parallel edge of the sheet opposite to the one at which flange **21** is located, can be overlapped one or more rows of indentations with the adjoining sheet **10***a* to the right, as illustrated in Fig. 2. Thus the reinforcing portion **21** of adjoining sheet **10***a* forms a flange which also reinforces the overlapping sheet **10** when the two sheets are fastened together. They may be secured by any suitable means, such as metal screws, nuts and bolts, spot welding, nails, adhesives, or other suitable means according to the material used for the sheet. One example of the use to which a panel of this character can be put, is a free standing screen in which the screen is composed of a plurality of individual panels **10** which extend substantially vertically and overlap each other as illustrated in Fig. 2, the upturned flanges being vertically extending and formed by bending along vertical bend lines.

If it is desired to add to the action of the reinforcing element at the edge of the sheet, this may be accomplished by making additional bends in any one of a number of ways. One such way is shown diagrammatically in Fig. 4. The initial row of indentations are bent along the line V_1 through an angle of 180°. The two rows are then bent together through an angle of 90° along the bend line V_2 producing an upstanding reinforcing flange **21***a* of double thickness. In case it is desired to secure still greater stiffening along the edge of a sheet and at the same time produce an ornamental effect, a hollow reinforcing column may be formed as shown in Fig. 3. This involves making three successive 90° bends along the bend lines V_1, V_2, and V_3. The result is a hollow four-sided column **21***b* constituting a reinforcing element located along the edge of the sheet.

In order to simplify the drawings and description, these figures illustrate the treatment at only one edge of a sheet; but it will be understood without further disclosure how a sheet may be similarly treated at each of two parallel edges, or two intersecting edges. In the latter case, it is necessary to notch or cut away a portion at the corner of the sheet, according to the type of edge treatment used. Examples of notching will be disclosed in connection with a later described form of the invention.

Formation of at least two reinforcing elements disposed at right angles to each other provides reinforcement across all bend lines; and it produces a surface element that can be self-supporting as a cantilever.

It is not necessary to limit the location of the bent portion of the sheet to an edge or a marginal portion. A reinforcing flange can be located at any point intermediate two sides of a sheet, as shown in Figs. 5 and 7. In Fig. 5 there is illustrated a single thin flange **21***c* of double thickness formed by three separate bends. This may be done, for example, by first bending the sheet 180° along an intermediate bend line, as bend line V_2. Bends in opposite directions of 90° each are then made in succession about parallel bend lines, as lines V_1 and V_3, bringing the sections of the sheet at either side of the flange into alignment with each other.

Fig. 7 illustrates the formation of a three-sided column **21***d* of rectangular outline intermediate the sides of a sheet, four bends being used in this case. All bends are of 90° each, the two interior bends being in the same direction relative to each other while the two external bends are opposite to the direction of the interior bends.

Fig. 6 illustrates a combination treatment in which the bends are near the edge of the sheet, but the flange **21***e* is located inwardly of the edge of the sheet. The bend of Fig. 6 is shown at the right-hand edge of the sheet, but the corresponding bend at the left-hand edge of the sheet is accomplished by making a 180° bend along the line V_2 and then a bend of 90° in the opposite direction along the line V_1 to produce an upstanding flange of equal thickness. This has the advantage that the resultant edge of the sheet is a straight line and permits the sheet to butt against a smooth surface.

All the foregoing description has been based on the assumption that the bends are made at succeeding natural bend lines so that the flanges or reinforcing elements formed have a dimension in any direction of a single row of indentations; but it will be realized that the dimensions may be made larger by any whole number of rows of indentations. This may be done either for decorative effect or in order to produce a reinforcement of greater strength. It will be appreciated from Fig. 1, that the larger flanges result if the bends are made about lines V_1, V_2 and V_3 spaced apart by two rows of indentations, or a distance 2L, rather than by one row of indentations, or a distance L as shown in Fig. 1.

The present invention is concerned primarily with sheets which are used as surface elements for wall constructions in order to give a decorative finish treatment to the wall. They may be attached to the vertical side walls of a room, or to a horizontal wall, as the ceiling of a room. Under these circumstances, light weight and dimensional stability are extremely important. The sheets need to have a substantial degree of strength and rigidity so that they do not buckle or flex under their own weight or under light applied loads. A thin metal sheet embossed in the manner described has considerable inherent rigidity and strength; but when the sheet is made into large panels, such as 4' x 6', it is desirable to add some reinforcing to the sheet, especially in order to reinforce the sheet against forces which tend to deform it along the bend lines. One method of reinforcing a sheet is shown in my co-pending application Serial No. 785,610, filed on November 13, 1946, now Patent 2,481,046, issued September 6, 1949, which comprises the addition of a surface sheet to an embossed core sheet. This is highly satisfactory when combination of two sheets is used as a structural member and is subjected to externally applied loads of greater magnitude. But for a simple surface element on a wall the addition of a second sheet to the embossed core sheet adds unnecessary weight and makes the resultant structure unnecessarily costly.

An advantageous method of reinforcing the sheet is to bend a portion of the sheet itself at one or more edges or at an intermediate position in the sheet in the manner described. This bending forms an integral reinforcing element or elements that reinforce the sheet across natural bend lines, and utilize to the fullest extent the inherent rigidity of the sheet itself. At the same time nothing is added to the weight of the sheet so that the completed decorative panel has a minimum weight and a maximum rigidity for that mass.

As compared with a flat, unembossed sheet of metal or similar material, bending up a portion of the embossed sheet to form a reinforcing flange has two marked advantages which produce new and unexpected results. In the first place, advantage can be taken of the natural bend lines in the sheet to make one or more bends very easily at a definite location and dimension without the aid of any special or expensive tools. When a flange is formed from an embossed portion of the sheet, the flange is embossed and stiffened in the same manner as the sheet so that the flange is more effective as a reinforcing member than a flat, smooth member having the same weight of material in it. This eliminates the need for any brackets or ties holding the upturned flange in position, because the flange has such inherent rigidity that it does not deflect or become less efficient within the range of loading normally applied to the main portion of the sheet.

As explained before, the sheet after embossment is relatively stiff and rigid, but has a minimum resistance to bending along naturally formed lines. In an embossed sheet having an integral flange as described, wherein one set of lines is parallel to the flange, and the other set is perpendicular to and intersects the flange, the flange provides a resistance to bending about the latter set of bend lines. This still leaves the original minimum resistance to bending the sheet along the first set of bend lines; and this resistance may likewise be greatly increased by forming a second flange, at right angles to the first flange, reinforcing the sheet in the other direction. A still further reinforcement is obtained by making additional flanges at the remaining one or two sides of the sheet. In the case of a flat unembossed sheet, there is very little inherent stiffness in any direction and the effect of a flange turned up along one edge to resist deformation is of very limited extent. Thus, a large flat sheet, even though flanged at all four edges, buckles and deflects considerably at the center under no load but the weight of the sheet itself. By adding a flange to an embossed sheet, the stabilizing or restraining effect of the flange is carried out into the sheet far beyond the limits possible with a flat, unembossed sheet. Consequently, the result of turning up a portion of an embossed sheet as a reinforcing member is to add rigidity or dimensional stability to the sheet over a far greater area than has heretofore been possible; and this is true whether or not the bent up portion of the sheet forming the reinforcing flange is itself embossed or not.

In addition to the foregoing advantages of this construction, using an embossed portion of a sheet for a reinforcing flange has the additional advantage, as will be apparent from subsequent description, of forming side faces at the edge of the sheet that can be nested together in a manner which prevents lateral displacement of adjoining sheets. This is particularly true with the trays illustrated in Figs. 8, 9 and 10.

A specific application of the embossed sheet with turned up edges is illustrated in Figs. 8, 9 and 10 in which the sheet **10** is used to form a tray-like surface member **22** that has all four edges channel-shaped after forming the reinforcements. These are the result of making two successive bends of 90° each along the bend lines V_1 and V_2, and the corresponding bend lines on the opposite parallel side of the sheet, and making similar bends of 90° each along the bend lines H_1 and H_2 and the corresponding bend lines at the other parallel side of the sheet. Thus the tray has a side face the height of one row of indentations which is returned along each of the four sides for an equal distance. Since it is undesirable to overlap the bent-up flanges, the corners of the sheet are notched before bending. One simple treatment is to cut off the corner along the diagonal line D—D of Fig. 1. When the sides are bent up, the resultant corner is as shown at the lower left corner in Fig. 8. An alternative method of notching the corner is to cut along several bend lines in a stepped formation, as along the lines H_2—V_2—H_1—V_3. When bent up, the completed corner appears as shown in the lower right-hand corner in Fig. 8. The former treatment of the corner is more economical and is used for interior corners of the tray where other trays abut; while the latter type of treatment is used where the finished corner is an exterior corner and it is therefore desired to completely close the sides of the tray, not only to enclose the contents, but to improve the external appearance of the completed product.

The same reference numerals are used in Fig. 8 to indicate the various portions of the indentations as are used in Fig. 1; but confusion from viewing the drawing will be eliminated if it is noted that along the marginal portions of the tray, the upper surface is the former under surface of the main portion of sheet **10**, and the numerals have been applied assuming the sheet to be viewed in the same aspect as in Fig. 1 with the marginal reinforcing portions turned up and back over the sheet.

Panels constructed as described have been made in sizes up to 4' x 6' and used as decorative surface treatment for walls. However, advantage may be taken of the tray-like formation of the panels to give them sound and thermal insulating characteristics and also to utilize them as radiant heating elements. For this latter purpose, a bracket member **24** of electrically non-conducting material is mounted in the panel at each of two opposite sides. Bracket **24** is preferably angle-shaped so that it can be attached to the upwardly turned sides of tray member **22** by bolts **25** or other suitable means. This holds the bracket in place.

Mounted at intervals along each braket **24** are spools **26** each fastened to the bracket by a bolt **27**. Spools **26** are preferably made of ceramic or other electrically nonconducting material. Extending between spools at opposite sides of the tray, is a length of resistance wire **30** which serves as the electric heating element of the panel. Wire **30** is covered with a high-temperature resistant, nonconductive coating so that the bare wire does not touch the panel at any place. Heating element **30** may be arranged in any fashion desired, and is here shown as being

stretched between spools **26** at opposite sides of the tray in a zig-zag fashion. The arrangement of this wire depends somewhat upon the length of wire for a panel, and this in turn is determined by the heat or energy output, measured in watts, per unit area of sheet surface that is desired. For any given length of wire **30**, it is distributed over the total area of the panel in such a manner that heating is reasonably uniform.

After the heating element and its mounting brackets **24** are in place on the top face of the sheet, the whole upper face of the panel is then covered with a layer of insulation, the heating element being between the sheet and the insulating layer. As typical of such materials that are particularly suited for this purpose, but without any necessary limitation thereto, there may be mentioned mineral wool and spun glass. Layer **32** of insulation may be of any desired thickness, but is preferably of a thickness equal to the spacing between rows of indentations which is the height of the marginal flange. If desired, the final bend along lines H_1 and V_1, forming the return portion of the reinforcing channel at the edge, may be made after the heating element and the insulation are in place. Finally the marginal row of indentations is bent down over the insulation and serves to hold the insulation in place as it is parallel to but spaced from the upper face of the sheet.

A panel constructed as just described can operate as a radiant heating element when placed on a wall or ceiling of a room. The layer of insulation **32** forms in a barrier to the passage of heat from heating element **30** in a direction rearwardly of the panel and toward the wall on which it is mounted, so that substantially all of the heat is radiated outwardly from the front side of the panel. Obviously, for this purpose embossed sheet **10** should be made of a thermally conductive material, such as metal.

It is possible to add to the panel a high degree of acoustic treatment by perforating the front side of the panel to a greater or lesser extent. For this purpose, there is shown in Fig. 8 openings **33** which are located in embossed surfaces **14**. As the sheet is viewed in Fig. 8, surfaces **14** are in the downwardly disposed group of indentations I_2, and are consequently usually spaced somewhat from the layer of insulation **32**. The result of these openings **33** is to create on the face of the panel a plurality of small sound absorbent areas. The presence of these areas, coupled with the fact that normally about three-fourths of the total frontal area of the panel is composed of inclined surfaces **16**, prevents sound waves from being reflected as a unit from the face of the panel, even though the panel is of metal, or other hard, dense material which is itself sound-reflective. The inclined surfaces **16** serve to diffuse or break up the sound waves upon reflection, while openings **33** absorb them; and the result is a very high degree of sound insulation. Insulation layer **32** contributes to this because it absorbs or diffuses the sound waves after they pass through openings **33** from the outer side of the panel. These waves are trapped and do not leave the openings.

The complete tray or panel **22** may be used as a surface element for walls of various types, and the means for attaching the tray to the wall may be varied to suit conditions.

If a plurality of trays are used, the adjacent corners of two or more trays may be held in place by special hangers, one type of which is shown in Figs. 9 and 11. Hanger **34** consists of a square plate with the central portion domed as at **34***a* and punched at **35** so that a bolt or screw **36** can pass through the opening **35** to fasten the hanger to a rafter, stud, or other structural member in a wall, the surface of which is indicated in Fig. 9 at **37**. As shown in the figure, the outermost surfaces of the indentations in the marginal flange thus bear against the wall to position the tray or panel **22** with respect thereto.

In order to receive a hanger **34**, the two upturned flanges are notched or slotted inwardly from the corner as at **39** in Fig. 9. The width of the slot is equal to the thickness of the plate portion of hanger **34**, and the length corresponds to the distance from the domed portion **34***a* of the hanger to its outer edge. Slots **39** at the corner extend at right angles to each other and the general length of each is parallel to the bend lines about which the associated reinforcing flange is bent. A hanger of the type shown is adapted to engage and hold as many as four trays meeting at a common point.

When two or more panels are used in abutting relation, they are mutually supporting. This condition is shown in Fig. 10 which shows the adjoining and abutting sides of two trays **22** and **22***a* in cross section. The indentations I_1 of one tray nest with the indentations I_2 of the other tray; and since each indentation consists of a flat square surface **12** or **14** surrounded by four sloping surfaces **16**, the nesting action of the two sets of indentations I_1 and I_2 on two trays holds the trays against lateral or shearing displacement relative to each other as long as the indentations are held in a firmly nested position. Fig. 12 is another sectional view through the engaging side flanges of two trays, taken at right angles to the section of Fig. 10. From these two views, the interlocking nature of the indentations at the sides of the two trays is readily apparent. The embossed nature of the turned-up reinforcing flange on each tray **22** and **22***a* not only causes the trays mutually to resist lateral displacement with respect to each other, but also aligns the two trays with each other and closes the gap between them without resort to any extraneous fastening means.

I have shown in Fig. 13 a modified form of my invention in which a marginal portion of the original sheet has been left unembossed. The main portion of sheet **10** has been embossed in the manner described above, while the smooth, flat marginal portion is indicated at **10***a* in dot-dash lines in its original position. Since the indentations I_1 and I_2 have been struck respectively upwardly and downwardly from the position of the original sheet, the marginal portion **10***a* lies at the medial plane of the sheet. In order to secure a reinforcing action in the manner and for the purposes described above, I may make one, but preferably two, 90° bends in the portion **10***a* to produce a bent-up portion of the sheet which acts as a reinforcing element. This sheet is shown in Fig. 13 with two 90° bends, resulting in the reinforcing flange **10***b*.

Referring now to Figs. 14, 15 and 16, there is shown a portion of a sheet **40** which has a plurality of triangular indentations in the form of hollow truncated triangular pyramids arranged in two groups. The two groups extend in opposite directions from the medial surface **45** 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 triangular outer walls or surfaces **42** 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 triangular outer walls or surfaces **44** which also define truncated portions of the full pyramidal indentations.

With this form of embossment also, the medial plane at **45** may be assumed to indicate the position of the original flat sheet from which the embossed sheet **40** is made. As in the case of the embossed sheet first described, outer wall portions **42** are uniformly spaced from the medial surface at one side thereof, and the other outer wall portions **44** are likewise uniformly spaced from the medial surface at the other side thereof. In the preferred form of embossed sheet illustrated in Figs. 14 to 16, inclusive, surfaces **42** and **44** are equally spaced from the medial surface.

The indentations of each group I_3 and I_4 are congruent or of the same size and shape, and are symmetrically interspaced between indentations of the other group. In the preferred form of my invention herein illustrated, in which the medial surface **45** coincides with the neutral

surface of the sheet, indentations I_3 are of the same size and shape as the identations I_4, that is, all the identations of the sheet are congruent. Each identation has three inclined side walls **46**; and triangular surfaces **42** are connected with triangular surfaces **44** by these sloping side wall portions which extend divergently away from the three sides of outer faces **42** and **44**. 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 continuing planes which extend from one side of the sheet to the other between triangular surfaces **42** and **44**. The continuous character of these flat coplanar side walls **46** may be seen when the embossed sheet is viewed in plan, as in Fig. 14, but as also clearly evident when the sheet is seen in section as in Fig. 16.

The coplanar side walls of adjacent pyramids intersect at a common point **48** substantially at the medial surface **45**. The formation of the panel at and around this point of intersection **48** is discussed in greater detail in my companion application Serial No. 785,610 filed on November 13, 1946, now Patent 2,481,046, issued September 6, 1949, referred to above, but it will be seen that the intersection of six inclined walls **46** at a single point **48** defines a total of six angle portions, three of which are salient and three reentrant. Three salient angle portions **49** alternate with three reentrant angles **50** so that the six angle portions are alternately arranged around the common point of intersection **48**. All three salient angles **49** are located above the medial plane, while the reentrant angles **50** are located below the medial plane.

The range of dimensions or proportions previously mentioned as preferred, also apply to the triangular form of indentation in order to attain the most favorable results. The dimension L is always taken 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, as shown in Fig. 14. The dimensions T and *t* are measured as before, as shown in Fig. 16.

Triangular surfaces **42** and **44** are equilateral triangles, and there are six inclined side walls **46** intersecting at each point **48**, the inclined side walls being equi-angularly spaced about the point of intersection. This condition produces three sets of lines along which the inclined sides **46** intersect the medial plane, these lines of intersection being natural bend lines along which the body of the sheet is at the medial plane and so has a minimum resistance to bending. The bend lines of each group are parallel to each other and intersect the other two groups at 60°. The three groups of bend lines have been indicated in Fig. 14 by the letters X, Y and Z respectively, with subscripts to indicate individual lines in each group. As before, advantage may be taken of the presence of these bend lines to bend the sheet deliberately about one or more bend lines to produce one or more bent portions of the sheet which constitute integral reinforcing elements.

Without going into a detailed description thereof, it will be evident from the drawings and the previous description, that sheet **40** can be bent along any one line of three sets of bend lines to produce a bent-up portion along one edge, similar to the construction shown in Fig. 2; and that this bent-up portion along the edge may be further reinforced as in Figs. 3 or 4. Likewise, bent stiffening portions may be placed in the sheet at a location removed from one edge by a plurality of successive bends in the manner of Figs. 5, 6 and 7.

It is of course possible to bend portions of sheet **40** about more than one line or along more than one edge of the sheet. If bends are made along two parallel bend lines of each of the three sets of lines X, Y and Z the result is a triangular tray-shaped panel with a channel-shaped edge around its three sides. The reinforcing flange is shaped similar to the reinforcing flange of the tray illustrated in Fig. 8, and has a portion disposed angularly relative to the sheet and another portion parallel to but spaced from the sheet. A side view of such a tray is shown in Fig. 15, the side of the reinforcing flange being shown in elevation. Although the basic shape of a surface member made from a sheet with triangular indentations is an equilateral triangle, a tray may be made having a shape corresponding to a multiple of such equilateral triangles, for example a diamond, a parallelogram, or a hexagon. For example, starting with a triangular sheet as shown in Fig. 14 and retaining the lower and left hand edges, a diamond-shaped tray is formed by cutting away excess material and then bending a reinforcing flange to form two edges of the tray along lines X_3 and Y_3 or any other two similar bend lines that are parallel to and equidistant from the lower and left hand edges respectively. If these same two new lines or sides are not each equidistant from the present lower and left edges respectively, as lines X_2 and Y_4, the tray produced is a parallelogram. A hexagon shape may be obtained by bending reinforcing flanges to form the side sides of the tray along lines Z_6, Y_0, X_4, Z_4, Y_4, and the present bottom edge.

A triangular tray made from the embossed sheet **40** may be used by itself for surface treatment of a wall to obtain a decorative effect or, it may have electrical heating elements and insulation added to it in the manner described above in connection with Fig. 8, to produce a panel which also may be used as a radiant heating element and has thermal insulation characteristics. By the addition of openings in surfaces **44**, corresponding to openings **33** in sheet **10***a*, there may be produced a panel with sound insulating characteristics; and these may be in addition to the heating and thermal insulation properties.

Trays or panels formed with angular reinforcing elements along the edges may be used singly or in conjunction with other similar panels, in the manner previously described. It will be seen from Fig. 16 that panel **40** may be used in conjunction with a second panel **40***a*, also having triangular indentations, in such a manner that the edges of the panels nest together and mutually resist relative lateral or shearing displacement. When indentations I_3 of one panel engage and nest with indentations I_4 of the other panel, because the indentations have three sloping sides in engagement, they hold the panels together to resist all forces in a plane generally parallel to the side of the tray.

When portions of the sheet are bent along two or more intersecting lines, so that the bent-up portions intersect at the corners of the sheet, it is necessary to cut away or notch the corner in any suitable manner that eliminates interference between the bent-up reinforcing portions.

I claim:

1. A surface member for wall construction comprising a relatively dense thin rigid sheet member provided over an extended area 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 inclined side wall portions of said indentations intersecting said medial surface along a plurality of straight lines about which the sheet has a minimum resistance to bending, and a reinforcing flange

extending transversely to said medial surface and attached to the indented area of the sheet along one of said lines, whereby the sheet is reinforced against bending about any of said lines intersecting said reinforcing flange and is stiffened for a substantial distance away from the reinforcing flange.

2. A surface member as in claim 1 in which the reinforcing flange is indented similarly to and in extension of the indented area of the sheet.

3. A surface member as in claim 2 in which the reinforcing flange comprises a plurality of similar sections integrally connected together along one or more parallel straight lines similar to said straight lines of the sheet and parallel to said one straight line along which the reinforcing flange is attached to the sheet.

4. A surface member as in claim 1 in which the sheet has two integral reinforcing flanges disposed at an angle to each other and connected to the indented area of the sheet along two intersecting ones of said lines.

5. A surface member for wall construction comprising a relatively dense thin rigid sheet member provided over an extended area 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 inclined side wall portions of said indentations intersecting said medial surface along a plurality of straight lines about which the sheet has a minimum resistance to bending, and a reinforcing flange integrally joined to the sheet along one of said lines and disposed at substantially a right angle relative thereto whereby the sheet is reinforced against bending about any of said lines intersecting said reinforcing flange and is stiffened for a substantial distance away from the reinforcing flange.

6. A tray-shaped surface member for wall construction comprising a relatively dense thin rigid sheet member provided over an extended area 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 inclined side wall portions of said indentations intersecting said medial surface along a plurality of straight lines about which the sheet has a minimum resistance to bending, and a reinforcing flange at each edge of the sheet comprising an integral portion of the sheet, each reinforcing flange comprising a section disposed at an angle to said medial surface of the sheet and connected to the indented area of the sheet along one of said lines and a second similar section integrally connected to the first section and disposed at an angle thereto but generally parallel to and spaced from one face of the sheet.

7. A tray-like surface member as in claim 6 having openings in one group of outer wall portions of the sheet, and additionally comprising a layer of sound absorbing material covering said one face of the sheet and engaging the other group of outer wall portions of the sheet whereby the layer of sound absorbing material is spaced from said openings.

8. A surface member for wall construction comprising a relatively dense thin rigid sheet member provided over an extended area 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 co-planar 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 inclined side wall portions of said indentations intersecting said medial surface along a plurality of straight lines about which the sheet has a minimum resistance to bending; a reinforcing flange extending parallel to one set of said straight lines in restraining engagement with the sheet along one margin of the indented area to restrain the sheet at the location of such engagement against bending about any of said lines intersecting the reinforcing flange; and a second reinforcing flange adjoining the first reinforcing flange extending parallel to a second set of said straight lines in restraining engagement with the sheet along a second margin of the indented area to restrain the sheet at the location of such engagement against bending about any of said lines intersecting the second reinforcing flange, both said reinforcing flanges extending away from the medial surface of the sheet at substantially a right angle, whereby the sheet is stiffened to a marked degree and for a substantial distance away from the reinforcing flanges against bending about any of said straight lines intersecting one of said reinforcing flanges.

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