PANEL CONSTRUCTION

Filed July 13, 1959 5 Sheets-Sheet 1

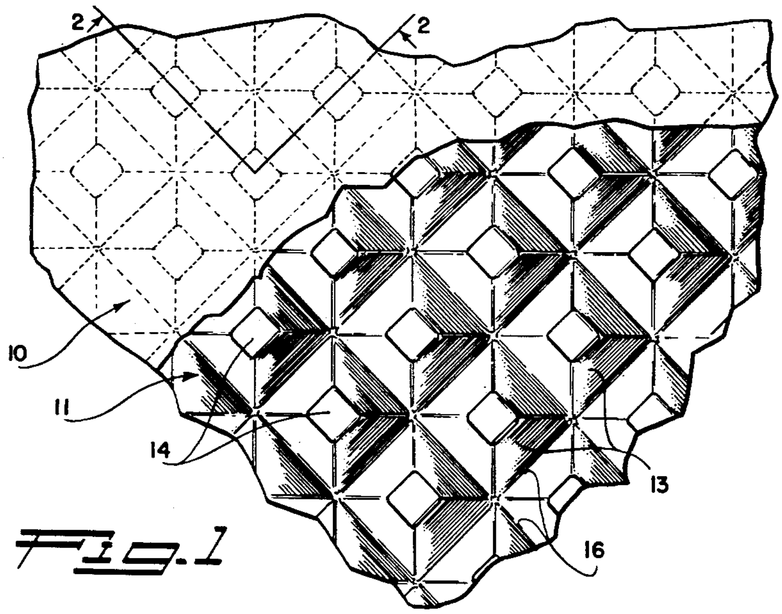

Fig. 1

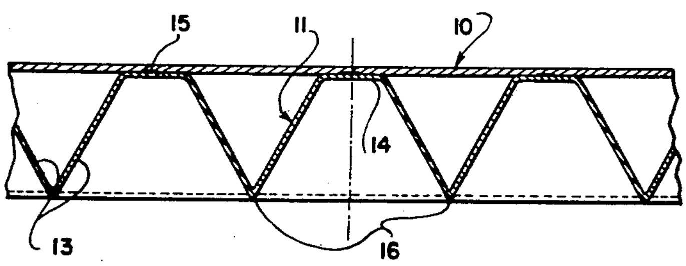

Fig. 2

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PANEL CONSTRUCTION

Filed July 13, 1959 5 Sheets-Sheet 2

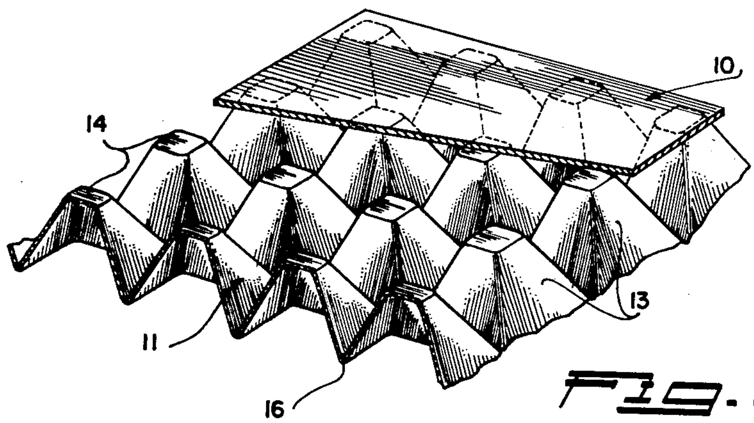
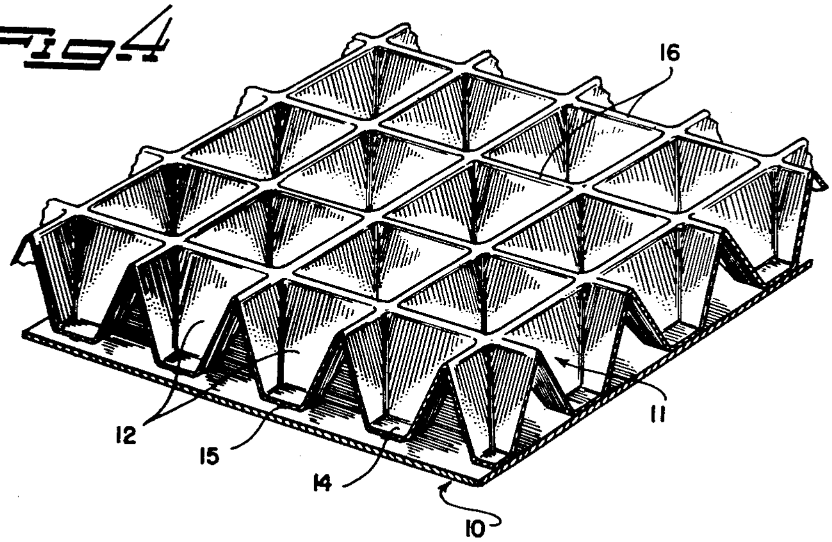


Fig. 3

Fig. 4



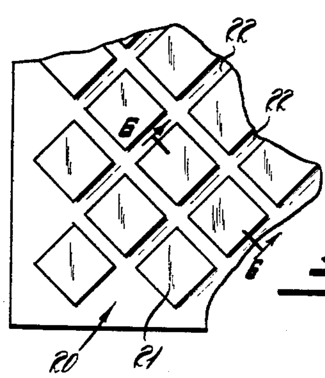
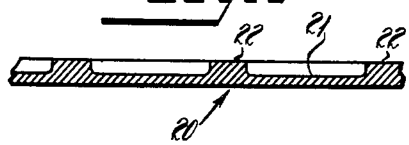


Fig. 5

Fig. 6



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PANEL CONSTRUCTION

Filed July 13, 1959 5 Sheets-Sheet 3

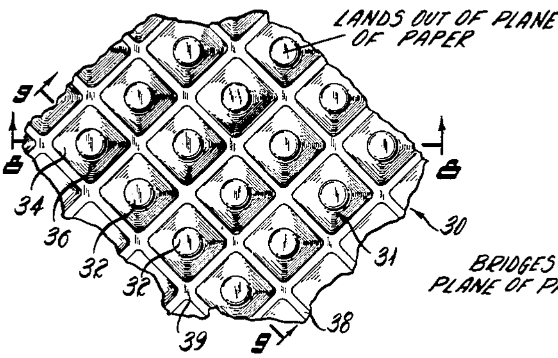


Fig. 7

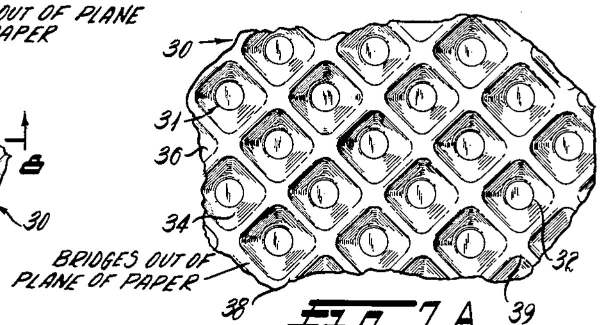


Fig. 7A

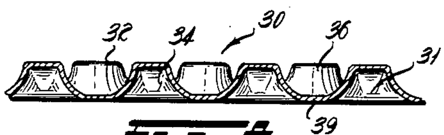


Fig. 8

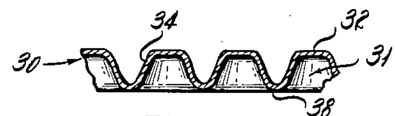


Fig. 9

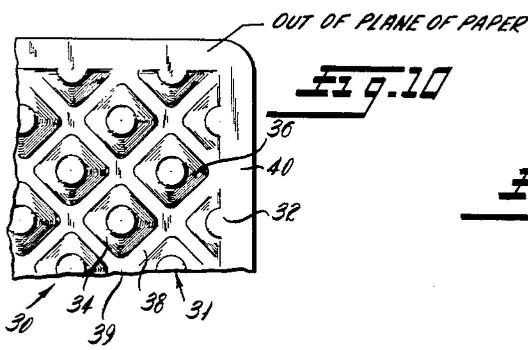


Fig. 10

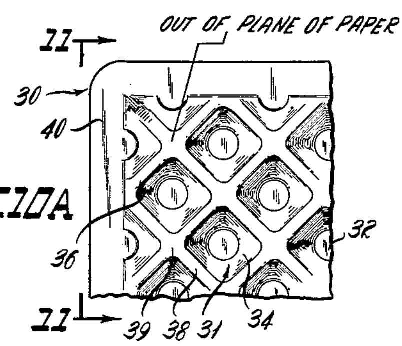


Fig. 10A

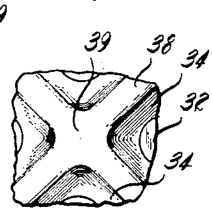


Fig. 12

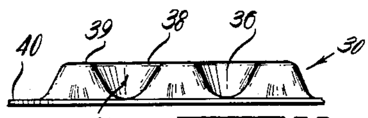
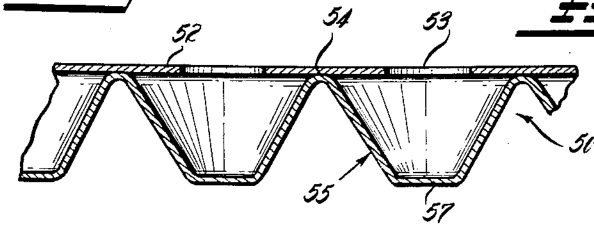


Fig. 11

Fig. 13



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PANEL CONSTRUCTION

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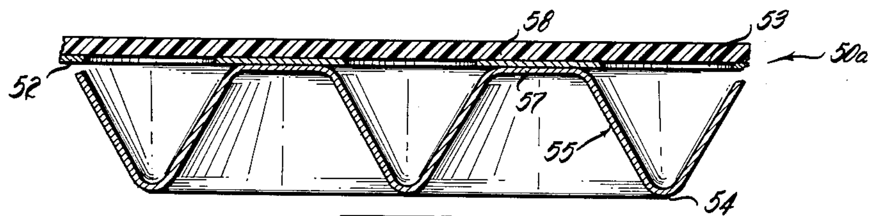


Fig. 14

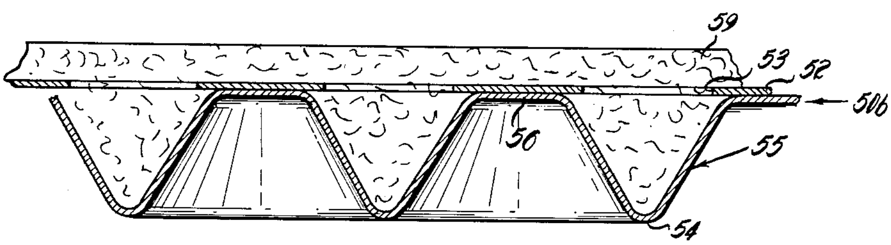
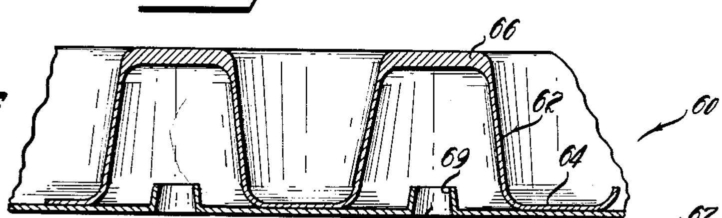


Fig. 15

Fig. 16



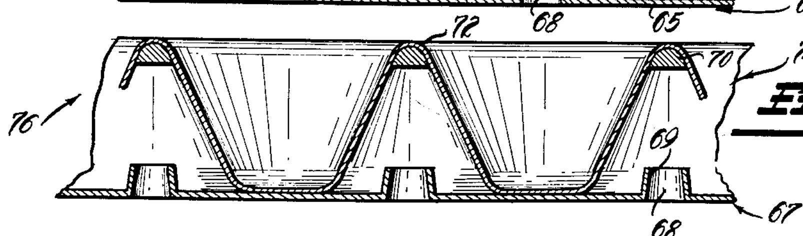


Fig. 17

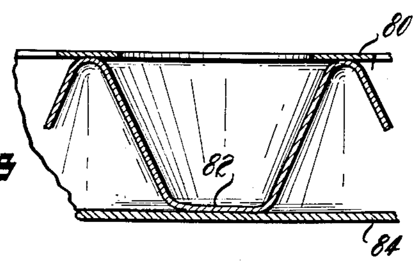


Fig. 18

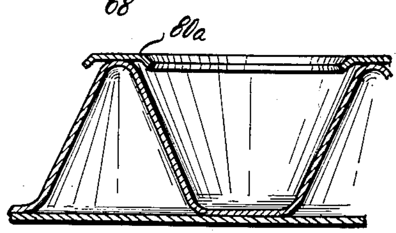


Fig. 19

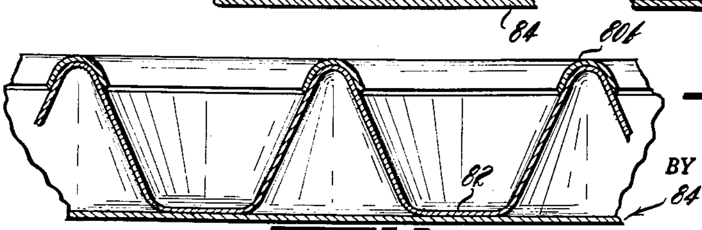


Fig. 20

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PANEL CONSTRUCTION

Filed July 13, 1959

5 Sheets-Sheet 5

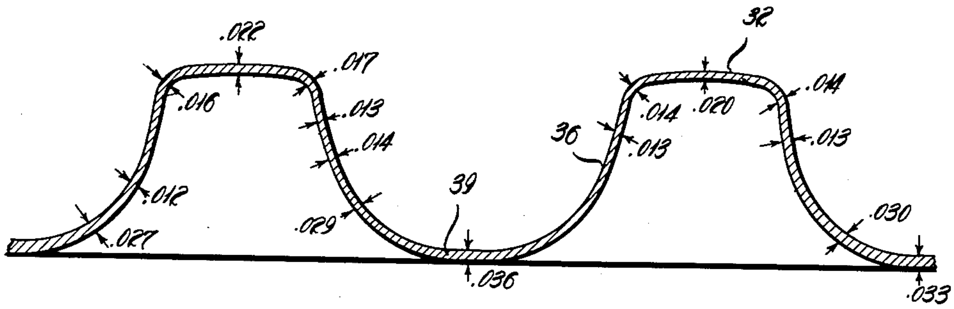

Fig. 21

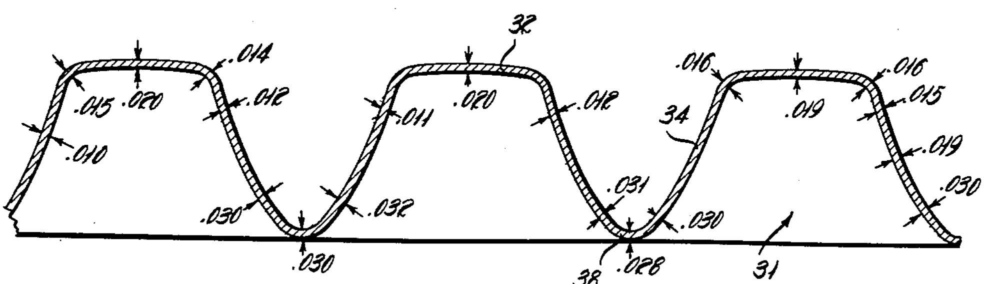

Fig. 22

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PANEL CONSTRUCTION

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Filed July 13, 1959, Ser. No. 826,721
6 Claims. (Cl. 189—34)

This invention relates to panel structures and relates more particularly to panels incorporating a skin sheet and an embossed or formed sheet secured to the skin sheet to impart materially increased structural strength and rigidity thereto.

This application is a continuation-in-part of Serial Number 607,642, filed September 4, 1956, now abandoned.

It is the general object of the invention to provide a single skin sheet panel of extraordinary rigidity and physical strength characteristics. Panels have been proposed and introduced having two-spaced external sheets or skins of metal, or the like, and an embossed or formed sheet therebetween having special "waffle patterns" intended to lend rigidity and strength to the assembly and yet permit the assembly to remain relatively light in weight. Scurlock 2,481,046 is representative of such panels. In these prior panel arrangements the inner rigidity imparting sheet has usually been formed or embossed to have a multiplicity of indentations on each side providing the sheet with a plurality of elevations at each side, terminating in flat or relatively flat plateaus or lands to which the spaced skins are secured by welding, riveting, brazing, cementing, or the like.

In such prior double-faced panels the pyramids or other elevated regions are joined one with another by what we will term "bridges" and because the lands or apices of the elevated regions occupy the outermost planes of the embossed sheet these bridges occupy planes between said outermost planes and usually about midway therebetween. We have found that the bridges add greatly to the rigidity of the sheet but that the location of the bridges in areas or planes spaced between the planes to be occupied by the skin sheets is not conducive to the development of maximum strength and rigidity in the panel, particularly, in the case of single skin sheet panels. Therefore, it is an object of this invention to provide panels of the class referred to having an inner or reinforcing sheet of special configuration, particularly designed to impart greatly increased strength and rigidity to the panel.

Another object of the invention is to provide a panel construction of the class referred to wherein the angular portion or bridges join the elevated areas or projections at or occupy the plane most remote from the plane occupied by the lands to which the skin sheet is attached. The angular bends or bridges joining the embossed elevations are in the plane which defines the side of the panel opposite the side to which the skin sheet is attached and are, therefore, in the most advantageous locations from the standpoint of imparting strength and rigidity to the panel structure.

Another object is to provide a panel of high heat transferability. In high speed aircraft the skin of the panel used on the exterior surface becomes heated due to the friction of the air. It is, therefore, particularly advantageous to develop an exterior skin surface for aircraft which will permit the dissipation of heat.

As a solution to this problem this invention presents a structural panel which has excellent heat transfer properties due to the fact that air may circulate on the back side of the skin sheet and within the space around the embossed projections on the embossed sheet. In present aircraft construction panels there is no chance for this type of air circulation to cool the skin sheet.

This particular panel arrangement is, also, particularly configured to be a safe guard against explosive decompression. If a rupture occurs in the panel it will first occur in the skin sheet and the backing sheet will then not rupture as easily, so as to permit decompression of the fuselage of the aircraft, as it will sustain a higher stress load due to its non-planar configuration.

It is further object to provide a panel which is less expensive to construct and easier to shape and to work with than the presently employed honeycomb panels. There are various difficulties arising with the manufacture of honeycomb panels and, in particular, bonding difficulties exist in bonding the honeycomb portion to the two outside skin sheets.

Yet another object is to provide a panel having a lower weight per square foot than the honeycomb panels in present use. A weight comparison for steel panels constructed by the teachings of the present invention and by the conventional honeycomb raised sandwich structure is the following:

The single skin sheet embossed panel of the present invention has a weight of from 2.3 to 2.5 lbs. per square foot and the double skin honeycomb structure from 2.8 to 3.0 lbs. per square foot.

Other objects and features of this invention will become apparent from the following description of typical preferred embodiments throughout which reference will be made to the accompanying drawings in which:

FIGURE 1 is a plan view of a panel constructed in accordance with the invention with a portion of the skin sheet broken away to show the formed reinforcing sheet;

FIGURE 2 is an enlarged fragmentary vertical sectional view taken as indicated by line 2—2 on FIGURE 1;

FIGURE 3 is a fragmentary perspective view of the panel with the skin sheet and the reinforcing sheet appearing in partial cross section;

FIGURE 4 is a perspective view of a portion of the reverse or inner side of the panel illustrating the configuration of the backing sheet and showing portions of those sheets in cross section;

FIGURE 5 is a plan view of a modification of the planar skin sheet in which the skin sheet has been contoured to conform to the embossed projections;

FIGURE 6 is a view taken on the line 6—6 of FIGURE 5;

FIGURE 7 is a plan view of the preferred modification of the embossed panel, in which the land portions of the panel are placed out of the plane of the paper;

FIGURE 7*a* is the reverse view of a panel as positioned in FIGURE 7; in this view of the bridges portion are displaced from the plane of the paper;

FIGURE 8 is a view taken on the line 8—8 of FIGURE 7;

FIGURE 9 is a view taken on the line 9—9 of FIGURE 7;

FIGURE 10 shows the margin portion of an embossed sheet;

FIGURE 10*a* is a view of the reverse side of an embossed panel with a margin portion as shown in FIGURE 10;

FIGURE 11 is a view taken on the line 11—11 of FIGURE 10*a*;

FIGURE 12 is an enlarged fragmentary view in plan of the intersection of the bridges portion of the embossed sheet of FIGURES 7 through 11;

FIGURE 13 is a modification of the present invention in which a perforated skin sheet has been attached to the bridges portion of the embossed panel;

FIGURE 14 is a modification of the present invention in which a perforated skin sheet has been attached to the lands portion of the embossed sheet and a heat-resistant plastic layer has been laminated to the skin sheet;

FIGURE 15 shows another modification of the present invention in which a ceramic filler material has been disposed within the spaces between the projections and also disposed to form an outside layer;

FIGURE 16 is a modification showing both an increased bridge thickness and a perforated and sculptured skin sheet;

FIGURE 17 is an alternative structure of that shown in FIGURE 16. This modification of the structural panel has a bead of metal deposited in the otherwise normally shaped bridge portion;

FIGURE 18 is a modification showing an orthogonal grid attached to the bridges of the embossed panel and thereby increasing the strength of said bridges area;

FIGURE 19 is a further modification of the orthogonal grid of FIGURE 18; and

FIGURE 20 is yet another modification of the orthogonal grid of FIGURE 18.

FIGURE 21 is an enlarged and dimensioned cross section view of the embossed sheet taken on the line **8—8** of FIGURE 7.

FIGURE 22 is an enlarged and dimensioned cross section view of the embossed sheet taken on the line **9—9** of FIGURE 7.

The panel of the invention comprises generally two sheets, namely a skin sheet and an embossed sheet or backing sheet. It will usually be found most desirable to form the sheets of metal, such as steel, stainless steel, aluminum alloy or the like, and where the panel is to be employed in aircraft constructions both sheets are preferably relatively thin.

SKIN SHEET

The skin sheet (FIGURES 1–4) is shown as a plane flat member having parallel surfaces, it being understood the sheet **10** may be shaped or contoured as required for given applications of the panel. The shaped or contoured skin sheet **20** shown in FIGURES 5 and 6 may be formed with sheet areas **21** of reduced thickness which will contact the flat land portions of the truncated pyramidal configurations of the embossed sheet, to be described below. Between these areas **21** are ridges or grids **22**. Areas **21** may be formed by such conventional processes as chemical milling, for example. A second modification is shown in FIGURES 13, wherein the skin sheet **52** is perforated with perforations **53**. A third modification of a contoured skin sheet is shown in FIGURES 16 and 17 in which skin sheet **67** has perforations **68** in those portions of the skin sheet not contacting the lands as does the portion **65** of the skin sheet. Perforations **68** are shown with upturned edges **69**, which edges impart further structural rigidity to the panel as a whole.

BACKING SHEET

The core sheet or backing sheet may be formed from a single flat piece of material by embossing or pressing or plating but is preferably configured by stretch-forming, said stretch-forming operation being performed by rigidly anchoring the margin portions of the flat piece of material to be embossed and then striking or stretching the pyramidal projections into the sheet by means of coacting dies. This method of forming thus differs from the die-shaping procedure of drawing wherein the margins of the blank being shaped are fed from the outside toward the center of the blank during the forming process. The stretch-forming formation of the embossed panel imparts superior flexure properties to a panel including the present embossed sheet.

In accordance with the invention as shown in FIGURES 1 through 4, the embossed or backing sheet **11** has a multiplicity of depressions or indentations **12** pressed or stretch-formed in one side thereof to leave or provide a multiplicity of projections **13** on the other side of the sheet, said depressions **12** being the underside of projections **13**. While the invention contemplates that the indentations **12** and, therefore, the projections **13** may be of selected configuration, it is preferred to make them of generally truncated pyramidal shapes. Preferably, the projections are a configuration which approximates the combination of a truncated cone and a truncated rectangular pyramid.

FIGURES 1 through 4 show the embossed sheet having truncated rectangular pyramidal projections formed therein. Indentations **12** and projections **13** have tapered sides which converge toward the rectangular flat land **14**. These lands **14** are flat and are disposed adjacent to the skin sheet **10** so as to be conveniently and effectively joined to the skin sheet by riveting, welding, brazing, cementing or otherwise. In the drawings the numeral **15** designates welds such as spot welds, joining the tops or lands **14** of the pyramidal projections **13** to the under or inner side of skin sheet **10**. While the spacing of the lands **14** may be varied considerably, depending upon the particular general proportions and applications of a panel, it is of course desirable to make the lands sufficiently extensive to have adequate engagement with the sheet **10** and to be readily and effectively secured thereto by the rivets, welds, cement, or the like.

The embossed or backing sheet **11** is further characterized by areas or regions which join the adjacent projections **13**, which regions will be termed bridges **16**. As seen in the drawings and as best illustrated in FIGURES 2 and 4, these bridges **16** are in the nature of abrupt or sharp angled ridges or bends. The bridges **16** preferably lie in a common plane, parallel with the plane of the lands **14** and the skin sheet **10**, assuming the panel to be planar. Thus the bridges **16** join the projections **13** and occupy the plane most remote from the sheet **10**. We have found that this location of the flexure resisting bridges is most advantageous in imparting rigidity and structural characteristics to the composite panel. Furthermore, by inspecting FIGURES 1 and 4 of the drawing, it will be seen that the bridges **16** are joined one with another to constitute a grid-like pattern of a multiplicity of inter-connected squares or diamonds positioned in diagonal or orthogonal patterns. This diamond pattern of the flexure resisting bridges **16** further imparts extraordinary physical strength characteristics and flexure resisting characteristics to the panel.

The preferred projection configuration, shown in FIGURES 7 through 12, is resonant between a truncated cone and a truncated rectangular pyramid-shape. These projections ar described by having a pyramidal frustoconical configuration. The embossed backing sheet **30** has projections **31** of the resonant structure described having circular lands **32** disposed at the converging apices of the slightly curved sides **34**. The sides **34** of the projections **31** intersect each other along curvilinear bends **36**. The projections are joined at the bases thereof by bridges **38**, which bridges intersect one another to form the intersection of said bridges **38**. The cross section of this panel shown in FIGURE 8 shows the broadest dimension of this intersection **39**.

It has been found, as a practical matter, that for a one inch base dimension of the projections the maximum height to which the pyramidal projections can be stretched-formed is approximately ¾ of an inch. A height of ½ inch for a one inch base dimension has been found desirable for the proper flexure characteristics of the panel. The maximum height to which the metal can be stretched-formed without tearing is, of course, a physical property of the metal used in the formation of the embossed sheet.

MODIFICATIONS

In a modification adapted for convenient usage, the embossed sheet is formed with a margin portion around the periphery of the sheet. These margins may be prepared to adapt the panel for ready installation for various intended purposes. The margins **40**, shown in FIGURES 10 and 10*a* are preferably coplanar with the lands **32** of the embossed sheet **30**. The skin sheet may be readily attached to the lands and to the margin portion of the sheet so as to provide an integral panel unit. This unit presents a flat surface on both sides since the plane presented by the skin sheet and the margin portion of the embossed core sheet would present one flat surface and a second surface would be presented by the flat plane of the bridge grid work **38** and **39**.

FIGURE 12 is an enlarged fragmentary view showing the intersection of four of the bridges **38** to form the rounded cornered intersection **39** of the embossed sheet **30**. This intersection **39** is formed by the integrated intersection of the four bridges **38** as well as the lower portions of the four curvilinear bends **36** of the four adjacent projections **31**. As shown, the intersection is disposed coplanar to the flat portions of the bridges and has rounded corners due to the round cornered rectangular base of the projections **31**. The curvilinear bends of the four adjacent projections are curved so as to define the sides of two normally intersecting parabolas, which parabolas would have flattened apices as would be formed by the planar intersection **39** of the bridges **38**.

FIGURE 13 shows a modification of the present invention in which the panel **50** is composed of skin sheet **52**, formed with preforations **53**, attached to the bridges portions **54** of the embossed sheet **55**. This panel modification is particularly suitable for acoustical boards or panels for use in aircraft, buildings, and other structures requiring panels with sound-proofing characteristics. It is also useful as a "button board" or lath board in that it is adapted to receive plaster and other surfacing materials. In this modification the backing sheet **55** may be the same as above described.

When intended for acoustical or sound-absorbing and damping purposes, the skin sheet **52** may be secured to the bridges **54** of the backing sheet, as illustrated in FIGURE 13, or may be secure to the lands **57** of the backing sheet **55**, as in FIGURES 14 and 15. As shown in FIGURE 13 the perforations **53** are opposed or aligned with the lands **57**. The panel shown in FIGURE 13 is especially well adapted as a plaster backing board or "lath" since the plaster, or like material, when applied thereto enters the openings **53** to form buttons behind the skin sheet **52** which effectively locks the plaster to the panel.

This type of panel is also well adapted for a heat insulating panel as a layer of heat-resistant plastic material may be attached to the perforated skin sheet. A modification of this type is shown in FIGURE 14, wherein the panel **50***a* consists of embossed backing sheet **55** having attached thereto, at the lands **57**, a perforated skin sheet **52** with perforations **53** therein, and a heat-resistant plastic layer **58** attached to the outer surface of the perforated skin sheet.

Also, as shown in FIGURE 15, the perforated panel of this modification is easily adapted to have a ceramic material such as an insulating ceramic compound **59** poured into the perforations of the skin sheet **52** and then smoothed over in a cover layer so as to provide an insulating building panel.

FIGURE 16 shows a modification of the instant invention in which the panel **60** is composed of a special embossed panel **62** which has lands **64** and a thickened bridge portion **66**. Alternatively to a flat skin sheet as has been heretofore described in connection with various panels, a contoured skin sheet **67** may be provided for any of the embossed backing sheets. As shown in FIGURE 16 such a contoured sheet **67** has perforations **68** in those portions of the skin sheet not contacting the land portions **64** of the embossed sheet. These perforations **68** are shown with up turned edges **69**, which edges impart further structural ridgity to the panel.

FIGURE 17 shows another modification of the present invention including a deposite of a bead of metal **70** on the inner portion of the bridges **72** of the embossed

sheet **74** of panel **76** so that a thickened area may be presented for resisting excess stresses placed upon the panel. Both this modification and the modification shown in FIGURE 16 would serve this same function in resisting excess strsses. FIGURE 17 is also shown with a contoured skin sheet which has been described in the foregoing paragraph.

A third modification is shown in FIGURES 18 through 20. In this modification a thickening of the bridges portion of the embossed sheet is accomplished by attaching an orthogonal grid **80** to the embossed sheet which is attached through its lands **82** to a skin sheet **84**. A slightly different configuration of the orthogonal grid **80** is shown in FIGURE 19 as **80***a*, in which the outer edges of the orthogonal grid, at each opening in the grid, are slightly downturned. FIGURE 20 shows the orthogonal grid **80***b* conforming to the contour of the bridges.

The embossed sheet of FIGURE 16 may be formed by any method from a blank sheet which has an integral grid work of portions which are thicker than the remaining portion of the blank. This blank sheet may be formed by such processes as selective chemical-milling, which is a chemical etching process to thin the metal not in the grid work, selective machining, or roll forging, etc.

PANEL CHARACTERISTICS

The panel herein described is extremely light in weight and yet possesses great strength in shear and in compression, both transverse and edgewise, and is highly resistant to recurring bending forces. This well adapts the panel for use in large sections where it may be required to span considerable distances between supports or framed members of the building, aircraft, or other structure in which it is to be used.

It should also be noted that the panel described herein will have superior bending characteristics over the panel presently employed in the aircraft industry, i.e. the panel may be formed into a cylinder. Once this panel has been bent into the desired shape by the conventional techniques such as employing drop hammers, hydraulic presses, power brakes, stretch-forming machines, etc.; it will retain its structural characteristics in these various shapes. In connection with the superior bending characteristics above mentioned, the flexure characteristics are also outstanding as this panel will resist biaxial stretching in the event of overloading. But upon overloading the panel will stretch with the forces imposed upon it rather than crumbling or completely collapsing. It has been concluded from test runs on the panel and on other various structural panels that the core configuration of this panel gives the panel these superior properties.

The above superior properties of the panel of the instant invention formed with the particularly configured embossed sheet are partly due to two physical characteristics of the embossed sheet.

One of these physical characteristics of a stretch-formed embossed panel is that the thickness of the panel varies according to various positions on the embossed panel. This varying thickness is shown in FIGURE 21, which figure is an enlarged view of the cross section shown in FIGURE 8. The dimensions shown in FIGURE 21 are the dimensions resulting from the stretch-forming of a sheet blank which was originally 0.04 inch thick. As will be noted from FIGURE 21 the intersections of the bridges portions **39** have an average thickness of .035 inch while the average thickness of the lands portions **32** is 0.021 inch. The curvilinear bends **36** have an ever decreasing dimension from the intersection of the bridges portions **39** to the edge of the lands portions **32**. As the curvilinear bends begin to taper away from the intersection of the bridges portions **39** the average dimension is 0.030 inch while the approximate center of the curvilinear bends **36** have a dimension of 0.014 inch and decreases slightly thereafter before they join the lands, which joining as a dimension average of 0.015. The FIGURE 21, as shown, is a representation of actual micrometer readings, and thus, the variation between the various readings due to micrometer measurement error. A second view of the embossed panel stretch-formed by the present invention is shown in FIGURE 22, which view is a cross section similar to the cross section shown in FIGURE 9. As this figure shows, the average dimension of the bridges **38** is 0.029 inch while the lands **32** have an average dimension of 0.02 inch. Intermediate the bridges and the lands are the arcuate sides **34** which have, from the bridges, an ever decreasing dimension tapering from 0.032 inch to 0.011 inch at the end of the side nearest the lands **32**, the junctions of the side **34** with lands **32** have a dimension of 0.015 inch.

The percentage thinning factors at the various positions throughout the embossed panel stretch-formed as taught by this invention and as shown in FIGURES 21 and 22 may be computed by the following formula:

$$\text{Thinning factor} = \frac{\text{area thickness, inches}}{0.04}$$

The thinning factor for various portions of the embossed panel are represented in the following table:

Table I

Portion of Sheet	Number of Portion	Average Thickness	Average Thinning Factors
Intersection of bridges	39	0.035	0.875
Bridge end of bends	36	0.030	0.75
Center of bends	36	0.014	0.30
Lands end of bends	36	0.016	0.40
Lands	32	0.020	0.50

An important advantage of the stretch-forming of a sheet in accordance with the present invention lies in the fact that the thinning occurs in areas which are of small consequence structurally, as they do not carry the primary loads. It is the bridges portion which carry the primary stresses, as far as the backing sheet is concerned, and it will be noted from the Table I the highest average thinning factors are present in the area of the bridges. Thus, it is concluded that by stretch-forming the embossed sheet a considerable weight saving over other forming methods is realized, due to this thinning of the metal.

A second physical characteristic which is present in the stretch-formed embossed sheet constructed by the teachings of the present invention is that, stretch-forming causes the embossed panel to become strain hardened in certain portions. This strain hardening further increases the strength of the panel. In a draw forming operation metal is fed in from the outer periphery of the blank being so formed, which drawing reduces the amount of the stretching required to form a given sheet and thus does not allow this same strain hardening of the metal to take place. In connection with this strain hardening effect as a stretch-forming operation the embossed panel is also left with residual stresses in certain portions of the embossed sheet and in particular, residual stresses are set up in the bridges portion of the embossed sheet.

It should be noted that this same hardening feature is of significance only under conditions where heat treatment following stretch-forming is not employed, for when a panel is manufactured for high-strength efficiency requirements the panel is subjected to heat treatment in order that it will obtain high-strength levels.

The strain hardening and residual stresses effect of the stretch-forming operation result particularly in causing those curved portions of the embossed panel, such as the bridges, the intersection of the bridges, the arcuate sides, and the curvilinear bends of the projections, to act as individual spring systems which are integrated through the continuity of the metal into one continuous resilient sheet.

As has been above explained it is occasionally desirable to increase the thickness of the metal at the bridges portion of the embossed sheet. This disclosure is shown in FIGURES 16 and 17 which is shown with a preforated and contoured skin sheet **67**. It should be noted that where an increased thickness of metal is used in the bridges the skin sheet is preferably perforated as shown in those figures so as to permit proper resiliency characteristics.

While the invention has been described in connection with different embodiments thereof, it will be understood that it is capable of further modification, and this application is intended to cover any variations, uses, or adaptations of the invention following, in general, the principles of the invention and including such departures from the present disclosure as come within known or customary practice in the art to which the invention pertains, and as may be applied to the essential features hereinbefore set forth and as fall within the scope of the invention or the limits of the appended claims.

Having thus described our invention what we claim is:

1. A high-strength light-weight sheet adapted for use as a panel component consisting of an embossed sheet having formed therein a plurality of projections spaced in mutually adjacent relationship to one another in a rectangular gridwork, said projections being of a generally pyramidal frusto-conical configuration, said projection having curved sides, said projections having a round cornered rectangular base and a circular top, said top having a planar portion and having rounded edges conneting said planar top with said curved sides, bridges interconnecting the projections at their bases, the center portion of said bridges being generally flat and the portion of said bridges contacting said sides of said projections being curved, four intersecting bridges forming a flattened intersection, said intersection being disposed coplanar with the flattened portion of said bridges, and said bridges occupying the plane farthest removed from the top of the said projections.

2. A panel as described in claim 1 wherein, said curved sides at the end of said sides nearest said bridges of said embossed sheet have a range of thinning factors of 0.70 to 0.80, a range of 0.20 to 0.40 in the center of said sides, and a range of thinning factors of 0.30 to 0.50 at the top end of said sides, said tops having a thinning factor range of 0.40 to 0.60, said bridges having a thinning factor range of 0.60 to 0.85, and said intersection of said bridges having a thinning factor range of 0.80 to 0.95.

3. A sheet as described in claim 1 wherein, said bridges have a thickness of at least twice the thickness of the remainder of said embossed sheet.

4. A sheet as described in claim 1 wherein, said projections have a maximum ratio of height dimension to base dimension of ¾.

5. A sheet as described in claim 1 wherein, said curved sides of said projections are bowed inwardly toward the height axis of said projections.

6. A panel as described in claim 1 wherein, said bridges have portions thereof which are strain hardened.

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