

[54] **METHOD AND APPARATUS FOR FORMING A PANEL FOR USE AS A STRUCTURAL ELEMENT**

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[51] Int. Cl. **E04b 2/28, E04c 2/00**

[58] Field of Search 161/109, 110, 111, 69; 156/252, 253, ; 52/276, 615, 618, 622, 511, 443, 615, 627, 277, 278; 220/80; 229/49; 161/69

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Primary Examiner—Henry C. Sutherland
Attorney, Agent, or Firm—Elliott I. Pollock

[57] **ABSTRACT**

Two or more thin flat metal, paper or plastic panels are combined by perforating areas or tabs in the plane of the panels, bending the portions of such perforations that are freed, at right angles to the plane of the panels, and attaching said extended members to one another, thus forming a link or intermediary-connecting web or section between the two or more panels. A parallel panel spacing can be achieved or by the variation of the perforated area, the panels can be proportionally spaced to achieve a desired panel contour or shape between panels. A third panel element, provided with larger tabs, can be affixed to the joined panels, and its larger tabs can be forced through the preexisting perforations in one panel to form additional struts engaging the opposite panel to increase the strength of the structure.

16 Claims, 29 Drawing Figures

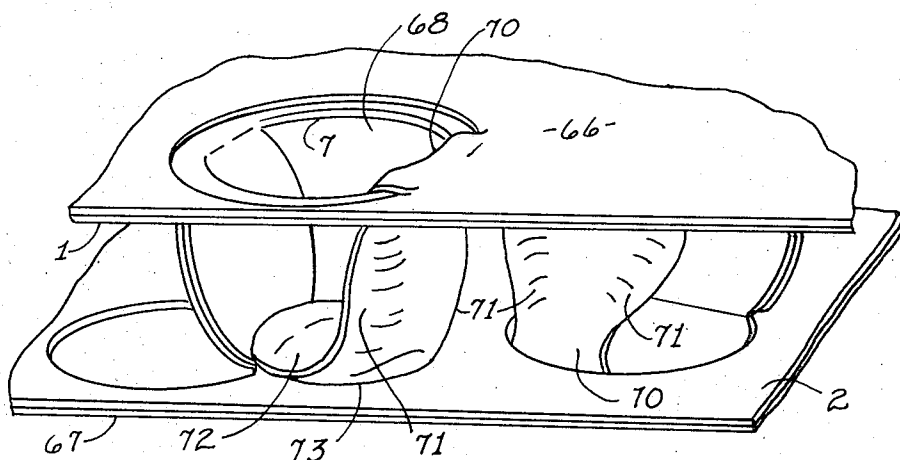


Fig. 1

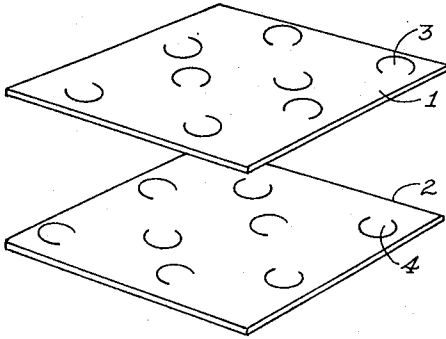


Fig. 2

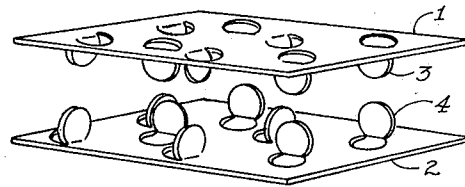


Fig. 3

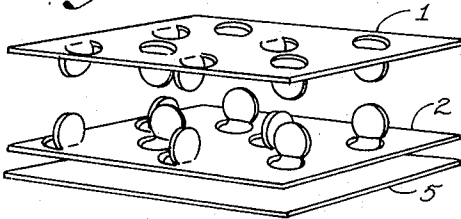


Fig. 4

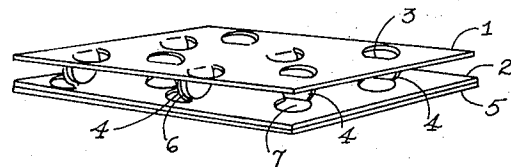


Fig. 5

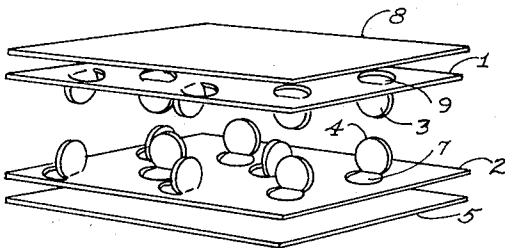


Fig. 6

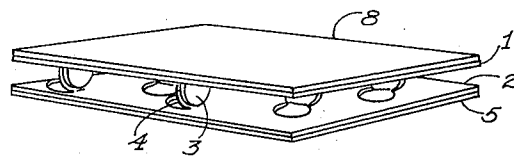


Fig. 8

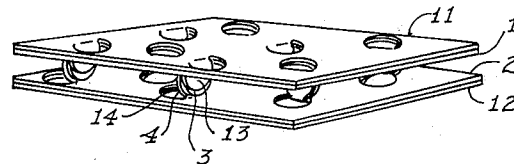
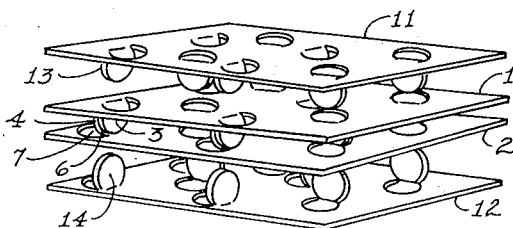


Fig. 7



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William A. Woollen

Fig. 9

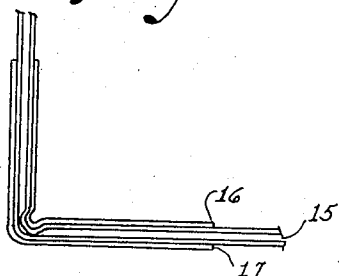


Fig. 10

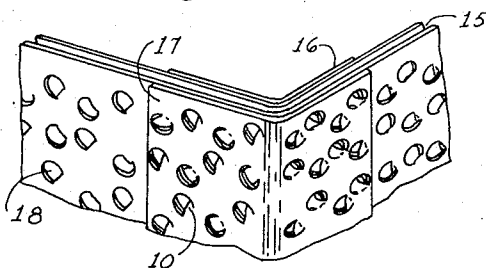


Fig. 11

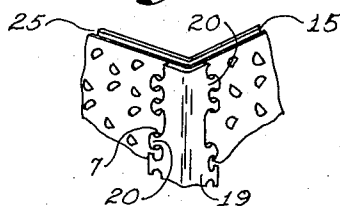


Fig. 12

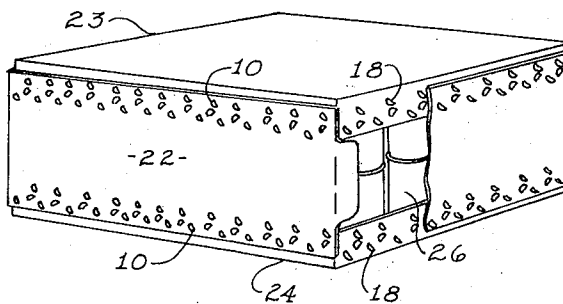


Fig. 13

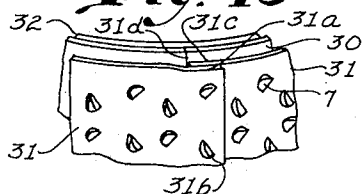


Fig. 15

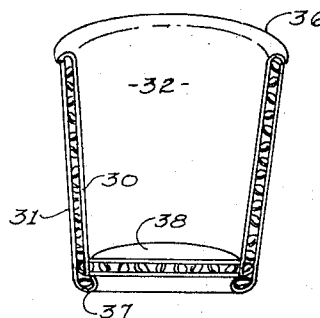
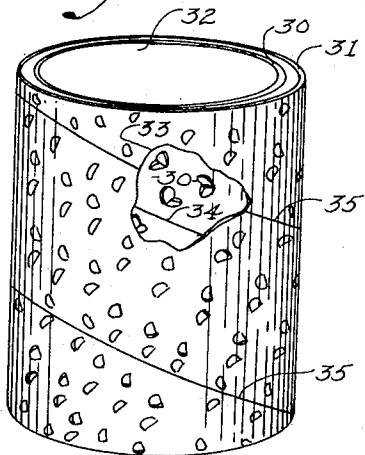


Fig. 14



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Fig. 16

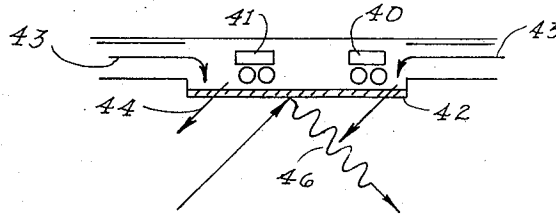


Fig. 17

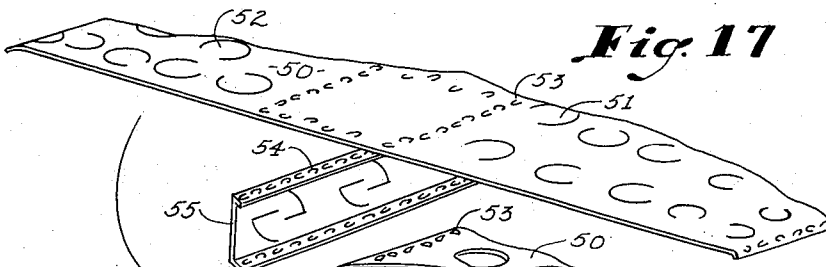


Fig. 18

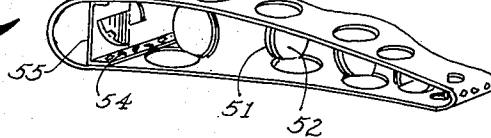


Fig. 19

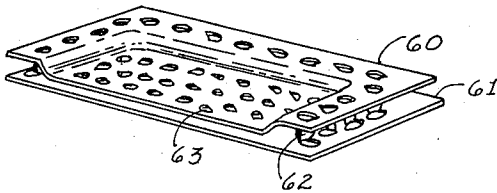


Fig. 20

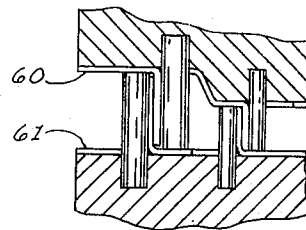
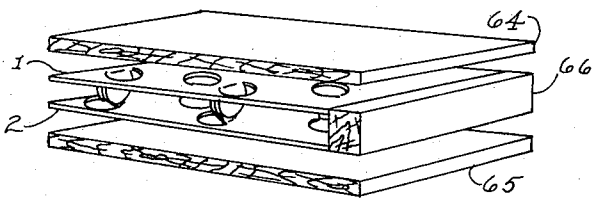


Fig. 21



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Fig. 22

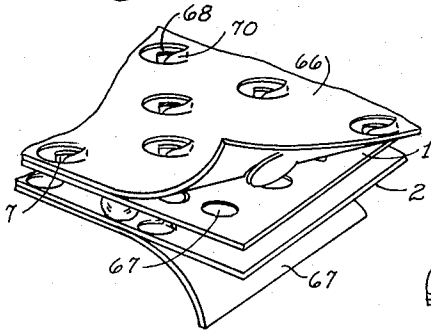


Fig. 23

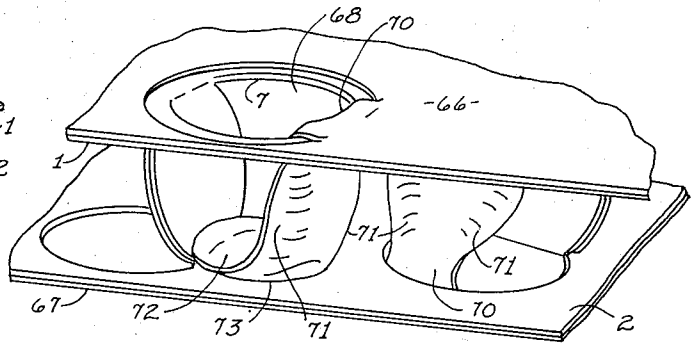


Fig. 24

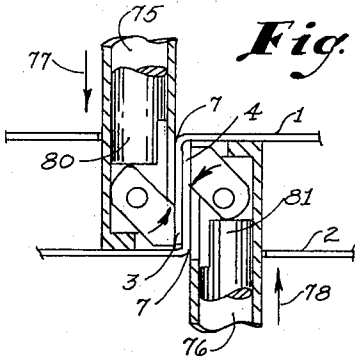


Fig. 25

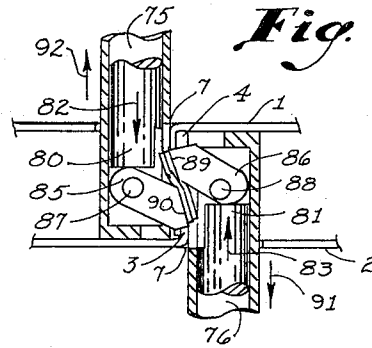


Fig. 26

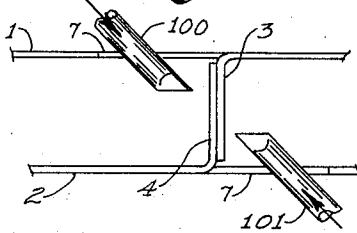


Fig. 27

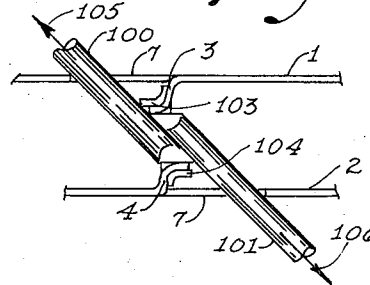


Fig. 28

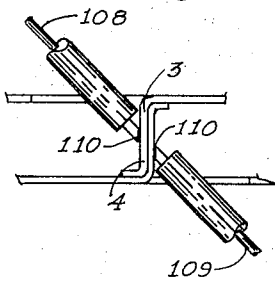
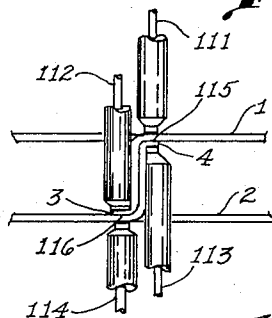


Fig. 29



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METHOD AND APPARATUS FOR FORMING A PANEL FOR USE AS A STRUCTURAL ELEMENT

CROSS REFERENCE TO RELATED APPLICATIONS

Wooten application Ser. No. 170,120 filed Aug. 9, 1971 for Method and Apparatus for Forming a Fiber or Paper Board Structure, and Wooten application Ser. No. 178,183, filed Sept. 7, 1971 for Paper Board Connecting Method.

BACKGROUND OF THE INVENTION

The present invention relates generally to a method for the mechanical joining of metal, paper or plastic sheets in the form of thin, flat panels to achieve by this joining a combination or an expanded geometry for use as a semi-rigid structural panel in the assembly of articles or in the construction of buildings or in the manufacture of vehicles.

There is at present one generally accepted method for the joining of flat sheets of metal, paper board or plastic material in the form of a product or board greater in dimension than the thickness of the panels employed in the make-up of such a structure. This is usually referred to as "honeycomb" and is made up of numerous perpendicular webs arranged in angular planes with respect to one another, the edges of which are attached to the plane surface of two flat sheets to form a "sandwich" with uniform or parallel spacing between these sheets or panels.

Normally, the mechanical adjoining of this "honeycomb" is accomplished by machine formation of the standing internal elements by employing alternate involute forms or folds that are cut to a length equal to the width of the final assembly and combined with final enclosure panels. The product that results is placed between two panels and is laminated between these two sheets with the edge standing structure bonded to the inside planes or flat surfaces using adhesives or, in the case of metal, welding techniques, thus forming the assembly of the unit. The combination exhibits an isotropic rigidity and is generally inflexible in all directions.

This invention teaches use of two panels joined by mechanical interlocking means using the attachment of extended latching panels, area tabs or partially perforated components that, when bent at right angles to the plane of the pre-perforated panels, form portions of an intermediate linkage which are connected to one another by adhesives, mechanical joining, welding or any one of the common mating procedures, thus connecting two said parallel panels or sheets in a continuous combination.

A variation of this structure employs graduated partial perforation sizes to accomplish either a spacing difference between the panels being joined or to accommodate a contouring of one or both panels with respect to each other or the center line of the structure, as for example, a boat hull, airfoil, or a tray unit containing spacing or cavities and the like.

The production of this board provides a reduction in the usage of material in the manufacture of such an expanded configuration. Variable rigidity in two directions can be provided while exhibiting tension and compression strength comparable to that of "honeycomb" board but with less material usage and in a form producible with an easier procedure compatible with high speed production. For the purposes of full enclosure, the nature of this perforated configuration requires an overlay sheet of light weight material that dresses or finishes the external surface of the package. A similar overlay sheet can be applied to the opposite face for dress, adding strength in the completion of an assembled article.

For certain applications where high crush strength is required, an overlay sheet containing larger partial perforations than those of the panel combination is employed. The larger tabs extending from this third sheet are forced into the openings of one panel in the previously formed panel combination in such a way that each enlarged tab element from the third sheet forms a contoured strut completely bridging the space between the original panels and positioned 180° from the previously formed tab connection, on the opposite side of the panel opening.

In general usage, board or panels of the type produced with "honeycomb" form are utilized in comparatively exotic applications; as for example, aircraft construction and usually in circumstances where prime weight conditions warrant the expense of this structure which is, at best, difficult to produce. In contrast, the board of this invention is producible with simple tooling, exhibits many of the same structural traits associated with "honeycomb", uses less material and can be made up with convenient and accepted procedures common to the arts of fabricating the specific materials in question.

It is an object of this invention to produce a structural panel with a thickness dimension greater than the sum of the thickness of the panels employed in the combination using numerous extensions or tabs perforated from the panel planes and attaching said panels by the connecting of these tabs using adhesives, welding, or mechanical means, thus achieving a parallel spacing between said panels and thus forming the combination of this invention.

It is a further object of this invention to employ varying tab dimensions to accomplish a spacing between the panels that is non-uniform and, consequently, to achieve a contouring or variational configuration and shape by such dimensional difference.

It is an additional object of this invention to provide added strength in this combination by variation of the angular placement of the uncut portion of the perforations in each of the panels, thus making the tabs join the coinciding tab element of the opposite sheet in a common plane but rotated about the perforation center, thus providing angular variation of the vertical plane to achieve maximum torsional compression strength in the vertical assembly of the panels of this combination.

It is an object of this invention to make supplementary mechanical connections to assembled combinations by the addition of similar panels without the use of adhesives or other bonding means and depending entirely upon mechanical connections or friction between the partial perforations of a third or secondary component joined with said combination panel assembly. Such an arrangement can be used at corners where folds are to be accomplished, and effects reinforcing by the employment of heavier weight materials on one or both sides of such a corner formation to add structural strength and, in effect, produce a corner post as required in the assembly of a carton element.

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It is another object of this invention to provide a seam by the staggering or overlapping of panel elements to achieve a connection with edge abutment and thru use of the normal tab connecting procedure in the combination of such a seam.

It is a further object of this invention to employ one or two additional partially perforated panels to be superimposed on the planes of the previously assembled combination, and to employ the tabs of these additional panels for engagement with and bonding to the openings of the combination, thus increasing significantly the crush strength due to the added area tab volume resulting in this addition.

It is a further object of this invention to construct a structural frame of varied dimensional thickness, by the use of intermediary tab connections of various size, partially perforated from the panels, but placed in a graduated size pattern, the resultant area tabs being bent from such a pattern of perforations to cause different spacing between the center line and the panel surfaces or between the panels themselves, either as a graduated change in space relationship or as control of contouring with formation of the board product accomplished by using the mechanical, welding or adhesive connection of said tabs.

A further object of this invention is to make a product that exhibits physical improvement, tension and compression equal to or better than that exhibited by "honeycomb" products, and to accomplish this improvement by the angular placement of the partially perforated area tabs, in respect to the combination boundaries and by attachment of said tabs to connect the panels in the combination of this invention.

It is a further object of this invention to produce an acoustical product by the panel formation of two or three elements utilizing ideal acoustical materials in the form of soft or semi-soft, fire retardant sheet products joined by adhesives and formed expressly for this purpose.

It is an additional object of this invention to provide, in a plastic sheet exhibiting translucent or light transmitting properties, partial perforations and connections in two such sheets for the purpose of closing the boundary of an air plenum as in a ceiling which at once serves as means for the passage of air through the normal openings in this combination and also permits the passage of light while functioning as well to provide an acoustical sound barrier.

It is another object of this invention to reduce the spacing of partial perforations in one panel as related to the second panel to make, in their connection, a curved combination as in a cylinder wall.

It is an additional object of this invention to employ apparatus in the final closing or assembly of this combination to apply heat with contact pressure means to set previous coatings of thermo-plastic material and, in such apparatus, to employ devices operative to mechanically fit and engage the perforations for alignment and bonding of the two panel tab areas in the formation of the combination of the invention.

It is an additional object of this invention to employ apparatus in the closing or assembly of this combination to provide spot welding of the tab areas as a means of connection.

It is an additional object of this invention to employ apparatus in the final closing or assembly of the combination that stakes or upsets the two tab parallel planes

in contact by partially perforating the tab areas and engaging them mechanically to accomplish the connection of this invention.

SUMMARY OF THE INVENTION

These and the objects of the present invention are achieved by converting two or more flat metal, paper or plastic panels into a combination flat or contoured board element with a dimensional thickness greater than the combined thickness of the two paper board panels employed.

The combination is formed by the adjoinment of tabs or extensions bent from the plane of the panels used. These tabs are provided by the partial perforation of the plane surface of the panels being joined. When bent from the plane of the panel, the tab portion of the perforation that is cut can be made to extend perpendicularly to the plane of the sheet, hinging on that portion that is uncut. Perforating is done at regular intervals or with spacing that places the hinged portion of said perforations or the uncut section of the perforation circle in a variety of angular positions. The result of this cutting procedure is to provide tabs which, when deflected from the plane of the sheet, assume a variety of angles with respect to the longitudinal direction of the board being formed but with all tabs or extensions standing at 90° or perpendicular to the plane of the sheet.

The pattern or arrangement of perforations and the bending of the tabs from the plane of the sheet is planned so that a second sheet with similar perforations and tabs can be placed with the tabs of one sheet closely adjoining those of a second sheet or panel. The arrangement of this spacing is to place the tab of one panel back to back with that of the second. By the application of adhesives to the sheet following partial perforation, these extensions or tabs can be bonded, cemented or attached to one another so that a tight adjoinment exists between an intermediary tab pair extending between the two sheets.

The adjoinment of area tabs can be accomplished by other means, as for example, by spot welding in the case of metal, or heat sealing under conditions where a sealant is applied to the material being joined in this configuration. In instances where plastic makes up the combination, chemical fusing of the tabs to one another can be accomplished by the addition of solvents to the tab faces at the time of connection.

Because of the angular displacement of the various perpendicular elements thus joined together, the two sheets are closely united by standing webs with the plane of one such web being directed at the edge of another, to produce conditions of maximum strength in the structural arrangement. The doubling of the sheet by addition of one or more panel laminations and tab connections gives additional strength together with such rigidity and crystallization properties as may exist in the adhesive employed.

The combining of these two or more flat panels with extended tabs at 90° to the plane of the panels and with the arrangement of these tabs in the form of a rhombus or equilateral parallelogram provides uniform strength characteristics in all directions.

The variation of angular arrangement of the extended tabs can change the isotropic and uniformly rigid characteristics of this board to anisotropic properties when the angular shape of the parallelogram favors one direction.

EXAMPLE I

The combining of plastic and paper sheets can be accomplished by hand, particularly if thin materials are employed. Under these circumstances, a simple set of suitably sized pins or dowels are placed in a board or plate and arranged in number equivalent to the number of perforations and in the same position with respect to the spacing of the perforated areas or panels being joined in the sheet. A similar dowel board can be used for the second sheet and the two units registered so that each pair of opposing dowel elements coincide in a side to side position as they deflect or bend the tabs inward, thus causing the wetted adhesive coated areas of these tabs to join forming a link or web. After a reasonable amount of time passes and the adhesive has set, the dowel boards can be opened. The sheets will be joined by the intermediary tab or extension at each point of perforation.

An accessory to this operation that is helpful is a section or frame unit disposed between the dowel boards to maintain a specific dimension with respect to thickness and eliminate the necessity for the dowel pins to "bottom out" on the surface of the sheet which, as noted earlier, is bearing an adhesive material. This eliminates the tendency of the tooling to adhere to the sheet and thus be troublesome.

The production of this type of hand-made panel is suitable only for very small applications, thin sheets of material and circumstances where tests and laboratory experiments may be desirable.

EXAMPLE II

In circumstances where metal or extremely heavy paper or plastic panels are to be joined and the individual panels are prepared as units, it may be desirable to use one of two types of perforating means; the first being the standard and expensive, male and female punch equipment and, the second, heavy duty die cutting steel bent to the partial cutting circle required and mounted in the conventional flat or rotary cutting unit. This latter type of die cutting procedure is common in the paper board art and would be applicable in very light board and even in board of moderate weight.

In the use of metal or heavy weight materials, steel rule die cutting procedures is not adequate and, under these circumstances, conventional tooling in the form of male and female punch and die sets may be required to achieve the desired partial perforation associated with this system. Such die cutting procedures are well known and common to the art of cutting heavy stocks, although not usually applied in connection with paper board due to the costs. In order to achieve the desired partial perforation, it is necessary to form the cutting face of the punch with an angular contour to permit penetration of the stock in a shearing action which limits the cut so that a section remains uncut to later provide a hinge for the partially perforated area or tab when deflected.

In the preferred embodiment of this invention, a punch of the foregoing type can be used in conjunction with a tough resilient material, such as rubber or plastic, or for example, 60 shore so that an effective punching or cutting is made in the sheet without completely passing through it. The rubber or plastic material constitutes a back-up for the punch and offers just enough resistance to provide a clean cut.

In the forming of heavy board stocks that probably would be handled in sheets, it is presumed that large tabs and comparatively heavy thicknesses of finished board is the objective. With panel thicknesses in the order of one to two inches and the sheet stock making up these units as heavy as one quarter of an inch in thickness, the partial perforation or tab cutting can be an inch or an inch and one half in diameter. In a paper board sheet cut in this fashion, the resistance to bending is considerable and, even with suitable pre-scoring, after the application of the adhesive, it will be essential to use some form of hydraulic or compressed air actuated pin board or button board, preferably made from a flat steel block with dowel pins inserted or a cast aluminum block with button forms on its face coinciding with a similar block to provide the strength and pressure required for the deflection of the tabs and to retain them during adjoinment or until adhesives have been set by heat or other means.

In the formation of steel and metal stocks generally, after punching employing the previously described heavy duty male and female die equipment, similar reciprocating die elements in the form of pin or button plate units coinciding with the openings of the partial perforations in the components being joined are required to deflect the area tabs and prepare the sheets for adjoinment. This operation takes place in several steps, the first being the deflection of the area tab by the placement of the sheet over a perforated female die plate and forcing pins through the partial cut perforations to upset the metal and place the tabs in a partially erect position. With this accomplished in both plates, the second step is to adjoin the button or pin plates which have been forced on the two sheet elements in registry, thus engaging the plate units face to face in a common relationship with the tabs adjoined but not connected.

In the final steps of this process, the punching function, to connect the area tab surfaces, is accomplished in an operation wherein one line of tabs is joined at once and the tabs of a given plate assembly are joined at the same time.

In spot welding, it is desirable to weld progressively one or more connections to avoid the current consumption associated with the mass welding of the entire series simultaneously. This is accomplished by utilization of circuitry to intermittently switch from one welding station to another as is common in certain steel fabricating procedures.

EXAMPLE III

In the assembly of metal, plastic or paper structures constructed in accordance with the present invention, it is frequently desirable to utilize continuous machinery and to employ roll stock. Under these circumstances, conventional roll handling equipment normal to the utilization of webs is employed. It is customary with machinery of this type to use unwind equipment and web guide devices to maintain the directional movement of the sheet stock continuously and in alignment with follow-on units.

The specific apparatus required for the handling of metal, plastic and paper is common and widely used in the industry related to each material. In the application and converting of all three material forms two or three separate operational stations in the processing line are required. The first of these provides the function of cut-

ting the pattern of partial perforations in two sheets of stock simultaneously, and in synchronization, so that a second station or roll stand holding peripherally mounted pins on cylinder faces can be employed to upset the tabs of the partial perforations and cause them to adjoin with one another between the panels. In the case of paper, plastic and other comparatively soft and resilient materials, bonding agents in the form of adhesive or thermo-plastic pre-coating materials can be employed. However, in the utilization of metal panel assemblies, it is essential to employ welding techniques such as spot welding, brazing and the like.

Even the lightest gauge metals tend to remain in position after upsetting of the tabs and their adjoinment to one another, unlike the more resilient products such as plastic and paper. It is thus possible to follow the punching and upsetting equipment, in the case of metal, with a third rotary welding function in which the rolls employed are insulated members and the pin elements, which are also insulated, are faced with conductive points that, upon closing against the tab surface from opposite directions and through the surface of each panel function to complete an electrical circuit, thus fusing the two planes together by spot welding. Such equipment and apparatus, circuits and devices are common to the metal fabricating art.

An additional embodiment of this process is the preparation of tab units by partially perforating a third panel element with cuts slightly larger in diameter than those in the two previously assembled panels of this invention. After formation of these larger partial perforations, this third sheet or panel is attached to the previously assembled combination, and the tabs of the third panel are forced through the existing openings with the result that the larger size tab assumes a partial cylinder configuration and, because of the greater length between the hinge point and the extremity of the larger tab (due to its larger diameter) a slight bend is made in the tab parallel to the plane of the panel on the opposite side of the combination, thus affording a connection between the third panel and the extreme panel of the previously joined pair. The contoured or partial cylinder configuration of this tab adds rigidity in compression and, when mated with the previous combination, so that the tab is 180° displaced from the plane of the prior tab connection, a second strut is established between the panel members and within the confines of the same opening in which the first strut or intermediary connection was made.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective and separated view of two components of the sheet of material as partially perforated for assembly.

FIG. 2 is a perspective illustration of the two components separated and illustrating the deflection or bending of the partial perforated tabs preparatory to the assembly of the product of this invention.

FIG. 3 is a perspective and separated illustration showing the components when a third unperforated cover sheet is applied to the product of this invention.

FIG. 4 is a perspective illustration of the assembled configuration of the FIG. 3 embodiment of this invention with the single cover sheet in place.

FIG. 5 is a perspective and separated illustration of the components of this invention with two cover sheets.

FIG. 6 is a perspective illustration of an assembled section of the FIG. 5 embodiment of this invention.

FIG. 7 is a perspective and separated illustration showing the normal assembly of another embodiment of this invention employing superimposition of two additional partially perforated panels.

FIG. 8 is a perspective illustration of the assembled form of the additional embodiment of FIG. 7.

FIG. 9 is a cross-sectional illustration of a structural corner assembly employing a superimposed component attached to the panel for reinforcing of folds.

FIG. 10 is a perspective illustration showing the assembly of FIG. 9.

FIG. 11 is a perspective illustration of an additional embodiment of corner reinforcing in which a single row of spaces between perforations is engaged using special punching to align with the corner assembly for reinforcing.

FIG. 12 is a perspective illustration of a product application of the assembled panels of this invention and the attachment of an identically perforated sheet to connect two tray components.

FIG. 13 is a perspective illustration of an overlapping seam connection accomplished by the use of an extension of one sheet of each of two panels overlaying the abutting assembly.

FIG. 14 is a perspective illustration of a cylinder employing the assembly system of the invention, utilizing spiral winding techniques.

FIG. 15 is a perspective and cross-sectional view in cutaway of the assembly procedure using the invention to form a cup, tub or bucket.

FIG. 16 illustrates a cross-sectional application in a ceiling panel, produced in plastic of translucent material, that serves as an exhaust opening of air passage from a plenum, light transmission and diffusion device, while exhibiting acoustical properties.

FIG. 17 is a disassembled perspective illustration of components in the make-up of a contoured configuration.

FIG. 18 is a perspective illustration and cutaway showing the assembly of the components of FIG. 17.

FIG. 19 is a perspective illustration of an additional embodiment of this invention showing another contouring technique, with various materials.

FIG. 20 is a cross-sectional view of a die achieving the assembly of contoured components.

FIG. 21 illustrates, in perspective, the assembly of a combination paper board and wood product, such as a door or wall panel.

FIG. 22 illustrates a partially assembled form in perspective of an additional embodiment in which the superimposed perforations are of larger size than those of the previously assembled combination of this invention.

FIG. 23 is an enlarged perspective view of the distortion of the enlarged tab produced in the FIG. 22 embodiment.

FIG. 24 illustrates an apparatus form for staking or interlocking metal tabs in the assembly of this invention.

FIG. 25 illustrates the second or completed assembly step in the apparatus of FIG. 24.

FIG. 26 illustrates an additional assembly method for metal components showing apparatus prior to closure in a staking operation.

FIG. 27 illustrates the second position of the staking operation for tab assembly as shown in FIG. 26.

FIG. 28 illustrates a spot welding technique for the assembly of metal tabs.

FIG. 29 illustrates a spot welding technique in which the tabs are of sufficient length to be joined to the opposite panel by spot welding.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The embodiments shown in FIGS. 1 through 6 are described and claimed in my prior copending application Ser. No. 170,120, relative to a paper board product. They are nevertheless described herein for purposes of completeness, and to facilitate understanding of the embodiments of the invention claimed herein.

FIG. 1 shows the basic panel components 1 and 2 which panels are perforated at 3 and 4 with corresponding round, partial perforations, a portion of each perforation being uncut to produce a hinge line about which a tab or free area can be bent perpendicular to the plane of the panels. The hinge lines are, as illustrated, disposed at angles to one another, preferably in groups of four hinge lines disposed respectively along the sides of a parallelogram. As a result, when the tabs are bent about their hinge lines, they extend perpendicular to each panel in a plurality of different planes.

FIG. 2 illustrates the panels of FIG. 1 at 1 and 2 with the tabs 3 and 4 deflected or bent inward to a position perpendicular to the plane of the panels in a line so that the plane of tab 3 is parallel to the plane of the tab 4.

FIG. 3 shows the panels of 1 and 2 of FIG. 1 and 2 with the addition of a third non-perforated sheet 5 for the purpose of closing the perforated areas.

FIG. 4 shows the panels of FIG. 3 in assembled position. The panels 1 and 2 are adjoined by area tabs 3 and 4 with the substantially completely overlapping tab interfaces bonded to one another at 6. The finishing panel 5 is bonded to the surface of panel 2 to close openings 7 from which openings the area tabs 4 have been bent.

FIG. 5 is an exploded or separated view of the panel members described in reference to FIG. 1 thru 4 with an additional panel 8 added for the purpose of closing openings 9 created by the deflection of area tabs 3.

FIG. 6 illustrates in perspective the assembled configuration of the panel components of FIG. 5.

FIG. 7 illustrates an additional embodiment in which the components of FIG. 2 are associated with additional panels 11 and 12 which have been partially perforated in the same tab area form and with the same perforation alignment as is employed in panels 1 and 2. The additional panels are illustrated in a position preparatory to superimposition within the openings of the assembled panels 1 and 2 with tabs 13 positioned to pass through the openings of panel 1 and tabs 14 positioned to pass thru the openings of panel 2.

FIG. 8 is an assembled perspective illustration showing the components of FIG. 7 joined to one another. The panels 11 and 12 are laminated to the assembly of panels 1 and 2 with all tabs 3 and 4, 13 and 14 assembled and bonded in common planes.

FIG. 9 is a cross-sectional illustration of a corner construction employing assembled components like that of FIG. 2 to produce a panel 15 which is folded into two orthogonal sections defining a corner. Perforated strips with openings coinciding with those of panel 15 are su-

perimposed over the inner and outer sides of panel 15 bridging the corner fold, and are connected to both sides of panel 15 by deflecting the tabs of panels 16 and 17 into the openings in both faces of panel 15.

FIG. 10 is a perspective illustration of the arrangement described in reference to FIG. 9, showing the panel 15 with superimposed strips in place at 16 and 17. The tabs of the superimposed panels 16 and 17 are deflected into the openings of the tabs 18 and are retained in place with or without the use of bonding agents.

FIG. 11 is an additional embodiment of a corner connection in which panel members 15 and 25 are bridged by a special perforated strip 19 that has been perforated to provide special spacing of tabs 20 that are distorted and bent into openings 7 to retain or connect the panel members or to provide reinforcing of a corner.

FIG. 12 is a perspective illustration of two tray elements 23 and 24 formed from panel material assembled from components like that of FIG. 2. The openings 18 in the standing edges of these tray elements are connected by deflected perforations 10 bent from the plane of tapes 22 that are wrapped around the assembly to retain trays 23 and 24 in a plane parallel relationship to one another and to retain articles of commerce 26. Retention is accomplished by the deflection of the tabs 10.

FIG. 13 is a perspective illustration of a curved panel 30 in which the hole placement and spacing of partial perforations causes a curvature when joined with panel 31. Upon completion of the curvature to a full circle, panel 31 is brought to an overlapped position where tabs 31b are connected through openings of the assembly like those of perforation 7. Adhesive bonding is provided in space 31c, and liner material 32 closes the butt joint 31d of panel 30.

FIG. 14 is a perspective illustration of a cylinder configuration in which components are combined by tab elements prepared with different hole spacings in panels 30 and 31 respectively so that, when the tabs are connected, the closer hole spacing of panel 30 permits the tab adjoinment to accomplish a circle configuration. An internal liner 32 is added. The overlapping of components is illustrated in cutaway 33 to show the overlapping of component sheets 30 at the abutment line 34 as opposed to the opposite direction of overlap in sheets 31 as illustrated by line 35. It is possible to continuously wind and assemble such a form by employing a spiral technique as illustrated by the curve and angle of line 35.

FIG. 15 illustrates in perspective and cutaway a tapered bucket, tub or cup-like configuration in which panels are combined using the varied tab space considerations of FIG. 14 but with the spacing being selected to accommodate a taper. The panels 31 and 30 are adjoined in this manner to form a cup having a rolled overlapping seam as extended at 36 extending from panel 30 and acting as a drinking or closing lip. The lower edge of panel 31 is also expanded to roll form to close the lower perforated area of the combination while providing a stop 37 in the bottom of the cup against which the circular cut bottom form 38 rests.

FIG. 16 is a cross-sectional view of a ceiling showing fluorescent illuminating fixtures 40 and 41 positioned above a plastic panel assembly 42 fabricated from components like that of FIG. 2. Air passing from the ceiling plenum is shown at arrows 43 and due to the perforated

nature of panel 42, air passes outward and in varied directions with relation to the panel placement as shown by arrows 44. Sound waves 45 striking the surface of the panel are deflected and attenuated as shown by wiggly line 46. The panel of this invention, when fabricated of translucent plastic, can thus serve as a light transmission means, an air deflection control unit and an acoustical surface.

FIG. 17 illustrates in perspective the preparation of components in the assembly of an air foil in which a wing surface 50 is pre-perforated in the partial perforations as shown at 51. These perforations 51 align with and adjoin to similarly placed perforations 52 at the opposite extremity of the same sheet 50 while perforations 53 of panel 50 attach to perforations 54 of spar section 55.

FIG. 18 is a perspective cutaway illustration showing the assembly of the contoured configuration of this invention in the formation of an air foil using the sheet 50 and the spar 55 of FIG. 17 and employing the assembly of tabs as perforated at 51, 52 and 53, 54. As illustrated in FIGS. 17 and 18, the perforations 51 and 52 are patterned in different sizes, to provide tabs of similarly different sizes and of different angular inclinations between the panels, thereby to achieve a desired contour in each panel and a desired variation in spacing between the panels.

FIG. 19 is a perspective illustration of a product in the form of a tray-like component. The assembled components have been formed and partially perforated to achieve a product with a contoured configuration, and rigidity is achieved in the assembly by the connection of area tabs which link the two surfaces in various planar relationships to one another. Panels 60 and 61 are joined by tabs 62 of large dimension where the spacing is greater and tabs 63 of smaller diameter are used where the spacing between parts is of lesser dimension.

FIG. 20 is a cross-sectional view of a die set functioning as an assembly means to connect panel components 60 and 61.

FIG. 21 is a perspective cross-sectional view of panels like that of FIG. 2 in which sheets 1 and 2 are enclosed by thin wood laminations 64 and 65. A wood end or edge element 66 is also provided to fully encapsulate the assembly of this invention achieving a rigid structural member capable of use, for example, as a door frame.

FIG. 22 is a partially assembled perspective illustration of the component of FIG. 2, consisting of the assembly of panels 1 and 2, associated with overlay sheets 66 and 67 having perforations larger than those of the panels 1 and 2. The overlay sheets are superimposed on the outer sides of the panels 1 and 2, and the larger tabs extending therefrom are pressed through the tab openings of panels 1 and 2 to increase the strength of the overall structure.

FIG. 23 is an enlarged perspective illustration of panels the FIG. 22 arrangement, showing 1 and 2 with the overlay sheets 66 and 67 in place. Each enlarged perforated opening 68 in the overlay sheets forms a relatively large area tab 70 which is deflected through a smaller perforation opening 7 causing edge distortion of tab 70 into a channel form 71. Since the length of each tab 70 is greater than the spacing between panels 1 and 2, an additional deflection or bending of tab 70 occurs at 72 to form a parallel tab section which lies against the plane of panel 2 and which is bonded

thereto on line 73. Each deflected tab 70 is disposed in facing relation to an interconnected tab pair on the opposite side of each perforation opening 7.

FIG. 24 illustrates the first step in a staking operation for interconnecting the tabs of metal panels 1 and 2 like those of FIG. 2. The tabs are joined to one another by mechanical reciprocating units 75 and 76 that move into place in the direction of arrows 77 and 78 through openings 7 of panels 1 and 2 to displace tabs 3 and 4 from the planes of panels 1 and 2 into overlapping relation to one another, after which coaxial rods 80 and 81 move within rod sleeve units 75 and 76 to stake the tabs to one another.

FIG. 25 is a cross-sectional illustration of the panels 1 and 2 showing the rods 75 and 76 in a final position preparatory to staking. Co-axial rods 80 and 81 are moved with force in the direction of arrows 82 and 83 causing cutters 85 and 86, pivotally mounted on pins 87 and 88, to move cutting edges against tabs 3 and 4 displacing staked elements 89 and 90 from the plane of tabs 3 and 4 and, in so doing, latching them together. This action is followed by the retraction of rod sleeves 75 and 76 in the direction of arrows 91 and 92 thus completing the staking operation of FIGS. 24 and 25.

FIG. 26 illustrates a different method and apparatus for staking the overlapping tabs of metal panels like those of FIG. 2. Machine tool staking components 100 and 101 are moved through panel openings 7 against tabs that have previously been positioned in the overlapping adjoinment relationship previously described.

FIG. 27 is a cross-sectional view showing the tool elements 100 and 101 in final position after punching tabs 3 and 4 of panels 1 and 2. The punching operation causes a distortion or deflection 103 and 104 to produce an interlocking of said tabs, after which tool units 100 and 101 are retracted from the hole positions 7 in the direction of arrows 105 and 106.

FIG. 28 is a cross-sectional illustration showing how the overlapping tabs of metal panels 1 and 2 can be spot welded together after being properly positioned by tooling like that of FIG. 20. Spot welding electrodes 108 and 109 are brought into contact against tabs 3 and 4 at position 110 to cause a bonding or connection by fusing the metal.

FIG. 29 is a cross-sectional view of an assembly like that of FIG. 2 in which the tabs of panels 1 and 2, previously joined by a spot welding apparatus like that of FIG. 28, are subjected to a second spot welding operation in which the extremity of tab 3 and tab 4 is attached to the opposite panel in the plane of said panel. This second operation is effected by the application of electrodes 111, 112, 113 and 114, the conductors of which cause a fusing of the metal at positions 115 and 116 to attach the extremity of each tab to the inner face of the opposing metal panel.

I claim:

1. A structural element comprising:

two planar panels disposed in spaced facing relation to one another, each of said panels having a plurality of similarly shaped partial perforations cut therein defining similarly shaped tabs each of which is bent about an uncut linear hinge line in said panel at an angle to the plane of said panel to provide an opening in said panel, and each of which tabs extends from its uncut hinge line at an edge of said opening toward the other of said panels across substantially the entire space between

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said panels, each of said tabs being shaped to provide a tab portion, spaced outwardly from its hinge line, which is wider than said hinge line in a direction parallel to said hinge line, the hinge lines for different ones of said tabs being at angles to one another,

corresponding pairs of said tabs extending respectively from said panels being disposed in contiguous substantially completely overlapping planar relation to one another,

said contiguous overlapping tabs in each corresponding pair being attached to one another to form intermediary members that retain said panels in fixed position relative to one another,

and a cover sheet overlying and contiguous with the outer surface of one of said panels, said cover sheet having a plurality of further partial perforations cut therein to define a plurality of integral further tabs extending outwardly from said cover sheet, each of said further tabs being bent at an angle to the plane of said cover sheet about an uncut hinge line in said cover sheet and into one of the openings in said one of said panels each of said further tabs being shaped to provide a portion, spaced outwardly of its associated cover sheet hinge line and wider than the linear hinge line portion of said one of said openings in a direction parallel to said cover sheet hinge line whereby each of said further tabs is mechanically locked into its associated opening in said one of said panels.

2. The structure of claim 1 wherein each of said further tabs is similar in shape to, and larger in size than the openings in said one of said panels, each of said further tabs comprising a flexible material which is distorted in configuration as it is forced into an opening in said one of said panels.

3. The structure of claim 2, wherein each of said further tabs is distorted into a channel shaped configuration and retained in said configuration by the boundary edges of the panel opening with which said tab is associated.

4. The structure of claim 1 wherein each tab in each of said panels is bent about a hinge line disposed at one edge portion of a partial perforation in said panel, each of said further tabs being bent about a hinge line in said sheet disposed adjacent a different edge portion of said partial perforation in said panel, whereby the plane of each of said further tabs passing through a given operating in said panel is displaced from the plane of the overlapping tabs associated with said given opening.

5. The structure of claim 4 wherein the plane of each of said further tabs is disposed in spaced, substantially parallel facing relation to the plane of the overlapping tabs associated with said given opening.

6. The structure of claim 1 wherein said panels are

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folded about a fold line to define a corner structure, said cover sheet bridging said fold line and having said further tabs extending through the openings in said one of said sheets on both sides of said fold line to reinforce said corner structure.

7. The structure of claim 1 including a further cover sheet overlying the outer surface of the other of said panels, said further cover sheet also having a plurality of partial perforations therein to define still further tabs which are bent at an angle to the plane of said further cover sheet into the openings in said other of said panels.

8. The structure of claim 7 wherein said panels include panel portions angularly disposed to one another relative to a line to form a corner structure, each of said cover sheets bridging said line to reinforce said corner structure.

9. The structure of claim 1 wherein said two panels constitute a first portion of a container, said cover sheet extending beyond a boundary edge of said first portion to a second portion of said container which is spaced from said boundary edge thereby to attach said first and second container portions to one another.

10. The structure of claim 1 wherein each of said partial perforations and each of said tabs has a round shape.

11. The structure of claim 1 wherein at least some of said pairs of tabs extend at right angles to their associated panels to produce intermediary members which are oriented perpendicularly to both of said panels.

12. The structure of claim 1 wherein said tabs are disposed in a plurality of rows, the hinge lines for different ones of said tabs in each of said rows extending at angles to the hinge lines for the tabs in others of said rows.

13. The structure of claim 12 wherein the tabs extending from each of said panels in different ones of said rows are differently dimensioned whereby said overlapping attached tabs retain said panels in varying spaced relation to one another.

14. The structure of claim 1 wherein said tabs are disposed in a plurality of rows, the tabs extending from each of said panels in different ones of said rows being differently dimensioned whereby said overlapping attached tabs retain said panels in varying spaced relation to one another.

15. The structure of claim 1 wherein the partial perforations in one of said panels are spaced from one another by a spacing which differs from that between the partial perforations in the other of said panels, whereby said attached tabs retain said panels in a contoured configuration.

16. The structure of claim 15 wherein said contoured configuration is a cylinder.

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