

May 21, 1957

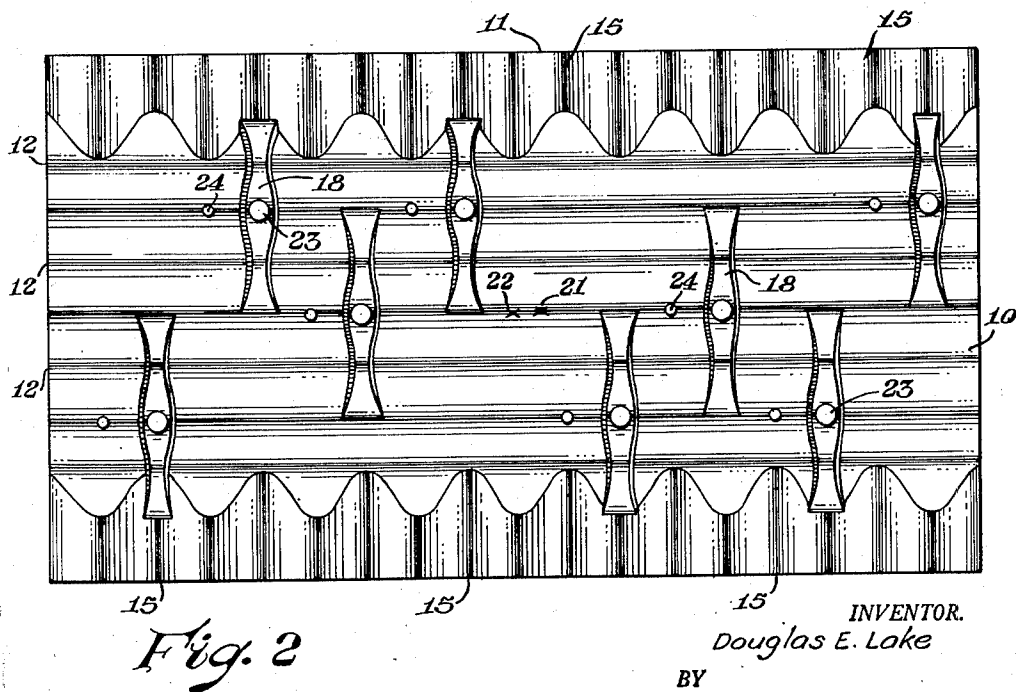
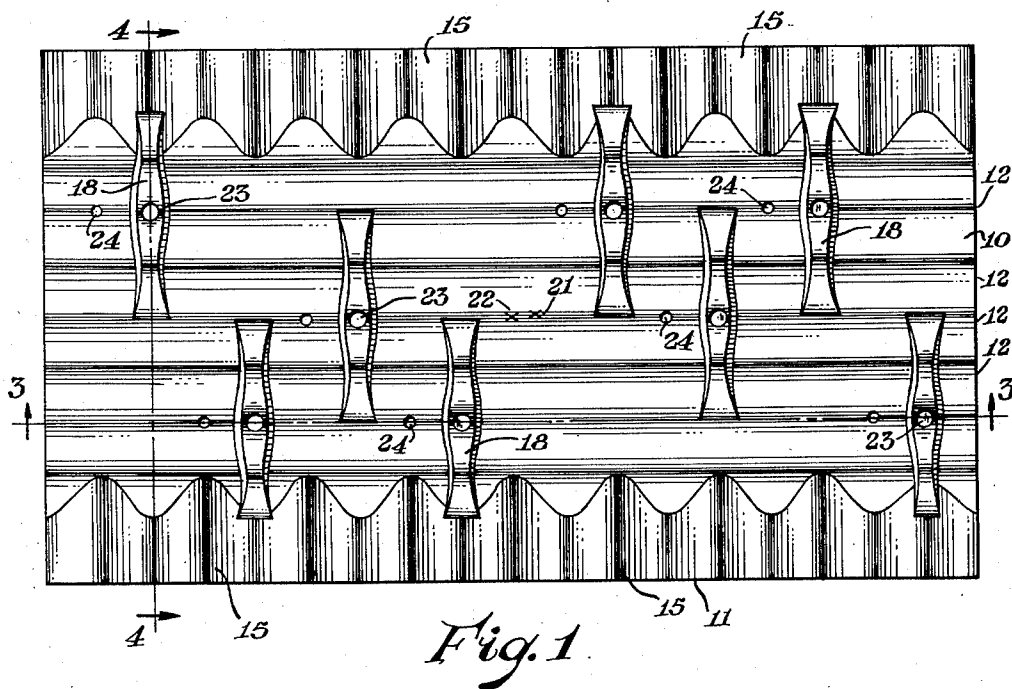
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2,793,017

APPARATUS FOR DISTRIBUTING FALLING LIQUID IN THIN FILMS

Filed Oct. 4, 1954

3 Sheets-Sheet 1



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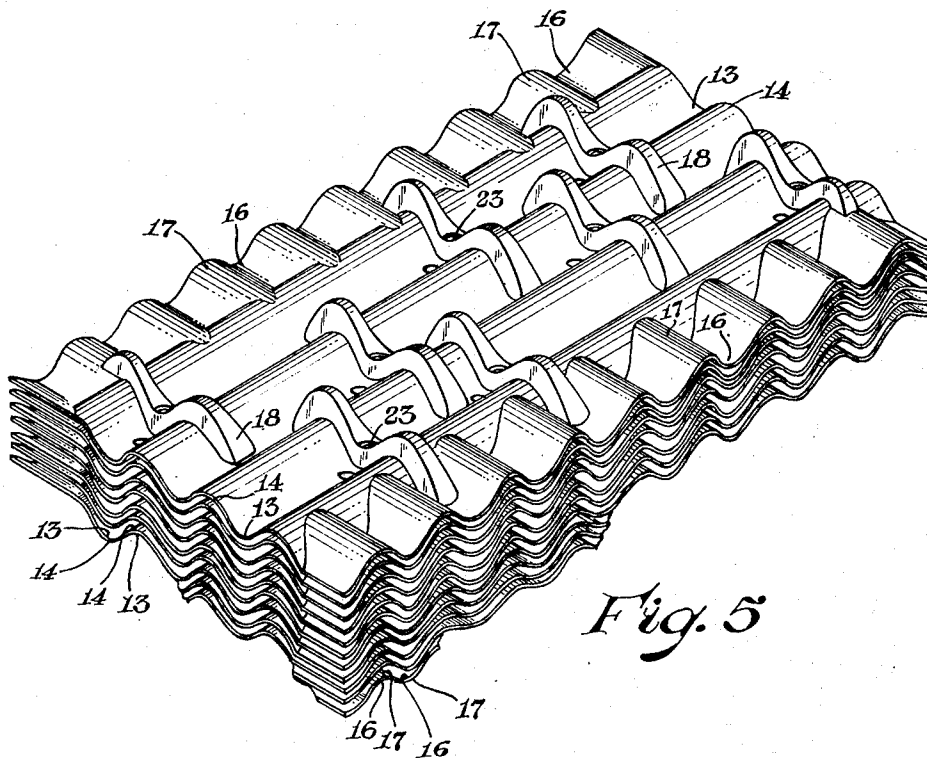
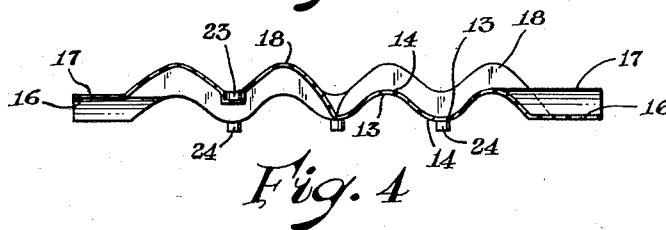
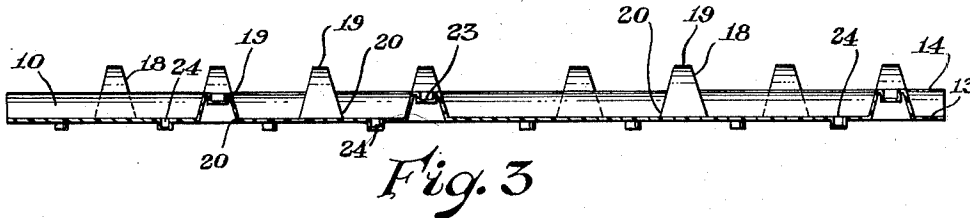
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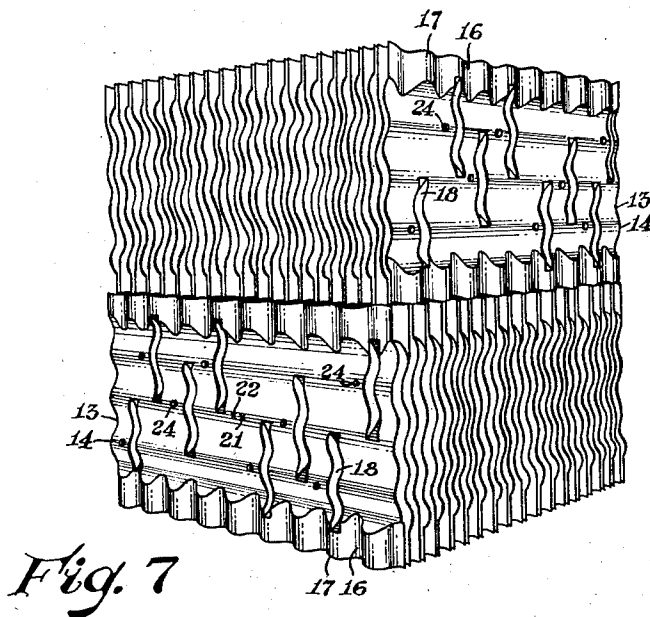
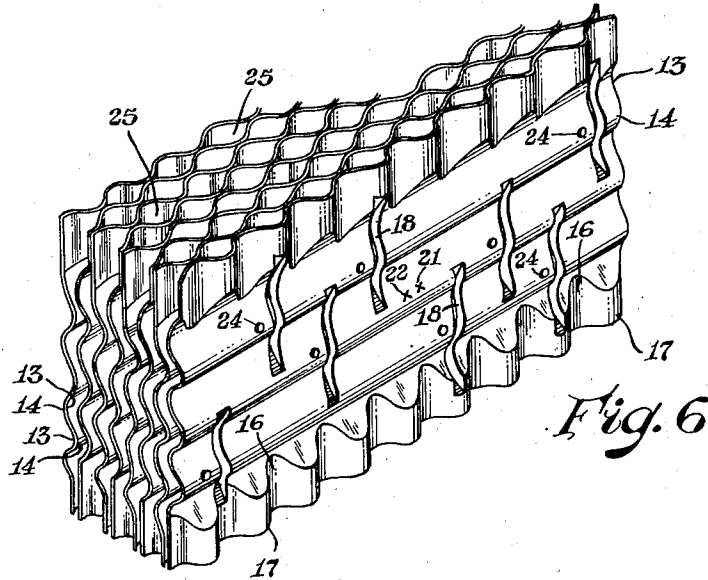
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APPARATUS FOR DISTRIBUTING FALLING LIQUID IN THIN FILMS

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Application October 4, 1954, Serial No. 459,960

6 Claims. (Cl. 261—112)

This invention relates to a corrugated sheet element, an assembly of such elements, and apparatus comprising such an assembly for distributing a falling liquid as a plurality of thin films. It relates in particular to an extended surface element for gas-liquid contact as in trickle filters, cooling towers, absorption towers, blowing-out towers, and other apparatus in which it is necessary or desirable to expose a large liquid area in a small volume or in a short distance.

Among the characteristics often desired in gas-liquid contact apparatus of the suggested types are high void volume, to provide low resistance to the flow of fluids, coupled with large surface areas per unit volume, and low density, to simplify the structural support required by the apparatus. It has been proposed heretofore to use flat sheet material, with its plane faces vertical, as distributing elements in gas-liquid contact apparatus. When plane sheets are used, however, the necessary spacing between sheets for counterflow of gas provides too great an opportunity for the free fall of liquid between the sheets, and the desired complete distribution as liquid films is not obtained. Accordingly, it has also been proposed to employ vertically disposed sheets with horizontal corrugations. These, too, must be spaced to permit counterflow of gas, and such sheets have not prevented the free fall of liquid through the spaces. Further, when corrugated sheets have been used, of thin enough gauge to provide the desired low bulk density, the sheets have tended to slump, and, when reinforced by affixing vertical ribs to overcome this tendency, they have tended to break along the lines of the ribs. Finally, a simple corrugated sheet gives no assurance that liquid falling on its exposed upper edge will be distributed over both of the corrugated surfaces. Most configurations of such sheets naturally deflect such liquid to one face only, thereby providing one wet wall and one dry wall, and the latter necessarily represents waste or unused capacity in the apparatus.

It is among the objects of the present invention to provide a modification of corrugated sheet material for the suggested purposes which will provide the necessary low resistance to counterfluent streams without permitting any liquid to fall freely through the spaces between the sheets when the latter are assembled in working relationship. Another object is to provide such sheets with a configuration which assures their operation with two wet walls. A further object is to provide such sheets with corrugations of large amplitude and with reinforcing spacers which do not create strain lines in the sheet. Related objects include the provision of assemblies of such sheets and apparatus comprising such assemblies.

The invention is an extended surface element for gas-liquid contact apparatus, trickle filters and similar assemblies in which it is desired to distribute a falling liquid as thin films, consisting essentially of a thin sheet of a material inert to the fluids with which it is intended to serve. The sheet is designed to stand vertically on one of its longitudinal edges and has a plurality of longitudinally

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disposed corrugations with smoothly interconnected alternate troughs and ridges covering most of the area of the sheet. It is also provided with a plurality of relatively short corrugations disposed transversely of the sheet along each of its two longitudinal margins and covering the remaining area of the sheet. Each of these short corrugations extends from the edge of the sheet into open communication with a surface of the nearest longitudinal corrugation. The sheet is reinforced by several spaced ribs disposed transversely of the sheet on at least one face thereof. These ribs preferably span only a few corrugations, and are preferably of such a sigmoidal shape as to follow the transverse contour of the sheet. Further details will become apparent from a consideration of the following description and the accompanying drawings, in which

Fig. 1 is a plan of one face of a preferred embodiment of the corrugated sheet element;

Fig. 2 is a plan of the opposite face of the same element;

Fig. 3 is a longitudinal section taken along the line 3—3 of Fig. 1;

Fig. 4 is a transverse section taken along the line 4—4 of Fig. 1;

Fig. 5 is an isometric view of a plurality of the elements of Fig. 1, in non-operative, nested relationship;

Fig. 6 is an isometric view of a plurality of the elements of Fig. 1, in operative assembly; and

Fig. 7 is a simplified perspective view of a plurality of the assemblies of Fig. 6, in a preferred tiered relationship;

The drawings illustrate a preferred embodiment of the invention in which the extended surface elements and their reinforcing ribs are molded, stamped or pressed from a single sheet. For those elements and assemblies intended for use in contact with aqueous liquids, the elements may be made conveniently from organic thermoplastic sheet material, such as a polymer or copolymer of styrene, suitably by the simple vacuum drawing procedure. For other service, the elements may be made of any suitably inert material which, in some cases may be of various metals, resin impregnated paper or fiberboard, cast concrete, ceramics or other material capable of being formed into the proper shape.

The thin sheet element 10, detailed in Figs. 1—4, is adapted to stand vertically on one of its longitudinal edges 11, as shown in Figs. 6 and 7. The element 10 has a plurality of longitudinal corrugations 12 with smoothly interconnected troughs 13 and ridges 14 on each face, as may be seen most clearly in Figs. 5—7. The longitudinal corrugations 12 cover most of the area of the elements 10. The remaining area of each element 10 is covered with a plurality of relatively short corrugations 15 disposed transversely of the sheet, extending from the longitudinal edges 11 element 10 into open communication with a surface of the nearest longitudinal corrugation 12. The transverse corrugations 15 have smoothly interconnected troughs 16 and ridges 17, preferably of about the same amplitude as that of the longitudinal corrugations 12. The troughs 16 along one margin of element 10 are preferably aligned with ridges 17 along the other margin.

Each element 10 is reinforced by several spaced ribs 18 disposed transversely of the sheet and projecting from at least one face thereof a distance less than the amplitude of the corrugation. In the illustrated and preferred embodiment the ribs 18 are integral with the element 10, projecting from one face thereof, each rib 18 spanning two complete corrugations and being of a generally sigmoidal shape so as to follow the transverse contour of the element 10. This is shown most clearly in Figs. 4 and 5. The preferred sigmoidal ribs 18 are hollow drawn, with narrower lands 19 than roots 20 (Fig. 3), to permit

nesting the elements 10 when these are stacked for storage or shipment in non-operative assembly (Fig. 5). To provide essentially uniform rigidity in all parts of each element 10, the ribs are symmetrically disposed about a center of symmetry 21 (Figs. 1 and 2). It is preferred that the said center of symmetry 21 be displaced from the true center 22 of the element 10 toward one end thereof a distance approximately the width of a rib 18. As a result, there is a greater distance from one end of element 10 to the closest rib than that from the other end of the element to its closest rib. When assembling a plurality of the elements 10 to provide a distributor for falling liquid, all of the elements are turned with the ribs 18 projecting in the same direction, and alternate elements 10 are turned with their centers of symmetry 21 on opposite sides of their true centers 22. The ribs serve as spacers between the assembled elements.

It is convenient to provide a small cup-like indentation 23 in the internal angle of each sigmoidal rib 18 and a smaller indentation 24 in the trough 13 of the closest longitudinal corrugation 12 displaced toward the longer end of the element 10 a distance equal to that between the center of symmetry 21 and the true center 22. When the elements 10 are assembled in operative relationship, the indentations 24 mate with the cups 23, providing a slip-stop to reduce or prevent movement of the individual elements in the assembly. If desired, the cups 23 may be filled with an adhesive, just before assembly, and the elements will then be held together without need for confining frames.

When assembled to form a gas-liquid contact body, the elements are disposed on their longitudinal edges, i. e., with their transverse short corrugations 15 vertical and their longitudinal corrugations 12 horizontal. Such an assembly is shown in Fig. 6. Liquid falling on the assembly enters the honeycomb-like openings 25. Such of the liquid as impinges on one of the surfaces of the vertically disposed transverse corrugations flows smoothly therefrom, spreading over the longitudinal corrugations as it falls, until it passes to the vertical corrugations at the lower margin of the sheet and flows out of the assembly. Such of the liquid as falls through an opening 25 must fall on one of the horizontally disposed corrugated surfaces because of the amplitude of the corrugations, i. e., there is no opportunity for free fall through the assembly. Hence, all of the falling liquid is distributed as a film on the walls of elements 10. For many purposes it is desirable to have multiple tiers of the assembly of elements, and it has been found that optimum distribution of the falling liquid is obtained if the elements in the assemblies of each tier are oriented at 90° to the corresponding elements in adjacent tiers, as shown in Fig. 7.

The following examples illustrate two practical applications of the article of the present invention.

Example 1.—Application of the invention to trickling filters for the bacterial oxidation of phenolic waste liquors

The conventional trickle filter for phenolic wastes is a bed of graded rock or blast furnace slag, carrying a coating of a bacterial slime. In one large industrial filter of this type the stones present an average of 20.5 square feet of surface area per cubic foot of the filter bed, and the porosity, or void volume, of the bed is about 15 percent. In contrast, the assembly of Figs. 6 and 7 presents 25 square feet of area per cubic foot and the void volume is 94 percent. In a specific and comparative test, a large upright cylindrical tank was divided into two equal portions by a vertical diametric partition. One side was packed with the assembled elements of this invention, in several tiers, and the other side was filled with graded rocks from the large industrial filter bed. A 4-arm rotary distributor head, driven by the reaction of many jets along each arm was used to distribute liquid evenly and continuously over the top of the so-filled tank. Provision was made to sample effluent liquor separately from the two halves of the tank. Initially the filter was inoculated

for several days in the usual manner with an aqueous nutrient, phenol and bacteria culture. Thereafter, a solution of nutrient and a known concentration of phenol was supplied continuously at the prevailing water temperature of 21° C. and at a rate of about 11 million gallons per acre of filter area per day. The phenol feed was increased periodically, and the effluent liquors were analyzed for phenol. The results are tabulated below:

CONCENTRATION OF PHENOL, PARTS PER MILLION

Days	Feed	Effluent		Phenol removed, Parts per million	
		This invention	Rock	This invention	Rock
6.....	76.5	15.8	28.4	60.7	50.1
3.....	98.7	28.8	36.8	71.8	61.9
10.....	114	17.8	40.9	95.2	73.1
2.....	107	24.7	83.7	142.3	83.3

It is apparent that the free-flow characteristics of the new liquid distributing body results in a very favorable condition for oxygen transfer from air to the waste liquor while trickling over bacterial slimes adhering to its surface.

Example 2.—Application of the invention to water cooling towers

An induced draft cooling tower, 38 inches square, was filled successively with various packings, including the packing shown in Fig. 7, in which each element was 21 inches high and 37 inches long. The elements were spaced one inch apart, while the peak to peak amplitude of each corrugation was about 1.5 inches. The elements were made of a styrene copolymer, and the bulk density of the packing was 2.8 pounds per cubic foot. The air and water flow rates were adjustable over a wide range and provision was made for measuring the temperature of both water and air at various points in the system. The water used was from an industrial process condenser and temperatures from 90° to 120° F. were available at will on the incoming water. The cooling tower efficiency was determined, using Merkel's theory, as discussed by Simpson et al. in *Refrigerating Engineering*, 52, 535-543 and 574-576 (1946). The coefficient of total heat transfer for a cooling tower packing, in B. t. u. per hour (cubic foot of packing) is in inverse proportion to the tower height to accomplish a given job, and hence is directly proportional to the relative efficiencies of the packings being studied. It was found that, under the conditions in which conventional commercial cooling towers with wood slat packing have coefficients of 54-60, the new packing has a coefficient of 230, or about 4 times as great. Other tests showed that, at an air flow rate of 1300 pounds per hour (square foot of tower cross section) and a water rate, pounds per hour (square foot of tower cross section) of 1000, a tower packed with a 16 foot depth of 2-inch Raschig rings would have the same heat transfer efficiency as a tower packed to 30 foot depth with the new assemblies of this invention, but that the Raschig ring filled tower presents a prohibitive back pressure of 8.8 inches of water under these conditions, while the greater height of the new packing causes a back pressure of only 0.6 inch of water.

I claim:

1. An extended surface element for gas-liquid contact apparatus, trickle filters and the like, consisting essentially of a thin sheet of material inert to the fluids with which it is intended to serve adapted to stand vertically on one of its longitudinal edges, having a plurality of parallel corrugations longitudinally disposed and with smoothly interconnected alternate troughs and ridges covering most of the area of the sheet; a plurality of relatively short corrugations disposed transversely of

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the sheet along each of its two longitudinal margins and covering the remaining area of the sheet, each said transverse corrugation being at right angles to said longitudinal corrugations and extending from the edge of the sheet into open communication with a surface of the nearest longitudinal corrugation; and a plurality of spaced reinforcing ribs disposed transversely of the sheet on one face thereof, each such rib being of generally sigmoidal shape conforming to the corrugations, and spanning at least two adjacent longitudinal corrugations.

2. The element claimed in claim 1, wherein each reinforcing rib is hollow drawn with narrower lands than roots to permit nesting of a plurality of the elements when not in working assembly.

3. The element claimed in claim 2, wherein the reinforcing ribs are disposed symmetrically about a point displaced from the true center of the element toward one end thereof a distance approximating the width of a rib, providing greater length beyond the last rib at one end of the element than at the other.

4. The element claimed in claim 3, wherein each sigmoidal rib has an indentation in its internal angle and a slightly smaller indentation is provided in the trough of the closest corrugation of the element displaced the same distance as that between the true center and the center of symmetry toward the end of the element which extends the greatest distance beyond its closest rib, to

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provide slip-stops between contiguous elements when stacked in working assembly.

5. An assembly of the elements claimed in claim 4, wherein a plurality of such elements is disposed with their longitudinal axes parallel and horizontal, their transverse axes parallel and vertical, their ribs all oriented toward the same face of the assembly, and consecutive members having their centers of symmetry on opposite sides of the true center.

6. The element claimed in claim 1, wherein the transverse corrugations along one margin have their troughs aligned with the ridges of those along the other margin.

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