July 14, 1970 R. C. BRUNER 3,520,357

OPEN CORE SANDWICH-STRUCTURE

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FIG. 1

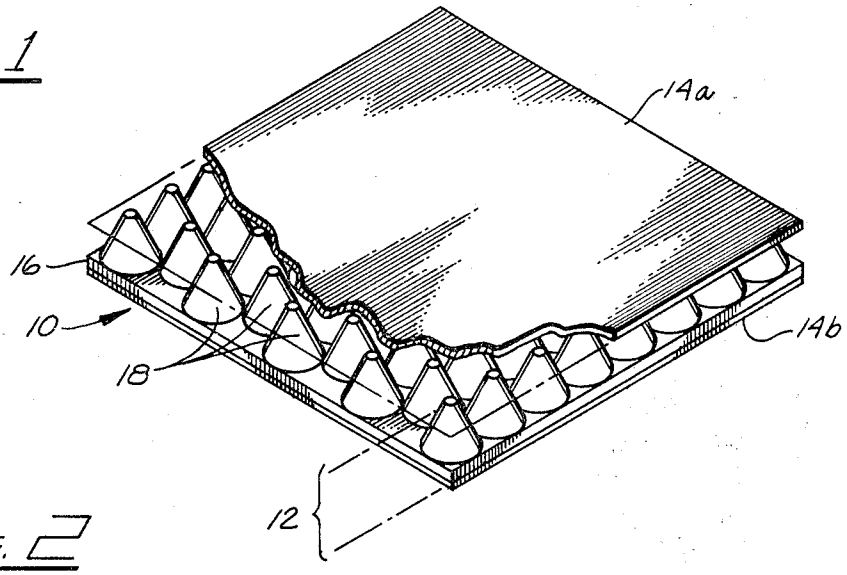


FIG. 2

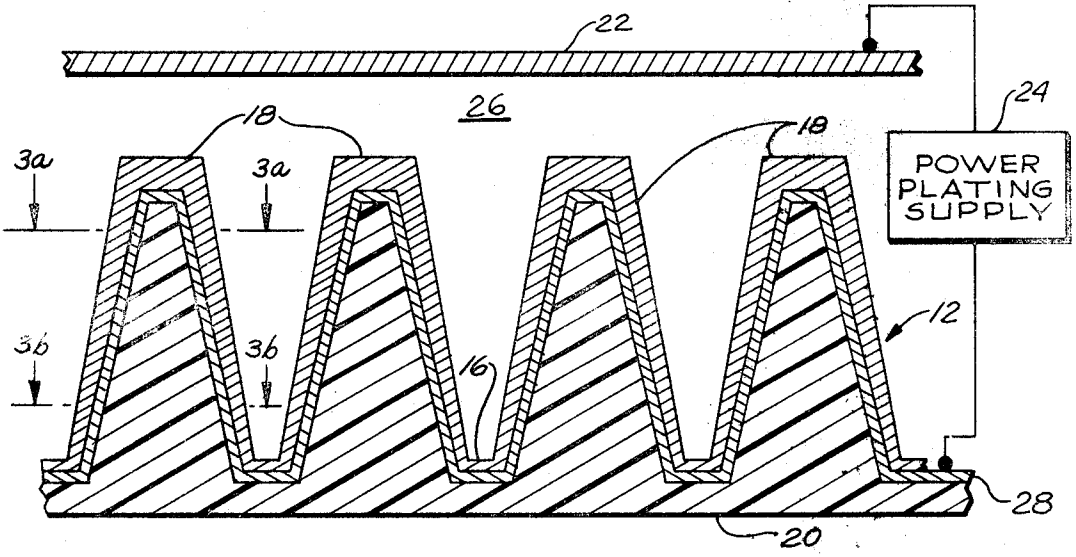


FIG. 3a

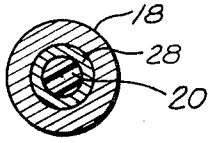
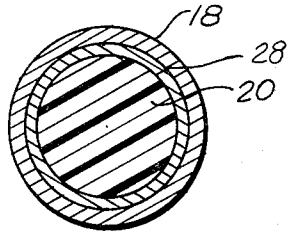


FIG. 3b



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FIG. 4

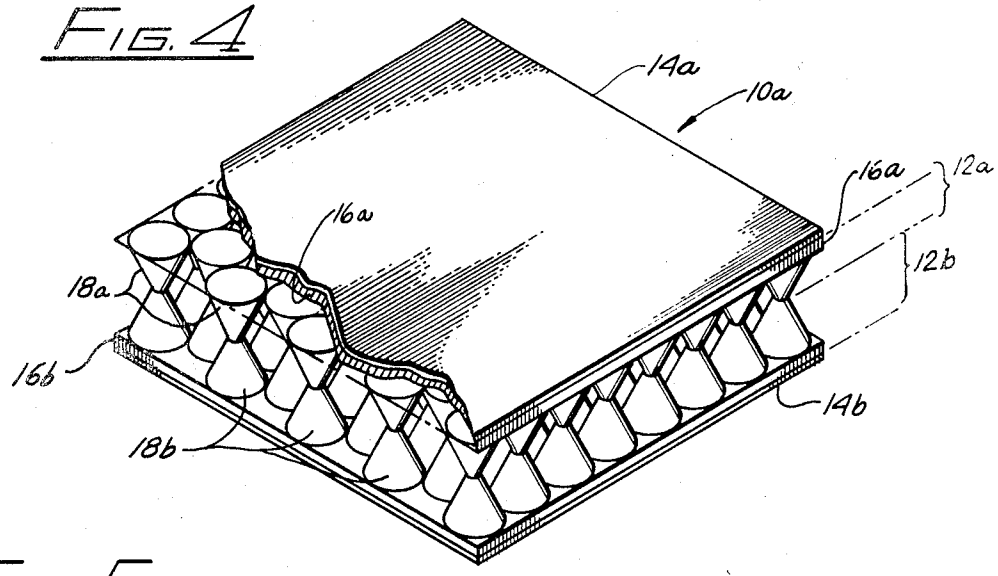
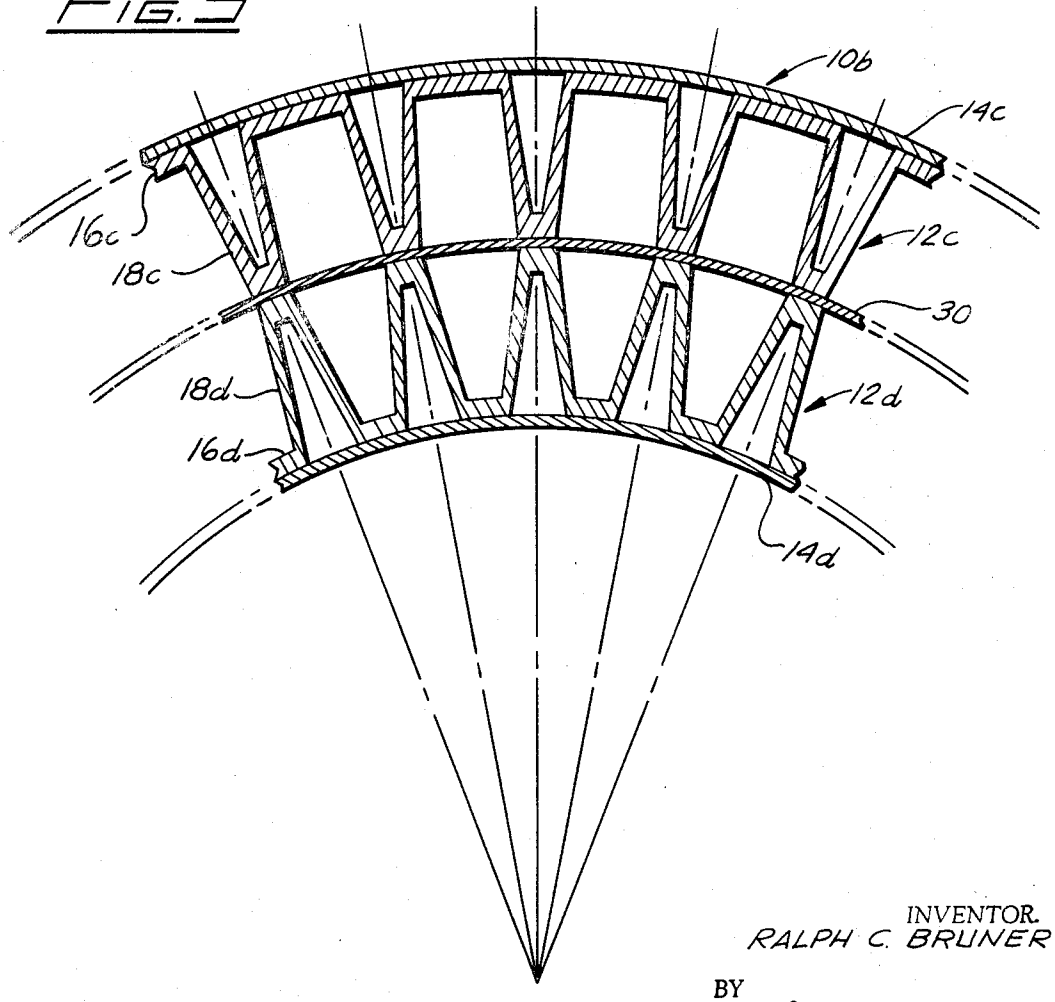


FIG. 5



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FIG. 6

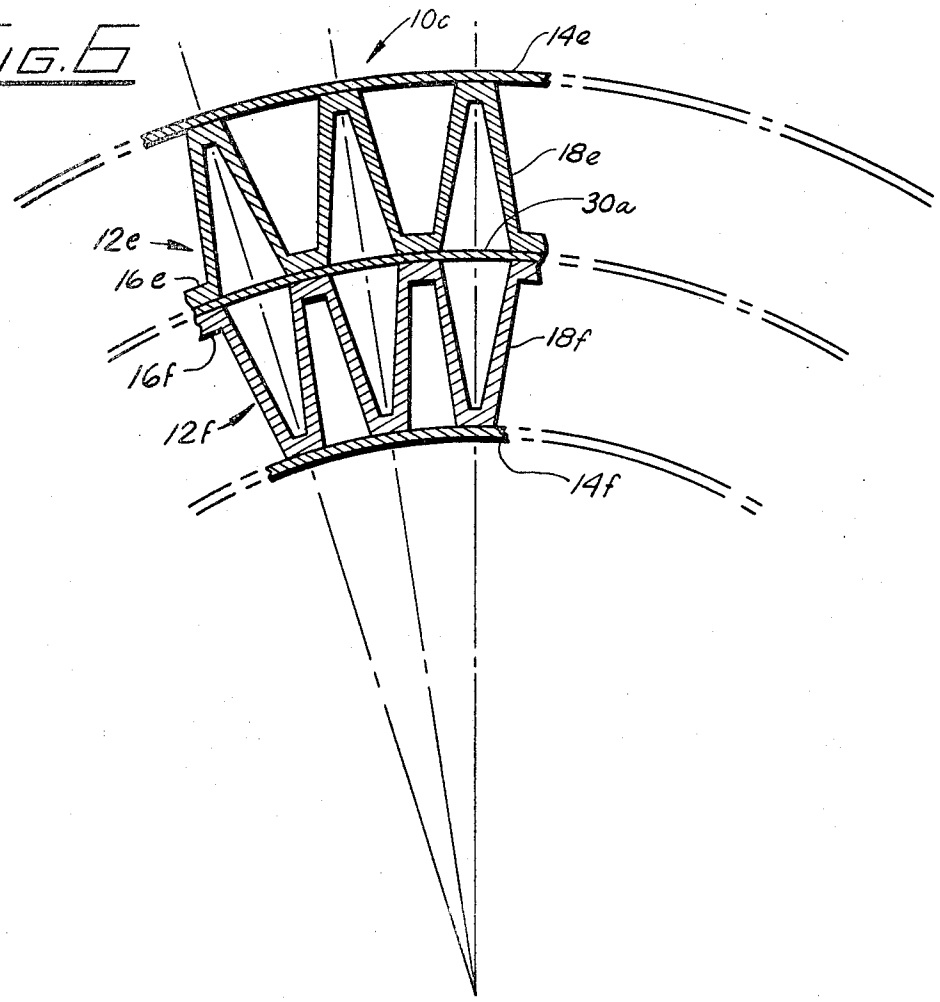
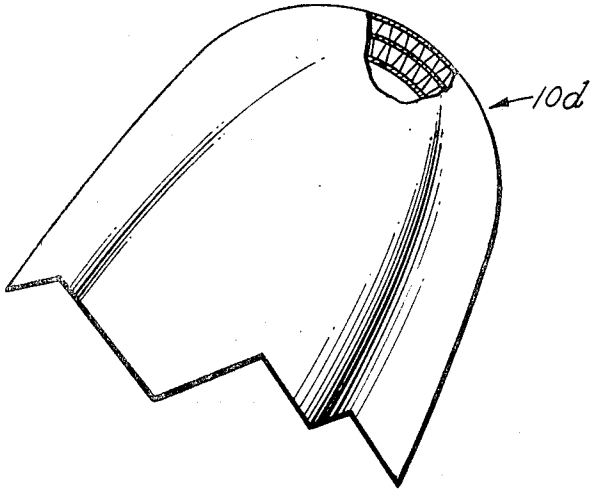


FIG. 7



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OPEN CORE SANDWICH-STRUCTURE

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U.S. Cl. 165—166 2 Claims

ABSTRACT OF THE DISCLOSURE

A strong, lightweight structural-element (and a method for making the structural-element) that may—if desired—be used with skin-sheets, comprising one or more electroformed cores having a base-sheet and a plurality of frusto-conical, frusto-polyhedral, or frusto-quasi-spherical configurations protruding from the base-sheet—the configurations being affixed to each other or to a common sheet.

BACKGROUND

This invention relates to a structural-element having low weight and high strength; and more particularly to a modification of the sandwich-type structural-element wherein a core is sandwiched between, and affixed to, two external skin-sheets.

At present the most widely used sandwich-type structural-element is the well known "honeycomb" panel—wherein a plurality of sheets of material are juxtapositioned in such a way as to form a core having a plurality of hexagonally-shaped cells, and two external skin-sheets are positioned and affixed to the honeycomb core in such a manner as to form a sandwich that closes and isolates each hexagonal cell. Structures of this type are extremely lightweight and strong, and have found wide usage. These uses have included the floors, walls, wings, and—in many cases—combined wings and fuel tanks of an aircraft; and have also included "heat exchangers" wherein a heating or a cooling fluid (liquid or gas) flows through the core, and transfers heat to the honeycomb walls and skin-sheets.

In these latter tank and fluid-flow usages, it becomes necessary—because of the orientation of the sealed honeycomb cells—to perforate the cell walls in order to permit the fluid to flow from one cell to another. This requirement for perforations tends to reduce the high-strength advantage of the honeycomb cell—because the perforations must be large enough to permit the flow of fluid; and yet, any perforations—however small—tend to weaken the structure.

Many attempts have been made to provide a more satisfactory sandwich-type structural-element; that is, a structural-element with an equivalent or improved strength-to-weight ratio that also permits better flow of fluid, greater strength or flexibility, etc. These prior-art structural-elements have generally sought to replace the honeycomb-core with other cores that have been formed in one of two ways. The first way has been to form the core by deforming or stretching a sheet to have shaped protrusions. The disadvantage of this technique is that high-strength metals can generally be stretched or deformed to only a limited extent, thus introducing limited wall-thickness, brittleness, metal-tearing, etc. An alternative way of forming the cores has been to fabricate separate protrusions of suitable size and shape, and to affix these by welding or brazing to suitable base-sheets. This particular arrangement has the disadvantage that it requires more manufacturing processes, and tends to be unreliable because of the inability to perfectly perform the numerous welding and/or brazing operations.

Another disadvantage of these prior-art techniques is that the metal-forming processes generally produce walls that tend to be of uniform or reducing thickness; and, therefore, certain wall areas tend to be more highly stressed under load than other wall areas. Structural-elements made by the above techniques have still another deficiency in common; this being the fact that they tend to be inherently planar structures. In order to achieve curved panels, they must be formed planar, and then bent to the desired shape; but this bending process introduces stresses and strains, and tends to buckle and weaken the material of which the sandwich-type structural-element is made.

OBJECTS AND DRAWINGS

It is therefore an object of the present invention to provide an improved, lightweight structure.

It is another object of the invention to provide an improved core that can be electroformed in any desired shape.

It is another object of the present invention to provide a structure core-component wherein the wall-thickness of the core is suitably tapered to have equivalent strength at all portions thereof.

The attainment of these objects, and others, will be realized from the teachings of the following detailed description; taken in conjunction with the drawings, of which

FIG. 1 shows a single-panel structure;

FIG. 2 shows a method of electroforming the core-component;

FIGS. 3*a* and 3*b* show typical resultant cross-sectional areas produced by tapering the wall-thickness of the core-component;

FIG. 4 shows a double-panel structure;

FIG. 5 shows a multi-panel structure;

FIG. 6 shows another multi-panel; and

FIG. 7 shows a double-curved structure.

SYNOPSIS

Broadly speaking, the disclosed structural-element comprises a core-component that is electroformed in such a way as to result in a base-sheet having integrally-formed configurations protruding therefrom; these protrusions preferably being in the form of frusto-cones, frusto-polyhedrons, or frusto-pseudo-spherical configurations, and being designated "apixially shaped."

DESCRIPTION

The basic inventive concept will be understood from FIG. 1, wherein a single-panel structure **10** is comprised of a core-component **12** and two skin-sheets **14***a* and **14***b*. As shown, core **12** comprises a base-sheet **16** and apixical configurations **18**—shown as frusto-cones—protruding from a base-sheet **16**. Since, as indicated previously, core-component **12** is produced by electroforming (to be discussed later), a base-sheet **16** and configurations **18** form a continuous integral structure; and the configurations **18** may be of any desired size, shape, height, angle, etc. Structure **10** is unitized by means of brazing, welding, adhesives, etc.; and provides the desired lightness associated with the desired strength. Moreover, the array of protrusions **18** permits conduit, pipes, tubing, wires, etc. to be readily inserted into—and through—the structure **10**. Moreover, the protrusion-array provides a relatively unimpeded path for fluid-flow along a channel formed by the two skin-sheets **14***a* and **14***b*, the protrusions **18** being positioned to provide either a substantially laminar flow, or mildly-turbulent flow, for conducting heat into or out of the flow.

As indicated previously, core-component **12** is electroformed, and this process may be understood from FIG. 2. Here core-component **12** is being formed on a matrix **20** which, in association with electrode **22** and a plating power-supply **24**, acts in a well known manner to deposit metal from plating solution **26** onto matrix **20**. In this way, core-component **12** assumes a shape and size determined by matrix **20**. Due to the electroforming process, a continuum of metal is deposited on matrix **20**, so that the base-sheet **16** is an integral continuous sheet, and is integral and continuous with protrusions **18**, to form an integral continuous core-component **12**.

As is known to those skilled in the art, the matrix **20**—or its surface—must be electrically conductive; and, in the case of a non-conductive matrix material, a surface-conductive coating—indicated at **28**—can be produced by the well known electroless-plating technique.

The process of electroforming is well known and widely used, and is described in many publications such as "Principles of Electroplating and Electroforming" by Blum and Hogaboom; "Metal Finishing Guide Book" published by the Metals and Plastics Publications, Inc. of Westwood, N.J.; and "Electroplating Engineering Handbook" by Graham. As is well known, electroforming is a form of electroplating wherein the plated material deposits upon a matrix in such a manner as to produce an object corresponding to the size, shape, and configuration of the matrix, the matrix being eventually removed from the electroformed workpiece, to leave a metal shell of the desired shape and dimensions. It is well known, that by suitable positioning of the electrodes, suitable composition of the plating solution, suitable positioning of so-called "rubber" electrodes, and suitable control of the plating current, the electroforming process may be caused to produce a workpiece whose thickness varies in a desired manner relative to the configuration of the matrix; and this thickness-control is discussed and illustrated on page 62 of the 1955 issue of the Electroplating Engineering Handbook cited above. Thus, the disclosed tapered wall-thickness of protrusions **18** may be readily electroformed by techniques well known to those skilled in the art.

It has been found that a satisfactory "peelable" matrix may be formed of the material designated as Flexible TC459 Black Epoxy manufactured by the Chemical Division, Electronic Production and Development, Inc., 509 North Prairie Ave., Hawthorne, Calif. However, because of the apixical shape of the protrusions, a peelable matrix is not essential; but where desired may also be formed of any material that can be cast, molded, or machined to the desired configuration. These materials would include polyurethanes, polysiulfides, various rubbers, silicones, etc.

It should be noted that becasue protrusions **18** are produced by the electroforming process, they may be as high and as sharply-angled as desired. This is a tremendous advantage over prior-art metal shaping and metal stretching techniques wherein, because of limitations of high-strength materials, the maximum height-to-diameter ratio is equal to a numerical value of about one. Much larger height/diameter ratios may be achieved by matrix design and electroforming; thus giving wider latitude to the designer.

Referring again to FIG. 2, it will be noted that the walls of configurations **18** have a tapered thickness that becomes thicker near the apex. The advantage of this tapered thickness will be recognized from FIG. 3. Here the "basal" cross-section (cross-section parallel to the base) of FIG. 3*a* indicates a smaller outer-diameter than the basal cross-section shown in FIG. 3*b*. However, due to the tapered-thickness concept, the basal cross-sectional area of the wall **18** shown in FIG. 3*a* is the same as the basal cross-sectional area of the wall **18** shown in FIG. 3*b*; in this way, permitting each basal cross-section to provide the same amount of material, for equalizing stresses and strains under load. Electroformed cores have proven satisfactory.

Under some conditions—for desired spacing, dimensions, volume, fluid-flow, flexibility, rigidity, etc., a double-panel structure may be desirable, and this is shown in FIG. 4. Here structure **10***a* is formed of two panels; an upper panel **12***a* and a lower panel **12***b*, each having its own base-sheet **16***a*, **16***b* and configurations **18***a* and **18***b*. In FIG. 4, the two panels **12***a* and **12***b* are affixed in an apixical relationship, with the apixical portions of configurations **18***a* and **18***b* in apixical contact. As previously indicated, skin-sheets **14***a* and **14***b* are affixed to the outside of the structure, in this case to base-sheets **16***a* and **16***b*. In the structure of FIG. 4, the spacing between the skin-sheets **14***a* and **14***b* may be much larger than previously indicated, and may thus accommodate different amounts of fluid-flow, pressure, conduits, etc.

FIG. 5 shows another multi-panel structure **10***b* that permits the containment or simultaneous or counterflow of two dissimilar gases or liquids. Structure **10***b* is similar to that previously shown, except that a separator sheet **30** is affixed in position between adjacent apices of the configurations **18***c* and **18***d*.

It should be noted that structure **10***b* of FIG. 5 is shown as part of a cylindrical wall, the individual core-components having been electroformed in this configuration, so that the cylindrical single-curved structural-element does not have any inherent strains.

FIG. 6 shows still another multi-panel structure **10***c*; comprising two structural-elements **12***e* and **12***f* containing base-sheets **16***e* and **16***f*, and protrusions **18***e* and **18***f* respectively. Skin sheet **14***e* and **14***f* complete the structure. Structural element **10***c* is similar to the previous arrangement, except that panels **12***e* and **12***f* are base-to-base rather than apex-to-apex. This is clear from the proximity of base-sheets **16***e* and **16***f* in FIG. 6, and the distance of base-sheets **16***c* and **16***d* in FIG. 5. The separator sheet **30***a* may be either used or omitted, depending upon requirements.

FIG. 7 shows a structural-element **10***d* of the disclosed type as used in a domed configuration, this being a double-curved structure rather than the single-curved structures previously discussed. Since the double-curved arrangement of FIG. 7 is also electroformed, it is free of inherent strains; and may be made integral with single-curved and/or planar section. This is a tremendous advantage over prior-art structures. As previously indicated, one of the disadvantages of prior-art attempts to produce a satisfactory structure of this type, was their inherent tendency to form planar structures; these prior-art structures taking this curved formation only at the expense of much rework and the introduction of highly strained portions.

Thus, the disclosed invention permits the panels to be electroformed on a matrix that is suitably sized, shaped, and curved so that the resultant panel—and therefore the structure—may be cylindrical (single-curved) or convex, concave, or compound-curved (double-curved). In this way, the disclosed structure has improved configuration advantages over prior-art structures.

In the above way, the disclosed structure provides a novel lightweight low-density structure that may be used where lightweight and high strength are desired; and still provide relatively unimpeded insertion of pipes, or flow of liquids and gases when used for means such as a fuel tank, heat exchanger, and the like.

Although the invention has been described and illustrated in detail, it is to be clearly understood that the same is by way of illustration and example only, and is not to be taken by way of limitation; the spirit and scope of this invention being limited only by the terms of the appended claims.

What is claimed is:

1. A core for a structural element of the type having a lightweight core that is sandwiched between external skin-sheets, said core comprising a continuous integral

base-sheet with a plurality of integral electroformed apixially-shaped configurations protruding from said base-sheet, said configurations having a tapered wall thickness, the wall of said configurations having substantially the same cross-sectional area at each basal cross section of said configuration, said configurations having a height/diameter ratio greater than one.

2. A dual-flow combination comprising:

a pair of cores of the type described in claim 1;

a separator sheet;

means affixing one of said cores to one side of said separator sheet; and

means affixing the other of said cores to the other side of said separator sheet for causing each core to accommodate its individual flow.

References Cited

UNITED STATES PATENTS

1,986,338	1/1935	Harrison	204—9
3,196,089	7/1965	Stoycos	204—281
3,445,348	5/1969	Aske	204—11

FOREIGN PATENTS

797,678	7/1958	Great Britain.

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U.S. Cl. X.R.

204—9, 11