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(54) Interrupted cell honeycomb structure.

(57) A honeycomb structure composed of corrugated strips (10) secured together at confronting walls (12, 14) in parallel longitudinal alignment, to form an integral panel having open cells extending through the thickness of the panel between opposite faces. Between the faces of the panel the cells are interrupted or restricted (24, 26) to reduce or block the cross section. When one face of the honeycomb structure is bonded to a backing or cover panel (28), the restrictions prevent the bonding material from creeping or wicking through to the other face.

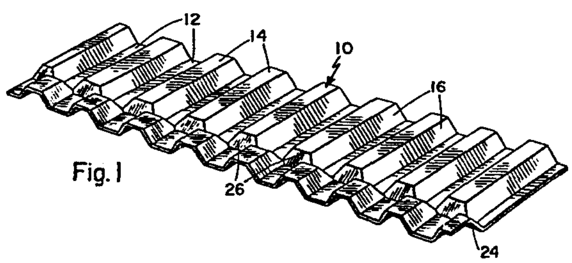

Fig. 1

EP 0 081 010 A2

Croydon Printing Company Ltd.

INTERRUPTED CELL HONEYCOMB STRUCTURE

BACKGROUND OF THE INVENTION

Honeycomb core material is used in a variety of structures for strength and rigidity with minimum weight. Most honeycomb structures, particularly metal types, are built up from corrugated strips assembled in parallel longitudinal alignment and secured together at confronting walls of the corrugations by spot welding, or similar means. The resultant structure has rows of open cells extending through the thickness of the panel between opposite faces. In a complete structural assembly, one or both faces of the honeycomb may be bonded to a backing or cover panel of sheet material, by brazing, adhesive, or other such bonding means.

When brazing or liquid adhesive material is used, the material tends to wick through the honeycomb from one face to the other by creeping along the walls and by capillary action between the confronting cell walls. In a panel which is enclosed on both faces this is not usually a problem, unless thermal conductivity is to be considered. However, in a honeycomb structure enclosed on one face only, it may not be desirable to have the open face contaminated by bonding material.

One particular example of the use of such honeycomb material is in a turbojet engine or the like. In the various turbine or compressor stages, peripheral clearance between the moving blade tips and their surrounding duct sections must be kept to a minimum. Due to heat and centrifugal force, the blades tend to creep or expand radially and the blade tips may strike the duct wall, unless the initial clearance is sufficient to allow for this. Excessive clearance is undesirable, but the blades may be damaged by striking the duct. In some installations certain duct sections have been lined with a material which can be deformed by a limited amount of blade contact without damaging the blades. Honeycomb material with an open face confronting the moving blades has been used satisfactorily and will allow the blades to wipe against the open cell face without damage. However, the contamination of the open cell face by bonding material, particularly hard braze, defeats the purpose and could cause chipping or abrading of the blades, leading to more severe damage.

SUMMARY OF THE INVENTION

The honeycomb structure described herein is constructed in such a manner that one face can be enclosed without the bonding material contaminating the open face. Strips of corrugated material are secured together in the conventional manner, to form a honeycomb structure with rows of cells extending through the thickness of the panel between the opposite faces. The corrugated strips are prepared, however, by restricting the corrugations so that, in the assembled structure, the cells are not continuous through the panel. The cells can be alternately staggered at opposite faces of the panel to break continuity, or can be basically continuous between the faces, the restriction being made by pinching the cells to reduce or block their open cross sections. When one face of the panel is enclosed by bonding a sheet of material to the cell structure, bonding material will creep along the cell walls and wick by capillary action between the confronting walls of the corrugated elements. But the separated walls at the restricted portions of the cells will prevent the bonding material from extending to the open face of the honeycomb structure. The uncontaminated face of open cells, which are not rigidly bonded together, is readily deformed by blade impact without causing damage to the blades.

The primary object of this invention, therefore, is to provide a new and improved interrupted cell honeycomb structure.

Another object of this invention is to provide a honeycomb structure in which the cells are restricted between the faces to separate the confronting cells walls and restrict the cell cross section.

A further object of this invention is to provide a restricted cell honeycomb structure which can be assembled by conventional apparatus and techniques, the novel restricted cell configuration being incorporated in the initial preparation of the corrugated strips.

Other objects and advantages will be apparent in the following detailed description, taken in conjunction with the accompanying drawings, in which:

Figure 1 is a perspective view of a preferred configuration of a corrugated strip with the cells staggered and restricted near one edge.

Figure 2 is a plan view of one face of a honeycomb panel assembled from strips as illustrated in Figure 1.

Figure 3 is a sectional view taken on line 3-3 of Figure 2.

Figure 4 is a sectional view taken on line 4-4 of Figure 2.

Figure 5 is a perspective view of an alternative corrugated strip with the cells staggered and restricted at the center.

Figure 6 is a perspective view of a further corrugated strip with the cells aligned but interrupted between their ends.

Figure 7 is a sectional view similar to a portion of Figure 3, showing the creeping action of the braze material.

Figure 8 is a diametrical sectional view of a typical turbine stage incorporating the pinched cell honeycomb material.

Figure 9 is an enlarged sectional view taken on line 9-9 of Figure 8.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The honeycomb structure is composed of a plurality of corrugated strips 10, illustrated in a preferred form in Figure 1. In a well known manufacturing technique the strips are made by passing thin sheet metal or other such material, between interfitting toothed rollers, having teeth corresponding to the required cell cross section. As shown, the cells are hexagonal but could be of square or other cross sectional configuration. The strip 10 has alternately offset or staggered side walls 12 and 14 connected by diagonal walls 16, the overall depth of the corrugated strip being half the width of a cell. Walls 12 are in one common plane and walls 14 are in another common plane, the planes being separated by the depth of the strip. The strips are joined at confronting walls in back to back pairs, with the walls 12 along one side of one strip attached to the walls 12 of the adjacent strip, as in Figure 2, consecutive strips being assembled to produce a honeycomb panel of the required size. The next pair is joined to the first pair at walls 14, the panel being built up to the required width.

With metal strips the conventional method of joining is by spot welding the confronting walls at one or more locations on each joined area. The walls are thus bonded together only at spots, rather than over the entire contacting area. Since the honeycomb structure by itself is not a self-supporting load bearing element, this spot joining is sufficient. Usually one or both faces of the honeycomb structure will be enclosed by bonding a backing or cover panel to the end edges of the cells. In a metal structure this is normally accomplished by brazing, with a brazing material applied to the edges of the cell structure and the cover panel heat sealed in place. One well known technique uses tape impregnated with brazing material in powder form, the tape burning and gassing off when heated and the powder melting and forming the bond. To ensure a complete bond, it is common to use ample brazing material, particularly in a fully enclosed structure, since direct internal inspection of the finished product is not practical. Excess brazing compound tends to flow over the cell surfaces as indicated at 18 in Figure 7 and, in particular, is drawn between the confronting walls by capillary action. The bonding material can thus wick to the opposite face of the honeycomb. In a honeycomb structure having one face open, it may not be desirable to have the open face contaminated by bonding material, so the cell openings are restricted to prevent migration of the braze material.

In the structure illustrated in Figures 1 - 4, the cells are longitudinally staggered along opposite edges, so that there is no cell extending completely through the panel. Cells 20 are spaced along one side or face of the panel and cells 22 along the other face. Cells 20 have closed inner ends 24 which are aligned with the spaces between cells 22, while cells 22 have closed inner ends 26 aligned with the spaces between cells 20. The closed ends are formed by pinching and inclining portions of side walls 12 toward walls 14.

It can be seen in Figures 3 and 4 that the contacting walls in the cells 20 are separated at the closed ends of cells 22, and the contacting walls in cells 22 are separated at the closed ends of cells 20. Thus there are no capillary channels extending completely through the panel.

The cells 22 are shown as being several times the length of cells 20, the closed ends being close to one face of the panel. The backing or cover panel 28, indicated in broken line in Figures 3 and 4, would be secured by brazing to the outer edges of cells 20. This limits the spread of the brazing material to the short length of cells 20, leaving cells 22 free of braze.

The honeycomb material can be made in various sizes, but one particular size developed for a specific purpose will emphasize the need for solving the problem of contamination by bonding material. For this use the honeycomb panel has a depth of about 6 mm between faces, with hexagonal cells about 1.5 mm across the flats. This very small size is particularly susceptible to braze contamination of the open face.

It can be seen in Figure 2 that, due to the geometry of the equal sized hexagonal cells. there are actually small openings 30 between cells which open the honeycomb structure through the thickness of the panel. These openings are too large to promote capillary flow of braze material, but too small to permit the braze to flow freely. In a proper application of braze material, there is insufficient braze to flow far enough to reach the openings, it is the capillary path which causes the undesirable migration, and this is interrupted.

The openings 30 allow the use of one well known technique for testing the quality of braze to the cover panel, which is not possible to inspect visually through the very small cells. In this technique a very free flowing liquid is injected into one or more cells in an area where poor braze is suspected. If the braze is incomplete the liquid will leak long the inside of the cover plate and appear in other cells, indicating the fault in the braze. Ultrasonic, x-ray and other conventional inspection techniques may also be used.

The open faced honeycomb is shown in a specific use in Figures 8 and 9, in which the material is used to line the interior of a duct section 32 of a turbojet engine. The turbine rotor 34 has blades 36 which are required to have a minimum tip clearance from the duct wall to prevent tip losses and maintain efficiency. Under excessive centrifugal loads and high temperatures the blades can expand or creep radially and strike the duct wall, resulting in damage to the blades and duct. To minimize blade damage under these conditions a technique has been developed in which the duct is lined with a deformable material which can absorb blade contact while maintaining a good seal. The open face honeycomb material has been found especially suitable for this purpose since the cellular structure can be struck and deformed by the blades, yet the multi-cellular body, even when partially crushed, will form a labyrinth to minimize gas leakage and tip losses. It has been found, however, that braze contamination of the open face cells can make the material harder than desired in contaminated areas, resulting in chipping of the blades and possible shedding of material from the honeycomb.

The honeycomb is thus installed in segments inside the duct 32 to form a lining 38. The outer face of the honeycomb material is bonded to a cover strip 40, by which the material is suitably secured to the duct, the open cell, braze free inner face 42 being adjacent to the blade tips. Under high stress conditions, the blades can thus rub on the honeycomb lining without damage.

For some purposes it may be desirable to make honeycomb material with cells of equal length, as in the corrugated strip 44 in Figure 5. All features are as described for strip 10, except that the cells 46 at one side and the cells 48 at the other side are of substantially equal length. This configuration is particularly suitable for enclosed type honeycomb panels with cover panels brazed to both sides. Such panels have been used as outer skin members of aircraft for structural lightness, strength and insulation. As an example, the honeycomb panel may be the outer shell of a fuel tank integral with a wing or fuselage component of an aircraft. At high speeds the skin is heated by friction and could cause vaporization or even boiling of the fuel, so thermal insulation is necessary. Honeycomb material will provide such insulation if the thermal conductivity through the panel can be minimized. Since the thermal conductivity of braze material is much higher than that of the stainless steel, or similar material used to make the honeycomb, it is necessary to prevent a conductive path of braze material through the panel. The interrupted cell arrangement effectively prevents such a thermally conductive path by controlling the migration of braze material.

A further configuration is illustrated in Figure 6, in which the cells on opposite sides are longitudinally aligned rather than staggered. Corrugated strip 50 has cells 52 along one side and cells 54 along the other side, the cells having confronting closed ends 56 and 58, respectively. Between the cells are flat walls 60 which extend across the width of the strip. To avoid any continuous capillary paths through the honeycomb the strips are joined with the flat walls 60 of one strip secured to the interrupted walls 62 of the next adjacent strip. This configuration is also suitable for single or double sided enclosure with no braze migration through the panel.

CLAIMS

1. An interrupted cell honeycomb structure, comprising:

a plurality of corrugated strips of sheet material each having alternately staggered walls spaced along opposite sides, the walls on one side of one strip being joined to confronting walls on the other side of the next adjacent strip, forming a honeycomb panel with rows of cells extending through the thickness of the panel and open to opposite faces of the panel;

said cells being interrupted between opposite faces of the panel and capillary paths between the confronting walls being discontinuous through the panel.

2. The structure of Claim 1, and including a cover panel bonded to and enclosing at least one open cell face of the honeycomb panel.

3. The structure of Claim 1, wherein said cells have closed ends intermediate to the faces of the honeycomb panel.

4. The structure of Claim 3, wherein the cells on opposite faces of the panel are staggered, the cells on each face having closed inner ends aligned with the spaced between the cells on the other face.

5. The structure of Claim 4, and including a cover panel bonded to at least one open cell face of the honeycomb panel.

6. The structure of Claim 5, wherein the staggered cells have a slight overlap with openings between the cells, the openings being too large to promote capillary flow but too small to permit free flow of bonding material between opposite faces of the panel.

7. The structure of Claim 4, wherein the cells on opposite faces of the panel are of substantially equal length.

8. The structure of Claim 3, wherein the cells are longitudinally aligned between opposite faces of the panel with confronting closed ends, each corrugated strip having flat continuous walls between cells and interrupted walls between the closed ends and the edges of the strip;

the interrupted walls of each strip being joined to the continuous walls of the next adjacent strip.

9. In combination with a duct having a rotor therein with a plurality of radially extending rotor blades, a honeycomb lining element fixed to the inner periphery of the duct, the honeycomb element having an inner face with minimum radial clearance from the rotor blades,

said honeycomb element comprising a plurality of corrugated strips of sheet material each having alternately staggered walls spaced along opposite sides, the walls on one side of one strip being joined to confronting walls on the other side of the next adjacent strip, forming a honeycomb panel with rows of cells extending substantially radially through the thickness of the panel and open to opposite faces of the panel;

said cells being interrupted between opposite faces of the honeycomb element and capillary paths between the confronting walls being discontinuous through the element.

10. The structure of Claim 9, and including a circumferential cover strip secured to the inner periphery of the duct, said honeycomb element having an outer face bonded to the cover strip.

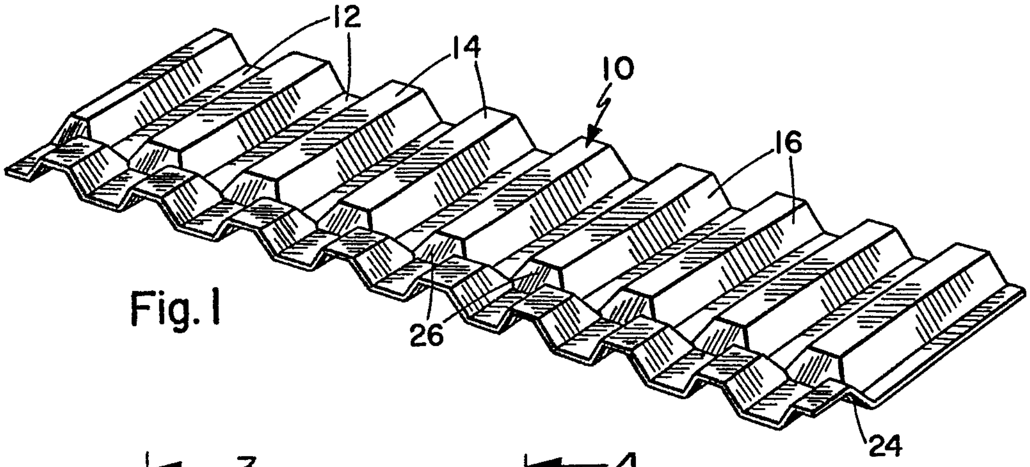

Fig. 1

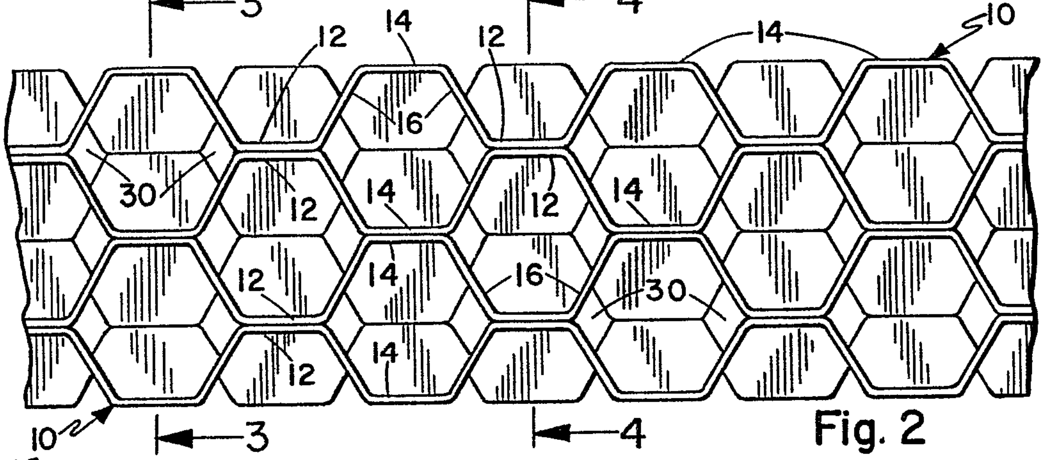

Fig. 2

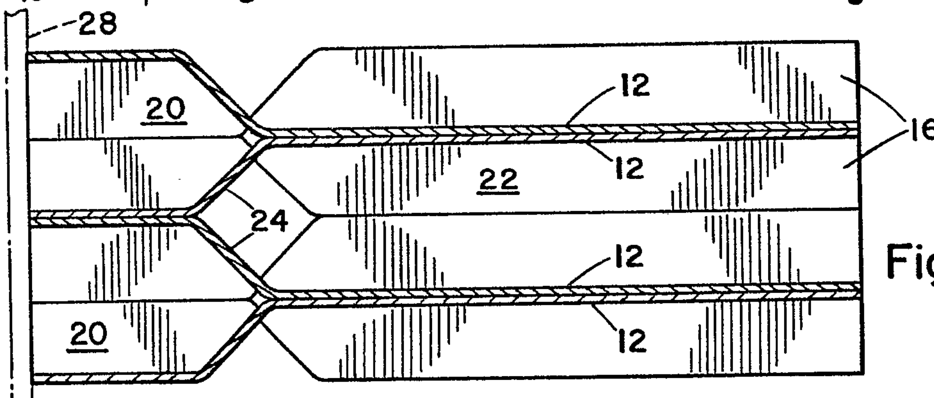

Fig. 3

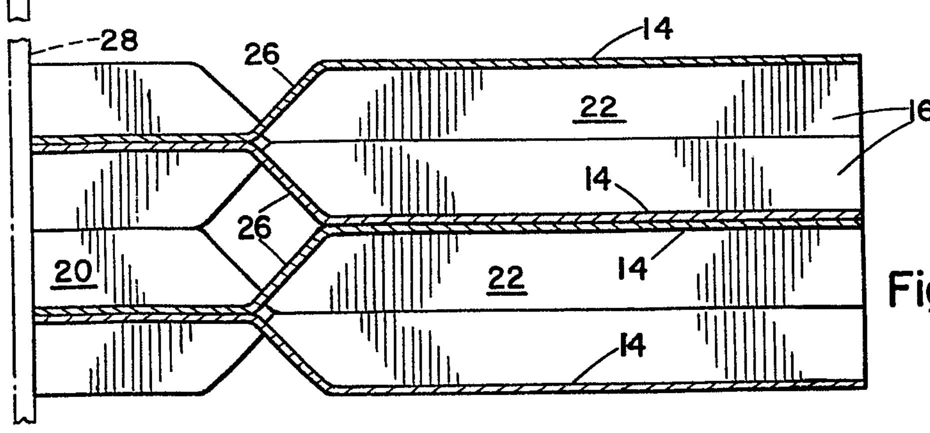

Fig. 4

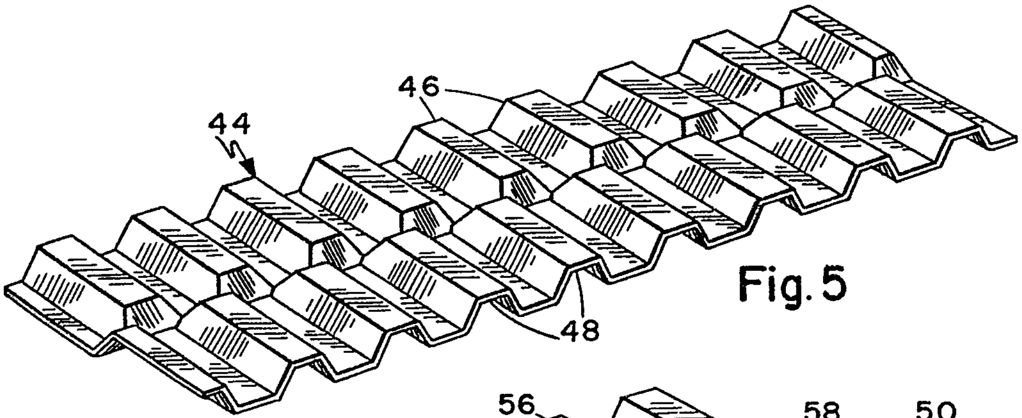

Fig. 5

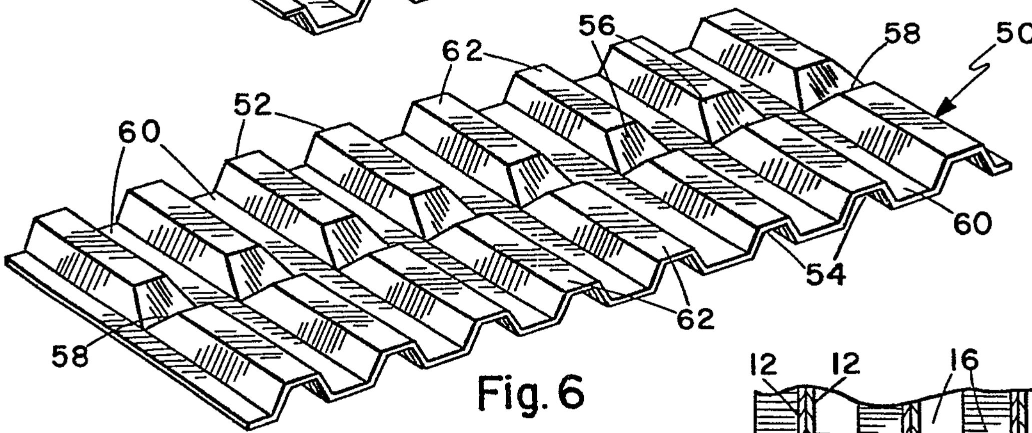

Fig. 6

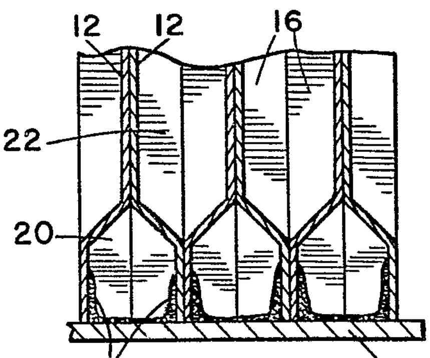

Fig. 7

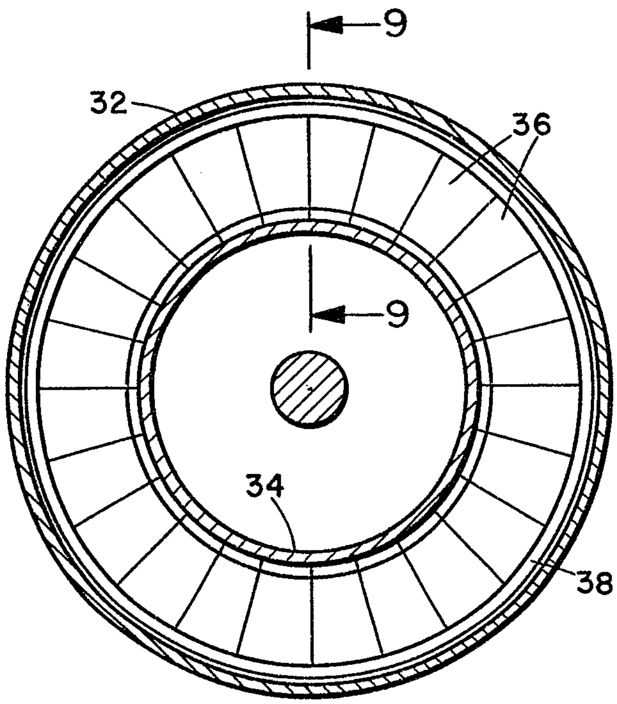

Fig. 8

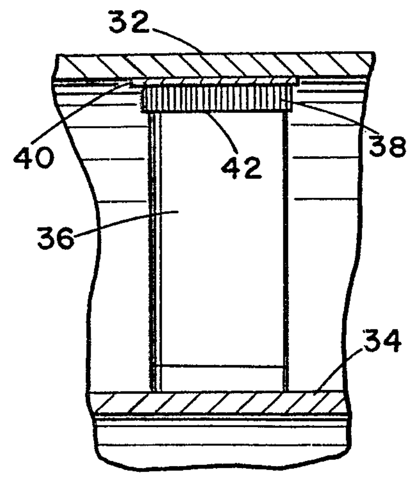

Fig. 9