

April 17, 1956

H. G. GIULIANI
REFLECTOR FOR ELECTROMAGNETIC RADIATIONS
AND METHOD OF MAKING SAME

2,742,387

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2 Sheets-Sheet 1

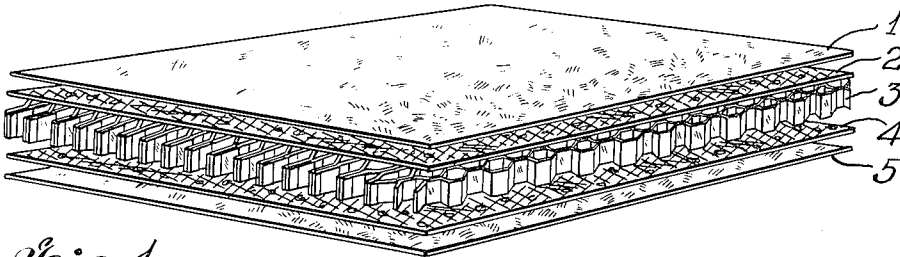
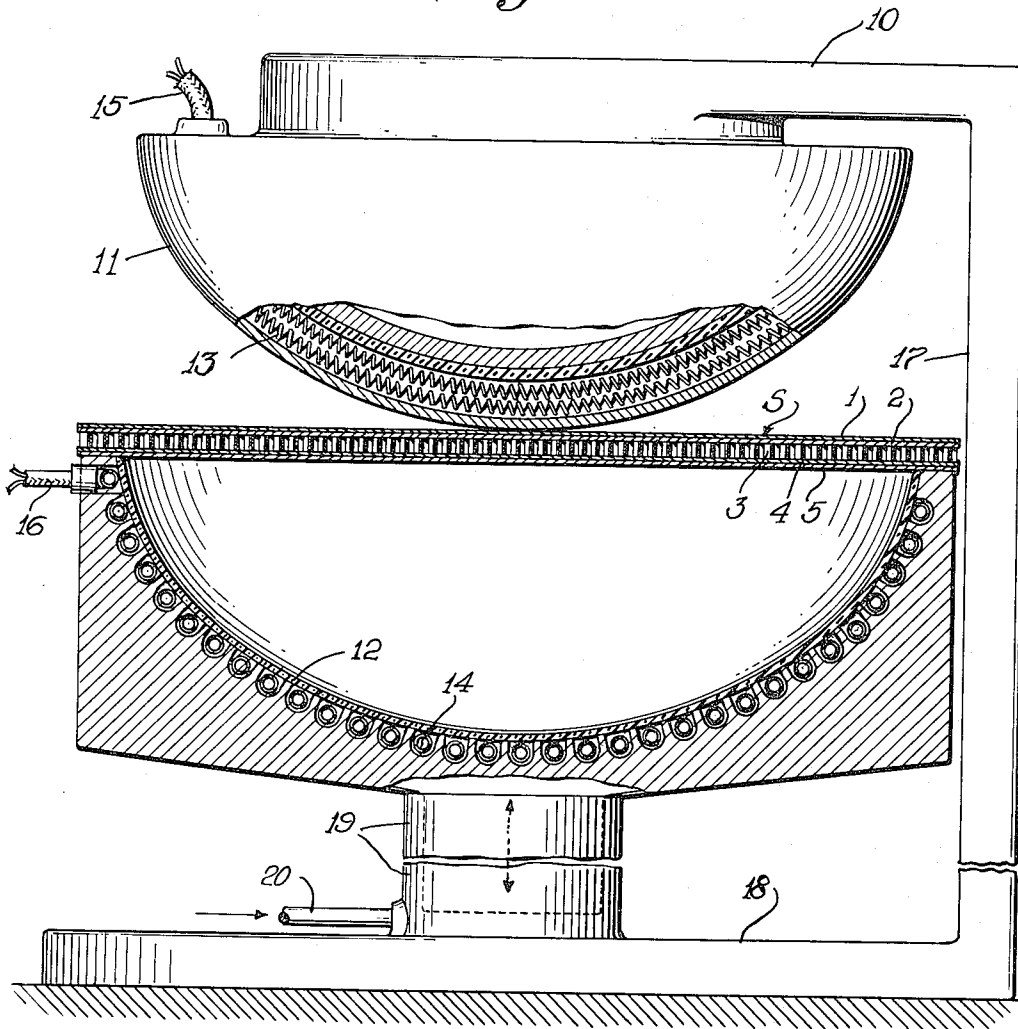


Fig. 1.

Fig. 2.



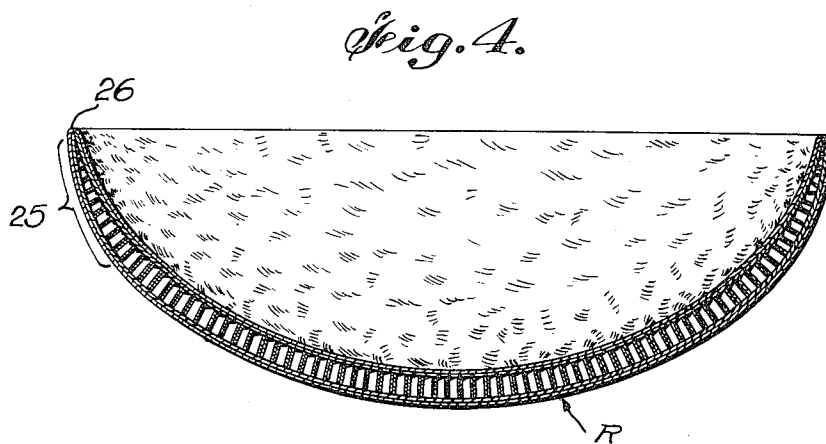
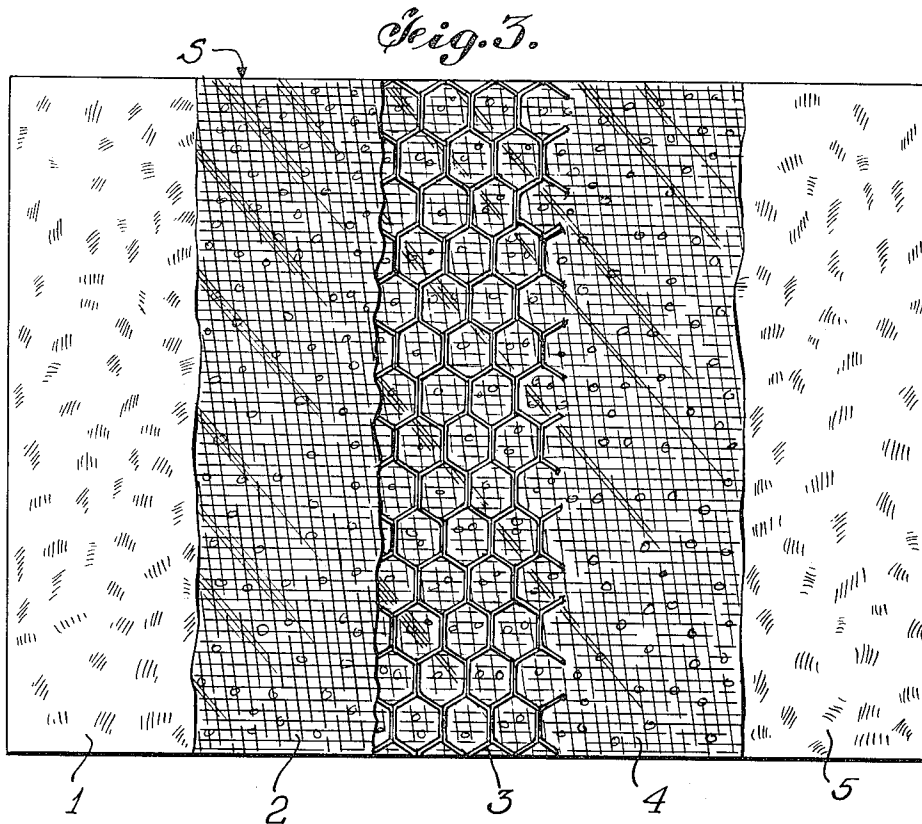
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REFLECTOR FOR ELECTROMAGNETIC RADIATIONS AND METHOD OF MAKING SAME

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7 Claims. (Cl. 154—110)

The present invention relates to laminated dish-shaped articles and to a method of making such articles. As the invention is particularly applicable to making reflectors for radar antennas and similar radiation-receiving or transmitting equipment, it will be described with reference to such reflectors but it is to be understood that reference to such reflectors in the specification and claims is by way of example and not limitation.

A radar antenna reflector is oscillated during operation of the radar equipment and its oscillation must be accurately controlled. Any spurious oscillations or vibrations of the reflector impair the accuracy and effectiveness of the equipment. It is therefore necessary to have a reflector that is rigid and yet is of light weight so that the structure for mounting and oscillating the reflector need not be unduly heavy. As radar reflectors are ordinarily used outdoors, they must be weather-proof.

It is an object of the present invention to produce a radar reflector or other dished article that is lightweight and yet highly rigid. A further object of the invention is to provide a method of producing such articles rapidly and economically so that they can be manufactured in quantity at low cost.

Other objects and advantages of the invention will become apparent from the following description and claims in conjunction with the accompanying drawings, in which:

Fig. 1 is a perspective view of the sheets of material from which an article in accordance with the invention is made, the sheets being shown slightly separated for clarity.

Fig. 2 is a side elevation, partly in vertical section, showing the assembled sheets in a die press.

Fig. 3 is a plan of a portion of the assembled sheets, successive sheets being broken away to show the sheets beneath.

Fig. 4 is a cross section of the completed article.

In accordance with the invention, a radar antenna reflector, or other dished article, is produced from a plurality of sheets which are superposed on one another to make a laminated structure. In the embodiment illustrated in the drawings, the composite sheet S is made up of five sheets or layers of material numbered consecutively 1 to 5.

Sheet 1 is a thin sheet of ductile metal, preferably aluminum or other light metal, the term "metal" being used to include alloys. When an aluminum sheet is used, it should have a thickness of from 0.001" to 0.005", corresponding thicknesses being used with other metals, depending on their ductility, strength and other characteristics. Sheet 1 is thus of a thickness commonly referred to as foil.

Sheet 2 is a sheet of fiber mesh material coated with a thermoplastic material, the term "thermoplastic" being herein used to include thermosetting plastics. The fiber used for the mesh must have sufficient heat resistance to withstand the curing temperature of the plastic material. Glass fiber has been found suitable for this purpose. The

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mesh is relatively open. For example, the threads of the mesh should be spaced from one another a distance of the order of $\frac{1}{32}$ to $\frac{5}{16}$ inch. A $\frac{1}{16}$ to $\frac{1}{8}$ inch mesh has been found preferable. The mesh may be either woven or unwoven, the threads in the latter case being held in position by the plastic coating. The plastic material with which the mesh is coated is of a type that adheres tightly to the fiber and to metal when suitably heated, to form a strong bond. Thermosetting resins of the phenol formaldehyde type have been found suitable. It will be understood that the plastic coating is in an uncured or air cured state, final curing being effected later, as will be described below. The coating is of sufficient thickness to fill the interstices between the threads of the mesh, the thickness of the coated sheet being preferably of the order of 0.025".

Sheet 3 is a sheet of honeycomb material. The honeycomb is formed of thin metal strips which are bent to form hexagonal cells, as clearly shown in Fig. 3, successive strips being suitably joined in their areas of contact, for example by spot welding or cementing. The metal strips forming the honeycomb material are preferably aluminum or other light metal. When aluminum is used, the strips are preferably of a thickness of the order of 0.003" to 0.006", corresponding thicknesses of other metals being used in accordance with the ductility, strength and other characteristics of the metal. The width of the strips, and hence the thickness of the honeycomb layer, is preferably of the order of $\frac{1}{4}$ " to $\frac{1}{2}$ " for an article of the size of a radar antenna reflector. The diameter of the individual cells is preferably of about the same order as the thickness of the honeycomb layer or a little less, for example $\frac{3}{16}$ to $\frac{3}{8}$ inch. The edges of the metal strip forming the honeycomb are preferably left rough, as, for example, from a shearing or sawing operation by which the honeycomb material is cut into layers of the desired thickness. It will be understood that the honeycomb material may be made thicker and then sliced up or may be made of strips precut to a width equal to the desired thickness of the honeycomb layer.

Sheet 4 is a sheet of fiber mesh coated with thermoplastic material, like sheet 2.

Sheet 5 is a sheet of thin metal or metal foil, like sheet 1. It will be understood, however, that, in some instances, it may be desirable to use different metals for sheets 1 and 5 or to have the sheets of somewhat different thickness.

The surfaces of the metal sheets are thoroughly cleaned.

For example, chemical cleaning may be effected by immersing the metal sheets for approximately ten minutes in a solution composed of:

Concentrated sulfuric acid	45 oz.
Sodium dichromate	4.5 oz.
Water	1 gallon.

the solution being at a temperature of 140° F. to 160° F. Alternatively, the metal sheets may be cleaned by immersing them for approximately ten minutes at room temperature in a solution composed of:

Parts by volume	
N butyl alcohol	4
Isopropyl alcohol	3
Phosphoric acid (85% technical)	1
Water	2

After the metal has been thoroughly cleaned, the sheets are assembled in superposed relationship in the order indicated above and shown in Fig. 1. The assembled sheets are then simultaneously pressed to the desired shape and bonded together by the action of heat on the thermoplastic material. As illustrated in Fig. 2, the bonding and shaping are effected by means of a die press 10 having

a convex male die 11 and a concave female die 12. One or both of the dies are heated, for example by electrical heating elements 13 and 14 to which power is supplied by electrical connections 15 and 16. Means is provided for moving the dies 11 and 12 toward one another. As illustrated in the drawings, the upper die 11 is stationary, being supported by a standard 17 extending upwardly from a base portion 18 and the lower die 12 is movable in a vertical direction toward and away from the upper die by means of a hydraulic piston and cylinder 19 to which fluid is supplied through a conduit 20, it being understood that suitable control mechanism is provided for regulating the movement of the die 12.

The composite sheet S made up of the layers 1, 2, 3, 4 and 5, described above, is positioned between the dies 11 and 12, as illustrated in Fig. 2. Before pressure is applied to the sheet to form it to the desired shape, the temperature of the composite sheet, and in particular the temperature of the plastic-coated mesh sheets, is raised to a point where the thermoplastic material is softened. This can be done either by heating in the press or by preheating the sheets immediately before they are positioned in the press. Thus, when using a thermosetting resin of the phenol formaldehyde type, the composite sheet is preferably preheated for about eight minutes at 300° F. The heated dies 11 and 12 are then moved toward one another to form the composite sheet material to predetermined shape and simultaneously press the individual sheets firmly together so that they are caused to bond to one another. The softened plastic material acts as an adhesive, firmly bonding the thin metal sheets or foil 1 and 5 to the central honeycomb layer 3. The edges of the strips forming the honeycomb layer are pressed into the plastic material so that there is substantially metal-to-metal engagement between the honeycomb material and the thin metal sheets 1 and 5. The rough edges of the strips forming the honeycomb layer assist in providing a strong bond.

It will be seen that, in the composite sheet S, the central layer of honeycomb material 3 serves as a spacer separating the metal sheets 1 and 5 with their associated plastic sheets 2 and 4, so that the composite sheet is hollow with a multiplicity of adjacent cells between the sheets 1 and 5. Over the major portion of the area of the composite sheet, the thickness of the honeycomb material remains substantially the same during the pressing operation although the overall thickness of the composite sheet is slightly reduced by reason of the fact that the edges of the strips forming the honeycomb material sink into the plastic. However, in a marginal edge portion 25 (Fig. 4) of the composite sheet, the honeycomb material 3 is compressed or crushed by the dies 11 and 12 to reduce its thickness, the thickness being reduced progressively toward the peripheral edge 26. As illustrated in Fig. 2, the dies 11 and 12 are shaped to produce the desired compression of the marginal portion of the composite sheet. Hence, in the marginal portion 25, the metal sheets 1 and 5 converge toward one another and, at the peripheral edge 26, they come substantially together and are bonded to one another by the plastic material of the sheets 2 and 4. The shaped reflector or other article R (Fig. 4) is thus provided with a gradually tapered edge. Moreover, since the outer metal sheets 1 and 5 come substantially together and are bonded to one another at the peripheral edge 26, there is formed a peripheral seal that protects the hollow honeycomb structure against the entry of water or vapors. The progressive reduction of thickness in the marginal portion provides a correspondingly greater increase in density of the material so that the edge portion is strong and rigid.

When a thermosetting plastic is used, the shaped article is held in the die press a sufficient time for the plastic to cure, or at least become sufficiently set so that the article is dimensionally stable. For example, when using a thermosetting resin of the phenol formaldehyde type, the curing time is approximately 12 minutes at 300° F. If

the plastic is of a type that is thermoactivated but not thermosetting, the formed article is permitted to cool sufficiently while still in the die press to attain dimensional stability before it is taken out.

If the sheets 1, 2, 3, 4 and 5 are cut to the exact shape required for the formed article, no subsequent trimming is required. Alternatively, the component sheets are made slightly larger than required and the excess is trimmed off after the die pressing operation. As the trimming is done in the zone where the outer metal layers 1 and 5 are pressed substantially together, it can be readily effected and will leave a neat, smooth edge.

While the invention has been described with reference to a preferred embodiment, it is in no way limited to the form shown by way of example in the drawings.

What I claim and desire to secure by Letters Patent is:

1. In a method of making a radar reflector, the steps of assembling in the order named a flat sheet of thin metal, a flat sheet of mesh fabric coated with thermoplastic material, a flat sheet of honeycomb material comprising thin metal strips disposed perpendicular to the plane of said sheet and bent to form honeycomb-like cells between successive strips, said strips being joined with one another at areas of contact, a second flat sheet of mesh fabric coated with thermoplastic material and a second flat sheet of thin metal, said sheets being superposed on one another with adjacent sheets in contact, positioning said sheets between male and female dies shaped to form a reflector of the desired shape, heating said superposed sheets and simultaneously pressing them between said dies to perform concurrently the steps of bonding said sheets together, forming the composite sheet material to the desired shape, and compressing and partially crushing the honeycomb material in a continuous marginal portion so that said metal sheets come substantially together in said marginal portion, said thermoplastic material bonding said metal sheets together to form a marginal peripheral seal.

2. In a method of forming a dished article from flat sheet material, the steps of assembling in the order named a flat sheet of thin metal, a flat sheet of glass fiber mesh fabric coated with thermoplastic material, a flat sheet of metal honeycomb material comprising thin metal strips disposed perpendicular to the plane of said sheet and bent to form honeycomb-like cells between successive strips, said strips being joined with one another at areas of contact, a second flat sheet of glass fiber mesh coated with thermoplastic material and a second flat sheet of thin metal, said sheets being superposed on one another with adjacent sheets in contact, heating said superposed sheets to soften said thermoplastic material, and pressing said heated sheets between male and female dies to perform concurrently the steps of bonding said sheets together, forming the composite sheet material to predetermined dished form, and compressing and partially crushing a marginal portion of said honeycomb material so that the metal sheet material on opposite sides of said marginal portion are pressed substantially into contact with one another and are bonded together by said thermoplastic material to form a marginal peripheral seal.

3. In a method of forming a dished article from flat sheet material, the steps of assembling in the order named a sheet of thin metal, a sheet of fiber mesh material coated with thermo-activated plastic, a sheet of metal honeycomb material comprising thin metal strips disposed perpendicular to the plane of said sheet and bent to form honeycomb-like cells between successive strips, said strips being joined with one another at areas of contact, a second sheet of fiber mesh material coated with thermo-activated plastic and a second sheet of thin metal, said sheets being superposed on one another with adjacent sheets in contact, heating said superposed sheets to soften said plastic, and pressing said superposed heated sheets between a concave female die and a convex male die to perform concurrently the steps of bonding said

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sheets together by the adhesive action of said plastic, forming the composite sheet material to predetermined dished form, and compressing a peripheral portion of said composite sheet to at least partially crush the honeycomb material in said peripheral portion so that the metal sheets of said peripheral portion are pressed and bonded together to form a marginal peripheral seal.

4. In a method of forming a dished article from flat sheet material, the steps of assembling in the order named a thin metal sheet, a sheet of fiber mesh coated with thermoplastic material, a sheet of metal honeycomb material comprising thin metal strips disposed perpendicular to the plane of said sheet and bent to form honeycomb-like cells between successive strips, said strips being joined with one another at areas of contact, a second sheet of fiber mesh coated with thermoplastic material and a second thin metal sheet, said sheets being superposed on one another with adjacent sheets in contact, heating said superposed sheets to soften said thermoplastic material and pressing said sheets while heated between a concave female die and a convex male die to perform concurrently the steps of bonding the said sheets together by heat and pressure, forming the composite sheet material to predetermined dished form, and compressing a marginal portion of said composite material to at least partially crush the honeycomb material in said marginal portion and press said metal sheets in said marginal portion substantially into contact with one another, the marginal portions of said metal sheets being thereupon bonded together by said thermoplastic material to form a peripheral seal.

5. A dished article formed of composite sheet material comprising in the order named a thin metal sheet, a sheet of glass fiber mesh coated with thermoplastic material, a sheet of metal honeycomb material comprising thin metal strips disposed perpendicular to the plane of said sheet and bent to form honeycomb-like cells between successive strips, said strips being joined with one another at areas of contact, a second sheet of glass fiber mesh coated with thermoplastic material and a second thin metal sheet, all of said sheets being bonded together by said thermoplastic material, marginal portions of said honeycomb material being crushed and said metal sheets in said marginal portions converging toward one another as they approach the periphery of said sheets and having their peripheral edge portions bonded together by said thermoplastic material to form a peripheral seal.

6. A dished article formed of composite sheet material comprising in the order named a sheet of aluminum foil having a thickness of the order of one to five thousandths of an inch, a sheet of glass fiber mesh coated with thermoplastic material, a sheet of metal honeycomb material having a thickness of the order of one-fourth to one-half inch, a second like sheet of glass fiber mesh coated with thermoplastic material and a second like sheet of aluminum foil, all of said sheets being bonded together by said thermoplastic material, said honeycomb material comprising strips of aluminum hav-

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ing a thickness of the order of three to six thousandths of an inch disposed substantially perpendicular to said foil sheets and bent to form honeycomb-like cells between successive strips, said strips being joined with one another at areas of contact, marginal portions of said honeycomb material being crushed and marginal portions of said foil sheets converging progressively toward one another as they approach the peripheral edge of said sheets, peripheral edge portions of said foil sheets being bonded together to form a peripheral seal.

7. A radar antenna reflector formed of composite sheet material comprising in the order named a sheet of aluminum foil having a thickness of the order of one to five thousandths of an inch, a sheet of glass fiber mesh coated with thermoplastic material, a sheet of metal honeycomb material, having a thickness of the order of one-fourth to one-half inch, a second like sheet of glass fiber mesh coated with thermoplastic material and a second like sheet of aluminum foil, all of said sheets being bonded together by said thermoplastic material, said honeycomb material comprising strips of aluminum having a thickness of the order of three to six thousandths of an inch disposed substantially perpendicular to said foil sheets and bent to form honeycomb-like cells between successive strips, said strips being joined with one another at areas of contact, said composite sheet being of a selected dimension and configuration and being of substantially uniform thickness except that marginal portions of said foil sheets converge progressively toward one another as they approach the edges of said antenna, marginal portions of said foil sheets being bonded together to form a peripheral seal at the edges of said antenna and marginal portions of said honeycomb material disposed between said marginal portions of said foil sheets being progressively crushed, the aluminum strips forming said honeycomb material being compressed by said crushing in a direction substantially normal to said foil sheets and cooperating with said foil and plastic-coated glass fiber sheets to form said peripheral seal.

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