May 19, 1953 R. L. OVERHOLT 2,639,248

DIELECTRIC MATERIAL

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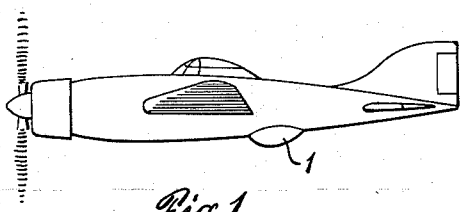
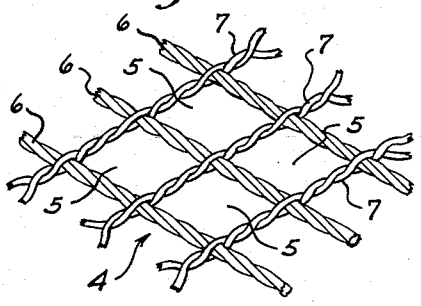



Fig. 1

Fig. 4



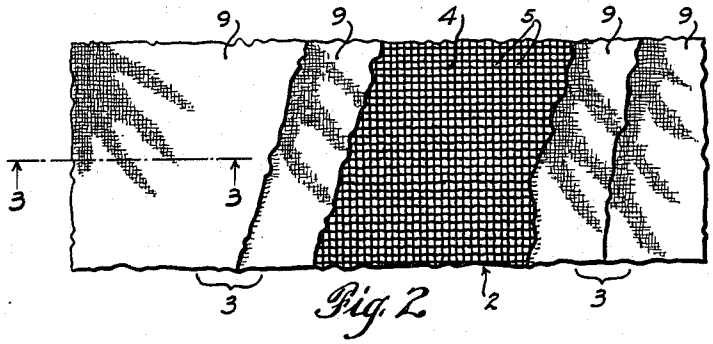




Fig. 2

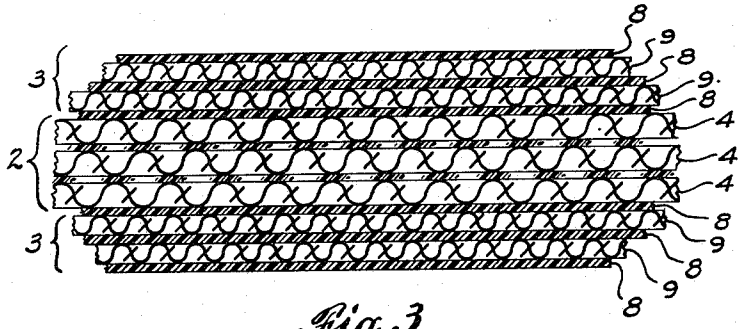



Fig. 3

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## DIELECTRIC MATERIAL

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10 Claims. (Cl. 154—43)

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This invention relates to dielectric materials and relates more particularly to dielectric units in the form of a thin sandwich structure capable of transmitting high frequency radar signals, for use as radomes, micro-wave windows and the like at extremely high frequencies of, for example, from about twelve thousand megacycles to thirty thousand megacycles and upwards.

Objects and advantages of the invention will be set forth in part hereinafter and in part will be obvious herefrom, or may be learned by practice with the invention, the same being realized and attained by means of the instrumentalities and combinations pointed out in the appended claims.

The invention consists in the novel parts, constructions, arrangements, combinations and improvements herein shown and described.

The accompanying drawing, referred to herein and constituting a part hereof, illustrates one embodiment of the invention, and together with the description, serves to explain the principles of the invention.

Dielectric units capable of transmitting high frequency signals, for use as radomes at extremely high frequencies of, for example, 24,000 megacycles (1.25 cms. wavelength), in the so-called K-band frequency, are necessarily thin-walled and, hence, are generally woefully weak. This holds true even when the devices are of sandwich construction, and deformities under aerodynamic loads are not infrequent. The wall thickness necessary to the satisfaction of the electrical requirements of the radome at a K-band frequency, for example, or at a higher frequency, is not only extremely critical but becomes even more critical as the frequency increases. Moreover, uniformity of thickness over the radome surface is of paramount importance if excessive reflection and consequent energy losses are to be avoided. Uniformity of electrical properties and uniformity of thickness go hand in hand and the obtainment of uniform electrical properties and of optimum mechanical properties in a sandwich construction intended for use at extremely high frequencies and especially under severe aerodynamic stresses has heretofore been defeated due, in part at least, to the unsuitability of known low density core materials generally employed at the lower frequencies. Thus, although low density core materials such as plastic foams and other homogeneous cellular materials typified by so-called cellular Hycar, and cellular laminates such as

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honeycombs typified by so-called Figerglas hexagonal grids, are suitable for use at the lower frequencies where the core thickness is neither as critical nor as small, such materials are not practically employable at the extremely high frequencies because they cannot be sliced reliably and accurately to provide the critically thin low density cores of uniform thickness and of requisite strength and stiffness required for electrical uniformity at K-band and higher frequencies. Even if they could be, the problem of handling such fragile cores would be a serious one.

It is therefore among the objects of this invention to enable the obtainment of both uniform electrical properties and optimum mechanical properties in dielectric units intended for use as radomes, micro-wave windows and the like at the aforementioned extremely high frequencies and especially in aircraft, through the provision of a new and improved dielectric material for the purpose.

In general and in accordance with this invention, a number of layers of substantially non-hygroscopic fibrous dielectric material are adhesively united over their entire contacting surface areas into a thin substantially non-hygroscopic sandwich unit of substantially uniform thickness possessing a high strength/weight and stiffness/weight ratio. In accordance with this invention also, at least one of said layers forms a low density cellular core of substantially uniform thickness for said unit and comprises a substantially non-hygroscopic netting of said dielectric material, preferably of high strength cellulosic material treated with a moisture-proofing resin, to be described more fully hereinafter, to make it substantially non-hygroscopic.

Other things being equal, coarsening the mesh of the netting tends to improve the electrical properties of the netting because of the reduction in density, but tends to degrade the mechanical properties because of reduction in strength and stiffness. Hence, the mesh to be employed necessarily must represent a compromise between the optimum mesh electrically and the optimum mesh mechanically. In general, a mesh of approximately one-eighth inch opening is advantageous at frequencies in the range mentioned.

The non-hygroscopic netting is preferably a woven fabric material and the weave may take various forms consistent with the obtainment of a sturdy "non-sleazy" netting of substantially uniform thickness capable of substantially re-

taining its shape when handled. The weave is preferably one in which the threads are knotted in cross screen form so that they will retain their relative spacing in handling and thus preserve uniformity of the mesh in position.

In accordance with this invention also, certain of said layers of fibrous dielectric material preferably form opposing skins spaced from each other substantially uniformly by said layer or layers of netting which form or forms the low density cellular core, the dielectric material of the skin layers being, preferably, a woven glass fibre cloth or other suitable non-hygroscopic fibrous fabric material.

In accordance with this invention also, the individual netting and skin layers, if they are cellulosic materials, are each first treated or impregnated, as by dipping or coating, with a suitable thermosetting phenolic resin in order to make them substantially non-hygroscopic. The moisture-proofing resin employed is necessarily one capable of rendering such normally highly moisture absorbent cellulosic material of the netting or of the skin layers, non-hygroscopic or substantially non-hygroscopic. For this purpose a water soluble phenol formaldehyde resin of such low molecular weight that it will diffuse into the cellulose cell wall and chemically combine with the cellulose molecules, to render them substantially non-hygroscopic, is employed. In order to impart greater flexibility to the respective layers, the moisture-proofing resin may be mixed with a suitable amount of a suitable furfural-formaldehyde resin. After this treatment, the individual netting and skin layers are impregnated with a suitable bonding resin having a low dielectric constant, preferably a styrene alkyd polyester resin, or an allyl polyester resin, meeting the requirements of U. S. Air Force Specification No. 12,049, Type III, and preferably while still wet therewith, are laid-up on a suitable mold to form an initial assembly of netting core and skins, of requisite thickness.

The initial lay-up or assembly is subjected on the mould to heat at a temperature advantageously in the range 70° to 290° F. and to pressure advantageously in the range 10 to 50 p. s. i. for a time sufficient to compress and/or mould the assembly into a plane or curved panel or piece of the desired configuration and thickness and to set the adhesive resin and bond the pieces adhesively to each other over their entire contacting surface areas into an integral non-hygroscopic low density sandwich unit of uniform desired thickness and configuration, possessing a high strength/weight and stiffness/weight ratio. The sandwich unit thus obtained is adapted particularly for use as a radome, microwave window or the like at the extremely high frequencies mentioned and under conditions of severe aerodynamic stress where surface distortion must be avoided to prevent impairment of critical electrical properties.

Of the drawings:

Fig. 1 is a somewhat diagrammatic view showing a typical application to an aircraft of a radome embodying this invention;

Fig. 2 is a fragmentary view in plan of a preferred embodiment of a sandwich type dielectric unit in accordance with this invention suitable for use in a radome installation such as is shown in Fig. 1, portions of the inner and outer stiffening skins being broken away in order to show details of the core construction more clearly;

Fig. 3 is a somewhat enlarged view in section taken along the line 3—3 of Fig. 2 showing the lay-up of the embodiment of Fig. 2; and

Fig. 4 is a fragmentary enlarged view in perspective of a portion of a preferred form of netting for the core of the embodiment of Fig. 2, showing the manner in which the netting threads are locked together.

Referring now more particularly to the drawings, the radome 1 is of sandwich construction as is best shown in Figs. 2 and 3 and, comprises a low density, low loss non-hygroscopic unit core 2 of substantially uniform thickness disposed between and adhesively bonded to each of a pair of spaced skins 3 constituting the inner and outer surfaces, respectively of the radome.

The core 2 as embodied comprises a number of layers 4 of non-hygroscopic netting disposed one on the other with the mesh openings 5 (Fig. 2) of each preferably in substantial alignment with the mesh openings 5 of the next thereby to provide a more or less open cellular core structure, as indicated in Fig. 2. Three such layers are shown in Fig. 3 but a larger or smaller number may be provided as required to obtain the exact and precise spacing of the skins 3 required in the finished radome material for use at the frequency at which the radome is to operate.

The non-hygroscopic netting of the core as embodied may be woven in any of the usual and conventional forms, marquisette or otherwise, providing the necessary sturdiness and operative to maintain the normal uniformity of the mesh and may be a glass fibre or other synthetic non-hygroscopic fabric, but as here preferably embodied and as is best shown in Fig. 4, each netting layer comprises a substantially square weave cotton thread fabric of approximately one eighth inch mesh, employing hard spun single warp threads 6 and double weft threads 7 of a good grade of high strength cellulose, the latter being interlocked with or "knotted" to the weft threads in cross screen form, substantially as shown. Such netting is commonly termed Textinet and is not only highly uniform in thread diameter, thickness and weave, but is very sturdy and hence admirably suited for use as a basic core material in accordance with this invention.

Each of the cellulosic netting layers 4 has its constituent cellulosic threads impregnated with a water soluble phenol formaldehyde resin of such low molecular weight that it will diffuse into the cellulose cell wall and chemically combine with the cellulose molecules to render them substantially non-hygroscopic. A furfural-formaldehyde resin may be added to impart additional flexibility. The phenolic resin serves to insulate the threads substantially completely against any absorption of moisture which would rapidly increase the dielectric constant of the core and materially adversely affect the electrical properties of the core. Advantageously, the moisture proofing resin in accordance with this invention may be prepared by mixing 500 parts of phenol with 1000 parts of 40% aqueous formaldehyde solution and 50 parts of 28% aqueous ammonia solution, by weight. The solution thus formed may be used as mixed, or heated just until water begins to separate, after which the reaction is stopped promptly by fast cooling and the "resin" which is actually a resin forming solution or a resin in the very early stages of manufacture, is ready to use. For good results, the resin solutions should be used fresh. The moisture proofing resin coating of the netting threads is not intended to form, nor is it desired that it shall

form, a continuous film or layer of resin between the netting layers 4 since this could unnecessarily increase the overall density of the core without materially adding to either its strength or stiffness. Hence, the mesh openings 5 are left substantially unobstructed. Subsequent impregnation with a resin such as a polyester resin does, however, serve as a firm bonding medium between the netting layers 4 at their contacting surface portions. It will be understood therefore that the netting layers 4 in Fig. 3 are bonded together at substantially their contacting surface portions only by a resin adhesive on the threads and that each of the netting layers 4 has its threads coated with a resin adhesive although a representation of a continuous resin adhesive layer on the netting threads is omitted for the sake of clarity.

The skins 3 as here preferably embodied consist each of one or more layers 9 of resin coated woven glass fibre cloth or other known suitable fabric skin materials, adhesively bonded to each other and to the core 2 over their entire contacting surface areas by means of coating layers 8 of resin adhesive. Preferably, the same polyester resin adhesive (with catalyst) used for adhesively treating the netting layers 4 of the core 2 following moisture proofing, is employed for adhesively treating the skins 3. The skins 3 as here preferably embodied each consist of two layers 9 of woven glass fibre cloth and coating layers 8 of the resin adhesive.

Fabrication of a dielectric unit such as the radome 1 may follow conventional moulding technique with such adaptation thereto and variations therefrom as will readily suggest themselves to those skilled in the art. By way of example, the non-hygroscopic netting layers 4 and skin layers 9, whether of naturally non-hygroscopic fabric material or of fabric material treated with a phenol-formaldehyde resin in accordance with this invention to render the same non-hygroscopic, are treated with resin adhesive and laid up in proper order on a mold of suitable configuration, the completed lay-up subjected to fluid pressure molding in an autoclave under conditions of time, temperature, and pressure suitable for curing the resin adhesive and moulding the assembly into an integral unit of the requisite thickness and configuration. The assembly may also be cured in an oven using an evacuated bag to supply the pressure.

The invention in its broader aspects is not limited to the specific embodiment shown and described but departures may be made therefrom within the scope of the accompanying claims without departing from the principles of the invention and without sacrificing its chief advantage.

What is claimed is:

1. A lightweight sandwich construction capable of transmitting high frequency radar signals comprising: a plurality of layers of fibrous dielectric materials adhesively united over their entire contacting surface areas into a thin sandwich unit of substantially uniform thickness, at least one of said layers forming a low density core of low dielectric constant and substantially uniform thickness, and certain of said layers forming oppositely disposed skins for said core substantially uniformly spaced thereby from each other over substantially their entire opposing surface areas, said core layer comprising a plurality of substantially non-hygroscopic nettings of said dielectric materials laid up upon each other in planes substantially parallel to those of said skins and bonded together at their contacting surfaces by a set resin which does not substantially extend into the mesh openings in each of said nettings to provide a multiplicity of unfilled spaces, and said other layers comprising a substantially non-hygroscopic dielectric material which provides a pair of continuously surfaced outer coverings for said core.



2. A lightweight sandwich construction capable of transmitting high frequency radar signals comprising: a plurality of layers of fibrous dielectric materials adhesively united over their entire contacting surface areas into a thin sandwich unit of substantially uniform thickness, at least one of said layers forming a low density core of low dielectric constant and substantially uniform thickness, and certain of said layers forming oppositely disposed skins for said core substantially uniformly spaced thereby from each other over substantially their entire opposing surface areas, said core layer comprising a plurality of nettings of said dielectric materials laid up upon each other in planes substantially parallel to those of said skins and bonded together at their contacting surfaces by a set resin which does not substantially extend into the mesh openings in each of said nettings to provide a multiplicity of unfilled spaces, said nettings being of cellulosic material having chemically combined therewith the reaction product of a water soluble phenol formaldehyde resin of low molecular weight which does not fill up said unfilled spaces whereby said nettings are rendered substantially non-hygroscopic, and said other layers each comprising a substantially non-hygroscopic dielectric material which provides a pair of continuously surfaced outer coverings for said core.

3. A lightweight sandwich construction capable of transmitting high frequency radar signals comprising: a plurality of layers of fibrous dielectric materials adhesively united over their entire contacting surface areas into a thin sandwich unit of substantially uniform thickness, at least one of said layers forming a low density core of low dielectric constant and substantially uniform thickness, and certain of said layers forming oppositely disposed skins for said core substantially uniformly spaced thereby from each other over substantially their entire opposing surface areas, said core layer comprising a plurality of substantially non-hygroscopic nettings of said dielectric materials laid up upon each other in planes substantially parallel to those of said skins and bonded together at their contacting surfaces by means of a set resin which does not substantially extend into the mesh openings in each of said nettings, said nettings being arranged with the openings therein in substantial alignment to provide a multiplicity of unfilled spaces extending in the direction of said thickness of said core, and said other layers each comprising a substantially non-hygroscopic dielectric material which provides a pair of continuously surfaced outer coverings for said core.

4. A lightweight sandwich construction capable of transmitting high frequency radar signals comprising: a plurality of layers of fibrous dielectric materials adhesively united over their entire contacting surface areas into a thin sandwich unit of substantially uniform thickness, at least one of said layers forming a low density core of low dielectric constant and substantially uniform thickness, and certain of said layers forming oppositely disposed skins for said core

substantially uniformly spaced thereby from each other over substantially their entire opposing surface areas, said core layer comprising a plurality of substantially non-hygroscopic nettings of substantially square weave cotton thread fabric laid up upon each other in planes substantially parallel to those of said skins and adhered together at their contacting surfaces by means of a resin which does not extend into the mesh openings in each of said nettings, said nettings being arranged with the substantially square openings therein in substantial alignment to provide a multiplicity of unfilled spaces extending in the direction of said thickness of said core, and said other layers comprising a substantially non-hygroscopic dielectric material which provides a pair of continuously surfaced outer coverings for said core.

5. A lightweight sandwich construction capable of transmitting high frequency radar signals comprising: a plurality of layers of fibrous glass materials adhesively united over their entire contacting surface areas into a thin sandwich unit of substantially uniform thickness, at least one of said layers forming a low density core of low dielectric constant and substantially uniform thickness, and certain of said layers forming oppositely disposed skins for said core substantially uniformly spaced thereby from each other over substantially their entire opposing surface areas, said core layer comprising a plurality of substantially non-hygroscopic nettings of said fibrous glass materials laid up upon each other in planes substantially parallel to those of said skins and adhered to each other at their contacting surfaces by means of a surface coating of an adhesive which does not substantially extend into the mesh openings in said nettings to provide a multiplicity of unfilled spaces, and said other layers comprising a substantially non-hygroscopic fibrous glass material having the spaces provided therein filled with a set resin to provide a pair of continuously surfaced outer coverings for said core.

6. A lightweight sandwich construction capable of transmitting high frequency radar signals comprising a plurality of layers of fibrous dielectric materials adhesively united over their entire contacting surface areas into a thin sandwich unit of substantially uniform thickness, at least one of said layers forming a low density core of low dielectric constant and substantially uniform thickness, and certain of said layers forming oppositely disposed skins for said core substantially uniformly spaced thereby from each other over substantially their entire opposing surface areas, said core layer comprising a plurality of substantially non-hygroscopic nettings of said dielectric materials laid up upon each other in planes substantially parallel to those of said skins with the mesh openings of said nettings unfilled to provide a multiplicity of unfilled spaces, and said other layers comprising a substantially non-hygroscopic dielectric reticulate material impregnated with a resin so as to have the spaces provided therein filled thereby, said other layers of each of said skins being laid up upon each other and bonded together by said resin to provide a pair of continuously surfaced outer coverings for said core, said skins likewise being bonded to said core by said resin.

7. A lightweight sandwich construction capable of transmitting high frequency radar signals comprising a plurality of layers of fibrous dielectric materials adhesively united over their entire contacting surface areas into a thin sandwich unit of substantially uniform thickness, at least one of said layers forming a low density core of low dielectric constant and substantially uniform thickness, and certain of said layers forming oppositely disposed skins for said core substantially uniformly spaced thereby from each other over substantially their entire opposing surface areas, said core layer comprising a plurality of nettings of said dielectric materials laid up upon each other in planes substantially parallel to those of said skins, said nettings being of cellulosic material having chemically combined therewith the reaction product of a water soluble phenol formaldehyde resin of low molecular weight whereby said nettings are rendered substantially non-hygroscopic, said nettings being bonded to each other at their contacting surface portions by an adhesive resin which does not substantially extend into the mesh openings in each of said nettings, and said other layers comprising a substantially non-hygroscopic dielectric reticulate material impregnated with a resin so as to have the spaces provided therein filled thereby, said other layers of each of said skins being laid up upon each other and bonded together by said resin to provide a pair of continuously surfaced outer coverings for said core.

8. A lightweight sandwich construction capable of transmitting high frequency radar signals comprising a plurality of layers of fibrous dielectric materials adhesively united over their entire contacting surface areas into a thin sandwich unit of substantially uniform thickness, at least one of said layers forming a low density core of low dielectric constant and substantially uniform thickness, and certain of said layers forming oppositely disposed skins for said core substantially uniformly spaced thereby from each other over substantially their entire opposing surface areas, said core layer comprising a plurality of nettings of said dielectric materials laid up upon each other in planes substantially parallel to those of said skins, said nettings being of cellulosic material having chemically combined therewith the reaction product of a water soluble phenol formaldehyde resin of low molecular weight limited in quantity so as not to fill up the mesh openings in said nettings whereby said nettings are rendered substantially non-hygroscopic, said nettings being bonded to each other at their contacting surface portions by an adhesive resin which substantially coats the threads of said netting without substantially extending into said mesh openings, and said other layers comprising a substantially non-hygroscopic dielectric reticulate material impregnated with a resin so as to have the spaces provided therein filled thereby to provide a pair of continuously surfaced outer coverings for said core.

9. A lightweight sandwich construction capable of transmitting high frequency radar signals comprising a plurality of layers of fibrous dielectric materials adhesively united over their entire contacting surface areas into a thin sandwich unit of substantially uniform thickness, at least one of said layers forming a low density core of low dielectric constant and substantially uniform thickness, and certain of said layers forming oppositely disposed skins for said core substantially uniformly spaced thereby from each other over substantially their entire opposing surface areas, said core layer comprising a plurality of nettings of said dielectric material laid up upon each other in planes substantially paral-

lel to those of said skins, said nettings being of cellulosic material having chemically combined therewith the reaction product of a water soluble phenol formaldehyde resin of low molecular weight whereby said nettings are rendered substantially non-hygroscopic, said nettings being bonded to each other at their contacting surface portions by an adhesive resin which substantially coats the threads of said netting without substantially extending into the mesh openings of said nettings, and said other layers of each of said skins comprising a substantially non-hygroscopic woven fabric of glass fibers impregnated with a resin so as to have the spaces provided therein filled thereby, said other layers of each said skin being laid up upon each other and bonded together by said last-named resin to provide a pair of continuously surfaced outer coverings for said core.

10. A lightweight sandwich construction capable of transmitting high frequency radar signals comprising a plurality of layers of fibrous dielectric materials adhesively united over their entire contacting surface areas into a thin sandwich unit of substantially uniform thickness, at least one of said layers forming a low density core of low dielectric constant and substantially uniform thickness, and certain of said layers forming oppositely disposed skins for said core substantially uniformly spaced thereby from each other over substantially their entire opposing surface areas, said core layer comprising a plurality of nettings of said dielectric material laid up upon each other in planes substantially parallel to those of said skins, said nettings being of



cellulosic material having chemically combined therewith the reaction product of a water soluble phenol formaldehyde resin of low molecular weight whereby said nettings are rendered substantially non-hygroscopic, said nettings being bonded to each other at their contacting surface portions by an adhesive resin which substantially coats the threads of said netting without substantially extending into the mesh openings of said nettings, and said other layers comprising a cellulosic material having chemically combined therewith a water soluble phenol formaldehyde resin of low molecular weight whereby said material is rendered substantially non-hygroscopic; said last-named material being impregnated with a second resin so as to have the spaces provided therein filled thereby to provide a pair of continuously surfaced outer coverings for said core.

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