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[72] Inventors **Richard O. Bayrd**
Wakefield;
Raymond P. Tuinila, Beverly, Mass.
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[73] Assignee **Raytheon Company**
Lexington, Mass.

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Primary Examiner—Rodney D. Bennett, Jr.
Assistant Examiner—Brian L. Ribando
Attorneys—Harold A. Murphy, Joseph D. Pannone and Philip
J. McFarland

[54] **RADIO FREQUENCY ABSORBER**
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343/18; 252/453

ABSTRACT: An absorber for radio frequency energy using incombustible materials to minimize adverse effects from the conversion of such energy to heat, including a fibrous mat of nonabsorbing material in which the absorbing material is distributed in such a manner that discontinuities in the index of refraction, meaning always the electrical index, in the path of the energy to be absorbed are minimized.

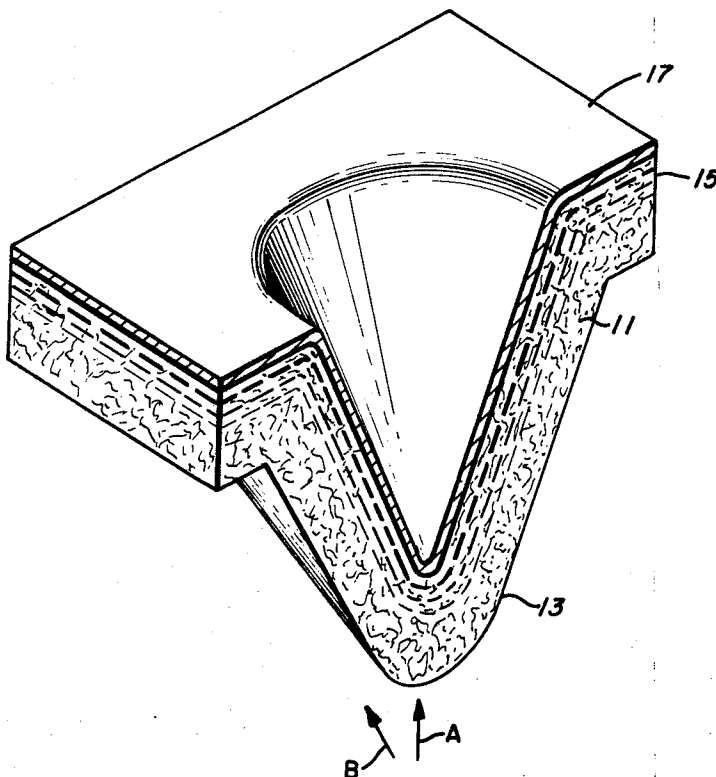


FIG. 1

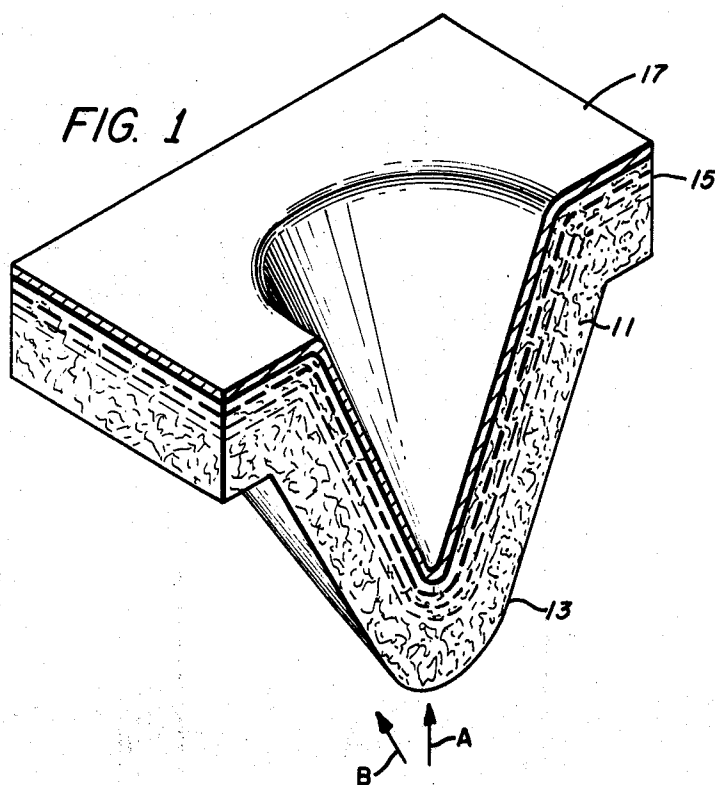
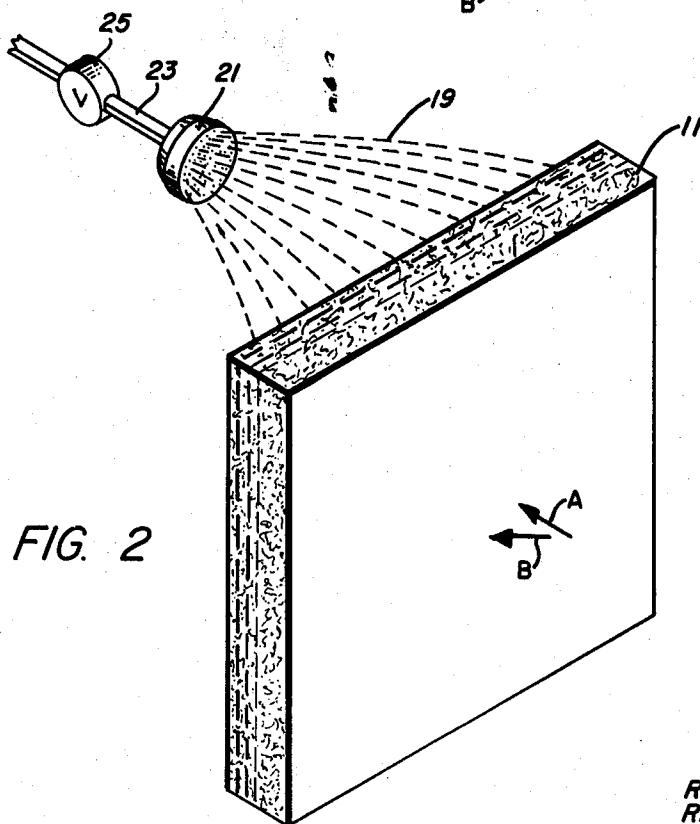


FIG. 2

INVENTORS

RICHARD O. BAYRD
RAYMOND P. TUINILA

BY

Philip McFarland
ATTORNEY

RADIO FREQUENCY ABSORBER

BACKGROUND OF THE INVENTION

This invention pertains generally to electromagnetic radiation absorptive articles and particularly to such articles having improved properties and a method for using such articles.

It has been known in the art that it is possible to construct absorbers for radio frequency energy by coating the individual nonconducting fibers in a fibrous mat with a suspension of conductive particles in a liquid adhesive and then drying the so-treated fibrous mat. For example, mats of excelsior, curled vegetable fiber or animal hair have been impregnated with aluminum flakes, graphite or conductive carbon black using organic adhesives such as latex emulsions as a binder to produce absorbers of value.

It is also known in the art, as shown in our application of Apr. 3, 1967, Ser. No. 628,039, now Pat. No. 3,441,933 "Radio Frequency Absorber", which application is assigned to the same assignee as this application, that an absorber may be constructed by laminating sheets together, each sheet consisting of closely packed ceramic spheres of substantially uniform diameter, the diameter of the spheres decreasing consecutively from the side of the absorber to be exposed to radio frequency energy. In our previously disclosed absorber just referred to, the spheres preferably are aluminum oxide and are bonded together with an adhesive such as barium titanate or aluminum phosphate cement.

While the various types of absorbers known today are satisfactory for many applications, there exist many applications for which, for one reason or another, all such absorbers are not satisfactory. Perhaps the most important shortcoming of known absorbers is that, no matter how they are shaped, the surfaces irradiated by radio frequency energy reflect a measurable amount of such energy. This reason this is so is that, in all known absorbers, the dielectric constant of the material differs appreciably at its boundary from the dielectric constant of the air through which the radio frequency energy was propagated; it follows then that the irradiated surface of the absorber becomes a good reflector of energy incident at an angle greater than the critical angle of the absorber, such angle being considered herein to be the largest angle, measured from a line perpendicular to the surface of the absorber on which energy impinges, of incidence of such energy for refraction. That is, when the angle of incidence of such energy exceeds the critical angle, reflection occurs. When, for example, the absorber is to be used to construct an anechoic chamber for testing a high powered radar transmitter such reflections are intolerable.

Another limitation of known absorbers also becomes evident when high powered radar transmitters are being tested. That is, when the power dissipated per unit area becomes large, say more than 15 watts per square inch, the temperature of the absorber may be raised so much that any organic material in the absorber is damaged or, because of differences in the coefficient or thermal expansion of the various materials used in the absorber, breakage occurs at localized parts of the absorber. For the latter reason it has been found to be extremely desirable that the body of the absorber be porous so as to permit forced air cooling. What is preferable, however, is to provide an absorber which contains no combustible materials, thus making it possible in many cases to eliminate the requirement of forced air cooling. Such elimination has the added advantage that there is no possibility of catastrophic failure in operation due to loss of cooling air.

SUMMARY OF THE INVENTION

Therefore, it is a primary object of this invention to provide an improved absorber for radio frequency energy utilizing incombustible materials.

Another object of this invention is to provide an improved absorber for radio frequency energy in which provision is made to eliminate, for all practical purposes, reflections from

the irradiated surfaces regardless of the angle of incidence of such energy thereon.

Still another object of this invention is to provide an improved method for absorbing radio frequency energy.

These and other objects of this invention are attained generally by charging an appropriately shaped mold with a slurry of inorganic nonconducting fibers of a material whose index of refraction is substantially the same as the index of refraction of air, curing the so-cast material to remove substantially all the liquid vehicle so that a fibrous sheet is obtained and then, alternatively: (a) covering one side of the fibrous sheet with a colloidal suspension containing a material which absorbs radio frequency energy so that particles of such material are absorbed in the fibrous sheet by capillary action with the density of such particles decreasing to zero at some plane within the fibrous sheet and again curing the resulting coated fibrous sheet to remove the liquid vehicle of the colloidal suspension, leaving particles of the latter material lodged in the interstices between fibers of the fibrous sheet; or, (b) while the fibrous sheet is being irradiated by radio frequency energy to be absorbed, covering one surface of such sheet with a power absorbing liquid which penetrates the fibrous sheet by capillary action, the amount of such liquid within such sheet varying inversely with distance from the wetted side thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of this invention reference is now made to the drawings in which:

FIG. 1 is a preferred embodiment of this invention, greatly simplified, showing a formed fibrous sheet containing energy absorbing material as herein contemplated; and,

FIG. 2 is another preferred embodiment of this invention showing a formed fibrous sheet used with a liquid as the energy absorbing material.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to FIG. 1, it may be seen that an absorber according to this invention consists of a sheet 11 of fibrous material which may, as shown here, be formed integral with a conical portion 13 using conventional casting techniques. A satisfactory fibrous material is felted alumina silica ceramic fibers. It is noted that the size and number of conical portions 13 is not essential to this invention, any such portions provided serving mainly to increase the surface area of the energy absorbing material. An energy absorbing material 15, as particles of graphite, is disposed on one side of the sheet 11 penetrating therein for a distance distance, which is not critical, but which is always less than the thickness of the sheet. As indicated by the gradations of the weight of the dashed lines representing the energy absorbing material 15, the average density thereof varies inversely with distance from the surface of the sheet 11 to which the energy absorbing material 15 is applied. It should be recognized, therefore, that because the energy absorbing material 15 consists of particles of a selected material, as graphite, the resistivity of the impregnated portion of the sheet 11 also varies inversely with distance from the covered surface. It should also be noted here that, as shown in the broken away part of the conical portion 13, the inside of that portion is similarly impregnated with energy absorbing material 15. A metallic coating 17, as aluminum paint, may be applied to cover the exposed portions of the energy absorbing material 15 to protect those portions.

With the description of the absorber shown in FIG. 1 in mind, its operation may now be explained by considering its effect on radio frequency energy incident normally, or nearly so, to the sheet 11 (such energy being represented by the arrow marked with the letter "A" in FIG. 1) and its effect on radio frequency energy incident obliquely to the sheet 11 (such energy being represented by the arrow marked with the letter "B" in FIG. 1). Thus, because the material of sheet 11 was intentionally chosen from the group of nonconducting in-

organic materials which have an index of refraction approximately that of air, radio frequency energy incident normally, or nearly so, passes into the sheet 11 without reflection. To put it another way, the critical angle is not exceeded for such incident energy is not exceeded. When such incident energy passes into the portion of the sheet 11 in which the particles of energy absorbing material 15 are randomly entrapped, such energy is then reflected back and forth between such particles until dissipated, i.e., converted to heat energy. Considering now the effect of the absorber on radio frequency energy impinging obliquely, as represented by the arrow "B", on the sheet 11, such energy also passes, without measurable change, through the interface between the sheet 11 and the air through which it was propagated. On reaching the energy absorbing material, however, such energy is subjected to refraction, the amount of such refraction increasing as the energy progressively passes into regions within the sheet 11 containing more densely distributed particles of the energy absorbing material 15. The cumulative effect of such progressively increasing refraction is to change the direction of the energy represented by the arrow "B" to the direction of the energy represented by the arrow "A". That is, the direction of obliquely incident energy is changed until its direction is normal, or nearly so, to the sheet 11. Consequently, such originally obliquely incident energy becomes entrapped and dissipated. Because the material of the sheet 11 and the energy absorbing material 15 are incombustible and because the particles of energy absorbing materials are not cemented on to the fibers making up sheet 11, such heating as occurs has no apparent effect until the temperature within the sheet 11 rises far above the ignition or charring temperature of any known organic adhesive. It is noted here that, if the metallic coating 17 is not applied, then the illustrated absorber is a porous structure which may be cooled by forced air cooling if it is desired to keep the temperature within the sheet 11 at a temperature approximating room temperature, as when a number of sheets 11 are used to construct an anechoic chamber.

Turning now to FIG. 2, it may be seen that the alternative form of an energy absorber consists simply of a sheet 11 of fibrous material which is disposed in the path of radio frequency energy to be absorbed, such energy being indicated again by the arrows lettered "A" and wetted by a spray 19 of an incombustible liquid, as water. Such a spray preferably is directed onto the sheet 11 from a nozzle 21 to which the selected liquid, hereinafter considered to be water, is brought from a source (not shown) through a pipe 23 and a valve 25.

When the surface of the sheet 11 is wetted by the spray 19, capillary action in the sheet 11 results in a portion of the water in the spray 19 being absorbed within the sheet 11, the amount of the absorbed water being adjusted so that the amount thereof in the sheet 11 varies inversely with distance from the wetted surface. When radio frequency energy, after passing through the dry portion of sheet 11, impinges on the water such energy is converted to heat energy which, in turn, changes the first encountered water to steam. When a "layer" of steam is generated, a constantly increasing index of refraction is created in the medium through which the impinging radio frequency energy passes. Consequently, impinging radio frequency energy, as indicated by the arrows "A" and "B", is refracted into the wetted portions of the sheet 11 (in a manner similar to that previously explained) and finally dissipated therein. Experience has proven that the embodiment shown in FIG. 2 possesses some advantage over that shown in FIG. 1 when great amounts, say 100 watts/square inch, of radio frequency energy impinges on the absorber shown in FIG. 2 the heat generated within the sheet 11 converts the water absorbed therein, or a portion of such water, into steam. Because of the porosity of the sheet 11, such steam escapes, being replaced by water from the spray 19. It will be recognized then that an equilibrium condition may be attained by adjusting the valve 25; when such a condition is attained the heat removed with the steam equals the heat generated by the conversion of the radio frequency energy to heat energy. It will also be

recognized that the temperature of the steam is the maximum temperature reached within the absorber and that the steam is essentially at atmospheric pressure. It will be observed also that the absorbing ability of the absorber of FIG. 2 may be easily adjusted simply by regulating the valve 25 to control the amount of water in the spray 19. It will also be observed that ancillary equipment may be used with the arrangement shown in FIG. 2 so that steam escaping from the sheet 11 may be condensed and recirculated if desired.

It is here noted that, in both of the illustrated embodiments of this invention, the porosity of the sheet 11 may be varied within wide limits as desired. It is, of course, easy to control that parameter in the casting process. It is also noted here that the overall shape of the absorber is not essential, it being evident that other shapes than those illustrated may be cast.

FIG. 2 may also be considered to be illustrative of the method herein contemplated. Thus, considering that FIG., it may be seen that the sheet 11 is simply, insofar as the absorbing liquid is concerned, a container which permits elimination of a sharply defined interface between such liquid and air. It is, therefore, not necessary in practicing the method to use the disclosed fibrous sheet with its randomly disposed fibers and concomitant interstices for capillary action. For example, any of the known mat material for absorbers could be used. With the foregoing in mind, it becomes obvious that the method herein contemplated only requires provision for maintaining a liquid, which may be converted to its gaseous phase in an endothermic process, in the path of radio frequency energy to be absorbed, irradiating such liquid with such energy to form at least a layer of the gaseous phase of the liquid on its irradiated surface, and adjusting a supply of the liquid so that an equilibrium condition is reached wherein the amount of liquid remains substantially constant.

It is felt, in view of the foregoing, that this invention should not be restricted to its disclosed embodiments, but rather should be limited only by the spirit and scope of the appended claims.

I claim:

1. An absorber for radio frequency energy comprising:

- a. a base, fabricated from randomly intertwined fibers of an inorganic nonconducting material having an index of refraction approximating the index of refraction of air to form a sheet of such material; and
- b. an energy absorbing material disposed in the interstices between such fibers, the density of such energy absorbing material decreasing from a maximum at one surface of the base to zero therewithin.

2. An absorber as in claim 1, wherein the randomly intertwined fibers of an inorganic nonconducting material are cast fibers of alumina silica to form the sheet in a desired shape and to adjust the density thereof.

3. An absorber as in claim 2 wherein the energy absorbing material consists of particles of an electrically conductive incombustible material.

4. An absorber as in claim 2 wherein the energy absorbing material is an incombustible liquid.

5. An absorber as in claim 4 wherein the incombustible liquid is water.

6. A method of absorbing radio frequency energy comprising the steps of:

- a. wetting the first surface of a sheet of a fibrous nonconducting material with an incombustible liquid to partially impregnate such sheet, such liquid being convertible into its gaseous phase by radio frequency energy impinging thereon;
- b. irradiating the liquid, through the second surface of such sheet, with radio frequency energy to be absorbed, thereby to convert a portion of the liquid to its gaseous phase and absorb such radio frequency energy; and
- c. rewetting the first surface of the sheet with additional liquid to replace the amount thereof converted to its gaseous phase by such radio frequency energy.