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(54) **Acoustically absorbent ceiling tile having barrier facing with diffuse reflectance and use of said tile**

Schalldämmende Deckenplatte mit Barrierefläche mit diffuser Reflexion und Verwendung der Deckenplatte

Tuile de plafond absorbante acoustique comportant une façade de barrière avec réflectance diffuse et l'utilisation de la tuile de plafond

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Description

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0001] The invention relates to ceiling tiles for use in a building interior.

2. Description of the Related Art

[0002] Acoustically absorbent ceiling tiles are known in the art for use reducing the amount of noise and/or reverberation within a given area, such as a building interior. In such ceiling tiles, a core of acoustically absorbing materials, i.e., materials having a high absorption coefficient, reduces noise by absorbing acoustic energy as sound waves strike and enter the acoustically absorbing material. Many known acoustically absorbing materials are formed of unconsolidated or partially unconsolidated, lofty fibrous materials including compressed fibers, recycled fiber or shoddy materials, fiberglass or mineral fiber batts and felts and require a facing to contain the core of fibrous materials. Other known acoustically absorbing core materials including foam, materials having a honeycomb structure, microperforated materials and acoustically absorbing materials utilizing air spaces also utilize a protective and/or decorative facing for use in a building interior.

[0003] Facings for covering acoustic absorbent ceiling tiles serve as durable coverings that protect the core during handling, use and maintenance. It is desirable that facings for covering acoustically absorbent materials be materials that are either acoustically transparent or absorbent, but not acoustically reflective, in order to enhance the absorption of sound. Facings which are acoustically reflective undesirably contribute to the ambient noise. Known facings for covering acoustically absorbent ceiling tiles include fabric, nonwoven sheet, paper, film and perforated solid materials.

[0004] U.S. Pat. No. 6,703,331 discloses a gypsum board suitable for use as a ceiling panel and having a facing comprising a flash spum plexifilamentary film-fibril sheat.

[0005] U.S. Pat. Nos. 5,824,973 and 6,877,585 disclose a sound absorption laminate useful as a ceiling tile comprising a porous insulation substrate and a paper, fabric or perforated film facing sheet having an air flow resistance between 200 and 1210 rayls. U.S. Pat. Appl. Pub. 2007/0151800 discloses an acoustic insulating sheet material comprising a primary sound absorbing sheet and a dense porous membrane which can be a spunbond web, melt blown web, spunlaced web, carded or airlaid staple fiber web, woven web, wet-laid web or combination of such webs having an airflow resistance of about 5,000 rayls or less. U.S. Pat. No. 3,858,676 discloses a thin sound-absorbing panel especially for frequencies below 500 Hz and its use in a ceiling system wherein the panel comprises a perforated backing, a heavy textile facing having a basis weight of 12 to 2,140 g/m^2 and a specific airflow resistance of 300 to 1,800 rayls, and a fiberglass core. U.S. Pat. No. 5,832,685 discloses a self-supporting sound absorbing panel and its use in a ceiling system comprising a nonwoven fabric having a basis weight of about 10 to 15 oz/yd^2 which can be a spunbond fabric or a fabric comprising bonded staple fibers. These known facing materials have the disadvantage that they are open to the penetration of water, dust, mold and microorganisms, thus limiting their application in critical environments.

[0006] It is desirable that visible light be reflected from the surface of ceiling tile facings in a diffuse, even distribution, as opposed to specular (mirror-like) reflection in which light is reflected only at an angle equal to the incident angle. Diffuse or Lambertian reflectance is the uniform diffuse reflection of light from a material in all directions with no directional dependence for the viewer, according to Lambert's cosine law. Diffuse reflectance originates from a combination of external scattering of light from features on the surface of a material, and internal scattering of light from features within a material. Internal light scattering can arise, for example, from features within a material such as pores and particles. The light scattering cross section per unit feature volume of materials containing closely spaced refractive index inhomogeneity is maximized when the mean diameter of the features is slightly less than one-half the wavelength of the incident light. The degree of light scattering is also increased when there is a large difference between the refractive index of the scattering feature and refractive index of the phase in which the feature is dispersed.

[0007] It would be desirable to have acoustically absorbing ceiling tiles having a combination of diffuse reflectance of light and acoustic absorption which are suitable for use in a variety of critical environments.

SUMMARY OF THE INVENTION

[0008] According to one embodiment, the invention is directed to a ceiling tile according to appended claim 1.

[0009] According to another embodiment, the invention is directed to a method of improving acoustic absorption and light reflectance according to appended claim 13.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010]

Figure 1 is a graph depicting the acoustic absorption, reflection and sound transmission of a flash spun sheet (block measurement).

Figure 2 is a graph depicting the acoustic absorption, reflection and sound transmission of a flash spun sheet (anechoic measurement).

Figure 3 is a graph comparing the acoustic absorption coefficients of an acoustic absorber without a facing and two acoustic absorbers with facings useful in the ceiling tile according to the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0011] According to an embodiment of the invention, a ceiling tile is provided having an advantageous combination of acoustic absorption, diffuse reflectance of light and barrier to the penetration of fine particles, microorganisms and moisture. Ceiling tiles according to the invention have facings that are durable, waterproof, hypoallergenic, non-linting, non-off-gassing and resistant to the penetration of moisture, dust, mold and microorganisms without impeding the reflectance and acoustic absorption capabilities.

[0012] The terms "acoustic absorbent" and "acoustically absorbing" herein refer generally to the ability of a material to absorb incident sound waves.

[0013] The term "diffuse reflectance" refers to the uniform diffuse reflection of light from a material in all directions with no directional dependence for the viewer, according to Lambert's cosine law. Diffuse reflectance can be approximated as the total reflectance minus specular reflectance.

[0014] The acoustically absorbing ceiling tile of the invention includes an acoustically absorbing core and a nonwoven facing covering at least one surface of the core. The facing is acoustically transparent, in that the facing does not detract from the acoustic absorption of the core, or the facing can enhance the acoustical absorption of the ceiling tile core. The nonwoven facing comprises a flash spun plexifilamentary film-fibril sheet having a coherent surface. By "coherent surface" is meant the surface of the sheet is consolidated and/or bonded. The bonding method can be any known in the art, including but not limited to thermal calendering, through-gas bonding, and point-bonding. The core and facing are bonded to each other, by any known suitable bonding techniques such as adhesive bonding, solvent bonding, ultrasonic bonding, thermal bonding, point bonding, stitch bonding or the like. The bonded material is subsequently cut into ceiling tiles.

[0015] The acoustically absorbing core includes any known acoustically absorbing material and/or an air space. The core has a noise reduction coefficient (NRC) between about 0.3 and about 0.9, as measured by ASTM C423, mounting A (without air space). Suitable acoustically absorbent materials include nonwoven fabrics, such as spunbonded nonwovens, carded nonwovens, needlepunched nonwovens, air-laid nonwovens, wet-laid nonwovens, spunlaced nonwovens, spunbonded-meltblown-spunbonded composite nonwovens and meltblown nonwovens, woven fabrics, knit fabrics, three-dimensional meshes, including honeycomb structures and foams, combinations thereof and the like. The term "nonwoven" means a web including a multitude of randomly distributed fibers. The fibers can be staple fibers or continuous fibers. The fibers can comprise a single material or a multitude of materials, either as a combination of different fibers or as a combination of similar fibers each comprised of different materials. Other materials suitable for use as the core are foams, such as open-cell melamine foam, polyimide, polyolefin, and polyurethane foams, and perforated sheets. According to preferred embodiments of the invention, the core is substantially free of volatile organic compounds (VOCs). One preferred material is formaldehyde-free fiberglass batting. In general, the greater the thickness of the core material, the greater the acoustic absorption of the ceiling tile will be, especially at low frequencies. An air space covered with the facing can serve as the absorbing core.

[0016] Acoustically transparent facings for use with acoustically absorbent articles including ceiling tiles are known in the art. Such facings typically have between about 5% and about 50% open area, i.e. the area of the pores on the surface with respect to the total surface area, depending on the need for acoustic absorption. If high frequency absorption is not required, 5-15% open area is appropriate. (M.D.Egan Architectural Acoustics, J.Ross Publishing, 2007,p.74-76). The percent open area and diameter of the holes affects the acoustic transparency by determining the critical frequency, the frequency after which the sound absorption decreases rapidly. The critical frequency (f_c) above which sound absorption drops rapidly can be approximated using the following equation:

$$f_c \sim 40P/D$$

where:

f_c represents the critical frequency, Hz
P represents open area, %
D represents pore diameter, in

[0017] Examples of known acoustically transparent facings include woven meshes, fabrics with low density and non-woven scrims. The drawback of such facings is very low barrier, e.g., resistance to penetration of water, dust, and/or microorganisms.

[0018] The facing for use in the ceiling tile of the invention is highly resistant to the penetration of water and fine particles including microorganisms. The void fraction of the facing, i.e., 1 minus the solids fraction, is between about 0.5 and about 0.7. The facing has a pore diameter as measured by mercury porosimetry (H.M. Rootare, "A Review of Mercury Porosimetry" from Advanced Experimental Techniques in Powder Metallurgy. PlenumPress, 1970, pp. 255-252) between about 100 nm and about 20,000 nm and even between about 100 nm and about 1.500 nm. For the purpose of this invention, the pores include intra-fiber pores and inter-fiber pores. Intra-fiber pores are randomly distributed throughout the interior of a fiber and have a mean pore diameter from about 100 nm to about 1,000 nm. Inter-fiber pores are randomly distributed interstices between fibers in a plexifilamentary film-fibril sheet. The porous structure of the plexifilamentary film-fibril sheet consist of both types of pores forming torturous pore structure, rather then through hole structure found in mechanically perforated prior art facings. The mean pore diameter of the facing is less than about 20,000 nm, even less than about 5,000 nm, even less than about 2,000 nm, even less than about 1,000 nm and even between about 10 nm and about 1,000 nm.. Pore sizes between 10 nm and 1000 nm represent intra-fiber pores. Summing the volume of pores with a diameter between 10 nm to 1000 nm gives the volume of intra-fiber pores, called for the purpose of this invention as Vpore. Specific pore volume SPV (in units of cm^3/m^2) is defined as mathematical product of the nonwoven sheet basis weight (in units of g/m^2) and the sheet pore volume (in units of cm^3/g) for pores of a given mean diameter as disclosed in US Pub.. No.2006/0262310, also assigned to DuPont.

[0019] For some uses, such as cases in which the absorbing material contains no dust or nutrients to support the growth of microorganisms, it may be desirable to mechanically perforate the facing in order to open the structure and to increase the critical frequency value. It has been found that by perforating the facing, the overall acoustic absorption of the ceiling tile can be improved.

[0020] For some uses, it is desirable for the facing of the ceiling tile to provide a barrier to microorganisms including bacteria, viruses and mold. The facing has a log reduction value (LRV), which is a measure of microbial filtration, at least about 2 or even at least about 4, as measured according to ASTM F2638-07 and ASTM F1608. It is desired for the facing to have no flow rate or time-dependent LRV such that the facing has stable barrier efficiency and does not build up barrier over time during use, such as is the case for known laminated paper. The facing further does not include nutrients that support the growth of microorganisms, including bacteria, yeast and fungus, without any additional anti-bacterial or antifungal treatment.

[0021] The nonwoven facing for use in the ceiling tile of the invention includes a plexifilamentary film-fibril sheet formed by flash spinning, also referred to herein interchangeably as a flash spun plexifilamentary film-fibril sheet or a flash spun sheet. The nonwoven facing of the invention is lightweight, thin and strong. The basis weight of the facing is less than about 140 g/m^2, even between about 34 g/m^2 and about 120 g/m^2. The thickness of the facing is not more than about 1 mm, even between about 0.02 mm and about 0.40 mm, and even between about 0.10 mm and about 0.25 mm. Previously used thin facing materials provided negligible acoustic absorption and a low level of strength and durability. The flash spun facing according to the invention imparts a high degree of isotropic strength and durability which is important for the assembly and handling of the ceiling tile of the invention and stable long term performance. The preferred tensile strength of the facing in both machine and cross directions is not less than about 20 N/2.54 cm as measured by ASTM D5035.

[0022] It has been generally believed that for effective acoustic absorption, the wavelength of the sound to be absorbed and the thickness of the absorptive material should be on the same order of magnitude. Fig. 1 shows that the acoustic reflection coefficient is nearly 1.0 for flash spun plexifilamentary sheet for use as the nonwoven facing when tested in a blocked configuration in an impedance tube, and there is no acoustic absorption detected. By contrast, as depicted in Fig. 2, the same flash spun plexifilamentary sheet surprisingly exhibits acoustic absorption demonstrated by absorption coefficients between 0 and 0.2 and low acoustic reflection when tested in an anechoic configuration (with an air space located behind the sheet in the impedance tube) at low- and midrange frequencies, e.g., between about 200 and about 1200 Hz. It was previously believed that only thick materials and thick perforated facings with continuous through-holes were able to act as acoustic absorbers near the individual hole resonant frequencies (Helmholtz resonators) with closed air space behind the facing. Surprisingly, the facing of the ceiling tile of the invention, which does not have through-holes and which is very thin, has been found to enhance acoustic absorption at low- and midrange frequencies.

[0023] The flash spun sheet is produced by the following general process, also disclosed in U.S. Pat. No. 3,860,369. The flash spinning process is conducted in a chamber which has a vapor-removal port and an opening through which sheet material produced in the process is removed. Polymer solution is prepared at an elevated temperature and pressure and provided to the chamber. The pressure of the solution is greater than the cloud-point pressure, which is the lowest pressure at which the polymer is fully dissolved in the spin agent forming a homogeneous single phase mixture. The single phase polymer solution passes through a letdown orifice into a lower pressure (or letdown) chamber where the solution separates into a two-phase liquid-liquid dispersion. One phase of the dispersion is a spin agent-rich phase which comprises primarily spin agent and the other phase of the dispersion is a polymer-rich phase which contains most of the polymer. This two-phase liquid-liquid dispersion is forced through a spinneret into an area of much lower pressure (preferably atmospheric pressure) where the spin agent evaporates very rapidly (flashes), and the polyolefin emerges from the spinneret as plexifilaments which are laid down to form the flash spun sheet. During the flashing process, impurities are flashed along with the spin agent, so that the resulting flash spun sheet is free of impurities.

[0024] The term plexifilamentary or plexifilaments as used herein refers to a three-dimensional integral network of a multitude of thin, ribbon-like, film-fibrils of random length and with a mean fibril thickness of less than about 4 micrometers and a median width of less than about 25 micrometers. In plexifilamentary structures, the film-fibrils are generally coextensively aligned with the longitudinal axis of the structure and they intermittently unite and separate at irregular intervals in various places throughout the length, width and thickness of the structure to form a continuous three-dimensional network. Such structures are described in further detail in U.S. Pat. Nos. 3,081,519 and 3,227,794.

[0025] The sheet is consolidated which involves compressing the sheet between the belt and a consolidation roll into a structure having sufficient strength to be handled outside the chamber. The sheet is then collected outside the chamber on a windup roll. The sheet can then be bonded using methods known in the art, such as thermal bonding, through gas bonding and point bonding.

[0026] The diameter of the film-fibrils of the flash spun facing, i.e. between about 4 micrometers and about 25 micrometers, is in the range of ultrasound wavelengths. At frequencies between about 100 Hz and about 1600 Hz, the wavelength of sound is several orders of magnitude larger than the diameter of the film-fibrils. Nevertheless, thin plexifilamentary film-fibrils of the facing according to the invention surprisingly enhance the acoustic absorption of the acoustic absorber between about 100 Hz and about 1600 Hz, even between about 100 Hz and about 1200 Hz. This is the range of frequencies most often emitted by mechanical equipment and the human voice, and therefore most often encountered as undesirable noise in building interiors. Without wishing to be bound by theory, it is believed that the pore size distribution of the plexifilamentary film-fibrils of the flash spun sheet enhances the acoustic absorption of an acoustically absorbing core of an acoustically absorbing material or air space when the sheet is used as a facing on at least one surface of the core. It has furthermore surprisingly been found that flash spun sheet exhibits extremely high airflow resistance.

[0027] Polymers from which facings of the acoustically absorbing ceiling tile according to the invention can be made include polyolefin (e.g., polyethylene, polypropylene, polymethylpentene and polybutylene), acrylonitrile-butadiene-styrene (ABS) resin, polystyrene, styreneacrylonitrile, styrene-butadiene, styrene-maleic anhydride, vinyl plastic (e.g., polyvinyl chloride (PVC)), acrylic, acrylonitrile-based resin, acetal, perfluoropolymer, hydrofluoropolymer, polyamide, polyamide-imide, polyaramid, polyarylate, polycarbonate, polyesters, (e.g., polyethylene napthalate (PEN)), polyketone, polyphenylene ether, polyphenylene sulfide and polysulfone. Preferred amongst the polymers are the polyolefins, e.g., polyethylene and polypropylene. The term polyethylene as used herein includes not only homopolymers of ethylene, but also copolymers wherein at least 85% of the recurring units arise from ethylene. A preferred polyethylene is linear high density polyethylene having an upper limit of melting range of about 130° to 137°C, a density in the range of 0.94 to 0.98 g/cm^3 and a melt index (as defined by ASTM D-1238-57T, Condition E) of between 0.1 to 100, preferably between 0.1 and 4. The term polypropylene as used herein includes not only homopolymers of propylene but also copolymers wherein at least 85% of the recurring units arise from propylene units.

[0028] Nonwoven facings can further comprise a known UV stabilizer, antistatic agent, pigment and/or flame retardant dispersed within the polymer of the fibers of the nonwoven substrate.

[0029] The facing of the ceiling tile has the desirable combination of barrier, i.e., resistance to penetration of water, dust and/or microorganisms, and porosity resulting in high air flow or permeability and good acoustical performance. Acoustical absorption is a function of acoustic impedance, which is determined by a complex combination of acoustical resistance and acoustical reactance. The acoustical reactance is governed largely by material thickness, while acoustical resistance is governed by air flow through the material. Significant porosity is needed for acoustically transparent facings. On the other hand, barrier properties are needed for particulate and liquid resistance of the facing.

[0030] Facings of the ceiling tile according to the present invention can comprise single or multiple layers of flash spun sheet provided the acoustical absorption is not compromised. The multilayer sheet embodiment is also useful for averaging out nonuniformities in single sheets due to nonuniform sheet thickness or directionality of sheet fibers. Multilayer laminates can be prepared by positioning two or more sheets face to face, and lightly thermally bonding the sheets under applied pressure, such as by rolling the sheets between one or more pairs of nip rollers. Laminates of sheets are preferably prepared by adhering the sheets together with an adhesive, such as a pressure sensitive adhesive. Adhesives of utility are those that maintain sufficient structural integrity of the laminate during normal handling and use. Adhesives of utility include moisture curable polyurethane, solvated polyurethane adhesives and water-borne acrylics.

[0031] The reflectance of the ceiling tile facing is at least about 86%, even at least about 88%, even at least about

90% and even at least about 94%, over the visible light spectrum, i.e., over wavelengths between about 400 nm and 700 nm. The reflectance of flash spun facings according to the present invention decreases with increased thermal bonding. Thermal bonding reduces the volume of intra-fiber pores having a high scattering cross section per unit pore volume that contribute substantially to diffuse reflectance. Thermal bonding also reduces the volume of inter-fiber pores that also contribute to the diffuse reflectance. Flash spun sheet of utility in ceiling tiles according to the invention is preferably not bonded so heavily that reflectance is less than about 86%. Flash spun sheet of utility in ceiling tiles according to the invention is consolidated, and is preferably bonded to a degree necessary to maintain structural integrity of the sheet during manufacture of ceiling tiles. In particular, the sheet should have sufficient structural integrity so that the edges do not fray as the sheet is laminated to the ceiling tile core and subsequently cut into tiles. Preferably, the delamination resistance of the flash spun sheet is at least about 0.028 N/m. Delamination resistance is a measurement reported in units of force/length defined by ASTM D 2724 and relates to the extent of bonding in certain types of sheet, for example bonding in nonwoven sheet made from plexifilamentary film-fibrils.

[0032] The scattering and diffuse reflection of light by flash spun facings is due to reflection of light at air-polymer interfaces of the inter-fiber and intra-fiber pores resulting from the flash spinning process. Reflection will increase with an increase in the difference between the refractive index of the pore phase (air, refractive index of 1.0) and the refractive index of the fiber polymer phase. An increase in light scattering is observed typically when the difference in refractive index between two phases is greater than about 0.1. Polymer comprising the flash spun facing preferably has a high refractive index (for example polyethylene, refractive index of 1.51) and low absorption of visible light.

[0033] Flash spun facings according to the invention can further comprise particulate filler dispersed in the polymer phase forming the flash spun sheet fibers. Particulate fillers of utility will have a refractive index larger than the polymer and thus light scattering of the nonwoven sheet will increase with an increase in the difference between the refractive index of the pore phase (air, refractive index of 1.0) and the refractive index of the fiber polymer phase. Particulate fillers of utility have a high refractive index, high light scattering cross section and low absorption of visible light. Particulate filler enhances light scattering and thereby use of particulate filler can provide higher average reflectance for a given sheet thickness. Particulate fillers can be any shape and have a mean diameter of from about 0.01 micrometer to about 1 micrometer, preferably from about 0.2 micrometers to 0.4 micrometers. Flash spun sheets containing particulate filler comprise at least about 50% by weight polymer, and particulate filler comprises from about 0.05 weight % to about 50 weight %, preferably 0.05 weight % to about 15 weight %, based on the weight of the polymer. Example particulate fillers include silicates, alkali metal carbonates, alkali earth metal carbonates, alkali metal titanates, alkali earth metal titanates, alkali metal sulfates, alkali earth metal sulfates, alkali metal oxides, alkali earth metal oxides, transition metal oxides, metal oxides, alkali metal hydroxides and alkali earth metal hydroxides. Specific examples including titanium dioxide, calcium carbonate, clay, mica, talc, hydrotalcite, magnesium hydroxide, silica, silicates, hollow silicate spheres, wollastonite, feldspar, kaolin, magnesium carbonate, barium carbonate, magnesium sulfate, barium sulfate, calcium sulfate, aluminum hydroxide, calcium oxide, magnesium oxide, alumina, asbestos powder, glass powder and zeolite. Known methods are used to make the present nonwoven sheets containing particulate filler, such as those disclosed in U.S. Patent Number 6,010,970 and PCT publication number W02005/98,119.

[0034] The acoustically absorbent ceiling tile of the invention is particularly useful in critical indoor environments in which indoor air quality and cleanliness are critical, such as in schools, hospitals, cleanrooms, and the like. As a result of the flashing process during flash spinning of the facing, the resulting facing is free of impurities and the facing does not generate off-gassing of any volatile compounds. Furthermore, the facing is non-linting in that it does not release particles or fibers as a result of the high degree of consolidation of the single film-fibrils within the sheet structure. Furthermore, the acoustically absorbing core preferably contains substantially no VOCs. The facing can be cleaned by wiping or washing. The facing can also be sterilized by known methods including solution cleaning, physical energy radiation or gas sterilization. In situations in which cleaning and sterilizing the facing are not convenient, the flash spun facing can be disposed of and replaced at minimal expense and effort.

[0035] The facing of the ceiling tile can be further printed with a graphic design such as a pattern, image and/or text in order to be aesthetically desirable for the intended use. It is convenient to have the ability to replace the facing in order to change the image and/or text. By changing the facing, the aesthetics of the ceiling tile can easily and inexpensively be changed.

[0036] The present invention further includes a method of improving acoustic absorption and light reflectance in an environment comprising: (i) providing a ceiling tile comprising a core of acoustically absorbent material covered by a facing of flash spun non-woven sheet having a plurality of pores wherein the pores have a diameter between about 100 nm and about 20,000 nm and even between about 100 nm and about 1500 nm and wherein the pores have a mean pore diameter of less than about 20,000 nm, even less than about 5,000 nm, even less than about 2,000 nm, even less than about 1,000 nm and even between about 10 nm and about 1,000 nm; and (ii) positioning the ceiling tile within the environment to cause ambient sound to be absorbed and light to be diffusely reflected by the ceiling tile.

EXAMPLES

Test Methods

[0037] Basis Weight was measured by the method of ASTM D 3776, modified for specimen size, and reported in units of g/m^2.

[0038] Tensile Strength was measured according to ASTM D5035 and reported in units of N/25.4 cm.

[0039] Gurley Hill Porosity was measured according to TAPPI T460 and reported in seconds.

[0040] Frazier Air Permeability was measured according to ASTM D737-75 in CFM/ft^2 at 125 Pa differential pressure.

[0041] Hydrostatic Head was measured according to AATCC TM 127, DIN EN 20811 with a test rate of 60 cm of H_2O per minute.

[0042] Parker Surface Smoothness was measured according to TAPPI 555 at a clamping pressure of 1.0 MPa and is reported in micrometers.

[0043] Specific Airflow Resistance is equivalent to the air pressure difference across a sample divided by the linear velocity of airflow measured outside the sample and is reported in Ns/m^3. The values reported herein were determined as follows. The volumetric air flow Q was calculated by dividing the air permeability of the sample at a differential pressure of 125 Pa by the sample area (38 cm^2), using the following equation:

$$Q\ (\text{in m}^3/\text{s}) = 0.000471947 \times (\text{air permeability (in CFM/ft}^2)/\text{area (in ft}^2)).$$

Gurley Hill porosity (in seconds) is used for relatively low air permeability materials. For flash spun sheet of less than 101 g/m^2, the Frazier air permeability of 0.6 m^3/min/m^2 (2 ft^3/min/ft^2) corresponds to about 3.1 seconds; therefore Frazier air permeability (in CFM/ft^2) of the samples herein was approximated as 3.1/Gurley Hill porosity (in seconds).

[0044] Next, the airflow resistance in units of Pa-s/m^3 was calculated by dividing the differential pressure by the air flow Q. Finally, the specific airflow resistance in units of Ns/m^{3}was calculated by dividing the airflow resistance by the area of the sample.

[0045] Transmission, Reflection, and Absorption Coefficients as reported in Figures 1 and 2 were determined in anechoic and blocked impedance tube configuration according to ASTM E1050 and ISO 10534.

[0046] Sound Absorption Coefficient as reported in Fig. 3 was measured using a laboratory setting including a reverberant room in compliance with ASTM C 423, specimen mounting A (without air space) according to ASTM E 795. The absorbers were placed on the floor of the reverberant room in a 1 inch high aluminum test frame. The edges of the frame were sealed to the floor using duct tape to eliminate flanking noise. The sound absorption measurements were conducted at 1/3 octave bands from 80 to 5,000 Hz. Ten decay measurements were taken for every microphone position.

[0047] Total Reflectance Spectra of flash spun sheets were obtained by the method of ASTM E1164-02 (Standard Practice for Obtaining Spectrophotometric Data for Object-Color Evaluation) using a SP64 Portable Sphere Spectrometer available from X-Rite, Grand Rapids, Michigan, USA. Diffuse white light is used as the illuminant and the reflectance was measured at 8 degrees using a spectral dispersion system. The output is a percent reflectance at each wavelength and the spectral range measured is 400 nm to 700 nm in 10 nm intervals. Detection is made by blue-enhanced silicon photodiodes. The X-Rite standard provided with the instrument is traceable to National Institute of Standards and Technology, Gaithersburg, Maryland, USA. Tristimulus values are calculated by the method of ASTM E308-01 using the CIE 10° 1964 standard observer and illuminant D65.

[0048] Noise Reduction Coefficient was calculated as an average of the Sound Absorption Coefficients at 250, 500, 1000, 2,000 and 4,000 Hz as measured in accordance with ASTM C423.

[0049] Porosity and pore size distribution data are obtained by known mercury porosimetry methodology as disclosed by H. M. Rootare in "A Review of Mercury Porosimetry" from Advanced Experimental Techniques in Powder Metallurgy, pp. 225-252, Plenum Press, 1970.

[0050] Total Porosity was estimated from basis weight, thickness and solids density as follows:

$$\text{Porosity} = 1-((\text{Basis weight/density of solid} \times \text{thickness}))$$

[0051] Microbial Filtration Efficiency was measured according to the ASTM F2638-07 and ASTM F1608. Log reduction value or LRV characterizes barrier efficiency of the membrane and is determined from the test. The test can use both, polystyrene particles and actual spores to challenge the membrane.

Examples 1-2

[0052] Samples of acoustically absorbing material according to the invention were formed using a layer of open cell melamine foam (from Illbruck Acoustic Inc., Minneapolis, Minnesota) having a thickness of 13 mm, a basis weight of 9.4 kg/m^3 and a specific airflow resistance of 120 rayls. A 0.1 mm thick, 17 g/m^2 basis weight nylon 6, 6 spunbond scrim was laid on both sides of the foam and the scrims and foam were quilted together using a pattern of approximately 11 cm x 11 cm diamonds. The acoustically absorbing samples were made by the lamination process described below. A vinyl acetate water based glue (WA 2173 available from efi Polymers, Denver, Colorado) was applied by a roller onto one surface of the quilted foam layer at a rate of approximately 0.3 kg/m^2. A melt blown polyester nonwoven layer having a thickness of 20 mm, a basis weight of 0.33 kg/m^2, and a specific airflow resistance of 130 rayls was laminated to the quilted foam layer to form the absorber core. A flash spun nonwoven facing available from DuPont under the trade name DuPont™ Tyvek® style 1055B was wrapped around the core to form Example 1. A flash spun nonwoven facing available from DuPont under the trade name DuPont™Tyvek® style 1443R was wrapped around the core to form Example 2. The total absorber thickness of each of the examples was about 25 mm. The table includes properties of the facings used in the example absorbers. The range indicated for Gurley Hill porosity of Example 1 is based on the typical range within which the flash spun nonwoven varies according to specification. The average reflectance is the average of 31 measurements at wavelengths between 400 nm and 700 nm taken at 10 nm increments. Flash spun facing of Example 1 has a hydrostatic head of at least 180 cm of H_2O and facing of Example 2 has a hydrostatic head of at least 24 cm of H_2O according to the product specification (tested per AATCC TM 127, DIN EN 20811 with a test rate of 60 cm of H_2O per minute). The Table includes properties of the facings used in the example absorbers.

[0053] The Gurley Hill porosity of Example 1 and 2 was measured experimentally and it is well in agreement with the typical range within which the flash spun nonwoven varies for both Tyvek® styles according to specification. Air permeability, as measured by Gurley Hill porosity and Frazier air permeability characterizes the general porosity or openness of the structure. The range for air permeability for various types of nonwoven structures is very wide. Typically, all nonwovens have much more open structure with Frazier air permeability of about 50 cfm or higher. Solid films have very closed, solid structure, which is why films are called impervious, with Gurley Hill porosity well above 10,000 s. The air permeability of the flash spun facing can be changed from Gurley Hill range of about 4,000 s, like for Example 1 to Frazier air permeability to about 30 cfm, giving a range of Specific Air Flow Resistance of about 31,000,000 to 800 rayls.

[0054] Total porosity of the structure can be roughly estimated from the facing's basis weight, thickness and density of the polymer. Knowing polyethylene has a density of about 0.98 g/cm^3, the total porosity can be estimated as being about 0.6 for facing of Example 1 and about 0.7 for facing of Example 2. This is well in agreement with total porosity as measured by mercury porosimetry. The pore size range was from 10 nm to about 8,000 nm for Example 1 and from 10 nm to about 10,000 nm for Example 2, as measured by mercury porosimetry. The mean pore size was about 2,000 nm for both, Example 1 and Example 2. Solid films have total porosity of about 0, which means they have no voids or pores inside the structure. This is why solid films have extremely good barrier properties. Despite being very porous, inventive flash spun facing exhibits the water resistance range similar to the water resistance of solid impervious films as measured by hydrostatic head. The typical range of hydrostatic head for the inventive facing is from about 24 to about 230 cm H_2O, as illustrated by Example 1 and 2.

[0055] As can be seen from the table, inventive flash spun facings have various surface features as was measured by Parker surface smoothness. Example 1 has a Parker surface smoothness of about 4.5 micrometers; therefore, it exhibits a smooth sleek surface, similar to the printing quality paper. Contrarily, Example 2 has a Parker surface smoothness of about 8 micrometers, representing a rough surface with 3-dimentional features, in this case, ribbon-like features. The wide range of Parker surface smoothness allows the production of aesthetically pleasing surfaces to compliment design in various architectural spaces. Inventive facings can further comprise graphical images.

Table

Ex. No	Basis weight, g/m^2	Thickness micrometer	Gurley Hill porosity, second	Parker surface smoothness, μm	Tensile strength N/ 25.4 mm	Specific airflow resistance, rayls	Avg. Reflectance, %
1	61	163	3860	4.54 (face side) 11.26 (reverse side)	89 (MD and CD)	30,800,000	88.9

(continued)

Ex. No	Basis weight, g/m^2	Thickness micrometer	Gurley Hill porosity, second	Parker surface smoothness, μm	Tensile strength N/ 25.4 mm	Specific airflow resistance, rayls	Avg. Reflectance, %
2	42.3	140	77	7.93 (face side) 4.22 (reverse side)	26 (MD and CD)	615,156	88.2

[0056] A comparative sample was prepared similarly without the flash spun facing. The thickness of the comparative sample was about 25 mm.

[0057] The examples and comparative sample were conditioned at room temperature for at least two weeks after manufacturing, and at controlled conditions (temperature of 23°C and RH of 60%) for 24 hours before acoustic testing. Absorption coefficient data were obtained for each sample.

[0058] As can be seen in Fig. 3, the absorbers of Examples 1 and 2 as represented by curves 1 and 2, respectively, provide continuously improved absorption as compared with the comparative example as represented by curve C over the frequency range from 400 Hz to 1200 Hz.

Claims

1. A ceiling tile comprising:

a core of acoustically absorbing material having two major surfaces; and
a facing for covering the core on at least one major surface thereof, the facing comprising a flash spun plexifilamentary film-fibril sheet, having a basis weight of no greater than 140 g/m^2, comprising a plurality of pores having a pore diameter between about 100 nm and 20,000 nm and a mean pore diameter of less than 20,000 nm and having a light reflectance of greater than 86%, **characterised in that** the said sheet has a coherent surface and the acoustically absorbing material is nonwoven fabrics, woven fabrics, knit fabrics, three dimensional meshes, honeycomb structures, foams, perforated sheets and combinations thereof.

2. The ceiling tile of claim 1, wherein the acoustic absorption of the ceiling tile at a frequency below 1200 Hz is at least 5% higher than the acoustic absorption of the ceiling tile without the facing.

3. The ceiling tile of claim 1, wherein the delamination resistance of the flash spun sheet is at least 0.028.N/m.

4. The ceiling tile of claim 1, wherein the facing is perforated.

5. The ceiling tile of claim 1, wherein the flash spun plexifilamentary film-fibril sheet comprises particulate filler having a refractive index greater than the refractive index of the polymer.

6. The ceiling tile of claim 1, wherein the core of acoustically absorbing material has a noise reduction coefficient of between 0.3 and 0.9 and the noise reduction coefficient of the ceiling tile is approximately equivalent to the noise reduction coefficient of the core.

7. The ceiling tile of claim 1, wherein the facing has a Parker surface smoothness not less than 6 micrometers.

8. The ceiling tile of claim 1, wherein the facing has a Tensile strength of at least 20 N/2.54 cm.

9. The ceiling tile of claim 1, wherein the facing comprises a graphical image printed thereon.

10. The ceiling tile of claim 1, wherein the facing is free of nutrients that support growth of microorganisms.

11. The ceiling tile of claim 1, wherein the facing has a log reduction value of at least 2.

12. The ceiling tile of claim 1, wherein the facing comprises a polymer selected from the group consisting of polyethylene and polypropylene.

13. A method of improving acoustic absorption and light reflectance in an environment comprising:

(a) providing a ceiling tile comprising a core of acoustically absorptive material as defined in claim 1 covered by a facing of flash spun sheet having a plurality of pores having a pore diameter between 100 nm and about 20,000 nm and a mean pore diameter of less than 20,000 nm and having a light reflectance of greater than 86%; and
(b) positioning the ceiling tile within the environment to cause ambient sound to be absorbed and light to be reflected by the ceiling tile.

14. A ceiling tile as defined in claim 1 or a method as defined in claim 13, wherein the acoustically absorptive material is selected from : spunbonded nonwovens, carded nonwovens, needlepunched nonwovens, air-laid nonwovens, wet-laid nonwovens, spunlaced nonwovens, spunbonded-meltblown-spunbonded composite nonwovens and meltblown nonwovens, foams, such as open-cell melamine foam, polyimide, polyolefin, and polyurethane foams, perforated sheets, and formaldehyde-free fiberglass batting.

Patentansprüche

1. Deckenplatte umfassend:

einen Kern aus akustisch absorbierendem Material, das zwei Hauptflächen aufweist; und
eine Verkleidung zum Bedecken des Kerns auf mindestens einer Hauptfläche davon, wobei die Verkleidung eine flash-gesponnener Plexifilament-Folienfibrillenplatte umfasst, die ein Grundgewicht von nicht mehr als 140 g/m^2 aufweist und eine Mehrzahl von Poren umfasst, die einen Porendurchmesser zwischen etwa 100 nm und 20000 und einen mittleren Porendurchmessser von weniger als 20000 nm und einen Lichtreflektionsgrad von mehr als 86 % aufweist, **dadurch gekennzeichnet, dass** die Platte eine kohärente Oberfläche aufweist und das akustisch absorbierende Material aus Vliesstoffen, Geweben, Strickstoffen, dreidimensionaler Maschenware, Wabenstrukturen, Schaumstoffen, perforierten Platten und Kombinationen davon besteht.

2. Deckenplatte nach Anspruch 1, wobei die akustische Absorption der Deckenplatte bei einer Frequenz unter 1200 Hz mindestens 5 % höher ist als die akustische Absorption der Deckenplatte ohne die Verkleidung.

3. Deckenplatte nach Anspruch 1, wobei die Delaminierungsresistenz der flashgesponnenen Platte mindestens 0,028 N/m beträgt.

4. Deckenplatte nach Anspruch 1, wobei die Verkleidung perforiert ist.

5. Deckenplatte nach Anspruch 1, wobei die flash-gesponnene Plexifilament-Folienfibrillenplatte teilchenförmigen Füllstoff umfasst, der einen Brechungsindex aufweist, der höher ist als der Brechungsindex des Polymers.

6. Deckenplatte nach Anspruch 1, wobei der Kern des akustisch absorbierenden Materials einen Lärmreduktionskoeffizienten zwischen 0,3 und 0,9 aufweist und der Lärmreduktionskoeffizient der Deckenplatte etwa dem Lärmreduktionskoeffizienten des Kerns äquivalent ist.

7. Deckenplatte nach Anspruch 1, wobei die Verkleidung eine Oberflächenglätte Parker gemäß von nicht weniger als 6 Mikrometern aufweist.

8. Deckenplatte nach Anspruch 1, wobei die Verkleidung eine Zugfestigkeit von mindestens 20 N/2,54 cm aufweist.

9. Deckenplatte nach Anspruch 1, wobei die Verkleidung ein darauf aufgedrucktes graphisches Bild umfasst.

10. Deckenplatte nach Anspruch 1, wobei die Verkleidung von Nährstoffen frei ist, die das Wachstum von Mikroorganismen unterstützen.

11. Deckenplatte nach Anspruch 1, wobei die Verkleidung einen Log-Reduktionswert von mindestens 2 aufweist.

12. Deckenplatte nach Anspruch 1, wobei die Verkleidung ein Polymer umfasst ausgewählt aus der Gruppe bestehend aus Polyethylen und Polypropylen.

13. Verfahren zum Verbessern der akustischen Absorption und des Lichtreflektionsgrads in einer Umgebung, umfassend:

(a) das Bereitstellen einer Deckenplatte umfassend einen Kern aus akustisch absorbierendem Material wie in Anspruch 1 definiert, das durch eine Verkleidung aus flash-gesponnener Platte bedeckt ist, die mehrere Poren aufweist, die einen Porendurchmesser zwischen 100 nm und etwa 20.000 nm und einen mittleren Porendurchmessser von weniger als 20.000 nm und einen Lichtreflektionsgrad von mehr als 86 % aufweist; und
(b) das Positionieren der Deckenplatte innerhalb der Umgebung, um zu verursachen, dass durch die Deckenplatte ein Umgebungslärm absorbiert und Licht reflektiert wird.

14. Deckenplatte wie in Anspruch 1 definiert oder Verfahren wie in Anspruch 13 definiert, wobei das akustisch absorbierende Material ausgewählt wird unter Spinnvliesstoffen, kardierten Vliesstoffen, Nadelvliesstoffen, luftgelegten Vliesstoffen, nassgelegten Vliesstoffen, Spunlaced-Vliesstoffen, spunbond-schmelzgeblasenenspunbond Verbundvliesstoffen und schmelzgeblasenen Vliesstoffen, Schaumstoffen wie offenzelligem Melaminschaumstoff, Polyimid-, Polyolefin- und Polyurethanschaumstoffen, perforierten Platten und formaldehydfreier Glasfaser-Wattierung.

Revendications

1. Tuile pour plafond comprenant:

un noyau de matériau acoustiquement absorbant ayant deux surfaces principales; et
un parement de recouvrement du noyau sur au moins une surface principale de celui-ci, le parement comprenant une feuille de film-fibrille plexifilamenteuse de filage éclair ayant un poids de base non supérieur à 140 g/m^2, comprenant une pluralité de pores ayant un diamètre de pore compris entre environ 100 nm et 20000 nm et un diamètre moyen de pore inférieur à 20000 nm et ayant une réflectance de la lumière supérieure à 86 %, **caractérisée en ce que** ladite feuille a une surface cohérente et le matériau acoustiquement absorbant correspond à des textiles non-tissés, des textiles tissés, des textiles tricotés, des tulles en trois dimensions, des structures en nid d'abeilles, des mousses, des feuilles perforées et leurs combinaisons.

2. Tuile pour plafond selon la revendication 1, dans laquelle l'absorption acoustique de la tuile pour plafond à une fréquence située en dessous de 1200 Hz est au moins 5 % supérieure à l'absorption acoustique de la tuile pour plafond sans le parement.

3. Tuile pour plafond selon la revendication 1, dans laquelle la résistance de déstratification de la feuille de filage éclair est d'au moins 0,028 N/m.

4. Tuile pour plafond selon la revendication 1, dans laquelle le parement est perforé.

5. Tuile pour plafond selon la revendication 1, dans laquelle la feuille de film-fibrille plexifilamenteuse de filage éclair comprend une charge sous forme de particule ayant un indice de réfraction supérieur à l'indice de réfraction du polymère.

6. Tuile pour plafond selon la revendication 1, dans laquelle le noyau du matériau acoustiquement absorbant a un coefficient de réduction des bruits compris entre 0,3 et 0,9 et le coefficient de réduction des bruits de la tuile pour plafond est approximativement équivalent au coefficient de réduction des bruits du noyau.

7. Tuile pour plafond selon la revendication 1, dans laquelle le parement a un lissé de la surface selon un procédé de Parker non inférieur à 6 micromètres.

8. Tuile pour plafond selon la revendication 1, dans laquelle le parement a une résistance à la traction d'au moins 20 N/2,54 cm.

9. Tuile pour plafond selon la revendication 1, dans laquelle le parement comprend une image graphique imprimée dessus.

10. Tuile pour plafond selon la revendication 1, dans laquelle le parement est exempt de nutriments qui supportent le développement de micro-organismes.

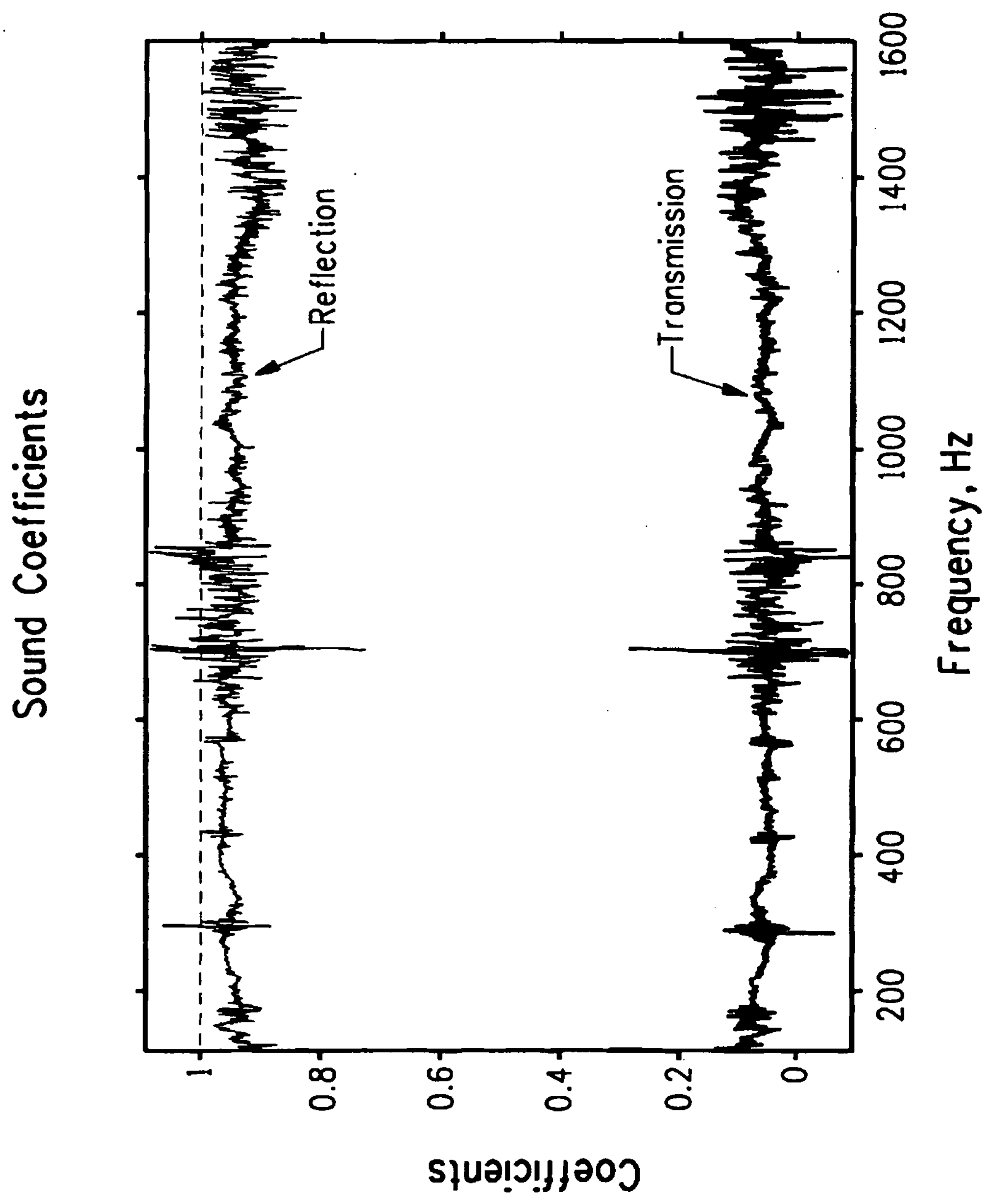
11. Tuile pour plafond selon la revendication 1, dans laquelle le parement a une valeur de réduction logarithmique d' au moins 2.

12. Tuile pour plafond selon la revendication 1, dans laquelle le parement comprend un polymère choisi parmi le groupe constitué du polyéthylène et du polypropylène.

13. Procédé d'amélioration de l'absorption acoustique et de la réflectance à la lumière dans un environnement comprenant:

(a) la fourniture d'une tuile pour plafond comprenant un noyau de matériau acoustiquement absorbant tel que défini selon la revendication 1, recouvert d'un parement de feuille de filage éclair ayant une pluralité de pores ayant un diamètre de pore compris entre 100 nm et environ 20 000 nm et un diamètre moyen de pore inférieur à 20 000 nm et ayant une réflectance à la lumière supérieure à 86 %; et
(b) le positionnement de la tuile pour plafond dans le milieu afin de provoquer l'absorption du son ambiant et la réflexion de la lumière par la tuile pour plafond.

14. Tuile pour plafond telle que définie selon la revendication 1 ou procédé tel que défini selon la revendication 13, dans laquelle(lequel) le matériau acoustiquement absorbant est choisi parmi: les non-tissés filés liés, les non-tissés cardés, les non-tissés piqués à l'aiguille, les non-tissés à couche appliquée par jet d'air, les non-tissés à couche appliquée par voie humide, les non-tissés liés par j et d'eau, les non-tissés composites de filés liés-de fusion soufflage-filés liés et les non-tissés de fusion soufflage, les mousses, telles que la mousse mélamine à alvéoles ouvertes, les mousses de polyimide, de polyoléfine et de polyuréthane, les feuilles perforées, et les nappes en fibre de verre sans formaldéhyde.


Sound Coefficients
Reflection
Transmission
Coefficients
Frequency, Hz
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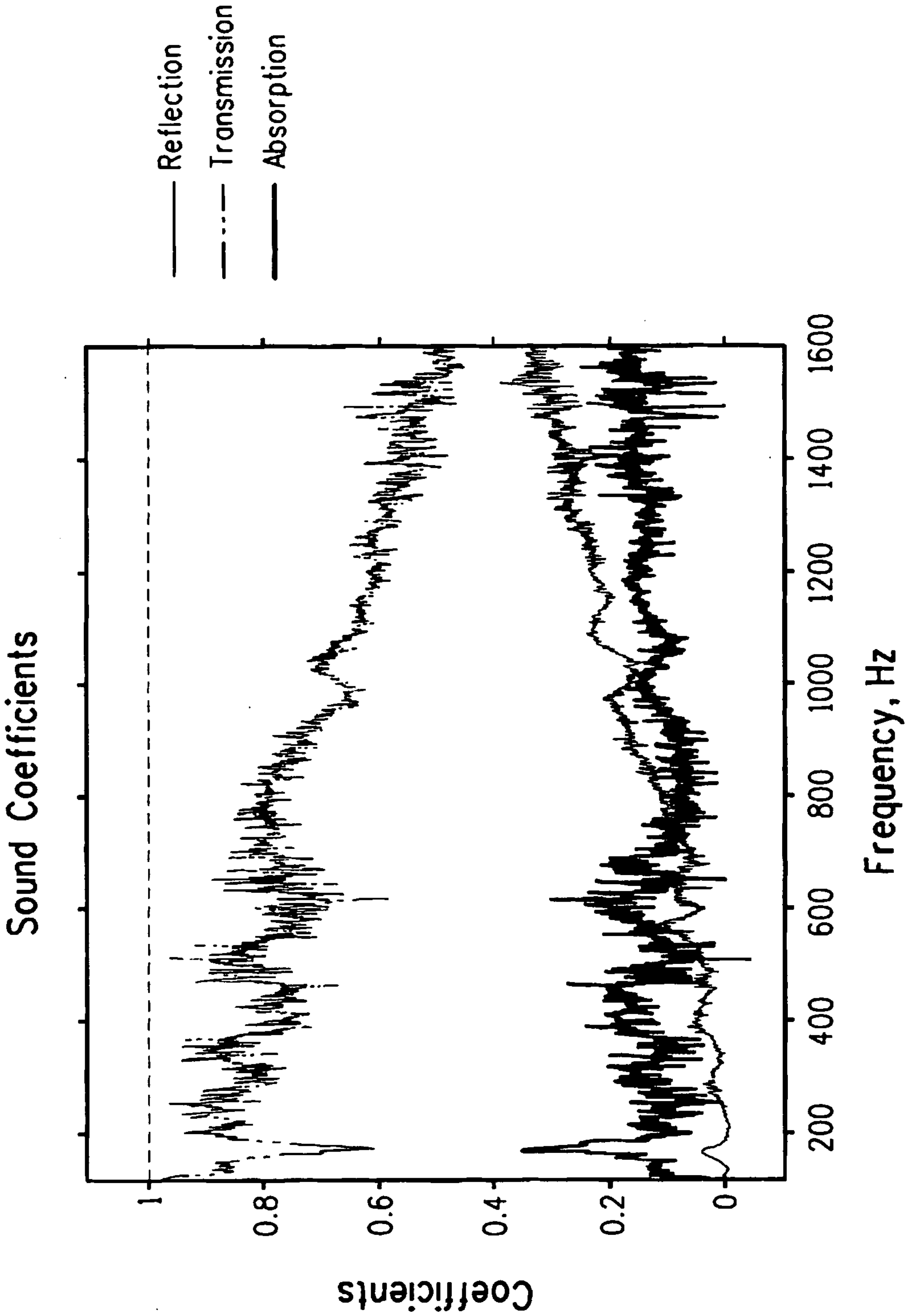
0.4
0.6
0.8
1
200
400
600
800
1000
1200
1400
1600

FIG. 1


Sound Coefficients
Reflection
Transmission
Absorption
Coefficients
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0.4
0.6
0.8
1
200
400
600
800
1000
1200
1400
1600
Frequency, Hz

FIG. 2

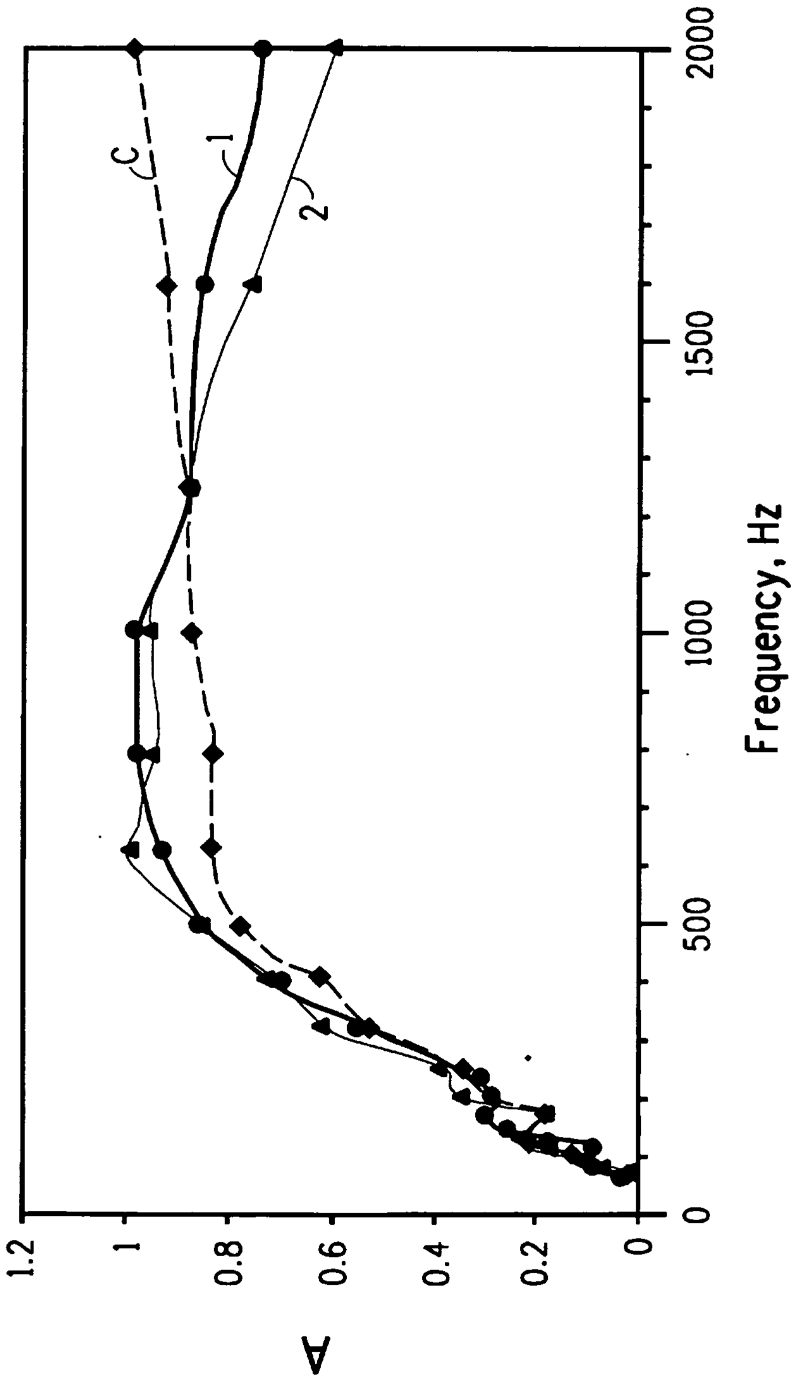

FIG. 3

REFERENCES CITED IN THE DESCRIPTION

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