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METHOD OF MAKING A TRANSDUCER DIAPHRAGM

Harold J. Luth, 397 W. 21st St., Holland, Mich.

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This invention relates to a transducer diaphragm and a method of making the same in which the diaphragm has a low weight to strength ratio and is acoustically substantially inert.

Most transducer diaphragms, such as loudspeaker cones, and particularly those of larger sizes, are made of paper and are produced by a felting process. In many of these of large size, the weight to strength ratio is relatively high so that the diaphragms have poor transient response. In order to have good transient response, the diaphragm such as a loudspeaker cone must be capable of being started abruptly by energization of the voice coil and must stop abruptly when this energization stops. In addition, in order to have good transient response, the diaphragm must transmit its force to the air sharply. These qualities mean that a diaphragm of good transient response must have low inertial characteristics. In addition, an ideal diaphragm must be acoustically inert.

The transducer diaphgrams of this invention have the above desired characteristics.

One of the features of this invention is to provide a transducer diaphragm comprising a lightweight uncompressed fibrous sheet and a self-sustaining cured resin coating on the sheet, the sheet being expanded and substantially uncompressed whereby the combined sheet and resin has an apparent density less than its absolute density.

Another feature of the invention is to provide an improved method of making a transducer diaphragm comprising providing a mold having a surface of the desired diaphragm shape and contour, applying to the surface a thin fibrous sheet material, applying to this material a liquid thermosetting resin and curing the resin while the material and resin are relatively free and unconfined.

Other features and advantages of the invention will be apparent from the following description of certain embodiments thereof.

In producing the diaphragms of this invention, a mold of the desired shape and contour is used. The uncured diaphragm is arranged on the surface of this mold and cured in a relatively free and unconfined state under substantially no pressure so that the resulting diaphragm will have a low apparent specific gravity when compared to its absolute gravity. As is well known, a material in an expanded open state will have a specific gravity, called the apparent specific gravity, that is much less than its absolute or true specific gravity or density. Thus, for example, pure cellulose has an absolute or true density of 1.583. Yet, certain forms of cellulose such as certain types of wood may have a density as low as 0.32.

In this invention, any type of mold may be used as desired. This mold must have a surface, preferably a convex surface when a cone is being molded, that has generally the shape and contours of the finished diaphragm. In the general process, a sheet of fibrous material somewhat larger than the finished diaphragm is placed on the mold surface and is coated with a binder to hold the sheet material in shape for subsequent treatment. In the preferred process, this binder is in the form of a water solution. After the sheet material is coated with the solution, it is heated to drive off the water which with most fibrous materials will also cause an expanding and loosening of the fibers and a setting of the binder. The dried sheet material with the binder is then coated with a liquid thermosetting resin and the resin is partially cured to an adherent yet flexible state. The sheet material is then removed from the mold, trimmed at the edges and center to the shape and dimensions of the final diaphragm, replaced on the mold surface and the cure is completed to produce a strong, self-sustaining low density diaphragm.

The following examples are illustrative only of methods and diaphragms embodying the invention:

Example 1

In this example, a conventional mold for a loudspeaker diaphragm was provided for a 10 inch cone. A disc of cotton muslin having a thread count of about 40 x 40 and about 5 mils thick was cut in circular shape with a diameter about two inches larger than the diameter of the cone. A 5% solution of polyacrylamide was prepared with the polyacrylamide being of such grade to produce a viscosity of about 5 poises in the 5% water solution. The mold was heated in an oven to about 115° C. and a mold release wax applied to the mold with the wax being made up of equal parts of paraffin wax and carnauba wax to which enough Stoddard Solvent had been mixed to produce a soft paste. After the mold had been coated with this release wax, the cotton muslin was dipped in water, most of the water squeezed out until the muslin was just damp and the muslin then stretched smoothly over the mold surface. Immediately the above polyacrylamide solution was brushed on the cloth with sufficient pressure being applied to press the cloth down in contact with the mold and to coat the cloth thoroughly. The heated mold caused the water to steam thereby driving off the water and causing the cotton fibers to swell. The mold was then placed in the oven to drive off the last traces of the water.

When the mold and muslin was dry, the mold was removed from the oven and a liquid resin mixture of 12 grams of epoxy resin (epoxide equivalent 175–210) and 3 grams of triethylene tetramine was brushed on the dry muslin in the mold. The mold and the thusly coated muslin were then returned to the oven and permitted to remain there until the resin had reached an intermediate gel stage in its curing but before the resin had hardened to its final cured state. The still pliable coated muslin was then removed from the mold and trimmed around the edge and in the center for the voice coil. The trimmed cone was then replaced in the mold, reshaped into intimate contact with the mold surface and returned to the oven for completion of the cure which took only about four or five minutes. At the end of the curing time, the mold and cone were removed from the oven and the cone removed from the mold.

During this procedure, the muslin sheet and the applied coating materials were left free and unconfined of any molding pressure. Thus the resulting cone was extremely strong, yet had good sound characteristics.

Example 2

In this example, substantially the same procedure was followed as given above. Here, the cotton cloth had a 36 x 46 count and the yarn had a nominal diameter of 4 to 5 mils. The cone here was also for a 10 inch speaker and had a maximum depth at the center of 2⅜ inches, an outside diameter of 8¼ inches and the finished cone had a center voice coil opening of 1 inch diameter. The resin used had the following ingredients:

Epoxy resin—epoxide equivalent 175–210	140.
Epoxy resin—epoxide equivalent 225–290	60 parts/wt.
Titanium dioxide	3.
Precipitate calcium carbonate 3–4 microns	27.
Of the above	12.
Triethylene tetramine	3.

In this example, the cloth was wet as set out above and uniformly formed in the hot mold with polyacrylamide as described above in Example 1. The mold and shaped cloth was held in the oven at 135° C. for 5½ minutes, and removed from the oven and the resin applied to the coth, returned to the oven and the resin precured for five minutes. At the end of this time, the partially cured cone is removed from the mold, punched and trimmed as described above and again cured for three minutes in the oven as set out above before the finished cone was removed from the oven. The entire procedure took about 17 minutes. The resulting cone weighed 13½ grams, had an average thickness of 15 mils and a specific gravity of 1.15 to 1.18.

This compares with conventional materials cured under heat and pressure which have specific gravities of from 1.45 to 1.5. The new cone had excellent strength and when installed in a loudspeaker was found to have excellent transient responses. The frequency response on sweep frequency was free of peaks and valleys.

Example 3

In this example, the cone was prepared by the method set out in Example 2, but here a polyester resin was used instead of the epoxy resin. The polyester resin was a copolymer of an alkyd resin and styrene. The polyester resin was a liquid with a styrene content of about 35% by weight. The resin mixture used had a viscosity of about 1 poise and the following constituents:

	Grams
Polyester resin	20
Calcium carbonate	3
Titanium dioxide	0.3
Peroxide catalyst	0.3

The same procedure in making the diaphragm was followed here as was followed in Example 2. The initial curing time was 8 minutes in the oven at 115° C. and the final curing was for 8 minutes. The cone weighed 14½ grams and had a mean thickness of 14 to 15 mils.

Example 4

In this example a series of cones were made by the method of Example 2, using the following binder solutions:

Methylcellulose	5% sol. in water of 15 cps. methylcellulose.
Methylcellulose	10% sol. in water of 15 cps. methylcellulose.
Hydroxyethylcellulose	5%—300 cps. H.E. cellulose.
Sodium carboxy methylcellulose	2% sol. in water—30–80 cps.
Polyacrylamide	1% water sol.
Polyacrylamide	2% water sol.
Polyacrylamide	3% water sol.
Polyacrylamide	4% water sol.
Polyacrylamide	5% water sol.

Example 5

In this example a series of cones were prepared by the method of Example 2, using in place of the triethylene tetramine, ethylene diamine, diethylene triamine, and tetraethylene pentamine.

Example 6

In this example, a cone was prepared by the same method as given in the above Example 2, except that glass cloth was used in place of the cotton. This glass cloth had a weight of 17 grams per square foot, a thickness of about 5 mils, and a 30 x 34 thread count. The resulting cone weighed 13½ grams and had a thickness of 11–12 mils.

Example 7

In this example, the cone was prepared by the method set out in Example 2, using the same materials and curing temperatures. The mold was such that the resulting cone had a maximum depth at the apex of 2⅛ inches and a diameter of 10¼ inches. The cone had a central opening for a 1½ inch voice coil and weighed 19 grams and had a thickness of 13–15 mils. When the cone was fitted as a part of a loudspeaker, the frequency response was found to be very smooth, extending down to approximately 30 cycles per second and had a barely audible harmonic response. The high frequency response extended to 15,000 cycles and transient response was very good.

In general, the diaphragm of this invention is made of fibrous sheet material preferably produced from fabrics such as cotton, wool, glass cloth or the various synthetic fabrics such as nylon, Orlon and Dacron and various combinations of these. The resins that may be used are any thermosetting resin that can be applied in a liquid state and that can be cured to a strong solid. These include epoxy resins, phenol or urea aldehyde resins and the various copolymer resins of alkyds and monomers copolymerizable therewith particularly styrene.

The water soluble binder or stiffener which is preferably initially applied to the fibrous material sheet includes polyacrylamide, the various alkyl celluloses, hydroxyalkylcelluloses, and alkali metal salts of carboxy akyl celluloses and polyacrylamide.

Having described my invention as related to the embodiments set out herein, it is my intention that the invention be not limited by any of the details of description, unless otherwise specified, but rather be construed broadly within its spirit and scope as set out in the accompanying claims.

I claim:

1. The method of making a transducer diaphragm, comprising: providing a mold having a surface of the desired diaphragm shape and contour; applying to said surface a thin fibrous sheet material; wetting said sheet material with water to aid in obtaining intimate contact of said material with the mold; heating said sheet material to above the boiling point of water to drive off the water and loosen the fibers in the material; applying to said material a liquid thermosetting resin; and curing said resin while said material and resin are free and unconfined.

2. The method of making a transducer diaphragm, comprising: providing a mold having a surface of the desired diaphragm shape and contour; applying to said surface a thin fibrous sheet material; wetting said sheet material with water to aid in obtaining intimate contact of said material wth the mold; coating said material with a water solution of a binder; heating said sheet material to above the boiling point of water to drive off the water and loosen the fibers in the material; applying to said material a liquid thermosetting resin; partially curing the resin to a self-sustaining condition to form a blank; removing the blank from the mold and cutting it to the desired dimensions; replacing the blank in the mold; and curing said resin while said material and resin are free and unconfined.

3. The method of claim 2 wherein said binder is a solution of a member of the class consisting of polyacrylamide, the alkyl celluloses, the hydroxy alkylcelluloses,

alkali metal salts of carboxy alkyl cellulose, and alkali metal salts of polyacrylamide, and said resin is a member of the class conssting of epoxy resins, phenol aldehyde resins, urea aldehyde resins, and alkyd-styrene copolymers.

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