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UNDERWATER ACOUSTIC DIAPHRAGM

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Fig. 1.

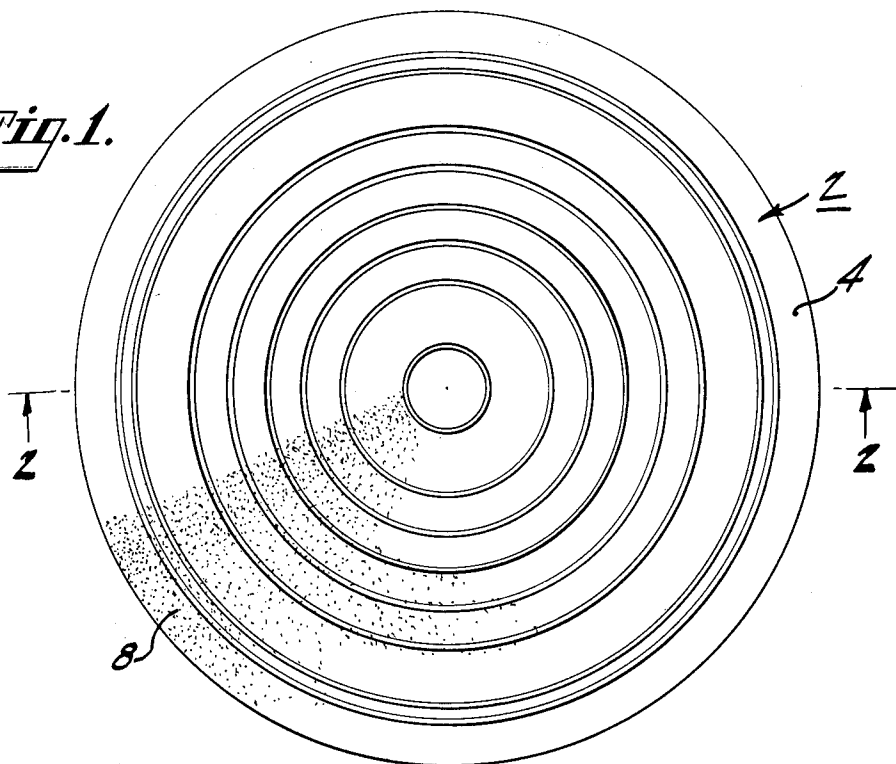
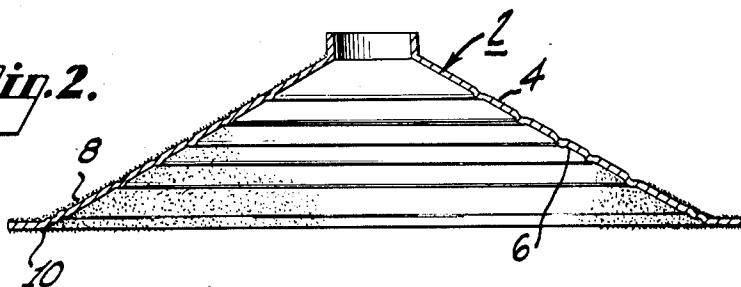


Fig. 2.



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UNDERWATER ACOUSTIC DIAPHRAGM

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3 Claims. (Cl. 181—32)

This invention relates to improved materials for making acoustic diaphragms and, more particularly, to acoustic materials intended to be used submerged in water.

Loudspeakers which are placed on the decks of submarines are necessarily exposed to water for extended periods of time whenever the submarine submerges. In the past, various types of loudspeakers have been used in this type of service, including cone-type speakers. All parts of the loudspeaker must be made of waterproof material. Waterproof materials suitable for loudspeaker cones have formerly been known and used. These cones, however, have been found to suffer from disadvantages in battle use. It has been found that ordinary waterproof speaker cones are often punctured by nearby, underwater explosions when the cone is submerged. A cone which has thus been punctured is useless for further service and must be replaced.

The present invention relates to an acoustic material comprising a web of flexible, fibrous material impregnated with a water-insoluble resin and having a surface coating of a water-insoluble, hydrophilic, film-forming substance. The invention also includes acoustic diaphragms made of this improved material.

One object of the present invention is to provide an improved waterproof material suitable for loudspeaker cones intended for underwater use.

Another object of the invention is to provide an improved waterproof acoustic diaphragm.

Another object of the invention is to provide an improved loudspeaker cone for underwater use.

Another object of the invention is to provide an improved loudspeaker cone which will resist the effects of underwater explosions.

These and other objects will be more apparent and the invention will be more readily understood from the following detailed description, including the drawings, of which:

Fig. 1 is a plan view of one form of acoustic diaphragm made of the improved material of the present invention, and

Fig. 2 is a cross section view taken along the line 2—2 of Fig. 1.

Acoustic diaphragms, such as used in loudspeaker cones, are usually made of a thin, flexible web of molded, felted, fibrous, cellulosic material. Small percentages of resinous binders may be mixed with the fibrous material. The cellulosic material is usually a good grade of wood pulp, which may be combined with various amounts of less expensive fibers, such as waste paper or textile fibers. Acoustic diaphragms may also be molded out of impregnated textile fabrics or even fine mesh wire screen material. If the diaphragm is to be exposed to water or if it must be submerged in water, the fibrous base material is usually impregnated with relatively high percentages of waterproof binder. The waterproof binder is usually a water-insoluble, thermosetting resin. Any water-insoluble, thermosetting, resin may be used. Preferred examples are condensation products such as urea

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formaldehyde resins, phenol formaldehyde resins, melamine formaldehyde resins, and phenol furfural resins. These and other thermosetting resins generally have water-repellent, or hydrophobic, properties.

It has been found, as previously mentioned, that speaker cones made of fibrous materials impregnated with these resins are subject to puncture if used in places subject to underwater explosions. The present invention is a result of the discovery that rupturing of the cones by explosions is due to entrapment of air bubbles on the surface of the cone. Air bubbles are trapped due to the hydrophobic properties of the waterproof resin binder. Apparently, when an explosion occurs nearby in the water, any entrapped air bubbles upon the surface of the cone rapidly contract and deliver a hammer-like blow to the surface of the cone over a small area. The blow often has sufficient force to cause a puncture. If an attempt is made to make the diaphragm out of material strong enough to withstand the puncturing force, the cone usually does not have sufficiently good acoustic response.

It has been found that the waterproof properties may be retained and, at the same time, the entrapment of air bubbles prevented by providing the surface of a waterproofed speaker cone with a coating of a water-insoluble, hydrophilic material. This is illustrated in the drawing wherein a typical loudspeaker cone 2, having an outer surface 4 and an inner surface 6, is provided with a coating 8 on the outer surface and a similar coating 10 on the inner surface.

The coating must be a water-insoluble, hydrophilic substance which adheres well to the base material. A hydrophilic substance is one which is readily wetted by water. That is, if a spray of water is directed to a surface composed of the substance, it will form a uniform film over the surface instead of gathering in droplets, as would be the case with a hydrophobic material.

A preferred coating substance for the present invention comprises an insolubilized and partially hydrolyzed polyvinyl alcohol. A suitable insolubilized polyvinyl alcohol can be made by first saponifying about 50% of the acetate groups of polyvinyl acetate. This polyvinyl alcohol is then made increasingly water resistant by giving it an insolubilizing treatment by any one of a number of well known methods. For example, the partially hydrolyzed polyvinyl alcohol may be acidified with hydrochloric acid to a pH of 4-5. A coating of this material may then be applied to the diaphragm by any convenient method, such as by dipping, spreading, or brushing. After draining off the excess solution, the diaphragm is heated in an oven for about 30 minutes at 150° C. The resultant surface is both waterproof and also sufficiently hydrophilic to prevent trapping of air bubbles when the diaphragm is under water.

The partially hydrolyzed polyvinyl alcohol may also be insolubilized by heating it with a small proportion of dimethylol urea, using ammonium chloride as a catalyst. An acoustic diaphragm may be provided with a coating of the material by, first, mixing the three ingredients, applying the mixture to the surface of the diaphragm, and heating for at least 15 minutes at 150° C. More specifically, the above solution may be made by first dissolving 10 parts by weight of the partially hydrolyzed polyvinyl alcohol, previously referred to, in a mixture composed of 100 parts by weight of any suitable solvent such as ethanol or propanol and 100 parts by weight of water. A second solution is made up by dissolving 5 parts by weight of dimethylol urea in 100 parts by weight of water. A third solution is made up by dissolving 5 parts by weight of ammonium chloride in 100 parts by weight of water. The coating mixture is made by mixing 5 parts by volume of the polyvinyl alcohol solution with 1 part by volume of the dimethylol urea solution, 1 part by volume

of the ammonium chloride solution, 10 parts by volume of water, and 12 parts by volume of ethanol or propanol. In a preferred form of carrying out the invention, a speaker cone composed of a cloth impregnated with phenol formaldehyde resin was treated with two coats of the above described solution. Each coat was permitted to dry in air and then each was heated for 15 minutes at 150° C. The cone was then further treated with a solution comprising 5 parts by volume of the ethanol or propanol solution of polyvinyl alcohol, described above, 15 parts by volume of alcohol (such as ethanol or propanol), 10 parts by volume of water and 0.5 part by volume of 10% hydrochloric acid. After treating with this solution, applied as a coating, the diaphragm was again permitted to air dry and then heated for 15 minutes at 150° C.

It was also found that the hydrophilic properties of the cones made as above described could be improved somewhat by scrubbing them in water with a soft bristle brush until the surface became uniformly wetted by the water.

In general, the polyvinyl alcohol should be hydrolized to the extent that it is still water-wettable. The partially hydrolized material should then be insolubilized just so that it is substantially insoluble in water. Any polyvinyl alcohol meeting these two requirements can be used in the present invention.

Although water-wettable, water-insoluble, polyvinyl alcohol is the preferred coating material for use in the invention, other materials can also be used. A film of rubber latex may be used, for example. This may be applied to the surfaces of a resin-impregnated acoustic diaphragm, either from aqueous emulsion or organic solvent solution. The volatile components are permitted to evaporate. An example of a suitable rubber latex is a copolymer of butadiene and acrylonitrile. Any of the commercially available copolymers may be used, such as "Hycar OR-15" or "Hycar OR-25." Copolymers of butadiene and styrene may also be used. An example of this type of copolymer is "Hycar OS-10." The latex films do not adhere firmly to all types of resinous surfaces, however. In general, the rubber latex which is used may be any synthetic rubber having hydrophilic properties. Natural rubber latex may also be used.

Another example of a film-forming substance which can be used as the water-wettable coating of the present invention is an emulsion of a polyvinyl chloride. Various wetting agents may be incorporated with the emulsion to improve its spreading properties when it is applied to the diaphragm. Suitable wetting agents include isopropyl naphthalene sodium sulfonate, dioctyl ester of sodium sulfosuccinic acid, sodium tetrahydronaphthalene sulfonate, and cetyl dimethyl benzyl ammonium chloride. Any other compatible wetting agent may also be used. As an example of use, an aqueous emulsion of polyvinyl chloride was prepared having 56.5% solids content by weight and containing 1.5% by weight wetting agent. A thin coating of this composition was applied to both surfaces of a waterproof speaker cone and the cone was then heated at 150° C. for 15 minutes. The wetting agent can be omitted if desired. It does not affect the hydrophilic properties of the dried film to any extent.

Still another example of a hydrophilic, film-forming, water-insoluble substance which can be used as the surface coating in the materials of the present invention is

hardened gelatin. The gelatin can be applied as a water sol and hardened by any wellknown method such as soaking in a solution of chrome alum, or a dichromate. Although resistant to the swelling action of water, the hardened, insoluble gelatin is hydrophilic.

There has thus been described an improved material having waterproof and water-wettable properties. Although the material is suitable for use in any application requiring a water-wettable but water-insoluble surface, it is particularly adapted to be used as the acoustic diaphragm in a loudspeaker which is submerged in water at least a part of the time. There has also thus been described an improved acoustic diaphragm for underwater use and not readily subject to rupture due to nearby underwater explosions.

I claim as my invention:

1. In underwater sound equipment, an acoustic diaphragm capable of resisting the shock of nearby underwater explosions, said diaphragm comprising a molded web of porous, flexible fabric impregnated with a water-insoluble, hydrophobic, thermosetting resin and having an exposed hydrophilic coating comprising a partially hydrolized, insolubilized polyvinyl acetate.

2. In underwater sound equipment, a loudspeaker diaphragm including a neck portion, a flanged rim and a main body portion of conical shape, said diaphragm comprising a molded web of porous flexible, fibrous material impregnated with a water-insoluble, hydrophobic, thermosetting resin and having an exposed surface coating consisting essentially of a water-insoluble, hydrophilic, film-forming, resinous material.

3. In underwater sound equipment, a loudspeaker diaphragm including a neck portion, a flanged rim and a main body portion of conical shape, said diaphragm comprising a web of flexible, porous, fibrous material impregnated with a water-insoluble, hydrophobic, thermosetting resin and having an exposed hydrophilic surface coating comprising a substance selected from the class consisting of partially hydrolized and insolubilized polyvinyl acetate, natural rubber latex, copolymers of butadiene and acrylonitrile, copolymers of butadiene and styrene, polyvinyl chloride and hardened gelatin.

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