Nov. 24, 1953 J. J. HOFFMAN 2,660,194

EXPANDED CELLULAR PLASTIC FLOTATION BODY

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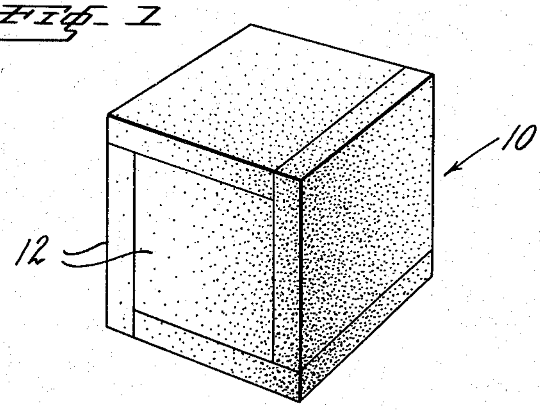
FIG. 1



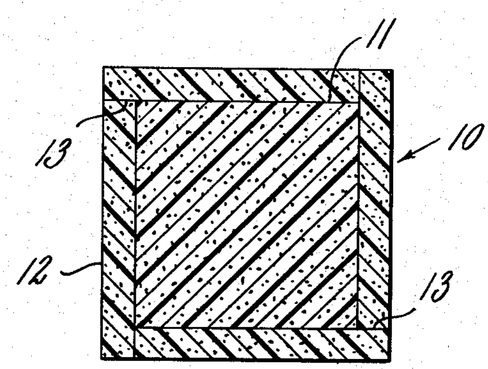


FIG. 2

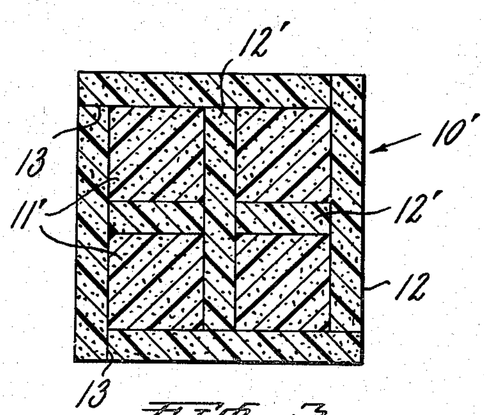


FIG. 3

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EXPANDED CELLULAR PLASTIC FLOTATION BODY

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10 Claims. (Cl. 137—452)

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This invention relates to a tough, durable flotation body which is formed of expanded cellular plastic materials in such a manner that the body will not shatter or otherwise lose its buoyancy to any substantial extent when it is subjected to abuse, and in particular it relates to such a flotation body which is designed to withstand such extreme abuse as gun fire without shattering.

Expanded cellular plastic materials consist of myriad small closed gas cells interspersed throughout a plastic mass, hence these materials have excellent flotation properties. The term "cellular" as used herein denotes a closed (non-intercommunicating) cell structure sometimes termed "unicellular" (see Gould, Rubber Chemistry and Technology, 17, 943 (1944). Expanded cellular materials can be formed in extremely low densities to have great buoyancy, and, since each cell is effectively a separate flotation cell, the material will not lose its buoyance to any substantial extent when any cell is destroyed. This invention utilizes this property of expanded cellular materials to produce flotation bodies which are suitable for use as buoys, parts of life rafts, boats, etc.

Because of its durability, the flotation body of this invention will find general use in applications such as these, but it is designed for, and will be particularly useful in, these and similar applications when the flotation bodies are to be used during military operations in which they will be subjected to gun fire. Thus, for example, a flotation body according to this invention will be particularly useful as a float which, when fixed to heavy military equipment such as tanks or trucks, is designed to float this equipment from ship to shore during amphibious military operations. Heretofore it has been proposed to fix inflatable pontoon tanks to such equipment for this purpose, but these tanks must be armored, and when they are pierced they immediately lose their buoyancy.

When flotation bodies are to be used during military operations, it is extremely important that they be able to withstand gun fire without losing their buoyancy. Further, since flotation bodies which are to be used in these operations may be stored for extended periods of time under very adverse conditions before being used, they must be constructed of materials which can retain their flotation properties under these storage conditions. Thus the bodies should be vermin proof; they should be chemically resistant to oils and other hydrocarbons; they should not support combustion; they should be capable of supporting high sustained pressures without crushing; etc. Further, since it will be used under such adverse conditions that the body may be damaged or destroyed in use, it should be constructed of readily available materials, so the body is expendable.

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The flotation body of this invention possesses all of these qualities, and because it combines these qualities with great buoyancy and shatter-resistance it is exceptionally well suited for flotation uses of the kind specified.

This invention particularly contemplates a flotation body formed of expanded cellular materials which comprises a relatively large core of readily available expanded cellular plastic material completely enclosed in a relatively thin shell of a tough rather rigid expanded cellular plastic material. The core and shell are combined into a flotation body of great buoyancy which is capable of withstanding extreme abuse, particularly gun fire, without shattering or otherwise losing its buoyancy to any substantial extent.

More specifically this invention contemplates a flotation body comprising a relatively large core of expanded cellular polystyrene resin completely enclosed in a thin shell of a tough rather rigid expanded cellular material selected from the group consisting of plasticized polyvinyl chloride, plasticized resinous copolymers of a major proportion of vinyl chloride and a minor proportion of a copolymerizable monomer, and mixtures of (A) from 50 to 80 per cent of a thermoplastic resin and (B) correspondingly from 50 to 20 per cent of a rubbery material compatible with this resin in which the percentages are based on weight and computed on the sum of the weights of (A) and (B). The core is formed as a single body, or as a plurality of bodies which are assembled to form the core, and the shell placed about the core to completely enclose it within the shell. The thickness of this thin shell may be varied to some extent, but preferably it is kept in the range of 1–4 inches, for when a flotation body is made in accordance with this invention having a shell of this thickness it is capable of withstanding .50 calibre and larger gun fire without shattering or crumbling under the impact of the shell. The densities of the core and shell material may also be varied somewhat, but preferably the raw materials are compounded with sufficient quantities of a blowing agent and processed in such a way as to yield a cellular body having a density not greater than 5 lbs. per cubic foot to provide the maximum buoyancy consonant with shatter-resistance of the body for the quantities of materials used.

For a better understanding of the nature of this invention and the manner in which it is constructed, reference should be had to the following description and the accompanying drawing, wherein:

Fig. 1 is a perspective view of a flotation body according to this invention in the form of a block which is suitable for floating heavy equipment such as military trucks and tanks when a plurality of these blocks are affixed thereto;

Fig. 2 is a central sectional view of a block such as that shown in Fig. 1 wherein the core of expanded polystyrene resin is in the form of a single block; and

Fig. 3 is a central sectional view similar to Fig. 2 of a modified form of flotation body according to this invention wherein the core of polystyrene resin is formed of a plurality of discrete blocks.

Referring now to the drawing, there is shown a flotation body according to this invention manufactured substantially in the shape of a cube which is adapted when affixed to a heavy piece of military equipment to help float the equipment when it is immersed in water. To float equipment such as a truck, a plurality of these blocks would be fixed to the truck about the same by suitable fittings, but since these fittings and the manner of attaching them to the equipment form no part of this invention and since many suitable means for performing these functions will readily occur to those skilled in these matters, they have not been illustrated in the drawing. The flotation body according to this invention shown in the drawing consists of a block 10 comprising a relatively large core 11 of expanded cellular polystyrene resin which is completely enclosed in a relatively thin shell of a tough rather rigid expanded cellular material. In the embodiment shown in Figs. 1 and 2, the core 11 is in the form of a single block of expanded polystyrene resin, and the shell is in the form of thin slabs or sheets 12 which have been formed to a suitable shape and placed about the polystyrene core. These slabs or sheets 12 may be bonded to each other in the areas 13 where they overlap to form a unitary flotation body, or preferably they may be bonded to each other in these areas, and to the polystyrene core 11 in the areas where the slabs abut against this core.

In the modified flotation block 10′ shown in Fig. 3, the core comprises a plurality of polystyrene blocks 11′ which are spaced apart by sheets or slabs 12′ of the shell material interposed between the blocks 11′. These blocks 11′ and sheets 12′ are suitably shaped so that a core may be assembled therefrom either with or without adhering the sheets 12′ to the blocks 11′ as desired, which core may be enclosed in a shell of the sheets 12 in the same manner as when the core is formed as a single block of polystyrene resin.

In forming the flotation bodies according to this invention, the expanded cellular polystyrene cores 11, 11′ may be made by the following technique. Solid polystyrene in pulverized form and a gas such as methyl chloride are heated in a closed vessel under a pressure at about 30 atmospheres to a temperature above the fusion point of the polymer, i. e., to about 170° C., to cause absorption of the gas by the polymer. A valve is then opened in the bottom of the vessel to permit flow of the polymer therefrom. During flow from the vessel, the polymer is swollen by expansion of the gas and is caused to assume the form of a somewhat elastic non-brittle cellular body composed for the most part of individual closed cells. The heated polymer may be discharged from the vessel into open air or into another vessel to shape the expanded polystyrene stock. The expanded polystyrene stock may be shaped in the configuration of a core 11 during this expanding operation, or it may be formed as a larger mass from which one or more cores may be severed in a separate operation.

To form the tough rather rigid shell, suitable plastic materials are compounded as described hereinafter and expanded by a similar process to form sheets or slabs suitable for covering the core of polystyrene resin. This shell material similarly may be manufactured in the ultimate shape of the slabs 12 during expansion of the material, or larger masses may be manufactured from which the sheets 12 of appropriate size and thickness are subsequently severed.

The tough rather rigid shell is made from an expanded material selected from the group consisting of plasticized polyvinyl chloride, plasticized resinous copolymers of a major proportion of vinyl chloride and a minor proportion of a copolymerizable monomer, and mixtures of (A) from 50 to 80 per cent of a thermoplastic resin and (B) correspondingly from 50 to 20 per cent of a rubbery material compatible with this resin.

For example, expanded cellular polyvinyl resin stocks suitable for this shell material may be formed of polyvinyl chloride, or of a coploymer of vinyl chloride and vinyl acetate, or of a copolymer of vinyl chloride and diethyl maleate. To produce a shell having the toughness and other physical characteristics requisite in the flotation body shell of this invention, these polyvinyl resins are not used alone, but they are plasticized with a suitable plasticizer. A liquid plasticizer such as dioctyl phthalate may be used, in which case from 15 to 30 parts by weight per 100 parts of resin are mixed with the resin to form the shell stock; or solid plasticizers such as dicyclohexyl phthalate, triphenyl phosphate, or diphenyl phthalate may be used, in which case 50 or slightly more parts by weight are mixed with the resin to form a shell material which when combined with the polystyrene core produces a shatter-resistant flotation body. The solid plasticizers may be used in greater proportions than the liquid plasticizers because the former are not as drastic in their softening effect on the resins as the liquid plasticizers. To produce an expanded cellular material having the requisite density, these plasticized polyvinyl resins are compounded with from 15 to 40 parts by weight, per 100 parts of plasticized resin, of a suitable blowing agent. The preferred blowing agent for this purpose is dinitroso penta methylene tetramine, but others such as diazoaminobenzene, p,p′-oxybis (benzene sulfonyl hydrazide) or alpha, alpha′-azobisisobutyronitrile may be used. As is customary, a small quantity (from 2 to 5 parts by weight per 100 parts of unplasticized resin) of a suitable heat or light stabilizer such as calcium stearate is added to the mix.

In compounding the polyvinyl resins, if a liquid plasticizer is used a plastisol may be formed of the ingredients by techniques well known in the plastic art. See for example the patent to Barton 2,484,397. This plastisol is then confined in a mold under pressure and subjected to heat in a manner similar to that taught by the patent to Cuthbertson to cause the resin to dissolve in the plasticizer and to decompose the blowing agent. The material is then removed from the mold and subjected to heat to expand it to its final shape. When a solid plasticizer is used, the materials may be mixed on a mill by techniques well known in the plastics art, and the gas liberated from the blowing agent and the mix subsequently expanded in the same way as when a liquid plasticizer is used. An additional advantage is achieved in a polyvinyl resin shell when solid plasticizers are used, for these plasticizers do not escape as readily upon aging as do the liquid plasticizers.

A further example of a material suitable for the tough shell is one formed of a mixture of a thermoplastic resin and a rubbery material compatible with this resin. A satisfactory mixture may be formed of from 50 to 80 per cent of a hard inelastic resinous copolymer of butadiene and styrene and correspondingly from 50 to 20 per cent of GR–S. Such a mixture containing 30 per cent of GR–S and 70 per cent of the resinous copolymer of butadiene and styrene (these ingredients being mixed with suitable quantities of zinc oxide, sulfur, an accelerator and an antioxidant as is usual in such mixtures) would be suitable for the shell material. This material similarly is mixed with from 15 to 40 parts by weight per 100 parts of the resin-rubber mixture of a suitable blowing agent such as those specified above to provide an ultimate expanded cellular material having the requisite low density, vulcanization of the GR–S component being effected during the expanding process.

A further example of a mixture of a thermoplastic resin and a rubbery material compatible therewith is a blend of polyvinyl chloride or a resinous copolymer of a major proportion of vinyl chloride and a minor proportion of a copolymerizable monomer and a rubbery coploymer of butadiene and acrylonitrile in proportions of from 50 to 80 per cent of the former and correspondingly from 50 to 20 per cent of the rubbery copolymer.

Still a further example of a mixture of a thermoplastic resin and a rubbery material compatible with this resin which is suitable for the tough shell of the flotation body according to this invention, and the material which is preferred for this tough shell, is a mixture of a resinous copolymer of styrene and acrylonitrile and a rubbery copolymer of butadiene and acrylonitrile as disclosed in the Daly Patent 2,439,202. These materials may be mixed in the proportions of from 50 to 80 per cent of the resinous coploymer of styrene and acrylonitrile and correspondingly from 50 to 20 per cent of the rubbery copolymer of butadiene and acrylonitrile to provide a shell which when combined with the polystyrene core will produce a flotation body having the requisite shatter-resistance, and a preferred mixture for this shell is one containing from 50 to 70 per cent by weight of the resinous copolymer of styrene and acrylonitrile and correspondingly from 50 to 30 per cent of the rubbery copolymer of butadiene and acrylonitrile. This mixture is similarly compounded with from 15 to 40 parts by weight per 100 parts of the resin-rubber mixture of a suitable blowing agent to produce an ultimate expanded material having the requisite density for the flotation body.

A more specific example of this preferred mixture for the shell material, and the manner of producing it is as follows:

	Parts
Styrene-acrylonitrile resin (85–15)	65
Copolymer butadiene-acrylonitrile rubber	35
Mixture of mono and di-heptylphenylamine	12
Zinc oxide	5
Benzothiazyl disulfide	0.25
Stearic acid	1
Sulfur	1.5
Dinitroso pentamethylene tetramine	25

The styrene-acrylonitrile resin and the Buna N rubber are charged into a Banbury mixer and masticated for 10–15 minutes at 320° F. All of the remaining ingredients except the blowing agent and the sulfur, are added and mixed with the rubber and resin until a homogeneous mixture results. The stock is then discharged from the Banbury and sheeted out. It is then banded on a rubber mixing mill where the sulfur and blowing agent are added without permitting the temperature of the stock to exceed 200° F.

If a smooth finish is desired on the final molded cellular material, the stock is calendered before molding. The composition is then converted into cellular blocks in accordance with the Cuthbertson process. The first step, which comprises molding under pressure without permitting any expansion, is carried out at 285° F. for 20 minutes. The stock is cooled before releasing from the mold. This slab is then expanded freely in space or in a larger mold for 45 minutes at 340° F. The density of the final product is controlled by the amount of expansion that is permitted. To obtain a density of 5#/cu. ft. or less, it is preferred to permit the material to expand to its maximum volume.

A rather large proportion of blowing agent (from 15 to 40 parts by weight) is used to expand the plastic materials making up the flotation block according to this invention because it is necessary to expand the materials to low densities. Preferably when used as an equipment float the density of the flotation body does not exceed 5 lbs. per cubic foot, for when the density gets much above this figure the bodies are not too satisfactory for floating heavy equipment such as a military truck or tank. A preferred flotation body for this purpose would have a density in the range of 4.75 to 5 lbs. per cubic foot.

Flotation bodies constructed in accordance with this invention having a relatively thin shell and a relatively large core are capable of withstanding gun fire without shattering or crumbling. Thus a body having over-all dimensions on the order of 2 to 5 feet and having a shell of 1 to 4'' in thickness, when subjected to gun fire from a .50 calibre machine gun will be pierced by a hole along the path of the shell. Larger calibre shells which do not tumble would leave a similar hole. In contrast with this performance, a cellular polystyrene flotation body will be blown to dust by such gun fire.

It will be evident from the foregoing that by utilizing this invention, a superior flotation body of great buoyancy can be produced, and that a tough and durable flotation body suitable for varied uses under extreme adverse conditions will be formed.

Having thus described my invention, what I claim and desire to protect by Letters Patent is:

1. A buoyant flotation body comprising in combination a core of expanded cellular polysty-

rene resin and a shell about the core formed of an expanded cellular material selected from the group consisting of plasticized polyvinyl chloride, plasticized resinous copolymers of a major proportion of vinyl chloride and a minor proportion of a copolymerizable monomer, and mixtures of (A) from 50 to 80 per cent of a thermoplastic resin and (B) correspondingly from 50 to 20 per cent of a rubbery material compatible with said resin.

2. A buoyant flotation body comprising in combination a relatively large core of expanded cellular material and a relatively thin shell of a tough expanded cellular material, said body having a density not greater than 5 pounds per cubic foot, said core being formed of cellular polystyrene resin and said shell being formed of a cellular material selected from the group consisting of plasticized polyvinyl chloride, plasticized resinous copolymers of a major proportion of vinyl chloride and a minor proportion of a copolymerizable monomer, and mixtures of (A) from 50 to 70 per cent of a thermoplastic resin and (B) correspondingly from 50 to 30 per cent of a rubbery material compatible with said resin.

3. A flotation body adapted to float heavy equipment in water when fixed thereto comprising in combination a core of expanded cellular polystyrene resin and a shell having a thickness in the range of 1 to 4 inches completely surrounding said core and bonded thereto, said shell being formed of a tough expanded cellular material selected from the group consisting of plasticized polyvinyl chloride, plasticized resinous copolymers of a major proportion of vinyl chloride and a minor proportion of a copolymerizable monomer, and mixtures of (A) from 50 to 80 per cent of a thermoplastic resin and (B) correspondingly from 50 to 20 per cent of a rubbery material compatible with said resin.

4. A flotation block comprising in combination a core of expanded cellular polystyrene resin and a relatively thin shell of a tough expanded cellular material bonded to the core, said shell being formed of a mixture of 50 to 80 per cent of a thermoplastic resin and correspondingly from 50 to 20 per cent of a rubbery material compatible with said resin.

5. A flotation body adapted to maintain heavy bodies afloat in water when attached thereto

comprising a core of expanded cellular polystyrene resin and a shell of tough expanded cellular material, said shell having a thickness in the range of 1 to 4 inches, said shell being formed of a mixture of 50 to 70 per cent of a resinous copolymer of styrene and acrylonitrile and correspondingly from 50 to 30 per cent of a rubbery copolymer of butadiene and acrylonitrile.

6. A flotation body having a density not greater than 5 pounds per cubic foot, said body comprising in combination a core of expanded cellular polystyrene resin and a shell of expanded cellular material completely enclosing said core, said shell having a thickness in the range of 1 to 4 inches, said shell being formed of a mixture of from 50 to 70 per cent of a resinous copolymer of styrene and acrylonitrile and correspondingly from 50 to 30 per cent of a rubbery copolymer of butadiene and acrylonitrile.

7. A non-shattering flotation body comprising in combination a core of expanded cellular polystyrene resin, a shell of expanded cellular material surrounding said core, and bonded thereto, said shell being formed of a plasticized polyvinyl resin and having a thickness in the range of 1 to 4 inches, said flotation body having a density not greater than 5 pounds per cubic foot.

8. A flotation body according to claim 7 in which said shell is formed of plasticized polyvinyl chloride.

9. A flotation body according to claim 7 in which said shell is formed of a plasticized copolymer of vinyl chloride and vinyl acetate.

10. A flotation body according to claim 7 in which said shell is formed of a plasticized copolymer of vinyl chloride and diethyl maleate.

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