July 29, 1958 H. J. STARK **2,845,025**

LOW DENSITY CELLULAR EXPLOSIVE FOAM
AND PRODUCTS MADE THEREFROM

Original Filed Sept. 20, 1950 3 Sheets-Sheet 1

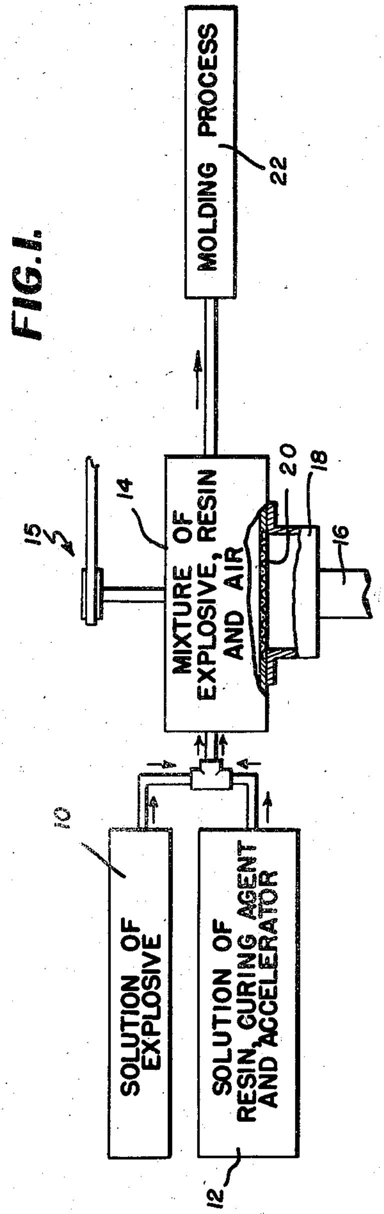

FIG. I.

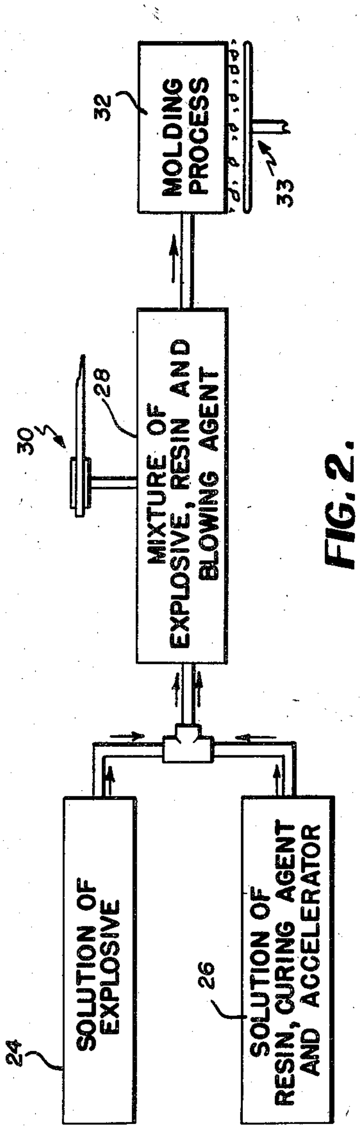

FIG. 2.

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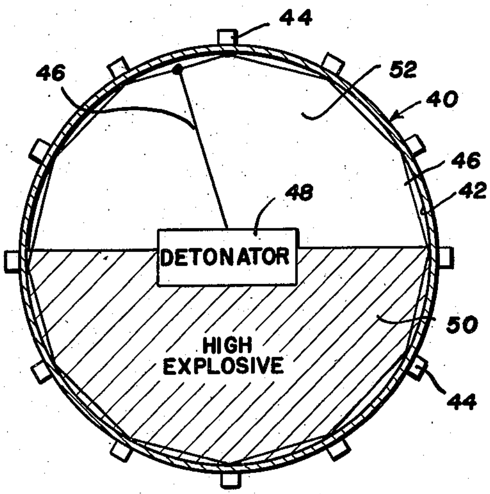

FIG. 3.

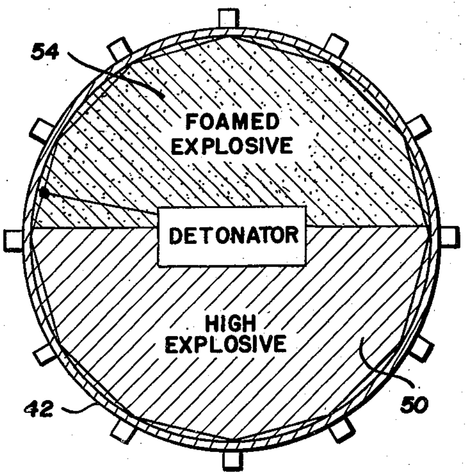

FIG. 4.

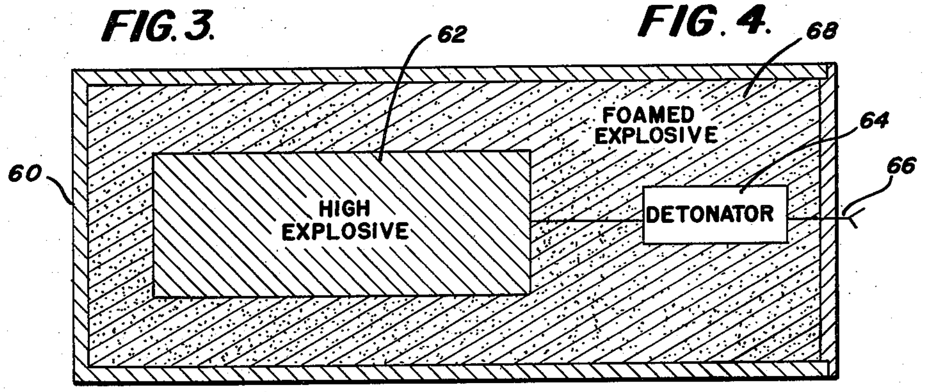

FIG. 6.

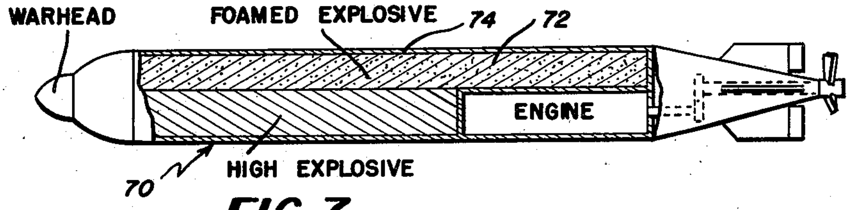

FIG. 7.

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FIG. 5.

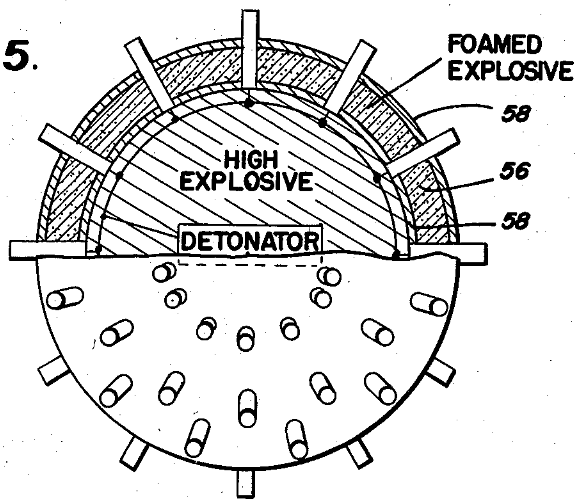
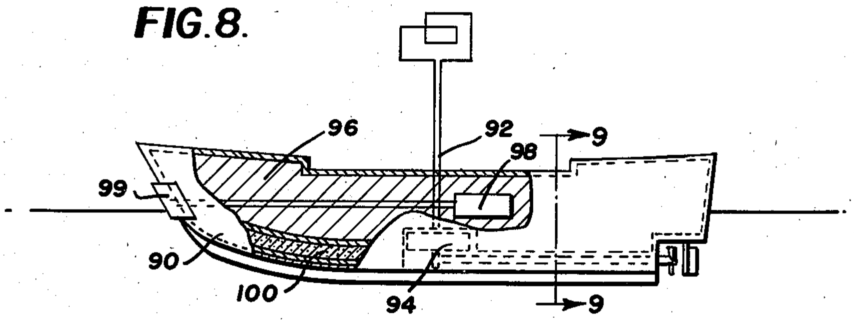


FIG. 8.



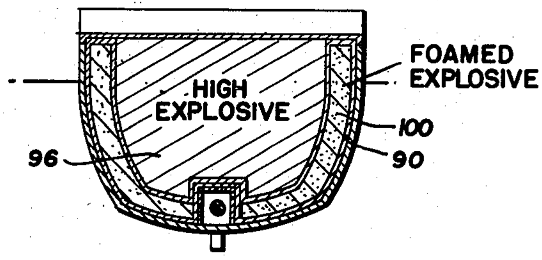


FIG. 9.

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United States Patent Office

2,845,025
Patented July 29, 1958

2,845,025

LOW DENSITY CELLULAR EXPLOSIVE FOAM AND PRODUCTS MADE THEREFROM

Howard J. Stark, Arlington, Va.

Continuation of abandoned application Serial No. 185,900, September 20, 1950. This application August 23, 1954, Serial No. 451,723

2 Claims. (Cl. 102—10)

(Granted under Title 35, U. S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to low density explosives and in particular to the use of low density, cellular explosive foam.

This is a continuation application based on my copending application Serial No. 185,900, filed September 20, 1950, now abandoned, and entitled, Low Density Cellular Foam.

The general object of the invention is to provide an explosive having a cellular foam structure which, because of such foam structure, is of relatively low density, is buoyant with respect to water, and of greater and more rapid shattering effect than the same weight of high density explosive.

It is also an object of the invention to provide an explosive having a cellular foam structure which is set and rigid and which is relatively strong and tough.

It is a further object of the invention to provide an explosive having a cellular foam structure which may be cast or molded into a particular shape prior to the setting or assumption of rigidity.

It is an additional object of the invention to provide for products which are made in part of a foamed or cellular buoyant explosive.

Other objectives will be apparent from the following description and from the drawings, hereto attached, which are illustrative of the method of making the cellular explosive and of the preferred embodiments of the invention.

In these drawings:

Fig. 1 is a flow chart of the dynamic air-set method of this invention;

Fig. 2 is a flow chart of the "chemical blowing" method of this invention;

Fig. 3 is a diagrammatic transverse section through a conventional floating mine;

Fig. 4 is a diagrammatic transverse section through a floating mine of the type illustrated by Fig. 3 but containing a relatively large quantity of the foamed explosive of this invention cast in situ;

Fig. 5 is a diagrammatic sectional-elevational view of a floating mine in which the shell is comprised of the molded foamed explosive of this invention encased in light weight metal or impregnated fabric and shows the increased high explosive charge possible with this type of construction;

Fig. 6 is a diagrammatic longitudinal section through a floating, harbor mine showing the combination in the explosive charge of the conventional high density explosive with the foamed explosive of this invention;

Fig. 7 is a diagrammatic longitudinally sectional-elevational view of a torpedo carrying a charge of high density explosive and foamed explosive of this invention; and

Figs. 8 and 9 are a diagrammatic longitudinal sectional-elevational view and a transverse sectional view taken on line 9—9 of Fig. 8, respectively, of a radio controlled "homing" vessel showing the foamed explosive of this invention cast and molded within the structure of the double walled hull.

Heretofore, it has been the practice, in the manufacture of explosives, to produce them with a relatively high density in order to have a great explosive effect in a given volume. Now a requirement has arisen in which it is desirable to have an explosive which is buoyant and which may have a greater explosive effect which may be additive to that of the conventional high density explosive. This requirement is present not only in floating mine structures, but also in the guided surface (the so-called "homing") vessels.

This inventor has met this requirement by providing a foam type explosive which resembles in physical appearance and characteristics cellular polystyrene or cellular acetate. It is relatively strong and tough and the density thereof can be varied by formulation within the range of from about 5 to about 50 pounds per cubic foot.

The cells of the foamed and set structure of the explosive are substantially non-communicating and referred to as closed-cells in contradistinction to spongy open-cells. Therefore, a molded plate of this material is relatively impervious to gas and water. In comparison with balsa wood, which has a buoyancy of about twenty pounds per cubic foot after twenty-four hours immersion under a ten foot head of water, this cellular explosive has a buoyancy of from about 20 to about 50 pounds per cubic foot under similar conditions.

The following explosives can be prepared in foam or cellular form:

(1) Trinitrotoluene
(2) Nitrocellulose (tri, hexa and dodeka nitrocellulose)
(3) Pentaerythritol
(4) RDX (cyclo trimethylenetrinitramine)

The foamed explosive consists essentially of any one of the above explosives bonded by a thermosetting resin. This inventor has found that polyesters of ethylene glycol-maleic anhydride intermixed with monomeric or polymeric methyl methacrylate is ideally suited as a resin in the carrying out of this invention. This resin is shown and described along with other resins which also are suitable in Carleton Ellis' Patent 2,255,313, which is incorporated by reference and forms a part of this specification. Of course a filler as used in the examples of Ellis is unnecessary and not used although such use would still fall within the scope of what is considered to be the present invention. These bonding thermosetting polyester resins are well known in the field of resin chemistry and their specific compositions form no part of this invention. The requirements thereof are that they be compatible with solutions of the explosives, that they gel at room temperature in a relatively short period of time such as about fifteen minutes, set permanently in about one hour and that they impart a viscosity to the solution of the explosive sufficient to prevent the escape of air therefrom and yet be sufficiently fluid for efficient molding and casting. The rate of setting of these resins is controlled by the addition thereto of a relatively small proportion (from about 2% to about 4% by weight) of an appropriate curing agent. Such agents have been found to include: benzol peroxide, ditertiarylbutyl peroxide, cumenehydro peroxide, methylisobutyl ketone peroxide, and dibenzaldeperoxide. The choice of the particular curing agent used depends upon its compatibility with the solution of the resin and the explosive and the rate of curing desired. Also an accelerator, such as cobalt naphthanate may be added in a proportional amount of from about 2% to about 5% by weight to give additional control on the rate of gelling and setting of the resin.

Commercially available resins which have been found to be suitable as a bond for the foamed explosives of this invention are "MR–28C and 29C" by Marco Chemicals, Inc., "Selectron 5003 and 5016" produced and marketed by the Pittsburgh Plate Glass Company, "Laminac 4128, 4129 and 4116 produced and marketed by the American Cyanamid Company, and "Paraplex P–43" by Rohm and Haas Company.

Two methods of the preparation of foamed explosive are preferred by this inventor. These are (1) the so-called dynamic air-set method, and (2) the chemical blowing method. These methods differ from each other mainly in the method of introduction of air or gas into the resinous solution of the explosive. In the dynamic air-set method (reference being had to Fig. 1 of the drawings), a solution of the explosive in styrene, ether, acetone, or a mixture of some of these solvents is made as indicated at **10**. Only as much explosive may be dissolved as will go into the solution with or without the application of a moderate heat, and with staying below the decomposition temperature of the explosive. A solution of a polyester type resin, curing agent or "catalyst" and accelerator is prepared as shown at **12** in the proportionate amounts above indicated. From about 10 to about 30% by volume of the liquid resin solution is mixed with the solution of the explosive as shown at **14**. The curing agent and accelerator will cause the resin to gel in about 15 minutes and to set permanently in about one hour. The mixture of solutions of the explosive and resin is stirred for about 5 minutes as indicated at **15** and allowed to rest for about 5 minutes. Compressed air from a source (not shown) is introduced into blowing chamber **18** and thence through foraminous member **20** which may be a glass frit or metal screen of a mesh in the range of from 75 to 300 and through the mixture at **14** for about 3 minutes which will foam the said mixture. The foamed mixture is then poured into molds or other containers within the remaining 2 minutes of the **15** at which time the foamed explosive gels or sets up and in one hour becomes a hard cellular mass. By a proper control of the viscosity of the mixture, above referred to, air bubbles do not appreciably escape therefrom after the completion of the blow or during the period that the mixture is in the mold prior to gellation. There is therefore no collapsing of the foamed structure in the mold.

In the chemical blowing process the explosive is dispersed in a suitable solvent such as acetone or styrene as indicated at **24** in Fig. 2 to obtain a saturated or highly viscous solution. The solution of the resin is prepared by the addition of a curing agent and an accelerator in the proportionate amounts above indicated and as shown at **26**. The resin may be a polyester type resin as above described or it may be of the alkyd peroxide curing type. In either case they are adjusted to gel in about fifteen minutes and to set in about one hour as in the process above described. The solutions of the explosive and the resin are conducted into mixing chamber **28**, the solution of the resin being added in the proportion by volume of from 10% to 30%. In this chamber there is added to the mixture from 10% to 30% by volume of a chemical blowing agent such as diazoaminobenzene or toluene diisocyanate. The mixture is stirred, as indicated at **30** for from five to ten minutes and is then poured or cast into molds as indicated at **32**. The molds are then heated as indicated at **33** to a temperature of about 120° C. but not above decomposition temperature of the explosive at which temperature the blowing agent evolves a relatively large volume of gas which causes the mass to expand forming a cellular structure.

The range in composition, on a percentage weight basis at various temperatures of formation, of the foamed

explosives of this invention is given in the following table:

°C. Temp.	Solvent	Percent Range in Comp.	Explosive	Percent Range in Comp.	Percent Range in Comp. of Resin
20	acetone	10–10	T. N. T	80–60	10–30
20	toluene	40–40	T. N. T	50–30	10–30
20	benzene	30–30	T. N. T	60–40	10–30
60	acetone	5–10	T. N. T	85–60	10–30
60	toluene	5–10	T. N. T	85–60	10–30
60	benzene	5–10	T. N. T	85–60	10–30
80	acetone	5– 5	T. N. T	85–65	10–30
20	do	70	PETN	25	5
60	do	50	PETN	40	10
112	toluene	60	PETN	30	10
25	cyclohexanone	78	RDX	12	10
60	acetone	67	RDX	18	15
97	cyclohexanone	60	RDX	25	15
25	do	78	HBX–1 & 2	12	10
60	acetone	67	HBX–1 & 2	18	15
97	cyclohexanone	60	HBX–1 & 2	25	15

Referring further to the drawings, in Fig. 3 a conventional floating mine is shown diagrammatically and generally at **40**. The mine comprises a metallic case **42**, contact elements **44** which are in electric circuits **46** with the detonating or exploding device **48**. This exploding device detonates the charge of high explosive **50** when any one of the elements **44** is actuated by contact with an object in the water. The interior volume of this type of mine is comprised of about 50% air space as shown at **52**.

In Fig. 4 the air space of the mine shown in Fig. 3 is filled with the foamed explosive of this invention as shown at **54** which has been cured and set in place. This foamed or cellular explosive not only gives an additive effect to the "brisance" of the high explosive, but in the event of leakage through metallic shell **42** due to erosion or corrosion thereof, the buoyancy of the mine will be maintained substantially as that existing when the mine is in leakproof condition.

Fig. 5 is illustrative of an embodiment of this invention in which the shell of the mine is comprised of molded cellular explosive **56** covered on the exterior and interior faces with relatively thin layer of metal or impregnated fabric **58**. The increased buoyancy of this type of construction over the conventional, heavy metallic case mine is readily apparent. In fact, the buoyancy is so much greater that substantially the entire interior space of the mine may be filled with high density explosive thereby producing a mine of greatly increased shattering effect when also considered in the light of the additive explosive effect of the cellular explosive comprising the shell.

Fig. 6 is a sectional illustration of a floating harbor mine showing the arrangement of a metallic casing **60**, a high density explosive charge **62**, detonating or exploder device **64**, actuating contact element **66** and foamed explosive of this invention **68** surrounding the high explosive charge and exploder device and filling the air space normally present within the casing of this type of mine. In the event of leakage of water through the casing due to corrosion thereof or otherwise, the foamed explosive prevents loss of buoyancy and the normally resultant loss of the mine.

Fig. 7 is a sectional-elevational view of a torpedo shown generally at **70** in which the foamed explosive **72** of this invention fills the normally present air-space within the shell **74**. The legends in this figure are believed to be self-explanatory. In this embodiment of the invention, the overall buoyancy of the torpedo is less than that of the torpedo having the conventional air space. But the total shattering effect of the explosion is much increased by this additional quantity of foamed high explosive. In charging this cellular explosive into this air space in the torpedo, the foamed explosive is poured into this space immediately prior to the gelling thereof. The space is completely filled and upon the curing and setting of the resin component the cellular explosive becomes rigid and reinforces the sidewalls of the shell.

Figs. 8 and 9 show the application of the foamed high explosive of this invention to the structure of an electronically controlled homing vessel in sectional-elevational views. Here the double walled hull **90** is shown provided with radio control **92** for motor drive mechanism **94**. High density high explosive **96** substantially fills the interior of hull **90** surrounding the exploder device **98**. The detonating contact element is shown at **99**. The space within the double wall structure of the hull is filled with the foamed high explosive of this invention as shown at **100**. As in the case of the torpedo above-described, the foamed explosive is poured into this hull wall space immediately prior to the gelling and after setting the foamed cellular explosive mechanically reinforces the structure. The advantage of this type of construction of these homing vessels is that the shattering effect of the explosion is greatly increased and that in the event of leakage through the outer wall of the hull due to corrosion or to any other cause the buoyancy of the vessel is maintained.

It should be understood, of course, that the foregoing disclosure relates to only preferred embodiments of the invention and that it is intended to cover all changes and modifications of the examples herein chosen for the purposes of the disclosure, which do not constitute departures from the spirit and scope of the invention as set forth in the appended claims.

I claim:

1. A floating mine comprising a casing, a detonator mechanism carried with said casing, a solid high explosive carried inside part of said casing and a foamed water impervious buoyant explosive, the cells of which are substantially non-communicating, filling the remaining space in said casing.

2. A floating mine comprising a casing, a solid high explosive occupying a portion of said casing, detonating means therefor occupying a further portion of said casing, and a foamed water impervious buoyant explosive, the cells of which are substantially non-communicating, filling the remainder of said casing, said foamed explosive adding to the shattering effect of said high explosive and serving as a buoyant means for said mine.

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