

Explosive Comprising a Foamed Sensitizer

FIELD OF THE INVENTION

The present invention relates to explosive compositions and, in particular, to sensitized explosive compositions.

DESCRIPTION OF THE RELATED ART

Semisolid colloidal dispersions of water-bearing explosives or blasting agents are well known. These products typically comprise an oxidizing component, usually predominantly ammonium nitrate, a fuel component and water. These blasting agents are referred to in the art as slurry explosives (or as water gels), and as emulsion-type explosives.

Slurry explosives typically comprise a discontinuous fuel phase which is dispersed in a continuous aqueous solution of the oxidizer salt. Thickening agents are added to the aqueous phase in order to increase the viscosity of the explosive, or to effect gelation, and thus stabilize the structure of the explosive.

Emulsion explosives typically comprise a discontinuous aqueous oxidizer salt solution which is dispersed in a continuous fuel phase. Emulsifying agents are generally added to the dispersion to stabilize the dispersion.

The addition of additives to both slurry and emulsion explosives to modify the performance of the blasting agent is similarly well known. These additives include, for example, the addition of aluminium or ammonium nitrate to the explosive to increase the strength and/or sensitivity of the blasting agent.

Of particular interest in the present invention is the addition of additives to create small voids within the blasting agent, which voids can be used to control the density of the explosive and to increase the sensitivity of the explosive. These sensitized explosives were described, for example, by Cattermole et al. in US Patent No 3,674,578; Bluhm in US Patent No 3,447,978; Wade in US Patent No 4,110,134 and Clay in US patent No 4,181,546.

One method of addition of voids in a blasting agent is the addition of hollow glass microballoons to an emulsion

explosive. While this method provides a suitable means for the creation of voids within the blasting agent, the microballoons are relatively expensive and can be difficult to handle due to their low bulk density.

5 The use of similar products to microballoons which products also have particles containing one or a number of gas bubbles, such as, for example, inorganic hollow microspheres made of glass, sirasu (Japanese volcanic ash), silicon sand, or sodium silicate and the like, is also
10 known. These materials suffer from the same disadvantages as glass microballoons.

 Edamura et al disclose in US Patent No 4,543,137, the use of a gas-retaining agent, such as, those made from foamed polystyrene, foamed polyurethane and the like. The
15 gas-retaining agents of Edamura et al can have a rigid structure similar to the inorganic microballoons described hereinabove, and which can be brittle and subject to breakage during handling or can be made soft and spongy so as to be more resistant to inadvertent breakage during
20 handling.

 These soft and spongy gas-retaining agents are produced by foaming a foaming agent in a thermoplastic resin and allowing the thermoplastic resin to set and thus entrap gas within the resin structure.

25 However, this route of adding gas voids to the blasting agent requires the initial preparation of a spongy or rigid microsphere structure which is added to the blasting agent.

In situ generation of air or gas voids within the blasting agent is an alternative method over the addition of
30 gas filled microballoons and, typically, comprises the addition of a material which reacts in the blasting agent to generate a gas bubble. This gas bubble is entrained within the blasting agent by the viscous nature of the semisolid blasting agent. The generation of a gas void within the
35 blasting agent by an in-situ chemical reaction is termed within the industry as chemical gassing.

 Chemical gassing of explosives is well known in the slurry and emulsion explosive industry. In US Patents

3,886,010 and 3,706,607, Thornley and Chrisp, respectively, describe the use of chemical gassing agents such as nitrites, weak acids, hydrazine and peroxides in slurry and/or emulsion explosives.

5 While chemical gassing is practised in the industry, its use is limited because of the difficulty in controlling the reaction rate of the chemical gassing reaction. The degree of gassing may be insufficient or may be excessively slow under cold production temperatures and may be excessive
10 under hot conditions so as to provide uncontrollable borehole densities.

A third route to introducing gas voids into an explosive blasting agent is to mechanically agitate the blasting agent composition in order to entrain an occluded
15 gas void within the blasting agent. This route has the disadvantage of intensive mechanical agitation of a sensitized explosive and can be subject to poor long-term blasting stability as gas is slowly lost from the blasting agent.

20 A further route to the production of gas voids within an explosive blasting agent is described by Curtin and Yates in UK Patent Application No 2, 179,035, wherein a gas bubble generating agent is added to the blasting agent prior to or while the blasting agent is subjected prior to super-
25 atmospheric pressure to dissolve at least part of the gas present. The blasting agent is returned rapidly to atmospheric pressure and, thus, creates a fine discontinuous gaseous phase in the composition. However, this production route requires the sensitized blasting agent to be prepared
30 under pressure and, thus, requires specialized equipment adapted to handle the pressurized explosive.

In light of the problems of the gas void addition methods of the prior art, it is an object of the present invention to provide a slurry or emulsion blasting agent
35 which is sensitized by the addition of gas voids, wherein said gas voids are prepared and added to the blasting agent by a route other than those routes described hereinabove.

SUMMARY OF THE INVENTION

Accordingly, the present invention provides a method of producing an emulsion explosive composition sensitized by dispersed gas bubbles, wherein the gas bubbles are introduced to said emulsion explosive composition by mixing a gas-in-liquid foam into an emulsion explosive composition whereby the liquid of said foam becomes part of a liquid phase of the emulsion whilst the gas in said foam becomes a dispersion of sensitizing gas bubbles in said emulsion explosive composition.

The term "foam" in this specification and claims, is used to describe a mass of bubbles which have been dispersed in a liquid. The bubbles are surrounded by and, thus, separated from each other by thin, flexible films of liquid with, optionally, viscosity control agents or foaming agent molecules absorbed at the gas/liquid interface in order to stabilize the film.

Most of the volume of a foam in the gas phase and typically, the gas phase comprises at least 90% by volume of the foam.

The foam used in the present invention may be produced by introducing or "sparging" a pressurized gas into a closed vessel containing the pressurized liquid component of the foam, mixing and subsequently releasing the pressure on the system so as to create small gas bubbles within the liquid component. The foam produced can then be added to and blended into the base explosive composition by, for example, a low shear or a static mixer.

The pressurized gas used to form the foam can be any gas which is compatible with other components of the explosive. Preferably, the gas is air, carbon dioxide or nitrogen but any other gas could be used provided that the solubility of the gas in the liquid is controllable over the time and temperature range to which the sensitized explosive will be stored prior to use.

Bubbles can also be dispersed in the liquid carrier to produce a foam by mechanical agitation, such as, for example, by a high shear mixer, such as an Oakes mixer, or by low shear mixing of the liquid carrier to entrain gas

voids within the liquid carrier. Mechanical agitation in the process of the present invention is, preferably, conducted on a non-explosive liquid carrier and, thus, is inherently safer and more effective than a process of entraining gas voids directly into the explosive composition.

The foams of the present invention, preferably, have a low density in order to effectively lower the density of the explosive to which the foam is added. Preferably, the foam has a density of less than 0.2g/ml and, more preferably, below 0.1g/ml and, even more preferably, below 0.06g/ml.

As soon as a foam is created, the liquid phase which surrounds the individual bubbles will begin to drain so as to create a thinner layer at the top of the bubble than at the bottom. Eventually, the thinner layer will break causing coalescence of the bubble or loss of gas from the foam and the loss or drainage of the carrier liquid from the foam. The loss of gas is, thus, related to the 'drainage' rate of the foam in that the gas volume is reduced as liquid drains from the foam. The stability of the foam can, thus, be measured by determining the half-life of the foam wherein the half-life is the time taken for the loss of half of the gas volume from the foam. The half-life is, thus, an indication of the shelf life of the foam after the foam is produced.

Control of the drainage rate and, thus, control of the half-life of the foam can be influenced and effectively controlled by the addition to the foam of additives which stabilize the liquid film around the bubble. If the foam is to be incorporated in the explosive shortly after it is produced, for example, within one to four minutes of production, foam stability is not as critical as for foams which are prepared and later added to the explosives.

Additives, such as high viscosity polyisobutylene, act to increase the viscosity of the liquid film around the gas bubble. Further, additional additives, such as foaming agents are, preferably, added to the liquid carrier in order to assist in formation of the foam.

Accordingly, the foams of the present invention, preferably, comprise a gas, a foaming agent, a viscosity control agent and a liquid carrier.

5 The foaming agent provides a film around the gas bubbles in order to prevent them from bursting or coalescing. Typical foaming agents would include materials such as proteins, and, more specifically, milk proteins, egg proteins, animal proteins, vegetable proteins, fish proteins, and any mixture thereof. The foaming agent can
10 also be a protein derivative or associated product, such as, phospholipids, lipoproteins, collagens, hydrolyzed proteins, and globulins. Steroids may also be used as a foaming agent.

The foaming agent may also include surfactants, such
15 as, for example, FC740* or FC751*, which are perfluorinated surfactants, or mixtures of other surfactants. Other foaming agents include lanolin oil, derivatives or succinic anhydride, glycerol monostearate, stearyl octazylene phosphate and long chain alcohols. [* TRADE MARK]

20 Casein is a mixture of proteins extracted from milk solids or soya beans, and can be used as is or can be fractionated into a water soluble portion or an oil soluble portion, each of which can be separately used as a foaming agent. The casein used may be totally or partially soluble
25 in the oil but is, generally, dispersable so as to not be detrimental to foam production.

The stability of the foam may also be enhanced by the addition of solid particles, such as, carbon black, talc or other materials known in the foam stabilization art.

30 Viscosity in the foam can be controlled by the addition of viscosity control agent materials, such as, for example, high viscosity polyisobutylene, butyl rubber, natural rubber, bifunctional high molecular weight acids and the like and mixtures thereof to the liquid carrier which will
35 increase the viscosity of the liquid component of the foam.

Excessively high viscosity in the liquid component of the foam, however, is not desirable since the high viscosity will make preparation of the foam difficult. Thus, an

optimum level of viscosity control agent is required in order to ensure that the drainage rate of the foam is low, but that the foam is relatively easy to produce.

In an oil-based foam, the viscosity of the oil selected will also influence the ease with which the foam can be produced and the drainage rate of the foam. Selection of the oil will, thus, depend on, inter alia, the method of manufacture of the foam, mixing conditions, temperature, residence times, pressure, type of gas and the like.

The foam can be added to sensitize any suitable explosive material wherein gas voids are advantageous. Explosive materials include, in particular, emulsion or slurry explosives but also include propellants, high heave explosives, such as, Heavy ANFO, modified emulsions, cast explosives, nitro ester based systems, and TNT, RDX or NG based systems.

The liquid carrier used to prepare the foam is a liquid which is, preferably, compatible with the continuous phase of the explosive and into which the preferred additives of the foaming system can be dispersed or dissolved. The liquid carrier may take part in the detonation as a fuel or comprise an oxidizer, a sensitizer, or it may be non-reacting.

In a slurry explosive, water miscible liquids are preferred. In particular, the most preferred liquid for slurry explosives is water as a solvent or dispersion medium for desired additives or solutes.

For an emulsion explosive, preferred liquids are non-aqueous oils and solvents which are miscible with the organic liquid phase. Most preferred, however, are liquids or liquifiable materials which act as fuels in the explosive reaction. Typically, fuels include, for example, paraffin oil and fuel oil. However, the liquid carrier need not be perfectly compatible with the continuous phase of the explosive provided that the explosive composition created remains sufficiently stable to allow adequate storage stability based on the proposed use of the explosive composition.

Emulsion explosives includes low and essentially non-aqueous emulsions.

The liquid carrier will, preferably, contribute to the total fuel phase present in the emulsion explosive and, thus, may be described as a fuel for the explosive, as described hereinabove. In the preparation of the foam, however, it is desirable to minimize the amount of liquid used in the production of the foam in order to maximize the amount of liquid which is available for pre-formation of the base emulsion explosive.

The use of a non-aqueous liquid in a slurry explosive may also provide fuel value to the explosive composition.

With the selection of a liquid carrier of a suitable viscosity, such as, for example, high viscosity paraffin oil, the use of a viscosity control agent can also be reduced or eliminated.

Accordingly, the present invention provides a gassed explosive composition as described hereinabove wherein the gassing is achieved by a dispersed pre-formed foam and of which the liquid in said gas-in-liquid foam comprises a liquid or liquifiable fuel and a foaming agent.

When the liquid carrier is water, it is preferable to add a material to the water which acts as a freezing point depressant and, thus, make the base explosive composition and/or the foam, to which the foam has been added, more stable in cold temperatures. A preferred freezing point depressant is ammonium nitrate. However, low-freezing point, water miscible liquids or liquid mixtures, such as, ethylene glycol and water can be used as a liquid carrier in place of water. The foam, once produced, is added to a base explosive composition, which base explosive composition is an insufficiently or non-sensitized emulsion or slurry explosive. The foam is, preferably, added to the base explosive composition shortly after its production, in order to minimize the need to create foams which are stable for long periods of time. It has been our experience that the use of foams having a half life of greater than one to four

minutes is desirable in order to have sufficient time to mix the foam into the explosive composition.

The foam is, preferably, added to the base explosive composition by a low shear mixing technique, such as, a static mixer or a ribbon mixer. During addition of the foam, the foam is broken and its gas bubbles are merely dispersed within the base explosive composition. At this stage, there is generally no need for intense mechanical agitation to entrain additional gas voids within the explosive composition.

The present invention, thus, provides an explosive as described hereinabove wherein the explosive composition is an emulsion explosive. Preferably, the liquid carrier used to prepare the gas-in-liquid foam, which is to be added to the emulsion explosive, is a fuel.

Further, the present invention also provides an explosive as described hereinabove wherein the explosive composition is a slurry explosive and, preferably, the liquid carrier used to prepare the gas-in-liquid foam, which is to be added to the slurry explosive, is water.

The base explosive composition to which the foam sensitizer is added can be any chemically compatible emulsion or slurry explosive, which base explosive compositions are described in the prior art. These base explosive compositions generally consist of an oil-in-water or water-in-oil dispersion of an aqueous solution of an oxidizing salt and a fuel.

The oxidizing salt may be any of the oxygen-containing salts typically used in the industry. These salts include, for example, nitrates, chlorates, and perchlorates. Most preferred, are salts, such as, sodium nitrate, calcium nitrate, potassium nitrate, and, most preferably, ammonium nitrate or mixtures thereof. In slurry explosives, the oxidizing salt is dissolved in water to provide the continuous phase of the explosive composition. For an emulsion explosive, the oxidizing salt may be melted, (e.g. as a eutectic mixture) to provide a liquid which can be dispersed as a discontinuous phase into the fuel or, more

preferably, may be dispersed into the fuel as a concentrated aqueous solution.

The fuel phase may be any liquid or liquifiable fuel known within the explosives art and may be the same as or different than the fuel used in the preparation of the foam. Suitable materials include mineral oil, waxes, paraffin oils, benzene, toluene, xylenes, and mixtures of petroleum distillates such as gasoline, kerosene and diesel fuel.

An emulsion explosive formed as an embodiment of the present invention, preferably, also include stabilizing surfactants, such as, for example, a mixture of sorbitan sesquioleate and a polyisobutylene succinic anhydride (PIBSA) based surfactant. These PIBSA based surfactants are described in Canadian Patent No 1,244,463 (Baker). However, any surfactant of use in the emulsion explosive art may be used to prepare the emulsion to be used in the present invention.

Many suitable conventional emulsifiers have been described in detail in the literature and include, for example, sorbitan esters, such as, sorbitan sesquioleate, sorbitan mono-oleate, sorbitan mono-almite, sorbitan mono-stearate and sorbitan tristearate, the mono- and diglycerides of fat-forming fatty acids, soya bean lecithin and derivatives of lanolin, such as, isopropyl esters of lanolin fatty acids, mixtures of higher molecular weight fatty alcohols and wax esters, ethoxylated fatty ethers, such as, polyoxyethylene lauryl ether, polyoxyethylene oleyl ether, polyoxyethylene stearyl ether, polyoxyalkylene oleyl laurate, and substituted oxazolines, such as, 2-oleyl-4,4'-bis-(hydroxymethyl)-2-oxazolines. Suitable mixtures of such conventional emulsifiers may also be selected for use, together with one or more modifiers, in the compositions of the present invention.

Accordingly, the present invention provides an emulsion explosive comprising a continuous fuel phase, a discontinuous oxidizer phase and a surfactant for stabilization of said emulsion which emulsion has been sensitized by the addition of a gas-in-liquid foam.

The slurry explosives formed as an embodiment of the present invention, preferably, also include viscosity controlling additives, such as, for example, guar in order to increase to viscosity of the explosives so as to entrain the gas voids from the foam in the sensitized explosive formed.

The explosive compositions of the present invention may also comprise additional additives to enhance or modify the properties of the explosive blasting agent. The use of these additives is commonly known within the explosives industry and include the solid dopes and sensitizers commonly added to emulsions, such as, aluminium, ferrosilicon, TNT, AN, MAN, PETN and the like. Further, additional sensitizing agents, such as, for example, glass microballoons, may also be used in combination with the foams of the present invention.

In a further aspect, the present invention also provides a method of manufacturing a sensitized emulsion explosive composition comprising:

preparing a base emulsion composition by emulsifying an aqueous solution of an oxidizer salt in a liquid or liquifiable fuel, or by emulsifying a liquid or liquifiable fuel in an aqueous solution of an oxidizer salt;

preparing an essentially gas-in-liquid foam by mixing a carrier liquid with a foaming agent to form a foaming solution and subjecting said solution to mechanical agitation, such as in a high shear mixer, low shear, or a static mixer, or other mixers known to those skilled in the art of foam manufacture, or to a pressurized gas sparge, or allowing it to foam by chemical reaction in the foam system; and

blending said gas-in-liquid foam into said base emulsion composition to render it functional as an explosive.

In a still yet further aspect, the present invention also provides a method of blasting which comprises placing an explosive detonator in operative contact with an explosive and detonating said detonator.

The invention will now be described by way of example only, with reference to the following examples.

EXAMPLE 1

A fuel (or oil) based foaming solution was prepared having the composition shown in Table 1. All percentage figures shown are percent by weight unless otherwise indicated.

TABLE 1: Oil Based Foaming Solution

Liquid carrier	Paraffin oil	89.5%
Foaming agent	Casein	1.5
Foaming agent	FC740*	3.0
Viscosity control agent	Polyisobutylene	6.0

		100.0

* Perfluorinated surfactant and bubble stabilizer

A foam was produced by sparging the foaming solution with a pressuring stream of nitrogen gas. A foam was produced having a gas volume of greater than 90% by volume, a foam density of 0.12g/ml and a half life greater than 45 minutes.

EXAMPLE 2

A water based foaming solution was prepared having the composition as shown in Table 2.

TABLE 2: Water Based Foaming Solution

Liquid carrier	Water	69.0%
Freezing point Depressant	Ammonium Nitrate	25.0
Foaming agent	FC751*	3.0
Foaming agent	Casein (water soluble)	3.0

		100.0

* A short chain perfluorinated amine ester mixture surfactant and bubble stabilizer

A foam was produced by mechanically agitating the foaming solution in a high shear mixer. A foam was produced having a gas volume of greater than 90% by volume, a foam density of 0.04g/ml and a half life of greater than 30 minutes.

EXAMPLE 3-6

Emulsion explosive compositions comprising an oil based foam were prepared according to the present invention, having the formulations set out in Table 3. In each example, the foam was prepared according to the method and formulation as set out in Example 1.

The oxidizer salt used in these examples was ammonium nitrate or an ammonium nitrate/sodium nitrate mixture.

Paraffin oil was used for the oil phase in each example and a sufficient amount was added to produce a sensitized emulsion explosive with a 5% total oil phase. The total oil phase includes surfactants.

In each example, the oxidizer salt solution was added to the oil phase containing a PIBSA based surfactant and sorbitan sesquioleate mixture while mixing in order to produce an emulsion explosive. Examples 3 and 4 were prepared using low shear mixing and Examples 5 and 6 were prepared by high shear mixing. The foam was dispersed into the emulsion by low shear mixing.

The sensitized emulsion for each example was placed into a 25 or 50 mm cartridge in order to test the blasting ability of the explosive.

The blasting ability of each composition was measured by determining the cap size need to detonate the composition. Thus, in Table 3 under blast results, the cap size used and the blast result for each example is shown. Where measured, the velocity of detonation (VOD) for a successful blast is indicated.

Examples 3 and 4 are typical of products which would be sold as "bulk" blasting agents and, thus, cap sensitivity is not expected. Examples 5 and 6 are typical of packaged products and cap sensitivity may be desirable. In all examples, explosives could be prepared using the foam sensitizer which had acceptable sensitivity for industrial use.

TABLE 3: Blasting Results of Foamed Explosives

Example 3	AN/water ¹ Oil phase ² Foam 3.3% Density = 1.07 g/ml 50 mm diameter	Blast Results⁴ 2.3g PETN/4811 m/s ⁴
Example 4	AN/water ¹ Oil phase ² Foam 3.4% Density = 1.07 50 mm diameter	0.78g/3800 m/s 2.3g/4790 m/s
Example 5	AN/SN/water ³ Oil phase ² Foam 3.7% Density 1.13 25 mm diameter	0.2g VOD 4100 m/s
Example 6	AN/SN/water ³ Oil phase ² Foam 3.6% Density 1.14 25 mm diameter	0.3g/4150 m/s 0.2g/4050 m/s
	after 1 month @ 22°C	0.39/4000 m/s
	after 2 months @ 22°C	0.3/4100 m/s
	after 3 months @ 22°C	0.3/3950 m/s

¹ An 81/19 mixture by weight of ammonium nitrate and water having a Fudge point of about 60°C.

² Paraffin oil (4% of total explosive weight), a PIBSA based surfactant (0.66) and sorbitan sesquioleate (0.34%) mixture was added to prepare an emulsion explosive having a total oil phase of 5%.

³ A 77/11/12 mixture by weight of ammonium nitrate, sodium nitrate, and water having a Fudge point of about 75°C.

⁴ Blast results are shown as grams of PETN in the detonator used for detonation, and the VOD for the resultant explosion.

Stability of the product produced was measured by storing the explosive composition of Example 6 for 3 months. As is shown in Table 3, the composition had an acceptable VOD after 3 months storage at 22°C.

EXAMPLE 7

A "doped" emulsion explosive which was sensitized by an oil based foam, which foam was prepared as in Example ¹/₂, was prepared having the following formulation:

- | | | |
|------|--|-----|
| i. | AN/SN/water ³
Oil phase ² | 68% |
| ii. | Ammonium nitrate
prills | 29% |
| iii. | Foam
Density 1.18 g/ml
100 mm diameter | 3% |

² Paraffin oil (4% of total explosive weight), a PIBSA based surfactant (0.66) and sorbitan sesquioleate (0.34%) mixture was added to prepare an emulsion explosive having a total oil phase of 5%.

³ A 77/11/12 mixture by weight of ammonium nitrate, sodium nitrate, and water having a Fudge point of about 75°C.

The explosive in this example was prepared by first emulsifying in a low shear mixer the AN/SN/water mixture in a paraffin oil and surfactant mixture. The emulsified mixture was, subsequently, mixed with ammonium nitrate prills to produce a doped emulsion and the oil based foam was added to sensitize the explosive. The doped emulsion had a VOD of 3970 m/s when initiated with a 40g Pentolite booster charge. The sensitivity of the doped emulsion was industrially acceptable for larger diameter applications.

EXAMPLE 8

A Heavy ANFO explosive which was sensitized by an oil based foam, which foam was prepared as in Example ¹/₂, was prepared having the following formulation:

- | | | |
|------|--|-------|
| i. | AN/SN/water ³
Oil phase ² | 50% |
| ii. | Ammonium nitrate
prills | 47.5% |
| iii. | Foam
Density 1.25 g/ml
100 mm diameter | 2.5% |

- 2 Paraffin oil (4% of total explosive weight), a PIBSA based surfactant (0.66) and sorbitan sesquiolate (0.34%) mixture was added to prepare an emulsion explosive having a total oil phase of 5%.
- 3 A 77/11/12 mixture by weight of ammonium nitrate, sodium nitrate, and water having a Fudge point of about 75°C.

The explosive in this example was prepared by first emulsifying in a low shear mixer the AN/SN/water mixture in a paraffin oil and surfactant mixture. The emulsified mixture was, subsequently, mixed with ammonium nitrate prills to produce a Heavy ANFO explosive and the oil based foam was added to sensitize the explosive. The doped emulsion had a VOD of 3300 m/s when initiated with a 40g Pentolite booster charge. The sensitivity of the doped emulsion was industrially acceptable for larger diameter applications.

Having described specific embodiments of the present invention, it will be understood that modification thereof may be suggested to those skilled in the art and it is intended to cover all such modifications as fall within the scope of the appended claims.

**CLAIMS**

1 A method of producing an emulsion explosive composition
sensitized by dispersed gas bubbles, wherein the gas bubbles
5 are introduced to said emulsion explosive composition by
mixing a gas-in-liquid foam into an emulsion explosive
composition whereby the liquid of said foam becomes part of
a liquid phase of the emulsion whilst the gas in said foam
becomes a dispersion of sensitizing gas bubbles in said
10 emulsion explosive composition.

2 A method of producing an explosive composition as
claimed in Claim 1 wherein the liquid in said gas-in-liquid
foam comprises a liquid or liquifiable fuel and a foaming
15 agent.

3 A method of producing an explosive composition as
claimed in Claim 2 wherein said foaming agent is casein or a
perfluorinated surfactant or a mixture thereof.

4 A method of producing an explosive composition as
claimed in Claim 2 additionally comprising a viscosity
control agent.

5 A method of producing an explosive composition as
claimed in Claim 4 wherein said viscosity control agent is
polyisobutylene or butyl rubber.

6 A method of producing an explosive composition as
30 claimed in Claim 1 wherein the liquid in said gas-in-liquid
foam comprises water and a foaming agent.

7 A method of producing an explosive composition as
claimed in Claim 6 wherein said foaming agent is water
soluble casein, or a perfluorinated surfactant or a mixture
35 thereof.



8 A method of producing an explosive composition as claimed in Claim 6 wherein said gas-in-liquid foam additionally comprises a freezing point depressant.

5 9 A method of producing an explosive composition in Claim 8 wherein said freezing point depressant is ammonium nitrate.

10 10 A method of producing an explosive composition as claimed in Claim 1 wherein said explosive composition comprises an oxidizing salt and a fuel.

15 11 A method of producing an explosive composition as claimed in Claim 1 wherein said foam comprises a liquid carrier miscible with the liquid phase of the emulsion.

20 12 A method of producing an explosive composition as claimed in Claim 1 wherein said gas-in liquid foam has a density of less than 0.2 g/ml.

25 13 A method of producing an explosive composition as claimed in Claim 1 wherein said gas-in-liquid foam comprises at least 90% by volume gas.

30 14 A method of producing an explosive composition as claimed in Claim 13 wherein said gas is carbon dioxide or nitrogen.

35 15. A method of producing an explosive composition as claimed in Claim 1 wherein said gas-in-liquid foam has a foam half life of greater than 4 minutes.

16. An emulsion explosive obtainable by a method according to any one of claims 1 to 15, and comprising an emulsion of a continuous fuel phase, a discontinuous oxidizer phase and a surfactant for stabilization of said emulsion, and blended therewith as a sensitizer, a pre-formed gas-in-liquid foam.



17. A method of manufacturing a sensitized emulsion explosive composition comprising:

preparing a base emulsion composition by emulsifying an aqueous solution of an oxidizer salt in a liquid or
5 liquifiable fuel, or by emulsifying a liquid or liquifiable fuel in an aqueous solution of an oxidizer salt;

preparing an essentially gas-in-liquid foam by mixing a carrier liquid with a foaming agent to form a foaming
10 solution and subjecting said solution to mechanical agitation, or to a pressurized gas sparge, or allowing it to foam by chemical reaction in the foam system; and

blending said gas-in-liquid foam into said base emulsion composition to render it functional as an
15 explosive.

18. A method of blasting comprising placing an explosive detonator in operative contact with an explosive as obtained
20 by a method according to claim 1 or as claimed in claim 16 and detonating said detonator.

19. A method of producing a foam-sensitized emulsion explosive substantially as described in the Examples 3 to 8
hereinbefore.

20. An emulsion explosive composition according to any one
25 of the Examples 3, 4, 5, 6, 7 or 8 hereinbefore.
