

[54] **EXPLOSIVE COMPOSITION HAVING A LIQUID HYDROXYALKYL NITRATE AS SENSITIZER**

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[56] **References Cited**
UNITED STATES PATENTS
3,653,992 4/1972 Fee 149/47 X

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[57] **ABSTRACT**
Hydroxyalkyl nitrates, particularly ethylene glycol mononitrate, propylene glycol mononitrate and hydroxychloropropyl nitrate are employed as part or whole replacements for nitroglycerine and/or ethylene glycol dinitrate in substantially non-aqueous gels, semi-gelatin, dynamites and dry explosive compositions.

7 Claims, No Drawings

EXPLOSIVE COMPOSITION HAVING A LIQUID HYDROXYALKYL NITRATE AS SENSITIZER

This application is a continuation-in-part of Ser. No. 305,337 filed Nov. 10, 1972, now abandoned.

This invention relates to a sensitizing agent for substantially water-free explosive compositions and hence to such explosive compositions deriving novelty through the presence therein of the said sensitizing agent.

In the explosives art it has long been a desideratum to provide a safe, economic and practical substitute for nitroglycerine and ethylene glycol dinitrate sensitizers, generally referred to as NG and EGD respectively, in explosive compositions of the types generally known as gelatins, semi-gelatins and dynamites. Since NG and/or EGD are hazardous to manufacture and to formulate into useable explosive mixtures and since the vapours of NG and/or EGD frequently produce undesirable physiological effects on individuals exposed thereto, their use poses a continuing problem in the explosive industry. It had been predicted that the non-toxic aqueous slurry explosives consisting of oxidizer salt/fuel mixtures in a gelled water matrix would eliminate most of the undesirable characteristics of NG/EGD-based explosives and eventually displace many of them from the market. While to a substantial extent this has happened, it has not been possible to match the sensitivity and power of NG/EGD-based explosives, especially in small diameters without adding to the aqueous slurries costly sensitizing materials. The need continues, therefore, to employ NG/EGD as explosive sensitizers and the search for safer substitutes for these sensitizers has like-wise continued.

Ideally, an explosive sensitizer should possess the economy and strength of conventional nitroglycerine/ethylene glycol dinitrate without the explosion and toxicity hazards associated therewith and at the same time the sensitizer must be fully compatible with the mixture of ingredients of an explosive composition so as to produce the optimum in blasting performance. Many sensitizers having a range of orders of sensitization are known in the explosives art which have particular utility in various types of explosives compositions. In addition to the liquid nitric esters like NG and EGD, these sensitizers include, for example, aromatic nitro compounds such as trinitrotoluene, nitroamine compounds such as nitroguanidine, powdered metals such as aluminium, nitrocellulose, smokeless powder, metalloids such silicon, and others. Each sensitizer finds specific utility in admixture with other compatible ingredients in particular types of explosive compositions.

In the field of sensitized slurry explosives, for example Henry R. Fee and Elden K. Hurley, disclose in U.S. pat. No. 3,653,992 granted on Apr. 4, 1972, that a liquid nitrate-alkanol (hydroxyalkyl nitrate) may be employed as the sensitizing constituent in pumpable or pourable aqueous slurry mixtures containing from 3 to 40% by weight of water. As noted by Fee and Hurley, a liquid nitrate-alkanol is particularly suitable for use as an aqueous slurry sensitizer since, in addition to being safe, it is freely soluble in the salt solution of a slurry, is compatible with the thickened water used in the slurry matrix, is pumpable and requires no separation from the salts and water which are introduced during its manufacture. However, even the improved nitrate-alkanol sensitized slurry of Fee and Hurley has

not matched, in terms of sensitivity and density, the NG/EGD sensitized type of explosives of the prior art. Indeed, the compositions of Fee and Hurley require the addition of gas bubbles in order to impart adequate sensitivity to these slurries. Such bubble additives preclude the use of these slurries, at the present state of technology, in the types of packages customarily provided by NG/EGD sensitized explosives, namely, small diameter paper cartridges used in underground mining.

It has now been surprisingly found that hydroxyalkyl nitrates, particularly exemplified by ethylene glycol mononitrate (EGMN), and propylene glycol mononitrate (PGMN) and hydroxychloropropyl nitrate (HCPN), previously disclosed as useful only in aqueous slurry explosives, are fully compatible with NG/EDG and may be successfully employed as part or whole replacements for NG and/or EGD in substantially non-aqueous gelatinous, semi-gelatinous and dry explosive compositions. By substantially non-aqueous is meant a composition containing 3% or less by weight of water.

This invention therefore provides novel, substantially non-aqueous explosive compositions containing as sensitizer constituents thereof hydroxyalkyl nitrates as substitutes for nitroglycerine and/or ethylene glycol dinitrate.

A practical industrial method for the preparation of hydroxyalkyl nitrate (HAN) consists in reacting an oxirane ring compound with an aqueous solution of ammonium nitrate and nitric acid. Ethylene oxide, for example, reacts to form ethylene glycol and EGMN in a diluted solution of nitric acid and ammonium nitrate. Other nitrate salts such as sodium nitrate and calcium nitrate may be included in the reactive mixture. The end reaction product containing EGMN may be subjected to an extraction treatment for recovery of substantially pure EGMN. Alternatively, the end product may in most instances be used as such as a replacement or diluent for NG and/or EGD in conventional explosives of the gelatinous, semi-gelatinous and dry dynamite types.

The invention is illustrated by the following Examples which are not meant to be limitative as to the scope thereof. Percentages in all Examples are by weight.

EXAMPLE 1

Preparation of Ethylene Glycol Mononitrate (EGMN)

One mole (44 g.) of ethylene oxide was bubbled into a solution containing 200 g. of ammonium nitrate, 40 g. of sodium nitrate, 80 g. of 98% nitric acid and 140 g. of water and the mixture was cooled in an ice bath. The reaction was exothermic and the temperature rose from 8° to 20°C. during the addition of the oxide. As soon as the addition of oxide ceased, the temperature fell rapidly and no ethylene oxide was evolved from the reaction vessel. This indicated a very rapid reaction. The EGMN formed did not separate from the aqueous solution, even when neutralized and saturated with ammonium nitrate/sodium nitrate. The aqueous solution was extracted with methylene chloride and a EGMN yield of 30-35% was obtained. This yield was very low and not representative of actual reaction yield but was the result of simple partition of the product between two phases in which it was completely miscible.

The EGMN isolated was shown by thin-layer chromatography and gas-liquid chromatography to consist mainly of EGMN with small quantities of ethylene gly-

col, ethylene glycol dinitrate and diethylene glycol mononitrate.

EXAMPLE 2

Another preparation of Ethylene Glycol Mononitrate (EGMN)

Ethylene oxide was bubbled into a solution containing 500 g. of ammonium nitrate, 80 g. of sodium nitrate, 160 g. of 98% nitric acid and 280 g. of water. The reaction temperature was maintained below 35°C. by external cooling. The oxide was metered into the solution at a rate of 1.2 l./min. while 160 g. of 98% nitric acid was added dropwise over a period of 57 minutes, the time required for the addition of 3 moles of oxide. An additional 6 moles of ethylene oxide and 320 g. of 98% nitric acid were added in a similar manner, after which an extra 4 moles of the oxide were introduced into the system in order to neutralize the excess nitric acid. In a typical case, after a total of 13 moles of the oxide had been absorbed, 2 ml. of 28% ammonium hydroxide solution ($\rho = 0.90$) were required to bring the pH of the final solution to 7.0. A material-balance calculation in the reaction products predicted approximately the following composition:

Ammonium nitrate	24.1 %
Sodium nitrate	3.9 %
Water	11.5 %
Ethylene glycol mononitrate	51.4 %
Ethylene glycol	9.1 %

EXAMPLES 4 - 8

Preparation of EGMN

In a pilot-plant batch reaction process as described in Example 2, the following EGMN liquors were produced. The quantities shown are expressed as percent by weight.

Example	4	5	6	7	8
Ammonium nitrate	23.4	22.0	24.7	23.9	22.8
Sodium nitrate	4.2	4.2	3.8	3.8	4.0
Water	12.8	15.7	11.9	11.5	15.3
EGMN*	54.2	51.3	54.7	55.8	52.4
Ethylene glycol	5.4	6.8	4.8	5.0	5.5

*Further additions of ethylene oxide and strong nitric acid can be made to provide even higher concentrations (e.g. 70%) EGMN

EXAMPLES 9 - 11

Continuous preparation of EGMN

A continuous process was employed to produce EGMN liquors. Three vessels were connected in series and comprised a mixing tank, a nitrator and a neutralizer. The vessels were equipped with mixing devices, cooling devices and inlet and outlet orifices. An acidic aqueous solution comprising from 26-33 parts by weight of ammonium nitrate, 46-52 parts by weight of strong 98% nitric acid and 15-25 parts by weight of water was prepared in the mixing tank. This solution was fed by pump into the nitrator where it was contacted with ethylene oxide vapor. The feed rates of the solution and the vapor were controlled so as to maintain a reaction temperature between about 30°C. and about 60°C. which range reduced the production of side products such as ethylene glycol or ethylene glycol

dinitrate. The desired nitration product on a weight percent basis is 1-12% nitric acid, 18-25% ammonium nitrate, 10-15% water, 2-8% ethylene glycol and 30-60% EGMN. The crude product from the nitrator overflowed continuously into the neutralizer where a gas sparger dispersed ammonia gas uniformly into the stirred reaction mixture. pH was controlled in the range 6.2 to 6.5. In this stage an additional 2-15% by weight of ammonium nitrate was produced from the reaction of ammonia gas with residual nitric acid present. The effluent from the outlet of the neutralizer was the desired final product which normally contained from 40-60% by weight EGMN, 2-8% by weight of ethylene glycol, 25-35% by weight of ammonium nitrate and 10-25% by weight of water. The following EGMN liquors were produced by the continuous process.

Example	9	10	11
Ammonium nitrate	27.5	29.2	25.9
Water	15.0	16.1	22.4
EGMN	53.6	49.4	46.8
Ethylene glycol	3.8	5.3	4.9

EXAMPLE 12

Sensitivity of Ethylene Glycol Mononitrate (EGMN)

The impact sensitivity of nitroglycerine (NG) and EGMN were compared in a falling weight impact test by absorbing both substances on a mixture of dopes consisting of 25% of wood pulp, 25% of sodium nitrate and 50% of ammonium nitrate. A 60% NG/40% dope mixture detonated when a 5 kg. weight was dropped 23 inches. However, a mixture of 70% of EGMN and 30% of dope failed to detonate with the fall of 5 kg. from 55 inches.

EXAMPLES 13-21

Preparation of PGMN and HCPN

Batches of propylene glycol mononitrate and hydroxychloropropyl nitrate were made by a method similar to that of Example 2. It was found, however, that high initial concentrations of ammonium nitrate led to its crystallization as the reaction proceeded and that the presence of sodium nitrate caused a liquid-liquid phase separation during the reaction. Typically 50 g. of ammonium nitrate and 63 ml. of 70% nitric acid served as a starting mixture. Propylene oxide or epichlorohydrin and 70% nitric acid were added through separate inlets at the same molar ratio until 16-30 mol of acid had been added followed by 5-17% excess of propylene oxide or epichlorohydrin. Additional ammonium nitrate can be added dissolved in the nitric acid to maintain a high nitrate concentration. Up to 470 g. of ammonium nitrate remained in solution. Neutralization of the excess acid with liquid ammonia led, in the case of the propylene glycol mononitrate synthesis, to a liquid-liquid phase separation with a more concentrated solution of the desired product, PGMN, in the upper layer. It was found with both syntheses that saturation of the system with sodium nitrate or calcium nitrate led to a more efficient separation in which the layer having the major portion of mononitrate ester contained comparatively little water. This technique was therefore well-suited to the aims of the present invention. The preferred compositions of the feeds to the reactor are

compatible with the operation of the continuous process of Examples 9 - 11.

Summarized are the analysis of representative batch reaction products:

with a No. 6 electric blasting cap. This represents an explosive with a controlled reduction in sensitivity when compared to a nitroglycerine gelatine of equivalent strength.

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Example	13	14	15	16	17	18	19	20	21
Analysis:									
H ₂ O	14.1	12.7	12.6	8.8	14.5	5.7	11.3	11.6	5.8
Ammonium nitrate	12.9	12.4	13.5	7.7	14.3	4.1	9.5	8.3	5.5
Sodium nitrate	—	—	—	1.7	—	0.33	—	—	0.74
Propylene glycol	7.3	7.2	7.7	7.4	7.8	—	—	—	—
Propylene glycol mononitrate	65.7	67.7	66.2	74.5	63.4	—	—	—	—
Chlorohydrin	—	—	—	—	—	9.2	8.6	9.3	9.1
Hydroxy-chloropropyl nitrate	—	—	—	—	—	80.7	70.6	70.8	78.9

Notes:

Examples 13, 14 and 15 were obtained by separation of the main liquor layer after neutralization with ammonia. Example 16 was obtained from Example 15 by saturation of the system with sodium nitrate and retention of the sensitizer-rich layer. Examples 19 and 20 were obtained as the one-phase product of the reaction after neutralization with ammonia.

Example 21 was obtained from Example 20 by saturation of the system with sodium nitrate and retention of the sensitizer-rich layer.

The preparation of compositions of hydroxyalkyl nitrate (HAN) which are analogous to the conventional high explosives based on nitroglycerine, ethylene glycol dinitrate or mixtures of these involves the isolation of substantially anhydrous HAN from aqueous liquors thereof. For illustrative purposes, this may be done by extraction of EGMN from reactor liquor with methylene chloride, which is then stripped off in an evaporator unit.

EXAMPLE 22

Gelatinized explosive composition

A gelatinized explosive was made with a liquid phase consisting of ethylene glycol mononitrate which contained about 3% of ethylene glycol. This mixture rapidly and effectively gelled dynamite grade nitrocotton and the resultant gel was resistant to deterioration when immersed in water. The following composition was prepared on laboratory scale by mixing procedures well known in the art, the proportions shown being percent by weight.

EGMN/EG	26.0
Nitrocellulose (dynamite grade)	0.7
Ammonium nitrate (blended fines)	55.5
Sodium nitrate (Chilean)	16.0
Vegetable meal	0.5
Wood pulp	0.5
Sulphur	0.4
Calcium carbonate (chalk)	0.4
	100.0

A very extrudable, full-bodied explosive composition was obtained which detonated (1 ¼ × 8 inch cartridge) when initiated either with a primer of 50% strength dynamite or with high strength electric blasting cap at a velocity of 2.57 km/sec. The cartridge was not initiated

While the toxicological properties of ethylene glycol mononitrate are not fully known, it is reported to be much less toxic than nitroglycerine. It has a vapour pressure very similar to ethylene glycol dinitrate which is the volatile and predominant constituent of all the nitroglycerines of modern commerce. Nevertheless, in both controlled exposures and in extensive work periods with EGMN, none of the characteristic "NG headaches" caused by dinitrate vapours were experienced. Thus, an additional property of explosives made with EGMN is the elimination of the headache-producing characteristics of NG-explosives.

Nitroglycerine was found to have remarkable and unexpected solubility characteristics with respect to EGMN liquors. When a nitroglycerine which has been made from a feedstock containing 15% glycerine and 85% ethylene glycol was mixed with the EGMN liquor of Example 13, no phase-separation occurred at up to 12% NG, in spite of the fact that the system contained about 14% water and 24% dissolved salts. At higher levels of nitroglycerine, clean efficient separation into layers was obtained, with good extraction of EGMN into the predominantly organic layer. Further dehydration of this layer could be accomplished by the addition of compounds immiscible with water. Dinitrotoluene or molten trinitrotoluene were found to be effective extractants for the hydroxy alkyl nitrate constituents from reactor liquors.

EXAMPLE 23 - 27

Gelatinized explosive compositions

Concentrated solutions of EGMN were prepared by mixing together reactor liquors with explosive ingredients which promote phase separation as described heretofore. Gelatin-type compositions were prepared from these solutions by techniques well known in the art with the results summarized below, the proportions shown being in percent by weight.

Example	23	24	25	26	27
% by weight of EGMN liquor	48 (Ex. 5)	77 (Ex. 6)	77 (Ex. 6)	71 (Ex. 6)	68 (Ex. 6)
% by weight of explosive separation promoter	52 (85 G-NG) ¹	23 (85 G-NG)	23 (85 G-NG)	23 (85 G-NG) (6% DNT)	18.5 (85 G-NG) (13.5% DNT)
% by weight of organic phase isolated	75	59.5	59.5	60.5	60.7
Explosive compositions					
Organic phase	31.00	30.0	25.0	30.0	25.0
Dynamite nitrocotton	0.95	0.5	0.4	0.5	0.5
Ammonium nitrate fines	51.50	55.8	46.9	52.0	52.0
Sodium nitrate	10.00	11.0	20.0	15.0	19.7
Wheat flour	2.65	—	—	—	—
Vegetable meal	1.50	1.0	1.0	1.0	1.0
Wood pulp	1.00	0.7	0.7	0.7	0.7
Sulphur	0.90	0.5	0.5	0.4	0.7
Calcium carbonate	0.50	0.5	0.5	0.4	0.4
TNT (flakes)	—	—	5.0	—	—
Detonations					
Paper cartridge	1 1/4"×8"	1 1/4"×8"	1 1/4"×8"	1 1/4"×8"	1 1/4"×8"
Primer	No. 6 EB cap	No. 6 EB cap	No. 6 EB cap	No. 6 EB cap	High strength cap
Temperature	40°F.	40°F.	40°F.	40°F.	40°F.
Vel. of det. (km/sec.)	3.18	2.26	2.37	2.63	2.21

¹Nitric ester mixture of 85% ethylene glycol and 15% glycerine

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Example 23 had a mixed density of 1.47 g./cm³, and had a soft consistency which extruded easily and cleanly for cartridgeing. the composition was still soft

were found to work more efficiently if a small amount of hydroxyethylcellulose of high molecular weight was added and swelled first.

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Example	28	29
Liquor	33.0 ¹	33.0 ²
Hydroxyethylcellulose	0.3	0.3
Nitrocotton	1.3	1.3
Sodium nitrate	35.0	35.0
Ammonium nitrate	28.5	28.5
Wood pulp	0.8	0.8
Wheat flour	0.7	0.7
Chalk	0.4	0.4
	(Contains about 25% propylene glycol mononitrate and about 2.9% water)	(Contains about 26% hydroxychloropropyl nitrate and about 1.9% water)
Detonation tests unconfined		
Polyethylene cartridge diameter	4 inches	4 inches
Primer (pentolite)	60 g.	60 g.
Results	Detonated	Detonated

¹Liquor concentrated from Example 17 by saturation with sodium nitrate

²Example 21

after 23 days storage in an environment cycling daily between 96°F. and 0°F.

These Examples further illustrate explosives with a graduated range of sensitivities. The estimated nitroglycerine content varies from 15 to 7%. Furthermore, since ethylene glycol mononitrate is an effective anti-freeze additive for glyceryl trinitrate, the latter can be used exclusively in the formulations for somewhat greater efficiency of separation and for the total elimination of the headache-producing vapours of ethylene glycol dinitrate.

EXAMPLES 28 -29

Gelatin-type explosive compositions

Gelatin-type explosives of a somewhat lower sensitivity were prepared from propylene glycol mononitrate and hydroxychloropropyl nitrate liquors. The low-water concentrate liquors swelled nitrocellulose, but

EXAMPLES 30 -33

Gelatinized explosive compositions

Sensitizer liquors were prepared by admixture of the low-water liquors like Examples 16 and 21 with standard EGMN liquors like Examples 9 - 11 and saturating amounts of salt. For example, 100 parts of PGMN liquor and 200 parts of EGMN liquor were mixed with sodium nitrate; 209 parts of sensitizer-rich layer separated which contained only 11% water and 15% ammonium nitrate.

The low water-levels attained in liquor concentrates were advantageous of the preparation of gelatinized compositions containing nitroglycerin, without need for additional liquid-phase-separation operations of the type described in Examples 23 - 27. These are illustrated in Examples 30 - 33 with compositions given in percent by weight.

	Semi-gelatin types		Gelatin types	
	Ex. 30	Ex. 31	Ex. 32	Ex. 33
Liquor	10 ¹	10 ²	15 ³	15 ⁴
Nitroglycerine	10	10	15	15
Nitrocotton	0.5	0.5	0.8	0.8
Ammonium nitrate (blended fines)	75.9	75.9	53.9	66.4
Sodium nitrate	—	—	12.0	—
Vegetable pulps	2.5	2.5	2.5	2.0
Sulphur	0.3	0.3	0.3	0.3
Stearic acid	0.5	0.5	—	—
Chalk	0.3	0.3	0.5	0.5
Detonation tests (unconfined in 1 1/4" diameter polyethylene cartridges)				
Initiator cap	No. 2 F/C	No. 4 F/C	No. 6 EB	No. 4 F/C
Velocity of detonation (km/sec.)	2.9	2.9	2.2	2.3

¹EGMN/PGMN liquor concentrate described above
²PGMN liquor, Example 16
³PGMN liquor concentrated from Example 17 by saturation with sodium nitrate
⁴HCPN liquor, Example 21

EXAMPLE 34

Substantially dry, dynamite type explosive composition

Low-nitroglycerine-containing dynamite compositions typically employ about 9% nitroglycerine. A typical EGMN liquor used at about a 15 – 20% level in place of nitroglycerine and in conjunction with usual oxygen-supplying salts and dopes formulated in dynamite would introduce 2 – 3% water and 8 – 11% ethylene glycol mononitrate into the formulation. These water levels were deemed to be acceptable and no drying of an EGMN liquor was necessary before use in such a composition. A composition was made up having the formula:

EGMN liquor (Example 9)	18.0%
Ammonium nitrate (fine)	63.3
Sodium nitrate (Chilean)	10.0
Vegetable meal	2.0
Wood pulp	2.0
Wheat flour	1.5
Tamarind flour	3.0
Calcium carbonate	0
	100.0%

The composition was of a damp, cohesive consistency typical of conventional dynamite and in a four inch diameter paper cartridge unconfined, this formulation gave a strong detonation at 70°F. when initiated with a high-strength cap.

EXAMPLE 35

Substantially dry, dynamite type explosive compositions

An explosive composition containing relatively large proportions of liquid hydroxyalkyl nitrate sensitizer,

thickened with nitrocellulose, and rendered rather dry in consistency by admixture with cellulosic pulp, is exemplified in the following formula:

Hydroxyalkyl nitrate liquor (Example 21)	45.0
Hydroxyethyl cellulose	0.2
Nitrocotton	1.2
Sodium nitrate	46.2
Cellulosic pulps	7.0
Chalk	0.4
Detonation tests (unconfined)	
Polyethylene cartridge diameter	3"
Primer (pentolite)	60 g.
Velocity of detonation (km/sec.)	2.4

On substitution for nitroglycerine in the dry powder type explosives it is found that difference between these and the class of compositions known as dry blasting agents becomes indistinct. Indeed, because of the mutual solubility of nitroglycerine in the liquid hydroxyalkyl nitrate sensitizer of the invention, a range of sensitive spanning both classes of explosives can be achieved.

EXAMPLES 36 – 43

Dry blasting agent compositions

Dry blasting agents normally employed in dry boreholes especially in open-pit mining and quarrying operations, are exemplified by the ammonium nitrate-fuel oil (ANFO) compositions. ANFO has been shown to be both economic and safe but suffers somewhat from an intrinsic insensitivity which requires substantial priming of a charge for initiation and propagation. It has now been found that the addition of hydroxyalkyl nitrate (HAN) liquor to typical ANFO compositions enhances their sensitivity. Advantage can also be taken of the solubility of nitroglycerine in HAN liquor to introduce small proportions of NG into dry blasting agents for the manufacture of compositions of exceptional sensitivity. Because the NG is soluble and dissolved, it can be uniformly distributed throughout the dry compositions in a highly dilute form.

Detonation tests on the dry blasting agent formulations shown below were carried out by placing the explosive in a 4-inch diameter polyethylene bag on a steel plate supported on a lead bar of 1 % × ¼ inch cross section bent into the form of a circle. A strong detonation severely flattened this lead bar.

All the examples are demonstrably more sensitive than the control, a standard ammonium nitrate/fuel oil explosive prepared with the porous prills. Standard ANFO normally requires a No. 6 EB cap plus five No. 8 blasting caps for a strong detonation. The proportions shown are in per cent by weight.

Example	Control	36	37	38	39	40	41	42	43
HAN liquor	—	10.5 ¹	10.0 ²	10.0 ²	9.9 ²	10.0 ³	8.0 ⁴	8.0 ⁵	9.2 ⁿ
Nitroglycerine (85 G)	—	—	—	—	1.1	—	—	—	—
Ammonium nitrate (prills)	94.0	85.0	—	—	83.0	—	—	—	—
(crushed prills)	—	—	84.0	—	—	—	—	—	—
(fine grain)	—	—	—	83.8	—	85.3	87.0	86.8	86.0

- Continued

Example	Control	36	37	38	39	40	41	42	43
Fuel oil (No. 2 diesel)	5.5	4.5	—	—	—	—	—	—	—
Ground coke	—	—	5.5	5.5	5.4	4.7	4.0	5.2	4.8
Tamarind flour	0.5	—	0.5	—	0.5	—	—	—	—
Wheat flour	—	—	—	1.0	—	—	1.0	—	—
Guar flour	—	—	—	—	0.1	—	—	—	—
Density	0.83	0.97	1.03	1.11	1.00	1.12	1.13	1.10	1.10
Detonation: Minimum primer for strong detonation in 4" diameter	6 + No. 8 EB caps	3 No. 8 EB caps	3 No. 8 EB caps	1 No. 6 EB caps	1 No. 2 E/C cap	1 high strength cap	3 No. 8 EB caps	1 high strength cap	—
Critical diameter using high strength cap and vel. in km/sec.	—	—	—	2" 2.40	1" 2.07	2 1/4" 2.90	—	—	2 3/4" 2.90

¹Ex. 6 (EGMN)

²Ex. 8 (EGMN)

³EGMN-PGMN liquor as in Ex. 30

⁴Distilled PGMN

⁵HCPN liquor Ex. 18

⁶8 parts Ex. 18 + 1.2 parts dissolved TNT

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What we claim is:

1. A substantially non-aqueous explosive composition having a water content of less than 3% by weight and having as a sensitizer at least one liquid hydroxyalkyl nitrate.
2. An explosive composition as claimed in claim 1 wherein the liquid hydroxyalkyl nitrate sensitizer is selected from ethylene glycol mononitrate, propylene glycol mononitrate, hydroxychloropropyl nitrate and mixtures thereof.
3. An explosive composition as claimed in claim 1 having an extrudable gelatinous consistency comprising essentially from 40 to 80% by weight of oxygen-supplying salt, from 1 to 15% by weight of carbonaceous material, at least 5% by weight of liquid hydroxyalkyl nitrate sensitizer and adjusted to a gelatinous consistency by the further incorporation of gel-producing liquid/thickener combination.
4. An explosive composition as claimed in claim 1 having a tappable, cohesive consistency comprising

essentially from 5 to 40% by weight of liquid hydroxyalkyl nitrate sensitizer, from 40 to 90% by weight of oxygen-supplying salt, from 1 to 15% by weight of carbonaceous material, up to 10% by weight of a gel-extending liquid and a thickening additive.

5. An explosive composition as claimed in claim 1 having a dry blasting agent consistency comprising essentially from 65 to 95% by weight of particulate ammonium nitrate, from 0.5 to 15% by weight of carbonaceous material and from 2 to 20% by weight of liquid hydroxyalkyl nitrate sensitizer.

6. An explosive composition as claimed in claim 1 also containing at least one supplementary sensitizer material.

7. An explosive composition as claimed in claim 6 wherein the supplementary sensitizer material is selected from particulate metal, ethylene glycol dinitrate, nitroglycerine, pentaerythritol tetranitrate, dinitrotoluene, alkylamine nitrate, alkanolamine nitrate, ammonium perchlorate and mixtures thereof.

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