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3,294,601

HEXAMETHYLENE TETRAMINE AND AMMONIUM NITRATE CONTAINING EXPLOSIVE COMPOSITION

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This application is a continuation-in-part of my co-pending Serial No. 287,291, filed June 12, 1963, now U.S. Patent 3,247,033.

This invention relates to novel high explosives and more particularly to a high explosive which can be used as a wet blasting agent and which is conveniently poured into a borehole, such as may be drilled in hard rock mining.

Explosive compositions may be broadly classified as molecular or "fixed" explosives, heterogeneous explosives, and hybrid explosives. A molecular explosive contains both fuel and oxidizer within the same molecule and usually consists of CH-type groups linked with NO-type groups. Examples of molecular explosives are nitroglycerin and trinitrotoluene. A heterogeneous explosive is a mixture of separate macroscopic particles (or sometimes films) of oxidizer and fuel. A mixture of ammonium nitrate and fuel oil is a good example of a heterogeneous explosive. A hybrid explosive is a mixture of a molecular explosive and a heterogeneous explosive. The hybrid explosives constitute the most common class of commercial explosives—that is the nitroglycerin dynamites. The molecular explosive portion in the hybrid explosive is nitroglycerin, and the heterogeneous portion consists of ammonium nitrate and/or sodium nitrate together with wood pulp and other carbonaceous substances.

A major objective in the explosive art has been to increase the proportion of the oxidizer, generally ammonium nitrate, and reduce the proportion of high cost, impact- and friction-sensitive molecular explosive ingredients in hybrid explosives. A further objective has been to develop a heterogeneous explosive composition that is free of molecular explosive ingredients and less hazardous than either a molecular explosive or a hybrid explosive while retaining the desirable properties of the latter. Some degree of success has been achieved in this last objective in that mixtures of petroleum oil and particulate ammonium nitrate in the form of prills are now in use as a blasting agent in strip mining applications. This heterogeneous explosive, while very inexpensive, is often variable in composition and physical state. Factors such as oil distribution and particle size are difficult to control: the oil tends to drain off or segregate or it is unevenly absorbed, giving a product of non-uniform composition; also the ammonium nitrate particles tend to sometimes disintegrate because of temperature-induced phase changes and sometimes the ammonium nitrate has a tendency to fuse or set up because of moisture, or because of certain crystalline transformations brought on by temperature cycling. Since the strength of the mixture and its ability to support detonation in the borehole are critically dependent on oil concentration and particle size, the simple "oil-prill" heterogeneous explosive blasting agents, for reasons like those just mentioned, often give variable and unsatisfactory results.

It would therefore be desirable to have available an inexpensive blasting agent which was stable over long periods of storage, essentially insensitive to moisture, or even the presence of water in the borehole, and which could be readily handled and used. Ideally, such a blasting agent should be pourable, relative insensitive to shock,

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but yet be capable of being set off either with a blasting cap or with the use of ordinary initiators such as tetryl pellets.

Wet blasting agents have been disclosed which include mixtures of ammonium nitrate, aluminum and water (see U.S.P. 3,024,727 and Re. 25,695); mixtures of ammonium nitrate, urea and water (see U.S.P. 3,052,578); and ammonium nitrate, urea, a freezing-point depressant, and a molecular explosive such as nitroglycerin or RDX (see U.S.P. 2,548,693). Those wet blasting agents which contain only aluminum in an ammonium nitrate water slurry are limited to about 12% in the amount of water which can be added; and if it is desirable to use more water, a molecular explosive such as TNT must be added. Those wet blasting agents consisting essentially of urea, water and ammonium nitrate apparently require mixing or blending just prior to use and must be used in a borehole substantially free of voids.

Thus, to the desirable characteristics previously set forth for a blasting agent may be added the requirements that it should be free from molecular explosive components, that it does not need to be blended or mixed just prior to use, and that it can be used in boreholes over a wide range of size, shape and configuration.

In accordance with this invention, I have now discovered that it is possible to make a new type of explosive, which may be termed a "simulated molecular explosive." This new type of explosive, which in the strictest sense remains a heterogeneous explosive, exhibits performance characteristics which approach or equal those of comparable true molecular explosives, but it does not possess their sensitivity to shock. This in turn means that they can be readily formulated, handled and shipped. These so-called "simulated molecular explosives" are formed by achieving molecular-scale mixing of at least a portion of the ammonium nitrate and hexamethylenetetramine, thereby breaking down the normal physical barriers between the oxygen atoms in the ammonium nitrate and carbon and hydrogen atoms in the hexamethylenetetramine. This in turn materially reduces the length of the reaction zone as evidenced by the ability of these simulated molecular explosives to exhibit detonation velocities approaching theoretical. The wet blasting agents of this invention are made by combining ammonium nitrate, hexamethylenetetramine, water and a thickening agent, along with one or more modifying agents (e.g., bulking agents and catalysts) if desired. The resulting wet blasting agents have relatively high detonation velocities and they can be made in consistencies ranging from putty to a pourable gel-like cohesive or adhesive paste. The actual character of the consistency is controlled by the amount of water and by the thickener used; and the paste-like consistency achieved through the use of the thickener is apparently responsible for maintaining the uniform distribution of the components, even over long periods of storage. An important aspect of this invention lies in the fact that at least a portion of the ammonium nitrate and hexamethylenetetramine are mixed in what might be termed a "molecular scale" thus giving rise to the simulated molecular explosive without incorporating the inherent dangers associated with the use of a true molecular explosive such as RDX, TNT or nitroglycerin. One or more secondary fuels may also be added in minor amounts.

It is therefore a primary object of this invention to provide an improved wet blasting agent which comprises ammonium nitrate and hexamethylenetetramine and which, without containing any molecular explosives, approaches or attains the performance of those blasting agents which contain molecular explosives.

It will be evident to those familiar with the subject that many ancillary advantages follow from the substitution of a heterogeneous explosive for a hybrid explosive that contains true molecular explosive ingredients in any proportion. Thus, another object of this invention is to reduce hazards to health and safety resulting from the presence of molecular explosives such as nitroglycerin, trinitrotoluene, tetryl and the like in explosive compositions, by the substitution for such compositions materials that are very insensitive to stimuli of impact, heat and friction, and which are not injurious to health in either manufacture or use. It is still a further object of this invention to eliminate the added cost of molecular explosives by providing heterogeneous explosives that use only inexpensive, readily available fuel components in conjunction with a major portion of a low cost oxidizer.

It is yet another primary object of this invention to provide a wet blasting agent in which the ammonium nitrate, as well as the hexamethylenetetramine in the role of a primary fuel, and the secondary fuel if used, remain uniformly dispersed over long periods of storage and hence one which exhibits uniformity in performance over a wide range of storage and use conditions. Other objects of the invention will in part be obvious and will in part be apparent hereinafter.

The invention accordingly comprises the several steps and the relation of one or more of such steps with respect to each of the others, and the composition of matter possessing the characteristics, properties, and the relation of components which are exemplified in the following detailed disclosure, and the scope of the invention will be indicated in the claims.

In U.S.P. 3,166,555, I have disclosed and claimed an adduct of ammonium nitrate and hexamethylenetetramine which may be prepared by dissolving the two components in water in a molar ratio of about 2 to 1 and then removing the water at a temperature below about 40° C. This adduct is in effect the crystalline form of the simulated molecular explosive. In U.S.P. 3,166,452, I have disclosed the use of this adduct in making an explosive composition which contains an additional amount of oxidizer, e.g., ammonium nitrate, to render the composition substantially oxygen balanced.

In my copending application Serial No. 287,291, now U.S. Pat. 3,247,033 of which this application is a continuation-in-part, I have disclosed the production of a melt explosive which contains a major portion by weight of ammonium nitrate as the oxidizer and a minor portion by weight of a fuel material wherein the explosive is characterized as having the ammonium nitrate in the form of crystals enveloped by or embedded in a matrix of the fuel and any reaction product of the oxidizer and fuel. The preferred fuel is hexamethylenetetramine and it has been shown that in the formation of the melt explosive, there is created some of the adduct. The melt explosive is formed by heating a mixture of the ammonium nitrate and hexamethylenetetramine to a temperature between 150 and 165° C. to form a homogeneous molten mass and thereafter rapidly cooling the molten mass to form the required structure of the ammonium nitrate crystals in the matrix. Finally, in U.S.P. 3,210,160, one form of apparatus by which the melt explosive may be made is disclosed and claimed.

The ammonium nitrate-hexamethylenetetramine adduct was found to possess characteristics of a molecular explosive, although it was considerably more resistant to shock than such molecular explosives as TNT and RDX. In contrast to this, purely physical mixtures of ammonium nitrate with a fuel such as hexamethylenetetramine present reaction zone lengths which are always considerably greater than in the case of molecular explosives. This, in turn, means that these physical mixtures always exhibit burning rates and detonation velocities lower than the true molecular explosives containing essentially the same atomic ratios. This is, of course, a

simplified statement of the theory but it may be summarized by saying that if it were possible, in some way, to mix the ammonium nitrate and the fuel on a "molecular scale" so that the molecules of the oxidizer and the fuel are in more intimate contact than in physical mixtures, the detonation velocity would approach the ideal detonation velocity for the combination. The adduct formed in the melt explosive or by the process of U.S.P. 3,166,555 achieves this molecular scale of mixing and thus imparts to solid cartridge explosives disclosed in U.S.P. 3,166,452 and in copending application Serial No. 287,291, now U.S. Patent 3,247,033 properties approaching true molecular explosives.

I have now found it possible to make a wet blasting agent with ammonium nitrate and hexamethylenetetramine in which mixing of the ammonium nitrate with this primary fuel approaches the desired molecular scale of mixing. This may be accomplished either by introducing at least a portion of the ammonium nitrate in the form of the melt explosive of Serial No. 287,291 now U.S. Patent 3,247,033 or the adduct disclosed in U.S.P. 3,166,555, or by directly dissolving a portion of the ammonium nitrate and hexamethylenetetramine in the water used in making the slurry. The resulting wet blasting agent is an explosive which may be characterized as one which contains at least a portion of the ammonium nitrate and the hexamethylenetetramine in the form of an association complex as evidenced by n.m.r. spectra measurements. This association complex which is present over a very wide range of ammonium nitrate-hexamethylenetetramine is likewise a simulated molecular explosive.

The ammonium nitrate suitable for use in the wet blasting agent of this invention may be any commercial grade ammonium nitrate. It may be completely dry or it may contain up to about 3 percent water, which means that the highly concentrated ammonium nitrate solutions can be taken from the high pans in the ammonium nitrate manufacture and used directly in the compounding of the explosive of this invention.

The secondary fuel materials, if used, may be substances which are water-soluble, such as sugar and other carbonaceous materials; or they may be particulate material which are dispersed in the water slurry. This latter type of secondary fuel includes carbon, atomized or flake aluminum, or fuel oil. The primary requirement of the secondary fuel is that it be capable of oxidation under the conditions of the explosion with the yield of a large quantity of heat and also preferably of a large amount of gas. Most carbonaceous materials and some finely divided metals such as aluminum can fill this function.

The thickeners used may be any of those materials which are capable of setting up the water slurry in a gel-like consistency or in the form of a relatively thick cohesive paste. Normally, these thickeners will be one of the well-known gums such as guar, okra, or locust bean. They may be supplemented by other thickeners such as wood flour, cellulose ester gum and the like. As indicated previously, one or more thickeners is required to impart the desired consistency (whether described as paste-like, gel-like, or otherwise) to the explosive. The consistency is preferably one which maintains all solid materials (undissolved ammonium nitrate, bulking agents, secondary fuels, etc.) uniformly distributed in the blasting agent over an extended period of time.

In addition to these compounds, other modifiers may be used. Among these are the so-called bulking agents such as wood pulp, perlite or urea-formaldehyde microballoons which reduce the density of the wet blasting agent. The microballoons typically have diameters between 20 and 40 microns and may be used to provide a multitude of tiny air pockets intimately distributed throughout the wet blasting agent. These microballoons, in addition to serving as bulking agents, may also

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serve as heat centers in the shock wave and improve the properties of some forms of the explosive. Other suitable bulking agents may, of course, be used. Other modifiers include such materials as sodium bicarbonate to generate gas and create voids in the wet blasting agent to reduce its density; catalysts such as one of the chromates, e.g., potassium dichromate, and the like. The use of such modifiers will depend upon such factors as the manner in which the blasting agents are to be employed, the performance desired (e.g., more or less brilliance) and the conditions under which they are to be initiated.

In the wet blasting agents of this invention the water dissolves a portion of the ammonium nitrate and the hexamethylenetetramine and there is formed in the resulting solution an association complex of the ammonium nitrate and the hexamethylenetetramine to effect a molecular-scale mixing. This may be shown by n.m.r. spectra data.

Proton nuclear magnetic resonance (n.m.r.) measures the structural environment around protons; and the spectra obtained, in terms of position, intensity and band width, are indicative of the structural surroundings of the proton (as used in organic structure interpretation) and its exchange rate with other protons. The half-width of an absorption peak is related to the kinetics of the exchange process (see for example J. E. Liffler and E. Grunwald, "Rates and Equilibria of Organic Reactions," John Wiley and Sons, Inc., N.Y., 1963) such that observing the effect of external variables such as temperature or of internal variables such as the addition of a reactant allows one to calculate and formulate the kinetics of the exchange processes and the reactions involved in these exchange processes.

Solutions of ammonium nitrate and hexamethylenetetramine were examined in H₂O solvent with an internal n.m.r. reference material included. This reference material was DSS (3-trimethylsilyl-1-propane sulfonic acid sodium salt). These solutions were made up to contain increasing concentrations of ammonium nitrate and into them were added successively increasing concentrations of hexamethylenetetramine. The half-widths of the water peaks were measured and the observations are summarized in the following table wherein concentrations are given in gram/milliliter of the water solvent and $\Delta\delta_{1/2}$ is used to designate the width of the water absorption peak at half-height in cps. at 37° C.

N.M.R. SPECTRA FOR AMMONIUM NITRATE/
HEXAMETHYLENETETRAMINE SOLUTIONS

AN, g.	Hexa, g.	Mole Ratio, AN/Hexa	δ_{Hexa}	δ_{H_2O}	$\Delta\delta_{1/2}$ (H ₂ O)
0	0	-----	-----	282	1.5
0.19	0	-----	-----	286	11
0.38	0	-----	-----	292	18
0.77	0	-----	-----	303	32
0	0.16	-----	280	282	1.5
0.19	0.16	2	280	291	1.5
0.38	0.16	4	281	299	1.5
0.77	0.16	8	281	312	1.5
0.19	0.32	1	279	291	1.5
0.39	0.32	2	280	298	1.5
0.77	0.32	4	280	310	1.5

The data in the table clearly show that the hexamethylenetetramine peak remains constant while the water peak shifts. The addition of hexamethylenetetramine to the ammonium nitrate solutions causes an increase in the ammonium nitrate-water exchange rate as evidenced by the narrow H₂O absorption band ($\Delta\delta_{1/2}$) in the mixture solutions.

The observed effect of the hexamethylenetetramine on the ammonium nitrate-H₂O exchange rate must be explained in terms of a catalysis of the exchange reaction. As a catalyst, the hexamethylenetetramine must be interacting with both the ammonium nitrate and H₂O to provide a lower energy pathway for the exchange. The

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two situations might reasonably be represented by the following equations:

Without hexamethylenetetramine:



association

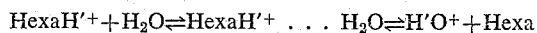
complex

With hexamethylenetetramine:



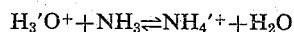
association

complex



association

complex



Although I do not wish to be bound by the following theory, it seems reasonable to postulate that in the water solution portion of the wet blasting agent, there is formed a mixture on a molecular scale of the ammonium nitrate with the hexamethylenetetramine. That there is a solution having an association complex is evidenced by the n.m.r. data. It may be further concluded that in this solution the normal physical barriers between the oxygen atoms in the ammonium nitrate and the carbon and hydrogen atoms in the hexamethylenetetramine are removed or substantially minimized. Thus, the water medium sets up the required molecular contact between the components to make the mixture of ammonium nitrate and hexamethylenetetramine the equivalent or near equivalent of a true molecular explosive in performance. The thickening agent maintains the undissolved and dispersed portion of the wet blasting agent uniformly held in the solution portion and thus forms an explosive which remains stable.

The wet blasting agent of this invention may be described further with reference to the following examples which are meant to be illustrative and not limiting.

Example 1

A wet blasting agent was made up which contained 67 percent by weight of a melt explosive (8.5 percent hexamethylenetetramine, 91.2 percent ammonium nitrate, 0.3 percent soap made in accordance with the teaching of my copending application Ser. No. 287,291), 7.4 percent wood flour, 8.9 percent ammonium nitrate, 11.9 percent sodium nitrate, 0.3 percent okra gum, 0.2 percent potassium dichromate and 4.4 percent water. The melt explosive, wood flour, okra gum, and part of the sodium nitrate were dry mixed, then mixed with a solution of ammonium nitrate, sodium nitrate, potassium dichromate, and water to obtain the wet blasting agent. The final explosive had a consistency resembling very moist brown sugar and could be poured into a borehole. Some tamping to the extent that it had a density of between 1.23 and 1.32 was necessary.

Example 2

A wet blasting agent was made up as in Example 1 and contained in addition 0.3 percent urea-formaldehyde microballoons mixed with the dry solids.

Example 3

A wet blasting agent was made up with the same composition as that of Example 1, except that one percent cellulose ether gum was substituted for one percent wood flour, and the okra gum was eliminated.

Example 4

A wet blasting agent was made composed of 64 percent melt explosive (as described in Example 1), 5 percent wood flour, 1 percent urea-formaldehyde microballoons,

0.3 percent okra gum, 14 percent ammonium nitrate, 7 percent sodium nitrate and 9 percent water. The solids, melt explosive, wood flour, microballoons, and okra gum were blended dry. A solution containing 30 percent water, 46 percent ammonium nitrate, 23 percent sodium nitrate, and 1 percent potassium dichromate was added slowly to the blended solids and mixed therewith.

Example 5

A wet blasting agent was made up as in Example 4 except that wood flour was used in an amount equivalent to 4 percent and the micro-balloons in an amount equivalent to 2 percent.

The following tabulation sets forth the performance of the wet blasting agents of Examples 1-5 in terms of the detonation velocity measured for various cartridge sizes using a 25-grams tetryl pellet as the initiator.

DETONATION VELOCITIES OF WET BLASTING AGENTS
[Initiated with a 25-gram tetryl pellet]

Example No.	Cartridge ^a Mat. D x L x W (in.)	Density (g./cm. ³)	Velocity (ft./sec.)
1	S 3 x 36 x 0.6	1.23	18,400
	S 3 x 36 x 0.6	1.32	18,200
2	C 2 x 12	1.18	14,700
	C 2 x 12	1.26	13,500
3	C 4 x 24	1.39	13,500
	S 3 x 36 x 0.6	1.39	18,800
4	C 4 x 24	1.30	17,000
	S 3 x 36 x 0.6	1.32	19,800

^a "Mat"=Material; "C" cardboard; "S" steel; "D" diameter; "L" Length; "W" wall thickness.

Example 6

A wet blasting agent was prepared having the following percent composition by weight:

Ammonium nitrate	68
Hexamethylenetetramine	6.5
Guar gum	1.9
Potassium dichromate	0.2
Perlite	4.7
Water	18.7

The explosive was formulated by mixing the ammonium nitrate, guar gum, potassium dichromate and perlite in a steam-jacketed vessel, and to this dry, hot mixture was slowly added the hexamethylenetetramine dissolved in boiling water. The hot mixture was then blended in suitable apparatus such as a food mill or ribbon blender until a cohesive mass was obtained. The resulting gel-like explosive could be poured slowly. When loaded into a 4-inch diameter, heavy-walled cardboard tube 20 inches long, it could be fired with a 25-gram tetryl pellet.

The quantity of water in the wet blasting agent may be as little as 4 or 5% or as much as 20% or even several percent greater. With the exception of a very few percent by weight of any additives used and a minor amount of a secondary fuel, if added, the remainder of the explosive is ammonium nitrate and hexamethylenetetramine, preferably present in a weight ratio to provide a substantially oxygen-balanced oxidant-fuel mixture. The amount of secondary fuel added will depend upon the character of the secondary fuel material and the performance required from the blasting agent. The quantity of thickener should be that which imparts the desired consistency to the wet blasting agent and at the same time maintains the undissolved material uniformly distributed throughout the mass. The effectiveness of thickeners varies greatly and it is within the skill of one familiar with their performance characteristics to use an appropriate amount consistent with the amount of water incorporated in the wet blasting agent. If a bulking agent is added, it may amount to a few percent, i.e., 0 to about 5%; and a catalyst may be used up to a few-tenths to about one percent.

It has been shown from the above description and examples that there is provided a wet blasting agent which is

stable, effective, and free from molecular explosives and their inherent disadvantages.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, are efficiently attained and, since certain changes may be made in the above method and composition of matter without departing from the scope of this invention, it is intended that all matter contained in the above description shall be interpreted as illustrative and not in a limiting sense.

I claim:

1. A detonatable wet blasting agent in the form of a cohesive mass, comprising ammonium nitrate as an oxidizer, hexamethylenetetramine as a fuel, water and a thickening agent; characterized in that at least a portion of said ammonium nitrate and said hexamethylenetetramine are in solution in said water whereby they form an association complex as evidenced by n.m.r. spectra, and the undissolved portion of said blasting agent is retained substantially uniformly distributed throughout said cohesive mass.

2. A wet blasting agent according to claim 1 wherein the amount of ammonium nitrate is present in a quantity sufficient to provide a substantially oxygen-balanced mixture with said hexamethylenetetramine.

3. A wet blasting agent according to claim 1 wherein said water is present in an amount ranging from about 4 to about 20% by weight of said blasting agent.

4. A wet blasting agent according to claim 1 wherein said thickening agent comprises a gum present in an amount up to about 2% by weight of said blasting agent.

5. A wet blasting agent according to claim 1 including a secondary fuel, present in an amount up to about 5% by weight of said blasting agent.

6. A wet blasting agent comprising ammonium nitrate in a water slurry and containing a fuel and a bulking agent, characterized in that at least a portion of said ammonium nitrate is introduced in the form of an intimate mixture of ammonium nitrate and hexamethylenetetramine, said mixture being characterized as primary crystals of ammonium nitrate sized no larger than 100 microns contained in a matrix of said hexamethylenetetramine and any reaction products of said ammonium nitrate and said hexamethylenetetramine.

7. A heterogeneous wet blasting agent comprising between about 68 percent and 75 percent ammonium nitrate, between about 5 percent and 6 percent by weight hexamethylenetetramine, between about 5 percent and 8 percent by weight wood flour, between about 6 percent and 12 percent sodium nitrate, between about .2 percent and .5 percent by weight okra gum, less than 1 percent potassium dichromate, and between about 4 percent and 9 percent water, said ammonium nitrate, hexamethylenetetramine, wood flour, sodium nitrate, okra gum, potassium dichromate, and water being homogeneously admixed to provide a wet blasting agent having a density of between 1.15 grams per cubic centimeter to about 1.4 grams per cubic centimeter, and having a detonation velocity of between 13,500 feet per second and 19,800 feet per second.

8. A heterogeneous wet blasting agent comprising between about 60 percent and 70 percent by weight of the product obtained by crystallizing the fused mixture of about 91 percent ammonium nitrate by weight and about 8 percent by weight hexamethylenetetramine, between about 7 percent and 14 percent by weight ammonium nitrate, between about 7 percent and 12 percent by weight sodium nitrate, between about .2 percent and .5 percent by weight okra gum, less than 1 percent by weight potassium dichromate, between about 4 percent and 9 percent water, and sufficient bulking agent to provide a wet blasting agent having a density of between about 1.15 grams per cubic centimeter and 1.4 grams per cubic centimeter when said crystallized product of ammonium nitrate and hexamethylenetetramine, ammonium nitrate, sodium

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nitrate, okra gum, potassium dichromate, water, and bulking agent are homogeneously admixed, and having a detonation velocity between 13,500 feet per second and 19,800 feet per second.

9. A method for preparing a heterogeneous wet blasting agent comprising between about 60 percent and 70 percent by weight of the product obtained by crystallizing the fused mixture of about 91 percent ammonium nitrate by weight and about 8 percent by weight hexamethylenetetramine, between about 7 percent and 14 percent by weight particulate ammonium nitrate, between about 7 percent and 12 percent by weight sodium nitrate, between about .2 percent and .5 percent by weight okra gum, between about 5 percent and 8 percent by weight wood flour, between about 1 percent and 3 percent urea formaldehyde microballoons, less than 1 percent potassium dichromate, between about 4 percent and 9 percent water, preparing a dry mixture of said crystallized product obtained by fusing ammonium nitrate and hexa-

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methylenetetramine, said wood flour, said microballoons and said okra gum, preparing a solution containing said water, said ammonium nitrate, said sodium nitrate and said potassium dichromate, adding said solution to said admixture and blending the same to provide a wet blasting agent having a density of between 1.15 grams per cubic centimeter and 1.40 grams per cubic centimeter, and having a detonation velocity between 13,500 feet per second and 19,800 feet per second.

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