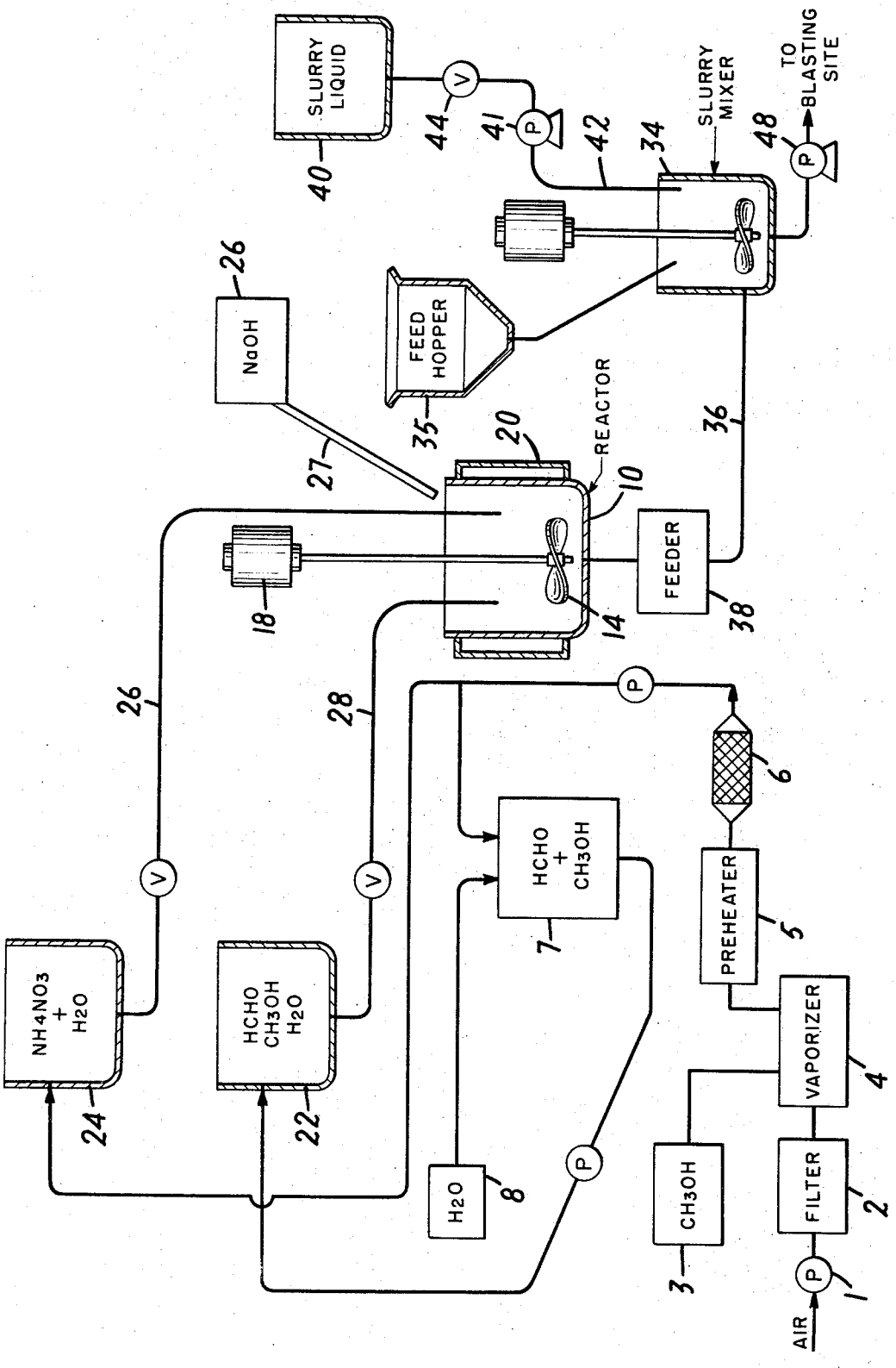
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METHOD OF BLASTING USING EXPLOSIVE SLURRIES MADE AT THE BLASTING SITE

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METHOD OF BLASTING USING EXPLOSIVE SLURRIES MADE AT THE BLASTING SITE

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This invention relates to a method of blasting using explosive slurries containing a polyalkylene polyamine sensitizer made in situ from non-explosive starting materials at the blasting site or in close proximity thereto, ready immediately after preparation for delivery to a desired location for detonation.

The use of slurried explosives based on ammonium nitrate, sodium nitrate, and like inorganic oxidizers, together with a fuel, such as fuel oil, and optionally an explosive sensitizer, such as trinitrotoluene, nitrostarch and like materials, has recently gained wide acceptance. These slurries are inexpensive, compared to many previously available materials, and are readily loaded in bore holes, in which location they can be used without undue danger of water insensitization. Aqueous explosive slurries of this type are described in U.S. Patents Nos. 2,930,685 to Cook and Farnam, patented Mar. 29, 1960, 3,083,127 to Griffith and wells, patented Mar. 26, 1963, 3,216,872 to F. B. Wells, patented Nov. 9, 1965, 3,147,163 to Griffith and Wells, patented Sept. 1, 1964, and 3,121,036 to Cook et al., patented Feb. 11, 1964.

Slurried explosives have, however, the disadvantage of having a relatively large volume, and an increased weight, as compared to dry, powdered formulations, due to the presence of the slurrying water. It has, accordingly, been proposed in U.S. application Ser. No. 315,908, filed Oct. 14, 1963, to Robert B. Clay, Douglas H. Pack, L. L. Udy, and M. A. Cook, and now abandoned, referred to in South African patent No. 64/4,735, filed Oct. 5, 1964, that such slurried explosives be prepared at the site by mixing and delivering the explosive materials there, pumping them directly into the bore hole from the mixing equipment. This objective is achieved, in accordance with that application, by simply adapting on a truck or other mobile device the mixing equipment that is normally used in the explosive plant for combining the ingredients of an explosive slurry, with the exception that it is now no longer necessary to package the slurried explosive, but it can be pumped directly from the mixer into the bore hole.

A loading system analogous to that described in this U.S. patent application and South African patent was used in 1961 by the Intermountain Research and Development Company, as reported in World Mining, October 1965, pages 33 to 37, and 91. This system was improved in 1962 by the use of field mixing and loading, using a pump truck, which was indicated to have several advantages over the prior pump loading system. It is asserted that when bulk slurry is formulated in a plant and force pumped into the drill hole, two serious problems are imposed. Firstly, in order to extrude the premixed slurry through a long hose, as required by the nature of many mines, it may often be necessary to increase the water content above the optimum range. Secondly, the explosive sensitizer requirement of the slurry might have to be increased, in order to cope with the desensitizing effect of the excess water. This means that in order to obtain optimum sensitivity, it is necessary to keep on hand quantities of explosive sensitizer, for blending with the slurry in the desired amount, when the slurry is diluted with additional water. It is, of course, undesirable to have large amounts of explosive sensitizer on hand at a mine site, but this disadvantage is not overcome, either, by the

use of mixing and loading equipment, because these simply premix the slurry with the sensitizer at the site, and also require a storage supply of explosive sensitizer, in addition to storage supplied of other explosive components, such as the inorganic nitrate and fuel.

In accordance with the instant invention, storage of explosive sensitizers at the blasting site is avoided entirely by forming the sensitized explosive slurry together with the polyalkylene polyamine as the sensitizer in situ at the site, starting from non-explosive materials. In consequence, not only are the starting materials safe to handle, but the reaction is carried out under conditions such that the reaction fixture itself is safe and insensitive during the reaction, so that there is virtually no likelihood of accidental detonation at any stage, even up to the moment the slurry is loaded into the bore hole.

The process in accordance with the invention of blasting using polyalkylene polyamine sensitized explosives made in situ proximate to the blasting site from non-explosive starting materials, comprises mixing and reacting formaldehyde and an ammonia-containing compound in an alkaline reaction medium, and which also functions as a desensitizing agent for the polyalkylene polyamine sensitizer produced. This reaction medium is preferably water, or is miscible with or dilutable with water, so as to form a homogeneous slurry medium for the resulting explosive composition. Following preparation of the polyalkylene polyamine explosive sensitizer, which may contain unreacted formaldehyde and methanol, in addition formulation of the slurried explosive is completed by incorporating any additional components, such as inorganic oxidizer and fuel, together with any additional slurrying medium, if necessary, after which the finished slurry can be brought into the bore hole or to any other blasting site.

It is to be understood that the term "ammonia-containing compound" includes ammonia and any ammonium compound such as ammonium nitrate, ammonium hydroxide, ammonium halides, ammonium sulfate, ammonium phosphate, and the like.

If desired, formaldehyde can also be prepared in close proximity to the blasting site for use in the formation of the polyalkylene polyamine, starting from methanol and air, by use of a suitable catalyst, using any of the known procedures, preferably one giving a reaction product containing a high proportion of methanol, such as the Hooker process, using a silver catalyst, Formaldehyde, third edition, by Walker (Reinhold Publishing Corp. 1964), pp. 17–19.

It is preferred in the practice of the instant invention that ammonium nitrate be employed as the ammonia-containing compound, in an amount in excess of that needed stoichiometrically to react with the formaldehyde, so that excess unreacted nitrate at the conclusion of the reaction remains in the reaction mixture, and serves as an oxidizer in the slurried explosive formulation. Such a slurry can accordingly be completed simply by addition of fuel, and and any required slurrying medium.

As reaction media, water and fuel oil or liquid paraffin hydrocarbons are preferred. The latter serve not only as slurrying media, but also as fuels.

The apparatus in accordance with the invention includes, in combination, a reactor in which reaction to form the polyalkylene polyamine explosive sensitizer is carried out, and in which blending of the other components of the slurry, following completion of the reaction, or in the course of the reaction, can also be effected, and pumping equipment and related delivery means for delivering the finished slurry to the blasting site where it is to be detonated. The reactor preferably includes stirring means for assisting in the reaction, and in the formulation of the

finished slurried explosives, together with heating means, if required, and means to mix and deliver the reactants as well as the finished slurry. Optionally, a reactor suitable for forming formaldehyde from methanol and air can be combined in the apparatus.

To facilitate use of the equipment by large-scale users, the invention also contemplates equipment adapted for the continuous mixing and reacting of the reactants to form the polyalkylene polyamine explosive sensitizer, means for continuously delivering the reaction medium, including the explosive sensitizer, to a separate site at which mixing with additional slurry components can be completed, and means for continuously delivering the resulting formulation to the blasting site.

It will be apparent that in this way the invention combines all of the advantages of on-site mixing of slurried explosives, and in addition has the advantage that no storage of explosive sensitizers at the blasting site or in the vicinity thereof is required. Explosive sensitizers can be prepared in the amounts desired for immediate use at any time, and can be used immediately after preparation.

The figure shows schematically a preferred embodiment of apparatus which can be used in carrying out the process of the invention, mounted on a mobile vehicle to facilitate movement of the apparatus to any desired blasting site.

As has been indicated, the process of the invention finds its greatest utility in the formulation and use at the blasting site of sensitized slurried explosives, in which the polyalkylene polyamine sensitizer is prepared from an excess of ammonium nitrate. Hexamethylenetetramine, heptamethylene pentamine, octamethylene hexamine, and like polyalkylene polyamines which are readily prepared in aqueous solution by reaction of formaldehyde (formed from methanol) and ammonium nitrate, are, accordingly, preferred explosive sensitizers for preparation in accordance with the invention.

The process by which formaldehyde or the polyalkylene polyamines can be prepared forms no part of the instant invention, which merely employs such processes for preparation of formaldehyde or the explosive sensitizer as one step in the combination of steps that facilitate an on-site blasting operation. Thus, for example, formaldehyde can be formed in close proximity to the blasting site from methanol prior to the formation of the polyalkylene polyamine, by passage of the methanol and air over a heated metal catalyst, such as platinum, copper or brass gauze, silver, gold, vanadium oxide, aluminum phosphate, and the like, Formaldehyde, pages 8 to 24, the disclosure of which is hereby incorporated by reference. In addition, the formaldehyde can be prepared from methane, propane and the hydrocarbon mixtures encountered in natural gas, or from butane, as is well known in the art.

The preferred methods of preparing formaldehyde in the process of the instant invention are those which are safe, can be easily controlled, and which ordinarily will not cause explosions. In the preferred method, methanol is fed to a vaporizer to produce methanol vapor at 85° C. and 18 p.s.i. This vaporizer maintains continuous delivery at the required rate through a superheater. Air is drawn in through a filter and a scrubbing column where it is washed with caustic soda to remove carbon dioxide and sulfurous compounds since the latter are stated to be injurious to catalyst activity. The air is then heated to about 70° C. and mixed in controlled ratio with methanol vapor. The mixture which contains approximately one volume of air for each volume of methanol vapor is filtered and fed to the reactors which contain a bed of prepared silver catalyst. These reactors operate in the range 450 to 650° C., the preferred temperature being around 635° C. Gases from the reactor burners are dissolved in water to produce a 20 to 37% formaldehyde solution. The gases contain about 28 to 30% formaldehyde and 20 to 22% methanol. The methanol-containing formaldehyde solution is fed to a storage tank and from here it eventually passes to the polyalkylene polyamine reactor.

In a preferred embodiment of the invention, hexamethylenetetramine-inorganic nitrate explosive slurry can, for example, be prepared in accordance with the following procedure.

To prepare a hexamethylenetetramine-ammonium nitrate slurried explosive composition, formaldehyde and ammonium nitrate are mixed and reacted in aqueous solution in stoichiometric proportions at a temperature within the range from about 15° C. to about 250° C. If the resulting slurried explosive is to be based on ammonium nitrate alone, or together with another inorganic nitrate as the inorganic oxidizer, then the ammonium nitrate can be used in an amount in excess of that stoichiometrically required to form hexamethylenetetramine, and in a sufficient amount to provide the desired amount of ammonium nitrate in the finished slurried explosive. The reaction is carried out in the presence of sufficient base, usually from 0.05 to 10% by weight of the solution, to ensure the formation of the hexamethylenetetramine and inhibit formation of methyleneimine, in accordance with the known reaction procedure.

These reactants are capable of forming lower and also higher polyalkylene polyamines, depending upon the relative proportions of formaldehyde and ammonia in the reaction mixture.

By the use of organic ammonia compounds and amines, substituted hexamethylenetetramine derivatives are obtained, the substituents of which correspond to the organic radical of the organic ammonia compound or amine. Thus, for example, formaldehyde and isobutyl amine form triisobutyltrimethylenetriamine, a substituted trioxymethylene.

After completion of the formation of the polyalkylene polyamine explosive sensitizer, additional components can be added to form the desired slurried explosive, in proportions to ensure oxygen balance, good explosive power, and sensitivity to detonation. In addition to the polyalkylene polyamine explosive sensitizer, any unreacted ammonium nitrate, formaldehyde and methanol, the slurried explosives in accordance with the invention will usually include an inorganic oxidizer, a fuel, and, if desired, thickening agents, and emulsifying agents, as desired, to ensure a homogeneous mixture at the blasting site.

The oxidizer employed can be an inorganic nitrate. Ammonium nitrate, and nitrates of the alkali and alkaline earth metals, such as soduim nitrate, potassium nitrate, calcium nitrate, magnesium nitrate, strontium nitrate and barium nitrate, are exemplary inorganic nitrates which can be mixed into the reaction mixture. Ammonium nitrate and mixtures of ammonium nitrate and another nitrate are preferred. Excellent results are obtained with mixtures of ammonium nitrate and other inorganic nitrates, and such mixtures are frequently preferred over a single nitrate.

As an inorganic oxidizer to be mixed into the reaction mixture there can also be used a chlorate or a perchlorate of an alkali or alkaline earth metal, such as sodium chlorate, potassium chlorate, barium chlorate, sodium perchlorate, potassium perchlorate, barium perchlorate, and calcium perchlorate, mixtures of nitrates, chlorates and perchlorates, of nitrates and perchlorates, and one of chlorates and perchlorates.

When mixtures of ammonium oxidizer and the other oxidizer are used, the relative proportion of ammonium oxidizer is important for good explosive shock and power. The ammonium oxidizer is employed in a proportion within the range from about 50 to 95% by weight of the total oxidizer, and the other oxidizer or oxidizers in the proportion of from about 5 to about 50% of the total oxidizer. For optimum power, the proportions are from 80 to 90% ammonium oxidizer, and from 10 to 20% other oxidizer or oxidizers. The proportions of oxidizers selected within these ranges will depend upon the sensitivity and explosive

effect desired and these in turn are dependent upon the particular oxidizer used.

The inorganic oxidizer can be fine, coarse, or a blend of fine and coarse materials. Mill and prill inorganic oxidizers are quite satisfactory. For best results, the inorganic oxidizers should be fine-grained.

The relative proportions of the explosive sensitizer and oxidizer when used in the explosive composition formed by the process of the invention will depend upon the sensitivity and explosive power desired, and these in turn are dependent upon the particular oxidizer and explosive sensitizer. For optimum effect, the oxidizer is used in an amount within the range from about 10 to 75%, and the explosive sensitizer in an amount within the range from about 5 to about 40%, by weight of the explosive composition. From about 25 to about 30% explosive sensitizer and from about 50 to 70% oxidizer give the best results.

In addition to these materials, the explosive compositions of the invention can include a fuel, when needed, which can be mixed into the explosive composition. The fuel can be either a metal fuel of a carbonaceous fuel, in an amount of from about 0.5 to about 30%. Formaldehyde and methanol are very satisfactory fuels. Additional carbonaceous fuels include powdered coal, petroleum oil, coke dust, charcoal, bagasse, dextrine, starch, wood meal, wheat flour, bran, pecan meal, and similar nut shell meals. The carbonaceous fuel will usually be used in an amount within the range from 0.5 to about 20%.

Satisfactory metal fuel include aluminum, which can be in the form of powder or flake, or in a very finely-divided form known as atomized aluminum, ferrosilicon and ferrophosphorus. The metal fuel will usually comprise from about 0.5 to about 15% of the composition.

The preferred slurrying liquid, as indicated previously, is water. Methanol will also serve. Other slurrying liquids also can be used, and among such organic liquids, polyhydric alcohols, petroleum oil and liquid hydrocarbons are preferred for many uses.

The amount of slurrying liquid is always enough to act as a suspending medium for the solid ingredients, and facilitate their conveyance to the blasting site. Consequently, following the addition of additional solid ingredients to the reaction mixture in forming the finished explosive slurry, it may in many cases be necessary to add additional slurry liquid to act as a suspending medium for the additional solid ingredients. Usually, 7% liquid is sufficient to barely slurry a mixture of the desired type, but much more may be required to make the slurry sufficiently flowable. The practical upper limit is set only by excessive dilution and reduction in sensitivity, together with dissipation of the explosive power. In most cases, the preferred range of slurrying liquid is from 10 to 40%, although in some cases, as much as 50% can be used. In these proportions, the viscosity of the finished slurry is, of course, a factor to be taken into account.

In the case of oils, any oil can be used as the suspending medium. Petroleum-derived hydrocarbon oils are readily available, and are preferred because of their low cost. The viscosity can range from very thin, such as 50 SSU at 100° F., to quite heavy oils, up to about 1200 SSU at 100° F. Kerosene, fuel oil, 100 SSU paraffin oil, light straw paraffin oil, SAE 10 to 50 lubricating oils, and hydraulic oils are exemplary.

The consistency of the slurry for any given amount of suspending liquid can be increased to meet any need by incorporating a thickening or gelatinizing agent for thickening the slurrying liquid. In this way, it is possible to prepare thin or thick slurries, containing a large proportion of suspending liquid. The thickener can be prepared for use as an alkaline medium, if the reaction mixture obtained in the invention is alkaline.

When relatively large proportions of water are present, water-soluble or water-dispersible thickeners can be added, for example, such as carboxymethyl cellulose, methyl cellulose, guar gum, psyllium seed mucilage, and pregelatinized starches, such as Hydroseal 3B. The amount of such thickening agent will depend upon the desired consistency, and usually will be within the range from 0 to about 5%.

Noncarbonaceous inorganic oil thickeners useful in making thickened oils and greases, such as finely-divided silica, available under the trade name Cab-O-Sil and Ludox, and silica aerogels, for example Santocel ARD and Santocel C, and like inorganic gelling agents, such as alumina, attapulgite, and bentonite, can be used. Other gelling agents are disclosed in U.S. Patents Nos. 2,655,476 and 2,711,393. These are well known materials, and any of these known in the art can be used. The amount of such thickening agent will depend on the consistency desired, and usually will be within the range from 0 up to about 5%. Enough thickener can be added to gel the oil after loading into the bore hole or other blasting site, if desired, and waterproofing agents such as are disclosed in U.S. Patents Nos. 2,554,222, 2,655,476 and 2,711,393, can be incorporated as well, to impart water resistance to the gelled slurry.

The finished slurry is readily prepared by simple mixing of the additional ingredients which are to be incorporated with the explosive sensitizer reaction mixture. The solid materials, including the inorganic nitrate, fuel and thickener, if any, would usually be mixed first, to form a homogeneous blend, which is then incorporated in the sensitizing reaction mixture, together with sufficient additional oil and water, and thickener, if required, to bring the mixture to the desired consistency, which can range from a gelled thixotropic oil or thick, barely pourable mixture, to a quick-flowing liquid.

The explosive slurry can be fired (after filling into the blasting site or bore hole) with the aid of a booster charge, and preferably under high confinement. Any conventional booster charge available in the art can be employed, of which pentaerythritol tetranitrate and pentolite are exemplary. The booster can be lowered into the bore hole before or after loading the explosive slurry.

In formulating the finished explosive, the blasting site requirements will of course be taken into account. Thus, a rather thick slurry can be formulated for use in wet bore holes, in which the water can be expected to considerably dilute the slurry after loading. Alternatively, waterproofing agents can be incorporated in the slurry, so as to resist dilution thereof by water present in the hole. Those skilled in the art will appreciate the variations that will be required to ensure detonation under the required conditions.

The drawing shows apparatus which can be used in carrying out the above-described process.

The apparatus shown in the figure comprises a reactor **10** in communication with a slurry mixer **34** via conduit **36**. The reactor **10** is equipped with a stirrer **14**, operated by motor **18**, and with a temperature control jacket **20**. A suitable feeder **38**, such as a vibrator, is attached to conduit **36** for uniformly and controllably delivering the explosive composition from the reactor to the slurry mixer. A third tank **40** for storing slurry liquid is in communication with the slurry mixer by means of a pipe **42** which contains valve **44** and pump **41**. A second pump **48** is in communication with the slurry mixer, for transporting explosive slurry from the mixer to the bore hole or other blasting site.

In operation, raw materials, for example, formaldehyde and ammonium nitrate, are fed from the storage tanks **22** and **24**, through conduits **26** and **28** respectively, and solid or aqueous base, such as sodium hydroxide pellets or solution, are fed from tank **26** via chute **27** at a predetermined rate into the reaction tank **10**, wherein the raw materials are mixed by mixer **14** and reacted to form an explosive composition of hexamethylene tetramine and ammonium nitrate, as well as formaldehyde, if this is in excess; this is a fuel. As the explosive composition is formed in the reactor **10**, it is fed into the slurry

mixer 34, along with slurrying liquid from the slurrying liquid storage tank 40, mixed in the slurry mixer 34, and thereafter pumped via pump 48 to the bore hole or other blasing site. A feed hopper 35 is provided for additional materials to be included in the slurry, such as gums and other thickeners.

The formaldehyde can be obtained as a formalin solution, and used as such. The apparatus as shown, however, includes apparatus for manufacturing formaldehyde from methanol and air. The air is supplied via pump 1 and filter 2 to the mixer and vaporizer 4, where methanol is fed in by gravity from reservoir 3. The gaseous mixture from the vaporizer is led to preheater 5, where it is brought to about 450° C. and then led into the reactor 6 which contains a silver catalyst bed. The reactor is held at 450 to 650° C., preferably 635° C. The reaction mixture is then pumped into the storage reservoir 7, when the mixture of 28 to 30% formaldehyde and 20 to 22% methanol is dissolved in water to form a 20 to 37% solution of formaldehyde, with accompanying methanol. The methanol is a fuel, and hence is not separated, since it is a valuable adjunct in the final explosive. In this case, the final slurry thus also contains methanol, and can contain formaldehyde, which is also a fuel.

The following examples, in the opinion of the inventor, represent the best embodiments of this invention.

Example 1

A hexamethylenetetramine-ammonium nitrate explosive composition was prepared at the blasting site using the apparatus shown in the figure. An aqueous 30% solution of formaldehyde was fed continuously with an aqueous ammonium nitrate solution providing 27% aqueous ammonia, with 5% sodium hydroxide, in a weight ratio $HCHO:NH_3$ of 4:3, at a temperature of about 30° C. The resulting solution contained 40% solids, and was concentrated at 60 to 70° C. to form a heavy slurry containing hexamethylenetetramine and ammonium nitrate.

The slurry was readily pumped into a two inch blast hole. When detonated with one pound pentolite primers, it detonated completely, with good rock breakage.

Example 2

The slurry of Example 1 was blended in the mixer 34 with additional ammonium nitrate, aluminum metal, and guar gum to give a final slurry of the composition:

	Parts by wt.
Hexamethylenetetramine	4.0
NH_4NO_3	65.0
Al (granular)	20.0
Guar gum	0.4
Water	10.6

The slurry was pumped into a four inch bore hole. It detonated readily with 1 pound pentolite primers, spaced every four feet, with good rock breakage.

Example 3

A mixture of one volume of air and one volume of methanol vapor was fed in the apparatus of the figure to a reactor at 635° C. and converted by the silver catalyst to a mixture of formaldehyde and methanol containing a ratio of $HCHO:CH_3OH$ of 15:11. This was dissolved in a 73% aqueous ammonium nitrate solution containg 12% sodium hydroxide, to produce a solution containing 30% HCHO, at a 2.5:1 ratio of $HCHO:NH_3$, as aqueous NH_3. This solution was reacted as in Example 1 to yield an aqueous hexamethylenetetramine - ammonium nitrate-formaldehyde-methanol solution, containing:

	Parts by wt.
Hexamethylenetetramine	4.0
NH_4NO_3	65.0
HCHO	2.0
CH_3OH	3.0
Water	23.0

To this was added 0.5 part of guar gum. The solution was then pumped into a bore hole, where it was detonated using 1 pound pentolite primers every four feet, with good rock breakage.

Example 4

To the slurry-reaction mixture of Example 3 there were added 20 parts wet nitrostarch containing about 23% water, and 0.5 part guar gum. The solution was then pumped into a bore hole, where it was detonated using 1 pound pentolite 10 primers every four feet, with good rock breakage.

Example 5

To the slurry-reaction mixture of Example 3 there were added 20 parts wet TNT containing about 23% water, and 0.5 part guar gum. The solution was then pumped into a bore hole, where it was detonated using 1 pound pentolite primers every four feet, with good rock breakage.

Example 6

To the slurry-reaction mixture of Example 3 there were added 20 parts wet 4:1 nitrostarch-DNT mixture containing about 23% water, and 0.5 part guar gum. The solution was then pumped into a bore hole, where it was detonated using 1 pound pentolite primers every four feet, with good rock breakage.

Having regard to the foregoing disclosure, the following is claimed as the inventive and patentable embodiments thereof:

1. A method of blasting using polyalkylene polyamine sensitized explosives made in situ proximate to the blasting site from nonexplosive starting materials, which comprises mixing and reacting formaldehyde and an ammonium containing compound forming a polyalkylene polyamine in an inert reaction medium which desensitizes the polyalkylene polyamine explosive sensitizer formed as a reactant product, thereby forming a reaction mixture comprising the explosive polyalkylene polyamine sensitizer, incorporating in the mixture additional formulating components, if necessary, to form an explosive composition comprising the explosive sensitizer, an oxidizer, and a fuel in amounts to oxygen-balance the mixture and ensure detonation, delivering the composition to the blasting site, and detonating the composition.

2. A method as in claim 1 wherein the reactants are formaldehyde and ammonium nitrate and form hexamethylenetetramine.

3. A method as in claim 1 which comprises incorporating excess ammonium-containing compound in the reaction mixture, to form an explosive composition including such compound as the oxidizer.

4. A method as in claim 1 in which the ammonia-containing compound is ammonium nitrate.

5. A method as in claim 1 which comprises incorporating aluminum in the explosive composition as an additional formulating component.

6. A method as in claim 1 which comprises incorporating a fuel in the explosive composition as an additional formulating component.

7. A method as in claim 1 including the step of concentrating the reaction mixture to form a slurried explosive composition for delivery to the blasting site.

8. A method as in claim 1 wherein the reaction medium is an aqueous reaction medium.

References Cited

UNITED STATES PATENTS

2,976,137	3/1961	Stengel	149—46 X
3,075,464	1/1963	Woodle et al.	102—23
3,127,835	4/1964	Alexander	102—23

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