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PROCESS FOR THE PREPARATION OF PENTAERYTHRITOL TETRANITRATE FREE FROM ACID AND EXPLOSIVE COMPOSITIONS HAVING AN IMPROVED SENSITIVITY AND COMPRISING SUCH PENTAERYTHRITOL TETRANITRATE

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ABSTRACT OF THE DISCLOSURE

A process is provided for the preparation of pentaerythritol tetranitrate that is substantially free from acid by dissolving or dispersing acid-containing pentaerythritol nitrate in a liquid explosive of low sensitivity in the presence of an excess of water or aqueous alkali. The process is capable of producing pentaerythritol tetranitrate containing less than 0.005% HNO₃.

The invention also provides explosive compositions having an exceptionally high sensitivity and composed of such pentaerythritol tetranitrate and an explosive of low sensitivity. Such compositions can contain less than 0.005% HNO₃, and from about 0.25 to about 10 parts of explosive of low sensitivity per part of pentaerythritol tetranitrate.

This application is a continuation-in-part of Ser. No. 654,969, filed July 21, 1967.

This invention relates to a process for the preparation of pentaerythritol tetranitrate that is substantially free from acid, and more particularly to a process for the preparation of acid-free pentaerythritol tetranitrate which comprises dissolving or dispersing the acid-containing pentaerythritol tetranitrate in a liquid explosive of low sensitivity in the presence of an excess of water or aqueous alkali, and to explosive compositions having an exceptionally high sensitivity and composed of pentaerythritol tetranitrate and an explosive of low sensitivity as obtained by such process, and containing less than 0.005% HNO₃.

Naoum, "Schiess- und Sprengstoffe," Dresden and Leipzig, 1927, page 244, describes the preparation of pentaerythritol tetranitrate having an acidity of less than 0.01% nitric acid, HNO₃. The finely-powdered pentaerythritol is added to nitric acid of a specific gravity of 1.52, while the temperature is maintained between 25 and 30° C. by efficient cooling. Pentaerythritol tetranitrate begins to crystallize out as the nitration proceeds, and the separation of the product is completed by the addition of concentrated sulfuric acid, with stirring and cooling. The cooled pentaerythritol tetranitrate is filtered off directly, and washed first with 50% sulfuric acid and then with water. It still contains occluded nitric acid, and is purified by dissolving in hot acetone, to which a little ammonium carbonate is added, filtering the hot solution into twice its volume of 90% alcohol, by which the pentaerythritol tetranitrate is precipitated in fine needles.

As a variation of this process, the acetone solution of pentaerythritol tetranitrate can be drowned in an excess of water with stirring. The pentaerythritol tetranitrate precipitates in fine crystals, which are filtered off, washed with water, and dried.

Both of these procedures are time-consuming and costly. However, these are the only procedures known which are capable of producing pentaerythritol tetranitrate

having an acidity of less than 0.01% nitric acid, HNO₃.

Consequently, the commercial procedure used for the working up of the crude pentaerythritol tetranitrate reaction mixture is to dilute the reaction mixture with cold water, recover the pentaerythritol tetranitrate by filtration, and then subject the product to a series of boiling water washes, with a filtration step following each wash. Even after ten boiling water treatments, however, the pentaerythritol tetranitrate still contains as much as 0.2% nitric acid, HNO₃.

Joseph A. Wyler, U.S. Patent No. 2,294,592, patented Sept. 1, 1942, describes the nitration of pentaerythritol to pentaerythritol tetranitrate, and dipentaerythritol to dipentaerythritol hexanitrate, by means of concentrated nitric acid, alone or combined with concentrated sulfuric acid. According to Wyler, the nitrated charge after completion of the nitration normally is flowed into water to recover the nitrated polyols. Wyler indicates that it is preferable to run the water into the nitration mixture, rather than run in the nitrated charge into the water, and he also describes a technique for nitration such that no dilution with water was necessary. Wyler worked up the product by filtering it out, washing it with cold water until substantially free from acid, then with hot water, then with an excess 2% sodium carbonate solution, then with water, and dried. In this way, Wyler was able to obtain a better separation of the pentaerythritol tetranitrate from the dipentaerythritol hexanitrate that is also formed in the reaction mixture, due to the presence of a small amount of dipentaerythritol with most commercial grades of pentaerythritol. However, this working up technique is no more successful than others in removing acid from the pentaerythritol tetranitrate.

The reason for the difficulty of separation of the acid from the pentaerythritol tetranitrate is not known. It is thought, however, that the acid is very closely held by the nitrated pentaerythritol, and that the alkali or water is incapable of penetrating the crystals to remove acid closely held or occluded within them.

In accordance with the invention, it has been found that if pentaerythritol tetranitrate in crude form, containing occluded or held nitric acid, is dissolved or dispersed in a liquid explosive of lower sensitivity than pentaerythritol tetranitrate in the presence of an excess of water, the acid contained in the pentaerythritol tetranitrate is extracted readily into the water, and a pentaerythritol tetranitrate is thereby obtained that is substantially free from acid. The resulting pentaerythritol tetranitrate and compositions thereof with such explosive can contain less than 0.005% HNO₃, and display improved explosive characteristics, such as an exceptionally high sensitivity, as compared to like explosive compositions containing an acetone-purified pentaerythritol tetranitrate of comparable HNO₃ acid content.

If desired, the water can contain a small amount of alkali, but this is not essential, and may in fact be inadvisable in the case of certain explosives, such as the nitrotoluenes, which are easily hydrolyzed by aqueous alkali solution.

The explosive of low sensitivity should be a solvent or dispersant for pentaerythritol tetranitrate, when the explosive is in the liquid or molten state. The term "dispersed" is used herein generically to encompass dispersing and dissolving. If the explosive of low sensitivity is a solid and not a liquid at ambient conditions, but can be liquefied at a temperature at which it can be safely handled, it can be used at such a temperature at which it is a liquid. In this event, it is preferred that it also be low-melting, so as to avoid the necessity of heating the pentaerythritol tetranitrate at a high temperature, at which

it may be unsafe to handle, during the dissolution of dispersion thereof in the liquid explosive. A solid or dispersant explosive should have a melting point below 100° C., so that it can exist in the molten condition in the presence of water at atmospheric pressure; preferably, the explosive has a melting point below 90° C. The term "liquid explosive" as used herein accordingly is inclusive of explosives liquid at ambient temperature or solid at ambient temperature but liquefiable under the processing conditions.

Liquid and low-melting solid solvent or dispersant explosives for pentaerythritol tetranitrate that can be employed in accordance with the invention include the nitrotoluenes, such as trinitrotoluene and dinitrotoluene, and the nitrated polyols, such as trimethylolethane, propylene glycol dinitrate, butylene glycol dinitrate, diethylene glycol dinitrate, and dipentaerythritol hexanitrate.

The relative proportions of the explosive of low sensitivity and of the pentaerythritol tetranitrate are not critical. The function of the liquid or liquefied low-melting solid explosive is to dissolve or disperse the pentaerythritol tetranitrate, thereby to free the acid held by the pentaerythritol tetranitrate so that it can be more readily extracted into the aqueous phase. Hence, a sufficient amount should be used to dissolve or disperse all of the pentaerythritol tetranitrate. Thus, the minimum amount will be determined by the solubility or dispersibility of pentaerythritol tetranitrate therein. Usually, as little as 0.25 part of the explosive of low sensitivity for each part of pentaerythritol tetranitrate will be sufficient. Much larger amounts can be used, and amounts of as much as 10 parts of the explosive of low sensitivity per part of pentaerythritol tetranitrate have been found to be satisfactory. Normally, however, it is not desirable to use more of the liquid explosive than is necessary to separate the acid from the pentaerythritol tetranitrate, since the sensitivity and explosive power of the latter may be deleteriously affected, unless at such a proportion of explosive a non-deleterious effect or an improved effect is obtained in the combination of the pentaerythritol tetranitrate and the explosive that is formed as a product of the process of this invention. Usually, therefore, the proportions will be at a ratio explosive of low sensitivity:pentaerythritol tetranitrate within the range from about 0.75:1 to about 5:1.

Combinations of pentaerythritol tetranitrate with explosives of lower sensitivity than pentaerythritol tetranitrate are known. The combination of one part of pentaerythritol tetranitrate to one part of trinitrotoluene is widely used, and is referred to as pentolite. The preparation of this material is described inter alia in U.S. Patent No. 2,407,805 to Joseph A. Wyler, patented Sept. 17, 1946. One process for preparing it, described in the patent involves the dispersal in 955 parts by weight of water of 235 parts by weight of pentaerythritol tetranitrate in the form of crystals, 235 parts by weight of trinitrotoluene are dissolved in 250 parts by weight of warm acetone, and this clear solution is added in a fine stream, with stirring, to the suspension of the pentaerythritol tetranitrate in water. The resulting product is granular, and can be used as such, or it can be heated to an elevated temperature of from 80 to 115° C. to provide a semi-fluid mixture which can be packaged in containers, in the solidified or cast form.

It will be apparent that by use of the process of this invention, it is now possible to prepare pentolite without the necessity of first freeing the pentaerythritol tetranitrate from acid, as has been the usual procedure heretofore. All that is necessary is that the crude acid-containing pentaerythritol tetranitrate be dispersed or dissolved in the molten trinitrotoluene, in the presence of an excess of water. The resulting pentolite has a higher sensitivity than pentolite prepared by the usual procedure.

In similar manner, the process of the invention makes it possible to employ crude acid-containing pentaerythritol tetranitrate in the formulation of dinitrotoluene-pentaerythritol tetranitrate compositions, and similar composi-

tions including trimethylolethane trinitrate and diethylene glycol dinitrate. Three-component compositions also can be prepared, such as the three component pentaerythritol tetranitrate - trinitrotoluene - dipentaerythritol hexanitrate compositions of Patent No. 2,407,805.

The water is employed in a sufficient amount to form a suspension of the liquid explosive particles that is easily handled and to take up the acid present in the pentaerythritol tetranitrate. Accordingly, there will be at least 0.5 part of water for each part of liquid explosive including the pentaerythritol tetranitrate. Very large amounts of water can be used, but of course there is no necessity for employing amounts that are so large that the volumes of composition being handled are inconvenient. For this reason, the amount of water would not normally exceed about twenty times the weight of liquid explosive, including the pentaerythritol tetranitrate.

A small amount of alkali can be added to the water, if desired, to aid in taking up the acid. Inasmuch as the pentaerythritol tetranitrate contains only very small amounts of acid, it is not necessary to employ more than 10% alkali by weight of the solution, and in most cases less than 1% is adequate. As little as 0.1% alkali will be sufficient in many cases.

Any alkali can be employed, such as sodium hydroxide, potassium hydroxide, sodium carbonate, ammonium hydroxide and potassium carbonate. The alkali should be water-soluble, so as to avoid contaminating the explosive composition with solid alkali.

In the practice of the process of the invention, it is normally desirable first to dissolve or disperse the pentaerythritol tetranitrate in the liquid explosive. If the explosive is a solid, it is necessary to melt the explosive of low sensitivity, and then incorporate the pentaerythritol tetranitrate in the liquefied explosive. Thereafter, the liquid explosive solution or dispersion is run into an excess of water or aqueous alkali, and dispersed uniformly or homogeneously therein.

However, it is also possible to add the liquid or low melting solid explosive to the water or aqueous alkali, bring the water or alkali to a temperature at which the explosive is molten, if necessary, and then run in the pentaerythritol tetranitrate. The pentaerythritol tetranitrate will dissolve or disperse in the liquid explosive droplets suspended or dispersed in the water or alkali, and the acid will dissolve in the water.

The dispersion of liquid explosive and water or alkali is well stirred, to ensure that all of the acid is removed from the pentaerythritol tetranitrate. Then, the explosive particles are separated from the water or alkali, washed with water one or several times, and dried.

Depending upon the nature of the explosive of low sensitivity and the relative proportions thereof to pentaerythritol tetranitrate, the final product, a solution or dispersion of the pentaerythritol tetranitrate in the explosive, will be a hard solid, or a soft to pasty solid, or viscous liquid. It can be employed as an explosive sensitizer in explosive formulations of all types, and will display properties contributed by each of the components thereof. If, for example, the product is pentolite, it can be used as is pentolite prepared by other processes. However, the product of the invention is characterized by a pentaerythritol tetranitrate component of low acidity, substantially free of nitric acid HNO₃ in many instances, despite the fact that crude pentaerythritol tetranitrate is used as a starting material. In effect, the process of the invention both free pentaerythritol tetranitrate from acid and dissolves or disperses it in the explosive of low sensitivity, thus consolidating in one process what the prior art effected in two separate and distinct processing operations. Moreover, the product that is obtained has a higher sensitivity.

The process of the invention is applicable to acid-containing pentaerythritol tetranitrate prepared by any nitration process, as well as to conitrated polyol mixtures pre-

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pared by nitrating two or more polyols, simultaneously, such as mixtures of pentaerythritol with trimethylolethane, ethylene glycol, diethylene glycol, propylene glycol, sorbitol or mannitol. In the case of conitrated mixtures, the polyol nitrate formed in conjunction with the pentaerythritol tetranitrate can serve as the liquid or low melting explosive to aid in expelling acid from the pentaerythritol tetranitrate in the presence of water or alkali, in accordance with the invention. In this case, the liquid explosive, being present ab initio, with the pentaerythritol tetranitrate dispersed in or in solution therein, all that is necessary to remove acid from the crude conitrated product is to wash it with water or alkali.

The nitration of pentaerythritol is well known, and forms no part of this invention. As is customary, pentaerythritol is normally nitrated in the presence of water with concentrated nitric acid. The pentaerythritol tetranitrate can be recovered from the reaction mixture by dilution with water, whereupon it precipitates. If nitric acid is employed, a mixture of sulfuric acid and water or sulfuric acid alone can be added to dilute the reaction mixture and precipitate the nitrated polyol. If a mixture of concentrated nitric and sulfuric acids is employed, the pentaerythritol tetranitrate will precipitate as the reaction proceeds.

The crude pentaerythritol tetranitrate that is recovered can then be subjected to the process of the invention, in order to remove the occluded or residual acid. It is not necessary to subject it to the usual washing techniques for removal of the acid, since in the process of the invention all of the acid contained therein will be removed. By simple trial and error, it is easy to ascertain the amount of water or aqueous alkali that is required to produce a pentaerythritol tetranitrate substantially free from acid.

In some cases, it is conventional to subject the pentaerythritol tetranitrate to repeated treatments in accordance with the invention, if the crude product recovered from the acid reaction mixture contains an exceptionally high amount of acid. Whether several treatments are necessary and how many depends upon the acidity of the pentaerythritol tetranitrate recovered after the first treatment. Usually, one treatment in accordance with the invention is sufficient, however.

The following examples in the opinion of the inventor represent preferred embodiments of the invention.

EXAMPLE 1

One part of pentaerythritol was slowly added with stirring and cooling to six parts by weight of 97.3% aqueous nitric acid. The addition required about one hour, during which time the temperature was kept between 25 and 30° C. The mixture was then stirred an additional half hour, transferred into an excess of cold water, stirred several minutes, and filtered to remove the precipitated pentaerythritol tetranitrate. The pentaerythritol tetranitrate that was collected was transferred to an excess of cold water, the mixture stirred several minutes, filtered, and again transferred to cold water, stirred and filtered. The product was analyzed, and found to contain 0.43% nitric acid HNO₃.

One portion of this crude acid-containing product was subjected to ten successive one hour boiling water treatments, with a filtration step after each treatment. The acidity of the pentaerythritol tetranitrate was determined after each step, with the following results;

Treatment:	Acidity of PETN, percent HNO ₃
Initial	0.43
Second	0.30
Third	0.31
Fourth	0.31
Fifth	0.27
Sixth	0.25
Tenth	0.20

It is evident that even after ten boiling water treatments, the product still contained 0.2% nitric acid, and

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that the residual acid was being very slowly removed, only 0.05% having been removed in the total of the seventh to tenth washes. It is equally apparent that it is not practical to prepare a product containing as little as 0.01% HNO₃ by this technique, which explains why the acetone solution technique is the one employed when pentaerythritol tetranitrate of such low acidity is required.

Another portion of this acid-containing pentaerythritol tetranitrate containing 0.43% nitric acid was then subjected to the process of the invention. 25 parts of dinitrotoluene was rapidly stirred in an equal weight of water at 95° C., forming a dispersion thereof in the water. 25 parts of the pentaerythritol tetranitrate was slowly added to this mixture, and the mixture stirred rapidly. The pentaerythritol tetranitrate dissolved in the dinitrotoluene, and an emulsion resulted, which was drowned in cold water. The grained solid product was separated, washed and dried. The acidity of the product was 0.02% HNO₃.

This experiment was repeated, using 35 parts of dinitrotoluene and 15 parts of the pentaerythritol tetranitrate with 35 parts of water. The acidity of the product was 0.004% HNO₃.

EXAMPLE 2

25 grams of commercial trinitrotoluene was melted in a beaker at 95° C. 10.7 grams of crude pentaerythritol tetranitrate containing 0.24% HNO₃ was dissolved in the molten trinitrotoluene, and the molten mixture was then slowly run, with stirring, into 35 grams of cold water. The mixture was then filtered at slightly above room temperature, washed with water, and dried. The acidity of the grained product was 0.006% HNO₃.

EXAMPLE 3

25 grams of commercial trinitrotoluene was melted under 25 grams of water, with stirring, at 95 to 100° C. Crude pentaerythritol tetranitrate (10.7 grams) containing 0.24% HNO₃ was slowly added to the mixture, and dispersed therein. The hot mixture was stirred for about one-half hour. The pentaerythritol tetranitrate dispersed in the trinitrotoluene. The mixture was then cooled to room temperature and filtered. The acidity of the grained product that was recovered was 0.003% HNO₃.

EXAMPLE 4

A mixture of 75 parts of trimethylolethane and 25 parts of pentaerythritol was slowly added with stirring and cooling to 600 parts by weight of 97.3% nitric acid. The addition required about one hour. The conitrated mixture was then stirred an additional half hour at 25° C., and transferred into an excess of cold water, stirred several minutes, and filtered.

The conitrated product on the filter was transferred to an excess of cold water, the mixture stirred several minutes, filtered, and again transferred to an excess of cold water, stirred, and filtered. The conitrated product had an acidity of 0.21% HNO₃.

This mixture was then subjected to two successive one hour boiling water treatments, with a filtration step between each treatment. After the first hour of treatment, the acidity of the product dropped to 0.07% HNO₃. After the second water boil, the acidity of the product was 0.019% HNO₃.

EXAMPLE 5

25 parts of dipentaerythritol hexanitrate were rapidly stirred at 90-95° C. in 25 parts of water. 25 parts of pentaerythritol tetranitrate containing 0.4% HNO₃ was then slowly added, with rapid stirring. The pentaerythritol tetranitrate dispersed in the dipentaerythritol hexanitrate, and an emulsion-like mixture resulted, which was drowned in cold water, and the grained product separated, washed and dried. The acidity of the product was 0.03% HNO₃.

This product was then subjected to a further water wash at 90–95° C. for one-half hour, the mixture cooled, and the product filtered. The resulting product contained 0.005% HNO₃.

EXAMPLE 6

A 50/50 pentolite was prepared as follows:

Three pounds of grained trinitrotoluene was melted in a kettle under twelve pounds of water, with stirring, at 85° C. 3.3 pounds of crude pentaerythritol tetranitrate containing 0.31% HNO₃ and 8.6% water was added to the mixture and dispersed therein by stirring for thirty minutes at 85 to 95° C. Nine pounds of hot water (90° C.) was added to the mixture and heating was discontinued. The mixture was stirred while cooling gradually until small pellets of pentolite formed. The mixture was then cooled to 60° C. and filtered, washed with water, and air-dried overnight. The acidity of the small pellets of pentolite recovered was 0.003% HNO₃.

The product was checked for screen size, with the following results:

Sieve Mesh Size	Percent	Density g./cm ³
On 10	61.0	0.71
Through 10, on 20	32.7	0.74
Through 20, on 30	2.5	0.75
Through 30, on 40	1.9	0.74
Through 40, on 60	1.0	0.80
Through 60	0.9	0.76
Total	100.0	

The product was subjected to a melting test, to determine its melting characteristics in comparison with two commercial 50/50 pentolite compositions.

One thousand grams of the pentolite of Example 6 melted completely in 15 minutes when placed on a steam table at 15 p.s.i. pressure. A temperature of 210–212° F. was needed to obtain the required consistency for pouring.

One thousand grams of a commercial 50/50 pentolite melted in approximately 10 minutes on a steam table at 15 p.s.i. pressure. A temperature of 200° F. was needed in order to obtain the proper consistency for pouring.

One thousand grams of a second commercial 50/50 pentolite required 30 minutes to melt on a steam table at 15 p.s.i. pressure. A temperature of 220° F. was needed to obtain a pouring consistency, but even at this temperature the pentolite was very thick.

One-third pound primers were cast from each of these pentolite mixtures while molten, and the sensitivity of the cast primers determined. In addition to the three pentolites described above, 1/3 pound primers were cast using blends of the molten pentolite of Example 6 in combination with the proportion of flake trinitrotoluene, in the amounts noted in the table below.

Composition:	Sensitivity
Example 6 50/50 pentolite	No. 1 Cap
90 parts Example 6 50/50 pentolite, 10 parts flake TNT	No. 1 Cap
80 parts Example 6 50/50 pentolite, 20 parts flake TNT	No. 1 Cap
75 parts Example 6 50/50 pentolite, 25 parts flake TNT	No. 4 Cap
70 parts Example 6 50/50 pentolite, 30 parts flake TNT	No. 6 Cap
50/50 Pentolite Mechanical Mill Mixture ¹ , Commercial 50/50 pentolite No. 1 (50.54% PETN, 49.46% TNT)	No. 3 Cap
80 parts Commercial 50/50 pentolite No. 1, 20 parts flake TNT	No. 6 Cap
Commercial 50/50 pentolite No. 2 (47.30% PETN, 52.70% TNT)	No. 1 Cap
80 parts Commercial 50/50 pentolite No. 2, 20 parts flake TNT	No. 6 Cap

¹ Determined over three days' production.

The increased sensitivity of the pentolite mixture of the invention as compared to the two commercial pentolite mixtures tested is evident in the above data. This improved sensitivity is retained, even when the pentolite is mixed with up to 20 parts of flake TNT. The presence of 25 to 30 parts of flake TNT reduces sensitivity considerably, but the resulting mixture is still at least as sensitive as the mixtures of the commercial pentolites with 20 parts TNT.

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

1. A process for removing acid from crude acid-containing pentaerythritol tetranitrate as recovered from an acidic nitration mixture, which comprises washing the acid-containing pentaerythritol tetranitrate while dispersed in a liquid organic explosive other than pentaerythritol tetranitrate with an amount of water sufficient to slurry the pentaerythritol tetranitrate and liquid organic explosive, extracting the acid from the pentaerythritol tetranitrate into the water, and recovering the mixture of pentaerythritol tetranitrate and liquid organic explosive from the resulting mixture.

2. A process in accordance with claim 1 which includes separating the liquid organic explosive from the pentaerythritol tetranitrate.

3. A process in accordance with claim 1 in which the liquid explosive is selected from the group consisting of nitrated toluenes and nitrated polyols.

4. A process in accordance with claim 1 in which the water contains up to 10% of an alkali.

5. A process in accordance with claim 4 in which the alkali is an alkali metal hydroxide.

6. A process in accordance with claim 4 in which the alkali is an alkali metal carbonate.

7. A process in accordance with claim 1 in which the ratio of liquid explosive to pentaerythritol tetranitrate is within the range from about 0.25:1 to about 10:1.

8. A process in accordance with claim 1 in which the proportion of water to pentaerythritol tetranitrate is within the range from about 0.5:1 to about 20:1.

9. A process in accordance with claim 1 in which the pentaerythritol tetranitrate is dispersed in liquid explosive, and the resulting mixture then run into the water.

10. A process in accordance with claim 1 in which a low melting explosive is dispersed in and melted in the water, and then the pentaerythritol tetranitrate is added.

11. A process in accordance with claim 1 in which the liquid explosive is trinitrotoluene.

12. A process in accordance with claim 1 in which the liquid explosive is trimethylolethane trinitrate.

13. A process in accordance with claim 1 in which the pentaerythritol tetranitrate and liquid explosive are conitrates.

14. A mixture of pentaerythritol tetranitrate and said explosive of low sensitivity, prepared in accordance with the process of claim 20.

15. A mixture containing less than 0.005% HNO₃ by weight and consisting essentially of pentaerythritol tetranitrate having improved explosive properties compared to acetone purified pentaerythritol tetranitrate and liquid or low melting solid organic explosive of low sensitivity other than pentaerythritol tetranitrate that when liquid is a solvent or dispersant for pentaerythritol tetranitrate, in a weight proportion within the range from about 0.25 to about 10 parts per part of pentaerythritol tetranitrate.

16. A mixture in accordance with claim 15 in which the liquid explosive is selected from the group consisting of nitrated toluenes and nitrated polyols.

17. A mixture in accordance with claim 15 in which the liquid explosive is trinitrotoluene.

18. A mixture in accordance with claim 15 in which the liquid explosive is trimethylolethane trinitrate.

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