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FREE FLOWING GRANULAR EXPLOSIVE COMPOSITION OF CONTROLLED PARTICLE SIZE

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This invention relates to explosive compositions particularly adapted for use in bore holes that contain water.

In blasting practice, it is often of advantage to fill a bore hole with free-flowing explosive granules rather than conventional cartridges or other detonatable packages. Cartridges do not completely fill the hole because there must be a certain amount of clearance in order to prevent the said units from becoming wedged and hung up as they are dropped into the hole. The air in the clearance space dampens the force of detonation and maximum work is not realized in moving the material surrounding the bore hole. When water is present in the bore hole, as is often the case, the damping effect is even more pronounced and the waterproofing materials customarily used on the explosive result in further loss of power.

It has heretofore been suggested that the water in the bore hole be replaced with a saturated solution of a water soluble, oxygen-supplying salt such as a chlorate, perchlorate or nitrate to overcome the damping effect of the water. While this technique can reduce the damping effect to some degree, it involves separate handling of materials and a sequence of separate steps in preparing the bore hole for loading with explosive granules and, for these reasons, it is not completely satisfactory.

Quite unexpectedly it has now been discovered that the damping effect of water in a bore hole can be substantially overcome by use of a free-flowing granular explosive composition which contains water insoluble explosive granules in admixture with a water soluble, oxygen-supplying salt such as a nitrate or a perchlorate. It is an important feature of the present invention to so control the particle size of the water soluble granules that they will readily enter into the interstitial spaces of the water insoluble explosive granules.

For best results the interstitial spaces of the water insoluble explosive granules are filled with the water soluble particles and when this is done there is no material increase in a given volume of the water insoluble explosive. When such an explosive composition is detonated in a wet bore hole, far greater explosive force is developed than can be obtained from detonation of the same amount of water insoluble explosive granules alone. Surprisingly enough if the water in the bore hole is replaced in conventional manner with an aqueous solution containing the same quantity of soluble, oxygen-supplying salt as is used in the dry solid compositions of the invention, it has been demonstrated by actual tests that the explosive compositions of the present invention are nevertheless far more effective in reducing or eliminating the damping effect of the water. As a result the number of bore holes can be reduced in carrying out the same amount of useful work and the charging of the bore holes is greatly simplified as compared to conventional practice involving the use of saturated solutions of the water soluble salt.

The explosive compositions of the invention contain

as the principal explosive component a water insoluble explosive in granule form. Such component may be any of the conventional non-initiating, water insoluble high explosives having a rate of detonation of at least 1000 m./sec. For example, explosive materials such as trinitrotoluene (TNT), pentaerythritol tetranitrate (PETN), mixtures of trinitrotoluene and pentaerythritol tetranitrate (Pentolites), cyclotrimethylenetrinitramine (Cyclonite), mixtures of trinitrotoluene and cyclotrimethylenetrinitramine (Composition B), erythritol tetranitrate, dipentaerythritol tetranitrate, dipentaerythritol hexanitrate (DPEHN), mannitol hexanitrate (MHN), nitrostarch, cyclotetramethylenetetranitramine (HMX), m-dinitrobenzene, 2,4,6-trinitrophenylmethylnitramine (Tetryl), and the like known water insoluble high explosives may be used in carrying out the present invention. The trade names by which these explosive materials are commonly known in the art are given above in parentheses. In addition to the above-mentioned materials, other known high explosive materials, wholely or partly soluble in water but waterproofed in conventional manner with a water insoluble coating may also be employed. These may be, for example, ammonium nitrate, ammonium perchlorate, potassium and sodium perchlorates, hydrazine nitrate and various nitrocarbonitrates.

While the actual particle sizes of the water insoluble explosive granules are not in themselves of a critical nature, it is preferred that the granules be of an average diameter ranging from about 1/16 to about 1/4 inch, and preferably to about 3/16 inch. These preferred granule sizes may be selected by conventional sieve screen grading using U.S. Standard sieves and all granules passing a 1/4 inch sieve, and preferably a No. 4, and retained on a No. 12 sieve of the U.S. Standard series may be employed. The shape of the granules may be spheroidal, cylindrical, oval or random with the term average diameter generally referring to the average of the smallest linear dimension of the granules.

In accordance with the invention, a water soluble, oxygen-supplying salt is admixed with the water insoluble explosive granules and this salt may be selected from the group consisting of ammonium, alkali metal and alkaline earth metal salts of perchloric and nitric acids. Since the water soluble salt particles must enter into the interstitial spaces formed by the water insoluble explosive granules, the particle size of the water soluble salt is critical. Thus, it is essential that substantially all of the particles of the water soluble salt be of an average diameter not more than about 1/5 the average diameter of the water insoluble granules. Since absolute uniformity of particle size is virtually impossible, it is recognized that some of the water soluble salt particles may be larger than the above-mentioned size, but certainly not more than 10% of the particles by weight should exceed 1/5 the average diameter of the water insoluble explosive granules.

As with the water insoluble explosive granules, the proper size water soluble salt particles may be selected by conventional sieve screen grading. Thus, if the diameter of the water insoluble explosive granules averages about 0.125 inch, the granules will be retained on a No. 7 sieve of the U.S. Standard series. In such case the particles of water soluble salt are selected so that not more than 10% of the particles by weight are retained on a No. 30 sieve.

No minimum size can be actually specified for the particles of water soluble salt since in most cases even very small particles in the nature of fines are useable. However, in order to prevent excessive segregation between the water insoluble granules and the particles of the water soluble salt during shipment or storage, it is preferred that only about 10% to 20% of the salt particles be of a size smaller than $\frac{1}{20}$ the average diameter of the explosive granules.

The quantity of water soluble salt that is mixed with the water insoluble explosive granules is important for maximum power. It has been found that consistent and exceptionally good results are achieved if the quantity of added water soluble salt is at least equal to the amount which would be contained in a saturated aqueous solution of the salt at ambient temperatures and in a volume the same as that of the sum of all of the interstitial spaces between the water insoluble explosive granules. The sum of all of the interstitial spaces between the explosive granules refers to the total space which remains void or unoccupied when any given volume has been apparently completely filled with the explosive granules without tamping or compression. The given volume to be filled with the water insoluble explosive granules will, of course, depend on the form of container which is to be used for shipment or storage of the explosive composition. Once the sum of the interstitial spaces between the water insoluble explosive granules filled into any one of such containers has been determined, in known manner, the proportion of water soluble salt which should be admixed with that given volume of explosive granules will be known and this proportion will remain the same for any larger quantity of the same explosive granules which is to be filled into a plurality of the same containers.

In determining the sum of the interstitial spaces in a given volume of the explosive granules, any one of several standard, conventional calculations based on sieve screen analysis, or actual or apparent densities may be employed. For example, one such calculation involves use of the following formula:

$$S = V - \frac{W}{D}$$

in which S equals the sum of the interstitial spaces, V represents the given volume which has been apparently filled with explosive granules, W the weight of the granules contained in that volume, and D the actual specific gravity of the substance of which the granules are comprised. Thus, if 135 g. of granules of an explosive compound apparently fill a volume of 100 cc., and the specific gravity of that compound is 1.5 then:

$$S = 100 \frac{135}{1.5}$$

$$S = 10 \text{ cc.}$$

Accordingly, the total unoccupied volume or the sum of the interstitial spaces between the granules in a 100 cc. volume is 10 cc. The quantity of water soluble salt particles that would preferably be admixed with such explosive granules would be at least that quantity which would be contained in 10 cc. of a saturated aqueous solution of the salt at ambient temperatures.

While excellent results are achieved when the quantity of added water soluble salt is that which would be contained in a volume of saturated aqueous solution the same as the sum of the interstitial spaces between the water insoluble explosive granules, the benefits of the invention may be realized with smaller or larger amounts of the salt also. Thus, some variation in the quantity of added salt is permissible and, in many cases, is actually desirable for purposes of oxygen balance in the explosive composition as will be more fully described hereinafter. In general, the smallest quantity of added water soluble salt which will give practicable results is about 0.5 times the quantity that would be contained in the volume of saturated aqueous salt solution which equals the sum of the interstitial spaces between the water insoluble explosive granules. As for amounts larger than the saturated aqueous solution quantity, the only actual limitation is an excessive increase in the given volume of the water insoluble explosive granules which should be avoided. Generally speaking, however, the addition of water soluble salt in amounts up to about 1.5 times the quantity that would be contained in the appropriate volume of saturated aqueous salt solution will not appreciably increase the given volume of explosive granules in view of the limited particle size of the salt, and such larger amounts of salt may therefore be employed. If desired, a plurality of different water soluble salts may be admixed with the explosive granules.

It is preferred that the explosive compositions of the invention be oxygen balanced as a whole, so that the total oxygen content of the composition will be sufficient to oxidize all carbon, hydrogen, and other readily oxidizable elements in the composition to carbon dioxide, water, etc. Addition of the relatively oxygen-rich water soluble salt in that amount which would be contained in an appropriate volume of the aqueous saturated salt solution may bring the overall composition into oxygen balance and, in other cases, may leave the composition deficient or oversupplied in oxygen balance. In the case of oxygen deficiency, more of the same salt, or another salt relatively richer in oxygen (i.e., NH_4NO_3v. $NaNO_3$), can be added to compensate for the deficiency.

Where the oxygen content of the overall composition is excessive for oxygen balance, the amount of added water soluble salt can be reduced by as much as the previously mentioned factor of 0.5, but this will also reduce the efficiency of the composition in overcoming the damping effect of water. For this reason, the procedure which is preferred for compensating for excess oxygen is to include an appropriate amount of organic fuel in the explosive composition which will provide additional oxidizable elements that will consume oxygen upon detonation of the composition. It has been found that water soluble organic alkyl compounds containing one or preferably a plurality of hydroxyl groups give excellent results when added to the explosive compositions as oxidizable fuels. More specifically, compounds such as ethylene glycol, propylene glycol, butylene glycol, etc., and low to medium molecular weight polymers thereof, 1,1,1-trimethylolethane and its water soluble homologues such as 1,1,1-trimethylolpropane, glycerine and water soluble polymers thereof, sugars, pentaerythritol, and water soluble mixed polyethylene-polypropylene glycols formed by copolymerization of ethylene and propylene oxides, and similar polyhydroxy compounds give best results and are preferred. In addition, monohydroxy compounds such as methanol, ethanol, propanols and similar water soluble alkylols may be employed. Where the organic fuel is to be employed, the quantity of added fuel preferably will be that required for bringing the overall explosive composition into oxygen balance.

Where the explosive compositions of the invention are to be filled into bore holes the depth and water content of which is relatively large, the admixed water soluble salt may be completely dissolved out of that portion of the insoluble explosive granules which reach the bottom of the hole while the salt in the upper regions of the hole may remain undissolved. This condition of imbalance reduces the efficiency of the explosive composition in overcoming the damping effect of water and, in order to prevent it, the water soluble salt particles should be protected against rapid dissolution. It has been found that if the particles are coated with a slowly water soluble solid coating of certain characteristics, nonuniform dissolution of the water soluble salt particles in the bore hole can be substantially prevented without adverse effect upon the power of the explosive composition. The preferred characteristics of the coating material are that a

3 mil film thereof should dissolve completely in not more than about 10 minutes when submerged in water at 1° C. Excellent results have been achieved with a blend of equal amounts of polyethylene glycols having two different molecular weights, one in the range of 380–420 and the other in the range of 3000–3700, as well as with a single polyethylene glycol having an average molecular weight of about 1000. However, other blends and other materials having the above-mentioned characteristics in water solubility may also be employed. The slowly soluble coating, where necessary, may be applied to the water soluble salt particles in any conventional manner, for example, the material may be heated to a melt, mixed with the salt particles under mechanical agitation and then permitted to cool and solidify.

In some cases, particularly where the explosive compositions are to be stored over a prolonged period of time or where they are to be used in deep bore holes with considerable depths of water it will be of advantage to mix the water soluble salt particles with the water insoluble explosive granules while the slowly soluble coating on the salt particles is still warm and more or less tacky. In this way, the coating will adhere not only to the salt particles but to the explosive granules as well and, with complete cooling and solidification of the coating, a certain degree of adhesion will develop between the explosive granules and the salt particles tending to maintain the salt particles dispersed in the interstitial spaces between the explosive granules whereby excessive segregation or premature dissolution of the salt particles can be minimized or prevented completely.

The various components of the explosive compositions of the invention may be admixed in conventional manner and packaged in any desired form of container. The compositions are ready for use immediately after mixing and they are simply poured into a bore hole, without tamping or compression, and then detonated with standard initiators.

Specific embodiments of the invention are given in the following examples for purposes of illustrating further details of the invention.

Example 1

In this example, the efficiency of mixtures of pelleted TNT and particles of ammonium nitrate and sodium nitrate in overcoming the damping effect of water was compared with that of saturated ammonium nitrate solutions. The tests were made by loading the materials to be tested in pipes 5 inches in diameter and 60 inches in length, and having a volume of 0.692 ft.^{3}. The pipe was closed at the bottom by a welded steel plate and at the top by a screwed-on pipe cap. Detonation was accomplished by means of a 1 lb. cast pentolite booster placed inside the pipe and initiated by a standard No. 6 cap fired by a miner's fuse passing through 5/16 inch hole in the pipe cap. Each pipe was placed into a hole 10 inches by 72 inches in the earth, and dirt was tamped firmly into place around the pipe, level with the ground surface. After detonation, the dimensions and volume of the craters formed, and the volume of earth moved per unit weight of explosive were recorded.

As the water insoluble granules, pellets of TNT averaging 3/32 to 5/16 inch in diameter were employed. One test pipe was apparently completely filled without tamping or compression by 45 lbs. of the TNT pellets and the sum of the interstitial spaces between this quantity of pellets was calculated to be about 0.24 ft.^{3}. The test pipe containing 45 lbs. of TNT alone was fired as Test A.

A second pipe was filled with 45 lbs. of TNT and 14.25 lbs. or 0.23 ft.^{3} of water to demonstrate the damping effect of the water upon the power of the explosive. This pipe was detonated as Test B.

A third pipe was filled with 45 lbs. of TNT and 19 lbs. of a saturated aqueous solution of ammonium nitrate containing 6.5 lbs. water and 12.5 lbs. ammonium nitrate.

This quantity of solution was sufficient to fill substantially all of the interstitial spaces between the TNT granules, and this pipe was detonated as Test C.

Into another 45 lb. batch of the TNT was uniformly admixed 12.5 pounds of ammonium nitrate particles of such a size that 99% by weight passed a No. 20 sieve, and not more than 2% passed a No. 80 sieve. Into a fourth pipe was first placed 6.5 lbs. of water and then the pipe was filled with the dry mixture of TNT and ammonium nitrate particles. This pipe was detonated as test D.

Another 45 lb. batch of TNT was uniformly mixed with 17 pounds of sodium nitrate particles of a size substantially the same as that of the ammonium nitrate particles used in Test D. This quantity of sodium nitrate was equivalent to the 12.5 pounds of ammonium nitrate in terms of the amount required for a volume of saturated aqueous solution that would fill the interstitial spaces between the 45 lbs. of TNT. Into a fifth pipe was first placed 6.5 lbs. of water and then the pipe was filled with the mixture of TNT and sodium nitrate. This pipe was fired as Test E.

The results of all tests are recorded in the following table:

Test	Dimensions of Crater (ft.)	Volume of Crater (ft.^{3})	Volume of Earth Moved (ft.^{3}/lb.)	
			TNT	TNT and Salt
A	16.7 x 7.6	553	12.1	
B	16 x 7.25	484	10.5	
C	16.75 x 7.5	550	12.0	9.2
D	17.75 x 7.9	650	14.2	11.1
E	18 x 7.83	682	14.9	10.8

As will be seen from comparison of Tests A and B, the presence of water resulted in a definite damping effect upon the power of the TNT explosive. Test C, representing conventional methods of replacing water in wet bore holes with a saturated aqueous solution of an oxygen-supplying salt, counteracted this damping effect to an appreciable degree. However, in Tests D and E, where equivalent quantities of the oxygen-supplying salt were instead admixed with the TNT granules, in controlled particle sizes and without substantial increase in the volume of the granules, the power of the compositions quite unexpectedly increased far beyond the counteracting effect noted in Test C.

Example 2

A second series of tests similar to those of Example 1 were carried out using pellets of 50/50 pentolite as the water insoluble explosive granules. This explosive is made of 50% PETN and 50% TNT and the average diameter of the granules was 3/32 to 7/32 inch.

The test pipe was apparently completely filled with 46 pounds of the pentolite granules and the space between the granules was calculated to be the same as that of Example 1. The pipe filled with 46 pounds of pentolite alone was detonated as Test A.

A second pipe was filled with 46 pounds of pentolite and 14.25 pounds of water, and was detonated as Test B.

A third pipe was filled with 46 pounds of pentolite and 19 pounds of a saturated aqueous solution of ammonium nitrate, with this quantity of solution filling substantially all of the interstitial spaces between the pentolite granules. This pipe was detonated as Test C.

A batch of 46 pounds of the pentolite granules was uniformly admixed with 12.5 pounds of ammonium nitrate particles which were of a size about the same as those used in Test D of Example 1. Into a fourth pipe was first placed 6.5 pounds of water and then the pipe was filled with the mixture of pentolite and ammonium nitrate. This pipe was detonated as Test D.

Another batch of 46 pounds of pentolite was uniformly admixed with 17 pounds of sodium nitrate particles

which were of a size the same of that of the ammonium nitrate particles. Into a fifth pipe was first placed 6.5 pounds of water and then the pipe was filled with the mixture of pentolite and sodium nitrate. This pipe was detonated as Test E.

The results of all tests are recorded in the following table:

Test	Dimensions of Crater (ft.)	Volume of Crater (ft.³)	Volume of Earth Moved (ft.³/lbs.)	
			Pentolite	Pentolite and Salt
A	17.83 x 7.75	642	13.9	----------
B	16.75 x 7.4	543	11.6	----------
C	17.9 x 7.75	650	13.9	10.8
D	18.5 x 8.1	720	15.4	12.1
E	18.6 x 8.16	738	15.8	11.6

The above noted results again demonstrate that the dry mixtures of water insoluble high explosive and water soluble oxygen-supplying salt were unexpectedly of far superior power than those in which the same quantity of salt was placed in the test pipe in the form of a saturated aqueous solution.

Example 3

A third series of tests similar to those of Example 1 was made using pelleted Composition B as the water insoluble explosive granules. Composition B is made of 59% cyclonite, 40% TNT and 1% mixed hydrocarbon waxes and the Composition B granules were of an average diameter of about 3/16 to 7/32 inch.

47 pounds of the Composition B granules apparently completely filled a test pipe and the total interstitial space between the granules was calculated to be the same as that of Example 1. The pipe containing 47 pounds of Composition B alone was detonated as Test A.

A second pipe was filled with 47 pounds of Composition B and 14.25 pounds of water. This pipe was detonated as Test B.

A third pipe was filled with 47 pounds of Composition B and 19 pounds of a saturated aqueous solution of ammonium nitrate. This pipe was detonated as Test C.

A batch of 47 pounds of the Composition B granules was uniformly admixed with 12.5 pounds of ammonium nitrate particles having a size the same as that used in Test C of Example 1. 6.5 pounds of water was placed into a fourth pipe and then the pipe was filled with the mixture of Composition B and ammonium nitrate. This pipe was detonated as Test D.

Another batch of 47 pounds of Composition B was uniformly admixed with 17 pounds of sodium nitrate particles having a size the same as that of ammonium nitrate particles. 6.5 pounds of water were placed in a fifth pipe and then the mixture of Composition B and sodium nitrate was also placed into the pipe. This pipe was detonated as Test E.

The results of all tests are recorded in the following table:

Test	Dimensions of Crater (ft.)	Volume of Crater (ft.³)	Volume of Earth Moved (ft.³/lb.)	
			Composition B	Composition B + Salt
A	18.25 x 8	698	14.6	----------
B	17.1 x 7.83	595	12.4	----------
C	18.5 x 8	713	14.9	11.6
D	19.2 x 8.25	794	16.7	12.9
E	19.5 x 8.25	816	17.1	12.6

It will be noted from the above results that the dry mixture of water insoluble granules and particles of water soluble salt were far more effective in overcoming the damping effect of water than those in which the same amount of salt was added in the form of a saturated aqueous solution.

Example 4

Tests A through D of Example 1 are repeated except that ammonium perchlorate is substituted for the ammonium nitrate as the water soluble oxygen-supplying salt. The particle sizes of the ammonium perchlorate are the same as that of the ammonium nitrate and the dry mixture of Test D is made with 45 pounds of the TNT granules and 13.75 pounds of the ammonium perchlorate particles.

The results of the tests are substantially equivalent to those noted in Example 1 so that the ammonium perchlorate results in far greater power when admixed dry with the TNT granules than where the ammonium perchlorate is added as a saturated aqueous solution.

Example 5

In this example the efficiency of mixtures of water insoluble explosive granules and particles of a water soluble oxygen-supplying salt, the latter being protected with a slowly water soluble coating, was measured against the same quantity of water soluble salt added in the form of a saturated aqueous solution. The test pipes used for all tests of this example measured 5 inches in diameter and 18 inches in length, having a volume of 0.208 ft.³. Waterproofed prilled ammonium nitrate having an average diameter of about 1/8 inch was used as the water insoluble high explosive granules.

11.5 pounds of uncoated ammonium nitrate prills apparently completely filled a test pipe which was detonated as Test A for a control.

60 pounds of the ammonium nitrate prills were mixed with 3.5 pounds of micro crystalline petroleum wax in a molten state. The mixture was tumbled during cooling to give a water insoluble coating on the prills the density of which was slightly less than that of the prills alone. 11.2 pounds of the wax-coated ammonium nitrate prills was placed in a second pipe where the interstitial space was calculated to be 0.07 ft.³. The second pipe was detonated as Test B.

A third pipe was filled with 11.2 pounds of the wax-coated ammonium nitrate prills and 4.2 pounds of water which was sufficient to fill all the interstitial spaces between the wax-coated ammonium nitrate prills. The third pipe was detonated as Test C.

A fourth pipe was filled with 11.2 pounds of the wax-coated ammonium nitrate prills and 5.55 pounds of saturated ammonium nitrate solution containing 3.58 pounds of ammonium nitrate. The quantity of solution was sufficient to substantially fill all the interstitial spaces between the wax-coated ammonium nitrate prills. This pipe was detonated as Test D.

Another batch of 11.2 pounds of wax-coated ammonium nitrate prills was uniformly admixed with particles of ammonium nitrate substantially the same in size as that of Example 1 to which had been applied a slowly water soluble coating. This coating comprised a blend of equal parts of polyethylene glycols with one of the glycols having a molecular weight of 380 to 420 and the second glycol having a molecular weight of about 3,000 to 3,700. 10 pounds of the polyethylene glycol blend were melted at about 50 to 55° C. and then mixed with about 90 pounds of the fine particles of ammonium nitrate, the whole being then cooled during tumbling to give a coating of the polyethylene glycol blend around the ammonium nitrate particles. 3.45 pounds of the polyethylene glycol-coated ammonium nitrate particles were uniformly admixed with 11.42 pounds of the wax-coated ammonium nitrate prills to form the dry mixture. After 1.8 pounds of water was first placed in a test pipe, the pipe was filled with dry mixture and detonated as Test E.

In order to check the effectiveness of the polyethylene coated ammonium nitrate particles, Test E was repeated except that the dry mixture was prepared with 3.11 pounds of uncoated fine ammonium nitrate particles mixed with 11.2 pounds of the wax-coated ammonium nitrate prills. After 1.8 pounds of water were placed into another test pipe, this mixture with the untreated fine ammonium nitrate particles was filled into the pipe and the pipe was detonated as Test F.

To further check fuel efficiency, Test E was repeated except that 3.11 pounds of untreated fine ammonium nitrate particles mixed with 0.405 pounds of ethylene glycol were substituted for the 3.45 pounds of the polyethylene glycol-coated ammonium nitrate particles used in Test E. After 1.8 pounds of water were placed into another test pipe, this mixture was added to the pipe and the pipe was detonated as Test G.

The results of all tests are recorded in the following table:

Test	Dimensions of Crater (ft.³)	Volume of Crater (ft.³)	Volume of Earth Moved (ft.³/lb.)	
			Amount Prills	Prills and Nitrate
A	9.05 x 4.34	94	7.3	
B	12.46 x 4.92	207	18.6	
C	8.88 x 4.67	96	8.1	
D	10.56 x 4.96	144	12.7	9.5
E	13.21 x 5.42	242	21.9	17.0
F	10.58 x 4.5	144	12.7	9.8
G	11.54 x 5.00	175	15.6	12.1

As will be seen from the above results, in all cases where a dry mixture was employed in place of the saturated aqueous solution of water soluble oxygen-supplying salt, larger craters were formed evidencing the greater explosive power that was produced.

Example 6

Tests B through G of Example 5 were repeated except that a coating of a thermoplastic turpene resin melting at 137° C. and sold under the trade name Piccolyte 100 was employed for water-proofing the ammonium nitrate prills. The results were substantially the same as those noted for Example 5.

Example 7

In this example a water insoluble explosive was first prepared as follows. A mixture of 47 lbs. of ammonium nitrate and 40 lbs. of sodium nitrate was heated to about 150° C. until it became dough-like, and then 2.5 lbs. of atomized aluminum, 1.5 lbs. of sulfur, 2 lbs. of wood flour, and 2 lbs. of finely ground bituminous coal were blended in successively. This mixture was formed into granules which were coated with 5 lbs. of microcrystalline petroleum wax as in Example 6. The final granules had a diameter averaging a little more than ⅛ inch.

A 5" x 18" pipe was apparently completely filled with 11.25 lbs. of these explosive granules and this pipe was detonated as Test A.

A second pipe was filled with 11.25 lbs. of the explosive granules and 4.2 lbs. of water. This pipe was detonated as Test B.

A third pipe was filled with 11.25 lbs. of the explosive granules and 5.55 lbs. of saturated aqueous ammonium nitrate solution, this quantity of solution containing 3.45 lbs. of ammonium nitrate and being sufficient to fill substantially all of the interstitial spaces between the water insoluble explosive granules. This third pipe was detonated as Test C.

A batch of 11.25 lbs. of the water insoluble explosive granules was uniformly admixed with 3.45 lbs. of the coated ammonium nitrate particles used in Test E of Example 6. After 1.8 pounds of water was placed into a fourth pipe, the pipe was filled with this mixture and detonated as Test D.

The results of all tests are recorded in the following table:

Test	Dimensions of Crater (ft.)	Volume of Crater (ft.³)	Volume of Earth Moved (ft.³/lb.)		
			Explosive	Nitrate and Explosive	Explosive and Total Additive
A	11.5 x 5.17	163	13.6		
B	10.34 x 5.00	139	11.6		
C	10.58 x 5.00	160	13.3	10.1	
D	11.21 x 5.17	169	14.1	11.1	10.8

The results again showed that a dry mixture of water insoluble explosive granules and particles of water soluble oxygen-supplying salt is more effective in overcoming the damping effect of water than where the same quantity of salt is added in the form of a saturated aqueous solution.

Example 8

84 lbs. of calcium nitrate tetrahydrate and 16 lbs. of the blend of polyethylene glycols of Example 6, dissolved in acetone, were tumbled in a current of air. After volatilization of all of the acetone, a coating of the polyethylene glycols was deposited on the calcium nitrate particles which were of a size approximately the same as that of the ammonium nitrate particles of Example 1. A mixture was formed with 11.25 lbs. of the water insoluble explosive granules used in Example 7, Test A, and 3.45 lbs. of the coated calcium nitrate. After 1.8 lbs. of water was placed in a 5 x 18 inch pipe, the mixture was filled into the pipe and the pipe was detonated as Test A.

86 lbs. of strontium nitrate tetrahydrate were coated with 14 lbs. of the blend of polyethylene glycols in the manner described above, and a mixture formed with 3.8 lbs. of the strontium nitrate and 11.25 lbs. of the water insoluble granules mentioned above. After 1.8 lbs. of water was placed in another test pipe, the mixture was filled into the pipe and the pipe was detonated as Test B.

The results of the tests are given in the following table:

Test	Dimensions of Crater (ft.)	Volume of Crater (ft.³)	Volume of Earth Moved (ft.³/lb.)		
			Explosive	Explosive and Nitrate	Explosive and Total Additive
A	10.67 x 5.08	150	12.4	9.9	5.5
B	10.79 x 5.08	156	12.8	9.9	5.5

It will be understood that it is intended to cover all changes and modifications of the preferred embodiments of the invention, herein chosen for the purpose of illustration, which do not constitute departures from the spirit and scope of the invention.

What is claimed is:

1. An explosive composition comprising a dry mixture of substantially water insoluble granules of a detonable high explosive having a rate of detonation of at least 1000 meters per second and, contained in interstitial spaces between said granules, particles of at least one water soluble salt selected from the group consisting of ammonium, alkali metal and alkaline earth metal salts of perchloric and nitric acids, said particles having an average diameter substantially not greater than about ⅛ the average diameter of said granules with not more than about 10% by weight of said particles exceeding said ⅛ average granule diameter.

2. An explosive composition in accordance with claim 1 in which the quantity of said particles is from about 0.5 to about 1.5 times the quantity containable in a volume of saturated aqueous solution thereof which volume is substantially equal to the sum of the interstitial spaces between said granules.

3. An explosive composition in accordance with claim

1 which includes a sufficient quantity of an aliphatic compound having at least one hydroxy group to bring the entire composition substantially into oxygen balance.

4. An explosive composition in accordance with claim 1 in which said particles are coated with a slowly soluble material which in the form of 3 mil film dissolves completely in water at 1° C. in not more than about 10 minutes.

5. An explosive composition in accordance with claim 1 in which said particles completely fill all of said interstitial spaces.

6. An explosive composition comprising a dry mixture of substantially water insoluble granules of a detonatable high explosive having a rate of detonation of at least 1000 meters per second, said granules having an average diameter of from about 1/16 to about 1/4 inch and, contained in interstitial spaces between said granules, particles of at least one water soluble salt selected from the group consisting of ammonium, alkali metal and alkaline earth metal salts of perchloric and nitric acids, said particles having an average diameter substantially not greater than about 1/5 the average diameter of said granules with not more than about 10% by weight of said particles exceeding said 1/5 average granule diameter, said particles being present in a quantity of from about 0.5 to about 1.5 times the quantity containable in a volume of saturated aqueous solution thereof at ambient temperature which volume is substantially equal to the sum of the interstitial spaces between said granules, whereby said particles and said granules may be mixed without substantial increase in a given volume of said granules.

7. An explosive composition in accordance with claim 6 which includes a water soluble hydroxy compound selected from the group consisting of ethylene glycol, propylene glycol and water soluble low to medium molecular weight polymers thereof, 1,1,1-trimethylolethane and water soluble homologues thereof, glycerine and water soluble polymers thereof, sugars, pentaerythritol, and water soluble mixed polyethylene-polypropylene glycols, the quantity of said compound being sufficient to bring the entire composition substantially into oxygen balance.

8. An explosive composition in accordance with claim 6 in which the substantially water insoluble high explosive granules are formed of 2,4,6-trinitrotoluene.

9. An explosive composition in accordance with claim 6 in which said substantially water insoluble high explosive granules are formed of a mixture of equal parts of 2,4,6-trinitrotoluene and pentaerythritol tetranitrate.

10. An explosive composition in accordance with claim 6 in which said substantially water insoluble high explosive granules are formed of a mixture of 59 parts cyclotrimethylenetrinitramine, 40 parts 2,4,6-trinitrotoluene and 1 part hydrocarbon wax.

11. An explosive composition in accordance with claim 6 in which said particles are coated with polyethylene glycol of low to medium molecular weight.

12. An explosive composition comprising a dry mixture of from 45 to 47 parts of substantially water insoluble granules of a detonatable high explosive selected from the group consisting of 2,4,6-trinitrotoluene, a mixture of equal parts of 2,4,6-trinitrotoluene and pentaerythritol tetranitrate, and a mixture of 59 parts cyclotrimethylenetrinitramine, 40 parts 2,4,6-trinitrotoluene and 1 part hydrocarbon wax, said granules having an average diameter of from about 3/32 to 7/32 inch and, contained in interstitial spaces between said granules, from 12.5 to 17 parts of particles of a water soluble salt selected from the group consisting of ammonium and sodium nitrates, the average diameter of said particles being substantially not greater than about 1/5 the average diameter of said granules with not more than about 10% by weight of said particles exceeding said 1/5 average granule diameter, whereby said particles may be uniformly admixed with said granules without causing substantial increase in the volume of said granules.

13. In a method of blasting which involves the detonation of explosives in a bore hole, the steps which comprise mixing substantially water insoluble granules of a detonatable high explosive having a rate of detonation of at least 1000 meters per second with particles of at least one water soluble salt selected from the group consisting of ammonium, alkali metal and alkaline earth metal salts of perchloric and nitric acids, said particles having an average diameter substantially not greater than about 1/5 the average diameter of said granules with not more than about 10% by weight of said particles exceeding said 1/5 average granule diameter and said particles being contained in interstitial spaces between said granules, filling the bore hole with said mixture and detonating said mixture.

14. A method in accordance with claim 13 which includes the step of adding a sufficient quantity of an aliphatic compound having at least one hydroxy group to said mixture to bring the entire mixture substantially into oxygen balance prior to the step of filling the bore hole.

15. In a method of blasting which involves the detonation of explosives in a bore hole, the steps which comprise determining the sum of the interstitial spaces between substantially water insoluble granules of a detonatable high explosive having a rate of detonation of at least 1000 meters per second when said granules are contained in any given volume, mixing said granules with particles of at least one water soluble salt selected from the group consisting of ammonium, alkali metal and alkaline earth metal salts of perchloric and nitric acids, said particles having an average diameter not substantially greater than 1/5 the average diameter of said granules with not more than about 10% by weight of said particles exceeding said 1/5 average granule diameter and said particles being contained in interstitial spaces between said granules, the quantity of said particles being from about 0.5 to about 1.5 times the quantity containable in a volume of saturated aqueous solution thereof at ambient temperature which volume is substantially equal to the sum of said interstitial spaces, filling the bore hole with said mixture and detonating said mixture.

16. A method in accordance with claim 15 which includes the step of adding to said mixture a water soluble hydroxy compound selected from the group consisting of ethylene glycol, propylene glycol and water soluble low to medium molecular weight polymers thereof, 1,1,1-trimethylolethane and water soluble homologues thereof, glycerine and water soluble polymers thereof, sugars, pentaerythritol, and water soluble mixed polyethylene-polypropylene glycols, the quantity of said compound being sufficient to bring the entire mixture substantially into oxygen balance.

17. A method in accordance with claim 15 in which said particles are coated with a polyethylene glycol of low to medium molecular weight.

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