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SLURRY BLASTING EXPLOSIVES CONTAINING INORGANIC PERCHLORATE OR CHLORATE

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This invention relates to explosive compositions and, more particularly, to blasting agents in slurry form containing chlorate or perchlorate oxidizing agents.

Sodium chlorate and other chlorates or perchlorates have been found in the past to be very hazardous materials for use in explosives because of their high sensitivity to shock, friction and heat. Prior art chlorate explosives are very easily ignited and burn with extremely hot flames which may cause them to detonate under confinement when accidentally ignited. According to the present invention, blasting agents are provided utilizing chlorate or perchlorate oxidizing agents which are safe to manufacture, handle and utilize in blasting operations. The explosive compositions of this invention are relatively insensitive to shock, impact, friction and heat.

It is accordingly among the objects of the invention to provide a chlorate-based blasting explosive in slurry form which is inexpensive, safe to handle and which may safely be detonated by inexpensive boosters.

It is among the further objects of the invention to provide slurry blasting agents which may be used in both large and small diameter bore holes whether the bore holes be wet, dry or water-filled.

Other objects and advantages of the invention will be apparent to those skilled in the art.

The compositions of the invention comprise an aqueous slurry of solids, said solids comprising about 13 to 85 percent by weight of TNT and 87 to 15 percent by weight of chlorate or perchlorate, the water content of the slurry being from 4 to 25 percent by weight and the TNT being of coarse particle size in the range of 4 to 30 standard Tyler mesh. The slurry may optionally be thickened by a hydrophilic colloid.

Examples of chlorate salts which have been found useful in the invention are sodium chlorate, potassium chlorate and ammonium perchlorate. A portion of the chlorate salt content (up to 50 percent by weight) may be replaced by nitrates, such as ammonium nitrate or sodium nitrate.

The particle size of the chlorate or perchlorate in the slurry explosives of this invention is not critical. Screen sizes ranging from 20 to 150 mesh have been used with equivalent results. The screen analysis of a typical grade of sodium chlorate used in the examples herein is as follows:

Mesh size:	Percent
+20 standard Tyler mesh	0.2
−20+28 standard Tyler mesh	17.7
−28+35 standard Tyler mesh	45.6
−35+48 standard Tyler mesh	23.00
−48+65 standard Tyler mesh	6.6
−65+100 standard Tyler mesh	3.3
−100 standard Tyler mesh	3.6

The term TNT as used herein means TNT per se as well as mixtures of TNT with other explosives such as amatol (ammonium nitrate-TNT), sodatol (sodium nitrate-TNT), cyclotol (RDX-TNT), Ednatol (EDNA-TNT), tetrytol (tetryl-TNT) and pentolite (PETN-TNT). These TNT-containing products must be in coarse form from 2 to 30 standard Tyler mesh and may be in the form of flakes, prills or coarse shot power products. The

use of fine TNT, i.e. finer than 30 standard Tyler mesh, renders slurry explosives prepared therefrom too insensitive to be commercially useful.

The slurry explosives of the present invention may optionally contain solid fuels, such as powdered coal, aluminum particles, and the like, to bring the oxygen balance closer to zero. From one percent to ten percent by weight of the solids may comprise such fuels.

The hydrophilic colloids which may be used for controlling the viscosity may be, for example, guar gum or guar gum which has been cross-linked with borax. Other suitable materials are starch, wheat flour, and the like. Such materials are preferably utilized in the amount of one to ten percent by weight of the water used in the slurry, and should be pre-dispersed in the water prior to making up the slurry.

The amount of water is in the range of 4 to 25 percent by weight of the total slurry, depending on the amount of chlorate or perchlorate, which is soluble, in the composition. Preferably the amount of water is just sufficient to provide an easily pourable slurry, which is generally in the range of 7 to 13 percent by weight of the total slurry. The density of the slurry is in the range of 1.65 to 1.85 g./cc.

The slurry explosives of the invention provide high maximum available energy and because of their relatively high density, the "bulk strength," namely, the product of density and maximum available energy, is very high. We have discovered that the chlorate slurries of this invention have higher "performance" sensitivity (ability to perform satisfactorily in the borehole) than prior art slurry blasting explosives as determined by conventional unconfined minimum booster and critical diameter propagation tests.

The "hazard" sensitivity or sensitivity toward ignition, shock and friction of the chlorate slurries also are all satisfactorily low. For example, in a high velocity impact test in which a heavy metal plate was hurled at the explosive at a velocity of about 4,000 feet/second, it was discovered that the impact sensitivity of a sodium chlorate slurry made in accordance with this invention, although having a considerably higher performance sensitivity, was no greater than for ammonium nitrate-fuel oil (94 percent kieselguhr-coated prilled ammonium nitrate, 6 percent #2 fuel oil), a product commonly used in large diameter borehole blasting. Until the advent of slurry blasting agents it had been thought that the ammonium nitrate-fuel oil product was almost the ultimate in explosive safety. As an example of this, it was discovered that the 94/6 kieselguhr-coated, prilled ammonium nitrate/fuel oil could be detonated about 50 percent of the time in a 9" diameter, 18" long charge by a high velocity steel plate impact of 140 kcal. using a 4" diameter x 4" long composition B plate-hurling charge at 20 feet standoff. In the same tests, the 50/50 detonation failure point of a chlorate slurry having a composition of 62 parts sodium chlorate, 38 parts 4 to 30 mesh TNT and 12 parts water containing 1.6 percent guar gum, which showed a much higher performance sensitivity (minimum booster 10 to 20 g. cast 50/50 pentolite, unconfined critical diameter 1.25") than the 94/6 product (minimum booster—40 grams cast 50/50 pentolite and unconfined critical diameter 4") also was 140 kcal. showing that the chlorate slurry had about the same hazard sensitivity but a higher performance sensitivity than 94/6 ammonium nitrate/fuel oil.

The following examples will illustrate the desirable properties of the sodium chlorate blasting agents of this invention, in which all parts and percentages are by weight.

Example I

In the determination of the explosive properties of

chlorate slurry blasting agents compared with the standard 94/6 ammonium nitrate/#2 fuel oil made with prilled ammonium nitrate containing 2.5–35% kieselguhr-coating, the following experimental results were obtained:

Composition	A	B	C	D	94/6 AN/Fuel Oil
Sodium Chlorate	62.5	64.3	67.0	67.0	
TNT (4–20 mesh, predominantly 8–10 Mesh)	22.3	17.8	15.2	13.4	
Coal	4.5	7.2	7.1	8.9	
Water	10.7	10.7	10.7	10.7	
Density (g./cc.)	1.70	1.77	1.83	1.77	0.82
Unconfined critical diameter (measured at a length/diameter ratio of 6 or more) inches	2.5	4	5	6–9	4
Minimum booster (g. cast 50/50 pentolite measured at d_c+1")		80	160	100 to 380	40
Relative strength by seismic method		1.18			1.0
Detonation velocity (km./sec.):					
5" (unconfined)		4.3			2.77
5" (steel pipe)		4.4			3.75
Detonation pressure (kilobars) measured by "aquarium" method:					
5" (unconfined)		55			13.5
5" (steel pipe)		68			37.5

By increasing the coarse (−4+30 mesh) TNT content, the minimum booster and critical diameters decrease rapidly in the sodium chlorate slurries. Example II illustrates a preferred small diameter blasting agent made in accordance with this invention.

Example II

A slurry was prepared having the following composition:

	Parts
Sodium chlorate	52
TNT (4–20 mesh)	32
Water containing 1.6 guar gum crosslinked with 0.16% borax	12

The following properties were experimentally determined:

Density (g./cc.)	1.78.
Unconfined critical diameter	1.25".
Minimium booster in 1.5" size	10 g. cast 50/50 pentolite.
High velocity plate impact sensitivity	1.35.
Relative strength [1] (seismograph method)	140 kcal.
Bulk strength [1]	2.9.

Detonation velocity: [2]

	km./sec.	Detonation Pressure (kilobars)[2] (aquarium method)
2" Unconfined	5.0	93
2" Steel pipe (⅛" thick)	5.43	112
5" Unconfined	5.23	96

[1] Based on the 94/6 product as unity.
[2] At a density of 1.72 g./cc.

The following example illustrates slurry explosives according to the invention in which a portion of the chlorate is replaced by ammonium nitrate:

Example III

The following composition was prepared:

	Parts
Sodium chlorate	32
Ammonium nitrate	32
TNT (4–30 mesh)	27.5
Water containing 2% guar gum	8.5

The above slurry had a density of 1.67, an unconfined critical diameter of only 1.5", a minimum booster sensitivity of 10 grams cast 50/50 pentolite and a bulk strength of about 2.35 based on the 94/6 ammonium nitrate/fuel oil standard. It had the same high velocity impact sensitivity as the 94/6 standard, namely 140 kcal.

Since sodium chlorate is about twice as expensive as ammonium nitrate, the favorable properties of the blasting agent in Example III illustrates that a partial substitution of ammonium nitrate for chlorate in slurries is economically desirable.

The following examples illustrate other satisfactory slurry explosives prepared in accordance with the invention:

Example IV

	Parts
Ammonium perchlorate	64
TNT (4–30 mesh)	24
Water containing 1.5% guar gum	10

Example V

Potassium chlorate	60
Composition B (50% RDX, 39% TNT and 5% wax 8–10 mesh)	28
Water	9

The blasting explosives of this invention may be dependably detonated by relatively inexpensive boosters of high brisance, such as pentolite, RDX, and the like. The booster and fuse, therefore, are simply lowered into the borehole containing the slurry explosive and thereafter fired.

The slurry explosives of the invention may be safely manufactured, stored and shipped and hence may be prepared in a processing plant and transported to the blasting site. Additionally, the slurries may be prepared on the site if desired, which is particularly desirable in blasting in water-filled boreholes.

While the invention has been described in terms of certain examples, they are to be considered illustrative and not limiting and it is intended to cover all modifications and embodiments that fall within the spirit and scope of the appended claims.

We claim:

1. An aqueous slurry blasting explosive consisting essentially of a slurry of solids in water, said solids comprising about 13 percent to 85 percent by weight of trinitrotoluene having a particle size in the range of 2 to 30 standard Tyler mesh, and 87 percent to 15 percent by weight of an inorganic salt selected from the group consisting of alkali metal and ammonium chlorates and perchlorates, the water content of the slurry being from 4 percent to 25 percent by weight of the total slurry.

2. The explosive set forth in claim 1 wherein the water contains from one percent to 10 percent by weight of a hydrophilic colloid.

3. The explosive set forth in claim 1 wherein said inorganic salt is sodium chlorate.

4. The explosive set forth in claim 3 wherein up to 50 percent by weight of said sodium chlorate is replaced by ammonium nitrate.

5. The explosive set forth in claim 1 wherein said trinitrotoluene has a particle size of 8 to 10 standard Tyler mesh.

6. The explosive set forth in claim 1 wherein said solids additionally contain from one percent to 10 percent by weight of finely divided oxidizable solid fuel.

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