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METHOD OF BLASTING

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Our invention relates to an improved method of blasting in which a relatively insensitive explosive is utilized as the main charge in combination with a priming charge comprising a more sensitive explosive. The invention relates more particularly to such an assembly in which the main charge comprises an explosive of regulated sensitiveness.

In blasting work in hard rock the use of detonating high velocity explosives is required in order that the material blasted may be properly broken down and disintegrated. For such blasting work nitroglycerin and nitrostarch explosives have for many years proved to be the most satisfactory. More recently a portion of the nitroglycerin in such explosives has been replaced by ammonium nitrate but the use of a considerable amount of nitroglycerin has still been considered necessary for complete detonation and for the development of the full explosive force of the ammonium nitrate.

These explosives as described above, have given satisfaction in so far as their explosive execution is concerned. Some unavoidable disadvantages have, however, been connected with their use. These explosives are not only sensitive to shock and friction but are distinctly inflammable and a reasonable amount of care must therefore be exercised in their handling and transportation. Furthermore, they are relatively expensive due primarily to the use of a high percentage of a costly sensitizer and also to the extra care required in their manufacture and transportation.

It has heretofore been considered necessary in order that no misfires should occur in practical blasting, to employ explosives readily detonated by the blasting caps in common use. This is due to the fact that such failures bring hazards in removing the unexploded charge as well as undesirable expenditures for labor. It is apparent, therefore, that the less sensitive explosives can be and yet be satisfactory for use, the greater and more numerous are the resulting advantages.

The use of insensitive explosives would be particularly desirable in quarry blasting where the amount of explosive used for a single blast is very large, often ranging from 10,000 to 30,000 lbs. When blasting on this scale the number of men involved in the operations of handling and loading explosives is considerable and all of these men are of necessity exposed to greater hazards when using sensitive explosives. Furthermore, the most common method of blasting now used in quarries, and known as the "well drill" method, employs drill holes which range from 4 to 8 inches

in diameter and are often from 60 to 200 feet deep. The danger connected with loading large cartridges of sensitive explosives is apparent since it is accomplished by dropping the paper wrapped cartridges of explosives into the holes. The charge when in place is fired either by an electric blasting cap or by a section of Cordeau running the entire length of the hole.

Various means have been suggested heretofore in an effort to replace the usual relatively sensitive explosives such as nitroglycerin or nitrostarch dynamites with main explosive charges either of a lower degree of sensitiveness or of a lower velocity.

Favier for example (in U. S. Patent 393,634) made use of a high density ammonium nitrate explosive that was characterized by a particularly low degree of sensitiveness. His explosive was in the shape of a hollow cylinder and detonation was brought about by the use of a center core of a more sensitive explosive, such for example as dynamite or gun cotton which is detonated with fulminate. Various disadvantages are however, associated with such an explosive. The use of a hollow cylinder for example, makes it necessary to either ship the assembled explosive with the center core of sensitive primer in place, in which case little advantage can be obtained with respect to insensitiveness to shock, or the hollow cylindrical explosive and priming charge must be shipped separately and assembled at the place of use with resulting inconvenience and danger to the user.

Attempts have also been made to utilize black blasting powder in place of nitroglycerin explosives in cases where a high velocity was desirable. Black blasting powder however customarily burns with a velocity of combustion of around 300 meters per second whereas the velocity of detonation of nitroglycerin explosives is usually not below 2000 meters per second. Attempts have been made to increase the velocity of the black powder under such circumstances by the use of a line of high velocity detonating fuse, for example, Cordeau (5000 meters per second) placed along the entire length of a bore hole filled with the black powder.

A further attempt to make a suitable explosive has been made by Pratt (U. S. Patent 1,785,529) who used an explosive assembly comprising a main charge of black blasting powder with a center core of a sensitive detonating dynamite.

These attempts to produce a practical explosive assembly have, however, in the main, been unsatisfactory. In the two latter cases this has

been due to the fact that the velocity of the black powder is really not increased even though its initiation does take place more rapidly throughout the entire bore hole. Furthermore, 5 black powder presents considerable hazard because of its inflammability. In the case of the explosive charges suggested by Favier, the center core priming is not sufficient to impart the desired high velocity to the surrounding explosive. 10 Favier's compositions were, in addition, too insensitive to propagate detonation except as a center core primer was used throughout the entire length of the charge.

Also low strength, low velocity detonating explosives, both of the nitroglycerin and nitrostarch types, have long been made for blasting purposes but have found very limited application in hard rock quarry blasting because they have insufficient and unsatisfactory strength and velocity. 15 The velocity of such dynamites is materially low, for example, less than 2000 meters per second, and their strength under that of 25% dynamite, whereas for hard rock quarry blasting the usual practice is to use explosives having 40% strength 20 or above and velocities of over 3000 meters per second.

A further disadvantage common to all of the foregoing explosives lies in the fact that such compositions have but little water resistance. 30 Their use, therefore, has been limited to dry bore holes, a condition which is the exception rather than the rule in the "well drill" method of quarry blasting.

Heretofore the practice has been to evaluate explosives as regards their practical use on the basis of their sensitiveness when initiated unconfined in a diameter of approximately 1 1/4 inches by a commercial blasting cap, that is, a No. 6 or No. 8 cap. Those failing to show consistent propagation under such test conditions 40 have generally been considered as too insensitive to be of practical use.

We have now discovered that under the confinement normally supplied by the surrounding medium to be blasted many explosive compositions incapable when unconfined of detonation by blasting caps or Cordeau, can be made to detonate and propagate when primed with adequate boosters. We have found, however, that for 50 such insensitive explosives to function even with a booster, the degree of insensitiveness must be regulated between certain limits and that the column or mass of explosive should have a cross sectional area preferably equal to or greater than that of a two-inch circle or a cross-sectional area 55 of approximately three (3) square inches.

Various ingredients of existing explosives may be used in our blasting method and assembly. As examples may be cited inorganic nitrates including those of ammonium, sodium and potassium, and inorganic chlorates and perchlorates such as those of ammonium, sodium and potassium, or equivalent compounds. Since the materials just mentioned are of themselves relatively 60 insensitive, and furthermore since they carry an excessive amount of oxygen, it is necessary to add certain combustible substances which act both as sensitizers and fuels to combine with the excess oxygen present.

It has been found that the degree of sensitiveness and the strength of the finished explosive can be satisfactorily regulated by properly choosing the sensitizer and by controlling the amount used. However, for various reasons, both 70 economical and technical, we prefer to use am-

monium nitrate as the main explosive ingredient.

Our method of blasting comprises among other things loading a drill hole with such an explosive the sensitiveness of which has been regulated as just described, so that it is incapable when 5 unconfined of detonation by the strongest commercial blasting cap, and in detonating the main charge by means of one or more booster charges of a more easily detonated explosive. We prefer to have the booster in contact with the insensitive explosive or embedded in a small portion of the same. Both these methods of priming are possible and in all cases the full efficiency of the explosive is developed if the sensitiveness of the main charge has been properly regulated. 15 Depending upon special conditions, we may either place the booster on top of the charge in the drill hole, at the bottom of the drill hole or finally at various intermediate points in the column of insensitive explosive. We may also use the center 20 core booster running substantially the full length of the charge. This is not preferred however since our regulated sensitiveness does not require it and furthermore because it is less economical and more hazardous. The position, however, is 25 immaterial so long as the sensitiveness of the explosive has been properly regulated.

For practical use according to our method of blasting, the main explosive charge must as stated previously, have a degree of sensitiveness 30 within definite limits. For example, it must be sufficiently insensitive so that it will consistently fail, when unconfined, to propagate when initiated by the strongest commercial deonator in general use, namely a No. 8 cap. As a matter 35 of fact our explosive compositions will fail to detonate with several No. 8 caps fired simultaneously, or with from 5 to 20 grams of TNT primed with a single blasting cap. It is apparent, therefore, that the sensitiveness of the composition is 40 far below that necessary to detonate consistently with a single commercial blasting cap of maximum strength.

On the other hand, the explosive must not be less sensitive than a uniform composition comprising 94.5% ammonium nitrate and 5.5% paraffin, these proportions being such that the excess oxygen of the ammonium nitrate is practically sufficient to combine with the carbon and hydrogen of the paraffin. As further defining 50 this standard the ammonium nitrate should be of such fineness that 25% to 40% will pass a 100 mesh screen and finally the density of the finished explosive should not exceed 1.15.

The sensitiveness of the standard mix just 55 described, namely 94.5% ammonium nitrate and 5.5% paraffin, may also be expressed in terms of a trinitrotoluene primer when using the subsequently described testing method. By a trinitrotoluene primer is meant the quantity of this 60 material at a density of .95 which is capable of giving a positive result by the test used.

The procedure consists in detonating a single paper-wrapped 4 1/2 x 8 inch cartridge of the explosive to be tested after first placing it vertically on a cylindrical lead test block 2 1/4 inch in diameter and 4 inches long supported on a substantial steel plate.

The primer to be used in this method is understood to have the same diameter as that of 70 the explosive under test, namely 4 1/2 inches, and consist of trinitrotoluene compressed to a density of 0.95.

More specifically the procedure consists in determining the minimum amount of the said 75

primer when enclosed in a paper wrapper which will cause the insensitive explosive under test to consistently detonate and propagate throughout its entire length of 8 inches. The lead test block is used simply as a convenient means of indicating whether the detonation has traveled through the 8 inches. Obviously the compression will vary, and will not only depend upon the completeness of the propagation but also on the velocity of detonation. Approximately 20 tests with each primer will be sufficient to determine the true value.

It is further desirable that the upper end surface of the explosive under test in contact with the primer be exposed, but it is not necessary that the paper covering of the primer be so removed. The primer in all cases should be initiated by a No. 8 cap. In this test the primer length is varied in one inch increments and the weight of trinitrotoluene is determined to the nearest inch giving the desired compression.

Experiments have shown that the amount of primer determined by the method just described is greatly in excess of that necessary to produce the required compression particularly when the primer is of a smaller diameter than the main explosive and embedded therein. The use of different length embedded primers of smaller diameter than the main charge however, results, with the standard 8 inch length of main explosive, in a variable distance between the lower end of the primer and the lead block which condition prevents the quantity of the explosive under test from being constant. We therefore prefer to employ a primer of the same diameter as the main explosive and in this way so standardize the test that the single variable present is the length of primer. The employment of such large primers therefore, is for the sole purpose of insuring a reproducible and definite method and the amounts as referred to sensitiveness are to be considered as comparative and not in any sense to represent the minimum amount necessary.

The previously described uniform standard composition (94.5 ammonium nitrate 5.5 paraffin) when tested at a density of 1.15 by the procedure just described can be made to detonate and produce the desired compression when primed with 1000 grams of trinitrotoluene.

This same test procedure may be employed when determining the sensitiveness to detonation with a No. 8 cap, or for determining the minimum booster required with the exception that in the case of the cap it is obvious that it would be inserted directly in the explosive. By a No. 8 cap we wish to designate one containing the standard charge of 2 grams of mercury fulminate or fulminate composition as described in Bulletin 59 of the United States Bureau of Mines.

The standard primer employed in the method for determining sensitiveness is, however, not particularly well adapted for practical use as a booster charge. For this purpose there are available many explosives among the existing commercial dynamites. Although certain of the lower grades of dynamite can be used, we prefer the higher ones, for example, 40% or over. It is desirable that the booster be readily detonated by a commercial blasting cap for example, a No. 6 cap, by which we wish to designate one containing a charge of one gram of mercury fulminate or fulminate composition.

While it is possible to detonate our insensitive explosive by means of a booster of relatively small diameter embedded in the explosive, or by a

booster of appreciably smaller diameter than the main charge, said booster not being enclosed thereby but in direct contact with the main explosive, we prefer to bring about detonation by the use of a primer butted against and of substantially the same diameter as the main column of explosive. As previously stated, the booster charge may be placed at either or both ends of the main explosive column. It may also be located at one or more intermediate points in the column depending upon special conditions.

Our invention renders available for blasting many compositions fundamentally more economical than those heretofore used and at the same time makes possible a great increase in safety. While our invention is intended to include the use with the booster of any explosive coming within the limits of sensitiveness already defined, we find ammonium nitrate particularly well adapted for use in explosive compositions capable of use in our preferred method of blasting.

The ease of detonation of ammonium nitrate can be varied within wide limits depending on the nature of sensitizer or carbon carrier added to it. Variation in density of the finished explosive and also in the fineness of the nitrate of ammonia produces marked changes in the sensitiveness. For any given composition the density must not be too high or else the explosive will be too insensitive. Likewise for any given fineness of nitrate of ammonia there are certain compositions and densities which favor the proper sensitiveness.

A mixture of 94.5 per cent. ammonium nitrate and 5.5 per cent. paraffin has already been cited as representing an explosive approximating the upper limit of sensitiveness satisfactory for our method of blasting, provided the ammonium nitrate has a certain fineness and the finished explosive a density not exceeding 1.15. This combination can be rendered well suited for use in our method of blasting by a number of means. For example, by materially increasing the fineness of the nitrate of ammonia or by lowering the density to a point approximating 1.0 the sensitiveness of this mixture is improved. Likewise by replacing either a portion or all of the paraffin by more efficient sensitizers, such as for example nitro aromatic compounds, the above composition can be rendered well adapted for use in our combination method of blasting, provided of course due attention is given to maintaining a reasonable oxygen balance.

Ammonium nitrate explosives are, however, not suitable for use in bore holes where water is present except as they are properly protected from its solvent action. In the case of dry bore holes unprotected ammonium nitrate explosives may be used in our blasting assembly. We prefer however, to enclose the main explosive charge in water proof containers made preferably of metal. In the use of explosives in "well drill" holes, water is very frequently present, and in the case of deep holes containing considerable water the pressure of this water makes it necessary that the explosive be completely protected. A rigid container, such as can be made from sheet metal has other advantages such as keeping out atmospheric moisture and preventing a change in the density when loaded in deep holes which change can be brought about normally by excessive tamping or by dropping the charges for considerable distances. In other words, a tightly sealed metal container helps to preserve during storage and use the regulated sensitiveness provided in the explosive at the time of its manufacture. Furthermore, the

safety of such explosives permits of the use of metal containers without any question as to hazard, which is not the case with the dynamites heretofore used in mines and quarries.

5 As an example of the procedure involved in our method of blasting we may cite the following. An ammonium nitrate explosive so regulated as to sensitiveness as to fall within the previously given limits is cartridge in cylindrical
10 water tight containers, for example, $4\frac{1}{2}$ x 16 inches at a density consistent with both sensitiveness and strength. These containers may then be loaded one on top of the other in the proper amount in a "well drill" quarry hole of
15 100-foot depth filled with water. The main charge can then be detonated with full efficiency by the use of one $4\frac{1}{2}$ x 16 inch paper cartridge of 60% gelatin dynamite placed directly on top of the last container of insensitive explosive. The
20 gelatin may in turn be detonated either by means of an electric blasting cap or by Cordeau fuse.

Having described in detail our invention, many modifications of which are possible, we wish to be limited only by the following claims. It is
25 understood that the degree of sensitiveness in the said claims is that determined by the method of testing herein described.

We claim:

1. A blasting assembly comprising a cap-sensitive
30 booster charge, an initiator for the booster, and a detonating explosive consisting of at least one charge having a length substantially greater than the booster and capable of complete detonation when once initiated by said booster, and
35 having a degree of sensitiveness such that its initiation requires a booster charge in addition to a blasting cap, but having an insensitiveness not greater than that of a composition at a density of 1.15 comprising 94.5% ammonium
40 nitrate, of such fineness that 25% to 40% will pass a 100-mesh screen, and 5.5% paraffin.

2. A blasting assembly comprising a cap-sensitive booster charge, an initiator for the booster,
45 and a detonating explosive charge having a length substantially greater than the booster and capable of complete detonation when once initiated by said booster, and having a degree of insensitiveness, when tested unconfined, such
50 that its complete detonation requires, in addition to a blasting cap, a booster charge not to exceed 1000 grams of TNT at a density of 0.95.

3. A blasting assembly comprising a cap-sensitive booster charge, an initiator for the booster,
55 and a charge of an ammonium nitrate detonating explosive having a length substantially greater than the booster and capable of complete detonation when once initiated by said booster, and having
60 a degree of insensitiveness, when tested unconfined, such that its complete detonation requires, in addition to a blasting cap, a booster charge not to exceed 1000 grams of TNT at a density of 0.95.

4. A blasting assembly comprising a cap-sensitive booster charge, an initiator for the booster,
65 and a plurality of charges of a detonating explosive capable of complete detonation when once initiated by said booster, and comprised of ammonium nitrate, the combined length of said
70 charges being substantially greater than the booster, said explosive having a degree of insensitiveness, when tested unconfined, such that its complete detonation requires, in addition to a blasting cap, a booster charge not to exceed
75 1000 grams of TNT at a density of 0.95, said cap-

sensitive booster charge being in contact with one of the plurality of explosive charges.

5. A blasting assembly comprising a cap-sensitive booster charge, an initiator for the booster,
5 and a detonating explosive capable of complete detonation when once initiated by said booster, and comprised of ammonium nitrate enclosed in a waterproof container, said charge having a
10 cross-sectional area of not less than 3 inches and a length substantially greater than the booster, said explosive having a degree of insensitiveness, when tested unconfined, such that its complete
15 detonation requires, in addition to a blasting cap, a booster charge not to exceed 1000 grams of TNT at a density of 0.95.

6. A blasting assembly comprising a cap-sensitive booster charge, an initiator for the booster,
20 and a plurality of charges of a detonating explosive capable of complete detonation when once initiated by said booster, and comprising ammonium nitrate in a waterproof container, said
25 charges having a length substantially greater than the booster, said explosive having a degree of insensitiveness, when tested unconfined, such that its complete detonation requires, in addition
30 to a blasting cap, a booster charge not to exceed 1000 grams of TNT at a density of 0.95, said cap-sensitive booster charge being in contact with one of the plurality of explosive charges.

7. A blasting assembly comprising a cap-sensitive booster charge, an initiator for the booster
35 and a detonating ammonium nitrate explosive capable of complete detonation when once initiated by said booster, and having a diameter not less than two inches and a length substantially
40 greater than the booster and having a degree of insensitiveness, when tested unconfined, such that its complete detonation requires, in addition to a blasting cap, a booster charge
45 not to exceed 1000 grams of TNT at a density of 0.95.

8. A blasting assembly comprising a cap-sensitive booster charge, an initiator for the booster,
50 and a detonating explosive charge substantially greater in length than the booster and capable of complete detonation when once initiated by said booster, and comprised of ammonium
55 nitrate enclosed in a metallic waterproof container, to prevent a change in density of the explosive, and having a diameter of not less than two inches, said explosive having a
60 degree of insensitiveness, when tested unconfined, such that its complete detonation requires, in addition to a blasting cap, a booster charge not to exceed 1000 grams of TNT at a density
65 of 0.95.

9. A blasting assembly comprising a cap-sensitive booster charge, an initiator for the booster,
70 and a detonating ammonium nitrate explosive capable of complete detonation when once initiated by said booster, and having a diameter of not less than two inches, and a length substantially
75 greater than the booster, said explosive having a degree of insensitiveness, when tested unconfined, such that complete detonation with the propagation of the explosive wave throughout the entire charge requires, in addition to a
80 blasting cap, a booster charge not to exceed 1000 grams of TNT at a density of 0.95.

10. The method of blasting with a booster
85 which comprises loading a blasting cavity with an explosive charge whose length is substantially greater than the booster, detonating a limited amount of the explosive by means of a booster
90 and propagating the detonation throughout the

length and breadth of the charge unaided except by means of the limited amount of the charge detonated by the booster, said explosive having a regulated sensitiveness so that it is incapable, when unconfined, of detonation by means of a No. 8 cap but having a sensitiveness not less than that of a composition comprising 94.5% ammonium nitrate of such a fineness that 25% to 40% will pass a 100-mesh screen and 5.5% paraffin at a density of 1.15.

11. The method of blasting with a booster which comprises loading a blasting cavity with a plurality of explosive charges, causing the detonation of one of the charges only, by priming said charge with a booster and propagating the detonation throughout the plurality of charges by the inherent characteristics of the explosive, said explosive having a regulated sensitiveness incapable, when unconfined, of detonation by means of a No. 8 cap but having a sensitiveness not less than that of a composition comprising 94.5% ammonium nitrate of such fineness that 25% to 40% will pass a 100-mesh screen and 5.5% paraffin at a density of 1.15.

12. The method of blasting with a booster which comprises loading the blasting cavity with an explosive charge substantially greater in length than the booster, detonating a limited amount of the explosive by means of a booster and propagating the detonation throughout the length and breadth of the charge unaided except by means of the limited amount of the charge detonated by the booster, said charge having a regulated sensitiveness so that it is incapable, when unconfined, of detonation by means of a No. 8 cap but having a sensitiveness such that it can, when unconfined, be detonated by means of 1000 grams of trinitrotoluene at a density of 0.95.

13. The method of blasting with a plurality of boosters which comprises loading a blasting cavity with an explosive charge having an aggregate length substantially greater than the length of the booster, detonating a limited amount of the explosive by means of separated booster charges and propagating the detonation throughout the length and breadth of the charge unaided except by means of the limited amount of the charge detonated by the booster charges, said explosive having a regulated sensitiveness so that it is incapable, when unconfined, of detonation by means of a No. 8 cap but having a sensitiveness such that it can, when unconfined, be detonated by means of 1000 grams of trinitrotoluene at a density of 0.95.

14. The method of blasting with a booster which comprises loading the blasting cavity with a plurality of explosive charges, and causing the plurality of charges to detonate and propagate only by priming one of said charges with a booster, said charges having a regulated sensitiveness incapable, when unconfined, of detonation by means of a No. 8 cap but having a sensitiveness such that it can, when unconfined, be detonated by means of 1000 grams of trinitrotoluene at a density of 0.95.

15. The method of blasting with a booster which comprises loading the blasting cavity with a plurality of explosive charges, and causing the plurality of charges to detonate and propagate by a plurality of booster charges, said charges having a length substantially greater than the length of the booster and being capable of complete detonation when once initiated by said booster, and having a

regulated sensitiveness incapable, when unconfined, of detonation by means of a No. 8 cap but having a sensitiveness such that they can, when unconfined, be detonated by means of 1000 grams of trinitrotoluene at a density of 0.95.

16. The method of blasting with a booster which comprises loading a blasting cavity with an ammonium nitrate detonating explosive charge having a length substantially greater than the booster, detonating a limited amount of the explosive by means of a booster charge and propagating the detonation throughout the length and breadth of the main charge unaided except by means of the limited amount of the charge detonated by the booster, said detonating explosive having a regulated sensitiveness so that it is incapable, when unconfined, of detonation by means of a No. 8 cap but having a sensitiveness such that it can, when unconfined, be detonated by means of 1000 grams of trinitrotoluene at a density of 0.95.

17. The method of blasting with a multiplicity of boosters which comprises loading a blasting cavity with an ammonium nitrate detonating explosive charge, having an aggregate length substantially greater than the length of the boosters, detonating a limited amount of the explosive by the plurality of separated booster charges and propagating the detonation throughout the length and breadth of the charge unaided except by means of the limited amount of the charge detonated by the boosters, said detonating explosive having a regulated sensitiveness so that it is incapable, when unconfined, of detonation by means of a No. 8 cap but having a sensitiveness such that it can, when unconfined, be detonated by means of 1000 grams of trinitrotoluene at a density of 0.95.

18. The method of blasting with a booster which comprises loading a blasting cavity with a plurality of charges of an ammonium nitrate detonating explosive, causing the plurality of charges to detonate and propagate only by priming one of said charges with a booster charge capable of detonation by a No. 6 cap, said explosive having a regulated sensitiveness incapable, when unconfined, of detonation by means of a No. 8 cap, but having a sensitiveness such that it can, when unconfined, be detonated by means of 1000 grams of trinitrotoluene at a density of 0.95.

19. The method of blasting with a booster which comprises loading a blasting cavity with an ammonium nitrate detonating explosive having a cross-sectional area of not less than approximately 3 square inches and a length substantially greater than the length of the booster, detonating a limited amount of the explosive charge by means of a booster charge and propagating the detonation throughout the length and breadth of the main charge unaided except by means of the limited amount of the charge detonated by the booster, said explosive having a regulated sensitiveness so that it is incapable, when unconfined, of detonation by means of a No. 8 cap but having a sensitiveness not less than that of a composition comprising 94.5% ammonium nitrate of such fineness that 25% to 40% will pass a 100-mesh screen and 5.5% paraffin at a density of 1.15.

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