

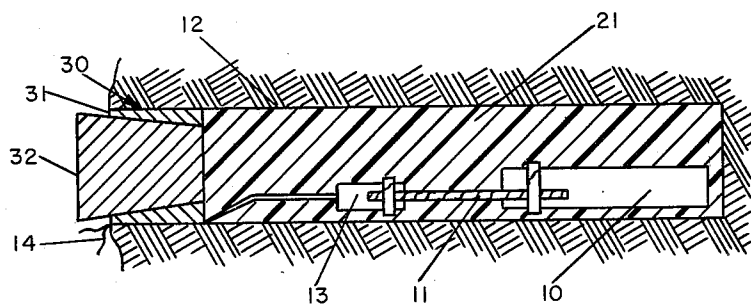
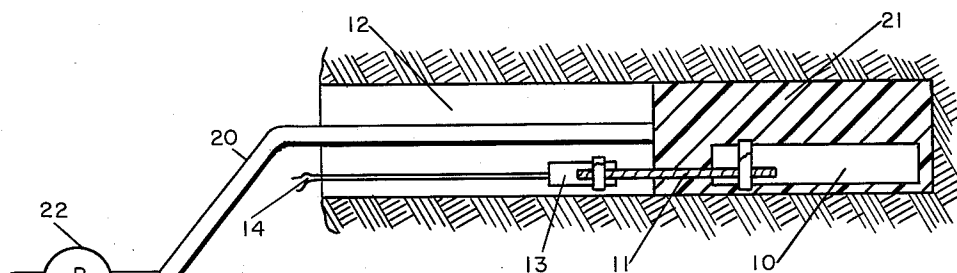
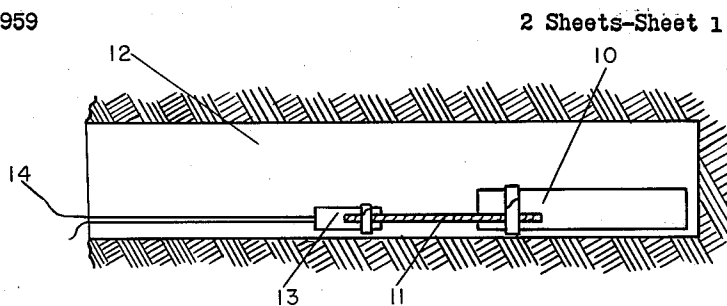
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R. D. BODDORFF ET AL

3,063,373

METHOD OF BLASTING

Filed June 8, 1959



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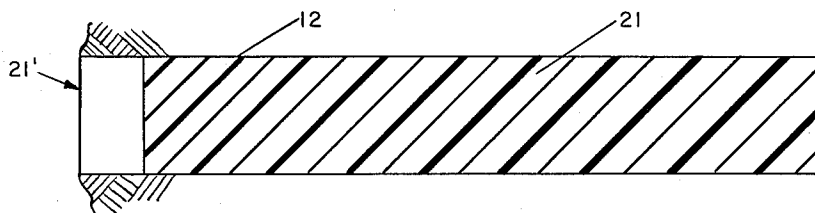


FIG. 4

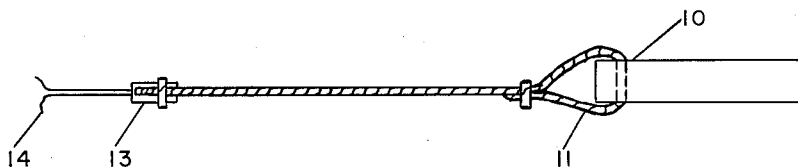


FIG 5

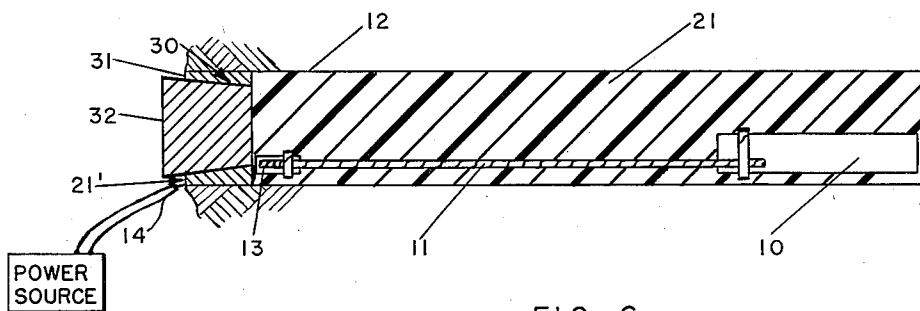


FIG. 6

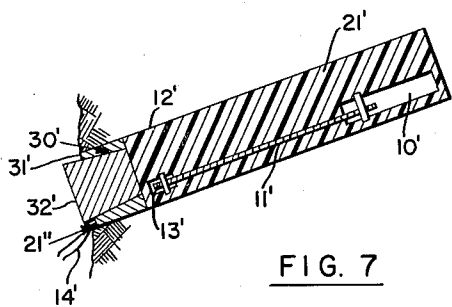


FIG. 7

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3,063,373

METHOD OF BLASTING

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This invention relates to a method for blasting in a borehole wherein the hole is filled with a gel disposed around a detonatable blasting charge so as to uniformly transmit energy from the blast to the borehole wall. In another aspect the invention relates to a blasting method above described wherein the blasting charge is detonated by a fuse type detonator extending from the charge through the gel body to a point near the opening of the hole, the detonator fuse or cord being initiated at a point near its end extended from the charge whereby a particularly high efficiency of distribution of blasting energy to the hole wall is accomplished. This application is a continuation-in-part of our application Serial No. 520,760, filed July 8, 1955, now abandoned.

Since the early history of blasting operations, various cartridges have been suggested in which the explosive charge is surrounded by a flame-quenching material in order to adapt the charge for use in a mine where inflammable gas is likely to be present. In earlier years, many of these cartridges employed water as the flame-quenching material. However, these structures were not always satisfactory in view of the fact that the outer container would often leak and thus permit the loss of the flame-quenching medium or else the water would find ingress into the main blasting charge with deleterious effect. Consequently, the more recent development of the art has been to employ solid materials in the form of a sheath around the main explosive charge such as sodium bicarbonate and the like.

More recently it has been realized that with more water-resistant explosives, additional beneficial effect can be obtained by the use of water in a borehole as a means of hydraulically transferring the effect of the explosion to the wall of the borehole. This system of blasting is known as pulsed infusion blasting, and has in recent years become quite popular in Great Britain and on the continent. In accordance with this system, the explosive charge is loaded in the hole and water is introduced under pressure into the hole through a sealing plug. In view of the fact that the rock formations often encountered in blasting operations contain numerous fissures and cracks, it is necessary to maintain the water under pressure until the explosive is actually detonated. Thus, large amounts of water are necessary and where these fissures and cracks are numerous, the entire formation to be blasted is saturated with water, in many instances adversely affecting the entire operation. Moreover, pressure-producing means are necessary and the adequate sealing of the mouth of the hole is difficult. Obviously, the pulsed infusion technique requires considerable expensive equipment. In addition, the high pressure in the borehole requires the use of special pressure resistant explosives which in some instances of such operations are uncertain in their action.

We have discovered that the principal benefits of pulsed infusion shooting can be obtained without saturating the formation to be blasted with liquid and, moreover, without maintaining a fluid in the borehole under pressure at any time. The method of the invention, moreover, not only uniformly transfers the force of the blast to the wall of the borehole but also gives considerably enhanced flame-quenching capabilities.

In accordance with the invention a blasting method is provided which comprises introducing into a borehole

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a detonatable blasting charge, having a volume substantially less than that of the said borehole, and a noncombustible nonexplosive gel; retaining said charge entirely within said borehole and disposing said gel around said charge in sufficient amount to also substantially fill the remaining space in said borehole; and then detonating said charge.

The blasting charge can be detonated by any suitable means including detonating fuse such as Primacord or Cordeau, electric blasting caps, or combinations of detonating fuse and blasting caps. However, as described hereinafter, a detonating fuse connected with the explosive charge, and extending from the charge through the gel column to substantially the mouth of the hole, is preferred, in which embodiment a suitable detonating means for initiating detonation of the detonator cord is affixed in detonating relationship with the cord at the end thereof nearest the mouth of the hole.

The invention is further illustrated with reference to FIGS. 1-6 of the drawings of which FIGS. 1-3 and 4-6, respectively, illustrate separate method embodiments. FIGURE 7 is the same as FIGURE 6 except that it is illustrative of method employing a borehole extending upwardly from the horizontal. In FIG. 1, a cartridge 10 of permissible dynamic primed with a length of detonating fuse 11, such as Primacord, has been inserted into a borehole 12. The fuse 11 is in turn primed with an electric blasting cap 13, the lead wires of which extend from the hole. In FIG. 2, a tube 20 for delivery of gel into the borehole has been inserted into the borehole, preferably as far back into the hole as possible and a non-explosive gel 21 is pumped by pump means 22 through tube 20 into the hole. As the hole fills with the gel 21, the tube 20 is forced therefrom and the hole is filled substantially to the mouth. The gel is forced by pump means 22 into the hole and around the charge 10. In FIG. 3, the loaded hole is sealed by means of a conventional tamping plug 30 such as an asbestos tubular cylinder 31 with conical insert 32. The tubular cylinder 31 is initially positioned in the mouth of the hole 12 and the conical insert is then driven into the cylinder 31 to expand the cylinder, thus sealing the mouth of the hole around the lead wires 14. When the cartridge 10 is detonated by initiating detonation of the fuse 11, by means of the blasting cap 13, the energy from the exploding cartridge and fuse is transmitted to the wall of the borehole through the medium of the gel, to produce lump coal of improved uniformity in size.

In accordance with the now preferred method embodiment of the invention, a fuse type detonator is affixed to a detonatable explosive charge, as by taping, and the detonating fuse is extended from the charge to a point in close proximity to the mouth of the hole, at which point a suitable detonator for the detonating fuse, for example, an electric blasting cap, is affixed, but at a point still within the borehole. The lead wires, or other line of communication for the detonator, extend from the open end of the hole to a suitable energy source. Preferably the hole is closed at the mouth by a tamping plug 30 after introduction of the gel as illustrated with reference to FIGURES 3 and 6 of the drawings.

In order to assure complete filling of the holes with gel so as to minimize possibility for the presence of air pockets, it is advantageous to first fill the hole 12 with a gel 21 up to a point near the mouth 21', as shown with reference to FIGURE 4. A detonating fuse, e.g., 50 grain Primacord, is secured at one end of the main detonatable charge 10 as by a loop with taping as illustrated with reference to FIGURE 5 although, of course, any suitable means for securing the detonating fuse to the cartridge can be employed, such as taping as illustrated with reference to FIGURE 6, fuse 11 being thereby

affixed in detonating relationship with main charge 10. Fuse 11 is affixed at its end opposite charge 10 with an electric blasting cap 13 in detonating relationship therewith. The resulting cartridge-fuse-blasting cap assembly is then inserted, cartridge first, into borehole 12 through the gel column 21 to any suitable point preferably so that the main charge 10 is disposed in the closed end of the borehole as illustrated with reference to FIGURE 6. Any suitable means, for example, a small diameter wood rod, can be utilized for directing the primed cartridge assembly of FIGURE 6 into the desired position. The length of detonating fuse 11 of FIGURE 6 is sufficient if it extends from cartridge 10 in borehole 12 to a point in close proximity to the mouth 21' but at a length sufficient to permit enclosure of blasting cap 13 attached thereto within borehole 12 and adjacent plug 30 when the latter is utilized. Generally, when utilizing a plug 30, termination of fuse 11 at a point say about 6-8 inches from the open end of borehole 12 to allow for insertion of closure plug 30 is sufficient. Lead wires 14 extend from the borehole 12 through the open end thereof to a suitable power source. When closing the mouth of the borehole with a closure plug such as plug 30 of FIGURE 3, the lead wires 14 extend from the borehole intermediate the plug assembly and the hole wall as illustrated with reference to FIGURES 3 and 6.

Although the entire assembly of FIGURE 6 is preferably assembled by first loading the gel followed by insertion of the primed charge assembly as above described to minimize air pockets, the gel can be charged subsequent to insertion of the cartridge assembly as illustrated with reference to FIGURES 1 to 3.

FIGURE 7 illustrates practice of the invention as applied to blasting in a borehole inclined above the horizontal, generally, 20 to 30 degrees, and is otherwise in all respects the same as FIGURE 6. The single primed numerals, and numeral 21'', of FIGURE 7 correspond respectively to the same numbers unprimed, and to 21', of FIGURE 6.

The following examples are presented as illustrative of preferred embodiments of the invention.

Example 1

A hole 7 feet deep and 1.75 inches in diameter was drilled in a coal face 3 feet above an undercut in a coal seam. Three 1¼ in. by 8 in. cartridges of a permissible explosive were taped to one end of a 6-ft. length of 50 grain Primacord. An electric blasting cap was taped to the other end of the Primacord. The primed cartridges of dynamite were inserted in the hole and about 2.8 liters of a gel consisting of water, 0.5% carboxymethylcellulose and 0.1% $Al_2(SO_4)_3$ was forced into the hole by compressed air. When the hole was filled to the 6-ft. mark, a conventional tamping plug was inserted and expanded. When the dynamite was shot, coal was brought down in excellent lump size with a remarkable reduction in dust, smoke and fumes as compared to a conventional shot.

Example 2

A shot was loaded similar to that in Example 1, except that only two 1¼ in. by 8 in. cartridges of the permissible explosive were employed. This shot again brought down the coal in excellent lump size with a remarkable reduction in dust, smoke and fumes.

Example 3

A third hole similarly disposed was loaded with three cartridges of the permissible dynamite which were taped to one end of a 2-ft. length of Primacord. An electric blasting cap was taped to the other end of the Primacord. The gel was similarly introduced and the hole sealed with the tamping plug. Again the shot brought down coal in excellent lump size with a similar reduction in dust, smoke and fumes.

Example 4

A fourth hole of the same dimensions was similarly shot except that two 1¼ in. by 8 in. cartridges of the permissible dynamite were taped to one end of a 2-ft. length of Primacord. The gel was similarly introduced and the hole sealed with a tamping plug. Once more this shot brought the coal down in excellent lump size with great reduction in dust, smoke and fumes.

Although in the practice of the invention transmission of energy to the hole walls is effected by detonating the main charge in any suitable manner, superior results are obtained when employing a detonating fuse for detonation of the main charge. It appears that a detonating fuse functions by release of energy from its own detonation along the borehole length to unexpectedly facilitate uniform transmission of energy from detonation of the main charge to the wall and therefore for improved amount and quality of breakdown. The following example demonstrates the unique function of a detonating fuse in the practice of the invention.

Example 5

A series of three blasting tests was conducted, in each of which a permissible dynamite was detonated in a coal formation in gel-filled boreholes. In one of the tests the dynamite charge was detonated by action of an electric blasting cap only, and in the remaining tests the dynamite was initiated by detonating action of varying lengths of Primacord, the cord extending substantially to the mouth of the borehole in the one instance and through only a portion of the hole in the other.

In each test three spaced apart boreholes were filled with a thixotropic gel consisting of 88-89% water and 11-12% bentonite. Each of the nine holes shot was 6½ ft. in length. The coal face in each test was 10 ft. wide and 5½ ft. high with an undercut 7 ft. deep and 8 in. high.

In each of the tests an "effectiveness factor" was determined as a measure of the efficiency of energy distribution obtained, the higher the numerical value of the factor, the greater the efficiency of energy distribution. The said factor was calculated by multiplying the product of (1) coal production factor (the ratio of coal loosened by blasting to the total coal in the cut, i.e., 10 ft. x 5½ ft. x 7 ft. 8 in. above described), (2) breakage factor (the ratio of coal breakage exceeding three inch lump to the coal loosened by the blasting), and (3) powder factor (ratio of tons of coal loosened to pounds dynamite detonated), by a volume correction, namely, the ratio of the volume of a "standard cut" which is 120 in. wide by 84 in. deep by 66 in. high, to the volume of the "cut" tested.

Data summarizing these tests are tabulated as follows:

Test No. ¹	Main explosive Charge ²		Length of Detonating Fuse Employed, ³ Inches	Effectiveness Factor
	Total Wt., lbs.	Cartridge Dimensions, inches		
1.....	2.4	1¼ x 16	0	1.2
2.....	2.4	1¼ x 16	16	1.6
3.....	2.4	1¼ x 16	55	2.3

¹ A No. 6 electric blasting cap utilized to directly detonate the main charge in test 1 and the Primacord in each of tests 2 and 3.

² A permissible dynamite—8,200 ft./sec. detonation velocity; 60 percent weight strength; 44 percent volume strength.

³ Primacord, 50 grains PETN per foot.

In tests 1, 2 and 3 the effectiveness factor increased from 1.2 to 1.6 to 2.3 when, respectively, no detonating fuse cord was used, the cord was 16 inches in length, and 55 inches in length. Without use of the detonating fuse, the said factor averaged about 1.1. The magnitude of the effectiveness factor thus shown expresses the effectiveness of the explosive charges in the blasting of lump coal and

the markedly improved energy transmission to the borehole wall that is obtained when a detonating fuse is utilized for detonation of the dynamite charge. Thus, the highest effectiveness factor, 2.3, was observed when utilizing a 55-inch length of detonating fuse under which conditions exceptionally high quality lump breakage with minimum formation of fines was obtained. When the dynamite charge was detonated by electric blasting cap only, a satisfactory breakage was obtained but was accompanied by considerably higher yields of fines and a broader gradation of lump coal as demonstrated by the effectiveness factor of test 1. The unpredicted function of the detonating fuse is further demonstrated by a comparison of tests 2 and 3 which show an increase in effectiveness factor with increased length of detonating fuse utilized.

Although a permissible dynamite was employed in shooting down coal in the practice of the process exemplified hereinabove, it is to be understood that the present invention is not limited to coal mining operations or to the use of permissible explosives.

Any suitable means for charging the gel to the borehole can be utilized. In Examples 1-3 the gel was introduced into the hole by means of a pressure cylinder filled with compressed air which exerted air pressure upon the gel in a reservoir and forced it through the tube and into the hole. In Example 4 and 5 the gel, in all tests, was charged by positive displacement pump. The hole in the tests of Examples 4 and 5 was partially filled with the gel and the cartridge and detonator assembly then inserted through the gel body into position for shooting followed by filling the remaining hole space with gel and insertion of a stemming plug.

While bentonite gel is now preferred both from the standpoint of economy and operation, and a gel comprising water, carboxymethylcellulose and a precipitating agent such as aluminum sulfate can be advantageously employed, other gelling agents can be utilized. Agents suitable for gelling water include:

Bentonite

Water soluble cellulose such as carboxymethylcellulose, sodium carboxymethylcellulose, methyl cellulose, hydroxymethyl and hydroxyethyl cellulose, and cellulose sulfate

Polyvinyl alcohol

Polyacrylic acid, its copolymers and salts

Copolymers of maleic anhydride with styrene or vinyl acetate

Sodium vinyl sulfonate

Alginate

Starch

Natural gums such as guar

Psyllium seed

Locust bean

Irish moss

Animal proteins such as gelatin, glue or casein

It is, of course, desirable to the economy and simplicity of the operation that agents be chosen which require only small amounts to produce a gel of the desired viscosity. Preferably, the gel will have a viscosity such that it will remain in a hole even when the hole is inclined from 20-30° above the horizontal.

As illustrated, the use of a tamping plug is desirable but not essential, since the gel transmits the force of the explosion or expanding gases to the wall of the hole before it is forced out of the borehole at the instant of the shot. Moreover, it will be seen that the use of a gel instead of water obviates the necessity of saturating the entire strata with fluid, the necessity of maintaining the fluid under pressure and the necessity of practically hermetically sealing the mouth of the borehole. The advantages of the invention are multiplied as the number of holes is increased. Thus, all of the advantages of the use of a fluid are obtained with much greater economy

and facility in the blasting operation. The reduction in smoke and fumes, moreover, makes it possible to employ the process of the invention in on-shift operations and, moreover, permits miners engaged in tunnel operations to return to the scene of the blast much sooner than with permissible explosives currently employed. The method of the invention may be employed in multiple hole shooting with either regular or short period delay techniques.

Since many modifications may obviously be made in the invention as disclosed, it is intended that the scope of the invention shall be limited only by the appended claims.

What we claim and desire to protect by Letters Patent is:

1. A method for blasting coal deposits which comprises forming an elongated borehole in a coal deposit, introducing into said borehole, as elements of a blasting system therein, a detonatable blasting charge, having a volume substantially less than that of the said borehole, and a noncombustible nonexplosive gel; retaining said charge entirely within said borehole and disposing said gel around said charge in sufficient amount to also substantially fill the remaining space in said borehole; and then detonating said charge.

2. In a blasting method of claim 1, closing the mouth of said borehole prior to detonating said charge.

3. A blasting method of claim 1 wherein said borehole is first filled with said gel and said charge is then introduced through the gel body into the said borehole.

4. A blasting method of claim 1 wherein said charge is introduced into said borehole prior to introduction of said gel into said hole.

5. A blasting method of claim 1, wherein said blasting charge is a dynamite, affixing a detonating fuse to said dynamite charge of sufficient length to extend from said dynamite charge to a point within said borehole in close proximity to the open end thereof, and initiating said dynamite charge by detonating said fuse at its end near the borehole open end.

6. A method of claim 1 wherein said gel is formed from water and bentonite.

7. A method for blasting coal deposits which comprises substantially filling a borehole in a coal deposit with an aqueous noncombustible nonexplosive gel; affixing to a dynamite cartridge a detonating fuse of sufficient length to extend from said cartridge as described hereinafter and affixing blasting cap means for detonating said fuse to the end thereof opposite said cartridge; introducing the resulting primed cartridge assembly, cartridge first, into said borehole toward the closed end thereof through the column of gel therein so as to dispose said cartridge in said hole surrounded by said gel, and extending said detonating fuse and blasting cap means affixed thereto from said cartridge to a point within said hole in close proximity to the mouth thereof, positioning a closure plug in said hole at the mouth thereof and extending lead wires from said blasting cap means from the borehole intermediate said plug and the borehole wall into communication with a suitable power source for initiating said blasting cap means; and then detonating said charge by electrically initiating said blasting cap means, whereby coal deposits in the area of said hole are brought down in uniform lump size; and recovering lump coal product so produced.

8. A method of claim 7 wherein said gel comprises bentonite and water.

9. A method for blasting coal deposits to produce lump coal, comprising affixing a detonating fuse to a dynamite cartridge; affixing an electric blasting cap to the remaining unattached end of said fuse; forming an elongated borehole in a coal deposit; inserting the resulting primed cartridge assembly into the said borehole; introducing a noncombustible nonexplosive gel into said hole around said cartridge and in an amount to substantially fill said hole; closing the resulting filled hole with a closure plug and detonating the dynamite charge by initiating said

blasting cap, whereby coal deposits in the area of said hole are brought down in uniform lump size.

10. A method of claim 7 wherein said borehole extends into said deposit at an angle of from about 20 to 30° above the horizontal, and said gel is formed from bentonite and water.

11. A method for blasting coal deposits which comprises forming an elongated borehole in a coal deposit substantially filling said borehole in a coal deposit with an aqueous noncombustible nonexplosive gel; affixing a detonating fuse to a dynamite cartridge and affixing blasting cap means for detonating said fuse to the end thereof opposite said cartridge; introducing the resulting primed cartridge assembly, cartridge first, into said borehole toward the closed end thereof through the column of gel therein so as to dispose said cartridge in said hole surrounded by said gel, and then detonating said charge by electrically initiating said blasting cap means, whereby coal deposits in the area of said hole are brought down in uniform lump size; and recovering lump coal product so produced.

12. A method of claim 11 wherein said borehole extends into said deposit at an angle of from about 20 to 30° above the horizontal, and said gel is formed from bentonite and water.

13. In a method of claim 9, extending said fuse in said borehole from said dynamite cartridge to a point in close proximity to the mouth of said borehole.

14. A method for blasting coal deposits to produce lump coal, comprising affixing a detonating fuse to a dynamite cartridge; affixing an electric blasting cap to the remaining unattached end of said fuse; forming an elongated borehole in a coal deposit inserting the resulting primed cartridge assembly into the said borehole; introducing a noncombustible nonexplosive gel into said hole around said cartridge and in an amount to substantially fill said hole; and detonating the dynamite charge by initiating said blasting cap, whereby coal deposits in the area of said hole are brought down in uniform lump size.

15. A method for blasting coal deposits which comprises forming an elongated borehole in a coal deposit, introducing into the said borehole, as elements of a blasting system therein, a detonatable blasting charge, having a volume substantially less than that of the said borehole, and a noncombustible nonexplosive gel formed from

water and carboxymethylcellulose with a minor proportion of a suitable precipitating agent therefor; retaining said charge entirely within said borehole and disposing said gel around said charge in sufficient amount to also substantially fill the remaining space in said borehole; and then detonating said charge.

16. The method of claim 15 wherein said precipitating agent is aluminum sulfate.

17. A method for blasting coal deposits which comprises substantially filling a borehole in a coal deposit with an aqueous non-combustible non-explosive gel formed from water and carboxymethylcellulose with a minor proportion of a suitable precipitating agent therefor; affixing to a dynamite cartridge a detonating fuse of sufficient length to extend from said cartridge as described hereinafter and affixing blasting cap means for detonating said fuse to the end thereof opposite said cartridge; introducing the resulting primed cartridge assembly, cartridge first, into said borehole toward the closed end thereof through the column of gel therein so as to dispose said cartridge in said hole surrounded by said gel, and extending said detonating fuse and blasting cap means affixed thereto from said cartridge to a point within said hole in close proximity to the mouth thereof, positioning a closure plug in said hole at the mouth thereof and extending lead wires from said blasting cap means from the borehole intermediate said plug and the borehole wall into communication with a suitable power source for initiating said blasting cap means; and then detonating said charge by electrically initiating said blasting cap means, whereby coal deposits in the area of said hole are brought down in uniform lump size; and recovering lump coal product so produced.

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