

Nov. 29, 1966

J. D. FERGUSON ETAL

3,288,658

AERATED EXPLOSIVE COMPOSITIONS

Filed July 20, 1965

5 Sheets-Sheet 1

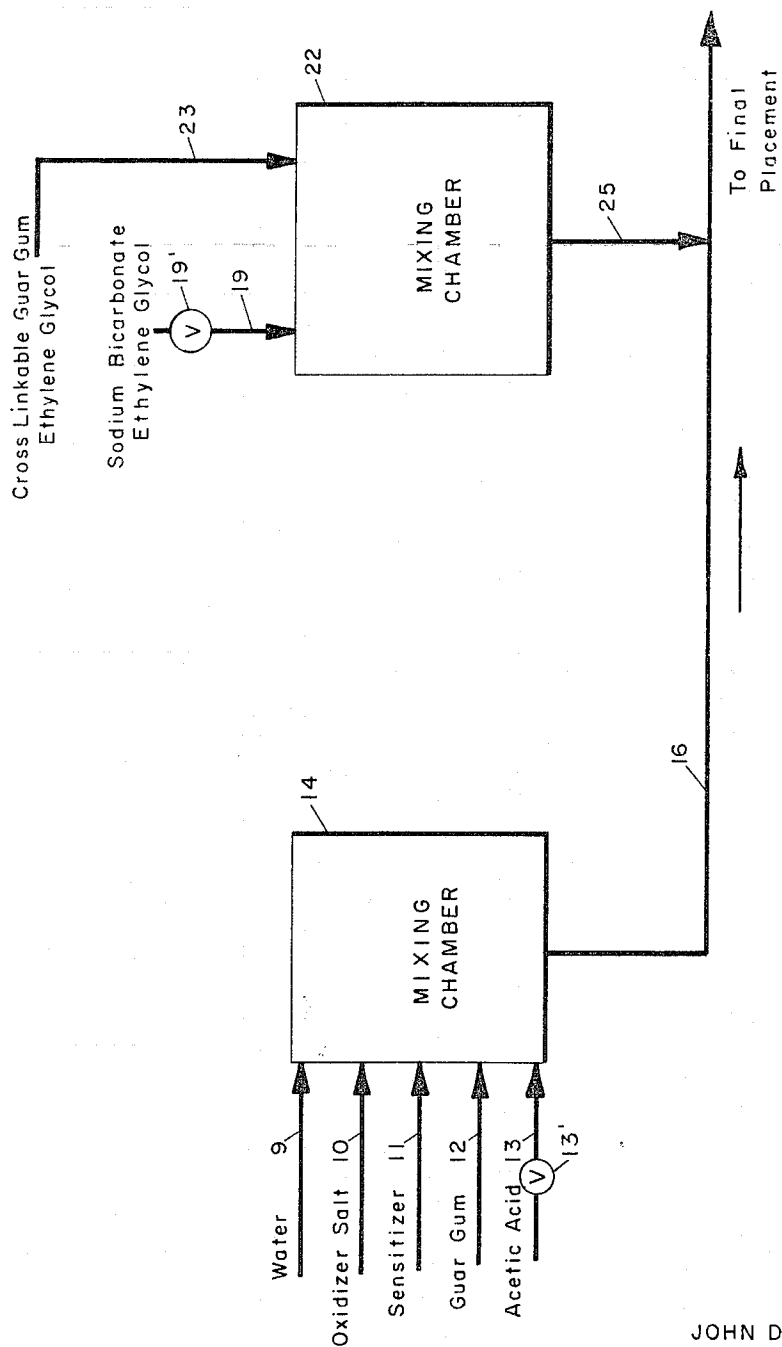


FIG. 1

JOHN D. FERGUSON
ROBERT B. HOPLER JR.
INVENTORS.

BY *Ernest G. Peterson*

AGENT

Nov. 29, 1966

J. D. FERGUSON ET AL

3,288,658

AERATED EXPLOSIVE COMPOSITIONS

Filed July 20, 1965

5 Sheets-Sheet 1

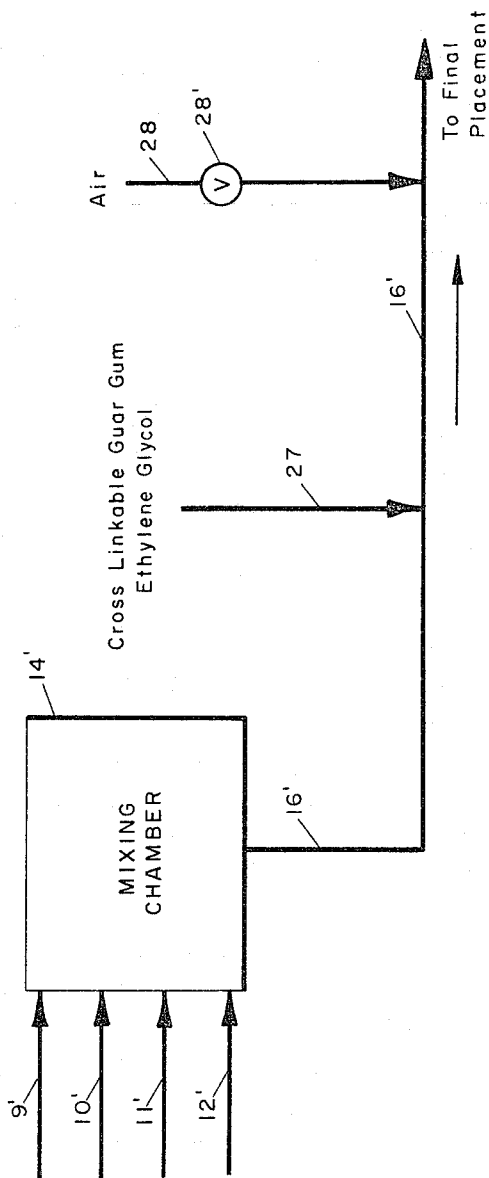


FIG. 2

JOHN D. FERGUSON
ROBERT B. HOPLER JR.
INVENTORS.

BY

AGENT

Nov. 29, 1966

J. D. FERGUSON ET AL

3,288,658

AERATED EXPLOSIVE COMPOSITIONS

Filed July 20, 1965

5 Sheets-Sheet 3

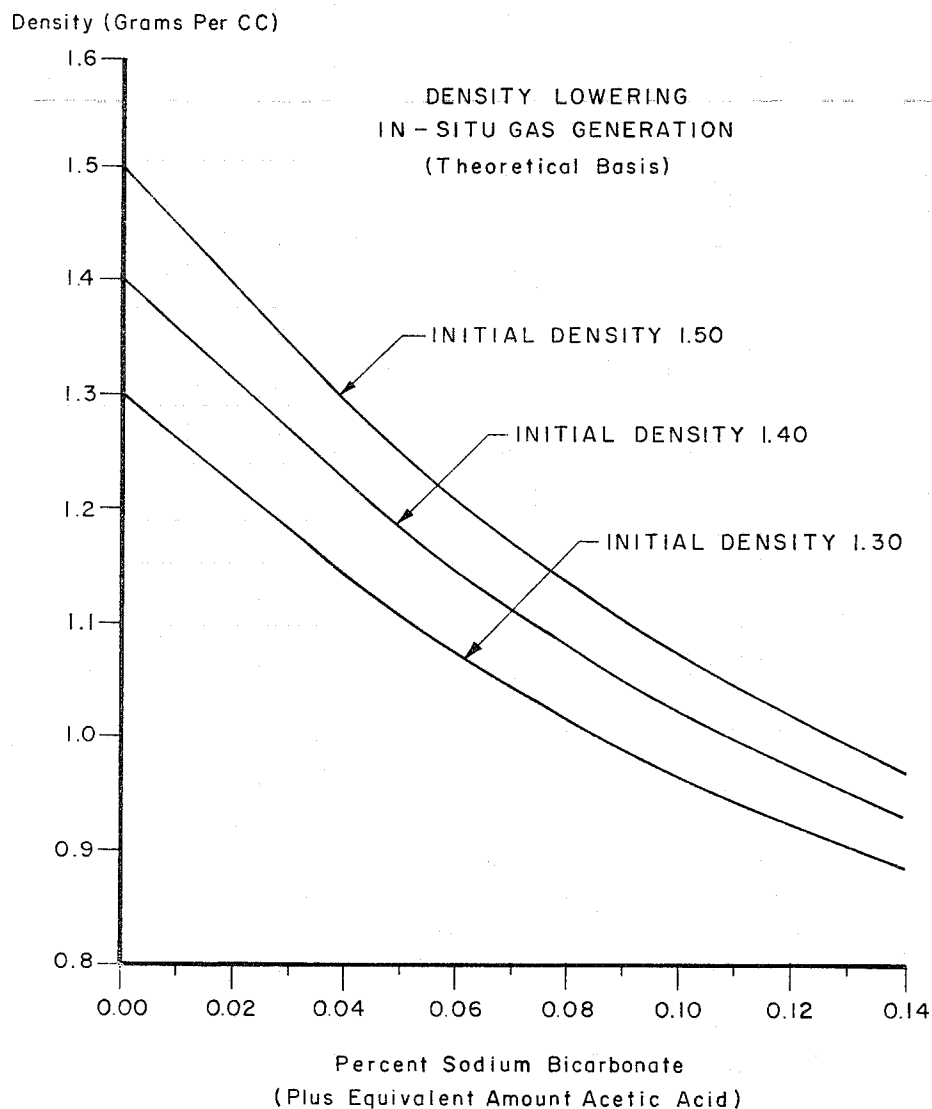


FIG. 3

JOHN D. FERGUSON
ROBERT B. HOPLER JR.
INVENTORS.

BY

AGENT

Nov. 29, 1966

J. D. FERGUSON ETAL

3,288,658

AERATED EXPLOSIVE COMPOSITIONS

Filed July 20, 1965

5 Sheets-Sheet 4

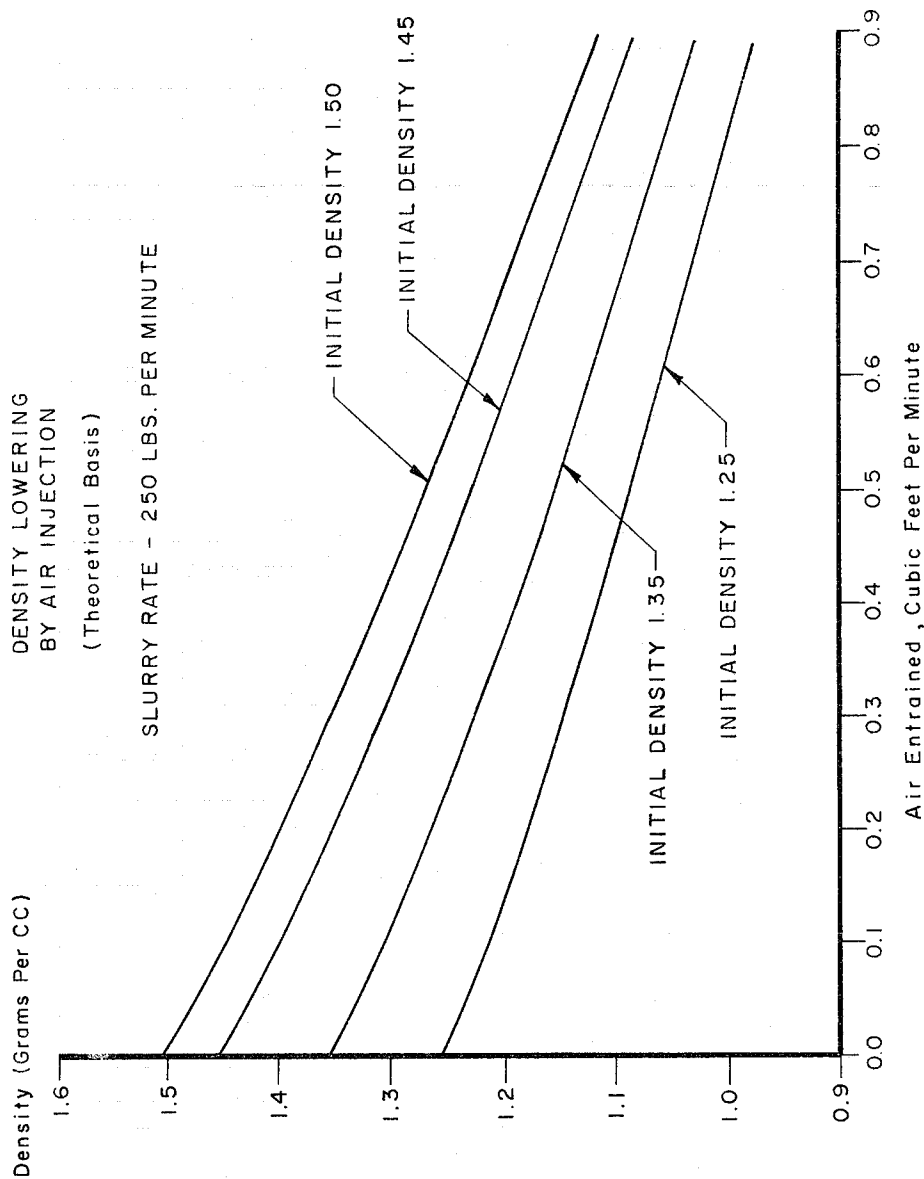


FIG. 4

JOHN D. FERGUSON
ROBERT B. HOPLER JR.
INVENTORS.

BY

AGENT

Nov. 29, 1966

J. D. FERGUSON ET AL

3,288,658

AERATED EXPLOSIVE COMPOSITIONS

Filed July 20, 1965

5 Sheets-Sheet 5

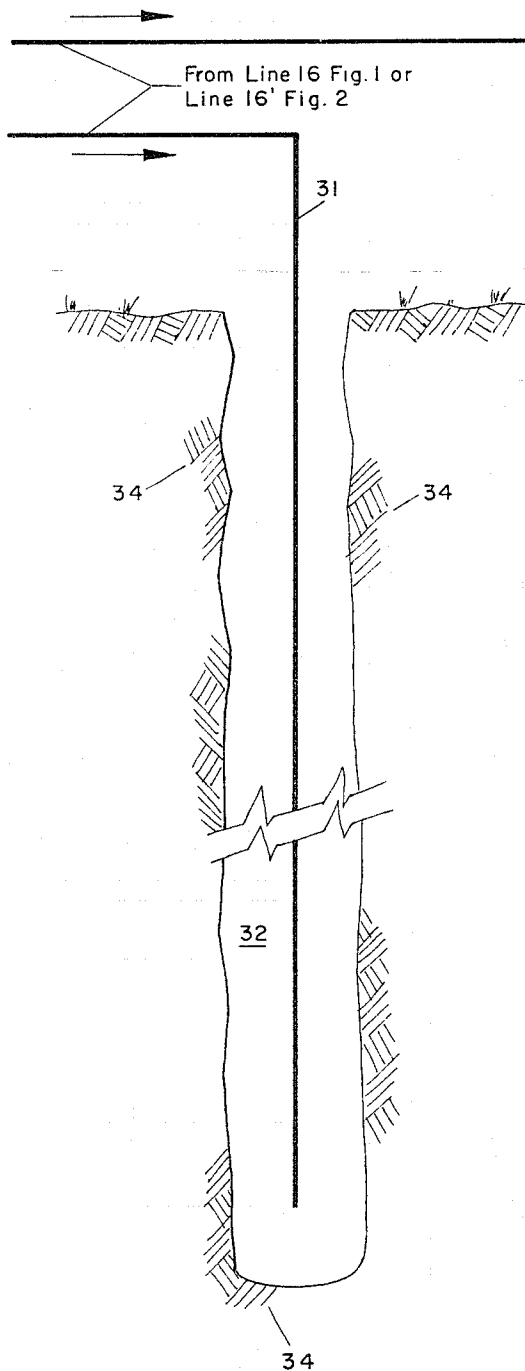


FIG. 5

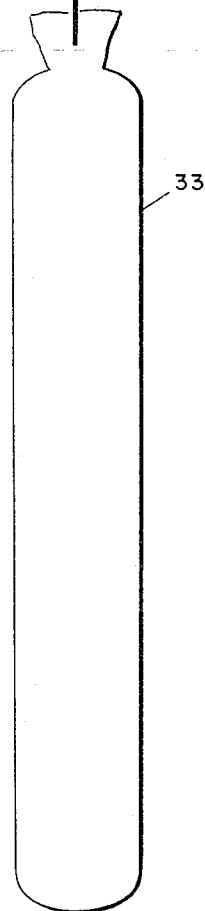


FIG. 6

JOHN D. FERGUSON
ROBERT B. HOPLER JR.
INVENTORS.

BY

AGENT

1

3,288,658

AERATED EXPLOSIVE COMPOSITIONS

John D. Ferguson, Wilmington, Del., and Robert B. Hopler, Jr., Kenil, N.J., assignors to Hercules Incorporated, a corporation of Delaware
Filed July 20, 1965, Ser. No. 473,380
21 Claims. (Cl. 149—2)

This invention relates to inorganic oxidizer salt blasting compositions of the aqueous slurry type containing a gas dispersed therein in an amount providing for a predetermined lowering of density to thereby regulate explosive strength. In one aspect this invention relates to a process for manufacture of the above-described blasting compositions. In another aspect this invention relates to a method for charging a borehole with a blasting composition above described. In another aspect this invention relates to a method for charging a borehole with a blasting composition above described, in accordance with which the proportion of the gas component to be incorporated into the slurry is varied as the length of the resulting columnar charge increases, so as to regulate density and thereby provide a predetermined distribution of explosive strength commensurate with the blasting energy requirements of the surrounding formation. In still another aspect this invention relates to columnar explosive charges prepared in accordance with method above described. Other aspects will be apparent in light of the accompanying disclosure and the appended claims.

Inorganic oxidizer salt blasting compositions of the aqueous slurry type have had rather wide use in the explosives industry in recent years. These compositions contain an oxidizer salt or a mixture of such salts as the basic explosive ingredient, together with water, and, as a sensitizer, a high explosive such as TNT, tetryl, or PETN, a finely divided metal such as aluminum, or a magnesium alloy, or smokeless powder. Generally, a thickener is included to impart additional consistency to preclude settling of the individual ingredients and to facilitate handling. Such inorganic oxidizer salt blasting compositions of the aqueous slurry type are disclosed and claimed in the copending application U.S. Serial No. 67,513, filed November 7, 1960, now Patent No. 3,235,425 and in U.S. 2,930,685, U.S. 2,836,484, and others.

Various packaging and loading procedures have been employed in the manufacture and use of slurry compositions of the type above described. A recent technique involves direct pumping of the slurry into the borehole. In carrying out that procedure the practice has been to charge a bottom-most section of the borehole with such a slurry of high energy content and to load one or more intermediate sections with a packaged slurry of progressively lower energy content and then loading an uppermost section with a still lower energy blasting material such as ammonium nitrate prills with fuel oil. This practice has been followed inasmuch as, in general, the blasting energy requirements of the surrounding formation to be blasted decrease in the direction toward the ground surface. However, this practice had been varied to place the charges in a nonprogressive order of blasting energy content when so required. Another technique has involved packaging the charge for placement and detonation in the borehole by partially filling one or more plastic bags with the slurry so that when placed in the borehole

2

the charge in each bag flows laterally with accompanying change in shape of the package to provide for maximum loading density. The separately packaged slurries forming the charge in the borehole are of varying composition, or are utilized with other explosives, to meet the particular blasting requirements.

Heretofore, these loading techniques, involving handling and the placement of a plurality of different blasting charges, have required a large number of operating steps as well as maintenance of an inventory of different blasting materials. This invention is concerned with a slurry-type explosive which precludes the need for use of a plurality of different charges in a borehole, and concomitantly, precludes the need for the necessary inventory and numerous operating steps associated with that practice.

In accordance with the invention, a process for the manufacture of an inorganic oxidizer salt blasting composition is provided, which comprises the steps of mixing water, an inorganic oxidizer salt, a sensitizer, and a thickener to form a resulting blasting composition of the aqueous slurry type, and incorporating a gas into the resulting slurry in an amount sufficient to cause a predetermined lowering of the density thereof to thereby regulate its explosive strength.

The slurry into which the gas is incorporated, in the practice of the invention, contains, on a weight basis, generally from 0.2 to 5 percent thickener, from 20 to 75 percent oxidizer salt, from 4 to 60 percent sensitizer and from 4 to 35 percent water. More preferably the said slurry contains from 20 to 60 percent ammonium nitrate with up to 30 percent sodium nitrate as the oxidizer salt, from 10 to 30 percent water, from 8 to 45 percent sensitizer and from 0.5 to 2 percent guar gum as the thickener.

The compositions of the invention are those prepared as described herein and are, in preferred practice, in columnar form; they contain the dispersed gas in proportions to provide a predetermined variance in density, and thus in explosive strength, along the length of the column to meet the blasting energy requirements of the surrounding formation. Generally the columnar blasting compositions contain the gas ingredient in an increasing concentration from bottom to top inasmuch as the blasting energy requirements often gradually decrease in that direction.

In preferred practice of process of the invention, the oxidizer salt, water and sensitizer are admixed in the proportions above described together with a portion of the thickener for imparting a sufficient increase in consistency to prevent settling of the ingredients from the resulting admixture, and then, as the last step, the remaining portion of the thickener is added and the gas is dispersed throughout the charge. The final thickening action imparts the necessary consistency for supporting the dispersed gas ingredient over prolonged periods. However, it is sometimes advantageous to admix the total contemplated proportion of thickener with all other slurry ingredients, except for the gas ingredient, in a single mixing step, particularly when charging the total gas-containing slurry directly from the mixer into bags at the plant site.

When pumping the slurry into individual containers, the proportion of gas added to the final ingredient mixture is often varied from one container to another or from one set of containers to another, for regulation of

3

density to provide a plurality of charges for placement in series, to form a columnar charge of predetermined variance in explosive strength along its length. In carrying out this embodiment, the concentration of gas in each succeeding container, or sets of containers is preferably increased progressively to provide for a gradient of explosive strength along the column that is to be formed.

Any suitable gas can be utilized in the practice of the invention. Although dispersion of the gas in the charge is preferably done by direct injection, such as by air injection, it can be accomplished by generation of the gas in situ.

In the embodiment involving in situ gas generation, any suitable gas-generating material can be utilized by which it is meant any water-soluble compound, or combination of such compounds, reactable in the slurry to form a gas which is substantially nonreactive with any of the ingredients of the slurry while dispersed therein. For example, the generation and dispersion of carbon dioxide can be accomplished by in situ reaction of a water-soluble carbonate and an acid as the gas-generating material. Ammonium carbonate and alkali metal carbonates particularly sodium bicarbonate and potassium bicarbonate, each in combination with any suitable mineral, oxidizing or carboxylic acid as for example, hydrochloric acid, acetic acid, nitric acid, sulfuric acid and the like, are further exemplary of suitable gas-generating materials utilized in the practice of this embodiment.

Guar gum as the preferred thickener is present in cross-linked form to impart the desired plastic but easily deformable consistency for retaining the dispersed gas ingredient over prolonged periods.

When adding the guar gum in two separate steps, the initially added guar gum is generally in natural form and, in all events, is readily hydratable. It is added in limited amount to provide hydration for sufficient increase in consistency to preclude settling of ingredients, but to permit uniform mixing and pumpability of same, prior to incorporation of the gas ingredient the latter generally added in close proximity to placement of the finished slurry composition. However, if desired, the initially added guar gum can be in inhibited form, by which term it is meant that it contains one or more agents which, alone or together, subsequent to hydration, promote crosslinking, and also alter the rate of hydration and crosslinking to meet the particular mixing and placement requirements. When the initially added guar gum is in inhibited form, it is desirable to adjust the mixing temperature upwardly to permit the desired degree of immediate hydration which might otherwise be delayed unduly by the particular agent or agents present.

The remaining portion of the guar gum ingredient is crosslinkable and is added to the slurry ingredient mixture at a time in close proximity to that at which dispersion of the gas ingredient is initiated, being added for the most part substantially concurrently with, or prior thereto, to permit uniform dispersion of the gas ingredient and pumpability of the slurry mixture which might otherwise be impaired by prematurely imposed increase in consistency due to crosslinking.

When the guar gum is charged in toto with the other slurry ingredients in a single mixing step, it is in inhibited form and adapted to undergo sufficient hydration for limited thickening to permit uniformity of mixing and pumpability of the total gas-containing slurry without extensive crosslinking until after placement.

Various inhibited crosslinkable guar gum formulations are available commercially and contain well-known inhibiting and crosslinking agents. pH and temperature conditions for accomplishing inhibiting and crosslinking as above described, vary somewhat, dependent upon the particular agent or agents. For example, as is well

4

known, sodium borate functions as both an inhibitor and a crosslinking agent, but under different pH conditions, while on the other hand, a combination of potassium antimonate and fumaric acid functions to promote crosslinking.

Other suitable thickeners include carboxymethylcellulose, methyl cellulose, water-soluble starches, cereal flour, and the like.

By the term "oxidizer salt" as is well known in the explosives art, is meant one which, under the conditions of the detonation supplies oxygen for the oxygen balance required. Ammonium nitrate is in many instances the only oxygen-supplying salt component. However, other inorganic oxygen-supplying salts can be used alone or with ammonium nitrate as a supplementary oxidizer salt. Of these, the alkali metal nitrates are now preferred. Exemplary oxygen supplying salts that can be used alone or together with ammonium nitrate as supplementary oxidizer salts are alkali metal and alkali earth metal nitrates and perchlorates (including ammonium) as for example, sodium nitrate, magnesium nitrate, calcium nitrate, potassium nitrate, barium nitrate, sodium perchlorate, ammonium perchlorate, calcium perchlorate and magnesium perchlorate.

Often when ammonium nitrate is utilized with a supplementary salt, it comprises at least a major proportion, i.e., at least 50 percent of the total oxidizer salt component; however, weight ratios of ammonium nitrate to supplementary oxidizer salt, sodium nitrate now preferred, are generally in the range of from about 4:1 to 1:1.

Particle size of the oxidizer salt ingredients is not critical. For example, ammonium nitrate can consist of prills, such as used in the fertilizer industry, or it can be granular and in that form vary from coarse to fine. Other oxidizer salt ingredients are generally of comparable particle size.

The compositions of the invention are in most instances insensitive to detonating action of a commercial No. 8 blasting cap but detonable by conventional "booster" charges of PETN (pentaerythritol tetranitrate), RDX (cyclotrimethylenetrinitramine), Pentolite (PETN-TNT), tetryl, Composition B (RDX-TNT), and the like. One booster advantageously employed is a dispersion of a crystalline high explosive e.g., PETN or RDX, in a plastic carrier such as described in U.S. Patent 2,965,466 and which is detonated by either a commercial blasting cap or detonating fuse.

The sensitizer can be any suitable secondary explosive such as Composition B, PETN, TNT, RDX, tetryl or the like, a finely divided metal such as aluminum or a magnesium alloy, fuel oil or smokeless powder. Aluminum as a sensitizer is generally in flake form.

The invention is illustrated with reference to the drawings of which FIGS. 1 and 2, respectively, diagrammatically illustrate preparation of the charge utilizing in situ generation, and air injection, of the gas ingredient; FIGS. 3 and 4 are plots illustrating, on a theoretical basis, utilization of different proportions of gas and gas-generating materials, and the density lowering accomplished in each instance; and FIGS. 5 and 6 diagrammatically illustrate placement of the total gas-containing slurry.

With reference to FIG. 1, water, oxidizer salt, sensitizer, guar gum as the thickener and acetic acid as a component of the gas-generating material are introduced into mixing chamber 14 via lines 9, 10, 11, 12 and 13, respectively, for the formation of a slurry mixture containing, on a weight basis, from 4 to 35 percent water, from 20 to 75 percent oxidizer salt, from 4 to 60 percent sensitizer, acetic acid, in an amount described herein-after, and from 0.2 to 0.8 percent natural guar gum, preferably added in an amount from about 10 to 50 per-

5

cent of the total guar gum contemplated, the latter being up to about 2.0 percent based on the total slurry formed.

Mixing in chamber 14 is generally carried out at a residence time of from about 1 to 10 minutes, at any suitable temperature ranging up to about 50°C., and at a pH from about 4.0 to about 6.5. Under these conditions, the guar gum forms a sol with the water, almost instantly to impart sufficient thickening to the mixture to preclude settling of the ingredients. The resulting admixture in chamber 14 is discharged into line 16 for ultimate delivery to the borehole or container.

Sodium bicarbonate, as a now preferred gas-liberating salt for in situ generation of the gas ingredient, is added to mixing chamber 22, via line 19, in anhydrous form, advantageously as a suspension in ethylene glycol, together with inhibited and cross-linkable guar gum also advantageously in suspension in ethylene glycol via line 23. The resulting guar gum-sodium bicarbonate admixture is discharged from chamber 22, via line 25, into line 16 under cross-linking conditions e.g., at ambient temperature, e.g., 25° C., and a pH of about 4.0 to 5.5. Sodium bicarbonate from line 19 and acid from line 13, in combination, react as a gas-generating material in line 16 to liberate carbon dioxide for dispersion in the ingredient mixture in line 16. At this point, hydration of the guar gum from chamber 22, inhibited briefly to permit uniform mixing of the guar gum and complete dispersion of the gas-generating material in line 16 takes place with subsequent crosslinking, to impart an increase in consistency to the ingredient mix to facilitate entrainment of the carbon dioxide, as liberated, which continues until after the final ingredient mixture is pumped to placement where crosslinking is completed. Total slurry is passed to placement from line 16 and upon completion of crosslinking is of a plastic, but easily deformable, structure which retains the uniformly dispersed gas ingredient over prolonged periods.

The amount of sodium bicarbonate added via line 19 is regulated to provide carbon dioxide in the resulting admixture in line 16 in a concentration within a range of from about 0.005 to 0.10 weight percent of the finished slurry-type product so as to effect the predetermined density lowering. The amount of acid added via line 13 is regulated to provide for its reaction with substantially all the sodium bicarbonate from line 19 to produce carbon dioxide.

As charging is continued via line 16, the proportion of sodium bicarbonate from line 19 can be adjusted as desired to vary the amount of carbon dioxide in the slurry composition to accomplish a predetermined change in density as required to thereby regulate explosive strength. A suitable rate of addition of sodium bicarbonate in accordance with this embodiment is initially in the order of from 0.0002 pound per pound of total ingredients from chamber 14, with an increase as desired up to about 0.004 pound, per pound of the said ingredients, the efficiency of the entraining action, i.e. based on the amount of carbon dioxide entrained and the amount liberated according to theory, being generally in the range of from about 30 to 70 percent.

Although in situ gas generation is initiated in line 16, it is generally not completed until after the total slurry has been pumped from line 16 to placement. The ambient conditions of pH and temperature for completion of crosslinking of the guar gum in placement are also suitable for completion of the in situ gas generation in placement.

In accordance with the embodiment of FIG. 2 which illustrates the now preferred practice of the invention, water, oxidizer salt, sensitizer and guar gum ingredients are added to mixing chamber 14' via lines 9'-12', respectively, and the resulting admixture is discharged via line 16' for delivery to placement, all as described with reference to FIG. 1. Guar gum, inhibited and cross-

6

linkable, in suspension in ethylene glycol, is passed via line 27 into line 16'. Hydration of guar gum from line 27, briefly inhibited in line 16' to permit uniform mixing of the guar gum and uniform dispersion of air from line 28, takes place with subsequent crosslinking to impart an increase in consistency to the ingredient mixture to facilitate entrainment of the injected air, and the crosslinking continues under the ambient conditions of pH and temperature until after the final ingredient mixture is pumped to placement where it is completed. Total slurry is passed to placement from line 16' and upon completion of crosslinking is of a plastic, but easily deformable structure which retains the entrained air over prolonged periods.

The amount of air injected into line 16' via line 28 is generally from about 0.0002 to about 0.1145 cubic feet (standard conditions) per pound of total ingredients in line 16' to provide on a volume basis from about 2 to 50 percent air dispersed into the slurry to be discharged to final placement, the efficiency of air entrainment, i.e. based on the total amount of air added, being generally in the order of about 10 percent.

It is an important feature of this invention that when the final mixture is discharged from line 16' into a borehole the proportion of air dispersed during injection can be regulated so as to vary the composition density, as desired, to thereby regulate explosive strength along the entire length of the resulting columnar charge.

Even with no variance in the proportion of air added via line 28, there is a general gradient of density from bottom to top of the resulting columnar explosive due to the compression effect of the head of explosive. Often, however, it is most advantageous to gradually increase the proportion of air injected into the slurry to provide for a substantial gradient of density. For example, the proportion of air can be varied from bottom to top of the column such that the decrease in density along the column can be from about 1.5 to as low as about 0.8 grams per cc. However, it will be appreciated that the final choice is always dependent upon the particular formation to be blasted and the particular slurry composition.

In preferred practice, the total slurry mixture from lines 16 or 16' is passed directly into placement in a borehole to provide a resulting columnar charge of the mixture.

FIG. 3 illustrates, on a theoretical basis, the relationship of density lowering of three different slurries, utilizing the in situ gas generation embodiment of the invention, to the amount of sodium bicarbonate introduced into the system as the gas-liberating material.

FIG. 4 illustrates, on a theoretical basis, density lowering for four different slurries in the practice of the air injection embodiment of FIG. 2 and the relationship of the lowering to the amount of air entrained.

As illustrated with reference to FIGS. 5 and 6 total ingredient mixture from line 16 of FIG. 1 or line 16' of FIG. 2 is pumped for final placement either into a borehole or into a container.

Referring to FIG. 5 total ingredient mixture is pumped from line 16 or 16' through flexible hose line 31 into a borehole 32 in the earth formation 34 to be blasted, line 31 extending into borehole 32 and terminating at a point near the bottom thereof. In the practice of this embodiment, the ingredient mixture is delivered to placement intact from the hose 31 and the hose is preferably raised as the borehole fills. When desired, the hose line 31 can be positioned for delivery and withdrawal in any suitable manner.

As the level of explosive rises in the borehole 32 the proportion of gas to be incorporated into the slurry, as illustrated with reference to FIGS. 1 and 2, can be regulated to vary the amount dispersed, and hence enhance the density and explosive strength, along the length of

the resulting column of explosive. This practice provides for a combined manufacture and loading of a borehole, with a single explosive "tailored" to meet the particular blasting energy requirements of the formation to be blasted at any and all levels in the borehole.

Referring to FIG. 6, total ingredient mixture from lines 16 or 16' to be packaged is pumped through line 31' into a suitable container such as an elongated plastic bag 33. It is the general practice in carrying out this embodiment to maintain the added proportion of gas ingredient constant for a given bag or set of bags and to vary the said gas proportion, when desired, from one bag, or set of bags, to another. In this manner individual bags, or sets of such bags, of predetermined density and explosive strength can be formed for placement in series in a borehole to provide the desired columnar charge of predetermined variance in explosive strength along its length.

Each bag 33 is preferably only partially filled to permit lateral expansion in the borehole to afford maximum loading density. Each finished bag of explosive is closed in any suitable manner, such as by a wire tie.

In practice of various embodiments, and particularly as applied to the combined manufacture and loading of a borehole, the entire system can be part of a truck assembly at the blasting site. Alternatively the base mixture e.g., formed in chambers 14 or 14', can be formed at the plant and stored on a truck assembly for delivery to a "main line" such as lines 16 or 16' of FIGS. 1 and 2, with subsequent incorporation of gas and thickener for discharge from the assembly.

It is to be understood that when referring herein to a change in the proportion of gas incorporated into the ingredient mixture it is meant that such is accomplished by any suitable valving arrangement diagrammatically illustrated with reference to the valves 13' and 19' of FIG. 1 and valve 28' of FIG. 2, dependent on whether the gas is added by in situ generation or by direct injection.

Chemical generation as a source of inert gas for the regulation of density and explosive strength in the practice of the invention is illustrated with reference to Example 1 and 2 following:

EXAMPLE 1

A "base" slurry mixture was formed by admixing the following ingredients at an average temperature in the order of about 50° F. for about 2 minutes in the proportions shown:

	Weight percent
Water	22.5
Smokeless powder ¹	25.0
Ammonium nitrate ²	31.0
Sodium nitrate ³	19.4
Ethylene glycol	1.5
Guar gum ⁴	0.6

100.0

¹ Ground single base.

² Prills.

³ Granular.

⁴ Natural guar gum.

A suspension of guar gum in ethylene glycol and acetic acid was formed by admixing the following at a temperature of about 20° C. for about 3 minutes in the proportions shown:

	Parts per 100 parts of the base ingredient mixture
Guar gum ⁵	1.5
Ethylene glycol	3.0
Acetic acid (glacial)	0.3

⁵ Crosslinkable.

A suspension of 50 weight percent sodium bicarbonate in ethylene glycol was formed and divided into three portions containing 0.10, 0.15 and 0.20 part sodium bicarbonate per 100 parts of base mixture ingredients.

The following formulations, Nos. 1-4, were prepared by admixing the above components, i.e., the base ingredient mixture, the guar gum-ethylene glycol suspension, and the sodium bicarbonate-ethylene glycol suspension in the proportions shown except that formulation No. 1 was devoid of the sodium bicarbonate component. Density of the final composition was measured in each instance.

	Formulation No. ⁶			
	1	2	3	4
Water	21.47	21.42	21.39	21.35
Smokeless powder	23.85	23.78	23.76	23.72
Ammonium nitrate	29.59	29.49	29.45	29.41
Sodium nitrate	18.51	18.45	18.49	18.41
Ethylene glycol	4.29	4.47	4.50	4.65
Guar gum ⁴	0.57	0.57	0.57	0.57
Guar gum ⁵	1.43	1.43	1.42	1.42
Acetic acid	0.29	0.29	0.28	0.28
Sodium Bicarbonate		0.10	0.14	0.19
Density, Grams per cc.	1.26	1.20	1.08	1.04

⁴ See Footnote (4) supra.

⁵ See Footnote (5) supra.

⁶ Weight percent basis.

As demonstrated above, the basic, or initial, ingredient admixture containing natural guar gum was formed, the guar gum hydrating to impart sufficient thickening to hold all the ingredients in suspension. The base mixture was then mixed with guar gum in inhibited form, for ultimate crosslinking, and then with sodium bicarbonate (except Composition 1) as the gas source prior to crosslinking. Gas (CO₂) generation was the result of reaction of sodium bicarbonate with the acetic acid present, the acid also serving to regulate pH of the final explosive mixture to permit crosslinking of the guar gum. During crosslinking, the gas was held throughout the final composition in form of discrete bubbles dispersed therethrough for permanent retention in the final crosslinked product. The density values illustrate the effect of the varied proportions of gas component, and the example demonstrates the role of added sodium bicarbonate and acid as the gas generating material.

The invention is particularly adaptable to the formation of slurry mixtures at the blasting site to permit "bulk delivery" with elimination of packaging and auxiliary handling at the mixing plant. The bulk delivery system involves a motor truck assembly equipped with facilities for storing separate components for pumping into a single slurry stream for discharge into the borehole. A process for carrying out bulk delivery of slurry-type explosives is disclosed and claimed in the copending application of Robert B. Hopler, Jr., Serial No. 386,317, filed July 30, 1964 now abandoned.

EXAMPLE 2

This example illustrates a preferred practice of the invention, which is associated with bulk delivery above described.

A base ingredient mixture was formed at an average temperature in the order of about 50° F. with agitation over about a 20-minute period and then stored in a first storage tank in accordance with the following formulation:

	Pounds	Weight Percent
Water	150	22.8
Smokeless powder ¹	350	25.2
Ammonium nitrate ²	314	30.2
Sodium nitrate ³	204	19.6
Ethylene glycol	15.75	1.5
Guar gum ⁴	6.12	0.6
Acetic acid	0.5	0.05

¹⁻⁴ See footnotes 1-4 resp. of Example 1.

A guar gum ethylene glycol-acetic acid suspension was formed, and stored in a second tank in accordance with the following formulation:

	Pounds	Parts per 100 parts by weight base ingredient mixture
Guar gum (Inhibited).....	15	1.0
Ethylene glycol.....	25	1.7
Acetic acid, 50 percent.....	5	0.3

A suspension of sodium bicarbonate in ethylene glycol was stored in a third storage tank in accordance with the following formulation:

	Pounds	Parts per 100 parts by weight base ingredient mixture
Sodium bicarbonate.....	10	0.20
Ethylene glycol.....	20	0.40

The natural guar gum in the base mixture underwent hydration, substantially immediately upon contact with the water to hold all ingredients in suspension but was, nevertheless, easily flowable as were the separate guar gum and sodium bicarbonate suspensions.

In the delivery system of this example, the main (first) pump (capacity 250 lbs./min.) was powered by an air motor to provide a pump speed of 500 r.p.m. and was located downstream from the entire assembly, for delivery of the final slurry explosive from the "main line" into the borehole. A second pump (capacity 7.5 lb./min.) was operatively connected with the main pump by a V belt and clutch assembly to operate at a speed of 1200 r.p.m. A third pump (1.5 lb./min.) was operatively connected with the second pump by a V belt and clutch assembly to also operate at a speed of 1200 r.p.m.

The base mixture under a head of air pressure of 15 p.s.i.g. and open to the main line was pumped from the first storage tank by the main pump through the main line at a rate of about 250 pounds per minute. The sodium bicarbonate-ethylene glycol suspension under atmospheric pressure and open to the third pump, was pumped by the latter from the second storage tank into the main line in admixture with the base mixture therein (from the first tank) at a rate of 1.5 pounds per minute. The ethylene glycol-acetic acid-guar gum suspension under atmospheric pressure and open to the second pump was pumped by the latter from the third tank into the main line at about 3.0 pounds per minute. Total resulting slurry and mixture in the main line was then discharged from the main (first) pump into the borehole at a total rate of about 254.5 pounds per minute.

The resulting slurry, with liberation of carbon dioxide was discharged from the main pump into a borehole. Final cross-linking was completed after about 40 minutes, forming a plastic, but easily deformable mixture containing the gas bubbles in uniform dispersion throughout.

It is not essential that the amount of gas dispersed in the explosive be varied in order to obtain a predetermined variance in density along the column. Indeed, once the gas ingredient is incorporated into the slurry, compression due to the head of slurry as positioned in the borehole often results in a suitable density gradient. Nevertheless, it is often advantageous to vary the amount of gas incorporated into the columnar explosive so as to provide a greater degree of variance in order to more often meet the blasting energy requirements of the surrounding formation.

The following examples are illustrative of the use of air injection as a source of gas ingredient in the regulation of density and explosive strength in the practice of the

invention, carried out in a modified delivery system of Example 2.

EXAMPLE 3

A base ingredient mixture was formed at an average temperature in the order of about 50° F. with agitation, over a period of about 20 minutes, in accordance with the following formulation:

	Pounds	Weight Percent
Water.....	300	22.8
Smokeless powder ¹	700	25.2
Ammonium nitrate ²	626	30.1
Sodium nitrate ³	468	19.6
Guar gum.....	14.75	0.7
Ethylene glycol.....	32	1.5

¹⁻³ See footnotes 1-3 resp. of Example 1.

The resulting base mixture was then stored in a first tank.

A guar gum-ethylene glycol suspension was formed by mixing a crosslinkable guar gum with ethylene glycol at 25° C. and then stored in a second tank in accordance with the following formulation:

	Pounds	Pounds per 100 Pounds Base Ingredient Mixture
Guar gum.....	50	1.0
Ethylene glycol.....	100	2.0

The base ingredient mixture, was pumped from storage under air pressure head of about 15 p.s.i.g. into the "main line" to a borehole at a rate of about 250 pounds per minute as in Example 2. The ethylene glycol-guar gum suspension was pumped from storage into the main line downstream from a point of addition of the base ingredient mixture at a rate of 7.5 pounds per minute.

Air was injected into the final ingredient mixture in the main line, downstream from the point of addition of the guar gum suspension through a 1/8 inch bar stock needle-type valve. The amount of air injected was recorded in terms of the number of turns of the control valve, which was varied from zero to one-fourth to one-half turn with corresponding increase in air delivery and concomitant decrease in density. The relationship of the air injection to density is shown in the following tabulation:

Final Ingredient Mixture (Charge) Subjected to Air Injection Pounds	Air delivery		Density (grams/cc.) of the Charge After Air Injection and Crosslinking
	Turns of the Valve	Approximate cubic feet entrained (S.C.)	
160.....	0	0	1.30
160.....	1/4	0.4	1.10
160.....	1/2	0.8	0.96

EXAMPLE 4

One hundred pounds of a base ingredient mixture was formed at an average temperature in the order of about 50° F. with agitation over a period of about 20 minutes in accordance with the following formulation:

	Weight percent
Water.....	22.5
Smokeless Powder ¹	25.0
Ammonium Nitrate ²	31.3
Sodium Nitrate ³	19.0
Ethylene Glycol.....	1.5
Guar Gum ⁴	0.7

¹⁻⁴ See footnotes 1-4 resp. of Example 1.

The resulting base mixture was then stirred in a first tank.