APPARATUS AND METHOD FOR BLASTING OR DEMOLITION

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ABSTRACT OF THE DISCLOSURE

A length of expandable tubing is distended and filled with a sensitive easy flowing liquid or plastic explosive blasting or demolition slurry. By unrolling a tube as it is filled it may be protected across inaccessible terrain, e.g., for breaching obstructions, destroying enemy installations in military operations, etc. Portable mechanical or manual equipment is included for preparing the slurry and extruding it into the tube. Pumpable aqueous slurries of ammonium nitrate and other oxidizer salts are well sensitized with fuels which include small amounts of finely divided aluminum, carbonaceous materials, etc.

PRIOR ART AND BACKGROUND

It has been known in the past in military operations to use elongated tubular devices such as pipes and hoses filled with an explosive composition for demolition work. For example, so-called Bangalore torpedoes have been made by filling lengths of metal pipe with molten explosive which is run into the pipe or cooled and solidified. Several lengths of such explosive-filled pipe may be joined together to make a long torpedo or detonation device. These devices may be pushed into place manually across hostile terrain or may be carried or pushed ahead of military vehicles, such as tanks. After emplacement they are detonated for blasting operations or demolition work, such as clearing mine fields, demolishing barbed wire entanglements or for destroying various kinds of military structures or installations. The U.S. Army Corps of Engineers used Bangalore torpedoes of this general type during World War II. Hoses have been filled similarly with materials which solidify to produce rigid charges of explosive.

While rigid elongated blasting charges or demolition devices as described above have definite utility for many types of operations, the lengths or distances to which they can be extended or pushed ahead of the user often are quite limited. In military operations their use often requires a large protective vehicle such as an armored tank for pushing them into positions for use. Otherwise the person who handles them may be exposed to enemy fire. In some military operations, there are many civilian uses for long blasting charges which can be laid out or projected ahead for long distances and then detonated. It is desirable to avoid requiring human operators to carry them into place. An example is clearing a path across a swamp or terrain which is difficult for a man to cross. Obviously, it is highly desirable to be able to form an elongated device, analogous to the Bangalore torpedo but non-rigid, which can be extended to greater length as it is filled. Such a device may be self-propelled in a sense, to a considerable distance by propulsion from the filling point, according to one aspect of the present invention.

While attempts also have been made in the past to fill flexible hoses and the like with explosive material to make them relatively rigid and then detonate them in the field, these have not been particularly successful. The difficulties already mentioned in handling rigid pipe apply even more in handling a hose and trying to move it into an advanced position where it is to be used. One example of such a device is disclosed in U.S. Patent No. 3,004,462 to Cook, one of the present inventors, et al. The present invention has several advantages over such an arrangement.

One object of the present invention is to both prepare and move into place an explosive slurry composition in the field. Such a composition is preferably a free flowing or easy flowing, readily pumpable smooth slurry made of a combination of ingredients which, by themselves, are not explosive or hazardous to store and handle. A slurry of low viscosity, preferably not exceeding 200 cp., which can be pumped to 1000 feet in a tube, is preferred. The ingredients can be mixed readily in the field. As they are mixed they can be dispensed into an expandable, elongated flexible tube which is ordinarily carried unexpanded or collapsed in a compact package before filling. Filling is done in such a way as both to distend and fill the tube; simultaneously it may be propelled into the desired position by the filling operation. The tube conveniently may be in the form of a compact roll of flattened plastic tubing of relatively small dimensions, hence, easy to transport to the point of use. A compartmented vessel, or system of vessels, may be employed for first mixing the ingredients and then feeding or extruding the mixture or slurry into the tube. A liquid component or solution of one of the explosive constituents, for example, a concentrated aqueous solution of a strong oxidizer salt, such as an inorganic nitrate, chlorate or perchlorate may be placed in a compartment while another compartment or zone contains particulate dry ingredients such as metals and other high energy fuels. These ingredients when blended with the liquid component or solution, will produce a powerful and adequately sensitive blasting slurry. The composition produced should be fluid and readily extrudable or pumpable into the tube. Simple mechanical or manually operable means are shown for proceeding through out the blending and/or pumping or extruding operations. More elaborate means may be used, if desired, both for blending the components together and then for forcing the explosive gel or slurry into the elongated plastic tube which can be pre-laid or can be moved into place as it is filled. This tube preferably is a collapsible or unexpanded thin-walled material, such as nylon, rubber, polyethylene, etc. It is preferably a water-tight plastic tubing capable of withstanding pressure up to a few pounds per square inch without bursting. Such tube material can be conveniently stocked and carried, prior to use, either in the form of a roll or flattened tubing, or a zig-zag folded stack of such tubing, etc. The collapsed tubing material can be unraveled or unfolded as it is filled and thus it may be projected longitudinal as it distends, to a considerable distance and length by the same operation that fills it with explosive.

BRIEF DESCRIPTION OF DRAWINGS

FIG. 1 shows a front elevation view partly diagramatical, of a preferred embodiment of the invention.
FIG. 2 is a plan view of the main apparatus of FIG. 1.
FIG. 3 shows a modified form adapted to fill and project a plurality of tubes simultaneously.
FIG. 4 shows somewhat diagrammatically a simple apparatus for making the slurry composition and expelling it into a long tubular explosive container which unrolls as it is filled.

3,610,089
Patented Oct. 5, 1971
FIG. 5 shows a safety manifold device for connecting a tube of packaging material to be filled with explosive to the source of supply.

DESCRIPTION OF PREFERRED EMBODIMENT

Referring now to FIG. 1, a mixing vessel 11 is shown in the form of a hollow cylindrical-walled tank of suitable capacity. It may contain from one or two to several hundred gallons of slurry, or ingredients therefor, when filled. This vessel has side walls of suitable material, e.g., metal or reinforced plastic of adequate tensile strength for holding and confining under pressure a flowable or pumpable slurry composition.

The slurry consists of a suspension of finely divided insoluble particles in a liquid such as a concentrated solution of ammonium nitrate in water. Some other highly active oxidizer salt or salts, as already mentioned, may be used as a major ingredient. Particularly suitable liquid phase compositions may be made up of a combination of sodium nitrate with ammonium nitrate, or of one or more of the chlorates or perchlorates of ammonia or of the alkali metal chlorates. These salts may be used singly or in combinations of two or more, as will be obvious. The liquid component which is usually saturated with oxidizer salt, or nearly so, is blended in vessel 11 with solid particulate materials which do not dissolve therein, such as finely divided aluminum, coal dust, sulfur, and combinations of these and other materials. Additional oxidizer which cannot dissolve because the solution is already saturated may be added in dry or particulate form. These suspended ingredients add energy and make the whole composition sensitive to detonation in a column of reasonable cross-section. Compositions of this general type are now well known in the explosives industry.

The vessel or tank 11 has convex upper and lower ends or heads 13 and 15, the top end 13 being provided with a large filler opening 17, to which is connected a funnel filler device 19. A closure 18 can be held in place in openings against pressure inside tank 11 by a wing nut 20, screwed into place or unscrewed on bolt 21. These latter parts may be removed for introducing liquid or other ingredients into the vessel. Bolt 21 can be anchored inside head 13 by a cross bar 22. The bottom wall 15 of tank 11 has an outlet line 24 threaded or otherwise secured thereto, which connects through elbow 25 to a pipe or conduit 26 equipped with a valve 27 having an operating handle 28 to open or close the valve. Connected to valve 27 is a coupling or short length of pipe 29 which may be equipped with a pressure gauge 30 so that the pressure on the material being dispensed can be observed. Tank 11 may have its own separate pressure gauge (not shown), if desired.

The mixing apparatus comprises a stirrer 32 on a rotatable shaft 34 mounted in bearings 35 supported in a sleeve member 36 secured to the upper end member or tank head 13. Shaft 34 has secured to its upper end a belt pulley 38 adapted to be driven through belt 39 by a pulley on the lower end of the drive shaft of an electric or other suitable drive motor 40. The latter is mounted through support ports 42 on a base plate 43 secured by bolts, welding or other means to the general tank structure. An air compressor 45 is mounted on base plate; its drive pulley 46 is adapted to be driven through belt 47 by a pulley 48 also on the drive shaft of motor 40. Compressed air from the compressor flows through line 49, under control of valve 50, into the upper end of vessel 11, thus applying pneumatic pressure to its contents. The slurry will flow at a good rate through outlet line 24, 26, etc., when valve 28 is opened. Valve 50 of course is not opened or the compressor is not operated until a batch of explosive slurry is mixed and ready for use. An automatic clutch or equivalent, contained below the compressor shaft to ride idly until compressed air is called for by opening valve 50. Alternatively, a manual clutch may be used to start and stop the compressor which motor 40 is running. A pressure gauge 51 is shown in line 49 to indicate the air pressure.

Connected to the coupling 29 is a conduit or flow line 53, which may be a pipe but is preferably a flexible hose at least a few feet in length. This line 53 is attached to a safety manifold 54. See FIG. 5. The purpose of the manifold is to choke off any explosion down line, that is, to prevent any unintentional or premature explosion which might occur in the detonable blasting charge or torpedo line, as will be described later, from firing back to the mixing apparatus. This is a safety device for protection of personnel as well as the apparatus. The safety device consists of two lengths of header tubing 55 and 57, preferably of metal or reinforced plastic, connected by a plurality of small tubular conduits 59 of subcritical diameter. That is, their diameter is too small to conduct a detonation wave. Critical diameter varies for different explosives. In a typical case the header tubes 55 and 57 may be, for example, two to three inches in diameter or more whereas the connecting tubes 59 are considerably smaller, e.g. one-half inch or less in diameter, and are definitely below the critical diameter of the explosive slurry to be used. With this construction, a premature explosion occurrence in the filled tube line 80, to be mentioned further below, the explosion or detonation wave cannot be propagated through the slender tubes 59 so as to reach the header 55 and blow up the apparatus connected thereto.

As one example, if an explosive has a critical diameter of about one inch, which may be considered typical or roughly so for slurries of the type used herein, the slender tubes 59 should be considerably smaller than one inch, say, 1/8 to 1/2 inch in diameter or even smaller. Where the slurry explosive composition has a two inch critical diameter, these tubes should not exceed one inch in diameter and may preferably be somewhat smaller, as will be readily understood by those skilled in the art.

In use, the device of FIG. 1 is filled to a suitable level, at least up to mixer level indicated at line 70, with an aqueous solution of a powerful inorganic oxidizer. A saturated aqueous solution of ammonium nitrate, to which some sodium nitrate may be added, is very satisfactory and is usually preferred. Ammonium nitrate is more soluble and more easily detonated (when sensitizers are used) than sodium nitrate. This solution, or the final slurry, preferably may contain a small amount of a thickening agent, such as a guar gum or starch, so that the slurry will not flow too freely down a grade or be lost through small cracks or perforations in the tubing. A slurry made up of 10 to 20% of water, 30 to 60% of a nitrate selected from the group which comprises ammonium nitrate, sodium nitrate and mixtures thereof, balanced with fuels which may comprise coarse particulate aluminum, and 0.05 to 5% of a fine flaked or point grade aluminum is very satisfactory. Desirably, the slurry is a fairly sensitive one, detonable in a 1/4 inch tube, for example, and is readily pumpable.

The fill level 70 should be low enough that a sensitizing amount of the particulate solid material or materials may be added through the opening 17 to make up the explosive composition. This solid material is usually a "pre-mix," consisting typically of a small amount of finely divided metallic aluminum, preferably a paint grade aluminum, along with finely divided non-metallic fuel, such as carbon, coal, gilsonite, sulfur, etc. Coarser aluminum granules also may be included. Suitable compositions of this general type are well known in the art. The sensitivity of the mix needs to be controlled carefully, however, by a careful choice of sensitizer and fuel ingredients, as will be mentioned further below. U.S. Reissue Pat. No. 25,695, to Cook and Furrin, gives some general formulae for making this mixture, which may be modified, as desired, for the purposes of this invention.

After suitable dry or "pre-mix" ingredients, such as those described above, have been added through the opening 17, the vessel is sealed by replacement of closure 18. Motor 40 is started up to drive mixer 32; the compressor may operate idly. This mixer causes an intimate mixing of the liquid oxidizer solution with the particulate
materials so as to suspend the insoluble particles and produce a homogeneous slurry. Use of a small amount of a thickener, either in a dry pre-mix or in the liquid solution, not only contributes to the viscosity of the slurry, as already mentioned, but also renders the composition sufficiently viscous that the finely divided solid and undissolved particles of aluminum and other fuels or sensitizers will not segregate or settle out by gravity, or at least will not settle out too soon for use. This mix or slurry is now highly explosive in character, having the characteristic sensitivity to detonation that conventional initiators or detonators can be used for setting it off. It then forms a powerful demolition or blasting agent.

When air compressor valve 59 is opened the propellant gas pressurizes tank 11 and forces the fluid slurry, which preferably is easy flowing in character, out of the mixing tank through the outlet 24, 26 when valve 23 is opened. The slurry then flows through the connecting lines 29, 53 to the upper manifold 55 of the safety device. From here it flows in small streams through the slender safety or blast extinguisher tubes 59 into the other header 57. Header 59 connects to a suitable length of collapsed flexible plastic tubing, which may be flat, rolled, or folded, as already mentioned. This tubing is ordinarily made of nylon, polyethylene or similar flexible sheet material. It should have sufficient tensile strength to resist the amount of pressure that will be applied in forcing the slurry through it to a desired distance but it need not be a heavy tube. Pressure of the order of two to twenty lbs./sq. inch ordinarily will be adequate. The pressure required depends, of course, on the viscosity of the slurry and the diameter and length of the tube and conduits being filled. A flexible rolled or folded tube is filled it begins to unroll or straighten out and push ahead. If desired, however, the tube may first be unrolled or unfolded and extended manually before filling. Where feasible, it is desirable that the tube be pre-laid into the position desired. Then the slurry is merely pumped in to fill it.

After a flexible tube 80 has been extended by unrolling or unfolding and filled to the desired length or distance, the charge it contains may be detonated by use of a suitable initiator, such as a detonating cap set in tube 80 at the near end or at any intermediate point. A suitable booster may be used with a cap, if required, as is well known in the art.

Should premature accidental detonation of the charge occur due, for example, to accident, or to enemy fire or to setting off an enemy mine, etc., the safety device 57, 59, which will be considered expendable in military operations, cuts off the explosion and prevents the blast from coming back to the apparatus and destroying it or injuring the personnel attending it. The tube 80, on the other hand, may and preferably will be disconnected from the filling device before detonation. In some cases the safety device 57, etc., may not be considered necessary. In military operations, where there may be risk of enemy fire or of other possibilities of premature detonation, as by a mine or some other explosive device, the safety device 57, etc., should be interposed between the dispensing mechanism and the filled tube that is to be detonated, for the safety of personnel and equipment. The safety device normally will be detached, even in military operations, before detonating the charge in tube 80 to keep the safety device for further use.

The next step involves filling the tube and relatively explosive, ready for dispensing into the tube, of course can be a dangerous device. It must always be handled with care after mixing a batch of explosives in it. Obviously the tank should be protected against enemy fire and other hazards.

Referring next to FIG. 3, there is shown another system incorporating a mechanical mixing and dispensing system such as a mobile mixer-pumper. Devices of this type are used for mixing and pumping explosive slurry in rock blasting operations, etc. Unit 111 comprises a mixing station 112 in which the explosive slurry is prepared and from which it is promptly withdrawn and dispensed by a pump station 113 to an outlet line 114. Line 114 leads to the present case to a pair of tubular conduits 116, 117 by a three-way slider valve 118. A safety device such as 55, 57, 59, FIG. 1, is not shown here but may be interposed in line 114 for use in military operations. Such a device may be placed in each of lines 116 and 117, if desired. A pair of rolled collapsed plastic tubes 119 and 120 on reels 121, 122 are fixed to a rigid axle member 123. When valve 118 is opened and set to divide the pumped stream into two equal parts the pump fills both tubes simultaneously. The pair of rolls and their supporting axle move forth like a cart as both tubes are filled, thus extending a pair of tubular parallel explosive charges to a desired extended distance. By manipulation of valve 118, the filling rate of either or both tubes 119, 120 can be controlled to steer the pair on their axle as they roll forward.

Instead of using a mechanical pump or a compressor to fill the tubes, any source of pressure may be applied to a vessel containing a supply of explosive. Such a source of pressure may be a tank of any suitable gas or liquefied gas, such as tank of "Freon," carbon dioxide, nitrogen or the like. When pressure is applied to the slurry, the slurry will flow through the connecting tube or tubes and into the collapsed tubing which is then filled out and which also may be propelled to a desired distance by the actual filling operation.

A simpler system may be made up which is totally expendable, consisting merely of a pressurized container of pre-mixed slurry, or a tank of slurry connected to a source of fluid pressure for expelling the slurry into collapsed tubing. The necessary components and flow control valves may be provided, as will be obvious. In such a case, the safety devices such as 55, etc., FIG. 1, might be eliminated under some conditions. Personnel, of course, would evacuate to safe positions before detonating charges.

In FIG. 4 a simple system of the general type just mentioned is shown, wherein a premixed explosive slurry is forced from a suitable vessel 149 into outlet line 150 by gas pressure from a tank 140. The vessel 149 may be like tank 11 in FIG. 4. The vessel 149 may be like tank 11 in FIG. 4. The vessel 149 may be like tank 11 in FIG. 4. The vessel 149 may be like tank 11 in FIG. 4. The vessel 149 may be like tank 11 in FIG. 4. As shown, it contains a manually operable mixing device 142, adapted to be turned by a handle 144 to stir the ingredients together. Tube 150 may be connected to an intervening safety device like device 55, etc., FIG. 1, but as shown here, it is connected directly to a roll of collapsed tubing that is to be filled.

The collapsed tube should be selected for appropriate capacity and strength. For example, a two-inch tube of nylon or of polyethylene in a gauge or thickness common available when filled to a length of 400 ft. with a wall strength of 15 lbs./sq. inch of pressure, is adequate to bursting strength to confine and force the slurry to its far end when using a typical fine aluminum sensitized slurry of ammonium nitrate, sodium nitrate and water type. The pressure requirements may vary a great deal, depending on the composition as well as the viscosity of the slurry, also on the diameter and length of the tube which is to be filled. Thin slurry in a large tube flows at very low pressure, whereas thick slurry in a small tube may reach fairly high pressures. Also, the terrain over which the device is to be used has some influence. Obviously, it takes more pressure to pump a slurry uphill than down, and undulating terrain requires more propulsion force and, hence, more pressure on the slurry than flat terrain. The slurry, in any case, should be thick enough to prevent gravitational segregation or at least premature segregation, of the sensitizing solid particles from the liquid. That is, the particles should remain in homogeneous suspension throughout the liquid phase.
Where feasible, the flexible tubing may be controlled somewhat better if it is unrolled by hand and laid along the precise path to be detonated prior to filling. However, this may not be feasible in military operations, especially where there are enemy mine fields or other impediments to be crossed or penetrated. It is desirable, under many circumstances, to be able to fill and roll out a length of flexible tubing, unrolling it full of slurry, without maintaining immediate manual control over the rolling. The devices of FIGS. 1, 3 and 4 are all of use in such situations.

In some cases the tubing may be simply unfolded or unrolled by propelling its rolls or package along a ditch, or through a guiding corridor or tube, as it is filled. With such guidance the force of pumping will unroll the tubing throughout the length of passageway preparatory to detonation.

The far end of the collapsed tube, when it is to be fully unrolled, may be sealed if desired, to prevent the slurry from draining out, e.g., in cases where the tube is laid out on a down-hill slope. It may be desirable, too, to maintain a distending pressure on the tube after the device is fully extended so as to keep the tube filled throughout its length until the moment of detonation. This can prevent drainage of the fill slurry away from elevated parts to those at lower elevation, which otherwise might leave voids and cause discontinuity in the explosive column.

A number of experimental tests were performed to demonstrate the safety, versatility and other advantages of using slurry explosives, in the manner described above, for military application, such as those described above. One goal was to load a long length of small diameter tubing and roll it out to a distance of several hundred feet by simply pumping slurry into it.

Single spirally wound rolls of nylon tubing were employed without further modification. Some directional control was realized. However, a slippery plastic tubing sometimes has a tendency to slide off the sides of its roll and become tangled as it unrolls. By simply taping the roll on each side to prevent premature uncoiling, it was found possible to pump and roll it along the ground; pressure unrolling or sliding off the side of the roll was largely prevented.

The devices described above, either single tube or double parallel tubes, are obviously useful in military applications for mine clearing. They can be used for trenching and other operations that can be undertaken across rough terrain by simply inflating. Generally speaking, they rolled smoothly while they were filling.

Nylon rolled, collapsed tubes were filled with type D slurry, described below, primed with a 3C booster and detonated. Some 1.75-inch diameter filled tubes, detonated on top of the ground, blasted trenches about three inches deep. A mixer-pumper apparatus which mixed dry and liquid ingredients together and filled the tube at about 200 lbs./min. was employed. Dirt was loosened in the trenches down to a depth of about six inches. This loose dirt was later dug out and the enlarged trench was filled with a fairly high viscosity slurry of type D. This consisted of about 46% ammonium nitrate, 16.8% sodium nitrate, 17% water, 10% aluminum, of which about 15% was paint-grade flaked aluminum, 5% ethylene glycol, 4% sulfur. A small amount of guar gum, not over 1%, may be used as a thickener. The slurry used is a very insensitive mixture. It may be modified by adding a small amount of cross-linking agent to increase its viscosity. As noted above, viscosity should not exceed 200 cp. Both the slurry D, without gum thickener, and the one described next below should contain some fine grade aluminum. In general, they should contain over 0.1% but less than 5% of paint grade flaked aluminum. This paint grade aluminum makes the slurry smooth and pumpable at higher viscosity than those which contain little or none of it. A total quantity of about 400 lbs. of slurry D was pumped into the trench. This was detonated very successfully and the whole charge exploded, including some which had fanned out into a puddle from 1/2 to 1-inch deep. This blast formed a trench about 18 inches deep.

Another composition, suitable for the purposes described above, was made up of 39% by weight of ammonium nitrate, 10% sodium nitrate, 35% aluminum, 15% water, and 1% almost completely uncontrolled. A small portion of the aluminum should be fine flaked paint grade, up to but not exceeding 5% of the total composition.

Another collapsible plastic tubing of 3-inch flat width (1.9 inch diameter when filled) of nylon, having a 6 mil wall thickness, was rolled out manually to a length of 350 ft. on the ground. In a configuration forming five right angle turns and rising over two boxes that were 10 inches high. The tubing was then filled by pumping the slurry of composition D above. No difficulty was encountered in filling. Pressure at the slurry pump increased to about 16 p.s.i. by the time the slurry reached the far end of the tube. The entire length was detonated successfully.

Another test was made using a 1,000 ft. length of large diameter, i.e. 4.5-inch flat polyethylene tubing (2.86 inch diameter when filled) having a 10 mil wall thickness. This was laid out on the ground with ten right angle bends spaced about 100 ft. apart. Care was taken to keep the tubing out straight between bends without any twisting. It was then filled with slurry D, described above. The cross-linking agent was omitted. This was pumped at a rate of 200 lbs./min. from a pump truck through a short length of hose and then into the tube. Care was taken to flatten out into thin sections in parts. After 470 ft. of tubing were filled with about 2,000 lbs. of explosive, the tubing ruptured near the connection to the input hose. Pressure at this time was about 4 p.s.i. The ends of the tubing were then left open, which allowed some of the slurry to drain away from some of the high points along the length of the tube. This also allowed the tubing to flatten out into thin sections in parts. This long tube was detonated from one end with a 3C booster. Surprisingly, the slurry detonated across sections of tubing where the slurry thickness was only about 1/4 inch, without cut-off. However, failure did occur at a high point about 250 ft. away from the initiator end where the slurry had completely drained away. The remaining length of this large tubing was shot with another primer and detonated completely.

The seismic strength and other properties of slurries can be adjusted, as is known by those skilled in the art, to obtain almost any reasonable levels of blasting performance desired. The experiments described above show clearly that the system is applicable for various purposes, including demolitions to clear pathways, destroying enemy installations and structures, blasting paths through barbed wire entanglements and for analogous uses, including commercial blasting, as in trenching, excavating, etc.

In the claims which follow, it will be understood that the tubing either may be filled when already stretched out to a distance, or may be unwound or unfolded as it is filled, as described above. The term "expanding" or "expanded" is intended to cover either the filling or lateral distension of an extended tube or its lateral plus longitudinal unrolling, unfolding or extension of any kind. It will be understood also that various tubing elements to be filled and detonated, which are described as being connected, in sequence for example, may be connected immediately or mediately through connections not named.

While various modifications of the particular procedures, apparatus and compositions will occur to those skilled in the art, it is clear that the invention has broad scope. It is intended by the claims which follow to cover such invention and its variations so as to keep with the spirit of the invention, as broadly as the prior art properly permits.

What is claimed is:

1. The method of blasting along a predetermined elongated path, which comprises forcing a flowable slurry
of particulate solids suspended in liquid, said slurry having a predetermined critical diameter, into a roll of flattened but expandable tubing or wrapping material, thereby opening up and filling said tubing and causing said tubing to unroll and travel along said predetermined path, continuing said filling until the tubing is unrolled and filled for the full length of said path, and then detonating the tube of slurry throughout its filled length.

2. Method according to claim 1 wherein the explosive slurry is flowed through tubing of subcritical diameter before flowing into the expandable tubing to provide a safety barrier.

3. Apparatus for preparing and delivering explosive slurry blasting material of predetermined critical diameter along a predetermined elongated path, comprising, in combination, a pressure vessel for holding liquid and particulate solid material, means in said vessel for mixing and suspending said solid material in said liquid to form said slurry, delivery line means of subcritical cross-section for connecting said vessel to a roll of flattened tubular container material, and means for moving said slurry through said connecting means whereby filling of said tubular material opens the flattened material to a tubing of diameter greater than said critical diameter and also unrolls the tubular material along said path.

4. System according to claim 1 wherein the tubular delivery line includes a safety section of flow line of diameter substantially below the critical diameter of said explosive slurry.

5. System according to claim 1 which includes a pressurizing vessel to supply a propelling fluid to said vessel thereby to expel the slurry through said delivery line into said expandable tubing.

6. A blasting charge comprising a flexible tube which, when empty, is flat and rollable into snug or spiral configured convolutions, said tube being filled and distended for at least a substantial part of its length to a rounded, filled and unrolled condition by a filling of blasting slurry composition comprised of an aqueous solution of strong inorganic oxidizer salt, said solution holding in suspension a particulate solid fuel and sensitizer material, and filler connector means of subcritical diameter, as compared to the critical diameter of said blasting slurry, attached to said tubing for supplying said slurry thereto, the slurry filling said connector in continuation of the filling in the flexible tube to form a single continuous mass of explosive material.

7. Blasting charge according to claim 6 wherein the particulate fuel-sensitizer comprises 0.1 to 5%, based on the total slurry of fine flaked paint grade aluminum.

8. A blasting device according to claim 6 which includes an elongated plurality of tubular safety structure having a tubular explosive-filled cross-section tubes of subcritical diameter connected to the tubing to prevent propagation of a detonation beyond said safety device.

9. A blasting device according to claim 6 wherein the slurry is easy flowing and has a viscosity not substantially exceeding 200 centipoises.

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