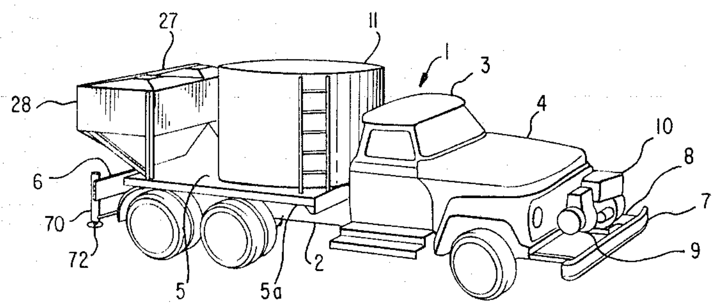
Feb. 14, 1967 R. B. CLAY ET AL 3,303,738

METHOD FOR MIXING AND PUMPING OF SLURRY EXPLOSIVE

Filed June 2, 1965 4 Sheets-Sheet 1

FIG. I



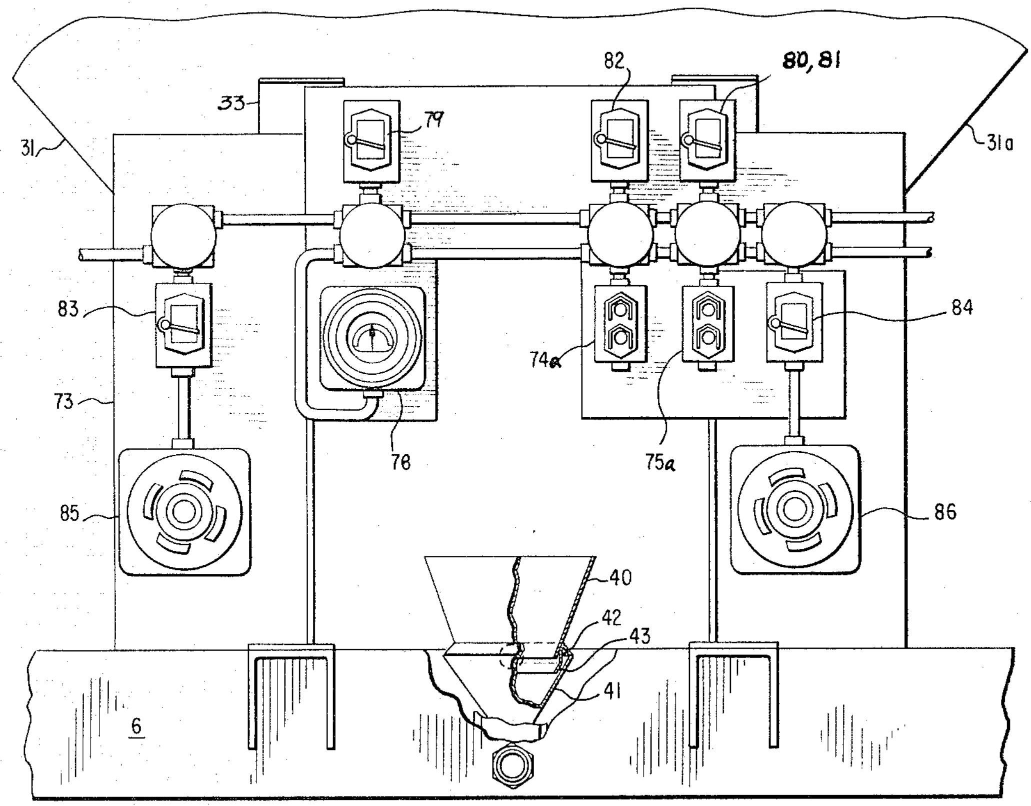


FIG. 2

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METHOD FOR MIXING AND PUMPING OF SLURRY EXPLOSIVE

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FIG 3

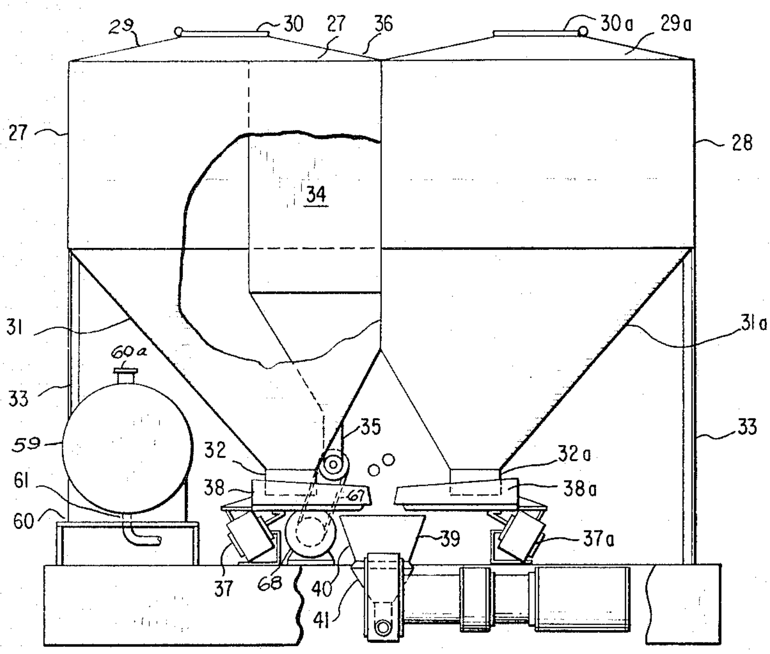
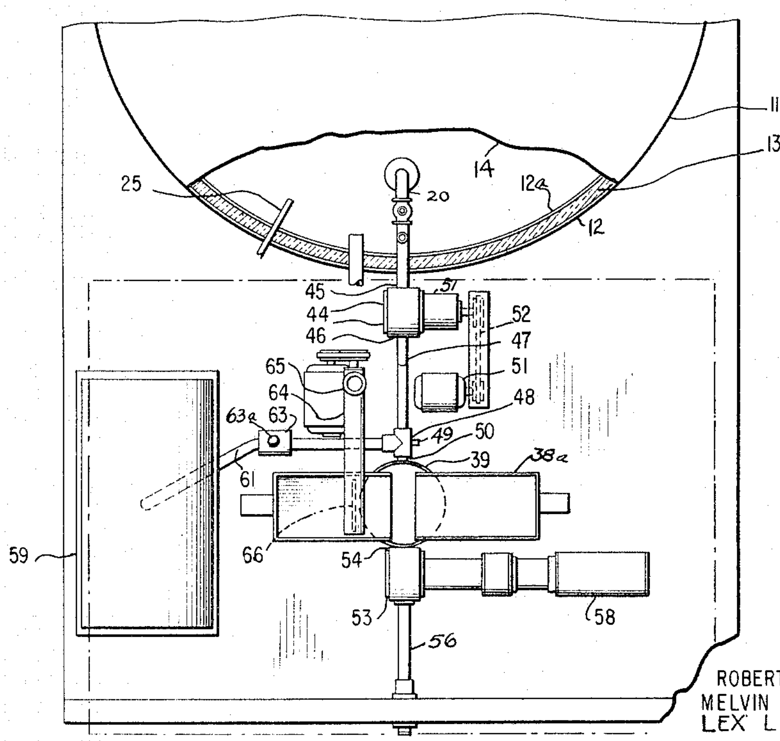


FIG 4



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METHOD FOR MIXING AND PUMPING OF SLURRY EXPLOSIVE

Filed June 2, 1965 4 Sheets-Sheet 3

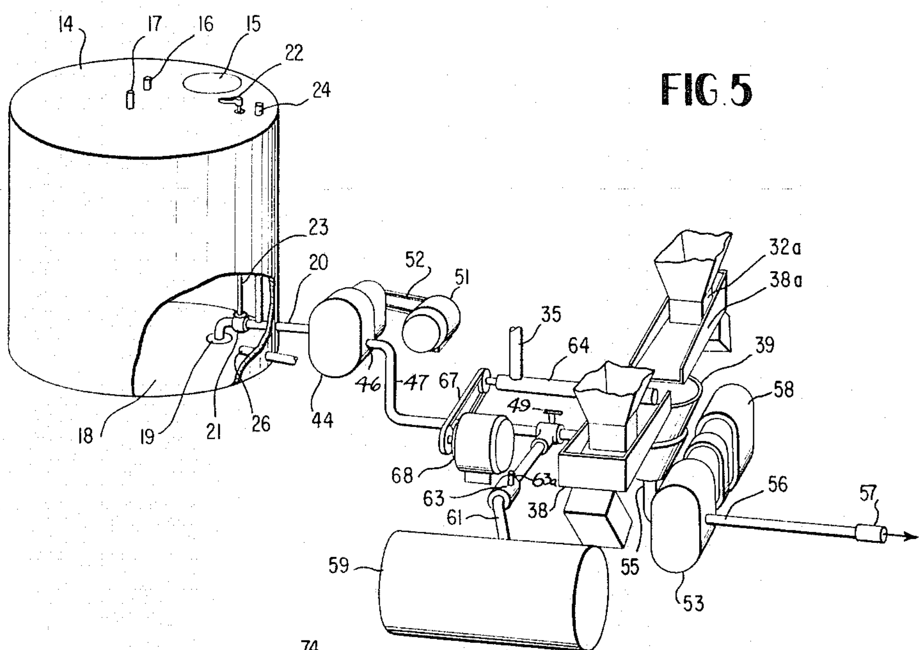

FIG 5

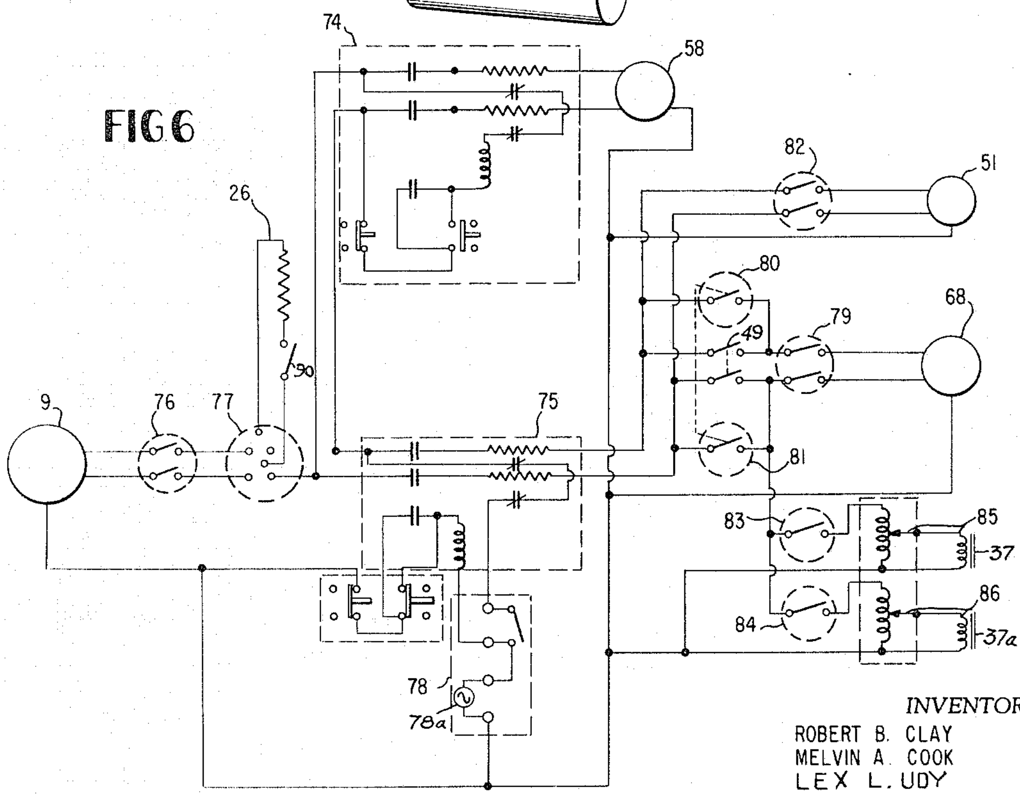

FIG 6

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METHOD FOR MIXING AND PUMPING OF SLURRY EXPLOSIVE

Filed June 2, 1965 4 Sheets-Sheet 4

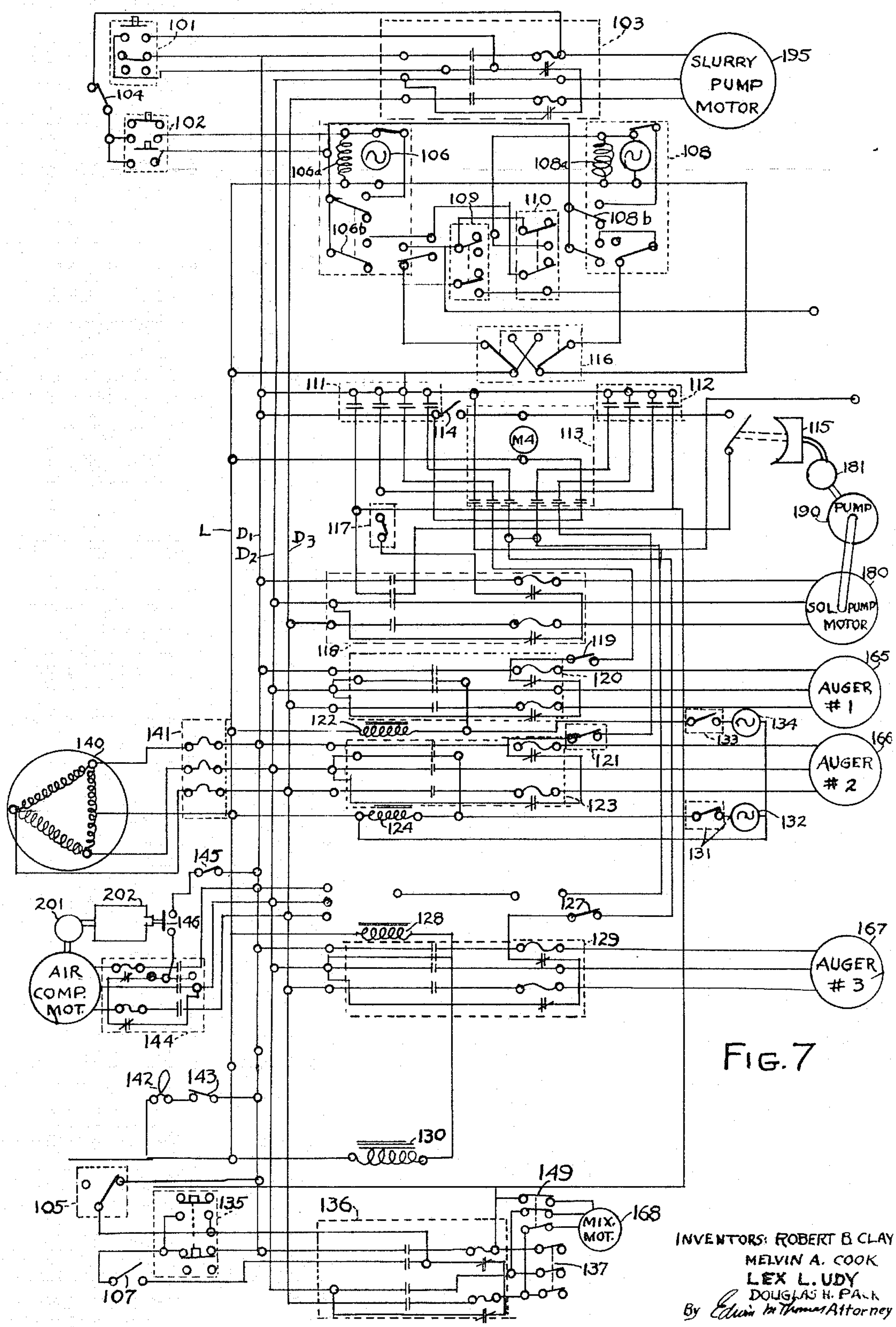

FIG. 7

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3,303,738
METHOD FOR MIXING AND PUMPING OF SLURRY EXPLOSIVE

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Filed June 2, 1965, Ser. No. 460,792
25 Claims. (Cl. 86—20)

This application is a continuation-in-part of application Serial No. 315,908, filed October 14, 1963, now abandoned.

The present invention relates to a system for mixing and pumping of slurry explosives. It relates, more particularly, to a self-contained mix-pump truck or truck system having means for on-site mixing of ingredients into a slurry explosive and also having means for immediate delivery of the slurry explosive to one or more boreholes, or other blasting sites, together with a method for mixing and delivering the same. The invention also comprises improved methods for controlling and varying the mix during single operations.

Slurry blasting agents, such as those described in Cook and Farnam U.S. Patent No. 2,930,695 and U.S. Reissue Patent No. 25,695, have enjoyed wide acceptance because of their low cost, low hazard sensitivity, high bulk strength and high dependability. This invention provides both a safer and a more economical method and apparatus for the safe preparation and delivery of such blasting agents at and to the blasting site.

It has been proposed hitherto that blasting agents of a type which can be pumped for large operations could be delivered effectively to the boreholes by a pumping method. Known methods of pumping such explosives, however, generally have involved (1) manufacture of the slurry explosive in a plant, (2) transporting the explosive to the site of use, (3) pumping the slurry explosive by mechanical or pneumatic means to the point of application. In some cases dry ingredients and liquids have been combined and dumped together into the blasting hole. Many different types of units have been proposed for pumping a fluid or flowable explosive into boreholes, including holes containing ground water. Generally speaking, all of these units that have encountered water conditions in the boreholes have not met with real success. The use of such pumping units in small diameter boreholes and in underground mines wherein water was not encountered, has been accomplished, but such operations generally have not been economical.

It is recognized that a successful pumping application for pumpable explosives must satisfy several conditions: (1) The slurry explosive must be readily pumpable without ingredient separation or stratification; (2) once in the borehole a slurry explosive must be relatively unaffected, i.e. not leached out or washed away, by running water. These two conditions are somewhat mutually contradictory and often diametrically opposed to each other. If the slurry is mixed or manufactured in a plant so as to have a sufficiently thin consistency to be easily pumped, the slurry is so thin that it has very poor resistance to water and undissolved components will readily separate. With high liquid content the mix may not be sensitive enough to be economically detonable. On the other hand, if the slurry is manufactured so as to have good resistance to water in the blasting hole, the mixture becomes extremely difficult to pump.

It has been suggested further that the above two conditions might be easily resolved by maintaining a plant-manufactured slurry at sufficiently high temperature that it could be pumped into the borehole where it would

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thereafter partially solidify. However, there are several objections to this proposal. For example, (1) the high temperatures necessary for fluidity may be above the melting point of certain ingredients which should remain solid. The sensitizer used may be one of these. Moreover, heating to a fairly high temperature may also render the composition unduly sensitive. (2) The low viscosity of plant manufactured explosive slurry held at high temperatures allows the solid particulate sensitizers to become quickly segregated, e.g. by gravity, from the solution. This not only yields non-uniform mixes, but frequently will result in misfires or partially detonated explosive masses, leaving unexploded materials in boreholes as a hazard for future operations.

While various attempts have been made to pump a plant manufactured slurry that would meet these conditions and still be economically feasible, as far as it is known at the present time, no proposed method other than that described in the parent application mentioned above, has been commercially successful or received widespread acceptance.

It is, therefore, the principal object of the present invention to provide a method and apparatus for the effective on-site mixing and delivery of a slurry blasting agent.

It is another object of the present invention to provide a method and apparatus for the mixing of a liquid, e.g. cold or hot water, or aqueous solution of an oxidizer, with a sensitizer which is not dissolved and with other modifying components, and pumping the resulting slurry to the bottom of a borehole in a few seconds before there is time for segregation of the several components by settling.

It is a further object of the present invention to provide a method and an apparatus or system for continuously and uniformly mixing on-site the ingredients of a slurry explosive and then quickly pumping the slurry into the boreholes. In some cases, absolute continuity of operation may not be essential. Uniformity or completeness of mixing, of course, is highly desirable.

A still further and important object methodwise, is to make it possible to change or vary the mix, either continuously or stepwise, while it is being pumped.

It is a further object of the present invention to provide a novel and improved mix-pump vehicle or vehicle system, for on-site mixing and pumping of slurry explosives.

A characteristic feature of the preparation method of the invention resides in mixing up the explosive composition at or close to the site of the borehole. This has the advantages of eliminating: (1) Any need for a special mixing plant. (2) The expense and danger of transporting the completed explosive to a desired location. (3) Need of packaging the explosive mixture for handling, although packaging may be done if desired. (4) Much of the manpower otherwise necessary to load the explosive into the bottom of the borehole.

By using certain sensitizers, such as aluminum or other non-explosive metals and fuels, the hazards of handling the finished explosive compositions are substantially completely eliminated since the raw ingredients, generally speaking, are not explosive by themselves. Only after the various ingredients are mixed and combined together does the composition become detonatable. Since this mixing takes place at or close to the location where the explosive will be used, and in relatively small quantities in the mixing unit (in many cases the largest mass of finished explosive may still be below the critical diameter or mass at which the composition will detonate), there is virtually no explosive hazard. The method of the present invention encompasses the preparation of certain combinations of raw materials which per se are not detonable explosives. In fact, they may be prepared and handled in such a way that they cannot ordinarily be set off until they are actually in the borehole.

One form of apparatus for carrying out the aforementioned method consists of a self-contained mixing and pumping vehicle. This vehicle comprises a frame having mounted thereon one or more tanks for liquids, preferably including an oxidizer solution tank, and at least one and preferably a plurality of storage bins for dry ingreditents. Underneath the discharge openings of the storage bin or bins are provided suitable feeders, such as augers, vibrators, or other types of feeders for uniformly and controllably delivering the dry ingredients to means for blending. The ingredients are delivered to a mixing station. This station may be of any suitable form, such as a funnel which is connected with a flow line to the oxidizer solution tank. A solution pump is provided which is preferably a constant rate pump, e.g. of the positive displacement type. The wet and dry ingredients are blended into a slurry and the resulting slurry, formed preferably right in the mixing funnel or station, is then further conveyed to a suitable delivery pump. The latter is preferably but not always necessarily a positive displacement slurry pump. It pumps the slurry through a delivery hose directly to the boreholes.

The apparatus in preferred form is controlled by a completely automatic control system which enables presetting of the mixing ratios and control over the whole pumping process to insure that predetermined quantities of the slurry are properly mixed in the right proportions and pumped immediately to the boreholes.

The mobile mixing and pumping unit described in this particular embodiment of the invention makes it possible to transport the separate and individually non-hazardous ingredients of an explosive composition from one or more supply sources to the point of use and then facilitates the combining of these ingredients in the field in a unique and efficient manner. Because some of the ingredients dissolve best at elevated temperature, the equipment is so arranged that the explosive may safely be mixed and dispensed at a fairly high temperature. The necessary heat is applied to the heated oxidizer solution. The latter is preferably an aqueous ammonium nitrate solution but may comprise other materials. The resulting slurry explosive is sufficiently fluid that it may be easily pumped through the delivery device, e.g. a hose to the borehole. There, the material may thicken appreciably, e.g. to form a gel, even a thick or substantially solid gel. Under some circumstances the slurry actually solidifies quite quickly in the borehole as it comes in contact with the cold rock.

Some of the advantages of this pumping method can be summarized as follows:

(1) The several feeding and dispensing devices permit efficient bulk handling of the dry ingredients as well as the oxidizer solution and/or other liquid.

(2) Separate operations of slurry packaging, storing and/or transporting and loading into boreholes are thereby eliminated.

(3) The low viscosity of the slurry as freshly mixed permits the pumping directly into the borehole to be conducted through a small diameter delivery hose. This enables small diameter boreholes to be easily filled to substantially 100% of borehole volume.

(4) The slurry normally has some resistance of its own to dilution by extraneous waters but if it is desired to obtain complete water resistance for a long period of time, a thin-walled flexible plastic tube or sock can be slipped over the end of the hose. This may be pushed to the bottom of the borehole and then pumped full of the slurry explosive to fill the borehole to the height desired.

Other objects and advantages of the present invention will be apparent upon reference to the accompanying description when taken in conjunction with the following drawings, wherein:

FIGURE 1 is an overall small scale perspective view of the mixer-pumper vehicle looking at the front thereof;

FIGURE 2 is a rear elevational view on a larger scale, of the vehicle of FIGURE 1, showing the control panel;

FIGURE 3 is a rear view of the vehicle with the control panel removed to show the bins, vibrator feeders and mixing funnel;

FIGURE 4 is a top plan of the vehicle showing only a portion of the solution tank and layout of the components;

FIGURE 5 is an overall perspective view, showing somewhat schematically, the arrangement of the various components for mixing of the ingredients into the slurry and then delivering the slurry;

FIGURE 6 shows diagrammatically the electrical control circuit for the components illustrated in FIGURE 5;

FIGURE 7 shows an alternative system diagrammatically by wiring diagram and schematic apparatus elements.

With reference to the drawings wherein like reference symbols indicate the same parts throughout the various views, specific embodiments of this invention will be described in detail. As can best be seen in FIGURE 1, the mobile mixer-pumper unit of this particular form of the invention comprises more or less conventional automotive truck **1** with a frame **2** upon which are mounted a conventional cab **3** and engine hood **4**. Rearwardly of the cab is a body frame **5*a*** supporting a platform **5.** The rear ends of the truck frame **2** are closed by a rear channel piece **6**. On the front of the truck between a bumper **7** and the hood **4**, is mounted a front platform **8.** Upon the latter is secured an electrical generator **9**, suitably a 7–10 kilowatt single or multi-phase electrical generator which is driven by an engine **10**, such as a diesel engine, so that the engine and generator form a complete power unit. Alternatively, such a generator may be driven by power take-off from the truck engine.

If desired, the energy for heating, dispensing, mixing and pumping may be supplied from other outside sources such as electric power means. Suitable electric or fuel-fed heaters or steam sources may be used to supply heat. Separate prime movers, etc., may be provided for the mixing and pumping functions. Pneumatic or hydraulic systems may be used if desired for operating moving parts where needed. Such frequently have the advantage of increased safety around explosive and combustible materials.

Immediately behind the cab there is mounted on the platform **5** a liquid tank **11** of large capacity. This is a tank suitable for holding an aqueous oxidizer solution. Preferably it is constructed of stainless steel or other corrosion resistant material suitable for hot solutions of nitrate salts. The tank, as shown, is essentially cylindrical in shape and comprises an outer wall **12**, and an inner wall **12*a*** of fiber glass or stainless steel, for example. The latter may have a thickness of about ¼ inch or less and there is insulation material **13** between the inner and outer walls of the tank. The top **14** of the tank is provided with a manhole opening **15**, a fill pipe **16**, and an air vent **17**. The tank preferably is adapted to be heated and it may contain a mixer for preparation of oxidizer solution such as saturated aqueous ammonium nitrate. In some cases heat may not be necessary. The arrangement is such that a fairly large supply of hot liquid may be kept available for extended operations.

The bottom of the solution tank **11**, indicated at **18**, is shown as provided with a sump **19** from which extends an outlet pipe **20**. The outlet pipe has a suitable valve, here shown as a ball valve **21**, which is controllable by appropriate means. As shown, a control handle **22** is provided on the upper end of an extension **23**. A water pipe **24** which can be used for flushing passes vertically downwardly through the tank and connects to the outlet pipe **20**.

Located in the side wall of the solution tank in the vicinity of the outlet pipe, is a thermometer 25, FIG. 4, and an electric resistance heater unit 26 which is controlled by a thermostat switch.

Positioned behind the solution tank in side-by-side relationship in the form shown in the drawings, are two bins 27 and 28. Each is adapted for holding one or more dry ingredients to be used in the slurry explosive. The tops 29 and 29*a* of the bins each have openings 30 and 30*a* therein. Each bin has a sloping bottom 31 and 31*a* with a discharge opening 32 and 32*a* at the lower extremity of the respective sloping bottom. The bins are firmly mounted on the frame in a suitable manner, being suitably reinforced or braced as by vertical braces 33.

Bin 27, as shown, has a separate compartment 34 built therein for containing a further or separate dry ingredient, such as a gel forming component or thickener. Compartment 34 has a discharge opening 35 at the bottom. The top 36 of compartment 34 preferably has a suitable lid or door, not shown, which can be opened to permit filling of the compartment.

Positioned beneath the bin discharge openings 32 and 32*a* are devices for feeding and dispensing dry material at a predetermined and controlled rate. As shown, some of these devices are vibrator feeders 37 and 37*a* which can be adjusted to vary their flow rates. Each of them has a tray 38 or 38*a* provided with a removable gate. These gates are located immediately beneath the bin discharge openings to receive the dry ingredients therefrom. The discharge ends of the vibrator feeder trays 38 and 38*a* are directed toward each other to uniformly deliver the dry ingredients to receiving means 39 located between them and substantially at the center of the vehicle frame, as can be seen in the drawings.

The receiving means just mentioned comprise a mixing funnel 39 which includes a conical upper funnel portion 40, FIG. 2, nesting into the upper end of another conical lower funnel portion 41. The top edge of the lower funnel portion 41 is bent over inwardly to form an annular chamber 42 with the extreme end of the top being bent downwardly and parallel with the inner surface of the lower funnel portion. The lower funnel is spaced outwardly from the upper, as shown at 43. The space 43 (usually on the order of a fraction of an inch) is designed to keep the wet and dry ingredients from mixing prematurely and then adhering to the surface of the upper funnel. Accordingly, the arrangement prevents any accumulation of semi-wet ingredients on the funnel walls. The arrangement largely eliminates blocking of the funnel which might otherwise occur.

A pump is provided for dispensing the oxidizer liquid from the tank at a precisely controllable rate. The pump preferably is a positive displacement solution pump 44 having a built-in relief valve. Since the pump is also a metering device, it must be so designed that its feed rate can be controlled accurately, independent of the height of liquid and consequent static liquid pressure in tank 11. The pump has its inlet 45 connected to the outlet pipe 20 of the solution tank. The pump also is provided with an outlet 46 which is connected to a tubular conduit 47 bent downwardly and connected to a cross or modified T 48. To the latter is connected a pressure actuated switch 49, FIG. 5, of a known commercial type for actuating the vibrator feeders to control the flow of the dry ingredients. See also FIG. 6. This may be a diaphragm operated switch which does not close a circuit until a desired pressure is imposed on the diaphragm. A pipe 50 then connects the cross or T 48 to the annular chamber or space 42 between the upper and lower mixing funnels. The function of switch 49 is to make sure that the dry materials normally are not fed to the upper funnel until the solution is being pumped into the lower section of the funnel. This prevents building up deposits of wet solids on the walls of the equipment.

The solution pump 44 is driven preferably by an explosion proof motor 51. The latter is drivingly connected to the pump by a static proof V-belt drive enclosed within a belt guard 52, FIG. 5. The liquid is forcibly injected into the lower funnel for rapid and complete mixing with solids falling from the upper funnel.

Mounted near the rear pump of the truck frame 2 and between the frame members is a final and main dispensing slurry pump 53. It is shown here as a positive displacement pump. This is the pump that delivers the slurry to the point of use or to a point of packaging if the material is to be packaged. It also has a built-in relief valve not shown. The slurry pump 53 has its inlet 54 connected to the discharge outlet 55 of the mixing funnel. The slurry pump is further provided with an outlet 56 which leads to a quick detachable coupling 57 for rapid and convenient hose connection. The latter may be mounted in the rear channel piece 6 of the truck frame. A high pressure delivery hose is preferred and which is wire countered and kink-proof. Such hose is connected to the quick detachable coupling 57 and serves to deliver the slurry explosive to the point of use. The hose can be removed readily when the system is not dispensing explosive.

The slurry pump 53, as shown herein, is powered by a suitable drive, preferably a variable speed drive unit. This drive is indicated at 58 and includes, preferably, an explosion proof motor.

In addition to the main tank for oxidizer solution, a water tank 59 is provided for a supply of hot water. The water tank may be supported separately on the body platform 5 as shown herein or it may be incorporated within or otherwise closely associated with the larger tank 11. The hot water tank, FIG. 3, is provided with a filler cap on the top thereof. At the bottom there is an outlet 61 connected through pipe or hose 62 to the T or cross 48 previously mentioned. A control valve is connected to the outlet line 61. When the hot water tank is located within the solution tank 11, as is desirable sometimes for convenient heating, the connections will be appropriately modified. An access 60*a* to the top of the water tank of conventional type is shown.

A water circulating pump 63, powered by an explosion-proof motor, is connected with the outlet hose or line 61 to pump the water from the tank. A valve 63*a* is provided also and the arrangement is such that the pump can run without delivering water when valve 63*a* is closed. The water supply is normally used for rinsing and cleaning the equipment before or after regular mixing operations. However, water may be added during mixing if desired, or other liquids such as liquid fuels, e.g. glycol, formamide, etc. may be supplied from tank 59. Where the tank arrangement permits feed can be accomplished by gravity flow, and such a pump is not always necessary. A pump has the advantage, however, of providing a more accurate control of flow rate. This is important for ingredients used in the mix.

Connected to a dry ingredient compartment discharge opening or outlet 35 is an auger feed device 64 enclosed in a tubular housing. The auger and its housing may be of either a suitable plastic or a metal construction. The auger takes material from the discharge 35 to the upper funnel 40 directly or via vibrator tray 38 if desired. At the delivery end of the auger housing, on the undersurface thereof, is located a longitudinal discharge slot 66, FIG. 4. The slot 66 opens just above the vibrator feed tray 38 which functions to uniformly distribute the material fed thereby. Material such as guar gum which is a galacto-mannan material or any other suitable solid particulate ingredient may be delivered into the tray. The auger feed preferably is powered by a variable speed drive 67. This also is driven by an explosion proof motor 68. By varying the drive speed, the proportions of this particular dry ingredient may be varied as desired.

In order to insure accurate predetermined flow rates for all the vibratory and auger feeders and the pumps, the vehicle is desirably provided with leveling means. For this purpose the engine of the truck is provided with a power take-off for driving a conventional hydraulic pump, not shown. The pump supplies fluid to a hydraulic system which communicates with two hydraulic leveling cylinders. One of these is shown at **70**. The leveling devices are located immediately behind the rear wheels of the truck and are suspended from the rear channel member **6**. The lower ends of the leveling cylinders are provided with swivel end members or feet **72** to provide a firm footing on uneven ground. In some cases, the leveling means may not be essential.

Suitable controls are provided for the various pumps and feeding devices so that the feed rate for each ingredient may be closely regulated. As shown in FIGURE 2, the primary controls are located at the rear of the truck, between the sloping bottoms of the bins **27** and **28** and the truck frame **2**. An electric control panel is indicated at **73**, which is secured against the vertical braces **33**. Most of the primary controls for the whole feeding system described herein are located on this panel. The preferred arrangement is such that the solution pump cuts off at the same time as the dry material feeders but the residual liquid in the line continues to flow very briefly after the dry ingredients stop. This is sufficient to flush them down.

The electrical control system is illustrated in FIGURE 6 and contains conventional units interconnected to obtain the proper relationship between the operations of the several components of a truck. All of the wiring for the control system is in explosion proof conduits. Explosion proof junction boxes are also used.

With the exception of the generator **9**, a slurry pump magnetic starter **74** located near the slurry pump motor, an ingredient control magnetic starter **75** located near the solution pump motor **51**, and the pressure actuated switch **49** on the conduit leading from the solution pump to the mixing funnel, most of the components of the control system are located on the electrical control panel **73**, in the form shown in FIGURES 1 to 6. These other components include a main circuit breaker **76** in line with the generator **9** and a double pole double throw switch **77** to connect the heater **26** (in the tank **11**) across the generator. There is a first timer unit **78**, including a synchronous motor **78a**, connected to the ingredient control magnetic starter unit **75**. A switch **79** is connected between the pressure actuated switch **49**, controlled by liquid pressure, and the auger motor **68**. In normal operation, the auger **64** cannot start delivering dry materials until liquid has started flowing into the lower funnel **41**. Calibration by-passes **80** and **81** are connected across the pressure actuated switch **49**. These make it possible to dispense dry material without solution, e.g. for calibration purposes. Ordinarily, the dry ingredients do not start feeding until liquid is flowing and they are stopped before liquid ceases to flow. This prevents building up pasty deposits on the walls of the funnels and other parts.

A control switch **82** is provided for the solution pump motor **51**. The vibrator feeders which supply other dry materials such as metal particles, granular fuels, etc. are energized at appropriate times by switches **83** and **84**. The rates of vibration of the vibrator feeds can be adjusted by suitable means, shown herein as Variacs or rheostats **85** and **86**. By these means, the feed rates of the various solids can be closely controlled. As noted above, auger feeds and the like can be used with or in lieu of the vibrators if desired, to dispense the dry, solid materials. In some cases, augers have been successfully substituted for all the vibrator elements. They are more positive in operation.

OPERATION

The operation of this mixer-pumper system essentially comprises three phases, each of which will be described in detail:

(a) Charging
(b) Calibration
(c) On-site operation

(a) *Charging.*—The mix-pump unit is prepared for charging by first turning off the truck engine and by assuring that at least one grounding chain is in contact with the ground. After checking to assure that the solution tank valve **21** is closed, that the hot water valve is closed, and that gates, where used, are closed on the vibrator feeder trays, the hatches and filling pipes are opened, taking care not to admit any foreign matter. Appropriate quantities of oxidizer solution, sensitizer material, thickener material and hot water for flushing are then brought into the respective tanks and bins. For a typical slurry blasting agent, typical charges would be—

Charge weights

Ingredients	Percent	Weights (lb.)
Ammonium Nitrate Liquor*	75.0	18,750
TNT Pellets	24.0	6,000
Guar Flour	1.0	250
	100.0	25,000

*In a typical case, ammonium nitrate liquid should be 84.0% strength ammonium nitrate. For hot slurry operation it may be at a temperature of about 170° F.±5° F. Actual weights of ammonium nitrate and water in the specific case above are ammonium nitrate equals 15,750 pounds and water equals 3,000 pounds. Total equals 18,750 pounds.

Alternatively, finely divided aluminum may be used in lieu of or in addition to TNT and other materials such as pulverized coal or gilsonite, nitrocellulose, etc. may be used. Sugar is a useful fuel for some situations.

The filling pipes and hatches are then closed, and the generator **9** is started. The solution tank heater **26** may be turned on, if needed to maintain temperature when hot slurry is to be used, and the hot water circulation pump, where one is employed, is also energized. This pump can run idly without delivering water until valve **63a** is opened.

(b) *Calibration.*—Prior to commencing calibration, the mix-pump truck should be preferably leveled by use of the hydraulic leveling cylinders **70**, particularly if the truck is on a slope. For a first operating formula flow rates in a typical case may be about as shown below:

Flow rates

Ingredients	Percent	Lb./Min.
Ammonium Nitrate Liquor (63.0 AN) (12.0 H_2O)	75.0	375.0
TNT Pellets	24.0	120.0
Guar Flour	1.0	5.0
	100.0	500.0

As indicated previously, the formulas may be varied widely. For example, a solution of ammonium nitrate, plus dry particulate ammonium nitrate, particulate aluminum, gelling agent, inhibitor for preventing premature reaction between aluminum and hot water, and solid or liquid fuel may be used. Sodium nitrate may be substituted in part or even fully for the solids ammonium nitrate or for that in solution, or for some in both places. Other ingredients such as inorganic chlorates and perchlorates may be employed.

If the solution pump **44** varies from the desired flow rate, the guar flour and other solid ingredient flow rates may be adjusted to compensate or the pump **44** itself may be adjusted, proportionately, to obtain proper relative rates.

The generator is checked to assure that a proper voltage is being delivered and that a standard desired frequency, e.g. 60 cycles±5% is being obtained.

The ammonium nitrate liquid pump (solution pump 44) is preferably calibrated by running hot water through it and determining accurately, e.g. by weighing, the amount of water delivered in a measured period of time. The vibrator feeders **37** and **37***a* are then independently calibrated by weighing their respective outputs per unit of time. The auger feed **64** is similarly calibrated by catching its output in a tared bag and then weighing it. As noted above, all these units are designed for adjustment of feed rates.

After completion of the foregoing calibration steps, the apparatus is then prepared for normal working operation. This is done by turning off the calibration by-pass switches **80**, **81**, FIGURE 6, and then turning on the switches **82** to the solution pump, **83**, **84** to the vibrator feeders and **79** to the auger feed, etc. and by turning on the heaters. See switch **90**. This calibration may be carried out at either a mixing plant or at the site where the explosives are to be mixed and pumped into boreholes. If carried out at a mixing plant the hydraulic leveling cylinders normally will not be used and in any case they should be inactivated or raised before driving the truck to the blasting site.

(c) *On-site operation.*—At the site, the following conditions should exist before commencing operation.

At least one grounding chain should be touching the ground;

The generator, the heater (if used), and the water circulating pump (when used, i.e. to keep lines hot, etc.), should be turned on;

The truck engine should be running, only if hydraulic mechanism or power take-off is needed. Otherwise, it is shut off.

The calibration by-pass switches are turned off;

The solution pump switch and the vibrator and/or auger feeder switches are turned on;

The slurry or delivery pump switch and the main solid ingredient feed switch will be off;

The valve in the hot water flush line should be closed;

The ammonium nitrate liquor valve **21** inside the solution tank will be closed until ready for operation.

The mix-pump truck is first leveled, if necessary, by use of the hydraulic leveling cylinders **70**, etc. The vibrator feeder tray gates are next removed or opened so that the dry ingredients can flow during operation. The water flush valve is then opened to pump a few gallons of hot water through the entire ammonium nitrate liquor and slurry pipe system. This is done to warm up the system and it may be desirable also for a rinsing. The delivery hose is then inserted in the borehole. The timer **78** can be set for any desired operational time, up to say three minutes, or more if desired. The amount of slurry to be pumped into the particular borehole is precalculated and timer **78** is set to run the unit for a sufficient length of time to pump that amount of material. If the borehole contains water the hose should be pushed first to the bottom of the borehole and is then retracted about 6 inches. The main switch **77** is turned from heater position to operation position because, ordinarily, heating is not continued during operation. For long continued operations, however, the heater can be kept on by appropriate and obvious modification of switch **77**.

After the calculated pumping time for the desired weight of explosive is preset into the timer **78**, the slurry delivery pump **53** is started and then the solution pump **44** is turned on. The dry ingredient feed is then started immediately after solution begins to flow into the lower funnel, so that the slurry explosive will be mixed and pumped directly into the borehole until the set time has elapsed. The dry ingredient feed system will then automatically stop and the solution pump will stop at the end of the timed cycle, but the slurry pump will continue to operate to empty the funnel **41** and clear the delivery line **56**.

As the ammonium nitrate solution is pumped by the positive displacement solution pump **44**, the solution will actuate the pressure switch **49**. This will start the flow of the dry ingredients. Dry ingredients of course may be mixed into one or more of the bins **27**, **28**, and additional bins with either vibratory or auger feeders may be used. With some solids, simple gravity flow can be used. If aluminum is used, one dispenser may be used for it, otherwise both vibrators may be used to dispense TNT or TNT-ammonium nitrate mixtures. This operation will continue until the timer **78** has turned off the dry material feeds and the solution pump. After the dispensing hose is emptied of slurry, and removed from the column of explosive, hot water may be admitted into the mixing funnel to flush the system. After flushing, the slurry pump is turned off. Several boreholes may be loaded in turn without interim flushing if the interruption is short.

Other slurry blasting agents which may be mixed and loaded with the apparatus of the invention include those based on ammonium nitrate plus sodium nitrate, and/or chlorates, perchlorates and other oxidizers. These ingredients may be supplied either dry or in solution; solid fuels such as gilsonite, starch, sulfur, urea, sugar, coal dust may be used. Thickeners such as guar gum and/or startch and heat or energy producing metals such as aluminum, magnesium and/or ferrophosphorus may be added. Explosive sensitizers such as the various types of smokeless powders, TNT, and other equivalent materials may be employed. Liquid fuels, such as ethylene glycol, propylene glycol and the like may be added, either in the solution tank or separately. Typical slurries which have been used include the following (all parts by weight):

	TNT	Solution			Guar Gum	Aluminum	Potato Starch	Gilsonite	Sulfur	Inorganic Nitrate
		Ammonium Nitrate	H_2O	Sodium Nitrate						
A	20	50	12	0	1	0	0	0	5	12
B	10	66	13	0	1	10	0	0	0	------
C	0	46	13	0	1	20	0	0	0	20
D	0	60	15	10	1	9	1	2	2	------

In aluminized slurry explosives it is often desirable to use a suitable stabilizer to prevent premature aluminum-water reaction. Such is known in the art.

Typical charges per borehole may be in the range of 100 to 1500 pounds of blasting agent. The unit is preferably designed to mix and deliver slurry at the rate of about 300 to 600 pounds per minute though lower or higher rates may be used. The dispensing hose is preferably long enough that a number of boreholes can be filled from one location without moving the truck.

An advantage of the present invention not stressed above resides in the provision for heating the liquid solution. By this means slurries which are too insensitive to be detonated when cold often can be used effectively. In large boreholes the hot slurry requires some time to reach ambient temperature. Accordingly it can be fired while still at a somewhat elevated temperature. Detonation of the slurry in any case is preferably accomplished by suitable explosive boosters, since aqueous slurries based on ammonium nitrate as primary oxidizer are not usually cap-sensitive or Primacord sensitive.

A special advantage of this invention which requires emphasis is the fact that the mixing station, such as funnel assembly **39**, **41** can and should be kept substantially empty at all times. In other words, the discharge pump or slurry pump **53** has adequate capacity to prevent any large build-up of slurry ahead of this pump. This tends to reduce explosion hazards and also avoids difficulties in handling the slurry. Otherwise slurry in the funnel would tend to set up prematurely or its components tend to separate. It is possible, however, to operate with some inventory in the funnel, or to make the funnel larger, purposely, so as to form a reserve of prepared slurry, by so operating the slurry delivery pump as to permit accumulation of an inventory. This can be done when the consistency of the slurry in the funnel is such that particulate materials will not settle out by gravity. At the same time, the slurry pump should not have such excessive capacity as to pull substantial amounts of air into the slurry as it is delivered. Large air masses cause discontinuities in the explosive in the borehole. Should there be water in the hole, large quantities of air cause foaming or turbulence which may leach out and destroy the desired gel structure of the explosive. This gel structure gives protection against excessive dilution by ground waters.

The above mentioned difficulties due to pumping air are avoided by equipping the pump **53** with an air by-pass valve of conventional type. However, it is desirable to keep slurry above the inlet to the pump at all times and this can be done by adjusting the delivery rate so that it does not substantially exceed the slurry manufacture rate.

The system described in FIGURES 1 to 6, inclusive, has been found in practice to be highly successful. A particular feature in the process involves the formation of a relatively quick setting gel, which will now be discussed.

A thickening agent which sets up fairly rapidly is usually included in the composition. It may be predissolved, if desired, or added dry. In the procedure described above, it is usually added dry. The reasons for thickening the slurry to a gel are several. A gel resists water penetration and leaching of soluble components, such as ammonium nitrate, etc., out of the slurry in the borehole. In addition, by thickening the slurry, segregation of undissolved particles of sensitizers and/or fuels is prevented or greatly reduced. Particles of metallic aluminum, of TNT, smokeless powder, coal, gilsonite and the like tend to separate by gravity. The thickening agent preferably is one which sets up at least to some extent by the time the slurry reaches the borehole, but does not set up so rapidly as to interfere with pumping the slurry through the delivery hose.

Guar gum, preferably ground rather finely, or socalled guar flour, is a particularly suitable thickener for the purposes just described. However, other thickeners such as starches and flours and related materials may be used. Some of these have fuel value as well as thickening power. For the purposes of the present invention, the important point is that the slurry be thickened in time and sufficiently to prevent substantial water leaching in wet boreholes and to prevent substantial separation or stratification of undissolved constituents. The thickening effect should be delayed sufficiently that the slurry or gel can be delivered by pumping through a delivery hose without undue difficulty.

Referring now to FIGURE 7, there is shown a modification wherein the bins or hoppers (not shown) for dry ingredients are each provided with motor driven augers. These are each equipped with explosion proof motors shown respectively at **165**, **166** and **167**. While three are shown, the number of feeding augers, like the number of supply bins for dry ingredients, may be varied as desired. When there are more dry ingredients to be used than there are hoppers and feeding devices, some of them can be

combined by premixing. Soluble solids, where used, can be predissolved into the main liquid solution. The latter is usually a concentrated solution of ammonium nitrate or ammonium nitrate combined with sodium nitrate in water, or in water containing a compatible liquid fuel such as an alcohol, glycol, amine or amide, etc. In the modification of FIGURE 7 a mechanical mixing device of conventional type is used at the mixing station. The mixer is not shown but is driven by an appropriate motor **168** which is indicated. A solution pump, indicated diagrammatically at **190** is also driven by an explosion proof motor **180**. A suitable pressure responsive unit **181** is provided for operating a switch closing mechanism **115** when liquid pressure builds up to a desired level.

A slurry delivery pump, not shown, but analogous in all respects to the pump **53**, FIGURE 5, is driven by a motor **195**, shown at the top of FIGURE 7. The slurry pump is also a mixer and mixing continues through the delivery hose, due to shear and wall friction.

A plurality of timer units **106** and **108** are provided in the system of FIGURE 7. A timer operating for three minutes allows the pump truck to charge about 1200 to 1500 pounds slurry explosive into a borehole without interruption. For many operations this is sufficient. For very deep or large boreholes, or wherever a larger batch is needed, the plural timers can be set to operate sequentially so that a continuous mixing and pumping cycle of up to six minutes duration may be obtained.

The arrangement is such also that the individual rates of feed for the liquid solution pump and for each of the dry ingredient feeders **165**, **166** and **167** can be varied. They may be operated also so that one or more of the dry ingredient feeders will operate during only part of the cycle.

Frequently, in blasting operations, particularly where the boreholes are deep and where massive quantities of rock are to be broken up, it is desirable to use a more powerful explosive in the bottom of the borehole and a less powerful or less expensive composition in the top portion. The apparatus of this invention makes this possible. The operator can vary at will any of the component feeders. Thus a composition may include more aluminum or more granular TNT, etc., at the bottom of the hole, and less at the top. Or the slurry mix may be a stiffer slurry, to compensate for water in the borehole at the bottom and be more dilute, i.e. include more water at or towards the top. By manipulating the controls and the timers, the desired mixes may be stopped and started so as to change compositions at any point in the borehole filling operation.

The apparatus of FIGURE 7 also includes an air compressor **201** and a receiver **202**. Compressed air is thus available for various purposes and, if desired, a suppily of the slurry may be stored in a tank (not shown) and expelled therefrom through an outlet line by using compressed air as the propellant.

In the system shown in FIGURE 7, a three phase generator **140** is driven by a suitable prime mover, not shown. It may be driven by power take-off from the truck motor, or it may have its own separate motor, as in the case of the apparatus of FIGURE 1.

Power from the generator **140** passes through a main circuit breaker **141** to distributor lines D_1, D_2, and D_3. From the latter it is distributed through control devices to the various motors that drive the feeders, mixer, and pumps, as already described.

A start-stop switch station **101** controls the slurry pump. A timing start-stop station **102** supplies power to the timers **106** and **108**. Timer **106** ordinarily operates first and if the batch is not a large one, it will start and stop the whole batch mixing operation. Only if a batch is so large that mixing and delivery time exceeds the time capacity of timer **106** (in the production of one mixture) will timer **108** come into operation. In this case, feeding, mixing and slurry pumping will continue until the full batch is mixed and timer **108** will stop the operation that timer **106** initiated. Electromagnetic coils **106***a* and **108***a*, respectively, operate switches **106***b* and **108***b* for this purpose.

Operation of the augers by motors **165**, **166**, **167**, respectively, is controlled by auger sequence and timer control by means of elements **109** and **110**. Unit **109** can be energized by closing switch **106***b* through a line L and the motor starter unit **120**. A bin vibrator unit **122**, is included in FIGURE 7 and can be energized by the same means and employed with the auger #1 driven by motor **165**. This vibrator thus insures that the material will feed into the auger. By means of auger reversing switch **116**, which reverses the auger-timer relationship, auger #2, driven by motor **166**, can be reversed in time relationship with auger #1. Motor **166** is controlled by motor starter **123**. Power for these controls comes through pressure switch unit **113** under control of liquid pressure supplied by pump **190**. Ordinarily, the solids feeders cannot operate until the pressure switch unit is activated. This prevents feeding dry solids into the mixer before there is liquid present. For calibration purposes, however, the pressure switch unit can be by-passed by means of a manually operated bypass switch **114**. Relays **111** and **112** supply power to the timers **106** and **108**, respectively.

A switch **117** controls power to the motor starter **118** for the solution pump motor **180**. Bin vibrator units **124**, **128** and **130** are operated in the same manner as similar unit **122**. Motor **167** which operates auger #3 is under control of magnetic starter **129**. Manual switches **119**, **121**, and **127** are provided respectively for bringing the respective auger motors **165**, **166**, and **167** into or out of operation.

A switch **115** is directly operated by the liquid pressure when pump **190** starts to operate. The closing of switch **115** activates the relay unit **113**, bringing the latter under timer control, i.e. under timer **106** or **108**.

A timer totalizer **132**, under control of a switch **131**, is provided for auger #2 and a similar totalizer **134**, under control of switch **133**, for auger #1. The arrangement of the auger controls is such that they can be operated together or independently. By appropriate setting of timers **106** and **108**, either of them can be cut in or cut out at a predetermined point in the cycle. Thus, the composition of the mix being pumped into a borehole can be changed at any point in the batch cycle, by a presetting of the timers **106** and **108**.

The third unit, or auger #3, driven by motor **167**, is not provided with a time totalizer although it may be if desired. Control of augers #1 and #2 gives adequate flexibility for most situations.

Other controls which need not be explained in detail include a plug outlet **135** for auxiliaries, if needed, a spare motor starter unit **136**, which can be used for mixer motor **168** if desired, a main circuit breaker **141**, a signal light **142** to indicate availability of power, and air compressor controls including the compressor contactor **144**, on-off switch **145**, and pressure cut-off switch **146** associated with the receiver **202**.

A manually operable mixer switch is shown at **105** by means of which the mixer can be turned on or off as needed. In many cases the turbulence of the liquid and of the dry solids as they come together, plus the mixing at the pump and through the delivery hose is quite adequate. The slurry delivery pump and hose are not indicated in FIGURE 7 but these are essentially the same as the parts shown in the previous figures.

The whole arangement is such that the feed rates of liquid and of solids by the several augers or other feeders for solid materials can be predetermined, preset and controlled with precision. Either auger #1 or #2, or both, can be cut in or cut out at any point in the batch cycle, to change the composition and get a different mix with precision control. The time, in the batch cycle, at which the change is made, also can be predetermined and controlled precisely. The composition can be changed more than once in each borehole, if desired. Thus, in filling a borehole, the bottom half, or some other fraction, can be filled with composition containing more of ingredient A than the upper part or parts or an ingredient B may be cut off entirely at a predetermined point and/or another ingredient C started or stopped. Similar controls, not shown, also can be applied to the liquid supply so that a wetter slurry can be brought in on top or vice versa.

An important aspect of this invention is its control over the degree or rate of thickening of the gel or slurry in the blasting site. Thickening should occur at such a rate and to such a degree as to prevent gravitational separation of suspended solids after mixing ceases. The suspended solids, of various types as previously mentioned, may be insoluble by nature, as is the case with aluminum, TNT, nitrocellulose (smokeless powder), etc. in aqueous slurries, or they may be only insoluble at the moment because the solution is oversaturated, e.g. when a saturated solution mixed at elevated temperature is cooled substantially. In the latter case, the solids coming out of solution and crystallizing will necessarily add to the undissolved particulate solids present and thus will thicken the gel or slurry suspension. By using a delayed action thickener, i.e. one which does not instantly or immediately cause substantial or full thickening but is effective a few seconds or moments later, the gel or slurry may be pumped into the borehole or other blasting site while quite fluid or non-viscous. By appropriate choice of solution temperature, as compared with site temperature, and by use of the appropriate solvent(s) and solute, and/or by choice of appropriate type and quantity of thickener, the gel or slurry can be pumped thin and still set up or thicken enough to substantially inhibit separation of the solid particles when the material becomes quiescent in the site or borehole.

The delivery conduit, usually a tubular hose, although a pipe may be used if desired, is preferably of such diameter or capacity relative to the capacity of the slurry pump (delivery pump) that effective mixing of liquid and suspended solids continuous throughout the full length of the conduit and all during the pumping operation. There is thus essentially no stratification or separation, segregation, aggregation, agglomeration, etc. of solids possible until the slurry is in the blasting site. By insuring that the viscosity or thickness of the slurry will increase sufficiently by the time of actual delivery to the borehole (or very soon thereafter) it is not difficult to hold the solids quite effectively in proper suspension. Further cooling or setting which may continue to occur, e.g. in a borehole, will only enhance stability of the blasting agent against gravitational separation or segregation.

It will be understood, of course, that it is highly desirable that the gel or slurry composition be reasonably homogenous in the macro-sense, although of course it is quite heterogeneous in the true physical and chemical sense. Some heterogeneity, even in the coarse or macro-sense, is unavoidable in many cases, especially where the solid particles are large or vary considerably in size but a reasonable uniformity throughout the charge is needed. This does not preclude the possibility, and strong desirability in some instances, of changing proportions or ingredients or both while a borehole is being filled. Such may be very desirable, as previously pointed out. However, a grossly uneven distribution of solids within a given section of borehole is to be avoided.

In normal and preferred use, the pumper-mixer apparatus is employed to mix ingredients at the site and deliver them directly into boreholes. One borehole after another is filled, a delivery hose long enough to reach several holes (and reach to the bottom of each hole) preferably being employed. In fact it is customary and desirable to have a hose several hundred feet long so that the apparatus can be used where mining regulations require substantial distances between explosive loading vehicles and mine equipment.

It is possible, however, to use the equipment to fill tubes or packages and various kinds of containers for further transport when conditions require it. Experience has shown that the method is so much more efficient than prior methods and so susceptible of good control that it is highly desirable to mix and fill at the blasting operation. The cost of transporting materials that are not explosive per se is less than that for explosives. Special and expensive transportation of the latter is largely eliminated by the present procedure.

It will be obvious to those skilled in the art that the invention is capable of numerous variations, modifications, embodiments and applications without departing from the spirit thereof. It is intended by the claims that follow to cover all such as broadly as the prior art properly permits.

We claim:

1. The method of preparing and placing an explosive gel or slurry in a blasting site, which comprises, in combination, the steps of feeding together simultaneously materials which when combined form a gel or slurry explosive composition and which include a liquid solution containing oxidizing salt and particulate matter including particles which are insoluble in said liquid and subject to oxidation by said salt and also normally subject to gravity separation from said liquid, including in said mixture a sufficient quantity of a delayed action thickening agent to prevent such separation when the agent becomes effective, continuously mixing the liquid and particulate matter together and forcibly pumping the resulting slurry mixture to the site while continuing the mixing, and timing the placement in the site so that substantial thickening takes place by the time said placement is accomplished, thereby to substantially inhibit said gravity separation of particulate matter in the site.

2. The method of preparing and delivering to a blasting site a flowable mass of gel or slurry type blasting agent, which comprises, in combination, the steps of feeding together simultaneously a liquid solution containing oxidizer salt, a particulate solid material which comprises oxidizable particles and is normally susceptible to gravity separation from said liquid, and a delayed action thickening agent in sufficient quantity to prevent said gravity separation when the agent becomes effective, mixing the ingredients together as they are fed to form a relatively unthickened explosive gel or slurry and placing the mixture in the site, such placing being accomplished at a time when sufficient thickening has taken place to substantially inhibit said gravity separation in the site.

3. Method according to claim 1 wherein the material is forced into the site through a delivery tube in which substantial and continued mixing takes place.

4. Method according to claim 1 wherein the mixture is formed at a temperature above that at the site whereby cooling in the site increases the viscosity of the gel or slurry.

5. The method of preparing and placing an effective blasting gel or slurry in a blasting site which comprises, in combination, the steps of feeding together and simultaneously mixing a liquid which contains dissolved oxidizer material and is at elevated temperature with particulate solids including sensitizer materials and including particles not soluble in the liquid and having a normal tendency to separate from said liquid by gravity, including in the mixture a means to cause a thickening effect and thereby to inhibit said gravity separation, and delivering the mixture to the site while continuing mixing said delivery being so timed with respect to the thickening effect that gravitational separation of solids in the slurry is substantially prevented after the slurry reaches the blasting site.

6. Method according to claim 5 wherein the thickener is of delayed action type and does not become fully effective until delivery is substantially accomplished.

7. Method according to claim 5 wherein temperature of the mixture is made substantially higher than the site temperature so that cooling contribute substantially to thickening of the gel or slurry in the blasting site.

8. Method according to claim 5 wherein the mixture is at higher temperature than the site and includes liquid soluble materials which come out of solution upon cooling and contribute substantially to thickening at the site.

9. A method for preparing and delivering a gel or slurry blasting agent to a point of use which comprises the steps of delivering a concentrated liquid solution of an oxidizer salt at a predetermined controlled rate to a mixing point, simultaneously adding solid particulate material which includes particles insoluble in said liquid some at least of which are susceptible to oxidation by said salt to the liquid at said mixing point also at a predetermined rate, said particulate material being of different specific gravity from said liquid, forcing the mixture to flow from the mixing point to said point of use while mixing is continued, and promptly causing sufficient thickening of the slurry to take place at the point of use to substantially inhibit gravity separation of particulate material while at the point of use.

10. Method according to claim 9 wherein there is added to the mixture a thickening agent of delayed action which does not thicken so rapidly as to substantially impede said forcing but thickens at a sufficient rate to become substantially effective by the time the slurry is in place at the point of use.

11. Method according to claim 9 wherein an ingredient of the solution is caused to separate out in time to effect substantial thickening at the point of use.

12. In a method for mixing and delivering a slurry blasting agent the improvement which comprises maintaining separate supplies of an aqueous concentrated solution of oxidizer and a dry solid non-explosive sensitizer containing particles not soluble in said solution, separately but simultaneously delivering said oxidizer solution and said sensitizer to a mixing conduit at individually predetermined and controlled rates, said mixing conduit having a diameter smaller than the critical diameter necessary for detonation of the resulting blasting agent, and while mixing is continued delivering the slurry to a borehole having a diameter in excess of said critical diameter whereby a detonable blasting agent is present only in the borehole.

13. Method according to claim 12 wherein the aqueous concentrated solution is heated.

14. In a method for mixing and delivering to a blasting site a slurry or gel blasting agent, the improvement which comprises essentially simultaneously (1) metering a liquid including an oxidizer from a source of supply to a mixing point and (2) metering particulate solid material including particles not soluble in said liquid from a source of supply to said mixing point, forming at said mixing point an explosive mixture of higher temperature than that at the blasting site and having a given critical diameter, immediately pumping the mixture through a conduit of subcritical diameter substantially as fast as it is formed while continuing mixing in the conduit, and preventing substantial gravity separation of the insoluble particles by allowing the delivered mixture to thicken due to cooling in the blasting site.

15. Method according to claim 14 wherein a thickening agent is added to the mixture to further inhibit gravity separation of the particles.

16. The method of blasting in a borehole, which comprises selectively and separately feeding to a mixing point ingredients which include (1) a liquid solution of oxidizer material and (2) particulate solids which have a gravitational tendency to separate from said solution when suspended therein, said ingredients including such fuel and

sensitizer materials as to form an explosive slurry when combined, mixing said ingredients together to form a relatively unthickened explosive slurry at the mixing point, forcibly pumping said relatively unthickned slurry from said point directly to the borehole before substantial gravitational separation of said solids occurs, and so controlling the ingredients selectively fed and mixed as aforesaid as to cause a substantial thickening of the slurry to occur when the slurry reaches the borehole, such thickening being effective to substantially prevent gravitational separation of the solids in the borehole.

17. Method according to claim **16** wherein substantial thickening of the slurry in the borehole is caused by cooling the mixture in the borehole below its mixing temperature.

18. Method according to claim **16** wherein substantial thickening in the borehole is caused by adding to the mixture a delayed action thickener which becomes effective by the time the slurry is in the borehole.

19. Method according to claim **16** wherein the composition of the mix is changed during filling of the borehole and without interruption of the pumping.

20. The method of blasting which comprises the steps of continuously feeding a fluid or plastic slurry blasting agent of predetermined and pumpable composition into the deepest part of a borehole, causing the agent to thicken as it reaches the borehole and changing the composition of the agent to alter its blasting properties to a predetermined degree while continuing uninterrupted filling of the borehole.

21. The method of slurry blasting with mobile slurry blasting agent which comprises selectively combining materials which include liquid oxidizer and fuel components to make a pumpable blasting agent, continuously pumping first a more powerful fluid and pumpable slurry blasting agent, to the bottom part of a borehole and changing the composition of said agent to a less powerful but predetermined composition while continuing filling by pumping the changed composition into the borehole in physical continuation of the first composition.

22. The method of preparing a gel or slurry type explosive composition which comprises mixing, in predetermined proportions, a liquid solution containing a powerful

inorganic oxidizer salt which is non-explosive per se with predetermined proportions of a dry particulate ingredient which is insoluble at least to some extent in the said liquid solution and is subject to gravitational separation therefrom, incorporating into the mixture a viscosity increasing agent for said liquid solution, pumping the mixture through a restrictive conduit to a blasting site before said agent becomes so fully effective as to make such pumping impracticable, and controlling the timing of the pumping and of incorporating the viscosity improving agent so that said agent acts to increase the viscosity of the slurry or gel after it is in place in the blasting site to a degree sufficient substantially to prevent gravitational separation of the undissolved components in said blasting site.

23. Method according to claim **22**, wherein the agent comprises a galacto-mannan material such as guar gum.

24. Method according to claim **22**, wherein explosive particles per se are included in the dry ingredient.

25. Method according to claim **22**, wherein the dry ingredient includes aluminum powder.

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