SYSTEM FOR PRODUCING A BLENDED FLUID EXPLOSIVE COMPOSITION

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The present invention relates to a system for producing a blended fluid explosive composition. More specifically, it relates to a method and an apparatus or plant for producing slurrying type explosive compositions for use in blasting operations. Still more particularly, it pertains to a system, including method and apparatus, for blending a liquid component with one or more dry components in the manner to produce a safe, but powerful and efficient explosive material in the form of a liquid slurry which is sufficiently fluid that it can be poured into receptacles and/or into bore holes. The first named or liquid component preferably either includes originally or is later combined with an inorganic oxygen-supplying material prior to incorporation of dry ingredients useful as sensitizers, fuels, etc. This oxygen-supplying material should be water soluble to a very considerable degree. Ammonium nitrate is usually preferred as the water soluble, although it may consist of a blend of ammonium nitrate and sodium nitrate. In some cases the latter may be used to the exclusion of the ammonium nitrate for certain special compositions. In general, the liquid starting material is usually a solvent, such as water, or a solution of a salt, such as a concentrated aqueous solution of a highly soluble salt which is a potent component of the final blasting agent. However, other types of liquids than water or aqueous solutions may sometimes be employed since the apparatus and the process are applicable to various materials.

The invention particularly contemplates equipment and methods for making charges of flowing liquid-like explosive material which emerge as fluent though often viscous liquid slurries. These slurries may be produced by combining a concentrated solution of an oxygen supplying salt, such as ammonium nitrate, with suitable sensitizers and/or fuels. For example, in U.S. Patent No. 2,930,685 to Cook et al., there is described and claimed an explosive composition of this general type which comprises ammonium nitrate, water and trinitrotoluene (TNT) as a sensitizer. As set forth in said patent, certain other materials also may be included. While the present invention relates rather to equipment and to a process, and is not limited to the production of particular compositions, it will be understood that this invention contemplates the production of explosive materials such as those described in the Cook et al. patent above identified. It also relates to a system and process for making other compositions including some which have departed from prior concepts, e.g., substitution of other components. Preferably, however, all such compositions are sufficiently plastic or fluid that they will flow at least slowly, so that they may properly be described as fluid or slurred explosives.

One difficulty that has been encountered in the past in production of compositions of this type involves the bringing together and the proper mixing of the respective components. For maximum safety, it is desirable that the separate ingredients be kept apart for as much of the time as is convenient. By combining sensitizers and/or fuels with oxidizers at the latest practical moment it is possible to substantially reduce explosion hazards. Obviously, materials of the type described above could be mixed in very large batches for high plant efficiency but for safety reasons this is not desirable. Obviously, there is always possibility around powerful explosives of a mishap which might detonate a charge. The explosion of such large masses, or even a remote portion of such detonation, would be extremely dangerous. An explosion if it occurred, would be devastating. Hence, mixing in large batch mixers comparable to those used for mixing concrete, for example, is considered highly undesirable and usually impractical. One object of the present invention is, therefore, to make such batch mixing unnecessary.

Another difficulty which has arisen in the past in preparation of explosive compositions of this type, involves the lack of homogeneity or consistency from the beginning to the end of a particular batch or charge. If dry solids are first dispersed, then to be joined later by liquid, it is quite difficult to obtain any degree of homogeneity without excessive mixing. Prolonged or energetic mixing of explosive ingredients, of course, is hazardous and is preferably avoided or at least minimized. One object of the present invention is to render unnecessary to mix dry ingredients in an energetic or vigorous manner that might lead to an explosion. Gentle mixing is made possible by an effective control over the order and rate at which various components are brought together.

A particular aspect of the present invention involves the production of fluid explosives in relatively small batches. These batches are small and relatively safe and each batch can be loaded into a tube or package of reasonably safe dimensions. For example, if a batch of explosives weighing 20 to 100 pounds, specifically about 50 pounds, is mixed up and dispensed into a bag and then removed from the equipment, the explosion hazard of such an unconfined charge is not unreasonable. The hazard would be much greater if the batch were many times as large. Obviously, however, in large scale production, it is desirable to be able to produce modest sized packages rapidly in succession for economical and near-continuous production is necessary to take care of requirements for large scale blasting operations. To accomplish such production with reasonable safety is another object of the present invention.

Explosive compositions of the general characteristics referred to above frequently involve different ingredients having widely varying specific gravities. If sufficient water or aqueous solution is present to make a very dilute mix, there is likely to be considerable separation and segregation of the various components, due to their differences in specific gravity. To avoid such settling or separation, it is desirable to be able to mix a given batch quickly and in such a manner that settling does not occur during the mixing. It is also essential that the material be so processed, packed and/or thickened that the settling and separation of components is not likely to occur after the mixing. To prevent settling and separation during the mixing of the composition, while the slurry is of thin consistency, it is obviously necessary to have a certain minimum amount of mixing or turbulence imparted to the various ingredients. To prevent settling thereafter it is equally necessary that the finished composition attain such viscosity or stiffness as to resist substantial separation of its components due to gravity. A further object of this invention is to accomplish this.

Combining various ingredients, wet and dry, to make an explosive composition of the character to which this invention relates, involves necessarily certain hazards. It is frequently desirable to add ingredients, usually in dry
form, which in themselves are powerful explosives, such as trinitrotoluene (TNT), smokeless powder (cellulose nitrate) and the like. In cases where these materials can be finely subdivided, the problem of destruction separating from a slurry is obviously less serious than when they are or must be incorporated in larger particles or pieces. A typical slurry composition, for example, may have an overall specific gravity of about 1.3. Smokeless powder, on the other hand, has a specific gravity of about 1.6. Where fine fraction smokeless powder or the TNT, etc. should be subdivided as finely as is consistent with economy of preparation and safety of operation.

Another and particular difficulty that is encountered in mixing liquid materials with dry ingredients is that of lack of physical homogeneity. There is frequently a tendency for a portion of the charge to be unduly liquid or "sloppy" whereas other parts of the same charge tend to be too thick or stiff for good fluidity. This obviously contributes to settling or segregation of suspended particles, which is very objectionable. The present invention contemplates that this tendency can be overcome by feeding to a mixing zone the liquid components slightly ahead of the dry ingredients and regulating the rate of addition of dry ingredients in such a manner that a given charge is produced with uniform consistency from top to bottom. In a gradual change in composition from one end of a single charge or package to the other may be desired. This invention makes it possible to produce such a result consistently when desired.

In adding dry ingredients to a system of this type, to which this invention pertains, there is also a tendency for the ingredients, particularly when they fall some distance, e.g., due to gravity, to classify themselves into different particle sizes. It is usually quite objectionable, from a standpoint of homogeneity and of quality in general, to have parts of a given batch or charge filled with components of grain or particle size substantially different from those in other parts of the same batch or charge. The present invention makes it possible to overcome this tendency by a simple, safe and efficient mixing procedure. The present process also makes it possible to obtain a relatively dry mix, when desired. Thereby it becomes possible to reduce the proportions of water or of aqueous solution so as to obtain maximum power in the final product.

For special uses, it is frequently desirable to vary the proportions of a particular ingredient, or, in some cases, of several ingredients, in a part of a batch. For example, consider a long charge to be placed in a bore hole. It may be desirable to have relatively high or hard brittleness properties at one end of the charge and softer brittleness at another. Other properties, such as heat content, etc., may desirably be varied progressively from one part of a charge or package to another. The present invention makes it possible to accomplish these variations by simple adjustments of the feed rates of the various components which are supplied to the mixing zone.

Various other objects will appear and features to achieve them are incorporated in the present invention. These will be more apparent as a detailed description proceeds. The invention, for example, contemplates increased safety of the equipment over prior art equipment by pressurizing pneumatically those areas or elements of apparatus where, otherwise, finely divided explosive materials might tend to accumulate and build up dangerous depositions.

The invention further contemplates relatively simple segregation and automatic control of the proportions of the several ingredients which are combined into the final explosive slurry composition. Features for these purposes include separate hoppers or analogous containers for a number of dry ingredients with variable dispensing means for each such container. It also includes variable flow rate control means for the liquid component or components, including automatic control means for starting and stopping the flow of liquid in accurately timed relation to the starting and stoppage of flow of one or more of the dry or solid ingredients. As will be explained in further detail below, this sort of control contributes to the satisfactory and rapid production of uniform or purposely graded or controlled non-uniform mixes. It will be understood that the term "uniform" as here used, does not necessarily mean that a given charge is completely homogeneous or perfectly uniform in chemical composition at any instant of separation, or from one extreme of a charge or package to another. It may indeed be continuously or gradually variable in one or more of its ingredients, but within the limits imposed by the granular character of the ingredients which make up the solids in a slurry, it is obviously desirable that the material have a good degree of homogeneity at any given point or cross section. For example, in an elongated column or package of the composition there is good homogeneity or uniformity in the macro-particle sense at least, at any given cross section. The present invention has a particular object of accomplishing such homogeneity or uniformity.

The invention, then, will be more fully understood by reference to the accompanying drawings and a detailed description of the particular physical embodiment therein illustrated. In such drawings:

FIGURE 1 is a vertical sectional view, with certain parts cut away and certain parts omitted, of a presently preferred apparatus or mechanical system for carrying out the present invention.

FIGURE 2 represents a detailed wiring diagram, showing controls for various of the elements of mechanical equipment illustrated in FIGURE 1.

FIGURE 3 is another wiring diagram, generally similar to a portion of FIGURE 2, showing certain modifications in the equipment, particularly in the electrical control elements.

FIGURE 4 is a horizontal cross sectional view with certain parts omitted, taken substantially on the line 4-4 of FIGURE 1 and looking downward as indicated by the line 4-4 of FIGURE 1.

FIGURE 5 is a sectional view, showing a part of the apparatus, taken substantially on the line 5-5 or FIGURE 1 and looking upwardly as indicated by the arrows.

FIGURE 6 is a detail perspective view, showing one of the dispensing elements for feeding dry ingredients from one of the hoppers.

Referring first to FIGURE 1, there is disclosed an apparatus which may have a substantial framework, which is not shown, for supporting the solid and liquid ingredients, etc. Any suitable framing may be used, which will be obvious to those skilled in the art. Thus a foundation structure with vertical posts or columns, not shown may be provided to support the element frame member 10 which, in turn, supports a flared or funnel receptacle element 11 which is adapted to underlie and receive ingredients from a number of hoppers 13, 15, 17 and 19. As seen in FIGURE 4, there are preferably a considerable number of dry ingredient feeding units, eight of them being shown specifically. However, the number may be obviously varied as desired. In this particular embodiment with eight hoppers, 13, 15, etc., four are visible in FIGURE 1.

Each of the hoppers 13, 15, etc. has an outlet tube 16a its bottom indicated at 23, 25, 27 and 29 respectively. Each of these tubes joins a receiving trough 31, 33, 35, 37, etc. which is secured to or associated with the appropriate tube or downcomer 23, etc., in such a manner that dry ingredients do not flow unless the trough is moved or vibrated. Hence, under ordinary conditions, the ingredients, such as dry TNT, granular or ammonium nitrate salt or sodium nitrate salt for example, or sulfur or smokeless powder etc., will not flow at all from any of the hoppers unless there is an intentional vibration or movement of the associated trough.

Associated with each of the feed troughs 31, 33, etc.
is an electrically operated vibrating mechanism. These mechanisms are indicated respectively at 41, 43, 45 and 47 in FIGURE 1. One of them, 41, is shown in detail in FIGURE 6. The vibrator device 41 in FIGURE 6 is of commercial design and forms, so, no part of the present invention. It consists of an electro-mechanical vibrator box operating on the solenoid principle, indicated at 48, power being supplied from a source not shown in FIGURES 1 or 6 to leads 49 to cause the support plate 50 which is attached to the trough 31 to vibrate at a suitable frequency, for example, 60 cycles per second. The particular frequency is a matter of choice depending on the type of electrical power available and any suitable vibration speed within the limits of 10 to 100 or more cycles per second is quite satisfactory.

As indicated above, each of the dispensing troughs 31, etc. is attached to a tube 23 or 25 etc. in such a manner that solids will not flow simply by gravity but still flow only when the trough is vibrated. The rate of flow depends primarily on the amplitude of the vibrator which can be varied at will as explained below. The angle of inclination of each trough can be varied somewhat, depending on the particular ingredients involved, but usually runs between about 5° and 20° of slope.

The outlet of each trough 31, 33 etc. is open, as indicated at 53 for trough 31 at the right of FIGURE 1. This open end overlies the funnel 11 which receives the dry ingredients from all the various hoppers 13, 15, 17, 23, 25 etc., through the downward sloping troughs 31, 33 etc. Hence, when any of these troughs is vibrated, ingredients from the appropriate hopper are spilled into the funnel 11.

The walls of the funnel 11 are preferably sloped steeply enough that all ingredients will slide freely down them. However, in case a broad funnel is needed, e.g., for multiple hoppers, or in connection with particular types of solids such as finely divided powders which do not slide freely, it may be desirable under some circumstances to attach one or more vibrators to the wall of the funnel. Such vibrators may be of the same general type as that shown in FIGURE 6.

As noted above, the funnel 11 is supported in the transverse frame member 10, where it is clamped in suitable fashion for rigid support. The hoppers 13, 15, etc., with their appended outlet and vibrator means, may be built in as a single unit, or may have separate frame member supports, as desired. Below the frame member 10 there is provided a tubular mixing vessel 61.

This vessel or receptacle 61 constitutes a mixing zone. Mounted above the funnel on suitable support means, not shown, is a powerful mixing drive comprising a motor 63, a shaft 65, an impeller or mixing head, unit 67. The mixer 67 operates in the lower part of the receptacle 61. It can be adjusted in height and its propeller-shaped blades are so constructed as to cause a circulatory movement of ingredients from the center of the bottom of the receptacle outwardly and upwardly as indicated by the arrows. A suitable closure valve 71, is pivotally mounted on a transverse shaft 73 which is appropriately supported in suitable journal elements, not shown. This valve can be closed to hold the ingredients, including liquid, in the bottom of the receptacle 61. The valve is shown in its closed position in full lines but it can be opened as indicated by the dotted lines to discharge the contents of the receptacle to a receiving tube 75 below.

The receptacle 61 is mounted in frames elements 77, 78, and the tube 75 below is mounted on or in a transverse frame. Although not shown, the tube 75 which projects below the valve is designed to receive a suitable bag or tube for packaging the slurry explosive in unit packages or charges. Such charges, as noted above, may vary between about 20 and 100 pounds each.

Means are provided for feeding liquids into the receptacle 61, two such devices being shown. In the usual types of slurry compositions a single liquid, such as a concentrated aqueous solution of ammonium nitrate, is all that is used. However, for some types of compositions, it may be desirable to add two, three, or even more liquid components. One or more of these may be a fuel such as a hydrocarbon oil, or a carbohydrate solution, an alcohol, etc. For this purpose, additional dispensing units for liquids may be employed although not shown in the drawings. At the right of FIG. 1 is shown a main liquid dispenser, indicated generally at 80. It comprises a liquid receptacle 81 and a circulating pump 83, preferably of the centrifugal type having an inlet 82 connected to the bottom of the tank 81. A recycle line 87 is provided so that when one or more of the valves in the line 95, such as shown at 89, 91 are closed, the liquid in the receptacle will simply recycle to the tank 81.

The valve 89 is preferably adapted for a variable setting. Hence it constitutes a metering device so that the flow rate of liquid, e.g., water or aqueous solution of an oxidizer salt, may be accurately controlled. Valve 91, on the other hand, is an open-shunt type valve which either is fully opened or fully closed. When fully open, the feed rate of liquid through the tube 95 which leads from the receptacle 61 is controlled entirely by the adjustment or setting of the metering valve 83. When valve 83 is closed, the by-pass line 89 makes it possible to maintain a rather accurately uniform pressure head on the liquid in line 95, regardless of the liquid level in tank 81.

A somewhat simpler dispensing unit for a secondary liquid is shown at the left, comprising a supply tank or vessel 101, a pump 103, a variable orifice valve 105 and an open-shunt valve 107. Both the valves 91 and 107 are adapted to be operated automatically. Where a pneumatic source is available they may be preferably operated by compressed air, under control of an electric solenoid of known type. These controls are shown only diagrammatically, respectively, at 108 and 109. Operating power is supplied to them by appropriate means, not shown. Here again, the pump 103 tends to maintain an even pressure head on the liquid line 110a, independent of liquid level in tank 101.

Each of the vibrator units 41 has a variable control for its amplitude of vibration. This is indicated in FIGURE 6 by the pointer 110 which can be adjusted to vary the rate of feed of dry materials through the particular tube and trough with which the vibrator is associated. Hence, by setting the pointers 110 on the various vibrators to appropriate settings the feed rates of the various ingredients in the respective hoppers 13, 15, 17, 23, 25, etc., may be accurately adjusted.

In addition, the control supplies means by which valve 91 (and 107 when the latter is used) is opened and closed may be operated to open the valve at any desired instant.

In most cases the liquid valve should open before the solid ingredients begin to flow. This arrangement makes it possible to start the liquid feed into the mixer vessel 61 at any desired instant. The reason for preferring to open the liquid valve first is to insure that there will be full and adequate mixing of the liquid and solid components, particularly at the bottom of vessel 61. If the solid ingredients start to flow first, with liquid being added later, it has generally been found very difficult in practice to get full and adequate mixing of solids and liquids at the bottom of the vessel 61. On the other hand, when liquid flow starts first the solids can flow into the small body of liquid which is already in circulation at the bottom of the vessel, due to the operation of the impeller 67. This impeller may be raised or lowered to suit as near the bottom of the receptacle (as the bottom is defined by the closed valve 71), as may be desirable, to insure appropriate circulation and mixing of the ingredients.

In a batch type operation, then, the main liquid from vessel 81 preferably starts to flow a short time interval
before the solid ingredients begin to move into the funnel 11. The latter are dispensed, each at the appropriate individual rate, and they fall by gravity through the funnel 11 into the receptacle 61. There they meet the down-flowing primary liquid flow 8, e.g., a concentrated aqueous solution of ammonium nitrate from tube 95. The latter liquid may be injected as a spray, if desired, to keep the solids washed down the sides of the vessel. The mixing action of the impeller 67 is usually adequate to insure a homogeneous charge throughout the mass which accumulates in vessel 61 before the valve 71 opens.

If desired, mixing may be continued after valve 71 is opened or partially opened. This makes it possible to start feeding a batch through tube 75 into a suitable receptacle or container, or alternatively directly to a bore hole where it is to be used, before all the ingredients have reached vessel 61. Thereafter, when desired, the operator may vary the composition of the charge as it flows through the valve 71, by changing proportions or adding or cutting off certain components. Hence by changing the feed rate at particular vibrators 41, etc., varying the intensity or amplitude of the vibration of one or more of the vibrator units 41, etc., the composition may be varied from bottom to top as it enters a package or a bore hole.

The mixing device 67 may be of any suitable type. A commercial mixer known as the "Lightning Mixer," operating at about 300 r.p.m., is quite satisfactory. However, any mixing device that uses appropriate circulation at modest velocities and which is not unduly productive of friction and hence dangerous, may be employed. The device preferably has an overload release, not shown, for its driving clutch to cut off power in the case the consistency of the mixture around the impeller becomes too great for relatively low friction operation. This, of course, is a safety precaution.

Ordinarily, in operating the mixing plant, the butterfly valve 71 is kept closed until the batch is fully mixed. It is then opened fully and the charge, for example, of about 50 pounds weight, flows by gravity into tube 75 and on into the receiver. In a typical operation, a 50 pound bag may be mixed in about 6 seconds, giving a plant capacity about 500 pounds of slurry per minute. During such a short mixing period, there is generally little or no noticeable thickening of the composition, even though further slurry thickening in the final state is usually essential. Ordinarily, slurry type explosive mixes of the character for which this invention is particularly designed include a thickening agent. This agent is usually added as a dry ingredient in the form of a dry starch or gum. Guar gum is frequently preferred and one of the hoppers 13 or 15, etc., ordinarily will contain a supply of this material. If guar gum is not used, another thickener will replace it, as a rule. During the normally short mixing period of about 6 seconds, as noted above, there is little or no noticeable thickening of the slurry. Thickening usually begins very soon, however, e.g., within about 15 seconds from the time the thickener is mixed with the liquid. After a period of about 2 minutes a typical batch fed from tube 75 into the eventual receptacle or bag, etc., will be pretty well thickened, reaching something like 90% of its final consistency, in this time period. At such consistency the slurry is quite stable, mechanically. That is to say there is little tendency for solid ingredients to separate from the liquid or from each other and segregate by gravity. By using small proportions of the thickener, in a typical case about 1/4 to 1% of guar gum, based on the weight of the total mixture, adequate thickening of the slurry in a very short time is secured. This is adequate to prevent the undesirable separation or differential gravitation of the particulate components 61, 62, etc.

The flow of liquid to the mixing zone will ordinarily be cut off at a different time from the flow of the solid ingredients. Usually, the liquid supply from line 95 will be cut off slightly before the flow of the other ingredients is terminated. However, in some cases, it may be desirable to continue flow of the liquid after the dry ingredients cease to flow, in order to prevent accumulation of deposits on such walls.

For feeding a large number of dry ingredients it may be necessary to make the funnel 11 wider and to increase the angle of inclination of its walls from the vertical. This may result in a tendency to accumulate dry solids on the funnel walls when the solids, e.g., finely powdered materials, do not fall freely down the funnel. In this case, as noted above, mechanical vibrating means may be attached directly to the sloping wall of the funnel to prevent lodgment of the solids.

The plant so far described is entirely suitable for using large particle materials, such as smokeless powder, TNT and the like, of substantial size grain. Since the necessary blending is accomplished ordinarily within about 5 or 6 seconds and since the slurry begins to set up to a good degree shortly thereafter, no considerable difficulty is encountered as a rule, with the settling or segregation of these ingredients. Ordinarily the mixing will not be so rapid or the thickening action so slow or viscosity increase so slow that thickening action does not occur with reasonable promptness after the slurry material is dispensed into the receiving package or bore hole.

As noted above, the natural tendency to classification of dry ingredients as they fall is largely overcome by the blending action of the mixer 67. It is possible in some cases to leave the gate or butterfly valve 71 open and to mix the dry ingredients into the liquid as they pass by the impeller, allowing the liquid to flow freely to flush solid particles down into the tube 75. By use of a suitable prompt-acting thickener the mixture may be made of adequate uniformity and the required setting up to prevent particulate segregation by gravity can take place after packaging.

Valves 91 and 107 as indicated above, are preferably operated by pneumatic means, controlled electrically. In some cases, however, they may be operated by a solenoid means equipped with suitable electric controls.

It is obvious that, when desired, the feeding of one or more of the dry ingredients may be delayed with respect to others. Such timing control for feed of various ingredients makes it possible, for example, to add such ingredients as smokeless powder (cellulose nitrate) or TNT to only a part of the charge, for example, to the first or the last part. Hence advantage may be taken of particular characteristics of materials like smokeless powder or TNT, with low or high brisance, etc. Low brisance at the top of the charge, for example, will often be more useful than in the deeper or lower part of the charge.

Referring now to FIGURE 2, there is shown a wiring diagram for a control panel. This is only generally indicated at 180 in FIGURE 1. This panel preferably is pressurized, e.g., by compressed air brought in by a line 141, to prevent accumulation of explosive gases in the panel. Air leakage thus is outward of the panel, not inward. At the right of FIGURE 2 are indicated diagrammatically the solenoid vibrator means which are incorporated in the respective vibrator mechanisms 41, etc. These are shown respectively at 141, 143, 145, 147, 149, 151 and 155. Each of these solenoids is controlled by a varistor, these being indicated at 161 to 168, respectively. The control wiring assembly shown in FIGURE 2 is mounted within and on the panel unit 180 as shown in FIGURE 1. As seen in FIGURE 2, power is supplied to the panel through a pair of leads 181 from any suitable conventional power source. A master switch 182 is connected to fuses 163, 164. A line 185 from fuse 183 goes to the normal control switch 186 for energizing the circuit. A normally closed emergency switch 187 or "panic button" is provided, however, which can be quickly
manipulated to inactivate the whole circuit in case of difficulty. When switch 248 is closed power normally flows from line 245 to line 248, thence to inductance 160 and on to line 190. The latter has two branches, one of which, shown at 191, connects with inductance coils 192, 193, and 195. Each of these coils has a line 193, 1930 and 1935 which connects to a delay timer. Thus line 193 is connected to an intermediate point of a mixer delay timer 194M, line 1930 connects to delay timer 194O and line 1935 to delay timer 194S. The other branch of line 190 from line 190 connects to the base terminals 197M, 197O and 197S of the three timers 194M, 194O and 194S. These timers govern the operation of valves 91, 107 and 71, respectively. See FIG. 1. A line 260 from the main control switch 186 connects to a line 241 which in turn is connected to one of the terminals of each of a series of condensers 202 to 213, inclusive.

From the fuse 184 at the power line a line 220 connects to one of the terminals of variometers 161, which controls one of the vibrators associated with a device 41, FIG. 6 or 43, etc., FIG. 1. This line also connects to a bus bar or line 221 which connects to the opposite terminals of each of the variometers 162 to 165, respectively. Switches 223 to 230, inclusive, which may be closed individually or in groups as desired, are provided to energize the variable vibrator elements 141 to 155, inclusive. A line 222 which connects the terminals of all the switches 223 to 230, inclusive, together also connects to a line 241 which in turn connects to condensers 209 and 210.

A manually operable switch is shown at 259' to control delay of solids feed, this being a double pole-double throw switch. In the on position shown, it connects a liquid delay timer switch 240 through line 245 and line 246. The line 246 is connected to one of the variometers, 163; the latter connects with line 221 and completes the circuit.

In the alternative open position, the switch 250' connects line 245 with a line 247. This leads to a 2-pole single throw switch 248. It has the bolts L1 and L2 for operating valves 91 and 107, respectively. When switch 248 in line 247 is in the position shown, it activates a circuit, comprising line 249 and a solenoid 250. The circuit is completed by a line 261 back to fuse 184. As soon as delay switch 240 operates, valve 91 will open. The solenoids 252, 255 and 251, respectively, control the slurry valve 71 at the bottom of the receptacle 61. FIGURE 1, the main liquid valve 91, and the secondary liquid valve 107, respectively.

When switch 248 is moved to the other position, it energizes a line 260. The latter connects to the solenoid 251 and will operate valve 91. The solenoids 252, 255 and 251, respectively, control the slurry valve 71 at the bottom of the receptacle 61. FIGURE 1, the main liquid valve 91, and the secondary liquid valve 107, respectively.

A double-pole double-throw switch 270 is provided to leave the time delay 240 operable, when it is closed, as it is shown in FIG. 2. When thrown to the other position, this switch effectively bypasses delay 240 and activates through line 272 and condensers 206, 207, a manual switch 280. When the switch 250' is in the on position, as shown in FIGURE 2, current flows from line 245 through delay 240, switch 270, line 275, and line 244 to condenser 212.

Three manual switches 280, 281 and 282 are provided for controlling valves 71, 107 and 91 respectively. Switch 280 is for the purpose of tripping the slurry valve 71, which may be operated either by electrically controlled pneumatic means or by a solenoid. The switches 281 and 282 serve to open the secondary liquid valve 107 or to open the timer liquid valve 91, respectively.

A switch 290 also is provided which may be closed manually to connect the power line 200 with the main slurry valve control solenoid 252 through line 291. By the means just described and by selective closing of vibrator switches 223 to 230, or any of them, plus ad-

justment of the desired variometers 161 to 168, inclusive, or such of them as are desired to be operated, the feed rate of all the ingredients may be accurately established. The sequence of starting and stopping the feed of any liquid ingredient may be controlled automatically. All the dry ingredients are under a single control, except that variometer 163 and the associated controls make it possible to delay the feeding of one dry ingredient with respect to the others. The functions of certain elements of the electrical circuit, such as condensers which have not been specifically mentioned, will be self-evident to those skilled in the art.

Referring now to FIG. 3, there is shown a modification of that part of the electrical circuit which controls the feeding of dry ingredients from the hoppers 13, 15, etc. This modification comprises providing a motor drive for automatically changing the feed rate of certain particular dry components progressively during a given batch operation. The vibrator elements 141, 143, 145, 147, 149, 151 and 153, also 155 are the same as in FIG. 2. However, a group of them, i.e., 149, 151, 153 and 155 are connected to variometers 365, 366, 367 and 368 which are individually adjustably attached to a movable operating bar 370. The latter is attached to a rotatable arm 371 which is secured to or forms part of a gear 372. The arm 371 is mounted on an axle suitably secured to a rigid support, not shown. Gear element 372 meshes with a driving worm 373 on the output shaft of a reversible motor device 374. When the latter is operated, by a suitable control circuit not shown in detail, it progressively changes the setting of variometers 365 to 368 which are ganged together by bar 370. The initial feed rate of each vibrator element 149, 151, etc., is set by adjusting the connection of each variometer control arm, 365, 366, etc., to the bar. Once these have been adjusted they all move in unison as arm 371 moves up or down, depending on the direction of motor device 374.

The plant or system, and the method or process of this invention, are highly suitable for the sequential production of a series of batches of explosive composition which will be highly uniform in composition, consistency and homogeneity.

To review operation of the system briefly, when it is desired to mix a batch or a series of batches of slurry explosive, appropriate hoppers 13, 15, 17, etc. are filled with appropriate solids, and tank 81 is filled with the slurry forming liquid. The latter may be water, or in case one of the hoppers will contain a highly soluble oxidizer salt, preferably ammonium nitrate. Ordinarily, the tank 81 will be filled with a concentrated solution of ammonium nitrate, e.g., an 85/15 (parts by weight) heated ammonium nitrate-water solution which normally comprises 5 to about 25 parts by weight of water, based on 100 parts in the final composition. Where a concentrated salt solution is used as the slurry-forming liquid, this solution will constitute 50 to 95% of the total. A small proportion of the ammonium nitrate may desirably be replaced with another soluble material such as sodium nitrate, sodium perchlorate, urea or the like. The solids in proportions of 5 to 95 of the total weight of the final slurry, are to be dispersed from the dry material hoppers 13, 15, etc. Such solids may include granulated TNT, nitrocellulose, aluminum powder, sulfur, etc. As a rule, a gel-forming thickener such as guar gum or starch, or gelatin, or two or more of these, will be included in the dry ingredients to be dispersed.

The other liquid tank 101 may contain a fuel oil, an aqueous fuel such as a hydrocarbon, or a hydrocarbon derivative such as alcohol, glycol or ether like.

In operation, when power is turned on, the mixer 67 immediately begins to rotate. Valve 71 normally will be closed. The valve 91 usually will be opened first, valve 89 having been set to an adjusted metering position. The total quantity of liquid fed from tank 81 is a function of the setting of valve 89 and of the time during which valve
91 remains open. Pump 83 has adequate capacity to feed a full stream with valves 89 and 91 wide open, if desired, and it maintains a substantially constant head of pressure on the liquid in line 95 unless otherwise in some cases, the vibrator elements 141, 143, etc., are activated. In each case the associated variometer 161, 162, etc. will have been preset to give the desired feed rate for its particular dry ingredient.

The flow of ingredients continues in a typical case for a period of 3 to 5 seconds or so. Therefore, the feeders can be stopped at a rate of the liquid at a controlled rate, means for blending liquid to solids into zone at a controlled rate, means for blending liquid to solids and solids in said zone, means independent of each other and including said on-off valve for terminating and controlling the sequence and duration of both said feedings so as to obtain a homogeneous slurry, and means for controlling discharge of the blended batch from said zone.

2. A mixing plant for preparing an explosive liquid slurry composition comprising, in combination, a tank for slurry forming liquid, a hopper for granular solid material, means including a pump, variable flow rate control and a shutoff for feeding said liquid and separate variable rate feeder means for feeding said solid material at predetermined rates, impeller means for blending said liquid and said solid material together, and automatic selective timed delay means for separately initiating the feed of liquid with respect to the feed of the solid material to avoid non-homogeneous slurry production.

3. Combination according to claim 2 wherein means are included for pumping the liquid under a predetermined pressure head which head is substantially independent of the level of liquid in the tank.

4. Combination according to claim 2 wherein a vibrator actuated feeder is used to feed the solid material at a predetermined and accurately controlled rate.

5. In a system for producing explosive comprising a liquid containing suspended particulate material, the combination which comprises a liquid supply tank, a mixing zone, an outlet line for liquid from said tank to said zone, means for causing the liquid to flow through said line at a substantially constant pressure, means for adjusting the flow rate in said line, separate controllably variable rate means for feeding particulate material to said zone for suspension in said liquid, means for blending said liquid and said particulate material together, and means comprising an adjustable and selectively operable flow barrier and a rotary impeller for causing the liquid to circulate from said barrier and blend effectively with said particulate material.

6. In combination, a tank for slurry forming, liquid, means connected with said tank for dispensing liquid therefrom at a substantially constant pressure which is essentially independent of liquid level in said tank and flow rate therefrom, variable orifice means for accurately metering the flow rate, an automatically operable cut-off valve for the liquid flow from said tank, a mixing vessel adapted to receive metered liquid, a blending means in said vessel, separate means for accurately feeding each of a plurality of particulate solid materials into said vessel, and automatic means for differentially timing the initiation of said liquid flow and the start of feeding of the solid materials.

7. Combination according to claim 6 wherein the mixing vessel is equipped with an exit control valve at its bottom, whereby liquid is retained for blending with the solid materials.

8. In combination, a blending vessel having a bottom outlet, a valve for selectively closing said outlet, timed flow meter means for supplying a slurry suspending liquid to said vessel at a controlled rate, positive on-off means for cutting off flow of said liquid from said meter, an impeller in said vessel adapted to cause turbulence and recirculation of liquid above said vessel, solid metering means for supplying at least one particulate solid material to said vessel at a controlled supply rate, and automatic means operable in various preselected sequences to control sequentially the opening of said valve, the operation of said flow meter and the operation of said solid metering means.

9. In a system of the character described, the combination which includes a mixing vessel having a bottom outlet, a flow control valve in said outlet, a slurry blender in said vessel, a liquid supply tank, a liquid flow line from said supply tank to said vessel, a variable metering means in said line, means associated with said line for maintain-
ing a substantially constant hydraulic pressure head in
said line, regardless of liquid level in said tank and re-
gardless of flow rate through said metering means, a
positive automatic cut-off valve in said line, a plurality
of hoppers for solid particulate material, a selectively
variable rate feeder from each of said hoppers, means
for bringing fed particulate material from said hoppers
to said vessel, and automatic timed means for selectively
controlling the opening of said cut-off valve, the initiation
of said feeders and the opening of said flow control valve.

10. A system according to claim 9 wherein the variable
rate feeders comprise electrically operated vibrator means.

11. A system according to claim 5 which is operable
continuously and which includes automatic means for
variably and selectively controlling both the sequence and
timing of the liquid and particulate material.

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