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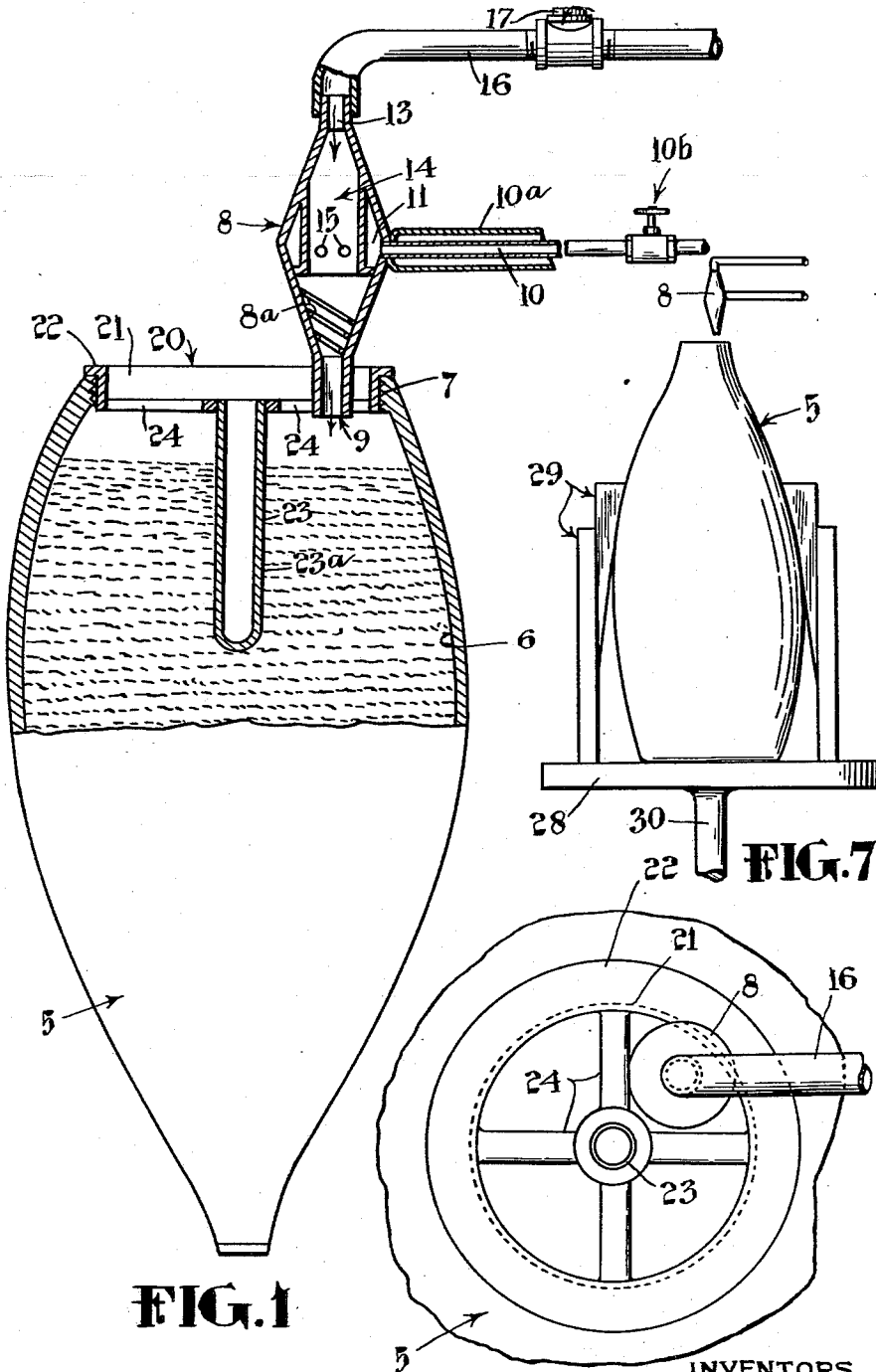
T. E. ARNOLD ET AL

2,364,415

METHOD OF FILLING EXPLOSIVE DEVICES

Filed Dec. 31, 1941

2 Sheets-Sheet 1



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2 Sheets-Sheet 2

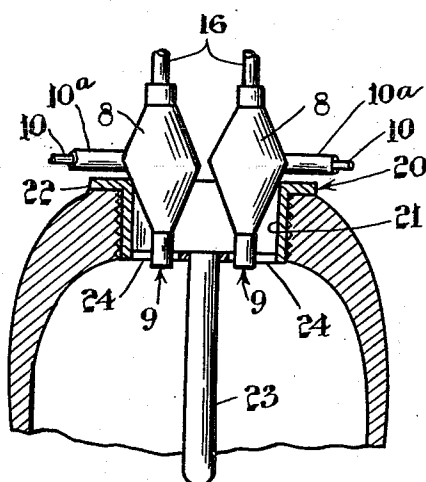


FIG. 3

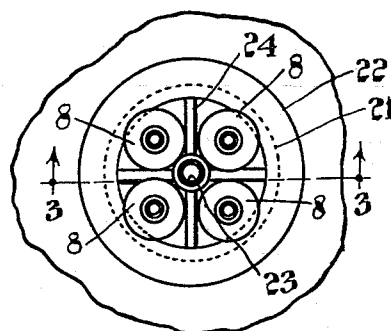


FIG. 4

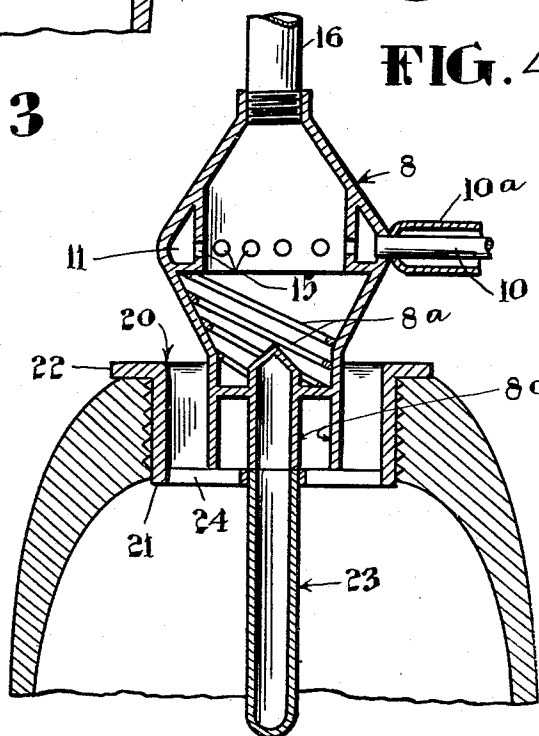


FIG. 5

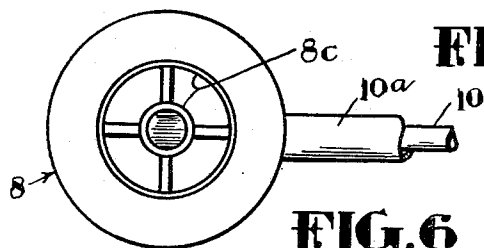


FIG. 6

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METHOD OF FILLING EXPLOSIVE DEVICES

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2 Claims. (Cl. 86—31)

This invention relates to the filling of explosive devices with explosive materials, the term "explosive devices" being intended to cover artillery shells, aerial bombs, trench mortar bombs, and other types of bombs, anti-tank mines, depth charges, torpedo warheads, and all other explosive devices including a shell or casing containing an explosive charge. Consequently, while the present description of the invention deals more particularly with the filling of bombs and artillery shells, it will be understood that the invention is not limited to these applications.

The conventional method of filling the casing of a shell or the like with "Amatol" (a mixture of TNT and ammonium nitrate) and similar explosive material consists in depositing successive charges of such material in the casing and subjecting each charge to a tamping down operation before introducing the next charge. The explosive material is deposited in the casing in a heated fluid, semi-fluid, or pasty condition and tends to "freeze" or set quickly when it strikes the relatively cool metal of the casing. It must therefore be broken down by a tamping operation to eliminate cavities and to ensure complete filling of the casing with an explosive charge of the required weight or density. In some cases the explosive material, after being introduced into the shell casing, is subjected to hydraulic pressure to increase the density of the charge. The conventional procedure here referred to is slow and tedious and is also characterized by various other disadvantages, some of which may be summarized as follows:

(1) With present methods of filling shell, bomb or other casings with "Amatol" there is an appreciable time interval between commencement of the mixing operation and commencement of the filling operation. Consequently, in order to prevent excessive cooling down and contraction of the explosive mixture prior to the filling operation it is necessary that both the TNT and ammonium nitrate be heated to a temperature of about 190° F. to 200° F. before being mixed together to form the explosive charge. Aside from requiring a considerable amount of heat this procedure increases the contraction of the mixture during subsequent cooling thereof within the shell or other casing into which it is introduced during the filling operation.

(2) Another objection to present methods is that the so-called lean "Amatol" mixtures cannot be used satisfactorily without resorting to very expensive equipment. By "lean Amatol mixtures" is meant mixtures in which the proportion

of TNT to ammonium nitrate is relatively small such, for example, as 80/20 "Amatol" mixtures in which the major proportion consists of ammonium nitrate.

(3) When the explosive material is introduced into a shell or casing in the form of a semi-fluid or pasty mass, the tamping down operations, even when followed by hydraulic pressing, do not always give a filling which is of satisfactory density.

(4) The mixing and heating of the explosive ingredients and the filling of the casings must be carried out on the "batch" operation principle.

(5) The mixing and heating of the explosive ingredients requires considerable time and involves the use of expensive and inconvenient apparatus including various moving parts and valves which frequently give trouble due to breakage and other causes.

(6) The method of mixing and heating the ingredients of the explosive charge is wasteful of heat and requires that an appreciable amount of time be allowed for subsequent cooling of the charge.

(7) The maximum explosive effect of the charge is not always realized owing to the imperfect distribution of the component ingredients.

(8) The method of filling does not lend itself to the proper filling of casings in which the cavity and the filling openings are of such relatively small dimensions as to prevent effective tamping down or pressing of the charge.

According to our invention the foregoing objections are eliminated by the provision of what may be termed a continuous pressure injection method of filling explosive devices. When this method is used for filling explosive devices with "Amatol" or other explosive mixtures which are formed by mixing a dry component with a liquid component it enables the mixing and filling operations to be carried out in a continuous manner, the dry and liquid components being continuously and separately fed, under pressure, to a mixing chamber from whence the resulting mixture is immediately discharged, under pressure, into the cavity of the shell or casing to be filled. It will thus be seen that, with this procedure, there is no appreciable time interval between the mixing of the dry and liquid components and the pressure injection of the resulting mixture into the cavity to be filled. This makes it feasible to heat only the liquid component of the charge and to convey the dry component to the mixing chamber in a cold condition. For example, in the case of "Amatol" it is feasible to supply the ammonium nitrate in a cold, dry condi-

tion to a mixing chamber where it is mixed with hot liquid TNT so that the resulting mixture is discharged into the cavity to be filled before there is any substantial cooling or contraction thereof. This not only saves heat as compared with the usual procedure of heating both the TNT and ammonium nitrate but also reduces the contraction of the charge during subsequent cooling thereof in the cavity of the shell.

A very important advantage of our novel process is that it requires the mixing at one time of only a small amount of explosive mixture, and such mixing takes place in the mixing chamber of a nozzle located closely adjacent to the shell being filled. Therefore any explosion would be limited to the mixture in the nozzle and in the shell, and would involve no large amount of previously prepared explosive mixture, as must be the case in loading practice heretofore.

Another advantage of the procedure described herein is that it readily lends itself to the use of very lean "Amatol" mixtures since the mixing of the two ingredients, TNT and ammonium nitrate, is immediately followed by injection of the mixture into the cavity to be filled.

A further advantage of our improved method is that it results in an explosive charge which is of substantially greater density as compared with conventional methods of filling. It also lends itself to a more satisfactory distribution of the component ingredients throughout the mass of the charge and thus increases the explosive effect.

Another feature of the invention consists in utilizing compressed air to convey the dry component of the explosive charge to the mixing chamber where it is mixed with the hot liquid component which is pumped to the mixing chamber under pressure, the compressed air being also utilized to blow the hot explosive mixture from the mixing chamber into the cavity of the shell or other explosive device to be filled. For example, when the explosive charge to be formed and introduced into the cavity to be filled is "Amatol" the ammonium nitrate in a cold dry state is entrained in a stream of compressed air which is forced through the mixing chamber and into the cavity to be filled. Hot liquid TNT is simultaneously pumped to the mixing chamber where it is mixed with the dry ammonium nitrate, the resulting homogeneous mixture being immediately blown through the outlet of the mixing chamber and directly into the cavity to be filled. This procedure may be followed not only in cases where solid and liquid components are to be brought together to form the explosive charge but also in any cases in which two different ingredients or two component parts of the explosive material are to be mixed together to form the final charge which is to be introduced into the cavity to be filled.

A further feature of the invention consists in effecting pressure injection of an explosive charge into the cavity of a shell, bomb, or other casing while rotating said casing at a sufficient rate of speed to effect a desirable centrifugal distribution of the explosive material within said casing. In practice we have found that, when the casing being filled is rotated at a suitable speed during the filling operation, the centrifugal force developed in the mass of liquid or semi-liquid explosive material introduced into the casing tends to ensure a better dispersion or distribution of the component ingredients of the mass and a greater density of the charge.

In the case of "Amatol" and similar explosive charges, including a liquid component, a further feature of the invention consists in decreasing the surface tension of the liquid component by adding thereto a suitable surface tension decreasing chemical or wetting agent such, for example, as "Aeresol." In practice, when "Amatol" and similar explosive charges are injected into the cavity to be filled in accordance with our pressure injection method, a better dispersion of the component ingredients of the charge may be obtained when the surface tension of the liquid component of the charge is decreased as here suggested.

Proceeding now to a more detailed description of this invention reference will be had to the accompanying drawings, wherein—

Fig. 1 is a view illustrating a preferred application of the invention to the filling of the cavity of a bomb.

Fig. 2 is a plan view of the adapter and filling nozzle shown in Fig. 1.

Fig. 3 is a view illustrating a modification of the invention in which a plurality of small nozzles are employed for introducing the explosive material into a cavity having a relatively small filling opening.

Fig. 4 is a plan view of the nozzle arrangement shown in Fig. 3.

Fig. 5 is a view illustrating a further modification of the invention in which a single nozzle of special design is employed for introducing the explosive material into a cavity having a relatively small filling opening.

Fig. 6 is a bottom plan view of the nozzle shown in Fig. 5.

Fig. 7 is a view illustrating one arrangement which may be used for rotating a bomb, shell or other casing during the filling thereof in accordance with this invention.

In Fig. 1 of the drawings our invention is illustrated as applied to the filling of a conventional bomb casing 5 presenting a cavity 6 and a threaded filling opening 7. The mixing nozzle 8 herein illustrated has an outer casing which tapers from a central zone of maximum diameter upwardly to an inlet or entrance passage 13 and downwardly to an outlet or discharge passage 9. In this case the explosive charge is formed by mixing a cold, dry, granular or powdered component with a hot liquid component within the nozzle 8 from whence the resulting mixture is immediately blown or forced into the cavity 6 through the nozzle outlet 9. The liquid component of the charge is pumped through a liquid line 10 to an internal annular chamber 11 of the nozzle 8, said chamber being located in the widest part of the nozzle intermediate the discharge end 9 and the entrance end 13 of the main nozzle passage 14 and being provided with openings 15 in the walls of the passage 14 through which the liquid passes into said main passage 14. The dry component of the charge is entrained by a stream of compressed air which is delivered to the entrance end 13 of the main nozzle passage 14 through a compressed air line 16, the dry explosive component being introduced into the air stream prior to its passage into the mixing chamber, as through a T connection 17 in the pipe 16. The liquid and dry portions of the charge are mixed together in the passage 14 as the liquid portion passes through the openings 15 and transversely into the dry component stream, and the consistency of the mixture thus obtained may, of course, be regulated by varying the ratio of the

liquid to the dry component. The portion of the nozzle lying between the chamber 11 and the discharge end 9 is preferably provided with baffles or rifling generally indicated at 8a which assists by a turbulent action in effecting the necessary mixing together of the liquid and dry components of the charge.

In the present case it will be assumed that the explosive charge is to be formed by mixing together within the nozzle 8 liquid TNT (trinitrotoluol) and dry ammonium nitrate. In this case hot liquid TNT is pumped to the nozzle through the liquid line 10 and the latter is preferably provided with a steam jacket 10a into which steam is introduced to prevent cooling of the TNT on its way to the mixing chamber of the nozzle. The ammonium nitrate is introduced into the compressed air line 16 in a cold dry condition. The consistency of the resulting charge will depend on the relative proportions in which the two ingredients are mixed together and this may be varied within very wide limits.

As previously stated, a suitable chemical may be added to the hot liquid TNT to decrease the surface tension thereof since this tends to ensure a better dispersion of the ingredients of the explosive charge within the casing or cavity into which it is introduced.

The arrangement shown in Fig. 1 may also be used for the mixing and pressure injection of explosive charges consisting mainly of TNT with a small amount of binder such as beeswax. In this case the beeswax will be melted and supplied through the line 10 as the liquid component of the mixture to be formed, the TNT being supplied in the solid state through the compressed air line 16. Similarly, TNT biscuit may be supplied through the compressed air line 16 to the nozzle 8 and there mixed with liquid TNT supplied through the liquid line 10. It will thus be seen that the invention lends itself to the continuous preparation and injection of various explosive mixtures involving the mixing of liquid and solid components.

In using the apparatus described herein it is, of course, important that the air and liquid pressure be suitably regulated to give the required velocity to the mixture at the mixing nozzle 8. The consistency of the mixture formed within the mixing nozzle 8 depends, of course, upon the relative amounts of dry and liquid explosive material supplied through the lines 16 and 10. The amount of dry explosive material supplied through the line 16 should therefore be carefully regulated in relation to the amount of liquid supplied through the line 10, the latter being regulated by a suitable valve 10b. We have not thought it necessary to show the machine or apparatus for controlling the supply of dry explosive material through the line 16 but it will be understood that this may be accomplished in various ways.

In the case of bombs, shells and other explosive devices it is necessary that a cavity be provided in the explosive charge adjacent the filling opening of the casing to accommodate the conventional exploder tube. When following the conventional method of filling, the casing is filled with the explosive material and, when the latter has solidified, it is drilled or cored to provide the necessary cavity for the exploder tube. When the filling is carried out in accordance with the present invention it is possible to fill the casing in such a way that the exploder tube cavity is formed during the filling operation. In this con-

nection it will be noted that, as shown in Fig. 1, a cavity forming adapter 20 is inserted in the filling opening 7 of the casing 5. This adapter comprises a ring 21 which overlies and protects the threads of the opening 7 and which is supported in place by an outwardly directed flange 22 which rests on the upper end of the bomb casing. A centrally disposed cavity forming tube 23 is supported from the ring 21 by radially extending spokes or spider arms 24. During the filling operation the discharge end of the nozzle 8 is directed downwardly between two of the spokes 24 and the hot explosive mixture is forced into the casing 5 until it fills the casing to approximately the level of the upper end of the cavity forming tube 23. When the explosive material has cooled and solidified the adapter 20 is removed and the tube 23 may or may not be left in place within the cavity 23a.

When the filling opening of the casing 5 is relatively small as shown in Fig. 3 the single nozzle 8, described in connection with Fig. 1, is replaced by a plurality of small nozzles 8 which are of the same construction. The small nozzles 8 shown in Fig. 3 are positioned between the spokes 24 of the adapter 20 which corresponds to the previously mentioned adapter 20 except that it is considerably smaller in size.

In Fig. 5 we have shown a single nozzle 8 which is provided with an annular discharge outlet 8c. In this case the annular discharge outlet of the nozzle is placed on the spokes or spider arms 24 of the adapter 20 so that the upper end of the forming tube 23 lies within the circle formed by the inner cylindrical wall of said annular outlet which is supported by radial spokes within the barrel of the nozzle as shown in Fig. 6. In this case the explosive material is discharged from the nozzle in the form of an annular stream encircling the cavity forming tube 23.

In Fig. 7 we have shown one method of rotating a bomb shell or other casing during the filling operation but it will be understood that various other methods and arrangements may be resorted to for accomplishing the same purpose. As shown in Fig. 7, the casing 5 is mounted on a turn-table 28 and is caused to rotate with said table by means of suitable holding means generally indicated at 29. The table 28 is carried by a supporting shaft 30 which, during the filling operation, is rotated at a suitable speed by means of a motor or other means (not shown). The speed of rotation of the table 28 and casing 5 should be such as to develop an appreciable centrifugal force within the mass of the explosive charge which is introduced into said casing through the pressure injection nozzle 8.

Our novel and improved method of filling casings as herein described will now be clearly apparent from the above description taken in connection with the accompanying drawings. Compressed air is forced through the nozzle 8 from the conduit 16 together with the proper amount of dry explosive which is added to the air stream before mixing the liquid explosive and ingredients therewith. Detonating efficiency of the charges is dependent upon various factors, among which the intimate mixing together of the ingredients and the density of the charges are of great importance. Our invention contemplates the effective achievement of the first of these factors by a thorough intermingling of the ingredients in the mixing chamber 8 where the liquid explosive and other liquid ingredients are projected under pressure transversely into the air-conducted

stream of dry explosive, the liquid preferably being directed into the dry stream in a plurality of jets disposed in opposed relation, as through the holes 15. It will be readily apparent that such directing of the liquid forcibly and transversely into the dry stream effects a thorough mixing together of the ingredients within the chamber 8 and from which they are continuously blown into the shell being loaded. The ingredients may be given a further turbulent and mixing action as they pass through the mixing chamber by the employment of baffle plates as indicated at 8a. It is furthermore and particularly pointed out that this thorough mixing action is as essential with such ingredients as wetting agents, liquid binders, etc. as with the liquid explosive itself since full and complete diffusion of such ingredients is required if they are fully to perform their intended functions. The density of the charge is facilitated by the thorough mixing of the ingredients and this, together with the centrifugal action effected by rotating the casing at proper speed during filling, results in securing charges of maximum density and maximum detonating effectiveness.

Having thus described what we now conceive to be the principle and several preferred arrangements of our invention, it will be understood that various modifications may be resorted to within the scope and spirit of the appended claims.

Having thus described our invention what we claim is:

1. The method of filling shell or other casings with explosive charges, which consists in continuously conducting two individual explosive components of the charge, both of which are solid at room temperature, in separate streams from distant sources of supply to the vicinity of the shell to be filled, and includes the steps of injecting under pressure a stream of fluid pressure carrying one of said explosive components in dry granular form in suspension therein through a

passage into a mixing space located adjacent to the shell, projecting the other of said explosive components in the form of a heated liquid stream transversely and under pressure into the fluid-borne stream of granular component in the said mixing space, thereby effecting a turbulent action intimately combining the said components together into a hot homogeneous mixture, continuing the movement of said stream of compressed air and hot explosive mixture directly and forcibly from the mixing space and compactly into the casing to be filled, and solidifying the charge by cooling from the walls of the casing.

2. The method of filling shells with explosive charges, which consists in continuously conducting individual explosive components of the charge, each of which is solid at room temperature, in separate streams from distant sources of supply to the vicinity of the shell to be filled, and includes the steps of injecting under pressure a stream of compressed air carrying one of said explosive components in dry granular form in suspension therein in a confined stream into a mixing space located adjacent to the shell and of substantially larger volume than the said stream, projecting the other of said explosive components in the form of a heated liquid in a plurality of intersecting jets transversely and under pressure into the air-borne stream of granular component in the said mixing space, thereby effecting a turbulent action intimately combining the said components together into a hot homogeneous mixture, continuing the movement of said stream of compressed air and hot explosive mixture directly and forcibly from the mixing space and compactly into the casing to be filled, and solidifying the charge by cooling, at least in part, from the walls of the shell casing.

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