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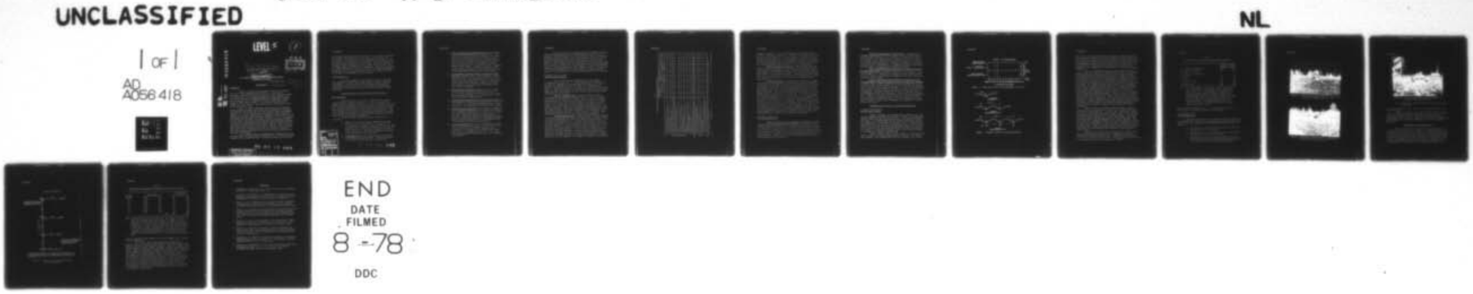

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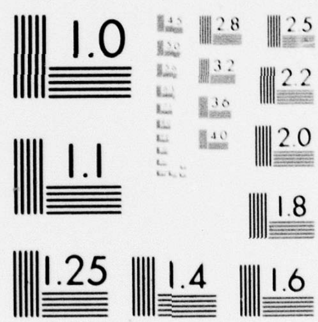

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MILITARY USE OF BULK EXPLOSIVES

JUN 1978

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Introduction

Background

"Battle in Central Europe against forces of the Warsaw Pact is the most demanding mission the U. S. Army could be assigned....Warsaw Pact doctrine anticipates use of nuclear weapons in...future war, but teaches preparedness to fight without them. For both conditions, it *emphasizes heavy concentrations of armor*.... Forces opposing Soviet equipped and trained troops must expect intense, highly mobile combat. [If initiated,] battle will be fought on a scale and at a tempo rarely seen in all history" (from Field Manual 100-5 (1)).

The U. S. Army is presently developing a bulk explosive system intended to make possible the rapid excavation of obstacles and defensive positions, and to be used against large, prechambered targets. It is also intended that this system will be useful for quarry work, and as a substitute for standard military explosives as may become necessary under emergency conditions. It is not generally recognized that the Army has no truly suitable explosive available for the size of demolition mission between those normally undertaken with military high explosives and those considered suitable for the employment of atomic demolition munitions (ADM's). Bulk explosives will also be desirable in certain cases to substitute for low-yield ADM's where field commanders must have the ability to respond to tactical situations unencumbered by nuclear release procedures and employment constraints.

It is apparent that large quantities of explosives will be routinely used on bulk explosive system missions. It is also readily apparent that the greatest need for obstacle creation will occur at early times during the battle, and that, to be effective, obstacles will have to be prepared with great speed. The conclusion is inescapable: during the most critical engagements, there will not be time to use a bulk explosive system that requires transport from ammunition supply points to obstacle sites. The system must be suitable for safe storage and use in forward areas, so that it may be rapidly employed as threats are perceived. Also, bulk explosives will have to be used in conjunction with a truly rapid emplacement capability, since timely availability of these explosives will do little good if emplacement means are wanting.

Purpose and scope

This paper summarizes the characteristics of available bulk explosive systems, and evaluates them in terms of military requirements. It also discusses the continuing development of techniques intended to place effective obstacles and defensive positions on time using bulk explosives under anticipated combat conditions.

An Evaluation of Existing Bulk Explosives Systems

Bulk explosives

Bulk explosives are a class of explosives that may be handled by bulk loading techniques, i.e., that are pourable or pumpable during emplacement operations. They are characteristically used in large quantities, and their costs per unit weight are normally very low compared with those of high explosives. Bulk explosives may be used in cartridge form, as are high explosives. However, during the excavation and quarrying applications, for which they are most suited, they are more typically placed directly into holes in the ground without packaging.

In this report, eight bulk explosive types will be discussed:

a. ANFO is a dry blasting agent composed of ammonium nitrate and fuel oil, usually in a 94 percent to 6 percent ratio by weight. Neither ANFO nor any other blasting agent contains any chemical classified as an explosive, and all require high-explosive primers to induce detonation. ANFO may be purchased from explosives manufacturers or field-mixed.

b. Aluminized ANFO is ANFO containing up to 28 percent particulate aluminum by weight. It may be purchased from explosives manufacturers or field-mixed.

c. Basic field-mix slurry blasting agents are ammonium nitrate-based formulations that may be mixed in the field from commonly available chemicals using pioneer handtools or transit-mix concrete delivery trucks. These and other blasting agents are essentially mixtures of oxidizers (such as ammonium nitrate) and fuels (such as fuel oil or aluminum) in a liquid medium thickened with a gum and gelled with a chemical called a cross-linker. Slurry blasting agents are strongly water-resistant, and may be used in wet soil charge emplacements without protective packaging.

d. Developmental field-mix aluminized slurry blasting agents are advanced two- or three-component slurries that may be mixed in large quantities in the field without heating, using equipment no more complex than transit-mix concrete delivery trucks. A few explosives manufacturers have done research to develop such products, and are presently considering their sale on the open market.

e. Commercial slurry blasting agents are, for the purposes of this evaluation, commercially available slurry blasting agents that contain less than 25 percent aluminum by weight. These products are factory-mixed by explosives manufacturers.

f. Highly aluminized commercial slurry blasting agents are commercially available slurry blasting agents that contain from 25 to 35 percent aluminum by weight. These products are factory-mixed by explosives manufacturers.

g. Commercial slurry explosives are similar to commercial slurry blasting agents except that they contain explosive compounds as sensitizers in place of (or in addition to) nonexplosive fuels such as fuel oil or aluminum. They may or may not be cap-sensitive, but all are classified as explosives for shipping purposes, whereas blasting agents are not. These products are factory-mixed by explosives manufacturers.

h. Gelled nitromethane is a mix of nitromethane (a chemical used in the pharmaceutical, dye, insecticide, and textile industries), a modified guar gum, and, sometimes, a cross-linker that increases the thickness and water resistance of the mix. It is field-mixed with specialized equipment, and is not normally cap-sensitive.

The fact that blasting agents contain no chemicals that are classified as explosives can be misleading under certain circumstances. ANFO can be produced in cap-sensitive form by using finely pulverized ammonium nitrate, and slurry blasting agents incorrectly made with finely flaked aluminum become similarly cap-sensitive. Because of the extreme variability possible with these products, care must be taken to ensure that the particular product being considered for use in the field will be properly handled. A more complete background on blasting agents and slurry explosives (2-4), a description of a recent experiment in the field mixing of a slurry blasting agent (5), and a discussion of gelled nitromethane (6) are available.

Candidate systems versus
required characteristics

Table 1 lists required characteristics and mission statements provided by the U. S. Army Engineer School (USAES), and the author's judgment of the acceptability of each of the eight defined bulk explosive systems for each listed requirement or mission. Though the order of the listed items has been changed somewhat, the number associated with each item is that from the original USAES listing. This section and the following section qualify the evaluations found in Table 1.

ANFO and aluminized ANFO. These products are rated unsatisfactory for required characteristics 4, 5a, and 9 because they become ineffective when exposed to water. ANFO is considered unsatisfactory for required characteristic 11 because it is bulky and the least efficient cratering explosive (in terms of charge weight) of the eight bulk explosives being considered herein. Its great popularity in industry is explained by its extremely low cost and ease of mixing. Watertight packaging is frequently used to protect ANFO products from ground moisture, but such packaging is not always effective and may lead to other difficulties such as static electricity hazards or toxic gas formation upon detonation.

Slurry blasting agents. These products are rated marginal for required characteristic 5b because many slurries become rigid at freezing temperatures, in addition to becoming less sensitive. However, special formulations are available that maintain fluidity at freezing temperatures. Factory-produced slurries have a shelf life of from 6 months to 1 year, depending on storage conditions. Thus, they have been rated unsatisfactory for required characteristic 2. As with the dry blasting agents, slurry blasting agents become more efficient cratering explosives with the addition of significant amounts of aluminum. The basic field-mix slurry blasting agent has been rated as unsatisfactory for required characteristic 4 because several of its six components are damaged if exposed to water before

Table 1

Author's Evaluation of Bulk Explosive Systems for Military Purposes

		Dry Blasting Agents		Slurry Blasting Agents				Commercial Slurry Explosives	Gelled Nitro-methane
		ANFO	Aluminized ANFO	Basic Field Mix	Develop-mental Field-Mix Aluminized	Commercial	Highly Aluminized Commercial		
REQUIRED CHARACTERISTICS	3. Number of components required in the field.	2	3	6	2 or 3	1	1	1	2 or 3
	1. Meets all safety requirements in storage, mixing, transportation, and handling.	+	+	+	+	+	+	o	o
	2. Storage as stable, nonexplosive components.	+	+	o	o	-	-	-	o
	4. Capable of mixing in all weather conditions with simple equipment.	-	-	-	o	N/A	N/A	N/A	-
	5a. Capable of wet weather emplacement and firing.*	-	-	+	+	+	+	+	o
	5b. Capable of emplacement and firing through wide temperature variation.*	+	+	o	o	o	o	o	+
	6. Mixed explosive not bullet- nor cap-sensitive.	+	+	+	+	+	+	o	o
	7. Mixed explosive has low sensitivity to variations in mix proportions and mixing times.	+	+	o	+	N/A	N/A	N/A	-
	8. Components and mixed explosive should be nontoxic and nonirritating.	+	+	+	+	+	+	+	o
	9. Mixed explosive should remain potent for 5 days minimum in all types of ground emplacement.	-	-	+	+	+	+	+	o
	11. Maximum power to weight ratio.	-	+	o	+	o	+	o	o
	10. Note: Manufacturers show great flexibility in packaging;	all systems can be made to meet the single-man-lift packaging requirement.							
MISSIONS	1. Rapid, efficient, economic explosive excavation for creation of large, effective antiarmor obstacles.	-	o	o	+	o	o	o	-
	2. Nonnuclear alternative to small ADM's.	-	o	o	+	o	o	o	-
	3. Safe, economical storage near planned obstacles for minimum logistics impact.	+	+	+	o	-	-	-	-
	4. Able to replace military dynamite and ammonium nitrate cratering charges for a wide variety of military explosive missions.	o	o	o	+	-	-	-	-

Key to rating symbols: + = satisfactory; O = marginal; - = unsatisfactory; N/A = not applicable. Ratings are qualified in the accompanying text.

* Using standard caps and TNT or C-4 primers.

mixing is completed. It is rated marginal for required characteristic 7 because the addition of the minor constituents (guar gum and cross-linker) must be carefully handled to get the right consistency in the final mix. The developmental field-mix aluminized slurry blasting agents are rated marginal for required characteristics 2 and 4 because these are foreseen as potential problem areas for which satisfactory performance is yet to be demonstrated.

Commercial slurry explosives. These products have many characteristics in common with commercial slurry blasting agents. Thus, they are rated unsatisfactory for required characteristic 2, and marginal for required characteristic 5b for the same reasons as the commercial slurry blasting agents. Because they contain components that are classified as explosive for shipping purposes, they have been placed in the marginal category for required characteristics 1 and 6.

Gelled nitromethane. The guar gum used in this formulation must be quickly dispersed throughout the liquid nitromethane during mixing to prevent the formation of lumps that are difficult to break up. Thus, this product is rated unsatisfactory for required characteristic 7. Liquid nitromethane is soluble in water, and in fact can be sensitized somewhat by the addition of small amounts of water. It is therefore rated as unsatisfactory for all-weather mixing (required characteristic 4). It is rated marginal for required characteristics 1 and 6 because it is not compatible with several materials, some of which are used in containers. Its storage is also subject to special rules. High-explosive primers need protection when used in nitromethane, since this chemical can partially dissolve most military high explosives. For this reason, and because gelled nitromethane is more susceptible to charge deterioration under severe groundwater conditions than are slurries, it is rated marginal for required characteristics 5a and 9. It is rated marginal for required characteristic 8 because liquid nitromethane vapors are considered a moderate health hazard.

Candidate systems versus military missions

Rapid, efficient, economic explosive excavation for creation of large, effective, antiarmor obstacles. Because of their cratering efficiency and water resistance, highly aluminized slurry blasting agents are the products of choice for this mission. However, the factory-mixed product does not meet storage requirements, and frequent stock turnover would be uneconomical. The ANFO products do not have the required water resistance to guarantee mission accomplishment. Safety is considered problematical with slurry explosives and gelled nitromethane.

Nonnuclear alternative to small ADM's. The comments of paragraph 13 apply also to this mission. However, charge compactness has added importance in this application because the ADM's to be replaced are very small devices in proportion to their yields. Even a very compact, efficient bulk explosive might not be suitable for certain small ADM missions. Because confinement is especially beneficial to the performance of an aluminized product, some surface missions might be accomplished at reduced efficiency.

Safe, economical storage near planned obstacles for minimum logistics impact. The ANFO products and the field-mix slurry blasting agents are the products of choice for this mission. Long-term storage is not practical with state-of-the-art factory-mixed slurries. Safety is considered problematical with slurry explosives and gelled nitromethane.

Able to replace military dynamite and ammonium nitrate cratering charges for a wide variety of military explosive missions. A readily mixed, two-part aluminized slurry blasting agent would be ideal for these missions because of its efficiency and the elimination of the explosive storage requirement. All of the factory-mixed slurries would require some sort of special storage, as would gelled nitromethane. The ANFO products and the basic field-mix slurry blasting agents would be susceptible to water damage during mixing, and the ANFO products could be rendered ineffective by groundwater as well. However, it should be kept in mind that the ANFO products, because of the universal availability of their components and their ease of mixing, could be used as emergency supplements to the Army demolitions system.

Techniques for the Use of a Bulk Explosive System

A concept for explosive barrier ditch creation

Figure 1 presents an explosive barrier ditching plan that enables troops in the field to use single-, double-, or triple-ditch designs, depending upon the perceived threat and available preparation time. It is anticipated that the single-ditch design would be most appropriate for use where the barrier trace is to be mined and adequately covered by the fires of defending units. However, where the defeat of armored vehicle launched bridges (AVLB) is a requirement, as might be the case where defending fires are overcommitted, the double- or triple-ditch designs could be used (time permitting) to increase the obstacles' effectiveness.

Figure 2 shows schematic cross sections of the ditches produced by each of the three designs shown in Figure 1. The double-ditch option is the double-ditch tank trap described in an earlier

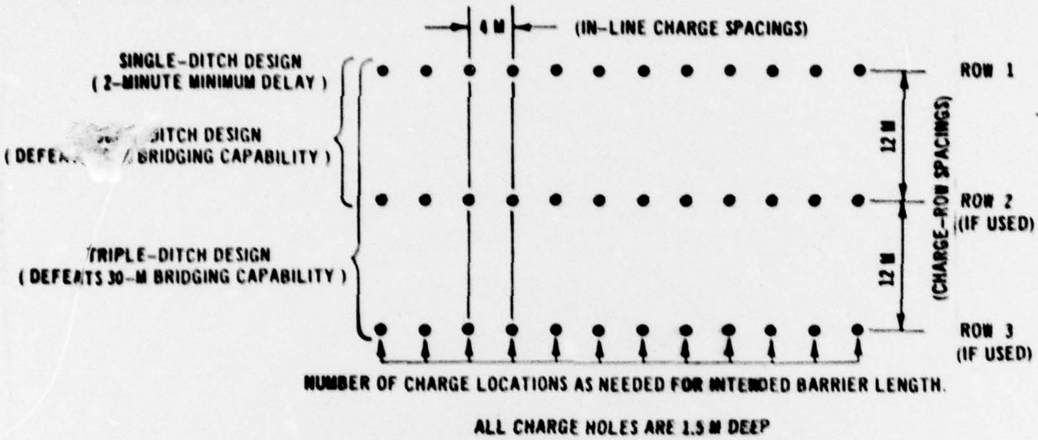

Figure 1. Explosive barrier ditching designs (plan view)

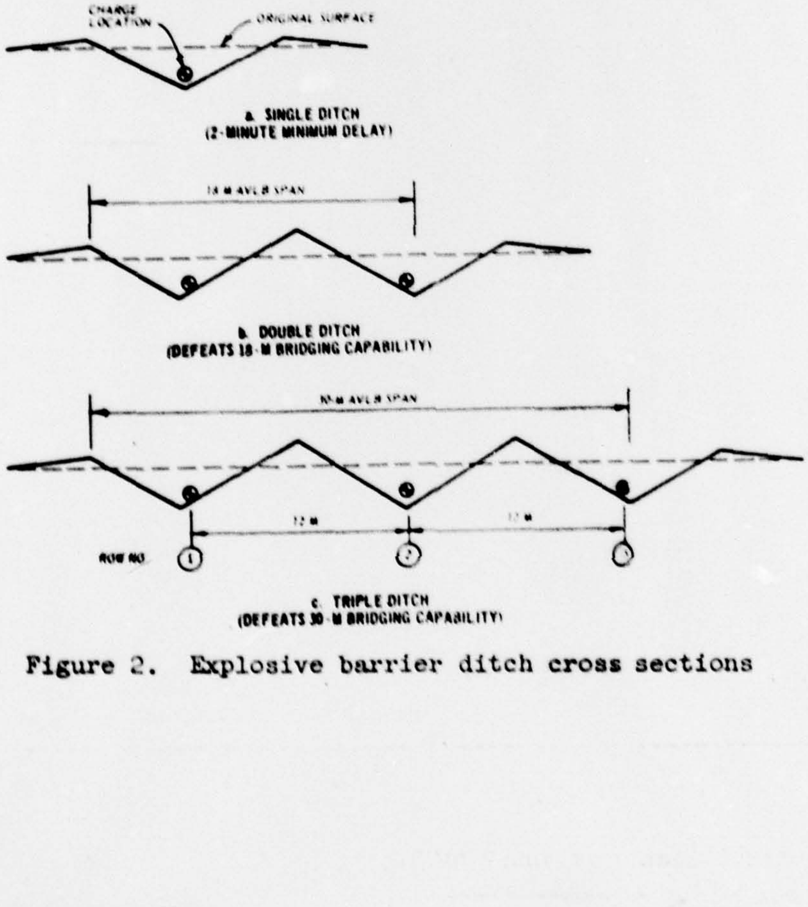

Figure 2. Explosive barrier ditch cross sections

report (7). Note that the charge hole depths (1.5 m*), the in-line spacings between charges (4 m), and the spacings between charge rows (12 m, if used) are always the same, regardless of the nature of the medium being cratered. All three ditching designs are excavated by the simultaneous detonation of all of the buried charges after the charge holes have been stemmed (backfilled above the emplaced charges) to the original surface with native soil from the digging operation.

The 1.5-m charge hole depth has been chosen because it is normally practical with shaped charges and hand tools, rapidly excavated with backhoe or auger, and close to the average of optimal charge burial depths for cratering purposes in a variety of soils. The availability of the JD 410 tractor within the Army materiel system allows troops to use either the backhoe or an auger to make charge holes, depending upon the specific conditions with which they are faced. The backhoe will generally be best for the digging of charge holes for stacked charges such as TNT, and for the emplacement of large charges of any type explosive. Preliminary field test results also indicate that for smaller charges in clay soils, backhoe-dug charge emplacements produce steeper crater side slopes than do auger-dug charge emplacements. Thus, the use of the backhoe may be advantageous for the production of obstacles and defensive positions in certain situations. However, any such advantage may be offset by the greater digging speeds possible with the auger in many situations. Further field tests have been scheduled to quantify the differences between backhoe- and auger-dug charge emplacements in a variety of soils, and to investigate new techniques for charge emplacement.

Table 2 shows the explosive charge weights required in each hole for any of the plans in Figure 1 for obstacle ditching in a variety of earth materials. As can be seen from the wide variation in the weights of the required charges, crater size is greatly influenced by the composition of the cratered medium. The effects of soils on ditch size may vary greatly, even within a very small area where composition differences are not readily apparent. For this reason the recommended charge sizes have been chosen to produce at least the minimum required effect in typical earth materials of the types named. However, in cases where the soil type has not been determined, the largest individual charge weight for the explosive considered (shown in boldfaced type in Table 2) may be used as a rule of thumb.

By projection from earlier estimates (7), a 10-man crew with a JD 410 tractor should be able to complete 150 m of the triple-ditch design in a 12-hour day. Alternately, the same crew

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* To convert metres to feet, multiply by 3.280839.

Table 2

Design Data for Explosive Barrier Ditch Production

Cratered Medium	Individual Charge Weight of TNT* kg	lb
Saturated silty clay	20	44
Dry sand, weak sandstones, and shales	40	88
Wet clay	60	132
Dry gravelly sand	100	221
Dry sandy clay	160	353

Note: For all designs in this table: charge hole depths = 1.5 m; in-line charge spacings = 4 m; spacings between rows = 12 m. (Design basis is Reference 8.)

* If used, highly aluminized slurry blasting agent charges would be about 60 percent as large as equally effective TNT charges. Exact charge weights for any bulk explosive to be adopted by the Army will be available before the scheduled date for type classification. Note: To convert kilograms to pounds (mass), multiply by 2.205.

should be able to complete 225 m of the double-ditch design, or 450 m of the single-ditch design, in a 12-hour day.

An explosively excavated tank position

Figures 3-5 show front, side, and rear views, respectively, of an explosively excavated tank position created during recent field tests at Fort Polk, Louisiana. Requirements for the design were as follows:

a. The tank hull must have full protection from the front and both sides of the position.

b. The tank's main gun must be able to make a full-circle traverse at normal firing elevations.

c. The tank must be able to enter and leave the position from the rear without difficulty, and without any additional preparation after the initial excavation.

Figure 3. Front view of an M60 tank in an explosively excavated defensive position

Figure 4. Side view of an M60 tank in an explosively excavated defensive position

Figure 5. Rear view of an M60 tank in an explosively excavated defensive position

d. The explosive excavation must be done without the use of delay caps.

All design requirements were met by the experiment, which was completed in 1 hour.

Figure 6 and Table 3 give specifications for the creation of the hull-down tank position using TNT in a wet clay soil. It should be remembered, however, that this design is still under development. Tests have been scheduled to simplify the charge array, and to examine the effects of different soils on its successful execution.

Conclusions and Recommendations

When the primary bulk explosive system requirements for cratering efficiency, water resistance, and long-term nonexplosive storage are considered together, only one candidate system survives: the easily field mixable, highly aluminized, slurry blasting agent. However, such an advanced system is still at a developmental stage within the industry. The present Army effort to accelerate completion of this development appears very likely to succeed; it is recommended that the project be given appropriate priorities to

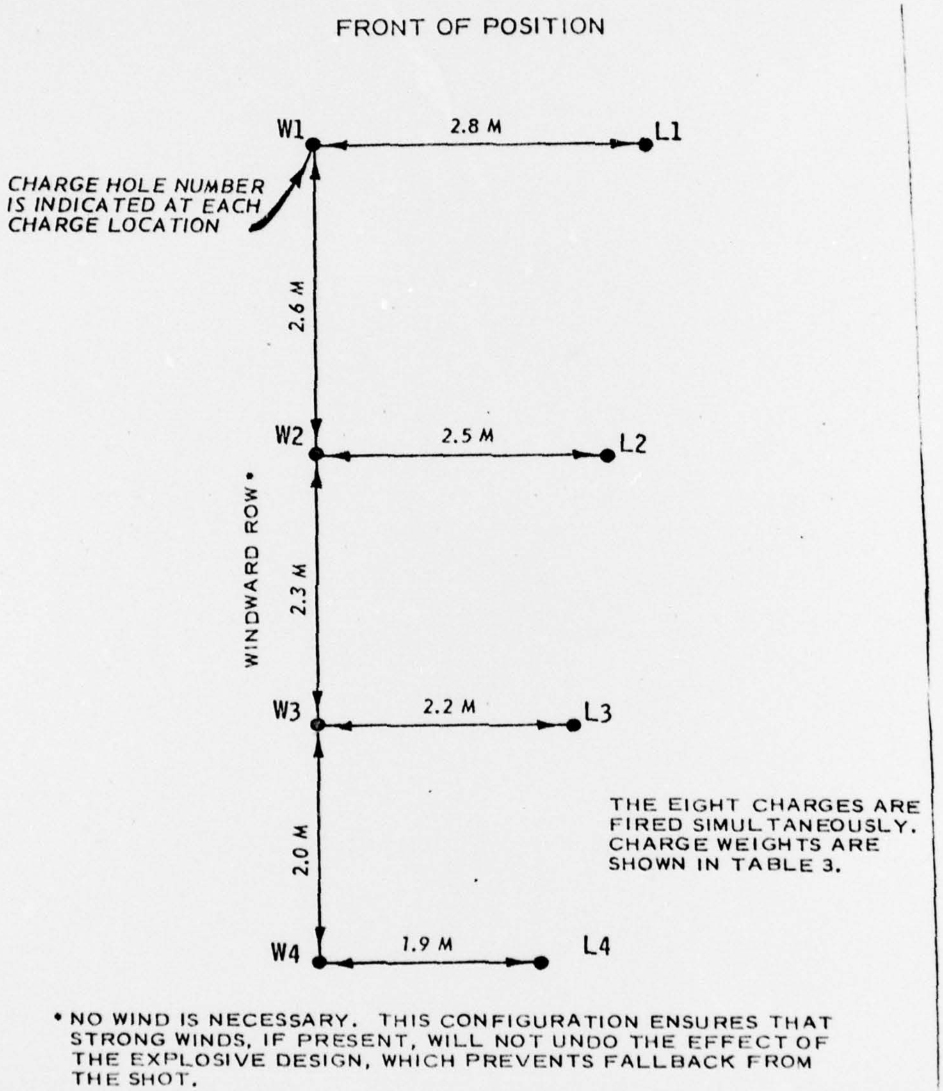

Figure 6. Explosive hull-down tank position design (plan view)

Table 3

Design Data for Explosive Hull-Down Tank Position Production

Charge Hole No.	Hole Depth m	Hole Depth ft		Charge Weight of TNT kg	Charge Weight of TNT lb
W1	0.60	2.0		41	90
W2	0.52	1.7		27	60
W3	0.46	1.5		18	40
W4	0.40	1.3		12	27
L1	1.15	3.8		20	45
L2	1.01	3.3		14	30
L3	0.88	2.9		9	20
L4	0.77	2.5		6	13
			Total	147	325

Note: Design basis is wet clay curve (8). Hole depth refers to the depth of the empty charge hole before the charge is added. Holes must be backfilled after charges are placed to get full excavation. If used, highly aluminized slurry blasting agent charges would be about 60 percent as large as the TNT charges listed above. Slurry blasting agents are also much more readily emplaced than block munitions. A final design for this excavation using the bulk explosive to be developed for the Army will be available before its scheduled type classification date.

enable the DARCOM Project Manager for Selected Ammunition to achieve on-time completion.

The constant charge depth and spacing technique for single-, double-, and triple-ditch obstacle production (Figure 1) is ideal for use with a bulk explosive system. Use of the DARCOM slurry blasting agent with this simple employment technique should give the Army an improved capability for swift and effective ditch production. Future emphasis in the Military Engineering Applications of Commercial Explosives (MEACE) program will be on increasing charge emplacement speed, determining the exact cratering characteristics of the DARCOM selected slurry blasting agent, and completing designs for explosively excavated defensive positions. It is recommended that close coordination be maintained between USAES and the U. S. Army Engineer Waterways Experiment Station to ensure that newly developed bulk explosive system employment techniques will be ready for incorporation into doctrinal literature prior to the system's availability to troop units.

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