EXPLOSIVES AND PROPELLANTS

From Commonly Available Materials

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INTRODUCTION

Thrust into jungle or underdeveloped areas for lengthy periods, how do Special Forces synthesize and compound explosives and propellants from indigenous materials? This, in essence, is the problem. With more-or-less sophisticated components and materials like blasting caps, primacord and military explosives it is relatively easy to construct a host of ingenious and effective weapons (e.g. guns, grenades, time bombs, mines, demolition and incendiary devices). But what if ready-made components and even basic raw materials are not available? This problem was the basis for an investigation into an Improvised Munitions Program. Through this program relatively simple procedures have been developed to fabricate munitions. This study is one such investigation of the program.

The development and dissemination of practical methods for field synthesis of explosives from commonly available materials may substantially increase the independence, mobility and effectiveness of Special Forces in remote areas while reducing logistic support requirements.

APPROACH

Ways and means were developed[1] to produce worthwhile quantities of the materials basic to the formulation of a propellant, primary and secondary high explosives. These materials extracted by field processes are described in the Improvised Munitions Handbook[2] and were considered to be of sufficient quality to manufacture black powder and certain high explosives. In view of these efforts, the following approach was delineated:

1. Manufacture of black powder with field extracted potassium nitrate by techniques previously evolved.

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[1] See REFERENCES

2. Manufacture of mercury and/or silver fulminate(s) or other primary explosives using field synthesized nitric acid and field grade ethyl alcohol (redistilled whiskey).

3. If the manufacture of fulminates is successful, construct simple flame initiated detonator system(s) using field produced fulminates.

4. Investigation of other potentially useful primary explosives based on field synthesized or other accessible chemicals.

5. Investigation of the manufacture of high explosives from field synthesized materials, e.g., nitroglycerin and/or Sprengel-type explosive mixtures.

MANUFACTURE OF BLACK POWDER FROM FIELD GRADE POTASSIUM NITRATE[3]

A total of twelve pounds of potassium nitrate was extracted and used in the field manufacturing of both black powder and nitric acid. Approximately 250 grams of black powder manufactured with field grade potassium nitrate performed as well as black powder manufactured with commercial grades of potassium nitrate. An additional five pounds of black powder was manufactured for further studies.

Improvised Black Powder Process

1. Three cups of potassium nitrate, 2 cups of powdered charcoal, 1/2 cup of sulfur and 3 cups of water are mixed in an iron skillet or similar container.

2. The mixture is slowly heated and stirred for about 1/2 hour.

3. The slurry is poured into 5 pints of alcohol (any kind) and stirred for approximately 5 minutes.

4. The slurry is then poured onto a cotton cloth and the alcohol is allowed to drain until the mixture is nearly dry (about 1/2 hour).

5. The mixture is then granulated through a screen with approximately 1/16" diameter holes.

6. The granules are spread on a dry surface and allowed to completely dry in open air (about one hour at 90°F).

IMPROVISED PRIMARY HIGH EXPLOSIVES

Field Manufacture of Fulminates

Fulminating compounds were prepared as early as the 18th century, however, until Howard's research in the beginning of the 19th century, little reliable information appears in the literature.[5] Mercury fulminate was employed by Nobel[6] in the mid-19th century on a commercial scale, and remained in use for nearly 75 years until supplanted by lead azide and other materials.[7,8]

Tests indicated that it is practical to manufacture both mercury and silver fulminate in the field. Both fulminates are readily synthesized; both have drawbacks:

1. Mercury metal may not be readily available in many areas.

2. Silver fulminate is extremely sensitive to impact or abrasion.

Since silver is commonly available (silverware, jewelry) some effort was devoted to reducing the impact sensitivity of the silver fulminate. This was accomplished with partial success by adding easily available desensitizers such as cornstarch to the wet fulminate.

Experimental Data

The requisite materials for the production of silver or mercury fulminates are the metals, nitric acid and ethyl (grain) alcohol. Early probe tests, using commercial reagents, indicated that field production of fulminates was quite practical. Subsequent tests, using field synthesized ingredients, brought to light several problems: Field synthesized nitric acid is almost anhydrous and there is almost no reaction between the metal and the acid. This problem was simply eliminated by gradually adding water to the acid until a vigorous reaction was initiated. Ethyl alcohol posed a somewhat greater problem. Commercial whisky was found to be too dilute to work properly. However, whisky and/or wine can be redistilled to produce a satisfactory grade of concentrated ethyl alcohol. (See Figure 1.) Apropos, the quality of ethyl alcohol produced by field distillation techniques was briefly investigated.

A crude distillation unit was built from a 15-gallon trash can and fitted with a condenser coil made from 15 feet of 3/8 inch diameter copper tubing. A mash of crushed corn and water was prepared, yeast added and the mixture allowed to ferment for five days. On distillation the brew yeilded a substantial amount of approximately 87% ethyl alcohol; a concentration satisfactory for fulminate manufacture. Alcohol production was not investigated at great length as competent technology in this area is almost universal. A typical method for field manufacture of ethyl alcohol is described in the following pages.

Initially, fulminate was produced by dissolving five grams of the metal in 30 cc of diluted field grade nitric acid and adding the solution to 50 cc of field grade ethyl alcohol. Subsequent tests showed that satisfactory yields could be produced with reduced amounts of acid; the optimized procedure is presented in the Appendix.

Generally, a batch of fulminate can be produced in 1/2 hour or less, although we have occasionally observed, with silver, delayed reactions of up to 1-1/2 hours. While the fulminate reaction is relatively safe, the dense fumes evolved are toxic and the entire procedure should be carried out in a well ventilated area or outdoors.

Since silver (in the form of coins) is generally more readily available than mercury, attempts were made to reduce the silver salt's extreme impact sensitivity.

We found that the addition of cornstarch and/or tapioca to wet fulminate would significantly reduce impact sensitivity. On a crude falling-weight test device, it appeared that cornstarch would double and tapioca triple the drop height necessary to detonate silver fulminate. (See Table I)

TABLE I. Impact Sensitivity Tests of Improvised Primary Explosives

Primary	Minimum Detonation Height (in.)	Average Detonation Height (in.)
Pure Ag fulminate	2	3.4
Dime Ag fulminate	3	4.4
Mercury fulminate	4	5.4
Cornstarch/Ag fulminate	6	7.2
Tapioca/Ag fulminate	9	10.5
Double Salts	12	14.1
HMTD*	18	19.1

*Hexamethylenetriperoxidediamine

It is believed that diluent desensitization of silver fulminate in the field is not reliable; differences in particle size and purity of both the fulminate and the desensitizer are likely to produce erratic results. For this reason silver fulminate should be used only when no other alternatives are available.

TABLE II. Field Manufacture of Ethyl Alcohol

Materials Required	Sources
Grain (wheat, corn, rice, etc.)	Crops, silos, rice paddies, etc.
Large drums	Clean oil drums, etc.
Metal tubing	Plumbing, vehicles
Yeast	Bakeries, food stores
Buckets	
Stirring stick or paddle	
Heat source	

Procedure

1. Fill a gallon bucket with dry grain and moisten with three cups of water. Cover bucket lightly and allow grain to sprout (about 1 week).

2. When the grain has sprouted, crush or grind it.

3. Crush or grind additional 5 gallons of dry grain.

4. Mix the crushed dry and sprouted grain and add 3/4 gallon of water. Heat this mash until hot but not unbearable to the hand. Maintain at this temperature for 3 hours. Remove heat and allow mash to cool to about blood temperature.

5. Add 6 teaspoons of yeast to the mash and stir well; cover but do not seal and stand in warm place for 5 days. After 5 days, pour fermented mash into the still and heat as shown in Figure 1. Stop heating and discard mash after 1 pint of alcohol per gallon of mash has been collected.

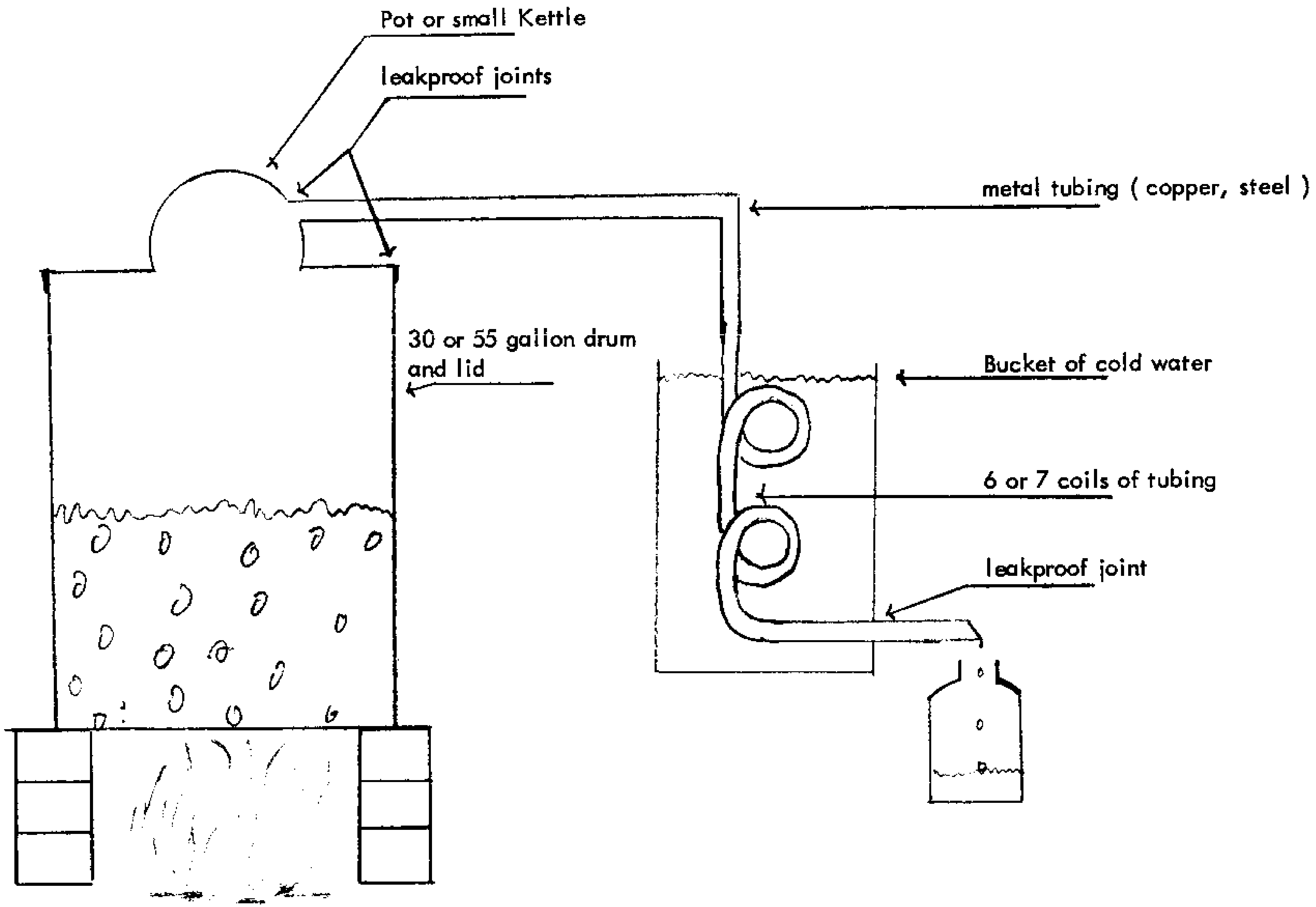


Figure 1. Schematic Alcohol Still

Field Manufacture of Double Salts

While not generally well known, and not used commerically, the double salt of silver acetylide/silver nitrate ($Ag_2C_2/AgNO_3$) appears to be a suitable material for improvised initiators. Double salts may be synthesized in the field from silver (silverware, jewelry), field synthesized nitric acid, and acetylene generated from calcium carbide.

Experimental Data

Our first attempt at producing double salts followed the preparation given in the literature.[9, 10, 11] This preparation called for the purification of the acetylene by bubbling it through permanganic acid. We quickly determined that not only was this step unnecessary, but in fact quite dangerous: approximately 10 seconds after the acetylene contacted the permanganic acid, there was a sharp explosion that demolished the apparatus. After elimination of this step, the process appeared to be relatively safe, and subsequent field production tests proceeded without incident. The optimized procedure for the field manufacture of double salts is presented in the Appendix.

Field Manufacture of HMTD

Hexamethylenetriperoxidediamine (HMTD) is perphaps the only organic peroxide that has been seriously considered for commercial initiators.[12] This primary explosive is probably the easiest and safest to manufacture in the field. The requisite materials for the production of HMTD are as follows:

1. Hexamethylenetetramine, a common drug used for bladder infections and marketed under the names Urotropine, Methenamine, Hexamin and others.

2. Hydrogen peroxide

3. Citric acid, obtainable in drug stores and in food stores under the name "Sour Salt".

Experimental Data

Davis[4] gives the following preparation for HMTD:

"Preparation of Hexamethylenetriperoxidediamine. Fourteen grams of hexamethylenetetramine is dissolved in 45 grams of 30% hydrogen peroxide solution which is stirred mechanically in a beaker standing in a freezing mixture of cracked ice with water and a little salt. To the solution 21 grams of powdered citric acid is added slowly in small portions at a time while the stirring is continued and the temperature of the mixture is kept at 0° or below. After all the citric acid has dissolved, the mixture is stirred for 3 hours longer while its temperature is kept at 0°. The cooling is then discontinued, the mixture is allowed to stand for 2 hours at room temperature, and the white crystalline product is filtered off, washed thoroughly with water, and rinsed with alcohol in order that it may dry out more quickly at ordinary temperatures."

Our efforts were focused on the examination of Davis' procedure and its potential modification for field use.

A brief analysis of the availability of the components indicated that only the 30% hydrogen peroxide would be a problem. However, drug stores commonly carry a 6% hydrogen peroxide solution for use as a hair bleach. We found that HMTD could be produced with bleach grade peroxide. In addition, Davis's preparation calls for extended agitation of the solution at 0° C. to obtain maximum yields. It was found that satisfactory yields could be obtained with little agitation at room temperature if the precipitation time was extended. The optimized process for HMTD in presented in the Appendix.

Improvised Detonator Systems

Once a primary explosive has been improvised the next problem is to safely and effectively utilize it. To this end, tests were conducted with improvised primary explosives to determine optimum method(s) of use. A standard improvised cap and alternate systems were evolved; an arbitrary cap was used to check performance of various improvised high explosives. Figure 2 illustrates a standard cap configuration.

It is evident that the cap envelope should be capable of being manufacturable from readily available materials. On the surface this seems to be a simple problem; one merely needs a small tube in which to load the explosive. This, however, is not the case. For example, caps fabricated with tubes made from rolled paper or aluminum foil did not provide adequate confinement; hence, such caps did not reliably initiate high explosives. In addition, foil or paper tube caps tended to leak when used in conjunction with liquid explosives. With the exception of .22 caliber long rifle cases and 5.56mm cases, small arms cartridge cases are generally too large.

The optimum cap envelope material, judging from probe tests, seems to be small diameter metal tubing and, specifically, 1/4" diameter soft copper tube such as that used in vehicles, plumbing, etc.

Initial tests were conducted with 1/4" diameter copper tube caps 3-1/2" long containing straight, unconfined charges of improvised mercury fulminate. These caps were fired into 50 gram target charges of prilled TNT (duPont "Pelletol") confined in paper cups. Results were erratic. Radically improved reliability was observed when the mercury fulminate was hand-pressed into crimped tubes. As expected, compression also increased the initiating efficiency of other improvised primary explosives.

Compound caps, that is, caps containing a base charge of high explosives, are generally the most efficient and reliable. When suitable solid high explosives are available they can be used to extend the supply of improvised primaries and provide more powerful initiators.

To provide boundary data on efficiency and reliability, both compound and straight improvised caps were tested with a variety of military and improvised high explosive target charges. The results of these tests are presented in Tables III and IV.

TABLE III. Initiation Tests of Improvised Compound Caps (5 shots each primary)

Cap Base Charge	Target Charge	Mercury Fulminate	HMTD	Double Salts
1 in. Col. TNT	50 gm Pelletol in Paper Cup	5/5 Positive	5/5 Positive	5/5 Positive
1 in. Col. C4	50 gm C4	4/5 Positive	4/5 Positive	4/5 Positive

NOTE: Caps ignited with Bickford Safety Fuze. All caps made with 1/4 inch diameter soft copper tube with 5/16 inch hand-pressed columns of each primary over base charge. (See Figure 2)

In summary, it appears that improvised mercury fulminate is generally the most reliable initiator. Also, compound caps containing base charges of solid high explosives have greater output and are, therefore, more reliable. Improvised and commercial dynamite apparently can be reliably initiated with any of the improvised caps.

Straight caps (without base charge) containing 5/16 inch column heights of desenitized silver fulminate failed to detonate pipe-confined and unconfined 50 gram charges of prilled TNT, C4, Urea Nitrate and CTA. However, straight silver fulminate caps reliably initiated all improvised and commercial 40% nitroglycerin dynamite. Compound silver fulminate caps containing a base charge of 1 inch hand-pressed PETN extracted from primacord reliably initiated pipe-confined prilled TNT, CTA, nitric acid/paper and all unconfined dyamites. Initiation of C4 (2 out of 5 shots, unconfined) was erratic, and there were no detonations in 5 trails of pipe-confined improvised urea nitrate. Because of the extreme sensitivitiy of silver fulminate, we do not recommend its manufacture or use if other materials are available.

TABLE IV. Initiation Tests of Improvised Straight Caps

(5/16" compressed columns of each primary in 1/4" dia. copper tubes)

Target Charge (50 gms)	Confinement	Primaries		
		Mercury Fulminate	HMTD	Double Salts
CTA[1]	1-1/2" dia. Pipe	5/5 Positive	4/5 Positive	3/5 Positive
Urea Nitrate[2]	1-1/2" dia. Pipe	0/5 Positive	0/5 Positive	0/5 Positive
Nitric Acid/Paper[3]	Paper Cup	0/5 Positive	0/5 Positive	0/5 Positive
Nitric Acid/Paper	1-1/2" dia. Pipe	5/5 Positive	3/5 Positive	3/5 Positive
Methyl Nitrate Dynamite[4]	Paper Cup	5/5 Positive	5/5 Positive	5/5 Postive
Nitroglycol Dynamite[5]	Paper Cup	5/5 Positive	5/5 Positive	5/5 Positive
Nitroglycerine Dynamite[6]	Paper Cup	5/5 Positive	5/5 Positive	5/5 Positive
Amm. Nitrate Dynamite[7]	Paper Cup	5/5 Positive	5/5 Positive	5/5 Positive
Commercial 40% NG Dynamite	Paper Cup	5/5 Positive	5/5 Positive	5/5 Positive

[1] Carbon tetrachloride/aluminum 3.5:1 by weight

[2] Improvised from field grade nitric acid and urine

[3] Improvised with field grade nitric acid and urine

[4] Improvised methyl nitrate blended with 60% by wt. sawdust

[5] Improvised nitroglycol blended with 60% by wt. sawdust

[6] Improvised nitroglycerin blended with 60% by wt. sawdust

[7] Ammonium nitrate blended with 15% by wt. improvised nitroglycerin

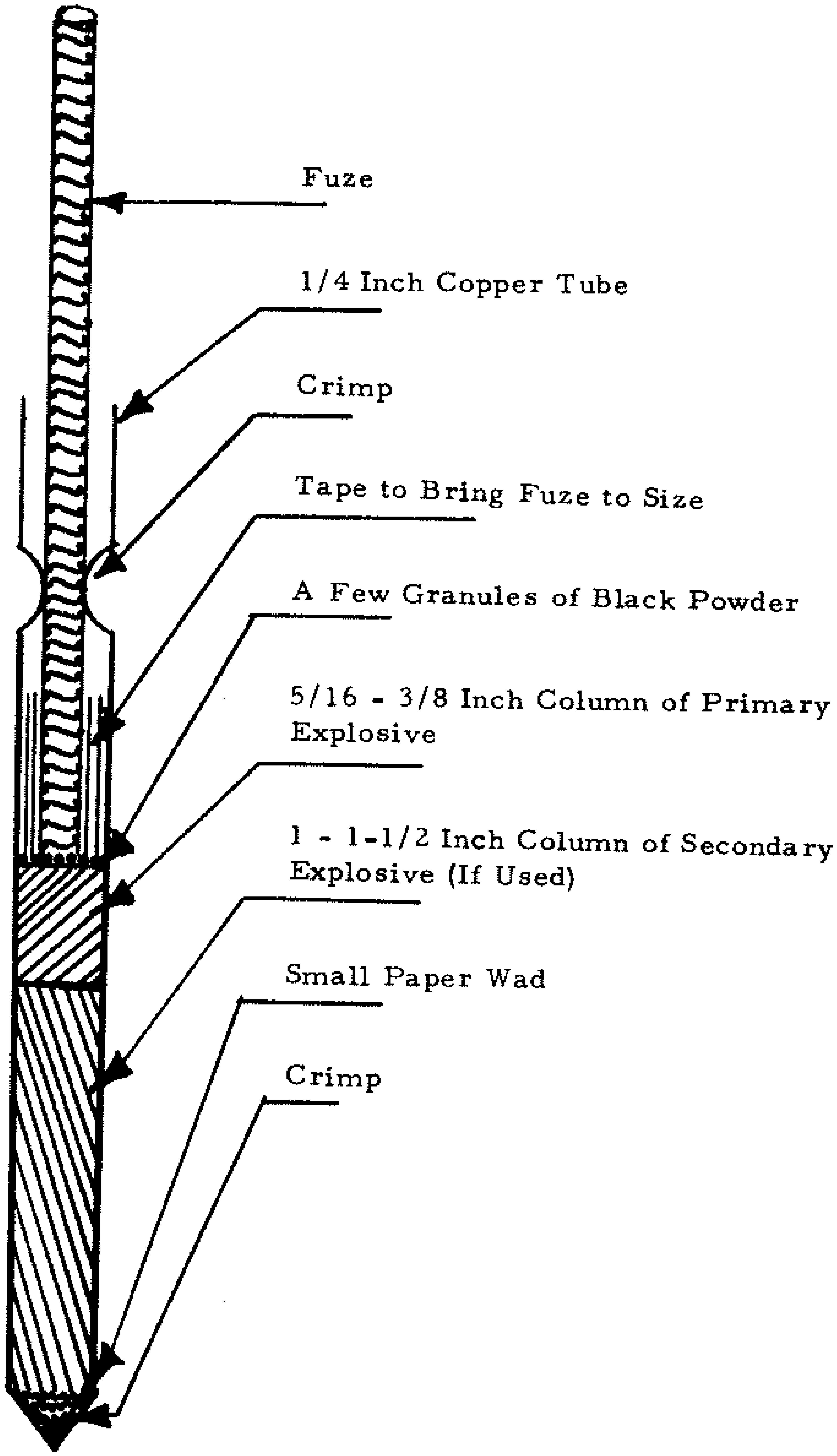


Figure 2. Typical Assembly - Improvised Cap

OPTIMIZED PROCEDURE FOR FIELD MANUFACTURE OF IMPROVISED DETONATORS

TABLE V. Field Manufacture of Improvised Detonators

Materials Required	Source
Primary Explosive	Improvised
1/4 in. diameter Soft Copper or Aluminum Tubing	Plumbing, vehicles
Wood, brass or aluminum ram to fit tubing	Improvised
Fuze to fit tubing	Commercial or military blasting fuze Improvised fuze
Black Powder	Commercial or military munitions Improvised
Booster Explosive	TNT, C4, PETN

Procedure

1. Make a 2-1/2 inch deep hole in a large piece of wood, or into ground behind small barricade, or into a tree stump. (See Figure 3)

2. Cut a piece of copper or aluminum tubing 3 inches long and close one end with rammed paper plug or by hammering shut.

3. Place the tube on the wood block or in the hole behind the barricade, open end up.

4. Firmly press on 1 to 1-1/2 inches column of crushed TNT, C4 pieces or PETN extracted from primacord with wood, aluminum or brass ram.

5. Gently (but firmly) press in about 3/8 inch column of dry primary explosive, as shown in sketch. Carefully remove ram.

6. Sprinkle a few granules of black powder into the tube (optional).

7. Wrap fuze with tape or strip of paper to fit inside diameter of cap tube (sliding fit), if necessary.

8. Press fuze firmly into cap and crimp lightly with pliers or tape securely in place.

CAUTION! Shield body behind or below barricade and keep head and face clear when pressing in primary explosive.

NOTE: If no secondary explosive is used in cap, a fired. 22 caliber long rifle case may be used as a container for the charge.

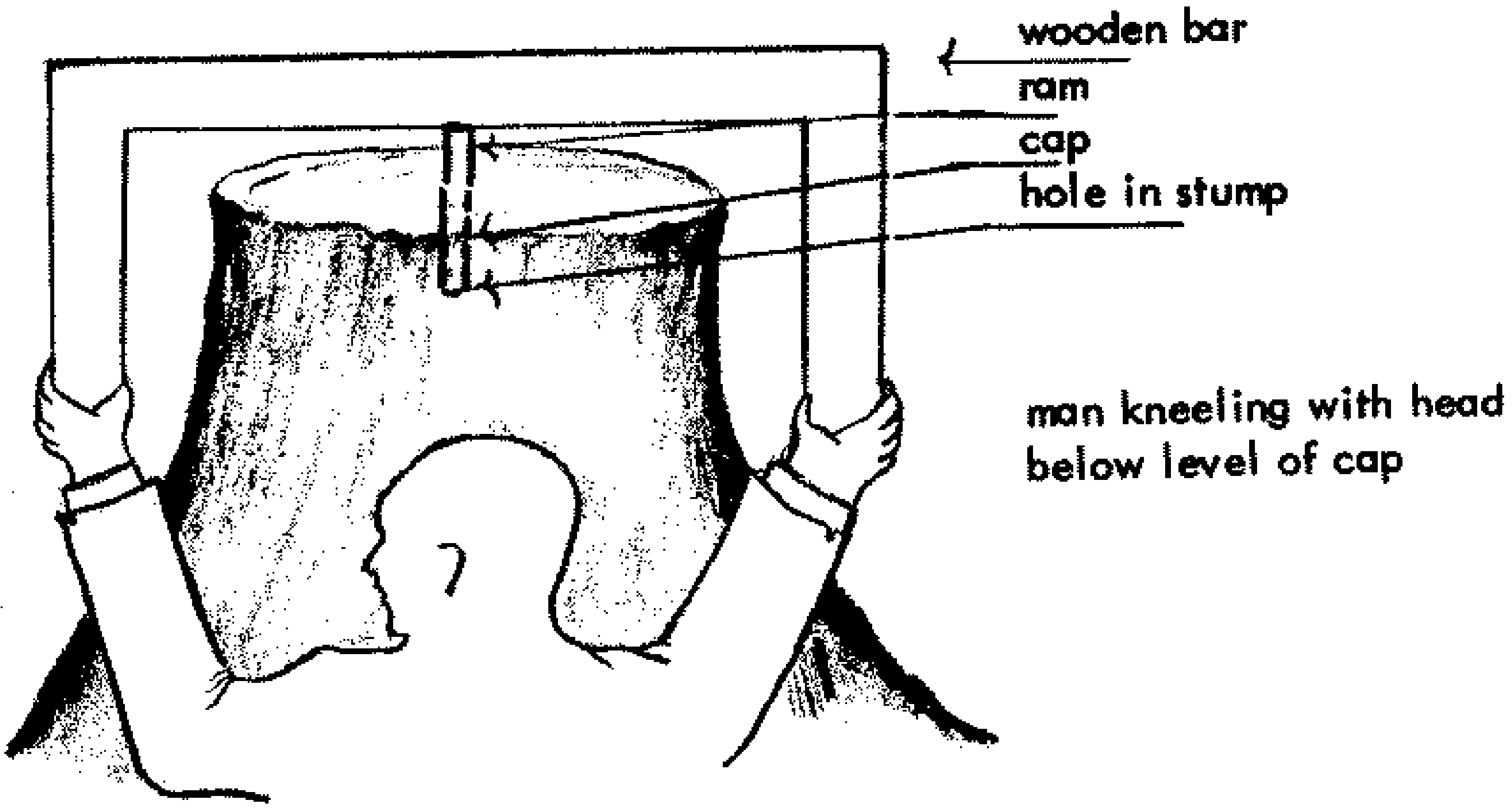


Figure 3. Safe Method to Ram Caps

IMPROVISED SECONDARY HIGH EXPLOSIVES

Field Manufacture of Nitric Esters

A literature search disclosed three common alcohols of potential interest: methyl alcohol, ethylene glycol, and glycerin.[12,13]

Methyl nitrate appears to be the safest and easiest of the three esters to prepare in the field. Among its advantages are:

1. low sensitivity to acid contamination

2. distillation point much below explosion temperature (BP = 65° C., explosion temperature = 150° C.) thus reducing preparation hazards.

Methyl nitrate is relatively volatile and, for this reason, is not used commercially.[13] However, its volatility may be an advantage in field manufacture as it avoids decontamination problems from spillage. Conversely, explosive mixtures containing methyl nitrate should be well wrapped to avoid undue evaporation. Ethylene glycol dinitrate ranks as second choice for improvised production. While slightly more powerful than methyl nitrate,[13] it has the disadvantage of slower separation from the nitration acids and a greater sensitivity to contamination.

Glyceryl trinitrate (nitroglycerin)[13,14,15] is the least desirable for field manufacture because of greater sensitivity to acid contamination and mechanical shock. However, the availability of glycerin via animal fat is a distinct advantage.

All of the latter explosives are liquids and therefore difficult to employ in munitions. Nobel solved the problem by absorbing nitroglycerin into diatomaceous earth.[13,14] Other common absorbents can, of course, be used in improvised manufacture. Shredded paper, cloth and sawdust, for example, provide quite satisfactory absorbents for improvised dynamites.

In addition, any of the latter nitric esters can be used to sensitize and increase the brisance of ammonium nitrate explosives. Thus, relatively small quantities of these powerful high explosives can be greatly extended.

Experimental Data

Prepartion of the nitric esters of methyl alcohol, ethylene glycol and glycerin are quite similar.[6,12,13,14,15] The simplest procedure is to slowly add the alcohol to concentrated nitric acid and then drown the mixture in a large excess of water, permitting the explosive ester to settle out. While this process is relatively safe and easy, it is very wasteful of nitric acid. Nitration with mixed acids (nitric and sulfuric) conserves nitric acid and improves explosive yield. And, since sulfuric acid is required to improvise nitric, it is beneficial to conserve both materials, sulfuric acid in particular. Hence, our efforts were devoted to evolving a field process that conserved acid and provided for acid recovery after nitration.

Field purification of spent acid is a somewhat hazardous process. This hazard is greater with acid remaining from the nitration of ethylene glycol and glycerin that it is with acid from methyl nitrate preparation. Spent acids contain trace amounts of explosive that will not separate on standing. Since purification and recovery of spent acid requires boiling to drive off impurities, there is some change of violent decomposition of dissolved explosive. Such decomposition usually splashes acid from the vessel; high order detonation is unlikely unless there is an acutal layer of explosive left in the container.

Fortunately, spent acid recovery/purification does not require close attendance and, for this reason, the hazard can be minimized.

Optimized process for field manufacture of methyl nitrate, ethylene glycol dinitrate and nitroglycerin are presented along with spent acid recovery procedure. Improvised dynamite formulation procedures are described in the following pages.

Optimized Process for Field Manufacture of Methyl Nitrate, Ethylene Glycol Dinitrate and Nitroglycerin

TABLE VI. Field Manufacture of Nitric Esters

Material Required		Sources	
Sulfuric Acid		Clear battery acid boiled until white fumes appear	
Nitric Acid		Field Grade Nitric Acid	
Methyl Alcohol		Methanol Wood alcohol (not denatured alcohol). Anti-freeze	
Ethylene Glycol		Anti-freeze (permanent) Glycol	
Glycerin		Drug Stores	
Eyedropper		Drug Stores Medicine bottles	
Aluminum Stainless Steel Wax Coated	Teaspoon		
Ceramic			
Sodium Carbonate or Sodium Bicarbonate		Washing soda Baking soda	Optional
Large Diameter (2qt) Jars			
Narrow Clear Glass Jar			

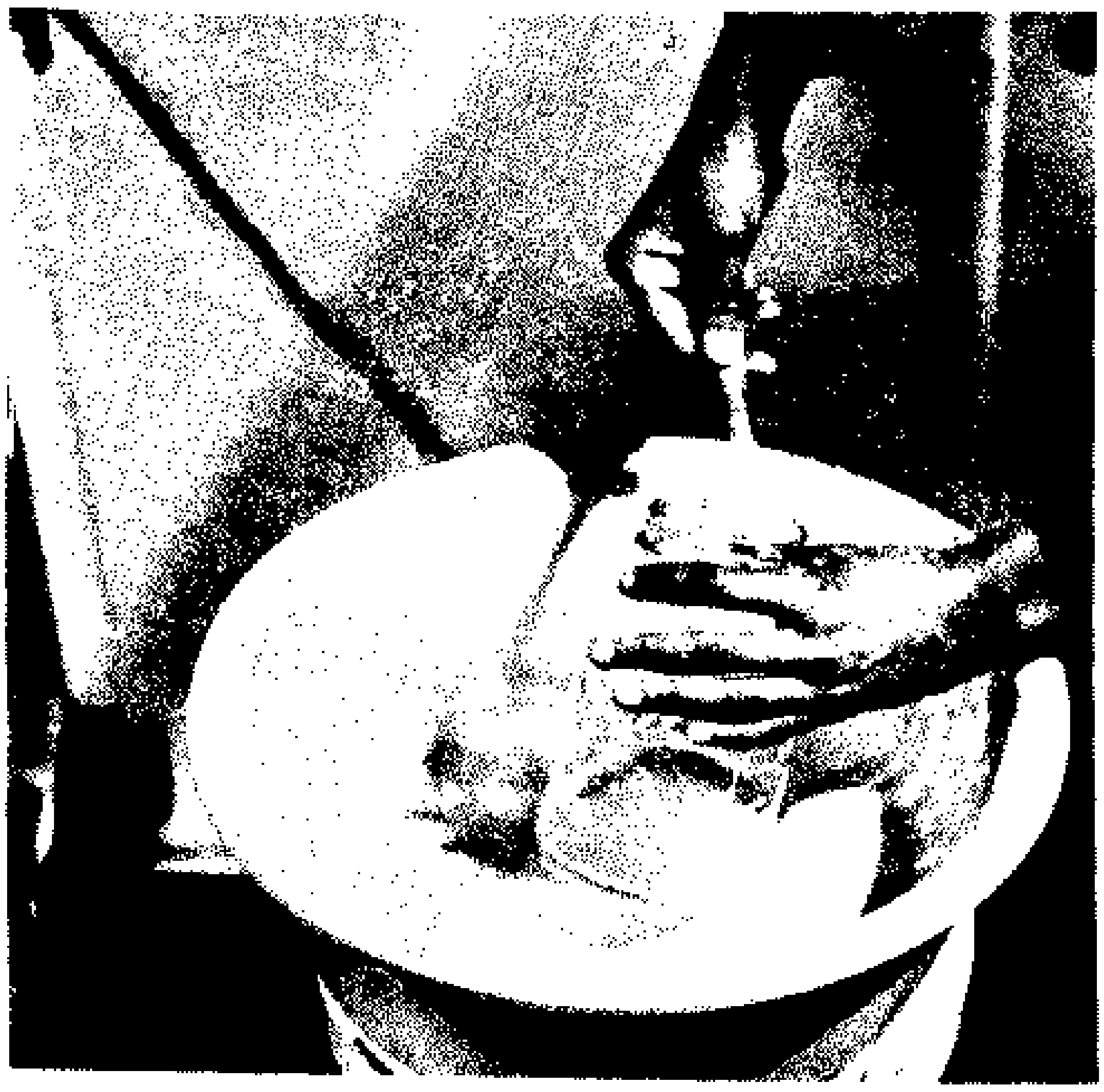
Procedure

1. Add 24 teaspoons sulfuric acid to 16-1/2 teaspoons nitric acid in a 2 quart size bottle.

CAUTION! Acid will burn skin and destroy clothing. If any is spilled, wash it away with a large quantity of water. Do not inhale fumes.

2. Place the bottle in a stream or large basin (3-5 gallon) of cold water and allow acid to cool.

3. Rapidly swirl the bottle to create a whirlpool in the liquid (without splashing) while keeping the bottom portion of the jar in the water.



Step 3. Swirling bottle in basin of water while adding alcohol

4. While continually swirling, add, 1/2 teaspoon at a time, 13-1/2 teaspoons methyl alcohol or 9 teaspoons ethylene glycol or 8 teaspoons glycerin allowing mixture to cool between additions.

NOTE: Complete addition should take approximately 10 minutes.

CAUTION! If there is a sudden increase in the amount of fumes produced or if the solution suddenly turns much darker or begins to froth, immediately dump charge in the water. (Note: within 10 seconds.) This will halt the reaction and prevent an accident. Any explosive formed may be recovered if basin is used. See Step 7 in procedure for separation.

5. After the final addition, swirl for another 30-45 seconds and then allow bottle to stand in water until the two layers separate. (methyl alcohol 5 minutes, glycerin 10 minutes, ethylene glycol 20-25 minutes).

NOTE: This separation and those to follow are best done in smaller, narrower jars to allow a sharper distinction between layers.

6. With an eye dropper, or aluminum, stainless steel, ceramic or wax-coated spoon,. remove top layer and put in another bottle. This liquid is the explosive.

Step 6. Removing top layer of explosive with eyedropper

7. Add an equal quantity of water to the explosive and swirl. Allow to separate again. The explosive is now the bottom layer.

8. Carefully remove the water (see Step 6) and repeat Step 7 with a solution of tablespoon of sodium carbonate or bicarbonate and water (1/2 tablespoon carbonate/quart of water). The explosive may be stored under the salt solution. If carbonate is not available use plain water.

Step 8. Removing water from explosive - now the bottom layer

Acid Recovery Procedure

1. After removing the explosive from the acid, place the acid in a safe place where it will not be disturbed for 6-8 hours, and cover lightly to prevent contamination.

> CAUTION! Acid will burn skin and destroy clothing. If any is spilled, wash it away with a large quantity of water. Do not inhale fumes.

2. After 6-8 hours remove any explosive on top of the acid (See Step 6 on page 20).

3. Place 1/8 the acid's volume of water in a clean heat-resistant glass or ceramic jar and slowly pour the acid into the water.

4. Place the acid/water jar in a safe place (away from people or materiel) in the sun; leave jar for one day.

5. Place jar on a slow fire at least 25 yards from people or property and watch from that distance. When dense white fumes appear remove from heat. The liquid remaining is plain sulfuric acid. Allow to cool before using again.

TABLE VII. Improvised Dynamites

Materials Needed:

Improvised Explosive	Methyl nitrate Nitroglycol Nitroglycerin
Absorbent	Fine sawdust Shredded paper Shredded cloth
Stabilizer (optional)	Baking soda Washing soda Slaked Lime

Cup
Pans
Teaspoon
Wooden stick

Procedure

Straight Dynamite

1. Place one firmly packed cup of absorbent and 1/2 teaspoon of stabilizer in a small pan.

2. While stirring with a wooden stick, slowly add explosive until the mass is very damp but not wet enough to drip. If mix gets too wet add more absorbent.

> CAUTION! Do not handle liquid explosive or allow to contact skin. If this happens, flush away immediately with large quantity of water. Keep any grit, sand or dirt out of mix.

If making ammonium nitrate-base dynamite

1. Place one firmly packed cup of fine ground ammonium nitrate, 1/2 teaspoon of stabilizer and about 1/4 cup loosely packed fine sawdust (if very fine use less, if coarse more), in a small pan.

2. While stirring with a wooden stick, slowly add about 4-1/2 to 6 teaspoons of liquid explosive. When properly made the material is just damp looking, but do not use less than 3 teaspoons of liquid explosive, - the more used, the more brisant the dynamite.

NOTE: Store methyl nitrate dynamites in sealed containers to prevent evaporation.

Step 2. Adding explosive to sawdust and shavings

Nitrocellulose

Some consideration was given to field manufacture of nitrocellulose and subsequent preparation of improvised smokeless powder. The nitration of cellulose suitable for smokeless powder manufacture requires relatively large quantities of pure sulfuric and nitric acids, and extensive purification and control processes. In addition, many of the components (e.g. acetone) are not likely to be available in the field. Davis's laboratory preparation[4] of nitrocellulose, given below, is indicative of the problems.

"Preparation of Pyrocellulose"

Equal volumes of sulfuric acid (1.84) and nitric acid (1.42) are mixed by pouring the sulfuric acid with stirring into the nitric acid, and the mixture is allowed to cool to room temperature. Five grams of absorbent cotton, previously dried at 100° for 2 hours, is thrust quickly into 150 cc. of this mixed acid and allowed to remain there for 30 minutes while it is stirred occasionally with a glass rod. The cotton is removed, freed as much as possible from acid by pressing against the side of the vessel, and introduced quickly into a large beaker of cold water where it is stirred about in such manner as to accomplish the prompt dilution of the acid with which it is saturated. The product is washed thoroughly in running water, and boiled for an hour with distilled water in a large beaker, then boiled three times with fresh portions of distilled water for a half hour each time. If the water from the last boiling shows the slightest trace of acidity to litmus paper, the pyrocellulose ought to be rinsed and boiled once more with distilled water. Finally, the excess of water is wrung out, and the pyrocellulose is dried in a paper tray for 48 hours at room temperature."

"Guncotton is made in substantially the same way as pyrocellulose except that a stronger mixed acid containing approximately 24% nitric acid, 67% sulfuric acid, and 9% water is used. Long-fiber high-grade guncotton is usually manufactured by the pot process and with the use of mixed acid which is nearly anhydrous. Iron pots are generally used. For the nitration of 4 pounds of dry cotton, 140 pounds of acid is introduced into the pot and the cotton is immersed in it, pressed down, and allowed to digest for 20 or 30 minutes. The contents of several pots are centrifuged at once, and the product is stabilized in the same way as pyrocellulose except that it is not pulped."

In view of logistic and stability problems, and the relatively difficult synthesis of nitrocellulose, we discarded it as a candidate for improvised systems. An alternate form of nitrocellulose was, however, evolved in the high explosive system described previously.

RDX

RDX, cyclotrimethylenetrinitramine, is the major constituent of a number of powerful military explosives (C4, for instance). When first considered, RDX appeared to be a worthwhile addition to the family of field improvised explosives.

The base material for synthesizing RDX is hexamethylenetetramine, a common urinary disinfectant, available under many trade names (Hexamin, Urotropin, etc.) RDX can be synthesized with field grade nitric acid; however, the yields are approximately 20% lower than laboratory preparations. Thus, the tradeoff of time and material is poor, and effort is better directed to higher yield explosives such as nitric esters.

In preparing RDX in the field we followed Davis's procedure[4] (given below), substituting field grade nitric acid and deleting precise cooling.

> "It has feebly basic properties and forms a nitrate, $C_6H_{12}N_4 \cdot 2HNO_3$, m. p. 165°, soluble in water, insoluble in alcohol, ether, chloroform, and acetone. The product, $C_3H_6O_6N_6$, prepared by nitrating this nitrate and patented by Henning[34] for possible use in medicine, was actually cyclonite. Herz later patented[35] the same substance as an explosive compound, cyclotrimethylenetrinitramine, which he found could be prepared by treating hexamethylenetetramine directly with strong nitric acid. In his process the tetramine was added slowly in small portions at a time to nitric acid (1.52) at a temperature of 20-30°. When all was in solution, the liquid was warmed to 55°, allowed to stand for a few minutes, cooled to 20°, and the product precipitated by the addition of water. The nitration has been studied further by Hale[36] who secured his best yield, 68%, in an experiment in which 50 grams of hexamethylenetetramine was added during 15 minutes to 550 grams of 100% nitric acid while the temperature was not allowed to rise above 30°. The mixture was then cooled to 0°, held there for 20 minutes, and drowned.
>
> The formaldehyde which is liberated by the reaction tends to be oxidized by the nitric acid if the mixture is allowed to stand or is warmed. It remains in the spent acid after drowning and interferes with the recovery of nitric acid from it.
>
> 34 Ger. Pat. 104,280 (1899).
> 35 Brit. Pat. 145,791 (1920); U.S. Pat. 1,402,693 (1922).
> 36 J. Am. Chem. Soc., 47, 2754 (1925)."

Urea Nitrate

Urea Nitrate, mentioned in the literature [1, 8, 8] as an explosive, also appeared to be a good candidate for field synthesis. While relatively easy to prepare, it suffers from several disadvantages. Namely, urea nitrate requires heavy confinement and very strong initiation to achieve high order detonation. Additionally, improvised urea nitrate, even when successfully detonated, is not a particularly brisant explosive. Urea nitrate has, as its sole advantage, the ready availability of its basic component - urine. Procedures for the field preparation of urea nitrate is presented in the Appendix.

Sprengel Explosives

According to Davis,[4] Sprengel explosives were introduced in 1871 by Herman Sprengel. The distinguishing features of Sprengel explosives are their preparation just prior to use, and that one or more of their components are liquids. Generally, Sprengel explosives contain strong nitric acid and fuel. Accordingly, these explosives are difficult to handle. Sprengel-type explosives are, generally, brisant and easy to manufacture. Since they are normally mixed just prior to use, they are in a sense tailored to field improvisation.

This investigation covered potential candidate fuels to be used in conjunction with field grade nitric acid. Table VIII summarizes the results of this study.

The three candidates from the latter tests, cotton cloth, paper towels, and mononitrobenzene were subjected to further evaluation.

Nitric Acid/Cellulose Explosives

Several types of commonly available cellulose were tested in combination with field grade nitric acid. These included: printed and sized paper, new-dyed and printed cotton cloth, plain paper

TABLE VIII. Field Nitric Acid/Fuel Mixture Tests

Material	
Turpentine	Violent reaction on contact with acid
Sugar	Violent reaction on contact with acid
Kerosene	Immiscible - no reaction
Sawdust	Violent reaction on contact with acid
Gasoline	Immiscible - no reaction
Bore cleaner - Military	Immiscible - no reaction
Bore cleaner - Commercial	Violent reaction on contact with acid
Mononitrobenzene (oil of Mirbane)	Miscible - no immediate reaction
Paper towels	No immediate reaction
Washed cotton cloth	No immediate reaction

towels and well-washed cotton cloth. Printed paper, sized paper, and dyed or printed cotton cloth reacted quickly with the acid and were therefore eliminated. Plain paper towels and washed cotton cloth, however, appeared reasonably stable.

Tests were then conducted with the latter Sprengel-type explosives to determine their brisance and reliability. The results of these tests are shown in Table IX.

Additional initiation data on cellulose-Sprengel explosives with improvised caps is given in Table IV.

Although these explosives are easy to prepare, there are a number of problems associated with their use and handling. The nitric acid component will attack most containers and it is usually necessary to protect surfaces with a coating of wax or acid-resistant paint. Aluminum-cased blasting caps resist the acid but wires and/or fuze junctions must be protected. Copper-cased caps (such as improvised devices) are rapidly corroded and acid protection is mandatory. There is considerable acid fuming when these explosives are prepared and mixture should take place only in well ventilated areas or outdoors.

TABLE IX. Initiation Tests of Sprengel Cellulose Explosives[3]

Test	Material[1]	Confinement[2]	Remarks
1.	Paper Towels/Acid	1-1/2" dia. Pipe	High order detonation
2.	Paper Towles/Acid	1-1/2" dia. Pipe	High order detonation
3.	Paper Towels/Acid	1-1/2" dia. Pipe	High order detonation
4.	Paper Towels/Acid	1-1/2" dia. Pipe	High order detonation
5.	Paper Towels/Acid	1-1/2" dia. Pipe	High order detonation
6.	Washed white cotton Cloth/Acid	1-1/2" dia. Pipe	High order detonation
7.	Washed white cotton Cloth/Acid	1-1/2" dia. Pipe	High order detonation
8.	Washed white cotton Cloth/Acid	1-1/2" dia. Pipe	High order detonation
9.	Washed white cotton Cloth/Acid	1-1/2"dia. Pipe	High order detonation
10.	Washed white cotton Cloth/Acid	1-1/2" dia. Pipe	High order detonation

[1] Absorbent spread out on foil and saturated with acid, rolled into tube and placed into pipe bomb.

[2] Pipe precoated internally with wax to prevent acid attack

[3] Pipe bombs initiated with No. 6 commercial blasting caps, wax coated.

Here again, as with urea nitrate and nitrocellulose, the tradeoff of materials is poor. The cellulose/acid system consumes an inordinate amount of nitric acid that could be more effectively utilized in producing large quantities of explosive such as the nitric esters. Thus, the Sprengel explosives offer alternate systems that can be employed only where conditions warrant.

Procedure for preparation of cellulose/acid explosives is given in the Appendix.

Nitric Acid/Monomitrobenzene ("Hellhoffite") Explosives

A Sprengel explosive comprised of a mixture of mononitrobenzene and nitric acid has been patented[4] and apparently used under the name of "Hellhoffite". The literature recommends an optimum mixture of 28 parts mononitrobenzene to 72 parts strong nitric acid.

Little work was done with this mixture other than to check its general characteristics. In use, the mononitrobenzene is simply poured into the acid and stirred. Attempts to absorb the mixture onto clean cotton or paper were defeated by violent reaction. Tests of mononitrobenzene with field grade nitric acid indicated that the materials were compatible. A 1-1/2 inch diameter by 6 inch length wax-coated pipe "bomb" was loaded with volumetrically mixed acid/mononitrobenzene and initiated with a commercial No. 6 wax-coated electric blasting cap. The bomb detonated high order, with an estimated strength equal to at least 50% nitroglycerin dynamite.

As with other Sprengel explosives, "Hellhoffite" is extremely corrosive and metal munitions components must be protected by wax or acid-resistant paint. The doubtful availability of mononitrobenzene on the field relegates this explosive to the alternate choice class. Field technique for the manufacture of this explosive is presented in the Appendix.

CONCLUSIONS AND RECOMMENDATIONS

Previously procedures were determined[1,2] for field synthesis of three critical raw materials: potassium nitrate, sulfuric and nitric acids. With these materials, a series of explosives, propellants, and munitions capable of successful field improvisation were evolved.

Boundary parameters such as safety, reliability and availability of ingredients and equipment must be considered in any improvised munitions/explosives system. Thus, in many instances, tradeoffs are mandatory. For this reason we have wherever possible, offered alternate choices to men in the field. Our data indicates with reasonable certainty that certain materials and procedures are superior to others. On this basis, we recommend the following preferential lists:

a. Improvised Propellant:

    1. Black Powder

b. Improvised Primary Explosives:

    1. Mercury Fulminate

    2. HMTD

    3. "Double" Salts

    4. Desensitized Silver-Fulminate

c. Improvised Blasting Caps:

    1. Compound Caps (with high explosive base charge)

    2. Straight Caps (no base charge)

d. Improvised Secondary High Explosives

    1. Methyl Nitrate

    2. Nitroglycol

    3. Nitroglycerin

4. Nitric Acid/Mononitrobenzene
5. Nitric Acid/Cellulose
6. Urea Nitrate

There is no totally safe way to improvise powerful explosives with crude materials and equipment. All of the proposed improvised systems are inherently dangerous; all must be executed with discretion and common sense. However, with safety as a major consideration, we have attempted to minimize risks by evolving processes that are safe or that give fair warning of impending difficulty. (The manufacture of nitric esters, for example, is proposed in relatively small quantities that offer clearly readable danger signs).

We have evolved methods of manufacturing explosives and munitions for men who are assumedly in a highly hazardous predicament; men who are without logistic support and perhaps surrounded by hostile forces. Such circumstances prescribe reasonable calculated risks.

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APPENDIX

Field Expedient Methods for Explosive Preparation

Section I
No. 24

MERCURY FULMINATE

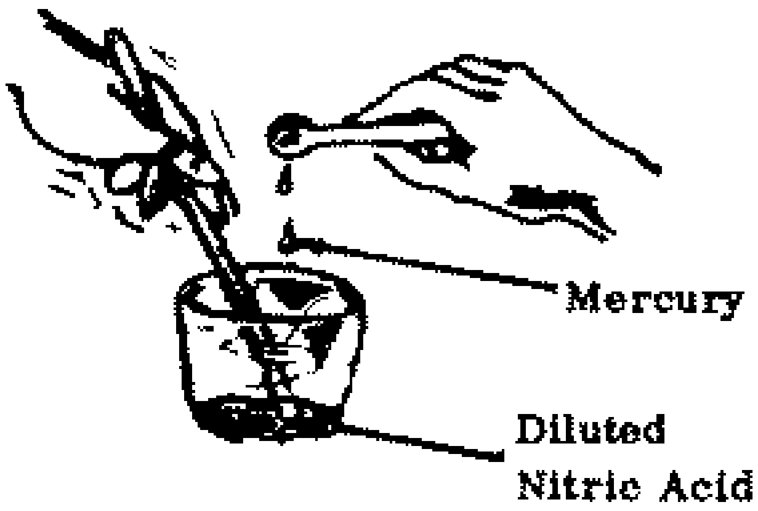
Mercury Fulminate is used as a primary explosive in the fabrication of detonators (Section VI, No. 13). It is to be used with a booster explosive such as picric acid (Section I, No. 21) or RDX (Section I, No. 15).

MATERIAL REQUIRED:	SOURCE:
Nitric Acid, 90% conc. (1.48 sp. gr.)	Field grade (Section I, No. 4) or industrial metal processors
Mercury	Thermometers, mercury switches, old radio tubes
Ethyl (grain) alcohol (90%)	
Filtering material	Paper towels
Teaspoon measure (1/4, 1/2, and 1 teaspoon capacity) - aluminum, stainless steel or wax-coated	
Heat source	
Clean wooden stick	
Clean water	
Glass containers	
Tape	
Syringe	

PROCEDURE:

1. Dilute 5 teaspoons of nitric acid with 2-1/2 teaspoons of clean water in a glass container by adding the acid to the water.

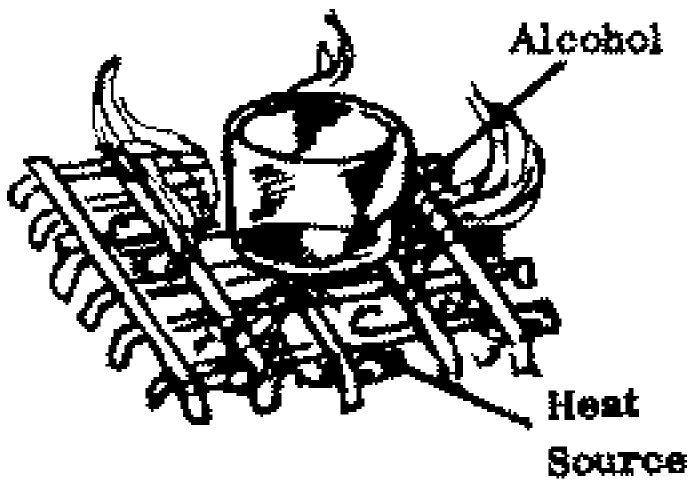
2. Dissolve 1/8 teaspoon of mercury in the diluted nitric acid. This will yield dark red fumes.



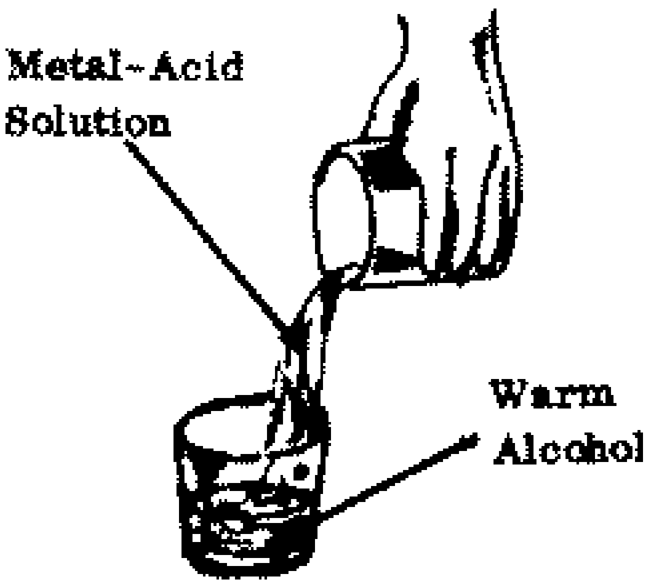
NOTE: It may be necessary to add water, one drop at a time, to the mercury-acid solution in order to start reaction.

CAUTION: Acid will burn skin and destroy clothing. If any is spilled, wash it away with a large quantity of water. Do not inhale fumes.

3. Warm 10 teaspoons of the alcohol in a container until the alcohol feels warm to the inside of the wrist.

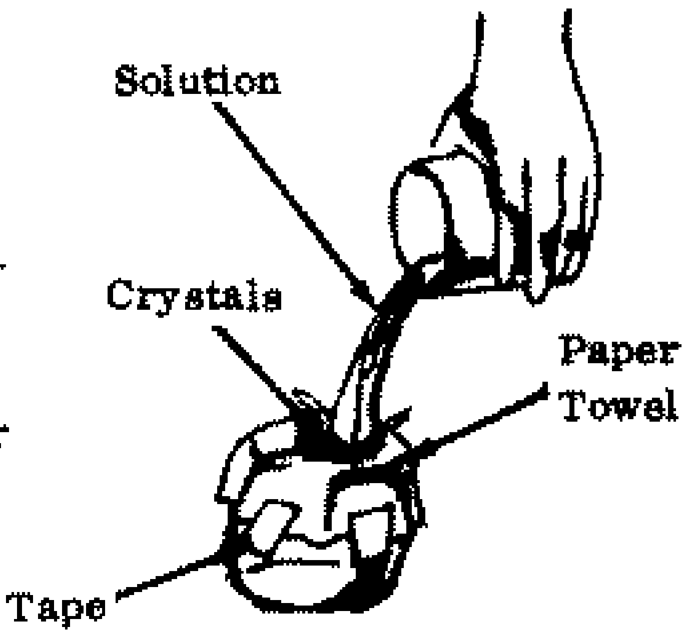


4. Pour the metal-acid solution into the warm alcohol. Reaction should start in less than 5 minutes. Dense white fumes will be given off during reaction. As time lapses, the fumes will become less dense. Allow 10 to 15 minutes to complete reaction. Fulminate will settle to bottom.

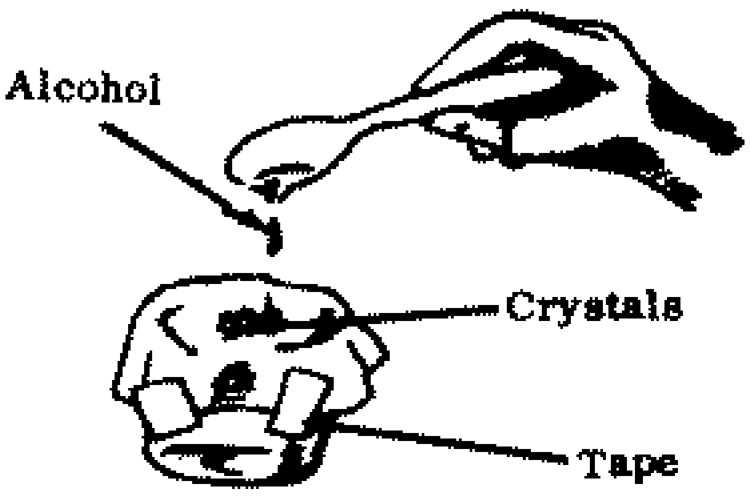


CAUTION: This reaction generates large quantities of toxic, flammable fumes. The process must be conducted outdoors or in a well ventilated area, away from sparks or open flames. Do not inhale fumes.

5. Filter the solution through a paper towel into a container. Crystals may stick to the side of the container. If so, tilt and squirt water down the sides of the container until all the material collects on the filter paper.



6. Wash the crystals with 6 teaspoons of ethyl alcohol.



7. Allow these mercury fulminate crystals to air dry.

CAUTION: Handle dry explosive with great care. Do not scrape or handle it roughly. Keep away from sparks or open flames. Store in cool, dry place.

DOUBLE SALTS

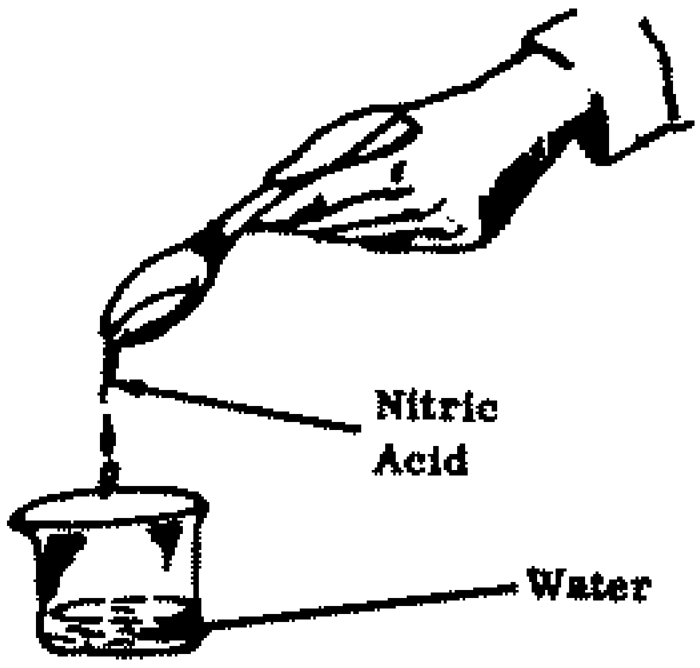
Double Salts is used as a primary explosive in the fabrication of detonators (Section VI, No. 13). It can be made in the field from silver (coins), nitric acid, calcium carbide, and water.

MATERIALS REQUIRED:

Nitric acid (90% conc.) (Section I, No. 4)
Silver metal (silver coin, about 5/8 in diameter)
Calcium carbide (acetylene or calcium carbide lamps)
Rubber and glass tubing (approx. 1/4 in. inside diameter)
Paper towels
Heat-resistant bottles or ceramic jugs, 1 to 2 quart
capacity, and one cork to fit. (Punch hole in cork
to fit tubing.)
Teaspoon (aluminum, stainless steel or wax-coated) or equivalent
measure
Glass container
Heat source
Long narrow jar (olive jar)
Tape
Water
Alcohol

PROCEDURE:

1. Dilute 2-1/4 teaspoons of nitric acid with 1-1/2 teaspoons of water in a glass container by adding the acid to the water.

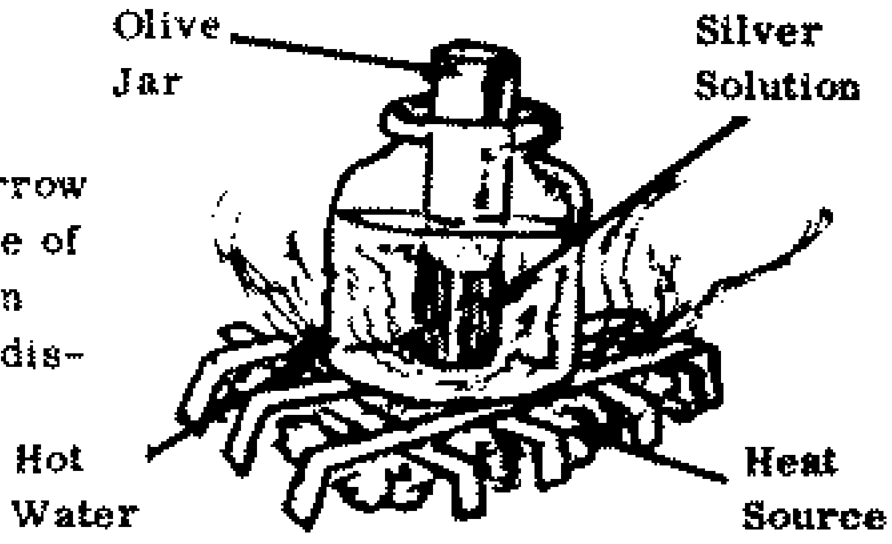


2. Dissolve a silver coin (a silver dime) in the diluted nitric acid. The solution will turn to a green color.

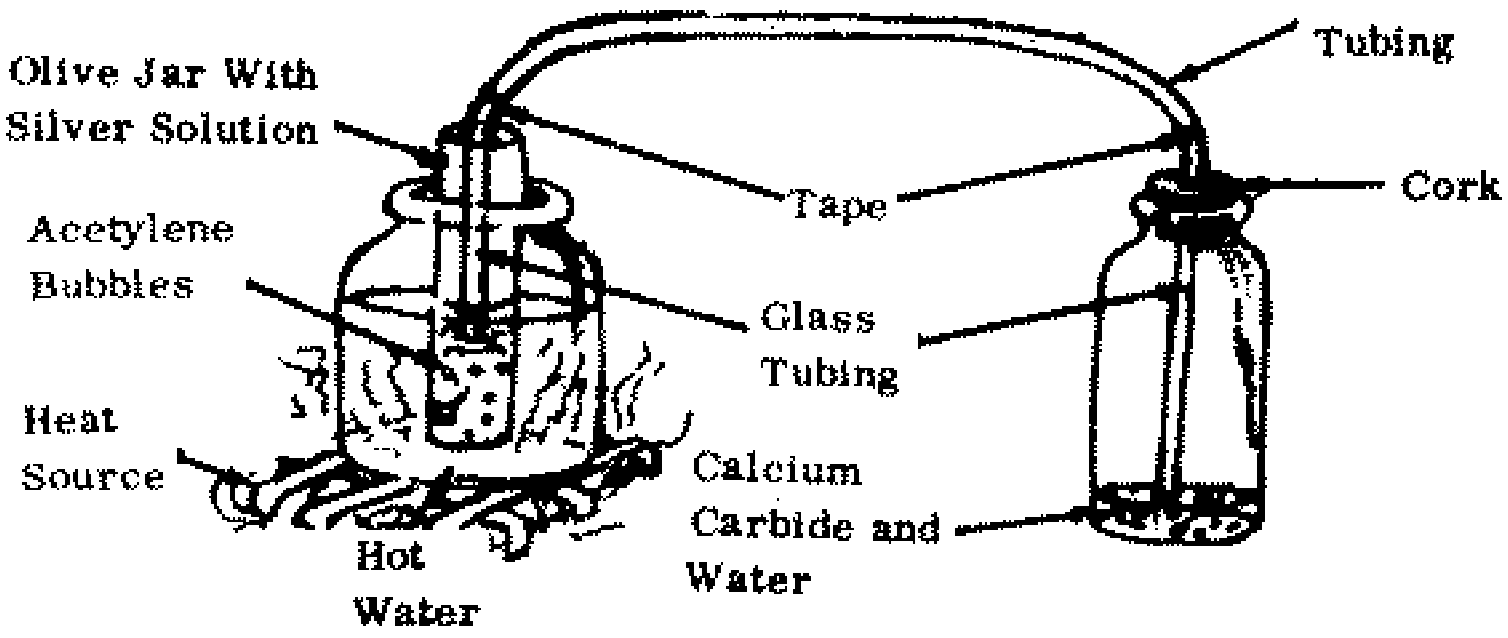
NOTE: It may be necessary to warm the container to completely dissolve the silver coin.

CAUTION: Acid will burn skin and destroy clothing. If any is spilled, wash it away with a large quantity of water. Do not inhale fumes.

3. Pour solution into a long narrow (olive) jar and place it in a bottle of hot water. Crystals will form in the solution; heat until crystals dissolve.

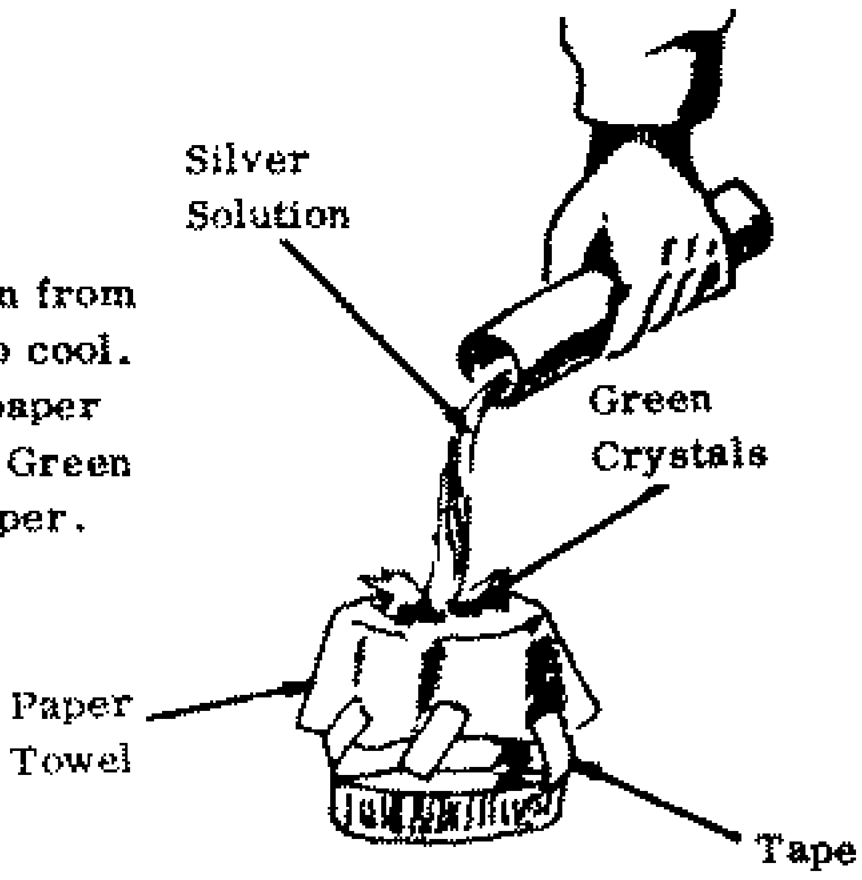


4. While still heating and after crystals have dissolved, place 10 teaspoons of calcium carbide in another glass bottle and add 1 teaspoon of water. After the reaction has started add another teaspoon of water. Then set up as shown.

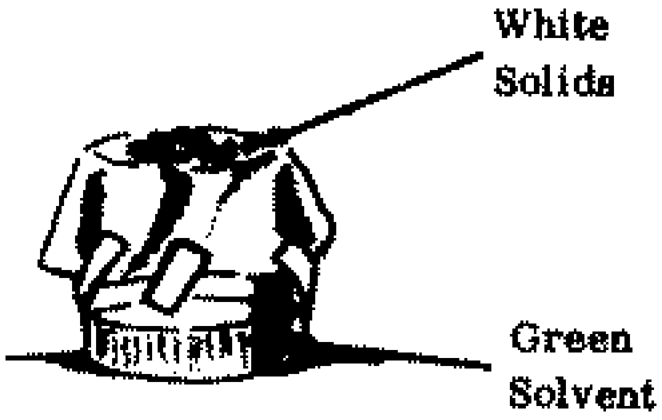


5. Bubble acetylene through the solution for 5 to 8 minutes. A brown vapor will be given off and white flakes will appear in the silver solution.

6. Remove the silver solution from the heat source and allow it to cool. Filter the solution through a paper towel into a glass container. Green crystals will collect on the paper.



7. Wash the solids collected on the paper towel with 12 teaspoons of alcohol. The solid material will turn white while the solvent in the container will have a green color.



8. Place the white solid material on a clean paper towel to air dry.

CAUTION: Handle dry explosive with great care. Do not scrape or handle it roughly. Keep away from sparks or open flames. Store in cool, dry place.

HMTD

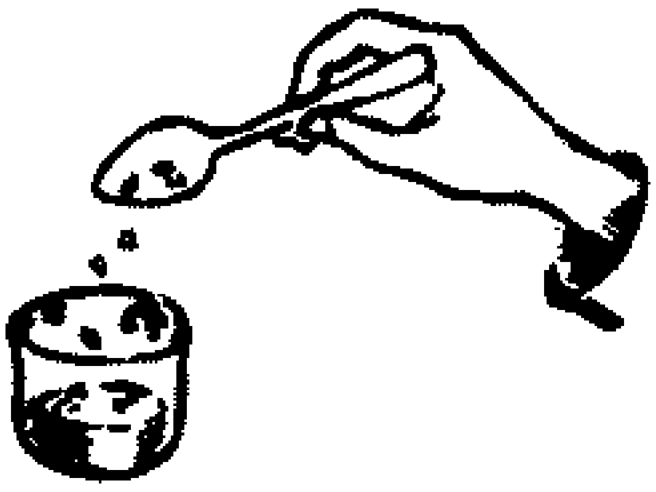
HMTD is a primary explosive that can be made from hexamethylenetetramine, hydrogen peroxide and citric acid. This explosive is to be used with a booster explosive such as picric acid (Section I, No. 21) or RDX (Section I, No. 15) in the fabrication of detonators (Section 6, No. 13).

MATERIAL REQUIRED:	SOURCES:
Hexamethylenetetramine	Drugstores under names of urotropine, hexamin, methenamine, etc. Army heat tablets.
Hydrogen peroxide	6% hair bleach (or stronger if possible)
Citric acid	Drug stores or food stores ("Sour Salt")
Containers, bottles or glasses	
Paper towels	
Teaspoon	
Pan	
Water	
Tape	

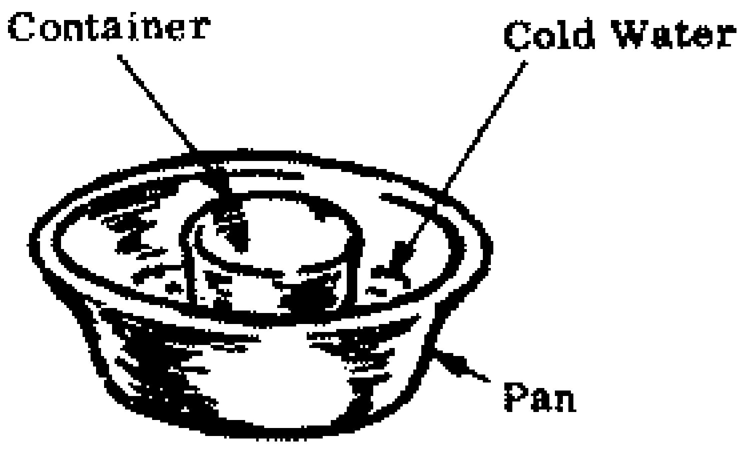
PROCEDURE:

1. Measure 9 teaspoons of hydrogen peroxide into a container.

2. In 3 portions, dissolve 2-1/2 teaspoons of crushed hexamethylenetetramine in the peroxide.



3. Keep the solution cool for 30 minutes by placing container in a pan of cold water.



4. In 5 portions, dissolve 4-1/2 teaspoons of crushed citric acid in the hexamethylenetetramine-peroxide solution.

5. Permit solution to stand at room temperature until solid particles form at the bottom of container.

NOTE: Complete precipitation will take place in 8 to 24 hours.

CAUTION: At this point the mixture is a primary explosive. Keep away from flame.

6. Filter the mixture through a paper towel into a container to collect the solid particles.

7. Wash the solid particles collected in the paper towel with 6 teaspoons of water by pouring the water over them. Discard the liquid in the container.

8. Place these explosive particles in a container and allow to dry.

CAUTION: Handle dry explosive with great care. Do not scrape or handle it roughly. Keep away from sparks or open flames. Store in cool, dry place.

UREA NITRATE EXPLOSIVE

Urea nitrate can be used as an explosive munition. It is easy to prepare from nitric acid and urine. It can be detonated with a blasting cap.

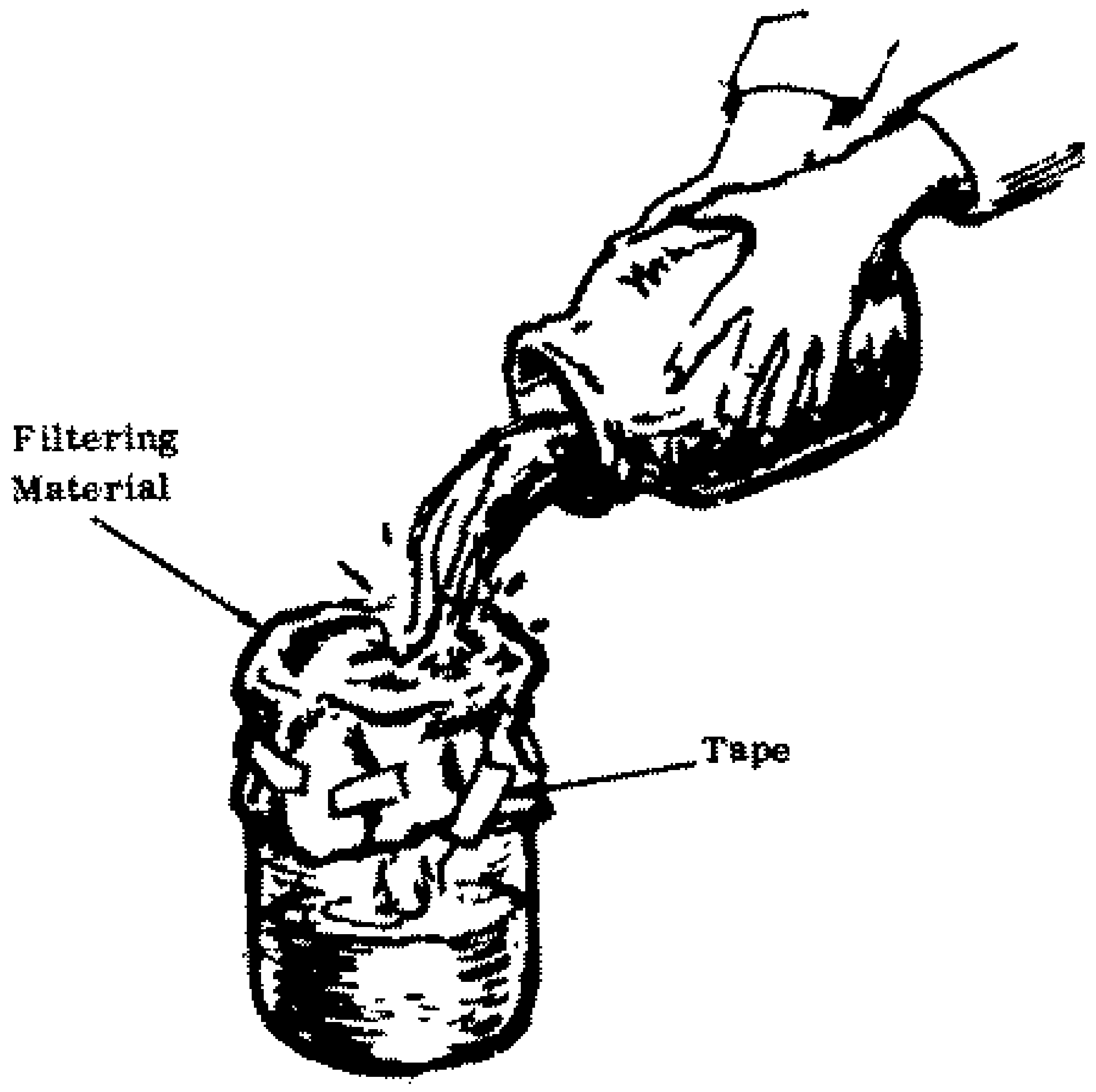
MATERIAL REQUIRED:	SOURCE:
Nitric acid, 90% conc. (1.48 sp. gr.)	Field grade (Section I, No. 4) or industrial metal processors
Urine	Animals (including humans)
2 one gallon heat and acid-resistant containers (glass, clay, etc.)	
Filtering material	Paper towel or finely textured cotton cloth (shirt, sheet, etc.)
Aluminum powder (optional or if available)	Paint stores
Heat source	
Measuring containers (cup and spoon)	
Water	
Tape	
Blasting cap	
Steel pipe and end cap (s)	

NOTE: Prepare mixture just before use.

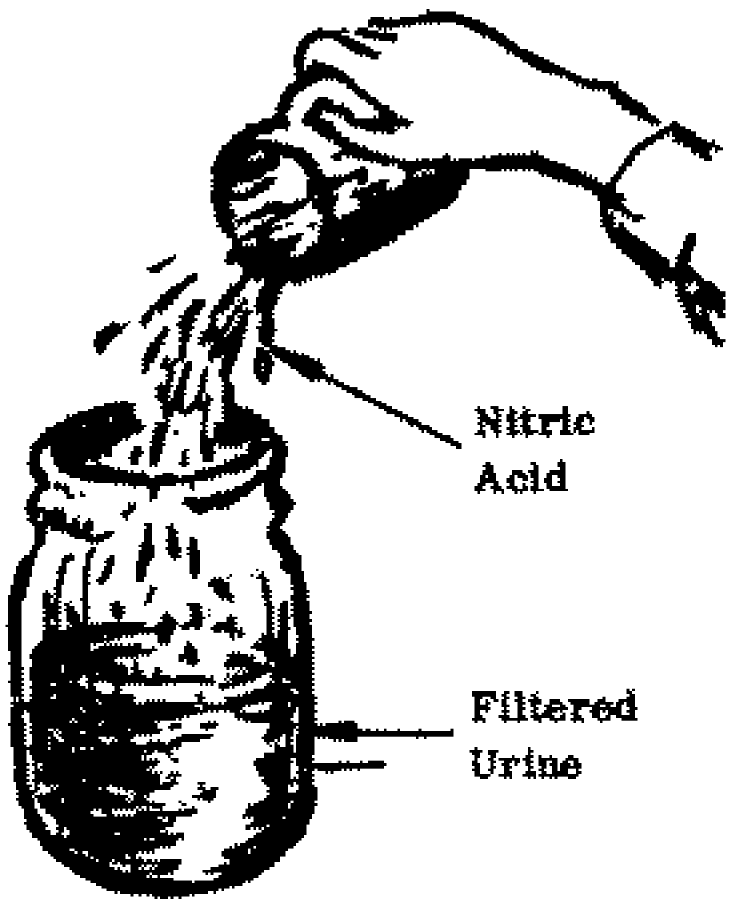
PROCEDURE:

1. Boil a large quantity of urine (10 cups) to approximately 1/10 its volume (1 cup) in one of the containers over the heat source.

2. Filter the urine into the other container through the filtering material to remove impurities.

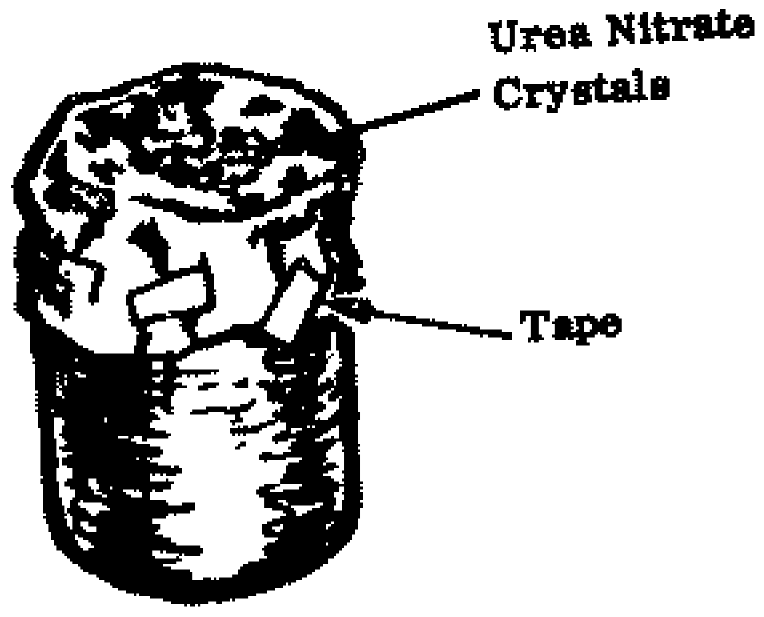


3. Slowly add 1/3 cup of nitric acid to the filtered urine, and let mixture stand for 1 hour.



CAUTION: Acid will burn skin and destroy clothing. If any is spilled wash it away with a large quantity of water. Do not inhale fumes.

4. Filter mixture as in step 2. Urea nitrate crystals will collect on the paper.



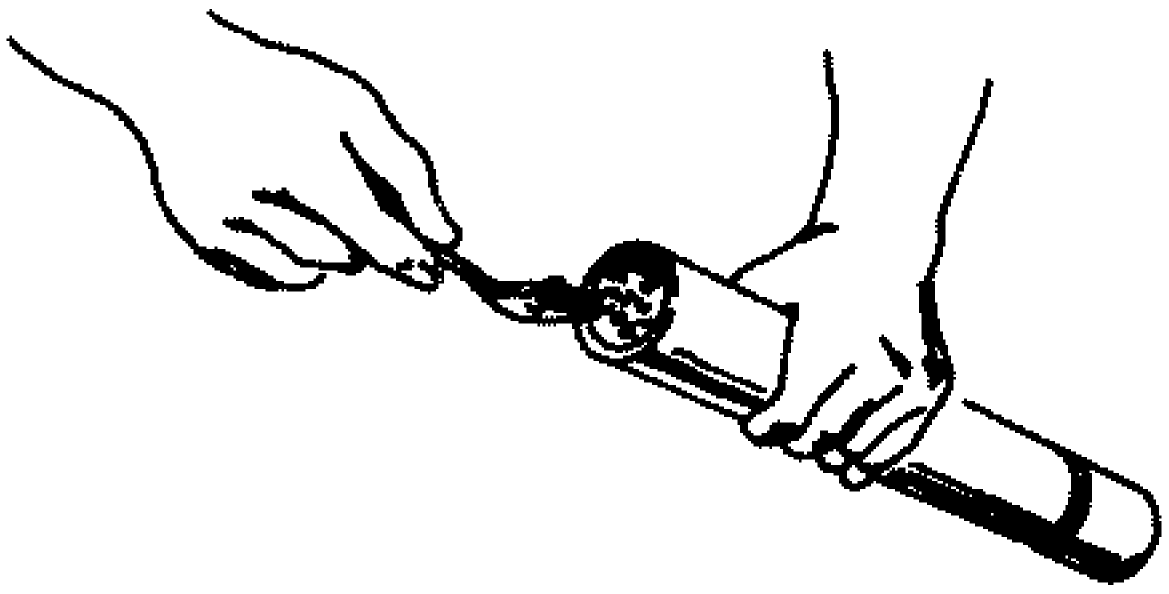
5. Wash the urea nitrate by pouring water over it.

6. Remove urea nitrate crystals from the filtering material and allow to dry thoroughly (approximately 16 hours).

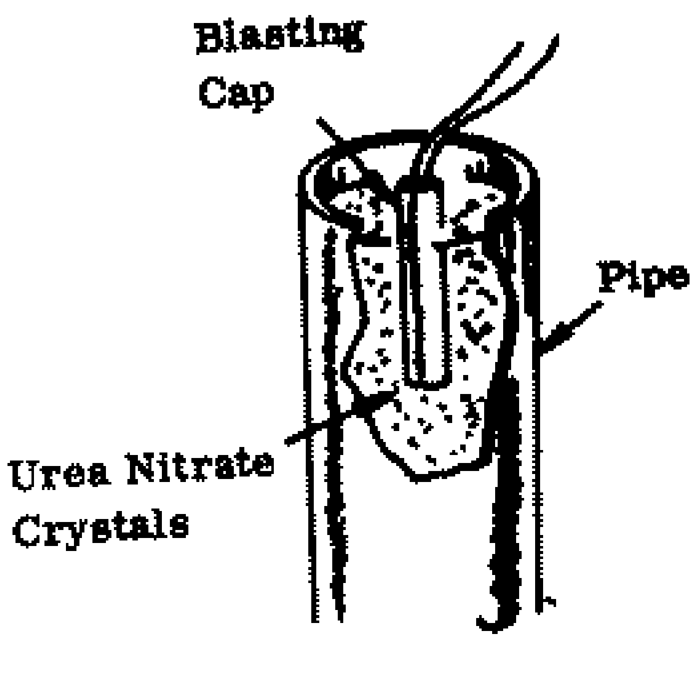
NOTE: The drying time can be reduced to two hours if a hot (not boiling) water bath is used. See Step 5 of Section I, No. 15.

HOW TO USE:

1. Spoon the urea nitrate crystals into an iron or steel pipe which has an end cap threaded on one end.



2. Insert blasting cap just beneath the surface of the urea nitrate crystals.



NOTES: This explosive can be made more effective by mixing with aluminum powder (can be obtained in paint stores) in the ratio of 4 to 1. For example, mix 1 cup of aluminum powder with 4 cups of urea nitrate

Confining the open end of the container will add to the effectiveness of the explosive.

OPTIMIZED PROCESS FOR CELLULOSE/ACID EXPLOSIVES

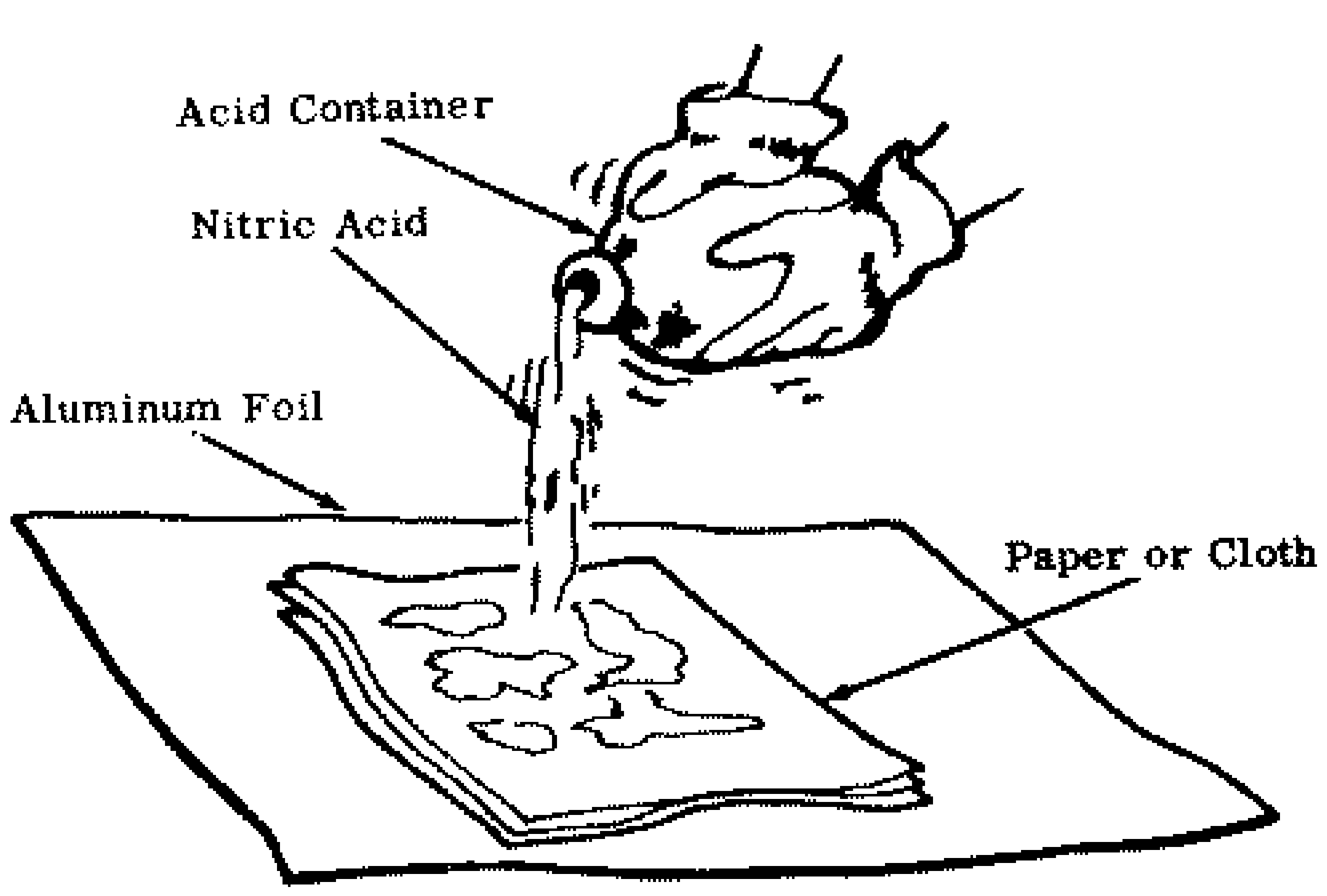
An acid type explosive can be made from nitric acid and white paper or cotton cloth. This explosive can be detonated with a commercial #8 or any military blasting cap.

MATERIAL REQUIRED:	SOURCE:
Nitric Acid	Industrial metal processors, 90% concentrated (specific gravity of 1.48) Field grade (See Section I, No. 4)
White unprinted, unsized paper	Paper towels, napkins
Clean white cotton cloth	Clothing, sheets, etc.
Acid resistant container	Wax coated pipe or can, ceramic pipe, glass jar, etc. Heavy-walled glass containers
Aluminum foil or acid resistant material	Food stores
Protective gloves	
Blasting cap	
Wax	

PROCEDURE:

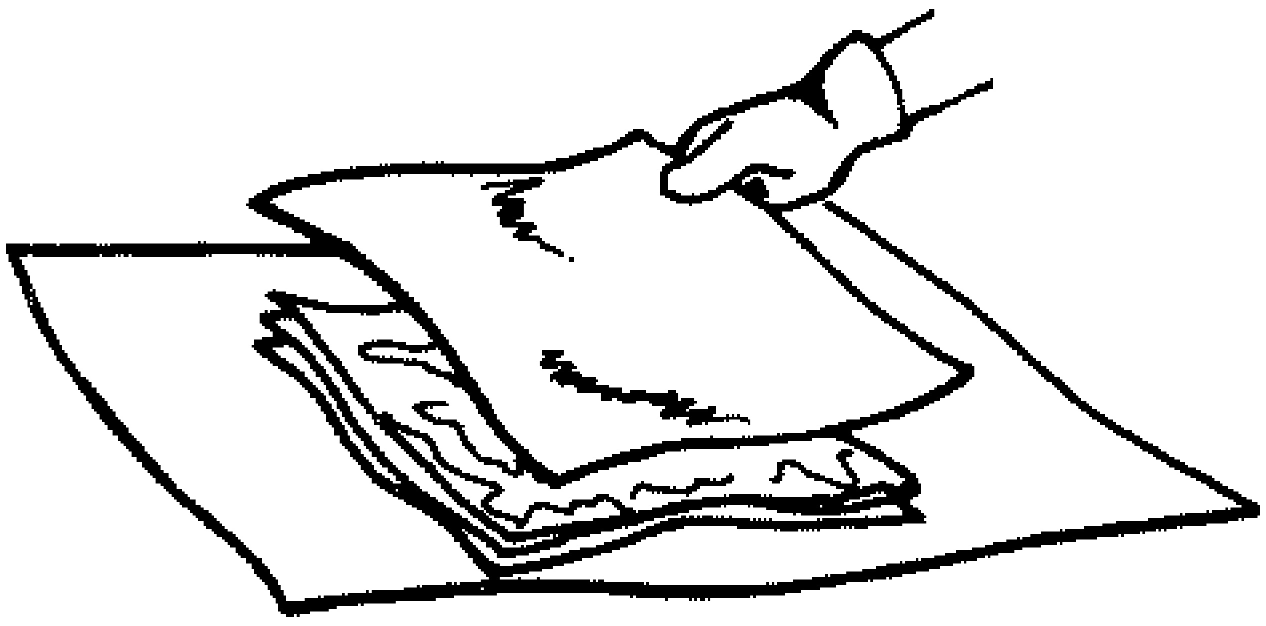
1. Put on gloves.

2. Spread out a layer of paper or cloth on aluminum foil and sprinkle with nitric acid until thoroughly soaked. If aluminum foil is unavailable, use an acid resistant material (glass, ceramic or wood).

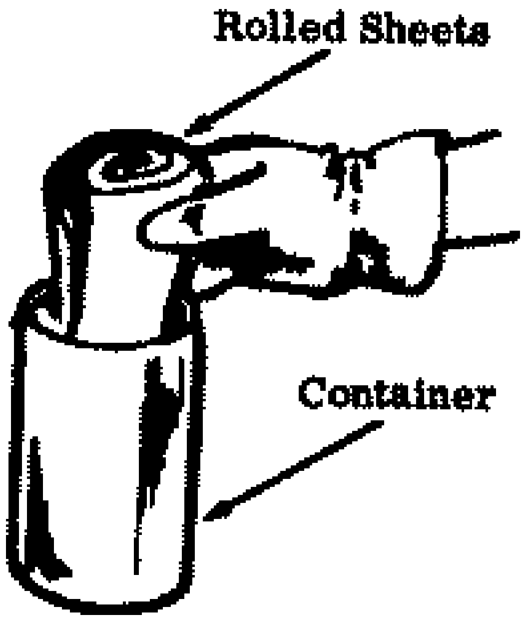


CAUTION: Acid will burn skin and destroy clothing. If any is spilled, wash it away with a large quantity of water. Do not inhale fumes.

3. Place another layer of paper or cloth on top of the acid-soaked sheet and repeat step 2 above. Repeat as often as necessary.



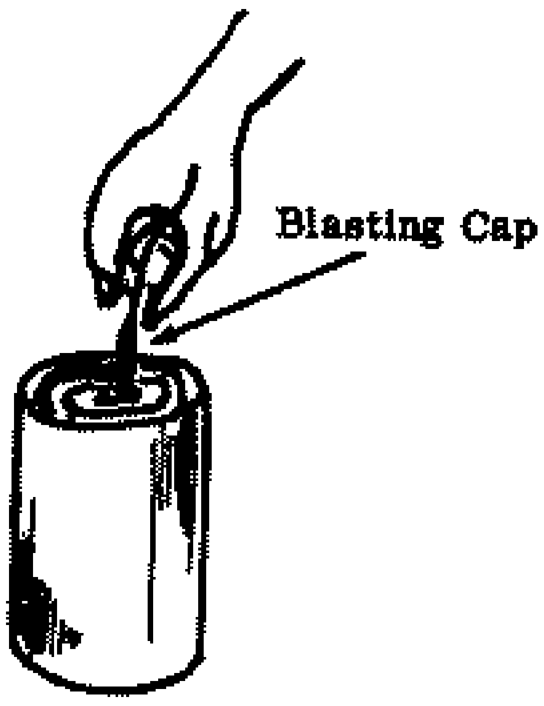
4. Roll up the aluminum foil containing the acid-soaked sheets and insert the roll into the acid resistant container.



NOTE: If glass, ceramic or wooden tray is used, pick up sheets with two wooden sticks and load into container.

5. Wax blasting cap.

6. Insert the blasting cap in the center of the rolled sheets. Allow 5 minutes before detonating the explosive.



NITRIC ACID/NITROBENZENE ("HELLHOFFITE") EXPLOSIVE

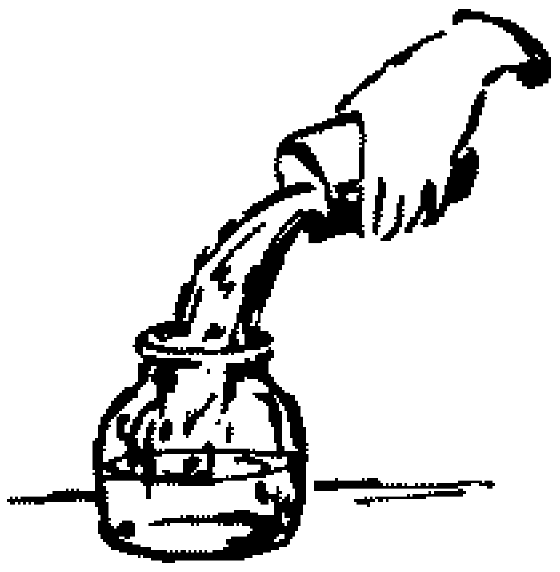
An explosive munition can be made from mononitrobenezene and nitric acid. It is a simple explosive to prepare. Just pour the mononitrobenzene into the acid and stir.

MATERIAL REQUIRED:	SOURCE:
Nitric acid	Field grade or 90% concentrated (specific gravity of 1.48)
Mononitrobenzene (also known as nitrobenzene)	Drug store (oil of mirbane) Chemical supply house Industries (used as solvent)
Acid resistant measuring containers	Glass, clay, etc.
Acid resistant mixing rod	
Blasting cap	
Wax	
Steel pipe, end cap and tape	
Bottle or jar	

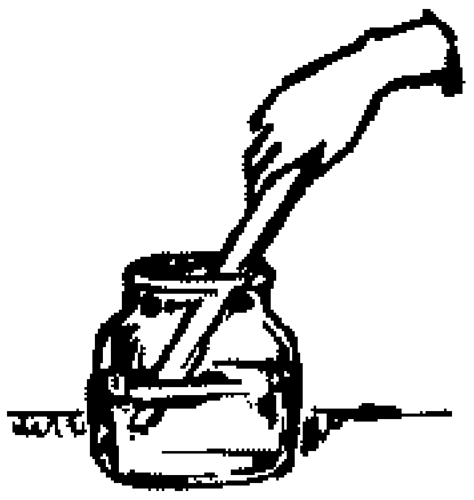
NOTE: Prepare mixture just before use.

PROCEDURE:

1. Add 1 volume (cup, quart, etc.) mononitrobenzene to 2 volumes nitric acid in bottle or jar.



2. Mix ingredients well by stirring with acid resistant rod.



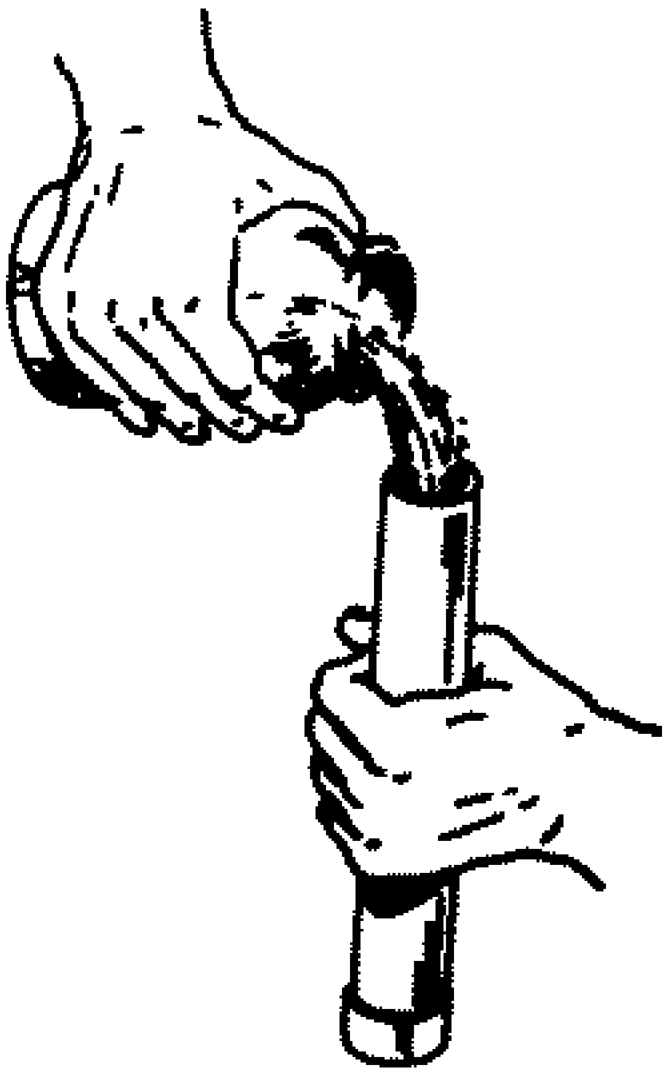
CAUTION: Nitric acid will burn skin and destroy clothing. If any is spilled, wash off immediately with large amount of water. Nitrobenzene is toxic; do not inhale fumes.

HOW TO USE:

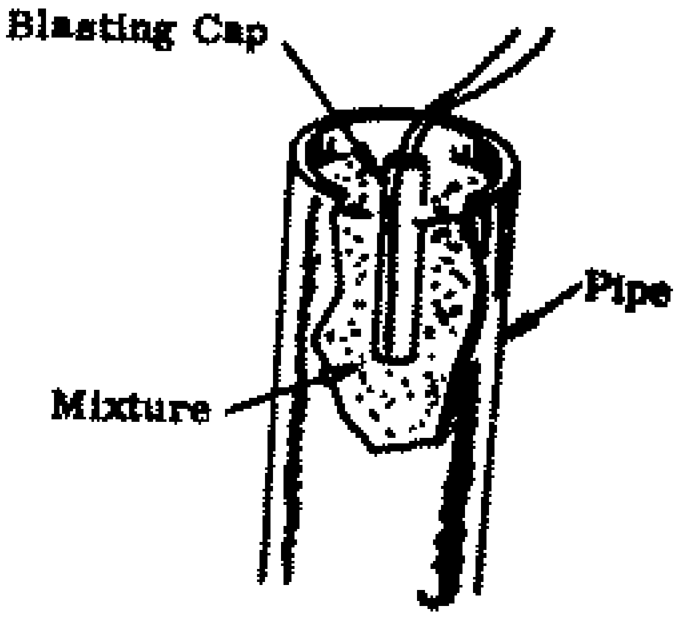
1. Wax blasting cap, pipe and end cap.

2. Thread end cap onto pipe.

3. Pour mixture into pipe.



4. Insert and tape blasting cap just beneath surface of mixture.



NOTE: Combining the open end of the pipe will add to the effectiveness of the explosive.