

AD-A074 705

DEFENCE RESEARCH ESTABLISHMENT VALCARTIER (QUEBEC)
DEVELOPMENT OF A METHOD TO PRODUCE HIGH ENERGY BLASTING PRILLS, (U)
JAN 76 J F DROLET, R R LAVERTU

F/G 9/1

UNCLASSIFIED

DREV-R-4044/76

NL

| OF |

AD
A074705



END
DATE
FILMED
11-79

DDC

UNCLASSIFIED

3
B.S

UNLIMITED
DISTRIBUTION
ILLIMITEE

CRDV RAPPORT 4044/76
PROJET 10-28-48
JANVIER 1976

✓ DREV REPORT 4044/76
PROJECT 10-28-48
JANUARY 1976

LEVEL II

A074705

DEVELOPMENT OF A METHOD TO PRODUCE
HIGH ENERGY BLASTING PRILLS

DDC
RECEIVED
OCT 5 1979
REGISTRY
E

J.F. Drolet

R.R. Lavertu

This document has been approved
for public release and sale; its
distribution is unlimited.

SDC FILE COPY

Centre de Recherches pour la Défense
Defence Research Establishment
Valcartier, Québec

BUREAU RECHERCHE ET DEVELOPPEMENT
MINISTERE DE LA DEFENSE NATIONALE
CANADA

RESEARCH AND DEVELOPMENT BRANCH
DEPARTMENT OF NATIONAL DEFENCE
CANADA

NON CLASSIFIE
79 10 02 024

CRDV R-4044/76
PROJ: 10-28-48

UNCLASSIFIED

14 DREV-R-4044/76
PROJ: 10-28-48

12) 28

3

11) Jan 76

DDC
RECEIVED
OCT 5 1979
E

6
DEVELOPMENT OF A METHOD TO PRODUCE HIGH ENERGY BLASTING PRILLS,

10) J.F. / Drolet R.R. / Lavertu

This document has been approved
for public release and sale; its
distribution is unlimited.

CENTRE DE RECHERCHES POUR LA DEFENSE

DEFENCE RESEARCH ESTABLISHMENT

VALCARTIER

Tel: (418) 844-4271

Québec, Canada

January/janvier 1976

NON CLASSIFIE

404 945

sk

UNCLASSIFIED

i

RESUME

Les auteurs ont mis au point une méthode permettant la préparation d'explosifs de grande énergie en grains à base de tolite et d'aluminium additionnés ou non d'hexogène; ces grains ont un diamètre moyen de 3 mm. Leur écoulement semblable à celui des liquides, leur résistance à l'eau, leur longue durée de vie et leur utilisation possible dans une large gamme de températures en font des explosifs très intéressants pour certaines applications dans le domaine du génie militaire. La méthode repose sur la formation de gouttelettes d'une suspension liquide d'explosif à l'extrémité d'une buse de petit diamètre immergée au sommet d'une colonne d'eau. Les gouttelettes se solidifient lors de leur chute dans la colonne d'eau. Pour éviter l'accumulation d'électricité statique sur les grains secs, on les rend partiellement conducteurs en les enrobant d'une mince couche de carbone. Les études, d'abord entreprises en laboratoire, ont été poursuivies à l'échelle de l'usine-pilote dans une colonne de 44 cm de diamètre pouvant produire jusqu'à 90 kg d'explosifs par coulée. Dans le cadre de l'évaluation du pouvoir excavateur de ces nouveaux produits, on a fabriqué environ deux tonnes d'explosifs de deux compositions différentes. (NC)

ABSTRACT

A method has been developed for the production of high energy blasting prills (HEBP) containing TNT/Al or TNT/RDX/Al; the average particle size of the prills is approximately 3 mm. Such HEBP explosives seem attractive for special military engineering applications because they are free-flowing, water resistant, have a long shelf life and can be used over a wide temperature range. The method consists of forming fluid droplets of a molten mixture of explosive at the tip of a small-diameter nozzle immersed in the top of a water column. After the droplets leave the nozzle, they solidify as they fall through the remainder of the column. To avoid building up static charges, the prills are made semi-conductive by coating them with a thin layer of graphite. Studies were first undertaken in the laboratory and then scaled up to a 44-cm diameter pilot-plant prilling column that can produce about 90 kg of prills per batch. Some 1000 kg of each of two different compositions were produced for determination of their cratering characteristics (in a separate study). (U)

TABLE OF CONTENTS

RESUME/ABSTRACT i

1.0 INTRODUCTION 1

2.0 LABORATORY-SCALE STUDIES 1

 2.1 Method 1

 2.2 Apparatus 3

 2.3 Procedure 7

 2.4 Results 7

 2.4.1 Compositions 7

 2.4.2 Effect of Temperature on Prill Formation 8

 2.4.3 Effect of Temperature on Production Rate 10

 2.4.4 Effect of Nozzle Diameter on Size of Prills 10

3.0 PILOT-PLANT PRILLING TOWER 12

 3.1 Details and Operation of the Tower 12

 3.1.1 Melting Hopper 12

 3.1.2 Drop Pan and Nozzle Assembly 12

 3.1.3 Column and Catch Pot 12

 3.1.4 Operating Temperature 13

 3.1.5 Level of Explosive in Drop Pan 13

 3.1.6 Graphitization of Prills 13

 3.2 Results 14

 3.2.1 Formulation TNT/RDX/A1:40/40/20 14

 3.2.2 Formulation TNT/A1:80/20 15

4.0 CONCLUSIONS 20

5.0 ACKNOWLEDGEMENTS 20

6.0 REFERENCES 21

TABLES I to VI

FIGURES 1 to 8

APPENDIX A - Ingredients used in the Production of
Prilled Explosives 22

SEARCHED FOR	<input checked="" type="checkbox"/>
FILE	6121
DOE TAB	
Unannounced	
Identification	
By	
Distribution/	
Availability Codes	
Avail and/or	
Special	
Dist	A

UNCLASSIFIED

1

1.0 INTRODUCTION

A study was undertaken at Defence Research Establishment Valcartier (DREV) in June 1972 to investigate the production and properties of multi-ingredient explosive prills with a typical size of 3 to 5 mm. Subsequently renamed as high energy blasting prills (HEBP), they are attractive for special military engineering applications because they are free-flowing, water resistant, have a long shelf life and can be used over a wide temperature range. Another possible application is as a replacement for the less powerful TNT prills in slurry explosives.

HEBP explosives consist of one or more energetic ingredients supported by a fluid (TNT) that solidifies upon cooling. Several formulations of different ratios of TNT, RDX, aluminum and ammonium perchlorate were produced on a laboratory scale to determine their processing characteristics, and to evaluate some of their physical and explosive properties; these latter properties will be described in a future report. The process was then scaled up to pilot-plant size, and two formulations of about 1000 kg each were produced. These explosives were sent to Defence Research Establishment Suffield (DRES) for determination of their cratering characteristics in the fall of 1974 (1).

This document covers the studies conducted at DREV on HEBP explosives from their inception in June, 1972, through to mid-1974. The work was carried out under Project 10-28-48 (Explosives Research and Engineering).

2.0 LABORATORY-SCALE STUDIES

Laboratory studies established an experimental procedure for producing HEBP explosives and determined the parameters controlling the properties of the finished product. Moreover, these studies were necessary to acquire the knowledge to scale-up the process.

2.1 Method

The method developed for producing HEBP explosives consists of forming fluid droplets of a molten mixture of explosive at the tip of a small-diameter nozzle immersed in the top of a water column, the uppermost part of the column being heated. After the droplets leave the nozzle, they fall through a colder portion of the water column where they solidify keeping their initial shape. Finally, the prills accumulate in a catch pot at the bottom of the column.

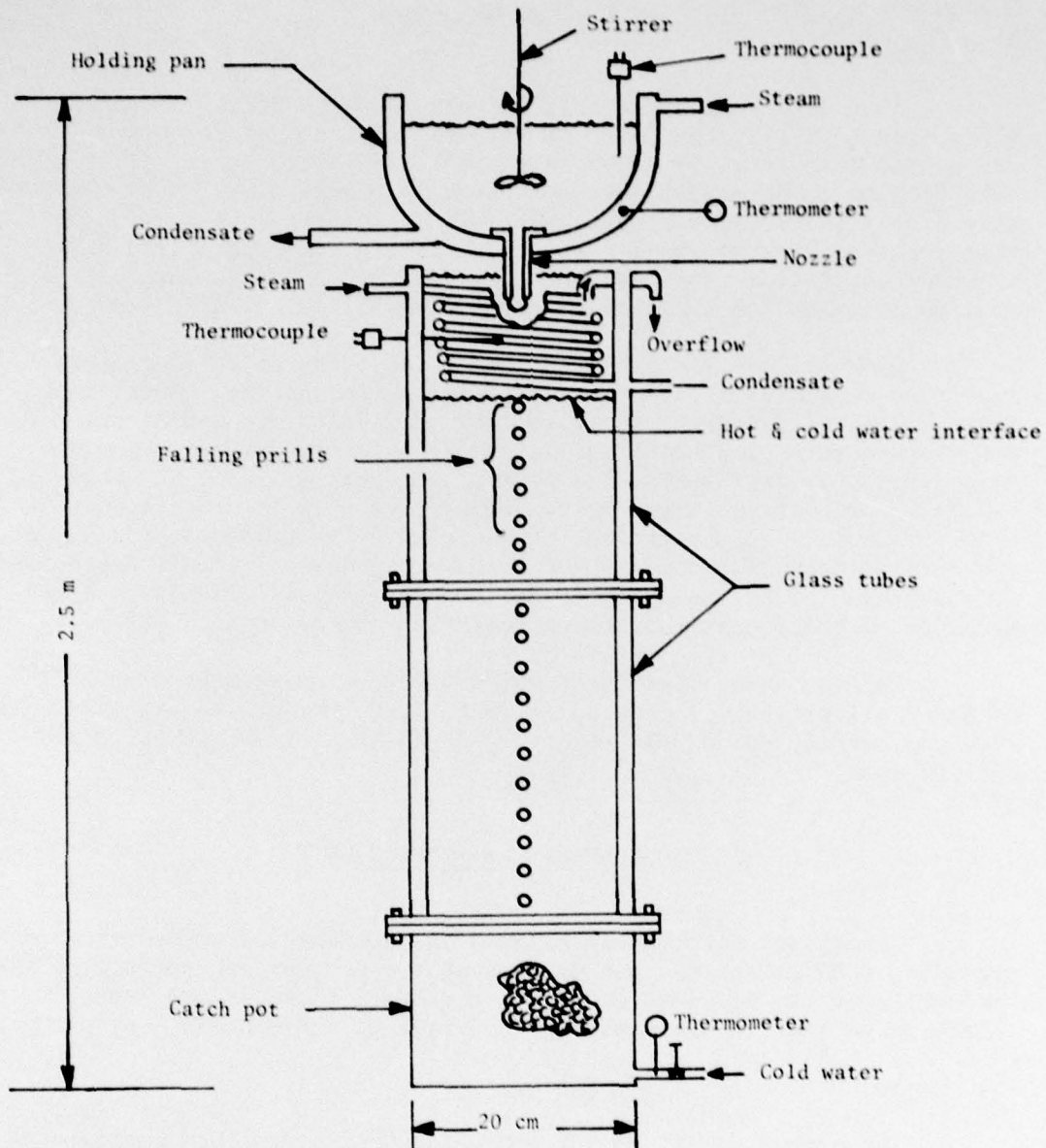


FIGURE 1 - Schematic of the laboratory scale apparatus

2.2 Apparatus

The basic apparatus consists of a holding pan and a nozzle supported by a vertical tower filled with water and terminated at the bottom by a catch pot. A diagram and photograph of the apparatus are shown in Figs. 1 and 2, respectively. The jacketed holding pan, where the explosive is melted, is cylindrical at the top with a 23-cm diameter by 20-cm deep spherical bottom. The molten explosive is stirred lightly by an air turbine rotating at about 50 r/min.

As shown in Fig. 3, a nozzle is located in the centre of the bottom of the pan; nozzle diameters used were 1.52, 2.06 and 2.54 mm. To ensure that the heat barrier is low, the nozzle tubes are made of thin stainless steel. A brass holding ring is press fit onto the nozzle, prior to press fitting this assembly into the pan.

A jacketed nozzle was also designed to prevent blockage due to cooling of the molten liquid in the nozzle. It was subsequently determined that blockage, when it occurred, was not caused by cooling, but rather by the build-up of explosive crystals and aluminum particles at the tip. This jacketed nozzle was therefore discarded since it did not solve the problem, and was cumbersome and complicated to build.

To obtain a good reproducibility of the prill distribution and to avoid frequent blockage of the nozzle, the tip of the nozzle must be immersed in at least 4 cm of hot water. Reproducibility is even better when the water level is about 2 mm beneath the holding pan. The temperature of the hot water in the section of the column close to the nozzle must also be at least equal to or slightly higher than the temperature of the explosive in the pan.

Initially, it was felt that agglomeration of the prills might occur in the catch pot because the prills tended to fall from the nozzle down through the column in a straight line, thereby all landing in the same place. Two methods of agitation in the upper portion of the column were investigated to disperse the falling prills somewhat. The first consisted of bubbling air in the column, and the second consisted of mechanical agitation. Both were discarded at a later stage because the agglomerated prills came apart easily when the catch pot was emptied. In addition, agitation raised new problems: by forming air bubbles at the nozzle tip with the first method; and by giving less control of the water temperature in both sections of the column with the second.

The upper end of the 20-cm diameter by 2.15-m high tower was equipped with an adjustable overflow for controlling the water level in the column and a 13-cm diameter by 30-cm high copper coil for heating the water in this section of the column. The bottom of the column was closed by a catch pot made of stainless steel; a cold-water inlet was connected to the side of this pot.

UNCLASSIFIED

4

The temperatures in the different sections of the apparatus were normally measured by thermometers or thermocouples and manually controlled.

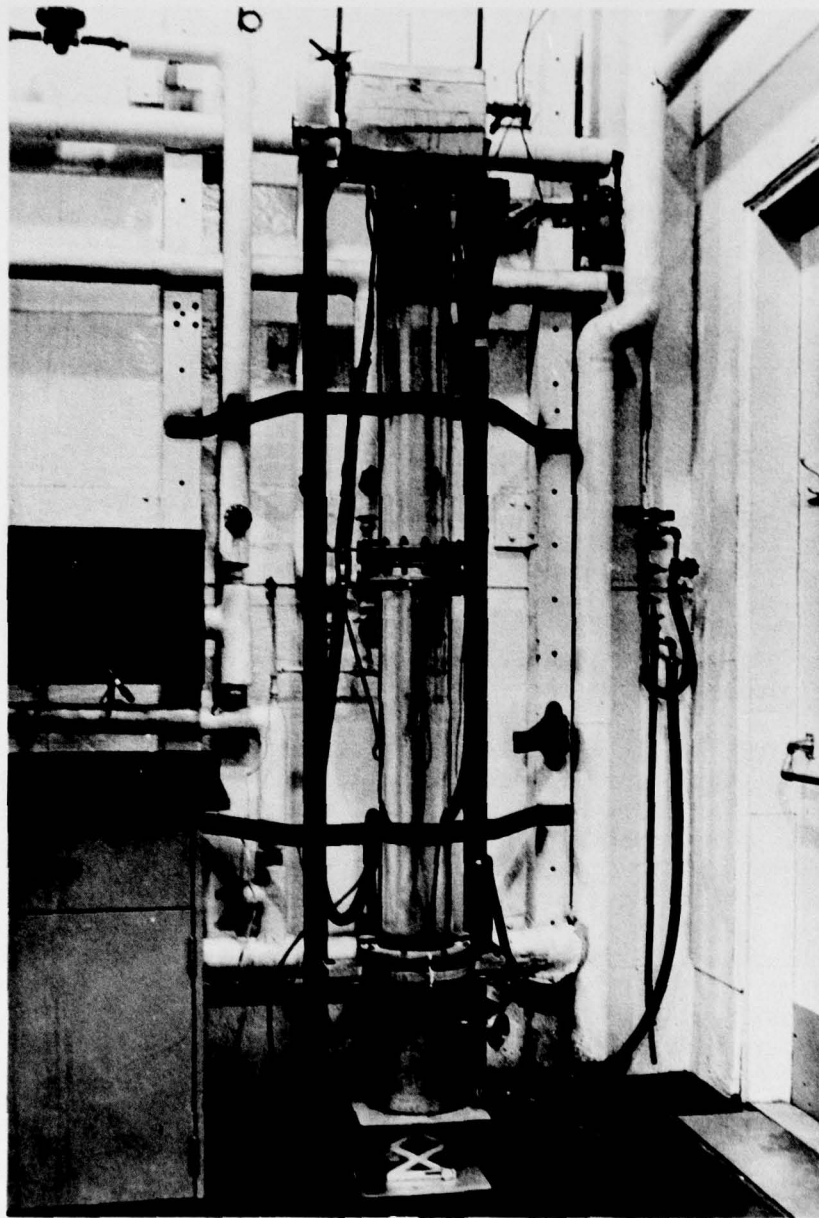


FIGURE 2 - Laboratory-scale HEBP column

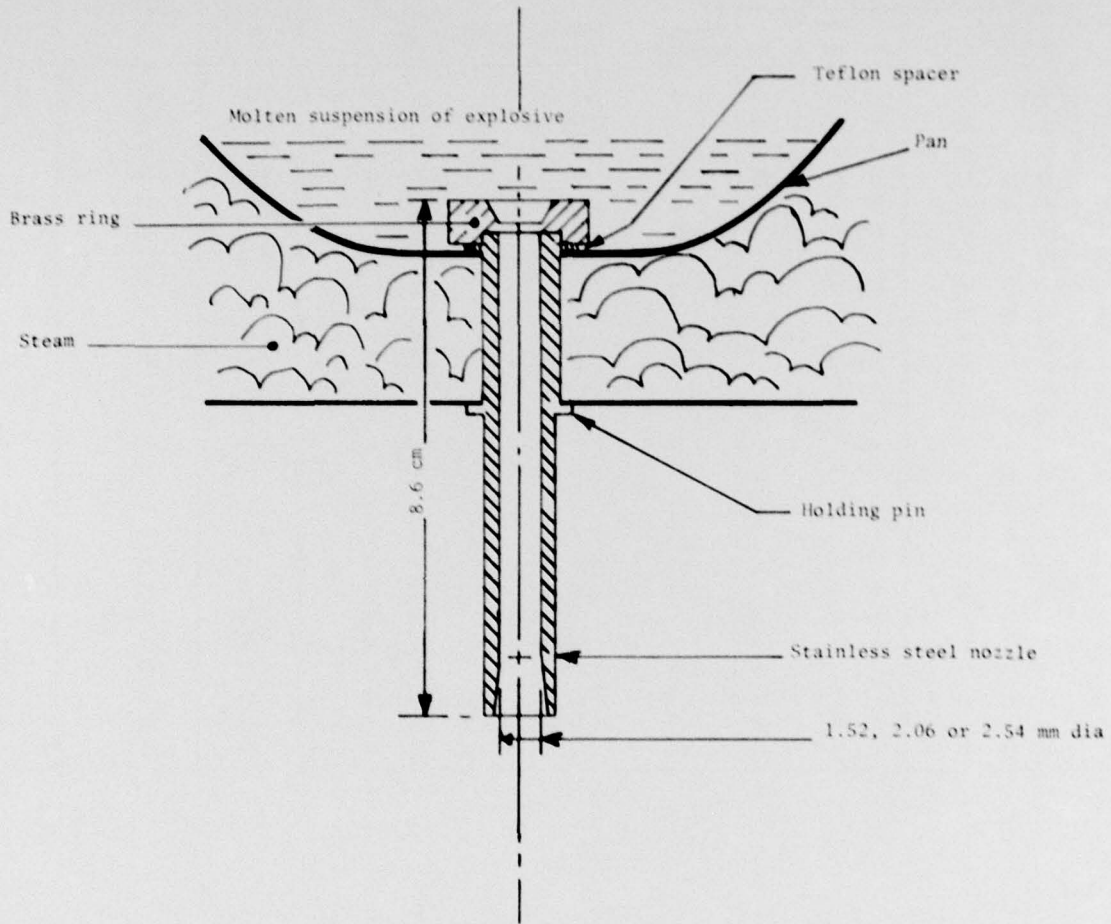


FIGURE 3 - Nozzle assembly

UNCLASSIFIED

6

TABLE I

Data From Laboratory-Scale Experiments

Run	Composition, % by weight								Density g/cm ³		Prill size (mm) % by weight				Nozzle diameter mm	Explosive temperature °C	Production rate kg/h
	nominal				measured				absolute theoretical	bulk typical	0-1.5	1.5-3	3-5	>5			
	TNT	RDY	Al	AP	TNT	RDX	Al	AP									
1	100	---	---	---	100	---	---	---	1.65	1.04	---	1	17	82	2.06	85	----
2	80	---	20	---	80	---	20	---	1.86	1.13	5	9	88	---	1.52	86	0.9
3	80	---	20	---	80	---	20	---	1.86	1.13	1	25	58	16	2.06	86	3.6
4	48	35	17	---	50	35	15	---	1.89	1.20	1	26	44	29	1.52	88	----
5	45	45	10	---	46	43	11	---	1.83	1.18	---	5	95	---	2.06	83	----
6	42	42	16	---	41	40	19	---	1.90	1.20	---	77	23	---	1.52	86	----
7	42	42	16	---	42	39	19	---	1.90	1.21	2	72	26	---	1.52	89	----
8	42	42	16	---	41	42	17	---	1.90	1.19	4	63	32	1	1.52	93	----
9	42	42	16	---	41	42	17	---	1.90	1.20	1	---	99	---	2.06	83	----
10	42	42	16	---	42	40	18	---	1.90	1.20	1	20	79	---	2.06	86	----
11	42	42	16	---	42	41	17	---	1.90	1.21	1	35	66	---	2.06	93	----
12	42	42	16	---	41	42	17	---	1.90	1.20	0	1	57	42	2.54	83	----
13	40	60	---	---	40	60	---	---	1.75	1.14	2	3	95	---	2.06	91	----
14	40	40	20	---	39	40	21	---	1.93	1.22	2	42	55	1	2.06	91	0.59
15	40	40	20	---	41	39	20	---	1.93	1.21	1	50	47	2	2.06	91	0.63
16	40	40	20	---	41	39	20	---	1.93	1.21	1	42	54	3	2.06	91	0.54
17	40	40	20	---	42	38	20	---	1.93	1.22	2	13	85	---	2.06	83	0.32
18	40	40	20	---	42	39	19	---	1.93	1.20	2	12	86	---	2.06	83	0.36
19	40	40	20	---	42	39	19	---	1.93	1.22	2	12	86	---	2.06	83	0.36
20	40	25	15	20	40	23	16	21	1.91	1.20	12	51	35	2	2.06	86	----
21	40	30	---	30	41	31	---	28	1.79	1.14	3	7	89	1	2.06	91	0.32
22	40	30	20	10	40	28	20	12	1.94	1.19	10	51	38	1	2.06	91	0.64
23	40	35	---	25	43	37	---	20	1.78	1.12	3	2	95	---	2.06	91	0.27
24	40	40	---	20	41	42	---	17	1.77	1.14	1	2	97	---	2.06	91	0.45
25	35	35	30	---	35	35	30	---	2.02	1.26	1	1	98	---	2.06	83	----

2.3 Procedure

The column was prepared by introducing tap water (-15°C) through the cold-water inlet on the catch pot and, once the column was full, discharging it through the overflow. Hot water and/or steam were circulated through the heating coil inside the column and the holding pan. The water level was adjusted so that the nozzle was immersed in at least 4 cm of hot water. In most instances, 500 to 1000 g of explosive were melted and mixed in the holding pan prior to being ejected through the nozzle. Upon completion of each run, the prills accumulated in the catch pot were dried and weighed, and then their size distribution, composition, bulk and absolute densities were determined.

2.4 Results

Table I summarizes the experiments performed to develop the laboratory-scale technique of pelletizing multi-ingredient explosives. A total of 25 runs are reported, involving 13 different HEBP compositions. Some runs carried out are not reported because they were of little significance and judged unnecessary for a sound understanding of the process.

2.4.1 Compositions

All compositions contained TNT as the carrier fluid for other ingredients. Run 1 contained only TNT whereas, in the others, a fraction of this energetic fluid was replaced by some combination of RDX, aluminum (Al) and ammonium perchlorate (AP) to investigate the possibility of substituting some of the TNT by these materials. The RDX content varied between 0 and 60% while the AP and Al contents ranged from 0 to 30%. The theoretical densities calculated from the crystal density of each of the ingredients ranged from 1.65 g/cm^3 for pure TNT (2) to 2.02 g/cm^3 for the formulation TNT/RDX/Al: 35/35/30. The bulk densities of these two formulations measured in a 5-cm diameter cylinder were 1.04 and 1.26 g/cm^3 respectively.

Table I also gives the chemical analyses of the prills produced and their size distributions. The analyses, based on the preferential dissolution of TNT in benzene and RDX in acetone, show that the TNT content was often 1 to 2% higher than the formulated composition. The prill size fractions, obtained by dry sieving of pellets with a DREV-designed round-hole sieve, were generally between 0 and 5 mm.

The formulations containing RDX were prepared from a combination of Composition B, TNT and either Al or AP. Since Composition B contains some wax, the prills produced also contained wax as a desensitizing additive. No desensitizer was added to runs 1, 2 and 3, which did not contain RDX.

To impede the possible reaction of aluminum with water or water vapour, ammonium lignosulfonate (a deactivating agent) was added, in a concentration of about 0.1% by weight, to formulations containing aluminum. Subsequent testing, however, showed that no gas evolved when prills, with or without lignosulfonate, were submerged in water at 20°C for 50 days.

2.4.2 Effect of Temperature on Prill Formation

Two temperature ranges of the molten suspension of explosive were mainly investigated: the first between the melting point of TNT (81°C) and 86°C, where the viscosity of the suspension is relatively high and varies rapidly with temperature (3); and the second from 90 to 93°C, where the viscosity is lower and relatively constant.

The effect of temperature on the formation of prills was studied with the formulation TNT/RDX/Al: 42/42/16; data from Table I has been reproduced in Table II for ease of comparison. Here it can be seen that the size of prills decreased with increasing temperature. At 83°C,

TABLE II

Effect of Temperature on Prill Size Distribution

(TNT/RDX/Al:42/42/16; 2.06 mm nozzle)

Temperature °C	Bulk density g/cm ³	Size of prills (mm) % by weight				Run
		0-1.5	1.5-3	3-5	>5	
83	1.20	1	--	99	--	9
86	1.20	1	20	79	--	10
93	1.21	1	33	66	--	11

99% by weight of the prills were between 3 and 5 mm, while at 93°C only 66% were of this size, 33% being between 1.5 and 3 mm. This change in size, however, had no effect on the bulk density, which remained at about 1.20 g/cm³. These results indicate that if a uniform prill size is required, the fluid temperature should be as low as the process permits (-83°C). On the other hand, if a wider distribution is acceptable, the pellets can be produced at a higher temperature.

Why this is so can be explained by observing the formation of the prills. At temperatures slightly above the melting point of the TNT (83-86°C), the viscosity is relatively high and the flow through the nozzle slow enough so that the droplets are formed one by one at the tip of the nozzle; when enough mass is present to overcome the surface tension at the

UNCLASSIFIED

9

nozzle tip, the droplet falls off. It is still molten at this point and tends to flatten slightly, due to the resistance of water. When the explosive fluid is at a high temperature ($> 90^{\circ}\text{C}$), the viscosity is substantially lower and the fluid flows in a continuous manner into the water column and breaks up into droplets of different sizes, likely due to the stalling effect of the flow into a stationary medium. A variety of droplet sizes are obtained at this temperature, often with a needle hole appearing in the cooled prills. A photograph of typical prills is shown in Fig. 4; although they appear spherical here they are, in fact, somewhat flattened.

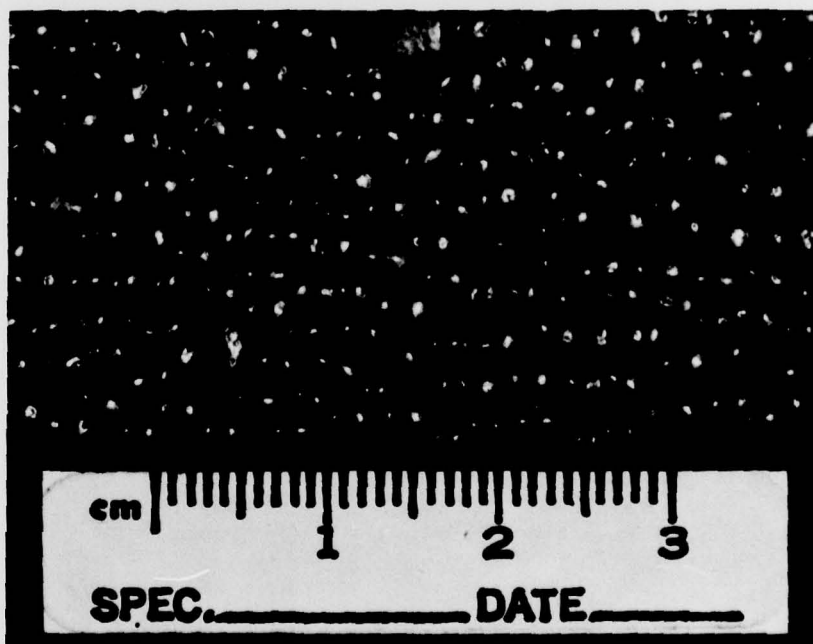


FIGURE 4 - HEBP containing RDX/TNT/A1

2.4.3 Effect of Temperature on Production Rate

The rate of production of HEBP was mainly studied at 83 and 91°C with the formulation TNT/RDX/Al:40/40/20, using the 2.06-mm nozzle. Table III gives the results of three runs conducted at each temperature. Here

TABLE III

Effect of Temperature on Production Rate

(TNT/RDX/Al:40/40/20; 2.06-mm nozzle)

Run	Temperature °C	Production rate kg/h
17	83	0.32
18	83	0.36
19	83	<u>0.36</u>
		Ave = 0.35
14	91	0.59
15	91	0.63
16	91	<u>0.54</u>
		Ave = 0.59

it can be seen that the average production rate increased by about 68% from 0.35 to 0.59 kg/h when the temperature was raised from 83 to 91°C. Although not measured, the viscosity at 91°C can be estimated from Ref. 2 to be about 60% of that at 83°C.

Using data from run 3 of Table I, the production rate of TNT/Al:80/20 prills from the same nozzle diameter (2.06 mm) was 3.6 kg/h at 86°C. That is, the addition of RDX to the composition greatly reduced the production rate (a direct comparison is not possible because the temperatures were not the same).

2.4.4 Effect of Nozzle Diameter on Size of Prills

An effective nozzle must have a diameter permitting a continuous flow (i.e. no blockage) and production of prills of about 3 mm. With this in mind, nozzles of 1.52, 2.06 and 2.54 mm in diameter were tested with two formulations (TNT/RDX/Al:80/0/20 and 42/42/16); the results are reported in Table IV.

TABLE IV

Prill Size Distribution for Three Nozzle Diameters

Nozzle diameter mm	Temp °C	Composition			Bulk density g/cm ³	Prill size (mm) % by weight				Run
		TNT	RDX	Al		0-1.5	1.5-3	3-5	>5	
1.52	86	80	0	20	1.13	3	9	88	0	2
	86	42	42	16	1.20	0	77	23	0	6
	93	42	42	16	1.19	4	63	32	1	8
2.06	86	80	0	20	1.13	1	25	58	16	3
	86	42	42	16	1.20	1	20	79	0	10
	93	42	42	16	1.21	1	33	66	0	11
2.54	83	42	42	16	1.20	0	1	57	42	12

When both the 1.52- and 2.06-mm nozzles were used with the 42/42/16 composition, the prill size decreased with increasing temperature, as previously noted in Sec. 2.4.2. In addition, the 42/42/16 prills were smaller than 5 mm for both nozzles at both test temperatures (86 and 93°C). On the other hand, with the 80/0/20 composition 16% of the prills were greater than 5 mm using the 2.06-mm nozzle at 86°C, whereas none were with the smaller nozzle.

While not directly comparable, because the temperature was different, virtually all the prills were greater than 3 mm and nearly half were greater than 5 mm when the 42/42/16 composition was prilled through a 2.54-mm nozzle at 83°C. These prills, however, were less rounded than those from the other two nozzle sizes.

In general it was noted that the bulk density was not affected by either nozzle size or temperature, and that the 1.52-mm nozzle tended to block with the 42/42/16 composition.

3.0 PILOT-PLANT PRILLING TOWER

The second phase of this investigation was to scale up from the single-nozzle laboratory column to a pilot-plant prilling tower capable of much higher production rates. With this larger installation, processing methods suitable for industrial exploitation were established and about two tons of HEBP explosives were produced for evaluation in cratering trials (1).

3.1 Details and Operation of the Tower

A schematic of the tower, with its 44-cm diameter water column, is given in Fig. 5, and a photograph in Fig. 6. The increased production rate was achieved by placing 39 nozzles, rather than just one, at the top of the enlarged water column. Batches of approximately 90 kg of prills were processed with the basic TNT/Al:80/20 formulation; this was reduced to about 70 kg when RDX was added.

3.1.1 Melting Hopper

The melting hopper consists of a 140-ℓ stainless-steel jacketed kettle. The agitation of the explosive in this steam-heated kettle, which is operated at atmospheric pressure and a preselected temperature, is obtained by a U-shaped stirrer rotating at 80 r/min. The kettle is equipped with an automatically controlled flush-mounted dumping valve, located at the centre of its round bottom, and a 3.8-cm diameter heated pipe that feeds the dropping pan.

3.1.2 Drop Pan and Nozzle Assembly

The sides of the drop pan are formed by a 30-cm diameter by 30-cm deep stainless steel cylindrical jacket. A bore plate, attached to this cylinder with screws, forms the bottom of the pan. The 39 nozzles (2.06-mm inside diameter) are inserted into the bore plate symmetrically around three different diameters, as illustrated in Fig. 7. Each stainless steel nozzle, 7 cm long, is press fit into a brass cylinder which is, in turn, press fit into the bore plate. The nozzle is depicted in Fig. 5, and a photograph of one is shown in Fig. 8. The level (head) of the molten explosive over the inlet of the nozzles can be adjusted at will, something that could not be readily done in the laboratory-scale setup.

3.1.3 Column and Catch Pot

The 44-cm inside diameter column is made of 1-cm thick plexiglass. At the top and bottom there are aluminum flanges held together by steel rods running outside the column; and the bottom flange is firmly bolted to a supporting steel frame that also holds the catch pot (Figs. 5 and 6). The water in the upper part of the column is heated by a 30-cm diameter

by 33-cm high copper tube coil fed with condensing steam; the coil is immersed in the water of the column. Thermocouples and thermometers are located at several positions in the column.

The aluminum catch pot, with an inside diameter of 46 cm and an equal depth, has a capacity of 80 l; it is bolted to the tower support under the column. The valve used to drain the column after completion of a batch is fitted with a filter to stop prills from draining with the water.

3.1.4 Operating Temperature

Although laboratory studies into the effect of temperature on prill formation (Sec. 2.4.2) and production rate (Sec. 2.4.3) had been conducted, the operating temperature of the pilot-plant tower was dictated almost solely by performance of the tower after it had been started up. It was found that a temperature of 83 to 86°C gave a satisfactory production rate with an acceptable prill size distribution. If the temperature was increased above this level, the prills were formed too rapidly, leading to problems of accumulation in the column. Also, these lower temperatures resulted in less TNT vapour being formed in the working area, a factor that was not significant in the laboratory tests.

The molten explosive suspension is fed into the drop pan when the recorded temperatures of the hot water (in the upper section of the column) and of the molten explosive in the melting pot and the drop pan constantly oscillates between 83 and 86°C. The temperature is controlled by proportional pneumatic valves, which are actuated by monitoring units each connected to a thermocouple. The water in the lower part of the column is about 10°C, but there is no temperature control for the tap water injected into the column at about 1 l/min.

3.1.5 Level of Explosive in Drop Pan

The level of explosive in the drop pan is maintained by a controller actuating a flush-mounted dumping valve, at the bottom of the hopper, which is proportionally operated. This level is maintained at 6 cm for formulations containing RDX and at 1 cm for the less viscous TNT/A1 formulation.

3.1.6 Graphitization of Prills

After completion of a batch, the column is drained and the catch pot removed from its support. Then the prills are put in trays and dried overnight by circulating warm air (~40°C) across the trays. A sample of about 1 kg is taken to determine the particle size distribution and bulk density.

To avoid the build-up of static charges, the next operation consists of making the surface of the prills semi-conductive by covering them with a very thin film of graphite. This graphitization is achieved

by plunging and shaking about 10 kg of dry prills at a time, in a wire mesh basket, in a colloidal suspension of graphite (8% by weight) in isopropanol for about one minute. Finally, the prills are again put in trays and dried overnight; the conductance is then checked and the prills stocked in semi-conductive bags.

The electrical resistance of coated prills, measured between two 18-cm² cylindrical plates 2.5 cm apart, was lower than $0.5 \times 10^6 \Omega$ compared to values higher than $20 \times 10^6 \Omega$ for uncoated prills. In practice, the graphitization of prills proved to eliminate the build-up of static charges.

3.2 Results

After the operating conditions of the pilot-plant prilling tower were established, the production of 1000 kg of each of TNT/RDX/Al:40/40/20 and TNT/Al:80/20 was undertaken. Chemical details of the ingredients used are contained in Appendix A. As previously noted in Sec. 1.0, these HEBP explosives were subsequently sent to DRES for determination of their cratering characteristics (1).

3.2.1 Formulation TNT/RDX/Al:40/40/20

Sixteen batches were required to produce about 1000 kg of 40/40/20 prills; the production rate, prill size distribution and bulk density for each of these batches are listed in Table V.

The average production rate was 14.7 kg/h (= 0.38 kg/h/nozzle), which compares favourably with the 0.34-kg/h average of laboratory runs 17 and 19 (Table I) with the same composition, nozzle and operating temperature.

The prill size distributions are also similar to those obtained during the laboratory studies. Slight differences from batch to batch and from the laboratory studies can be explained by the larger variation of the temperature in the plant scale ($\pm 3^\circ\text{C}$) than in the laboratory studies ($\pm 1.5^\circ\text{C}$).

The bulk density of the prills obtained was about 1.22 g/cm³, the same value measured during the laboratory studies.

The TNT, RDX and Al content of the prills was determined by chemical analysis for runs CR-1 to 3. Since the percentage of each ingredient was identical to the calculated formulation for two of the three runs, and only 1% off for TNT and RDX in the third run, this test was judged unnecessary and discontinued.

The water content of many samples of the finished product, determined by the Karl Fisher method, showed that the prills generally contained between 60 to 90 ppm of water.

3.2.2 Formulation TNT/Al:80/20

Thirteen batches were required to produce about 1000 kg of 80/20 prills; the production rate, prill size distribution and bulk density for each of the batches are listed in Table VI.

The average production rate was 73.0 kg/h (1.87 kg/h/nozzle), which is only about half the 3.6 kg/h obtained from laboratory run 3 (Table I) with the same composition, nozzle and operating temperature. This was due to the much lower head of molten explosive over the nozzle in the drop pan of the tower, which was only 1 cm (Sec. 3.1.5) as compared to anything from 1 to 10 cm in the laboratory run.

The much higher production rate of the 80/20 prills, 73.0 kg/h compared to 14.7 kg/h for the 40/40/20 prills, is explained by the much lower viscosity of the molten suspension of the former. The molten explosive containing 80% of TNT and 20% of solids is obviously much more fluid than one that contains only half that amount of TNT and three times the quantity of solids.

A comparison of the average prill size distribution of the tower prills to that of laboratory run 3 shows that the percentage of prills in excess of 5 mm was greatly reduced in the tower. This can again be explained by the lower head of explosive over the nozzles because the prills will form more slowly and, therefore, more uniformly.

The average bulk density of the tower prills was 1.12 g/cm³, which compares favourably with the 1.13 g/cm³ obtained in the laboratory.

The TNT and Al content of the prills was determined by chemical analysis for runs TR-1, 2 and 5. When they were found to be identical to the formulated composition, this determination was discontinued.

UNCLASSIFIED

16

TABLE V

Tower Performance for TNT/RDX/Al:40/40/20 Prills

(Temperature = 83 - 86°C; 2.06-mm nozzle)

Batch	Bulk density g/cm ³	Prill size (mm) % by weight				Production rate kg/h
		0-1.5	1.5-3	3-5	>5	
CR-1	1.20	-	5	97	-	13.6
CR-2	1.22	3	21	74	2	14.1
CR-3	1.22	4	28	64	4	22.7
CR-4	1.22	3	17	79	1	14.1
CR-5	1.23	2	13	85	-	10.6
CR-6	1.22	2	10	88	1	12.7
CR-7	1.23	2	19	78	1	14.7
CR-8	1.21	4	24	72	-	16.9
CR-9	1.22	2	14	84	-	15.1
CR-10	1.21	4	18	78	-	13.4
CR-11	1.24	2	16	82	-	15.1
CR-12	1.22	2	23	75	-	15.8
CR-13	1.22	5	25	70	-	14.9
CR-14	1.21	2	30	66	-	14.2
CR-15	1.22	4	20	76	-	13.6
CR-16	1.22	4	18	78	-	13.6
MEAN	1.22	3	19	77	1	14.7

TABLE VI

Tower Performance for TNT/Al:80/20

(Temperature = 83 - 86°C; 2.06 mm nozzle)

Batch	Bulk density g/cm ³	Prill size (mm) % by weight				Production rate kg/h
		0-1.5	1.5-3	3-5	>5	
TR-1	1.13	4	41	51	4	56.8
TR-2	1.13	2	36	61	1	45.5
TR-3	1.14	4	43	52	1	50.0
TR-4	1.11	2	38	59	1	67.3
TR-5	1.11	4	39	55	2	68.2
TR-6	1.13	4	38	56	2	68.2
TR-7	1.11	2	41	55	2	72.7
TR-8	1.11	2	40	56	2	90.9
TR-9	1.12	2	31	61	6	79.5
TR-10	1.13	3	37	57	3	81.8
TR-11	1.12	4	40	54	2	90.9
TR-12	1.12	4	40	53	3	90.9
TR-13	1.12	4	40	53	3	86.4
MEAN	1.12	3	39	55	3	73.0

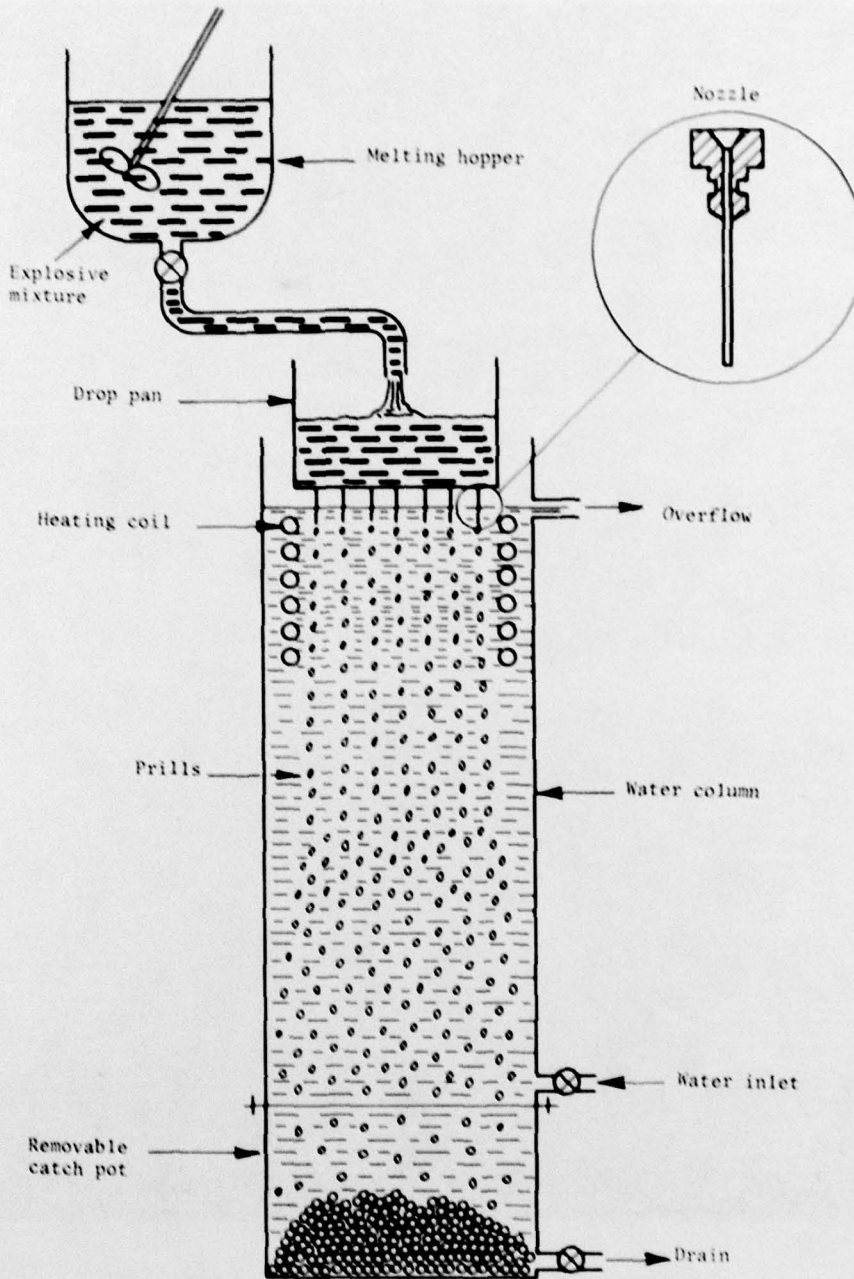


FIGURE 5 - Schematic of pilot-plant prilling tower

UNCLASSIFIED
18

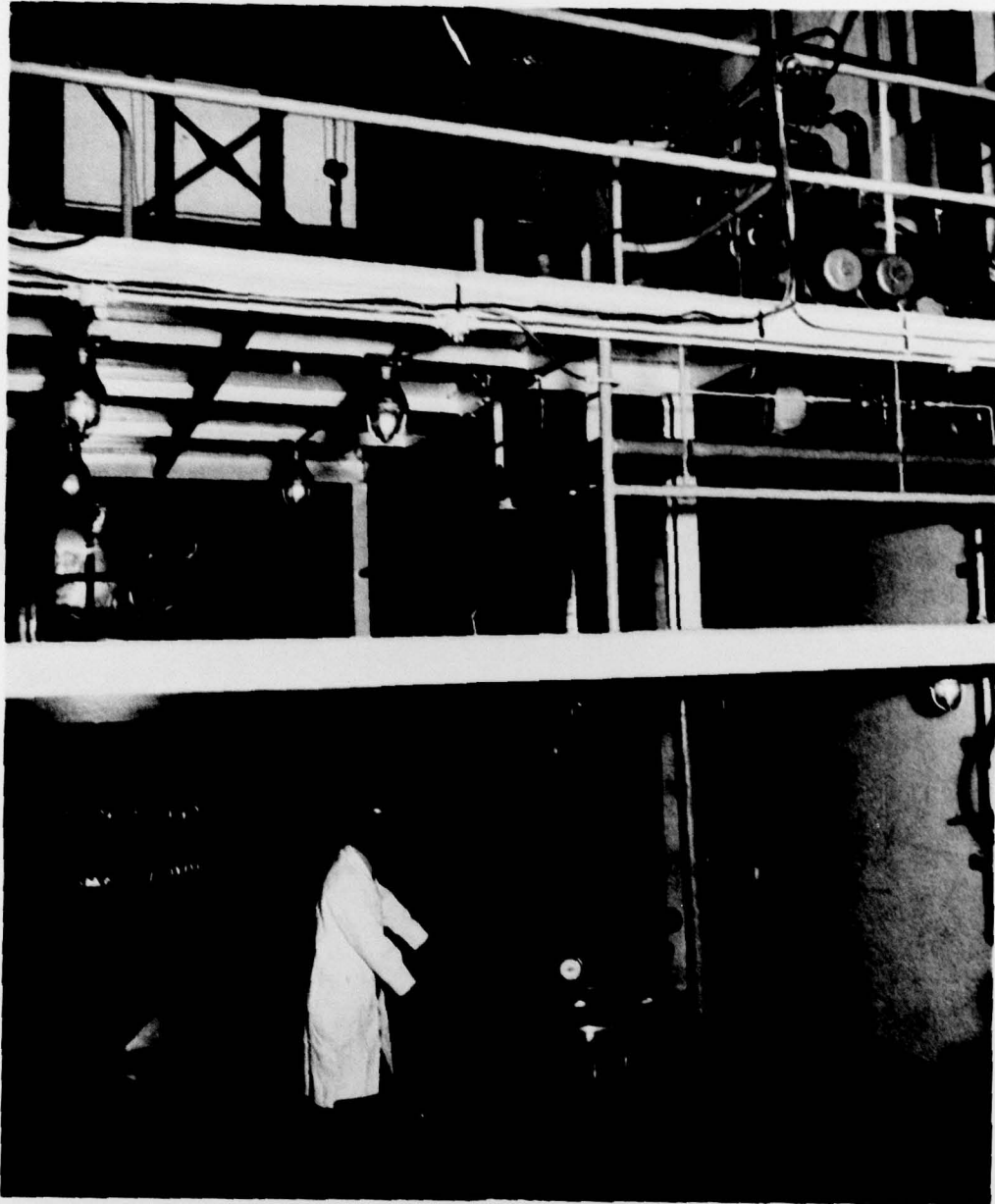


FIGURE 6 - Pilot-plant prilling tower

UNCLASSIFIED
19

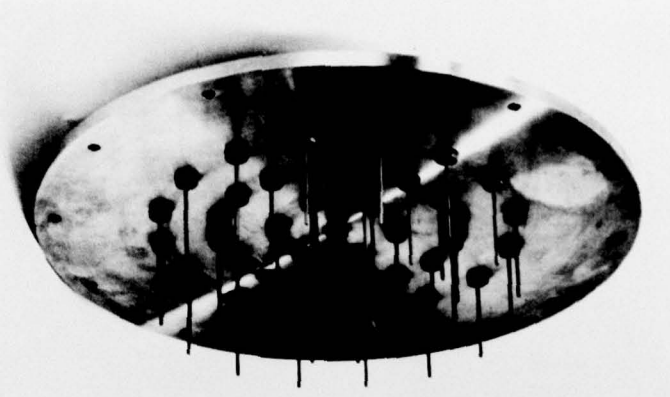


FIGURE 7 - Bottom of drop pan showing 39 nozzles

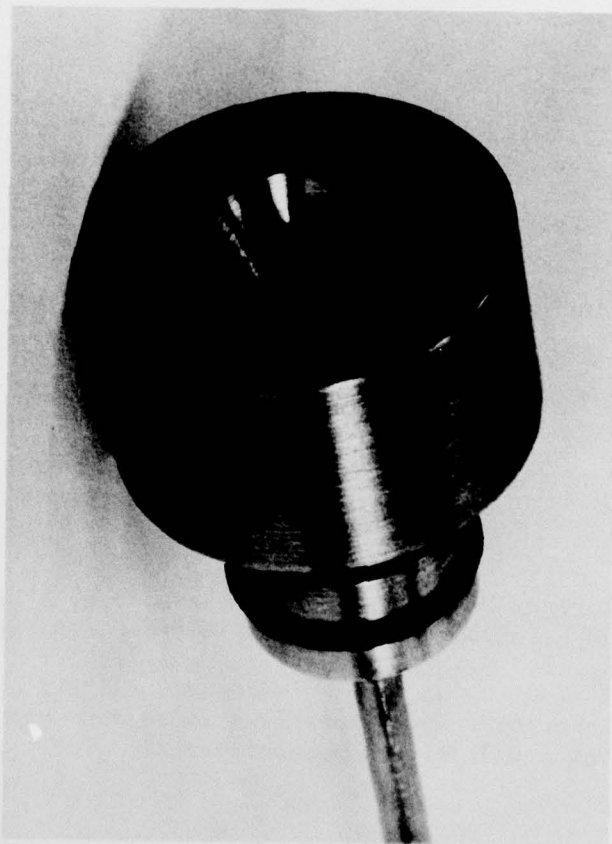


FIGURE 8 - Nozzle

UNCLASSIFIED

20

4.0 CONCLUSIONS

A pilot-plant prilling tower for the production of high-energy blasting prills (HEBP), as conceived at DREV, has been developed, built and put into operation. It can produce about 90 kg per batch at rates of 73.0 kg/h of TNT/Al:80/20 prills or 14.7 kg/h of TNT/RDX/Al:40/40/20 prills. The difference in production rates depends solely on the much lower viscosity of the formulation with 80% of TNT.

Chemical analyses conducted on both types of prills found the final composition to be identical to the formulated composition, indicating that the molten explosive suspension was homogenous in both the melting hopper and the drop pan.

For a given formulation, the production rate and prill size distribution depend on the nozzle size, the operating temperature and the head of explosive above the nozzles. An operating temperature of 83 to 86°C with 2.06-mm diameter nozzles was used for the production of prills in the tower. The head of explosive was maintained at 6 cm for the 40/40/20 prills and at 1 cm for the less viscous 80/20 prills. Under these conditions the average particle size of the prills was about 3 mm.

To eliminate the build-up of static electrical charges on the prills, a graphitization process was developed that deposits a thin coat of graphite over the prills. By so doing, the electrical resistance was reduced from 20×10^6 to $0.5 \times 10^6 \Omega$ and thereby rendered the prills safe to handle and store for long periods. In addition, the HEBP does not react with water.

It is felt that these HEBP explosives have excellent properties for special military applications. The 1000-kg productions of each of the 80/20 and 40/40/20 compositions were sent to DRES (Defence Research Establishment Suffield) for determination of their cratering characteristics. The results of these trials are given in Ref. 1.

5.0 ACKNOWLEDGEMENTS

The authors would like to thank Messrs. J.Y. Bélanger, T.S. Sterling and A.K. Roberts for valuable discussions and their interest in this work. Dr. K.S. Kalman was responsible for the preliminary laboratory-scale studies, and Dr. R. MacDonald carried out the chemical analyses. The laboratory and pilot-plant scale runs were conducted by Messrs. J. Jacques and J. Bigras respectively.

UNCLASSIFIED

21

6.0 REFERENCES

1. Bauer, A., Crosby, W.A., Allen, E.J. and Heater, R.D., 1975 "Evaluation of Pelleted RDX/TNT/Al as a Cratering Explosive" (Contract No. 8SQ4 0079), Mining Engineering Department, Queen's University, Kingston, Ontario.
2. Tomlinson Jr., W.R., "Properties of Explosives of Military Interest" (U), PIC TR-1740 Rev. 1, April 1958, UNCLASSIFIED.
3. Roch, H.W. and Freiwald, H., "Ueber die Rheologischen und Andere Eigenschaften der Suspensionen von Hexogen in Geschmolzenem Trinitrotoluol," Explosivstoffe, Vol 9, No. 10, 1961.

UNCLASSIFIED

22

APPENDIX A

Ingredients Used in the Production of Prilled Explosives

The following is a list of the raw materials used as ingredients in the preparation of prilled explosives:

Trinitrotoluene (TNT): Grade 1, TNT MIL-SPEC-T-248A, produced by Canadian Industries Limited, Montreal.

Composition B: Grade A of nominal viscosity of 5 s, MIL SPEC C-401D, produced by Canadian Industries Limited, Montreal.

Aluminum (Al): Atomized grade SA-24, mean particle size 2 μm , produced by Aluminum Company of Canada, Montreal.

Ammonium perchlorate (AP): Technical grade, produced by American Potash and Chemical Corporation, California. It was ground at DREV to a mean particle size of 15 μm .

Ammonium lignosulfonate (TSD): Technical grade, produced by Lignosol Chemicals, Quebec.

Colloidal graphite: Technical grade, type 1540, dispersed in isopropanol, produced by Acheson Colloids Company, Port Huron, Michigan.

DREV REPORT 4044/76 (UNCLASSIFIED)

Bureau - Recherche et Développement, Ministère de la Défense nationale, Canada.
CRDV, C.P. 880, Courcellette, Qué. G0A 1R0.

"Development of a Method to Produce High Energy Blasting Prills"
by J.F. Drolet and R.R. Lavertu

Les auteurs ont mis au point une méthode permettant la préparation d'explosifs de grande énergie en grains à base de tolite et d'aluminium additionnés ou non d'hexogène; ces grains ont un diamètre moyen de 3 mm. Leur écoulement semblable à celui des liquides, leur résistance à l'eau, leur longue durée de vie et leur utilisation possible dans une large gamme de températures en font des explosifs très intéressants pour certaines applications dans le domaine du génie militaire. La méthode repose sur la formation de gouttelettes d'une suspension liquide d'explosif à l'extrémité d'une buse de petit diamètre immergée au sommet d'une colonne d'eau. Les gouttelettes se solidifient lors de leur chute dans la colonne d'eau. Pour éviter l'accumulation d'électricité statique sur les grains secs, on les rend partiellement conducteurs en les enrobant d'une mince couche de carbone. Les études, d'abord entreprises en laboratoire, ont été poursuivies à l'échelle de l'usine-pilote dans une colonne de 44 cm de diamètre pouvant produire jusqu'à 90 kg d'explosifs par coulée. Dans le cadre de l'évaluation du pouvoir excavateur de ces nouveaux produits, on a fabriqué environ deux tonnes d'explosifs de deux compositions différentes.

DREV REPORT 4044/76 (UNCLASSIFIED)

Bureau - Recherche et Développement, Ministère de la Défense nationale, Canada.
CRDV, C.P. 880, Courcellette, Qué. G0A 1R0.

"Development of a Method to Produce High Energy Blasting Prills"
by J.F. Drolet and R.R. Lavertu

Les auteurs ont mis au point une méthode permettant la préparation d'explosifs de grande énergie en grains à base de tolite et d'aluminium additionnés ou non d'hexogène; ces grains ont un diamètre moyen de 3 mm. Leur écoulement semblable à celui des liquides, leur résistance à l'eau, leur longue durée de vie et leur utilisation possible dans une large gamme de températures en font des explosifs très intéressants pour certaines applications dans le domaine du génie militaire. La méthode repose sur la formation de gouttelettes d'une suspension liquide d'explosif à l'extrémité d'une buse de petit diamètre immergée au sommet d'une colonne d'eau. Les gouttelettes se solidifient lors de leur chute dans la colonne d'eau. Pour éviter l'accumulation d'électricité statique sur les grains secs, on les rend partiellement conducteurs en les enrobant d'une mince couche de carbone. Les études, d'abord entreprises en laboratoire, ont été poursuivies à l'échelle de l'usine-pilote dans une colonne de 44 cm de diamètre pouvant produire jusqu'à 90 kg d'explosifs par coulée. Dans le cadre de l'évaluation du pouvoir excavateur de ces nouveaux produits, on a fabriqué environ deux tonnes d'explosifs de deux compositions différentes.

DREV REPORT 4044/76 (UNCLASSIFIED)

Bureau - Recherche et Développement, Ministère de la Défense nationale, Canada.
CRDV, C.P. 880, Courcellette, Qué. G0A 1R0.

"Development of a Method to Produce High Energy Blasting Prills"
by J.F. Drolet and R.R. Lavertu

Les auteurs ont mis au point une méthode permettant la préparation d'explosifs de grande énergie en grains à base de tolite et d'aluminium additionnés ou non d'hexogène; ces grains ont un diamètre moyen de 3 mm. Leur écoulement semblable à celui des liquides, leur résistance à l'eau, leur longue durée de vie et leur utilisation possible dans une large gamme de températures en font des explosifs très intéressants pour certaines applications dans le domaine du génie militaire. La méthode repose sur la formation de gouttelettes d'une suspension liquide d'explosif à l'extrémité d'une buse de petit diamètre immergée au sommet d'une colonne d'eau. Les gouttelettes se solidifient lors de leur chute dans la colonne d'eau. Pour éviter l'accumulation d'électricité statique sur les grains secs, on les rend partiellement conducteurs en les enrobant d'une mince couche de carbone. Les études, d'abord entreprises en laboratoire, ont été poursuivies à l'échelle de l'usine-pilote dans une colonne de 44 cm de diamètre pouvant produire jusqu'à 90 kg d'explosifs par coulée. Dans le cadre de l'évaluation du pouvoir excavateur de ces nouveaux produits, on a fabriqué environ deux tonnes d'explosifs de deux compositions différentes.

DREV REPORT 4044/76 (UNCLASSIFIED)

Bureau - Recherche et Développement, Ministère de la Défense nationale, Canada.
CRDV, C.P. 880, Courcellette, Qué. G0A 1R0.

"Development of a Method to Produce High Energy Blasting Prills"
by J.F. Drolet and R.R. Lavertu

Les auteurs ont mis au point une méthode permettant la préparation d'explosifs de grande énergie en grains à base de tolite et d'aluminium additionnés ou non d'hexogène; ces grains ont un diamètre moyen de 3 mm. Leur écoulement semblable à celui des liquides, leur résistance à l'eau, leur longue durée de vie et leur utilisation possible dans une large gamme de températures en font des explosifs très intéressants pour certaines applications dans le domaine du génie militaire. La méthode repose sur la formation de gouttelettes d'une suspension liquide d'explosif à l'extrémité d'une buse de petit diamètre immergée au sommet d'une colonne d'eau. Les gouttelettes se solidifient lors de leur chute dans la colonne d'eau. Pour éviter l'accumulation d'électricité statique sur les grains secs, on les rend partiellement conducteurs en les enrobant d'une mince couche de carbone. Les études, d'abord entreprises en laboratoire, ont été poursuivies à l'échelle de l'usine-pilote dans une colonne de 44 cm de diamètre pouvant produire jusqu'à 90 kg d'explosifs par coulée. Dans le cadre de l'évaluation du pouvoir excavateur de ces nouveaux produits, on a fabriqué environ deux tonnes d'explosifs de deux compositions différentes.

DREV REPORT 4044/76 (UNCLASSIFIED)

Research and Development Branch, Department of National Defence, Canada.
DREV, P.O. Box 880, Courcellette, Que. G0A 1R0.

"Development of a Method to Produce High Energy Blasting Prills"
by J.F. Drolet and R.R. Lavertu

A method has been developed for the production of high energy blasting prills (HEBP) containing TNT/Al or TNT/RDX/Al; the average particle size of the prills is approximately 3 mm. Such HEBP explosives seem attractive for special military engineering applications because they are free-flowing, water resistant, have a long life and can be used over a wide temperature range. The method consists of forming fluid droplets of a molten mixture of explosive at the tip of a small-diameter nozzle immersed in the top of a water column. After the droplets leave the nozzle, they solidify as they fall through the remainder of the column. To avoid building up static charges, the prills are made semi-conductive by coating them with a thin layer of graphite. Studies were first undertaken in the laboratory and then scaled up to a 44-cm diameter pilot-plant prilling column that can produce about 90 kg of prills per batch. Some 1000 kg of each of two different compositions were produced for determination of their cratering characteristics (in a separate study).

DREV REPORT 4044/76 (UNCLASSIFIED)

Research and Development Branch, Department of National Defence, Canada.
DREV, P.O. Box 880, Courcellette, Que. G0A 1R0.

"Development of a Method to Produce High Energy Blasting Prills"
by J.F. Drolet and R.R. Lavertu

A method has been developed for the production of high energy blasting prills (HEBP) containing TNT/Al or TNT/RDX/Al; the average particle size of the prills is approximately 3 mm. Such HEBP explosives seem attractive for special military engineering applications because they are free-flowing, water resistant, have a long life and can be used over a wide temperature range. The method consists of forming fluid droplets of a molten mixture of explosive at the tip of a small-diameter nozzle immersed in the top of a water column. After the droplets leave the nozzle, they solidify as they fall through the remainder of the column. To avoid building up static charges, the prills are made semi-conductive by coating them with a thin layer of graphite. Studies were first undertaken in the laboratory and then scaled up to a 44-cm diameter pilot-plant prilling column that can produce about 90 kg of prills per batch. Some 1000 kg of each of two different compositions were produced for determination of their cratering characteristics (in a separate study).

DREV REPORT 4044/76 (UNCLASSIFIED)

Research and Development Branch, Department of National Defence, Canada.
DREV, P.O. Box 880, Courcellette, Que. G0A 1R0.

"Development of a Method to Produce High Energy Blasting Prills"
by J.F. Drolet and R.R. Lavertu

A method has been developed for the production of high energy blasting prills (HEBP) containing TNT/Al or TNT/RDX/Al; the average particle size of the prills is approximately 3 mm. Such HEBP explosives seem attractive for special military engineering applications because they are free-flowing, water resistant, have a long life and can be used over a wide temperature range. The method consists of forming fluid droplets of a molten mixture of explosive at the tip of a small-diameter nozzle immersed in the top of a water column. After the droplets leave the nozzle, they solidify as they fall through the remainder of the column. To avoid building up static charges, the prills are made semi-conductive by coating them with a thin layer of graphite. Studies were first undertaken in the laboratory and then scaled up to a 44-cm diameter pilot-plant prilling column that can produce about 90 kg of prills per batch. Some 1000 kg of each of two different compositions were produced for determination of their cratering characteristics (in a separate study).

DREV REPORT 4044/76 (UNCLASSIFIED)

Research and Development Branch, Department of National Defence, Canada.
DREV, P.O. Box 880, Courcellette, Que. G0A 1R0.

"Development of a Method to Produce High Energy Blasting Prills"
by J.F. Drolet and R.R. Lavertu

A method has been developed for the production of high energy blasting prills (HEBP) containing TNT/Al or TNT/RDX/Al; the average particle size of the prills is approximately 3 mm. Such HEBP explosives seem attractive for special military engineering applications because they are free-flowing, water resistant, have a long life and can be used over a wide temperature range. The method consists of forming fluid droplets of a molten mixture of explosive at the tip of a small-diameter nozzle immersed in the top of a water column. After the droplets leave the nozzle, they solidify as they fall through the remainder of the column. To avoid building up static charges, the prills are made semi-conductive by coating them with a thin layer of graphite. Studies were first undertaken in the laboratory and then scaled up to a 44-cm diameter pilot-plant prilling column that can produce about 90 kg of prills per batch. Some 1000 kg of each of two different compositions were produced for determination of their cratering characteristics (in a separate study).