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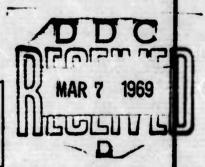
# **EVALUATION AND LOADING** OF NEW EXPLOSIVE FORMULATIONS (U)

J. T. Hamrick L. C. Rose Aerospace Research Corporation

TECHNICAL REPORT AFATL-TR-68-90

AUGUST 1968

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#### FOREWORD

- (U) This report was prepared by Aerospace Research Corporation on Air Force Contract F08635-68-C-0030. The cratering evaluation and filling of the BLU-31 bombs was administered under the direction of the Advanced Technology Branch, Weapons Division, Air Force Armament Laboratory, Eglin Air Force Base, Florida. Capt. J. Trossbach was project scientist for the Armament Laboratory. The cardboard cylinders were furnished by Picatinny Arsenal and the tritonal was furnished by the Naval Weapons Station. The explosive evaluations by Lawrence Radiation Laboratory, the Naval Ordnance Laboratory, and the Naval Ordnance Test Station were made at the request of the Advanced Technology Branch with samples furnished without charge by Aerospace Research Corporation. Mixing, loading, test preparations, and testing of explosives at Aerospace Research Corporation were performed under the direction of Leslie C. Rose. The inclusive dates of the research reported are March 1965 to August 1968.
- (U) Except as noted thermal evaluations, cycling tests, and shelf life evaluations were made by Aerospace Research Corporation. Thermal Stability tests performed by the U. S. Naval Ordnance Test Station were provided in a confidential memorandum which is included in Appendix I. Susan impact sensitivity test results were provided in confidential correspondence from the U. S. Naval Weapons Laboratory and are included in Appendix VI.
- (C) The polyether urethane, nitramine formulations with and without aluminum are covered by patent. The patent (application serial number 659313) has been allowed but not issued due to a secrecy order issued by the Commissioner of Patents. Specific exclusion of any claim by the U. S. Government to patent rights to the explosive was made in Air Force Contract F08635-68-C-0030.
- (U) Information in this report is embargoed under the Department of State International Traffic In Arms Regulations. This report may be released to foreign governments by departments or agencies of the U. S. Governments subject to approval of the Air Force Armament Laboratory (ATWT), Eglin AFB, Florida 32542, or higher authority within the Department of the Air Force. Private individuals or firms require a Department of State export license.
- (U) This technical report has been reviewed and is approved.

George P. Brenner, Colonel, USAF

7 Chief, Weapons Division

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#### CONFIDENTIAL ABSTRACT

(C) An evaluation has been made of AeReCo explosives 459-23 and 475. The explosives withstand 350°F for at least one hour and 300°F for eight hours. Their storability qualities are excellent and they are not affected by moisture at any climatic temperature. In cratering tests the AeReCo 459-23 equalled tritonal. Batch type loading techniques were evaluated by loading BLU-31 bombs.

In addition to security requirements which must be met, this document is subject to special export controls and each transmittal to foreign governments or foreign nationals may be made only with prior approval of the Air Force Armament Laboratory (ATWT), Eglin AFB, Florida 32542.

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#### SECTION I

#### INTRODUCTION

- (C) The new explosive formulations for which mixing, loading, and test results are provided herein show promise as candidates for filling bombs, land mines, and other armaments which will be subjected to high impact after being launched from high speed aircraft or to aerodynamic heating when externally mounted on supersonic aircraft or missiles. As a result, BLU-31 bomb cases were filled with both aluminized and nonaluminized formulations for subsequent sled testing by the U. S. Air Force. Preliminary to sled testing, Susan Impact tests were made by the U. S. Navy at Dahlgren, Virginia and the results are included in this report.
- (C) The explosives for which the results of exploratory development work are presented utilize a polyether urethane rubber binder-fuel in combination with cyclotrimethylene trinitramine (hereafter referred to as RDX) and, optionally, aluminum powder. Most of the work to date has been directed toward evaluation of the explosives rather than manufacture. The results of thermal evaluations at several different laboratories as well as at Aerospace Research Corporation, cratering capability tests at the Aerospace Research Corporation high explosive test site, and hazard classification tests are presented herein. In addition, information which is preliminary in nature on mixing and loading of BLU-31 bomb cases is included. Stowage in 300 to 350°F environments, good physical characteristics, good cratering capability, and castability which have been demonstrated are discussed.
- (C) The two formulations chosen for evaluation have been designated as AeReCo 475 and AeReCo 459-23. AeReCo 475 contains 25 percent binder and 75 percent RDX. AeReCo 459-23 contains 18 percent binder, 59 percent RDX, and 23 percent aluminum powder.

#### SECTION II

#### SELECTION OF INGREDIENTS

- (C) Of the ingredients used in the explosive, the binder is the one that sets it apart from other explosives. The binder possesses the right combination of properties to allow mixing and curing with nitramines and aluminum and after curing to have excellent physical characteristics over a wide range of environmental conditions. RDX alone or with aluminum powder is mixed with the binder to form a viscous slurry-like mixture which is then cured to the solid state. The binder is a polyether urethane and is derived from a combination of ether glycols and toluene diisocyanate with diols and polyols or polyols alone as cross linking agents. The binder in combination with aluminum and the nitramines are covered by a patent (Serial No. 659313) for which notice of allowance has been received, but which is being withheld from issue due to a secrecy order issued by the Commissioner of Patents. Ingredients for preparing the polyether prepolymer are not limited by the patent to those indicated herein. Ingredient selection factors are considered in the following subsections.
- (C) <u>Binder Selection</u> Both polyester and polyether urethanes were evaluated for this application. It was found that all types of polyester urethanes disintegrate when exposed to 95 percent relative humidity and 160°F for prolonged periods whereas the polyether urethanes do not. Exposure of the polyether urethane composites to 95 percent relative humidity and 160°F for six months resulted in no visible change in the shape or physical characteristics. The binder alone withstood 350°F for ten hours without significant degradation. The specimen was slightly less resilient but showed no tendency toward slumping or stickiness. Flexibility is retained at -65°F. The binder has been designated AeReCo 400. For RDX or RDX-aluminum mixtures, the ciphers are replaced by the percent of RDX and a dash number after the percent RDX is followed by the percent of aluminum powder when it is present.
- (C) Aluminum Additive The amount of aluminum that can be added to RDX is, percentage-wise, considerably larger than the amount that can be added to TNT while still increasing the effective explosive capability. It is indicated by results shown in reference 1 that the reaction of aluminum with oxygen in the primary explosive produces Al<sub>2</sub>0 in the gaseous state and that Al<sub>2</sub>0<sub>3</sub> which is the normal oxide of aluminum does not exist in the gaseous state. Further, it is indicated that the gaseous phase of the oxide A120 does not exist below approximately 3500°K. Therefore, the heat of explosion of the primary explosive usually determines the percentage of aluminum which will produce optimum explosive power rather than the amount of oxygen available. It is further pointed out by Cook that the brisance of the explosive is considerably degraded by the use of aluminum but that the explosive power is significantly increased, thereby allowing a sizable increase in demolition capabilities by the addition of aluminum. With the decrease in brisance it does not follow that there will be an accompanying decrease in impact sensitivity of the explosive mixture. The particle size of aluminum to be used most effectively in this application has not been determined but there is some indication that particle size below 35mesh screen size will not produce any additional effectiveness. This is a factor that will have to be determined together with the optimum particle size of RDX. For high temperature explosives it is probable that determination of

the maximum amount of aluminum that can be used effectively will be well worth investigating both from a cost reduction and impact sensitivity standpoint. Further, it may be desirable in the future to evaluate perchlorate salts as an additive because of their high heat evolvement upon their reaction with metals. Perchlorates, however, do not have the moisture resistance that may be required.

- (U) Oxidizer Selection A comparison of chemical and physical properties of HMX and RDX is shown on the chart (Table I) furnished by Holston Arsenal. Note that at 150°C (302°F) there is gas evolution from HMX although it is not as great as that for RDX. Therefore, for any application where there is continuous exposure to 300°F, gas will be evolved with both. The effect of this gas evolution and the length of time it can be tolerated can be determined only by laboratory testing of the end device. It should also be noted that with HMX there is a change in crystal density with change in temperature. The crystal density of HMX decreases with increasing temperature which means that the volume taken up by the crystals will increase. In going from beta crystals to alpha crystals at 115°C, there is approximately a four percent volume increase which takes place within the temperature range required for this application. There are no data available to show that the crystal phase change has given trouble in the past. However, past applications were for temperatures below 115°C and it is significant to note that ammonium nitrate which has a similar volume increase in going from room temperature to -65°F, has resulted in significant propellant grain growth in starter cartridges and extrusion of the propellant out of the cartridge case as a result of temperature cycling. is not subject to this crystal phase change and may be more trouble free. Therefore, even though the detonation velocity of the HMX is a slightly higher than that for RDX as are the decomposition and explosion temperatures this crystal phase change may cause it to be less desirable in some applications. One advantage of the proposed system is that HMX can be substituted for RDX in applications where HMX may prove more suitable. All evaluations were made with type B, class A RDX. Type B RDX which is made by the Acetic Anhydride Process contains five to fifteen percent HMX. Therefore, compatibility of HMX with the other ingredients used in the formulation is assured to a large degree.
- (C) Mixing Procedure To prepare the urethane prepolymer, mix under a nitrogen atmosphere 46 parts of 2000 molecular weight polypropylene glycol and 31 parts of 3000 molecular weight propylene oxide adduct of 1,2,6 hexanetriol. Hold at 1500F until both components are liquid. Add 18.4 parts of 2,4 tolylene disocyanate and 4.6 parts of 2,6 tolylene disocyanate by means of a dropping funnel. Continue heating until a reaction temperature of 212°F is reached. Hold this temperature until a viscosity of 5000 cp at 77°F is attained. To prepare AeReCo 475, place 23.85 parts of the urethane prepolymer in a mixing bowl held at 2000F. Add 75 parts of RDX and mix until homogeneous. Add 1.15 parts of molten trimethylolpropane and mix until the trimethylolpropane is well distributed but not more than approximately five minutes. Mix in a vacuum mixer or evacuate the mix prior to pouring. Cure at 200°F for approximately 15 hours. To prevent foaming, all ingredients used in making the explosive must be kept water free. To prepare AeReCo 459-23, place 17.17 parts of the prepolymer in a mixing bowl held at 200°F. Add 23 parts of finely atomized aluminum powder and 59 parts of RDX and mix until homogeneous. Add .83 parts of molten trimethylolpropane and mix until the trimethylolpropane is well distributed but not more than approximately 5 minutes. From this point the procedure is the same as that for AeReCo 475.

### TABLE I COMPARISON OF CHEMICAL AND PHYSICAL PROPERTIES

(RDX AND HMX)

RDX	HMX
H.	NO:
H s—C N—NOs	H:-C C-H:  N-NO:
0 W W 0	

Formula

C<sub>3</sub> H<sub>6</sub> N<sub>6</sub> O<sub>6</sub>

C<sub>4</sub> H<sub>8</sub>N<sub>8</sub> O<sub>8</sub>

Molecular Weight	222.13	296.17
Melting Point (°C)	204 (dec)	280 (dec)
Explosion Temp (5 sec)	260°C	327°C
Vacuum Thermal Stability		
(cc gas/gm in 48 hr)		
at 100 °C	0.10	0.10
at 150°C	3.0	0.60
Confined "Cook Off" Temp (°C)	180	210
Crystal Density (gm/ml)	1.802	1.90 (Beta)
		1.82 (Alpha)
		1.76 (Gamma)
		1.80 (Delta)
Heat of Combustion (kcal/mole)	501.82	667.41
(kcal/gm)	2.260	2.255
Heat of Formation (kcal/mole)	-14.71	-17.93
Heat of Detonation (calc)		
(H <sub>2</sub> O gas) (cal/gm)	1228	1222
Heat of Explosion (calc)		
(H <sub>2</sub> O liq) (cal/gm)	1362	1356
Detonation Velocity (m/sec)		
97% Voidless Density	8743	912 <del>4</del>
Slope (m/cc/sec/gm)	3700	3700

#### SECTION III

#### PHYSICAL CHARACTERISTICS

- (C) The cured explosives are not brittle, even at low temperatures. They may be machined with the precaution of frequently removing shavings and are easily sawn. Remote cutting and machining has not been found necessary because of the poor burning characteristics in air.
- (C) <u>Density</u> The computed density of AeReCo 459-23 is 1.88 grams per cc. Density based on weight and physical measurement is 1.72 grams per cc. The computed density of AeReCo 475 is 1.65 grams per cc. The average density based on physical measurement is 1.5 grams per cc.
- (C) <u>Linear Coefficient of Expansion</u> Measurements were made after stabilization at -65°F and 180°F for AeReCo 459-23. Based on these measurements the average linear coefficient of expansion is .33 x 10<sup>-4</sup>. Determination of the expansion coefficient was not made for AeReCo 475.
- (C) Physical Strength Tensile tests have not been made with the explosive primarily because of erratic results obtained as a result of notch sensitivity with machined specimens. Shear strength testing with 24 percent AeReCo 400 binder and 76 percent ammonium perchlorate cast in an impregnated fibre tube showed an average shear strength of 1030 pounds per square inch for the explosive and the bond interface between the fibre tube and explosive. The perchlorate explosive is adequately physically similar to the RDX explosive to expect a similar strength for the AeReCo 475 and possibly a lesser value for the AeReCo 459-23.

#### SECTION IV

#### THERMAL EVALUATION AND SHELF LIFE

- (C) Ability of the explosive to stand up at +350°F for one hour without physical deterioration, reaction with surrounding medium, sutoignition, or explosion was set as the goal in thermal stability evaluations. Shelf life expectancy is based on both storage at ambient conditions and temperature cycling results.
- (C) Thermal Stability The thermal stability evaluation was made with 3/8 inch cubes of material, center drilled with a sheathed 1/16 inch diameter thermocouple injected into the center of and supporting the cube. in which the specimen was tested was controlled so that the wall temperatures remained at  $350 \pm 3^{\circ}F$  throughout the test. The thermocouple in the specimen indicated that the center of the cube reached +350°F within six minutes after the wall of the oven reached +350°F. Samples of AeReCo 459-23 and 475 explosive were thus exposed to +350°F in air for one hour without slumping, melting or undergoing significant change in geometrical proportions. However, there was approximately a three percent weight loss which is attributed to loss of the RDX. The confined cook-off temperature of RDX is 180°C (356°F) as shown by the comparison of chemical and physical properties in Table I. "Cook-off" in ordnance terminology is generally used in reference to rounds left in a hot gun in case of jamming (ref. 2, page 28-24) and it is assumed that with RDX a high degree of confinement would be required at +356°F before an explosion would occur. Based on tests with propellants containing 65 percent RDX, cook-off in this manner would not result in detonation until an extremely high pressure, in excess of 500,000 psi, is reached. The types of armament, degree of confinement, etc., would determine the statistical chances of reaching a high pressure under conditions of +350°F and the hazard involved in the use of such armament can be determined only by environmental tests which simulate field use conditions. Independent and more definitive thermal stability tests for AeReCo 459-23 were performed by the U.S. Naval Ordnance Test Station at China Lake, California and the results are included in Appendix I of this report. Those tests confirm the ability of AeReCo 459-23 to withstand 350°F for at least one hour.
- (C) Differential Thermal Analysis Tests that were made at the Naval Ordnance Test Station, Appendix I, also included differential thermal analysis among others. Additional differential thermal analysis tests were performed by Lawrence Radiation Laboratory and are included in Appendix II. The results of these tests are adequately discussed in Appendices I and II and, therefore, are subjected to no further comment. Two binder specimens with different ether glycols were given vacuum stability tests at the U.S. Naval Ordnance Laboratory and the results are contained in a letter which has been included as Appendix III. Binder 400 A was used in all samples for which tests are reported in Appendices I and II.

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(C) Shelf Life - An eight pound specimen containing 63 percent RDX, thirty one percent binder, and remainder an inert ingredient has been exposed to the ambient environment under shelter, at Roanoke, Virginia for 42 months without any visible change. In addition to ambient exposure a specimen of AeReCo 459-23 5 inches by 5 inches by 2.8 inches was cycled from -65 to 180°F for 27 cycles without any visible change. The cycles consisted of 16 hours in a -65°F chamber followed by 8 hours in a 180°F chamber except for two weekends in which the specimen was kept at 180°F for 56 hours each, and one weekend in which it was kept at -65°F for 48 hours. The 2 inch cubes for which the test results are shown in Appendix III were cut from this specimen after the cycling tests were completed. The shelf life can be expected to greatly exceed five years.

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#### SECTION V

#### IMPACT SENSITIVITY AND HAZARD CLASSIFICATION

- (C) Drop weight impact sensitivities were run on the Lawrence Radiation Laboratory machine using a 5 kilogram weight and type 12 tools with sand-paper. The results are shown in Appendix II. The AeReCo 459-23 is less than half as sensitive as HMX from a drop height standpoint and more sensitive than the AeReCo 475. Additional sensitivity tests were made with two inch cubes of explosive which were subjected to the impact of a number 8 blasting cap. The results of these tests are given in Appendix IV. No detonations occurred in these tests. As noted in Appendix IV, both AeReCo 459-23 and 475 are classified as Class B explosives by the Bureau of Explosives. Class B is not equivalent to Military Class II in that the impact criterion for Class B by current practice of the Bureau of Explosives is insensitivity to a number 8 blasting cap whereas the impact criterion for Class II by the military is insensitivity to 2 pentolite boosters 1 inch long by 2 inches diameter through seventy 0.01 inch cellulose acetate cards which delivers a much greater impact than a number 8 cap.
- (C) The tests which were made to determine military classification are included in the summary sheet in Appendix IV. Card gap tests were not performed, but by comparison, it is estimated that approximately 140 cards 0.01 inch thick will be required to prevent detonation of the AeReCo explosives. From the results of the test and the known fact that in the card gap test the number of cards will exceed 70, the military classification of both explosives is Class 7.
- (C) Susan impact sensitivity tests on AeReCo 475 and AeReCo 459-23 were conducted by the U. S. Naval Weapons Laboratory and the results are included herein as Appendix VI. Tests with desensitized tritonal were made and the results are also included. The results indicate that desensitized tritonal is less sensitive than the AeReCo explosives under the conditions to which the explosives were exposed. It is possible that the AeReCo explosives can be made less sensitive by using a finer than Class A RDX. However, the finer RDX could make processing more difficult. The physical strength of AeReCo explosives is much greater than that of tritonal, and therefore both of the types tested would offer greater resistance to crushing upon impact. Thus, a proportionately greater amount of heat should be generated within the specimen. Encasement of the explosive within a shield which together with the explosive is strong enough to withstand crushing may provide a significantly improved result. If this should be true a reduction in bomb case wall thickness might be possible for the AeReCo explosives over that now required for tritonal.

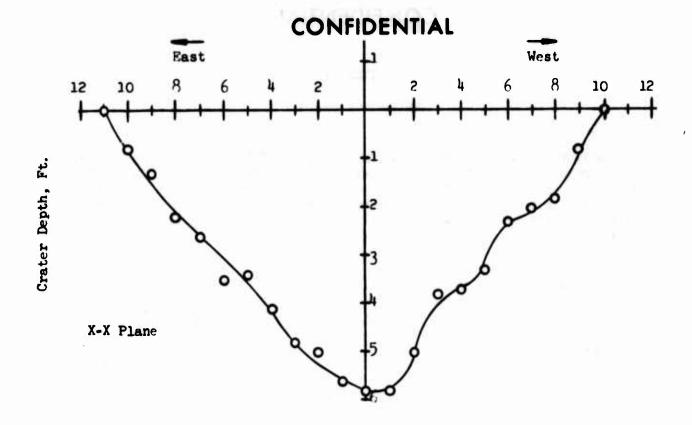
#### SECTION VI

#### DETONATION ENERGY

- (C) A measure of the detonation energy of both AeReCo 459-23 and AeReCo 475 were determined from cratering tests with thirty pound charges. The procedure used in reference 3 was followed as closely as possible in order to allow comparison with the results given therein for thirty pound charges. The experimental approach and experimental results for the cratering tests are presented in this section.
- (C)Experimental Approach-Thirty pound explosive charges of AeReCo 459-23, AeReCo 475, and tritonal were cast in cardboard cylinders of 7 inches inside diameter by 1/4 inch thick walls. Four of each were detonated with their centers of gravity either 6 or 7 feet below ground surface in a 9 1/2 + 1/2 inch diameter hole. Each was covered with fill 2.5 feet above the charge C.G. More specific details are provided in Appendix V. Prior to testing and boring the holes the ground was leveled so as to provide a square plot of virgin soil approximately 20 feet on a side for each specimen. Soil samples were taken at 0, 3, and 6 feet and sealed in a glass jar for future analysis if desired. The soil varied from a soft to hard, deteriorated schist.
- (C)Experimental Results-The results of the tests are given in figures 1 through 28 and Tables II through XIII. It can be seen from figures 1 through 12 that the cratering capabilities of AeReCo 459-23 and tritonal are similar and that both are much superior to AeReCo 475. That both aluminized explosives are superior in cratering capability to a nonaluminized explosive is in agreement with reference 1. The crater volumes and averages for each type explosive at each depth including results obtained for 30 pound charges of tritonal in reference 3 are as follows:

Sample No.	Depth Ft.	AeReCo 459-23 Vol. Cu. Ft.	AeReCo 475 Vol. Cu. Ft.	Tritonal Vol. Cu. Ft.	Tritonal From Ref. 3 Vol. Cu. Ft.
1 2	6	700 197	171 207	379 326	301 268
3	7 7	141 621	0	3 <sup>4</sup> 5 651	205 2 <u>3</u> 4

It is indicated from the results that the soil variation was a major factor. Large chunks of hard soil can be seen in figure 19 for sample 3 of AeReCo 459-23. The hardness of the soil may account for the quite low volume of 141 cubic feet. The reason for the larger hole volume for tritonal at the Aerospace Research Corporation site than at the Corps of Engineers site probably is also due to differences in the soil.





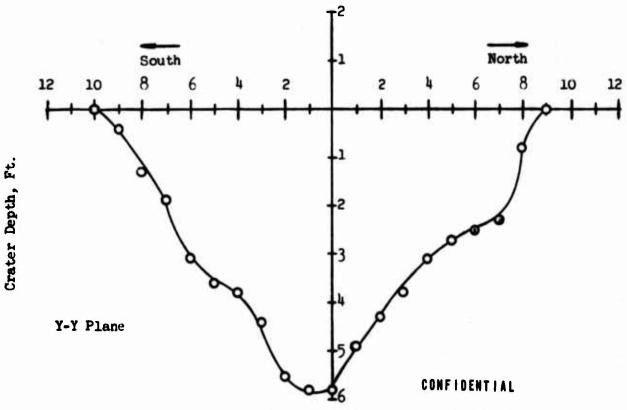
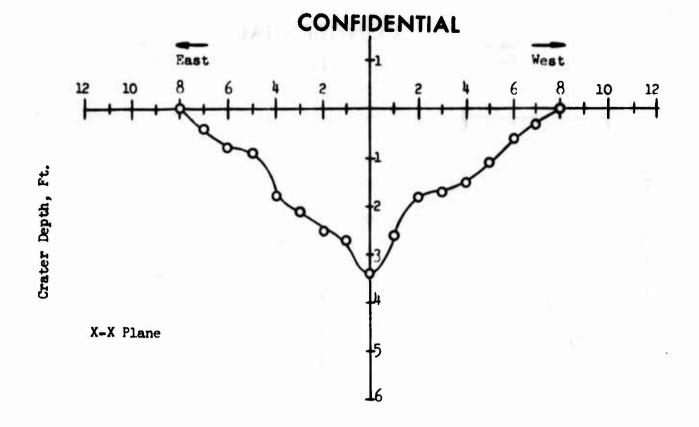


Figure 1 - Crater Profile - Sample: AeReCo 459-23, 1.

10



Crater Radius, Ft.

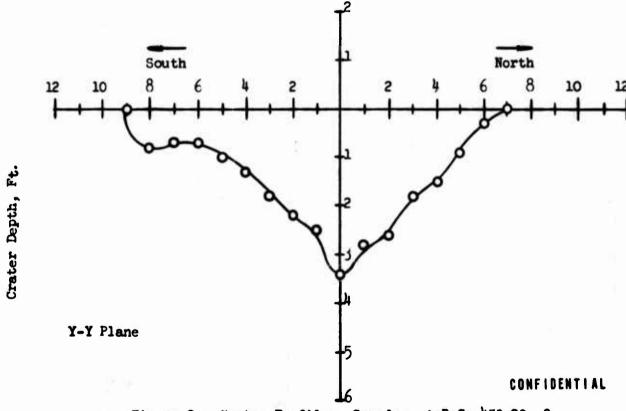
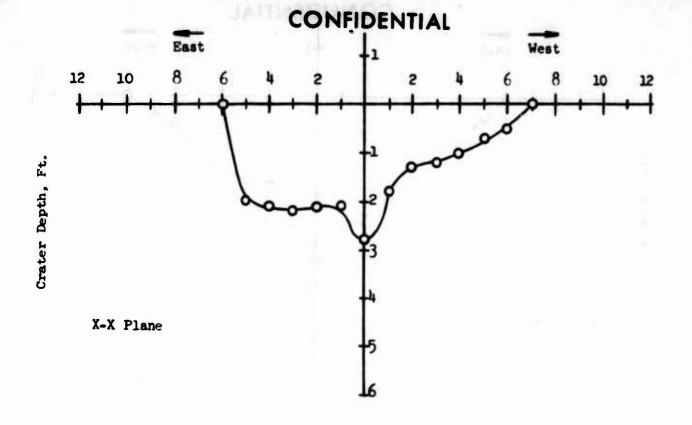


Figure 2 - Crater Profile - Sample: AeReCo 459-23, 2.



Crater Radius, Ft.

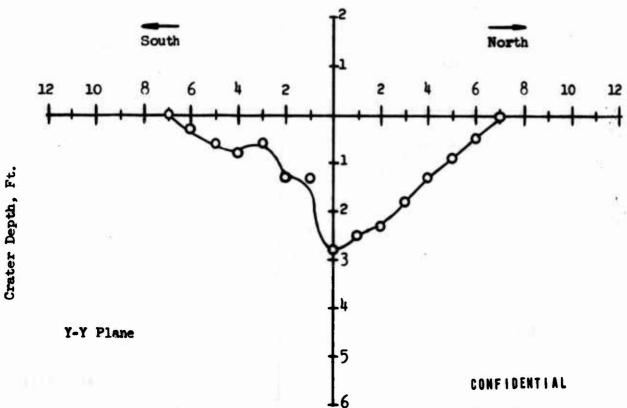
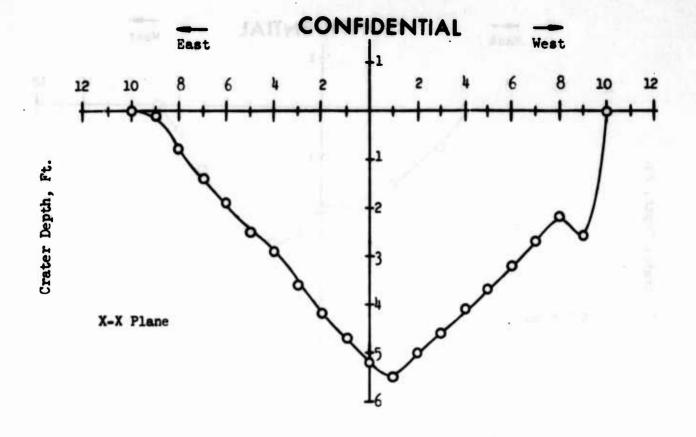
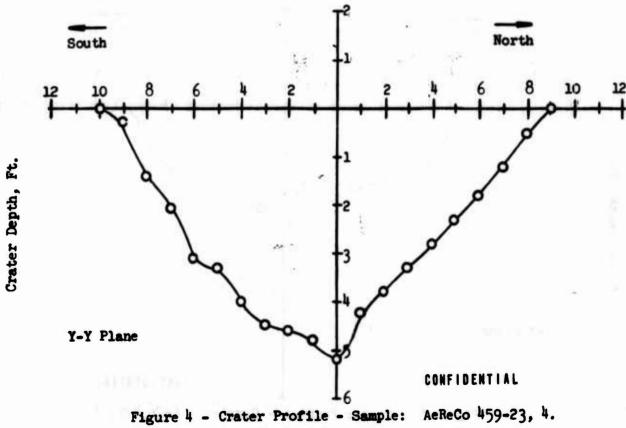


Figure 3 - Crater Profile - Sample: AeReCo 459-23, 3.

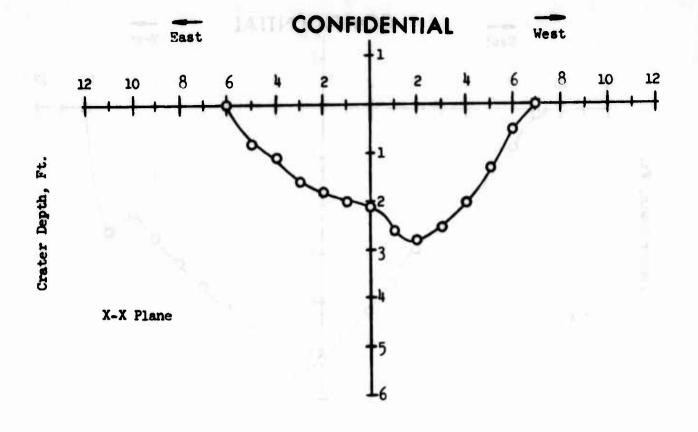
12



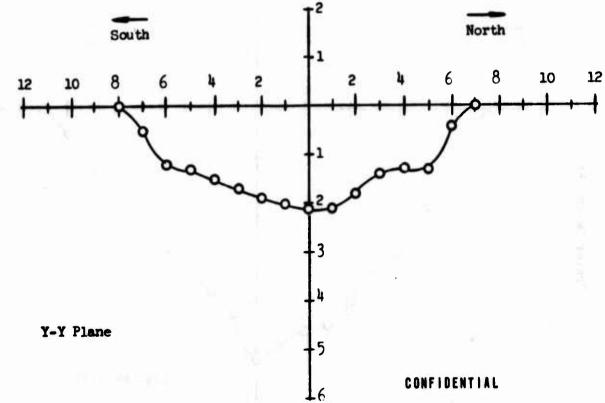
Crater Radius, Ft.



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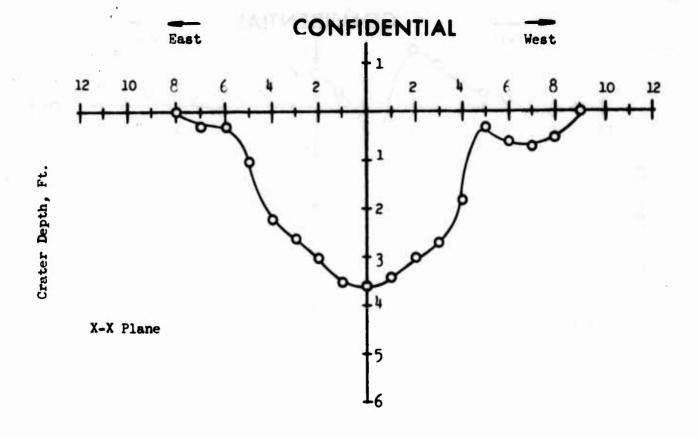
Crater Radius, Ft.



Crater Depth, Ft.

Figure 5 - Crater Profile - Sample: AeReCo 475, 1.

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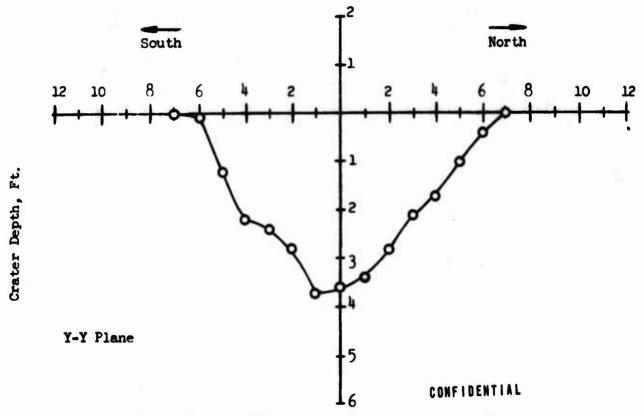
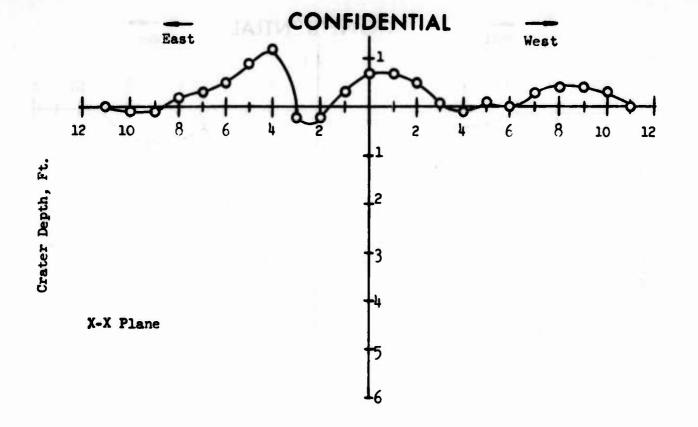
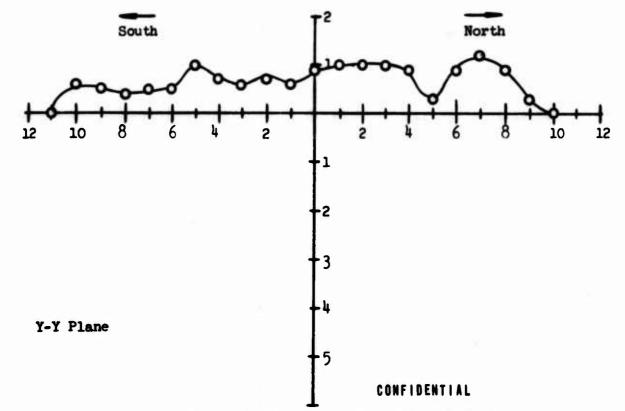


Figure 6 - Crater Profile - Sample: AeReCo 475, 2.

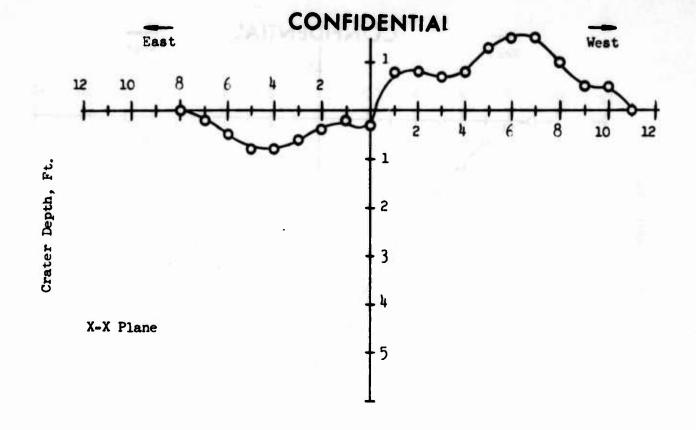




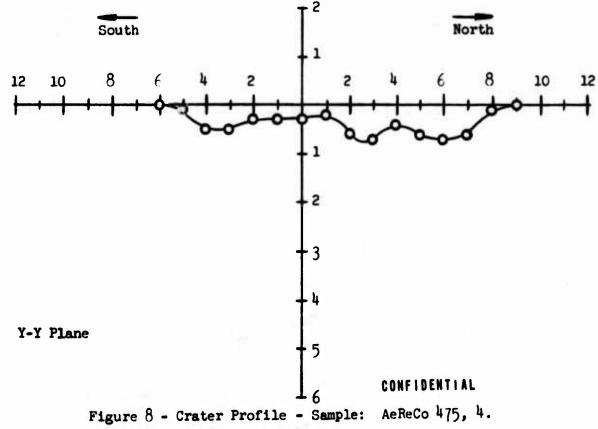


Crater Depth, Ft.

Figure 7 - Crater Profile - Sample: AeReCo 475, 3.



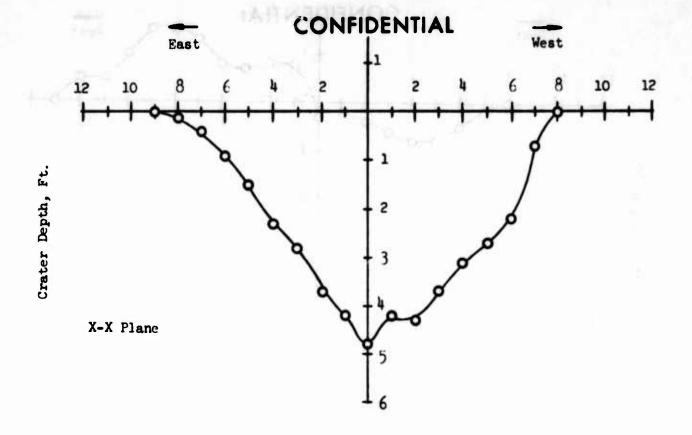
Crater Radius, Ft.



Crater Depth, Ft.

17

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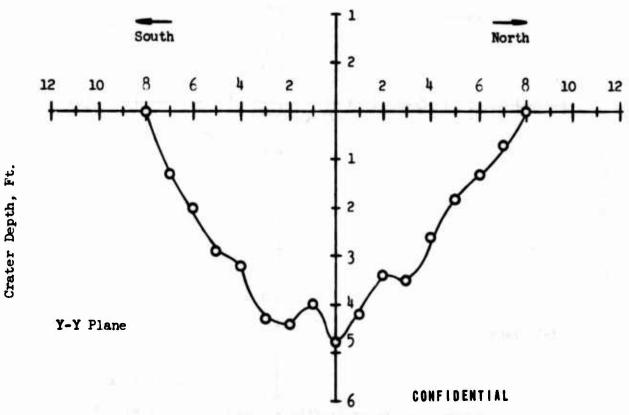
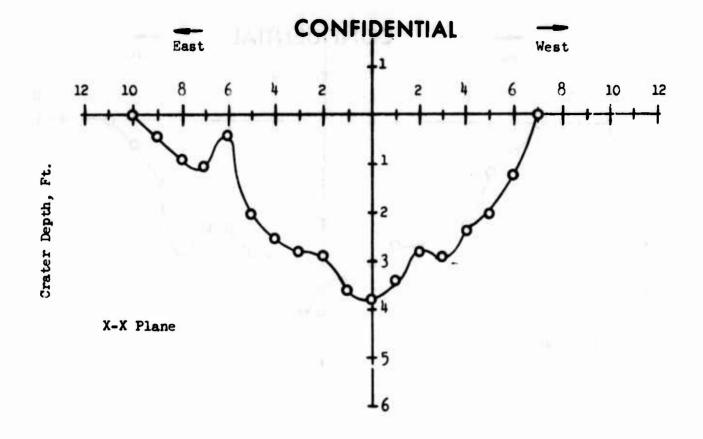
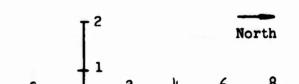


Figure 9 - Crater Profile - Sample: Tritonal, 1.





Crater Radius, Ft.

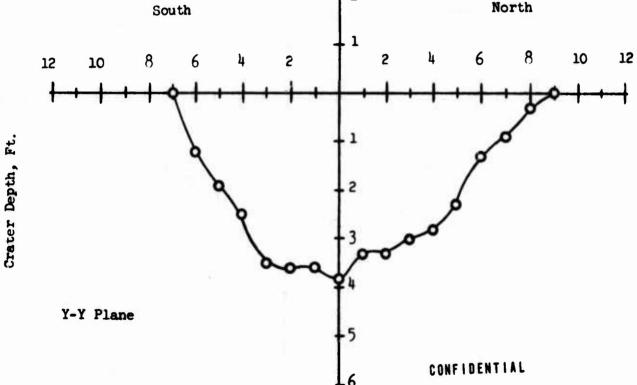
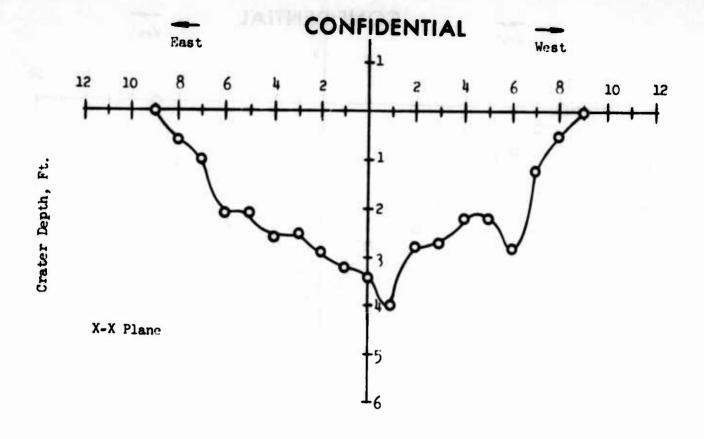
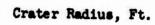
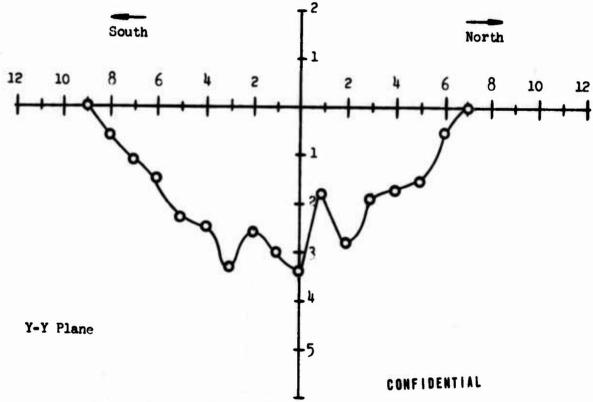


Figure 10 - Crater Profile - Sample: Tritonal, 2.



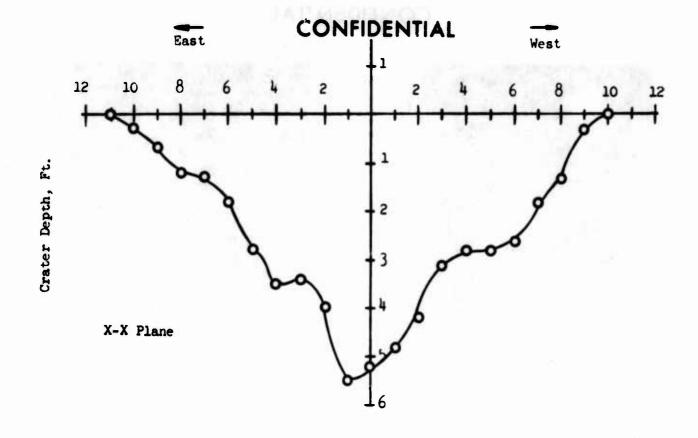




Crater Depth, Ft.

Figure 11 - Crater Profile - Sample: Tritonal, 3.

20





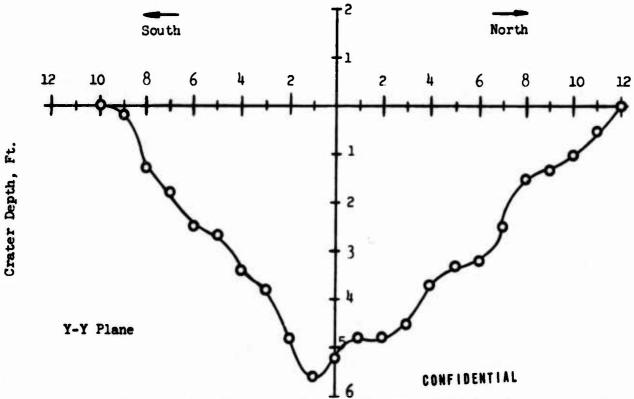


Figure 12 - Crater Profile - Sample: Tritonal, 4.

21



Figure 14 - Test Sample with Pentolite and Blasting Caps



Figure 16 - View of AeReCo 475, Sample 1 and Test Hole

Figure 15 - View of Tritonal Sample i and Test Hole



Figure 13 - Photograph of Test Area



22



Figure 18 - Blast Crater, Sample 2, AeReCo 459-23



rigure 20 - Blast Crater, Sample 4, AeReCo 459-23



Figure 17 - Blast Crater, Sample 1, AeReCo 459-23



Figure 19 - Blast Crater, Sample 3, AeReCo 459-23



Figure 22 - Blast Crater, Sample 2, AeReCo 475



Figure 24 - Blast Crater, Sample 4, AeReCo 475



Figure 21 - Blast Crater, Sample 1, AeReCo 475



Figure 23 - Blast Crater, Sample 3, AeReCo 475



Figure 26 - Blast Crater, Sample 2, Tritonal



Figure 28 - Blast Crater, Sample 14, Tritonal

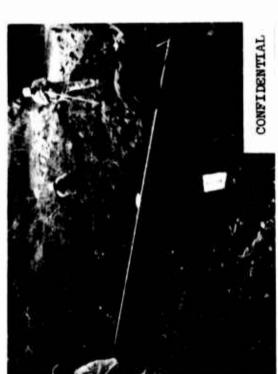


Figure 25 - Blast Crater, Sample 1, Tritonal



Figure 27 - Blast Crater, Sample 3, Tritonal

TABLE II. CRATERING TEST SAMPLE NUMBER 1, AeReCo 459-23

Data Sheet USAF F08635-68-C-0030 Cratering Tests
Test Sample No. 3 Date 6-29-68
Explosive Type AePeCo 459-23 Batch No. 17 Charge Wt., 1bs. 30 Charge Volume, in 593
Pentolite Detonator Size: 1" x 2" dia, No. Used 2 Total wt., gms 159,6 Cap Size No. 6 No. Used 2
Ground Conditions: Wet ( ) Dry ( ) Damp (x) Weather: Rain ( ) Sun (x) Cloudy ( ) Temp. F 92 R.H. 7 40
Hole Diameter, in. 93/4 Depth to C.G., ft. 6 Hole Depth to Loose Fill Cover, ft. 3.5
35 mm Photo: Before Explosion x After Explosion x Polaroid Photo: Before Explosion After Explosion x

Crater Diameter, X-X Plane	Dia	neter	X-X	r Plan	ne	21	21 ft.				5	Crater Diameter, Y-Y Plane	Diame	ter,	Y-Y 1	lane_	1	7	19 ft.			
Crater Depth, X-X Plane:	Dep	th, ×	-x P1	ane:					East	st	1		1	West	ŭ							
Radius, feet		10 9	6	8	7	9	5	4	3	2	1	0	1	2	3	4	5	9	7	80	6	10
	ft.	0	1	2	2	3	3	ħ	ħ	5	5	5	5	5	3	3	3	2	2	1	0	0
neptn:	fn.	in. 8.5 3	3	2	L	9	5	τ	9.5	0	7	6	6	0	6	8	3	3	0	6	8.5	0

ciatet Depen, 1-1 fiane.	, m.	1 1 - 1	14116					3	2000	•			}								
Radius, feet	10	6	8	7	9	5	7	3	2	1	0	1	2	3	4	5	9	7	8	6	10
barth. ft. 0 0	0	0	1	1	3	3	3	4	5	5	5	#	· †	3	3	2	2	2	0	0	၁
in.	0	5	5 3.5 11	11	1	6.5	30	5	9	8.5	6	11	11 3.5	8.5	٦	8	5.5	ħ	70	0	0
		1	,																4	1	

0

2

0

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Jepth: ft.

Remarks:

œ

10

Radius, feet

North

South

Crater Depth, Y-Y Plane:

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TABLE III. CRATERING TEST SAMPLE NUMBER 2, AeReCo 459-23

						ď	ata Si	leet 1	USAF	F0863	2-68-	c-003	O Crai	terin	Data Sheet USAF F08635-68-C-0030 Cratering Tests							
Test Sample No.	ıp le	8		2				Test	Sequ	Test Sequence No	₽		9		ă 	Date 7-1-68	1-1-1	88	1	ı		
Explosive Type AeReCo 459-23	ő E	ype	Ae Re(	Co 45	9-23		Batcl	Batch No		<u>ਵੇਂ</u> 	Charge Wt., 1bs	He., 11		20	Chai	Charge Volume, in	lume,	tn3	9	637	244	1
Pentolite Detonator Size: 1"	ë	etona	tor	Size			x 2" dia, No. Used 2	S	. Use	d 2	ř	otal 1	et.,81	ns 15	Total wt., gms 159,6 Cap Size No. 6	Jap Si	ze No	او	اً	No. Used	sed	7
Ground Conditions: Wet ( )	ond	ition	 9	Wet	<u> </u>	Dry	$\overline{C}$	Damp	(x)	Weath	er: R	) uim	S (	×) un	Dry ( ) Damp (x) Weather: Rain ( ) Sun (x) Cloudy ( ) Temp. F 84 R.H. 7 62	ybuc	-	emp.	8	<u> </u>	н. 2	8
Hole Diameter, in. 95/8	ime to	er, i	ļ	9.5	8	٦	Depth to C.G.,ft.	to C	.G., f		9		_ Hole	e Dep	Hole Depth to Loose Fill Cover, ft. 3.5	Loose	Fi11	Cove	r, ft		3.5	
35 mm Photo: Before Explosion	oto	 	fore	Exp	losio	×	_ Aft	er Ex	plosi	710	<u>۾</u> اي	laroi	d Phot	to:	After Explosion x Polaroid Photo: Before Explosion After Explosion	Exp]	osion		After	Exp	losior	×
Crater Measurements:	feas	ureme	nts:																			
Crater Diameter, X-X Plane	)iamk	eter,	X-X	Plar	, e			16 ft.			5	rater	Diame	eter,	Crater Diameter, Y-Y Plane	lane.	1	97	16 ft.			
Crater Depth, X-X Plane:	<b>e</b> ptl	h, x-	X P1	ane:					S	East	1		1	West	st							
Radius, feet	\ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \	10	6	8	7	9	5	4	3	2	-	0	1	2	3	4	5	9	7	8	6	10
Į.	r.	0	0	0	0	0	0	1	2	2	2	3	2	1	1	1	1	0	0	0	0	ပ
1 1	in.	0	0	0	5	01	11	οτ	1	9	8	5	1	०र	7.5	9	1	7	3	0	0	၁

CRATERING TEST SAMPLE NUMBER 3, AeReCo 459-23 TABLE IV.

Data Sheet USAF FO8635-68-C-0030 Cratering Tests

Test Sample No.	Explosive Type AeReCo 459-23	Pentolite Detonator Size: 1" x 2" dia. No. Used 2 Total wt., gms 159.6 Cap Size No. 6 No. Used 2	Ground Conditions: Wet ( ) Dry ( ) Damp (x) Weather: Rain ( ) Sun (x) Cloudy ( ) Temp. F 92 R.H. 7 40	Hole Diameter, in. $923/32$	35 mm Photo:	Crater Measurements:	Crater Diameter, X-X Plane	Crater Depth, X-X Plane:	Radius,
8	ype	etona	lition	er, t	 8	ureme	eter,	.h, x-	10
	AeRe	tor S		٩.	Before Explosion	nts:	X-X	X Pla	6
	30 45	fze:	et (	23/3	Explo		Plan	ne:	8
	9-23	=		2	ston				7
		x 2"	Dry (	اً	×		13		9
	Batch	dia.	-	epth	Afte		13 ft.		2
Test	<b>№</b>	ž Į	Jamp	to C	ir Ex				4
Sequ	2	, Use	(x)	Depth to C.G.,ft	losi			East	3
Test Sequence No.	Batch No. 2 Charge Wt., lbs. 30 Charge Volume, in 603	4 2	Weath		x After Explosion x			st	2
<u>و</u>	arge	<b>H</b>	er: R	7	<u>۾</u> ا		: 	ı	-
	Ht., 1	otal	ain (		laroi		rater		0
*	bs.	wt.,8	s (	_ Ho1	d Pho		Diam	1	-
	စ္က	ms 15	() un	e Dep	to:		eter,	¥.	2
اً	r Ga	9.6	()	th to	Befor		¥-Y	West	3
Date	rge V	Cap S	oudy	Loos	e Exp		Crater Diameter, Y-Y Plane		4
	olume	ize N	0	e Fil	10810				S
6-29-68	tm <sup>3</sup>	9	Temp.	Hole Depth to Loose Fill Cover, ft.	Polaroid Photo: Before Explosion After Explosion x		큐		9
8	8	٦	F 92	er, fi	After		14 ft.		_
	2	lo. U	~	إ	Exp		ĺ		8
		sed	H. 7	4.5	losior				6
		2	9		×				10

North	
South	
Y-Y Plane:	
rater Depth,	

9

	9 10	0	0
	80	0	0
	7	ဝ	0
	9	0	9
	2	0	11
	4	1	#
	3	1	10
	2	2	4
	1	2	į
	0	2	9
	-	1	3.5
	2	1	3
	3	0	7
I	4	0	70
	5	0	7
	9	0	3
	7	0	0
	00	0	0
	6	0	0
10		0	0
	Radius, feet	Depth: ft.	

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CRATERING TEST SAMPLE NUMBER 4, AeReCo 459-23 TABLE V.

Data Sheet USAF FO8635-68-C-0030 Cratering Tests

35 mm Photo: Before Explosion X After Explosion X Polaroid Photo: Before Explosion After Explosion X R.H.7 62 Pentolite Detonator Size: 1" x 2" dia, No. Used 2 Total wt., gms 159,6 Cap Size No. 6 No. Used 2 4.5 Hole Depth to Loose Fill Cover, ft.\_ 597 Ground Conditions: Wet ( ) Dry ( ) Damp (x) Weather: Rain ( ) Sun (x) Cloudy ( ) Temp. F 80 30 Charge Volume, in<sup>3</sup> Charge Wt., 1bs. Test Sequence No. Depth to C.G., ft. AeReCo 459-23 Batch No. 2 9 1/2 Hole Diameter, in. Test Sample No. Explosive Type

Crater Measurements:

Crater Diameter, Y-Y Plane 20 ft. Crater Diameter, X-X Plane

East

Crater Depth, X-X Plane:

10

Radius,

feet

West 0 0 N œ 1.5 5.5 7

0

Crater Depth, Y-Y Plane:

2 0

Depth:

North South

Radius feet	•	10	6	80	7	9	2	7	3	2	-	0	1	2	3	7	2	9	7	80	6	10
Depth:	ft.	0	0	7	2	3	3	4	. ₹	7	ħ	5	ħ	3	3	2	2	1	٦	0	0	0
	in.	0	4	5	1	1	3.5	0	5.5	7	10	2	1.5	10	3	6	3	6	2	9	0	0

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Remarks:

TABLE VI. CRATERING TEST SAMPLE NUMBER 1, AeReCo 475

Tests
Cratering
F08635-68-C-0030
USAF F
Sheet
ata

Test Sequence No. 7 Date 6-29-68	Batch No. 18 Charge Wt., lbs. 30 Charge Volume, in 688	Pentolite Detonator Size: 1" x 2" dia, No. Used 2 Total Wt., gms 159,6 Cap Size No. 6 No. Used 2	Dry ( ) Damp (x) Weather: Rain ( ) Sun (x) Gloudy ( ) Temp. F 82 R.H. 7 62	Depth to C.G., ft. 6 Hole Depth to Loose Fill Cover, ft. 3.5	x After Explosion x Polaroid Photo: Before Explosion x After Explosion x	
1	lbs. 30 ch	wt.,gms 159,6	) Sun (x) C	_ Hole Depth t	id Photo: Befo	
ence No.	Charge Wt., ]	1 2 Total	Weather: Rain (	t. 6	on x Polaro	
Test Seque	atch No. 18	ia. No. Used	) Damp (x)	pth to C.G., fl	After Explosio	
1	AeReco 475 B	ze: 1" x 2" d		3 5/8 De		
ole No.	Explosive Type AeReC	e Detonator Si	Ground Conditions: Wet (	dole Diameter, in.	35 mm Photo: Before Explosion	
Test Sample No.	Explosiv	Pentolit	Fround C	dole Dian	35 mm Ph	

Crater Diameter, X-X Plane	meter	× .	r Pla	ا و		13 ft.	اند			5	rater	Crater Diameter, Y-Y Piane	ter,	Y-Y	P1 ane		15	15 ft.			
Crater Depth, X-X Plane:	th, 3	-X P	lane:					East	st	ı		4	West	ñ							
Radius, feet	10	9	8	7	9	2	7	3	2	1	0	1	2	3	7	5	9	7	80	6	10
ft.	0	0	၁	၀	0	0	1	1	1	2	2	2	2	2	1	-	0	0	0	0	٥
tn.	0	0	ပ	0	0	οτ	1	7	10	0	1	6.5	10	9	11.5	3.5	9	0	0	0	0

Plane:
Y-Y 1
Depth,
ter

Radius, feet	10	6	8	7	9	5	4	3	2	-	0	1	2	3	4	5	9	7	8	6	2
Denth. ft. 0		၁	0	ပ	1	1	1	1	1	2	2	2	1	1	н	1	0	၁	o	0	0
in.	0	0	0	9	2	7	ڼ	<b>∞</b>	77	0	-	٦	6	5	~	77	2	0	0	0	0

CRATERING TEST SAMPLE NUMBER 2, AeReCo 475 TABLE VII.

Toote
Oretorian
0.000
9725700
TICAP T
Choot
Do to

Test Sample No.	Explosive Type	Pentolite Detonator Size: 1" x	Ground Conditions:	Hole Diameter, in. 9 5/16	35 mm Photo: Before Explosion_	Crater Measurements:	Crater Diameter, X-X Plane	Crater Depth, X-X Plane:	Radius, 10 9	ft. 0 0	o o lui
2	AeRe	or Siz		6	ore Ex	ts:	X-X P1	Plane	8	0	0
	AeReCo 475	e: 1" x	Wet ( ) Dry ( ) Damp (x) Weather: Rain ( ) Sun (x) Cloudy ( ) Temp. F 86 R.H. 7 62	5/16	plosion		ane	**	1 2	0	3.5
	Batc	2" dia. No. Used 2	( ) &	_ Depth			17 ft.		5 5	0 1	3 0
Test	Batch No. 2	S.	Damp	Depth to C.G., ft	After Explosion_				4	2	2
Seque	2	, Used	(x)	, G. , ft	plosic			East	3	2	1
Test Sequence No	Char	1	leather		×			Ħ	2	3	0
	ge Wt.	Tota	: Rain	9	Polar		_ Crat	1	1 0	3 3	9
7	Charge Wt., 1bs. 30	1 wt. ,	3 0 0	.e	oid Pho		er Dia	1	1	3	5
	30	gms 159	Sum (x	le Depi	oto:		meter,	West	2	3	0
Date	_ Charge	Total wt., gms 159,6 Cap Size No. 6	:) Cloud	Hole Depth to Loose Fill Cover, ft.	Polaroid Photo: Before Explosion		Crater Diameter, Y-Y Plane	st	3 4	2	8
	Volume	Size	( ) A	ose Fi	xplosic		ine		5	0	10 2.5
7-1-68	Charge Volume, in 671	9	Temp.	11 Cove	nc l				9	0	1
83	119	1	F 86	r, ft.	After		14 ft.		7	0	8
		No. Used_	R.H.?	3.5	After Explosion x				6 8	0	0 9
	1	2	62		x no				10	0	0
					1		- 1			_	-

South Crater Depth, Y-Y Plane:

North

TABLE VIII. CRATERING TEST SAMPLE NUMBER 3, AeReCo 475

Tests
F08635-68-C-0030 Cratering
3-C-0030
F08635-68
USAF
Sheet
Data

Test Sample No.		3				Test	Sequ	Test Sequence No	Š	8		1	Ĕ	Pate		7-1-68	89	-		П
Explosive Type_		Ae Re Co 475	475		Batcl	h No.	m	Batch No. 3 Charge Wt., 1bs. 30	rge 1	Æ., 11	S.		Chai	rge V	olume	in <sup>3</sup>	Charge Volume, in <sup>3</sup> 683		į	
Deto	Pentolite Detonator Size: 1" x	Size		x 2"	dia.	, No.	. Use	2" dia. No. Used 2 Total wt., gms 159,6 Cap Size No. 6	Ĕ	stal v	t.,gm	ls 155	9.6	Cap S.	ize N	9		Vo. U	No. Used 2	2
nditi	:suo	Wet	0	Dry	· ( )	Damp	(×)	Ground Conditions: Wet ( ) Dry ( ) Damp (x) Weather: Rain ( ) Sun (x) Cloudy ( ) Temp.°F 84	r: R	in (	Su	x) H	) C1	ondy	0	Temp.	£ .		R.H. % 62	29
Hole Diameter, in.	fn.	9 5/8	8		Depth to C.G.,ft	to C,	.G., f				_ Hole	Dept	th to	Loos	e Fil	1 Cove	Hole Depth to Loose Fill Cover, ft		4.5	
35 mm Photo:	Before Explosion	e Exp	losio		_ Aft	After Explosion X	plosi	x uo	Po	laroid	Polaroid Photo: Before Explosion	.0:	3e for	e Exp	losio	_	After	Exp	After Explosion x	×
Crater Measurements:	ments	••.																		
Crater Diameter, X-X Plane	r, X-	X Pla	ا		22	22 ft.			5 	rater	Crater Diameter, Y-Y Plane	ter,	Y-Y	Plane			22 ft.	.;		
Crater Depth, X-X Plane: (See Remarks)	X-X	lane:	(See	Кета	rks)		E	East	1		1	West	ĭť							
10	6	8	7	9	5	4	3	2	-	0	1	2	3	7	5	9	_	80	6	101
2	2	1	1	1	1	0	2	2	1	1	1	1	1	2	2	2	1	7	п	п
in. 2	2	11	10	7	2	π	3	2.5	6	5	4.5	7	11.9 1.5	1.5	0	1	91	7.5	ထ	6

Reference X-X Plane raised 2' 1" and Y-Y Plane 2' 23" due to formation of mound instead of crater. Remarks:

ន

10 10.5

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Depth:

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2.5

11.5 5

North

South

Crater Depth, Y-Y Plane:

10

Radius,

eet

0

CRATERING TEST SAMPLE NUMBER 4, AeReCo 475 TABLE IX.

# Data Sheet USAF FO8635-68-C-0030 Cratering Tests

Test Sample No.	e No		<b>4</b>				Test	Sequ	Test Sequence No	Se		2		යි 	Date		6-2	6-29-68			
Explosive Type AeReCo 475	Type	Aei	ReCo	475		Batc	h No.	#	Batch No. 4 Charge Wt., 1bs. 30	arge	Ht., 1b	š.	1	Char	Se Vo	lume,	Charge Volume, in <sup>3</sup> 663	99	E		ı
Pentolite Detonator Size: 1" x 2" dia, No. Used 2	Deto	nator	Size	4	× 2"	dia.	울 	. Use	2 p	E	otal v	Total wt., gms 159,6 Cap Size No. 6	ıs 159	9	Jap Si	ze Nc	9	<b>z</b>	No. Used	ed	7
Ground Conditions:	diti	: suo	Wet ( )	<b>C</b>	Dry	<u></u>	Damp	(x)	Dry ( ) Damp (x) Weather: Rain ( ) Sun (x) Cloudy ( ) Temp.° F 92 R.H.7 40	er: R	ain (	) Su	m (x	) CIc	) dpnc	( )	remp.°	F 92	<b>~</b>	7 H	읓
Hole Diameter, in. 9 11/16	ter,	in.	9.1	7/16		Depth to C.G.,ft	to	.G., f	ا	7		_ Hole	Hole Depth to Loose Fill Cover, ft. 4.5	h to	Loose	Fi1]	l Cove	r, ft	]	5	
35 mm Photo: Before Explosion	:	Befor	e Exp	losio	Ę	_ Aft	er Ex	plosi	After Explosion x	<u>۾</u>	laroid	Polaroid Photo: Before Explosion	ea : 0	efore	Exp]	losior		After	Exp	After Explosion x	×
Crater Measurements	Sure	ments	••.																		
Crater Diameter, X-X Plane_	ime te	r, X-	X Pla	ine		19 ft.	ان			: 	rater	Crater Diameter, Y-Y Plane_	ter,	Y-Y	lane.		15 ft.	ŗ.		1	- }
Crater Depth, X-X Plane:	th,	X-X	lane:					2	East	I		4	West	ñ							
Radius, Seet	10	6	8	7	9	5	7	3	2		0	-	2	3	4	5	9	7	80	6	10
ft.	0	0	0	0	0	C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
e in dead	c	c	C	c	7	0	2	7	u	1 7E	37 C 37 L	10	3.0	α	5	7.	٥٠	ď	1.5	,	1

œ 10 Radius,

91-

North

South

Crater Depth, Y-Y Plane:

20

Remarks: Minus dimension for X-X Plane indicates formation of mound above original ground level. 6.5 6.5 7.75 0 0 2 4 0  $\infty$ 0 0 0 2.75 0 0 2.5 0 0 0 0 0 0 0 0 0 0 0 0 Depth: feet

0

TABLE X. CRATERING TEST SAMPLE NUMBER 1, TRITONAL

		Used 2	R. H. Z. 40	3.5	After Explosion x Polaroid Photo: Before Explosion x After Explosion x				9 10	0 0	0
	191	No.	2	<u>بر</u> ا	er Ex				8	0	Ó
89	- 1		F.	rer, 1	Afte		16 ft.		7	0	8
6-29-68	# #3	9	Temp.	.1 Cov	×		97		9	2	1.5
	olume	ize N	$\hat{\ }$	e Fil	losio				5	2	8
Date	Charge Wt., 1bs. 31.9 Charge Volume, ix3	Cap S	ondy	Hole Depth to Loose Fill Cover, ft	е Ехр		Crater Diameter, Y-Y Plane		4	3	8 0.75 8
	G G	9.6	t) C1	th to	Befor		Y-Y	st	3	3	8
	677	ms 15	() m	e Dep	to:		eter,	West	2	4	3.5
	Sq.	wt.,8	S	- H61	d Pho		Diam	1	1	7	2
	He., 1	otal .	) ute		laroi		rater		0	17	
١	arge	£i	er: R	9	<u>۾</u>		5	1	1	ħ	1.75
Test Sequence No	<u>ਝੌ</u> 	2	leath	ı	×			Ť	2	3	8
Seque	•	Usec	(x)	G., ft	losic			East	3	2	6
Test	Batch No	Š.	Jamp	Depth to C.G., ft	er Exq				4	2	2.75 9 8 1.75 9
	Batch	dia,	-	epth			17 ft.		5	1	9
		x 2"	Dry (	٦	×				9	0	
		티	<u></u>	4	Before Explosion		<u>و</u>		7	0	5.25 10.75
-	tonal	Size	Wet.		Exp]		Plar	lane:	8	0	1
	H	ator	ns:	in.	efore	ents	χ-,	(-X P)	6	0	0
e No.	Type_	Deton	ditio	ter,		suren	meter	ch, X	10	0	0
Test Sample No	Explosive Type Tritonal	Pentolite Detonator Size: 1" x 2" dia, No. Used 2 Total wt., gms 159,6 Cap Size No. 6 No. Used	Ground Conditions: Wet ( ) Dry ( ) Damp (x) Weather: Rain ( ) Sun (x) Cloudy ( ) Temp. F 92 R.H.7 40	Hole Diameter, in	35 mm Photo:	Crater Measurements:	Crater Diameter, X-X Plane	Crater Depth, X-X Plane:	Radius, feet	ft.	in.

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Hole size larger than specified.

South

Crater Depth, Y-Y Plane:

0

Depth:

10

Radius, feet

TABLE XI. CRATERING TEST SAMPLE NUMBER 2. TRITONAL

Grater Diameter, X-X Plane	Crater Depth, X-X Plane:	Radius, 10 9 8	ft. 0 0 C	in. 0 5 11
Plane	ie:	8	0	1
		7	1	0
		9	0	5
17 ft.		5	2	0 5.5
		4	2	5.5
	East	3	2	6
	ر با	2	2	11
5 		1	3	11 6.5 9.5
Crater Diameter, Y-Y Plane		0	3	9.5
Diame		1	3	5
ter,	West	2	2	6
Y-Y	ñ	3	2	п
lane		4	2	5
		5	2	0
		9	1	2
16 ft.		7	0	0
نے		ક	0	0
		6	0	0
		7	0	0

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Crater Depth, Y-7 Plane:	Deptl	h, Y.	-7 P	ane:					So	South	1		1	North	rth							
Radius, feet		01	10 9	8	7	9	5	4	3	2	1	0	1	2	3	4	5	9	7	8	6	10
Depth: ft. 0 0 0	ft.	0	0	0	0	1	1	2	3	3	3	3	3	3	3	2	2	1	0	0	0	0
	in.	0	0	in. 0 0 0	0	2	π	9	9	7	7	5.6	3	3	0	6	4	3	11	3.5	0	0
Remarks																						

TABLE XII. CRATERING TEST SAMPLE NUMBER 3, TRITONAL

Tests
Cratering
3-C-0030
F08635-68
USAF
Sheet
Data

Test Sample No.	e No.						Test	Sequ	Test Sequence No.	ا		3		<b>8</b>	Date		7-1-68	8			Ì
Explosive Type	Type		Tritonal	Tag 1		Batch	Batch No.	1	- Charge Wt., lbs. 30.9 Charge Volume, in <sup>3</sup>	arge 1	W., 1b	š.	6.9	Char	ge Vo	lume,	fn3	191	22		ı
Pentolite Detonator Size: 1" x	Detor	ator	Size		x 2"	dia.	Š	Use	d 2	ë	stal v	rt.,gm	s 159	9	ap Si	ze No	۰	2" dia, No. Used 2 Total wt., gms 159,6 Cap Size No. 6 No. Used 2	. Use	9	~
Ground Conditions: Wet ( )	ditic	: suc	Wet	0	Dry	-	) dump	(x)	Weath	er: R	) uje	os (	x) u	) C1º	udy (	1	emp.	Dry ( ) Damp (x) Weather: Rain ( ) Sun (x) Cloudy ( ) Temp. F 79 R.H. % 62		1.7.6	,2
Hole Diameter, in. 9 11/16	ter,	ā.	9.1	1/16		Depth	to C.	,G., fi	Depth to C.G.,ft	H		. Hole	Dept	h to	Loose	Fi11	Cove	Hole Depth to Loose Fill Cover, ft	4.5	2	
35 mm Photo: Before Explosion	.0:	Be for	e Exp	losio		_ Afte	er Ex	losi	× uo	S S	laroid	l Phot	0: B	efore	Expl	OS 10n	Ì	After Explosion x Polaroid Photo: Before Explosion x	Explo	sion	×
Crater Measurements:	sure	nents	••																		
Crater Diameter, X-X Plane	une te 1	r, x-	X Plan	a		83	18 ft.			5 	rater	Crater Diameter, Y-Y Plane	ter,	Y-Y	lane	ı	16 ft.	اند			
Crater Depth, X-X Plane:	th, 1	K-X P	lane:					East	st	T		1	West	ų.							
Radius, feet	10	6	80	7	9	5	4	3	2	-	0	-	2	3	4	5	9	7	8	6	101
Penth. ft.	٥	0	0	1	2	2	2	2	2	3	3	#	2	2	2	2	2	1	0	0	0
in.	0	0	7	0	7	1	6.5	9	11	2	5	0	9	7.5 1.5		2	6	2	9	0	0
																ł	l			1	l

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10 10.5

South

Crater Depth, Y-Y Plane:

5 o

Radius, feet 0

Remarks:

36

TABLE XIII. CRATERING TEST SAMPLE NUMBER 4, TRITONAL

Data Sheet USAF F08635-68-C-0030 Cratering Tests

			2		×				01	0	0
		ed 2	( ) Damp ( ) Weather: Rain ( ) Sun ( x ) Cloudy ( ) Temp. F 85 R.H. 7 62	4.5	Polaroid Photo: Before Expl sion X After Explosion X				6	0	2.5
		No. Used	<b>4</b>		Exp1				8	1	3
7-1-68	191		8	Hole Depth to Loose Fill Cover, ft.	After		22 ft.		7	7	6
7-	Charge Wt., lbs. 30.8 Charge Volume, in 3	No. Used 2 Tatal wt., gms 159,6 Cap Size No. 6	Гешр.	l Cove	×		2		9	2	7
	olume	ize M	0	e Fil]	l'sior				S	2	10
Date	rge V	Cap S	ondy	Loos	e Exp		Crater Diameter, Y-Y Plane		4	2	10
	G Ba	9.6	x ) C1	th to	Befor		Y-Y	West	3	3	1
	30.8	ms 15	C)	e Dep	to:		eter,	*	2	<b>†</b>	2
2	bs.	wt.,g	S	Hol	d Pho		Diam	ı	1	7	8.5
	Wt.,1	btal	ain (		laroi		rater		0	5	2
왕	arge		er: B	7	1		ا			5	9
Test Sequence No	ਰ 	2 p	Weath	إ	After Explosion X			East	2	4	0
Sequ	-	. Use	0	.G., f	plosi		1	2	3	3	5
Test	Batch No.	1	Damp	Depth to C.G.,ft	er Ex				7	3	9
	Bate	2" dia,	0	Depth	_ Aft		21 ft.		2	2	6
		"x 2"	Wet (x) Dry (		×		2		9	7	8.5
4	4	Pentolite Detonator Size: 1" x	(x)	716	35 mm Photo: Before Explosion		ine		7	7	4
	Explosive Type Tritonal	Size	We t	Hole Diameter, in. 9 9/16	e Exp	::.	Crater Diameter, X-X Plane	Crater Depth, X-X Plane:	8	1	2
	Ę.	nator	:suo	ţ.	Befor	Crater Measurements:	r, x-	X-X	6	0	တ
Test Sample No	Type	Deto	Ground Conditions:	eter,	; ;	sure	ame te	pth,	10	0	#
Samp ]	sive	lite	d Cor	Diame	Pho	r Me	r Dia	r De	s,	ft.	in.
est	xp10.	ento	ronn	ole	5 mm	rate	rate	rate	Radius, feet	Penth.	ا ا ا
[=4		ρ.	G	Æ	m	3		S	(OK 44)		
			C	~ ^				) IT		•	
			C	Jľ	41	IL		I	IA	L	

Crater Depth, Y-Y Plane:

North

South

10	7	0
6	1	~
8	1	9
7	2	9
9	3	2
2	3	3.5
4	3	8
3	ħ	9
2	4	9.5
	<b>7</b>	9.5
0	5	2
1	5	7
2	<b>†</b>	8.5
3	3	10
4	3	4.5
5	2	7.5
9	2	9
7	1	97
8	1	3
6	0	2
10	0	0
Radius, feet	Depth: ft.	in.

Remarks:

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#### SECTION VII

#### PROCESSING AND LOADING

- (C) The ingredients of the explosive were mixed in a vertical mixer with a single bladed planetary mixing arm and heated bowl (180 - 200°F.) Immediately after mixing the mixture was evacuated to remove entrapped gases. The resulting slurry-like mixture did not pour freely but had adequate fluidity to conform to the contour of the vessel into which it was poured. The AeReCo 459-23 was noticeably more viscous than the AeReCo 475. Precaution is required in processing the ingredients to assure that they are well dried and that the cast mixture is moisture free as the urethane reacts with moisture to form carbon dioxide that can cause porosity. Air which contacts the mixture during and after casting must contain less than approximately 40 grains of moisture per pound of dry air. Also, surfaces and subsurfaces of vessels into which the explosive is cast must be moisture free. The mixture begins to set in approximately twenty minutes after mixing and cures hard at 200°F in approximately sixteen hours. Three to ten days are required for curing at ambient temperatures. Eight BLU-31 bombs were loaded under the contract cited in the foreword and samples were cast in cylinders for crater testing. In all formulations MIL A 512-A, Type III, grade F, class 7 aluminum powder and type B, class A RDX were used.
- (C) The BLU-31 cases which are more than 6 feet long and 1 foot in diameter presented a filling problem in that there was no access for consolidating the cast mixture by hand making it necessary to depend on its fluidity and gravity. Four of the bomb cases were coated with binder which was allowed to cure before filling with explosive and four were uncoated. There were four filled with AeReCo 475 (two each coated) and four with AeReCo 459-23 (two each coated). In order to evaluate pouring and consolidation prior to filling the bomb cases, mixtures using salt as a substitute for RDX were made and poured into a 6 inch diameter methacrylate tube to simulate pouring conditions. The bomb case has a threaded fuse well in the loading port (also threaded) which necessitated making a special loading fixture with a center hub to hold the fuse well in place and to pour around it. It was found in loading the test mixture that vacuum pouring was necessary. Therefore, the loading fixture was modified to provide continuous evacuation during pouring. The filled bombs were kept at 180°F to 200°F during and after filling to assure adequate fluidity to consolidate the explosive and to speed curing. After filling the bombs, the explosive was capped with neat binder. The quantity of binder required to cap the AeReCo 459-23 filled bombs as well as visual inspection indicated that the explosive in curing had shrunk away from the walls near the filling This did not appear to occur with the AeReCo 475. Evacuation of the filled bomb and filling with binder the space left by shrinkage may be superior to precoating with binder. X-Ray photographs of the bombs indicate that lengthwise shrinkage of AeReCo 459-23 occurred which probably caused the Pulling away from the inside of the cone shaped nose. The parting lines made by filling with successive batches were discernable on the X-Ray photographs along with some voids in the AeReCo 459-23.

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- (C) Where the opening is unobstructed, it is possible to load easily without evacuating. The primary precaution required in loading the cardboard cylinders was that they be coated on the inside with the binder before filling to prevent moisture in the paper from penetrating the mixture after casting. In thin layers, carbon dioxide that forms, escapes the surface without detriment thus allowing coating without difficulty.
- (U) Based upon the experience in processing and loading to date, this appears to be the area with the greatest number of unknowns. There is little question that the explosive can be produced by batch process. However, there is good reason to believe that a continuous mixing process will be far more economical and safer. The cost could thus be well below \$1.00 per pound as the present market price of the ingredients is approximately \$0.53 per pound.

#### SECTION VIII

#### DISCUSSION AND RECOMMENDATIONS

- (C) The results of the AeReCo explosives evaluation show that in all of the tests performed it is stable under extremes of environment, high impact, and burning. The aluminized version, AeReCo 459-23 equals tritonal in the cratering tests performed. The following are its most significant features:
  - 1. It will withstand  $350^{\circ}$ F for at least one hour in air at 14.7 psia and  $300^{\circ}$ F for eight hours.
  - 2. It has excellent storability and is not affected by moisture at any climatic temperature.
  - 3. It equals tritonal in cratering capability in the tests performed. Additional tests are recommended.
  - 4. It has promise of being economical to process (average cost of ingredients is approximately 53 cents per pound.)
  - 5. Processing and loading techniques should be improved and it is recommended that a continuous mixing process be evaluated.

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#### APPENDIX I

THERMAL STABILITY OF AeReCo 459-23

J. M. Pakulak, Jr.

U.S. Naval Ordnance Test Station

China Lake, California 93555

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U. S. NAVAL ORDNANCE TEST STATION CHINA LAKE, CALIFORNIA 93555

4532/JMP:mve Reg. 4532-20 27 March 1967

#### MEMORANDUM CONFIDENTIAL

From: J. M. Pakulak, Jr., Thermal Analysis Branch (Code 4532)

To: Head, Explosives Research Branch (Code 4541)

Via: Head, Thermal Analysis Branch (Code 4532)

Subj: Thermal Stability of AeReCo-459-23 Explosive (U) RDX 59 /A1 23 / Binder 18

Ref: (a) Memo 4532/JMP:mve Reg 4532-18 of 2 Mar 1967 (CONFIDENTIAL)

Encl: (1) Table 1. Thermal Stability of AeReCo-459-23 Explosive (CONFIDENTIAL)

(2) Fig. Nos. 1 through 6. DTA Thermal Patterns of AeReCo-459-23 Explosive (CONFIDENTIAL)

(3) Fig. No. 7. Plot of DTA Data for AeReCo-459-23 Explosive (CONFIDENTIAL) (4) Fig. Nos. 8 through 16. Deflagration Times at Selected Temperatures

(4) Fig. Nos. 8 through 16. Deflagration Times at Selected Temperatures for AeReCo-459-23 Explosive in Al Tube Ovens (CONFIDENTIAL)

(5) Fig. No. 17. Plot of Deflagration Time Versus Oven Temperature for AeReCo-459-23 and H-6 Explosives (CONFIDENTIAL)

1. This is a progress report on samples of AeReCo-459-23 explosive received from Code 4541 for thermal analysis. Each sample was 3.375 inches in diameter and about 2 inches long. The method of thermal analysis is covered in reference (a). For this report, no thermogravimetric analysis was performed nor isothermal tests on the 3.375-inch diameter samples in air-type ovens. Three isothermal tests were performed on 2-inch cubes in air-type ovens and the data given in enclosure (1).

2. A summary of the DTA data on AeReCo-459-23 explosive is given in enclosure (1). The thermal patterns are shown in enclosure (2). The thermal patterns showed one exothermic peak in the temperature range of 204-223°C for heating rates of 1 to 5°C per minute. A shallow endotherm occurs about when the exotherm starts and continues until about a quarter way or less through exotherm. This endothermic action is believed to be caused by the melting of the RDX present in the explosive. The activation energy was determined by the variable heating rate method and had a value of 37.8 kcal per mole (enclosure (3)). The log frequency factor was 14,432. This is a lower value for the activation energy than normally expected for the decomposition of RDX. The critical temperature was predicted from the DTA data using equation (3) of reference (a). Other data used were:

S = 2.00

 $\rho = 1.7g \text{ per cm}^3 \text{ (estimated)}$ 

a = 4.29 cm (3.375 in. dia.)

R = 1.987 cal per mole - K

 $\lambda = 0.00055$  cal per cm-sec-OC (see test)

c = 0.3 cal per gram (estimated)

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4532/JMP:mve Reg. 4532-20 27 March 1967

Subj: Thermal Stability of AeReCo-459-23 Explosive (U)

The value for  $\lambda$  was derived from the thermal diffusivity ( $\alpha$ ) measured from the explosive grains in the aluminum tube ovens using equation (7) in reference (a). The values of  $\alpha$  determined at different temperatures and tests are given in enclosure (1) and an average value was 0.00108 cm<sup>2</sup> per sec. This data yielded a value of 130°C for the predicted critical temperature of a 3.375-inch in diameter grain.

- 3. Twelve samples of AeReCo-459-23 explosive were tested in an aluminum sleevetype oven. The samples were 3.375 inches in diameter and about 2 inches long. Two samples were used in each isothermal test so that the overall length was about four inches. Thermocouples were placed at the center between the samples, at the surface and in the aluminum sleeve reached the selected temperature. The six selected temperatures were 146.1, 153.9, 162.8, 164.4, 173.9 and 177.2°C and the time-to-deflagration after the aluminum sleeve had come up to temperature were 7.7, 4.3, 2.5, 2.5, 1.2 and 1.35 hours respectively. The individual deflagration tests are shown in enclosure (4) and the data given in enclosure (1). A plot of log time versus oven temperature is shown in enclosure (5) and is used in calculating the experimental critical temperature. In calculating the critical temperature, equations (5) and (6) were used from reference (a). The value of the activation energy for equation (6) was taken from the DTA study. The experimental value of  $\alpha$  was used to calculate the reduced time in equation (5). The experimental critical temperature so determined was 145°C. This is about 15 higher than that predicted by the DTA data on AeReCo-459-23 explosive. The second DTA exotherm from the H-6 explosive predicted a critical temperature of 154°C for this sample diameter which is 9°C higher than the experimental value. The second DTA exotherm in the H-6 explosive is believed to be caused by the decomposition of the RDX present. Although the H-6 explosive has a higher experimental critical temperature for a given size than the AeReCo-459-23 explosive, the actual time-to-deflagration was longer at the higher temperature (170°C region) for AeReCo-459-23 than the H-6 explosive. This may be explained by the fact that the H-6 explosive is in a liquid state during the time of the deflagration study whereas the AeReCo-459-23 explosive is not and that the AeReCo-459-23 explosive has a lower activation energy value. This fact is shown in enclosure (5) where H-6 deflagration data from reference (a) is included for a comparison with the AeReCo-459-23 deflagration data.
- 4. The AeReCo-459-23 explosive just barely passed the one hour test at 177°C (350°F) whereas the H-6 explosive did not. The reasons for the differences in thermal stability is mentioned above and shown in enclosure (5). The next series of scheduled tests are for the Tritonal explosive followed by tests for RDX only.

JACK M. PAKULAK, JR.

Copy to: 4504 453 4541 (Falterman, Stanton, Stott) 5052 (Ayres)

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#### TABLE 1. THERMAL STABILITY OF AeReCo-459-23 EXPLOSIVE

#### (A) DTA Data

Test No.	°C/Min.	Exo. Peak	Wt.
5-22-6	1.03	204.4	19.5
5-13-5	1.04	202.8	33.7
5-23-1	2.06	212.2	21.4
5-23-3	3.27	217.8	20.0
5-23-5	4.1i	221.1	19.2
5-26-1	5.17	223.3	22.8

## (B) Chemical and Physical Data

Density = 1.7g per cm<sup>3</sup> (estimated)

Heat of Reaction = 300 cal per g (estimated)

Shape factor = 2.00

Gas constant = 1.987 cal per mole-OK

Thermal conductivity = 0.0005 cal per cm-sec-°C

#### (C) Predicted Critical Temperature (DTA)

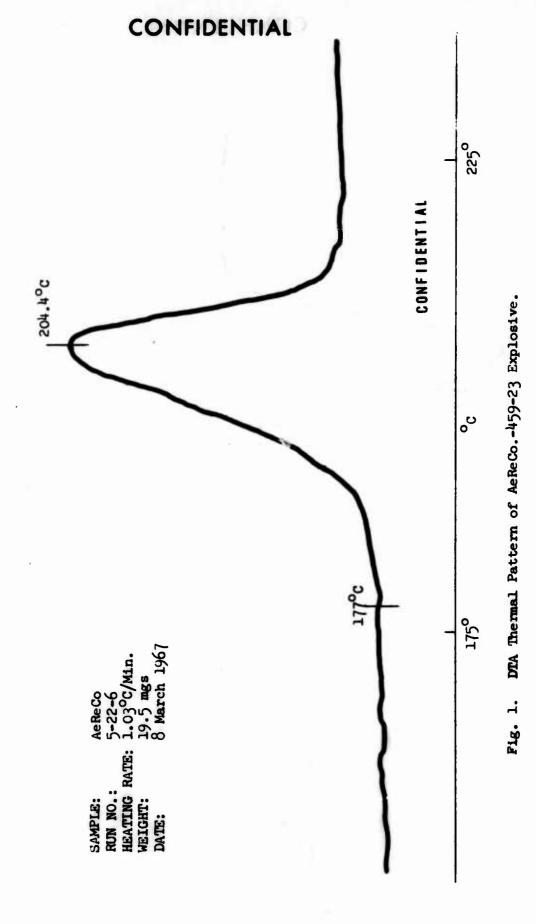
Size (inches)	Temperature OC
1	153
2 5	140 123

#### (D) Deflagration Data

Diameter (inches)	Temperature (°C)	Time-to-Deflagration at temp. (hours)	Oven Type
2-in. cube	120	23*	Air
2-in. cube	151	9.5	Air
2-in. cube	175	2.1	Air
3-375	146.1	7.7	Aluminum
3.375	153.9	4.3	Aluminum
3.375	162.8	2.5	Aluminum
3.375	164.4	2.5	Aluminum
3.375	173.9	1.2	Aluminum
3.375	177.2	1.35 CONFIDENTIA	Aluminum

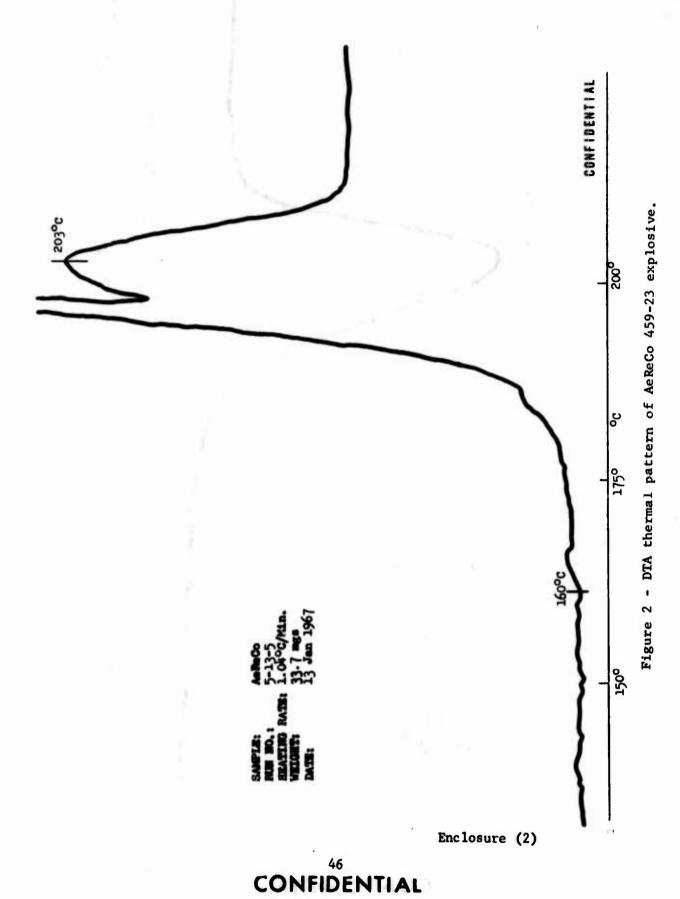
<sup>\*</sup>No deflagration occurred in 23 hours after which the temperature was raised to about 204°C to terminate the test.

Enclosure (1)



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Enclosure (2)



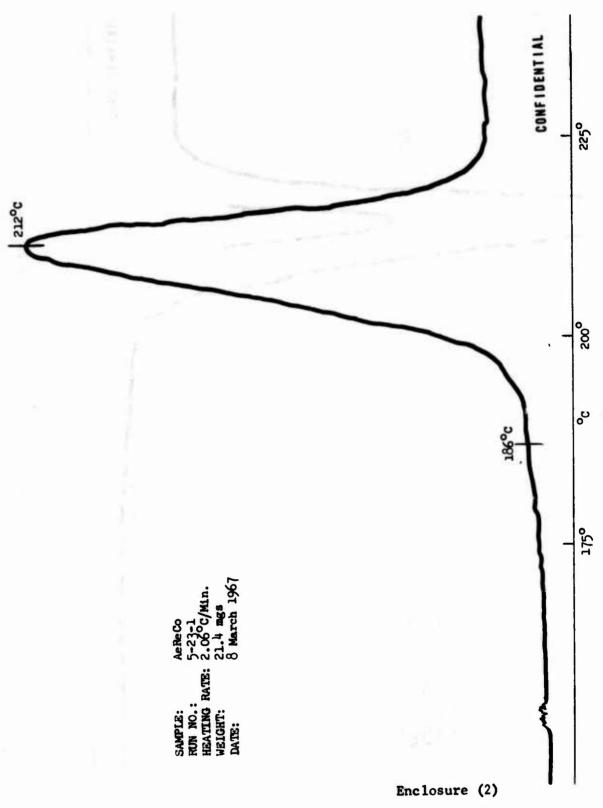


Figure 3 - DTA thermal patterns of AeReCo 459-23 explosive.

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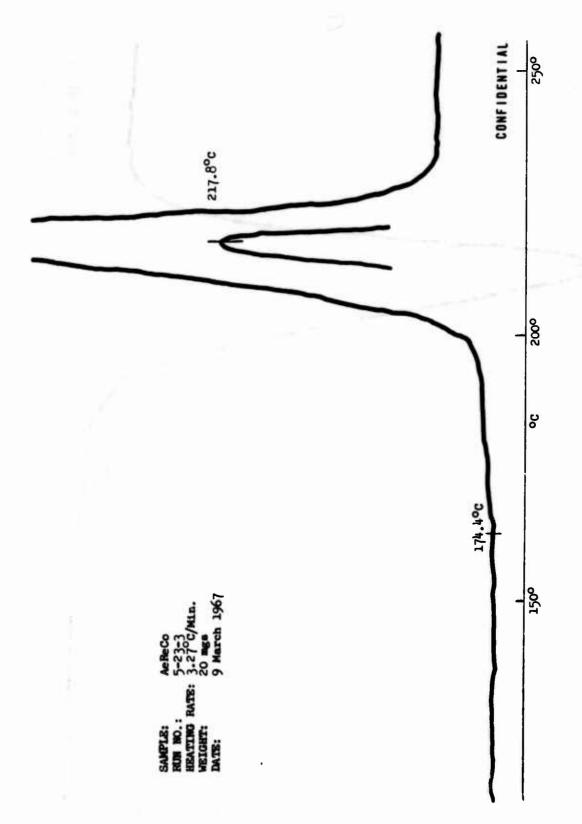
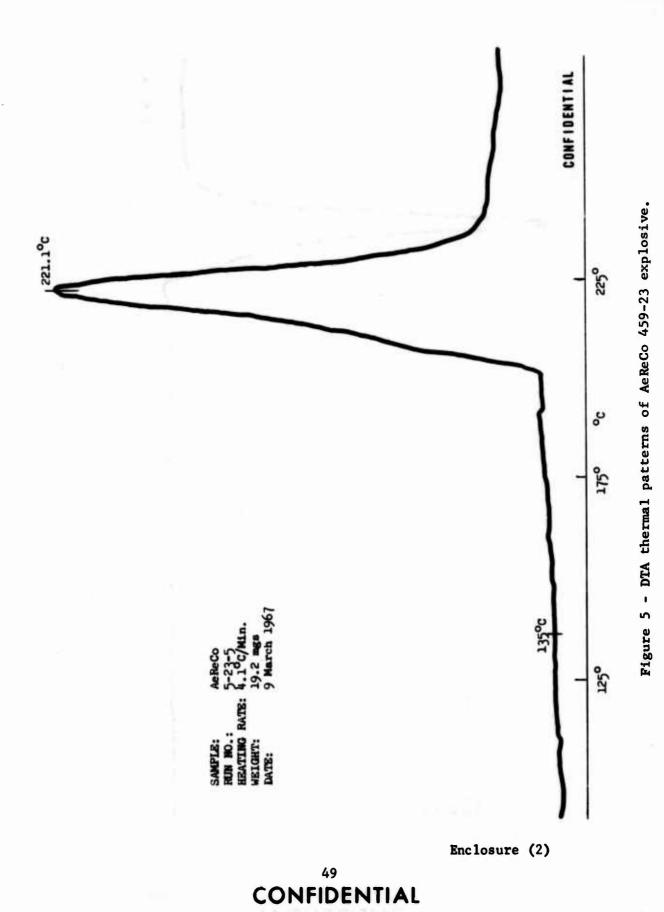


Figure 4 - DTA thermal patterns of AeReCo 459-23 explosive.

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Enclosure (2)



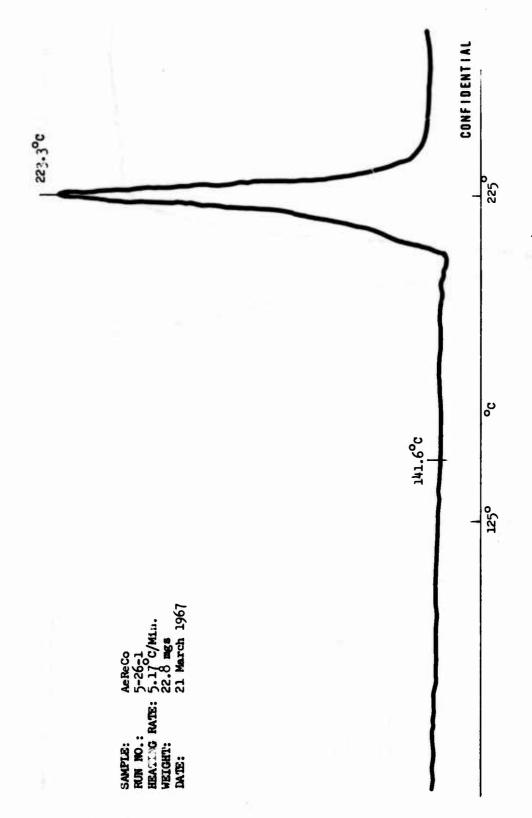


Figure 6 - DTA thermal patterns of AeReCo 459-23 explosive.

50 CONFIDENTIAL Enclosure (2)

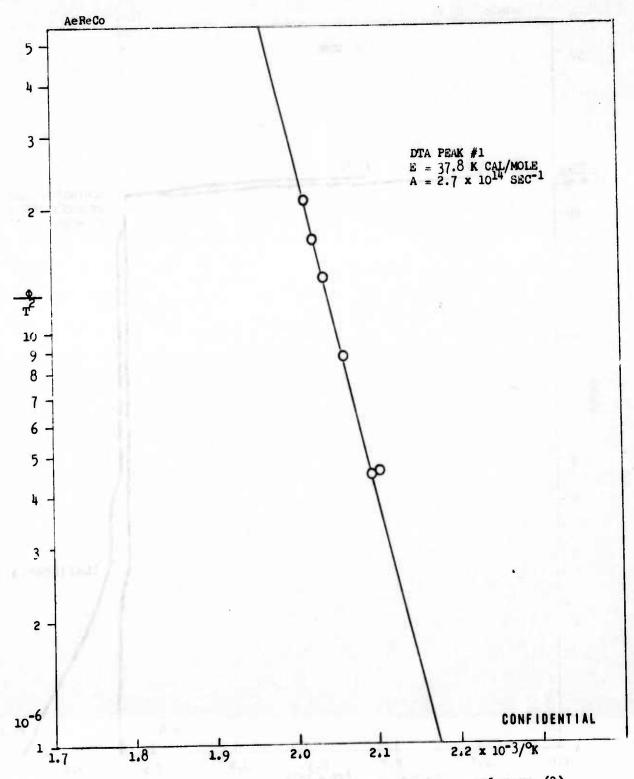


Figure 7 - Plot of DTA for AeReCo 459-23 explosive, enclosure (3).

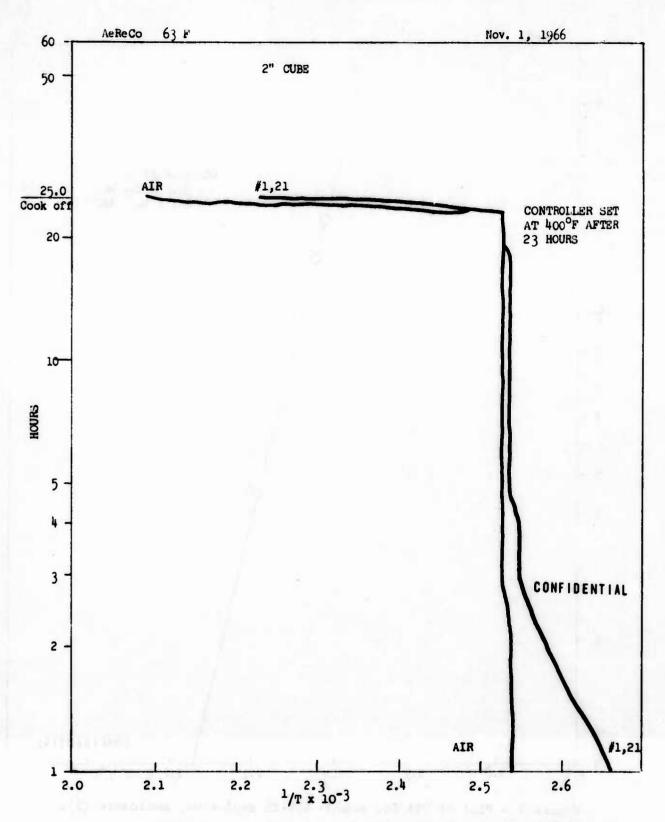


Figure 8 - Deflagration times at selected temperatures for AeReCo 459-23 explosive in aluminum tube ovens, enclosure (4).

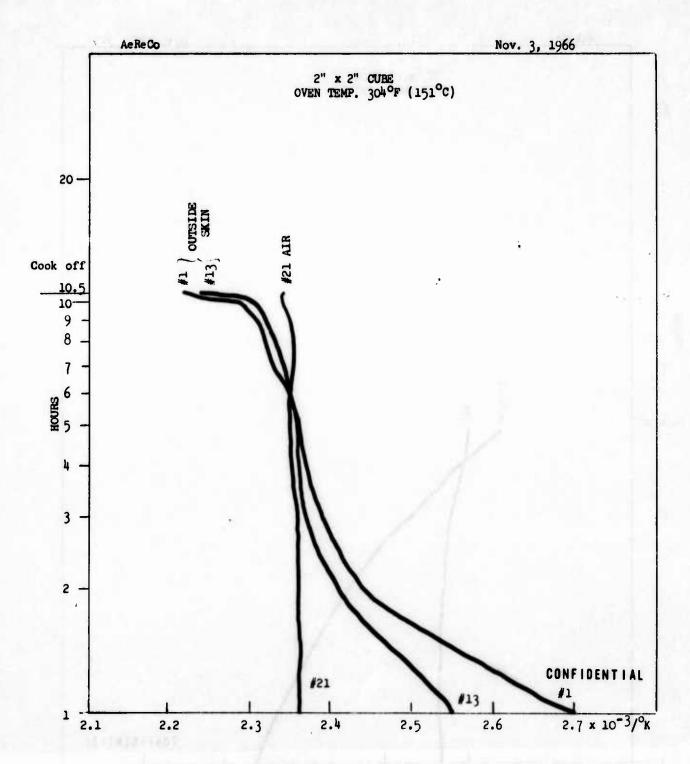


Figure 9 - Deflagration times at selected temperatures for AeReCo 459-23 explosive in aluminum tube ovens, enclosure (4).

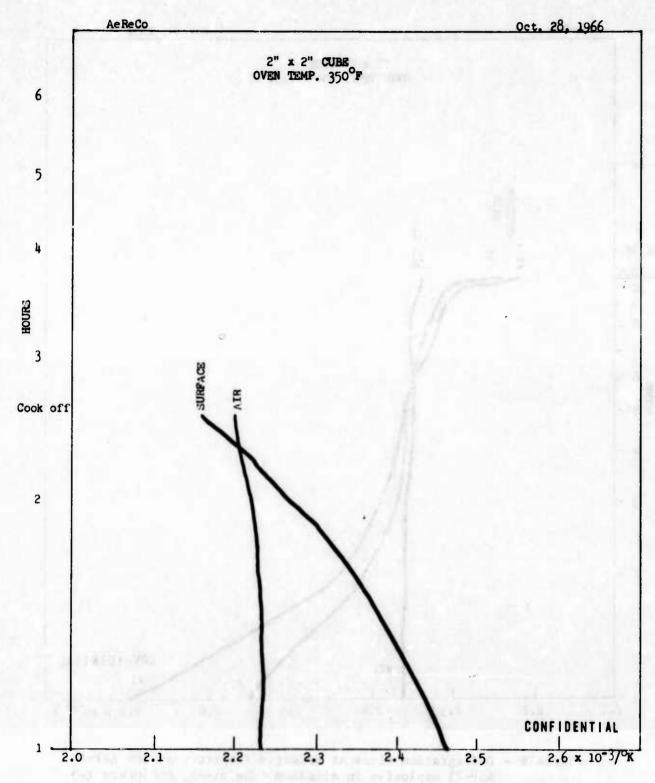


Figure 10 - Deflagration times at selected temperatures for AeReCo 459-23 explosive in aluminum tube ovens, enclosure (4).

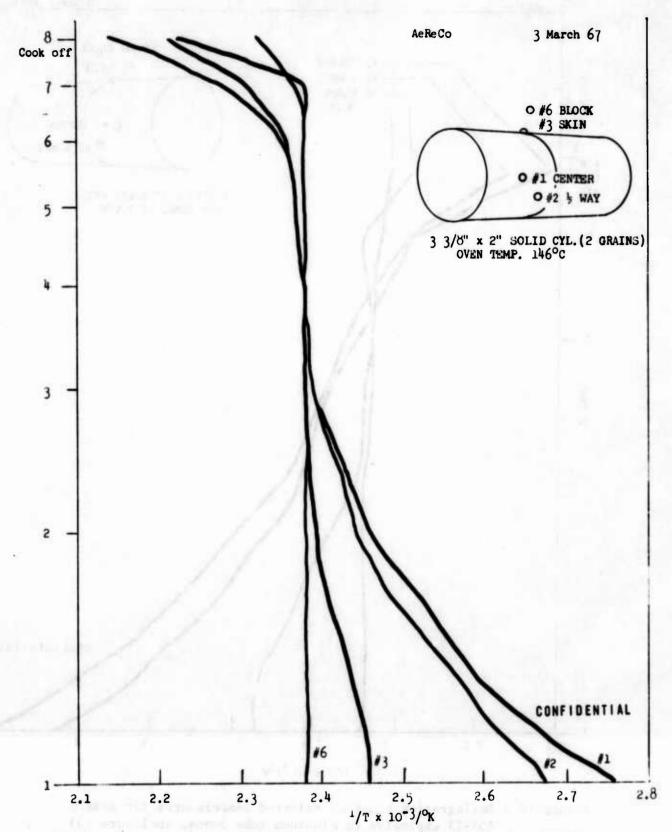


Figure 11 - Deflagration times at selected temperatures for AeReCo 459-23 explosive in aluminum tube ovens, enclosure (4).

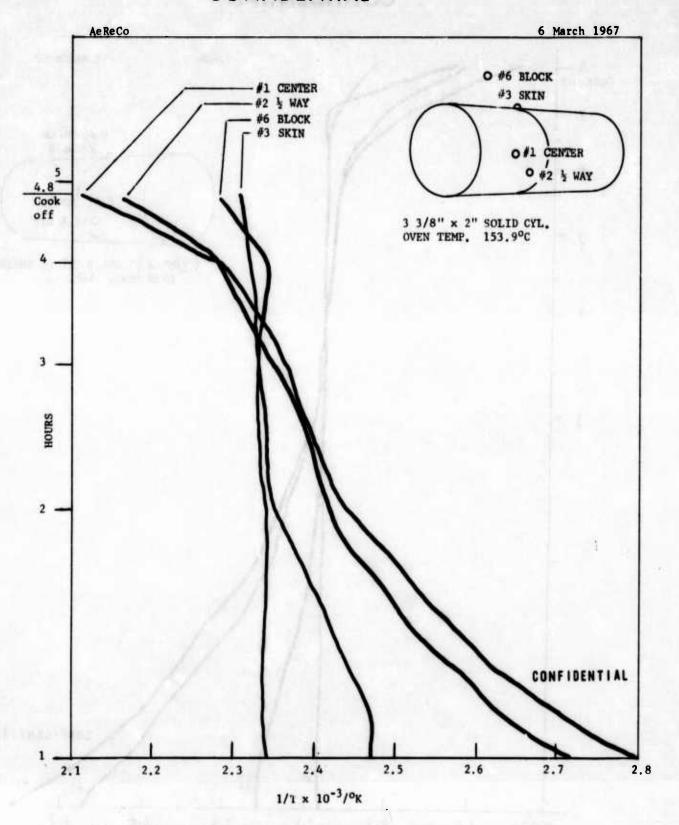


Figure 12 - Deflagration times at selected temperatures for AeReCo 459-23 explosive in aluminum tube ovens, enclosure (4).

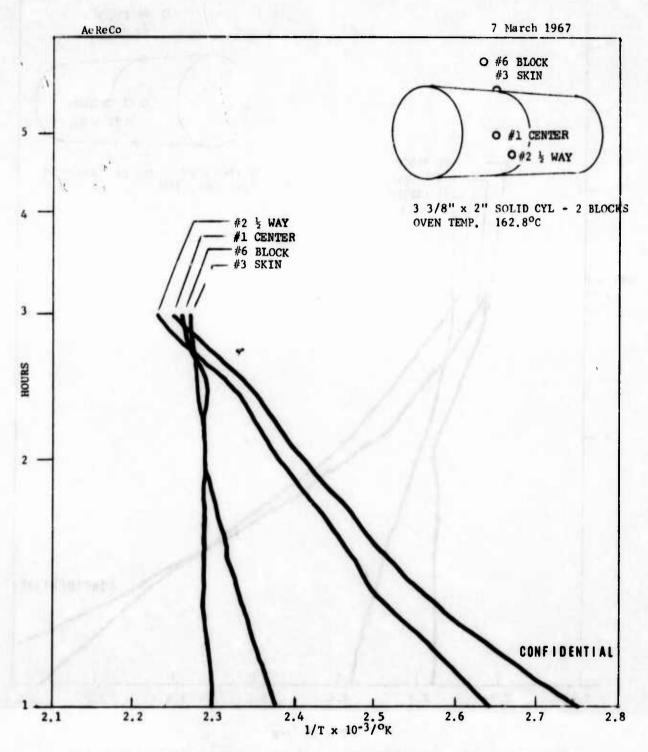


Figure 13 - Deflagration times at selected temperatures for AeReCo 459-23 explosive in aluminum tube ovens, enclosure (4).

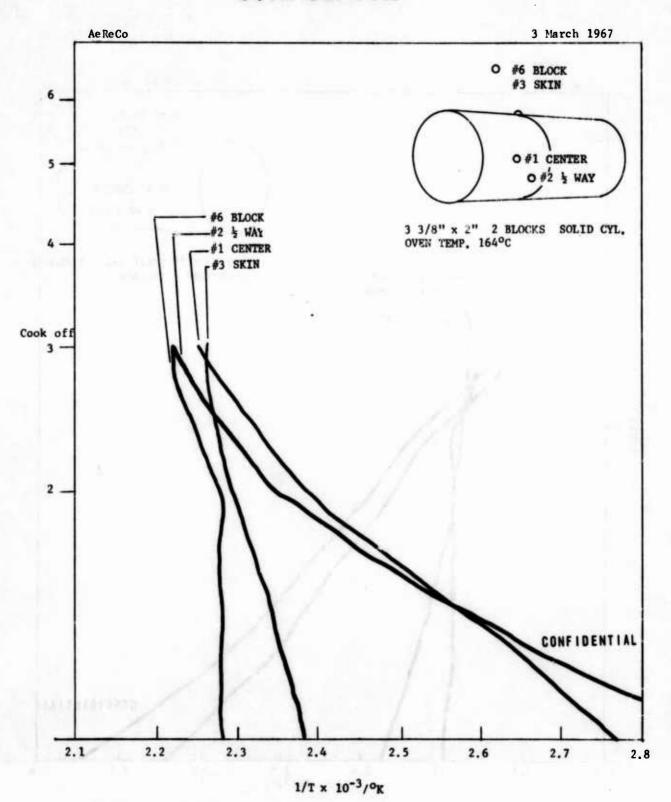


Figure 14 - Deflagration times at selected temperatures for AeReCo 459-23 explosive in aluminum tube ovens.

Enclosure (4)

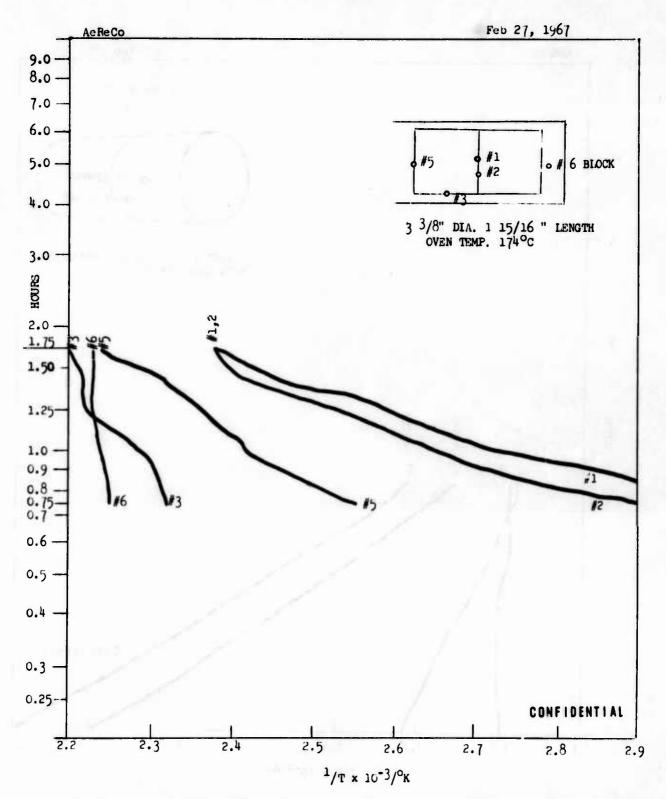


Figure 15 - Deflagration times at selected temperatures for AeReCo 459-23 explosive in aluminum tube ovens, enclosure (4).

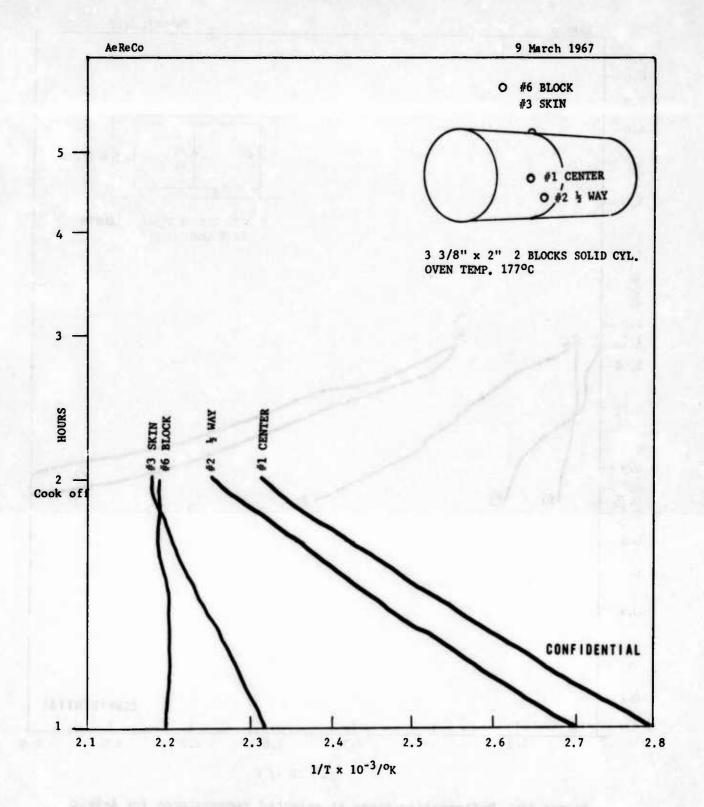


Figure 16 - Deflagration times at selected temperatures for AeReCo 459-23 explosive in aluminum tube ovens, enclosure (4).

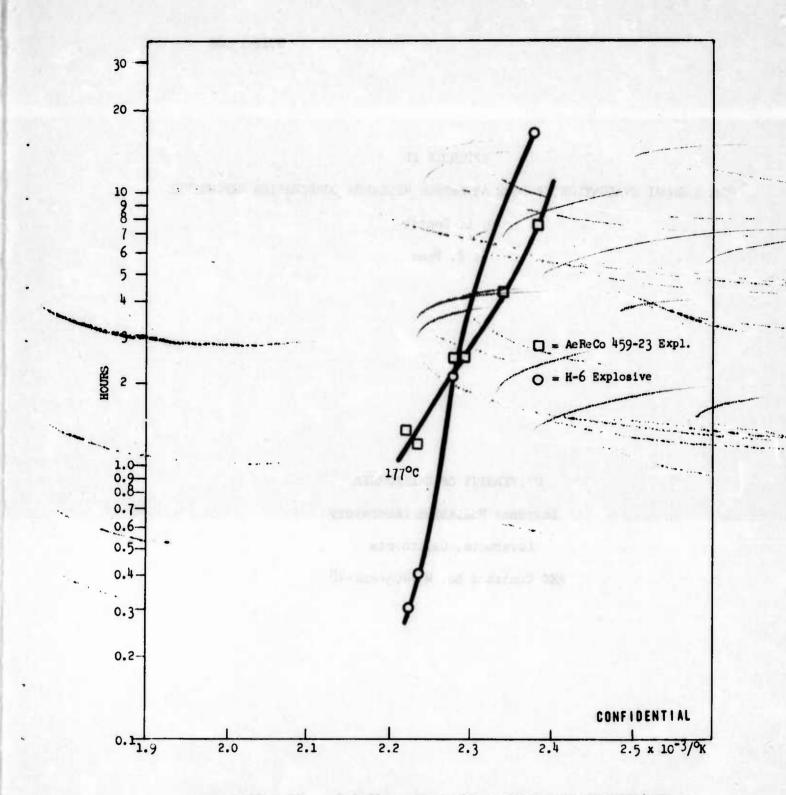


Figure 17 - Plot of deflagration time versus oven temperature for AeReCo 459-23 and H-6 explosives, enclosure (5).

UCID-15002

#### APPENDIX II

THE THERMAL EVALUATION OF SOME AEROSPACE RESEARCH CORPORATION EXPLOSIVES

D. L. Seaton

A. J. Pane

UNIVERSITY OF CALLFORNIA

Lawrence Radiation Laboratory

Livermore, California

AEC Contract No. W-7405-eng-48

THE THERMAL EVALUATION OF SOME AEROSPACE RESEARCH CORPORATION EXPLOSIVES\*

D. L. Seaton and A. J. Pane

University of California, Lawrence Radiation Laboratory

Livermore, California

Three Aerospace Research Corporation explosive formulations were submitted to LRL for small scale thermal testing. These materials, designated as 459-23, 475, and 465-10 are based on RDX, with a polyurethane binder.

Each of these formulations was subjected to the LRL chemical reactivity test and differential thermal analysis. In addition, 459-23 and 475 were examined microscopically on the Koefler hot stage.

#### Chemical Reactivity Test

In the test a 0.25 g sample, confined in a stainless steel reaction vessel, under approximately 2 atm pressure of He, is heated for 22 hrs. at 120°C. The products are analyzed chromatographically to give both a qualitative as well as quantitative measure of the decomposition products. The results of this test are given in Table 1.

TABLE 1

			<b></b>		Volu	ne (cc S	TP)	
Explosive	Wt.(g)	Temp.	Time Hrs.	N <sub>2</sub> + O <sub>2</sub>	NO + CO	N <sub>2</sub> 0	co <sup>S</sup>	Total
459-23	0.2508	120	22	0.005	0.003	0.010	0.013	0.031
459-23	0.2499	120	22	0.008	0.004	0.010	0.013	0.035
465-10	0.2514	120	22	0.010	0.009	0.018	0.022	0.059
465-10	0.2500	120	22	0.010	0.006	0.019	0.024	0.059
475	0.2500	120	22	0.009	0.006	0.013	0.013	0.041
PBX-9010 <sup>a</sup>	0.2498	120	22	0.007	0.001	0.009	0.003	0.020

aPBX-9010 is 90/10 RDX/Kel F

<sup>\*</sup> This report was prepared as a part of a cooperative effort between the LRL and the AFSC. The details of the agreement and areas of responsibility are contained in correspondence between General B. A. Schriever, Air Force Systems Command, and John S. Foster, Jr., Director, Lawrence Radiation Laboratory.

<sup>1)</sup> Letter: John S. Foster, Jr., to General B. A. Schriever; Proposal for LRL and AFSC cooperation in certain research and technological developments; May 25, 1965.

May 25, 1965.

2) Letter: General B. A. Schriever to John S. Foster, Jr.; Acceptance of proposal 1; June 30, 1965.

Differential Thermal Analysis

The DTA curves for these three formulations were generated using NaCl as the reference material and a programmed temperature rise of ll<sup>O</sup>C/min. Copies of the DTA records are attached. None of the materials show any unusual behavior. The endotherm at ca 200°C is the melting endotherm of RDX. The drifting base line is a characteristic of the instrument and not the explosive.

Koefler Hot Stage Observations

Two of these formulations, 475 and 459-23, were observed on a hot stage microscope as the temperature was raised 4°C/min up to the melting point. Sublimation was observed at ca 150°C, as is expected for RDX. Melting, with subsequent rapid decomposition, occurs at ca 200°C.

Drop Weight Impact Sensitivity

Drop weight impact sensitivities were run on the LRL machine using a 5 kiloweight and Type 12 tools with sandpaper. The results are given in Table 2.

TABLE 2

Explosive	H <sub>50</sub> cm.	
HMX Standard	19.5	0.05
459-23	43.8	0.05
465-10	54	0.05
475	56.1	0.06

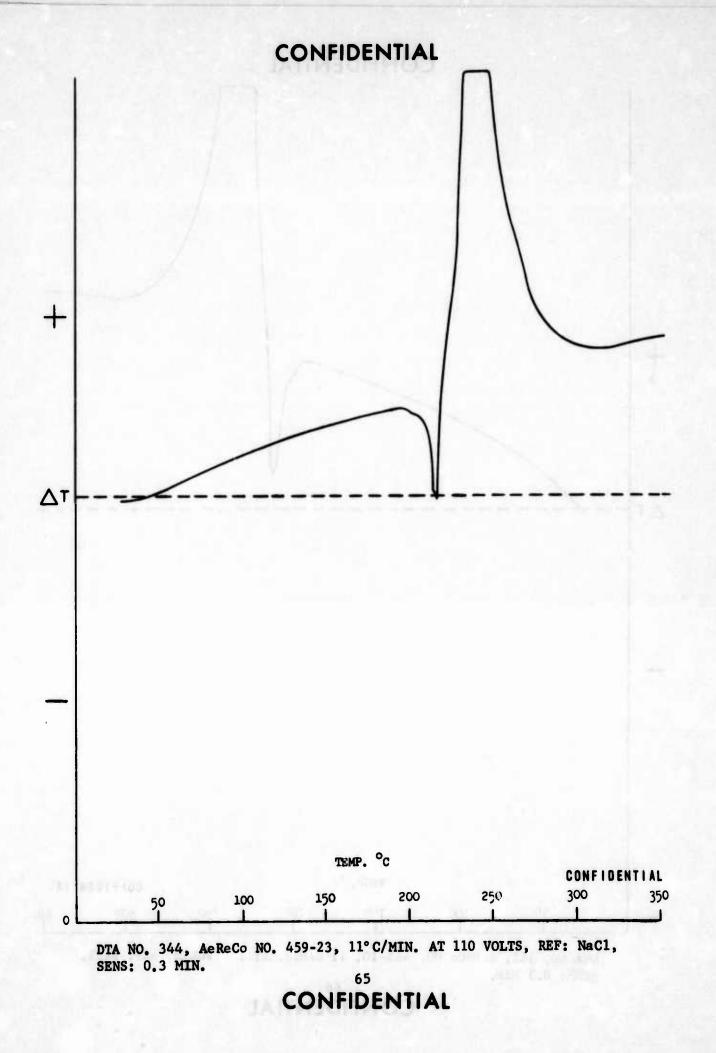
Conclusions

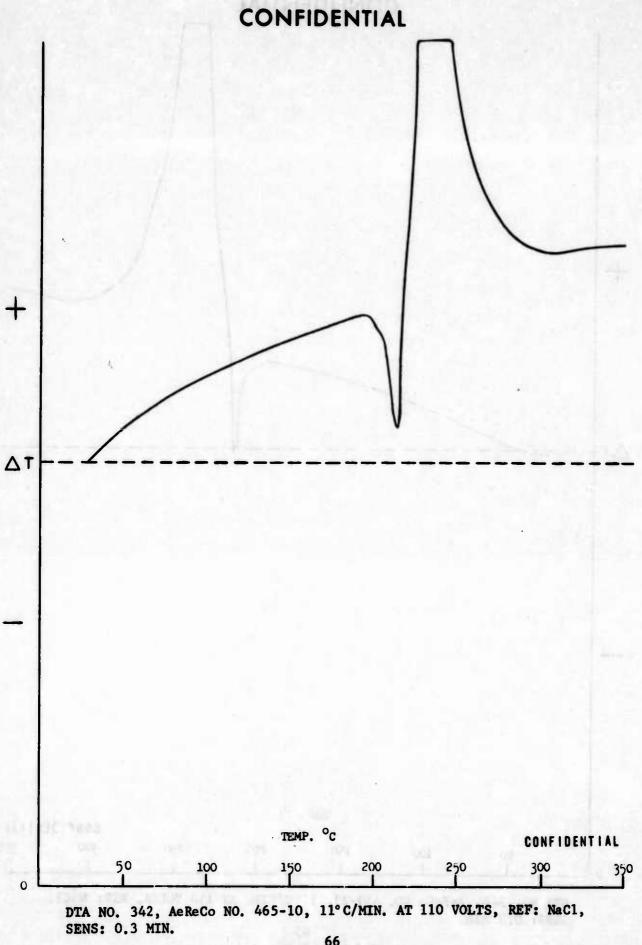
The only test still to be run on these materials is the Henkin or time to explosion test. Unless the times to explosion are greatly reduced, as compared to RDX, the results will not be reported formally.

As expected, from our experience with similar materials, these formulations appear to be quite stable, and there should be no problem with stockpile storage life. Larger scale tests, however, would be required to decide whether or not they could safely meet the high temperature requirements of the Air Force.

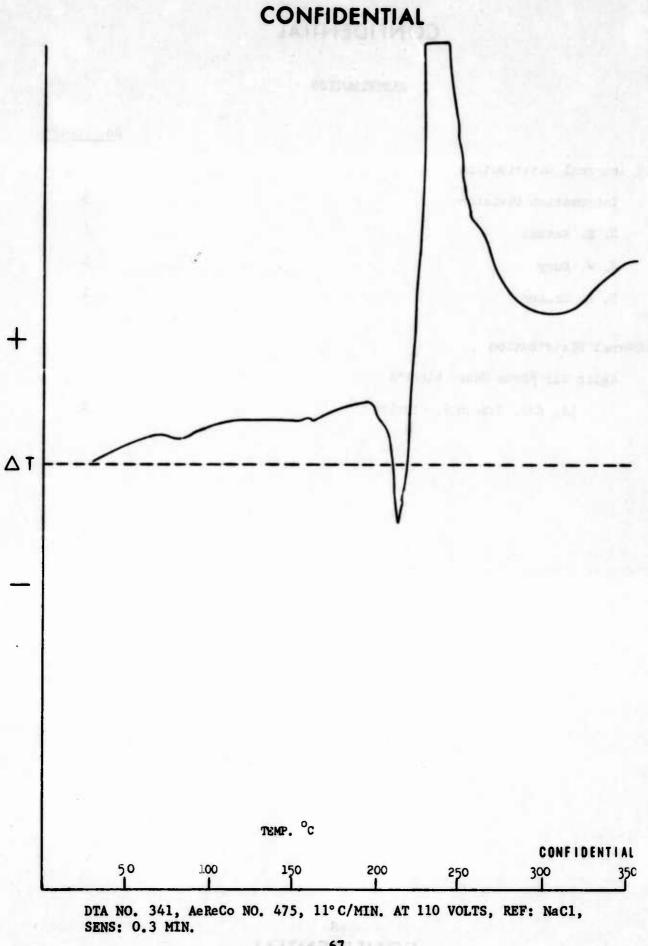
Acknowledgment

We wish to thank Mr. E. Ellison for carrying out the impact sensitivity tests.





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# APPENDIX III

## RESULTS OF BINDER VACUUM THERMAL STABILITY TESTS by

U.S. Naval Ordnance Laboratory Silver Spring , Maryland



# U.S. NAVAL ORDNANCE LABORATORY WHITE OAK

SILVER SPRING, MARYLAND

29341011bo

10330 Ser 6346

8 DEC 1966

Prom: To: Commander, U. S. Naval Ordnance Laboratory, White Oak Director, Air Force Armament Laboratory (AFSC) Eglin Air Force Base, Florida 32542 Mr. Kyselka, ATWR

Subj: Thermal Stability of Explosive Binders

1. At your request we have tested two binder materials submitted by the Aerospace Research Corporation for vacuum stability. Samples 400A and 400B evolved 1.9 and 0.4 ml gas/g/48 hrs at 150°C respectively.

2. By our criteria both binders were considered to have passed this test satisfactorily.

E. F. SCHREITER

B. E. WHITE By direction

Copy to: Aerospace Research Corp. 5454 Jae Valley Rd. Roanoke, Va., 24014 (Mr. J. T. Hamrick)

#### APPENDIX IV

ESPIRO PURE TO DATERNE

#### RESULTS OF HAZARD CLASSIFICATION TESTS

Tests were performed on AeReCo 459-23 and 475 to determine the hazard classification for handling and shipping. Results of tests by both the Bureau of Explosives and Aerospace Research Corporation are included in this appendix. Drop weight impact sensitivity tests were not performed by either but, were performed by Lawrence Radiation Laboratory and the results are reported in Appendix II of this report.

Both explosives have been classed as Class B explosives for shipment under Department of Transportation regulations.

#### BUREAU OF EXPLOSIVES

ASSOCIATION OF AMERICAN RAILROADS

#### REPORT FROM CHEMICAL LABORATORY

T. C. GEORGE. DIRECTOR AND CHIEF INSPECTOR

C W. SCHULTZ, CHIEF CHEMIST

15-145 FILE NUMBER..... LABORATORY NUMBER 60166

EDISON, N. J., July 1, 196 8

Propellant Explosive(Solid), Class D

Ac Re Co 459-23

#### AEROSPACE RESEARCH CORPORATION

Samples of a material identified as Ae Re Co 459-23 were received from Aerospace Research Corporation of Rosnoke, Virginia.

The material was a dense, light gray solid said to contain 59% RDM, 23% aluminum powder and a synthetic rubber binder.

A two inch cube was stable when maintained at 75°C for 48 hours.

When a two inch cube was initiated with a number 8 electric blasting cap it did not explode or ignite. This test was repeated with the same result.

Several two inch cubes were placed in contact with each other on a bed of kerosene-soaked sawdust which was ignited. When the fire reached the samples they did not really burn but appeared to carbonize and decompose.

Material represented by these samples is properly described as Propellant Explosive(Solid), Class B and classed as Class B Explosive under the DOT Regulations.

C.W. Schultz

(JAD)

#### BUREAU OF EXPLOSIVES

ASSOCIATION OF AMERICAN RAILROADS

## REPORT FROM CHEMICAL LABORATORY

T. C. GEORGE. DIRECTOR AND CHIEF INSPECTOR
C. W. SCHULTZ, CHIEF CHEMIST

FILE NUMBER 15-145
LABORATORY NUMBER 60165

EDISON, N. J., July 1, 196 8

Propellant Explosive (Solid), Class B
Ae Re Co 475

#### AEROSPACE RESEARCH CORPORATION

Samples of a material identified as Ae Re Co 475 were received from Aerospace Research Corporation of Roanoke, Virginia.

The material was a dense white solid said to contain 75% RDX in a synthetic rubber binder.

A two inch cube was stable when maintained at 75°C for 48 hours.

When a two inch cube was initiated with a number 8 electric blasting cap it did not explode, ignite or break apart. This test was repeated with the same results except that about half the cube was blown away by the cap.

Several two inch cubes were placed in contact with each other on a bed of kerosene=soaked sawdust which was ignited. When the fire reached the samples they did not really burn but appeared to carbonize and decompose.

Material represented by these samples is properly described as Propellant Explosive(Solid), Class B and classed as Class B Explosives under the DOT Regulations.

C.W. Schultz

(JAD)

Sponsoring Ag	oney Denartmen	t of the Air		ate <u>May 2</u> : AFSC, Eglin AFB,	71968
Contract No.		-68-C-0030			
	ntity (Type No.) A		arch Corp.	AeReCo 475	
	c. Bot availab		Batch	No. 1	
Mfg. Date			oaten		
Mig. Date	7-20-00				
Detonation Tea	TAGES MAIN MIST	Vacavasan			
		Explo-led	Bt	urned	Fragmented
ST. 6 BL 41-1		Yes No			Yes No
No. 8 Blasting		<u>x</u> .		_ <u>x</u>	
	Test II Test III	<del>-</del>		- <del>- X</del>	<u> </u>
	Test IV	_ *		. <u> </u>	
	Test V	<u>x</u>			<u>x</u>
Samples: Five			Test: On ble	sting cap per sample.	
•					
ignition & Und	confined Burning Tes	Enthal III THINK	Exploded Yes No		urning Time
One 2-inch cub			168 No		
One 2-inch cub			<b>= ±</b>	상 본	n. 21 sec.
Four 2-inch cul	•		_ <del>*</del>		n. 56 sec.
Samples: Six				burn unconfined.	
Thermal Stabil	ity Test	Explos ion	_		in Configuration
0		Yes No			es No
One 2-inch cub				<u> </u>	
Samples: One	2-inch cube		Test: 48 hours	at 75° C. in vented ov	
Card Gap Test	By compar	Lson	50% Value	(No. of Card	s) over 70
Impact Sensitiv	ity Test	110			
		Bureau of Explosi	ves Impact Appa	ratus	
Te	n 8%" (± 1/16") D	rop Test	Te	n 10" (± 1/16") Drop	Test
	10 Trials			10 Trials	
	No. of Trials Exhib	iting		No. of Trials Exhibit	ing
Explosion	Decomposition	No Reaction	Explosion	Decomposition	No Reaction
Flame and	Smoke	No Smoke	Flame and	Smoke	No Smoke
Noise	No Noise	No Noise	Noise	No Noise	No Noise
Approved:		Committee No.			
Test Direct	tor LC	R	Test Departm	ment Head	CR
	Ol- 18			DOD Approval W1	tnessing
Assigned	Classification		6	27	SHED NOT THE
ICC Forbidde	en		Signature	A MERGE	2
ICC Restricte	ed*			AR	
	-		Title		
ICC Class A					

Figure 1. Sample summary data shoot.

AGO TRALA

Sponsoring Age	ncy Department	t of the Air		rec May 23, FSC Relin AFB, 1	
Contract No.		-68-c-0030 <u> </u>			
Propellant Iden		Annual Control of the		AeReCo 459-23	
Propellant Spec	Not availa	bler	Batch	No. 1	
Mfg. Date	5-20-68				
Detonation Test	i amenta		mount and a to to to	nimering libe 15	con all
		Exploded		irned	Fragmented
No. 8 Blasting (	Can Test I	Yes No		No x	Yes No
TO DESCRIBE	Test II	_ 1		1	_ ±
	Test III			T.	<u> </u>
	Test IV	_ <del>x</del>		Ī	<b>= =</b>
	Test V	<u>x</u>		X	<b>= =</b>
Samples: Five			Test: One blas	sting cap per sample.	
	onfined Burning Tea	t	Exploded		Burning Time
			Yes No		conds
One 2-inch cube				5.1	in. 17 sec.
One 2-inch cube				5.1	in. 46 sec.
Four 2-inch cub	es			5_1	in. 18 sec.
Samples: Six 2-	-inch cubes.		Test: Ignite &	burn unconfined.	
Thermal Stabilit	ly Test	Exploi ion			in Configuration
		Yes No	= 14.5	No	Yes No
One 2-inch cube				<b></b>	
Samples: One 2	l-inch cube		Test: 48 hours	at 75° C. in vented of	ven.
Card Gap Test	By compariso	n	50% Value	(No. of Care	ds) over 70
Impact Sensitivi	·	Bureau of Explosi	ves Impact Appa	ratus	
Ten	3%" (± 1/16") Di			n 10" (± 1/16") Dro	p Test
	10 Trials			10 Trials	
	No. of Trials Exhib	iting		No. of Trials Exhibit	ling
Explosion	Decomposition	No Reaction	Explosion	Decomposition	No Reaction
Flame and	Smoke	No Smoke	Flame and	Smoke	No Smoke
Noise	No Noise	No Noise	Noise	No Noise	No Noise
Moise				/	
Approved:	/	1	Test Departm		. C. R.
	L. C. R.				6 C 6 TG
Approved: Test Directo	L. C. R.			Transver steps	
Approved: Test Directo	L. C. R.		6	Transver steps	
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Assigned ( ICC Forbidder ICC Restricted ICC Class A	L. C. R.		Signature Title	DOD Approval	etitnessus
Approved: Test Director  Assigned ( ICC Forbidder ICC Restricted	L. C. R.			DOD Approval	

Figure 1. Sample summary data sheet.

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## APPENDIX V

## METHOD OF PROCEDURE - CRATERING TESTS

- 1. Record all preliminary data required on data sheet.
- 2. Prepare test area as shown in figure 1.
- 3. Drill  $9\frac{1}{2}$  -inch diameter test holes to the depths shown in Table V-I.

Table V-I CRATERING TEST SEQUENCE AND TEST HOLE DEPTHS

Sample	Batch No.	Test Sequence	Hole Depth to Center of Gravity Feet		Depth, Inches
AeReCo 459-23					
1.	17	3 .	6	6	10.00
2.	1	9	6	6	9.50
3.	2	4	7	7	9.75
4.	2	6	7	7	9.75
AeReCo 475					
1.	18		6	6	10.25
2.	2	11	6	6	10.00
3.	3	8	7	7	10.25
ч.	4	2	7	7	10.00
Tritonal					
1.		1	6	6	7.50
2.	- 1819	12	6	6	7.50
3.		5	7	7	7.50
4.	-	10	7	7	7.50

- 4. Take a one-pint sample of dirt from test hole at 0 feet, 3 feet, and 6 feet depths.
- 5. Place 3/4-inch steel pipe centering stakes around the hole as shown in figure 2 in order that the center of the bore hole can be located after the explosion.
- 6. Prepare test charges as follows:
  - a. Label and identify all test samples by sample and test number.
  - b. Tape two No. 6 blasting caps to the sides of two pentolite boosters 180° apart and tape both to sample charge with pentolite booster charge against bottom center of sample. The pentolite charge should be positioned so that the wire leads from the No. 6 caps point away from the bottom of the 30-pound charge.
  - c. Attach sling made from two pieces of Nylon cord wrapped around the bottom of the charge 90° apart and taped to the sides.
- 7. Lower charge into hole making sure that no debris or dirt prevents the charge from being at the proper depth for test.
- 8. Make Polaroid and 35 mm photographs of the sample charge and test hole area before lowering charge into hole on any two of the tests.
- 9. Backfill hole with loose dirt to within 3 1/2 feet of the top of hole for the 6 feet depth and 4 1/2 feet for the 7 feet hole.
- 10. Clear the area of all vehicles and personnel.
- 11. Post guards and block all entrances to the test area.
- 12. Ground initiating circuit at firing shelter and splice wire to blasting caps.
- 13. When the "ALL CLEAR" signal is given by the Test Supervisor unground circuit and fire charge.
- 14. Photograph the crater with both Polaroid and 35 mm cameras.
- 15. After the explosion determine hole profile as shown in figure 2 and record data on data sheet.

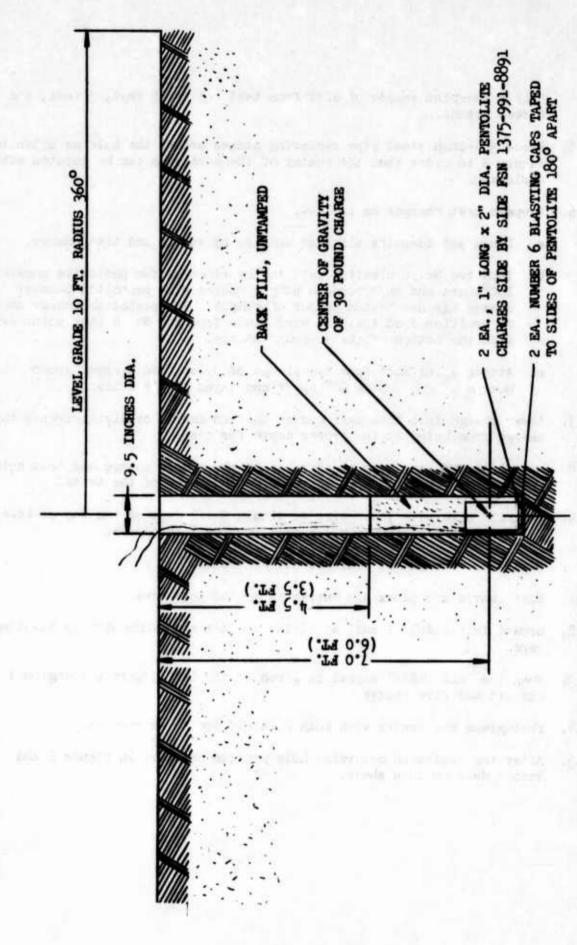


Figure V-1 - View of thirty pound charge in place for cratering test. Pentolite charge and blasting cap are taped to the 30 pound charge prior to lowering into hole. Scale - 1/2 inch equals 1 foot.

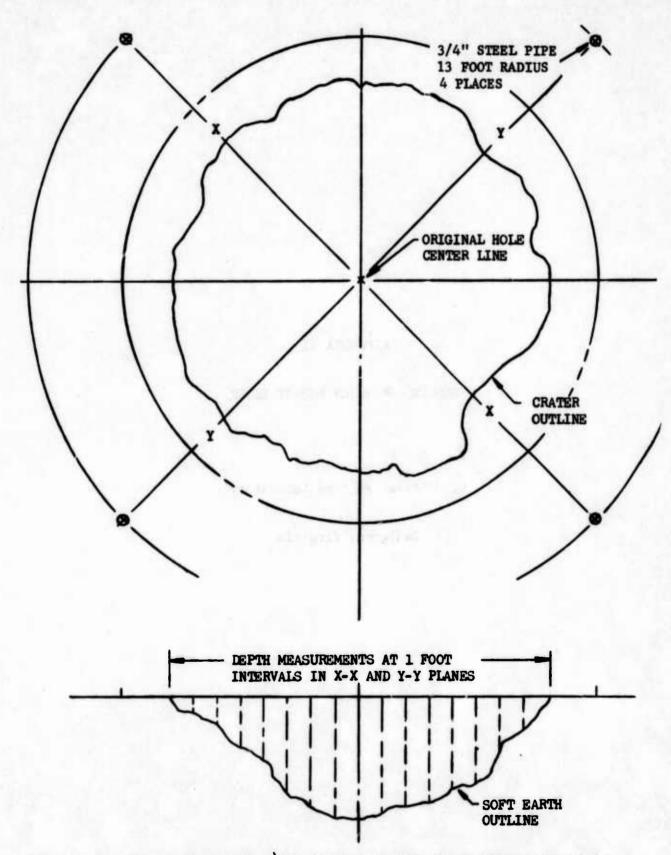


Figure V-2 - Crater shape and cross section showing depth measuring points.

Steel pins installed before explosion are used for locating original hole center line after explosion.

#### APPENDIX VI

#### RESULTS OF SUSAN IMPACT TESTS

by

U. S. Naval Weapons Laboratory

Dahlgren, Virginia



U. S. NAVAL WEAPONS LABORATORY

DAHLGREN, VA. 22448

TEP:HPB:hwm 8010/1-10 Ser 0681563

SEP 2 7 1855

(Unclassified when enclosures are removed)

From: Commander, U. S. Naval Weapons Laboratory

Dahlgren, Virginia 22448

To: Commanding Officer

Eglin Air Force Base, Florida 32543 Attn: ATWT/LT Trossback/882-2963

Subj: Susan impact sensitivity test of high explosives

Ref: (a) Eglin Air Force Base ltr ATWT/LT Trossback/882-2963 of 7 May 1968

(b) NWL Dahlgren Conf Report No. 1805 of 30 Apr 1962

Encl: (1) Explosive compositions

(2) Summary of Susan impact sensitivity results

1. Susan impact sensitivity tests were conducted on 15 and 16 August 1968 on three explosive formulations as requested by reference (a). The Susan test procedures are described in detail in reference (b).

- 2. Eighteen Susan projectile assemblies were loaded with explosives at NWS Yorktown; six each with approximately one pound of desensitized tritonal, AeReCo 475, and AeReCo 459-23. The latter two were formulated by Aerospace Research Corporation, (AeReCo) Roanoke, Virginia. The composition of each explosive is given in enclosure (1). The projectiles were gunfired against a steel target plate at impact velocities ranging from 121 to 1250 ft/sec. Instrumentation used to assess the reaction obtained at impact consisted of high speed framing cameras, piezo-electric overpressure gauges, and silicon diode light gauges. Velocities were measured on each firing and were intentionally varied in an attempt to obtain: (1) an approximation of the highest velocity at which no chemical reaction (dud) occurs and (2) the lowest velocity producing a violent reaction (overpressure at 10 ft of 4 psi or greater).
- 3. A round-by-round summary of the test results is given as Table 1 of enclosure (2). Table 2 lists the estimated threshold velocities for each explosive tested. It should be noted that these estimates are based on very few firings and are subject to change if more rounds are fired. The overpressures given in Table 1 should be considered as approximations and used as comparative values rather than absolute pressures. The numerous reflective surfaces present at the test site influenced the pressures "seen" by the piezo-electric gauges, but were the same throughout all the tests.

Page 1 of 2 pages

TEP:HPB:hwm 8010/1-10 Ser 0681563

4. The results of the Susan tests, as shown in Tables 1 and 2, indicate that the explosive tritonal (desensitized) is much less sensitive to crushing impact than the other two explosives tested. It is further indicated that the explosive AeReCo 475 is less sensitive to crushing impact than AeReCo 459-23.

pm & myeni

By direction (a) Built his firm has live ordered Translated Petrology of 7 May

Air Force Armament Laboratory Eglin AFB, Florida 32542

NAVORD (ORD-03321) Washington, D. C. 20360

UCLRL Box 808 Livermore, Calif. 94551 Livermore, Calif. 94551
Attn: Chemistry Division (Mr. L. Green)

NWS/Yorktown 23491
Code ORREP

NOS (SADR) Indian Head, Md. 20640

NOL/WO Bldg. 613 Silver Spring, Md. 20910

> Page 2 of 2 pages CONFIDENTIAL

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TEP: HPB: 8010/1-10 Ser 0681563

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#### COMPOSITIONS OF EXPLOSIVES TESTED

Explosive	Formulation (Weight Pe	rcent)
Tritonal (desensitized)	TNT Aluminum D-2 wax	80.00 20.00 Added
	Lecithin Acetlyene black	Added Added
AeReCo 475	RDX Polyether urethane binder	75.00 25.00
AeReCo 459-23	RDX Aluminum Polyether urethane binder	59.00 23.00 18.00

Enclosure (1)

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TEP: HPB: hwm 8010/1-10 Ser 0681563

# SUMMARY OF SUSAN IMPACT SENSITIVITY TESTS ROUND BY ROUND RESULTS

#### Table 1

Projectile Serial	Explosive	Impact Velocity	Average	eroected.
No.	Loading	(ft/sec)	overpressure at 10 ft (psi	.) Reaction Description
<b>**</b> *****				
BW-70	Tritonal	121	0.0	No detectable reaction
BW-69	Tritonal.	320	0.0	No detectable reaction
BW-74	Tritonal	396	1.0	Slight burning
BW-73	Tritonal	494	1.0	Slight burning
BW-71	Tritonal	749	1.1	Slight burning
BW-72	Tritonal	1250	3.8	Moderate burning
BW-76	AeReCo 459-23	123	0.0	No detectable reaction
BW-80	AeReCo 459-23	203	1.0	Slight burning
BW-75	AeReCo 459-23	302	1.4	Slight burning
BW-79	AeReCo 459-23	520	6.1	Near detonation
BM-77	AeReCo 459-23	761		Near detonation
BW-78	AeReCo 459-23	832	5.3 6.5	Near detonation
BW-82	AeReCo 475	122	0.0	No detectable reaction
BW-86	AeReCo 475	200	0.0	No detectable reaction
BW-81	AeReCo 475	314	1.0	Slight burning
BW-85	AeReCo 475	517		Near detonation
BW-83	AeReCo 475		5.2 4.3	Vigorous burning
BW-84		737		
DM - 04	AeReCo 475	980	4.7	Vigorous burning

Enclosure (2)

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## SUMMARY OF SUSAN IMPACT SENSITIVITY TESTS THRESHOLD VELOCITIES

#### Table 2

Explosive Loading	Highest "No Reaction" " Velocity (ft/sec)	Lowest "Violent Reaction"** Velocity (ft/sec)
Tritonal	360	1250
AeReCo 459-23	160	400
AeReCo 475	260	450

<sup>\*</sup>This velocity is an estimate of the maximum impact velocity that would produce no chemical reaction.

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<sup>\*\*</sup>This velocity is an estimate of the minimum impact velocity that would produce a reaction greater than moderate burning, accompanied by an overpressure at 10 ft of 4 psi or greater.

#### REFERENCES

- 1. The Science of High Explosives Melvin A. Cook Reinhold Publishing Company 1958.
- 2. The Ordnance Safety Manual ORD M7-224.
- 3. Earth Cratering With Aluminized Explosives, James A. Dennis, U.S. Army Engineer Research and Development Laboratories 18 Dec 1963 AD349660.

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(Security classification of title, body of abstract and indexing anno priginating activity (Corporate author)  Aerospace Research Corporation  5454 JAE Valley Road, S. E.  Roanoke, Virginia 24014  REPORT TITLE  EVALUATION AND LOADING OF NEW EXPLOSIVE FOR DESCRIPTIVE NOTES (Type of report and inclusive dates)  Final Report - March 1965 to August 1968  AUTHOR(S) (First name, middle initial, last name)  Joseph T. Hamrick		20. REPOR	T SECURITY CLASSIFICATION
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13. ABSTRACT

(C) An evaluation has been made of AeReCo explosives 459-23 and 475. The explosives withstand 350°F for at least one hour and 300°F for eight hours. Their storability qualities are excellent and they are not affected by moisture at any climatic temperature. In cratering tests the AeReCo 459-23 equalled tritonal. Batch type loading techniques were evaluated by loading BLU-31 bombs.

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