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LAWRENCE LIVERMORE LABORATORY

University of California/Livermore, California

PARTICIPATION OF LLL IN JSEXP

PART A: PERFORMANCE OF NON-IDEAL HE

PART B: CHARACTERIZATION OF ECX FOR CONVENTIONAL MUNITIONS

(Unclassified)

30 December 1973

F. E. Walker

MASTER

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TECHNICAL REPORT

LAWRENCE LIVERMORE LABORATORY

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LLL PROPOSAL OMD-72-7

"PARTICIPATION OF LLL IN JSEXP"

ARPA Order No. 2502

Program Code No. 3G10

Effective Date of Contract: 13 April 1973

Contract Expiration Date: 31 December 1974

Amount of Contract: \$100,000 FY-73 (\$235,000 FY-74)

Principal Investigators:	M. Finger	Ext. 7856	(Task A)
	K. Scribner	Ext. 7366	(Task B)
	H. Hornig	Ext. 3717	(Task C)

Project Scientist:	F. Walker	Ext. 3746
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Sponsored by:

Advanced Research Projects Agency
ARPA Order No. 2502

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TECHNICAL REPORT

PARTICIPATION OF LLL IN JSEXP

REPORT SUMMARY

- PART A: Performance of Non-Ideal HE
- PART B: Characterization of ECX for Conventional Munitions
- PART C: Optimization of Active Warhead Designs for Appropriate
Targets (Classified; Forwarded Separately)

30 December 1973

This research was supported by the Advanced
Research Projects Agency of the Department of
Defense and was monitored by Dr. Charles Church
under ARPA Order No. 2502.

TECHNICAL REPORT SUMMARY

Introduction

The research program reported on in this summary was developed as a cooperative effort between the Advanced Research Projects Agency (ARPA), the Office of the Director of Defense Research and Engineering (DDR and E), and the Joint Services Explosives Program (JSEXP). Funding for the projects, which are the subject of this report, was provided by ARPA, and these projects are an integral part of the JSEXP Research Agenda.

Program Purposes

Three distinct purposes were established for this program, and they have been designated as Tasks A, B and C.

Task A:

Complete experiments and code calculations to determine a hydrodynamic model for the initiation and detonation of composite explosives. This information is important to the success of the Alternate Fills Program.

Task B:

Complete formulation studies and experiments with extrusion cast explosives (ECX) for application to the improvement of shaped charge performance at acceptable costs.

Task C:

Complete parametric and fundamental studies of the "active warhead" concept for application to the design of specific munition systems.

Discussion

A short discussion of the technical problems, general methodology, technical results, and the implications of the research for each task follows:

Task A: Performance of Non-Ideal HE

1. Several technical problems are being addressed in Task A. The fundamental problem is that of understanding and then being able to calculate the kinetics and, thus, the performance of composite explosives (those formulated from two or more oxidizer and fuel ingredients). In order to solve this fundamental problem, hydrodynamic data from experiments with specified geometries (cylinders and spheres) of explosive samples must be collected and compared with hydrodynamic code calculations based on the assumed kinetic model. In this way the model is adjusted and refined until the kinetics and performance are understood.
2. This work involves some literature study, theoretical calculations and modeling, precise instrumentation and firing of explosive samples, and analysis of the data obtained.
3. A model has been formulated for the kinetics and the hydrodynamic effects. A series of cylindrical charges of the composite explosive selected (potassium perchlorate and gelled nitromethane) has been instrumented and fired. A series of hemispherical charges has been loaded in specially designed and fabricated containers. Data from the cylindrical charges in which the particle size of the KClO_4 (oxidizer) was varied are reasonably consistent with the first model selected. (See Part A.)

4. The implications for further research are that the kinetic and hydrodynamic model selected is probably reasonably accurate, so that comparison and iteration with the data to be obtained from the spherical charges and the balance of the cylindrical charges should provide a satisfactory model and, thus, understanding of the kinetics of selected composite explosives.

Task B: ECX for Conventional Munitions

1. The technical problems in the ECX study are not too difficult. The ECX must be formulated and extruded into the shaped charge to leave no voids and to provide a smooth and homogeneous explosive layer next to the shaped charge liner. We have had considerable experience in the formulation and processing of ECX materials.

2. This work involves some formulation and processing, but it is mainly an experimental program to compare the effectiveness in penetration of shaped charges loaded with conventional explosives to those loaded with our ECX.

3. The data obtained thus far in the test firing program show that at 6 cone diameters the penetration is ~20% greater with the ECX charges than with the conventional charges. The reproducibility of effects at this distance also appears to be better with the ECX charges (see Part B).

4. The implication of further research is that we have some data now that gives us clues to the understanding of improved and more reproducible shaped charge performance, and additional experimentation and analysis with the ECX system can elucidate what has been a disturbing problem. Additional improvement in performance seems feasible, and a reduction in the cost of the ECX explosive may be obtained.

Task C: Active Warhead Designs for Appropriate Targets

1. The most important technical problem in the "active warhead" study is obtaining an understanding of the effects of changing the parameters in the "active warhead" system. We are also looking for improvements by changing the basic design geometries, since this is a relatively new technology.
2. The general methodology for this project involves some literature study, but it is primarily a parametric experimental program with computer analyses and modeling.
3. Some of the parametric experiments have been completed, and we have observed significant enhancement of the explosive properties involved. (See Part C, Classified).
4. The principal implication of further research is that a significant advance in weapon technology in many specific applications of explosive devices appears to be feasible, and the research completed to date has shown the concept can provide some unique weapon effects.

5. The "active warhead" concepts are classified as Secret, NSI.

Please see Part C, Classified, for specific information on this task.

Equipment Purchased or Developed

No important equipment has been purchased or built under the terms of this contract.

Conclusions

Task A

The kinetic and hydrodynamic model we have proposed appears to be a good basic model for understanding the performance of composite explosives. The experimental studies are progressing well.

Task B

The shaped charges loaded with ECX which have been tested in this project show improved performance at 6 cone diameters. The work completed indicates we can obtain further understanding of the important factors which determine shaped charge performance through the experiments we are conducting.

Task C

We have observed significant enhancement of explosive effects in the parametric experiments completed. We are confident that important advances in weapon technology can be achieved and unique weapon effects can be demonstrated.

PART B

PARTICIPATION OF LLL IN JSEXP

TASK B: CHARACTERIZATION OF ECX FOR CONVENTIONAL MUNITIONS

K. Scribner

J. Hallam

GLOSSARY

ECX	Extrusion Cast Explosive
DINOL	2,2,8,8-tetranitro-4,6-dioxa-1,9-nonane diol.
FEFO	<u>bis</u> (2-fluoro-2, 2-dinitroethyl) formal
HMX	1,3,5,7-Tetranitro-1,3,5,7-tetrazacyclooctane
AFNOL	Polymerization product of DINOL and 4,4-dinitropimeloyl chloride
FEFO SOL	35 wt% FEFO in ethyl acetate solution
HMDI	Hexamethylene Diisocyanate

SUMMARY

The objective of this program is to determine if improved homogeneity, increased energy and improved filling techniques will significantly upgrade the performance of shaped charges. The explosive used in the initial tests is an extrusion cast explosive (ECX) designated RX-08-BA.⁽¹⁾ The shaped charges are 2.2 in. diam. precision made units, exactly the same as units made and tested with RDX and Composition-B by Firestone Tire and Rubber Company.⁽²⁾ The study includes the development of penetration vs standoff curves; determination of the jet tip formation, velocity and breakup; and calculating theoretical performance based on existing empirical formulas.

Thirty shaped charge assemblies were fabricated, inspected and filled with RX-08-BA. Each charge was x-ray inspected for homogeneity. A total of twelve charges have been test fired, including 3 each at 0.5, 1.5, 3 and 6 cone diameter (CD) standoffs. At 0.5 CD standoff the average penetration was 14% less than both RDX and Composition B, and at 1.5 and 3 CD standoffs the penetrations were about equal. However, at 6 CD standoff the penetration of RX-08-BA was 22% greater than either RDX or Composition B, and the corresponding hole volumes were larger. The targets are stacked discs, 5 in. diam. x 3 in. high, Type 4340, 300-320 Brinell hardness armor plate steel.

Ten units have been sent to Firestone, Akron, Ohio for test firing. We have requested flash x-ray diagnosis of the jets and penetration data at 9, 12, and 20 CD standoffs.

(1) RX-08-BA = HMX/FEFO/AFNOL 78/18.6/3.4 wt.%.

(2) Final Report, Shaped Charge Scaling Study, Contract No. 8AAA21-68-C-0124 The Firestone Tire & Rubber Co., Defense Research Division, Akron, Ohio, March 1970.

INTRODUCTION

We have developed recently at LLL a new explosive technology to produce extrusion cast explosives (ECX's). We are studying the application of this technology to the development of improved shaped charge performance. Our work will include formulation studies of ECX's that can provide improved performance at acceptable costs and the firing of test models of shaped charges to obtain the performance data. ECX has some attractive features, including: ease of formulation, can be extruded like a paste, good energy, relatively good sensitivity, and superior mechanical properties in the cured state.

ECX FORMULATION

Dry HMX was hand mixed with AFNOL and FEFO SOL followed by remote mixing in a vertical mixer at 70°C for 10 min. The ethyl acetate solvent in the FEFO SOL was then removed by air sweep and vacuum stripping at 70°C until there was no longer an acetate odor in the mix. After cooling to 25°C HMDI curing agent was mixed into the paste. The finished product was stored in a freezer to impede cross linking of the AFNOL binder. Prior to loading, the ECX was allowed to thaw at room temperature. After loading a device the ECX was cured at 28°C for 72 hours. A sample of each batch was cured for Shore hardness testing and compositional analysis (see Table I).

TABLE I
COMPOSITION, WT.%

<u>Batch No.</u>	<u>HMX</u>	<u>FEFO</u>	<u>AFNOL</u>	<u>Shore Hardness</u>
1	77.8	18.2	4.0	62
2	77.9	18.5	3.6	60
3	77.5	18.4	4.1	55
4	77.8	18.4	3.8	50
5	76.5	18.9	4.6	60

LOADING

The precision shaped charges were loaded with the 50 cubic in. Deaerator-Loader at Bldg. 826, Site 300. Drawings of the shaped charge (AAA 73-105448, 105449, 105550, 102322) and the loading fixture (AAA 73-105555) are attached. The loading procedure was as follows:

1. A quantity of ECX sufficient to load 5 charges was placed in the Deaerator-Loader and deaerated at a vacuum of 0.15 torr or less and at room temperature (28°C).

2. The shaped charge assembly was placed into the loading fixture, connected to the loader, and the explosive cavity evacuated to a vacuum of 0.15 torr or less.

3. The ECX was extruded into the cavity at 28°C using a pressure of 350 psi. At this pressure each charge was filled in 2-3 minutes.

4. The fixture was unclamped from the loader, and the filled shaped charge was removed from the fixture. The charge was then placed in a 28°C environment for 3 days to allow the ECX to cure.

Using this procedure, two operators can load 5 shaped charges per hour.

After curing, the shaped charges were weighed and radiographically inspected using two orthogonal views (see Table II).

TABLE II

LOADING DATA

<u>Charge No.</u>	<u>ECX Batch No.</u>	<u>ECX Wt gm</u>	<u>Radiograph Inspection</u>
1	1	464.3	Several low density areas from cone tip to base
2	1	465.1	Low density area in top center, 2 mm in size
3	1	465.0	No defects
4	1	465.3	Two low density areas in top, 3mm in size
5	1	465.2	No defects
6	1	465.0	No defects
7	2	466.0	No defects
8	2	462.5	Low density streak around cone tip
9	2	465.5	Low density area near top, 2 mm in size
10	2	464.1	* (one or two low density areas,
11	2	464.3	* 1-3 mm in size located near
12	2	464.5	* top in * marked charges.)
13	3	463.8	*
14	3	464.0	*
15	3	465.0	No defects
16	3	465.1	No defects
17	4	464.3	No defects
18	4	465.3	*
19	4	465.1	No defects
20	4	464.7	*
21	4	464.7	*
22	4	464.9	No defects
23	4	465.3	No defects
24	5	464.9	No defects
25	5	465.2	No defects
26	5	465.0	No defects
27	5	464.1	No defects
28	5	465.7	*
29	5	465.4	No defects
30	5	465.1	No defects

TEST FIRING

The basic setup for test firing is shown in Figure 1. A plastic detonator holder was centered on the top of the charge with a centering fixture and taped in place. The SE-1 detonator was then inserted into the holder and secured with a nut. The charge was centered over the targets by aligning with a level and plumb line.

After firing was completed, the total penetration was measured. The hole volumes were determined by filling the holes with water measured from a burette. The results are summarized in Table III and plotted in Figure 2 along with data from the Firestone experiments with RDX and Composition B.

TABLE III
PENETRATION AND HOLE VOLUME VS. STANDOFF DATA

<u>Standoff</u>		<u>Penetration</u>			<u>Volume, Cubic Inches</u>
<u>Charge Diameters</u>	<u>Inches</u>	<u>Charge No.</u>	<u>Charge Diameters</u>	<u>Inches</u>	
0.5	1.1	1	3.52	7.74	3.11
		2	3.42	7.52	3.66
		<u>3</u>	<u>3.53</u>	<u>7.78</u>	<u>3.90</u>
		Ave.	3.48	7.68	3.54
1.5	3.3	4	5.34	11.76	4.02
		5	5.12	11.28	3.97
		<u>6</u>	<u>4.78</u>	<u>10.51</u>	<u>3.90</u>
		Ave.	5.09	11.18	3.97
3.0	6.6	7	5.91	13.00	3.54
		8	5.08	11.17	3.48
		<u>9</u>	<u>6.37</u>	<u>14.02</u>	<u>3.84</u>
		Ave.	5.78	12.73	3.60
6.0	13.2	10	7.00	15.40	3.17
		11	6.90	15.18	3.36
		<u>12</u>	<u>6.96</u>	<u>15.32</u>	<u>3.36</u>
		Ave.	6.95	15.30	3.30

Figure 1.

Test Firing Setup.

Figure 2. Performance of 2.2 inch diameter shaped charges with 42° copper cones and 1 cone diameter explosive heads.

DISCUSSION

ECX offers some decided advantages over conventional explosives with respect to production techniques and equipment. Procedures for loading shaped charges with Composition B and Octol are presented for comparison with the relatively simple procedure used for loading charges with ECX.

EXPLOSIVE LOADING (3)

The loading procedure for the test charges was as follows:

Composition B

1. Preheat the metal parts to 200°F.
2. The metal parts were placed on a platen heated to 227°F. Each assembly had a conical mandrel that fitted the inside of the cone. The bottom end of the mandrel was in contact with the platen to improve heat conduction between the platen and the molten charge.
3. The pouring temperature of the explosive was 200°F. After pouring, the heated platen was moved under a heated hood and the test charges were raised into the hood. The charges were vibrated for 15 minutes and were then lowered so that the funnels were still inside the heated hood. The platen was cooled by circulating cold water through it while the funnels were kept hot. After one hour, the test charges were removed from under the hood to permit the explosive to cool to room temperature.

Octol

1. The metal parts were preheated to 200°F.
2. Same as 2 above.
3. The pouring temperature of the explosive was 215°F. The vibration period was 20 minutes. The cooling cycle was the same as 3 above.

After loading the test charges were faced off to the drawing and the explosive charge was radiographically inspected using two orthogonal views.

CONCLUSIONS

Based on the results of this study to date, it is apparent that there is a significant improvement in the performance of shaped charges loaded with RX-08-BA over charges loaded with either RDX or Composition B at 6 cone diameter standoffs. Further test firings will show if this improvement continues at longer standoffs. Additional diagnostics to be used in these tests (such as flash x-rays, high speed cameras, and foil switches) are designed to study the variables that influence performance.

- (3) Shaped Charge Linear Studies Using Various Materials, Contract Report No. 92, DRD-44, Firestone Tire & Rubber Co., Defense Research and Products Division, Akron, Ohio, March 1973.

R. E. D. and C. H. M.

CHARGE	TEST ASSY.	Q3 901	689-10	J. KESTNER	DATE	2-7-73
INSTRUMENT				CHECKED BY		
				W. W. WILKINS		247
				APPROVED		
RING-KEEPER						

LET	DRN	CH	DATE	ZONE	CHANGE

NOTES:

- 1) 63/ FINISH UNLESS OTHERWISE NOTED.
- 2) BREAK SHARP EDGES .02R MAX.

K.E.L. GEN LHM

JOB NO.

DATE	6-7-74
DR	J. L. L. L. L.
CHK	J. L. L. L. L.
APPROVED	J. L. L. L. L.
NO. REQ'D	1
MATERIAL	STEEL
SPEC. NO.	73-105550
STOCK NO.	73-105550

ITEM	PART NO.	DESCRIPTION	NO. REQ'D	MATERIAL	SPEC. NO.	STOCK NO.
		TUBE (SEAMLESS)		STEEL	73-105550	73-105550

1. DIMENSIONING AND TOLERANCING ARE PER USASI-Y14.5.

2. POSITIONAL AND FORM TOLERANCES APPLY R. F. S. (REGARDLESS OF FEATURE SIZE).

3. SURFACE TEXTURE PER USAS-B46.1.

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SHAPE CHARGE TEST ASSY JOB 401

BODY

LET	DRN	CH	DATE	ZONE	CHANGE

NOTES:

1.) 63/ F.A.O.

2.) VARIATION IN WALL STRAIGHTNESS SHALL NOT EXCEED .002 IN ANY AXIAL PLANE, VARIATION IN WALL THICKNESS SHALL NOT EXCEED .0005 IN ANY TRANSVERSE PLANE.

R.E.D. GEN. MEM.

JOB NO.

DATE	DR	ACCT. NO.	OR	DATE	DATE	DATE	DATE	DATE	DATE
4-9-73	JIT KESTNER	6886-10	CH	7-10-53	7-10-53	7-10-53	7-10-53	7-10-53	7-10-53
APPROVED	APPROVED	APPROVED	APPROVED	APPROVED	APPROVED	APPROVED	APPROVED	APPROVED	APPROVED

ITEM	PART NO.	DESCRIPTION	NO. REQ'D	MATERIAL	SPEC. NO.	STOCK NO.
1.		DIMENSIONING AND TOLERANCING ARE PER USASI-Y14.5.		COPPER	QQ-C-576-ETP	
2.		POSITIONAL AND FORM TOLERANCES APPLY R. F. S. (REGARDLESS OF FEATURE SIZE).				
3.		SURFACE TEXTURE PER USAS-B46.1.				

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LET	DRN	CH	DATE	ZONE	CHANGE

A.E.D. NEW LHM

JOB NO.

DATE	BY	CHK	APPROVED
4/10/75	W. KESTER	CHK	APPROVED
4/11/75	W. KESTER	CHK	APPROVED

ITEM	PART NO.	DESCRIPTION	NO. REQ'D	MATERIAL	SPEC. NO.	STOCK NO.
4		H.E. (SUPPLIED BY LLL)	1			
3	73-105449	BODY	1			
2	73-105448	CONE	1			
1	73-102322	RING-KEEPER	1			

NO. REQ'D PER ASSEM.
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2. POSITIONAL AND FORM TOLERANCES APPLY R. F. S. (REGARDLESS OF FEATURE SIZE).
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SHAPE CHARGE TEST ASSY JOB # 9101

DETAIL

LET	DATE	CH	DATE	ZONE	CHANGE

NOTE:

1. FOR REF. ONLY, DWG. NO 73-110485, HEMISPHERE, 8" & 16" NOT SHOWN.

FIGURE 2.
Sphere Test Assembly.

1-15	73-110472-2	ALIGNMENT PIN				
1-14	73-110474-2	INNER HEMISPHERE				
1-13	73-110473-2	LID				
1-12	73-110477-2	TABLE				
1-11	73-110478	OUTER HEMISPHERE, 16"				
1-10	73-110475	ALIGNMENT FIXTURE-16"				
-1	9	73-110472-1	ALIGNMENT PIN			
8-4	8	CLAMP, C 1" OPENING 1/2" DEPTH	STEEL		5120-25916	
3-3	7	PLUNGER, SPRING "STUBBY" 1/4-20NC	STEEL		VLIER *NM-55N OR EQ.	
-1	6	73-110474-1	INNER HEMISPHERE			
-1	5	73-110473-1	LID			
-1	4	73-110477-1	TABLE			
-1	3	73-110479	OUTER HEMISPHERE, 8"			
1-1	2	NUT, JAM HEX. HD. 3/8-16NC	STEEL CAB PLATED			
-1	1	73-110476	ALIGNMENT FIXTURE-8"			

73-110480-2	73-110480-1	ITEM	PART NO.	DESCRIPTION	NO. REQ'D	MATERIAL	SPEC. NO.	ILL STOCK NO.	
73-110480-2		1.	DIMENSIONING AND TOLERANCING ARE PER USAS-Y14.5.						
73-110480-1		2.	POSITIONAL AND FORM TOLERANCES APPLY R. F. S. (REGARDLESS OF FEATURE SIZE).						
		3.	SURFACE TEXTURE PER USAS-B46.1.						
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 JOB NO. 694566
 DATE 8-10-73
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 CHECKED BY J. T. KOSKIE
 APPROVED BY J. T. KOSKIE
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