

Mechanical Properties of Aerojet, Thiokol, and JA2 High-Energy Gun Propellants at 1.5 m/s Deformation Rate

by Michael G. Leadore

ARL-TR-2654

January 2002

Approved for public release; distribution is unlimited.

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Citation of manufacturer's or trade names does not constitute an official endorsement or approval of the use thereof.

Destroy this report when it is no longer needed. Do not return it to the originator.

Army Research Laboratory

Aberdeen Proving Ground, MD 21005-5069

ARL-TR-2654

January 2002

Mechanical Properties of Aerojet, Thiokol, and JA2 High-Energy Gun Propellants at 1.5 m/s Deformation Rate

Michael G. Leadore
Weapons and Materials Research Directorate, ARL

Approved for public release; distribution is unlimited.

Abstract

Five lots of high-energy gun propellants were tested in uniaxial compression at temperatures of 21°, 63°, and -32 °C. The materials were taken to ~60% strain using a deformation rate of 1.5 m/s. The stress at failure, strain at failure, compressive modulus, failure modulus, incremental energy density, and the fracture assessment values were recorded for each test.

Contents

List of Figures	v
List of Tables	v
1. Introduction	1
2. Background	1
3. Approach and Results	2
4. Conclusions	2
5. References	7
Distribution List	9
Report Documentation Page	25

INTENTIONALLY LEFT BLANK.

List of Figures

Figure 1. M1 Abrams tank with 120-mm gun	1
Figure 2. Aerojet, Thiokol, and JA2 lots of gun propellants as received.....	2
Figure 3. Preparing to test energetic material using high-rate load frame.	3
Figure 4. Stress vs. strain plot of Aerojet, JA2, and Thiokol propellants tested at 21 °C.....	5
Figure 5. Remains of specimens tested at 21°, 63°, and -32 °C.....	5
Figure 6. Stress vs. strain plot of Aerojet, JA2, and Thiokol propellants tested at 63 °C.....	6
Figure 7. Stress vs. strain plot of Aerojet, JA2, and Thiokol lots at -32 °C.	6

List of Tables

Table 1. Mechanical properties of Aerojet, Thiokol, and JA2 lots at 21°, 63°, and -32 °C	4
---	---

INTENTIONALLY LEFT BLANK.

1. Introduction

The following is the U.S. Army Research Laboratory's (ARL's) report of the material test systems (MTS) servo-hydraulic tester (SHT) high-rate mechanical response of one lot of Aerojet 3744 lot no. 8194D, and three lots of Thiokol lot no. JA-1835-2-01, JA-1835-2-02, and JA-1835-2-03. The Aerojet and Thiokol materials are Future Combat System candidate (Figure 1) gun propellants (test sets 65-80 Fiscal 01). A production lot of JA2 lot no. HCL93-J014-001 was also tested using similar test conditions for comparative purposes.



Figure 1. M1 Abrams tank with 120-mm gun.

2. Background

ARL received four lots of Aerojet and Thiokol gun propellants (Figure 2) from Ms. Thelma Manning of the U.S. Army Armament Research, Development, and Engineering Center (ARDEC). The Aerojet next-generation high-energy propellant was manufactured in a mixer and extruded thermally into a solid-sheet configuration. The sheet material had a thickness of ~1.3 mm. Several sheets from the lot of experimental gun propellant were shipped to Dr. Robert Lieb of ARL. The Thiokol lots were extruded into solid-stick configuration and also shipped to Dr. Lieb. Also, a production lot of JA2 granular propellant was procured from Aberdeen Proving Ground (APG) for comparison testing. All of these materials were tested during August 2001 for high-rate uniaxial compression mechanical response evaluation.

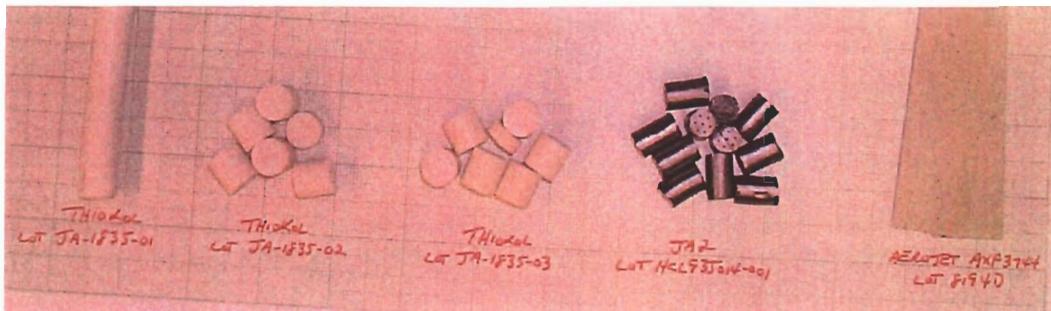


Figure 2. Aerojet, Thiokol, and JA2 lots of gun propellants as received.

3. Approach and Results

The Aerojet propellant was received in solid-sheet form and was without perforations. The lot was cut into test specimens with a length-to-diameter (L/D) ratio of 0.96.

Specimen preparation was accomplished using a 12.7-mm-diameter hole punch. Sample ends were machined so that the surfaces were flat, parallel to each other, and perpendicular to the extruded axis. The Thiokol lots were received as solid-stick with a diameter of 12.68 mm and were cut into test specimens using a double-bladed diamond saw. The JA2 lot was granular with a diameter of 9.80 mm and was also cut using a diamond saw.

MTS SHT mechanical properties tests [1-7] were conducted on several specimens under each test condition (Figure 3). Strain rates of 125.0 s^{-1} were achieved. The specimens were taken to failure at ambient pressure to ~50% end strain while conditioned at temperatures of 21° , 63° , and -32°C . The stress at failure, strain at failure, modulus, failure modulus, incremental energy density, and fracture assessment value were recorded for each test. The average values achieved from the tests are listed in Table 1.

4. Conclusions

One lot of Aerojet 3744 lot no. 8194D, three lots of Thiokol high-energy gun propellants, and one production lot of JA2 were tested for mechanical response at ambient pressure while conditioned at 21° , 63° , and -32°C . The materials were tested in uniaxial compression to ~50% end strain using a deformation rate of 1.50 m/s .



Figure 3. Preparing to test energetic material using high-rate load frame.

At 21 °C, the Aerojet lot, Thiokol lots, and the JA2 lot all showed good response to uniaxial compression. The positive failure modulus values achieved indicated each lot's abilities to sustain load beyond 50% strain. Note the stress vs. strain plot (Figure 4) shows the JA2 lot workhardening beyond 50% strain. The tested specimens (Figure 5) suffered permanent deformation with minimal fracturing.

At 63 °C, again, the mechanical response of all lots were quite good. The Young's modulus values showed some "softening" as a result of the higher testing temperature, as would be expected. The stress/strain plot (Figure 6) shows all lots able at sustaining load. The tested specimens (see Figure 5) again showed very minimal axial fracture and deformation.

At -32 °C, the tested specimens (see Figure 5) suffered moderate amounts of axial and shear fracture; however, the core area of the tested specimens remained mostly whole. Note the stress/strain plot at -32 °C (Figure 7) shows the JA2 lot able at sustaining load and workhardening up to 50% strain and thus the only lot yielding a positive failure modulus value. The Thiokol lots showed more strength at yield than the Aerojet lot.

Overall, each material's mechanical response at 21° and 63 °C was quite good. At -32 °C, the JA2 lot was clearly the better material, followed by the Thiokol and Aerojet lots.

Table 1. Mechanical properties of Aerojet, Thiokol, and JA2 lots at 21°, 63°, and -32 °C.

Lot	Stress at Failure (MPa)	Strain at Failure (%)	Modulus (GPa)	Failure Modulus ^a (GPa)	IED ^b (MPa)	FAV ^c (MPa)
at 21 °C						
Aerojet 3744 Lot 8194D	17.60	13.32	0.251	0.0034	11.60	1AB
Thiokol Lot JA-1835-01	37.02	7.75	0.642	-0.0271	8.31	1AB
Thiokol Lot JA-1835-02	31.28	8.01	0.502	0.0311	7.87	1AB
Thiokol Lot JA-1835-03	35.33	14.05	0.346	0.0177	7.10	2AB
JA2 Lot HCL93J014001	16.87	4.56	0.722	0.0523	5.37	1B
at 63 °C						
Aerojet 3744 Lot 8194D	7.74	11.05	0.094	0.0046	1.54	1AB
Thiokol Lot JA-1835-01	13.81	10.33	0.202	-0.0212	2.76	1B
Thiokol Lot JA-1835-02	12.58	14.12	0.122	0.0067	2.30	1B
Thiokol Lot JA-1835-03	12.03	17.55	0.085	0.0071	2.20	1B
JA2 Lot HCL93J014001	8.86	4.59	0.244	0.0290	2.57	1B
at -32 °C						
Aerojet 3744 Lot 8194D	67.56	7.73	1.78	-0.260	13.07	5AS
Thiokol Lot JA-1835-01	111.91	7.03	2.79	-0.352	19.88	5AS
Thiokol Lot JA-1835-02	106.43	7.12	2.15	-0.220	19.40	5AS
Thiokol Lot JA-1835-03	108.35	7.05	2.38	-0.180	21.41	6AS
JA2 Lot HCL93J014001	54.03	7.09	1.61	0.067	13.82	5AS

^aThe failure modulus (slope of the curve after failure) has been added. Generally, the lower the value, the worse the material (i.e., negative value indicates the material is unable to sustain load). A positive value indicates a positive failure slope (i.e., the material is better able to support load after failure).

^bThe incremental energy density (IED) value reported is the amount of energy per unit volume absorbed at 25% strain; this includes a portion of the area located beneath the stress/strain curve.

^cThe tested specimens were assigned a fracture assessment value (FAV). The values range from 0 (no observed fracturing) through 9 (severe fracturing observed). The type of fracture was also characterized using the following methodology: A = axial fracture, S = shear fracture, B = barreling/deformation, R = radial splitting (i.e., 9A indicates the tested specimens showed a severe amount of axial fracture).

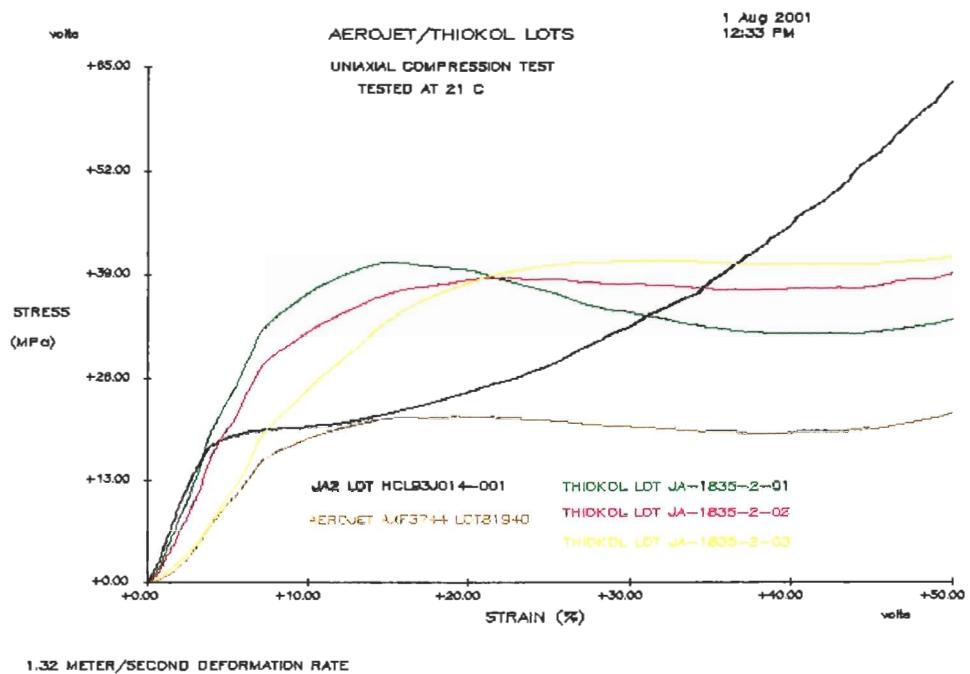


Figure 4. Stress vs. strain plot of Aerojet, JA2, and Thiokol propellants tested at 21 °C.

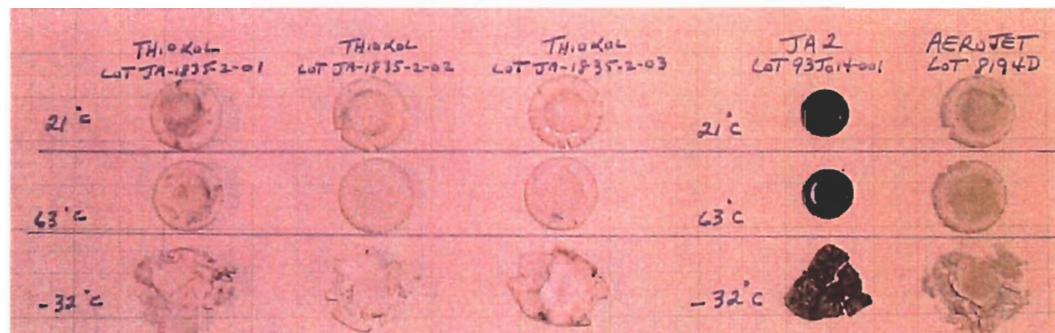


Figure 5. Remains of specimens tested at 21°, 63°, and -32 °C.

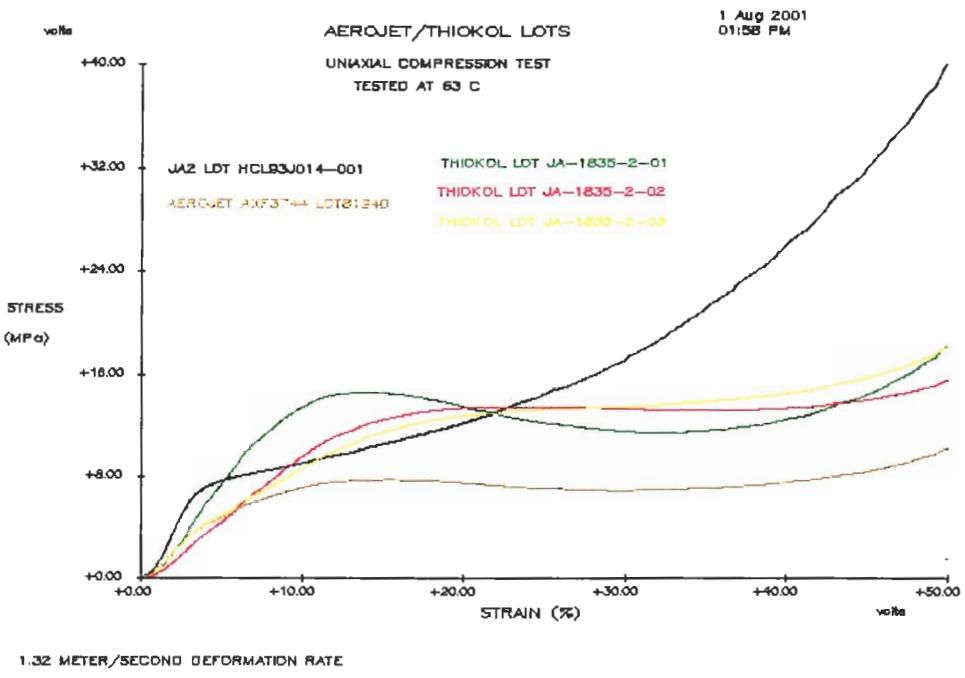


Figure 6. Stress vs. strain plot of Aerojet, JA2, and Thiokol propellants tested at 63 °C.

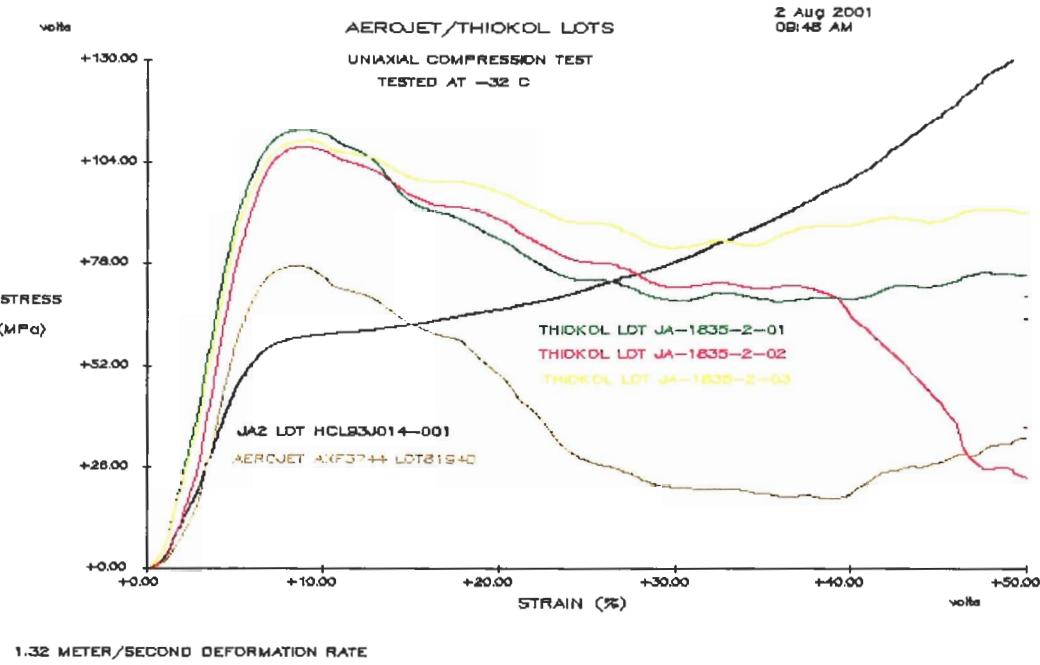


Figure 7. Stress vs. strain plot of Aerojet, JA2, and Thiokol lots at -32 °C.

5. References

1. Gazonas, G. A. "The Mechanical Response of M30, XM39, and JA2 Propellants at Strain Rates From 10-2 to 250 Sec-1." BRL-TR-3181, U.S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, MD, January 1991.
2. Lieb, R. J. "Impact-Generated Surface Area in Gun Propellant." BRL-TR-2946, U.S. Army Ballistic Research Laboratory, Aberdeen Proving Ground, MD, November 1988.
3. Lieb, R. J., and J. J. Rocchio. "High Strain Rate Mechanical Properties Testing on Lots of Solid Gun Propellant With Deviant Interior Ballistic Performance." *1982 JANNAF Structures and Mechanical Behavior Subcommittee Meeting*, CPIA Publication 368, pp. 23-38, October 1982.
4. Leadore, M. G. "MTS Servo-Hydraulic Tester (SHT) Mechanical Properties Evaluation of M43 Propellants." ARL-TN-5, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, March 1993.
5. Leadore, M. G., and C. J. Gillich. "Material Testing System (MTS) Servo-Hydraulic Tester (SHT) Mechanical Response of Energetic Thermal Plastic Elastomer (ETPE) RDX-Based Propellants." ARL-TN-28, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, April 1994.
6. Leadore, M. G. "Mechanical Response of Energetic Thermoplastic Elastomer Low-Vulnerability Ammunition (ETPE-LOVA) RDX-Based, TNAZ-Based, and CL-20-Based Gun Propellants." ARL-TN-64, U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, March 1996.
7. Lieb, R. J. Personal communication. U.S. Army Research Laboratory, Aberdeen Proving Ground, MD, August 2001.

INTENTIONALLY LEFT BLANK.

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>	<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
2	DEFENSE TECHNICAL INFORMATION CENTER DTIC OCA 8725 JOHN J KINGMAN RD STE 0944 FT BELVOIR VA 22060-6218	3	DIRECTOR US ARMY RESEARCH LAB AMSRL CI LL 2800 POWDER MILL RD ADELPHI MD 20783-1197
1	HQDA DAMO FDT 400 ARMY PENTAGON WASHINGTON DC 20310-0460	3	DIRECTOR US ARMY RESEARCH LAB AMSRL CI IS T 2800 POWDER MILL RD ADELPHI MD 20783-1197
1	OSD OUSD(A&T)/ODDR&E(R) DR R J TREW 3800 DEFENSE PENTAGON WASHINGTON DC 20301-3800	<u>ABERDEEN PROVING GROUND</u>	
1	COMMANDING GENERAL US ARMY MATERIEL CMD AMCRDA TF 5001 EISENHOWER AVE ALEXANDRIA VA 22333-0001	2	DIR USARL AMSRL CI LP (BLDG 305)
1	INST FOR ADVNCED TCHNLGY THE UNIV OF TEXAS AT AUSTIN 3925 W BRAKER LN STE 400 AUSTIN TX 78759-5316		
1	US MILITARY ACADEMY MATH SCI CTR EXCELLENCE MADN MATH THAYER HALL WEST POINT NY 10996-1786		
1	DIRECTOR US ARMY RESEARCH LAB AMSR D DR D SMITH 2800 POWDER MILL RD ADELPHI MD 20783-1197		
1	DIRECTOR US ARMY RESEARCH LAB AMSR CI AI R 2800 POWDER MILL RD ADELPHI MD 20783-1197		

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>	<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	DIRECTOR US ARMY RESEARCH LAB AMSRL CP CA D SNIDER 2800 POWDER MILL RD ADELPHI MD 20783-1145	1	COMMANDER US ARMY ARDEC AMSTA AR FSE PICATINNY ARSENAL NJ 07806-5000
1	DIRECTOR US ARMY RESEARCH LAB AMSRL CI IS R 2800 POWDER MILL RD ADELPHI MD 20783-1145	1	COMMANDER US ARMY ARDEC AMSTA AR TD C SPINELLI PICATINNY ARSENAL NJ 07806-5000
3	DIRECTOR US ARMY RESEARCH LAB AMSRL OP SD TL 2800 POWDER MILL RD ADELPHI MD 20783-1145	6	COMMANDER US ARMY ARDEC AMSTA AR CCH A W ANDREWS S MUSALLI R CARR M LUCIANO E LOGSDEN T LOUZEIRO PICATINNY ARSENAL NJ 07806-5000
1	DPTY ASST SECY FOR R&T SARD TT THE PENTAGON RM 3EA79 WASHINGTON DC 20301-7100	1	COMMANDER US ARMY MATERIEL CMD AMXMI INT 5001 EISENHOWER AVE ALEXANDRIA VA 22333-0001
1	COMMANDER US ARMY ARDEC AMSTA AR CC G PAYNE J GEHBAUER C BAULIEU H OPAT PICATINNY ARSENAL NJ 07806-5000	1	COMMANDER US ARMY ARDEC AMSTA AR CCH P J LUTZ PICATINNY ARSENAL NJ 07806-5000
4	COMMANDER US ARMY ARDEC AMSTA AR CC G PAYNE J GEHBAUER C BAULIEU H OPAT PICATINNY ARSENAL NJ 07806-5000	1	COMMANDER US ARMY ARDEC AMSTA AR FSF T C LIVECCHIA PICATINNY ARSENAL NJ 07806-5000
2	COMMANDER US ARMY ARDEC AMSTA AR AE WW E BAKER J PEARSON PICATINNY ARSENAL NJ 07806-5000	1	COMMANDER US ARMY ARDEC AMSTA ASF PICATINNY ARSENAL NJ 07806-5000
		1	COMMANDER US ARMY ARDEC AMSTA AR QACT C C PATEL PICATINNY ARSENAL NJ 07806-5000

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>	<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	COMMANDER US ARMY ARDEC AMSTA AR M D DEMELLA PICATINNY ARSENAL NJ 07806-5000	1	US ARMY ARDEC INTELLIGENCE SPECIALIST AMSTA AR WEL F M GUERRIERE PICATINNY ARSENAL NJ 07806-5000
3	COMMANDER US ARMY ARDEC AMSTA AR FSA A WARNASH B MACHAK M CHIEFA PICATINNY ARSENAL NJ 07806-5000	9	COMMANDER US ARMY ARDEC AMSTA AR CCH B P DONADIA F DONLON P VALENTI C KNUTSON G EUSTICE S PATEL G WAGNECZ R SAYER F CHANG PICATINNY ARSENAL NJ 07806-5000
2	COMMANDER US ARMY ARDEC AMSTA AR FSP G M SCHIKSNIS D CARLUCCI PICATINNY ARSENAL NJ 07806-5000	6	COMMANDER US ARMY ARDEC AMSTA AR CCL F PUZYCKI R MCHUGH D CONWAY E JAROSZEWSKI R SCHLENNER M CLUNE PICATINNY ARSENAL NJ 07806-5000
1	COMMANDER US ARMY ARDEC AMSTA AR FSP A P KISATSKY PICATINNY ARSENAL NJ 07806-5000	5	PM SADARM SFAE GCSS SD COL B ELLIS M DEVINE W DEMASSI J PRITCHARD S HROWNAK PICATINNY ARSENAL NJ 07806-5000
2	COMMANDER US ARMY ARDEC AMSTA AR CCH C H CHANIN S CHICO PICATINNY ARSENAL NJ 07806-5000	2	PEO FIELD ARTILLERY SYS SFAE FAS PM H GOLDMAN T MCWILLIAMS PICATINNY ARSENAL NJ 07806-5000
1	COMMANDER US ARMY ARDEC AMSTA AR QAC T D RIGOGLIOSO PICATINNY ARSENAL NJ 07806-5000		
1	COMMANDER US ARMY ARDEC AMSTA AR WET T SACHAR BLDG 172 PICATINNY ARSENAL NJ 07806-5000		

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>	<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	COMMANDER US ARMY ARDEC AMSTA AR WEA J BRESCIA PICATINNY ARSENAL NJ 07806-5000	1	DIRECTOR AIR FORCE RESEARCH LAB MLLMD D MIRACLE 2230 TENTH ST WRIGHT PATTISON AFB OH 45433-7817
12	PM TMAS SFAE GSSC TMA R MORRIS C KIMKER D GUZIEWICZ E KOPACZ R ROESER R DARCY R KOWALSKI R MCDANOLDS L D ULISS C ROLLER J MCGREEN B PATTER PICATINNY ARSENAL NJ 07806-5000	1	OFC OF NAVAL RESEARCH J CHRISTODOULOU ONR CODE 332 800 N QUINCY ST ARLINGTON VA 22217-5600
1	COMMANDER US ARMY ARDEC PRODUCTION BASE MODERN ACTY AMSMC PBM K PICATINNY ARSENAL NJ 07806-5000	1	US ARMY CERL R LAMPO 2902 NEWMARK DR CHAMPAIGN IL 61822
1	COMMANDER US ARMY TACOM PM SURVIVABLE SYSTEMS SFAE GCSS W GSI H M RYZI 6501 ELEVEN MILE RD WARREN MI 48397-5000	1	COMMANDER US ARMY TACOM CHIEF ABRAMS TESTING SFAE GCSS W AB QT T KRASKIEWICZ 6501 ELEVEN MILE RD WARREN MI 48397-5000
1	COMMANDER US ARMY TACOM PM ABRAMS SFAE ASM AB 6501 ELEVEN MILE RD WARREN MI 48397-5000	1	COMMANDER WATERVLIET ARSENAL SMCWV QAE Q B VANINA BLDG 44 WATERVLIET NY 12189-4050
1	COMMANDER US ARMY TACOM AMSTA SF WARREN MI 48397-5000	3	ARMOR SCHOOL ATZK TD R BAUEN J BERG A POMEY FT KNOX KY 40121
1	COMMANDER US ARMY TACOM PM BFVS SFAE GCSS W BV 6501 ELEVEN MILE RD WARREN MI 48397-5000		

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>	<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
2	HQ IOC TANK AMMUNITION TEAM AMSIOSMT RCRAWFORD WHARRIS ROCK ISLAND IL 61299-6000	1	DIRECTOR US ARMY AMCOM SFAE AV RAM TV DCALDWELL BLDG 5300 REDSTONE ARSENAL AL 35898
2	COMMANDER US ARMY AMCOM AVIATION APPLIED TECH DIR JSCHUCK FT EUSTIS VA 23604-5577	1	NAVAL SURFACE WARFARE CTR DAHlgren DIV CODE G06 DAHlgren VA 22448
14	COMMANDER US ARMY TACOM AMSTA TR R RMCCLELLAND D THOMAS JBENNETT DHANSEN AMSTA JSK SGOODMAN J FLORENCE KIYER D TEMPLETON ASCHUMACHER AMSTA TR D DOSTBERG L HINOJOSA B RAJU AMSTA CS SF HHUTCHINSON FSCHWARZ WARREN MI 48397-5000	2	US ARMY CORPS OF ENGINEERS CERD C TLIU CEW ET TTAN 20 MASS AVE NW WASHINGTON DC 20314
		1	US ARMY COLD REGIONS RSCH & ENGRNG LAB PDUTTA 72 LYME RD HANOVER NH 03755
		1	USA SBCCOM PM SOLDIER SPT AMSSB PM RSS A JCONNORS KANSAS ST NATICK MA 01760-5057
14	BENET LABORATORIES AMSTA AR CCB RFISCELLA MSOJA EKATHE MSCAVULO GSPENCER PWHEELER SKRUPSKI JVASILAKIS GFRIAR R HASENBEIN AMSTA CCB R SSOPOK EHYLAND DCRAYON RDILLON WATERVLIET NY 12189-4050	2	USA SBCCOM MATERIAL SCIENCE TEAM AMSSB RSS JHERBERT MSENNETT KANSAS ST NATICK MA 01760-5057
		2	OFC OF NAVAL RESEARCH DSIEGEL CODE 351 JKELLY 800 N QUINCY ST ARLINGTON VA 22217-5660
		1	NAVAL SURFACE WARFARE CTR TECH LIBRARY CODE 323 17320 DAHlgren RD DAHlgren VA 22448

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>	<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	NAVAL SURFACE WARFARE CTR CRANE DIVISION M JOHNSON CODE 20H4 LOUISVILLE KY 40214-5245	8	US ARMY SBCCOM SOLDIER SYSTEMS CENTER BALLISTICS TEAM J WARD W ZUKAS P CUNNIEFF J SONG MARINE CORPS TEAM J MACKIEWICZ BUS AREA ADVOCACY TEAM W HASKELL AMSSB RCP SS W NYKVIST S BEAUDOIN KANSAS ST NATICK MA 01760-5019
2	NAVAL SURFACE WARFARE CTR U SORATHIA C WILLIAMS CD 6551 9500 MACARTHUR BLVD WEST BETHESDA MD 20817		
2	COMMANDER NAVAL SURFACE WARFARE CTR CARDEROCK DIVISION R PETERSON CODE 2020 M CRITCHFIELD CODE 1730 BETHESDA MD 20084		
8	DIRECTOR US ARMY NATIONAL GROUND INTELLIGENCE CTR D LEITER MS 404 M HOLTUS MS 301 M WOLFE MS 307 S MINGLEDORF MS 504 J GASTON MS 301 W GSTATTENBAUER MS 304 R WARNER MS 305 J CRIDER MS 306 220 SEVENTH ST NE CHARLOTTESVILLE VA 22091	9	US ARMY RESEARCH OFC A CROWSON H EVERETT J PRATER G ANDERSON D STEPP D KISEROW J CHANG PO BOX 12211 RESEARCH TRIANGLE PARK NC 27709-2211
1	NAVAL SEA SYSTEMS CMD D LIESE 2531 JEFFERSON DAVIS HWY ARLINGTON VA 22242-5160	8	NAVAL SURFACE WARFARE CTR J FRANCIS CODE G30 D WILSON CODE G32 R D COOPER CODE G32 J FRAYSSE CODE G33 E ROWE CODE G33 T DURAN CODE G33 L DE SIMONE CODE G33 R HUBBARD CODE G33 DAHLGREN VA 22448
1	NAVAL SURFACE WARFARE CTR M LACY CODE B02 17320 DAHLGREN RD DAHLGREN VA 22448	2	NAVAL SURFACE WARFARE CTR CARDEROCK DIVISION R CRANE CODE 2802 C WILLIAMS CODE 6553 3A LEGGETT CIR BETHESDA MD 20054-5000
1	EXPEDITIONARY WARFARE DIV N85 F SHOUP 2000 NAVY PENTAGON WASHINGTON DC 20350-2000	1	AFRL MLBC 2941 P ST RM 136 WRIGHT PATTERSON AFB OH 45433-7750

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>	<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	AFRL MLSS R THOMSON 2179 12TH ST RM 122 WRIGHT PATTERSON AFB OH 45433-7718	2	SERDP PROGRAM OFC PM P2 C PELLERIN B SMITH 901 N STUART ST STE 303 ARLINGTON VA 22203
2	AFRL F ABRAMS J BROWN BLDG 653 2977 P ST STE 6 WRIGHT PATTERSON AFB OH 45433-7739	1	US DEPT OF ENERGY OFC OF ENVIRONMENTAL MANAGEMENT P RITZCOVAN 19901 GERMANTOWN RD GERMANTOWN MD 20874-1928
1	WATERWAYS EXPERIMENT D SCOTT 3909 HALLS FERRY RD SC C VICKSBURG MS 39180	1	OAK RIDGE NATIONAL LABORATORY R M DAVIS PO BOX 2008 OAK RIDGE TN 37831-6195
5	DIRECTOR LLNL R CHRISTENSEN S DETERESA F MAGNESS M FINGER MS 313 M MURPHY L 282 PO BOX 808 LIVERMORE CA 94550	1	OAK RIDGE NATIONAL LABORATORY C EBERLE MS 8048 PO BOX 2008 OAK RIDGE TN 37831
1	AFRL MLS OL L COULTER 7278 4TH ST BLDG 100 BAY D HILL AFB UT 84056-5205	3	DIRECTOR SANDIA NATIONAL LABS APPLIED MECHANICS DEPT MS 9042 J HANDROCK Y R KAN J LAUFFER PO BOX 969 LIVERMORE CA 94551-0969
1	OSD JOINT CCD TEST FORCE OSD JCCD R WILLIAMS 3909 HALLS FERRY RD VICKSBURG MS 29180-6199	1	OAK RIDGE NATIONAL LABORATORY C D WARREN MS 8039 PO BOX 2008 OAK RIDGE TN 37831
3	DARPA M VANFOSSEN S WAX L CHRISTODOULOU 3701 N FAIRFAX DR ARLINGTON VA 22203-1714	4	NIST M VANLANDINGHAM MS 8621 J CHIN MS 8621 J MARTIN MS 8621 D DUTHINH MS 8611 100 BUREAU DR GAITHERSBURG MD 20899
1	DIRECTOR LOS ALAMOS NATIONAL LAB F L ADDESSIO T 3 MS 5000 PO BOX 1633 LOS ALAMOS NM 87545		

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>	<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	HYDROGEOLOGIC INC SERDP ESTCP SPT OFC S WALSH 1155 HERNDON PKWY STE 900 HERNDON VA 20170	2	3TEX CORPORATION A BOGDANOVICH J SINGLETON 109 MACKENAN DR CARY NC 27511
3	NASA Langley RSCH CTR AMSLR VS W ELBER MS 266 F BARTLETT JR MS 266 G FARLEY MS 266 HAMPTON VA 23681-0001	1	3M CORPORATION J SKILDUM 3M CENTER BLDG 60 IN 01 ST PAUL MN 55144-1000
1	NASA Langley RSCH CTR T GATES MS 188E HAMPTON VA 23661-3400	1	DIRECTOR DEFENSE INTLLGNC AGNCY TA 5 K CRELLING WASHINGTON DC 20310
1	FHWA E MUNLEY 6300 GEORGETOWN PIKE MCLEAN VA 22101	1	ADVANCED GLASS FIBER YARNS T COLLINS 281 SPRING RUN LANE STE A DOWNINGTON PA 19335
1	USDOT FEDERAL RAILRD M FATEH RDV 31 WASHINGTON DC 20590	1	COMPOSITE MATERIALS INC D SHORTT 19105 63 AVE NE PO BOX 25 ARLINGTON WA 98223
3	CYTEC FIBERITE R DUNNE D KOHLI R MAYHEW 1300 REVOLUTION ST HAVRE DE GRACE MD 21078	1	JPS GLASS L CARTER PO BOX 260 SLATER RD SLATER SC 29683
1	MARINE CORPS INTLLGNC ACTVITY D KOSITZKE 3300 RUSSELL RD STE 250 QUANTICO VA 22134-5011	1	COMPOSITE MATERIALS INC R HOLLAND 11 JEWEL CT ORINDA CA 94563
1	DIRECTOR NATIONAL GRND INTLLGNC CTR LANG TMT 220 SEVENTH ST NE CHARLOTTESVILLE VA 22902-5396	1	COMPOSITE MATERIALS INC C RILEY 14530 S ANSON AVE SANTA FE SPRINGS CA 90670
1	SIOUX MFG B KRIEL PO BOX 400 FT TOTTEN ND 58335	2	SIMULA J COLTMAN R HUYETT 10016 S 51ST ST PHOENIX AZ 85044

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>	<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
2	PROTECTION MATERIALS INC M MILLER F CRILLEY 14000 NW 58 CT MIAMI LAKES FL 33014	1	NATIONAL COMPOSITE CENTER T CORDELL 2000 COMPOSITE DR KETTERING OH 45420
2	FOSTER MILLER M ROYLANCE W ZUKAS 195 BEAR HILL RD WALTHAM MA 02354-1196	3	PACIFIC NORTHWEST LAB M SMITH G VAN ARSDALE R SHIPPELL PO BOX 999 RICHLAND WA 99352
1	ROM DEVELOPMENT CORP R O MEARA 136 SWINEBURNE ROW BRICK MARKET PLACE NEWPORT RI 02840	2	AMOCO PERFORMANCE PRODUCTS M MICHNO JR J BANISAUkas 4500 MCGINNIS FERRY RD ALPHARETTA GA 30202-3944
2	TEXTRON SYSTEMS T FOLTZ M TREASURE 1449 MIDDLESEX ST LOWELL MA 01851	8	ALLIANT TECHSYSTEMS INC C CANDLAND MN11 2830 C AAKHUS MN11 2830 B SEE MN11 2439 N VLAHAKUS MN11 2145 R DOHRN MN11 2830 S HAGLUND MN11 2439 M HISSONG MN11 2830 D KAMDAR MN11 2830 600 SECOND ST NE HOPKINS MN 55343-8367
1	O GARA HESS & EISENHARDT M GILLESPIE 9113 LEESAINT DR FAIRFIELD OH 45014		
2	MILLIKEN RSCH CORP H KUHN M MACLEOD PO BOX 1926 SPARTANBURG SC 29303	1	SAIC M PALMER 1410 SPRING HILL RD STE 400 MS SH4 5 MCLEAN VA 22102
1	CONNEAUGHT INDUSTRIES INC J SANTOS PO BOX 1425 COVENTRY RI 02816	1	SAIC G CHRYSSOMALLIS 3800 W 80TH ST STE 1090 BLOOMINGTON MN 55431
1	BATTELLE NATICK OPNS B HALPIN 209 W CENTRAL ST STE 302 NATICK MA 01760	1	AAI CORPORATION T G STASTNY PO BOX 126 HUNT VALLEY MD 21030-0126
1	ARMTEC DEFENSE PRODUCTS S DYER 85 901 AVE 53 PO BOX 848 COACHELLA CA 92236	1	APPLIED COMPOSITES W GRISCH 333 NORTH SIXTH ST ST CHARLES IL 60174

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>	<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	CUSTOM ANALYTICAL ENG SYS INC A ALEXANDER 13000 TENSOR LANE NE FLINTSTONE MD 21530	1	GENERAL DYNAMICS OTS L WHITMORE 10101 NINTH ST NORTH ST PETERSBURG FL 33702
1	OFC DEPUTY UNDER SEC DEFNS J THOMPSON 1745 JEFFERSON DAVIS HWY CRYSTAL SQ 4 STE 501 ARLINGTON VA 22202	3	GENERAL DYNAMICS OTS FLINCHBAUGH DIV E STEINER B STEWART T LYNCH PO BOX 127 RED LION PA 17356
3	ALLIANT TECHSYSTEMS INC J CONDON E LYNAM J GERHARD WV01 16 STATE RT 956 PO BOX 210 ROCKET CENTER WV 26726-0210	1	GKN AEROSPACE D OLDS 15 STERLING DR WALLINGFORD CT 06492
1	PROJECTILE TECHNOLOGY INC 515 GILES ST HAVRE DE GRACE MD 21078	5	SIKORSKY AIRCRAFT G JACARUSO T CARSTENSAN B KAY S GARBO MS S330A J ADELMANN 6900 MAIN ST PO BOX 9729 STRATFORD CT 06497-9729
3	HEXCEL INC R BOE PO BOX 18748 SALT LAKE CITY UT 84118	1	PRATT & WHITNEY C WATSON 400 MAIN ST MS 114 37 EAST HARTFORD CT 06108
5	AEROJET GEN CORP D PILLASCH T COULTER C FLYNN D RUBAREZUL M GREINER 1100 WEST HOLLYVALE ST AZUSA CA 91702-0296	1	AEROSPACE CORP G HAWKINS M4 945 2350 E EL SEGUNDO BLVD EL SEGUNDO CA 90245
1	HERCULES INC HERCULES PLAZA WILMINGTON DE 19894	2	CYTEC FIBERITE M LIN W WEB 1440 N KRAEMER BLVD ANAHEIM CA 92806
1	BRIGS COMPANY J BACKOFEN 2668 PETERBOROUGH ST HERNDON VA 22071-2443	1	UDLP G THOMAS PO BOX 58123 SANTA CLARA CA 95052
1	ZERNOW TECHNICAL SERVICES L ZERNOW 425 W BONITA AVE STE 208 SAN DIMAS CA 91773		

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>	<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
2	UDLP R BARRETT MAIL DROP M53 V HORVATICH MAIL DROP M53 328 W BROKAW RD SANTA CLARA CA 95052-0359	1	NORTHROP GRUMMAN CORP ELECTRONIC SENSORS & SYSTEMS DIV E SCHOCH MS V 16 1745A W NURSERY RD LINTHICUM MD 21090
3	UDLP GROUND SYSTEMS DIVISION M PEDRAZZI MAIL DROP N09 A LEE MAIL DROP N11 M MACLEAN MAIL DROP N06 1205 COLEMAN AVE SANTA CLARA CA 95052	1	GDLS DIVISION D BARTLE PO BOX 1901 WARREN MI 48090
4	UDLP R BRYNSVOLD P JANKE MS 170 4800 EAST RIVER RD MINNEAPOLIS MN 55421-1498	2	GDLS D REES M PASIK PO BOX 2074 WARREN MI 48090-2074
2	BOEING ROTORCRAFT P MINGURT P HANDEL 800 B PUTNAM BLVD WALLINGFORD PA 19086	1	GDLS MUSKEGON OPERATIONS W SOMMERS JR 76 GETTY ST MUSKEGON MI 49442
1	BOEING DOUGLAS PRODUCTS DIV L J HART SMITH 3855 LAKEWOOD BLVD D800 0019 LONG BEACH CA 90846-0001	1	GENERAL DYNAMICS AMPHIBIOUS SYS SURVIVABILITY LEAD G WALKER 991 ANNAPOLIS WAY WOODBRIDGE VA 22191
1	LOCKHEED MARTIN SKUNK WORKS D FORTNEY 1011 LOCKHEED WAY PALMDALE CA 93599-2502	6	INST FOR ADVANCED TECH H FAIR I MCNAB P SULLIVAN S BLESS W REINECKE C PERSAD
1	LOCKHEED MARTIN R FIELDS 1195 IRWIN CT WINTER SPRINGS FL 32708		3925 W BRAKER LN STE 400 AUSTIN TX 78759-5316
1	MATERIALS SCIENCES CORP G FLANAGAN 500 OFC CENTER DR STE 250 FT WASHINGTON PA 19034	2	CIVIL ENGR RSCH FOUNDATION PRESIDENT H BERNSTEIN R BELLE 1015 15TH ST NW STE 600 WASHINGTON DC 20005

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>	<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	ARROW TECH ASSO 1233 SHELBOURNE RD STE D8 SOUTH BURLINGTON VT 05403-7700	2	PENN STATE UNIV R MCNITT C BAKIS 212 EARTH ENGR SCIENCES BLDG UNIVERSITY PARK PA 16802
1	R EICHELBERGER CONSULTANT 409 W CATHERINE ST BEL AIR MD 21014-3613	1	PENN STATE UNIV R S ENGEL 245 HAMMOND BLDG UNIVERSITY PARK PA 16801
1	UCLA MANE DEPT ENGR IV H T HAHN LOS ANGELES CA 90024-1597	1	PURDUE UNIV SCHOOL OF AERO & ASTRO C T SUN W LAFAYETTE IN 47907-1282
2	UNIV OF DAYTON RESEARCH INST R Y KIM A K ROY 300 COLLEGE PARK AVE DAYTON OH 45469-0168	1	STANFORD UNIV DEPT OF AERONAUTICS & AEROBALLISTICS S TSAI DURANT BLDG STANFORD CA 94305
1	UMASS LOWELL PLASTICS DEPT N SCHOTT 1 UNIVERSITY AVE LOWELL MA 01854	1	UNIV OF MAINE ADV STR & COMP LAB R LOPEZ ANIDO 5793 AEWC BLDG ORONO ME 04469-5793
1	IIT RESEARCH CENTER D ROSE 201 MILL ST ROME NY 13440-6916	1	JOHNS HOPKINS UNIV APPLIED PHYSICS LAB P WIENHOLD 11100 JOHNS HOPKINS RD LAUREL MD 20723-6099
1	GA TECH RSCH INST GA INST OF TCHNLGY P FRIEDERICH ATLANTA GA 30392	1	UNIV OF DAYTON J M WHITNEY COLLEGE PARK AVE DAYTON OH 45469-0240
1	MICHIGAN ST UNIV MSM DEPT R AVERILL 3515 EB EAST LANSING MI 48824-1226	5	UNIV OF DELAWARE CTR FOR COMPOSITE MTRLS J GILLESPIE M SANTARE S YARLAGADDA S ADVANI D HEIDER 201 SPENCER LABORATORY NEWARK DE 19716
1	UNIV OF WYOMING D ADAMS PO BOX 3295 LARAMIE WY 82071		

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>	<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	DEPT OF MATERIALS SCIENCE & ENGINEERING UNIVERSITY OF ILLINOIS AT URBANA CHAMPAIGN J ECONOMY 1304 WEST GREEN ST 115B URBANA IL 61801		<u>ABERDEEN PROVING GROUND</u>
1	NORTH CAROLINA STATE UNIV CIVIL ENGINEERING DEPT W RASDORF PO BOX 7908 RALEIGH NC 27696-7908	1	US ARMY MATERIEL SYSTEMS ANALYSIS ACTIVITY P DIETZ 392 HOPKINS RD AMXSY TD APG MD 21005-5071
1	UNIV OF MARYLAND DEPT OF AEROSPACE ENGNRNG A J VIZZINI COLLEGE PARK MD 20742	1	DIRECTOR US ARMY RESEARCH LAB AMSRL OP AP L APG MD 21005-5066
1	DREXEL UNIV A S D WANG 32ND & CHESTNUT ST PHILADELPHIA PA 19104	90	DIR USARL AMSRL CI AMSRL CI S A MARK AMSRL CS IO FI M ADAMSON AMSRL SL BA AMSRL SL BL D BELY R HENRY AMSRL SL BG AMSRL SL I AMSRL WM J SMITH AMSRL WM B A HORST AMSRL WM BA D LYON AMSRL WM BC P PLOSTINS J NEWILL S WILKERSON A ZIELINSKI AMSRL WM BD B FORCH R FIFER R PESCE RODRIGUEZ B RICE AMSRL WM BE C LEVERITT AMSRL WM BF J LACETERA AMSRL WM BR C SHOEMAKER J BORNSTEIN
3	UNIV OF TEXAS AT AUSTIN CTR FOR ELECTROMECHANICS J PRICE A WALLS J KITZMILLER 10100 BURNET RD AUSTIN TX 78758-4497		
3	VA POLYTECHNICAL INST & STATE UNIV DEPT OF ESM M W HYER K REIFSNIDER R JONES BLACKSBURG VA 24061-0219		
1	SOUTHWEST RSCH INST ENGR & MATL SCIENCES DIV J RIEGEL 6220 CULEBRA RD PO DRAWER 28510 SAN ANTONIO TX 78228-0510		

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>	<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
<u>ABERDEEN PROVING GROUND (CONT)</u>		<u>ABERDEEN PROVING GROUND (CONT)</u>	
	AMSRL WM M D VIECHNICKI G HAGNAUER J MCCUALEY AMSRL WM MA L GHIORSE S MCKNIGHT AMSRL WM MB B FINK J BENDER T BOGETTI R BOSSOLI L BURTON K BOYD S CORNELISON P DEHMER R DOOLEY W DRYSDALE G GAZONAS S GHIORSE D GRANVILLE D HOPKINS C HOPPEL D HENRY R KASTE M KLUSEWITZ M LEADORE R LIEB E RIGAS J SANDS D SPAGNUOLO W SPURGEON J TZENG E WETZEL A FRYDMAN AMRSL WM MC J BEATTY E CHIN J MONTGOMERY A WEREZCAK J LASALVIA J WELLS AMSRL WM MD W ROY S WALSH AMSRL WM T B BURNS M ZOLTOSKI		AMSRL WM TA W GILICH T HAVEL J RUNYEON M BURKINS E HORWATH B GOOCH W BRUCHEY M NORMANDIA AMRSL WM TB D KOOKER P BAKER AMSRL WM TC R COATES AMSRL WM TD A DAS GUPTA T HADUCH T MOYNIHAN F GREGORY M RAFTENBERG M BOTELER T WEERASOORIYA D DANDEKAR A DIETRICH AMSRL WM TE A NIILER J POWELL AMSRL SS SD H WALLACE AMSRL SS SE DS R REYZER R ATKINSON

<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>	<u>NO. OF COPIES</u>	<u>ORGANIZATION</u>
1	LTD R MARTIN MERL TAMWORTH RD HERTFORD SG13 7DG UK	1	DYNAMEC RESEARCH AB AKE PERSSON BOX 201 SE 151 23 SODERTALJE SWEDEN
1	SMC SCOTLAND P W LAY DERA ROSYTH ROSYTH ROYAL DOCKYARD DUNFERMLINE FIFE KY 11 2XR UK	1	ISRAEL INST OF TECHNOLOGY S BODNER FACULTY OF MECHANICAL ENGR HAIFA 3200 ISRAEL
1	CIVIL AVIATION ADMINISTRATION T GOTTESMAN PO BOX 8 BEN GURION INTERNL AIRPORT LOD 70150 ISRAEL	1	DSTO WEAPONS SYSTEMS DIVISION N BURMAN RLLWS SALISBURY SOUTH AUSTRALIA 5108 AUSTRALIA
1	AEROSPATIALE S ANDRE A BTE CC RTE MD132 316 ROUTE DE BAYONNE TOULOUSE 31060 FRANCE	1	ECOLE ROYAL MILITAIRE E CELENS AVE DE LA RENAISSANCE 30 1040 BRUXELLE BELGIQUE
1	DRA FORT HALSTEAD P N JONES SEVEN OAKS KENT TN 147BP UK	1	DEF RES ESTABLISHMENT VALCARTIER A DUPUIS 2459 BOULEVARD PIE XI NORTH VALCARTIER QUEBEC CANADA PO BOX 8800 COURCELETTE GOA IRO QUEBEC CANADA
1	DEFENSE RESEARCH ESTAB VALCARTIER F LESAGE COURSELETTE QUEBEC COA IRO CANADA	1	INSTITUT FRANCO ALLEMAND DE RECHERCHES DE SAINT LOUIS DE M GIRAUD 5 RUE DU GENERAL CASSAGNOU BOITE POSTALE 34 F 68301 SAINT LOUIS CEDEX FRANCE
1	SWISS FEDERAL ARMAMENTS WKS W LANZ ALLMENDSTRASSE 86 3602 THUN SWITZERLAND	1	ECOLE POLYTECH J MANSON DMX LTC CH 1015 LAUSANNE SWITZERLAND

NO. OF
COPIES ORGANIZATION

- 1 TNO DEFENSE RESEARCH
R IJSELSTEIN
ACCOUNT DIRECTOR
R&D ARMEE
PO BOX 6006
2600 JA DELFT
THE NETHERLANDS
- 2 FOA NATL DEFENSE RESEARCH
ESTAB
DIR DEPT OF WEAPONS &
PROTECTION
B JANZON
R HOLMLIN
S 172 90 STOCKHOLM
SWEDEN
- 2 DEFENSE TECH & PROC AGENCY
GROUND
I CREWTHER
GENERAL HERZOG HAUS
3602 THUN
SWITZERLAND
- 1 MINISTRY OF DEFENCE
RAFAEL
ARMAMENT DEVELOPMENT
AUTH
M MAYSELESS
PO BOX 2250
HAIFA 31021
ISRAEL
- 1 TNO DEFENSE RESEARCH
I H PASMAN
POSTBUS 6006
2600 JA DELFT
THE NETHERLANDS
- 1 B HIRSCH
TACHKEMONY ST 6
NETAMUA 42611
ISRAEL
- 1 DEUTSCHE AEROSPACE AG
DYNAMICS SYSTEMS
M HELD
PO BOX 1340
D 86523 SCHROBENHAUSEN
GERMANY

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188
<p>Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project 0704-0188, Washington, DC 20503.</p>			
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED	
	January 2002	Final, July–September 2001	
4. TITLE AND SUBTITLE	Mechanical Properties of Aerojet, Thiokol, and JA2 High-Energy Gun Propellants at 1.5 m/s Deformation Rate		5. FUNDING NUMBERS 1L16P.102AH
6. AUTHOR(S)	Michael G. Leadore		
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	U.S. Army Research Laboratory ATTN: AMSRL-WM-MB Aberdeen Proving Ground, MD 21005-5069		8. PERFORMING ORGANIZATION REPORT NUMBER ARL-TR-2654
9. SPONSORING/MONITORING AGENCY NAMES(S) AND ADDRESS(ES)			10. SPONSORING/MONITORING AGENCY REPORT NUMBER
11. SUPPLEMENTARY NOTES			
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE
13. ABSTRACT (Maximum 200 words)	<p>Five lots of high-energy gun propellants were tested in uniaxial compression at temperatures of 21°, 63°, and -32 °C. The materials were taken to ~60% strain using a deformation rate of 1.5 m/s. The stress at failure, strain at failure, compressive modulus, failure modulus, incremental energy density, and the fracture assessment values were recorded for each test.</p>		
14. SUBJECT TERMS high-rate, deformation, mechanical properties, uniaxial compression, fracture			15. NUMBER OF PAGES 28
		16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL

INTENTIONALLY LEFT BLANK.