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The Mechanical Response of Virgin and Aged RDX/CL20/BAMO/AMMO-Based High-Energy Gun Propellants

by Michael G. Leadore

ARL-TR-2603

September 2001

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The Mechanical Response of Virgin and Aged RDX/CL20/BAMO/AMMO-Based High-Energy Gun Propellants

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Abstract

The subject of this report is the material test systems servohydraulic tester high-rate mechanical response of TSE-015-019 sample nos. 5 and 6 RDX/CL20/BAMO/AMMO-layered gun propellants that were aged for more than 2 years. The Thiokol manufactured materials identified by lot TSE-015-019 were initially tested (virgin lot) in September 1997 and January 2000. Sample no. 4 was a candidate propellant for the M829E3 120-mm tank gun round of test sets 28-34/FY00.

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1. Background

The U.S. Army Research Laboratory (ARL) received two lots of TSE-015-019 sample nos. 5 and 6 RDX/CL20/BAMO/AMMO-layered next generation high-energy 120-mm gun (Figure 1) propellants that were manufactured at Thiokol Propulsion Corporation, Elkton, MD. The materials were made in a mixer and extruded thermally into sheets. The sheet material had a thickness of ~2.80 mm. The sheet was cut into 25.40-mm × 25.40-mm squares, and several squares from the lot of the experimental gun propellant were shipped to Dr. Robert Lieb of ARL. The virgin material was first tested during September 1997, and aged sample no. 4 was tested during January 2000. The results are contained in Table 1. Subject material sample nos. 5 and 6, plus 2-year aged material, were last tested for high-rate compressive mechanical response evaluation in September 2000.

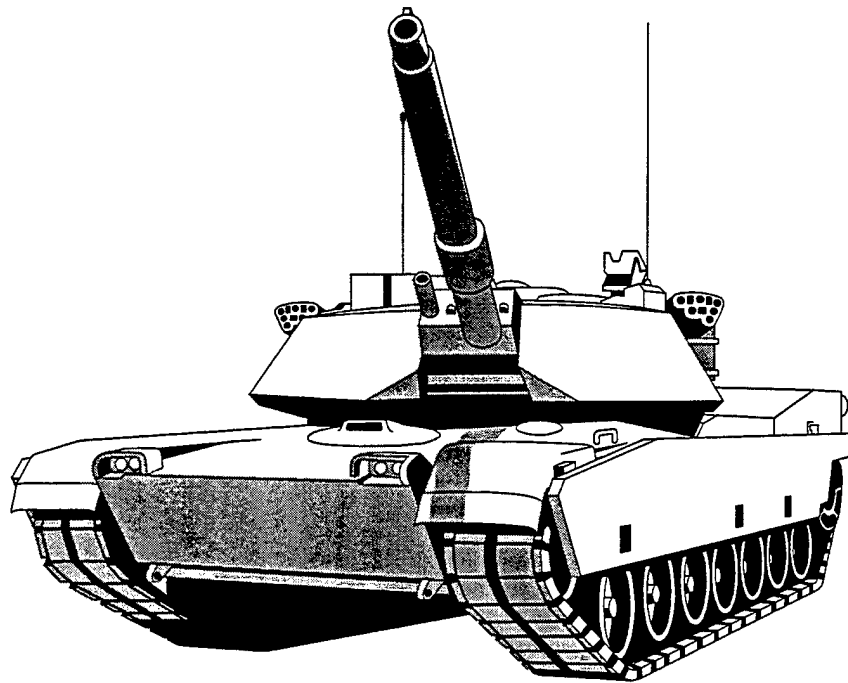


Figure 1. M1 Abrams With 120-mm Gun.

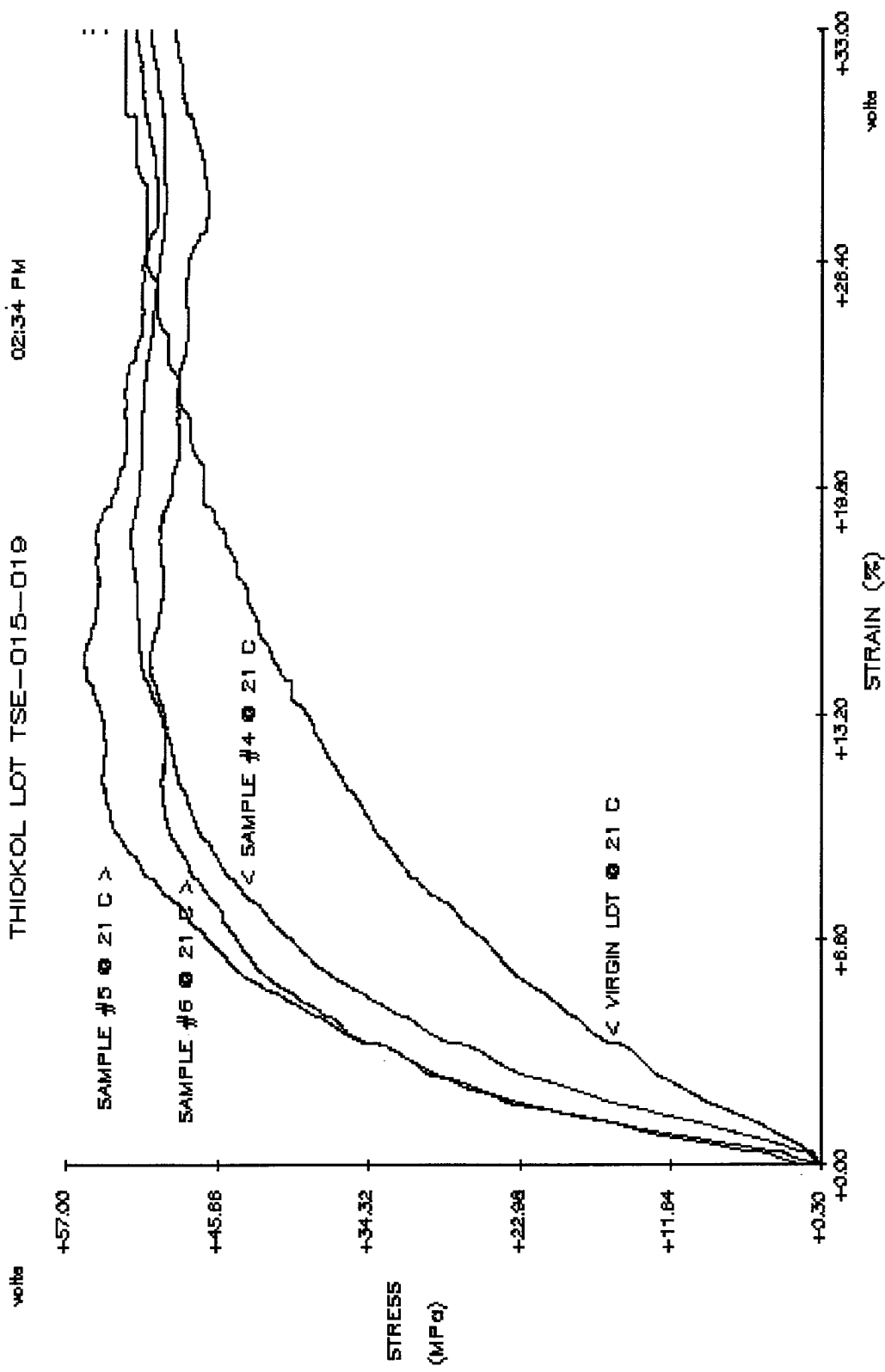
Table 1. Mechanical Properties of Lot TSE-015-019 Virgin and Sample No. 4 at 21 °C, 50 °C, and -20 °C

Lot CL20/BAMO/AMMO (78%/22%) RDX/BAMO/AMMO (76%/24%)	Stress at Failure (MPa)	Strain at Failure (%)	Modulus (GPa)	Failure Modulus (GPa)	IED (MPa)	FAV
21 °C						
Virgin Material	21.37	7.32	0.310	0.052	5.77	1AB
Sample No. 4	43.17	7.62	0.940	0.102	20.90	3AB
50 °C						
Virgin Material	10.88	8.13	0.119	0.030	2.89	1B
Sample No. 4	20.18	6.61	0.660	0.012	10.73	2AB
-20 °C						
Virgin Material	72.09	7.49	1.39	-0.155	13.17	5AS
Sample No. 4	112.01	6.40	2.79	-0.635	14.80	8AS

2. Approach and Results

The Thiokol Propulsion-layered propellant lot was received in solid sheet form and was without perforations. The lot was cut into samples and stacked, resulting in test specimens with a length-to-diameter (L/D) ratio of 0.96. Sample preparation was accomplished using a 12.68-mm stainless steel hole punch. Sample ends were machined so that the surfaces were flat, parallel to each other, and perpendicular to the extruded axis.

The Material Test Systems (MTS) servohydraulic tester (SHT) mechanical properties tests [1-7] were conducted on several specimens under each test condition. Strain rates of 141.5 (1/s) were achieved. The specimens were taken to failure at ambient pressure to ~60% end strain while conditioned at 21 °C, 50 °C, and -20 °C. The stress at failure, strain at failure, modulus, failure modulus, incremental energy density (IED), and fracture assessment value (FAV) were recorded for each test. The stress vs. strain plots are shown in Figures 2-4, and average values achieved are listed in Table 2.



UNIAXIAL COMPRESSION 1.32 METERS/SECOND DEFORMATION RATE

Figure 2. Stress vs. Strain Plot a 21 °C.

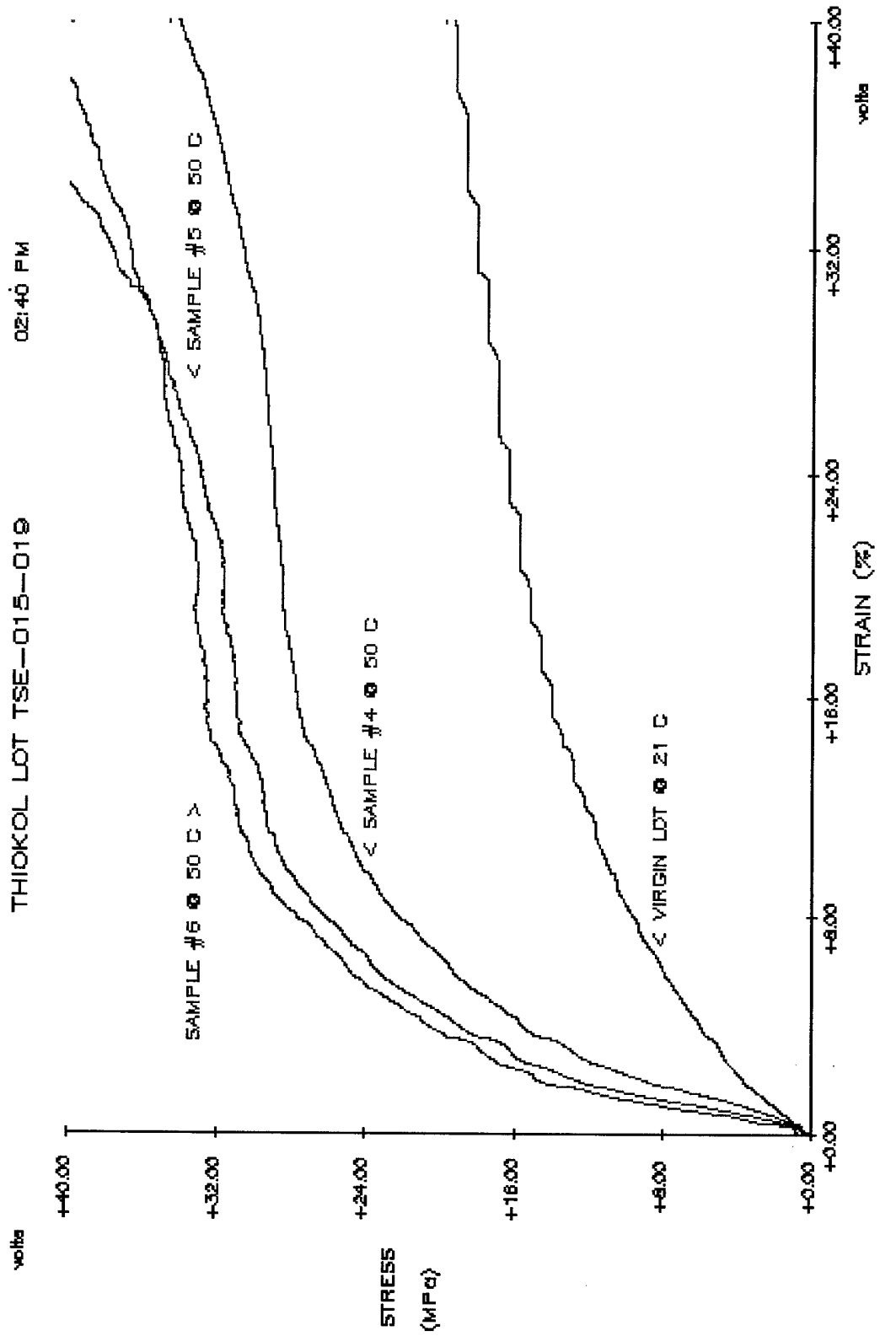
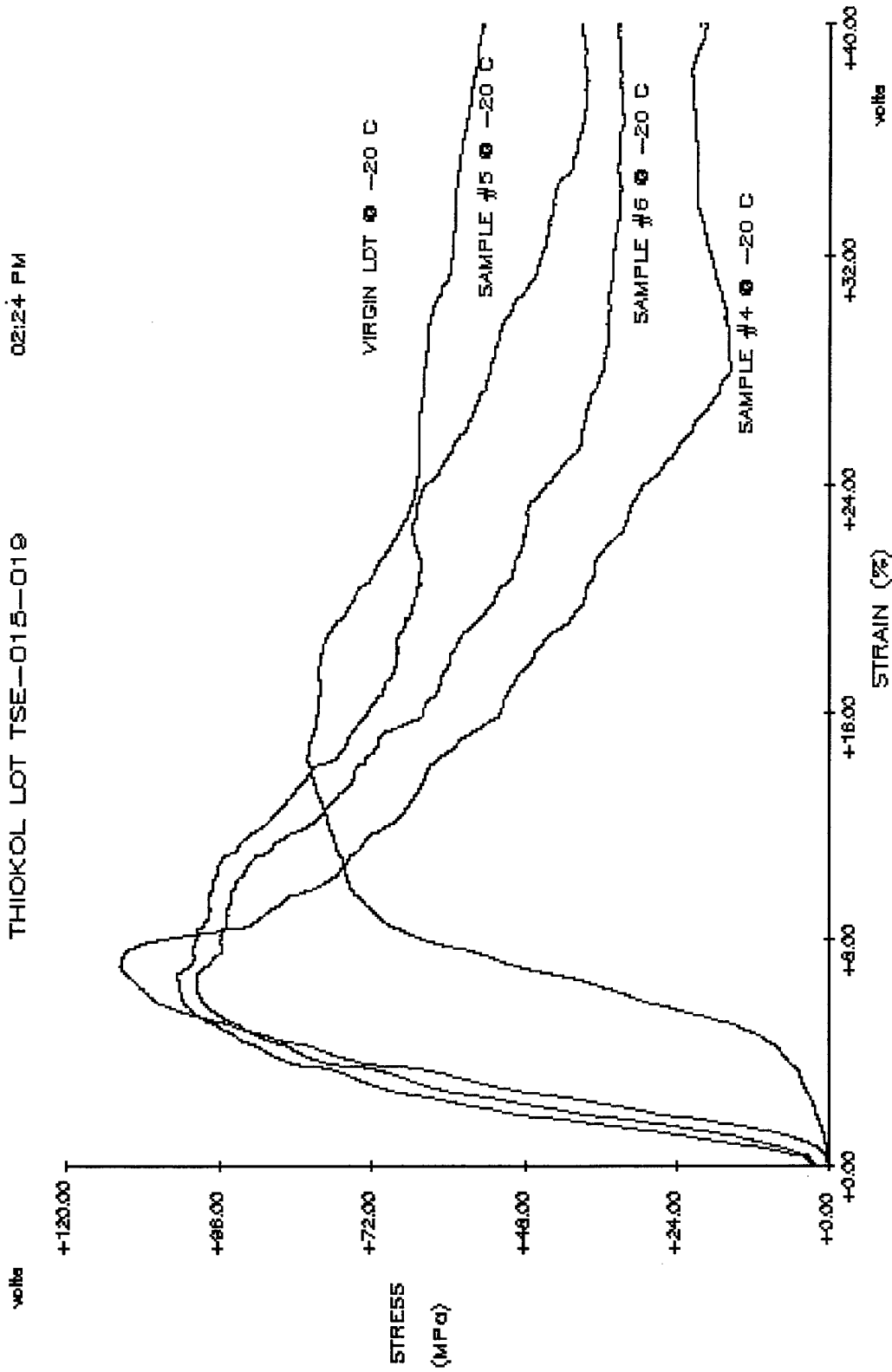


Figure 3. Stress vs. Strain Plot at 50 °C.



UNIAXIAL COMPRESSION 1.32 METERS/SECOND DEFORMATION RATE

Figure 4. Stress vs. Strain Plot at -20 °C.

Table 2. Mechanical Properties of Lot TSE-015-019 Sample Nos. 5 and 6 at 21 °C, 50 °C, and -20 °C

Lot CL20/BAMO/AMMO (78%/22%) RDX/BAMO/AMMO (76%/24%)	Stress at Failure (MPa)	Strain at Failure (%)	Modulus (GPa)	Failure Modulus ^a (GPa)	IED ^b (MPa)	FAV ^c
21 °C						
Sample No. 5	46.09	6.52	1.17	0.089	12.10	3A
Sample No. 6	38.56	5.72	1.00	0.101	11.20	3A
50 °C						
Sample No. 5	21.02	5.21	0.670	0.069	6.26	2AB
Sample No. 6	20.07	5.11	0.640	0.076	6.53	2AB
-20 °C						
Sample No. 5	100.81	6.80	2.69	-0.255	11.10	8AS
Sample No. 6	95.77	6.60	2.23	-0.185	17.80	8AS

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

^b The IED value reported is the amount of energy absorbed at 25% strain; this includes a portion of the area located under the stress/strain curve.

^c The tested specimens were assigned an FAV. The values range from 0 (no fractures) through 9 (severe fracturing). The type of fracture was also characterized using the following methodology: A = axial fracture, S = shear fracture, B = barreling/deformation, and R = radial splitting (i.e., 8AS would indicate the tested specimens suffered severe axial and shear fracture).

3. Conclusions

Two lots of TSE-015-019 sample nos. 5 and 6 RDX/CL20/BAMO/AMMO-layered gun propellant that was aged for more than 2 years were tested in uniaxial compression at 1.32 m/s. The materials were taken to ~60% end strain while conditioned at 21 °C, 50 °C, and -20 °C. The Thiokol Propulsion-manufactured materials identified by lot TSE-015-019 were also initially tested as virgin material during September 1997 and aged material in January 2000. The test results are included in Table 1.

At 21 °C, it was noted the Young's compressive modulus increased by a factor of more than 3 when compared with the virgin test results contained in Table 1. Note also the increase in compressive modulus when comparing sample nos. 5 and 6 and the aged material sample no. 4 in Table 1. This indicated that the materials may continue to stiffen with aging. The stress at yield also showed a factor of 2 increase when comparing the subject and virgin values. These observations indicated that the material had become much stiffer after being aged for several years. The tested specimens at 21 °C showed permanent deformation of the specimens, with axial fracture also present.

At 50 °C, when comparing the modulus of the aged sample nos. 4, 5, and 6 vs. the virgin material, a factor of more than 5 increase was noted. The stress at failure value also doubled. The tested specimens at 50 °C again showed axial fracture and permanent deformation. This is typical for most gun propellants, as fracture does not usually occur when testing other types of propellants (i.e., M30 and JA2) at 50 °C. This may be cause for concern, as the fractured material would increase the amount of surface area, thus resulting in an increased burn rate of the material.

At -20 °C, the tested specimens from samples nos. 5 and 6 suffered severe amounts of axial and shear fracture (Figure 5), likely causing significant increases in surface area. Note that the tested specimens from the virgin lot (Figure 6) at -20 °C showed less fracture. This indicated that the aged material had become more brittle. The stress vs. strain plot at -20 °C (included in this report) for the materials also correlated with the physical damage observed. The failure modulus values achieved indicated the inability of sample nos. 5 and 6 to sustain load. The uniaxial compression tests at -20 °C, plus the several years of aging, likely caused the material to suffer a glassy transition. It should also be noted that the strain at failure values for sample no. 5, and especially the virgin lot at -20 °C (see stress vs. strain plot at -20 °C), were a bit higher than actual due to material stacking of the test specimens while being conditioned. This could be averted with future tests by testing solid right-circular cylinder specimens instead of stacking the punched sheet material and thus creating air gaps between the layers.

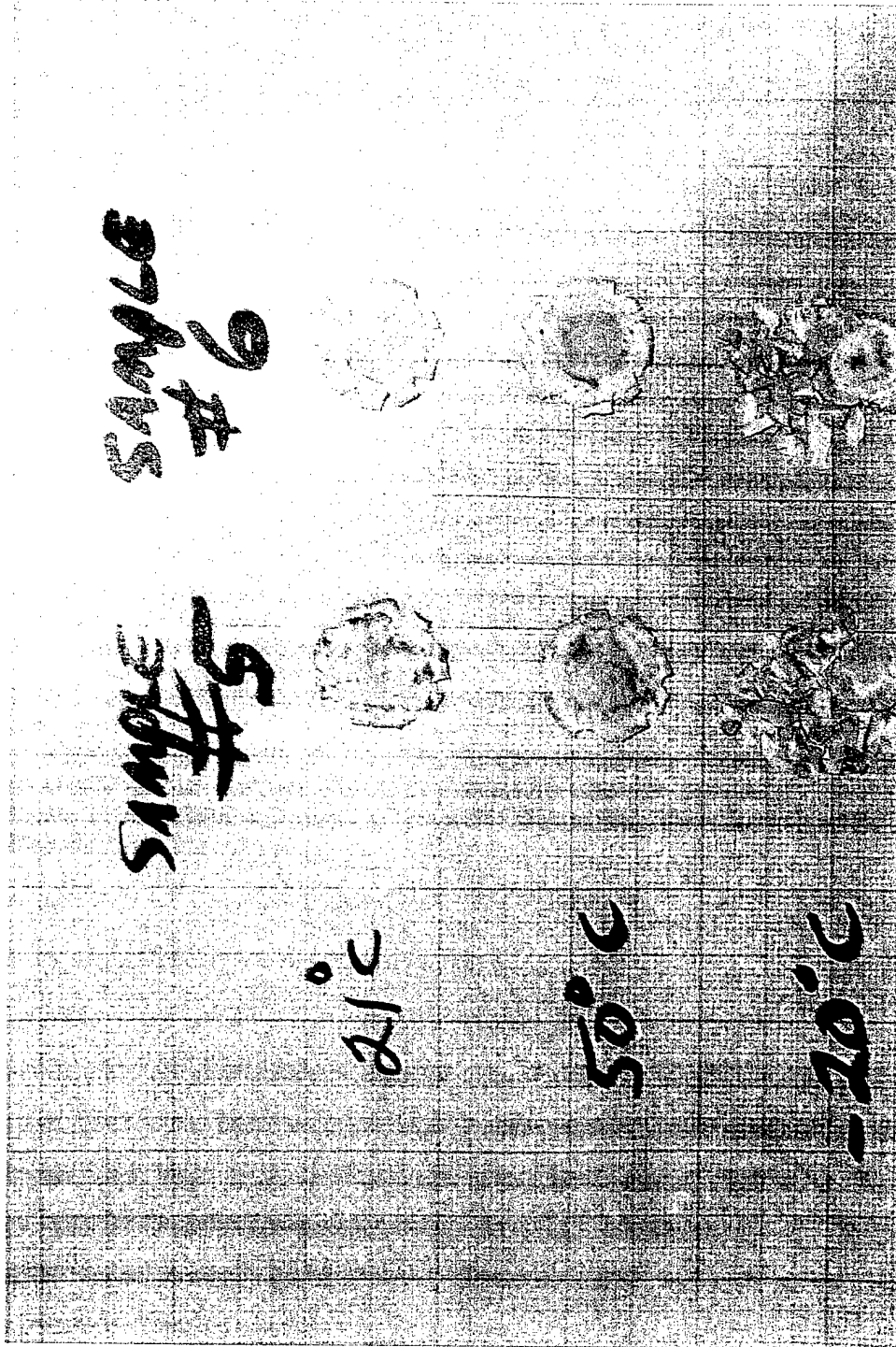
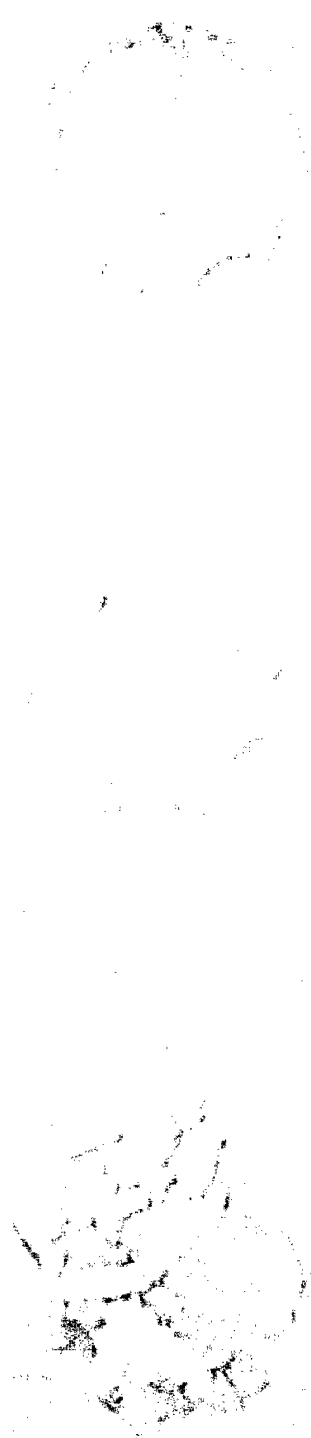


Figure 5. Photograph of Aged Sample Nos. 5 and 6 From Lot TSE-015-019 Tested Material.

LOT NO. TSE-015-019



-20°C 21°C 50°C

Figure 6. Photograph of Tested Material From Virgin Lot TSE-015-019.

Overall, lot TSE-015-019 showed poor mechanical properties when the virgin lot was initially tested several years ago, and the aging of the material (sample nos. 4, 5, and 6) has proven more detrimental. The -20 °C tests are cause for concern, as the test results indicated the lot was sensitive to the colder testing temperature, becoming “brittle” at -20 °C, and suffering prolific fracture.

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1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE September 2001	3. REPORT TYPE AND DATES COVERED Final, March 2000–October 2000
4. TITLE AND SUBTITLE The Mechanical Response of Virgin and Aged RDX/CL20/BAMO/AMMO-Based High-Energy Gun Propellants			5. FUNDING NUMBERS 1L161102AH43
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-2603
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) The subject of this report is the material test systems servohydraulic tester high-rate mechanical response of TSE-015-019 sample nos. 5 and 6 RDX/CL20/BAMO/AMMO-layered gun propellants that were aged for more than 2 years. The Thiokol manufactured materials identified by lot TSE-015-019 were initially tested (virgin lot) in September 1997 and January 2000. Sample no. 4 was a candidate propellant for the M829E3 120-mm tank gun round of test sets 28–34/FY00.			
14. SUBJECT TERMS CL20, RDX, BAMO/AMMO, uniaxial compression, high strain rate, stress, strain, mechanical properties, modulus, failure modulus, incremental energy density, fracture, deformation, high energy			15. NUMBER OF PAGES 32
			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

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