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SPECIAL PUBLICATION ARCCB-SP-01009

**INDEX TO BENET LABORATORIES
TECHNICAL REPORTS - 2000**

R. D. NEIFELD

MAY 2001

	<p>US ARMY ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER CLOSE COMBAT ARMAMENTS CENTER BENÉT LABORATORIES WATERVLIET, N.Y. 12189-4050</p>	
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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

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1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE May 2001	3. REPORT TYPE AND DATES COVERED Final	
4. TITLE AND SUBTITLE INDEX TO BENET LABORATORIES TECHNICAL REPORTS - 2000			5. FUNDING NUMBERS N/A	
6. AUTHOR(S) R.D. Neifeld				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Benet Laboratories, AMSTA-AR-CCB-O Watervliet, NY 12189-4050			8. PERFORMING ORGANIZATION REPORT NUMBER ARCCB-SP-01009	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) This is a compilation of technical reports published by Benet Laboratories during 2000.				
14. SUBJECT TERMS Benet Laboratories, Technical Publications, Bibliographies, Abstracts, Document Control Data			15. NUMBER OF PAGES 26	
			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	

TABLE OF CONTENTS

	<u>Page</u>
LIST OF REPORTS.....	1
AUTHOR INDEX.....	3
SUBJECT INDEX.....	5
AD NUMBERS.....	9
REPORT DOCUMENTATION PAGES.....	10

TECHNICAL REPORTS 2000

REPORT NUMBER	TITLE	AUTHOR	DATE
ARCCB-TR-00001	Erosion EFC Factors for Kinetic Energy Rounds Used in the 120-mm M256 Tank Cannon	S. Sopok R. Billington	Jan 2000
ARCCB-TR-00002	Lead-Tin Solder Characterization by Differential Scanning Calorimetry	M.F. Fleszar	Jan 2000
ARCCB-TR-00003	Preliminary Erosion Analysis for the Experimental M829E3 Kinetic Energy Round	S. Sopok R. Loomis G. Pflagl C. Rickard	Feb 2000
ARCCB-TR-00004	Dynamic Scaling in Cellular Automata Simulations of Deposition Processes	M. Johnson	Mar 2000
ARCCB-TR-00005	Energy Dispersive, X-Ray Reflectivity Density Measurements of Porous SiO ₂ Xerogels	D. Windover T.-M. Lu S.L. Lee A. Kumar H. Bakhru C. Jin W. Lee	Mar 2000
ARCCB-MR-00006	Critical Comments on Report Titled "Gray Layers and the Erosion of Chromium Plated Gun Bore Surfaces" by Cote and Rickard	J.H. Underwood	Apr 2000
ARCCB-MR-00007	A Fractographic Study of a Circa AD83 Roman Nail	A.A. Kapusta J.H. Underwood	May 2000
ARCCB-TR-00008	Evidence Against Hydrogen Cracking in Gun Bores: A Reply	P.J. Cote	May 2000
ARCCB-TR-00009	Simulation of Shot Impacts for the M1A1 Tank Gun	R. Gast S. Morris M. Costello	Jun 2000
ARCCB-TR-00010	Stress and Fatigue Life Modeling of Cannon Breech Closures Including Effects of Material Strength and Residual Stress	J.H. Underwood M.J. Glennon	Jun 2000
ARCCB-TR-00011	Image Plate X-Ray Diffraction and X-Ray Reflectivity Characterization of Protective Coatings and Thin Films	S.L. Lee D. Windover M. Doxbeck T.-M. Lu	Jul 2000
ARCCB-TR-00012	X-Ray Digital Image Plate Detector for Phase and Texture Analyses of Thin Tantalum Films	D. Windover E. Barnat J. Summers T.-M. Lu S.L. Lee	Jul 2000
ARCCB-SP-00013	Index to Benet Laboratories Technical Reports - 1999	R.D. Neifeld	Jul 2000

TECHNICAL REPORTS 2000

ARCCB-TR-00014	Effect of Sputtering Parameters on Tantalum Coatings for Gun Bore Applications	D.W. Matson E.D. McClanahan J.P. Rice S.L. Lee D. Windover	Aug 2000
ARCCB-TR-00015	Cannon Coating Erosion Model with Updated M829E3 Example	S. Sopok	Oct 2000
ARCCB-TR-00016	Recoil Considerations for Railguns	E.L. Kathe	Nov 2000

AUTHOR INDEX 2000

AUTHOR	REPORT NUMBER
Bakhru, H.	ARCCB-TR-00005
Barnat, E.	ARCCB-TR-00012
Billington, R.	ARCCB-TR-00001
Costello, M.	ARCCB-TR-00009
Cote, P.J.	ARCCB-TR-00008
Doxbeck, M.	ARCCB-TR-00011
Fleszar, M.F.	ARCCB-TR-00002
Gast, R.	ARCCB-TR-00009
Glennon, M.J.	ARCCB-TR-00010
Jin, C.	ARCCB-TR-00005
Johnson, M.	ARCCB-TR-00004
Kapusta, A.A.	ARCCB-MR-00007
Kathe, E.L.	ARCCB-TR-00016
Kumar, A.	ARCCB-TR-00005
Lee, S.L.	ARCCB-TR-00005 ARCCB-TR-00011 ARCCB-TR-00012 ARCCB-TR-00014 ARCCB-TR-00005
Loomis, R.	ARCCB-TR-00003
Lu, T.-M.	ARCCB-TR-00005 ARCCB-TR-00011 ARCCB-TR-00012
Matson, D.W.	ARCCB-TR-00014
McClanahan, E.D.	ARCCB-TR-00014

AUTHOR INDEX 2000

Morris, S.	ARCCB-TR-00009
Neifeld, R.D.	ARCCB-SP-00013
Pflegl, G.	ARCCB-TR-00003
Rice, J.P.	ARCCB-TR-00014
Rickard, C.	ARCCB-TR-00003
Sopok, S.	ARCCB-TR-00001 ARCCB-TR-00003 ARCCB-TR-00015
Summers, J.	ARCCB-TR-00012
Underwood, J.H.	ARCCB-MR-00006 ARCCB-MR-00007 ARCCB-TR-00010
Windover, D.	ARCCB-TR-00005 ARCCB-TR-00011 ARCCB-TR-00012 ARCCB-TR-00014

SUBJECT INDEX - 2000

SUBJECT	REPORT NUMBER
Abstracts	ARCCB-SP-00013
Austenite	ARCCB-TR-00011
Automata	ARCCB-TR-00004
Bibliographies	ARCCB-SP-00013
Binary Alloys	ARCCB-TR-00002
Bores	ARCCB-MR-00006 ARCCB-TR-00008 ARCCB-TR-00015
Breech Mechanisms	ARCCB-TR-00010
Cannons	ARCCB-TR-00010
Chromium	ARCCB-MR-00006 ARCCB-TR-00008 ARCCB-TR-00011
Coatings	ARCCB-TR-00015
Computerized Simulation	ARCCB-TR-00003 ARCCB-TR-00004
Cracking (Fracturing)	ARCCB-MR-00006 ARCCB-TR-00008
Damage	ARCCB-TR-00008
Density	ARCCB-TR-00005
Deposition Processes	ARCCB-TR-00004
Dielectric Films	ARCCB-TR-00005
Differential Scanning Calorimetry	ARCCB-TR-00002
Effective Full Charge (EFC)	ARCCB-TR-00001
Electrodeposition	ARCCB-TR-00002
Electromagnetic Guns	ARCCB-TR-00016

SUBJECT INDEX - 2000

Electromagnetic Guns	ARCCB-TR-00016
Embrittlement	ARCCB-MR-00007
Emission Spectroscopy	ARCCB-TR-00002
Erosion	ARCCB-TR-00001 ARCCB-TR-00003 ARCCB-MR-00006 ARCCB-TR-00008 ARCCB-TR-00015
Exterior Ballistics	ARCCB-TR-00009
Fatigue Life	ARCCB-TR-00010
Finite Element Analysis	ARCCB-TR-00010
Flexural Body Dynamics	ARCCB-TR-00009
Fractals	ARCCB-TR-00004
Fractography	ARCCB-MR-00007
Fracture (Mechanics)	ARCCB-MR-00007
Future Combat System Program	ARCCB-TR-00016
Gray Layers	ARCCB-MR-00006 ARCCB-TR-00008
Gun Tubes	ARCCB-TR-00001 ARCCB-TR-00003 ARCCB-TR-00014 ARCCB-TR-00015
Guns	ARCCB-TR-00009 ARCCB-SP-00013
Hydrogen Embrittlement	ARCCB-TR-00008
Image Processing	ARCCB-TR-00004 ARCCB-TR-00011 ARCCB-TR-00012
Indexes	ARCCB-SP-00013

SUBJECT INDEX - 2000

Iron	ARCCB-MR-00007
Kinetic Energy Projectiles	ARCCB-TR-00001 ARCCB-TR-00003 ARCCB-TR-00009
Lead-Tin Alloys	ARCCB-TR-00002
M1A1 Tank Guns	ARCCB-TR-00009
M829E3 Ammunition	ARCCB-TR-00003 ARCCB-TR-00015
Martensite	ARCCB-TR-00011
Metal Coatings	ARCCB-TR-00014
Microstructure	ARCCB-TR-00014
Modeling	ARCCB-TR-00010
Nails (Fasteners)	ARCCB-MR-00007
Nondestructive Testing	ARCCB-TR-00011
120-mm M256 Tank Cannons	ARCCB-TR-00001 ARCCB-TR-00003
Phase Analysis	ARCCB-TR-00012
Porosity	ARCCB-TR-00005
Protective Coatings	ARCCB-TR-00011
Railguns	ARCCB-TR-00016
Recoil Mechanisms	ARCCB-TR-00016
Reflectivity	ARCCB-TR-00005 ARCCB-TR-00011
Reports	ARCCB-SP-00013
Residual Stress	ARCCB-TR-00010
Simulation	ARCCB-TR-00009

SUBJECT INDEX - 2000

Sputtering	ARCCB-TR-00014
Stress Analysis	ARCCB-TR-00010
Tanks (Combat Vehicles)	ARCCB-TR-00009 ARCCB-TR-00016
Tantalum	ARCCB-TR-00011 ARCCB-TR-00012 ARCCB-TR-00014
Technical Publications	ARCCB-SP-00013
Texture Analysis	ARCCB-TR-00012
Thermal Analysis	ARCCB-TR-00002
Thermal Properties	ARCCB-MR-00006
Thick Films	ARCCB-TR-00011
Thin Films	ARCCB-TR-00011 ARCCB-TR-00012
Triodes	ARCCB-TR-00014
Xerogels	ARCCB-TR-00005
X-Ray Diffraction	ARCCB-TR-00011 ARCCB-TR-00012
X-Ray Reflectivity	ARCCB-TR-00005

AD NUMBERS 2000

REPORT NUMBER	AD NUMBER
ARCCB-TR-00001	A372 760
ARCCB-TR-00002	A373 333
ARCCB-TR-00003	A374 172
ARCCB-TR-00004	A375 200
ARCCB-TR-00005	A376 111
ARCCB-MR-00006	A377 513
ARCCB-MR-00007	A387 460
ARCCB-TR-00008	A378 900
ARCCB-TR-00009	A379 086
ARCCB-TR-00010	A379 634
ARCCB-TR-00011	A380 825
ARCCB-TR-00012	A380 800
ARCCB-SP-00013	A380 988
ARCCB-TR-00014	A382 266
ARCCB-TR-00015	A383 883
ARCCB-TR-00016	A387 401

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
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.				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE January 2000	3. REPORT TYPE AND DATES COVERED Final		
4. TITLE AND SUBTITLE EROSION EFC FACTORS FOR KINETIC ENERGY ROUNDS USED IN THE 120-MM M256 TANK CANNON			5. FUNDING NUMBERS PRON No. J5850E52M21A	
6. AUTHOR(S) Samuel Sopok and Roger Billington (PM-TMAS, Picatinny Arsenal, NJ 07806)				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Benet Laboratories, AMSTA-AR-CCB-O Watervliet, NY 12189-4050			8. PERFORMING ORGANIZATION REPORT NUMBER ARCCB-TR-00001	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES Presented at the 35 th AIAA Joint Propulsion Conference, Los Angeles, CA, 20-24 June 1999. Published in proceedings of the conference.				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) The U.S. Army and Air Force's standard manual for the evaluation of cannon tubes designates fatigue condemnation criteria for each cannon tube type. It also designates erosion condemnation criteria for each cannon tube type, and designates a cartridge/zone fatigue effective full charge (EFC) factor for each charge/projectile combination. These criteria help in cannon inventory management. However, the manual lacks a designated cartridge/zone erosion EFC factor for each charge/projectile combination. This represents a notable technology gap for tank and artillery cannon systems, since erosion condemnation occurs much quicker than fatigue condemnation when using the latest charge/projectile combinations. Our report outlines a detailed computational and experimental method using the Unified Cannon Erosion Code to compute a cartridge or round erosion EFC factor for the M865, M829, M829A1, and M829A2 kinetic energy round types used in the 120-mm M256 tank cannon at multiple round-conditioning temperatures. Our report further outlines the obvious extension of this method to any group of charge/projectile combinations used in a specific tank or artillery cannon. The following erosion EFC factors are based on an erosion EFC factor of 1.0 for the M865 round type at a 21°C round-conditioning temperature as requested by PM-TMAS. These erosion factors correspond to a peak erosion location approximately 2.2 meters from the rear face of the tube. For the M865, M829, M829A1, and M829A2 round types at a 49°C round-conditioning temperature, the respective erosion EFC factors are approximately 1.5, 4.2, 5.0, and 6.3. Similarly, the respective erosion EFC factors are approximately 1.0, 2.8, 3.3, and 4.2 at a 21°C round-conditioning temperature, and the respective erosion EFC factors are approximately 0.7, 1.9, 2.2, and 2.8 at a -32°C round-conditioning temperature. The respective erosion EFC factors are approximately 1.1, 3.0, 3.5, and 4.4 for an equal distribution of these three round-conditioning temperatures. M256 cannon fatigue life and fatigue EFC factors are officially specified in the above technical manual and help the Army manage its M256 inventory. They are not round type or conditioning temperature-dependent. M256 cannon erosion life and erosion EFC factors are unofficially specified in this work, and will further help the Army manage its M256 inventory. They are both round type and conditioning temperature-dependent. M256 cannon erosion-related inventory management is important, since its erosion life can be up to an order of magnitude more limiting than its associated fatigue life.				
14. SUBJECT TERMS Gun Barrel Erosion, Kinetic Energy Round EFC Factors, Kinetic Energy Round Erosion, 120-mm M256 Tank Cannons			15. NUMBER OF PAGES 18	
			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	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
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 Service, 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.				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE January 2000	3. REPORT TYPE AND DATES COVERED Final		
4. TITLE AND SUBTITLE LEAD-TIN SOLDER CHARACTERIZATION BY DIFFERENTIAL SCANNING CALORIMETRY			5. FUNDING NUMBERS PRON No. 4EE2B069EH1A	
6. AUTHOR(S) Mark F. Fleszar				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Benet Laboratories, AMSTA-AR-CCB-O Watervliet, NY 12189-4050			8. PERFORMING ORGANIZATION REPORT NUMBER ARCCB-TR-00002	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES Presented at the 27 th North American Thermal Analysis Society Conference, Savannah, GA, 20-23 September 1999. Published in proceedings of the conference.				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) The electrolytic deposition of chromium on the bore of thick-walled, high-pressure cylinders uses a lead-tin alloy as the anode for the plating process. The anode is prepared by melting a lead-tin solder over a cylindrical copper core, which is then machined to the proper diameter. Using differential scanning calorimetry, the melting temperature of various ratios of lead-tin can be measured and a portion of the phase diagram can be established between the solid and liquid states. The melting temperature of a solder can then be measured and the composition can be obtained from the phase diagram.				
14. SUBJECT TERMS Thermal Analysis, Lead-Tin Alloy, Differential Scanning Calorimetry, Inductively Coupled Plasma Emission Spectroscopy			15. NUMBER OF PAGES 7	
			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	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
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.				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE February 2000	3. REPORT TYPE AND DATES COVERED Final		
4. TITLE AND SUBTITLE PRELIMINARY EROSION ANALYSIS FOR THE EXPERIMENTAL M829E3 KINETIC ENERGY ROUND			5. FUNDING NUMBERS PRON No. J5850E52M21A	
6. AUTHOR(S) S. Sopok, R. Loomis (Picatinny Arsenal, Dover, NJ), G. Pfeigl, and C. Rickard				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Benet Laboratories, AMSTA-AR-CCB-O Watervliet, NY 12189-4050			8. PERFORMING ORGANIZATION REPORT NUMBER ARCCB-TR-00003	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES Presented at the 36 th JANNAF Combustion Meeting, NASA Kennedy Space Center, FL, 17-22 October 1999. Published in proceedings of the meeting.				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) The preliminary experimental 120-mm M829E3 kinetic energy round data described here represent a stage in the development cycle that occurred about a half year to a year ago. The computational erosion predictions are guided and supported by substantial field and laboratory data, including data from firing tests, laboratory tests, and nondestructive/destructive cannon erosion characterizations. This information is intended to provide a "snapshot" of development for that period, and is not directly related to the future type-classified M829E3 kinetic energy round. During that period, these modeling predictions put the program about 40 rounds shy of its required 180-round minimum program target, so further round optimization will likely contribute to the achievement of this goal. Further round optimizations will likely include changes in the weight and configuration of the propellant, projectile, case, and possible ablative. Results of this erosion analysis, erosion effective full charge factor analysis, and comparisons to the round's advanced type-classified counterpart are provided for the preliminary experimental M829E3 kinetic energy round used in the 120-mm M256 cannon at multiple round-conditioning temperatures. The computational method consisted of using our Unified Cannon Erosion Code. Differences exist between the preliminary experimental M829E3 kinetic energy round and its advanced type-classified counterpart including increased propellant weight, increased projectile weight, and RPD380 propellant instead of JA2 propellant. The preliminary experimental M829E3 kinetic energy round erosion analysis achieves erosion condemnation in a lesser number of rounds, and the worst eroded region has moved slightly more than a half meter up-bore compared to its advanced type-classified counterpart.				
14. SUBJECT TERMS Cannon Erosion Analysis, Experimental M829E3 Kinetic Energy Round			15. NUMBER OF PAGES 17	
			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	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
<small>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.</small>				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE March 2000	3. REPORT TYPE AND DATES COVERED Final		
4. TITLE AND SUBTITLE DYNAMIC SCALING IN CELLULAR AUTOMATA SIMULATIONS OF DEPOSITION PROCESSES			5. FUNDING NUMBERS AMCMS No. 6227.20.9471.2	
6. AUTHOR(S) Mark Johnson				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Benet Laboratories, AMSTA-AR-CCB-O Watervliet, NY 12189-4050			8. PERFORMING ORGANIZATION REPORT NUMBER ARCCB-TR-00004	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES To be presented at the High Performance Computing Symposium 2000, Washington, DC, 16-20 April 2000. To be published in proceedings of the symposium.				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) Cellular automata simulations can be used to capture many of the essential features of processes that are difficult to model. They are particularly useful in the study of nonlinear dynamical systems that have complex continuous solutions. In this study, cellular automata models have been employed to investigate the nature of the vapor deposition process by exploring the natural evolution of dynamical dissipative systems using self-organized critical system analysis and spatial scaling measures. A new numerical technique is introduced to analyze the intrinsic structure of evolving surface topography in an effort to better understand the dynamics of the growth processes. This technique is being used to validate the integrity of deposition models through a comparative analysis with experimental data and to determine if a correlation exists between intrinsic surface structure and parameters controlling the deposition process.				
14. SUBJECT TERMS Image Processing, Fractals, Cellular Automata			15. NUMBER OF PAGES 13	
			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	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
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1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE March 2000	3. REPORT TYPE AND DATES COVERED Final		
4. TITLE AND SUBTITLE ENERGY-DISPERSIVE, X-RAY REFLECTIVITY DENSITY MEASUREMENTS OF POROUS SiO ₂ XEROGELS			5. FUNDING NUMBERS AMCMS No. 6111.01.91A1.1	
6. AUTHOR(S) D. Windover (Benet and RPI, Troy, NY), T.-M. Lu (RPI), S.L. Lee, A. Kumar (SUNY Albany), H. Bakhru (SUNY Albany), C. Jin (Texas Instruments, Dallas, TX), and W. Lee (Texas Instruments)				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Benet Laboratories, AMSTA-AR-CCB-O Watervliet, NY 12189-4050			8. PERFORMING ORGANIZATION REPORT NUMBER ARCCB-TR-00005	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES Submitted to <i>Applied Physics Letters</i> .				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) X-ray reflectivity has been used to nondestructively measure the density of thin, porous, SiO ₂ -based xerogels. Critical angle, defined by total external reflection, was measured for multiple x-ray energies to correct for sample misalignment error in the determination of the density for the films. This density was used to extrapolate the percentage of porosity, assuming a bulk SiO ₂ density standard. The results were compared to those obtained by Rutherford backscattering and ellipsometry techniques.				
14. SUBJECT TERMS X-Ray, Reflectivity, Xerogels, Density			15. NUMBER OF PAGES 7	
			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	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
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 the 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 20563.				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE April 2000	3. REPORT TYPE AND DATES COVERED Final		
4. TITLE AND SUBTITLE CRITICAL COMMENTS ON REPORT TITLED "GRAY LAYERS AND THE EROSION OF CHROMIUM PLATED GUN BORE SURFACES" BY COTE AND RICKARD			5. FUNDING NUMBERS PRON No. TU9B9F101ABJ	
6. AUTHOR(S) J.H. Underwood				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Benet Laboratories, AMSTA-AR-CCB-O Watervliet, NY 12189-4050			8. PERFORMING ORGANIZATION REPORT NUMBER ARCCB-MR-00006	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) In June 1999, Dr. Cote supplied a prepublication copy of his and Mr. Rickard's report, "Gray Layers and the Erosion of Chromium Plated Gun Bore Surfaces," and requested this author's comments. These comments are offered here.				
14. SUBJECT TERMS Erosion, Thermal Damage, Cannons, Chromium Plate			15. NUMBER OF PAGES 4	
			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	

NSN 7540-01-280-5500

Standard Form 298 (Rev 2-89)
Prescribed by ANSI Std. Z39-18
298-102

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1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE May 2000	3. REPORT TYPE AND DATES COVERED Final		
4. TITLE AND SUBTITLE A FRACTOGRAPHIC STUDY OF A CIRCA AD83 ROMAN NAIL			5. FUNDING NUMBERS PRON No. ALLIANTTECH	
6. AUTHOR(S) A.A. Kapusta (Materials Analytical Services, Duanesburg, NY) and J.H. Underwood				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Benet Laboratories, AMSTA-AR-CCB-O Watervliet, NY 12189-4050			8. PERFORMING ORGANIZATION REPORT NUMBER ARCCB-MR-00007	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES Submitted to <i>Ironmaking and Steelmaking (UK)</i>				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) Results are presented of a scanning electron microscope fractographic study of a circa AD83 iron nail from the Roman fortress at Inchtuthil, Perthshire, Scotland. The fracture surface studied was created under embrittling conditions of low temperature, an added stress raiser, and high strain-rate loading. Fractographic features are discussed in relationship to the classic cataloguing and metallographic examination of the Inchtuthil nails in earlier work by Angus, Brown, and Cleere.				
14. SUBJECT TERMS Scanning Electron Fractography, Roman Nail, Iron, Roman Fortress			15. NUMBER OF PAGES 10	
			15. 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	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

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1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE May 2000	3. REPORT TYPE AND DATES COVERED Final		
4. TITLE AND SUBTITLE EVIDENCE AGAINST HYDROGEN CRACKING IN GUN BORES: A REPLY			5. FUNDING NUMBERS AMCMS No. 7780.45.E251.2	
6. AUTHOR(S) Paul J. Cote				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Benet Laboratories, AMSTA-AR-CCB-O Watervliet, NY 12189-4050			8. PERFORMING ORGANIZATION REPORT NUMBER ARCCB-TR-00008	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) The present report is a reply to J.H. Underwood's critique of the ARDEC Technical Report entitled "Gray Layers and the Erosion of Chromium Plated Gun Bore Surfaces" by Cote and Rickard. At issue is the evidence from the survey study by Cote and Rickard, that hydrogen cracking plays no role in damage initiation and chromium spallation. A brief review of the controversy relating to hydrogen cracking and damage initiation in gun bores is presented here. The question of hydrogen cracking beyond the initiation stage is also addressed. Consideration of some of the implications of the proposed hydrogen-cracking model and the general observations of the survey study offer reasons to doubt that damage initiation in gun bores is a result of hydrogen cracking, despite the plausibility of the proposed model.				
14. SUBJECT TERMS Gray Layers, Hydrogen Cracking, Chromium Spallation, Erosion, Damage Initiation			15. NUMBER OF PAGES 12	
			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	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 3-89)
Prescribed by ANSI Std. Z39-18
298-102

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
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.				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE June 2000	3. REPORT TYPE AND DATES COVERED Final		
4. TITLE AND SUBTITLE SIMULATION OF SHOT IMPACTS FOR THE M1A1 TANK GUN			5. FUNDING NUMBERS AMCMS No. 6226.24.H191.1	
6. AUTHOR(S) Ronald Gast, Steven Morris, and Mark Costello (Oregon State University, Corvallis, OR)				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Benet Laboratories, AMSTA-AR-CCB-O Watervliet, NY 12189-4050			8. PERFORMING ORGANIZATION REPORT NUMBER ARCCB-TR-00009	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES Presented at the 9 th U.S. Army Gun Dynamics Symposium, McLean, VA, 17-19 November 1998. Published in proceedings of the symposium.				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) Never has the need for simulation in design of components been more acute. Today's business environment requires innovative thinking in product development, especially for the 'big-ticket' ordnance items such as main battle tanks and armament. The manufacturing costs of these items and related components prohibit use of the classical method of product development, which includes initial design, prototype manufacture, system testing, and redesign. The answer lies in the use of virtual performance simulation to assess a system's response before any hardware is manufactured. Up-front costs are greatly reduced since the system components reside in virtual space, allowing for rapid electronic design changes and optimization by simulation rather than iterative testing of costly hardware. One must not be overly enamored by the power and function of the simulation tools. They are just mathematical models written by mere mortals, the execution of which closely mimics nature but does not actually reproduce it. Ultimately, these simulations need to be validated before one becomes comfortable in their use. There are various ways to validate a simulation code. First, one may use dedicated and controlled tests void of extraneous noise to establish relational characteristics among a few test variables. The results may then be directly compared to simulations, with validation achieved when output closely matches the test data. The second method involves comparing simulated results to inherently noisy field-generated test data. The best one may expect to achieve from this type of validation is trends in the responses relative to variations in the system parameters. It is the purpose of this report to validate a coupled simulation package for the accuracy assessment of large caliber weapons. The simulation packages include SIMBAD, a finite element gun dynamics code, and BOOM, a projectile flight dynamics code. These two models have been coupled so that the output of SIMBAD is the input to BOOM. Simulated results are compared to field-generated accuracy firings for the M1A1 tank, thus method two validation was used to assess the worth of this endeavor.				
14. SUBJECT TERMS Gun Dynamics, Tank Gun Accuracy, Flexural Body Dynamics, Exterior Ballistics, M1A1 Tank, Kinetic Energy Projectile			15. NUMBER OF PAGES 49	
			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	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
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.				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE June 2000	3. REPORT TYPE AND DATES COVERED Final		
4. TITLE AND SUBTITLE STRESS AND FATIGUE LIFE MODELING OF CANNON BREECH CLOSURES INCLUDING EFFECTS OF MATERIAL STRENGTH AND RESIDUAL STRESS			5. FUNDING NUMBERS PRON No. APPLIEDORNA	
6. AUTHOR(S) John H. Underwood and Michael J. Glennon				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Benet Laboratories, AMSTA-AR-CCB-O Watervliet, NY 12189-4050			8. PERFORMING ORGANIZATION REPORT NUMBER ARCCB-TR-00010	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES To be presented at the ASME Pressure Vessels and Piping Conference, Seattle, WA, 23-27 July 2000. To be published in proceedings of the conference.				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) Laboratory fatigue life results are summarized from several test series of high-strength steel cannon breech closure assemblies pressurized by rapid application of hydraulic oil. The tests were performed to determine safe fatigue lives of high-pressure components at the breech end of the cannon and breech assembly. Careful reanalysis of the fatigue life tests provides data for stress and fatigue life models of breech components, over the following ranges of key parameters: 380 to 745 MPa cyclic internal pressure; 100 to 160-mm bore diameter cannon pressure vessels; 1040 to 1170 MPa yield strength A723 steel; no residual stress; shot-peen residual stress; overload residual stress. Modeling of applied and residual stresses at the location of the fatigue failure site is performed by elastic-plastic finite element analysis using ABAQUS and by solid mechanics analysis. Shot-peen and overload residual stresses are modeled by superposing typical or calculated residual stress distributions on the applied stresses. Overload residual stresses are obtained directly from the finite element model of the breech, with the breech overload applied to the model in the same way as with actual components. Modeling of the fatigue life of the components is based on the fatigue intensity factor concept of Underwood and Parker, a fracture mechanics description of life that accounts for residual stresses, material yield strength, and initial defect size. The fatigue life model includes six test conditions in a stress versus life plot with an R^2 correlation of 0.94. The model shows significantly lower correlation when known variations in yield strength, stress concentration factor, or residual stress are not included in the model input, thus demonstrating the model sensitivity to these variables.				
14. SUBJECT TERMS Fatigue Life, Cannons, Finite Element Analysis, Stress Modeling, Fatigue Life Modeling, Residual Stress			15. NUMBER OF PAGES 12	
			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	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
299-102

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1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE July 2000	3. REPORT TYPE AND DATES COVERED Final	
4. TITLE AND SUBTITLE IMAGE PLATE X-RAY DIFFRACTION AND X-RAY REFLECTIVITY CHARACTERIZATION OF PROTECTIVE COATINGS AND THIN FILMS			5. FUNDING NUMBERS AMCMS No. 6111.02.H671.1	
6. AUTHOR(S) S.L. Lee, D. Windover (Benet and RPI, Troy, NY), M. Doxbeck, and T.-M. Lu (RPI)				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Benet Laboratories, AMSTA-AR-CCB-O Watervliet, NY 12189-4050			8. PERFORMING ORGANIZATION REPORT NUMBER ARCCB-TR-00011	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000			10. SPONSORING/MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES Presented at the 26th International Conference on Metallurgical Coatings and Thin Films, San Diego, CA, 12-15 April 2000. Published in proceedings of the conference. To be published in <i>Thin Solid Films</i> or <i>Surface and Coatings Technology</i> .				
12a. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) Two-dimensional image plate applications in x-ray diffraction and x-ray reflectivity characterization, using grazing-incidence geometry and radiation from a conventional x-ray tube, were explored. X-ray diffraction and x-ray reflectivity data were obtained from a conventional diffractometer with Si(Li) detector. These data complement image plate results to give more complete phase and structure information. Protective chromium coatings, electrochemically deposited onto the bore of steel cylinders, were investigated. Retained austenite content in martensitic steel was measured in simulated, inside-diameter, bore geometry. This approach demonstrates the versatility of the method for nondestructive chemical analysis and phase differentiation of interior bore surfaces in piping structures. MATLAB-based processing software was developed to facilitate quantitative image analysis, including multiple 2θ scans, χ-plots, and pole figure reconstruction from multiple φ images, where χ and φ designate, respectively, specimen tilt and rotation. In x-ray reflectivity applications, 12-nm tantalum and 80-nm tantalum oxide thin films sputtered on (100)-oriented silicon wafers were investigated. Density and thin-film thickness were obtained from specular reflectivity modeling involving the periodicity of the interference fringes. Two-dimensional Kiessig interference-fringe images were analyzed and compared to conventional specular x-ray reflectivity images for the measurement of thin-film thickness and thickness uniformity over a sample.				
14. SUBJECT TERMS Digital Film, Image Plate, Chromium, Tantalum, Tantalum Oxide, Austenite, Martensite, Coatings, Thin Films, X-Ray Diffraction, X-Ray Reflectivity			15. NUMBER OF PAGES 21	
			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 UJ	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
<small>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.</small>				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE July 2000	3. REPORT TYPE AND DATES COVERED Final		
4. TITLE AND SUBTITLE X-RAY DIGITAL IMAGE PLATE DETECTOR FOR PHASE AND TEXTURE ANALYSES OF THIN TANTALUM FILMS			5. FUNDING NUMBERS AMCMS No. 6111.01.91A1.1	
6. AUTHOR(S) D. Windover (Benet and RPI, Troy, NY), E. Barnat (RPI), J. Summers (RPI), T.-M. Lu (RPI), and S.L. Lee				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Benet Laboratories, AMSTA-AR-CCB-O Watervliet, NY 12189-4050			8. PERFORMING ORGANIZATION REPORT NUMBER ARCCB-TR-00012	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES Submitted to <i>Journal of Materials Research</i> .				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) An x-ray digital image plate detector was used to conduct phase and texture analyses of thin tantalum films in several seconds using a conventional, fixed copper anode, x-ray tube. This plate imaging method provides an expansion of grazing-incidence x-ray diffraction, out of the goniometer plane. The method exploits Laue flat plate geometries and "tall" Debye-Scherrer camera methods. The film studied shows 200-nm of sputter-deposited, α -phase tantalum, showing <110> fiber texture grown on a silicon (100) substrate. Image plate texture information was presented, and confirmed through comparison with conventional pole figure and 2 θ Bragg analyses.				
14. SUBJECT TERMS Image Plate, Digital Films, Tantalum, Phase, Texture			15. NUMBER OF PAGES 11	
			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	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
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298-102

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1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE July 2000	3. REPORT TYPE AND DATES COVERED Final		
4. TITLE AND SUBTITLE INDEX TO BENET LABORATORIES TECHNICAL REPORTS - 1999			5. FUNDING NUMBERS N/A	
6. AUTHOR(S) R.D. Neifeld				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Benet Laboratories, AMSTA-AR-CCB-O Watervliet, NY 12189-4050			8. PERFORMING ORGANIZATION REPORT NUMBER ARCCB-SP-00013	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) This is a compilation of technical reports published by Benet laboratories during 1999.				
14. SUBJECT TERMS Benet Laboratories, Technical Publications, Bibliographies, Abstracts, Document Control Data			15. NUMBER OF PAGES 34	
			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	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
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1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE August 2000	3. REPORT TYPE AND DATES COVERED Final		
4. TITLE AND SUBTITLE EFFECT OF SPUTTERING PARAMETERS ON TANTALUM COATINGS FOR GUN BORE APPLICATIONS			5. FUNDING NUMBERS AMCMS No. 6111.02.H671.1	
6. AUTHOR(S) Dean W. Matson (Pacific Northwest National Laboratory, Richland, WA), Edwin D. McClanahan (Pacific Northwest), Joseph P. Rice (Pacific Northwest), Sabrina L. Lee, and Donald Windover (Benet and RPI, Troy, NY)				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Benet Laboratories, AMSTA-AR-CCB-O Watervliet, NY 12189-4050			8. PERFORMING ORGANIZATION REPORT NUMBER ARCCB-TR-00014	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES Presented at the 26 th International Conference on Metallurgical Coatings and Thin Films, San Diego, CA, 12-15 April 2000. Published in proceedings of the conference. To be published in <i>Thin Solid Films</i> or <i>Surface and Coatings Technology</i> .				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) Tantalum offers a number of attractive properties for gun bore coating applications, including a high melting temperature, high ductility, and an environmentally friendly deposition method. However, vapor-deposited tantalum can appear in both the characteristic body-centered-cubic phase found in the bulk material, and in a very brittle and less desirable "beta" phase. Presence of the beta phase in bore coatings is considered undesirable because of its brittleness and resulting failure as the coating is stressed. A high-rate triode sputtering system with a cylindrical coating geometry was used to produce thick tantalum coatings on 4340 steel, smooth bore cylindrical substrates. A systematic series of tests was performed to evaluate the effects of sputtering gas species (argon, krypton, xenon) and substrate temperature (100° to 300°C) during deposition on the phase and microstructure of the coatings. Heavier sputtering gases and higher substrate temperatures were found to promote the formation of body-centered-cubic phase tantalum coatings. Use of a movable target assembly was shown to promote the production of dense, single-phase tantalum coatings.				
14. SUBJECT TERMS Sputtering, Tantalum, Triode, Alpha-Tantalum, Beta-Tantalum, Micrographs			15. NUMBER OF PAGES 15	
			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	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
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.				
1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE October 2000	3. REPORT TYPE AND DATES COVERED Final		
4. TITLE AND SUBTITLE CANNON COATING EROSION MODEL WITH UPDATED M829E3 EXAMPLE			5. FUNDING NUMBERS PRON No. GENERAL DYNAMICS	
6. AUTHOR(S) Samuel Sopok				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Benet Laboratories, AMSTA-AR-CCB-O Watervliet, NY 12189-4050			8. PERFORMING ORGANIZATION REPORT NUMBER ARCCB-TR-00015	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES Presented at the 36 th AIAA Joint Propulsion Conference, Huntsville, AL, 16-19 July 2000. Published in proceedings of the conference.				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) Cannons with bore coatings are necessary to reduce erosion in current and future high-performance combat systems. In 1996, we developed a unique erosion model for cannons with bore coatings. Since that time, our results from this model have been published for a number of important Army and Navy gun systems with bore coatings. The erosion model for cannons with bore coatings is guided and calibrated and correlates very well with considerable gun system firing data and subsequent laboratory analysis of fired specimens. Our confidence in the model has grown yearly such that we have decided to publish the details of this model. Coated cannon bore erosion does not simply proceed in an outward to inward progressive ablative fashion, since coatings typically spall instead of progressively ablate. This is the only known erosion model for cannons with bore coatings to account for all aspects of the typical firing-induced cannon erosion mechanism. The typical mechanism includes: <ul style="list-style-type: none"> • Heat-check cracking of the bore coating • Bore coating shrinkage leading to progressive widening of these cracks • Combustion gas-induced interface degradation of the exposed substrate metal • Abrupt interfacial spalling of the bore coating platelets due to linked interfacial degradation that forms pits • Subsequent substrate metal gas wash-to-erosion condemnation A very fine bore coating crack provides a narrow combustion gas path to the metal substrate thus producing limited interfacial substrate degradation. In contrast, a progressively widened/extended bore coating crack due to firing-induced bore coating shrinkage provides a wide combustion gas path to the metal substrate producing substantial interfacial substrate degradation. The purpose of this report is to review typical cannon erosion mechanisms, highlight the resultant cannon coating erosion model, show how this very critical coatings model incorporates into our overall cannon erosion code, and provide an example. The example is an updated erosion prediction for the experimental nonablative M829E3 kinetic energy tank round with and without HEAT-type rounds. The presence of HEAT-type rounds significantly alters the M829E3 erosion pattern compared to their absence.				
14. SUBJECT TERMS Cannon Coatings, Erosion Modeling, M829E3 Erosion Simulation			15. NUMBER OF PAGES 22	
			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	

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
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1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE November 2000	3. REPORT TYPE AND DATES COVERED Final		
4. TITLE AND SUBTITLE RECOIL CONSIDERATIONS FOR RAILGUNS			5. FUNDING NUMBERS AMCMS No. 6226.24.H191.1	
6. AUTHOR(S) Eric L. Kathe				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Benet Laboratories, AMSTA-AR-CCB-O Watervliet, NY 12189-4050			8. PERFORMING ORGANIZATION REPORT NUMBER ARCCB-TR-00016	
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) U.S. Army ARDEC Close Combat Armaments Center Picatinny Arsenal, NJ 07806-5000			10. SPONSORING / MONITORING AGENCY REPORT NUMBER	
11. SUPPLEMENTARY NOTES Presented at the 10 th Electromagnetic Launcher Symposium, San Francisco, CA, 25-28 April 2000. Accepted for publication in <i>IEEE Transactions on Magnetics</i> to be published in January 2001.				
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) The firing of any gun, electromagnetic or otherwise, imparts substantial momentum to the launcher, and ultimately the weapon platform. The objectives of the future combat system program call for similar lethality to a current heavy tank on an extremely lightweight vehicle of nominally twenty tons. Prior experience with the M551 Sheridan, a light tank first put into production by the United States in 1966, raises concern that firing large caliber armaments from light vehicles may result in unacceptable crew discomfort and vehicular reaction during recoil. This report provides a future combat system armament integration perspective for railgun recoil.				
14. SUBJECT TERMS Railgun Recoil, Mechanical Shock Isolation, Weapon System Integration, Recoil Tolerance			15. NUMBER OF PAGES 16	
			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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