AD-A056 107 ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND WATER--ETC F/G 19/6
INDEX TO BENET WEAPONS LABORATORY (LCWSL) TECHNICAL REPORTS - 1--ETC(U).
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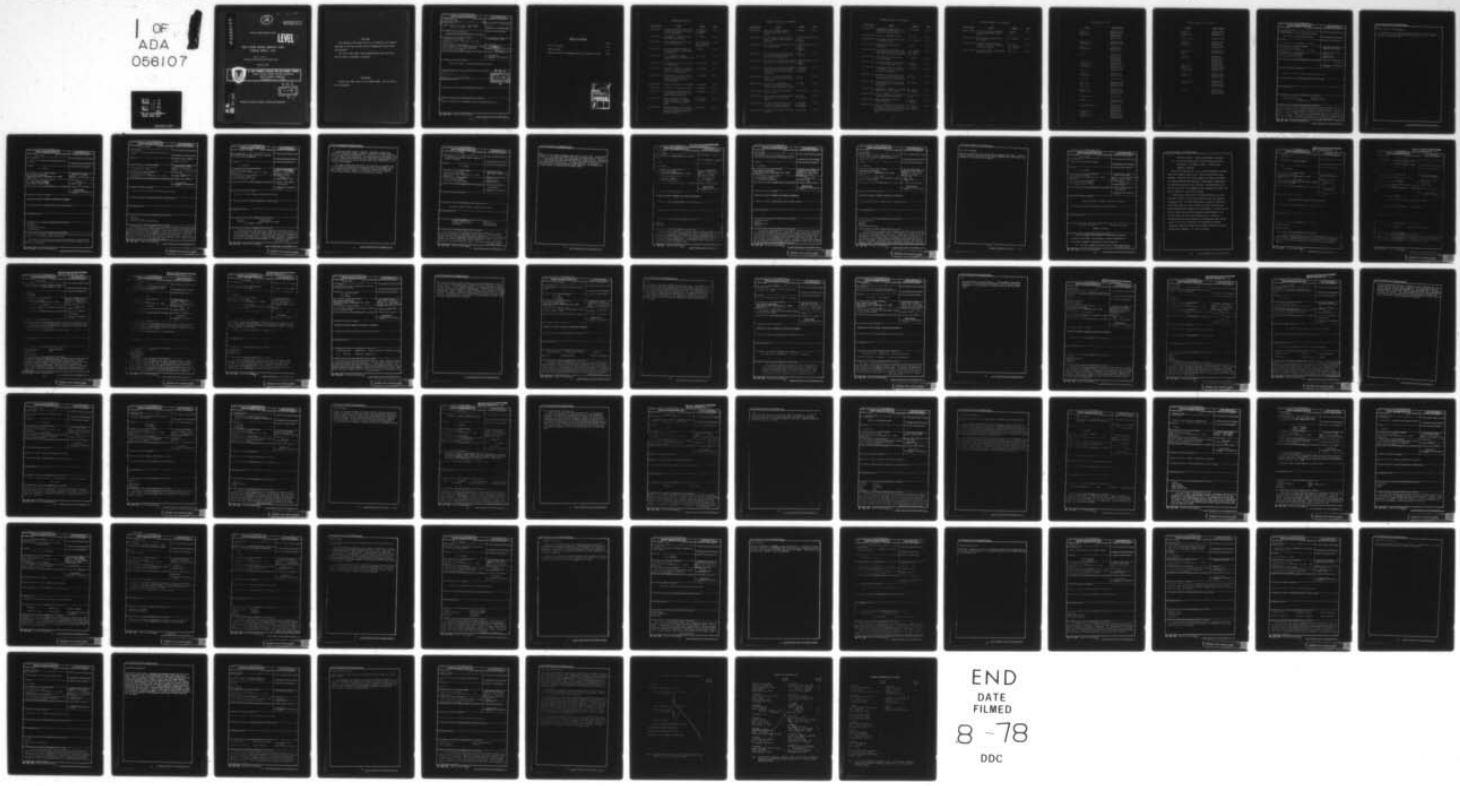

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SPECIAL REPORT ARLCB-SP-78003

LEVEL II

INDEX TO BENET WEAPONS LABORATORY (LCWSL) TECHNICAL REPORTS - 1977

Roy F. Tario
Technical Publications and Editing Unit

February 1978

US ARMY ARMAMENT RESEARCH AND DEVELOPMENT COMMAND
LARGE CALIBER WEAPON SYSTEMS LABORATORY
BENÉT WEAPONS LABORATORY
WATERVLIET, N. Y. 12189

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REPORT DOCUMENTATION PAGE

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5. TYPE OF REPORT & PERIOD COVERED: Special Rept.
6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): Roy F. Tario
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9. PERFORMING ORGANIZATION NAME AND ADDRESS
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11. CONTROLLING OFFICE NAME AND ADDRESS
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12. REPORT DATE: February 1978
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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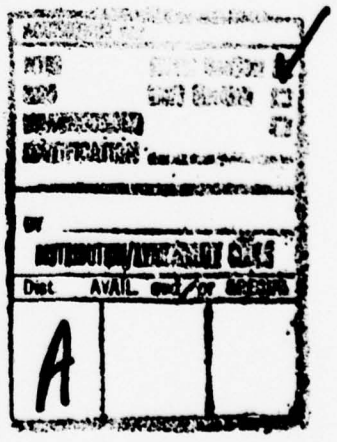

TECHNICAL REPORTS 1977

REPORT NUMBER	TITLE	AUTHOR	DATE
WVT-TR-77001	Computer Controlled X-Ray Stress Analysis for Inspection of Manufactured Components	G. Capsimalis R. Haggerty K. Loomis	Jan 77
WVT-TR-77002	Development of Improved Rifling Procedures and Equipment	C.H. LaRoss	Jan 77
WVT-CR-77003	Machining Tests and Analysis on 1018 and 4330 Steels	J.D. Christopher Metcut Research Associates, Inc.	Jan 77
WVT-TR-77004	Mechanism of Embrittlement and Brittle Fracture in Liquid Metal Environments	M. Kamdar	Jan 77
WVT-TR-77005	The Measurement of Dynamic Young's Modulus in Composite Laminates	Y.F. Cheng	Feb 77
WVT-TR-77006	The Stability of a Beam Subjected to a Moving Mass	G.L. Anderson	Feb 77
WVT-TR-77007	Qualitative Stability Characteristics of a Flexible Missile Subjected to a Circular Thrust	G.L. Anderson	Feb 77
WVT-TR-77008	The Influence of Support Characteristics on the Stability of an Elastic System Subjected to a Circulatory Force	G.L. Anderson	Mar 77
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WVT-TM-77010	Preparation of Economic Analyses	V. Montouri	Feb 77
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WVT-TR-77015	Electrodeposited C_u and C_u-Al_2O_3 Alloys: Physical and Mechanical Properties	G. Lakshmenarayanan E. Chen F. Sautter	Mar 77
WVT-TR-77016	Electrodeposition of Cobalt Using an Insoluble Anode	G. Lakshmenarayanan E. Chen J. Sadak F. Sautter	Mar 77
WVT-TR-77017	The Effects of Pulse Current Plating on the Mechanical Properties Of Cobalt and Cobalt-Al_2O_3	E. Chen F. Sautter	Mar 77
WVT-TR-77018	The Effects of Chloride Ion on the Codeposition of Alumina with Copper	G. Lakshmenarayanan E. Chen F. Sautter	Mar 77
WVT-TR-77019	Ultrasonic and Acoustic Holographic Techniques for Inspection of Composite Gun Tubes and Other Weapon Components	G. Capsimalis G. D'Andrea R. Peterson	Mar 77
WVT-TR-77020	Effects of Pressure and Thermal Loadings on a Thin Plating Inside a Thick Tube	S.L. Pu J.J. Wu	Mar 77
ARLCB-TR-77025	The Effect of Autofrettage on Fatigue Crack Propagation in Externally Flawed Thick Walled Disks	J.A. Kapp	Apr 77
ARLCB-MR-77026	Effects of Quenching Techniques Upon Gun Steel	E.H. Niccolls	May 77
ARLCB-TR-77027	Analytical and Experimental Tube Temperatures in the 8" XM201 Cannon	R.G. Gast P.M. Vottis	May 77
ARLCB-TR-77028	The Abrasion Characteristics of Certain Protective Coatings on Aluminum and Magnesium Alloys	A. Campbell W. Mortimer P. Thornton	May 77
ARLCB-TR-77029	A Probabilistic Model of Gun Tube Fatigue	R.L. Racicot	May 77

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ARLCB-TR-77031	Erosion in 81MM Mortar Tubes	V.P. Greco	Jun 77
ARLCB-TR-77032	Development of Prototype Production ESR Facilities	V.J. Colangelo	Jun 77
ARLCB-TR-77033	Automatic Step Threading of Breechblocks	C. Rose	Jun 77
ARLCB-TR-77034	The Influence of Late Wear Life 105MM M68 Gun Tubes on Discarding Sabot Ammunition Flight Stability	A.A. Albright E.E. Coppola G.S. Friar	Jul 77
ARLCB-TR-77035	Evaluation of 155MM M199 Tube Forging Producers	J. Passmore	Jul 77
ARLCB-TR-77036	Reinforced Cobalt Alloy Composite for Turbine Blade Application	I. Ahmad J. Barranco	Jul 77
ARLCB-TR-77037	Investigation of Fastener Failure in 105MM M68 Guns and 152MM M81 and M162 Gun Launchers	M. Longmate	Aug 77
ARLCB-TR-77038	Vibrations of a Helicopter Rotor Blade Using Finite Element-Unconstrained Variational Formulations	J.J. Wu C.N. Shen	Sep 77
ARLCB-TR-77040	Probabilistic Models on Gun-Tube Fatigue Based on a Fracture-Mechanics Model	E.E. Coppola	Oct 77
ARLCB-TR-77041	Isoparametric Elements as Singular Elements for Crack Problems	M.A. Hussain W.E. Lorensen	Oct 77
ARLCB-TR-77042	Effect of Damping at the Support of a Rotating Beam on Vibrations	J.D. Vasilakis J.J. Wu	Oct 77
ARLCB-TR-77043	Temper Embrittlement in 4140 Seamless Tubing	S. Tauscher P. Thornton	Nov 77
ARLCB-TR-77044	Design and Production of Ballistic Guns Nos. 2 and 3 and the Initial Test Bed Gun for the Medium Caliber Anti-Armor Automatic Cannon Program	P.M. Vottis R.L. Billington R.C. Sillery	Nov 77

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REPORT NUMBER	TITLE	AUTHOR	DATE
ARLCB-TR-77045	Structure Factors in Amorphous and Discorded Harmonic Debye Solids	L. Meisel P. Cote	Dec 77
ARLCB-TR-77046	Embrittlement of Gun Steel by Liquid Lead	M.H. Kamdar	Dec 77
ARLCB-TR-77047	Collapsed 12-Node Triangular Elements as Crack Tip Elements for Elastic Fracture	S.L. Pu M.A. Hussain W.E. Lorensen	Dec 77
ARLCB-TR-77048	Energy and Pressure Calculations for Metallic NH_4	D.M. Gray	Dec 77

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1. REPORT NUMBER WVT-TR-77001	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) COMPUTER CONTROLLED X-RAY STRESS ANALYSIS FOR INSPECTION OF MANUFACTURED COMPONENTS		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) G.P. Capsimalis, R.F. Haggerty, K. Loomis		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 SARWV-RT-TP		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 3297.06.7282 Pron No. M1-4-A1527
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Armament Command Rock Island, Illinois 61201		12. REPORT DATE January 1977 13. NUMBER OF PAGES 30
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

X-Ray Diffraction
Non-Destructive Testing
Residual Stress
Computer Automation
Real Time System

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A portable x-ray system has been constructed to measure automatically the surface residual stresses of gun tubes and other weapon components. The system includes a Siemens stress goniometer powered by a Norelco full wave x-ray generator and a set of Canberra modular electonics which consist of a dual axis positioner, a universal timer-scaler and a telecomputer interface for communicating with a minicomputer. The system is controlled by a PDP11/05 minicomputer having 12K words of memory, 1.2M-word removable-cartridge disk and can implement entire
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20.
problem solutions using FORTRAN IV.

All operations of the stress goniometer, the modular electonic hardware, logic operations and data processing are performed in real time and are completely computer controlled.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER WVT-TR-77002	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) DEVELOPMENT OF IMPROVED RIFLING PROCEDURES AND EQUIPMENT		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) C. H. LaRoss		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 SARWV-RT-TP		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 3297.06.7402 PRON No. M1-4-A1678-01-M7-M7
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Command Rock Island, Illinois 61201		12. REPORT DATE January 1977 13. NUMBER OF PAGES 40
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Broaching
Gun Barrels
Rifling Duplex Process
Rifling Machines

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes a process of rifling two 105mm M2A2 gun barrels simultaneously in a horizontal side by side position.

The purpose of the project was to reduce significantly rifling machining time of 105mm gun barrels by a process that would be readily adaptable to production line quantities.

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1. REPORT NUMBER WVT-CR-77003	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) MACHINING TESTS AND ANALYSIS ON 1018 AND 4330 STEELS		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s)		8. CONTRACT OR GRANT NUMBER(s) DAAA22-75-M-0419
9. PERFORMING ORGANIZATION NAME AND ADDRESS Metcut Research Associates Inc. Cincinnati, Ohio 45209		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 3297.16.7119 Pron No. M1-2-23084-01-M7-M7
11. CONTROLLING OFFICE NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 SARWV-RT-TP		12. REPORT DATE January 1977
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Carbide
High Speed Steel
Optimum Tool Geometry Application

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

An examination of the report "An Investigation to Determine the Single Point Cutting Tool Angles Which Yield Maximum Tool Life by Response Surface Methodology and Evolutionary Operation of Processes," Lloyd Louis Lehn (thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Mechanical Engineering in the Graduate College of the University of Illinois, 1967), necessitated determining the optimum tool geometry which could be used to grind back and side rake tool angles for high speed steel tools. Machining tests and analysis were done on 1018 and 4330 steels.

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1. REPORT NUMBER WVT-TR-77004	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) MECHANISM OF EMBRITTLEMENT AND BRITTLE FRACTURE IN LIQUID METAL ENVIRONMENTS		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) M. H, Kamdar		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N. Y. 12189 SARWV-RT-TP		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 611102.H540011 DA Proj No. 1L161102AH54 PRON No.M1-7-51700
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Fracture
Mechanism
Embrittlement
Liquid Metal Environment
Environmental Effects

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Polycrystals and single crystals of normally ductile metals fail in a catastrophic brittle manner when exposed to certain surface active liquid metal environments. The fracture mode changes from ductile to intergranular or transgranular mode or both. In some instances, propagation of cracks in liquid metal environments occur at speeds of order 100 cm/sec. Such effects are generally recognized as the phenomena of "Liquid Metal Embrittlement".

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Liquid metal embrittlement is presently considered to result from liquid metal "adsorption-induced reduction in cohesion" of atomic bonds at regions of high stress concentrations in a solid, such as at the tip of cracks or at the sites of crack nucleation. The prerequisites for embrittlement are the same as those for brittle fracture and liquid metal embrittlement is considered a special case of brittle fracture rather than a diffusion or a corrosion type of phenomena.

This paper presents some theoretical considerations (1) concerning the "reduced-cohesion" mechanism of embrittlement and (2) embrittlement to be a special case of brittle fracture. Experimental results utilizing ideal embrittlement systems in support of the mechanism and also in support of various brittle fracture criteria are presented and discussed.

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1. REPORT NUMBER: WVT-TR-77005	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): THE MEASUREMENT OF DYNAMIC YOUNG'S MODULUS IN COMPOSITE LAMINATES	5. TYPE OF REPORT & PERIOD COVERED
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Y.F. Cheng	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Benet Weapons Laboratory, Watervliet Arsenal, Watervliet, N.Y. 12189, SARWV-RT-TP	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AMCMS Code: 612105.11.H8400; PRON: A1-5-R0005-04-AW-M7
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Composite Materials
Dyanamic Young's Modulus
Boron-Epoxy
Laminates
Boron-Aluminium
Fibreglass-Epoxy

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The suitability of the resonance-free vibration method and the impact method in the measuring of the dynamic Young's modulus in boron aluminium, fibreglass-epoxy and boron-epoxy laminates has been studied. In the vibration method, the concept of equivalent length was developed. Using the equivalent length, the vibration method gave dynamic values of $(E_d)_1$ and $(E_d)_2$ which were practically the same as the static values. The impact method gave a dynamic

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value of Young's modulus noticeably lower than the static value. The difference between $(E_d)_{11}$ from impact and those from vibration increases with the ratio of E_f/E_m — thus showing the effect of the dispersion of stress velocity. In addition, $(E_d)_{22}$ from impact was always lower than those from vibration and was apparently not related to the ratio of E_f/E_m. It is concluded that, in the dynamic characterisation of fibre-reinforced laminate materials, the resonance-free vibration method is preferable to the impact method.

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1. REPORT NUMBER WVT-TR-77006	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) The Stability of a Beam Subjected to a Moving Mass		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) G.L. Anderson		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 WVT-TSP		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 611102.11.8530 DA Proj. No. 1T161102B14A Prog No. A1-5-51700
11. CONTROLLING OFFICE NAME AND ADDRESS Army Armament Command Rock Island, Illinois 61201		12. REPORT DATE February 1977 13. NUMBER OF PAGES 19
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19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Stability
Vibrations

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The parametric stability of a slender, elastic simply supported beam subjected to the action of a concentrated mass moving at constant velocity along its axis is investigated. The Galerkin procedure is applied to reduce the partial differential equation of motion to an ordinary differential equation in time with periodic coefficients. A perturbation procedure is employed to solve this differential equation, and the boundary curves of the fundamental region of instability are determined.

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1. REPORT NUMBER WVT-TR-77007	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Qualitative Stability Characteristics of a Flexible Missile Subjected to a Circulatory Thrust		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) G.L. Anderson		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 SARWV-RT-TP		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 611102.11.35D00 DA Proj. No. 1F161102A35D Pron No. EJ-5-Y0015
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Command Rock Island, Illinois 61201		12. REPORT DATE February 1977 13. NUMBER OF PAGES 29
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Circulatory Thrust
Dynamics
Flexible Missile
Stability

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The stability characteristics of an elastic, flexible missile of constant mass, modelled mathematically as a system consisting of three rigid bars elastically hinged at the joints and subjected to a constant circulatory thrust, are examined. Plots of eigencurves are presented and used to identify the regions of stability, divergence, and flutter in related stability maps. For anti-tangential and sub-tangential thrusts, the system is found to be divergent for any sufficiently small, positive thrust. Moreover, flutter does not occur for anti-tangential and super-tangential thrusts.

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1. REPORT NUMBER WVT-TR-77008	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) The Influence of Support Characteristics on the Stability of an Elastic System Subjected to a Circulatory Force		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) G.L. Anderson		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 DARWV-RT-TT		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 611102.11.35D00 DA Proj. No. 1F161102A35D Pron No. EJ-5-Y0015
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Dover, New Jersey 07801		12. REPORT DATE March 1977 13. NUMBER OF PAGES 33
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Circulatory Force
Dynamics
Stability
Support Characteristics

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The stability of a vertical double pendulum with elastic joints, mounted on a platform whose horizontal motion is constrained by an elastic spring and subjected to circulatory force, is examined. Attention is focused on the determination of the critical loads of divergence and flutter as functions of the platform mass and spring stiffness parameters, which characterize the effects of the support on the stability of the double pendulum. The frequency equation is derived, and several typical eigencurves are plotted in the load-frequency plane. Stability maps in the load-tangency coefficient plane indi-

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Block 20 (continued)

cate the existence of regions of stability, divergence and flutter. Certain boundary curves of these regions are strongly dependent upon the values of the parameters that characterize the support.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER WVT-TR-77009	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) PARAMETRIC RESONANCE IN GUN TUBES		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) T. E. SIMKINS		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 SARWV-RT-TP		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS DA Proj. No. M7-7-R00146-01-M7-M7 AMCMS No. 662603.H78001
11. CONTROLLING OFFICE NAME AND ADDRESS U.S. Army Armament Command Rock Island, Illinois 61201		12. REPORT DATE February 1977 13. NUMBER OF PAGES 63
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16. DISTRIBUTION STATEMENT (of this Report)

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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Vibrations, Gun Tube
Parametric Resonance
Dynamics, Gun Tube

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This work examines the likelihood of encountering parametric resonance in gun tubes. The resonance is induced conceptually by the periodic changes in transverse stiffness induced by

(i) the axial vibrations resulting from a single application of

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ballistic pressure - "single round parametric resonance".

(ii) the periodic applications of ballistic pressure such as encountered in an automatic weapon - "multiple round parametric resonance".

Results show that ballistic cycles currently employed in the 60mm MCAAAC semi automatic cannon are not likely to excite single round resonance. Unusually brief cycles, however, are shown to be capable of producing resonance amplifications of three orders of magnitude in less than twenty cycles of axial vibration. By proper design of the pressure cycle and/or the fundamental axial frequency of the tube, this type of resonance is rather easily avoided.

Further results show that for the 20mm M139 machine gun, amplifications in excess of fifty can be reached in under five seconds of continuous firing. A special application of the work of Krajcinovic and Herrmann leads to a set of instability contours from which the growth (characteristic) exponent can be determined as a function of the ratio of natural and excitation frequencies and the product of the ballistic impulse and the tube slenderness ratio. Control or elimination of multi-round resonance can be maintained either through control of the initial conditions or by designing for mismatch between the transverse frequencies and integral mulitples of one-half the excitation frequency, i.e., the firing rate.

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: WVT-TM-77010
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER:

4. TITLE (and Subtitle): PREPARATION OF ECONOMIC ANALYSES

5. TYPE OF REPORT & PERIOD COVERED:

6. PERFORMING ORG. REPORT NUMBER:

7. AUTHOR(s): V.Montouri

8. CONTRACT OR GRANT NUMBER(s):

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
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11. CONTROLLING OFFICE NAME AND ADDRESS:
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12. REPORT DATE: February 1977

13. NUMBER OF PAGES: 44

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Economic Analyses

Computer Program

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Economic Analyses are required for all MM&T and MOU projects. They require numerous modifications, recalculations and retypings. Computerization of this task has simplified the processes considerably. This memorandum contains instructions for processing data necessary to prepare Economic Analyses.

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1. REPORT NUMBER: WVT-TR-77011
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER:

4. TITLE (and Subtitle): VERIFICATION OF NUMERICALLY CONTROLLED MACHINE PROGRAMS BY THE AUTOMATIC DRAFTING MACHINE
5. TYPE OF REPORT & PERIOD COVERED:
6. PERFORMING ORG. REPORT NUMBER:

7. AUTHOR(s): D. Concordia
8. CONTRACT OR GRANT NUMBER(s):

9. PERFORMING ORGANIZATION NAME AND ADDRESS: Benet Weapons Laboratory, Watervliet Arsenal, Watervliet, N.Y. 12189, DRDAR-BT-TP
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AMCMS No. 3297.06.7484; PRON No. M1-4-A1559(01)M7 N/A

11. CONTROLLING OFFICE NAME AND ADDRESS: U.S. Army Armament Research and Development Command, Dover, New Jersey 07801
12. REPORT DATE: March 1977
13. NUMBER OF PAGES: 48

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Numerical Control Automatic Drafting Machine

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This is a report on the modifications made to the Gerber automatic drafting program to allow for the verification of numerical controlled machine programs on the automatic drafting machine. Programming changes were made so that the eleven most-used machines at Watervliet Arsenal can be verified.

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1. REPORT NUMBER WVT-TR-77012	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Dynamic Analysis of Constant Reaction Systems for a Medium Caliber, Anti-Armor, Automatic Cannon		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) P. M. Vottis J. K. Jorczak		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, NY 12189		10. PROGRAM ELEMENT, PROJECT, TASK AMCMS No. 662603.11.H7800 DA Proj No. 1W662603AH78 Pron No. M7-6-R0115-07-M7-M7
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Dover, New Jersey 07801		12. REPORT DATE March 1977 13. NUMBER OF PAGES 50
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Constant Reaction
Constant Force
Recoil
Medium Caliber
Automatic Weapons
Guns

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report addresses the methodology used in determining a constant reaction force recoil system for the Medium Caliber, Anti-Armor, Automatic Cannon (MC-AAAC) Program, Test Bed #2. General theory and equations of motion which describe the primary elements are discussed. Solution is effected by numerical math modeling techniques. The results of a parametric study across ranges of key independent variables and system sensitivity analyses are presented. An optimal system candidate is selected and essential parameters established.

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REPORT NUMBER: WVT-TR-77013	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
TITLE (and Subtitle): Hydraulic Analysis of the Recoil and Counter-recoil Cycle in Medium Caliber, Anti-Armor, Automatic Cannon, Test Bed No. 2	5. TYPE OF REPORT & PERIOD COVERED
	6. PERFORMING ORG. REPORT NUMBER
AUTHOR(s): H. J. Sneck	8. CONTRACT OR GRANT NUMBER(s)
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Medium Caliber Guns
Recoil Mechanisms
Hydraulic Analysis
Automatic Weapons
Recoil Buffer

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In this report the various stages of the recoil and counterrecoil stroke of the Medium Caliber, Anti-Armor, Automatic Cannon, Test Bed No. 2 are analyzed from a hydraulic point of view. The resulting equations relate the damping force created by flow of fluid within the device to the recoil velocity, the internal dimensions of the recoil mechanism, and the properties of the fluid. Working formulas are developed which can be integrated into a computer program for the recoil dynamics of the complete gun barrel-recoil mechanism.

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1. REPORT NUMBER: WVT-TN-77014
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle): Failure Investigation--105mm M68 Tubes (SN 16244, 7506, and 11837)
5. TYPE OF REPORT & PERIOD COVERED
6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): A. Campbell
8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS: Benet Weapons Laboratory, Watervliet Arsenal, Watervliet, N.Y. 12189
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Failure Analysis
Malfunction
Adiabatic Shear

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report summarizes the investigation of three 105mm M68 gun tube failures which occurred during routine training exercises in April and May of 1976. The tubes involved were Serial Numbers 16244, 7506 and 11837; the failures occured at Forts Knox, Lewis and Bliss, respectively. The conclusion of the investigation is that all three malfunctions were caused by premature, in-bore detonation of the projectiles involved.

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1. REPORT NUMBER WVT-TR-77015	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Electrodeposited Cu and Cu-Al_2O_3 Alloys: Physical and Mechanical Properties		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) G.R. Lakshminarayanan E.S. Chen F.K. Sautter		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 SARWV-RT-TP		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS Code: 611101.91A0011 DA Proj. No. 1T161101A91A PRON No. 1A-7-51701-02-M7-M7
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Dover, New Jersey 07801		12. REPORT DATE April 1977 13. NUMBER OF PAGES 5
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Electrodeposition Codeposition Physical properties Mechanical proper-ties Annealing Dispersion strengthining

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Cu and Cu-Al_2O_3 alloys were electrodeposited from copper sulfate and copper sulfate-Al_2O_3 plating solutions repectively. Aluminum oxides of different sizes and crystalline phases were used as disperoids in the plating solutions. The properties measured for the deposits include the room temperature yield strength, ultimate tensile strength, elongation, hardness and electrical resistivity. The results show that a codeposition of 1.2 to 2.3 vol per cent calcined gamma oxide

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with copper increased the yield strength for the as-plated deposits by 65 to 145 per cent and the ultimate tensile strength by 35 to 70 per cent. Hardness was also increased for the Cu-Al_2O_3 deposits. Elongation generally decreased with an increase in oxide content in the deposits. Annealed Cu-Al_2O_3 deposits retained their higher strength up to 480°C (800°F), after a decrease in strength was observed. Unlike Cu deposits, annealing decreased the ductility of Cu-Al_2O_3 deposits. The effects of cold rolling were about 6 to 10 per cent higher than those of Cu electrodeposits. The properties of electrodeposits prepared under ultrasonic agitation are also reported.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER WVT-TR-77016	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Electrodeposition of Cobalt Using an Insoluble Anode		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) G.R. Lakshminarayanan E.S. Chen J.C. Sadak F.K. Sautter		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 SARWV-RT-TP		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS Code: 611101.91A0011 DA Proj. No. 1T161101A91A PRON No. 1A-7-51701-02-M7-M7
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Dover, New Jersey 07801		12. REPORT DATE April 1977 13. NUMBER OF PAGES 6
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Electrodeposition Electroactive chemicals Oxidation

Reduction Insoluble anodes Mechanical properties

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A method has been developed which permits the use of an insoluble anode to electrodeposit cobalt by the addition of a sufficient amount of an electrochemically active substance such as vanadium pentoxide to the cobalt sulfate plating solution. In the absence of such additions, formation of Co^{3+} ions and cobalt oxide (Co_2O_3) at the platinum anode results during plating. The effects of the addition of vanadium pentoxide on the electrode process during plating have been investigated through the analyses of various electrolysis products

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as a function of additive concentration and plating time. The results show that besides cobalt deposition, vanadium ions of lower oxidation state (V++, V+++, VO++) are formed at the cathode and these ions seem to be responsible for the reduction and suppression of Co^{3+} ions and the oxide at the platinum anode. It has also been observed that the concentration of the added electro-chemically active substance changed very little indicating no incorporation of vanadium with the deposit during plating. The mechanical properties of the deposits prepared using an insoluble anode are compared with those obtained using a soluble anode.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER WVT-TR-77018	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) The Effects of Chloride Ion on the Codeposition of Alumina with Copper		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) G.R. Lakshminarayanan E.S. Chen F.K. Sautter		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 SARWV-RT-TP		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS Code: 611101.91A0011 DA Proj.No. 1T161101A91A PRON No. 1A-7-51701-02-M7-M7
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Dover, New Jersey 07801		12. REPORT DATE April 1977 13. NUMBER OF PAGES 2
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Electrodeposition Codeposition Additives Adsorption

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The inhibitory effect of chloride ions on the codeposition of Al_2O_3 from acid copper sulfate electrolytes was investigated. In general, increasing the chloride ion concentration in the copper electrolyte reduces the oxide codeposition in the deposits. The maximum chloride ion concentration tolerable is dependent on the size, crystalline phase and nature of the suspended particles.

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1. REPORT NUMBER WVT-TR-77017	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) The Effects of Pulse Current Plating on the Mechanical Properties of Cobalt and Cobalt-Al_2O_3		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) E.S. Chen F.K. Sautter		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 SARWV-RT-TP		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS Code: 611101.91A0011 DA Proj. No. 1T161101A91A PRON No. 1A-7-51701-02-M7-M7
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Dover, New Jersey 07801		12. REPORT DATE April 1977 13. NUMBER OF PAGES 6
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Electrodeposition Codeposition Pulse Current Plating

Mechanical Properties Structure Dispersion Strengthening

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The effect of high current pulses on the mechanical properties of electrodeposited cobalt and Co-Al_2O_3 was studied along with two other variables, ultrasonic agitation and superimposed direct current. The deposit were prepared at pulse current densities between 0 and 100 A/dm^2, a pulse width of 120 μsec and a pulse repetition time of 18 msec. The strength and hardness of both cobalt and Co-Al_2O_3 deposits made under these conditions showed substantial increases

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over conventionally prepared deposits. The improvement in mechanical properties is attributed to the refinement in grain structure and the enhancement of Al_2O_3 codeposition associated with the use of current pulses.

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1. REPORT NUMBER: WVT-TR-77019
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER:

4. TITLE (and Subtitle): Ultrasonic and Acoustic Holographic Techniques for Inspection of Composite Gun Tubes and Other Weapon Components

5. TYPE OF REPORT & PERIOD COVERED:

6. PERFORMING ORG. REPORT NUMBER:

7. AUTHOR(s):
George P. Capsimalis
Giuliano D'Andrea
Ralph E. Peterson

8. CONTRACT OR GRANT NUMBER(s):

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
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12. REPORT DATE:
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13. NUMBER OF PAGES:
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18. SUPPLEMENTARY NOTES:

19. KEY WORDS (Continue on reverse side if necessary and identify by block number):
Acoustics
Composite Materials
Holography
Ultrasonics

20. ABSTRACT (Continue on reverse side if necessary and identify by block number):

Ultrasonic and acoustic holographic imaging has been shown to be an effective procedure for the nondestructive inspection of flaws and voids in composite and other material structures. Techniques for quantitatively imaging the size, shape and dustribution of flaws in composites and conventional materials are discussed. Additionally a number of test results representing applications of ultrasonic and holographic imaging and their adaptation to typical material testing problems are presented.

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REPORT DOCUMENTATION PAGE	READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: WVT-TR-77020	2. GOVT ACCESSION NO. / 3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): Effects of Pressure and Thermal Loadings on a Thin Plating Inside a Thick Tube	5. TYPE OF REPORT & PERIOD COVERED / 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): San-Li Pu, Julian J. Wu	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Benet Weapons Laboratory, Watervliet Arsenal, Watervliet, N.Y. 12189, SARWV-RT-TP	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AMCMS No. 611102.11.H4500, DA Proj No. 1L161102AH45, Pron No. EJ-7-Y0011
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army Armament Research and Development Command, Dover, New Jersey 07801	12. REPORT DATE: March 1977 / 13. NUMBER OF PAGES: 46
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)	15. SECURITY CLASS. (of this report): UNCLASSIFIED / 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report): Approved for public release; distribution unlimited.	
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)	
18. SUPPLEMENTARY NOTES	
19. KEY WORDS (Continue on reverse side if necessary and identify by block number): Composite Tubes; Cracks; Plating; Stresses; Thermal Stresses	
20. ABSTRACT (Continue on reverse side if necessary and identify by block number): Stress distribution in a thin layer of plating on the bore surface of a thick tube is studied based on the linear theory of elasticity. Several simple mathematical models are used to represent a variety of material and loading conditions. Results from these simple mathematical models indicate that the chrome plating in a gun tube is very likely to crack. Relative mechanical properties of plating materials and tube materials are discussed in order to reduce the stress level in the plating.	

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARLCB-TR-77025	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) The Effect of Autofrettage on Fatigue Crack Propagation in Externally Flawed Thick-walled Disks		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) J. A. Kapp		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 DRDAR-LCB-TL		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 3110.15.0003 PRON No. 32-6-P4957
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Large Caliber Weapon System Laboratory Dover, New Jersey 07801		12. REPORT DATE May 1977 13. NUMBER OF PAGES 44
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS. (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

This report was presented as a thesis for Graduate Studies.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Pressure vessels	Fatigue	Fracture Mechanics
Autofrettage	Stress Analysis	NASTRAN

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The effect of the autofrettage residual stress distribution on the crack growth rate in externally flawed thick-walled disks has been investigated. The crack growth rate was modeled by using the Paris power law relation. Stress intensity factors were calculated for internally pressurized, externally flawed, non-autofrettaged cylinders, by an approximate technique and with the use of the NASTRAN finite element computer program. A simple experiment was devised to determine the effect of autofrettage on crack growth rate. The the test involved diametrically loading thin disks,

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cut from autofrettaged cylinders, NASTRAN was used to determine the stress intensity factors for this loading geometry. The experimentally observed results show that autofrettage increases the crack growth rate in externally flawed cylinders, but the test did not supply sufficient data to mathematically model the increase. The faster crack growth rate is believed to be caused by the local relaxation of the tensile autofrettage residual stresses due to large plastic zones accompanying crack growth.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARLCB-MR-77026	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) EFFECTS OF QUENCHING TECHNIQUES UPON GUN STEEL		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) E. H. NICCOLLS		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 DRDAR-LCB-TL		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No.3297.06.7236 PRON No.M1-6-A1735-01-M7-M7
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Large Caliber Weapon System Laboratory Dover, New Jersey 07801		12. REPORT DATE May 1977 13. NUMBER OF PAGES 20
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Quench Quench Cracking Hardenability Critical Diameter

Gun Steel

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The effects of a water, oil and 400°F salt quench upon mechanical properties and microstructure of a 2" thick block of gun steel were studied. The 400°F salt quench was found to be the mildest quenchant. The water and oil quenching effects were compared to the empirical predictions of Grossman with good qualitative agreement.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARLCB-TR-77027	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Analytical and Experimental Tube Temperatures in the 8" XM201 Cannon		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) R. G. Gast P. M. Vottis		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 DRDAR-LCB-TL		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 664602.12.38900 DA Proj. No. 1W664602D389 Pron. No. 26-6-94012
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Large Caliber Weapon System Laboratory Dover, New Jersey 07801		12. REPORT DATE May 1977 13. NUMBER OF PAGES 28
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Gun Barrels
Guns
Heat Transfer
Thermal Test
Temperature

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A comparison is made between measured and predicted temperatures in the 8" XM201 cannon. The gross construction of the thermal model is given and data from firing tests on the XM201 cannon are presented. Correlation is found to be good.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARLCB-TR-77028	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) The Abrasion Characteristics of Certain Protective Coatings on Aluminum and Magnesium Alloys		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) A. Campbell W. Mortimer P. Thornton		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 DRDAR-LCB-TL		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 3297.06.7234 Pron No. M1-3-23021-01-M7-M7
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Large Caliber Weapon System Laboratory Dover, New Jersey 07801		12. REPORT DATE May 1977 13. NUMBER OF PAGES 17
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Abrasion
Anodic Coatings
Films

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The abrasion resistances of two finishing systems, one applied to 2014 aluminum and the other to ZK60A magnesium, were evaluated. Both alloys were first anodized. Subsequently, a blue-wash primer and semigloss paint were applied to the 2014 aluminum; the ZK60A magnesium received a polyamide primer and a polyurethane topcoat. The tests, performed to compare the relative abrasion resistances of the two systems, were carried out using the Taber Abraser Model 503. Abrasion rates were measured by a weight-loss technique.

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Block 20 (cont)

Analysis of the data indicated that, under the test conditions applied, the topcoats contributed little to the overall abrasion resistance of the two coating systems; rather, the anodic layer of each appeared to be the most important parameter. Further, the rate of abrasion of the anodic layer was relatively constant in each case and could be approximated by a straight line relationship. The anodic film on the 2014 aluminum demonstrated significantly better resistance to abrasion than that on the ZK60A magnesium.

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: ARLCB-TR-77029	2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): A PROBABILISTIC MODEL OF GUN TUBE FATIGUE	5. TYPE OF REPORT & PERIOD COVERED
6. PERFORMING ORG. REPORT NUMBER	
7. AUTHOR(s): R. L. Racicot	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Benet Weapons Laboratory, Watervliet Arsenal, Watervliet, N.Y. 12189, DRDAR-LCB-TL	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: AMCMS No. 611102.H540011, DA Proj No. 1L161102AH54, PRON No. 1A-7-51700
11. CONTROLLING OFFICE NAME AND ADDRESS: US Army Armament Research and Development Command, Large Caliber Weapon System Laboratory, Dover, New Jersey 07801	12. REPORT DATE: May 1977 13. NUMBER OF PAGES: 35
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Cannon, Gun Barrel, Probability Model, Life Distribution, Variability, Statistical Analysis, Fracture Mechanics

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A probabilistic model of gun tube fatigue is constructed by casting existing crack initiation, growth and failure theories into a probabilistic framework. In the model, tube fatigue life is given as a function of random material and design parameters. The fatigue test results for the 105MM M137A1 and 175MM M113E1 tubes are used as a base to estimate and variances of the model parameters. Monte Carlo Simulation studies are then conducted by assuming various probability distributions for the model parameters and computing the statistics

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of the distribution of fatigue life.

Results of the Monte Carlo studies indicate that (1) the best fit theoretical distributions of fatigue lives are the 2- and 3-parameter lognormal; (2) the greatest variability in fatigue life results from variability in residual stresses followed by variability in initial crack and fracture toughness; and (3) an effective means of increasing safe life might be through better control of the autofrettage residual stresses. Finally, use of the probabilistic model of gun tube fatigue might lead to (1) improved methods for statistical computation of safe life from test data and (2) improvement in the initial design approach for proposed gun tubes.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARLCB-TR-77030	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) COMPUTERIZING THE EFFECT OF TEMPERING ON THE MECHANICAL PROPERTIES OF A Ni-Cr-Mo STEEL		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Peter Dombowski		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 DRDAR-LCB-TL		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 3297.06.7588 PRON No. M1-6-A1726-01 M7-M7
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Large Caliber Weapon System Laboratory Dover, New Jersey 07801		12. REPORT DATE June 1977 13. NUMBER OF PAGES 24
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Tempering

Alloy Steel

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

As part of an attempt to determine the optimum tempering cycle for gun tubes, mechanical properties of an AISI 4337 modified steel, i.e. gun steel, were determined for various tempering cycles. Austenitization temperatures of 845°C (1553°F) and 955°C (1750°F) were used, with tempering temperatures ranging from 425°C (797°F) to 595°C (1103°F) and tempering times ranging from 15 minutes to 240 minutes. This format, which allows the selection of tempering parameters from one plot to achieve desired properties, was developed. The mechanical property

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results for the material austenitized at 845°C are presented in the form of three dimensional plots and contour maps which interrelate the mechanical property of interest and tempering temperature and time. Examples showing the use of the plots are presented.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARLCB-TR-77031	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) EROSION IN 81MM MORTAR TUBES		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) V. Peter Greco		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 DRDAR-LCB-TL		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 3210.16.0008 Pron No. M1-3-1K501-(03)-M7-M7
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Large Caliber Weapon System Laboratory Dover, New Jersey 07801		12. REPORT DATE July 1977 13. NUMBER OF PAGES 36
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Coatings	Mortars
Erosion	Particles
Fins	Propellants
Gases	Tubes
Ignition	Wear

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A laboratory erosion tester has been designed and developed for predicting the service performance of protective coating materials in the bores of mortar systems using rounds with tail fins. Due to the use of newly designed ammunition, the service life of 81MM mortar tubes has been reduced to approximately one third of its original life as the result of the formation of three rings on annular groove erosion formed in the bore. Preliminary efforts to apply wear resistant bore coatings and test fire them in the field have been extremely costly and

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time consuming because of the large number of rounds required (approximately 7500).

The laboratory erosion tester has been designed to ignite the actual tail fin assembly (which causes the erosion) in a chamber which holds eight test specimens to be evaluated at the same time. The erosion rate of the test material can be increased so that less rounds are required, by merely reducing the distance of the jet stream and moving the specimens closer to the tail fin assembly which upon ignition, radially discharges the mixture of hot gases and associated burning particles onto the specimen surface.

This progress report presents the erosive behavior of eight candidate coatings which have been tested in the laboratory erosion tester. Laboratory results have shown that a five mil thick cobalt or cobalt alloy deposit should be suitable to resist erosion and increase the service life of the 81MM mortar system. An overlay of 2/10 of a mil of chromium over cobalt further increases the erosion resistance. Further testing is necessary to specifically determine the best cobalt system and chromium conbination. The next effort would be to field test the coating in the actual mortar system to verify the laboratory results.

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: ARLCB-TR-77032
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle): DEVELOPMENT OF PROTOTYPE PRODUCTION ESR FACILITIES
5. TYPE OF REPORT & PERIOD COVERED
6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): V.J. Colangelo
8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS
Benet Weapons Laboratory
Watervliet Arsenal, Watervliet, N.Y. 12189
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11. CONTROLLING OFFICE NAME AND ADDRESS
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16. DISTRIBUTION STATEMENT (of this Report)

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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Electroslag Remelting ESR Cast Hollows Near Net Shapes

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes the procedures employed to produce and develop a technique to manufacture Electroslag Refined Hollows under a contract granted to the Nutek Corp., Washington, Pa. The report describes the approaches taken together with the results obtained for each approach. Drawings and tooling designs are included in the report.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARLCB-TR-77033	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Automatic Step Threading of Breechblocks		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) C. Rose		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 DRDAR-LCB-TL		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 4497.06.6771 Pron No. M-1-1-23034
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Large Caliber Weapon System Laboratory Dover, New Jersey 07801		12. REPORT DATE June 1977 13. NUMBER OF PAGES 26
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Threads
Step Threads
Thread Shaping
Blade Type Tooling

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report details the engineering design, development and application of equipment to produce step threads (constant lead thread on two or more diameters) on the breechblock of cannon. The equipment uses a blade type tool with the part being threaded through shaper type cuts until finish size is reached. The use of this equipment will reduce the floor to floor time from 7.5 hours to 2.0 hours while producing better thread finishes and more accurate dimensional sizes.

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1. REPORT NUMBER ARLCB-TR-77034	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) THE INFLUENCE OF LATE WEAR LIFE 105MM M68 GUN TUBES ON DISCARDING SABOT AMMUNITION FLIGHT STABILITY		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Allan A. Albright Eugene E. Coppola Glenn S. Friar		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, NY 12189 DRDAR-LCB-DP		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. A4110.16.2976 PRON No. M1-5-X9098-01-M7-M7
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Large Caliber Weapon Systems Laboratory Dover, New Jersey 07801		12. REPORT DATE July 1977 13. NUMBER OF PAGES 56
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Ammunition
Ammunition Dispersion
Erosion
Gun Barrels
Guns
Tanks (Combat Vehicles)
Wear

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report describes testing and analysis of 105mm M68 Gun tube wear and its influence on discarding sabot (DS) ammunition performance. Tests, conducted to identify gun tube wear parameters which influence DS projectile flight stability, are described. Models are developed to characterize gun tube wear in the fielded population and estimate outcomes of wear life reductions to exclude undesirable wear conditions. Impacts of tube wear life reductions are discussed, with consideration given changes in ammunition usage.

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1. REPORT NUMBER ARLCB-TR-77035	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) EVALUATION OF 155MM M199 TUBE FORGING PRODUCERS		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) J. Passmore		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 DRDAR-LCB-TL		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 3210.16.0015 PRON No. M7-5-P4850-01-M7-M7
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Large Caliber Weapon System Laboratory Dover, New Jersey 07801		12. REPORT DATE July 1977 13. NUMBER OF PAGES 21
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Cannon Tubes
Forging
Steel

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Two 155mm M199 howitzer tube forgings, produced by different vendors, were destructively tested to determine the quality of each vendor's forgings. Vendor A's forging did not meet military specifications in all cases; several RA values were below specification. Vendor B's forging was found to be acceptable, exceeding the requirements of the specifications in all cases.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARLCB-TR-77036	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Reinforced Cobalt Alloy Composite for Turbine Blade Application		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) I. Ahmad & J.M. Barranco		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 DRDAR-LCB-TL		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 612105.H840011 DA Project No. 1L162105AH84 PRON No. AW-7-R0003
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Large Caliber Weapon System Laboratory Dover, New Jersey 07801		12. REPORT DATE July 1977 13. NUMBER OF PAGES 12
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office)		15. SECURITY CLASS (of this report) UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

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18. SUPPLEMENTARY NOTES

Published in SAMPE Quarterly, Volume 8, No. 3, April 1977.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Superalloys	Composites	Tungsten Filament
Investment Casting	Turbine Blade	High Temperature Mechanical Properties

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A composite of 0.42 V_f W-2% ThO_2 filament reinforced cobalt base alloy has been developed. It can be fabricated by convential investment casting process, has a 1093°C (2000°F), 100hr. stress-to-rupture of 206MN/M^2 (30Ksi) and a charpy impact strength of 280.0 in-lb at 835°C as compared with 20.6 in-lb for the unreinforced alloy. Also the feasibility of casting a prototype first stage blade of JT9D engine has been demonstrated.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARLCB-MR-77037	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Investigation of Fastener Failures in 105MM M68 Guns and 152MM M81 and M162 Gun Launchers		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) Morgan D. Longmate		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, NY 12189 DRDAR-LCB-DPD		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 3110.15.0003 PRON No. M7-5-P4818-10-M7-M7
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Large Caliber Weapon System Laboratory Dover, NJ 07801		12. REPORT DATE August 1977 13. NUMBER OF PAGES 61
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Hydrogen Embrittlement
Cadmium Embrittlement

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This study was performed to determine the cause(s) of the recurring bolt failures occurring on the 105mm M68 and 152mm M81, M162 Gun Systems.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARLCB-TR-77038	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) VIBRATIONS OF A HELICOPTER ROTOR BLADE USING FINITE ELEMENT-UNCONSTRAINED VARIATIONAL FORMULATIONS		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) J.J. Wu C.N. Shen		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 DRDAR-LCB-TL		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 611102.11.H4500 DA Proj. No. 1L161102AH45 PRON No. EJ-7-Y0011-01-EJ-M7
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Large Caliber Weapon System Laboratory Dover, New Jersey 07801		12. REPORT DATE September 1977 13. NUMBER OF PAGES 30
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17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Beams (Radiation)
Coupling Effect
Dynamics
Flutter
Helicopter Rotors
Rotation
Stability
Vibration

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In the past several years, a numerical method has been developed which is a generalized Rayleigh-Ritz - finite element discretization using the combined concept of Lagrange multipliers and adjoint variables. This approach enables one to deal with problems associated with nonconservative forces, coupling effects and all types of boundary conditions in a routine fashion; and it appears promising in solving the vibration and dynamic stability problems associated with the complicated equations of a helicopter rotor blade. This paper presents

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Block 20 (cont)

the first application of the general method of the vibration problem of such a rotor blade.

The basic differential equations in this paper are taken from the linear, but fully coupled set developed by Houbolt and Brooks in 1956. These equations are further reduced to a simplest possible case and yet still contain the coupling of flap and root torsion modes. An unconstrained, adjoint variational statement has been established which is both the necessary and sufficient condition for the coupled differential equations and some general, but physical meaningful boundary conditions. The finite element matrix equations are then derived from this variational statement illustrating the way that coupling terms could be handled in general.

The numerical results from some demonstrative examples show that instability of flutter can occur in the range of operational rotor speed due to the coupled motion of flapping and root torsion without any aerodynamic force, if the torsional spring (or the pitch control link) is not sufficiently stiff. This instability does not appear to have been reported previously.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARLCB-TR-77040	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* PROBABILISTIC MODELS OF GUN-TUBE FATIGUE BASED ON A FRACTURE-MECHANICS MODEL		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) E. E. Coppola		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 DRDAR-LCB-TL		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 611102.H540011 DA Proj. No. 1L61102AH54 PRON No. 1A-7-51700-1A-M7
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Large Caliber Weapon System Laboratory Dover, New Jersey 07801		12. REPORT DATE October 1977 13. NUMBER OF PAGES 52
14. MONITORING AGENCY NAME & ADDRESS*(If different from Controlling Office)*		15. SECURITY CLASS. *(of this report)* UNCLASSIFIED 15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

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18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Fatigue	Mathematical Models
Fracture (Mechanics)	Monte Carlo Method
Gun Barrels	Probability
Life Span	Simulation

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Two probabilistic models of gun tube fatigue (those of Racicot and of Proschan and Sethuraman) have been recently developed by adding probabilistic elements to a deterministic model of fatigue failure. These probabilistic models are examined to determine if they give adequate representations when certain questionable assumptions are lifted. In addition, the deterministic model is cast into a more general probabilistic framework, and the effects of certain statistical assumptions are examined.

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Monte Carlo simulation studies are conducted to approximate possible distributions for gun tube fatigue lives. These generated distributions are compared to various theoretical distributions to determine their adequacy in representing fatigue data. A randomizing method of selecting distributions for material properties of the gun tube is used to give some independence from unwarranted assumptions.

Results of the simulation studies indicate that the lognormal distribution generally gives the best fit to the fatigue lives, but in most cases the lognormal distribution can be rejected by goodness-of-fit tests.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARLCB-TR-77041	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) ISOPARAMETRIC ELEMENTS AS SINGULAR ELEMENTS FOR CRACK PROBLEMS		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) M. A. Hussain W. E. Lorensen		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 DRDAR-LCB-TL		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 611102.11.H4500 DA Proj. No. 1L161102AH45 PRON No. EJ-7-Y0011
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Large Caliber Weapon System Laboratory Dover, New Jersey 07801		12. REPORT DATE November 1977 13. NUMBER OF PAGES 56
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Finite Elements
Fracture (Mechanics)
Isoparametric

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The quadratic isoparametric elements, which embody the inverse square root singularity, are used for calculating the stress intensity factors at tips of cracks. The elements used are the quadratic quadrilateral (8-node), quadratic triangular (6-node) and three-dimensional quadratic 'brick' (20-node) elements. Singularity elements are obtained in a simple manner by placing the mid-side nodes at quarter points in the vicinity of the crack tip or an edge. These ele-

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Block 20 (cont)

ments are implemented in NASTRAN as dummy (user) elements. The method eliminates the use of special crack tip elements and in addition, these elements satisfy the constant strain and rigid body modes required for convergence. The stability of two-dimensional elements is also investigated.

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REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: ARLCB-TR-77042
2. GOVT ACCESSION NO.
3. RECIPIENT'S CATALOG NUMBER

4. TITLE (and Subtitle): EFFECT OF DAMPING AT THE SUPPORT OF A ROTATING BEAM ON VIBRATIONS
5. TYPE OF REPORT & PERIOD COVERED
6. PERFORMING ORG. REPORT NUMBER

7. AUTHOR(s): J.D.Vasilakis & J.J. Wu
8. CONTRACT OR GRANT NUMBER(s)

9. PERFORMING ORGANIZATION NAME AND ADDRESS: Benet Weapons Laboratory, Watervliet Arsenal, Watervliet, N.Y. 12189, DRDAR-LCB-TL
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11. CONTROLLING OFFICE NAME AND ADDRESS: U.S. Army Armament Research and Development Command, Large Caliber Weapon System Laboratory, Dover, New Jersey 07081
12. REPORT DATE: October
13. NUMBER OF PAGES: 1

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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Rotating Beam; Beam Vibrations; Damping; Finite Elements; Variational Statement

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The paper presents a formulation for the study of damping effects in dynamic structural problems and a specific application. A finite element formulation is first derived from the versatile unconstrained variational approach. The vibration of a rotating beam is used here as a concrete example. Viscous damping terms at the support can be present due to either local deflection or rotation. These terms can obviously affect the frequencies of the rotating beam. They are easily incorporated in the present formulation using the concept of unconstrained (See Reverse)

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variations. Numerical data will be presented to demonstrate the qualitative as well as quantitative effects on the vibratory behavior of this rotating beam due to such damping terms.

REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER: ARLCB-TR-77043
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER:

4. TITLE (and Subtitle): TEMPER EMBRITTLEMENT IN 4140 SEAMLESS TUBING

5. TYPE OF REPORT & PERIOD COVERED:

6. PERFORMING ORG. REPORT NUMBER:

7. AUTHOR(s):
Steve Tauscher
Peter Thornton

8. CONTRACT OR GRANT NUMBER(s):

9. PERFORMING ORGANIZATION NAME AND ADDRESS:
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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)
Split Ring
Temper Embrittlement
Transition Temperature

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

In November 1976, several 155mm Howitzer M185 split rings failed during various stages of manufacture. A failure analysis consisting of metallography, SEM, and mechanical testing, was undertaken. This investigation concluded that the heat treatment was responsible for embrittling the steel, thereby causing the failures. Furthermore, it was shown that the required hardness could not be achieved without seriously compromising the toughness of this material.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARLCB-TR-77044	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* DESIGN AND PRODUCTION OF BALLISTIC GUNS NOS 2 AND 3 AND THE INITIAL TEST BED GUN FOR THE MEDIUM CALIBER ANTI-ARMOR AUTOMATIC CANNON PROGRAM		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) P.M. Vottis R.L. Billington R.C. Sillery		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 DRDAR-LCB-DS		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Large Caliber Weapons Systems Laboratory Dover, New Jersey 07081		12. REPORT DATE Novermber 1977 13. NUMBER OF PAGES 67
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18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Medium caliber
Automatic cannon
Ballistic gun
Test gun

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Design rationale and construction details are presented for Ballistic Guns Nos 2 and 3 and the Initial Test Bed gun for the Medium Caliber Anti-Armor Automatic Cannon Program.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARLCB-TR-77045	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* STRUCTURE FACTORS IN AMORPHOUS AND DISORERED HARMONIC DEBYE SOLIDS		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) L.V. Meisel and P.J. Cote		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, New York 12189 DRDAR-LCB-RP		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 611101.91A0011 PRON No. 1A-7-51701-(02)-M7
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Large Caliber Weapon Systems Laboratory Dover, New Jersey 07081		12. REPORT DATE December 1977 13. NUMBER OF PAGES 3
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18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Amorphous Solids	Disordered Crystals	X-Ray Scattering
Neutron Scattering	Electrical Transport	Structure Factors

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Expressions for the static and dynamic structure factor of Van Hove and for the static structure factors appropriate for x-ray and neutron scattering and for resistivity are presented in harmonic approximation for amorphous and disordered solids having a Debye phonon spectrum. A useful model dynamic structure containing a temperature-dependent function of K is defined. The high- and low- temperature limiting forms are examined in detail and the entire

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temperature dependence is discussed qualitatively. Applications in the areas of resistivity and scattering of x-rays are discussed.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARLCB-TR-77046	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* EMBRITTLEMENT OF GUN STEEL BY LIQUID LEAD		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) M.H. Kamdar		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 DRDAR-LCB-TL		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS AMCMS No. 611102.H540011 DA Proj. No. 1L161102AH54 PRON. No. 1A-7-51700-1A-M7
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armanent Research and Development Command Large Caliber Weapon Systems Laboratory Dover, New Jersey 07801		12. REPORT DATE December 1977 13. NUMBER OF PAGES 20
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18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Fracture
Guns
Liquid Lead Embrittlement
Steel

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

A study has been made of the fracture behavior of gun steel in liquid lead and inert argon environments at 630°K in monotonic, static and cyclic fatigue test conditions. Smooth and notched specimens tested under the above conditions were severely embrittled by liquid lead and failed by intergranular mode as compared to a ductile mode in argon. Smooth specimens tested monotonically and in static fatigue failed in a catastrophic manner near the

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s
yield stress of the steel. Specimens with machined notches and with a fatigue crack at the root of the notch tested in liquid lead failed at the stress intensity values of 35 Ksi$\sqrt{in}$ and 7 Ksi $\sqrt{in}$ static fatigue and cyclic fatigue tests respectively, whereas in inert argon environment fatigue precracked specimens failed in cyclic fatigue at 135 Ksi $\sqrt{in}$. The susceptibility to embrittlement of steel specimens in liquid lead tested in cyclic fatigue was the same whether the notch was as machined or had a fatigue precrack at the root of the notch, i.e., embrittlement was independent of the sharpness of the root radii. These and other results are discussed in terms of the prevalent "reduction in cohesion" mechanism of liquid metal embrittlement proposed by Westwood and Kamdar. The critical conditions and prerequisites for the occurrence of embrittlement of gun steel in liquid lead are also duscussed.

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REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER ARLCB-TR-77047	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE *(and Subtitle)* COLLAPSED 12-NODE TRIANGULAR ELEMENTS AS CRACK TIP ELEMENTS FOR ELASTIC FRACTURE		5. TYPE OF REPORT & PERIOD COVERED 6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) S.L. Pu M.A. Hussain W.E. Lorensen		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Benet Weapons Laboratory Watervliet Arsenal, Watervliet, N.Y. 12189 DRDAR-LCB-RA		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS US Army Armament Research and Development Command Large Caliber Weapon Systems Laboratory Dover, New Jersey 07081		12. REPORT DATE December 1977 13. NUMBER OF PAGES 49
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16. DISTRIBUTION STATEMENT *(of this Report)*

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17. DISTRIBUTION STATEMENT *(of the abstract entered in Block 20, if different from Report)*

18. SUPPLEMENTARY NOTES

19. KEY WORDS *(Continue on reverse side if necessary and identify by block number)*

Fracture Mechanics	Finite-Element Method	Cubic, quadrilateral Elements
Isoprametric Elements	Singular Elements	Stress Intensity Factors

20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

For the 12-node bicubic, quadrilateral, isoparametric elements, it is shown that the inverse square root singularity of the strain field at the crack tip can be obtained by the simple technique of collapsing the quadrilateral elements into triangular elements around the crack tip and placing the two mid-side nodes of each side of the triangles at 1/9 and 4/9 of the length of the side from the tip. This is analgous to placing the mid-side nodes at

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quarter points in the vicinity of the crack tip for the quadratic, isoparametric element.

The advantage of this method are that the displacement compatibility is satisfied throughout the region and that there is no need of special crack tip elements. The stress intensity factors can be accurately obtained by using general purpose programs having isoparametric elements such as NASTRAN. The use of 12-node isoparametric element program APES may be simplified by eliminating the special crack tip elements.

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

It has long been known that the ammonium ion NH_4^+ behaves in many ways like an alkali metal ion. This report discusses a possible transition (under pressure) from a mixture of ammonia and hydrogen (NH_3-$\frac{1}{2}H_2$) to metallic NH_4 in the "funny sodium" form. This form may be defined as a lattice composed of metallic NH_4^+ ions and s-like electrons (one per ion). The ion has the sodium Z number but only seven protons (those from N) are in the nucleus; the

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other four protons (those from the four H atoms) form a tetrahedral arrangement around the N nucleus. This tetrahedral arrangement is then approximated by a spherical shell at a radius determined by a variational calculation for the total energy of the tetrahedral ion. (The resulting radius lies well out in the ion electron cloud.) Since a Wigner-Seitz polyhedra approach is used no specific lattice structure is considered. We comment on the earlier calculation of Bernal and Massey (BM) and the more recent calculation of Stevenson. Emphasis is on the BM metallic calculation which we have essentially repeated.

The concept of exchange is described, derivation of the Fock equations is given, and the principal equation of BM (one electron outside a closed shell) is then derived from the Fock equations.

The BM equation is then solved by computer for both the no-exchange and exchange-included cases. Our (unsuccessful) attempts to reproduce the BM results for the no-exchange case are described briefly. Our calculation for the exchange-included case is then described in some detail. For this case we find the internal energy at the equilibrium volume to be about 0.5 ev higher than that obtained by BM (our value is very close to Stevenson's -5.36 ev). Stevenson's equilibrium radius is 5.35 a.u., BM's is 4.23 a.u.; we obtain 4.99 a.u., i.e., shifted considerably toward Stevenson's value. In spite of these differences in U vs V between our results and BM's, our Gibbs energy vs pressure curve is about like theirs.

If the Stevenson mixture curve for U vs V is accepted, the BM and the present metallic calculation make a transition to "funny sodium" NH_4 unlikely (at least below the Mbar region). Acceptance of the Stevenson metallic U vs V curve would make such a transition unlikely at any pressure. We consider transition to the "funy sodium" form to be unlikely; transition to <u>other</u> metallic forms are probably in the Mbar (and above) range.

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