MEMORANDUM REPORT BRL-MR-3951

BRL

FAILURE ANALYSIS OF THE M825 BURSTER ASSEMBLY

JAMES M. BENDER

DECEMBER 1991

U.S. ARMY LABORATORY COMMAND

BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND

NOTICES

UNCLASSIFIED

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	December 1991	Final, 1 Jun 90 - 31 Mar 91

4. TITLE AND SUBTITLE

Failure Analysis of the M825 Burster Assembly

5. FUNDING NUMBERS

PR: 1L162618AH80

6. AUTHOR(S)

James M. Bender

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

U.S. Army Ballistic Research Laboratory
ATTN: SLCBR-DD-T
Aberdeen Proving Ground, MD 21005-5066

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

BRL-MR-3951

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

Recent firing tests of the M825 155-mm Smoke round produced an unacceptable number of nonfunctioning rounds. Commonly accepted theories focused on the burster tube housed inside the payload canister as the source of the problem. One possibility was that the burster well was failing or stretching at launch, producing an air gap and thus preventing the ignition of the small burster charge. This report addresses that possibility through a finite element analysis of the critical welded region where the burster tube joins the forward closure plate of the payload canister. It is shown that the burster tube remains basically intact except under one remotely possible circumstance unlikely in these firing tests.

14. SUBJECT TERMS

artillery; burster; canister; setback; finite element analysis

15. NUMBER OF PAGES

18

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL

NSN 7540-01-280-5500

UNCLASSIFIED

INTENTIONALLY LEFT BLANK.

TABLE OF CONTENTS

INTENTIONALLY LEFT BLANK.

LIST OF FIGURES

INTENTIONALLY LEFT BLANK.

1. INTRODUCTION

The M825 smoke projectile is a member of the M483 family of 155-mm cargo-carrying artillery projectiles. It has been in production since being type-classified in 1986. It consists of an M483 shell body, M577 time fuze, and a hermetically sealed canister containing 116 felt wedges saturated with white phosphorous (WP). The canister is ejected through the base and is burst apart after a brief delay by 21 grams (.05 lb) of high explosive which is housed in a tube down the center of the canister. The burning wedges fall to the ground and produce a smoke screen of 5–10 minutes in duration. A cutaway view of the projectile is shown in Figure 1.

Recent routine testing of production rounds has resulted in an excessive failure rate (4 of 14 shots, for example) in the functioning of the round (canisters failed to burst). The failures occurred mostly at zone 8 (M203A2) charge with a lesser amount failing at zone 3. All failures occurred with the rounds conditioned at a temperature under the melting point of the WP, 44° C (112° F). No failures have been observed with rounds conditioned at 63° C (145° F).

A root cause analysis of the problem was conducted by the U.S. Army Chemical Research, Development, and Engineering Center (CRDEC) (Miller et al. 1990). Structural failure of the burster charge well was identified as a possible source of the failures. At the request of CRDEC, this office was funded to perform a failure analysis of the burster assembly to determine if the burster well was separating from the forward closure plate during launch, preventing the ignition of the burster high explosive (HE). The following stress analysis was performed with boundary conditions existing using the PXR6297 charge at permissilbe individual maximum pressure (PIMP) + 5%. It is intended to serve as a supplement to that performed by the AAI Corporation (1978) in 1976.

2. FINITE ELEMENT ANALYSIS

The burster well was modeled and structurally analyzed using the ANSYS finite element program. The ANSYS program is widely recognized as a standard of the engineering mechanics community for computational stress analysis.

PROJECTILE, 155MM SMOKE, WP, M825

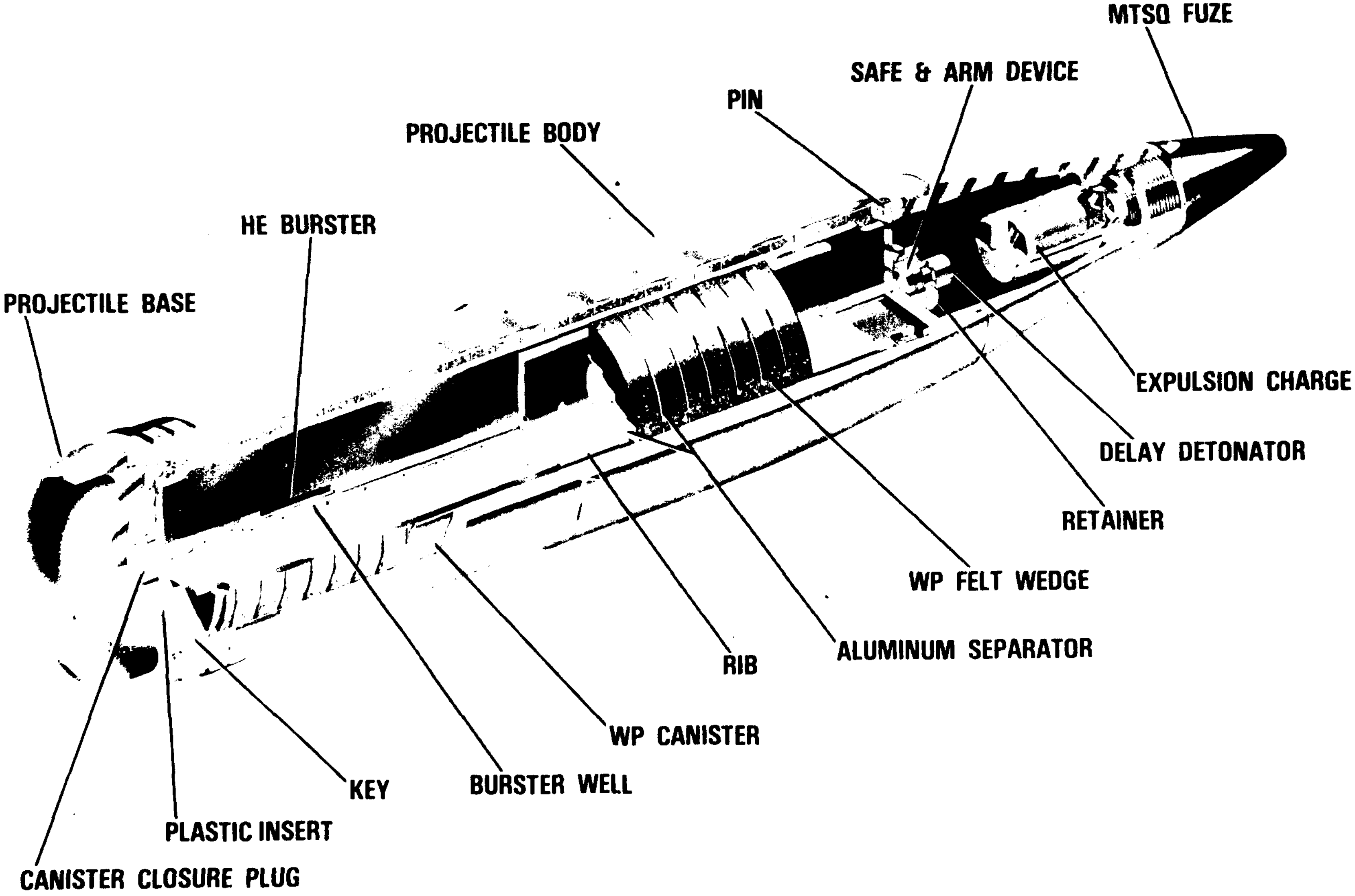

Figure 1. Cutaway View of the M825 Artillery Projectile.

The loads on the burster well generated with the proof charge (commonly known as the PXR charge, a TECOM survival standard) are its own weight, the weight of the burster tube and 21 grams of high explosive totaling 230 grams (.51 lb); acceleration, 15,600 g's; and hydrostatic pressure on the tip of the rod which is immersed in the WP. The WP provides about 1,050 kg (2,310 lb) of support to the tip of the burster well at peak g's, calculated as follows. It is assumed that the well is immersed in a 40-cm (16-in) depth of WP. This fluid, with a density of 1.73 g/cm^3 (.06 lb/in^3), produces a pressure of 6.9 kPa (1.0 psi) at 1 g. At 15,600 g's, the pressure rises to about 107 mPa (15.6 ksi). This pressure, acting on the tip of the well which has an area of .94 cm^2 (0.15 in^2), produces the 1,050-kg (2,310-lb) support.

An additional analysis was performed with the WP absent. In this case, the rod must sustain its own weight at 15,600 g's; a load of about 3,602 kg (7,925 lb).

The finite element grid used in the analyses is shown in Figure 2. The forward 5 cm (2 in) of the well, the weld, and forward plate are shown. The remaining 38 cm (15 in) of the well are below the field of view. The parts are gray-shaded for identification. The burster well is dark gray, the forward closure plate is black, and the weld region is light gray.

The welded region includes not only the weld but part of the burster well which has been essentially heat-treated by the welding process. Etched micrographs of sectioned samples in this region indicate 100% weld penetration of the .12-cm (.049-in) tube wall thickness to the inside surface. This heat treatment is evident in Figure 3, which displays hardness values along the inside of the tube plotted against distance from the end. The hardness values correspond roughly to material yield point. For 4130 steel, a hardness of Rockwell "C" 50 corresponds to a yield strength of 1,725 mPa (250 ksi), and a hardness of RC 20 indicates a yield strength of 517 mPa (75 ksi). The material properties of the three parts of the assembly are listed in Table 1.

3. RESULTS

The analysis of the unsupported burster well revealed stresses in excess of 140 ksi, far beyond the capability of the 4130 normalized steel. It is certain, therefore, that the WP does indeed support the burster significantly and was included for all subsequent analyses.

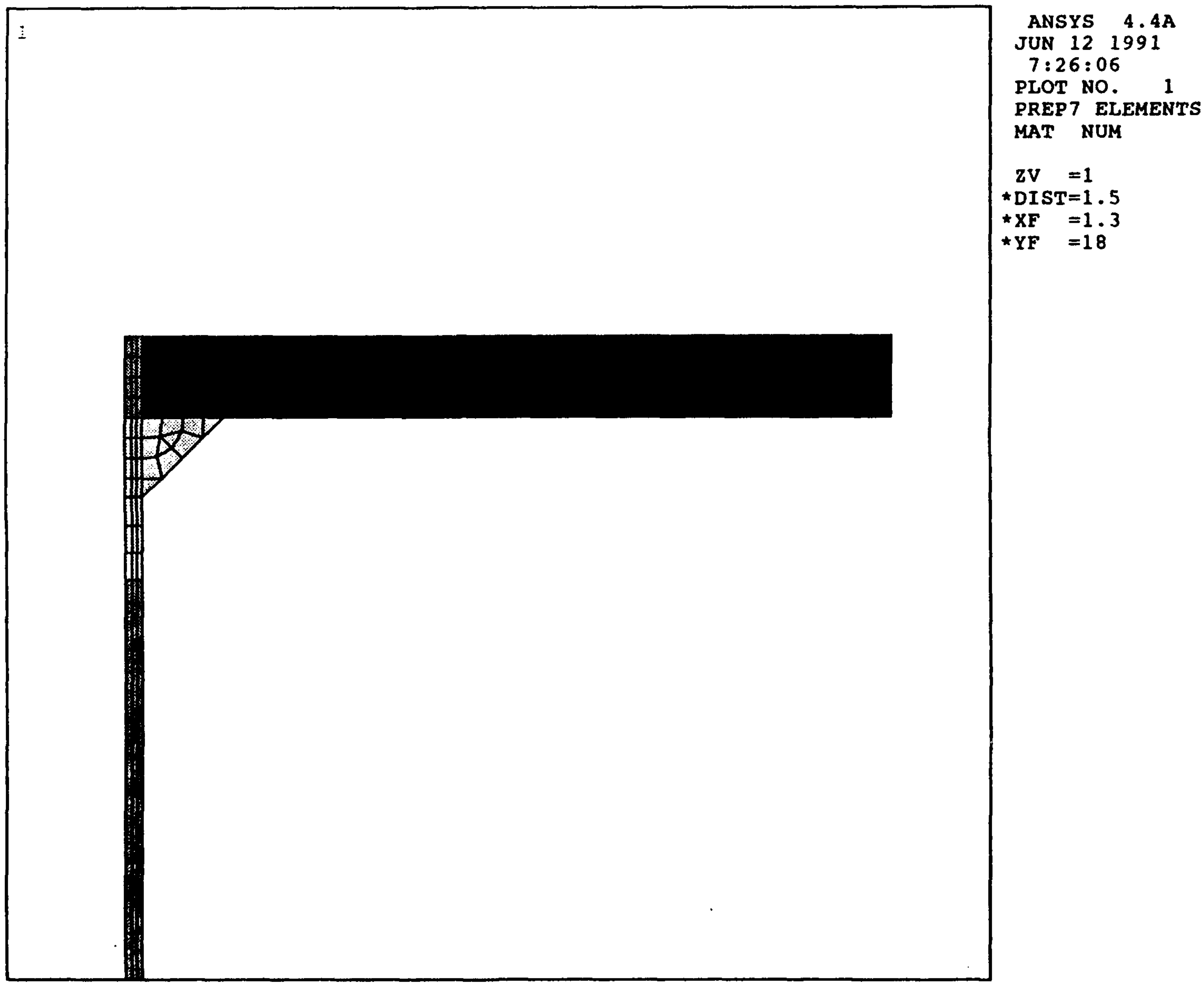

Figure 2. Finite Element Grid of Burster/Closure Plate Assembly.

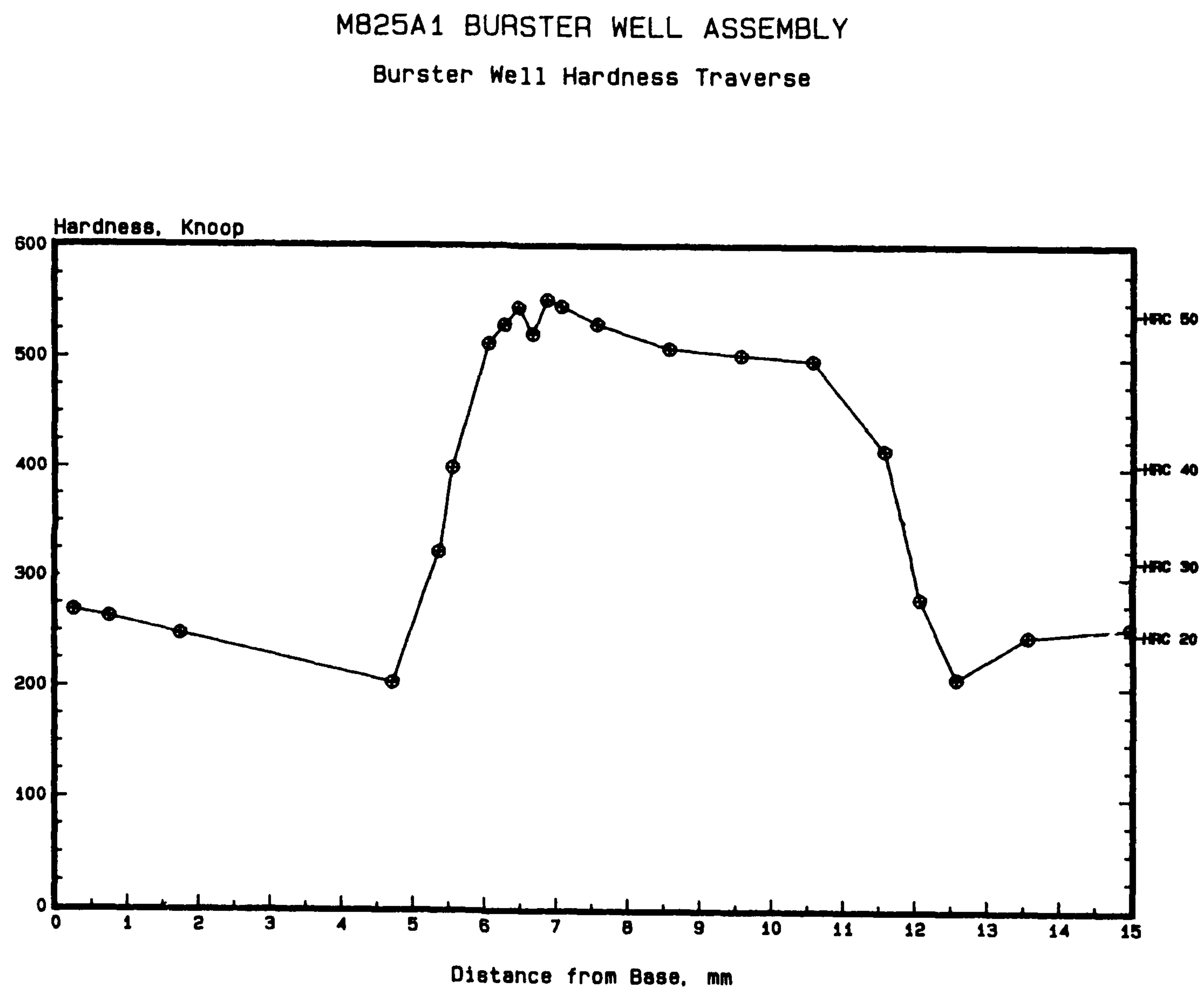

Figure 3. Hardness Values Along Inside of Burster Well Tube.

Table 1. Material Properties

Item	Composition	Yield Strength [mPa (ksi)]	Ultimate Strength [mPa (ksi)]
Burster Well	4130 Steel	517 (75)	655 (95)
Weld	Carbon Steel	1,725 (250)	1,794 (260)
Forward Closure Plate	C1020 Steel	345 (50)	414 (60)

In the supported burster analysis, the effective stress in the welded region is shown in Figure 4. The maximum stress in the welded region is about 1,139 mPa (165 ksi), far below the 1,725-mPa (250-ksi) capability of the material. The burster well has been isolated in Figure 5 to show that the maximum effective stress in the 4130 steel away from the weld is 642 mPa (93 ksi), which is just below its ultimate strength. The tube has elongated approximately .6 cm (.24 in). For the 46-cm-long (18-in) tube, this indicates a strain of 1.3%. The 4130 steel is capable of 12% elongation before failure, so it was able to deform in response to the initially high stress and not fail by fracture.

4. DISCUSSION

This analysis was performed using boundary conditions existing when the round is fired at 105% of PIMP with the PXR6297 charge, which is a requirement provided in ballistic acceptance tests. These tests are designed to assure that the projectile is safe to fire and has a safe trajectory. It does not require that the round necessarily function.

The rounds in this study were fired at zone 8, which produces a chamber pressure of 338 mPa (49 ksi), a base pressure of 300 mPa (43.5 ksi), and an acceleration of 12,338 g's, which is well below the 105% of PIMP condition. Certainly, burster failure is unlikely at these conditions.

The 155-mm howitzer has a pressure cycle which peaks at around 5 ms for the proof charge. The 1.3% strain seen in the burster occurs during this time. Figure 6 is a graph extracted from the U.S. Air Force Materials Handbook (Belfour Stulen, Inc. 1980) (SI units not

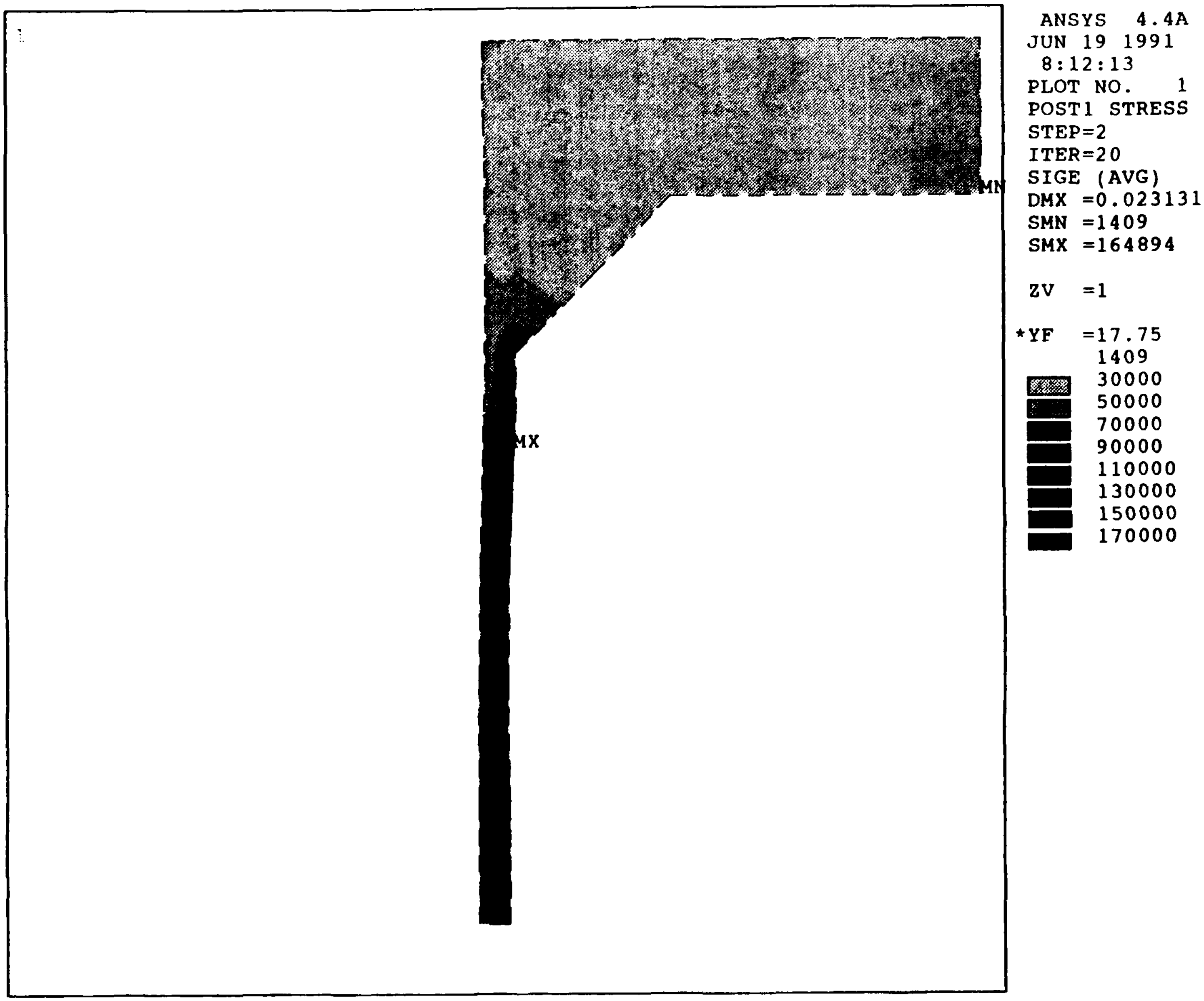

Figure 4. Effective Stress (von Mises) in Burster Weld Region.

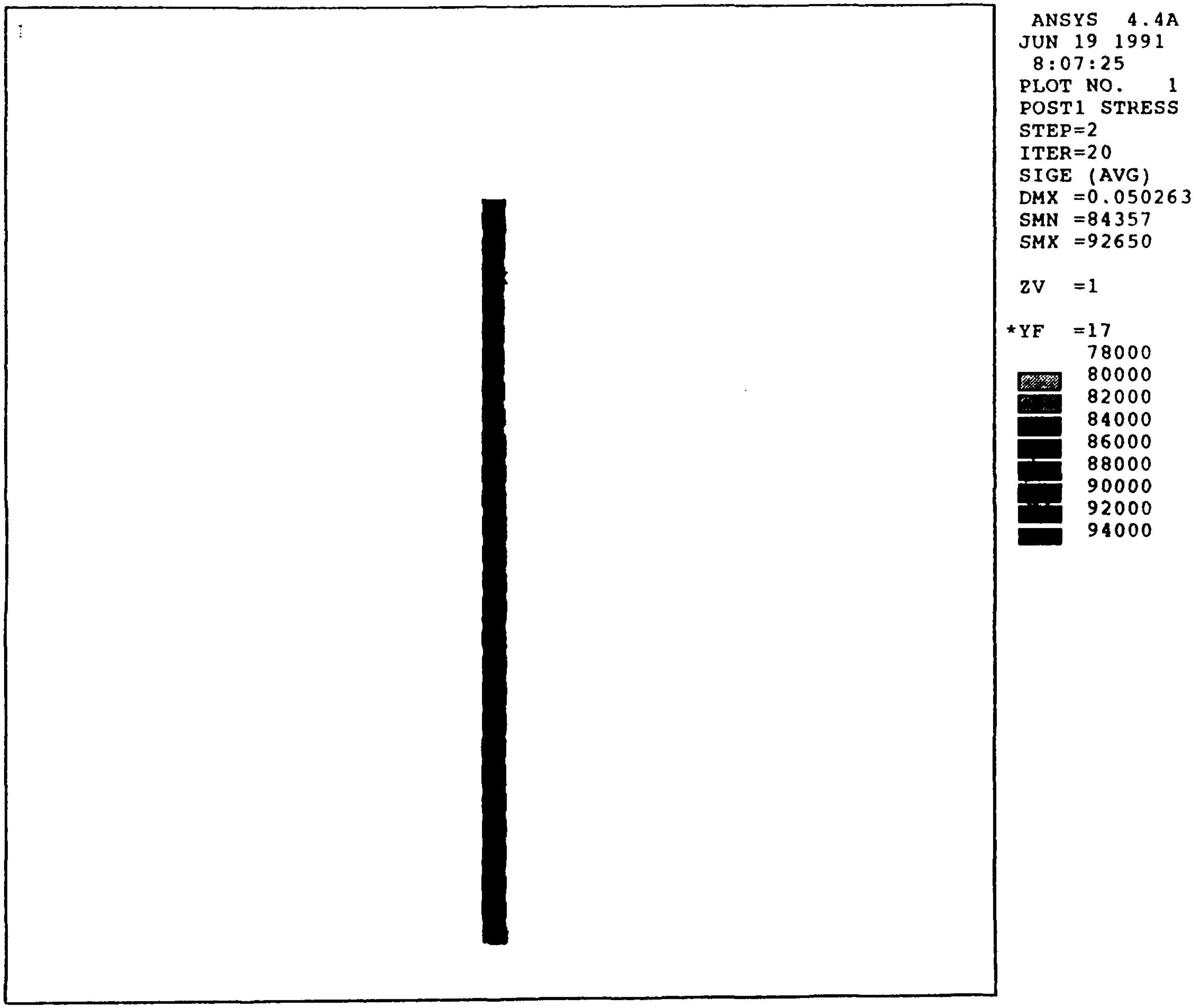

Figure 5. Effective Stress in Burster Well Tube Excluding Weld.

available) showing yield strength vs. temperature at various strain rates for 4130 steel. It shows that some increase in effective yield strength is gained with the high rate of loading in the 155-mm system. This phenomenon, viscoplasticity, cannot be modeled with the current version of ANSYS. It does, however, provide some increase in safety factor and may explain the successful test firings to date despite the apparent underdesign of the burster well. The rate effect drops off with lower zone propelling charges, but the stress level is likewise reduced.

As a result of the structural analysis, the only possible cause of burster failure at launch would be the absence of WP at the tip of the burster. There is no guarantee that the canisters and rounds are always base-down all the time. Should the WP solidify when the round is on its side, there may be no solid WP to support the burster tip, yet the felt wedges would be sufficiently saturated to prevent WP migration otherwise.

Failure of the well just below the weld is nearly certain if the tip is unsupported and the round is fired at 105% of PIMP.

Since a few rounds failed to function after having been launched at zone 3 charge (where the launch loads are less than 20% of those at the proof charge), it is further postulated that the burster's structural integrity is not the cause of the malfunction, even with no WP at the tip to support the burster.

With regard to the .6-cm (.24-in) elongation of the WP supported tube, it was found experimentally by others at CRDEC that if this strain had produced an air gap in the explosive, it was not enough to prevent detonation.

5. RECOMMENDATIONS AND CONCLUSIONS

Although the burster well would appear to be somewhat underdesigned, as pointed out in AAI Corporation (1978), it is not believed to be a serious problem since the designated material is capable of large deformation before failure. Also, 10–20% increase in yield strength is likely at the rate of loading applied by the proof charge (hot). This, plus the fact

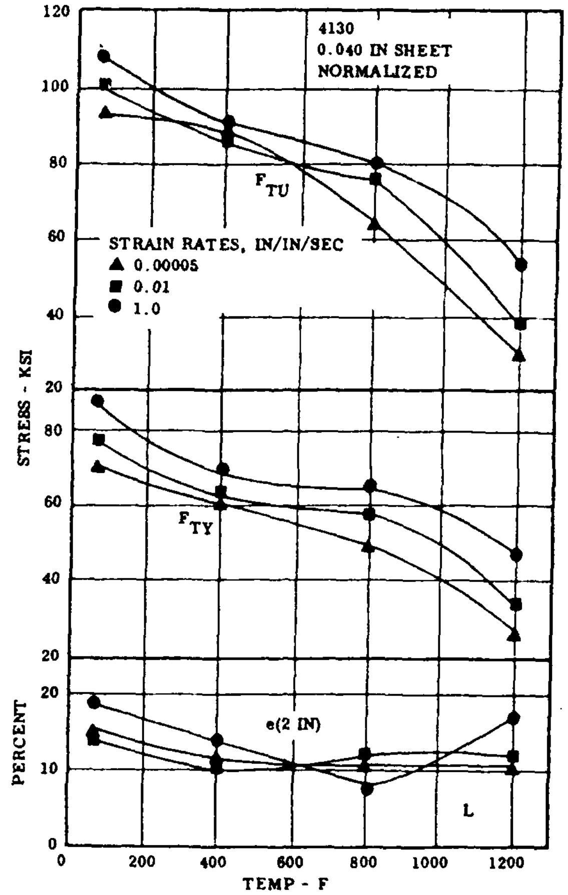

Figure 6. Yield Strength at Various Strain Rates for 4130 Steel.

that so many have been successfully launched to date, does not warrant a recall or modification of the stockpiled rounds. Furthermore, the elongation capability may even be desirable for proper functioning of the burster assembly and may have been the intention of the designer. Any tampering with the burster tube design to enhance its structural integrity at launch may affect its ability to properly burst and distribute payload. The pressures seen at 105% of PIMP, however unlikely, remains the customary design load. The increase in yield strength at the high rate of loading should provide enough safety factor for the design.

It is recommended that the canisters be stored in a base-down attitude to prevent the possibility of WP migration away from the tip of the burster. Currently, there is no requirement preventing the canisters from being stored on their side. If any canisters have been stockpiled on their side, they should be set up on their base and stored for 48 hours at a temperature well above the melting point of the WP.

6. REFERENCES

AAI Corporation. "Final Report - Design Analysis of Felt Wedge WP (FWWP) Projectile," Contract DAAK11-77-C-0101, Cockeysville, MD, 1978.

Belfour Stulen, Inc. Department of Defense Aerospace Structural Metals Handbook, Belfour Stulen, Inc., Columbus, OH, 1980.

Miller, M. C., D. W. Bromley, P. W. Szatmary, P. L. Stewart, and W. D. Fortune. "Root Cause Analysis, Canister Assembly Functioning Problem, M825A1, 155-mm Smoke Screening Projectile." CRDEC-SP-023, U.S. Army Chemical Research, Development, and Engineering Center, Aberdeen Proving Ground, MD, July 1990.

INTENTIONALLY LEFT BLANK.

No. of Copies	Organization
2	Administrator Defense Technical Info Center ATTN: DTIC-DDA Cameron Station Alexandria, VA 22304-6145
1	Commander U.S. Army Materiel Command ATTN: AMCAM 5001 Eisenhower Avenue Alexandria, VA 22333-0001
1	Commander U.S. Army Laboratory Command ATTN: AMSLC-DL 2800 Powder Mill Road Adelphi, MD 20783-1145
2	Commander U.S. Army Armament Research, Development, and Engineering Center ATTN: SMCAR-IMI-I Picatinny Arsenal, NJ 07806-5000
2	Commander U.S. Army Armament Research, Development, and Engineering Center ATTN: SMCAR-TDC Picatinny Arsenal, NJ 07806-5000
1	Director Benet Weapons Laboratory U.S. Army Armament Research, Development, and Engineering Center ATTN: SMCAR-CCB-TL Watervliet, NY 12189-4050
(Unclass. only)1	Commander U.S. Army Armament, Munitions and Chemical Command ATTN: AMSMC-IMF-L Rock Island, IL 61299-5000
1	Director U.S. Army Aviation Research and Technology Activity ATTN: SAVRT-R (Library) M/S 219-3 Ames Research Center Moffett Field, CA 94035-1000

No. of Copies	Organization
1	Commander U.S. Army Missile Command ATTN: AMSMI-RD-CS-R (DOC) Redstone Arsenal, AL 35898-5010
1	Commander U.S. Army Tank-Automotive Command ATTN: ASQNC-TAC-DIT (Technical Information Center) Warren, MI 48397-5000
1	Director U.S. Army TRADOC Analysis Command ATTN: ATRC-WSR White Sands Missile Range, NM 88002-5502
1	Commandant U.S. Army Field Artillery School ATTN: ATSF-CSI Ft. Sill, OK 73503-5000
(Class. only)1	Commandant U.S. Army Infantry School ATTN: ATSH-CD (Security Mgr.) Fort Benning, GA 31905-5660
(Unclass. only)1	Commandant U.S. Army Infantry School ATTN: ATSH-CD-CSO-OR Fort Benning, GA 31905-5660
1	Air Force Armament Laboratory ATTN: WL/MNOI Eglin AFB, FL 32542-5000
	Aberdeen Proving Ground
2	Dir, USAMSAA ATTN: AMXSY-D AMXSY-MP, H. Cohen
1	Cdr, USATECOM ATTN: AMSTE-TC
3	Cdr, CRDEC, AMCCOM ATTN: SMCCR-RSP-A SMCCR-MU SMCCR-MSI
1	Dir, VLAMO ATTN: AMSLC-VL-D
10	Dir, BRL ATTN: SLCBR-DD-T

No. of Copies	Organization
1	HQ AFSC/XTHO ATTN: MAJ Sarvaideo Andrews AFB, MD 20334-5000
10	Director Benet Weapons Laboratory U.S. Army Armament Research, Development, and Engineering Center ATTN: SMCAR-CCB, J. Vasilakis J. Zweig L. Johnson T. Simkins Watervliet, NY 12189-5000
3	Commander U.S. Army Armament Research, Development, and Engineering Center ATTN: SMCAR-FSA-M, R. Botticelli F. Diorio ATTN: SMCAR-FSA, C. Spinelli Picatinny Arsenal, NJ 07806-5000
7	Commander U.S. Army Armament Research, Development, and Engineering Center ATTN: SMCAR-CCH-T, S. Musalli P. Christian K. Fehsal SMCAR-CCH-V, E. Fennell SMCAR-CCH, J. DeLorenzo SMCAR-CC, R. Price J. Hedderich Picatinny Arsenal, NJ 07806-5000
2	Commander U.S. Army Armament Research, Development, and Engineering Center ATTN: SMCAR-TD, V. Linder T. Davidson Picatinny Arsenal, NJ 07806-5000

No. of Copies	Organization
1	Commander Production Base Mod. Agency U.S. Army Armament Research, Development, and Engineering Center ATTN: AMSMC-PBM-K Picatinny Arsenal, NJ 07806-5000
2	PEO-Armaments ATTN: SFAE-AR-PM, D. Adams T. McWilliams Picatinny Arsenal, NJ 07806-5000
1	Project Manager Advanced Field Artillery System Picatinny Arsenal, NJ 07806-5000
2	Commander U.S. Army Laboratory Command Harry Diamond Laboratories ATTN: SLCHD-TS-NT, A. Frydman 2800 Powder Mill Road Adelphi, MD 20783-1197
1	Commander U.S. Army Laboratory Command ATTN: AMSLC-TD, R. Vitali Adelphi, MD 20783-1145
1	Commander U.S. Army Missile Command ATTN: AMSMI-RD, W. McCorkle Redstone Arsenal, AL 35898-5010
1	Commander Watervliet Arsenal ATTN: SMCWV-QA-QS, K. Insco Watervliet, NY 12189-4050
2	Commander U.S. Army Ordnance Missile and Munitions Center and School ATTN: ATSK-CMM, CPT Stiene ATSK-XO Redstone Arsenal, AL 35897-6801

No. of Copies	Organization
1	Commander Anniston Army Depot ATTN: SDSAN-CS Anniston, AL 36201-500?
5	Commander U.S. Army Chemical School ATTN: ATZN-CM-CC ATZN-CM-CS, Deputy MLSD ATZN-CM-CT, Mr. Jennings ATZN-CM-MLB ATZN-CM-NC Fort McClellan, AL 36205-5020
1	Commander Pine Bluff Arsenal ATTN: SMCPB-MM, Mr. Dunemn Pine Bluff, AR 71602-9500
10	Commander U.S. Army Armament Munitions and Chemical Command ATTN: AMSCM-CG, MG Brailsford AMSCM-RT, R. Radkiewicz AMSCM-QA, J. Griffin AMSCM-ASN, J. Grobstein AMSMC-ASN, M. Dietrich AMSMC-ASN, E. Henning AMSMC-ESM-M, W. Fortune AMSMC-IMF-L, Technical Library AMSMC-IRD AMSMC-SFS Rock Island, IL 61299-6000
2	Commander U.S. Army Dugway Proving Ground ATTN: STEDP-SD-TA-F, Technical Library Dugway, UT 84022-5000
1	Commander U.S. Army Materiel Command ATTN: AMCCN 5001 Eisenhower Ave. Alexandria, VA 22333-0001
1	Commander U.S. Army Training and Doctrine Command ATTN: ATCD-N Fort Monroe, VA 23651-5000

No. of Copies	Organization
1	Commander U.S. Army Nuclear and Chemical Agency ATTN: MONA-CM 7500 Blacklick Road, Bldg 2073 Springfield, VA 22150-3198
4	Director Lawrence Livermore National Laboratory ATTN: R. Christensen W. Feng S. deTeresa F. Magness P.O. Box 808 Livermore, CA 94550
2	Pacific Northwest Laboratory A Division of Battelle Memorial Institute ATTN: M. Smith M. Garnich P.O. Box 999 Richland, WA 99352
5	Director Sandia National Laboratories Applied Mechanics Department, Division-8241 ATTN: C. Robinson G. Benedetti K. Perano D. Dawson P. Nielan P.O. Box 969 Livermore, CA 94550-0096
1	Director Los Alamos National Laboratory ATTN: D. Rabern WX-4 Division, Mail Stop B-787 P.O. Box 1663 Los Alamos, NM 87545
2	Materials Technology Laboratory ATTN: SLCMT-MEC, B. Halpin T. Chou Watertown, MA 02172-0001

No. of Copies	Organization
3	Alliant Techsystems, Inc. ATTN: C. Candland J. Bode K. Ward 5640 Smetana Drive Minnetonka, MN 55343
2	Chamberlain Manufacturing Corp. Waterloo Facility ATTN: T. Lynch 550 Ester St. P.O. Box 2335 Waterloo, IA 50704
2	Olin Corporation Flinchbaugh Division ATTN: E. Steiner B. Stewart P.O. Box 127 Red Lion, PA 17356
1	Olin Corporation ATTN: L. Whitmore 10101 9th St. North St. Petersburg, FL 33702

Aberdeen Proving Ground

No. of Copies	Organization
2	Cdr, USAMSAA ATTN: AMXSY-CR, C. Horley AMXSY-MP, H. Cohen
1	Cdr, USACSTA ATTN: SPECS-EN-PM, J. Faller
75	Cdr, CRDEC, AMCCOM SMCCR-DDR SMCCR-DDW SMCCR-DDP SMCCR-HV SMCCR-MSI SMCCR-MU, Dr. J. Ferriter D. Palughi SMCCR-MUM, A. Van de Wall SMCCR-MUP, C. Hyeman J. Novad N. Levett SMCCR-MUT, P. Szatmary SMCCR-MUP-O, M. Duggan SMCCR-MUS-P, J. Domanico SMCCR-MUS-T, J. Wienamd D. Bromley SMCCR-OPA SMCCR-OPF SMCCR-OPP SMCCR-OPR SMCCR-PPC SMCCR-PPI SMCCR-PPP SMCCR-RS, J. Vervier W. Collins R. Smardzewski SMCCR-RSC SMCCR-RSL SMCCR-RSP, A. Stuemfle SMCCR-RSP-A, D. Weber C. Hansen F. Wrede M. Mitchell J. Molnar D. Wise A. Miller SMCCR-RSP-B, D. Flanigan SMCCR-RSP-P SMCCR-RST SMCCR-SF SMCCR-SPS-T SMCCR-TD, M. Parker SMCCR-TDE, D. Shandle SMCCR-TDP, J. McKivrigan SMCCR-TDT, S. Lawhorne J. Savage AMSMC-HOA (A), Mr. J. K. Smart AMSMC-QAC (A) AMSMC-QAC-M, J. Pennington P. Stewart AMSMC-QAE (A) AMSMC-QAO-C (A), Dr. P. Patel AMSMC-QVA (A), D. Francis

USER EVALUATION SHEET/CHANGE OF ADDRESS

This laboratory undertakes a continuing effort to improve the quality of the reports it publishes. Your comments/answers below will aid us in our efforts.

1. Does this report satisfy a need? (Comment on purpose, related project, or other area of interest for which the report will be used.) ______________________________

2. How, specifically, is the report being used? (Information source, design data, procedure, source of ideas, etc.) ______________________________

3. Has the information in this report led to any quantitative savings as far as man-hours or dollars saved, operating costs avoided, or efficiencies achieved, etc? If so, please elaborate. ______________________________

4. General Comments. What do you think should be changed to improve future reports? (Indicate changes to organization, technical content, format, etc.) ______________________________

BRL Report Number BRL-MR-3951 Division Symbol ____________

Check here if desire to be removed from distribution list. ____

Check here for address change. ____

Current address: Organization ______________________
Address ______________________

DEPARTMENT OF THE ARMY
Director
U.S. Army Ballistic Research Laboratory
ATTN: SLCBR-DD-T
Aberdeen Proving Ground, MD 21005-5066

OFFICIAL BUSINESS

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES

BUSINESS REPLY MAIL
FIRST CLASS PERMIT No 0001, APG, MD

Postage will be paid by addressee

Director
U.S. Army Ballistic Research Laboratory
ATTN: SLCBR-DD-T
Aberdeen Proving Ground, MD 21005-5066