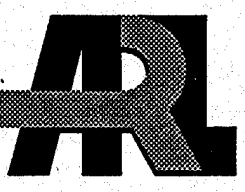
ARMY RESEARCH LABORATORY



Solventless Method for Determining Moisture Content of Solid Propellants

Rose Pesce-Rodriguez
Rhonda Cumpton

ARL-MR-290 February 1996

NOTICES

Destroy this report when it is no longer needed. DO NOT return it to the originator.

Additional copies of this report may be obtained from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, VA 22161.

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

The use of trade names or manufacturers' names in this report does not constitute indorsement of any commercial product.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	February 1996	Final, July - August 1994

4. TITLE AND SUBTITLE
Solventless Method for Determining Moisture Content of Solid Propellants

5. FUNDING NUMBERS
PR: 1L161102AH43

6. AUTHOR(S)
Rose Pesce-Rodriguez and Rhonda Cumpton

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Research Laboratory
ATTN: AMSRL-WT-PC
Aberdeen Proving Ground, MD 21005-5066

8. PERFORMING ORGANIZATION REPORT NUMBER
ARL-MR-290

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

10.SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*

A new method to determine moisture content of solid propellants has been developed. The method is based on mass spectrometric detection of thermally desorbed water. The main advantages of this method over existing methods is that sample preparation is very simple and no extraction with dry solvents is required. Furthermore, analysis can be performed even if only a very small quantity of a sample is available. The two main disadvantages of the method are that special instrumentation is required, and that multiple analyses must be performed to obtain representative results (since only small samples can be examined). Comparison with conventional methods of moisture analysis have not yet been performed.

14. SUBJECT TERMS
GC-MS, moisture content, solid propellant, solventless method

15. NUMBER OF PAGES
16

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	SAR

INTENTIONALLY LEFT BLANK.

TABLE OF CONTENTS

INTENTIONALLY LEFT BLANK.

LIST OF FIGURES

LIST OF TABLES

INTENTIONALLY LEFT BLANK.

1. INTRODUCTION

There are several methods that may be used to determine moisture content of solid propellants. Gravimetric techniques involve heating the propellant and monitoring weight loss. For single-base propellants, this is a simple matter. For double- and triple-base propellants, the presence of volatile plasticizers such as nitroglycerine (NG) and diethylene-glycol dinitrate (DEGDN) can complicate the determination. Other methods (i.e., MIL-STD-2668 and JANNAF 523.1) involve first extracting water with dry solvents, and then analyzing the extract by liquid or gas chromatography. Using these methods, extraction times can last as long as 16 hr; consumption of 50 mL of solvent per sample is not unusual. Furthermore, local environmental conditions such as high ambient humidity can make it difficult to keep solvents and glassware dry. Methods based on Karl Fisher titrations also require the use of dry solvents, reagents, and glassware. The disadvantages of these techniques are that they are time-consuming, require the use of volatile organic compounds (VOCs), and generate reactive hazardous waste.

An alternate method for moisture determination has recently been developed in response to an urgent request for analysis of JA2 samples suspected to have been exposed to excessive moisture. Conventional extraction methods could not be employed because there was neither time to dry the required solvents (MIL-STD-2868 recommends that solvents remain over molecular sieves for a minimum of two days before use) nor the local environmental conditions to keep the solvents dry (due to high ambient humidity and the absence of adequate air conditioning). To meet the suspense for the required analyses, it was decided that an alternate, solvent-free technique must be developed. This was successfully accomplished, and yielded results in a relatively short time (instrument calibration plus approximately 30 sample runs in 10 hr). In addition, the method did not require the use of VOCs and consumed only small amounts of propellant. Considering the high cost of disposal for reactive hazardous wastes, this resulted in a significant savings of both time and money.

The main disadvantages of the method are that 1) multiple analyses are required to assure representative results (since the test requires a very small sample size), and 2) the method required specialized instrumentation (e.g., a device in which materials may be desorbed from the propellant and then transferred directly into a gas chromatograph).

2. EXPERIMENTAL

2.1 Instrumentation. Moisture desorption was achieved via a CDS Model 122 Pyroprobe (coil type) connected to a heated interface chamber to the splitless injector of a Hewlett Packard GC-FTIR-MS system (Model 5890 GC, Model 5970 MSD, and Model 5965 IRD with narrow band MCT detector). The GC column used was a Quadrex capillary column (0.32 mm × 25 m; 3 μm OV-17 film). The injector temperature was 200° C. A 200° C isothermal GC program was used.

2.2 Procedure. Six JA2 samples (approximately 5 g each) were provided for chemical analysis (see Table 1 for sample description). A seventh sample of JA2 was also analyzed for comparative purposes. Using a razor blade, cross-sectional slices (<1 mm thickness) of the solid propellant were cut. Cross-sectional slices were then cut into strips (<1 mm diameter) and placed into preweighed quartz tubes containing a plug of glass wool. The glass wool was used to prevent propellant from coming out of the tube. Quartz tubes containing the propellant were then reweighed to determine propellant mass.

Table 1. Designation for JA2 Samples Analyzed

Sample	Lot No.	Designation
19 perf, Stick, Sample A	HCL94A015-002	A-19
19 perf, Stick, Sample B	HCL94A015-002	B-19
7 perf, Stick, Sample A	HCL93J014-001	A-7
7 perf, Stick, Sample B	HCL93J014-001	B-7
7 perf, Granular, Sample A	HCL93E-071425	A-G-7
7 perf, Granular, Sample B	HCL93E-071425	B-G-7
Unperforated, Stick, "STD"	RAD-PDI-002-1F	JA2-stk

The quartz tube containing the propellant was then placed within the coils of the pyroprobe heating element (see diagram in Figure 1), which was subsequently inserted into the pyroprobe interface and screwed into place. At the start of the GC run, a 150° C pulse (20-s duration) was given to the sample via the pyroprobe. It was confirmed that these conditions are sufficient for desorption of all moisture by giving a second pulse to the sample, and observing no subsequent moisture desorption. In preliminary

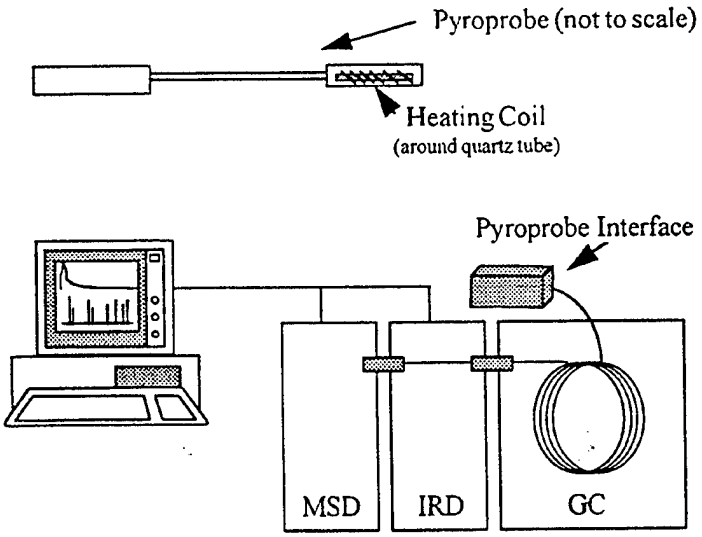


Figure 1. Schematic representation of experimental apparatus.

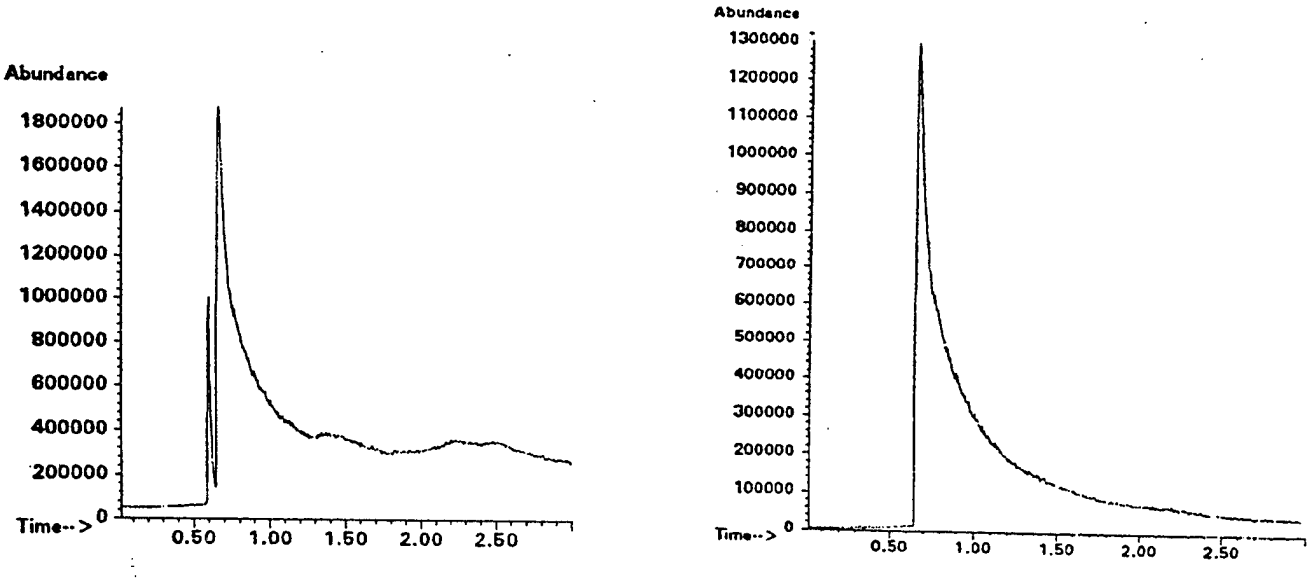
studies it was noted that if the sample size was too large (i.e., above 30 mg) or the propellant slices were packed too closely in the tube, it was difficult to desorb all the moisture with just one pulse.

For preparation of a calibration curve, aliquots (0.1–0.8 μL) of water were transferred to a plug of glass wool in a quartz tube, and then analyzed as previously described.

Gas chromatograms, total ion chromatograms (TICs) (based on MS response), and total response chromatograms (TRCs) (based on IR response) were collected. For the purpose of this analysis, only the TICs were necessary. Selected ion chromatograms (SICs) were also obtained to distinguish between response due to desorbed water and plasticizer (the peaks overlap with one another). Integration of the m/z = 18 SIC yielded the peak area for water. An example of a TIC and SIC are given in Figure 2.

3. RESULTS

3.1 Instrument Calibration. The calibration curve obtained by analysis of known volumes of water is given in Figure 3 (R^2 = 0.995).



(a) Total Ion Chromatogram

(b) Selected Ion Chromatogram (m/z = 18, water)

Figure 2. Gas chromatograms.

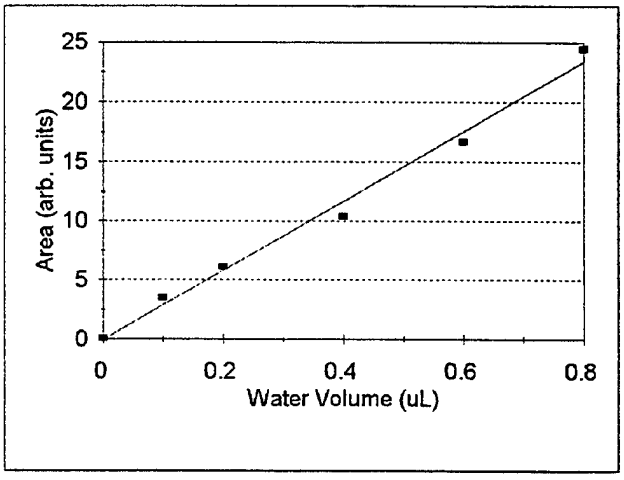


Figure 3. Calibration curve for moisture analysis.

3.2 Moisture Content. Table 2 gives the results for moisture analysis. Given that the specifications for JA2 propellant call for 0.5 ±0.3 weight-percent moisture, it is concluded that all seven samples fall within the limit of 0.2–0.8 weight-percent.

Table 2. Results for Moisture Analysis of JA2 Propellant

Sample ID	Peak Area (arb units)	Mass (mg)	Water (μL)	Water (weight-percent)
A-19	2.85	19.0	0.127	0.67
A-19	2.17	16.3	0.104	0.64
B-19	2.53	19.7	0.116	0.59
B-19	3.35	24.3	0.144	0.59
A-7	3.23	24.5	0.140	0.57
A-7	3.83	27.4	0.160	0.58
B-7	3.50	24.0	0.148	0.62
B-7	2.94	19.3	0.126	0.67
A-G	2.82	29.2	0.126	0.43
A-G	3.24	26.7	0.140	0.52
B-G	2.43	17.5	0.113	0.64
B-G	1.55	11.2	0.081	0.74
JA2-Stk	1.71	13.4	0.088	0.66
JA2-Stk	2.23	20.0	0.106	0.53

3.3 JA2 Soaked in Water. To confirm that JA2 grains would not absorb excessive moisture even if soaked in water, a stick of 7-perf stick (Sample A) was soaked overnight at room temperature in filtered water. Prior to analysis, the stick was patted dry with a paper towel and then analyzed as previously described. No significant increase in moisture level was observed.

4. CONCLUSIONS

To meet the deadline on a "short-suspense" analysis of JA2 propellant, a new solvent-free analytical method for moisture determination was developed. Although the method was not validated by comparison with traditional methods, it did provide what appear to be reasonable results for several JA2 samples. The method is quick, consumes little propellant, and does not require the use of solvents. However, it does

require special instrumentation and multiple analyses (due to limitations on sample size). It is recommended that this method be run side-by-side with traditional methods to confirm that its results are reliable and to demonstrate applicability to other propellant samples.

NO. OF COPIES	ORGANIZATION
2	ADMINISTRATOR DEFENSE TECHNICAL INFO CTR ATTN DTIC DDA CAMERON STATION ALEXANDRIA VA 22304-6145
1	DIRECTOR US ARMY RESEARCH LAB ATTN AMSRL OP SD TA 2800 POWDER MILL RD ADELPHI MD 20783-1145
3	DIRECTOR US ARMY RESEARCH LAB ATTN AMSRL OP SD TL 2800 POWDER MILL RD ADELPHI MD 20783-1145
1	DIRECTOR US ARMY RESEARCH LAB ATTN AMSRL OP SD TP 2800 POWDER MILL RD ADELPHI MD 20783-1145
	ABERDEEN PROVING GROUND
5	DIR USARL ATTN AMSRL OP AP L (305)

NO. OF COPIES	ORGANIZATION
1	HQDA ATTN SARD TT DR F MILTON PENTAGON WASHINGTON DC 20310-0103
1	HQDA ATTN SARD TT MR J APPEL PENTAGON WASHINGTON DC 20310-0103
1	HQDA OASA RDA ATTN DR C H CHURCH PENTAGON ROOM 3E486 WASHINGTON DC 20310-0103
4	COMMANDER US ARMY RESEARCH OFFICE ATTN R GHIRARDELLI D MANN R SINGLETON R SHAW P O BOX 12211 RSCH TRNGLE PK NC 27709-2211
1	DIRECTOR ARMY RESEARCH OFFICE ATTN AMXRO RT IP LIB SERVICES P O BOX 12211 RSCH TRNGLE PK NC 27709-2211
2	COMMANDER US ARMY ARDEC ATTN SMCAR AEE B D S DOWNS PCTNY ARSNL NJ 07806-5000
2	COMMANDER US ARMY ARDEC ATTN SMCAR AEE J A LANNON PCTNY ARSNL NJ 07806-5000
1	COMMANDER US ARMY ARDEC ATTN SMCAR AEE BR L HARRIS PCTNY ARSNL NJ 07806-5000
2	COMMANDER US ARMY MISSILE COMMAND ATTN AMSMI RD PR E A R MAYKUT AMSMI RD PR P R BETTS REDSTONE ARSENAL AL

NO. OF COPIES	ORGANIZATION
1	OFFICE OF NAVAL RESEARCH DEPARTMENT OF THE NAVY ATTN R S MILLER CODE 432 800 N QUINCY STREET ARLINGTON VA 22217
1	COMMANDER NAVAL AIR SYSTEMS COMMAND ATTN J RAMNARACE AIR 54111C WASHINGTON DC 20360
2	COMMANDER NAVAL SURFACE WARFARE CENTER ATTN R BERNECKER R 13 G B WILMOT R 16 SILVER SPRING MD 20903-5000
5	COMMANDER NAVAL RESEARCH LABORATORY ATTN M C LIN J MCDONALD E ORAN J SHNUR R J DOYLE CODE 6110 WASHINGTON DC 20375
2	COMMANDER NAVAL WEAPONS CENTER ATTN T BOGGS CODE 388 T PARR CODE 3895 CHINA LAKE CA 93555-6001
1	SUPERINTENDENT NAVAL POSTGRADUATE SCHOOL DEPT OF AERONAUTICS ATTN D W NETZER MONTEREY CA 93940
3	AL LSCF ATTN R CORLEY R GEISLER J LEVINE EDWARDS AFB CA 93523-5000
1	AFOSR ATTN J M TISHKOFF BOLLING AIR FORCE BASE WASHINGTON DC 20332

NO. OF COPIES	ORGANIZATION
1	OSD SDIO IST ATTN L CAVENY PENTAGON WASHINGTON DC 20301-7100
1	COMMANDANT USAFAS ATTN ATSF TSM CN FORT SILL OK 73503-5600
1	UNIV OF DAYTON RSCH INSTITUTE ATTN D CAMPBELL AL PAP EDWARDS AFB CA 93523
1	NASA LANGLEY RESEARCH CENTER ATTN G B NORTHAM MS 168 LANGLEY STATION HAMPTON VA 23365
4	NATIONAL BUREAU OF STANDARDS US DEPARTMENT OF COMMERCE ATTN J HASTIE M JACOX T KASHIWAGI H SEMERJIAN WASHINGTON DC 20234
2	DIRECTOR LAWRENCE LIVERMORE NATIONAL LAB ATTN C WESTBROOK W TAO MS L 282 P O BOX 808 LIVERMORE CA 94550
1	DIRECTOR LOS ALAMOS NATIONAL LAB ATTN B NICHOLS T7 MS B284 P O BOX 1663 LOS ALAMOS NM 87545
2	PRINCETON COMBUSTION RESEARCH LABORATORIES INC ATTN N A MESSINA M SUMMERFIELD PRINCETON CORPORATE PLAZA BLDG IV SUITE 119 11 DEERPARK DRIVE MONMOUTH JUNCTION NJ 08852

NO. OF COPIES	ORGANIZATION
3	DIRECTOR SANDIA NATIONAL LABORATORIES DIVISION 8354 ATTN S JOHNSTON P MATTERN D STEPHENSON LIVERMORE CA 94550
1	BRIGHAM YOUNG UNIVERSITY DEPT OF CHEMICAL ENGINEERING ATTN M W BECKSTEAD PROVO UT 84058
1	CALIFORNIA INSTITUTE OF TECH JET PROPULSION LABORATORY ATTN L STRAND MS 125 224 4800 OAK GROVE DRIVE PASADENA CA 91109
1	CALIFORNIA INSTITUTE OF TECHNOLOGY ATTN F E C CULICK MC 301 46 204 KARMAN LAB PASADENA CA 91125
1	UNIVERSITY OF CALIFORNIA LOS ALAMOS SCIENTIFIC LAB P O BOX 1663 MAIL STOP B216 LOS ALAMOS NM 87545
1	UNIVERSITY OF CALIFORNIA BERKELEY CHEMISTRY DEPARMENT ATTN C BRADLEY MOORE 211 LEWIS HALL BERKELEY CA 94720
1	UNIVERSITY OF CALIFORNIA SAN DIEGO ATTN F A WILLIAMS AMES B010 LA JOLLA CA 92093
2	UNIV OF CALIFORNIA SANTA BARBARA QUANTUM INSTITUTE ATTN K SCHOFIELD M STEINBERG SANTA BARBARA CA 93106
1	UNIV OF COLORADO AT BOULDER ENGINEERING CENTER ATTN J DAILY CAMPUS BOX 427 BOULDER CO 80309-0427

NO. OF COPIES	ORGANIZATION
3	UNIV OF SOUTHERN CALIFORNIA DEPT OF CHEMISTRY ATTN R BEAUDET S BENSON C WITTIG LOS ANGELES CA 90007
1	CORNELL UNIVERSITY DEPARTMENT OF CHEMISTRY ATTN T A COOL BAKER LABORATORY ITHACA NY 14853
1	UNIVERSITY OF DELAWARE CHEMISTRY DEPARTMENT ATTN T BRILL NEWARK DE 19711
1	UNIVERSITY OF FLORIDA DEPT OF CHEMISTRY ATTN J WINEFORDNER GAINESVILLE FL 32611
3	GEORGIA INSTITUTE OF TECHNOLOGY SCHOOL OF AEROSPACE ENGINEERING ATTN E PRICE W C STRAHLE B T ZINN ATLANTA GA 30332
1	UNIVERSITY OF ILLINOIS DEPT OF MECH ENG ATTN H KRIER 144MEB 1206 W GREEN ST URBANA IL 61801
1	THE JOHNS HOPKINS UNIV CPIA ATTN T W CHRISTIAN 10630 LITTLE PATUXENT PKWY SUITE 202 COLUMBIA MD 21044-3200
1	UNIVERSITY OF MICHIGAN GAS DYNAMICS LAB ATTN G M FAETH AEROSPACE ENGINEERING BLDG ANN ARBOR MI 48109-2140
1	UNIVERSITY OF MINNESOTA DEPT OF MECHANICAL ENGINEERING ATTN E FLETCHER MINNEAPOLIS MN 55455

NO. OF COPIES	ORGANIZATION
4	PENNSYLVANIA STATE UNIVERSITY DEPT OF MECHANICAL ENGINEERING ATTN K KUO M MICCI S THYNELL V YANG UNIVERSITY PARK PA 16802
2	PRINCETON UNIVERSITY FORRESTAL CAMPUS LIBRARY ATTN K BREZINSKY I GLASSMAN P O BOX 710 PRINCETON NJ 08540
1	PURDUE UNIVERSITY SCHL OF AERONAUTICS & ASTRONAUTICS ATTN J R OSBORN GRISSOM HALL WEST LAFAYETTE IN 47906
1	PURDUE UNIVERSITY DEPARTMENT OF CHEMISTRY ATTN E GRANT WEST LAFAYETTE IN 47906
2	PURDUE UNIVERSITY SCHL OF MECHANICAL ENGNRNG ATTN N M LAURENDEAU S N B MURTHY TSPC CHAFFEE HALL WEST LAFAYETTE IN 47906
1	RENSSELAER POLYTECHNIC INST DEPT OF CHEMICAL ENGINEERING ATTN A FONTIJN TROY NY 12181
1	STANFORD UNIVERSITY DEPT OF MECHANICAL ENGINEERING ATTN R HANSON STANFORD CA 94305
1	UNIVERSITY OF TEXAS DEPT OF CHEMISTRY ATTN W GARDINER AUSTIN TX 78712
1	VA POLYTECH INST AND STATE UNIV ATTN J A SCHETZ BLACKSBURG VA 24061

NO. OF COPIES	ORGANIZATION
1	APPLIED COMBUSTION TECHNOLOGY INC ATTN A M VARNEY P O BOX 607885 ORLANDO FL 32860
2	APPLIED MECHANICS REVIEWS ASME ATTN R E WHITE & A B WENZEL 345 E 47TH STREET NEW YORK NY 10017
1	TEXTRON DEFENSE SYSTEMS ATTN A PATRICK 2385 REVERE BEACH PARKWAY EVERETT MA 02149-5900
1	BATTELLE TWSTIAC 505 KING AVENUE COLUMBUS OH 43201-2693
1	COHEN PROFESSIONAL SERVICES ATTN N S COHEN 141 CHANNING STREET REDLANDS CA 92373
1	EXXON RESEARCH & ENG CO ATTN A DEAN ROUTE 22E ANNANDALE NJ 08801
1	GENERAL APPLIED SCIENCE LABS INC 77 RAYNOR AVENUE RONKONKAMA NY 11779-6649
1	GENERAL ELECTRIC ORDNANCE SYSTEMS ATTN J MANDZY 100 PLASTICS AVENUE PITTSFIELD MA 01203
1	GENERAL MOTORS RSCH LABS PHYSICAL CHEMISTRY DEPARTMENT ATTN T SLOANE WARREN MI 48090-9055
2	HERCULES INC ATTN W B WALKUP E A YOUNT P O BOX 210 ROCKET CENTER WV 26726

NO. OF COPIES	ORGANIZATION
1	HERCULES INC ATTN R V CARTWRIGHT 100 HOWARD BLVD KENVIL NJ 07847
1	ALLIANT TECHSYSTEMS INC MARINE SYSTEMS GROUP ATTN D E BRODEN MS MN50 2000 600 2ND STREET NE HOPKINS MN 55343
1	ALLIANT TECHSYSTEMS INC ATTN R E TOMPKINS MN 11 2720 600 SECOND ST NORTH HOPKINS MN 55343
1	IBM CORPORATION RESEARCH DIVISION ATTN A C TAM 5600 COTTLE ROAD SAN JOSE CA 95193
1	IIT RESEARCH INSTITUTE ATTN R F REMALY 10 WEST 35TH STREET CHICAGO IL 60616
1	LOCKHEED MISSILES & SPACE CO ATTN GEORGE LO 3251 HANOVER STREET DEPT 52 35 B204 2 PALO ALTO CA 94304
1	OLIN ORDNANCE ATTN V MCDONALD LIBRARY P O BOX 222 ST MARKS FL 32355-0222
1	PAUL GOUGH ASSOCIATES INC ATTN P S GOUGH 1048 SOUTH STREET PORTSMOUTH NH 03801-5423
1	HUGHES AIRCRAFT COMPANY ATTN T E WARD PO BOX 11337 TUCSON AZ 85734-1337

NO. OF COPIES	ORGANIZATION
1	ROCKWELL INTERNATIONAL CORP ROCKETDYNE DIVISION ATTN J E FLANAGAN HB02 6633 CANOGA AVENUE CANOGA PARK CA 91304
1	SCIENCE APPLICATIONS INC ATTN R B EDELMAN 23146 CUMORAH CREST WOODLAND HILLS CA 91364
3	SRI INTERNATIONAL ATTN G SMITH D CROSLEY D GOLDEN 333 RAVENSWOOD AVENUE MENLO PARK CA 94025
1	STEVENS INSTITUTE OF TECH DAVIDSON LABORATORY ATTN R MCALEVY III HOBOKEN NJ 07030
1	SVERDRUP TECHNOLOGY INC LERC GROUP ATTN R J LOCKE MS SVR 2 2001 AEROSPACE PARKWAY BROOK PARK OH 44142
1	SVERDRUP TECHNOLOGY INC ATTN J DEUR 2001 AEROSPACE PARKWAY BROOK PARK OH 44142
3	THIOKOL CORPORATION ELKTON DIVISION ATTN R BIDDLE R WILLER TECH LIB P O BOX 241 ELKTON MD 21921
3	THIOKOL CORPORATION WASATCH DIVISION ATTN S J BENNETT P O BOX 524 BRIGHAM CITY UT 84302
1	UNITED TECHNOLOGIES RSCH CENTER ATTN A C ECKBRETH EAST HARTFORD CT 06108

NO. OF COPIES	ORGANIZATION
1	UNITED TECHNOLOGIES CORP CHEMICAL SYSTEMS DIVISION ATTN R R MILLER P O BOX 49028 SAN JOSE CA 95161-9028
1	UNIVERSAL PROPULSION COMPANY ATTN H J MCSPADDEN 25401 NORTH CENTRAL AVENUE PHOENIX AZ 85027-7837
1	VERITAY TECHNOLOGY INC ATTN E B FISHER 4845 MILLERSPORT HIGHWAY EAST AMHERST NY 14051-0305
1	FREEDMAN ASSOCIATES ATTN E FREEDMAN 2411 DIANA ROAD BALTIMORE MD 21209-1525
3	ALLIANT TECHSYSTEMS ATTN C CANDLAND L OSGOOD R BECKER 600 SECOND ST NE HOPKINS MN 55343
1	US ARMY BENET LABORATORY ATTN SAM SOPOK SMCAR CCB B WATERVLIET NY 12189

NO. OF
COPIES ORGANIZATION

ABERDEEN PROVING GROUND

36 DIR USARL
ATTN: AMSRL-WT-P, A HORST
AMSRL-WT-PC,
R A FIFER
G F ADAMS
W R ANDERSON
R A BEYER
S W BUNTE
C F CHABALOWSKI
K P MCNEILL-BOONSTOPPEL
A COHEN
R CUMPTON
R DANIEL
D DEVYNCK
N F FELL
B E FORCH
J M HEIMERL
A J KOTLAR
M R MANAA
W F MCBRATNEY
K L MCNESBY
S V MEDLIN
M S MILLER
A W MIZIOLEK
S H MODIANO
J B MORRIS
J E NEWBERRY
S A NEWTON
R A PESCE-RODRIGUEZ
B M RICE
R C SAUSA
M A SCHROEDER
J A VANDERHOFF
M WENSING
A WHREN
J M WIDDER
C WILLIAMSON
AMSRL-CI-CA, R PATEL

INTENTIONALLY LEFT BLANK.

USER EVALUATION SHEET/CHANGE OF ADDRESS

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

1. ARL Report Number ARL-MR-290 Date of Report February 1996

2. Date Report Received _____

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

4. Specifically, how is the report being used? (Information source, design data, procedure, source of ideas, etc.) _____

5. 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. _____

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

CURRENT ADDRESS

_____
Organization

_____
Name

_____
Street or P.O. Box No.

_____
City, State, Zip Code

7. If indicating a Change of Address or Address Correction, please provide the Current or Correct address above and the Old or Incorrect address below.

OLD ADDRESS

_____
Organization

_____
Name

_____
Street or P.O. Box No.

_____
City, State, Zip Code

(Remove this sheet, fold as indicated, tape closed, and mail.)
(DO NOT STAPLE)