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Test Program to Demonstrate the Stability of Hydrazine in Propellant Tanks

Final Report

Clifford M. Moran
Roy A. Bjorklund

April 1983

Prepared for

United Kingdom Treasury and Supply Delegation
Washington, D C

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ABSTRACT

This document reports the analyses and results of a 24-month coupon test program to evaluate the decomposition of hydrazine by metallic components of propellant tanks. The propellant fuel evaluated was monopropellant-grade hydrazine (N_2H_4), which is normally a colorless, fuming, corrosive, strongly reducing liquid. The degree of hydrazine decomposition was determined by means of chemical analyses of the liquid and evolved gases at the end of the test program. The experimental rates of hydrazine decomposition were determined to be within acceptable limits.

The propellant tank materials and material combinations were not degraded by a 2-year exposure to hydrazine propellant. This was verified using change-of-weight determinations and microscopic examination of the specimen surfaces before and after exposure, and by posttest chemical analyses of hydrazine liquid for residual metal content.

ACRONYMS

ACS	attitude control system
ARDE	ARDE, Inc., Mahawah, NJ
BAT	Bell Aerospace Division of Textron, Inc., Buffalo, NY
BE	binding energy
Caltech	California Institute of Technology
CRES	corrosion-resistant steel
CPR	coupon preparation requirement
EB	electron beam
EPR	ethylene propylene rubber
ETS	Edwards Test Station, JPL
FEP	fluorinated ethylene propylene (Teflon)
HAS	hydrazine actuation system
HAZ	heat-affected zone
JPL	Jet Propulsion Laboratory
NASA	National Aeronautics and Space Administration
OAST	NASA Office of Aeronautics and Space Technology
OSS	NASA Office of Space Sciences
PES	photoelectron spectra
SEM	scanning electron microscope
STP	standard temperature and pressure
TBD	to be defined/determined/done
TIG	tungsten inert gas
UKTSD	United Kingdom Treasury and Supply Delegation, Washington, D.C.
XPS	X-ray photoelectron spectroscopy

SECTION I

INTRODUCTION

A. COUPON TEST PROGRAM

The Coupon Test Program has been an investigation of the reactive compatibility of hydrazine with various metallic components of a propellant storage tank. The hydrazine/material compatibility research reported here was performed by the Jet Propulsion Laboratory (JPL), California Institute of Technology (Caltech), under Contract NAS7-198 with the National Aeronautics and Space Administration (NASA) for the United Kingdom Treasury and Supply Delegation (UKTSD) in accordance with the UKTSD Letter Agreement F-2479, dated July 5, 1979.

This coupon test program is an extension of the ongoing JPL/NASA long-term propellant/material compatibility program. The same procedures, test methods, and test facilities developed under the JPL/NASA program have been applied to this program.

This document is the final report for the Coupon Test Program. An interim report from Program A was prepared in October 1981 (Reference 1).

B. BACKGROUND-RELATED TECHNICAL WORK

JPL has collaborated with other agencies on a variety of research, development, test, and evaluation projects. The laboratory, with its Pasadena facility and Edwards Test Station (ETS) at Edwards Air Force Base, California, maintains an institutional capability and technical expertise in evaluating and testing Earth- and space-storable liquid propellants and materials for spacecraft propulsion system applications. Specifically, JPL has been investigating material compatibility involving Earth-storable propellants, including hydrazine, since 1962 under sponsorship of the NASA Offices of Aeronautics and Space Technology (OAST) and of Space Sciences (OSS). The details of the JPL material compatibility program and interim experimental results of the long-term storage testing are reported in References 2 and 3. The long-term exposure testing continues, and the accumulated time for some test specimens exceeds 12 years.

The results obtained have provided reliable data for designing and qualifying chemical propulsion systems and components for long-life spacecraft. The work performed has directly supported the early JPL planetary flight projects such as Ranger, Surveyor, and Mariner, and the Viking 1975 and Voyager 1977 (Jupiter-Saturn-Uranus).

The general technology areas involved are propellant chemistry, metallurgy, long-term (10-year) propellant/material compatibility, metal fracture/toughness characteristics, and fracture mechanics design of pressurized systems. Typical Earth-storable propellants are hydrazine, refined-grade hydrazine (monopropellant grade), hydrazine-hydrazine nitrate, monomethylhydrazine, and nitrogen tetroxide. Spacecraft propulsion system materials include aluminum alloys, corrosion-resistant steels (CRES), titanium alloys, and elastometric materials, for example, AF-E-332.

C. OBJECTIVES OF THE COUPON TEST PROGRAM

The overall objective of the coupon test program was to verify the long-term compatibility of hydrazine actuation system (HAS) propellant tank materials and other material combinations with monopropellant-grade hydrazine. To accomplish this overall objective, the program was divided into two parts.

Program A was intended to evaluate short-term compatibility of the secondary propellant containment system shown in Figure 1-1. It should be noted that the secondary containment system will be exposed to hydrazine only if there is leakage from the primary containment system. The program objectives were:

(1) Determine rates of hydrazine decomposition at 43°C by means of pressure rise monitoring throughout the term of the test program.

(2) Verify that pressure containment materials and material combinations are not degraded by 6-month exposure to hydrazine propellant, using weight determinations and microscopic examination of specimen surfaces, after exposure.

Program B was intended to evaluate long-term compatibility of the primary propellant containment system shown in Figure 1-1. The program objectives were:

(1) Determine rates of hydrazine decomposition at 43°C and 60°C by monitoring pressure rise throughout the term of the test program.

(2) Determine degree of hydrazine decomposition by means of chemical analysis of liquid and evolved gases at the end of the test program.

(3) Verify that primary containment materials and material combinations were not degraded by 2-year exposure to hydrazine propellant, using weight determinations and microscopic examination of specimen surfaces, after exposure, and also by posttest chemical analysis of hydrazine liquid for metal content.

D. MATERIAL COUPON SOURCE

The material coupons used in this program were provided by the UKTSD. They were obtained from sections cut out of a HAS tank fabricated by Bell Aerospace Division of Textron (BAT). A total of 82 coupons from 26 different locations are listed in Table 1.[1] The locations on the tank from which the coupons were cut are shown in Figure 1-2. Each coupon was processed, weighed, cleaned, and individually sealed in a plastic bag by BAT before delivery to JPL. The coupons remained sealed until they were removed and placed immediately into glass capsule test units prepared at JPL.

[1] All tables are contained in Section V.

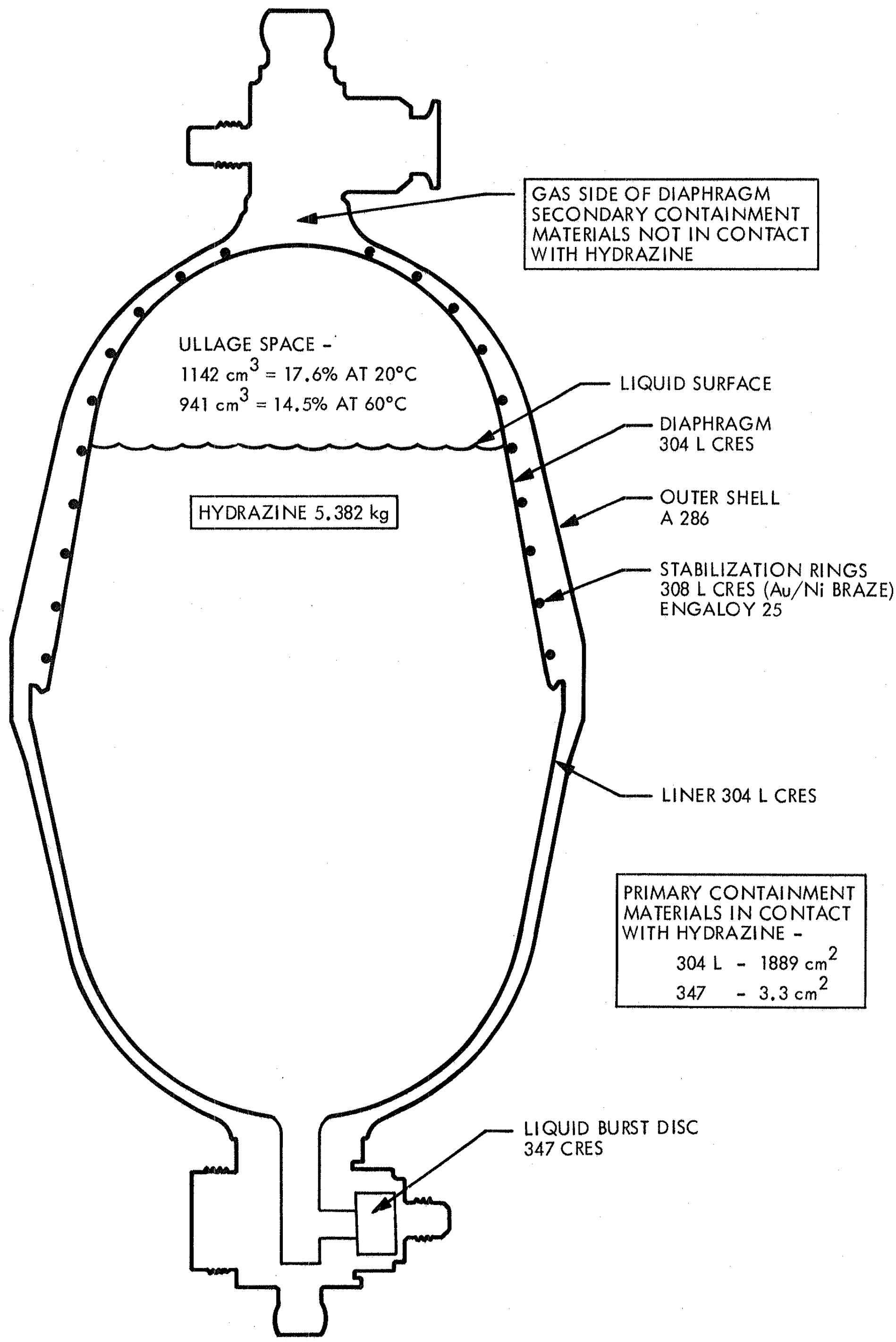

Figure 1-1. Hydrazine Actuation System (HAS) Propellant Tank Configuration

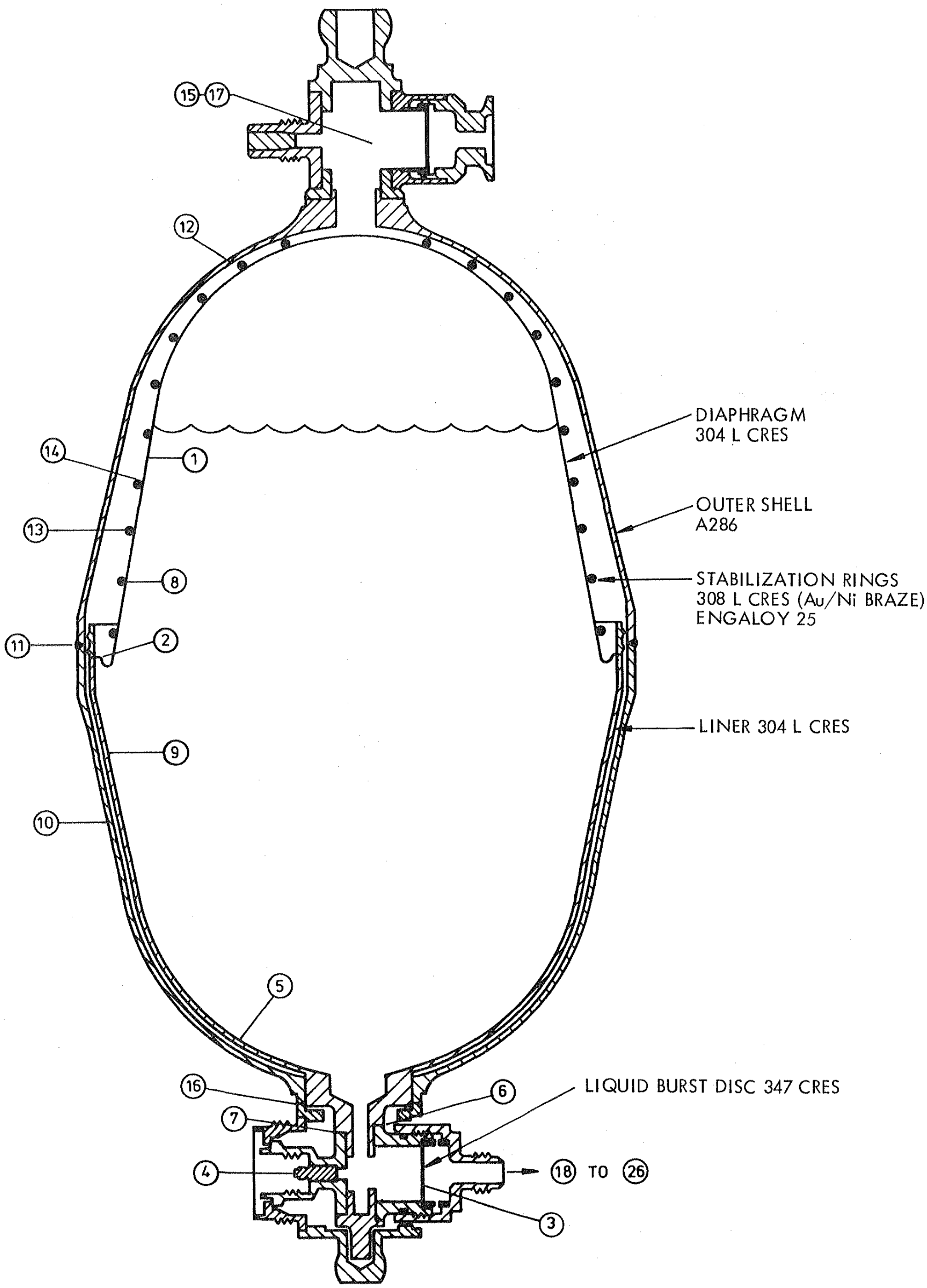

Figure 1-2. Coupon Location on HAS Tank

SECTION II

TEST PROCEDURES

A. TEST UNIT PREPARATION

Eighty-two hermetically sealed, glass-encapsulated test units were prepared by JPL with the materials specified and in accordance with the priorities established by the sponsor. All units were prepared in accordance with the procedures shown in Figure 2-1.

The test requirements for this program were specified in JPL Proposal 90-965, Revision 2, October 11, 1978 and are summarized below.

(1) Purified hydrazine (VL-75 grade) was supplied by JPL. Pretest analysis of this propellant is shown in Appendix A. This propellant met the BAT material specification (Reference 4).

(2) All test coupons were supplied by UKTSD, together with appropriate documentation prepared by BAT. For Program A, 38 coupons were designated; for Program B, 44 coupons were designated. The distribution of coupons by test storage temperatures was also designated.

(3) The test containers were Pyrex capsules, as described in Reference 2, and designed to have an internal volume, when sealed, of about 80 cm^3. Figure 2-2 is a photograph of a typical test unit.

Test equipment, instrumentation, and techniques duplicated those employed in the JPL 10-year test program and reported in Reference 2. The pretest procedures are summarized below.

(1) Strain gauges used to measure internal pressure buildup were mounted on the open capsules. A preliminary pressure calibration was used to check the sensitivities of the strain gauges.

(2) Test specimens were installed into the clean capsules in "as received" condition from BAT except for the EPR-515 O-rings which were coated with Krytox lubricant by JPL.

(3) Funnel necks were fused onto the capsules, with care taken not to overheat the strain gauges. Final pressure calibration of the gauges was then made.

(4) Internal volumes of the test capsules were measured by the expanding volume technique using high-purity gaseous nitrogen at ambient temperature.

(5) Capsules were then loaded with enough hydrazine so that the combined volume of propellant and specimen was 40 ± 0.5 cm^3, and the specimen was fully immersed. Three of the specimens were found to be oversized and additional quantities of hydrazine were added.

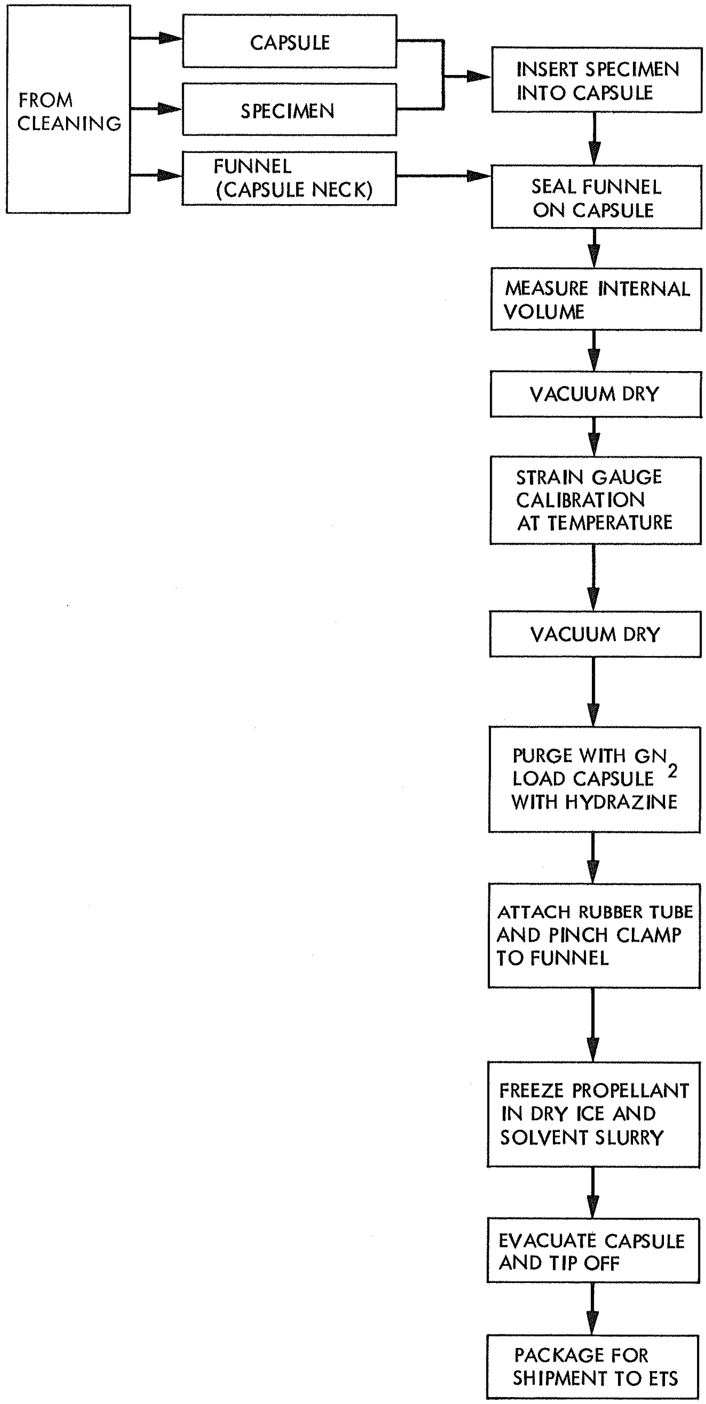

Figure 2-1. Procedures for Capsule Filling

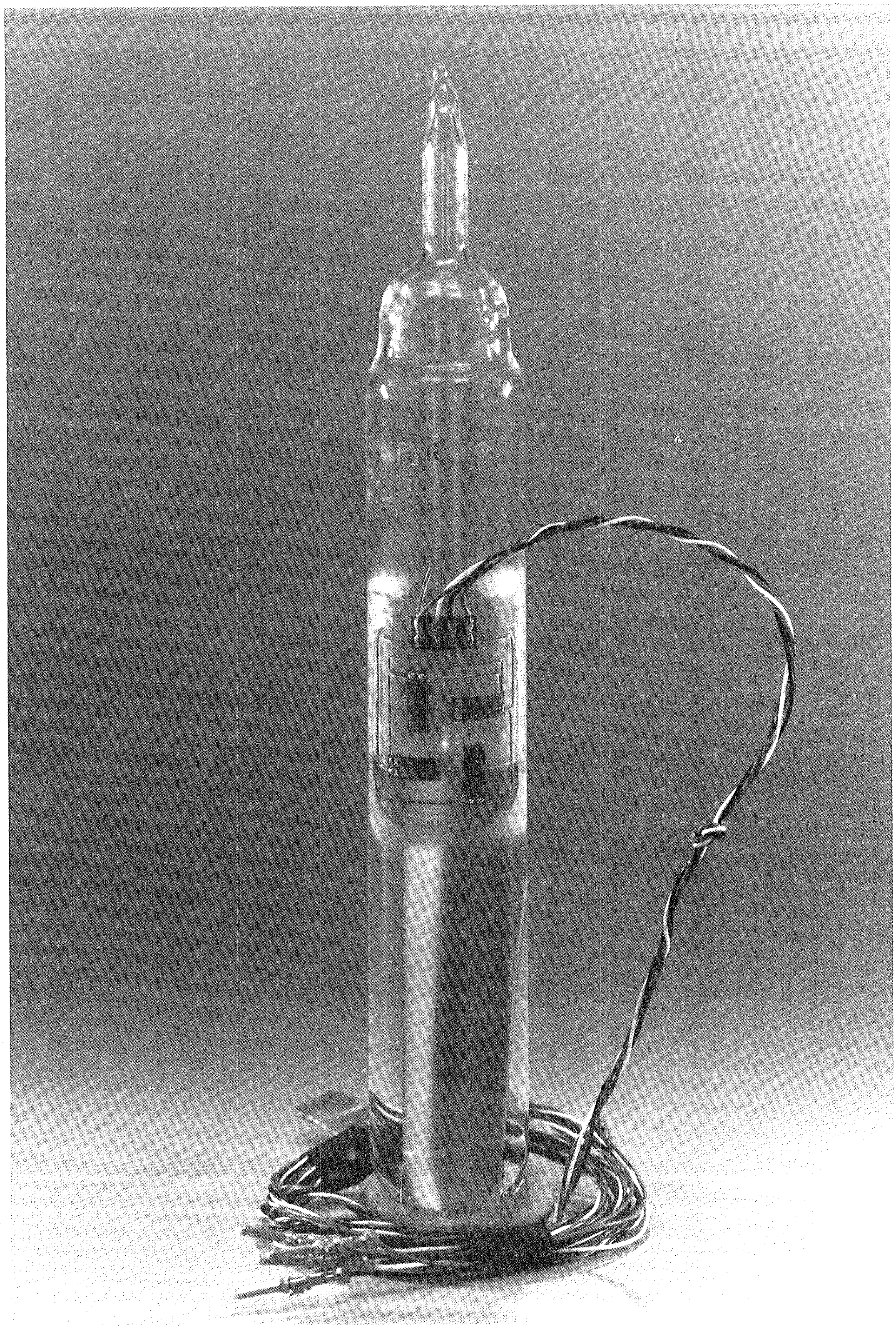

Figure 2-2. Typical Glass Capsule Test Unit

(6) The hydrazine was frozen in a dry-ice/alcohol slurry and the capsules were pumped down to a pressure of less than 1 mm Hg.

(7) The capsule necks were sealed off by fusing the glass tube, and the completed test units were made ready for shipment to Edwards Test Station (ETS).

The hydrazine was pretest-analyzed for purity in accordance with the JPL standard methods (Reference 2). A special CO_2 analysis of hydrazine in one test unit, representative of a typical encapsulation, was performed to verify the exclusion of air during filling. (See Appendix A). No examination or analyses were performed on the coupons.

B. STORAGE TESTING

The experimental storage phase was conducted at ETS to determine the compatibility of the hydrazine propellant with the materials. A photograph of the "Lazy-Susan" type of storage facility is shown in Figure 2-3. The exposure tests on the 82 units were conducted for a period of up to 24 months (730 days) at temperatures of either 43 $\pm 3^{o}$C (110 $\pm 5^{o}$F) or 60 $\pm 1^{o}$C (140 $\pm 2^{o}$F). The temperature of 43^{o}C was used in the JPL long-term program (Reference 2) as the "normal" temperature of a noncryogenic propellant in space. The higher temperature was chosen as being the highest temperature likely to be experienced by the propellant in service. During the 24-month exposure term, the following was accomplished:

(1) Pressure readings were taken once per week for the first month.

(2) Pressure readings were taken once per month for the next five months.

(3) Pressure readings were taken bimonthly for the remaining eighteen months.

(4) Test units were visually inspected after taking the pressure readings.

(5) All results were recorded for the above observations.

Details of all test units are presented in specimen logs in Appendix B.

C. POSTTEST ANALYSIS

1. Discussion

At the completion of the storage tests, all test units were analyzed in accordance with the JPL standard methods (from Reference 2). The capsules were opened and the decomposition gases, hydrazine, and coupons removed. The test coupons were weighed and their surfaces were visually examined at 50x magnification. The decomposition gases and hydrazine were analysed using post-test procedures developed and used in JPL's original program. The procedure

Figure 2-3. "Lazy-Susan"-Type Storage Facility

(Figure 2-4) provides for an analysis of all components. The choice of the posttest analyses to be applied is dependent on the test-unit history and the level of information required to permit satisfactory assessment of results. Details of the posttest analysis procedure are discussed in the following subsections.

2. Procedure - Complete Analysis

The hydrazine was frozen by immersion in liquid nitrogen (LN_2), and the capsule placed in the opening fixture (Figure 2-5). The capsule tip was broken and the volume of noncondensable gases (N_2 and H_2) measured in a calibrated vacuum system. The hydrazine was thawed and refrozen at -30°C (-22°F) and the gas at that temperature, mainly NH_3, measured. The residual hydrazine was removed using a syringe and the purity determined by a gas-chromatographic technique which measures NH_3 and H_2O. Metal content in the residual hydrazine was analyzed by atomic absorption techniques. A turbidimetric method was used for low concentrations of chloride; higher concentrations were titrated. Fluoride was determined colorimetrically.

3. Procedure - Limited Analysis

This procedure measures only the noncondensable gases, hydrogen and nitrogen. After thawing, the residual hydrazine was removed from the capsule using a syringe and was analyzed by gas chromatography for NH_3 and H_2O. If the NH_3 content is low, there may be an error due to NH_3 evolution before analysis.

4. Gases of Decomposition

a. Composition. The contents of the posttest capsule were frozen in liquid nitrogen and then prepared for sampling as follows: The strain gauge was very carefully scraped off with a sharp razor blade, a small scratch was made on the neck of the capsule, and the capsule was then enclosed in the opening fixture (Figure 2-5). The system was pumped down for several hours until moisture was removed from the outside of the capsule. The fixture was then filled with dry helium to 0.5 atmosphere to aid in heat transfer, and then immersed into liquid nitrogen to a depth equal to one-half the length of the capsule. After an hour, the helium was pumped out. When a satisfactory vacuum had been attained (1.3×10^{-2} N/m^2), the gas sampling system was isolated from the vacuum pump, and the neck of the capsule was broken by turning the handle on the fixture. By means of a Toepler pump, the released noncondensable gases were pumped off through a liquid-nitrogen trap. The volume of the collected gases was measured manometrically, and a sample was taken for mass spectrometric analysis.

The nitrogen-to-hydrogen ratio of noncondensable gas was determined in most of the test units containing more than 5 to 10 cc at standard temperature and pressure (STP). For most of these analyses, the hydrogen content was undetectable. With few exceptions, the hydrogen content of the remaining test units was no more than 4%, and these exceptions were welded or brazed specimens. An unexplainable exception was test unit 4019, which contained a Lee plug, and for which the hydrogen content of the noncondensable gas was 12.5%. The total amount of gas was also high, 4 to 5 times the quantity found with the other three Lee-plug test units.

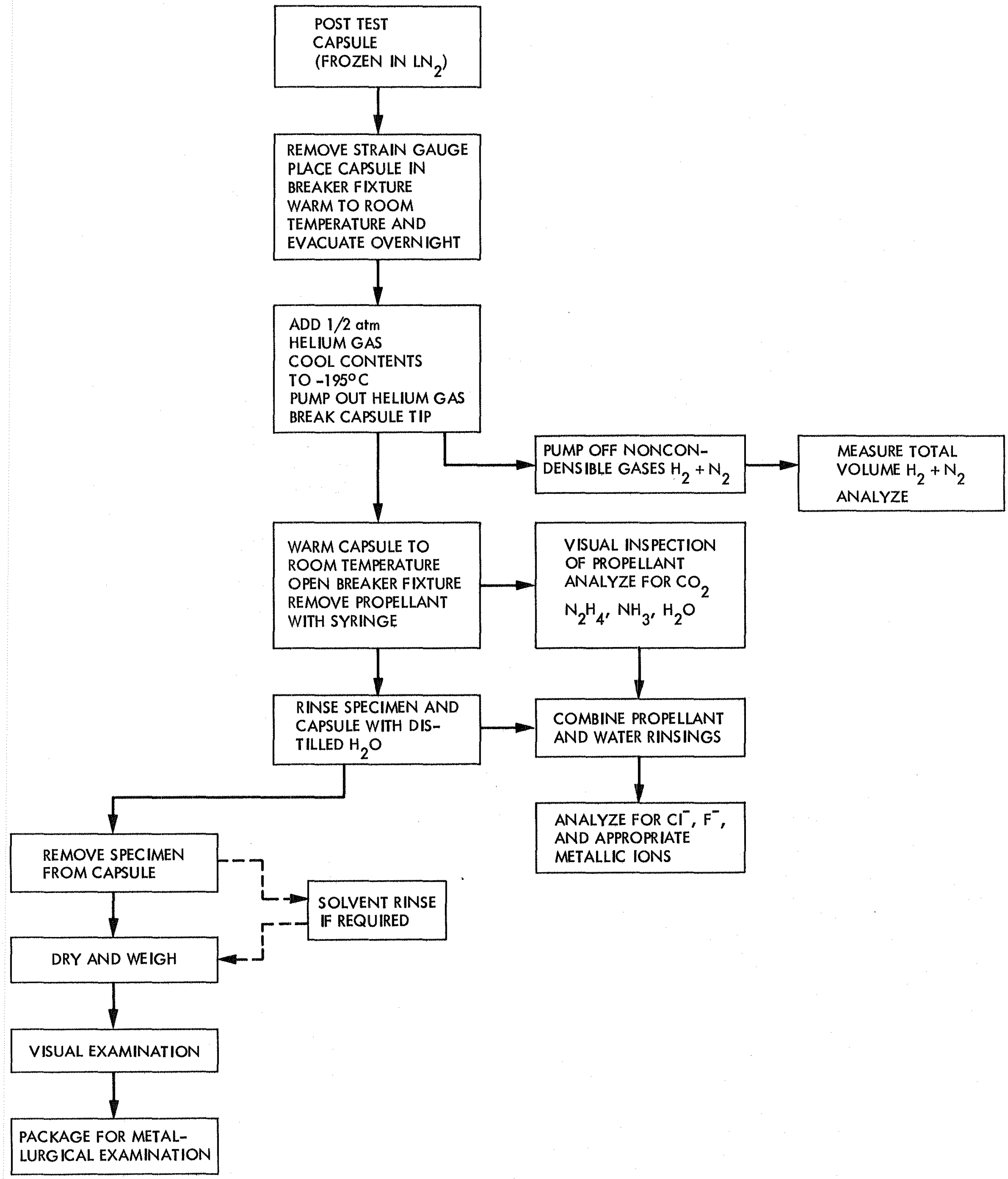

Figure 2-4. Procedure for Posttest Chemical Analysis

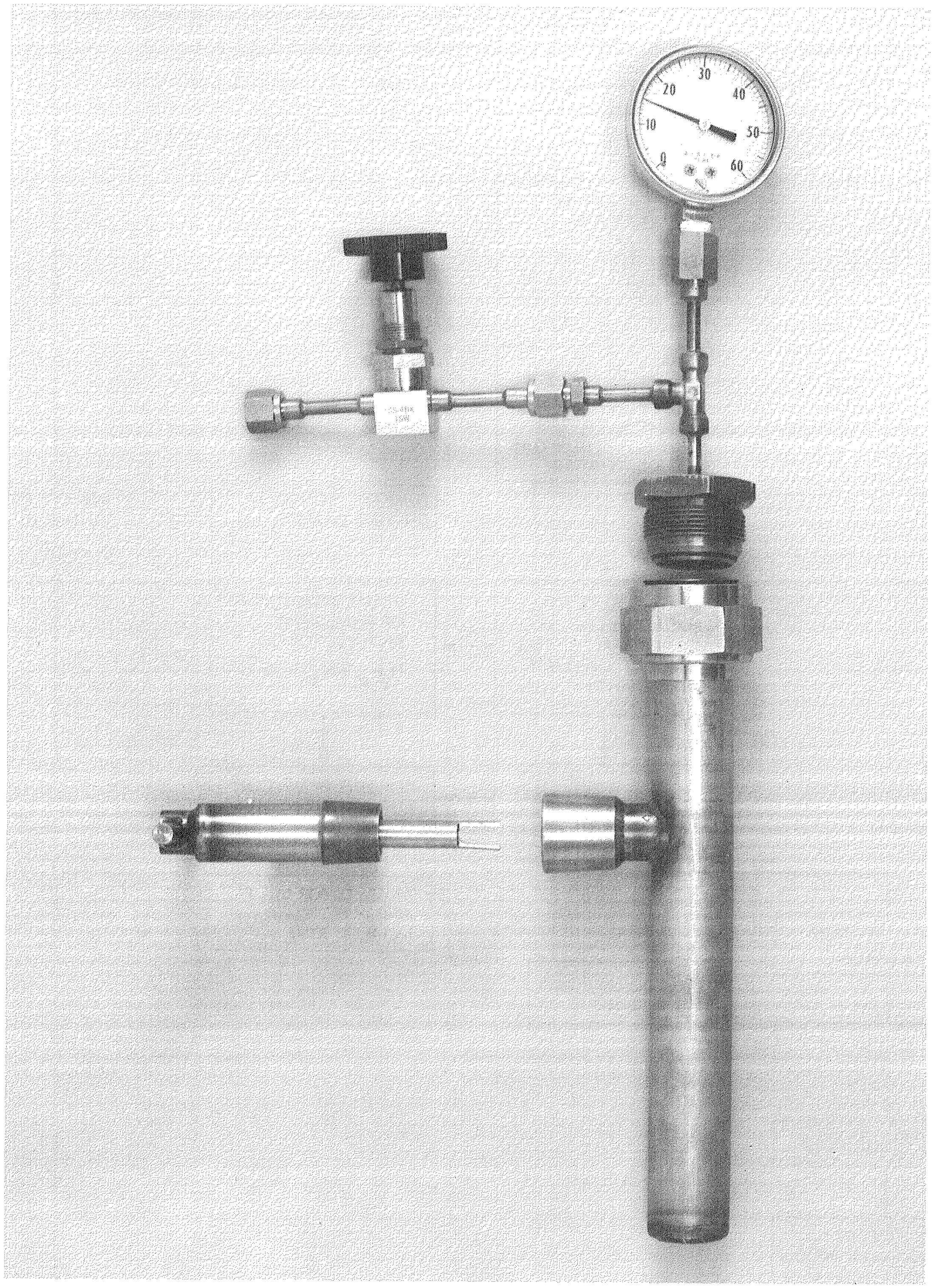

Figure 2-5. Specimen/Capsule Test Opening Fixture

The liquid nitrogen traps were replaced by traps at -30°C (-22°F). After repeated thawing and refreezing of the hydrazine, the remaining condensable gases (mainly NH_3) were pumped off, measured, and sampled. The fixture was opened and the hydrazine removed using a syringe.

b. Calculated Final Capsule Pressure. The mean volume of the test capsules was 82 cm^3. With 40 g of hydrazine and a standard metal coupon, the ullage was about 40 cm^3. The pressure calculations depend upon the volume of nitrogen plus hydrogen (assuming negligible solubility in the hydrazine) and the volume of ammonia in the vapor phase.

The contributions of nitrogen and hydrogen were calculated from the perfect gas law:

$$P_1 = \frac{NRT}{V} \tag{1}$$

where

P_1 = partial pressure of gas in atmospheres
N = moles of gas = cm^3 gas (STP)/22,400
R = universal gas constant = 82.05 cm^3-atm/deg-mole
T = 316.6 K (110°F) or 333 K (140°F)
V = ullage volume of capsule, cm^3.

The calculation of pressure due to the ammonia is not so simple and straightforward. Ammonia is highly soluble in hydrazine, and may not necessarily be an ideal gas at the temperatures and pressures considered.

Fortunately, solubility data for ammonia in hydrazine are available (Reference 5). Although the data do not cover the temperatures of interest, viz., 43°C and 60°C, it was possible to extrapolate the data of the above-referenced report. It can be shown that for the ammonia dissolved in hydrazine, the following relationship can be used to determine a close approximation of the ammonia pressure:

$$P \cong \frac{N/m}{K} \tag{2}$$

where

P = partial pressure of ammonia, atm
N = moles of ammonia in system
m = moles of hydrazine in system
K = equilibrium constant (0.0455 atm^{-1} at 43°C, 110°F), (0.0295 atm^{-1} at 60°, 140°F)

c. Pressure Rise Rate. It would be of interest, both practically and theoretically, to have curves expressing pressure as a function of time for each test capsule. Unfortunately, due to aging of the bonding material, some of the strain-gauge data have proven to be unreliable.

d. Percentage of Hydrazine Decomposed. The percentage of hydrazine decomposed is calculated from the total weight of the gaseous products of decomposition - viz, nitrogen and ammonia. Some hydrogen may arise from the attack of metals by acidic constituents, but the error, if any, is insignificant because of the low molecular weight of hydrogen.

5. Residual Hydrazine

The residual hydrazine was removed from the capsule and analyzed as follows:

a. Impurities: NH_3 and H_2O. The NH_3 and H_2O contents of the hydrazine were analyzed by gas chromatography using a 0.0065-m-diam x 2-m-long (1/4-in.-diam x 6-ft-long) column filled with powdered Teflon coated with 15 wt% tri-ethanolamine. The inlet and column temperatures were held at 90°C (194°F) and the helium flow set at 100 cm^3/min. This column separates NH_3, H_2O, and N_2H_4, in that order.

b. Contaminants: Metals, Halogen and CO_2.

(1) Metals. The capsule was cut open and the metal sample rinsed with water, while any adhering material was rubbed loose with a rubber policeman. Any residue in the capsule was also rinsed out. All washings and residue were acidified with 5% HNO_3, diluted to a known volume with water and analyzed for the appropriate metals by atomic absorption.

(2) Halogens. An aliquot of the acidified washings was checked for chloride by turbidimetry. If the chloride content was high, titration was used. The fluoride ion content was determined by a spectrophotometric method based on the bleaching of a zirconium alizarin color complex by fluoride ion. The absorbance was measured at 525 nm.

(3) Carbon dioxide. Hydrazine reacts with carbon dioxide to form the salt, hydrazinium carbazate. The equation for this reaction is

$$CO_2 + 2N_2H_4 \rightarrow (N_2H_5)(NH_2NHCOO).$$

The method of analysis involved the addition of a sample of hydrazine to an excess of sulfamic acid. The sulfamic acid liberates CO_2 from the hydrazinium carbazate. Sulfamic acid was selected for use in the analysis because hydrazinium sulfamate is soluble in water and sulfamic acid is nonvolatile.

The liberated CO_2 was swept out of solution with helium gas, through a trap containing concentrated sulfuric acid to remove the water, and then through a special trap containing small glass beads where the CO_2 present was frozen out at the temperature of liquid nitrogen.

The trap containing the frozen CO_2 was provided with a special four-way stopcock that permits the CO_2 to be isolated in its loop. This trap is attached to a special sample introduction system on a custom-built chromatograph that permits the collected CO_2 to be quantitatively transferred through a chromatographic column for separation and assay. (Refer to Appendix C for details of this method.)

SECTION III

TEST RESULTS

A. DESCRIPTION OF TEST SPECIMENS

To determine the hydrazine/tank material compatibility, tests were performed on 26 types of metallic and nonmetallic coupons obtained from a fabricated tank, as shown in Figure 1-2. A detailed description of these coupons by CPR numbers and the results of the posttest visual examination are discussed in this section and are compiled in Table 2. Photographs of all test coupons in the posttest condition are presented in Appendix D. Additional data on 347 CRES weld specimens from the JPL/NASA long-term program are presented in Appendix E. A summary of posttest visual examination of coupons is presented below.

a. CPR 1. Specimens 001 to 008 are Type-304L corrosion-resistant steel (CRES) coupons from the ARDE, Inc., diaphragm. All specimens were observed to have a matte finish with no visible corrosion on their surfaces.

b. CPR 2. Specimens 014 to 017 are Type-304L CRES coupons from the ACS tank liner/diaphragm assemblies, which were girth-welded. All four specimens were shiny in appearance with no surface corrosion apparent. Specimen 014 had a very thin film along the heat-affected zone (HAZ) of the liner. Specimens 015 and 016 also had thin films along the HAZ of the diaphragm.

c. CPR 3. Specimens 023 to 026 are coupons from burst-disc assemblies made of Type-347 CRES preformed sheet stock, which was electron-beam (EB) welded to a ring made of Type-304L CRES. Each specimen was shiny and bright with no evidence of corrosion on its surface. Each diaphragm had identification numbers and symbols inscribed on it, in addition to the preformed scoring marks. All specimens were observed to have very small parallel scratches on the surfaces.

d. CPR 4. Specimens 034 to 037 are commercial Lee plugs made of Type-304L CRES. All four specimens had shiny and bright surfaces with no corrosion evident.

e. CPR 5. Specimens 045 to 048 are coupon sections from the Type-304L CRES liner/diaphragm liquid outlet housing, which was tungsten-inert-gas (TIG) welded. All specimens appeared bright and shiny with no signs of surface corrosion apparent.

f. CPR 6. Specimens 056 to 059 are coupon sections from the Type-304L CRES EB weld joint No. 407. All specimens' metallic surfaces were shiny and bright with no signs of visible corrosion.

g. CPR 7. Specimens 067 to 070 are coupon sections from the Type-304L CRES EB weld joint No. 406. All coupons' metallic surfaces were shiny and bright with no signs of visible corrosion.

h. CPR 8. Specimens 078 to 081 are coupon sections of Types 308L and 304L CRES from the stiffening ring/diaphragm spot-welded subassemblies. All were shiny and bright with no evidence of surface corrosion.

i. CPR 9. Specimens 300 to 307 are coupon sections of Type-304L CRES from the ACS tank liner. All samples were shiny, with a matte finish. No corrosion was noted on these coupons.

j. CPR 10. Specimens 100 to 103 are coupon sections from the tank shell composed of Type-A286 CRES. The metal was still shiny with a minor amount of gray discoloration. No corrosion on the coupon was evident at 45x magnification.

k. CPR 11. Specimens 109 and 110 are coupon sections from TIG-welded joint No. 411 of Type-A286 CRES, which was a part of the ACS tank girth weld. The metal was shiny except for a gray discoloration in the HAZ along each side of the weld. No corrosion was evident.

l. CPR 12. Specimens 112 and 113 are coupon sections of the TIG-welded joint No. 417 composed of Type-A286 CRES, which was welded to Type-304L CRES. The specimen metal surfaces were shiny and bright with no evidence of corrosion.

m. CPR 13. Specimens 115 and 116 are sections of Type-308L CRES filler wire used in the diaphragm stiffening ring. The wire was shiny except for dark-gray bands about 1/2 in. from each end. No other corrosion was evident.

n. CPR 14. Specimens 118 to 121 are coupon sections of Type-304L CRES from the liner-diaphragm assembly with a gold-nickel brazed Type-308L CRES filler wire. All coupons were shiny and bright with no evidence of corrosion.

o. CPR 15. Specimens 127 and 128 are pieces of the Mylar plastic sensor disc from the vapor-detection assembly. Both specimens dissolved in the hydrazine propellant after three hours of testing. (The hydrazine became light yellow in color and contained 0.016 mg of iron.)

p. CPR 16. Specimens 130 and 131 are coupon sections of Type-304L CRES from the liquid outlet housing to the tank-half EB-welded joint No. 404. Specimen 130 was shiny except for some etching on the bottom of the coupon and a gray discoloration in the HAZ along each side of the weld. Specimen 131's surface was shiny and bright except for an irregular surface on the top. No corrosion was seen on either coupon.

q. CPR 17. Specimens 133 and 134 are fluorinated-ethylenepropylene-(Teflon-) coated samarium-cobalt magnets from the vapor-detection assembly. The Specimen 133 coating was intact, but uneven. No corrosion was evident. The posttest weight was significantly lower than the pretest weight. A reason for the loss was not readily apparent. However, it was observed that the magnet did influence the action of the scale balance; an accurate weight was obtained only after neutralizing the magnetic influence. The specimen-134 Teflon coating was irregular but apparently intact. There were dark spots on the magnet surface, but it was not possible to identify them as corrosion spots.

r. CPR 18. Specimens 200 and 201 are coupon sections of Type-17-4 PH CRES, H 1050 temper, and electropolished, from the piston in the flow-equalizer valve. The surface of the specimens was bright with no evidence of corrosion.

s. CPR 19. Specimens 210 and 211 are electropolished and chrome-plated sections of Type-17-4 PH CRES, H 1050 temper, from the shaft end of the flow-equalizer valve. The specimens were shiny and bright with no corrosion evident.

t. CPR 20. Specimens 220 and 221 are springs of electropolished Type-17-4 PH CRES, CH 900 temper, from the flow-equalizer valve. Specimen 220 is bright with a light-gray tarnish. No other corrosion was evident. Specimen 221 was shiny with no corrosion evident.

u. CPR 21. Specimens 230 and 231 are coupon sections of Type-17-4 PH CRES, TIG welded and electroplated, from the shaft end assembly of the flow-equalizer valve. The metal was shiny and bright with some etching near the coupon identifying number. No corrosion was seen.

v. CPR 22. Specimens 240 and 241 are bourdon tubes of Inconel 902 (Ni Span C) from the pressure-switch assembly. The metal surfaces have an even gray oxidized coating with no corrosion evident.

w. CPR 23. Specimens 250 and 251 are coupon sections and pieces of Type-347 CRES bar stock from the propellant distribution manifold fitting. Specimen 250 was shiny with a very light-gray mottling perceptible on the surfaces. No corrosion was apparent. Specimen 251, with circular machining marks, was shiny and bright. No corrosion was seen.

x. CPR 24. Specimens 260 and 261 are of Type-347 CRES tubing. A light-gray tarnish was evident on the surface, but no corrosion can be seen.

y. CPR 25. Specimens 270 and 271 are coupon sections of Type-347 CRES tubing Astroarc welded (Weld No. 78) to Type-347 CRES tubing. The tubing was shiny except for a gray discoloration in the HAZ on each side of the weld. No corrosion was evident.

z. CPR 26. Specimens 280 and 281 are O-rings made of Parker seal compound EPR 515. Microscopic examination of the O-rings revealed no crazing or cracking; the surface appeared smooth and unbroken. There was no Krytox 240AC coating on the specimens before cleaning.

B. DETAILS AND SUMMARIES OF POSTTEST ANALYSES AND RESULTS

The posttest analyses and results are summarized in Table 2. The duration of the test units in storage, test temperatures in degrees Celsius, and capsule posttest pressures at test temperature in N/cm^2 are given. The specimen material, configuration, and weight change in milligrams are listed. The percentage decomposition of hydrazine and the gas evolution rate in $cm^3 \times 10^{-3}$ $day^{-1} \cdot cm^{-2}$ are also given.

Data on the individual test units, test specimens, and the hydrazine propellant is given in Table 3. The BAT number is identified with the test unit number. The initial weight in grams and the change in weight is given for each specimen. The analysis of the hydrazine is given in milligrams for dissolved iron (Fe) and by percent for water (H_2O) and ammonia (NH_3). The hydrazine decomposition into the noncondensable gases nitrogen (N_2) and hydrogen (H_2) is given as total volume (cm^3) at standard temperature and pressure (STP); the gas evolution rate, both uncorrected and control corrected, is in $cm^3 \times 10^{-3} \cdot day^{-1} \cdot cm^{-2}$.

C. PROPELLANT CONTROLS

Table 4 presents data on the hydrazine propellant, unit number, days on test, temperature in degrees Celsius, capsule pressure at test temperature, and the H_2O and NH_3 analyses, by percent, along with information on hydrazine decomposition. The noncondensable gases (N_2 and H_2) are listed as total volume cm^3 at STP and the rate as $cm^3 \times 10^{-3} \cdot day^{-1}$.

D. SURFACE ANALYSIS

1. Introduction

As noted in Table 2, in a few pairs (or groups) of specimens, one of the test units shows a significantly higher gas evolution than the others in that group. For example, specimen BA 008 had twice the gas evolution rate of any of the others in the CPR 1 group. In the CPR 4 group, one of the Lee plugs greatly enhanced the decomposition of hydrazine. Other examples can be seen in Table 2.

Two sets of specimens were chosen for very scrupulous examination by X-ray photoelectron spectroscopy (XPS) and the scanning electron microscope (SEM). Both sets are from the primary containment system (Program B) and both are of 304L CRES. The specimens examined were BA 005 and BA 008 of the CPR 1 group, and BA 305 and BA 307 of the CPR 9 group. In each case an untreated specimen, i.e., one not exposed to hydrazine, was used as a control in the analysis.

2. XPS Techniques

The six specified stainless-steel samples were submitted for surface analysis by the XPS technique; Figure 3-1 shows the JPL XPS laboratory. The samples were cut from the original strips using metal shears. Then, immediately prior to insertion into the XPS spectrometer, each sample was cleaned ultrasonically in absolute ethanol for 10 minutes and dried with flowing nitrogen. The following samples were analyzed:

Set I	Set II
CPR 1 (CONTROL)	CPR 9 (CONTROL)
BA 005	BA 305
BA 008	BA 307

Figure 3-1. JPL XPS Laboratory

Analyses were performed with a modified Hewlett-Packard 5950A electron spectrometer under computer control. Photoemitted electrons, characteristic of the surface composition of the sample, were formed by interaction with 1486.6-eV incident photons from an aluminum Kα radiation source. For the instrumentation employed, the measured photoemission represents an average signal over an area of approximately 1 mm x 5 mm. Although the photoemitted electrons from a given atomic core level may sometimes originate as much as 100 Å below the sample surface, the immediate surface region of the sample will actually contribute significantly more to the measured signal due to an exponential attenuation (with depth) of photoelectrons by the solid.

For each sample, a wide energy-range (100 to 1300 eV) scan was run to determine the major contributors to the total photoelectron spectrum, followed by careful measurement of a 20 to 40 eV binding energy-range characteristic of each of eight elements of major interest. Each such run for a given sample took a total of 15.2 hours of instrument time to obtain adequate statistics. Photoelectron spectra (PES) of the following elements were obtained:

Element	Energy Levels	Measured Binding Energy Range, eV
C	1s	275 to 295
N	1s	390 to 410
O	1s	523 to 543
Cr	$2p_{3/2}$, $2p_{1/2}$	560 to 600
Mn	$2p_{3/2}$, $2p_{1/2}$	625 to 665
Fe	$2p_{3/2}$, $2p_{1/2}$	695 to 735
Ni	$2p_{3/2}$, $2p_{1/2}$	845 to 895
Zn	$2p_{3/2}$, $2p_{1/2}$	1010 to 1050

The XPS BE (binding energy) spectra can be used to identify different elements on a surface and to distinguish between the same element in different chemical environments. For example, oxidation of a metal causes an effective unbalanced positive change localized on the metal atom and the remaining electrons are therefore held more tightly; i.e., their binding energy <u>increases</u>.

3. Results

For the various spectral regions examined in this investigation, some general observations are presented below.

a. <u>Carbon 1s Region.</u> Carbon is the major constituent of the surface of all samples, amounting to 40 ±4 atomic percent (at.%) for five samples and to a significantly higher 68.8 at.% for CPR 1 (which also gave anomalous results in almost all the other measurements). The primary peak in the carbon spectra comes from aliphatic carbon compounds, while there are also substantial intensities in the regions expected for carbon-nitrogen compounds (≈286 eV) and carbon-oxygen compounds (≈288 eV). A quantitative measure of the relative amounts of these three carbon species may be obtained from the application of computer curve-fitting routines to the individual spectra.

b. Oxygen 1s Region. The apparent surface concentration of oxygen is approximately the same (46 ±3 at.%) for all samples, with the exception of CPR 1(24.7%). In the case of oxygen, a variety of metal oxides and hydroxides contribute to the measured signals and, in the absence of adequate reference data, it is very difficult to make any specific assignments to the various peaks and shoulders observed. It should be noted that the oxygen 1s binding energy for CPR 1 is shifted to a higher energy than that observed for the other five samples, suggesting a significantly different distribution of metal oxides/hydroxides for this particular sample, when compared to the others.

c. Nitrogen 1s Region. The apparent surface concentration of nitrogen is observed to be approximately the same (2.8 ±0.5 at.%) for all six samples. The measured binding energy of the nitrogen peak is, for all samples, consistent with that to be expected for protonated amines and amino polymers.

d. Chromium 2p Region. In both Sets I and II, the apparent surface concentration of chromium for the samples exposed of the control specimens, CPR 9 (4.3 at.%) or CPR 1 (0.8 at.%, anomalously low). The predominant species present in all samples are metallic chromium (relatively small) and chromium oxide or hydroxide (relatively large). The ratio of metallic to oxidized chromium is approximately the same for all samples.

e. Manganese 2p Region. In both Sets I and II, the apparent surface concentration of manganese for the samples exposed to hydrazine (1.0 ±0.2 at.%) is found to be greater than that for either of the control specimens CPR 9 (0.5 at.%) or CPR 1 (0.1 at.%, again low). The predominant species present in all samples is oxidized manganese as the monoxide; hydroxides may be present as well, due to the close similarity of binding energies.

f. Iron 2p Region. The dominant surface species present in all samples are metallic iron and ferric oxide; iron hydroxides are also possible since oxides and hydroxides exhibit similar binding energies. In both Sets I and II, the ratio of metallic iron to oxidized iron is much greater for the samples subjected to hydrazine than for the control specimens. In Set II, the control specimen CPR 9 has a greater total iron surface concentration (3.9 at.%) than that for the samples contacted by hydrazine (3.1 ±0.8 at.%). In Set I just the opposite occurs; the total surface iron for CPR 1 (1.0 at.%) appears to be anomalously low.

g. Nickel 2p Region. In all cases, the primary peak in the nickel spectrum is due to metallic nickel; a much less intense peak at higher binding energy is due to the monoxide. In both Sets I and II, the apparent surface concentration of nickel was approximately the same (0.3 at.%) for the samples exposed to hydrazine. The nickel concentration for control sample CPR 9 was somewhat lower (0.1 at.%), while for CPR 1 it was exceptionally low (0.2 at.%).

h. Zinc 2p Region. In all cases, the surface zinc is present in oxidized form, probably as the simple oxide. In Set I, the apparent surface concentration of zinc is approximately equal (0.2 at.%) for all three samples. In Set II, the control specimen, CPR 9, shows 2 to 3 times more zinc (0.6 at.%) than the samples subjected to hydrazine.

4. Discussion

Both the carbon and nitrogen binding energy spectra give strong evidence of surface contamination by carbon-nitrogen compounds such as amino polymers. It should be noted that although these samples were apparently stored in polyethylene bags in pretreatment steps, the final pretest step consisted of heat-sealing in nylon, a process which could readily provide the observed amino polymers on the surface.

The anomalous results for control CPR 1 were confirmed by a second run which gave results identical to the original run. This specimen was more reduced in oxygen and metals concentration, but more heavily contaminated by carbon than any of the other five samples. Therefore, more meaningful comparison may probably be made using CPR 9 as a control for both sets of samples subjected to hydrazine.

The overall picture is that, upon exposure to hydrazine, oxidized iron is removed, leaving a surface richer in the protective chromium oxide. A more thoughtful analysis may be aided by taking into account the information presented in Reference 6, and the references contained therein.

5. Scanning Electron Microscopy (SEM) Examination

These same specimens were then examined by SEM to look for differences in surface morphology. The surfaces of specimens BA 005 and BA 008 were identical in appearance when examined at 50x and 500x magnifications. When compared to the CPR 1 control, the specimens exposed to hydrazine appeared to have very minor surface pitting. The surfaces of specimens BA 305 and BA 307 also were identical and no differences could be seen when compared to the CPR 9 control.

In addition, the specimen BA 036, Lee plug, was thoroughly examined by SEM because of the greater decomposition rate of its test unit compared to the three other replicates. A direct comparison to specimen control BA 038 indicated no differences.

6. Conclusions

These highly detailed and sensitive analyses failed to indicate the causes for differences observed in the rates of hydrazine decomposition between pairs of nominally identical specimens. Some of the more subtle differences in surface character were unfortunately masked by the presence of significant contamination by carbon-nitrogen compounds from the sealed nylon storage bags. The thickness of this carbon-nitrogen layer is such ($<100 Å$) that it would have no effect on either the rate of hydrazine decomposition or the effect of corrosion of the coupons. SEM examination of the above-mentioned six coupons and Lee plug BA 036 again revealed no cause for the difference in decomposition rates.

SECTION IV

CONCLUSIONS

With few exceptions, mainly attributable to catalysis, possible contamination, or inherent sample-to-sample variation, the rate of hydrazine decomposition in these tests was very low -- producing less than 1.0 cc of gas per year per cm^2 of specimen area.

The degree of corrosion of the metal coupons was virtually unmeasurable in all instances. The elastomer EPR-515 did not appear to degrade, and the Mylar film dissolved as expected.

A. PROGRAM A: 6 MONTHS STORAGE

The rates of hydrazine decomposition were low in most test units -- less than 1.0 cm^3 gas per year per cm^2 of specimen area. The following were a few exceptions to the low rates:

(1) 304L liner-diaphragm with Au-Ni brazed 308L filler wire (BA 118-121), 1.0 to 3.7 $cm^3/yr/cm^2$

  (a) Possible catalysis by Au-Ni braze

  (b) Rate based on total coupon area.

(2) FEP-coated Sm-Co magnets (BA 133-134), 3.7 to 13.2 $cm^3/yr/cm^2$

  (a) FEP coating intact

  (b) Possible permeation and catalysis.

(3) ERP-515 O-rings

  (a) Catalysis by carbon black used in compounding elastomer

  (b) Very rapid decomposition, but area rate not meaningful.

(4) Mylar film (BA 127-128), 3.5 $cm^3/yr/cm^2$

  (a) Film dissolved

  (b) Area rate not meaningful.

The corrosion of metallic coupons was minimal and only very light tarnish was seen on a few specimens. The weight changes of coupons were negligible, and dissolved iron in the propellant was almost unmeasurable. Two nonmetals were included in Program A:

(1) Mylar film (BA 127-128), which dissolved as expected.

(2) EPR-515 O-rings (BA 280-281), which appeared unchanged after exposure to hydrazine.

B. PROGRAM B: 24 MONTHS STORAGE

The rates of hydrazine decomposition were low in most test units -- less than 1.0 cm^3 gas per year per cm^2 of specimen area. There were a few exceptions to low rates, but the results were not consistent:

(1) 304L liner/diaphragm girth weld (BA 017), 1.3 $cm^3/yr/cm^2$

(a) Only one of four specimens produced an anomalously large volume of gas

(b) Possible contamination or sample-to-sample variation.

(2) 304L Lee plug (BA 036), 5.2 $cm^3/yr/cm^2$

(a) Only one of four specimens showed a high rate of decomposition

(b) Possible contamination or sample-to-sample variation.

(3) 304L EB weld No. 407 (BA 058-BA 059), 2.3-3.3 $cm^3/yr/cm^2$

(a) Two specimens at 43°C showed low rate of gas formation

(b) Possible effect of 60°C storage

(c) Possible contamination or sample-to-sample variation.

(4) 304L EB weld No. 406 (BA 070), 1.8 $cm^3/yr/cm^2$

(a) Only one of two at 60°C was high

(b) Possible contamination or sample-to-sample variation.

None of the specimens appeared to corrode, and only a very light tarnish was seen on a few specimens. Weight changes of the coupons were negligible, and the dissolved iron in the propellant was almost unmeasurable.

In general, the results of this study agree very well with the JPL/NASA long-term compatibility program (References 2 and 3). The Type-304L CRES chosen for the primary containment of hydrazine in the propellant tank appears to be entirely suitable for use in systems requiring at least a 2-year service life. In the secondary containment side of the tank, the A286 CRES used in the outer pressure vessel is compatible with hydrazine for 6 to 12 months exposure. The Au-Ni braze material, FEP-coated Sm-Co magnets, and the EPR 515 O-rings have been shown to cause hydrazine decomposition that could result in an undesirable gas pressure buildup which must be accomodated in the system design. However, these materials would be in contact with hydrazine only if a leak occurred in the primary containment system.

SECTION V

DATA TABLES

The tables are, generally, self-explanatory. The following comments are given to expand on certain topics.

The strain gauge data shown in Table 2 indicate that this is not a reliable method of determining capsule pressures of less than one atmosphere. The strain gauges are normally calibrated at positive pressure only, and an extrapolation is made to zero pressure. Attempts to calibrate a capsule-mounted strain gauge at subatmospheric pressure produced results that indicated random shifting of the calibration line. At pressures greater than one atmosphere, the strain gauge data agree very well with the actual pressures found in the capsules. Posttest recalibration of several capsules indicates that while the zero point may shift, the sensitivity is maintained during handling and testing.

The decomposition of hydrazine in the control capsules (Table 4) presumably occurs through homogeneous (bulk) catalysis; glass should not act as an active surface for hydrazine decomposition. Purified hydrazine contains very little dissolved iron (a known catalyst) and, therefore, the rate of decomposition is predictably slow. With the introduction of a metallic specimen, there is the possibility of an active surface and heterogeneous (surface) catalysis. If metal is dissolved from the surface of the specimen, it is possible for both reaction mechanisms to occur. Obviously, from an inspection of some of the results (Tables 2 and 3), there are metallic surfaces which are not catalytically active towards hydrazine, especially Type-304L CRES Alloy.

Table 1. Listing of Coupon Test Numbers and Description

Test Numbers			
CPR	BAT	Test Unit	Material Compatibility Test Specimen Description
1	001-008	4001-4008	304L Arde diaphragm
2	014-017	4009-4012	304L/304L liner/diaphragm girth weld
3	023-026	4013-4016	347 burst disc
4	034-037	4017-4020	304L Lee plug
5	045-048	4021-4024	304L/304L liner/diaphragm outlet housing TIG weld
6	056-059	4025-4028	304L/304L EB weld #407
7	067-070	4029-4032	304L/304L EB weld #406
8	078-081	4033-4036	308L/304L ring/diaphragm spot welded
9	300-307	4037-4044	304L liner
10	100-103	4045-4048	A286 tank shell
11	109-110	4049-4050	A286/A286 girth TIG weld #411
12	112-113	4051-4052	304L/A286 polar TIG weld #417
13	115-116	4053-4054	308L stiffening ring
14	118-121	4055-4058	308L/304L wire/diaphragm, Au-Ni braze
15	127-128	4059-4060	Mylar sensor disc
16	130-131	4061-4062	304L/304L EB weld #404, liquid outlet housing to tank half
17	133-134	4063-4064	Samarium-cobalt magnet, FEP coated
18	200-201	4065-4066	17-4 PH, H 1050 temper, electropolished
19	210-211	4067-4068	17-4 PH, H 1050 temper, electropolished, chrome plated
20	220-221	4069-4070	17-4 PH, CH900 temper, spring
21	230-231	4071-4072	17-4 PH/17-4 PH, TIG weld, shaft end
22	240-241	4073-4074	Inconel 902, Ni span C, Bourdon tube
23	250-251	4075-4076	347 manifold fitting
24	260-261	4077-4078	347 tube, annealed
25	270-271	4079-4080	347/347 Astro-arc weld #78
26	280-281	4081-4082	EPR 515, Parker seal, O-ring, Krytox coated

Table 2. Summary of Analyses and Results

BAT No.	Test Unit	Days on Test	Test Temp., °C	Capsule Pressure at Test Temp., N/cm^2	Specimen				Propellant	
					(Strain Gage Reading)	Material	Configuration	Weight Change mg	Decomposition, %	Gas Evolution $cc \times 10^{-3} \cdot day^{-1} \cdot cm^{-2}$
BA001	4001	807	43	0.77	(0)	304L CRES	ACS Diaphragm	−0.4	0.02	0.01
BA002	4002	807	43	0.72	(0)	"	"	0.0	0.02	−0.01
BA003	4003	807	43	0.99	(0)	"	"	−0.2	0.03	0.06
BA004	4004	807	43	0.65	(0)	"	"	−0.1	0.01	−0.01
BA005	4005	765	60	1.70	(0)	"	"	+2.5	0.02	−0.10
BA006	4006	765	60	2.85	(0)	"	"	−0.2	0.05	0.10
BA007	4007	765	60	2.12	(0)	"	"	0.0	0.04	−0.03
BA008	4008	765	60	3.10	(0)	"	"	−0.3	0.06	0.19
BA014	4009	807	43	0.89	(0)	"	Liner/diaphragm,	−0.8	0.02	0.02
BA015	4010	807	43	1.41	(0)	"	Girth weld	−1.2	0.02	0.10
BA016	4011	807	60	3.25	(0)	"	"	−0.9	0.06	0.10
BA017	4012	765	60	33.39	(35.1)	"	"	−0.5	0.97	3.52
BA023	4013	378	43	2.07	(5.0)	CRES 347	Burst Disc	−0.4	0.12	0.74
BA024	4014	378	43	2.48	(0)	"	"	−0.4	0.16	0.95
BA025	4015	378	60	9.81	(0)	"	"	−0.4	0.41	3.91
BA026	4016	378	60	8.24	(0)	"	"	−0.1	0.35	3.14
BA034	4017	835	43	1.05	(0)	304L CRES	Lee Plug	−0.4	0.03	0.61
BA035	4018	835	43	1.95	(0)	"	"	−0.3	0.04	2.40
BA036	4019	835	60	10.98	(5.5)	"	"	+15.5	0.26	14.10
BA037	4020	835	60	3.77	(0)	"	"	+7.1	0.04	2.62
BA045	4021	835	43	1.12	(8.0)	"	TIG weld	+0.1	0.03	0.29
BA046	4022	835	43	1.30	(0)	"	"	−0.3	0.04	0.33
BA047	4023	835	60	2.80	(0)	"	"	−0.2	0.06	0.28
BA048	4024	835	60	7.44	(2.5)	"	"	0.0	0.14	2.90
BA056	4025	771	43	2.73	(0)	"	EB weld #407	−1.0	0.09	0.44
BA057	4026	771	43	6.81	(2.1)	"	"	−1.0	0.25	1.18
BA058	4027	729	60	49.35	(38.6)	"	"	−1.1	1.40	9.00
BA059	4028	715	60	35.34	(29.6)	"	"	−1.2	1.09	6.22

Table 2. Summary of Analyses and Results (continuation 1)

						Specimen			Propellant	
BAT No.	Test Unit	Days on Test	Test Temp., °C	Capsule Pressure at Test Temp., N/cm^2	(Strain Gage Reading)	Material	Configuration	Weight Change mg	Decomposition, %	Gas Evolution $cc \times 10^{-3} \cdot day^{-1} \cdot cm^{-2}$
BA067	4029	771	43	1.27	(0)	304L CRES	EB weld #406	−0.7	0.02	0.14
BA068	4030	771	43	2.97	(3.4)	"	"	−0.8	0.10	0.49
BA069	4031	757	60	8.10	(0)	"	"	+142.2[a]	0.28	1.28
BA070	4032	715	60	25.15	(16.5)	"	"	−0.8	0.77	4.80
BA078	4033	799	43	1.05	(0)	308L/304L CRES	Ring/diaphragm,	−0.4	0.03	0.05
BA079	4034	799	43	0.85	(0)	"	Spot weld	0.0	0.02	0.02
BA080	4035	785	60	6.17	(0)	"	"	0.0	0.16	0.57
BA081	4036	785	60	9.37	(1.8)	"	"	0.0	0.26	1.07
BA300	4037	807	43	0.85	(0)	304L CRES	Liner	−0.9	0.02	0.03
BA301	4038	765	43	b	(14.0)	"	"	+0.5	—	—
BA302	4039	807	43	0.70	(0)	"	"	−0.6	0.01	<0.01
BA303	4040	807	43	0.74	(0)	"	"	−1.2	0.02	<0.01
BA304	4041	765	60	c	(0)	"	"	−0.7	—	—
BA305	4042	765	60	3.81	(0)	"	"	+0.6	0.08	0.41
BA306	4043	765	60	3.59	(0)	"	"	0.0	0.08	0.31
BA307	4044	765	60	2.50	(0)	"	"	−0.5	0.04	0.08
BA100	4045	184	43	0.69	(0)	A286	Tank Shell	−0.7	<0.05	0.13
BA101	4046	245	43	2.02	(0)	"	"	−0.3	0.15	0.68
BA102	4047	308	43	1.21	(0)	"	"	−0.9	0.10	0.14
BA103	4048	365	43	1.02	(0)	"	"	+0.2	0.04	0.14
BA109	4049	245	43	1.43	(2.1)	"	TIG weld #411	−0.7	0.10	0.31
BA110	4050	365	43	1.74	(1.0)	"	"	−0.3	0.07	0.41
BA112	4051	245	43	3.04	(2.8)	A286/304L	TIG weld #417	−0.9	0.03	3.67
BA113	4052	365	43	3.57	(1.5)	"	"	−0.4	0.13	2.60
BA115	4053	245	43	1.31	(1.7)	308L	Wire	−0.7	0.01	2.07
BA116	4054	365	43	0.99	(0)	"	"	+0.1	0.08	0.14
BA118	4055	220	43	7.48	(11.6)	308L/304L	Liner/diaphragm,	−1.1	0.36	3.46[d]
BA119	4056	281	43	11.39	(10.0)	"	Au-Ni Braze	−0.3	0.40	5.05[d]
BA120	4057	344	43	10.53	(10.7)	"	"	−0.8	0.29	3.63[d]

Table 2. Summary of Analyses and Results (continuation 2)

BAT No.	Test Unit	Days on Test	Test Temp., °C	Capsule Pressure at Test Temp., N/cm^2	(Strain Gage Reading)	Specimen			Propellant	
						Material	Configuration	Weight Change mg	Decomposition, %	Gas Evolution $cc \times 10^{-3} \cdot day^{-1} \cdot cm^{-2}$
BA121	4058	401	43	29.04	(29.1)	308L/304L	Au-Ni Braze	−0.2	0.70	9.98[d]
BA127	4059	365	43	2.70	(2.4)	Mylar Film	(Specimen Dissolved)	—	0.16	9.15[e]
BA128	4060	365	43	2.44	(1.4)	"	"	—	0.09	9.43[e]
BA130	4061	308	43	1.61	(0)	304L	EB weld #404	−1.1	0.01	0.53
BA131	4062	340	43	0.97	(0)	"	"	−1.3	0.08	0.05
BA133	4063	308	43	4.67	(0)	Samarium-Cobalt	Magnet, FEP-	−28.7	0.11	36.17
BA134	4064	365	43	2.25	(0)	"	Coated	+0.8	0.11	10.46
SE200	4065	308	43	2.10	(0)	17-4 PH, H1050	Valve, Electro-	−0.5	0.02	0.90
SE201	4066	365	43	0.92	(0)	"	Polished	+0.1	0.04	0.08
SE210	4067	365	43	0.88	(3.4)	"	Valve, E.P.,	0.0	0.05	0.04
SE211	4068	184	43	0.58	(0)	"	Chrome plated	−1.1	$<$0.05	0.03
SE220	4069	184	43	0.81	(6.9)	17-4 PH, CH900	Spring	−2.4	$<$0.05	0.26
SE221	4070	365	43	1.05	(5.5)	"	"	+0.6	0.05	0.16
SE230	4071	308	43	0.56	(0)	17-4 PH	Valve, TIG weld	−0.4	—	0.01
SE231	4072	365	43	0.76	(0)	"	"	−0.4	0.04	0.01
SC240	4073	308	43	1.29	(0)	Inconel 902	Bourdon tube	−0.3	0.01	0.11
SC241	4074	365	43	1.71	(0)	"	"	−0.8	0.08	0.10
BA250	4075	245	43	1.04	(1.7)	347	Bar Stock	−1.2	0.06	0.18
BA251	4076	365	43	1.52	(0)	"	"	−0.2	0.06	0.35
BA260	4077	245	43	0.76	(4.5)	"	Tube, annealed	−0.8	$<$0.01	0.16
BA261	4078	365	43	0.81	(3.4)	"	"	−0.2	0.04	0.04
BA270	4079	245	43	1.97	(3.8)	"	Astro arc weld #78	−0.1	0.16	0.68
BA271	4080	365	43	7.34	(2.1)	"	"	−0.4	0.26	3.41
BA280	4081	37	43	27.34	(27.5)	EPR 515	"O" Ring,	+2.1	0.93	416.3[f]
BA281	4082	65	43	44.07	(44.0)	"	Krytox Coated	+3.5	1.62	370.0[f]

[a]Probable error in pretest weighing.

[b]Capsule tip had microscopic leak; gas data meaningless.

[c]Capsule broke in breaker fixture; gas lost.

[d]Rate of decomposition is proportional to the area of exposed gold-nickel braze.

[e]Mylar film dissolved in propellant; area rate is not relevant.

[f]Decomposition catalyzed by carbon black used in compounding; area rate values are meaningless.

Table 3. Details of Analyses and Results

BAT No.	Test Unit	Specimen Weight: Initial g	Specimen Weight: Change g	Analysis of Propellant[a,b]: Fe mg	Fe ppm	H_2O %	NH_3 %	Noncondensable Gas (N_2 + H_2): Total cc STP	Rate: Uncorrected cc x 10^{-3} • day^{-1}	Rate: Corrected for Control cc x 10^{-3} • day^{-1}	Specimen Surface Area cm^2	Area Rate cc x 10^{-3} • day^{-1} • cm^{-2}
BA001	4001	1.8307	−0.0004	<0.02	<0.5	0.63	0.02	0.67	0.83	0.16	19.4773	0.01
BA002	4002	1.8808	0.0000	<0.02	<0.5	0.66	0.02	0.45	0.56	−0.11	19.4926	−0.01
BA003	4003	1.8674	−0.0002	<0.02	<0.5	0.66	0.02	1.51	1.87	1.20	19.4926	0.06
BA004	4004	1.8745	−0.0001	<0.02	<0.5	0.68	0.01	0.39	0.48	−0.19	19.4773	−0.01
BA005	4005	1.8774	+0.0025	<0.02	<0.5	0.68	0.01	1.59	2.08	−1.92	19.4621	−0.10
BA006	4006	1.8189	−0.0002	<0.02	<0.5	0.65	0.03	4.60	6.01	2.01	19.4926	0.10
BA007	4007	1.8308	0.0000	<0.02	<0.5	0.84	0.03	2.58	3.37	−0.63	19.4926	−0.03
BA008	4008	1.8121	−0.0003	<0.02	<0.5	0.65	0.04	5.88	7.69	3.69	19.4773	0.19
BA014	4009	17.9183	−0.0008	–[c]		0.58	0.02	1.15	1.43	0.76	36.55	0.02
BA015	4010	19.7705	−0.0012	–		2.95	0.01	3.52	4.36	3.69	37.59	0.10
BA016	4011	20.5209	−0.0009	–		0.56	0.04	6.57	8.14	4.14	39.57	0.10
BA017	4012	19.8750	−0.0005	0.125	3.1	0.86	0.60	110.57	144.54	140.54	39.92	3.52
BA023	4013	10.5977	−0.0004	0.02	0.5	0.63	0.10	6.17	16.32	15.65	21.1697	0.74
BA024	4014	9.8477	−0.0004	0.02	0.5	0.50	0.14	7.69	20.34	19.67	20.7925	0.95
BA025	4015	10.4620	−0.0004	0.02	0.5	0.62	0.32	32.86	86.93	82.93	21.2021	3.91
BA026	4016	10.5614	−0.0001	0.02	0.5	0.70	0.27	28.31	74.89	70.89	22.5703	3.14
BA034	4017	0.6948	−0.0004	<0.02	<0.5	0.52	0.02	1.95	2.34	1.67	2.7429	0.61
BA035	4018	0.6995	−0.0003	<0.02	<0.5	8.21	0.02	5.99	7.17	6.50	2.7040	2.40
BA036	4019	0.6989	+0.0155	<0.02	<0.5	0.76	0.16	35.60	42.63	38.63	2.7392	14.10
BA037	4020	0.7015	+0.0071	<0.02	<0.5	0.71	0.02	9.27	11.10	7.10	2.7068	2.62
BA045	4021	2.0661	+0.0001	<0.02	<0.5	0.57	0.02	2.18	2.61	1.94	6.61	0.29
BA046	4022	2.1141	−0.0003	<0.02	<0.5	2.33	0.03	2.50	2.99	2.32	7.04	0.33
BA047	4023	2.1348	−0.0002	<0.02	<0.5	0.93	0.04	5.01	6.00	2.00	7.03	0.28
BA048	4024	2.0952	0.0000	<0.02	<0.5	0.90	0.08	19.80	23.71	19.71	6.80	2.90
BA056	4025	11.9468	−0.0010	<0.02	<0.5	1.03	0.06	7.86	10.19	9.52	21.75	0.44
BA057	4026	12.4409	−0.0010	<0.02	<0.5	1.21	0.18	20.57	26.68	26.01	22.06	1.18
BA058	4027	12.3262	−0.0011	0.050	1.3	0.70	0.89	155.32	201.45	197.45	21.93	9.00
BA059	4028	12.3092	−0.0012	0.125	3.1	0.86	0.74	108.45	140.66	136.66	21.96	6.22
BA067	4029	10.5426	−0.0007	–		0.81	0.01	2.76	3.58	2.91	21.42	0.14

Table 3. Details of Analyses and Results (continuation 1)

		Specimen Weight		Analysis of Propellant[a,b]				Noncondensable Gas ($N_2 + H_2$)				
				Fe				Rate				
BAT No.	Test Unit	Initial g	Change g	mg	ppm	H_2O %	NH_3 %	Total cc STP	Uncorrected $cc \times 10^{-3} \cdot day^{-1}$	Corrected for Control $cc \times 10^{-3} \cdot day^{-1}$	Specimen Surface Area cm^2	Area Rate $cc \times 10^{-3} \cdot day^{-1} \cdot cm^{-2}$
BA068	4030	11.2825	−0.0008	—		0.98	0.07	8.50	11.02	10.35	21.05	0.49
BA069	4031	11.6180	+0.1422[d]	—		0.86	0.20	24.00	31.70	27.70	21.59	1.28
BA070	4032	11.5931	−0.0008	<0.02	<0.5	0.92	0.52	76.87	107.51	103.51	21.56	4.80
BA078	4033	5.5458	−0.0004	<0.02	<0.5	1.18	0.02	1.66	2.08	1.41	26.8885	0.05
BA079	4034	5.6452	0.0000	<0.02	<0.5	1.26	0.02	0.99	1.24	0.57	28.3715	0.02
BA080	4035	5.6520	0.0000	<0.02	<0.5	0.52	0.11	15.23	19.40	15.40	27.0450	0.57
BA081	4036	5.5455	0.0000	<0.02	<0.5	0.55	0.18	26.42	33.66	29.66	27.7521	1.07
BA300	4037	5.2560	−0.0009	<0.02	<0.5	0.80	0.02	1.06	1.31	0.64	20.0694	0.03
BA301	4038	4.9612	+0.0005	<0.02	<0.5	0.65	0.04	—	—	—	20.0753	—
BA302	4039	4.3396	−0.0006	—		0.84	0.01	0.61	0.76	0.09	20.0754	<0.01
BA303	4040	4.8056	−0.0012	—		1.56	0.02	0.55	0.68	0.01	20.1092	<0.01
BA304	4041	5.1021	−0.0007	<0.02	<0.5	0.83	0.04	—[f]	—	—	20.2661	—
BA305	4042	5.2821	+0.0006	0.02	0.5	0.65	0.02	9.37	12.25	8.25	20.3587	0.41
BA306	4043	5.0690	0.0000	<0.02	<0.5	0.62	0.05	7.91	10.34	6.34	20.2475	0.31
BA307	4044	5.0142	−0.0005	<0.02	<0.5	0.70	0.03	4.36	5.70	1.70	20.0859	0.08
BA100	4045	8.3294	−0.0007	—		—	<0.05	0.63	3.42	2.75	21.2098	0.13
BA101	4046	8.3596	−0.0003	—		—	0.14	3.67	14.98	14.31	21.1961	0.68
BA102	4047	8.3758	−0.0009	—		—	0.10	1.10	2.90	2.90	21.1961	0.14
BA103	4048	8.3975	+0.0002	—		—	0.04	1.33	3.64	2.97	21.1825	0.14
BA109	4049	15.0951	−0.0007	—		—	0.10	1.97	8.04	7.37	23.9895	0.31
BA110	4050	14.6483	−0.0003	—		—	0.06	3.95	10.82	10.15	24.7093	0.41
BA112	4051	4.6890	−0.0009	—		—	<0.05	9.32	38.04	37.37	10.1851	3.67
BA113	4052	4.7486	−0.0004	—		—	0.10	9.85	26.99	26.32	10.1216	2.60
BA115	4053	2.7318	−0.0007	—		—	<0.05	3.15	12.86	12.19	5.8837	2.07
BA116	4054	2.7818	+0.0001	—		—	0.08	0.55	1.51	0.84	5.9570	0.14
BA118	4055	6.0872	−0.0011	—		—	0.30	21.89	99.50	98.83	28.58	3.46[g]
BA119	4056	5.9381	−0.0003	—		—	0.29	38.47	136.90	136.23	27.00	5.05[g]
BA120	4057	5.8159	−0.0008	—		—	0.18	34.54	100.41	99.74	27.45	3.63[g]
BA121	4058	5.8271	−0.0002	0.020	0.5	—	0.08	110.08	274.51	273.84	27.45	9.98[g]

Table 3. Details of Analyses and Results (continuation 2)

BAT No.	Test Unit	Specimen Weight: Initial g	Specimen Weight: Change g	Analysis of Propellant[a,b]: Fe mg	Fe ppm	H_2O %	NH_3 %	Noncondensable Gas ($N_2 + H_2$): Total cc STP	Rate: Uncorrected cc x 10^{-3} • day^{-1}	Rate: Corrected for Control cc x 10^{-3} • day^{-1}	Specimen Surface Area cm^2	Area Rate cc x 10^{-3} • day^{-1} • cm^{-2}
BA127	4059	0.0090	—	0.016	0.4	—	0.14	6.19	16.96	16.29	1.7806	9.15[h]
BA128	4060	0.0089	—	—		—	0.07	6.31	17.29	16.62	1.7620	9.43[h]
BA130	4061	21.7411	−0.0011	—		—	0.11	2.43	7.89	7.22	13.7489	0.53
BA131	4062	21.4048	−0.0013	—		—	0.08	0.48	1.41	0.74	13.5632	0.05
BA133	4063	0.6402	−0.0287	—		—	0.06	15.58	50.58	49.91	1.38	36.17
BA134	4064	0.6172	+0.0008	—		—	0.09	5.51	15.10	14.43	1.38	10.46
SE200	4065	12.1607	−0.0005	—		—	<0.05	6.41	20.81	20.14	22.4651	0.90
SE201	4066	11.7659	+0.0001	—		—	0.04	0.90	2.47	1.80	22.2418	0.08
SE210	4067	10.6931	0.0000	—		—	0.05	0.55	1.51	0.84	22.07	0.04
SE211	4068	10.9716	−0.0011	—		—	<0.05	0.24	1.30	0.63	22.15	0.03
SE220	4069	6.8595	−0.0024	—		—	<0.05	1.05	5.71	5.04	19.5243	0.26
SE221	4070	6.8879	+0.0006	—		—	0.04	1.36	3.73	3.06	19.5243	0.16
SE230	4071	12.1497	−0.0004	—		—	<0.05	0.24	0.78	0.11	22.07	0.01
SE231	4072	11.9301	−0.0004	—		—	0.04	0.35	0.96	0.29	22.22	0.01
SC240	4073	6.7289	−0.0003	—		—	<0.05	3.13	10.16	9.49	88.232	0.11
SC241	4074	6.7560	−0.0008	—		—	0.07	3.46	9.48	8.81	88.232	0.10
BA250	4075	12.7079	−0.0012	—		—	0.06	1.12	4.57	3.90	22.2552	0.18
BA251	4076	12.7510	−0.0002	—		—	0.05	3.10	8.49	7.82	22.1961	0.35
BA260	4077	7.1138	−0.0008	—		—	<0.05	1.00	4.08	3.41	21.21	0.16
BA261	4078	7.0385	−0.0002	—		—	0.04	0.52	1.43	0.75	20.95	0.04
BA270	4079	6.7365	−0.0001	—		—	0.15	3.24	13.22	12.55	18.56	0.68
BA271	4080	6.6650	−0.0004	0.023	0.6	—	0.18	23.40	64.11	63.44	18.58	3.41
BA280	4081	0.5132	+0.0021	0.010	0.3	0.56	0.61	98.60	2664.9	2664.2	6.40	416.3[i]
BA281	4082	0.5141	+0.0035	0.010	0.3	0.55	0.40	153.96	2368.6	2367.9	6.40	370.0[i]

a Based on actual weight of propellant in capsule.
b Halide level undetectable, i.e., < 0.02 mg.
c — Not measured; data not available.
d Probable error in pretest weighing.
e Capsule tip had microscopic leak; gas data meaningless.
f Capsule broke in breaker fixture; gas lost.
g Rate of decomposition is proportional to the area of exposed gold-nickel braze.
h Mylar film dissolved in propellant; area rate is not relevant.
i Decomposition was catalyzed by carbon black used in compounding; area rate values are meaningless.

Table 4. Summary of Analysis of Hydrazine Controls

					Propellant[a]					
					Analysis[b]			Non-Condensable Gas ($N_2 + H_2$)		
Test Unit	Days on Test	Test Temp., °C	Capsule Pressure at Test Temp., N/cm^2	(Strain Gage Reading)	H_2O, %	NH_3, %	Decomposition, %	Total cc STP	Rate cc x 10^{-3} • day^{-1}	Average
4100	220	43	0.81	(6.0)	–[c]	<0.05	<0.05	1.03	4.68[f]	
4101	365	43	0.75	(0)	0.74	0.04	0.04	0.26	0.71	
4102	549	43	–	(0)	0.72	0.02	–	–[d]	–	
4106	729	43	–	(0)	0.70	0.01	–	<0.25[e]	–	
4108	729	43	0.67	(0)	0.71	0.01	0.01	0.45	0.62	0.67
4103	220	60	<1.0	(0)	–	<0.05	<0.01	2.08	9.45[f]	
4104	401	60	2.21	(0)	0.56	0.10	0.11	1.26	3.14	
4105	547	60	2.00	(0)	0.72	0.02	0.03	2.45	4.48	
4107	729	60	1.71	(0)	1.55	0.01	0.02	2.82	3.87	
4109	729	60	2.17	(0)	0.65	0.01	0.02	3.25	4.46	4.00

[a] Based on 40.0 cc hydrazine.

[b] Metals and halides undetectable.

[c] – Not measured; data not available.

[d] Capsule broke in test fixture; gas lost.

[e] Insufficient quantity of gas to measure.

[f] Value not included in average.

SECTION VI

REFERENCES

1. Moran, C. M., Coupon Test Program to Evaluate Decomposition of Hydrazine by Metallic Components of Propellant Tanks, Interim Report for Program 'A' July 1979 to August 1981, JPL Document 715-139, Jet Propulsion Laboratory, Pasadena, California, October 1, 1981 (JPL internal document).

2. Toth, L., et. al., Propellant Material Compatibility Program and Results, Technical Memorandum 33-779, Jet Propulsion Laboratory, Pasadena, California, August 15, 1976.

3. Moran, C. M., and Bjorklund, R. A., Propellant/Material Compatibility Program and Results, Ten-Year Milestone, JPL Publication 82-62, Jet Propulsion Laboratory, Pasadena, California, July 15, 1982.

4. Material Specification, Anhydrous Hydrazine for the HAS System, Report 8803-947047, Revision A, Bell Aerospace Textron, Buffalo, New York, undated.

5. Chang, E. T., et al., Solubilities of NH_3, CO, CO_2, and SF_6 in Liquid Propellants, The Aerospace Corp., El Segundo, Calif., Air Force Report SAMSO-TR-71-17, November 1970.

6. Adams, R. O., "Review of the Stainless Steel Surface," Journal of Vacuum Science Technology, Vol. 1, No. 12, 1983.

APPENDIX A

PRETEST ANALYSIS OF HYDRAZINE

The pretest analysis of Drum H8367 indicated a very high purity which even meets the requirements of the current MIL-P 26536C, Amendment 2, High Purity Grade. The drum was from JPL's supply of hydrazine at ETS and was chosen because of the low CO_2 content. The full pretest analysis is presented in the report form contained in this appendix.

The handling of the propellant during the filling operation, and the process of removing it after completion of the storage period, can influence the CO_2 content through inadvertent exposure to air. A special test capsule was designated as a CO_2 control capsule. It was filled as part of a regular series of capsules being processed. After freezing and thawing, this control capsule was opened and the propellant removed by the standard procedure. The CO_2 content was determined to be 15 ppm, slightly higher than the 9 ppm in the original hydrazine, but considerably lower than the 30 ppm limit in the above-mentioned military specification. Although this determination was not normally part of the posttest procedure, two other test units were analyzed for CO_2: 4081 contained 5 ppm CO_2; 4082 contained 19 ppm CO_2.

The data from these three capsules indicated that the procedures employed in filling the capsule were adequate to maintain the desired low CO_2 content. The greatest risk for exposure to air occurs during the opening of the capsule and removal and transfer of the hydrazine to the analysis vial.

(PREPARED BY)	(DATE)	(REPORT NO.)
Toth	4 Dec. 1979	79X10201
Assay By Taylor/Moran	(DATE) 10 Dec. 1979	(PROJECT) N_2H_4 Compatibility

TITLE
ASSAY-HYDRAZINE JPL Drum H8367

Constituent or Property	Results	Specification
Hydrazine assay, % by weight Note 1	99.4	98.5% min.
Density at 298 K (77°F), g/cm^3	1.004	
Particulate, mg/cm^3	0.0007	1 milligram/1 liter
Water plus soluble impurities, % by weight	0.62%	1.0% max.
Major impurities, % by weight		
Ammonia (NH_3)	< 0.1%	0.4% max.
Aniline ($C_6H_5NH_2$)	None detected, n.d.	0.5% max.
Toluene ($C_6H_5CH_3$)	n.d.	
Carbon Dioxide (CO_2)	0.0009	50.0 ppm max.
UDMH	n.d. < 0.1%	
Other		
Sulfated Ash, % by weight	< 0.0005	
Atomic Absorption Analysis of ash		
Dissolved metals, μ g/g N_2H_4 (ppm)		
Iron	0.12	
Aluminum	< 0.1	
Nickel	0.15	
Manganese	< 0.03	
Cobalt	< 0.03	
Chromium	< 0.01	
Copper	< 0.03	
Zinc	0.03	
Silicon	< 0.1	
Magnesium	0.05	
Sodium	0.05	
Calcium	0.3	
Barium	< 0.1	
Boron	< 10	
Other Potassium	0.03	

jpl

(PREPARED BY)	(DATE)	(REPORT NO.)
Toth	4 Dec 1979	79X10201
Assay By Taylor/Moran	(DATE) 10 Dec 1979	(PROJECT) N_2H_4 Compatibility

TITLE
ASSAY-HYDRAZINE JPL Drum H8367

Constituent or Property	Results	Specification
Dissolved anions, μ g/g		
Fluoride	n.d. < 5 ppm	
Chloride	n.d. <1 ppm	5.0 ppm max.
Sulfate	n.d. <5 ppm	
Nitrate	n.d. <5 ppm	
Nonvolatile residue, mg/cm^3	< 0.005	
Identification/History	Notes 2, 3	Note 1
Specification		
Storage Container	JPL Drum H8367	
Test Sample (250 ml size)	2 bottles	

NOTES OR REFERENCES

1. Hydrazine must conform with Bell Aerospace specification 8803-947047 Revision A. Chemical composition requirements listed in Section 3.2 CO_2 requirement of 50 ppm maximum is critical.
2. W/A 4078-1 and shipper E6076; hydrazine received 7 December 1979.
3. Purified or refined grade hydrazine used on NASA-JPL flight projects "Voyager 1977", and "Mars Viking Lander 1975". Hydrazine manufactured by Martin Marietta Corp., Denver, Colorado, their specification STM N020, during CY 1973-1975 period.

CLASSIFICATION

JPL 0999-S (REV 11-68)

APPENDIX B

DETAILED LOGS OF ALL TEST UNITS

Log I is a listing of specimens grouped by specimen (BAT) numbers and test unit (JPL) numbers in ascending order. The "Material Description" column also lists the CPR number and the material scheduled for storage. The "Test Duration" column under "Cell" gives the dates of storage at test temperature. The "Refrigeration" column lists the dates for posttest storage in the freezer before analysis. The "Analysis Document" column lists the JPL internal memoranda reporting results of analysis. The "Remark" column lists test temperature (43°C unless otherwise noted), and other information.

Log II is a listing of specimens by ascending capsule number. The "Capsule" column also includes the total internal volume of each capsule. The "Material Description" column lists the date and time of capsule filling. The capsules were then kept in a freezer until the date shown in the "Cell" column, i.e., the beginning of the storage at test temperature. The "Remarks" column lists the volume of hydrazine placed in each capsule.

Report Number 79X07500

Project Hydrazine Compatibility

Classification Unclassified

JET PROPULSION LABORATORY
CALIFORNIA INSTITUTE OF TECHNOLOGY

SUMMARY

HYDRAZINE MATERIAL COMPATIBILITY

TEST SPECIMEN/CAPSULES

Prepared by L. R. Toth Date July 1979

Date

APPENDIX OR REVISION

Date	Pages Affected	Appendix OR Revision	Remarks	Changed by
28 May 1980	14	(A)	Terminate test units: 4081 (SE 280); 4082 (SE 281)	L. Toth

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PREPARED BY: TOTH | (DATE) July 1979 | (REPORT NO.) 79X07500

REVISION | (DATE) | (PROJECT) Material Compatibility JPL Proposal 90-965 rev. 2

TITLE: Hydrazine, Monopropellant Grade* JPL DRUM H8367

NUMBER		MATERIAL DESCRIPTION	TEST MONTHS	TEST DURATION		ANALYSIS DOCUMENT, IOM, etc.	REMARKS
SPECIMEN BAT No.	CAPSULE	BAT CPR No.		CELL IN/OUT	REFRIGERATION IN/OUT	DATE	
4001 BA001	7903	304L CRES DIAPHRAGM 1	24	28 Jan 80 14-Apr 82 807	14 APR 82 13 MAY 82 30	344AT-82-204 9 Sept. 82	
4002 BA002	7924	304L CRES DIAPHRAGM 1	24	28 Jan 80 14-[illegible] 82 80[illegible]	14 APR 82 11 MAY 82 28	344AT-82-204 9 Sept. 82	
4003 BA003	7929	304L CRES DIAPHRAGM 1	24	28 Jan 80 14-[illegible]	14 APR 82 12 MAY 82 29	344AT-82-204 9 Sept. 82	
4004 BA004	7947	304L CRES DIAPHRAGM 1	24	28 Jan 80 4-[illegible] 807	14 APR 82 14 MAY 82 31	344AT-84-204 9 Sept 82	
4005 BA005	7921	304L CRES DIAPHRAGM 1	24	28 Jan 80 03 Mar 82 765	3 MAR 82 30 MAR 82 28	344AT-82-117 13 May 82	60°C
4006 BA006	7902	304L CRES DIAPHRAGM 1	24	28 Jan 80 03 Mar 82 765	3 MAR 82 31 MAR 82 29	344AT-82-117 13 May 82	60°C
4007 BA007	7932	304L CRES DIAPHRAGM 1	24	28 Jan 80 03 Mar 82 765	3 MAR 82 18 MAR 82 16	344AT-82-117 13 May 82	60°C
4008 BA008	7936	304L CRES DIAPHRAGM 1	24	28 Jan 80 03 Mar 82 765	3 MAR 82 17 MAR 82 15	344AT-82-117 13 May 82	60°C

*Specification: Bell Aerospace Textron; Report No. 8803-947047, rev. A

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NUMBER		MATERIAL DESCRIPTION	TEST MONTHS	TEST DURATION		ANALYSIS DOCUMENT, IOM, etc.	REMARKS
SPECIMEN BAT No.	CAPSULE	BAT CPR No.		CELL IN/OUT	REFRIG-ERATION IN/OUT	DATE	
4009 BA 014	7937	304L CRES LINER 2	24	28 Jan 80 14-Apr 82 804	14 APR 82 4 MAY 82 21	344AT-82-204 8 Sept. 82	
4010 BA015	7955	304L CRES LINER 2	24	28 Jan 80 14-Apr 82 804	14 APR 82 4 MAY 82 21	344AT-82-204 8 Sept. 82	
4011 BA 016	7912	304L CRES LINER 2	24	28 Jan 80 14-Apr 82 804	14 APR 82 10 MAY 82 27	344AT-82-204 8 Sept 82	60 °C 42.0 cc N_2H_4
4012 BA017	7938	304L CRES LINER 2	24	28 Jan 80 03 Mar 82 765	3 MAR 82 26 MAR 82 24	344AT-82-117 13 May 82	60 °C
4013 BA 023	79202	347 CRES DISC 3	24	18 MAR 80 1 APR 81 378 DAYS	1 APR 81 7 APR 81 6 DAYS	344-AT-81-061 22 APR 81	Special capsule 1.25" dia
4014 BA 024	79204	347 CRES DISC 3	24	18 Mar 80 1 APR 81 378 DAYS	1 APR 81 7 APR 81 6 DAYS	344-AT-81-061 22 APR 81	special capsule 1.25" dia
4015 BA 025	79205	347 CRES DISC 3	24	18 Mar 80 1 APR 81 378 DAYS	1 APR 81 6 APR 81 5 DAYS	344-AT-81-061 22 APR 81	Special capsule 1.25" dia 60°C
4016 BA 026	79206	347 CRES DISC 3	24	18 Mar 80 1 APR 81 [illegible]	1 APR 81 6 APR 81 5 DAYS	344-AT-81-061 22 APR 81	Special capsule 1.25" dia 60°C

*Specification: Bell Aerospace Textron; Report No. 8803-947047, rev. A

TITLE Hydrazine, Monopropellant Grade*

(PREPARED BY) TOTH

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(DATE) July 1979

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(PROJECT) Material Compatibility JPL Proposal 90-965 rev. 2

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JPL Proposal 90-965 rev. 2
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4017 BA 034	7926	304L CRES PLUG 4	24	28Jan80 12MAY82 835	12 MAY 82 25 MAY 82 14	344AT-82-205 8 Sept 82	
4018 BA 035	7933	304L CRES PLUG 4	24	28 Jan 80 12MAY82 835 [illegible]	12 MAY 82 25 MAY 82 14	344AT-82-205 8 Sept 82	
4019 BA 036	7925	304L CRES PLUG 4	24	28 Jan 80 12MAY82 835	12 MAY 82 30 JUNE 82 50	344AT-82-205 8 Sept 82	60°C
4020 BA 037	7935	304L CRES PLUG 4	24	28 Jan 80 12MAY82 835	12 MAY 82 30 JUNE 82 50	344AT-82-205 8 Sept 82	60°C
4021 BA 045	7940	304L CRES WELD TIG 5	24	28Jan80 12MAY82 835	12 MAY 82 27 MAY 82 15	344AT-82-205 8 Sept 82	
4022 BA 046	7944	304L CRES WELD TIG 5	24	28 Jan 80 12MAY82 835	12 MAY 82 27 MAY 82 16	344AT-82-205 8 Sept 82	
4023 BA 047	7911	304L CRES WELD TIG 5	24	28Jan80 12MAY82 835	12 MAY 82 29 JUNE 82 49	344AT-82-205 8 Sept 82	60°C
4024 BA 048	7928	304L CRES WELD TIG 5	24	28Jan80 12MAY82	12 MAY 82 1 JULY 82 51	344AT-82-205 8 Sept 82	60°C

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4025 BA 056	7971	304L CRES WELD EB #407 6	24	4 Mar 80 14-Apr 82 771	14 APR 82 11 MAY 82 28	344AT-82-204 8 Sept 82	
4026 BA 057	7960	304L CRES WELD EB #407 6	24	4 Mar 80 14-Apr 82 771	14 APR 82 12 MAY 82 29	344AT-82-204 8 Sept 82	
4027 BA 058	7922	304L CRES WELD EB #407 6	24	4 Mar 80 03 Mar 82 729	3 MAR 82 26 MAR 82 24	344AT-82-117 8 Sept 82	60°C
4028 BA 059	7950	304L CRES WELD EB #407 6	24	18 Mar 80 03 Mar 82 715	3 MAR 82 30 MAR 82 27	344AT-82-17 13 May 82	60°C
4029 BA 067	7946	304L CRES WELD EB #406 7	24	4 Mar 80 14-Apr 82 771	14 APR 82 14 MAY 82 31	344AT-82-204 8 Sept 82	
4030 BA 068	7965	304L CRES WELD EB #406 7	24	4 Mar 80 14-Apr 82 771	14 APR 82 12 MAY 82 29	344AT-82-204 8 Sept 82	
4031 BA 069	7958	304L CRES WELD EB #406 7	24	18 Mar 80 14 Apr 82 [illegible]	14 APR 82 10 MAY 82 27	344AT-82-204 8 Sept 82	60°C
4032 BA 070	7939	304L CRES WELD EB #406 7	24	18 Mar 80 03 Mar 82 [illegible]	3 MAR 82 25 MAR 82 23	344AT-82-117 13 May 82	60°C

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4033 BA 078	7969	308L/304L CRES 24 RING-DIAPH. 8	4 Mar 80 12 MAY 82 799	12 MAY 82 26 MAY 82 15	344AT-82-205 8 Sept 82	
4034 BA 079	7978	308L/304L CRES 24 RING-DIAPH. 8	4 Mar 80 12 MAY 82 799	12 MAY 82 26 MAY 82 15	344AT-82-205 8 Sept 82	
4035 BA 080	7966	308L/304L CRES 24 RING-DIAPH. 8	18 Mar 80 12 MAY 82 785	12 MAY 82 10 JUNE 82 30	344AT-82-205 8 Sept 82	60°C
4036 BA 081	7970	308L/304L CRES 24 RING-DIAPH. 8	18 Mar 80 12 MAY 82 785	12 MAY 82 29 JUNE 82 49	344AT-82-205 8 Sept 82	60°C
4037 BA 300	7914	304L CRES 24 LINER 9	28 Jan 80 14-Apr-82 807	14 APR 82 13 MAY 82 30	344AT-82-204 8 Sept 82	Replace BA 085
4038 BA 301	7945	304L CRES 24 LINER 9	28 Jan 80 03 Mar 82 765	3 MAR 82 25 MAR 82 23	344AT-82-117 13 May 82	Replace BA 086
4039 BA 302	7954	304L CRES 24 LINER 9	28 Jan 80 14-Apr-82 807	14 APR 82 5 MAY 82 22	344AT-82-204 8 Sept 82	Replaces BA 087
4040 BA 303	7956	304L CRES 24 LINER 9	28 Jan 80	14 APR 82 5 MAY 82 22	344AT-82-204 8 Sept 82	Replace BA 088

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4041 BA 304	7918	304L CRES LINER 9	24	28 Jan 80 03 Mar 82 766	3 MAR 82 30 MAR 82 27	344AT-82-117 13 May 82	Replaces BA 089 60°C
4042 BA 305	7927	304L CRES LINER 9	24	28 Jan 80 03 Mar 82 766	3 MAR 82 19 MAR 82 17	344AT-82-117 13 May 82	Replaces BA 090 60°C
4043 BA 306	7943	304L CRES LINER 9	24	28 Jan 80 03 Mar 82 766	3 MAR 82 19 MAR 82 17	344AT-82-117 13 May 82	Replaces BA 091 60°C
4044 BA 307	7930	304L CRES LINER 9	24	28 Jan 80 03 Mar 82 766	3 MAR 82 17 MAR 82 15	344AT-82-117 13 May 82	Replaces BA 092 60°C
4045 BA 100	7982	A286 CRES TANK SHELL 10	6	4 Mar 80 4 SEPT 80 184 days	4 SEPT 80 15 OCT 80 41 DAYS	344AT-80-160 7 NOV 80	
4046 BA 101	7920	A286 CRES TANK SHELL 10	6	4 Mar 80 4 NOV 80 245 DAYS	4 NOV 80 19 NOV 80 15 DAYS	344AT-80-173 5 DEC 80	
4047 BA 102	7957	A286 CRES TANK SHELL 10	6	4 Mar 80 6 JAN 81 308 DAYS	6 JAN 81 20 JAN 81 14 DAYS	344AT-81-019 13 FEB 81	
4048 BA 103	7959	A286 CRES TANK SHELL 10	6	4 Mar 80 4 MAR 81 365 DAYS	4 MAR 81 1 May 81 58	344AT-81-086 15 MAY 81	

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PROJECT: Material Compatibility JPL Proposal 90-965 rev. 2

NUMBER: SPECIMEN (BAT No.)	NUMBER: CAPSULE	MATERIAL DESCRIPTION (BAT CPR No.)	TEST MONTHS	TEST DURATION: CELL IN/OUT	TEST DURATION: REFRIGERATION IN/OUT	ANALYSIS DOCUMENT, IOM, etc. DATE	REMARKS
4049 BA 109	7963	A286 CRES WELD TIG #411 11	6	4 Mar 80 4 NOV 80 245 days	4 NOV 80 20 NOV 80 16 DAYS	344-AT-80-173 5 DEC 80	
4050 BA 110	7981	A286 CRES WELD TIG #411 11	6	4 Mar 80 4 MAR 81 365 DAYS	4 MAR 81 23 APR 81 50	344-AT-81-086 15 MAY 81	
4051 BA 112	7974	A286 CRES WELD TIG #417 12	6	4 Mar 80 4 NOV 80 245 days	4 NOV 80 20 NOV 80 16 DAYS	344-AT-80-173 5 DEC 80	
4052 BA 113	7977	A286 CRES WELD TIG #417 12	6	4 Mar 80 4 Mar 81 365 days	4 Mar 81 22 Apr 81 49	344-AT-81-086 15 MAY 81	
4053 BA 115	7934	308L CRES FILLER WIRE 13	6	4 Mar 80 4 NOV 80 245 days	4 NOV 80 19 NOV 80 15 DAYS	344-AT-80-173 5 DEC 80	
4054 BA 116	7951	308L CRES FILLER WIRE 13	6	4 Mar 80 4 Mar 81 365 days	4 Mar 81 24 Apr 81 51	344-AT-81-086 15 MAY 81	
4055 BA 118	7915	308L/304L CRES LINER-DIAPH. 14	6	28 Jan 80 4 SEPT 80 220 days	4 SEPT 80 17 OCT 80 43 DAYS	344-AT-80-160 7 NOV 80	42 cc N_2H_4
4056 BA 119	7923	308L/304L CRES LINER-DIAPH. 14	6	28 Jan 80 4 NOV 80 281 days	4 NOV 80 18 NOV 80 14 DAYS	344-AT-80-173 5 DEC 80	42 cc N_2H_4

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4057 BA 120	7941	308L/304L CRES LINER-DIAPH. 14	6	28 Jan 80 6 JAN 81 344 DAYS	6 JAN 81 23 JAN 81 17 DAYS	344-AT-81-019 13 FEB 81	
4058 BA 121	7953	308L/304L CRES LINER-DIAPH. 14	6	28 Jan 80 4 Mar 81 401 days	4 Mar 81 21 Apr 81 48	344AT-81-086 15 MAY 81	
4059 BA 127	7964	MYLAR FILM TYPE G DISC 15	6	4 Mar 80 4 Mar 81 365 days	4 Mar 81 25 Mar 81 21	344AT-81-086 15 MAY 81	
4060 BA 128	7968	MYLAR FILM TYPE G DISC 15	6	4 Mar 80 4 Mar 81 365 days	4 Mar 81 30 Apr 81 57	344AT-81-086 15 MAY 81	
4061 BA 130	7972	304L CRES WELD EB #404 16	6	4 Mar 80 6 JAN 81 308 DAYS	6 JAN 81 21 JAN 81 15 DAYS	344-AT-81-019 13 FEB 81	
4062 BA 131	7998	304L CRES WELD EB #404 16	6	29 Mar 80 4 Mar 81 340 days	4 Mar 81 21 Apr 81 48	344-AT-81-086 15 MAY 81	a. capsule 7979 broken b. capsule 7980 broken c. specimen recleaned a, b.
4063 BA 133	7975	SAMARIUM COBALT MAGNET 17	6	4 Mar 80 6 JAN 81 308 DAYS	6 JAN 81 21 JAN 81 15 DAYS	344-AT-81-019 13 FEB 81	
4064 BA 134	7976	SAMARIUM COBALT MAGNET 17	6	4 Mar 80 4 Mar 81 365 days	4 Mar 81 29 Apr 81 56	344AT-81-086 15 MAY 81	

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4065 SE 200	7948	17-4 PH CRES H1050 ELECTRO POLISH 18	6	4 Mar 80 6 JAN 81 308 DAYS	6 JAN 81 23 JAN 81 17 DAYS	344AT-81-019 13 FEB 81	
4066 SE 201	7973	17-4 PH CRES H1050 ELECTROPOLISH 18	6	4 Mar 80 4 Mar 81 365 days	4 Mar 81 1 May 81 58	344AT-81-086 15 MAY 81	
4067 SE 210	7961	17-4 PH CRES H1050 ELECTRO POLISH CHROME PLATE 19	6	4 Mar 80 4 Mar 81 365 days	4 Mar 81 26 Mar 81 22	344AT-81-086 15 MAY 81	
4068 SE 211	7967	17-4 PH CRES H1050 ELECTRO POLISH CHROME PLATE 19	6	4 Mar 80 4 SEPT 80 184 days	4 SEPT 80 16 OCT 80 42 DAYS	344-AT-80-160 7 NOV 80	
4069 SE 220	7986	17-4PH CRES CH 900 SPRING 20	6	4 Mar 80 4 SEPT 80 184 days	4 SEPT 80 17 OCT 80 43 DAYS	344-AT-80-160 7 NOV 80	Special capsule neck 0.875 dia
4070 SE 221	7992	17-4PH CRES CH 900 SPRING 20	6	4 Mar 80 4 Mar 81 365 days	4 Mar 81 20 Apr 81 47	344AT-81-086 15 MAY 81	Special capsule neck 0.875 dia
4071 SE 230	7962	17-4PH/17-4PH CRES WELD TIG 21	6	4 Mar 80 6 JAN 81 308 DAYS	6 JAN 81 22 JAN 81 16 DAYS	344AT-81-019 13 FEB 81	
4072 SE 231	7991	17-4PH/17-4PH CRES WELD TIG 21	6	4 Mar 80 4 Mar 81 365 days	4 Mar 81 1 May 81 58	344AT-81-086 15 MAY 81	

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(TITLE) Hydrazine, Monopropellant Grade*

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4073 SC 240	7993	INCONEL 902 NI SPAN C TUBE 22	6	4 Mar 80 6 JAN 81 308 DAYS	6 JAN 81 22 JAN 81 16 DAYS	344AT-81-019 13 FEB 81	Special capsule neck 0.856 dia
4074 SC 241	7994	INCONEL 902 NI SPAN C TUBE 22	6	4 Mar 80 4 Mar 81 365 days	4 Mar 81 26 Mar 81 22	344 AT-81-086 15 MAY 81	special capsule neck 0.856 dia
4075 BA 250	7984	347 CRES V64 23	6	4 Mar 80 4 NOV 80 245 days	4 NOV 80 20 NOV 80 16 DAYS	344 AT-80-173 5 DEC 80	
4076 BA 251	7983	347 CRES V64 23	6	4 Mar 80 4 Mar 81 365 days	4 Mar 81 20 Apr 81 47	344AT-81-086 15 MAY 81	
4077 BA 260	7995	347 CRES ANNEALED TUBE 24	6	4 Mar 80 4 NOV 80 245 days	4 NOV 80 18 NOV 80 14 DAYS	344 AT-80-173 5 DEC 80	
4078 BA 261	7996	347 CRES ANNEALED TUBE 24	6	4 Mar 80 4 Mar 81 365 days	4 Mar 81 29 Apr 81	344 AT-81-086 15 MAY 81	
4079 BA 270	7987	347/347 WELD ASTRO ARC #78 25	6	4 Mar 80 4 NOV 80 245 days	4 NOV 80 19 NOV 80 15 DAYS	344-AT 80-173 5 DEC 80	
4080 BA 271	7989	347/347 WELD ASTRO ARC #78 25	6	4 Mar 80 4 Mar 81 365 days	4 Mar 81 22 APR 81	344AT-81-086 15 MAY 81	

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4081 SE 280	7988	EPR 515 SEAL PARKER KRYTOX 240AC 26	6	4 Mar 80 10 APR 80 37 days	10 APR 80 16 APR 80 6 DAYS	344AT-80-076 7 May 1980	Terminate - JPL report 90:965-9 (A)
4082 SE 281	7990	EPR 515 SEAL PARKER KRYTOX 240AC 26	6	4 Mar 80 8 May 80 65 days	8 MAY 80 13 MAY 80 5 DAYS	344AT-80-091 28 MAY 1980	Terminate - JPL report 90:965-9 (A)

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4100	7949	N_2H_4 only 40 cc	24	28 Jan 80 4 SEPT 80 220 days	4 SEPT 80 13 OCT 80 39 DAYS	344 AT-80-160 7 NOV 80	control
4101	7908	N_2H_4 only 40 cc	24	4 Mar 80 4 Mar 81 365 days	4 Mar 81 30 Apr 81	344AT-81-086 15 MAY 81	control
4102	7916	N_2H_4 only 40 cc	24	4 Mar 80 4 Sept 81 549	4 SEP 81 8 FEB 82	344AT-82-117 13 May 82	control
4103	7904	N_2H_4 only 40 cc	24	28 Jan 80 4 SEPT 80 220 days	4 SEPT 80 14 OCT 80 40 DAYS	344 AT-80-160 7 NOV 80	control 60°C
4104	7931	N_2H_4 only 40 cc	24	28 Jan 80 4 Mar 81 401 days	4 Mar 81 25 Mar 81	344 AT-81-086 15 MAY 81	control 60°C
4105	7942	N_2H_4 only 40 cc	24	28 Jan 80 28 July 81 547	28 JUL 81 10 FEB 82 198	344AT-82-117 13 May 82	control 60°C
4106	7985	N_2H_4 only 40 cc	24	4 Mar 80 03 Mar 82 [illegible]	3 MAR 82 31 MAR 82 29	344AT-82-117 13 May 82	control
4107	7910	N_2H_4 only 40 cc	24	4 Mar 80 03 Mar 82 [illegible]	3 MAR 82 24 MAR 82 22	344AT-82-117 13 May 82	control 60°C

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NUMBER: TEST BAT No.	NUMBER: CAPSULE	MATERIAL DESCRIPTION (BAT CPR No.)	TEST MONTHS	TEST DURATION: CELL IN/OUT	TEST DURATION: REFRIGERATION IN/OUT	ANALYSIS DOCUMENT, IOM, etc. DATE	REMARKS
4108	7919	N_2H_4 only 40 cc	24	4 MAR 80 / 03 Mar 82 / 729		344AT-82-117 13 May 82	control
4109	7913	N_2H_4 only 40 cc	24	4 MAR 80 / 03 Mar 82 / 729	3 MAR 82 / 24 MAR 82 / 22	344AT-82-117 13 May 82	control 60°C
4110	7907	Empty	24	10 Mar 80			calibration unit open funnel
4111	7917	Empty	24	10 Mar 80			calibration unit open funnel 60°C
4112	7905	Sealed Internal pressure 733 mm hg	24	18 Mar 80			Reference unit
4113	7997	Sealed Internal pressure 733 mm hg	24	18 Mar 80			Reference unit 60°C
4114	NONE No gauge	N_2H_4 only 40 cc	–	28 Feb 80 / 8 Apr 80 / 40 days	28 Feb 80 / 8 Apr 80 / 40 days	344AT-80-081 May 1980	Special for CO_2 analysis check Terminated
4115	79201	Empty	24	10 Mar 80			calibration unit open funnel

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4116	79203	Empty 24	18 Mar 80			calibration unit open funnel 60°C

*Specification: Bell Aerospace Textron; Report No. 8803-947047, rev. A

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Project N_2H_4 COMPATIBILITY

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JET PROPULSION LABORATORY
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SUMMARY
TEST CAPSULE/SPECIMEN NUMBERS
DETAIL INFORMATION

Prepared by L. TOTH Date July 1979
C. MORAN Date July 1979

APPENDIX OR REVISION

Date	Pages Affected	Appendix OR Revision	Remarks	Changed by

Classification

JPL 0988 MAR 6[illegible]

PRIORITY 1

SLOPE
STOP 110°F
FUNNEL 110°F
" 140°F

CLASSIFICATION	NUMBER: SPECIMEN	NUMBER: CAPSULE	MATERIAL DESCRIPTION	TEST DURATION: CELL IN/OUT	TEST DURATION: SEALED REFRIGERATION ~~IN/OUT~~	ANALYSIS DOCUMENT, IOM, etc. DATE	REMARKS
	BA	Vol. cm³	Vol. cm³				N_2H_4 Vol = 40.0 − Spec cm³
	NONE	7901	Capsule broken No capsule replacement				Broken 5.10
2	4006 006	7902 88.8	0.2311	28 Jan 80 8:30 AM	21 Jan 80 12 N 21°C		60°C 6.80 39.7689
2	4001 001	7903 83.9	0.2320	28 Jan 80 8:30 AM	21 Jan 80 3 PM 21°C		5.40 39.768
1	4103 NONE	7904 86.3	N_2H_4 40 cc 0	28 Jan 80 8:30 AM 4 Sept 80 220 days	18 Jan 80 1 PM 22°C	Evacuated to 1 mm max Freezing to −77°C	60°C 3.10 Control 40.00
	4112 NONE	7905 84.8	NOTHING PRESSURE: JPL 1 ATMOSPHERE 0 733 mm hg	18 MAR 80 8:30 AM	11 Mar 80 10:30 AM 23°C		3.82 2.70 Blank sealed
	NONE	7906	Experimental				Ref no s g reading
	4110	7907	NOTHING Open neck	10 MAR 80 8:30 AM			4.14 2.90 Blank calibration
	4101 NONE	7908 85.6	N_2H_4 40 cc 0	4 MAR 80 8:30 AM	27 Feb 80 9:30 AM 23°C	24	6.36 5.00 Control 40.00

*Specification: Bell Aerospace Textron; Report No. 8803-947047, rev. A

NOTE: 40.0 cc total volume unless noted otherwise

TITLE: Hydrazine, Monopropellant Grade*

REVISION (DATE)

(PREPARED BY) TOTH / MORAN

(DATE) July 1979

(REPORT NO.) 79X07501

(PROJECT) Material Compatibility JPL Proposal 90-965 rev. 2

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CLASSIFICATION	NUMBER SPECIMEN	NUMBER CAPSULE	MATERIAL DESCRIPTION	TEST DURATION CELL IN/OUT	TEST DURATION SEALED REFRIGERATION ~~IN/OUT~~	ANALYSIS DOCUMENT, IOM, etc. DATE	REMARKS
	BA	Vol cm³	Vol cm³				N_2H_4 vol
	NONE	7909	Experimental				Ref. unit for sg
1	4107 NONE	7910 85.8	N_2H_4 40cc 0	4 Mar 80 8:30 AM	27 Feb 80 9:30 AM 23°C		60°C 3.54 Control 4.80 40.00
14	4023 047	7911 87.2	0.2698	28 Jan 80 8:30 AM	22 Jan 80 10 AM 20°C		60°C 7.13 39.7302
14	4011 016	7912 87.9	3.3606	28 Jan 80 8:30 AM	22 Jan 80 10 AM 20°C		60°C 7.54 Total vol. 42.0 cc 36.6394
1	4109 NONE	7913 86.0	N_2H_4 40cc 0	4 Mar 80 8:30 AM	27 Feb 80 9:30 AM 23°C		60°C 9.0 Control 8.0 40.00
3	4037 300	7914 87.2	0.6657	28 Jan 80 8:30 AM	18 Jan 80 1 PM 22°C		4.14 39.3343
4	4055 118	7915 87.1	0.7679	28 Jan 80 8:30 AM	18 Jan 80 11 AM 21°C		4.18 Total vol. 42.0 cc 39.2321
1	4102 NONE	7916 84.8	N_2H_4 40cc 0	4 Mar 80 8:30 AM	27 Feb 80 10 AM 23°C		8.40 Control 40.00

*Specification: Bell Aerospace Textron; Report No. 8803-947047, rev. A

JPL 0999-S (REV 11-68)

(PREPARED BY) TOTH / MORAN

REVISION

(DATE) July 1979

(DATE)

(REPORT NO.) 79X0750d

(PROJECT) Material Compatibility JPL Proposal 90-965 rev. 2

TITLE Hydrazine, Monopropellant Grade*

	NUMBER SPECIMEN	CAPSULE	MATERIAL DESCRIPTION	TEST DURATION CELL IN/OUT	SEALED REFRIG-ERATION ~~IN/OUT~~	ANALYSIS DOCUMENT, IOM, etc. DATE	REMARKS
	BA	Vol cm³	Vol cm³				N_2H_4 vol
	4111	7917	NOTHING Open mech	10 MAR 80 8:30 AM			60 °C 8.36 7.50 Blank
3	4041 304	7918 87.0	0.6492	28 Jan 80 8:30 AM	18 Jan 80 1 PM 22°C		60°C 4.91 39.3508
1	4108 NONE	7919 84.8	N_2H_4 40 cc 0	4 Mar 80 8:30 AM	27 Feb 80 10 AM 23°C		8.2 Control 40.00
5	4046 101	7920 86.8	1.0618	4 Mar 80 8:30 AM	27 Feb 80 10 30 AM 23°C		5.3 38.938
2	4005 005	7921 88.6	0.2367	28 Jan 80 8:30 AM	21 Jan 80 12 N 21°C		60°C 7.0 39.7633
14	4027 058	7922 85.3	1.5605	18 Mar 80 9:00 AM	11 Mar 80 1:30 23°C	24	60°C 8.10 38.4395
4	4056 119	7923 88.7	0.7494	28 Jan 80 8:30 AM	21 Jan 80 3 PM 21°C		5.90 Total vol. 42.0 cc 39.2506
2	4002 002	7924 85.1	0.2371	28 Jan 80 8:30 AM	21 Jan 80 3 PM 21°C		5.35 39.7629

*Specification: Bell Aerospace Textron; Report No. 8803-947047, rev. A

CLASSIFICATION

TITLE Hydrazine, Monopropellant Grade*

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REVISION | (DATE) | (PROJECT) Material Compatibility JPL Proposal 90-965 rev. 2

TITLE: Hydrazine, Monopropellant Grade*

CLASSIFICATION	NUMBER: SPECIMEN BA	NUMBER: CAPSULE Vol cm³	MATERIAL DESCRIPTION Vol cm³	TEST DURATION: CELL IN/OUT	TEST DURATION: SEALED REFRIG-ERATION ~~IN/OUT~~	ANALYSIS DOCUMENT, IOM, etc. DATE	REMARKS N_2H_4 Vol
14	4019 036	7925 90.5	0.083	28 Jan 80 8:30 AM	21 Jan 80 11 AM 21°C		60°C 5.85 39.917
14	4017 034	7926 90.2	0.084	28 Jan 80 8:30 AM	21 Jan 80 4 PM 21°C		5.55 39.916
3	4042 305	7927 87.4	0.6706	28 Jan 80 8 30 AM	21 Jan 80 11 AM 21°C		60°C 5.1 39.3294
14	4024 048	7928 83.1	0.2653	28 Jan 80 8:30 AM	22 Jan 80 10 AM 20°C		60°C 6.95 39.7347
2	4003 003	7929 84.2	0.2345	28 Jan 80 8:30 AM	21 Jan 80 3 PM 21°C		5.9 39.7655
3	4044 307	7930 90.2	0.6360	28 Jan 80 8:30 AM	21 Jan 80 3 PM 21°C		60°C 9.25 39.364
1	4104 NONE	7931 88.0	N_2H_4 40 cc 0	28 Jan 80 8:30 AM	18 Jan 80 1 PM 22°C		60°C 9.5 40.00
	4007 007	7932 86.2	0.2324	28 Jan 80 8:30 AM	21 Jan 80 2 PM 21°C		60°C 6.75 39.7676

*Specification: Bell Aerospace Textron; Report No. 8803-947047, rev. A

JPL 0989 (REV 11-68)

Classification	Number: Specimen	Number: Capsule	Material Description	Test Duration: Cell IN/OUT	Test Duration: Sealed Refrigeration ~~IN/OUT~~	Analysis Document, IOM, etc. Date	Remarks
	BA	Vol cm³	Vol cm³				N_2H_4 vol
14	4018 035	79.33 91.9	0.086	28 Jan 80 8:30 AM	21 Jan 80 4 PM 21°C		5.50 39.914
9	4053 115	79.34 86.1	0.2815	4 Mar 80 8:30 AM	27 Feb 80 11 AM 23°C		5.90 39.7185
14	4020 037	79.35 87.6	0.087	28 Jan 80 8:30 AM	21 Jan 80 4 PM 21°C		60°C 5.85 39.913
2	4008 008	79.36 85.4	0.2301	28 Jan 80 8:30 AM	21 Jan 80 2 PM 21°C		60°C 6.75 39.7699
14	4009 014	79.37 86.2	2.2708	28 Jan 80 8:30 AM	21 Jan 80 11 AM 21°C		6.0 37.7292
14	4012 017	79.38 88.3	2.5323	28 Jan 80 8:30 AM	21 Jan 80 11 AM 21°C		60°C 7.9 37.4677
14	4032 070	79.39 86.2	1.4709	18 Mar 80 9:00 AM	11 Mar 80 1:30 PM 23°C	24	60°C 7.85 38.5291
14	4021 045	79.40 88.3	0.2620	28 Jan 80 8:30 AM	22 Jan 80 10 AM 20°C		5.65 39.738

*Specification: Bell Aerospace Textron; Report No. 8803-947047, rev. A

TITLE: Hydrazine, Monopropellant Grade*

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JPL 0999 (REV 11-68)

TITLE: Hydrazine, Monopropellant Grade*

PREPARED BY: TOTH/MORAN | DATE: July 1979 | REPORT NO.: 79X0750 | PROJECT: Material Compatibility, JPL Proposal 90-965 rev. 2 | REVISION | DATE | PAGE 6 OF ___

CLASSIFICATION	NUMBER: SPECIMEN	NUMBER: CAPSULE	MATERIAL DESCRIPTION	TEST DURATION: CELL IN/OUT	TEST DURATION: SEALED REFRIGERATION ~~IN/OUT~~	ANALYSIS DOCUMENT, IOM, etc. DATE	REMARKS
	BA	Vol cm³	Vol cm³				N_2H_4 ~~ml~~
4	4057 120	7941 83.8	0.7366	28 Jan 80 8:30 AM	18 Jan 80 1 PM 22°C		3.92 39.2634
1	4105 NONE	7942 88.3	N_2H_4 40cc 0	28 Jan 80 8:30AM	18 Jan 80 1 PM 22°C		60°C 8.08 Control 40.00
3	4043 306	7943 88.1	0.6430	28 Jan 80 8:30 AM	21 Jan 80 12 N 21°C		60°C 4.64 39.357
14	4022 046	7944 84.2	0.2676	28 Jan 80 8:30 AM	22 Jan 80 10 AM 20°C		6.68 39.7324
3	4038 301	7945 82.7	0.6299	28 Jan 80 8:30 AM	18 Jan 80 1 PM 22°C		4.0 39.3701
14	4029 067	7946 84.7	1.3348	4 Mar 80 8:30AM	27 Feb 80 2:30 PM 23°C	24	6.40 38.6652
2	4004 004	7947 86.8	0.2363	28 Jan 80 8:30AM	21 Jan 80 3 PM 21°C		5.88 39.7637
10	4065 SE200	7948 87.4	1.5647	4 Mar 80 8:30AM	27 Feb 80 1 PM 23°C	24	6.90 38.4353

*Specification: Bell Aerospace Textron; Report No. 8803-947047, rev. A

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CLASSIFICATION	NUMBER SPECIMEN	NUMBER CAPSULE	MATERIAL DESCRIPTION	TEST DURATION CELL IN/OUT	TEST DURATION SEALED REFRIGERATION ~~IN/OUT~~	ANALYSIS DOCUMENT, IOM, etc. DATE	REMARKS
	BA	Vol cm³	Vol cm³				N_2H_4 vol
1	4100 None	7949 88.8	N_2H_4 40cc 0	28 Jan 80 8:30 AM	18 Jan 80 1 PM 22°C		3.12 40.00
14	4028 059	7950 85.7	1.5595	18 Mar 80 9:00 AM	11 Mar 80 2 PM 23°C	24	Broken, replaced 7.4 60°C 38.4405
9	4054 116	7951 85.7	0.3517	4 Mar 80 8:30 AM	27 Feb 80 11 AM 23°C		5.0 39.6483
		7952	Spare	18 Mar 80 9:00 AM		24	7.4
4	4058 121	7953 87.7	0.7380	28 Jan 80 8:30 AM	18 Jan 80 1 PM 22°C		3.92 39.262
3	4039 302	7954 86.8	0.5506	28 Jan 80 8:30 AM	21 Jan 80 2 PM 21°C		3.8 39.4494
14	4010 015	7955 88.3	2.5024	28 Jan 80 8:30 AM	21 Jan 80 11 AM 21°C		6.08 37.4976
	4040 303	7956 85.3	0.6097	28 Jan 80 8:30 AM	18 Jan 80 1 PM 22°C		3.84 39.3903

*Specification: Bell Aerospace Textron; Report No. 8803-947047, rev. A

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(REPORT NO.) 79X07500
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CLASSIFICATION	NUMBER SPECIMEN	NUMBER CAPSULE	MATERIAL DESCRIPTION	TEST DURATION CELL IN/OUT	TEST DURATION SEALED REFRIGERATION ~~IN/OUT~~	ANALYSIS DOCUMENT, IOM, etc. DATE	REMARKS
	BA	Vol cm³	Vol cm³				N_2H_4 vol
5	4047 102	7957 86.3	1.0645	4 Mar 80 8:30 AM	27 Feb 80 10 AM 23°C		Broken, replaced 5.0 38.9355
14	4031 069	7958 84.1	1.4920	18 Mar 80 9:00 AM	11 Mar 80 2 PM 23°C	24	60°C 9.30 38.508
5	4048 103	7959 85.4	1.0666	4 Mar 80 8:30 AM	27 Feb 80 10:30 AM 23°C		5.0 38.9334
14	4026 057	7960 83.5	1.5745	4 Mar 80 8:30 AM	27 Feb 80 2:05 PM 23°C	24	6.0 38.4255
10	4067 SE210	7961 80.9	1.3813	4 Mar 80 8:30 AM	27 Feb 80 1 PM 23°C	24	6.9 38.6187
10	4071 SE230	7962 88.7	1.5657	4 Mar 80 8:30 AM	27 Feb 80 1 PM 23°C		5.6 38.4343
15	4049 109	7963 86.0	1.8789	4 Mar 80 8:30 AM	27 Feb 80 3 PM 23°C		5.1 38.1211
[illegible]	4059 127	7964 85.3	0.0056	4 Mar 80 8:30 AM	27 Feb 80 11 AM 23°C	24	6.0 39.9944

*Specification: Bell Aerospace Textron; Report No. 8803-947047, rev. A

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	NUMBER SPECIMEN BA	CAPSULE Vol cm³	MATERIAL DESCRIPTION Vol cm³	TEST DURATION CELL IN/OUT	SEALED REFRIGERATION ~~IN/OUT~~	ANALYSIS DOCUMENT, IOM, etc. DATE	REMARKS N_2H_4 vol
14	4030 068	7965 86.1	1.4278	4 Mar 80 8:30 AM	27 Feb 80 2:25PM 23°C	24	6.20 38.5722
14	4035 080	7966 84.6	0.7187	18 Mar 80 9:00 AM	11 Mar 80 1:30PM 23°C	24	60°C 8.20 39.2813
10	4068 SE211	7967 81.2	1.4163	4 Mar 80 8:30 AM	27 Feb 80 1 PM 23°C		4.36 38.5837
8	4060 128	7968 85.5	0.0061	4 Mar 80 8:30 AM	27 Feb 80 11 AM 23°C		5.9 39.9939
14	4033 078	7969 82.3	0.7104	4 Mar 80 8:30 AM	27 Feb 80 2:45 PM 23°C	24	6.9 39.2896
14	4036 081	7970 86.9	0.7048	18 Mar 80 9:00 AM	11 Mar 80 1:30 PM 23°C	24	60°C 9.0 39.2952
14	4025 056	7971 87.0	1.5112	4 Mar 80 8:30 AM	27 Feb 80 2:25PM 23°C	24	6.2 38.4888
	4061 130	7972 84.6	2.7659	4 Mar 80 8:30 AM	27 Feb 80 10:30 AM 23°C		4.50 37.2341

*Specification: Bell Aerospace Textron; Report No. 8803-947047, rev. A

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CLASSIFICATION

	NUMBER		MATERIAL DESCRIPTION	TEST DURATION		ANALYSIS DOCUMENT, IOM, etc.	REMARKS
	SPECIMEN	CAPSULE		CELL	SEALED REFRIG- ERATION		
	BA	Vol cm	Vol cm³	IN/OUT	~~IN/OUT~~	DATE	N_2H_4 vol
10	4066 SE201	7973 84.1	1.5179	4 Mar 80 8:30 AM	27 Feb 80 1 PM 23°C		4.44 38.4821
15	4051 112	7974 83.3	0.5820	4 Mar 80 8:30 AM	27 Feb 80 2:45 PM 23°C		5.6 39.418
6	4063 133	7975 86.7	0.1157	4 Mar 80 8:30 AM	27 Feb 80 10:30 AM 23°C		5.4 39.8843
6	4064 134	7976 87.5	0.1191	4 Mar 80 8:30 AM	27 Feb 80 11 AM 23°C		5.4 39.8809
15	4052 113	7977 83.9	0.5916	4 Mar 80 8:30 AM	27 Feb 80 2:45 PM 23°C		4.24 39.4084
14	4034 079	7978 84.4	0.7174	4 Mar 80 8:30 AM	27 Feb 80 2:45 PM 23°C	24	6.2 39.2826
6	(4062) (131)	7979	capsule broken during final calibration (4.96) Specimen moved to capsule number 7980 (2.7234) No capsule replacement (37.2766)				
6	4062 131	7980	capsule broken after final calibration during handling or transfer from E 75 for delivery to Pasadena 7.0 2.7234 Specimen moved to 7998 No capsule replacement			24	37.2766

*Specification: Bell Aerospace Textron; Report No. 8803-947047, rev. A

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CLASSIFICATION

	NUMBER			TEST DURATION			
	SPECIMEN BA	CAPSULE Vol cm³	MATERIAL DESCRIPTION Vol cm³	CELL IN/OUT	SEALED REFRIG-ERATION ~~IN/OUT~~	ANALYSIS DOCUMENT, IOM, etc. DATE	REMARKS N_2H_4 vol
15	4050 110	7981 87.3	1.8275	4 Mar 80 8:30 AM	27 Feb 80 3 PM 23°C		4.20 38.1725
5	4045 100	7982 87.2	1.0567	4 Mar 80 8:30 AM	27 Feb 80 10 AM 23°C		4.70 38.9433
15	4076 251	7983 85.5	1.6193	4 Mar 80 8:30 AM	27 Feb 80 3:15 PM 23°C		4.12 38.3807
15	4075 250	7984 87.6	1.6191	4 Mar 80 8:30 AM	27 Feb 80 3:15 PM 23°C		4.8 38.3809
1	4106 NONE	7985 85.0	N_2H_4 40 cc 0	4 Mar 80 8:30 AM	27 Feb 80 9:30 AM 23°C		4.70 control 40.00
11	4069 SE220	7986 90.5	Special dia .875 0.9018	4 Mar 80 8:30 AM	27 Feb 80 1 PM 23°C		3.9 39.0982
15	4079 270	7987 85.8	0.8548	4 Mar 80 8:30 AM	27 Feb 80 3:15 PM 23°C		3.88 39.1452
13	4081 280	7988 87.8	EPR 515 O-ring Krytox 240 AC 0.4024	4 Mar 80 8:30 AM 10 Apr 80 10:AM 37 dys	27 Feb 80 2:30 PM 23°C	344AT-80-076 May 80	WA 4102, 4103 3.92 39.5976

*Specification: Bell Aerospace Textron; Report No. 8803-947047, rev. A

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CLASSIFICATION

	NUMBER SPECIMEN	NUMBER CAPSULE	MATERIAL DESCRIPTION	TEST DURATION CELL IN/OUT	TEST DURATION SEALED REFRIGERATION ~~IN/OUT~~	ANALYSIS DOCUMENT, IOM, etc. DATE	REMARKS
	BA	Vol cm³	Vol cm³				N_2H_4 vol
15	4080 271	7989 85.2	0.8496	4 Mar 80 8:30 AM	27 Feb 80 3 PM 23°C		3.70 39.1504
13	4082 281	7990 86.6	EPR 515 O ring Krytox 240AC 0.4118	4 Mar 80 8:30 AM 8 May 80 10:30 AM 65 days	27 Feb 80 2:10 PM 23°C		W/A 4102, 4103 4.2 39.5882
10	4072 SE231	7991 90.3	1.5383	4 Mar 80 8:30 AM	27 Feb 80 1 PM 23°C		4.5 38.4617
11	4070 SE221	7992 83.8	Special dia. .875 0.9064	4 Mar 80 8:30 AM	27 Feb 80 2:10 PM 23°C		3.8 39.0936
12	4073 SC240	7993 87.2	special dia. .856 0.8975	4 Mar 80 8:30 AM	27 Feb 80 2:10 PM 23°C		3.76 39.1025
12	4074	7994 85.4	Special dia. .856 0.8975	4 Mar 80 8:30 AM	27 Feb 80 1 PM 23°C		3.8 39.1025
15	4077 260	7995 87.5	0.9202	4 Mar 80 8:30 AM	27 Feb 80 3:15 PM 23°C		3.5 39.0799
12	4078 261	7996 86.7	0.8960	4 Mar 80 8:30 AM	27 Feb 80 3 PM 23°C		3.6 39.104

*Specification: Bell Aerospace Textron; Report No. 8803-947047, rev. A

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NUMBER SPECIMEN	CAPSULE	MATERIAL DESCRIPTION	TEST DURATION CELL IN/OUT	SEALED REFRIGERATION ~~IN/OUT~~	ANALYSIS DOCUMENT, IOM, etc. DATE	REMARKS
BA	Vol cm³	Vol cm³				N_2H_4 Vol
4113	7997 85.1	NOTHING PRESSURE: JPL 1 ATMOSPHERE 0	18 Mar 80 9:00 AM	11 Mar 80 10:30 AM 23°C		60°C 3.80 Blank sealed
4062 131	7998 85.9	2.7234	19 Mar 80 SATURDAY 1:00 PM	25 Mar 80 2:30 PM 21°C		See 7980 3.5 37.2766
NONE	7999 86.8	NOTHING	11 Mar 80 10:30 AM	11 Mar 80 10:30 AM 23°C		Calib 3.76 open neck
4114 SPECIAL	NO NUMBER	40.0 CC N_2H_4 CO_2 analysis	28 Feb 80 8 Apr 80 40 dys	Sealed, placed in freezer	344AT-80-081 May 80	W/A 4103 40.00 CC

*Specification: Bell Aerospace Textron; Report No. 8803-947047, rev. A

TITLE: Hydrazine, Monopropellant Grade*

(PREPARED BY) TOTH/MORAN
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CLASSIFICATION

SLOPE

NUMBER SPECIMEN BA	CAPSULE Vol cm³	MATERIAL DESCRIPTION Vol cm³	TEST DURATION CELL IN/OUT	REFRIGERATION IN/OUT	ANALYSIS DOCUMENT, IOM, etc. DATE	REMARKS Special capsules 1.25 INCH O.D. N_2H_4 Vol = 40.0-spec cm³
4115	79201	NOTHING Open mech	10 Mar 80 8:30 AM			Blank calibration
4013 023	79202 103.6	1.3765	18 Mar 80 9:00 AM			38.6235
4116	79203	NOTHING Open mech	18 Mar 80 9:00 AM			60°C Blank calibration
4014 024	79204 105.1	1.2676	18 Mar 80 9:00 AM			38.7324
4015 025	79205 102.5	1.3479	18 Mar 80 9:00 AM			60°C 38.6521
4016 026	79206 106.5	1.3607	18 Mar 80 9:00 AM			60°C 38.6393

*Specification: Bell Aerospace Textron; Report No. 8803-947047, rev. A

NOTE: 40.0 cc total volume unless noted otherwise

TITLE: Hydrazine, Monopropellant Grade*

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APPENDIX C

CO_2 ANALYSIS

A. DETERMINATION OF CARBON DIOXIDE ABSORBED BY HYDRAZINE

The general laboratory test setup for CO_2 analysis is shown schematically in Fig. C-1. The sulfamic acid solution is prepared by dissolving 150 g of reagent grade material in 1.0 liter of distilled water. To reduce the CO_2 content of the sulfamic acid, high-purity helium, passed through Ascarite, is bubbled through the sulfamic acid solution via the glass frit, which provides a fine gas dispersion and efficient purging. The helium gas is passed through the sulfamic acid delivery tube for about 16 hours at 50-60 cm^3/min. The exit end of the helium gas from the sulfamic acid bottle is protected against air and CO_2 with an Ascarite tube. This Ascarite tube is replaced with a new one after the helium purge. With the precautions outlined, the blank CO_2 is under 2.0 ppm.

The apparatus is standardized by means of a $NaHCO_3$ solution prepared by dissolving 0.381 g of dried $NaHCO_3$ in 1.0 liter of distilled water. The solution is stored in glass, and air exposure is minimized. This solution provides 0.20 mg CO_2 per milliliter. Its CO_2 content is 200 ppm by weight.

The column is 6.0-mm-diam tubing, 3.66 m long (0.24-in.-diam, 12 ft long), filled with 60 to 80 mesh F & M Polypack No. 5. This packing gives good separation of CO_2 at ambient temperature. The peaks are sharp, permitting direct reading of the heights and eliminating the need for peak area measurements. The column is bent into a number of 0.7-m (2-ft) sections arranged close together and contained in a glass jacket. The filament-type thermal conductivity detector unit is kept at ambient temperature in a glass dewar to minimize temperature fluctuations. A 1.0-mV recorder records the detector output. Helium flow is 60 cm^3/min.

The first step in the analysis is the determination of the blank: the CO_2 picked up from the reagents and the system. The flow of the high-purity helium purge gas, after passage through Ascarite, is adjusted to 50 cm^3/min by means of a flowmeter in the system. A 60-ml sulfamic acid solution is run into the unit via the stopcock. The stirrer is adjusted to give vigorous constant stirring. Once set, the helium flow and stirring are kept fixed through the whole run.

After addition of the sulfamic acid, the helium gas is passed through the traps for 30 min to purge the system of air. The CO_2 trap is then immersed in liquid nitrogen to the top level of the glass beads. The flow of helium is continued for 20 min, after which time the stopcock on the CO_2 trap is turned to isolate the loop on the trap.

The trap, immersed in liquid nitrogen, is transferred to the gas chromatograph sampling system. The stopcock on the CO_2 trap is turned so as to evacuate the noncondensable gases in the trap and then turned to isolate the loop containing the frozen CO_2.

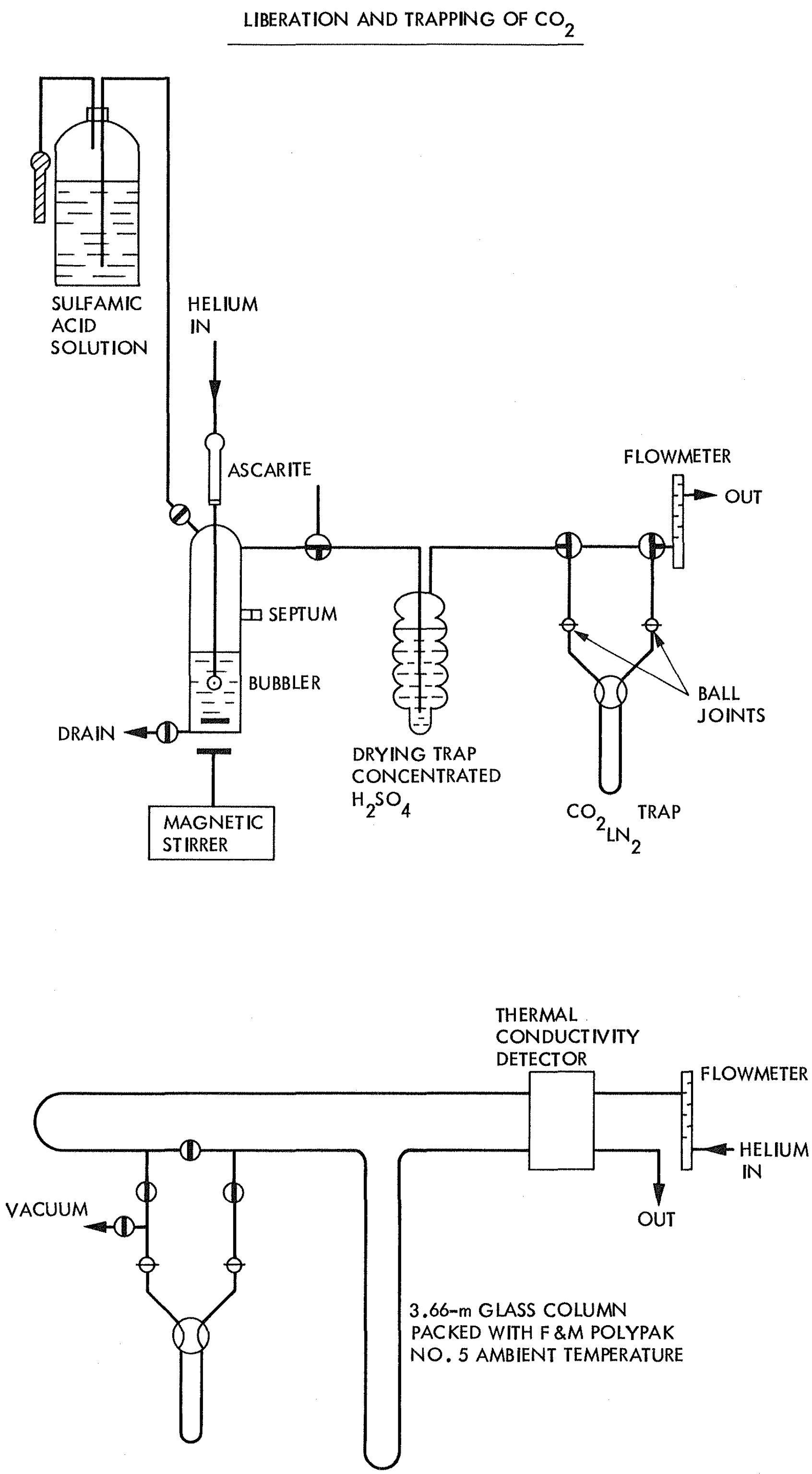


Figure C-1. Test Procedures for CO_2 Analysis

The next step is to flow the helium gas through the branched leg of the sampling system. During this operation the liquid nitrogen is removed, and the CO_2 trap thawed with warm water. After a few minutes, the stopcock is turned so as to flush the CO_2 with helium into the chromatographic column for separation and assay. The blank run is repeated until consistent, low values are obtained.

The standardization run is made in the same manner as the blanks, except that after a 5-min preliminary purge with helium, 0.50 ml of standard $NaHCO_3$ solution is injected into the vigorously stirred sulfamic acid via the septum on the sulfamic acid unit. The released CO_2 is frozen out during the 20-min duration in the CO_2 trap immersed in liquid nitrogen. The trapped CO_2 from the standard solution is transferred to the gas chromatographic sampling system. This yields a peak height for a standard of 100 ppm CO_2.

The CO_2 in the hydrazine is similarly determined. A 1.0-ml sample is injected into the sulfamic acid solution via the septum, and the released CO_2 is swept out of the solution for a period of 20 min. The hydrazine injections should be made rapidly with a minimum exposure to air. The sulfamic acid solution is sufficient to neutralize 1.0 ml of hydrazine and should therefore be discarded after each hydrazine analysis. If another sample is to be run, the sulfamic acid unit is refilled, and the blank and the standard determinations are made as before.

B. CALCULATION FOR CARBON DIOXIDE CONTENT

The formula for determining parts per million of carbon dioxide is

$$\frac{\text{peak sample} - \text{peak blank}}{\text{peak standard} - \text{peak blank}} \times 100$$

For hydrazine, where the density can be taken as 1.0, a density correction term is not applied. The error due to this omission is about 1%, well within the $\pm 10\%$ precision for CO_2 determination when the values are under 20 ppm.

C. CONCLUSION

The method described provides meaningful results for the determination of CO_2 in hydrazine or its methyl-substituted derivatives.

APPENDIX D

TEST COUPON PHOTOGRAPHS IN THE POSTTEST CONDITION

Figure D-1 shows test specimens from Program A, the secondary containment system; Figure D-2 shows test specimens from Program B, the primary containment system.

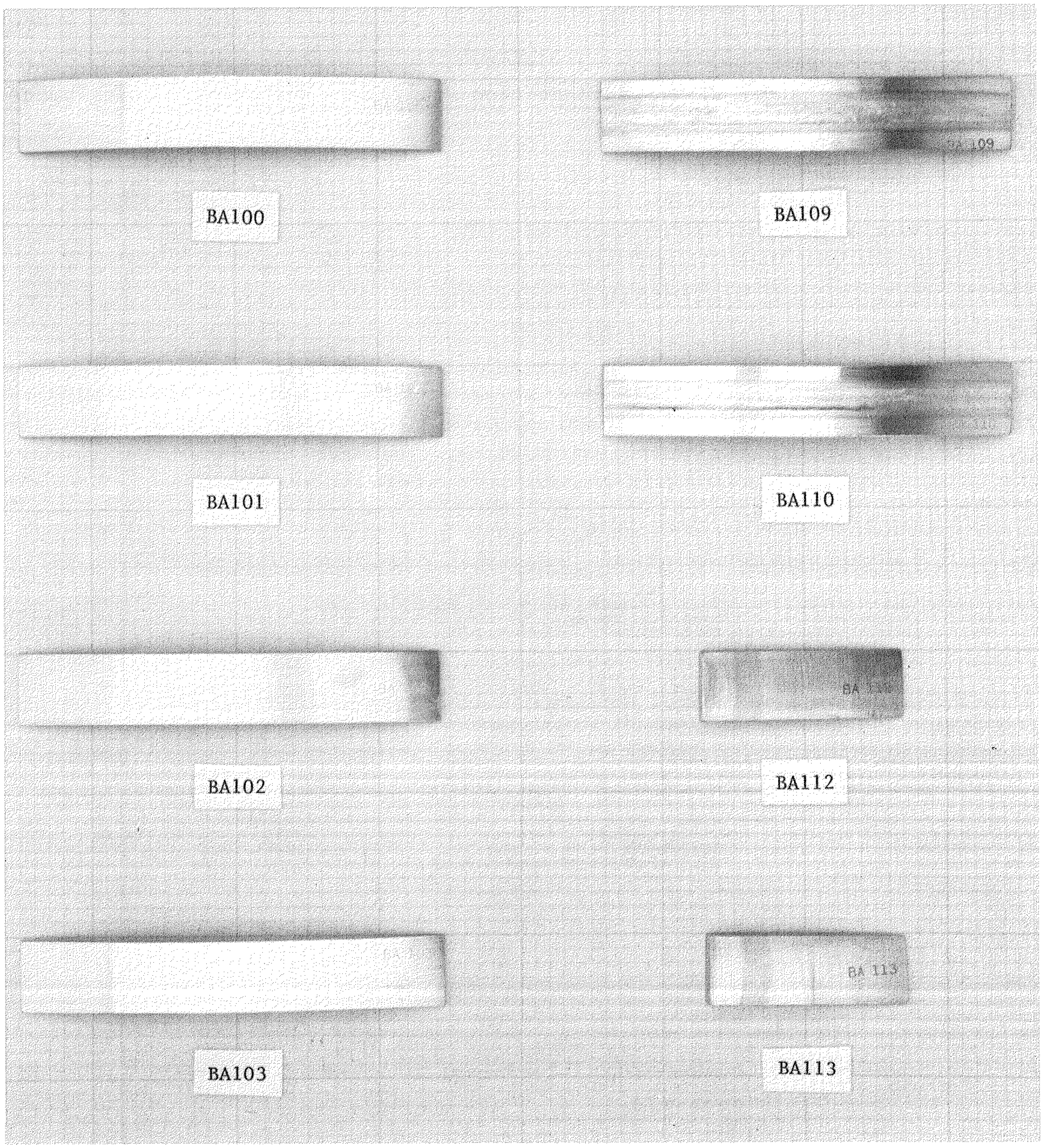


Figure D-1. Test Specimens, Hydrazine Decomposition Program "A" - Secondary Containment System

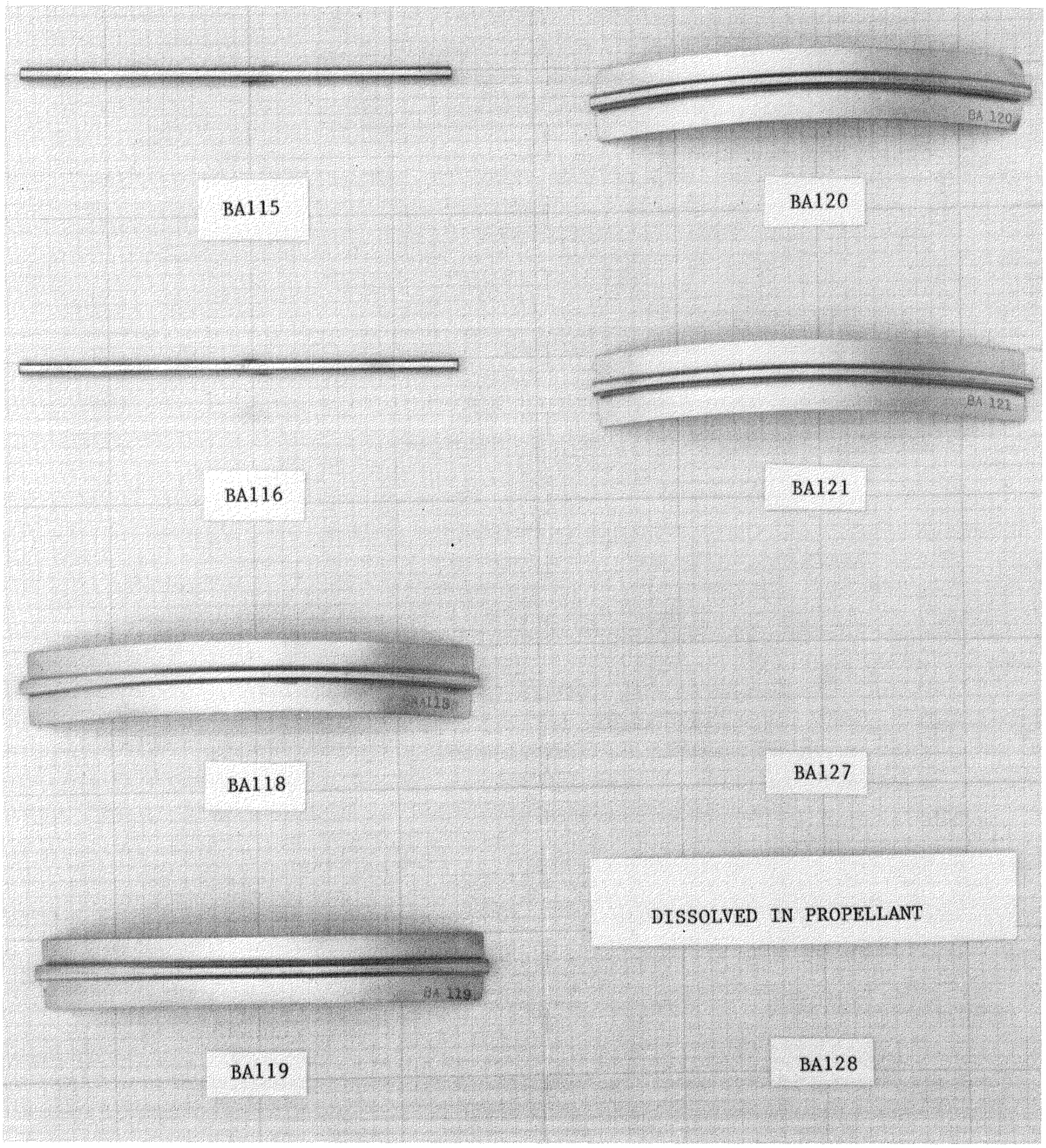


Figure D-1. Test Specimens, Hydrazine Decomposition Program "A" - Secondary Containment System (Continued)

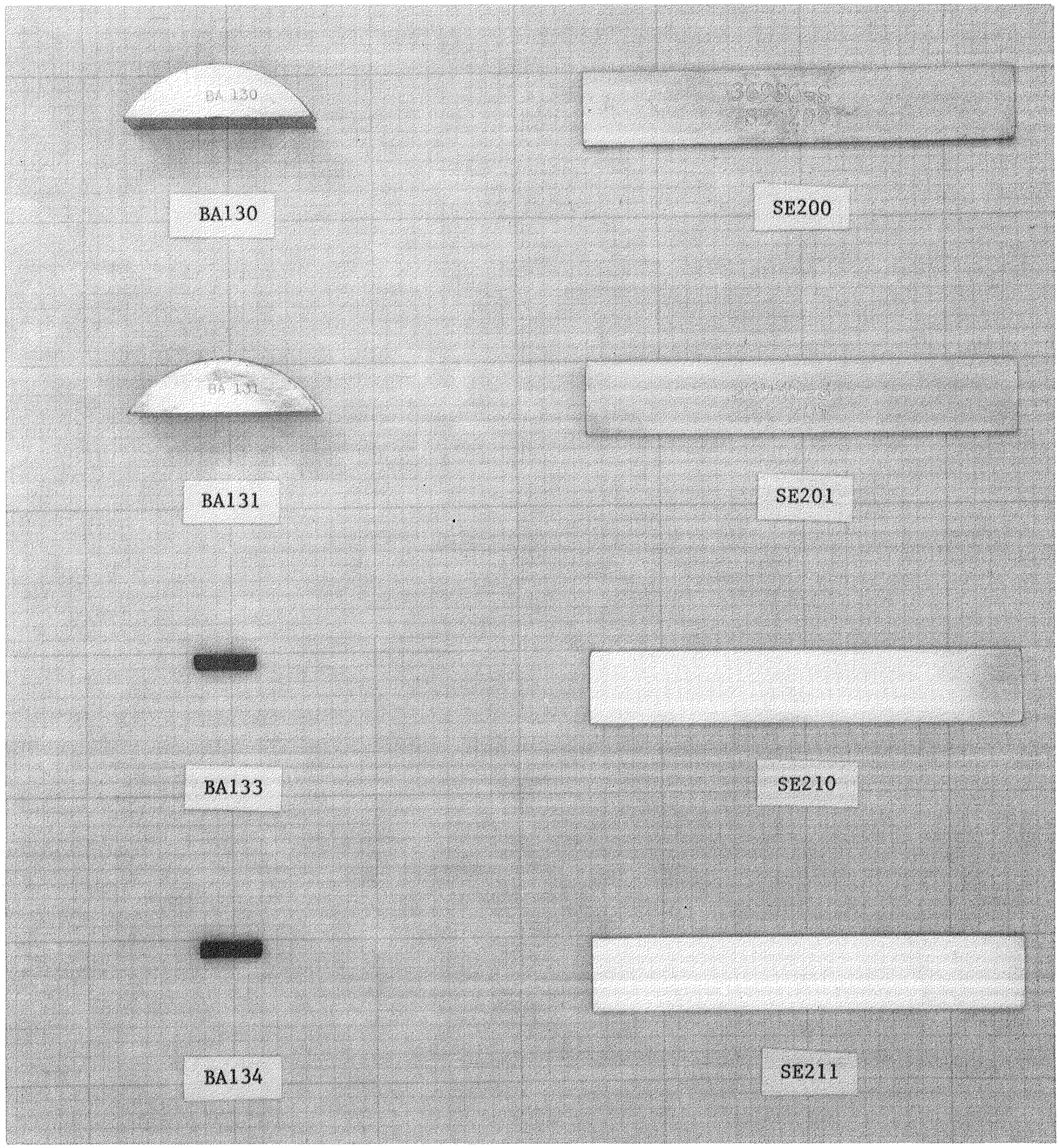


Figure D-1. Test Specimens, Hydrazine Decomposition Program "A" - Secondary Containment System (Continued)

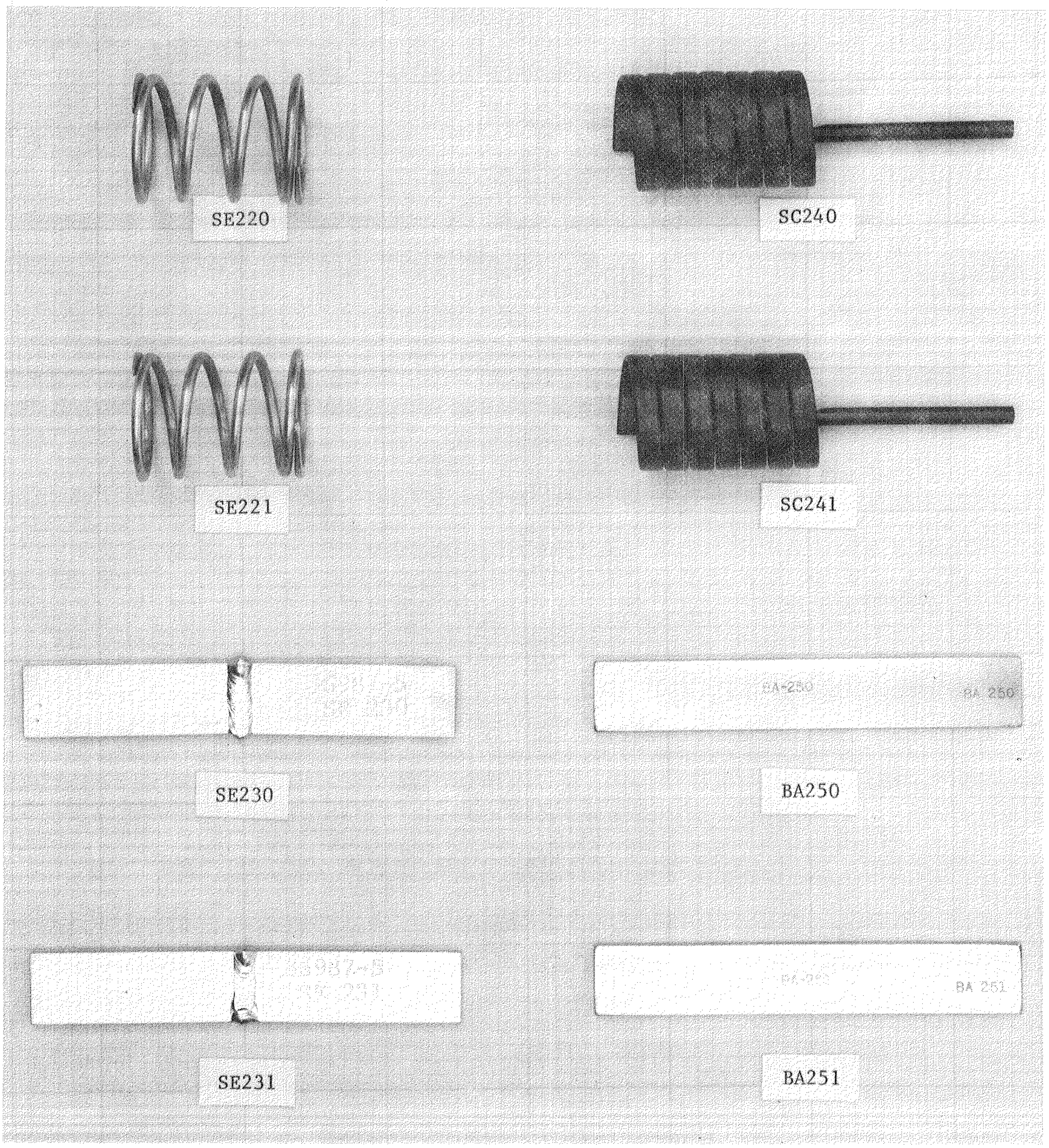


Figure D-1. Test Specimens, Hydrazine Decomposition Program "A" - Secondary Containment System (Continued)

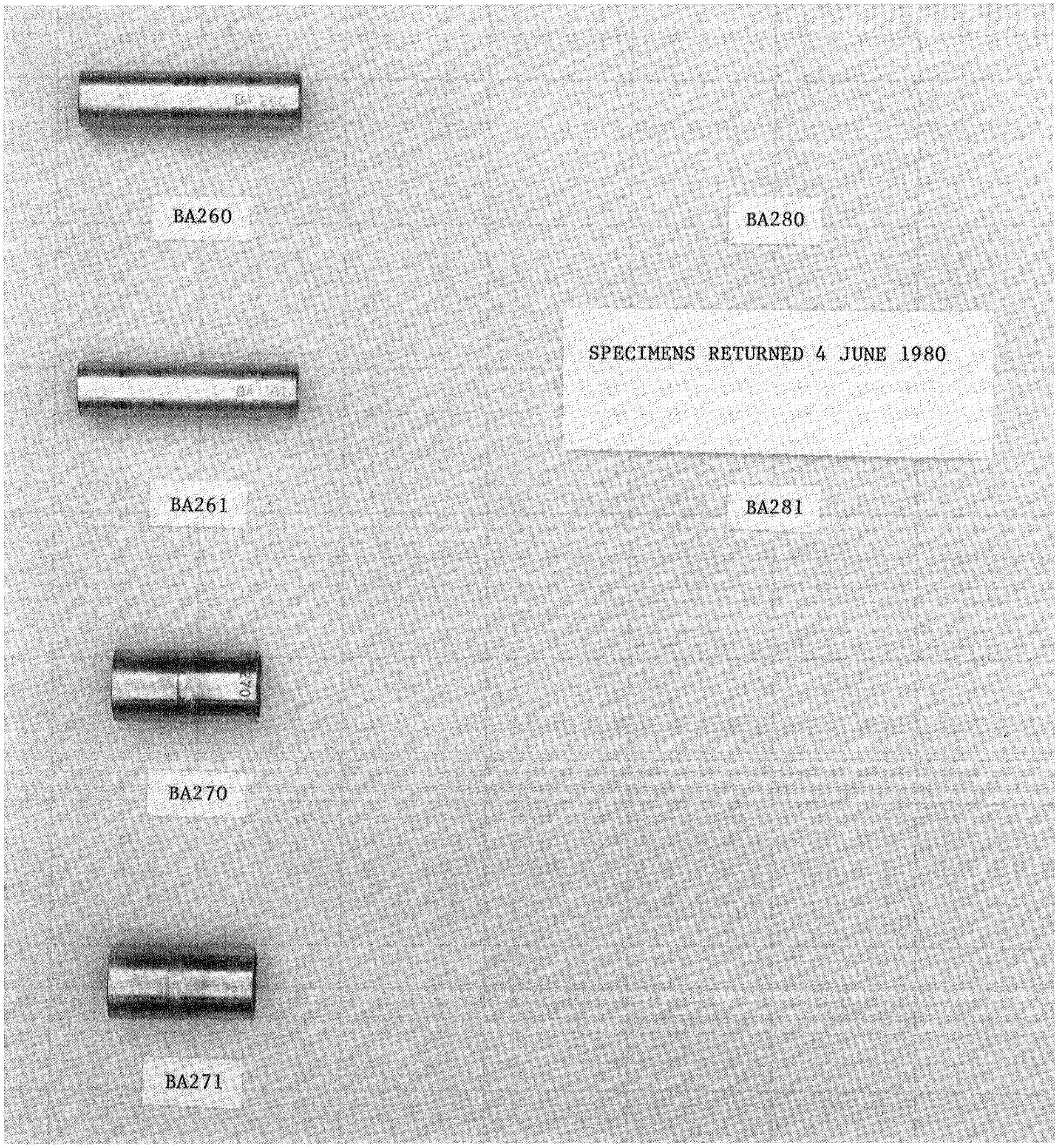


Figure D-1. Test Specimens, Hydrazine Decomposition Program "A" - Secondary Containment System (Concluded)

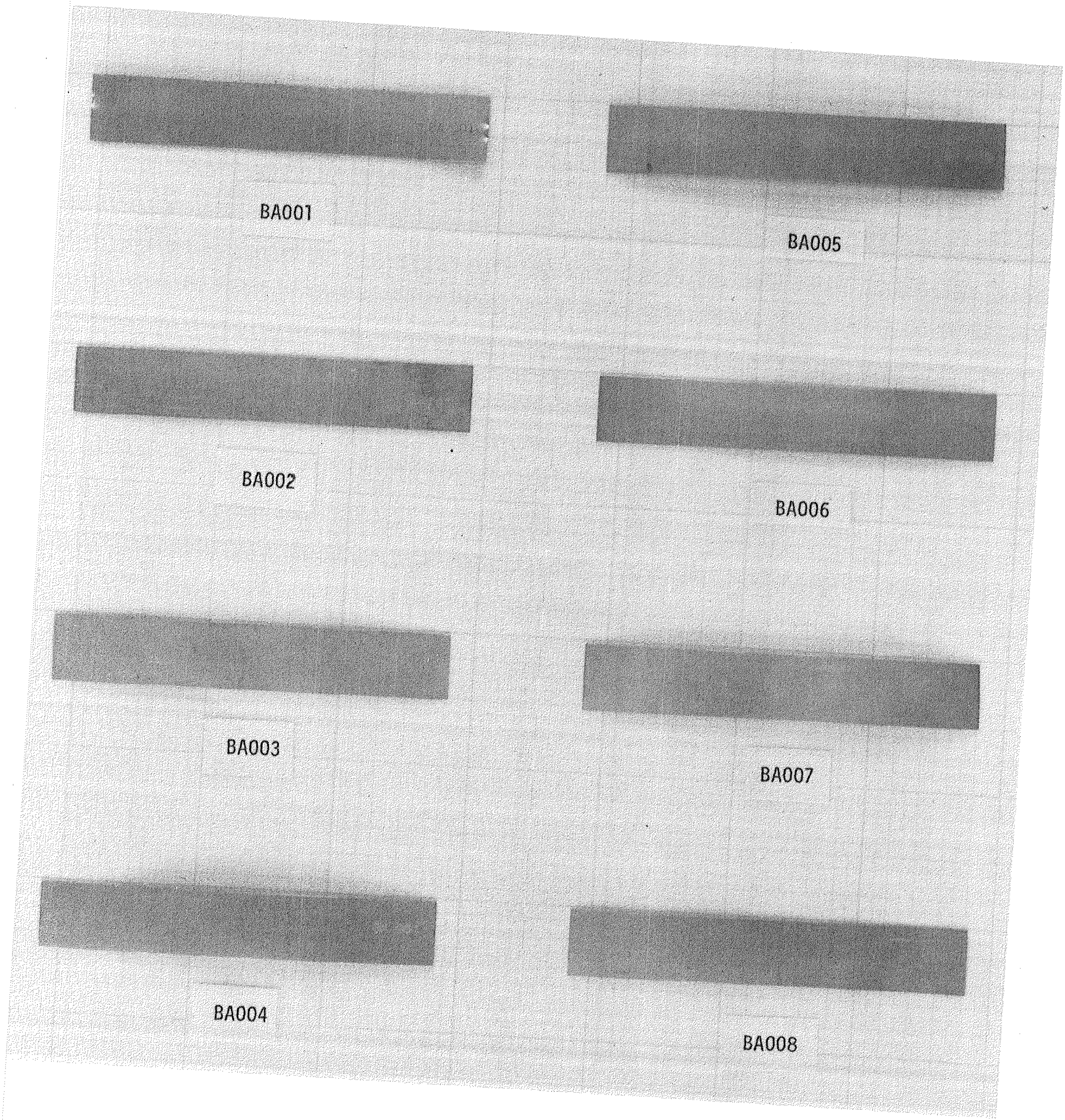


Figure D-2. Test Specimens, Hydrazine Decomposition Program "B" - Primary Containment System

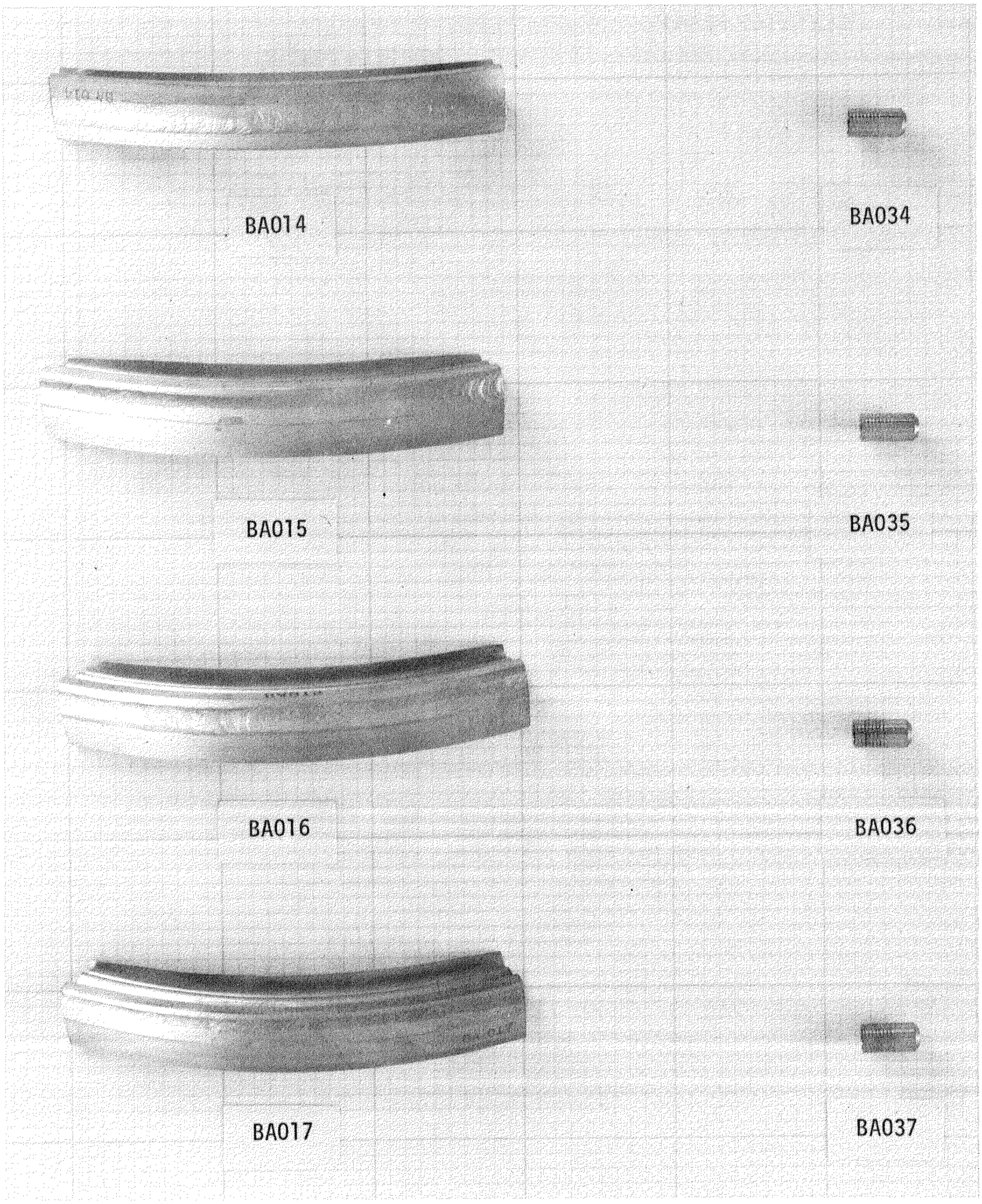


Figure D-2. Test Specimens, Hydrazine Decomposition Program "B" - Primary Containment System (Continued)

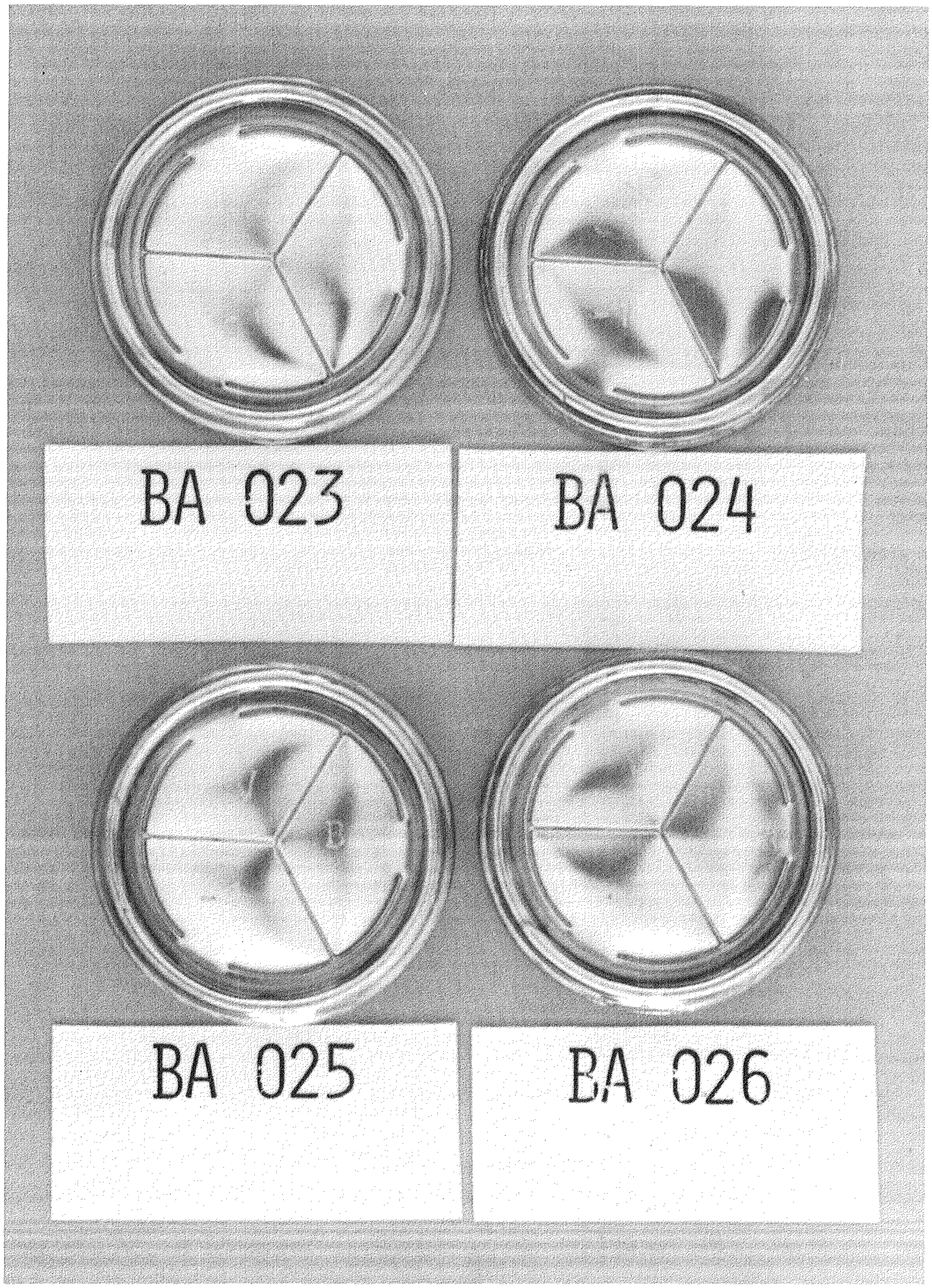


Figure D-2. Test Specimens, Hydrazine Decomposition Program "B" - Primary Containment System (Continued)

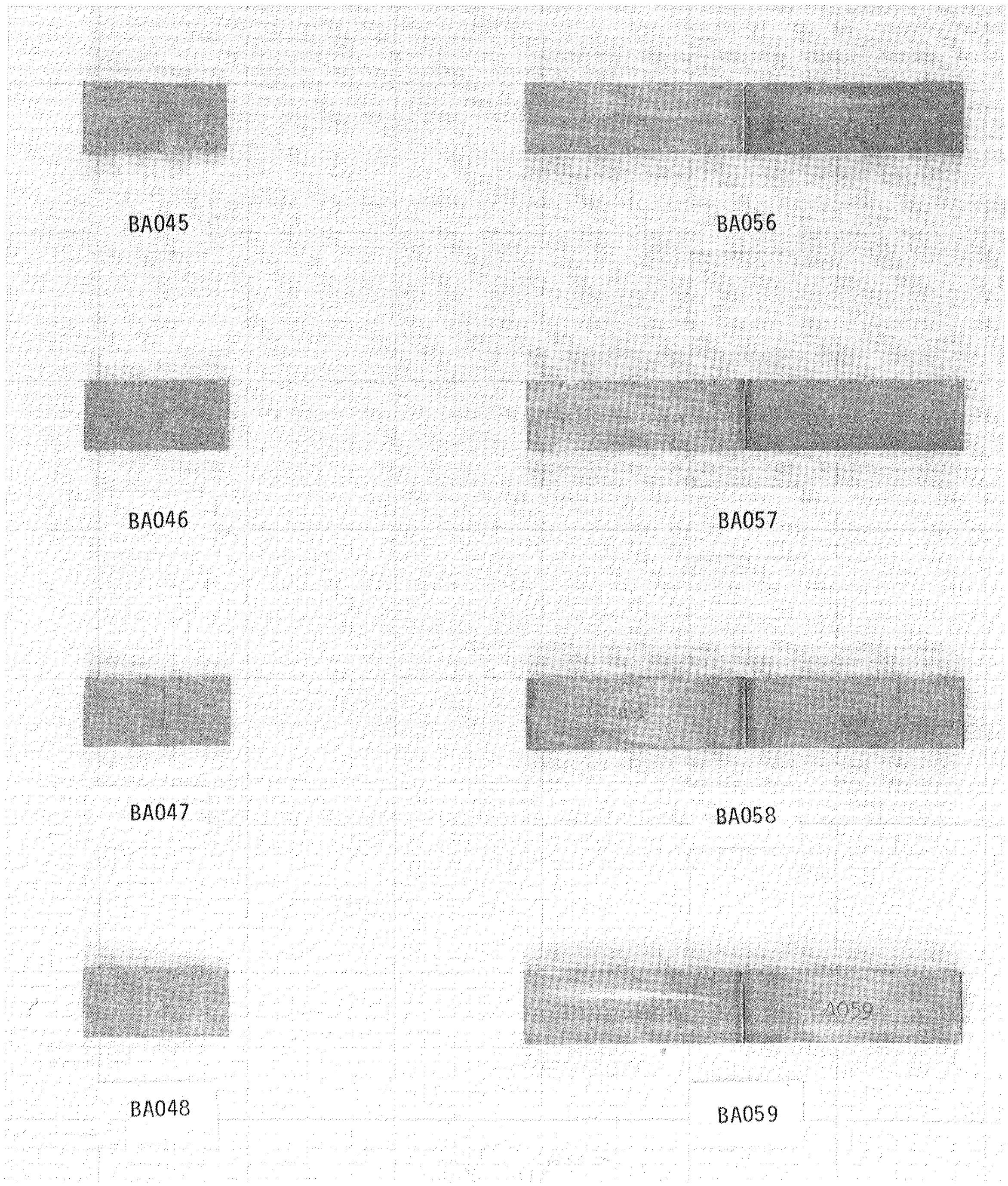


Figure D-2. Test Specimens, Hydrazine Decomposition Program "B" - Primary Containment System (Continued)

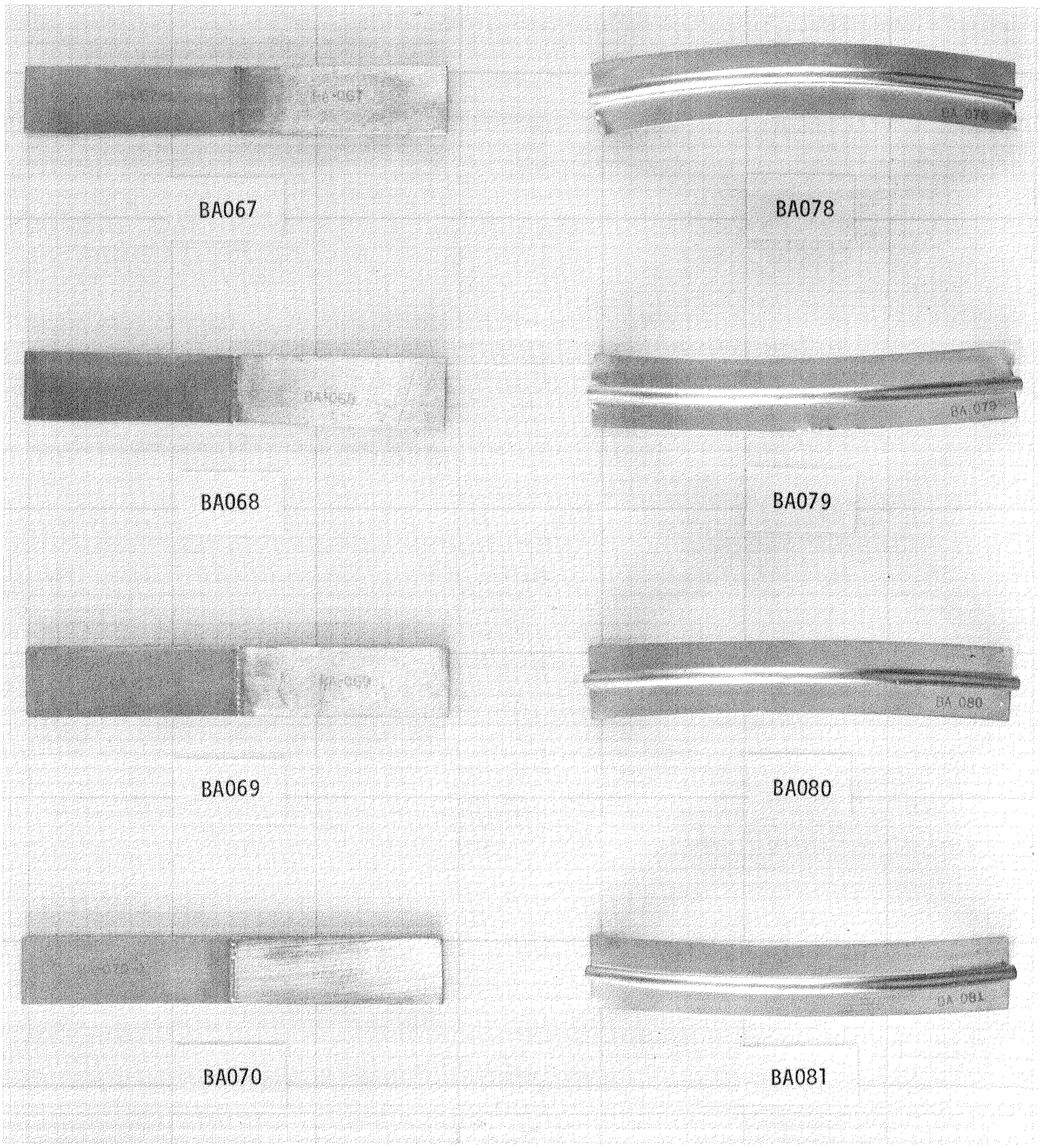


Figure D-2. Test Specimens, Hydrazine Decomposition Program "B" - Primary Containment System (Continued)

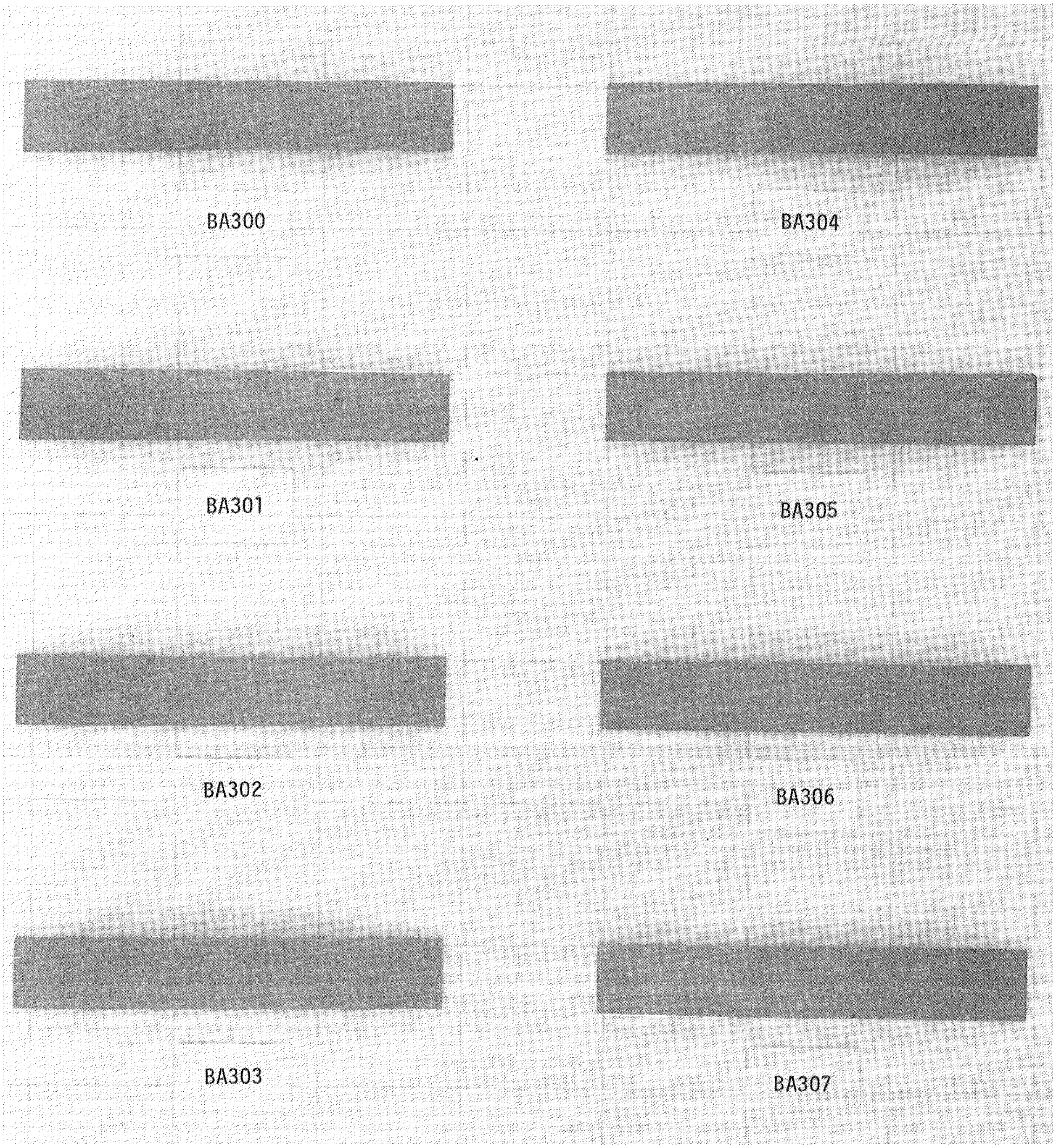


Figure D-2. Test Specimens, Hydrazine Decomposition Program "B" - Primary Containment System (Concluded)

APPENDIX E

347 CRES WELDS

A. INTRODUCTION

Some concern was expressed by the sponsor that the 347 CRES diaphragm in the burst disc assemblies (BA 023 to BA 026) might be subject to stress corrosion cracking in a hydrazine environment. All four specimens were removed from storage at 12.5 months rather than the scheduled 24 months. A cursory examination at JPL was inconclusive. However, a very thorough examination by BAT revealed that any crack formation in the diaphragms was due to the manufacturing and coining (crimping) process.

In the NASA long-term material compatibility test program, a few welded 347 CRES specimens were still in storage. Two were removed - one of which had been stored in the stressed configuration. These were thoroughly tested to determine the differences induced by storage while stressed versus storage while relaxed. Those results are not directly relatable to the 347 CRES diaphragms, but it was believed that the information gained would be useful to this program.

B. SAMPLES

All samples were Type-347 CRES which had been heliarc welded. For all samples, the area analyzed was from the "top" surface immediately adjacent to the weld. The samples analyzed were those described below:

JPL 0981 - welded, no N_2H_4 (control)

JPL 2005 - welded, in N_2H_4 - 4054 days

JPL 1977 - welded, stressed in N_2H_4 - 4054 days

For samples 2005 and 1977, the areas chosen had been at the liquid/gas interface during the testing. A dark discoloration of interest was particularly obvious in this area.

C. XPS EXAMINATION

All three samples had been rinsed with distilled water upon removal from the hydrazine. Prior to analysis with XPS technique, the samples were further cleaned in an ultrasonic cleaner by serial rinses in trichloroethylene, acetone, and absolute ethanol. Samples were then blown dry with dry nitrogen gas.

The XPS spectrometer (modified HP5950A) averages over a region approximately 1 mm x 5 mm in area and 50-100 Å in depth. Because of the exponential attenuation of the photoelectrons, the immediate atomic surface (approximately 30 Å) was weighted more heavily than the rest.

Except for Na, Zn, and N, all the observed elements are expected for 347 CRES. (The approximate theoretical composition of 347 CRES is 0.08% C, 2% Mn, 0.05% P, 0.03% S, 1% Si, 18% Cr, 10% Ni, 0.1% Ta, remaining % Fe.) Oxygen is present in the form of various metal oxides and hydroxides as discussed below.

1. Chromium Region

JPL 0981. Cr_2O_3, CrO_3, and some reduced Cr^{+3} species at lower binding energy (BE) than CrO_3, but higher than chromium metal, were observed. chromium hydroxides may also be present.

JPL 2005 and JPL 1977. No differences were observed between these two samples. Spectra were consistent with Cr_2O_3 and chromium hydroxides. The atomic percent of Cr observed increased in the order 0981 $<$2005 $\cong$ 1977.

2. Fe Region

The atomic percent of iron observed decreased in the order 0981 $>$ 2005 $\cong$ 1977. For all three samples, effectively Fe_2O_3 and iron hydroxides were observed. There were some differences in the high BE side of the oxide peak. A small amount of FeO was observed on the control (0981) as well as the possibility of low-level FeO or iron sulfides.

3. Mn Region

The atomic percent of manganese observed decreased in the order 0981 $>$2005 $\cong$ 1977. The spectra for all three samples may be assigned to MnO and manganese hydroxides.

4. Zn Region

The atomic percent of zinc observed decreases in the order 0981 $>$2005 $\cong$ 1977. ZnO was present in all three samples.

5. Ni Region

The atomic percent of nickel observed was approximately the same for all three samples, with perhaps slightly more for 2005 as compared to 1977. The Ni was present as Ni_2O_3 and nickel hydroxides. The lower BE on 0981 was probably due to Fe_2O_3.

6. Carbon Region

Approximately the same amount of carbon was observed on all three samples. Primarily aliphatic carbon was present although substantial intensities in the C-O and C-N regions were observed, showing some differences in detail between the samples.

7. Oxygen Region

Approximately the same amount of oxygen was observed on all samples. The primary peak was due to metal oxides and hydroxides. The lower BE on 0981 was probably due to Fe_2O_3.

8. Nitrogen Region

The nitrogen intensity increases significantly in the order 0981 <2005 ≅ 1977. The primary differences appear on the low binding energy side of 2005 and 1977, where a shoulder characteristic of reduced nitrogen species such as amines and ammonia transition metal complexes was observed. The high binding energy peak was consistent with a variety of species including protonated amines and amide polymers as well as hydrazine salts and nitrites.

D. CHEMICAL ANALYSIS

Chemical analysis of propellant and analysis of the decomposition gases indicated no significant differences between stressed and unstressed conditions (Table E-1). Both specimens were exposed to hydrazine for 4054 days.

Table E-1. Summary of Posttest Hydrazine Analysis

Specimen	Propellant		
	Decomposition (wt%/yr)	Dissolved Fe (mg)	N_2H_2 gas, cc $x10^{-3} \cdot day^{-1} \cdot cm^{-2}$
JPL 1977, stressed	0.174	0.21	1.48
JPL 2003, unstressed	0.154	0.21	1.15

E. SEM EXAMINATION OF SPECIMENS

SEM photomicrographs of the surfaces of the specimens indicated that some pitting has occurred at the liquid-vapor interface. As seen in the accompanying photographs, (Figures E-1 to E-4) the distribution of pit sizes varies between the stressed and unstressed specimens. These same samples were sectioned and etched. Photomicrographs of the cross sections revealed no intergranular or intragranular corrosion. The markings seen on the photographs are the result of over-etching.

F. CONCLUSIONS

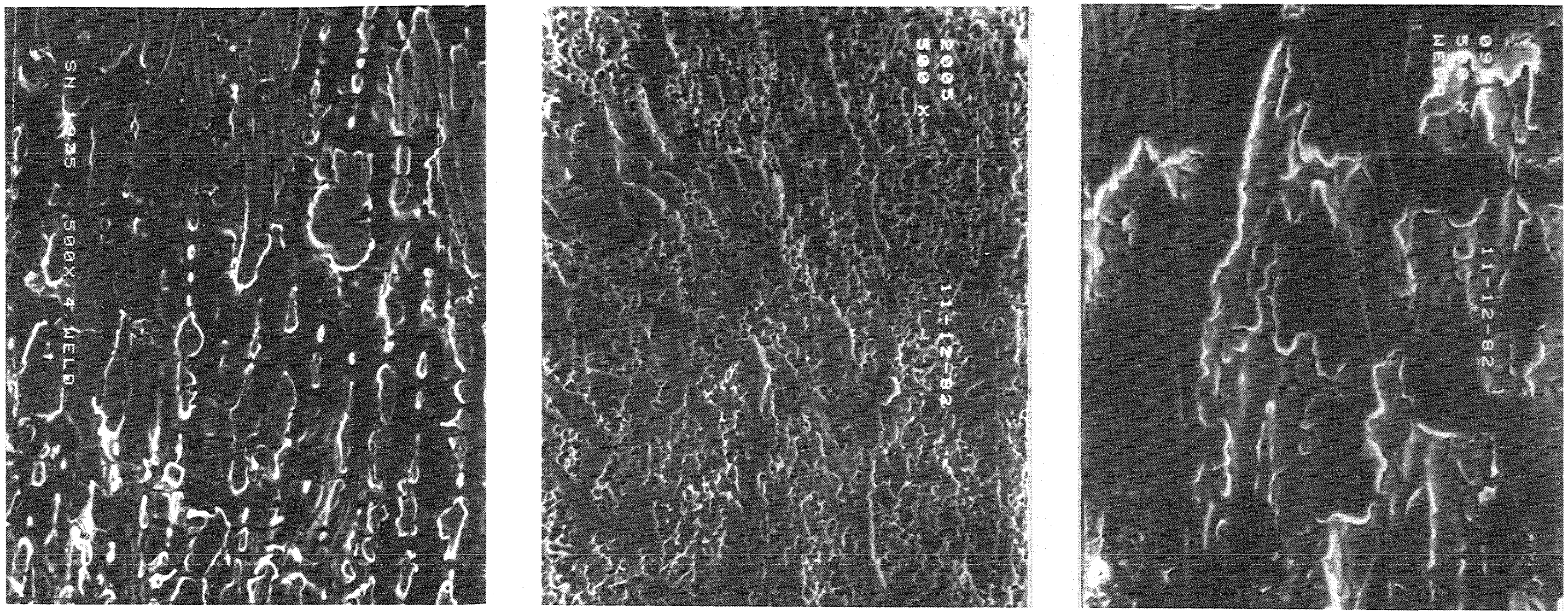
1. The pattern of surface corrosion was similar for each of the specimen examined.

2. No intergranular or intragranular corrosion was observed in stressed specimen.

3. Fe and Mn dissolved more readily than does Cr, leaving a corroded surface rich in chromium.

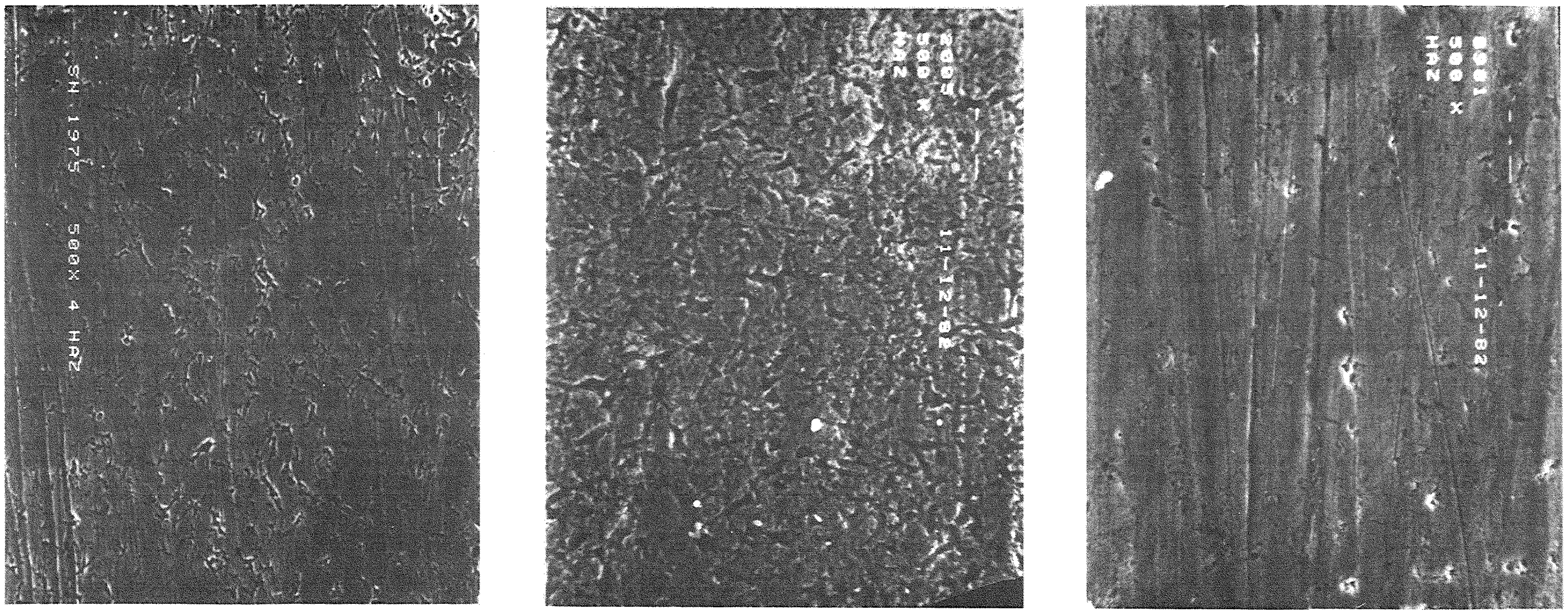
4. The XPS examination indicated no difference in the chemical nature of stressed and unstressed specimens.

5. Only minor differences were observed in metal content or decomposition of propellant between stressed and unstressed configurations.



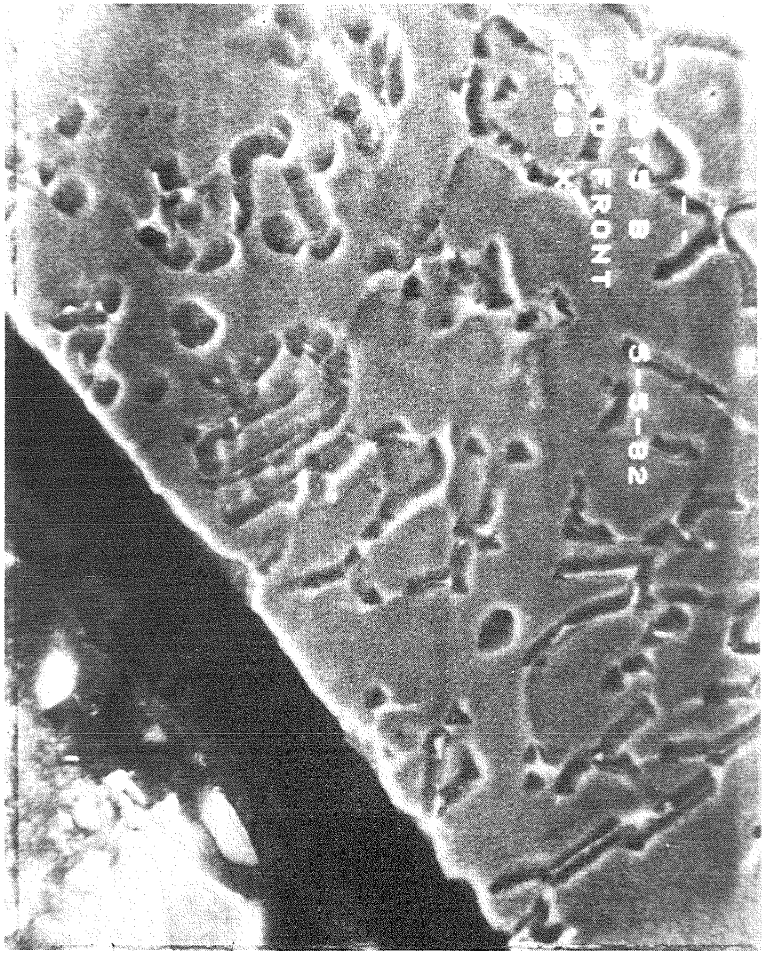
STRESSED WELD　UNSTRESSED WELD　CONTROL WELD

Figure E-1. CRES 347 Weld Specimens, Surface Features at Weld



STRESSED HAZ | UNSTRESSED HAZ | CONTROL HAZ

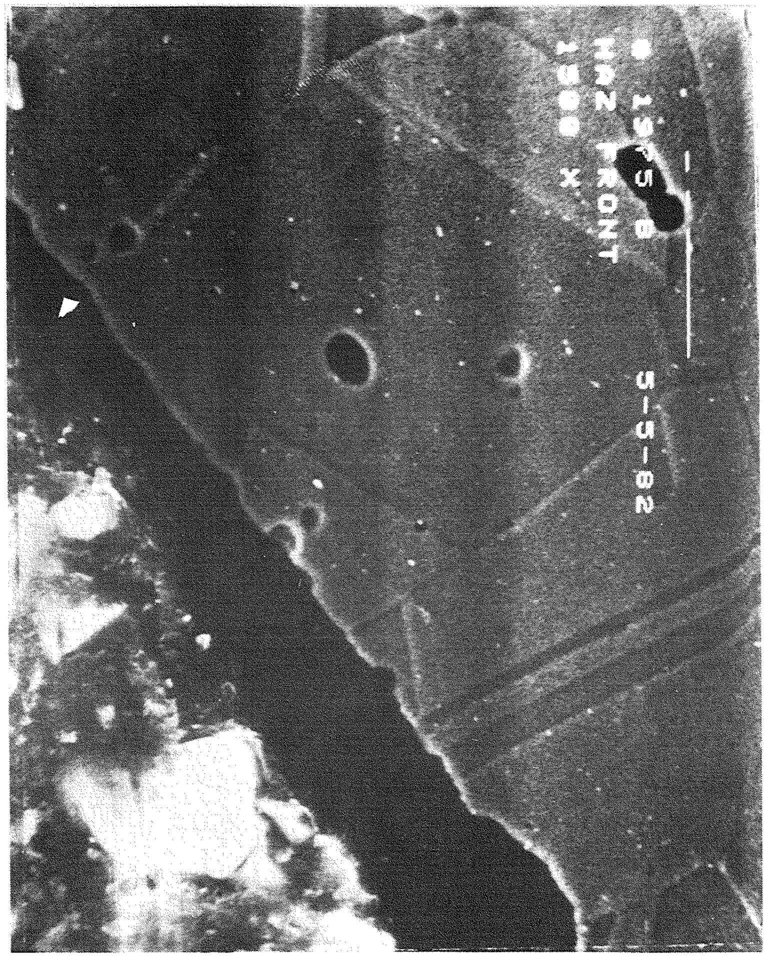
Figure E-2. CRES 347 Weld Specimens, Surface Features at Heat-Affected Zone



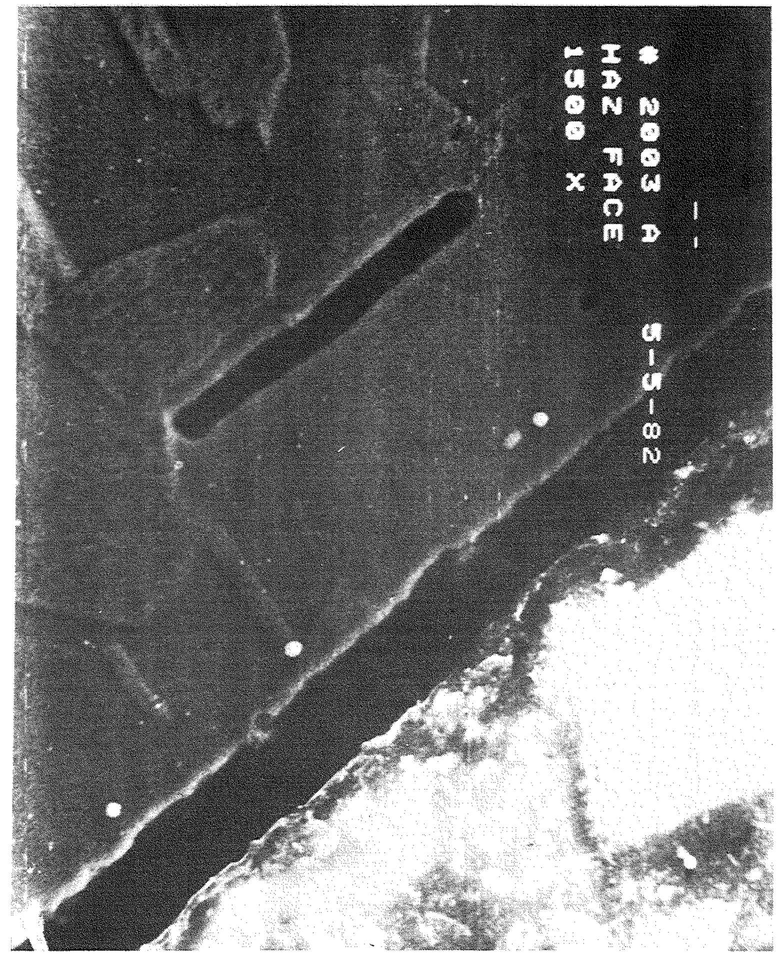
STRESSED WELD-TENSION

UNSTRESSED WELD

Figure E-3. CRES 347 Weld Specimens, Cross Sections at Weld



STRESSED HAZ-TENSION



UNSTRESSED HAZ

Figure E-4. CRES 347 Weld Specimens, Cross Sections at Heat-Affected Zone

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