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LARGE RADIOISOTOPE HEAT SOURCE
CAPSULE PROGRAM

Topical Report No. 7
Capsule Fire Test Results

MASTER

AEC Research and Development Report

ATOMICS INTERNATIONAL

A DIVISION OF NORTH AMERICAN ROCKWELL CORPORATION

P1820

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Topical Report No. 7
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By
J. M. HARRIS

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ABSTRACT

A test was performed to establish the behavior of the refractory metal Large Radioisotope Heat Source Capsule in the flame of a solid propellant, such as might be encountered in the event of a launch pad abort. An instrumented capsule was placed on top of a block of Algol IIB solid propellant. The propellant burned in ambient air for approximately 10 minutes, four minutes at a heat flux of $38 \text{ BTU/ft}^2/\text{sec}$ and thereafter at a reduced heat flux. Within one minute after propellant ignition the platinum oxidation cladding reached its melting point, exposing the tantalum alloy structural shell directly to the propellant flame and ashes. There was attack to the surface of the capsule by interstitial elements in the flame and air, and erosion from the molten platinum, rhodium, and aluminum. However, the structural shell was not breached and the fuel simulant was completely contained. The test established that the LRHS capsule can withstand the potentially severe environment of a launch pad abort fire, remain impermeable to helium and completely contain a radioisotope fuel.

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I. INTRODUCTION

The Large Radioisotope Heat Source Capsule is a test vehicle in a program to develop the technology of high temperature refractory metal capsules for the containment of alpha emitting fuels.

The capsule, depicted in Figure 1, uses tantalum base alloy structural members for the basic radioisotope fuel containment vessel. Ta-10W components position the fuel in a cylindrical annulus with an excluded volume available, as a plenum, for the helium as it is generated by alpha decay of the fuel. The T-111 (Ta-8W-2Hf) pressure vessel is encapsulated in a Pt-10Rh shell. The noble metal provides oxidation protection for the tantalum alloys during air exposure. The alumina diffusion barrier between the two prevents interdiffusion of the dissimilar noble and refractory metals. The Pt-10Rh shell is arc plasma sprayed with a high emissivity coating of iron titanate.

The LRHSC Program has established that second generation tantalum alloy components and assemblies can be fabricated with high quality and in a reproducible manner. As part of the program, capsules are being tested under a variety of conditions to determine the behavior of the materials and components over the full range of potential normal and accident conditions. Prime emphasis in the program has centered on high temperature diffusion tests evaluating the metallurgical interactions between components, biaxial creep tests of the components under varying internal pressure, and terminal velocity impact tests of the capsules at elevated temperature.

The tests to date have provided operational characteristics of the capsule over most of the mission profile, from the moment the capsule is fueled, through launch, steady state operation in space, subsequent reentry through the atmosphere and impact on the ground. However, the effect of one credible event in a space mission which could seriously affect the safety capability of the capsule concept had not been examined. This was: How would the capsule

8-F19-029-1

Figure 1. Large Radioisotope Heat Source Capsule

react to operating for some period of time in a very corrosive, high heat flux flame in the event of a launch pad accident where the launch vehicle disintegrated? If this incident were to occur, the initial explosion could separate the heat source from the generator and reentry protection. As a result the bare capsule could fall to the ground and be in contact with burning propellant and its debris.

A number of experts have postulated the flame face temperature for a solid propellant at atmospheric pressure to be in the range of 3300 to 5500°F. Clearly the melting temperature (approximately 3100°F) of the platinum alloy oxidation cladding could be exceeded, causing loss of that protection for the refractory metal. While the melting temperature of the tantalum container materials would certainly not be surpassed, the degree of oxidation and/or corrosion of the tantalum was unknown.

The test series performed to determine the effects of this potential accident included not only the LRHS Capsule, but also other capsules built from both refractory metals and superalloys. The tests exposed the various capsule designs, individually, to an Algol IIB* solid propellant fire. The design of the other fuel capsules and further details of the test matrix are to be published by Isotopes, Inc., a Division of Teledyne, who performed the tests. Atomics International supplied the LRHS instrumented test capsule, monitored its test, and evaluated the effects of the exposure. This report relates the results of the fire test on the LRHS Capsule.

* Product of Aerojet General Corp.

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II. LRHS FIRE TEST CAPSULE ASSEMBLY AND INSTRUMENTATION

A LRHS Capsule was tested in order to demonstrate the ability of the capsule to withstand a corrosive high heat flux flame typical of a launch pad accident. To provide the test vehicle a standard LRHS Capsule was fabricated and assembled to conform to the drawing shown in Figure 2. The capsule was instrumented with thermocouples internally as well as externally to gather thermal transient data. A mixture of tungsten-40 w/o molybdenum powder was used to simulate the radioisotope fuel.

The capsule was assembled to comply with the requirements of the test plan proposed by Isotopes, Inc.⁽¹⁾ The assembly sequence as shown in Figure 3, was similar to that employed for the LRHS Standard "C" Capsule, except for instrumentation required for this test⁽²⁾. A Pt vs Pt-10Rh thermocouple (T/C No. 1) was inserted through a penetration in the forward fuel retainer ring and attached to the inside of the Ta-10W outer liner. The fuel simulant, weighing a total of 502.7 grams, was loosely packed in the fuel annulus. The aft fuel retainer ring was put into place and electron beam welded to the Ta-10W outer liner cap and outer liner sleeve. To accommodate T/C No. 2 a groove 0.040-in wide by 0.040-in deep by 3-in long was machined into the inside wall of the 0.127-in thick T-111 structural shell. The T-111 structural shell was positioned over the inner capsule assembly so that T/C No. 1 and T/C No. 2 were in the same radial and axial plane. An outer liner end cap was installed to protect the thermocouple wires from the electron beam during final closure welding of the structural shell. A Ta-10W lead tube was welded to the structural cap which in turn was welded to the structural shell. The structural shell was arc plasma sprayed with approximately 0.002-in of Al_2O_3 and the coated capsule was slipped into the platinum-10% rhodium oxidation barrier shell. A 12-in Pt-10Rh lead tube was welded to the Pt-10Rh end cap and slipped over the Ta-10W tube. The end cap was then

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NOTES:

1. ALL T/C ATTACHMENTS POINTS WILL BE IN THE SAME PLANE
2. T/C #1 WILL BE BANDAID TO GRAPHITE & FEED-THRU TUBE
3. T/C #2 WILL BE PI-JEWELRY WITH PI & PI-4A LEADS MTD INSULATED RATED AT 3000°F.

FIRE TEST CAPSULE - LRHS
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Figure 2

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The Ta-10W Outer Liner
With T/C No. 1 Penetrat-
ing the fuel Retainer Ring

LRHS Fire Test Capsule
Assembly Sequence
Showing the T-111 Struct-
ural Shell with T/C No. 2
in Place

A 0.002-in Coating of
 Al_2O_3 was Plasma Sprayed
Over the T-111 Structural
Shell. Pt-10Rh Oxidation
Barrier Shell is Adjacent
to the Capsule

Prior to Plasma Spray-
ing the Emittance Coat-
ing of Fe_2O_3 , TiO_2 Over
the Pt-10Rh Oxidation
Barrier

Figure 3. LRHS Fire Test Capsule Assembly Sequence

welded to the Pt-10Rh shell. Gamma radiographs of the capsule were taken for comparison with post test radiographs.

A 90° bend was made in the lead tube to facilitate attachment of the completed capsule to the instrumentation column of the burn pit. The remaining thermocouples were then attached with Pt-10Rh wire. All the thermocouples were on a plane 90° from the surface to be in contact with the propellant.

A partial pressure of helium between the platinum shell and the structural shell was included to duplicate normal heat transfer. The following procedure was devised. The capsule was held for 12 hours at a pressure of 1×10^{-5} mm Hg, and then backfilled with reactor grade helium to one atmosphere. Epon 956* potting compound was poured into the annulus formed by the noble and refractory metal lead tubes and where the thermocouples exit the tube. The glove box was evacuated allowing the helium to flow out of the capsule through the potting compound until a partial pressure of approximately 1 psia was achieved. The capsule remained at this pressure during the cure cycle of the Epon 956.

An emittance coating of iron titanate ($\text{Fe}_2\text{O}_3 \cdot \text{TiO}_2$) was arc plasma sprayed over the Pt-10Rh shell and lead tube to a thickness of 0.004 to 0.005-in.

Based on available performance and thermal conductivity data, foamed silica was selected as an insulator for the instrumentation lead tube. Some laboratory tests were performed to evaluate its characteristics. A cromel-alumel thermocouple was attached to a Ta-10W tube. A 3/4-in thick piece of foamed silica was then positioned against the thermocouple to protect it from the flame of an oxy-acetylene torch. The temperature on the flame face of the foamed silica was monitored by an optical pyrometer and determined to be 3600°F. The temperature on the back side of the foamed silica reached 200°F in 3 minutes. The amount of the protective covering was an arbitrary selection designed to afford maximum protection to the lead tube, where possible, without interfering with

* Product of Shell Chemical Company

the performance of the fire test. Due to the location of the instrumented lead tube and because the capsule was to be in direct contact with the propellant, only 3/4-in of foamed silica could be placed between the lead tube and the solid propellant.

The assembled capsule with associated instrumentation and insulation is shown in Figure 4.

Figure 4. Fire Test Capsule Complete

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III. LRHSC LAUNCH ABORT FIRE TEST

A. TEST FACILITY

The test facility consisted of a 6 foot square reinforced concrete burn pit four (4) feet high which was open on the West side. A metal sand box was centered within the burn pit to accommodate the test block of solid propellant. Two instrumentation columns were provided, the first for the copper calorimeter and the second for the test capsule. The columns were counterbalanced to maintain the exact weight of the test vehicle in contact with the burning solid propellant throughout the test.

B. CALIBRATION

A calibration run was made prior to testing the capsules to determine the heat flux of the propellant in one atmosphere air. Two copper calorimeters, one water cooled and the other solid, were placed side by side on an 18-in square by 12-in high block of Algol IIB type solid propellant. The propellant was ignited. The water cooled calorimeter failed during the test, spraying water onto the fuel. The solid copper calorimeter appeared to function properly, although the heat flux may have been influenced by the water spray from the other calorimeter. The heat flux was calculated using the slope of the resultant time vs temperature curve.

The results of the calibration run, using the data from the solid block calorimeter, shown in Figure 5, indicated the heat flux of the fire to be ~ 38 BTU/ft²/sec. The maximum intense burning was timed at approximately 5 minutes. The propellant continued to burn at a reduced heat flux for an additional 5 minutes.

C. FIRE TEST

On March 27, 1969 at 1:00 p.m., the LRHS Fire Test Capsule was subjected to the solid propellant fire. Still photographs, movies, optical pyrometer

Total Exposed Surface Area 67.7 Sq. In.
 Weight 14 Pounds

Figure 5. Copper Slug Calorimeter

measurements of the flame temperature, heat flux, and thermocouple data were taken during the test. The solid propellant used was also Algol IIB in block form, 18-in x 18-in x 12-in with an inhibitor on all of the surfaces except the top.

The heat flux was measured with a solid copper block calorimeter, identical to the one used for the calibration run. The calorimeter was placed on the block of solid propellant next to the test capsule and instrumented with a Type P30 (Pt/30%Rh vs Pt/6%Rh) thermocouple.

The relationship of the capsule to the instrumentation column, solid propellant, solid copper calorimeter, and the propellant ignition media is shown in Figure 6. Using ordinary gun powder and electric matches as a starter, the solid propellant was ignited. The burn time, at intense heat, was 4.5 minutes with a maximum heat flux of approximately $38 \text{ BTU/ft}^2/\text{sec}$ and a flame temperature of approximately 4500°F . Figure 7 is an infra-red photograph of the test in progress. The propellant continued to burn at a reduced heat flux for an additional 5 minutes.

The thermal response of various portions of the capsule is shown in Figure 8. Immediately after the test was started the tungsten alloy thermocouple on the outer surface (T/C No. 6) failed. Thermocouples No. 2 and No. 3 reached the melting temperature of Pt-10Rh after 1 minute into the test. Thermocouples No. 1, 4 and 5 ceased operating simultaneously after 1 minute and 45 seconds into the test. The temperature in the fuel annulus at this time was 2800°F and increasing. Interpretation of the thermocouple data indicates that the surface temperature of the capsule reached the flame temperature of the solid propellant during the test.

The post test appearance of the capsule can be seen in Figure 9. The propellant residue covering the capsule gives an illusion of a severe reaction. The visual examination which followed the test revealed the instrumentation lead

Figure 6. LRHS Fire Test Capsule Installed in the Burn Pit

Figure 7. Infra-Red Photograph of Test in Progress

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Figure 8. Time vs Temperature Relationship of the LRHSC Fire Test

Figure 9. Capsule Immediately Following Fire Test

tube to be separated from the capsule. Evaluation of all the data strongly suggests that the intense heat recessed the insulation where it interfaced with the capsule, exposing the lead tube directly to the flame. After 1 minute and 45 seconds operation T/C's 4 and 5 failed, indicating the time of the lead tube burn through. The interior of the capsule was then also exposed to air at the high temperatures for the remaining 3 minutes of test.

IV. POST TEST EXAMINATION

A. VISUAL EXAMINATION AND HELIUM LEAK CHECK

Immediate visual examination indicated that the capsule had survived the solid propellant fire test with the fuel simulant totally contained within the fuel annulus. Three views of the post test capsule are shown in Figure 10. The large deposits of residue covering the capsule were generated by the propellant. The platinum shell appeared to be intact along the surface that was in contact with the fuel; but, due to the deposits of residue surrounding the rest of the capsule, it could not be immediately determined if the platinum shell was totally intact.

Radiographs of the capsule were taken to show the surface in contact with the propellant and the surface 90° to the propellant. Figures 11 and 12 compare these radiographs with those taken prior to the test.

It was apparent from the radiographs that the capsule configuration was only changed by a minor reduction of the metallic wall thickness. To determine the integrity of the T-111 structural shell, a mass spectrometer helium leak test was performed. The end of the capsule which had been penetrated for installation of the thermocouples was machined flat to provide a vacuum tight, sealing surface. The capsule was subjected to a vacuum $> 1 \times 10^{-3}$ mm of hg using a Veeco Mass Spectrometer Helium Leak Detector. The sensitivity of the leak detector was determined to be $> 1 \times 10^{-10}$ std cc/sec of helium at 1 atmosphere of differential pressure. The capsule was surrounded by a plastic shroud which was purged with helium for 1 hour. There was no indication of a leak. After the leak test the sensitivity of the leak detector was reconfirmed to be $> 1 \times 10^{-10}$ std cc/sec of helium.

The capsule was cut on a plane perpendicular to the tangent that was in contact with the solid propellant. The Ta-10W fuel liner was undamaged and the fuel simulant was totally contained. It was necessary to remove the fuel

Deposits primarily Al_2O_3
and Aluminum

Lead Tube Attach Point

Metallic Surface in Contact
with Burning Propellant

Figure 10. Post Test View of Capsule from Top, Center and Bottom

Surface in Contact with Solid Propellant

Figure 11. Comparison of Gamma Radiographs

This surface was 90° to the solid propellant

Figure 12. Comparison of Gamma Radiographs

simulant in order to grind and polish the capsule to show surface reactions; therefore, Figure 13, showing the capsule interior, does not show the fuel simulant. There are, however, isolated areas which can be seen in the photograph, where the fuel simulant did adhere to the Ta-10W outer liner.

B. ANALYTICAL ANALYSIS BY X-RAY DIFFRACTION, FLUORESCENCE, AND EMISSION SPECTROGRAPHY

Areas of interest along the capsule surface were selected and samples were taken for X-ray diffraction analysis. Samples representative of visual differences were taken first and were identified by color or substance. Samples were also taken from areas where extensive metallographic and electron beam microprobe examinations were performed.

Analysis of the X-ray fluorescence data indicated that the silvery metallic substance removed from the capsule surface, at approximately 90° to the interface of the propellant, contained major amounts of aluminum, tantalum and platinum. The phases could not be identified by X-ray diffraction. Nodules near the ends of the capsule, containing gold and green colored platelets, were determined to be Al_4C_3 , $\alpha\text{-Al}_2\text{O}_3$ and aluminum metal. A black porous deposit from near the top was primarily AlTaO_4 with a minor amount of $\alpha\text{-Al}_2\text{O}_3$. The white deposits from the top of the capsule were primarily $\alpha\text{-Al}_2\text{O}_3$. There was one isolated glassy appearing area approximately 1-in in diameter on the top of the capsule that was amorphous SiO_2 . It is reasonable to assume that the source of SiO_2 was the foamed silica lead tube protection material.

An analysis of the propellant residue ⁽⁴⁾ in previous fire tests indicated the ashes to be 75% Al_2O_3 , 20% aluminum and 5% Al_4C_3 . The presence of these materials alone and reacting with the capsule is as expected.

An oxidation test performed prior to the fire test showed that T-111 in an oxygen rich oxy-acetylene flame of 3350°F formed $\alpha\text{-Ta}_2\text{O}_5$. A comparison of the grain boundary attack found in the oxidation test (Figure 14) and the

Figure 13. Cross Sectional View of Capsule Interior

Figure 14. Oxidation of T-111 in Oxy-Acetylene Flame

surface reaction found in the fire test (Figure 15) indicated a very similar structure. After the oxidation barrier is penetrated, the formation of AlTaO_4 as a product of the propellant residue and the oxidized T-111 structural shell would be expected.

Of the samples taken for analysis from the locations corresponding to metallographic and electron beam microprobe examination, only the primary phase of Al_2Pt could be positively identified by X-ray diffraction. This phase of Al_2Pt , although interspersed with tantalum, tungsten and rhodium appears to be prevalent in all but the area immediately adjoining the structural shell. It was there that the elemental compounds were so intermixed that phase identification within a reasonable length of time was not possible.

Emission Spectrographic analysis of the above discussed areas (Table 1) showed the presence of elements in minor and trace amounts which had not been identified by X-ray diffraction. These elements are chromium, copper, iron, nickel, titanium and tungsten. The emittance coating of $\text{Fe}_2\text{O}_3 \cdot \text{TiO}_2$ accounts for the iron and titanium and the source of tungsten would be the T-111 structural shell. The chromium, copper and nickel are most likely from the solid propellant starter materials which consisted of electric matches, nails, wire and gun powder.

C. METALLOGRAPHIC EXAMINATION

Comparison of the radiographs and the sectioned capsule indicated that a reasonable estimate of uneffected wall thickness could be derived by examination of the radiographs. The radiographs were used to determine the area where the minimum wall existed and a section exhibiting one half the radial plane was removed by an abrasive cutting wheel for metallographic examination.

The sample was vacuum impregnated with hysol metallographic mounting compound and was ground, polished and etched for metallographic examination.

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Figure 15. Cross Sections of Tested Capsules
Reduced to 75-1/2 %
(Sheet 1 of 2)

Figure 15. Cross Sections of Tested Capsules

Reduced to 75-1/2%

(Sheet 2 of 2)

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TABLE 1
EMISSION SPECTROGRAPHY OF REACTION PRODUCTS

Element	Sample Number				
	2608	2609	2610	2611	2612
Aluminum	M*	M	M	M	T
Chromium	S**	T	T	T	
Copper	S	T	S	T	T
Iron	S	T	S	S	T
Nickel	S	T	T	T	
Platinum	S	T	S	S	T
Silicon	T***	T	T	T	M
Titanium	T	T	S	S	
Tantalum	S	T	M	M	
Tungsten	T	T	T	T	

* "M" indicates a major constituent

** "S" indicates a minor constituent

*** "T" indicates a trace constituent

Figure 15 contains a photomontage showing the microstructure of the Ta-10W inner and outer liners, the T-111 structural shell, and the intermetallic and ceramic formation surrounding the capsule. Figure 15 also shows a photomacrograph of the sample showing its relation to the solid propellant during the fire test.

It is clear from the figure that an intergranular attack has taken place at all of the interfaces with the exception of the outer wall of the Ta-10W outer liner. Precipitation at the inner wall of the Ta-10W outer liner occurred to a depth of 0.008-in, while precipitation in the grain boundaries at the surface of the outer wall of the Ta-10W inner liner was 0.006-in. Both the inner and outer liners were examined by an Electron Beam Microprobe (EBM) in an attempt to determine the composition of the precipitate. The liners were scanned for Fe, Pt, Al, W, Ta, Mo, Ti, Hf and Rh, and were void of all of the elements with the exception of the normal expected levels of Ta and W.

There is a transgranular attack at both surfaces of the T-111 structural shell, primarily, however, at the interface with the Ta-10W outer liner. The depth of the attack was 0.006-in and the measured minimum wall thickness of the T-111 was 0.041-in. These surfaces were scanned by the EBM at the same time as the Ta-10W liner, for the same elements, and with the same results. Only the normal expected levels of Ta, W and Hf were found.

The only elemental identifications made of non capsule materials were within the reaction zone between the Ta-10W outer liner and the T-111 structural shell. The reaction zone is approximately 0.003-in wide and consists of a phase identified by X-ray diffraction as the tantalum-aluminum intermetallic, sigma, denoted as Ta_xAl where $2 < x < 3$. The EBM scans taken across this same reaction zone identified the presence of tantalum, platinum and aluminum, with the notation that the beam fluoresced, not only in the reaction zone but also in the region of grain structure attack in the T-111. This is usually an indication of the presence of an oxide. The annulus between the Ta-10W and the T-111

contained a platinum clad T/C sealed with alumina. The presence of these elements in the interface was therefore expected. Figure 16 is a comparison of EBM area scans with a photomicrograph for visual reference.

Hardness of the T-111 structural shell falls within the range of fully recrystallized T-111 ($20R_c$ to $25R_c$)*, except at the outer 0.010-in of the T-111 structural shell where the hardness increases to as high as $55R_c$. Hardness of the Ta-10W inner and outer liners were higher at the surfaces in contact with the fuel simulant than that exhibited by fully recrystallized Ta-10W ($34R_c$ vs $25R_c$)*. The lead tube burned off approximately 1 minute and 45 seconds into the test; therefore, the increase in hardness was probably due to the >3 minute exposure to air at elevated temperature. The surfaces away from this interface were also slightly harder than fully recrystallized Ta-10W ($27R_c$ vs $25R_c$)*. Microhardness of the intermetallic region formed from the interreaction of the solid propellant residue with molten Pt-10Rh and T-111, ranges from 308 to 1581 K. H. N., while the phase identified as solid $\alpha\text{-Al}_2\text{O}_3$ has a hardness up to 3940 K. H. N.

Figure 15 has been detailed to locate areas representative of the phases identified by X-ray diffraction. These phases are Al_2Pt , Al_2O_3 , and Ta_xAl . Elements which were identified by the EBM are also called out on this figure wherever possible.

D. ELECTRON BEAM MICROPROBE ANALYSIS (EBM)

In all of the scans through the intermetallic layer surrounding the T-111 structural shell, the following was found to be true. Where platinum was present there was a presence of aluminum, and when tantalum was present there was a presence of tungsten. There were isolated areas where the elements were separate of each other, as in the case of Ta-10W, Figure 17, or when all were intermixed, Figure 18. The needle like structure in Figure 19a is Ta-W

* R_c Hardness numbers were converted from 500 gram load Knoop Hardness numbers.

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250X PHOTOMICROGRAPH ENLARGED 200%

E.B.M. AREA X-RAY SCANS
1 THRU 4

NOTE THAT THE CONCENTRATION OF
ALUMINUM CORRESPONDS TO THE
AREAS VOID OF TANTALUM

Figure 16. Electron Beam Microprobe
Scan of Capsule-T/C Reaction Products
(Sheet 1 of 2)

5 LINE SCAN FOR Ta

E.B.M. LINE X-RAY SCANS
5 THRU 7

NOTE THAT THE CONCENTRATION OF
ALUMINUM CORRESPONDS TO THE
AREAS VOID OF TANTALUM

6 LINE SCAN FOR W

7 LINE SCAN FOR PLATINUM

2 Ta X-RAYS 800X

3 W X-RAYS 800X

4 Pt X-RAYS 800X

Figure 16. Electron Beam Microprobe
Scan of Capsule-T/C Reaction Products
(Sheet 2 of 2)

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B. S. E. Area Scan

800 X

Tantalum X-Ray Area Scan

800 X

Tungsten X-Ray Area Scan

800 X

Figure 17. A Comparison of
Ta and W EBM Scans

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Tantalum X-Rays 800X

Tungsten X-Rays 800X

Platinum X-Rays 800 X

Aluminum X-Rays 800 X

Figure 18. · A Comparison of Ta, W, Pt and Al EBM Scans

rich in a primary matrix of Pt-Al. The darker structure was identified to contain all four of the elements. The stringers shown in Figure 19b are high in tantalum surrounded on one side by tantalum in a Pt-Al matrix, identified by X-ray diffraction to be Al_2Pt , and on the other side by a very brittle primarily tantalum phase. Figure 20 illustrates the relative distribution of platinum and aluminum to rhodium. Platinum has separated from the rhodium and alloyed solely with the aluminum leaving two separate and distinct phases, Al_2Pt and platinum-rhodium-aluminum. Platinum and aluminum are thoroughly mixed through both phases, as evidenced in area scans 2 and 3 of Figure 20. Area scan 4, of this figure, reflects the pattern formed by the matrix and by the back scattered electrons (area scan 1). Scan 4 shows that rhodium is found in only one of the two phases which would account for their apparent metallographic difference. Area scans 5 and 6, for tantalum and tungsten, fill the voids in area scans 2, 3 and 4 (dark areas). Tantalum is more prevalent than tungsten and appears to surround or over shadow the tungsten as though they were separate of each other, although this had not been distinguished microscopically.

Of all the elements scanned for in the intermetallic region surrounding the T-111 structural shell, only iron had a concentration level high enough to be detected by the EBM and was detected only in isolated areas near the surface of the T-111.

Figure 19. Photomicrographs of Intermetallic
Region

Figure 20. A Comparison of Pt, Al and Rh EBM Area Scans

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V. CONCLUSIONS

The LRHS Capsule will remain impermeable to helium and contain the radioisotope fuel in the event of a launch pad accident where the capsule is stripped of its reentry protection and exposed to a $>4000^{\circ}\text{F}$ flame of a solid propellant fire for 4 - 5 minutes.

The melting temperature of the oxidation cladding will be exceeded and the tantalum alloy containment vessel exposed directly to the propellant flame. There will be some reduction of the wall thickness due to oxidation and erosion from the flame and its residue. Erosion by alloying of the molten aluminum with the platinum and tantalum, reducing the melting temperatures of the components, will be the major cause of the surface recession of the capsule. If the aluminum were not present, the surface recession would be measurably reduced.

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