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LARGE RADIOISOTOPE
HEAT SOURCE CAPSULE (LRHSC)
TWELFTH QUARTERLY PROGRESS REPORT
APRIL-JUNE 1970

AEC Research and Development Report

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Atoms International
North American Rockwell

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FOREWORD

This is the twelfth and final quarterly progress report, describing the technical status of the Large Radioisotope Heat Source Capsule (LRHSC) Program. It covers the work accomplished by Atomics International during the period from April 1, 1970 through June 30, 1970 under contract AT(29-2)-2338 for the U. S. Atomic Energy Commission.

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I. INTRODUCTION

The Large Radioisotope Heat Source Capsule (LRHSC) Program was established to develop the technology of an isotope fuel capsule capable of operation in a space environment at a surface temperature of about 2000° F for five (5) years or more. The program included design, fabrication, and testing of a tantalum alloy capsule design meeting the operating requirements of a typical space mission oriented heat source.

During the first quarter of GFY 1970, the tantalum alloy capsule was selected for use in the Transit Program. At that time the LRHSC Program was reconstructed into two (2) series of tasks. The first series of tasks are a continuation of the high temperature fuel isotope fuel capsule technology program. The second series of tasks provides direct support to the development of the isotope fuel capsule for the Transit RTG. In the second quarter of FY 1970 the tantalum alloy capsule was selected for the Pioneer Program. The capsule design was modified by shortening the piece parts to reflect the reduced fuel inventory. This constituted the only change.

Contracts were received in the third quarter for fabrication of both Transit/Pioneer capsules. These capsules are to be used in the development test programs. All of the original fabrication orders and an additional order for replacement piece parts have been completed and delivered.

Section II of this report contains a description of and a progress report on each of the tasks in the High Temperature Capsule Technology Program. Section III contains the same information for the tasks in the Transit Support Program.

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II. HIGH TEMPERATURE CAPSULE TECHNOLOGY PROGRAM

The objective of this program continues to be the development of the technology for an isotope fuel capsule capable of operation in a space environment at a surface temperature of 2000°F or more for five (5) years or more. The work includes process, fabrication and test activities. The process and fabrication have included the work required to define an acceptable manufacturing specification for the reference design capsule and to manufacture the test items required for the program. The test program involves various coupons and capsules with evaluation of chemical compatibility, thermal cycling and adherence of coatings, capsule creep, capsule impact and capsule survival in potential abort environments. The data generated in this program will be used to validate design approaches and define design margins that would exist for high temperature capsules intended for flight systems.

The high temperature capsule technology program is being accomplished under the following tasks:

- A1 — Technology Program Management
- A3 — Hardware Design, Fabrication and Assembly
- A4 — Capsule Creep Testing
- A5 — Capsule Impact Testing
- A6 — Material Compatibility Testing

The objectives and progress during the quarter for each of the above tasks follow.

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TASK NO. A1 - TECHNOLOGY PROGRAM MANAGEMENT

Task Objectives

The objectives of this task are to provide management, direction and planning for all aspects of the High Temperature Capsule Technology Program. This includes technical direction, reporting, detailed plans and procedures.

Summary of Status

The technology program milestones are shown in Table A1-1. The program is on schedule with regard to the milestones with the exception that the coupon compatibility testing will be completed in June rather than March.

TABLE A1-1
TECHNOLOGY PROGRAM MILESTONES

	Dates
1. Complete Reference Capsule Impact Test Series	Completed
2. Release Reference Capsule Impact Test Topical (Topical Report No. 8)	Completed
3. Complete Compatibility Testing (out to 1,000 hours and up to 2500°F)	June 1970
4. Release Preliminary Creep Test Topical (Topical Report No. 10)	June 1970
5. Release Compatibility Test Topical (Topical Report No. 11)	June 1970

page blank

TASK NO. A3 - HARDWARE DESIGN, FABRICATION, AND ASSEMBLY

Task Objectives

This task contains all efforts related to hardware design, fabrication, and assembly in support of other program tasks. The principal effort will be the fabrication and assembly of five (5) capsules for the thermal and impact test tasks. One capsule will be fabricated which contains an internal heater to simulate capsule operation when fueled. All supporting test fixtures for the coupon test task will be built under this task.

Summary of Task Status

Tests on the internally heated LRHSC capsule were completed in June 1970. Temperature drops through the capsule elements were determined with helium in the gaps. Stabilized power for 400 watts was achieved with helium filled gaps with the liner temperature less than 1100°F.

Accomplishments During the Quarter

A new heater was fabricated using .032 diameter Nichrome wire. This heater was tested at 400 watts and reached a maximum temperature of 960°F. The heater was then placed into the liner and feed-through subassemblies and E.B. welded. After welding, thermocouples were attached as shown in Figure A3-1. Figures A3-2 through A3-5 show components used in the liner assembly.

The first test configuration was that of the liner assembly in a vacuum of 5.0×10^{-5} Torr. The second test was also on the liner assembly but in one atmosphere of high purity helium. Figures A3-6 and A3-7 show the results of these tests. Figure A3-8 shows the post test condition of the liner assembly.

The next test configuration was that of the structure assembly. A structure shell was slipped over the liner assembly and E.B. welded. Thermocouples were attached as shown in Figure A3-9. This assembly was also tested in vacuum and helium. Test results for the structure assembly are shown in Figures A3-10 and A3-11. Figures A3-12 and A3-13 show components used in this assembly and Figure A3-14 shows the post test condition.

Figure A3-1. Liner Assembly Thermocouple Location

The final test configuration was on the barrier assembly. A Pt-10% Rh barrier shell was placed over the structure assembly and tig welded. Thermocouples were attached as shown in Figure A3-15. TC No. 3 exits from the bottom of the barrier shell and is attached to the structure assembly. Testing was also conducted in vacuum environment and helium atmosphere. Test results are shown in Figures A3-16 and A3-17. Components used are shown in Figures A3-18 and A3-19.

A variable pressure test was also conducted on the barrier assembly. This consisted of placing one atmosphere of helium in the glove box and putting 109 watts of power on the capsule. When the temperature stabilized readings were recorded, then the pressure was reduced to 100 mm Hg and the temperatures recorded. This procedure was followed down to 10^{-2} mm Hg. Figure A3-20 shows the results of this test.

Figure A3-21 shows the testing box and instrumentation used. Figure A3-22 (SA-N73414004) shows the complete internally heated capsule design.

Heater Assembly

Structure Shell, Liner Body, and
Electrical Feed-Thru Assembly

Figure A3-2. Components Used in the Liner Assembly

View of Assembly Sequence

Liner Cap, Structure Cap, and Barrier Cap

Figure A3-3. Electrical Feed-Thru Assembly

External View

Internal View

Figure A3-4. View of Electrical Feed-Thru Flanges

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Welded Liner Assembly
Without Instrumentation

Mating of Electrical Feed-Thru Flanges

Figure A3-5. Components Used in Liner Assembly

Figure A3-6. Liner Assembly Vacuum Test

Figure A3-7. Liner Assembly Helium Test

Liner Assembly With Thermocouples

Complete Liner Assembly

Figure A3-8. Post-Test Condition of Liner Assembly

Figure A3-9. Structure Assembly Thermocouple Location

Figure A3-10. Structure Assembly Vacuum Test

Figure A3-11. Structure Assembly Helium Test

Liner Assembly in Structure Shell

Structure Shell Assembly Without Instrumentation

Figure A3-12. Components Used in Structure Assembly

Structure Shell Assembly with Thermocouple Slot

Structure Shell Assembly with Thermocouple

Figure A3-13. Components Used in Structure Assembly

Structure Shell Assembly with Thermocouples

Figure A3-14. Post-Test Condition of Structure Assembly

Figure A3-15. Complete Assembly Thermocouple Location

Figure A3-16. Complete Assembly Vacuum Test

Figure A3-17. Complete Assembly Helium Test

Structure Shell Assembly with Barrier Cap

Figure A3-18. Components Used in Structure Assembly

Barrier Sub-Assembly Showing TC Exit Point

Barrier Assembly With Thermocouples

Figure A3-19. Components Used in Structure Assembly

Figure A3-20. Complete Assembly Variable Pressure Test

Vacuum Glove Box with Vacuum Ion Controller
and Absolute Pressure Gage

Volt Meter, Ammeter, Wattmeter, and Variac

Figure A3-21. Testing Box and Instrumentation Used
on the Barrier Assembly

OR BY	G BURNETT	<i>s/mk</i>		American International Bank American National	c/o New York Savings Bank, Baltimore MD
CHE BY					
				INTERNALLY HEATED CAPSULE (LRHSC)	
				NITE CODE RIGHT SIDE	
			E	09974	73414004
			SCALE		SHEET

TASK NO. A4 - CAPSULE CREEP TESTING

Task Objectives

The LRHSC Program fuel capsule design utilizes a first generation tantalum alloy (TA-10W) for primary containment of the fuel, a second generation tantalum alloy (T-111) for secondary containment, and Pt-10%Rh for oxidation protection of the reactive refractory metal containers. The objective of this task is to provide and test a design approach that accounts for creep deformation at elevated temperatures for this capsule design.

To achieve this end a test series has been designed to evaluate heat-to-heat variations on the creep of the T-111 structural shell, determine the effects of variable stress on creep of the shell, relate uniaxial and biaxial stress states to creep of T-111 and finally to determine the interacting effects of capsule components on the creep of the structural member.

Creep testing activities during GFY 1970 are related to completing ongoing tests, post test evaluations and documentation of results. No new tests will be initiated during GFY 1970. Post test analysis and documentation will be completed on capsules tested in GFY 1969 and those completed in GFY 1970. A topical report summarizing this work will be released during the year.

Summary of Task Status

Creep testing of Capsule B-3a was completed. Creep testing of B-6a is being continued until July 1, 1970. These capsules are long term tests of the T-111 structure shell. Statistical analysis of the data generated by the program has been completed and the creep topical has been written and published.

Accomplishments During the Quarter

Creep capsule B6 has logged over 8600 hours at 2000°F under stress. The total apparent strain on the capsule is 1.35%. The strain history is shown in Figure A4-1. It is estimated that this test will continue another 3400 hours prior to achieving the target 5% strain.

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Figure A4-1. Creep Capsule B6a Test Behavior

Data analysis for the topical report is essentially complete. The stress-strain rate relationship indicates that there is a statistically significant difference between the very long term tests (B3a and B6) and the shorter tests. The difference is a slight increase in creep rate for the long term tests with an equivalent stress. Indications are that over very long periods of time the specimens are losing strategic interstitials in the very high vacuum. This has been observed in other tests of the same alloy in ultra high vacuum where the creep rate has changed by a few orders of magnitude due to loss of oxygen. This condition would more than account for the apparent factor of two difference observed by present analysis. While the difference is small, it does prevent, at this time, a unified equation describing the behavior for all of the tests. Further post-test analyses will be required in order to establish the cause for the creep rate variation and develop the equation. This does not, however, prevent utilizing the data for design of a sealed radioisotope heat source capsule.

Capsule B3-a remains in the test rig ready for immediate startup in the event that it is deemed desirable to further evaluate the very low stress rate behavior.

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TASK NO. A6 - MATERIAL COMPATIBILITY

Task Objectives

The LRHSC design requires that many dissimilar materials including noble metals, refractory metals and various ceramics be placed in close proximity or in contact with one another. The operating conditions for the capsule (2000 °F for 5 years) are in a temperature range where the rates of solid state diffusion and vapor transport may be increased to levels which would cause significant degradation of the mechanical properties of capsule materials. To insure structural integrity of present and future capsules, the compatibility task will determine the reactions that occur between the various materials proposed for capsule construction and evaluate what deleterious effect these reactions will produce during the lifetime of a capsule.

During GFY 1970, three (3) types of compatibility tests will be conducted. These are structural and liner materials, emittance coating and hold down materials, and reentry materials. Testing will be conducted at 2000 °F, 2250 °F, and 2500 °F for times of 10, 100, and 1,000 hours.

Summary of Task Status

The following coupon stacks have been fabricated and placed on test this Quarter:

CS-21-1, CS-22-1, CS-22-2, CS-23-2, CS-25-1,
CS-25-2, CS-27-1, CS-27-2.

All of the stacks have been tested and evaluated. The compatibility topical has been written and issued.

Accomplishments During the Quarter

Identification of the coupon stacks is being maintained according to Figure A6-1.

Figure A6-1

	10 Hr.	100 Hr.	1000 Hr.
2000 °F		CS-21-1 Test Complete 3/9/70 CS-21-2 Test Complete 3/8/70	CS-22-1 On Test CS-22-2 On Test
2250 °F	CS-23-1 Assembled 3/22/70 Test Complete 3/27/70 CS-23-2 Assembled 3/22/70 Test Complete 3/23/70	CS-24-1 Complete 1/2/70	Coupons & Holder Available Test Complete CS-25-1 CS-25-2
2500 °F		Coupons & Holder Available Test Complete CS-27-1 CS-27-2	

Key: CS-2X-Y

CS: Indicates "coupon stack"

CS-2X: The digit two indicates the second series of coupon stacks. The X digit will be from 1 to 8 and corresponds to the test parameters.

CS-2X-Y: The Y digit indicates the type of coupon stack. A-1 type contains only refractory metals, platinum alloys and alumina coating. The -2 type contains emittance coatings, reentry materials as well as refractory metals.

Testing was completed on CS-25-1, CS-25-2 (both 1000 hrs. at 2250 °F) and CS-27-1, CS-27-2 (both 100 hrs. at 2500 °F). These four coupon stacks have been mounted and sectioned for metallographic examination. The data on the refractory to noble metal interface of these stacks is included in this report (Table A6-1).

TABLE A6-1
 "Pt-Rh VS REFRACTORY METAL REACTION ZONES"

Interface	10 Hrs. 2250 °F	100 Hrs. 2250 °F	1000 Hrs. 2250 °F	100 Hrs. 2000 °F	1000 Hrs. 2000 °F	75 Hrs. 2500 °F
T-111 to Pt-20Rh		.00276	.0072	.00156		.0049
T-111 to Pt-10Rh					.0041	
Ta-10W to Pt-10Rh			.0046			
TZM to Pt-20Rh	.00144	.00276	.0063	.00144		.0031
Nb-1Zr to Pt-20Rh	.00132	.00252	.0056	.00156		.0043
Zone Widths in Inches						

CS-21-1 and CS-23-1, 100 hours at 2000 °F and 10 hours at 2250 °F respectively, were examined and the reaction zones measured. Table A6-1 shows the information that has been obtained from these stacks and others that have had platinum alloy and refractory alloy interface. The numbers are basically consistent though some differences arise from the fact that intimate contact has not always been maintained, usually due to variation in coating thicknesses in other areas of the coupon stack. Intimate contact is the worst case possible and in a practical sense can occur only in a few areas. Intermittent contact as witnessed in the coupon stacks is indicative of the reactions one could expect in capsule operation.

CS-22-1 and CS-22-2 were placed on test during June. The test time will be reduced to that which can be completed and evaluated within this fiscal year.

Metallographic examination was completed on CS-21-1, CS-21-2, CS-23-1, and CS-24-1. CS-24-1 was prepared for electron beam microprobe analysis. The analysis results are contained in the Compatibility Topical Report. A -2 type coupon stack will also be examined with the microprobe, however, the precise stack has not been determined.

AXF-5Q

Reaction Zone

TZM
100 Hr. 2000 °F

Figure A6-2. AXF-5Q vs. TZM

TZM

Reaction Zone

Iron Titanate
100 Hr. 2000 °F

Figure A6-3. Iron Titanate Plasma Sprayed
on Pt-20Rh vs. TZM

The examination of various interfaces at high magnification has shown small but definable reaction zones. Preliminary examination of CS-27-2 (100 hr. at 2500 °F) has indicated that these reactions will become significant even at short times (75 hrs.) at higher temperatures.

Figure A6-2 shows AXF-5Q (dark area) against TZM. The photo shows a reaction zone with a continuous well defined boundary. The width of the zone is approximately 0.0005 inches.

Figures A6-3 and A6-4 show Pt-20Rh that has been plasma sprayed with iron titanate against TZM. In A6-3 the small area indicated by the arrow appears as if it might be part of the iron-titanate coating. However, examination with polarized light shows the area to be composed of discrete units (Figure A6-4). The iron titanate does not react to polarized light.

Figure A6-5 shows platinized alumina against T-111. There appears to be a reaction product remaining in the interface. The zone is very small and it appears doubtful that the microprobe can isolate these areas.

Figures A6-6 and A6-7 from CS-23-1 (10 hr. 2250 °F) shows TZM against Ta-10W and Cb-3015. Again recrystallization has taken place near the interface. Figure A6-8, A6-9, and A6-10 are from CS-21-1 (100 hr. at 2000 °F). The interfaces are TZM to Ta-10W, Nb-1Zr and T-111. It is noteworthy that in this test there is no recrystallization of the TZM.

For times in the neighborhood of a capsule lifetime, the 100 hr. 2000 °F data is insufficient for indicating the recrystallization behavior of TZM.

Figures A6-11 and A6-12 show the interface of T-111 and Pt-20Rh. In A6-12, the T-111 has been etched but not the Pt-20Rh. A6-11 shows that one of the reaction zones etch much faster electrolytically than either the bulk T-111 or the Pt-20Rh. This would suggest that the reactive metal hafnium is diffusing into this area and producing this effect. Microprobe analysis will be necessary to verify or refute this hypothesis.

TZM

Reaction Area
Reacting to Polarized
light

Iron Titanate

Pt-20Rh
100 Hr. 2000 °F

Figure A6-4. Iron Titanate Plasma Sprayed
on Pt-20Rh vs. TZM

Pt-20Rh

Platinized Alumina

T-111
100 Hr. 2000 °F

Figure A6-5a. Platinized Alumina Plasma Sprayed
on Pt-20Rh vs. T-111

Pt-20Rh

Platinized Alumina

T-111

Figure A6-5b. Platinized Alumina Plasma Sprayed
on Pt-20Rh vs. T-111

TZM

Cb-3015
10 Hr. 2250 °F

200X

Figure A6-6. TZM vs. Cb-3015

Ta-10W

TZM
10 Hr. 2250 °F

200X

Figure A6-7. Ta-10W vs. TZM

Ta-10W

TZM
100 Hr. 2000 °F

Figure A6-8. Ta-10W vs. TZM

TZM

Nb-1Zr
100 Hr. 2000 °F

Figure A6-9. TZM vs. Nb-1Zr

TZM

T-111
100 Hr. 2000 °F

Figure A6-10. TZM vs. T-111

Pt-20Rh

Area A
After Etching

T-111
100 Hr. 2000 °F

Figure A6-11. Pt-20Rh vs. T-111

The remaining photos are all from CS-27-1 and CS-21-2 and are indicative of material behavior at a 2000 °F operating temperature.

<u>Figure</u>	<u>Interface</u>	<u>Magnification</u>	<u>Remarks</u>
A6-13	TZM vs. Mo 50 Re	100	Both coupons etched
A6-14	TZM vs. Mo 50 Re	500	Both coupons etched
A6-15	T-111 vs. Mo 50 Re	100	Both coupons etched
A6-16	T-111 vs. Cb 3015	500	Not etched; areas are diffusion bonded
A6-17	T-111 vs. RPG	500	No observable reaction
A6-18	T-111 vs. AXF-5Q	500	AXF-5Q below focal point
A6-19	Al ₂ O ₃ on T-111 vs. Pt-20Rh	100	No reaction
A6-20	Ta-10W vs. Nb-1Zr	100	Both etched; no reaction
A6-21	Ta-10W vs. RPG	100	Ta-10W etched; no reaction
A6-22	Nb-1Zr vs. Platinized alumina	500	Nb-1Zr etched; Epoxy in interface, no apparent reaction
A6-23	AXF-5Q vs. Iron titanate	500X	Good contact, no apparent reaction
A6-24	TZM vs. Platinized alumina	500X	No apparent reaction
A6-25	T-111 (after 100 hr. at 2000 °F)	500X	Polarized light; grain size smaller than ASTM 14
A6-26	RPG	500X	Polarized light

Pt-20Rh

↓
 (A)
 ↑
 Area Etches
 Very Rapidly

T-111
 100 Hr. 2000 °F

Figure A6-12. Pt-20Rh vs. T-111

TZM

Mo-50Re
 100 hr. 2000 °F

Figure A6-13. TZM vs. Mo-50Re

TZM

Mo-50Re
100 Hr. 2000 °F

Figure A6-14. TZM vs. Mo-50Re

T-111

Mo-50Re
100 Hr. 2000 °F

Figure A6-15. T-111 vs. Mo-50Re

Cb-3015

T-111
100 Hr. 2000 °F

Figure A6-16. Cb-3015 vs. T-111

RPG

T-111
100 Hr. 2000 °F

Figure A6-17. RPG vs. T-111

T-111

AXF-5Q
100 Hr. 2000 °F

Figure A6-18. T-111 vs. AXF-5Q

T-111

Al_2O_3 Plasma
Sprayed Coating

Unetched Pt-20Rh

Figure A6-19. Al_2O_3 Plasma Sprayed on T-111
vs. Pt-20Rh

Nb-1Zr

Ta-10W
100 Hr. 2000 °F

Figure A6-20. Nb-1Zr vs. Ta-10W

RPG

Ta-10W
100 Hr. 2000 °F

Figure A6-21. RPG vs. Ta-10W

Pt-20Rh

Platinized
Alumina

Epoxy

Nb-1Zr
100 Hr. 2000 °F

Figure A6-22. Platinized Alumina
Plasma Sprayed on Pt-20Rh vs. Nb-1Zr

AXF-5Q

Iron Titanate

Pt-20Rh

Figure A6-23. Iron Titanate Plasma Sprayed
on Pt-20Rh vs. AXF-5Q

Pt-20Rh

Platinized Alumina

TZM

Figure A6-24. Platinized Alumina Plasma Sprayed on Pt-20Rh vs. TZM

T-111

Polarized Light

After 100 Hr. at 2000 °F
Average Grain Size
ASTM 9

Figure A6-25. T-111

Figure A6-26. RPG Under Polarized Light
at 500X

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III. TRANSIT CAPSULE SUPPORT PROGRAM

The tasks being accomplished in direct support of the Transit Capsule Development Program are as follows:

- B1 - Transit Support Program Management
- B3 - Transit Capsule Impact Tests
- B4 - Transit Capsule Fire Tests
- B5 - Transit Capsule Explosive Overpressure Tests
- B6 - Transit Capsule Oxidation Resistance
- B8 - Transit Capsule Fragmentation Tests
- B10 - Fabrication of Transit Capsule Piece Parts

Task objectives, schedules and progress are detailed on the following pages.

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TASK NO. B1 - TRANSIT CAPSULE PROGRAM MANAGEMENT

Task Objectives

The objectives of this task are to provide management, direction and planning for all aspects of the Transit capsule support effort. This includes technical direction, reporting, detailed plans and procedures. Particular emphasis will be directed to maintaining a close liaison with TRW and MRC.

Summary of Status

The milestones for the Transit Support Program are shown in Table B1-1. All of the test milestones have slipped at least one month.

TABLE B1-1

TRANSIT SUPPORT MILESTONES	
	Dates
1. Complete Transit Sized Capsule Impact Tests	Completed
2. Complete Thermal Verification Testing	Completed
3. Complete Transit Capsule Impact Test Program	June 1970
4. Complete Transit Capsule Fire Test Program	June 1970
5. Complete Transit Capsule Overpressure Test Program	June 1970
6. Complete Transit Capsule Fragmentation Test Program	June 1970
7. Complete Transit Post-Impact Oxidation Testing	July 1970

The test dates for the Transit Design Verification Tests are slipping due to slips in delivery of the test capsules/heat sources. A meeting was held at MRC during the latter part of the month to review the status of the capsule/heat source assembly development and to project new assembly delivery dates. On the basis of the tentative dates for capsule/heat source delivery, the following test dates are estimated:

Overpressure	June 15-16
Fragmentation	June 19-22
Impact	June 15—→
Fire	June 24-26

These dates will be reviewed when a final test hardware delivery date is received.

Delivery of the initial Transit capsule piece part order was completed during the month. An additional piece part order has been received and a process upgrading program directed. Details on these items are contained in the Task B 10 report.

The following GFY 1970 tasks have been completed and are no longer reported:

- Task B2 — Transit Capsule Process Development and Qualification
- Task B7 — Transit Capsule Thermal Verification
- Task B9 — Transit Sized Capsule Fabrication and Testing

TRANSIT HEAT SOURCE DESIGN VERIFICATION TESTS

(Tasks B3, B4, B5, B6, and B8)

Task Objectives

B3 - Transit Capsule Tests

This task will provide the test data and complete post test evaluations of twelve (12) full scale Transit capsules.

B4 - Transit Capsule Fire Tests

This task will determine the response of the capsule to a solid propellant fire simulating a potential launch abort condition. Three (3) capsules will be exposed to fires resulting from burning blocks of propellant. Capsules will be instrumented to obtain the Transit temperature response. The test configuration may be with or without reentry shield, with or without oxidation clad, depending on results of overpressure and fragmentation tests. A comparison of fuel retention as well as complete post-test chemical and metallurgical examinations will be conducted.

B5 - Transit Explosive Overpressure Test

This test will evaluate the capability of the heat source to withstand the shock wave which may result from a launch pad abort. Two (2) capsules will be used for this test, one of which may subsequently be used for sequential testing in Tasks B4 and B8.

B6 - Transit Capsule Post-Impact Oxidation Resistance

This task will provide data with regard to the oxidation parameters of actual capsules. It will make use of two (2) impacted capsules from Task B3 and may include verification coupon testing as well as exposure of an internally heated capsule. Tests will vary temperature and exposure due to cladding breach. Full or partial burial may also be examined.

B8 - Transit Capsule Fragmentation Tests

This task will test and evaluate the damage to the heat source resulting from fragments or shrapnel produced by a launch pad abort. The test will be

performed under controlled conditions by using a sled facility and impacting the heat source into fragments representative of the shrapnel produced by an abort mode.

Accomplishments During the Quarter

During this Quarter, test procedures were written for the following tasks:

<u>Task</u>	<u>Title</u>	<u>Procedure No.</u>
B3	Transit Impact Tests	DTP-734-25-002
B4	Transit Fire Test	DTP-734-25-004
B5	Transit Explosive Overpressure Test	DTP-734-25-005
B8	Transit Fragmentation Test	DTP-734-25-003

These procedures were taken to Sandia for discussions and concurrence by Sandia test personnel. Final drafts of the procedures were reviewed with TRW. The final procedure and the final test plans for these four tests were distributed.

The meeting at Sandia also produced a number of action items. Four of these were resolved by AI. They were:

1. Coordinate a procedure with Sandia for sealing the capsule clad after the capsules have been arc-jet tested and prior to impact test (two capsules).
2. Prepare a sketch for Sandia showing the desired dimensions to be cut on the Algol IIB propellant blocks.
3. Determine the IR photographic technique for propellant fire tests.
4. Prepare a cost estimate and schedule and present the feasibility and problem areas of placing an internal heater in an impacted capsule for the post-impact oxidation test.

The clad sealing technique was discussed with Sandia and will be definitized when the arc-jet test plans are completed. Action Item 2 was accomplished.

The recommended technique for IR photography on the fire test is as follows: Use Kodak infrared film in a 4 x 5 camera with telephoto lens and an infrared filter, either a No. 87 or No. 88A. The lens opening should be

f-16 and the shutter speed 1/400th of a second. The distance from the camera to the propellant should be about 40 feet and the camera (on the contact test) should be elevated to account for the rim which forms along the inhibited edge of the burning propellant.

Ordinary color movie film can be used for documentation, providing the lens aperture of the movie camera is set appropriately for the neutral density filter being used. The following is the recommended technique for photographing high temperature flames with ordinary color film. Use K type Kodachrome color film, a camera with a framing rate of 24 frames/sec, a lens opening of f-16, and a 3.0 neutral density filter.

The temperature requirements for the internally heated, impacted capsule were calculated by TRW and provided to AI as follows:

	<u>Fragmented SSCS Fuel</u>	<u>Solid SSCS Fuel</u>
Good contact between capsule layers	2200 °F	1300 °F
10 mil gap between layers	2645 °F	1785 °F

The results of the Task 8 impact tests show the fuel to be fragmented and the materials to be in relatively good contact after impact. Therefore, the required heater temperatures will be greater than or equal to 2200 °F but less than or equal to 2600 °F (2200 X 2600). This temperature precludes the use of standard heater materials, and the requirement for the heater to operate in an oxidizing atmosphere precludes the use of refractory metals, all of which precludes the use of stock heaters. The tentative requirements for the heater are: 800 watts of power; operation in air for at least three (3) months at up to 2600 °F; approximately 1/2-inch diameter by 5-inches long with a 4-inch heat zone centered within 4-1/2-inches of the closed end of the heater.

The proposed method for installing the internal heater in an impacted capsule is to core drill a hole 5-1/2-inches deep into the non-PRD end of the capsule so that the hole runs as near to the center of the capsule as possible.

A platinum tube having a sealed end will be inserted. The sealed end will go in first. The opposite end will be flared or flanged to overlap the platinum cladding. This end will be welded to the clad. A heater having outside diameter which slip fits the inside diameter of the tube will be used.

Some of the problems involved with installing a heater in an impacted capsule follow. A hole must be drilled and/or cored from the non-PRD end, through the center of the capsule to a depth of approximately 5-1/2-inches. The hole will penetrate the platinum cladding, the strength member, the liner and the cermet fuel simulant (SSCS) as shown in the attached sketch. In order to prevent the internal surfaces of the capsule from becoming contaminated with grease or oils, all of the machining must be performed dry. There is no assured way, however, to prevent thoria contamination of the external surface of the strength member or cladding during the coring operation. If those surfaces become contaminated with thoria prior to initiating the test, it may be difficult to determine this contamination from true thoria release during the test.

Another potential problem is that the thoria may be fragmented to where the cored hole would not support itself and thereby prevent insertion of the platinum tube. After the tube is inserted, it will be welded to the platinum cladding. This leaves yet another path for thoria to escape from the strength member (and for air to enter it), as the hole through the strength member and liner would not be resealed. The access path then would depend on the fit of the cladding to the strength member and the location of the crack or cracks in the cladding relative to the heater penetration.

TASK NO. B10 - FABRICATION OF TRANSIT CAPSULE PIECE PARTS

Task Objectives

The objective of this task is to fabricate deep drawn tantalum alloy and Pt-20Rh clad piece parts in accordance with TRW Systems and Isotopes, Inc. drawings. The capsule piece parts are to be used in the development testing of the Transit and Pioneer programs.

Summary of Task Status

All of the Transit piece parts have been fabricated and delivered to MRC. In addition, replacement piece parts were fabricated and delivered this Quarter. About fifteen (15) equivalent piece parts were involved in the replacement order. Plans were completed for process upgrading with substantial completion expected this Quarter.

Accomplishments this Quarter

Fabrication and deliveries were concluded in accordance with Table B 10-1.

TABLE B10-1
TRANSIT/PIONEER DELIVERY SCHEDULE

	Production Order		Replacement Order	
	Transit	Pioneer	Transit	Pioneer
Liner Caps	59	22	19	15
Liner Bodies	59	22	15	8
Strength Member Caps	63	22	15	7
Strength Member Bodies	63	22	13	8
Clad Caps	64	22	6	4
Clad Bodies	64	22	8	1
Fuel Locator Rings	59	22	15	8

TABLE B10-2
CAPSULE DISCREPANCIES - LOT COMPARISON
NONCONFORMANCES - PERCENT

Statistical analysis was initiated this Quarter to determine the level of non-conformance, the need for process upgrading and the specific areas where additional effort was required. Table B10-2 and 3 illustrate the degree of non-conformance by lot fabricated. In all cases the nonconformances have decreased to a relatively low level of occurrence. However, certain critical characteristics such as dome end wall thinning and eccentricity in weld preparation areas dictate the need for process upgrading. The general status evaluation of this situation is indicated in Table B10-4.

Process upgrading to be investigated and checked out in June consist of the following activities:

The strength member drawing procedure will be modified to add a coining operation prior to the 6th draw. This operation may be accomplished by high energy forming if required to seat the punch in the coining die. In addition to this, the side walls will not be reduced on the 6th and final draws in an attempt to limit the extent of spring back. Other approaches may be used to produce the desired internal spherical radius, however; the techniques selected for trial is the minimum in terms of process change, time to perform and minimum change in metallurgical structure.

If this technique is successful for the strength member body, the strength member cap will likewise be formed to obtain an adequate inside spherical radius. Four (4) each T-111 die blanks have been committed to this investigation. (Chart 1 illustrates the specific approach selected for strength member bodies and caps.) Ta-10W material variations in the last shipment necessitate a process investigation to handle the different material characteristics. What is contemplated at present is a new concentricity ring at the 5th draw and less wall reduction at the 5th and final draws. No other changes are envisioned.

Several machining improvements are being evaluated. They are listed on Chart 2.

The schedule for the process upgrading activity is illustrated in Figure B10-1. As noted, most of the activities will be concluded this fiscal year.

The Transit/Pioneer production schedule for the flight hardware is as indicated in Figure B10-2.

TABLE B10-3

CAPSULE DISCREPANCIES - LOT COMPARISON
NONCONFORMANCES - PERCENT

TABLE B10-4
GENERAL STATUS EVALUATION

	PROCESS STATUS		YIELD ESTIMATE	REMARKS
	FORMING	MACH.		
LINER CAP	OK	OK	>80%	LAST SHIPMENTS (24 ea) WALL AND SPHERICAL RADIUS OK.
LINER BODY	OK	OK	>80%	MATERIAL VARIATION MAY RE- QUIRE PROCESS CHANGE
STR. MEMBER CAP	NO	NO	-	NEEDS WORK IN FORMING/COINING/ MACHINING
STR. MEMBER BODY	NO	NO	-	NEEDS WORK IN FORMING/COINING/ MACHINING
CLAD CAP	OK	OK	>80%	WALL THINING IN DOME END AND TRANSITION SOLVED
CLAD BODY	OK	OK	>80%	WALL THINING IN DOME END AND TRANSITION SOLVED

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CHART 1

SUGGESTED APPROACH
STRENGTH MEMBER BODY

A. ONE PART THRU FIVE DRAWS PLUS COIN PLUS 2700°F ANNEAL

- 1) DETERMINE WALL THICKNESS AND RADII.
(MAINTAIN REFERENCE PARTS)
- 2) WITH CONCENTRICITY RING COIN IN $\approx .160$ CLEARANCE
COINING DIE AT MINIMUM PRESSURE.
- 3) WHILE ON PUNCH INDICATE OD SPHERICAL RADIUS. IF GOOD,
REMOVE FROM THE PUNCH AND FULLY INSPECT WALL
THICKNESS, ID AND OD RADIUS.
- 4) IF RADIUS IS NOT GOOD AFTER STEP (1) INCREASE PRESSURE AND
DETERMINE AMOUNT OF MOVEMENT OBTAINED BY INCREASED
PRESSURE. PLOT THE DATA AND FROM THIS DETERMINE IF
RAPID HIGH ENERGY FORMING OF NOSE SHOULD BE ATTEMPTED.
- 5) IF NO CHANGE IS PRODUCED BY PRESSURE INCREASES, RAPID FORM
NOSE AT HIGH PRESSURE.
- 6) DRAW THROUGH $.103$ CLEARANCE DRAW RING. (PRESENT CLEARANCE)
- 7) REMOVE AND INSPECT - DETERMINE IF SPRINGBACK OR WALL
THICKNESS OR A COMBINATION OF THESE IS CAUSING THE
TAPERING EFFECT.

B. ONE PART THRU FIVE DRAWS PLUS COIN PLUS 2700°F ANNEAL

- 1) FOLLOW ABOVE PROCEDURE EXCEPT FOR STEP 6), DRAW
THRU $\approx .140$ CLEARANCE DIE.

CHART 2

MACHINING IMPROVEMENTS

1. SPHERICAL RADIUS MACHINING TOOL WITH RADIUS INSPECTION
CAPABILITY ATTACHMENT
 - a) IMPROVE DIMENSIONAL CHARACTERISTICS
 - b) IMPROVE INSPECTION CAPABILITY
2. INSTALL DIGITAL READOUT EQUIPMENT
 - a) IMPROVE OPERATOR EFFICIENCY -
FOR WELD PREP MACHINE
 - b) USE FOR IN-PROCESS INSPECTION ACCEPTANCE
3. INVESTIGATE LOW TEMPERATURE COOLANTS
 - a) IMPROVE SURFACE FINISHES
 - b) REDUCE TOOL WEAR (USE STANDARD TOOLS)
 - c) DECREASE MACHINE TIME
4. DESIGN AND FABRICATE LINER CAP FIXTURE
CHANGE OPERATION TO BORE HOLE IN END. THEN LOCATE
WELD PREPARATION FROM EDGE OF HOLE. THIS WILL ELIMINATE
LENGTH DISCREPANCY ON LINER CAP.

Figure B10-1. Process Upgrading Activity Schedule

Piece Part	7/1/70	8/1/70	9/1/70	10/1/70	11/1/70	12/1/70	12/30/70
1. Liner Caps	10	10	10	10	10	10	10
2. Liner Bodies	10	10	10	10	10	10	10
3. Strength Member Caps	10	10	10	10	10	10	10
4. Strength Member Bodies	10	10	10	10	10	10	10
5. Clad Caps	10	10	10	10	10	10	10
6. Clad Bodies	10	10	10	10	10	10	10
7. Fuel Locator Rings	10	10	10	10	10	10	10
<u>Die Blank Requirements</u>	7/1/70	8/7/70		10/13/70			Current Inventory
6-1/2" Dia. T-111	25 ea.	25 ea.		25 ea.			21 ea.
4" Dia. T-111	25 ea.	25 ea.		25 ea.			9 ea.
*6-1/2" Dia. Ta-10W	28 ea.	28 ea.		28 ea.			8 ea.
4" Dia. Ta-10W	25 ea.	25 ea.		25 ea.			55 ea.
7" Dia. Pt-20Rh	25 ea.	25 ea.		25 ea.			16 ea.
4" Dia. Pt-20Rh	25 ea.	25 ea.		25 ea.			8 ea.
* Fuel Locator Ring Stock 3 pieces each							
Drawings Required 7/1/70 (Isotopes Inc.)							

Figure B10-2. Transit/Pioneer Production Schedule