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LARGE RADIOISOTOPE
HEAT SOURCE CAPSULE (LRHSC)
SIXTH QUARTERLY PROGRESS REPORT
OCTOBER-DECEMBER 1968

AEC Research and Development Report

ATOMICS INTERNATIONAL

A DIVISION OF NORTH AMERICAN ROCKWELL CORPORATION

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FOREWORD

This is the sixth 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 October 1, 1968 through December 31, 1968 under contract AT(29-2)-2338 for the U. S. Atomic Energy Commission.

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I. INTRODUCTION

The LRHSC Program has been established to develop the technology of an isotope fuel capsule capable of operating in a space environment at a surface temperature of about 2000°F for five years or more. The objectives of the present phase are the design, fabrication, test and evaluation of a test capsule whose design takes into account the operating requirements of a typical heat source. The work includes process, fabrication and test activities. The process and fabrication includes 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 earth burial. In addition to indicating the suitability of the reference capsule for ground test, the data generated in this study will be used to validate presently accepted design approaches and define design margins that would actually exist for high temperature capsules intended for flight systems.

The LRHSC Program is being accomplished under the following tasks:

- 1) Program Management
- 2) Capsule Design
- 3) Process Development
- 4) Fabrication and Assembly
- 5) Capsule Creep Testing
- 6) Impact Testing
- 7) Soil Burial Testing

TABLE II-1
OFFICIAL MILESTONE SUMMARY

<u>Milestone</u>	<u>Target Dates</u>	
	<u>Approved</u>	<u>Projected Status</u>
1. Startup Creep Rig No. 2	July 1968	Complete
2. Startup Creep Rig No. 3	August 1968	Complete
3. Distribute Topical Report No. 5	September 1968	Complete
4. Complete First "A" Capsule	October 1968	Complete
5. Startup Creep Rig No. 4	October 1968	Complete
6. Complete First "C" Capsule	November 1968	Complete
7. Conduct Preliminary Impact Tests	November 1968	Complete
8. Complete First Creep Rupture Test	January 1969	January 1969
9. Distribute Topical Report No. 6	March 1969	March 1969
10. Complete "C" Capsule Short Term Tests	May 1969	May 1969
11. Distribute Topical Report No. 7	June 1969	June 1969

II. PROGRAM MANAGEMENT

A. TASK OBJECTIVES

The objectives of this task are to provide management, directions and planning for all aspects of the Large Radioisotope Heat Source Capsule Program. This includes technical direction, reporting, detailed plans and procedures.

B. SUMMARY OF TASK STATUS

The official milestones for GFY 1969 are shown in Table II-1. All milestones for the fiscal year have been successfully accomplished. The program completed the first half of the fiscal year on schedule. An overall plan showing the requirements for completion of the program in GFY 1970 has been prepared and is ready for review by the AEC and Sandia.

C. ACCOMPLISHMENTS DURING THE QUARTER

Long range planning has been accomplished during the quarter to define the requirements for completion of the LRHSC Program. The overall plan, including technical requirements, schedules and manpower, has been completed and review with Sandia and AEC management will take place in January. A number of reviews with AEC and Sandia personnel were held during the quarter on program status. Internal reviews of day-to-day problems were held with the performing functional organization to resolve priorities on funding and personnel.

III. CAPSULE DESIGN

A. TASK OBJECTIVES

The objectives of this task are to define the capsule and the test fixture requirements of the Large Radioisotope Heat Source Capsule Program. This encompasses capsule piece-part drawings, capsule assembly drawings, burial heater design and assembly drawings, and welding and test fixture design and drawings.

B. SUMMARY OF TASK STATUS

The forward fuel retainer ring was moved 0.37 in. to the rear to provide symmetry to the capsule at both ends.

C. ACCOMPLISHMENTS DURING THE QUARTER

Design changes have been completed which relocate the forward fuel closure ring to the rear 0.37 in. in order that both impact absorbers will have the same configuration. The Configuration Control Board has approved the baseline change requests and all changes have been incorporated in the respective drawings and released.

Retolerancing of the outer liner caps, inner liner caps, and the fuel closure ring has been approved by the Configuration Control Board. This change provides more realistic parameters for the fabrication process.

IV. PROCESS DEVELOPMENT

A. TASK OBJECTIVES

The objectives of the process development task are to provide the necessary technical guidance and control to all phases of the capsule fabrication in applications considered laboratory practice, to qualify fabrication, assembly and weld procedures, to perform the required experimental work in processes extending present technology, and to provide material and process specifications for the capsule fabrication program. The processes of interest include raw material and piece part fabrication, cleaning, annealing, joining, and non-destructive testing. Studies of alternate materials fabrication and assembly techniques are performed as required.

B. SUMMARY OF TASK STATUS

Development of the T-111 structural weld (W.P. 1238) was completed during the reporting period. This weld procedure is for joining 0.127-in. wall tubing to a 0.127-in. wall end cap. There are additional weld parameters presently being developed for capsules with reduced wall thickness of 0.080, 0.090, and 0.100 mil. Weld development for the 0.080-mil wall was completed during the reporting period. Weld development for the 0.090- and 0.100-mil weld is continuing.

C. ACCOMPLISHMENTS DURING THE QUARTER

Development of the T-111 structural weld (W.P. 1238) has been completed. Figure IV-1 shows a photomicrograph of this weld joint. Penetration for the full circumference of the shell without penetration of the liner has been demonstrated. Figure IV-2 shows a 90-mil T-111 structural weld sample. As can be seen, the weld buildup is minimum after the normal cosmetic pass.

The weld shown in Figure IV-1 has had no cosmetic pass. The specification on this weld is 90% t. The measured weld thickness, after machining, is 96% t. The small notch at the root of the weld is to insure no burn through of the 20 mil outer liner tube. It has been demonstrated that this weld is repeatable and reliable.

Figure IV-1. Photomicrograph of T-111 Structure
Shell to T-111 End Cap Weld

Figure IV-2. Weld Development
Sample 0.090 T-111 Structure
Shell E. B. Welded to
0.090 T-111 End Cap

V. FABRICATION AND ASSEMBLY

A. TASK OBJECTIVES

The objectives of this task are to obtain all raw materials, to fabricate all capsule, coupon piece-parts and assembly tooling, and to assemble all capsules and coupon stacks.

B. SUMMARY OF TASK STATUS

Fabrication of all GFY 1969 capsule piece-parts was completed during the reporting period with the exception of the N73420020 oxidation closure cap.

Assembly of 11 capsules was initiated and completed during the reporting period.

Creep Test Capsules: Creep test capsules A-1a and B-6a were assembled and delivered to test.

Creep Test Standard: Assembly of creep test capsule C-standard was initiated and is complete.

Impact Test Capsules: Impact test capsules B-1a and B-2 were assembled and tested to calibrate the impact facility.

Impact test capsules A-1a and A-2a were assembled and tested.

Impact test capsules A-3a; A-4a; A-5a; and A-6a have been assembled and delivered to test.

C. ACCOMPLISHMENTS DURING THE QUARTER

1. Capsule Piece Part Fabrication

Fabrication of all GFY 1969 capsule piece parts was completed during the reporting period with the exception of the N73420020, Oxidation Closure Cap. Figure V-1 shows the fabrication status.

The tooling necessary for the forming of the oxidation closure cap underwent final modification during the reporting period. Forming of the Pt-Rh caps will be completed during the next reporting period.

PART NO.	PART NAME	MAT'L.	SHAPE	BLANKS CUT	PO'S PLACED	QUANTITY REQUIRED (EACH)	FORMING COMP	FINAL MACH. (COMP EST)	DELIVERED TO AI (EST)
N73420018	INNER LINER END CAP	Ta-10W		COMP.	COMP.	40	COMP.	10-25-68	10-30-68
N73420019	INNER LINER SLEEVE	Ta-10W		N/R	COMP.	20	N/R	10-25-68	10-30-68
N73420027	STRUCTURAL SHELL END CAP	T-111		COMP.	COMP.	35	COMP.	10-30-68	11-06-68
N73420026	OUTER LINER END CAP	Ta-10W		COMP.	COMP.	20	COMP.	10-28-68	11-01-68
N73420024	IMPACT ABSORBER	Ta-10W		N/R	N/R	3	N/R	N/R	AVAIL.
N73420012	OUTER LINER SLEEVE	Ta-10W		N/R	COMP.	20	N/R	10-29-68	11-02-68
N73420010	CLOSURE RETAINER RING	Ta-10W		COMP.	COMP.	40	COMP.	10-15-68	10-21-68
N73420009	IMPACT ABSORBER	Ta-10W		N/R	N/R	3	N/R	N/R	AVAIL.
N73420008	OUTER LINER CLOSURE END CAP	Ta-10W		COMP.	COMP.	20	COMP.	10-29-68	11-05-68
N73420036	PRESSURE FEEDTHRU TUBE	Ta-10W		N/R	COMP.	15	N/R	N/R	AVAIL.
N73420005	STRUCTURAL SHELL	T-111		COMP.	COMP.	20	IN WORK	11-07-68	11-12-68
N73420085	PRESSURE FEEDTHRU TUBE CLAD	Pt-Rh		N/R	COMP.	6	N/R	N/R	AVAIL.
N73420020	OXIDATION CLOSURE CAP	Pt-Rh		COMP.	COMP.	7	IN WORK	1-15-69	1-15-69
N73420002	OXIDATION SHELL	Pt-Rh		COMP.	COMP.	7	IN DEV.	11-14-68	11-19-68

N/R = NOT REQUIRED = COMPLETE

Figure V-1. LRHSC Program - Piece-Part Fabrication Status

a. Pt-Rh Barrier Shell Fabrication

Forming of the Pt-Rh barrier shell, Serial No. 1, was completed during the quarter. Figure V-2 shows this shell after the fourth draw. Figure V-3 shows the shell after draw No. 5, and Figure V-4 shows the shell after the final ironing draw (draw No. 6). Intermediate annealing at 1800°F was accomplished after each draw on Serial No. 1. Table V-1 shows the complete deep drawing sequence used for the Pt-Rh shells. In an attempt to reduce the number of anneals required in this process, barrier shell Serial No. 2, shown in Figure V-5, was drawn through all 6 draws without an intermediate anneal. This part failed at the top of the shell during the final ironing draw. It was concluded that deep drawing of the barrier shell through the first 5 draws could be accomplished without intermediate annealing. Annealing after draw No. 5 at 1800°F prior to the final ironing draw will be required for barrier shell fabrication. Figure V-6 shows barrier shells, Serial No. 3 through Serial No. 8, drawn through 4 of the 6 draws without annealing. Figure V-7 shows barrier shells S/N 003, 004, and 005 after final ironing (draw No. 6).

The final drawn parts are over 7 in. long and have wall thicknesses of 0.020 ± 0.002 in.

b. T-111 Structural Shell Fabrication

As reported last quarter 18 T-111 blanks for structure shells S/N 024 through 041 had been drawn successfully through the first four draws. Fabrication of these shells was completed during the reporting period. Table V-2 shows the status of fabrication of all structural shells processed to date.

The last 18 structure shells were drawn through 6 draws, cleaned, and annealed. During the sixth draw S/N 029, 033, 037, 040, and 041 developed significant axial cracks at the top of the shell, the cause of which is being investigated. These shells were machined back to eliminate the cracked portion, were cleaned and then annealed at 2700°F/hour.

A purchase order was placed with Claiborne Metal Dynamics for fabrication of a new die and deep drawing of these four somewhat short T-111 shells to a final wall thickness of 90 mils. The draw through die No. 9 was completely successful. Figure V-8 shows the four 0.090-in. shells after being drawn through die No. 9. Figure V-9 shows these shells after final machining. The end product

Figure V-2. Pt-Rh Barrier
Shell S/N 001 After
Draw No. 4

Figure V-3. Pt-Rh Barrier
Shell S/N 001 After
Draw No. 5

Figure V-4. Pt-Rh Barrier Shell
S/N 001 After Final Ironing
(Draw No. 6)

TABLE V-1
Pt-Rh DEEP DRAW SEQUENCE
(Starting Blank = 6.25 in. Diameter x 0.030 Thickness)

Figure V-5. Pt-Rh Barrier Shell S/N 002
Drawn Through 6 Draws Without Inter-
mediate Anneals. Part Failed at
Top During Final Ironing Draw.

Figure V-6. Pt-Rh Barrier Shells S/N 003,
004, 005, 006, 007, and 008 Drawn
Through First 4 Draws

Figure V-7. Pt-Rh Barrier Shells
S/N 003, 004, and 005 After
Final Ironing Draw

TABLE V-2

T-111 STRUCTURAL SHELL FABRICATION HISTORY
(Sheet 1 of 2)

S/N	INITIAL BLANK SIZE	DIES USED								ANNEALED AFTER X DRAW	ANNEAL TEMP.	ANNEAL TIME	PART UTILIZA- TION	REMARKS
		1	2	3	4	5	6	7	8					
001	10"		X		X		X			None	None	None	Develop.	
002	8-1/2"		X		X		X	X	X	None	None	None	Develop.	
003	5-3/4"		X		X					None	None	None	Develop.	
004	5-3/4"		X		X					None	None	None	Develop.	
005	5-3/4"		X		X		X			4	2700°F	1 Hr.	Develop.	
006	5-3/4"		X		X		X			4	2700°F	1 Hr.	Develop.	
007	5-3/4"		X		X	X	X	X	X	6	2700°F	1 Hr.	Develop.	
008	5-3/4"		X		X	X	X	X	X	6	2700°F	1 Hr.	Develop.	
009	5-3/4"		X	X	X	X	X	X	X	6	2550°F	1 Hr.	Develop.	
010	5-3/4"		X	X	X	X	X	X	X	6	2550°F	1 Hr.	Develop.	
011	5-3/4"		X	X	X	X	X	X	X	6	2550°F	1 Hr.	Develop.	
012	5-3/4"		X	X	X	X	X	X	X	6	2550°F	1 Hr.	Develop.	
013	6-1/2"	X	X	X	X	X	X	X	X	6	2700°F	1 Hr.	Develop.	
014	6-1/2"	X	X	X	X	X	X	X	X	6	2700°F	1 Hr.	Develop.	Assigned to Creep B-1a
015	6-1/2"	X	X	X	X	X	X	X	X	6	2700°F	1 Hr.	Qual.	Assigned to Creep B-2a
016	6-1/2"	X	X	X	X	X	X	X	X	6	2700°F	1 Hr.	Qual.	Assigned to Weld Qual.
017	6-1/2"	X	X	X	X	X	X	X	-	None	None		Exp.	To certify annealing cycle
018	6-1/2"	X	X	X	X	X	X	X	X	6	2700°F	1 Hr.	Test	Assigned to Creep B-4a
019	6-1/2"	X	X	X	X	X	X	X	X	6	2700°F	1 Hr.	Test	Assigned to Creep A-1a
020	6-1/2"	X	X	X	X	X	X	X	X	6	2700°F	1 Hr.	Test	Scrap
021	6-1/2"	X	X	X	X	X	X	X	-	6	2700°F	1 Hr.	Test	Scrap
022	6-1/2"	X	X	X	X	X	X	X	X	6	2700°F	1 Hr.	Test	Assigned to Creep B-7a
023	6-1/2"	X	X	X	X	X	X	X	X	6	2700°F	1 Hr.	Test	Assigned to Creep B-5a
024	6-1/2"	X	X	X	X	X	X	X	X	6	2700°F	1 Hr.	Test	Assigned to Impact A-3a
025	6-1/2"	X	X	X	X	X	X	X	X	6	2700°F	1 Hr.	Test	Assigned to Impact A-5a
026	6-1/2"	X	X	X	X	X	X	X	X	6	2700°F	1 Hr.	Test	Assigned to Impact A-1a
027	6-1/2"	X	X	X	X	X	X	X	X	6	2700°F	1 Hr.	Test	To Be Assigned

TABLE V-2
T-111 STRUCTURAL SHELL FABRICATION HISTORY
(Sheet 2 of 2)

S/N	INITIAL BLANK SIZE	DIES USED								ANNEALED AFTER X DRAW	ANNEAL TEMP.	ANNEAL TIME	PART UTILIZA- TION	REMARKS
		1	2	3	4	5	6	7	8					
028	6-1/2"	X	X	X	X	X	X	X	X	6	2700°F	1 Hr.	Test	To Be Assigned
029	6-1/2"	X	X	X	X	X	X	X	X	6&8	2700°F	1 Hr.	Test	Drawn to .090 Wall Thru Draw No. 9 -
030	6-1/2"	X	X	X	X	X	X	X	X	6	2700°F	1 Hr.	Test	To Be Assigned Assigned to Creep B-6a
031	6-1/2"	X	X	X	X	X	X	X	X	6	2700°F	1 Hr.	Test	To Be Assigned
032	6-1/2"	X	X	X	X	X	X	X	X	6	2700°F	1 Hr.	Test	Assigned to C-Std
033	6-1/2"	X	X	X	X	X	X	X	X	6&8	2700°F	1 Hr.	Test	Drawn to .090 Wall Thru Draw No. 9 -
034	6-1/2"	X	X	X	X	X	X	X	X	6	2700°F	1 Hr.	Test	To Be Assigned To Be Assigned
035	6-1/2"	X	X	X	X	X	X	X	X	6	2700°F	1 Hr.	Test	Assigned to Impact A-6a
036	6-1/2"	X	X	X	X	X	X	X	X	6	2700°F	1 Hr.	Test	To Be Assigned
037	6-1/2"	X	X	X	X	X	-	-	-	-	--	--	Test	Scraped During Draw 5
038	6-1/2"	X	X	X	X	X	X	X	X	6	2700°F	1 Hr.	Test	Assigned to Impact A-2a
039	6-1/2"	X	X	X	X	X	X	X	X	6	2700°F	1 Hr.	Test	Assigned to Impact A-4a
040	6-1/2"	X	X	X	X	X	X	X	X	6&8	2700°F	1 Hr.	Test	Drawn to .090 Wall Thru Draw No. 9 - Assigned to Creep A-1a (Repl.S/N019)
041	6-1/2"	X	X	X	X	X	X	X	X	6&8	2700°F	1 Hr.	Test	Drawn to .090 Wall Thru Draw No. 9 - To Be Assigned

Figure V-8. T-111 Structural Shells S/N 029, 033, 040, and 041 Drawn Through Draw No. 9 to Form 0.090 Wall Shells

Figure V-9. T-111 Structural Shells S/N 029, 033, 040, and 041 After Final Machining

from the ninth draw was a better quality part than ever previously seen on the program.

Shell S/N 037 was cracked severely enough to be considered scrap.

2. Capsule Assembly

Assembly of 11 capsules was initiated and completed during the reporting period. Table V-3 shows the assembly status of each.

a. Impact Test Capsules

A total of 8 capsules were assembled for impact testing. Table V-4 shows the impact capsule configuration and test conditions.

Two dummy capsules of the "B" configuration were assembled, plasma coated with Al_2O_3 and delivered for testing. Figure V-10 shows a T-111 dummy capsule after welding. Figure V-11 shows it after being coated with Al_2O_3 and Figure V-12 shows the dummy capsule inserted in a graphite sabot ready for testing.

The six fueled prototype capsules for impact testing are of the "A" configuration which contains all liner assembly parts, the structural shell, Al_2O_3 coatings and a partial Pt-10Rh shell on the impact end. Three contain the foamed impact absorber and three are without this component. Testing should show whether the extra component provides any performance advantage. All six impact capsules were assembled during a semiproduction operation. Figures V-13 and V-14 show the Ta-10W inner liner assemblies and Figure V-15 show the six outer liner subassemblies after EB welding. These six subassemblies were loaded with tungsten moly fuel simulant; the fuel retainer ring, impact absorbers, and outer liner caps were then installed, positioned and welded. Figure V-16 shows the impact capsule A-1a fuel liner assembly after welding. Figure V-17 shows impact capsule A-1a fuel liner assembly after final machining and prior to insertion in the T-111 structural shell, and Figure V-18 shows this outer liner assembly inserted in the T-111 structural shell. Impact capsules A-1a and A-2a are shown in Figure V-19 after assembly and welding of the T-111 structural shell to the T-111 structural end cap. The before and after weld sample made for these two capsules is shown in Figure V-20. The first impact capsule after being coated

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CAPSULE PART JOINT CONFIGURATION CONFIG	CAPSULE PART / PART	TYPE OF WELD	MAT'L JOINING	CREEP B-6a	CREEP A-1a	IMPACT B-1	IMPACT B-2	IMPACT A-1a	IMPACT A-2a	IMPACT A-3a	IMPACT A-4a	IMPACT A-5a	IMPACT A-6a	CREEP STD "C"	CREEP C-2A	CREEP A-7A	CREEP A-6a	CREEP A-1a	CREEP C-1a	CREEP B-3a	CREEP C-4a	CREEP C-3a	REMARKS
N73420018-01 TO N73420019-01	WP1233 ELECTRON BEAM (FULL)	Ta 10W TO Ta 10W	NOT REQD	COMP 11-21-68	NOT REQD	NOT REQD	COMP 11-21-68	COMP 11-21-68	COMP 11-21-68	COMP 11-21-68	COMP 11-21-68	COMP 11-21-68	COMP 11-21-68						NOT REQD
N73420018-01 TO N73420019-01	WP1234 ELECTRON BEAM (STICH)	Ta 10W TO Ta 10W	NOT REQD	COMP 11-21-68	NOT REQD	NOT REQD	COMP 11-21-68	COMP 11-21-68	COMP 11-21-68	COMP 11-21-68	COMP 11-21-68	COMP 11-21-68	COMP 11-21-68						NOT REQD
N73420010-02 TO N73420017-01	WP1234a ELECTRON BEAM (FULL)	Ta 10W TO Ta 10W	NOT REQD	COMP 11-25-68	NOT REQD	NOT REQD	COMP 11-25-68	COMP 11-25-68	COMP 11-25-68	COMP 11-25-68	COMP 11-25-68	COMP 11-25-68	COMP 11-25-68						NOT REQD
N73420014-01 TO N73420017-01	WP1235 ELECTRON BEAM (FULL)	Ta 10W TO Ta 10W	NOT REQD	COMP 11-26-68	NOT REQD	NOT REQD	COMP 11-26-68	COMP 11-26-68	COMP 11-26-68	COMP 11-26-68	COMP 11-26-68	COMP 11-26-68	COMP 11-26-68						NOT REQD
N73420012-01 TO N73420014-01	WP1233 ELECTRON BEAM (FULL)	Ta 10W TO Ta 10W	NOT REQD	COMP 11-26-68	NOT REQD	NOT REQD	COMP 11-26-68	COMP 11-26-68	COMP 11-26-68	COMP 11-26-68	COMP 11-26-68	COMP 11-26-68	COMP 11-26-68						NOT REQD
N73420010-01 TO N73420017-01	WP1236 "TIG" (STICH)	Ta 10W TO Ta 10W	NOT REQD	COMP 11-27-68	NOT REQD	NOT REQD	COMP 12-3-68	COMP 12-3-68	COMP 12-3-68	COMP 12-3-68	COMP 12-3-68	COMP 12-3-68	COMP 12-3-68						NOT REQD
N73420008-01 TO N73420011-01	WP1237 ELECTRON BEAM (FULL)	Ta 10W TO Ta 10W	NOT REQD	COMP 12-2-68 *	NOT REQD	NOT REQD	COMP 12-5-68	COMP 12-5-68	COMP 12-5-68	COMP 12-5-68	COMP 12-5-68	COMP 12-5-68	COMP 12-5-68						NOT REQD			* FAILED TO COMP FINAL ASSY.
N73420005-01 TO N73420006-01	WP1238 ELECTRON BEAM (FULL)	T-III TO T-III	NOT REQD	COMP 12-20-68 **	NOT REQD	NOT REQD	COMP 12-9-68 *	COMP 12-9-68 *	COMP 12-20-68 *	COMP 12-20-68 *	COMP 1-6-69 *	COMP 1-6-69 *	COMP 12-20-68						NOT REQD			* COATED WITH Al ₂ O ₃ ** CAPSULE REBUILT AND ASSEMBLED
N73420005-01 TO N73420027-01	WP1238a ELECTRON BEAM (FULL)	T-III TO T-III	COMP 11-22-68	NOT REQD	COMP 11-22-68 *	COMP 11-22-68 *	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD		NOT REQD	NOT REQD	* COATED WITH Al ₂ O ₃
N73420027-01 TO N73420036-01	WP1242 ELECTRON BEAM (FULL)	T-III TO Ta 10W	COMP 11-15-68	COMP 12-20-68	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD						NOT REQD
N73420002-01 TO N73420003-01	WP1239 "TIG" (FULL)	PL-10RH TO PL-10RH	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD			NOT REQD	NOT REQD	NOT REQD		NOT REQD
N73420001-01	WP1240 "TIG" (PLUG)	PL-10RH	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD	NOT REQD			NOT REQD	NOT REQD	NOT REQD		NOT REQD			

Table V-3. Large Radioisotope Heat Source Capsule Assembly
Status GFY 1969

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TABLE V-4
INITIAL CAPSULE IMPACT CONDITIONS

Capsule No.	Configuration	Temp. (°F)	Impact Direction	Velocity (ft/sec)		Wall Thickness
				Object	If Prior Test Failed	
1	Dummy with fuel simulant to mockup mass	1200	End on	300	-	0.127"
2	Dummy with fuel simulant to mockup mass	1200	End on	350	250	0.127"
3	"A" Type <u>with</u> foamed Ta-10W	1200	End on	250	-	0.127"
4	"A" Type <u>with</u> foamed Ta-10W	1200	End on	250	-	0.127"
5	"A" Type without impact absorber	1200	End on	300	-	0.127"
6	"A" Type without impact absorber	1200	End on	350	250	0.127"
7	"A" Type <u>with</u> impact absorber	1200	End on	250	-	0.100"
8	"A" Type without impact absorber	1200	End on	300	200	0.100"

Figure V-10.
T-111 Dummy Impact
Capsule After Welding

Figure V-11.
T-111 Dummy Impact
Capsule After Al_2O_3
Coating Applied

Figure V-12.
T-111 Dummy Impact
Capsule Inserted in
Graphite Sabot

Figure V-13. Ta-10W Inner Liner
Subassembly for Impact Capsules
S/N A-1a, A-2a, A-3a, A-4a,
A-5a, and A-6a

Figure V-14. Ta-10W Inner Liner
Assembly for Impact Capsules
S/N A-1a, A-2a, A-3a, A-4a,
and A-5a

Figure V-15. Outer Liner Subassembly for
Impact Capsules S/N A-1a, A-2a, A-3a,
A-4a, A-5a, and A-6a

Figure V-16.
Impact Capsule A-1a
Outer Liner Assembly
After Welding

Figure V-17.
Impact Capsule A-1a Outer
Liner Assembly After
Final Machining

Figure V-18.
Impact Capsule A-1a Outer
Liner Assembly Inserted
in the T-111 Structural
Shell

Figure V-19. Impact Capsules A-1a and A-2a
After Assembly and Welding of the T-111
Shell to the T-111 End Cap

Figure V-20. Impact Capsule Before and
After Weld Sample

Figure V-21.
Impact Capsule A-1a Shown
With Graphite Sabot and
Pt-Rh Nose Cap. Cap-
sule Has Been Coated
With Al_2O_3

Figure V-22.
Impact Capsule A-1a Shown
With Graphite Sabot. Pt-Rh
Nose Cap Has Been As-
sembled With the
Capsule

Figure V-23.
Impact Capsule A-1a
Inserted in Graphite
Sabot

with Al_2O_3 is shown in Figure V-21. Also shown is the Pt-Rh nose cap and the graphite sabot. Figure V-22 shows impact capsule A-1a with the Pt-Rh nose cap assembled, and Figure V-23 shows the capsule inserted in the graphite sabot. Impact capsule A-2a assembled and inserted in the graphite sabot is shown in Figure V-24.

3. Creep Test Capsules

Creep capsule "C" Standard was completed during the quarter. The outer liner assembly was inserted in the T-111 structural shell and the shell was welded to the T-111 end cap. The T-111 shell was plasma spray coated with Al_2O_3 . After coating, the capsule was inserted in a Pt-Rh barrier shell which in turn was welded to the Pt-Rh barrier cap. After welding, the assembly was coated with iron titanate. Figure V-25 shows capsule C-Standard after coating with Al_2O_3 and prior to insertion into the Pt-10Rh shell.

Creep capsule B-6a was assembled during the reporting period and is shown in Figures V-26 and V-27. This capsule has been put on long term test.

The first "A" type creep capsule was built during the reporting period. The fuel liner assembly was completed and is shown in Figure V-29. The T-111 structural shell, Serial No. 19, is shown in Figure V-28 and was assigned to creep capsule A-1a. Insertion of the outer liner assembly into the T-111 structural shell was attempted using E. B. Weld Fixture T-6001654. The T-111 structural shell was heated to 1000°F providing a 5 mil clearance then the outer assembly was automatically inserted. The E.B. weld fixture had previously been checked out using stainless steel mock-up capsules and was found operative. However, when insertion of the Ta-10W outer liner assembly was attempted, excessive galling of both the T-111 shell and the Ta-10W fuel liner assembly was experienced. Figure V-30 shows capsule A-1a sectioned to expose the gall marks that developed during this assembly operation. Solutions to this galling problem are presently being investigated. It appears that a very thin layer, <1.0 mil, of Al_2O_3 on the liner assembly will solve the problem of providing assembly for an interference fit by acting as a dry lubricant film. This is to be tested next quarter. The easiest fix would be to use a slip fit. However, since this is less desirable and is an easy solution it will not be selected unless all other methods prove impossible.

Figure V-24. Impact Capsule A-2a Shown
Assembled and Inserted in the
Graphite Sabot

Figure V-25. LRHS Capsule C-STD After
Coating With Al_2O_3

Figure V-26. Creep Capsule B-6a After Final Assembly and the Structural Before and After Weld Sample

Figure V-27. Creep Capsule B-6a Structural Shell to Structural End Cap Weld and the End Cap to Pressure Feed Through Weld

Figure V-28. T-111 Structural Shell
S/N 019 Assigned to Creep A-1a

Figure V-29. Creep Capsule A-1a
Outer Liner Assembly After
Assembly and Final Machining

Figure V-30. Creep Capsule A-1a
Sectioned to Expose Gall Marks
Which Developed During As-
sembly of the Outer Liner
With the T-111 Shell

A new capsule of the "A" configuration was assembled and assigned to the creep A-1a test. The outer liner assembly was inserted into the T-111 shell with a line to line to 0.0005-in. clearance on the radius. The T-111 shell was welded to the T-111 cap and the capsule was delivered to test.

VI. CAPSULE CREEP TESTING

A. 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.

To achieve this end a test series has been established 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.

During the first year of the program three biaxial creep rigs were operated to observe the creep of capsule components at 2000°F in high vacuum. At the end of the first year preliminary creep data for test times less than 2000 hours had been obtained. During the second year additional creep rigs are being utilized and longer term creep data is being obtained.

B. SUMMARY OF TASK STATUS

As mentioned in the previous quarterly Report (AI-AEC-12753), a reduction in funding decreased the total number of capsules to be tested in GFY 1969 from 23 to 14. This reduction virtually eliminated all of the tests that exceeded one year's duration. The number of rigs to be constructed was reduced from 12 to 4. All four rigs have been complete and are operational. Three creep tests have been completed, and have undergone only limited post-test evaluation due to funding limitations. It is planned to post-test evaluate several capsules in parallel later in the fiscal year to minimize the cost per capsule. The first "A" capsule to be tested has been installed in the test rig and the test is under way. The "A" designation indicates that the test capsule contains both the structural T-111 member and the Ta-10W liners and end caps.

Preliminary observation of the data from the first five tests (three completed two in progress) indicates that the tangential (or hoop) stress at the mean diameter required to produce a pre-selected strain rate is greater by at least 30% than the stress to produce the same strain rate in uniaxial constant load tests. Insufficient data has been generated to establish exact relationships between the uniaxial and biaxial tests. It is felt that some of the differences are related to the classical relationships such as Von Mises, or its modifications, and possibly to the fabrication techniques involved in the production of the capsules. However, it has been demonstrated that this strength is not due to addition of contamination. A correlation between uniaxial and biaxial creep test results is one of the LRHSC Program goals.

The present program plan for the remainder of GFY 1969 and all of GFY 1970 results in the creep test schedule shown in Figure VI-1.

C. ACCOMPLISHMENTS DURING THE QUARTER

1. Test System Construction

A minor problem occurred during the quarter related to operation of Creep Capsule B5a. Twice during one short period the power controller shut itself down. Examination of the operations data indicated that the probable cause was a surge in the power demand by the silicon controlled rectifiers after a minor line power trip. While this surge may last only a few milliseconds, it can be sufficient to trip a circuit breaker. Steady state power limiters are installed in the control system, but they will not handle such a surge. It was considered desirable to have surge current limiters installed in the power controllers for Rigs 4 and 5, for these would contain the long term tests. After a review of available AEC and NAR inventory and discussions with SCR manufacturers, it was determined that the installation of the limiters would be almost as expensive as new SCR units. The cost of new SCR's is considered too high at the present program level. Since historically, AI line power has been quite reliable and stable, construction of the power controllers with existing SCR's, but without the surge limiters for Rigs 4 and 5, was completed.

Modifications to rig number 4 were completed, and the system operated well both in the cold evacuation tests and hot furnace integration tests. The

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CAPSULE DESIGNATION	CAPSULE CONFIGURATION	GFY 69	GFY 70	TOTAL
CREEP CAPSULE "A"		2	1	3
CREEP CAPSULE "B"		5	3	8
CREEP CAPSULE "C"		3	3	6
		10	7	17

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Figure VI-1. Large Radioisotope
Heat Source Program Capsule
Creep Testing

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total thermal gradient of the furnace during this first shakedown run was 8°F at 2000°F. Two new baffles were added to the furnace prior to the installation of capsule B6. These baffles brought the gradient down to an acceptable level (4°F). This final trimming has been necessary with each new furnace, and has consistently been accomplished during the second run after the initial response of a furnace is established. The rig is presently operational.

2. Equipment

During the quarter there was a scheduled electrical power outage of both power grids servicing the plant for tying in new equipment. A diesel auxiliary power unit was brought in to provide uninterrupted service for the creep tests. Problems were encountered during the switchover and the temperature of the tests dropped to below 1600°F for a few minutes. After the power returned and the temperature of the tests was stabilized at 2000°F, a malfunction in the APU caused a second power trip which, while very short in duration, damaged a silicon controlled rectifier supplying power to test B7. Another portable control unit was brought into place to maintain the test at the proper conditions. The test was brought back on line but early indications were that there was a stability problem with the control unit. The power controller that was damaged was repaired so that operation of the test could be maintained in a stable manner. Re-switching back onto the power grids after the tie-in occurred without incident. Evaluation of the data from the tests indicates that the creep rate and total strain were unaffected by the power outage.

3. Creep Testing

a. Status

(1) Creep Capsule B5*

Capsule B5* has now accumulated 2500 hours of operation under stress at 2000°F. The capsule was stressed initially by pressurizing with helium to a calculated maximum hoop stress of 16,500 psi. This was selected to induce 0.1% maximum diametral strain in 480 hours. After 740 hours of test, the maximum measured strain achieved was 0.1%. At that time the capsule pressure was increased to produce a hoop stress increase at a rate of 6.5 psi/hr. This was planned to produce 1% strain in the following 1000 hours. The test is to

continue until the capsule achieves 5% maximum measured strain. The test is now 1760 hours of operation into the ramp portion, the hoop stress is 27,500 psi and the maximum measured strain is slightly less than 0.7%. The present plan is to leave the capsule on the ramp even though the creep rate is less than initially planned.

(2) Creep Capsule B7

The testing mode for B7 uses the same stress schedule as Capsule B5* is undergoing. The test, however, will not be terminated until rupture. The capsule was pressurized to 16,500 psi hoop stress, and the maximum measured strain at 740 hours was somewhat less than that observed on B5* (0.08%). The ramp was then started at 740 hours. After 1400 hours on the ramp portion of the test the maximum strain is 0.25%. As is the case with the sister test B5*, the creep rate is lower than anticipated. The test will continue at its present stress rate until the planned termination rupture occurs.

Plots of the two ongoing tests are shown in Figures VI-2 and -3.

Figure VI-2. Creep Capsule B-5a* Stress Strain Conditions

Figure VI-3. Creep Capsule B-7a Stress Strain Conditions

VII. IMPACT TESTING

A. TASK OBJECTIVES

The objective of this task is to determine, by testing, the capability of the reference capsule design to survive impact. The developmental impact tests will also allow insight into the actual capsule deformation phenomena, determine the capsule failure modes and ascertain the relative influence of various capsule design and impact parameters on capsule survival. A total of 24 capsules will be impacted on a granite target at various velocities, impact angles, and temperatures. During GFY 1969 only six of these will be impacted.

B. SUMMARY OF TASK STATUS

Design modifications to the impact facility for impact testing of thermally hot capsules was completed and impact testing was initiated.

C. ACCOMPLISHMENTS DURING THE QUARTER

The modifications to the impact facility to allow hot breech loading are shown in Figure VII-1. One-half of the barrel diameter has been removed for a 10 in. length at the gas chamber end of the barrel. A removable saddle (-04), replaces the missing section of the barrel wall. To reenforce the barrel, a heavy wall section of tubing (-03) slides over the saddle.

The barrel ID is 2 in. while the capsule OD is 1.680 in. To support, insulate, and center the small capsules in the barrel, graphite sabots were manufactured. Because the sabot's weight is approximately 5% of the capsule weight, it is desirable to strip the sabot from the capsule before impact. Stripping is accomplished by reducing the muzzle ID of the barrel. The stripper (-07) threads onto the end of the barrel and arrests the sabot while allowing the capsule to continue on to impact.

The firing sequence is as follows:

- 1) Heat capsule and sabot in inert gas-filled oven.
- 2) Place capsule and sabot in barrel.
- 3) Cover capsule and sabot with saddle.

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4) Slide breech tube over saddle.

5) Pressurize and fire.

The loading and firing sequence takes one minute. The capsule temperature decreases 100°F during this time.

Impact testing was initiated during the reporting period. The impact parameters established are shown in Table VII-1.

- 1) Capsule No. 1 was a T-111 dummy which was tested end on at 1200°F at a velocity of 300 ft/sec.
- 2) Capsule No. 2 was a T-111 dummy capsule tested end on at 1200°F at a velocity of 250 ft/sec.
- 3) Capsule No. 3 was Impact Capsule A-1a. This capsule configuration consisted of a Ta-10W fuel liner assembly loaded with tungsten moly fuel simulant and inserted in a T-111 structural shell. This capsule also had a Ta-10W impact absorber installed in the inner assembly at the impact end and a partial Pt-10Rh clad. This capsule was tested end on at 1200°F at a velocity of 250 ft/sec.
- 4) Capsule No. 4 was Impact Capsule A-2a which was identical to capsule No. 3 in configuration with the exception of the impact absorber. This capsule was also tested end on at 1200°F at a velocity of 250 ft/sec.

The results of these first two tests were very good. Both capsules, shown in Figures VII-2 and VII-3, were leak tight. The Pt-10Rh on capsule A-1a (Figure VII-4) was also leak tight. Very little thinning of the 20 mil thickness occurred. The Pt-10Rh on capsule A-2a was cracked as can be seen in Figure VII-5. However, this Pt-Rh section was unannealed after drawing which explains its more brittle behavior. The structural end under the Pt-10Rh is shown in Figures VII-6 and VII-7. It can be seen that much of the Al_2O_3 under the Pt-10Rh remained on the capsule.

Evaluation of these first two impact capsules is underway. Capsule A-2a has been quarter sectioned and is shown in Figures VII-8 and VII-9. Figure VII-8 is an overall view into the capsule showing the fuel compaction, overall damage and capsule integrity. Figure VII-9 is a closeup view of the impacted end. It

can be seen that the fuel annulus is maintained intact by the inner liner tube and the fuel retainer ring. The fuel has undergone about 15% compaction. From all practical indications the Ta-10W outer liner assembly along with the T-111 structural shell remained leak tight.

The remaining four "A" type impact capsules with Pt-10Rh shells will be impacted during January.

TABLE VII-1
INITIAL CAPSULE IMPACT CONDITIONS

Capsule #	Configuration	Temp. (°F)	Impact Direction	Velocity (ft/sec)		Wall Thickness
				Object	If Prior Test Failed	
55 AI-AEC-12776	1 Dummy with fuel simulant to mockup mass	1200	End on	300	-	0.127"
	2 Dummy with fuel simulant to mockup mass	1200	End on	350	250	0.127"
	3 "A" Type <u>with</u> foamed Ta-10W	1200	End on	300	300	0.127"
	4 "A" Type <u>with</u> foamed Ta-10W	1200	End on	350	250	0.127"
	5 "A" Type without impact absorber	1200	End on	300	-	0.127"
	6 "A" Type without impact absorber	1200	End on	350	250	0.127"
	7 "A" Type <u>with</u> impact absorber	1200	End on	250	-	0.100"
	8 "A" Type without impact absorber	1200	End on	300	200	0.100"

Figure VII-2. Impact Capsules A-1a
and A-2a After Impact Testing
at 1200°F at a Velocity
of 250 ft/sec

Impact Capsule A-1a Impact Capsule A-2a

Figure VII-3. Impact Capsules A-1a
and A-2a After Impact Testing
at 1200°F at a Velocity
of 250 ft/sec

Figure VII-4. Impact Capsule A-1a
Nose Section After Impact Testing
at 1200°F at a Velocity of
250 ft/sec

Figure VII-5. Impact Capsule A-2a
Nose Section After Impact Testing
at 1200°F at a Velocity of
250 ft/sec

Figure VII-6. Impact Capsule A-2a
Nose Section Shown With
Pt-Rh Removed

Figure VII-7. Impact Capsule A-2a
Nose Section Shown With
Pt-Rh Removed

12-27-68

7734-4027

Figure VII-8. Quarter Section of Capsule A-2a

12-27-68

7734-4028

Figure VII-9. Close Up View of Capsule A-2a Impact End

AI-AEC-12776