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PRATT & WHITNEY AIRCRAFT ENGINES

To Messrs. L. M. Baring & G. U. Parks Confidential-R.D. Contract AT(30-1)-2789
CNIM-5449
Date January 3, 1964

From M. S. Freed RECEIVED
LAWRENCE RADIATION LABORATORY
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Subject Progress on SNAP-50 Fuel
Development During December 1963 TECHNICAL INFORMATION DIVISION
LIVERMORE

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Classification Group No. Authorized Classifier Date

Irradiation Specimen and Capsule Fabrication DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

1. Uranium carbide and uranium nitride development rigs were relocated.
2. Difficulties were experienced with new uranium carbide powder preparation rigs and were minimized by using atmospheric end point rather than zero pressure end point and by blending batches. Seven batches of uranium carbide were prepared in the rigs.
3. Ten percent enriched uranium carbide pellets were fabricated to specification. Evaluation showed slightly hyperstoichiometric composition, 4.86-4.88% carbon, 760-950 ppm oxygen, 770-810 ppm nitrogen, 94-95% of theoretical density, uniform grain size, and good visual appearance. A few large pores were present in the structure.
4. Cb-1 Zr alloy cladding for FW26-500 and FW26-600 series of inpile capsules was received from vendor after deposition of tungsten on ID. Inspection revealed that six of seven lengths were properly coated except that tungsten thickness was 2.5 to 3.0 mils vs specified 4.5 to 5.5 mils. Vendor was informed to make

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necessary process changes. Additional order of twelve lengths received were same tungsten thickness. Five lengths showed oxidation and will be replaced by vendor. Additional Cb-1 Zr alloy tubing for replacement was received from vendor, inspected and shipped to coating vendor.

5. Weld porosity problem in tungsten coated tubing was revealed by radiography and is under study. Rejection rate is 35 %.
6. Fuel specimens were fabricated using above pellets and tungsten-coated Cb-1 Zr alloy tubing. The first specimen container was assembled, filled with lithium, welded, thermocycled, inspected and released to the Shop for assembly into capsule FW26-500.
7. Difficulty was experienced in brazing capsule heater assemblies. Braze does not flow between bulkhead and heaters and thermocouples to form adequate fillets on the underside of the bulkheads. Also, some chromel/alumel thermocouple wires were melted during brazing. Revisions to the brazing process were made with improved results but no acceptable heater assemblies were completed. Capsule assembly is awaiting solution of this problem.
8. Preparation of uranium nitride powders for specimens for eight capsules (FW26-600 series) was started.
9. Cb-1 Zr alloy tubing with codrawn tantalum liner on ID for inpile capsule specimens is scheduled for delivery 2/15/64.
10. FWC-11 alloy tubing is scheduled for 2/15/64 delivery from vendor.

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Irradiation Testing

11. The following capsules are on test:

<u>Capsule</u>	<u>Test Reactor</u>	<u>Fuel</u>	<u>Barrier</u>	<u>Design Temp (°F)</u>	<u>Design Power Density (kw/cc)</u>	<u>Scheduled Irradiation (hours)</u>	<u>Completed Irradiation (hours)</u>
FW26-154	MTR	UC _{1.08}	Ta	2200	1.5	3000	2700
FW28-11	ETR	50 v/o UO ₂ -BeO	None	2000	.5	3000	200

Capsule FW28-10 completed one ETR cycle at approximately 2100F. Heater failure resulted in 1775F operation during the second cycle after which it was returned for examination.

12. Posttest examination of capsules were started or continued for following capsules:

<u>Cap- sule</u>	<u>Fuel</u>	<u>Bar- rier</u>	<u>Test Time hrs.</u>	<u>Clad- ding Ave.</u>	<u>Temp F Max.</u>	<u>Spec. Loca- tion</u>	<u>Gas Press, psia</u>	<u>Fuel Den- sity Δ, % TD</u>	<u>Spec. Dia. Δ, %</u>	<u>Fission BU % U²³⁵</u>	<u>Fission Density f/cc$\times 10^{-20}$</u>	<u>Power Density, kw/cc</u>	<u>Gas Release, % Xe</u>
FW26-241	UN	W	1100	2125	2150	T	15.3	4.9	0.20	7.56	2.46	2.03	5.8
	UN	W	1100	2225	2250	M	13.7	2.5	0.37	7.26	2.36	1.95	4.0
	UN	W	1100	2100	2125	B	13.6	4.9	Nil	7.28	2.34	1.93	3.9
FW26-174	UC _{1.08}	None	2600	-	-	T	15.4	7.4	0.6	12.0	3.7	1.29	5.9
	UC _{1.08}	None	2600	2200	2275	M	88.9	21.6	7.4	12.8	4.0	1.39	91.2
	UC _{1.08}	None	2600	2175	2250	B	24.9	16.5	2.1	15.6	4.6	1.69	14.2
FW26-160	UC _{1.08}	Ta	2370	2150	2225	T	11.8	10	2.7	11.3	3.37	1.18	12.5
	UC _{1.08}	Ta	2370	2200	2275	M	19.0	13	3.1	10.8	3.23	1.13	32.8
	UC _{1.08}	Ta	2370	2175	2250	B	12.6	11	2.7	11.6	3.46	1.21	16.4
FW26-240	UN	W	3000	2075	2125	T	38.2	5.8	0.95	13.1	5.4	1.6	17.2
	UN	W	3000	2200	2250	M	63.7	8.0	1.8	14.5	6.0	1.8	32.3
	UN	W	3000	2125	2175	B	41.8	7.8	0.88	12.0	4.9	1.5	21.9

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Cap- sule	Fuel	Bar- rier	Test Time hrs.	Clad- ding Ave.	Temp F Max.	Spec. Loca- tion	Gas Press, psia	Fuel Den- sity % TD	Spec. Dia. %	Fission BU % U ²³⁵	Fission Density f/cc ^{x10} ⁻²⁰	Fission Density, kw/cc	Gas Release, % Xe
FW26-192	UC _{1.0}	W	3850	-	-	T	73.0	11.7	Nil	-	-	-	-
	UC _{1.0}	W	3850	2200	2275	M			Specimen Failed				
	UC _{1.0}	W	3850	2000	2050	B	1.4	14.6	7.8	-	-	-	-
FW26-181	UC _{.94}	W	3120	2025	2075	T	80.6		0.3	-	-	-	-
	UC _{.94}	W	3120	2175	2225	M	1.9		14.2	-	-	-	-
	UC _{.94}	W	3120	2075	2125	B	90.9		11.8	-	-	-	-

Following observations were noted:

FW26-240 All claddings ductile, but tungsten barriers brittle. Cladding shows brittle ID phase to 5 mils. Fuel shows slight metallic phase. Pellets grew axially 2 to 7 mils.

FW26-192 Middle specimen failed. Bottom specimen bulged at top end of top pellet and probably leaked, ref. low gas pressure. Failure attributed to incomplete protection by tungsten. Top and bottom specimen cladding brittle, showed grain growth and grain boundary separation. Depth of incompatibility reactions were 17, 25 and 20 mils for top, middle and bottom specimens, respectively. Extensive reaction with end spacers was also observed.

FW26-181 Middle specimen showed alloyed or melted area on OD adjacent to top of fuel stack. Positive test for lithium was observed in top specimen, indicating leak.

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Compatibility

13. Eight compatibility specimens of UC vs W-lined or Ta-lined Cb-1 Zr alloy tubing and W disk and cup barrier protection at end plugs were tested for 200 hours at 2400F followed by 48 hours at 2800F. Six specimens examined to date showed no indication of incompatibility nor fuel particles behind barriers.
14. Sound and defected compatibility specimens of uranium carbide vs tantalum-lined and unlined Cb-1 Zr alloy cladding tested in 2200F lithium for 7500 hours were examined. Sound, tantalum-lined specimens showed no carbide or uranium penetration into cladding, nor any evidence of swelling. Unlined, sound specimens showed carbide penetration through full wall thickness but no uranium penetration in contrast to previously reported 6000 hour test which showed uranium penetration. Defected, unlined specimens showed uranium diffusion through full wall thickness. Defected, tantalum-lined specimens showed same results as sound specimens, probably due to lack of defect through tantalum liner.
15. Examination was continued on a 5000 hour, uranium carbide vs tungsten foil lined Cb-1 Zr alloy cladding that was intentionally defected and immersed in 2200F lithium. Fuel contained metallic uranium and evidence of uranium alloying was observed through the full wall thickness of the Cb-1 Zr alloy (25 mils). In previously reported tests similar specimens showed 9 to 13 mils penetration of uranium alloying after 2500 hours and no uranium alloying after 1000 hours.

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16. Compatibility specimens of uranium nitride vs tungsten foil lined Cb-1 Zr alloy cladding were tested for 3000 hours in 2200F lithium. Both sound and defected specimens showed fuel pellets intact by preliminary radiographic inspection technique. Unlined specimens showed spotty discoloration on OD not observed in tungsten-lined specimens.
17. No fuel-refractory metal interactions were observed in an 8000 hour test at 2200F of uranium carbide vs tungsten foil lined Cb-1 Zr alloy. However, a 0.4 mil reaction zone between the tungsten and Cb-1 Zr alloy was observed.

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