URANIUM SILICIDE ACTIVITIES AT BABCOCK & WILCOX

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Introduction

Babcock & Wilcox, Naval Nuclear Fuel Division (NNFD) in conjunction with Argonne National Laboratory (ANL) is actively involved in the Reduced Enrichment Research Test Reactor (RERTR) Program to produce low enriched fuel elements for research reactors. B&W and ANL have undertaken a joint effort in which NNFD will fabricate two low enriched uranium (LEU), Oak Ridge Reactor (ORR) elements with uranium silicide fuel furnished by ANL. These elements are being fabricated for irradiation testing at Oak Ridge National Laboratory (ORNL).

Concurrently with this program, NNFD is developing and implementing the uranium silicide and uranium aluminide fuel fabrication technology.

NNFD is fabricating the uranium silicide ORR elements in a two-phase program, Development and Production.

Development

Tungsten - Aluminum Compacts

NNFD fabricated ten (10) full size plates with tungsten-aluminum compacts provided by ANL. The compacts were 35% by volume tungsten. Tungsten was used to simulate the use of U_3SiAl since the densities of the materials are similar. Fabrication processes normally used to manufacture ORR type fuel plates with U_3O_8 were utilized. Results proved the feasibility of using our existing processes to fabricate full size uranium silicide plates.

U_3SiAl Compacts and Plates

NNFD fabricated compacts with 35% by volume U_3SiAl; U, 3.5 wt % Si, 1.5 wt % Al. The fuel was provided by ANL and was enriched to approximately 19.75%. NNFD blended the U_3SiAl with high purity aluminum and pressed them with a single-action 150-ton Hydraulic Press. It was observed that the uranium silicide compact charges slightly expanded upon ejection from the compact die. The expansion was limited to less than .3 percent. The compacts were vacuum annealed for approximately 1 to 1.5 hours at 200 to 250°C under .1 micron vacuum. No significant change in weight or size was detected.

The compacts were assembled with aluminum type 6061 covers and tandem frames. The assemblies were welded, hot rolled, blister annealed, cold rolled into plates, and inspected. To date nine fuel plates have been fabricated and inspected. Ultrasonic inspection and X-ray detected five plates with non-bonds at the trailing end of the fuel meat and one plate with non-bond at the leading end of the fuel meat.

Investigation of Non-bond Condition

Sections from two non-bond plates were evaluated by a Scanning Electron Microscope (SEM) at B&W's Lynchburg Research Center (LRC). One section was a longitudinal sample L-2 (See Figure 1) taken from the non-bond area of plate S3-003-2. The end clad was sheared off and the plate section separated in the fuel meat. A layer of black product covered the fuel meat on each half of the plate. Mechanical bonding was present at the fuel meat/cover plate interface. The black reaction product was analyzed by X-ray diffraction and U_3O_8 was identified as the major constituent. Other compounds, i.e., Al_2O_3, SiO_2, are suspected to also be present.

The other section evaluated by the SEM was a L-1 sample (See Figure 1) taken from the non-bond area of plate S3-004-1. The fuel meat pulled away from the sample during machining for metallurgical sample preparation. There was very little mechanical integrity (bonding) within the fuel meat. SEM photographs indicate that the fuel was pulled from the fuel meat by the cutting operation.

Based on the locations of the non-bond conditions and the identity of the reaction product, U_3O_8, it appears that the fuel meat underwent an oxidation reaction. Heating prior to hot rolling, $490^\circ C$ for 60 to 80 minutes, is believed to be the processing stage at which the reaction took place. To verify this conclusion, samples of compacts (aluminum and U_3SiAl - 35% vol) were oxidized in air from $490^\circ C$ to $100^\circ C$ (See Table 1) for several time periods.

The samples oxidized from $200/225^\circ$ to $490^\circ C$ into a dark reaction product. We oberved the thickness of the sample (No. 2-6) increase approximately 50 percent, and the weight increase approximately 5 percent. The sample appeared cracked, and was crumbling into a powder. The mechanical bonding between the aluminum matrix material and the fuel appeared absent. Two samples which were oxidized at $490^\circ C$ were analyzed by X-ray diffraction at LRC. Preliminary results show U_3O_8 as a major constituent. Again, other compounds are suspected to be present.

OXIDATION OF U_3SiAl + AL COMPACTS SAMPLES

Temp-Time (C°) (Min)	Sample No.	Before Wt. (Grams)	After Wt. (Grams)	Diff. Wt. (Grams)	% Diff. Wt. (Percent)	Thickness Diff. (Inches)	% Diff. Thickness (Percent)
490-45	1-1	10.315	10.762	+.447	+4.3	Not Measurable	
	1-2	8.601	9.018	+.417	+4.8	Not Measurable	
	1-3	9.170	9.608	+.438	+4.8	Not Measurable	
Avg.:					+4.6		
490-60	1-2	8.601	9.034	+.433	+5.0	Not Measurable	
	1-3	9.170	9.630	.460	+5.0	Not Measurable	
Avg.:					+5.0		
490-80	1-3	9.170	9.662	.492	+5.4	Not Measurable	
475-45	1-4	9.791	10.223	.432	+4.4	Not Measurable	
	1-5	9.842	10.290	.448	+4.6	Not Measurable	
	1-6	9.258	9.678	.420	+4.5	Not Measurable	
Avg.:					+4.5		
425-45	2-1	9.284	9.684	.400	+4.3	Not Measurable	
	2-2	8.975	9.385	.410	+4.6	Not Measurable	
	2-3	8.983	9.391	.408	+4.5	Not Measurable	
Avg.:					+4.5		
300-45	2-4	9.893	10.384	.491	+5.0	Not Measurable	
200-45	2-5	10.409	10.950	.541	+5.2	Not Measurable	
100-45	2-6	10.545	10.545	0	0	None	None
150-45	2-6	10.545	10.550	+.005	0	+.003	+1.0
175-45	2-6	10.550	10.557	+.007	.1	+.003	+1.0
200-45	2-6	10.557	10.557	+.020	.2	+.004	+2.0
225-45	2-6	10.577	11.177	+.600	+5.7	+.113	+55.4

TABLE 1

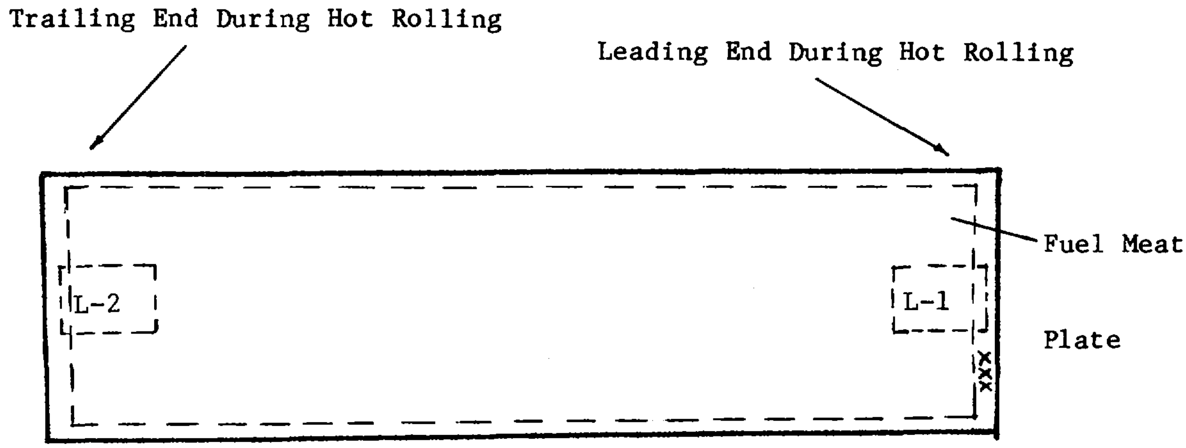

FIGURE 1

FUEL PLATE SAMPLE LOCATION

Since current data indicates that the non-bonds are related to a chemical reaction in the fuel meat, NNFD's solution of the fuel meat non-bonding involves preventing the oxidation of the fuel meat prior to hot rolling. To prevent fuel meat oxidation and subsequent non-bonding, the fuel meat (compact) must not be exposed to air (oxygen) at temperatures above 200/225°C.

NNFD has identified and is currently verifying the acceptability of an alternate process for welding and hot rolling uranium silicide pack assemblies while avoiding fuel meat oxidation.

Production

Plate Qualification

If the ANL uranium silicide plate irradiation experiment in the ORR is successful, NNFD will fabricate a limited number of ORR full size plates for ANL/ORNL examination. If acceptable, NNFD will proceed into production.

Production U_3SiAl ORR Elements

During production, two ORR elements will be fabricated with U_3SiAl provided by ANL. Each ORR 19 plate element will be loaded to 340 grams U^{235}. Aluminum type 6061 will be used to fabricate fuel plates and side plates. Plate fabrication processes will be based on ORR/ANL requirements modified as necessary for U_3SiAl fuel. Element processes will be identical to those currently qualified to fabricate ORR elements.

Summary

1. Full size fuel plates can be made with U_3SiAl but the fabricator must prevent oxidation of the compact prior to hot roll bonding.
2. Providing the ANL U_3Si_x irradiation results are successful, NNFD plans to provide two ORR elements during February 1983.
3. NNFD is developing and implementing U_3Si_x and UAl_x fuel fabrication technology to be operational in 1983.
4. NNFD can supply U_3O_8 high enriched uranium (HEU) or low enriched uranium (LEU) research reactor elements.
5. NNFD is capable of providing high quality, cost competitive LEU or HEU research reactor elements to meet the needs of the customer.

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