INVESTIGATION OF THE EFFECT OF FUEL FILLER SURFACE CONDITIONING
UPON FUEL ELEMENT PROPERTIES

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INVESTIGATION OF THE EFFECT OF FUEL FILLER SURFACE CONDITIONING UPON FUEL ELEMENT PROPERTIES

Stuart Weiss

This report summarizes the data of two test runs conducted with surface conditioned fuel fillers to evaluate the effect upon diffusion zone thickness, bond strength and corrosion properties of Zircaloy-2 clad Uranium-10 w/o Niobium. The results indicate the following:

1. There is no significant effect of fuel surface condition upon diffusion zone thickness.
2. The bonding interface of the rolled fuel element has greater strength than either the clad or the fuel.
3. The corrosion data were inconclusive because of the small number of tests, the uncontrolled variables, and the erratic corrosion properties of the particular U-Nb used.

This investigation was initiated because exposure to air of the finished machined fuel fillers produces a thin oxide film on the filler surfaces. It was anticipated that a surface preparation prior to assembly might be beneficial to bond strength, corrosion properties, and also aid reproducibility. Four surface conditions were chosen for evaluation; namely, (1) as-machined, (2) acid pickled, (3) anodically etched, and (4) oxidized. Also investigated were fuel elements that were degassed and transformed in the assembled pack prior to sealing.

The evaluation was conducted with HT-1 type plates, which are approximately 5-3/4" x 2" x 0.290" overall with fuel fillers 3-1/2" x 1-1/4" x 0.160" before rolling. The surface conditioning in detail was:

1. As-machined - slightly oxidized from normal exposure.
2. Acid pickled - concentrated HCl, 10 seconds - rinse - 5% HNO₃, balance H₂O 10 seconds - rinse.
3. Anodic etch - activate surface in 35% HNO₃ + 5% HF, etch in concentrated H₂SO₄, 6-8 volts, 15 seconds - rinse.
4. Oxidized - 1550°F for 1 minute in furnace - air atmosphere.
5. Degassed - 750°F for 8 hours under dynamic vacuum (to degas and also transform the fuel to alpha plus gamma₂).

The components were cleaned, assembled, and welded according to standard practices. All specimens were hot-rolled at 1450°F to a 3:1 reduction ratio in five equal passes with reheating between each pass. After cooling in air, the steel was removed and the fuel plates roller leveled. Coupons were prepared and subjected to various test procedures for determination of diffusion zone thickness, bond strength and corrosion properties. The structures were observed and diffusion zone thicknesses measurements recorded. Bend and shear test specimens, shown in Figure 1, were used to determine the relative bond strength, while the

bare fuel edge samples, illustrated in Figure 2, were tested in 680°F water to evaluate the corrosion properties.

Diffusion zone measurements, as listed in Table I, revealed no appreciable effect of the surface treatments, although the thicknesses of each run did vary by a significant amount. Possible explanations for the wider zones in run 2 are poor furnace control which might allow a temperature excursion or a long reheat before the last rolling pass.

The effect of surface conditioning upon inception of bonding and hence diffusion can be noted by the end configurations as seen in Figure 3. It should be noted from these results that early bonding produces more even movement of clad and core surfaces; therefore the fuel ends flow with the cladding (Items 3 and 4, Figure 3). Retarded bonding permits the end to pierce into the cladding causing some reduction in size but no appreciable surface flow (Item 5, Figure 3).

The effect of surface treatment on bend and shear properties for run 1 appears in Table II. The bend tests showed that a strong ductile bond existed for each treatment and the shear tests substantiated these results inasmuch as the failures occurred in either the clad or fuel, not in the bonding interface. The oxidized fuel specimens appeared to have the greater shear strength, but probably was caused by impurities diffusing into the cladding, thus increasing the Zircaloy tensile strength and causing failure to occur through the fuel. Such contaminants would be expected to be detrimental to corrosion properties, but the corrosion data from the first run indicated that the specimen with oxidized fuel had superior corrosion resistance. However, as can be seen in Table III, there is no apparent correlation between the preliminary testing of four samples per surface condition for each run.

From the limited tests performed, it can be stated that:

1. Surface conditioning treatments do not affect the final bonding layer thickness.
2. The strength of the bonding layer is not affected by the fuel surface preparations.
3. Inconclusive corrosion data were obtained because of the limited number of test samples.

It is recommended that surface conditioning and other pre-rolling treatments be conducted with Zircaloy-3 cladding and with in-specification U-Nb to properly determine the effect of these treatments upon the corrosion properties.

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TABLE III

CORROSION TEST RESULTS OF ZIRCALOY-2 CLAD SURFACE CONDITIONED
URANIUM-NIOBIUM FILLED IN 680°F WATER

<u>Surface Conditioning</u>	<u>Run 1</u>	<u>Run 2</u>
As-machined	Failed--9 1/2 days	Failed--28 days
Acid pickled	Failed--27 days	Failed--7 days
Anodic etched	Failed--9 1/2 days	Failed--28 days
Oxidized	No failure--101 days	Failed--7 days

Run 1 - Ingot G-1286 - no chemistry available
at present date

Run 2 - Ingot E-688 - C - 0.026, Nb - 9.5-10.2,
additional chemistry not
available

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FIGURE 1

Shear Test Specimen

~~Beard Test Specimen~~

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FIGURE 2

Bare Edged Corrosion Coupon

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TABLE 3

EFFECT OF CONDITIONING UPON END CONFIGURATIONS OF RUN 2

<u>Item</u>	<u>End Angle</u>	<u>Treatment</u>	<u>Core Bulge (Above Avg. Core of .054)</u>	<u>Shape</u>
1.	90°	As-machined	0.029
2.	90°	As-machined degassed	0.017
3.	60°	Acid-pickled	0.014
4.	60°	Anodic etched	0.011
5.	60°	Oxidized	0.016

Note: The above data were obtained from two specimens for each surface treatment.

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