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THE NEW ATR FRESH FUEL SHIPPING PACKAGE

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ABSTRACT

A replacement packaging has been developed for the existing Advanced Test Reactor (ATR) Fresh Fuel Shipping Container (FFSC). The existing packaging is nearing the end of its useful service life and a new package is needed to support the fuel deliveries required to continue ATR reactor operations. The A_2 value of a single ATR fuel element enables the package to be developed as a single element Type AF shipping container.

The package does not utilize traditional energy attenuation devices (impact limiters) but instead relies on the structural integrity of the fuel element itself to maintain geometry for purposes of criticality control. The lack of detailed certified mechanical properties of the fuel material required the use of a production fuel element containing highly enriched uranium (HEU) to support the structural certification activities. This paper discusses the design, development, and certification testing of the new ATR FFSC package.

INTRODUCTION

Since 1968, fresh fuel has been transported to the Idaho National Laboratory (INL) Advanced Test Reactor (ATR) using the ATR Fresh Fuel Shipping Container (ATR FFSC), USA/9099/B(U)F-85. The package has a payload capacity of four ATR fresh fuel elements.

The ATR package license expires on January 31, 2009, and a replacement package is needed to enable continued ATR operations. Design activity on the replacement package commenced in February of 2006. Certification tests of the package, using a fissile payload in the tests, were performed at Sandia National Laboratories in Albuquerque, New Mexico in May of 2007 and the application for a Certificate of Compliance to 10 CFR 71 was made to the Nuclear Regulatory Commission (NRC) on June 14, 2007.

DESIGN CONSIDERATIONS

The USA/9099/B(U)F-85 packaging (Figure 1) has enabled the safe shipment of fresh fuel to the ATR for almost 40 years. However, the packagings do present some operations related drawbacks. It was principally fabricated from plywood and was subject to handling damage. A four person crew is needed to handle the packaging overpack, and there is a large laydown footprint for the packaging once opened. Laydown area is limited in every facility in which it is used. The package is heavy and awkward to move in the limited available space.

The replacement for the existing packaging was originally planned as a Type B system with a capacity of four ATR fuel elements. However, it was recognized that an ATR fuel element represents less than one A_2 value and, as such, could be shipped in a Type A fissile package. The simplicity of a Type A package and the resultant improvement in package loading/unloading operations lead to the decision to replace the existing packaging with a Type A fissile package design.

Operations personnel at the various user sites were interviewed to obtain design input relative to ergonomic and general handling features. The principal design goals were as follows:

- capability for load/unload by one person
- a reduction in package footprint of at least 50%
- materials and structures resistant to normal handling damage
- a maintenance free service life
- operation without the use of tools.

PACKAGING DEVELOPMENT

The existing packaging is Type B. However, the containment function relied on the fuel cladding, which must be intact. A new Type B packaging would require a full containment boundary, since, unlike commercial fuel rods, the ATR fuel cladding is not leak testable. A full containment boundary would require seals, and the necessary thermal and structural protection would result in a relatively complex design, including multiple components that must be handled in the packaging load and unload operations. Additionally, performance of the package leakage rate test is time consuming and requires multiple disciplines to complete.

To address these concerns, the new packaging was chosen to be Type AF. Notable design features are as follows:

- No specific features to mitigate free drop or puncture impacts are included. ATR fuel elements possess adequate structural strength to remain intact, without buckling or loss of structural integrity, under worst-case impacts.
- No closure seals are used, since the contents represent less than an A_2 quantity of radioactive material.
- Thermal insulation is used to maintain the fuel safely below its melting temperature in the HAC fire.

PACKAGING CONFIGURATION

The ATR FFSC body (Figures 2 and 3) is a weldment consisting of two nested shells. The outer shell is a square stainless steel tube with a 3/16-inch wall thickness. The inner shell is a 6-inch diameter, 0.120-inch wall, stainless steel tube. There are three 1-inch thick stiffening plates secured to the tube by welds at equally spaced intervals. At the bottom end of the body, and in the closure, is an insulated cavity. The central tube is wrapped with insulation which is overlaid with 28 gauge stainless steel sheet.

The closure weighs 10 pounds and is equipped with a handle to facilitate use with gloved hands (see Figure 4). The closure engages with the body using an interlocking lug design. There are four lugs, uniformly spaced on the closure, that engage with four slots around the body opening. The closure is secured by placing it into the body opening, rotating through approximately 45^{o}, and releasing two spring loaded pins such that the pins engage with mating holes in the body. When the pins are properly engaged with the mating holes, the closure is locked.

The payload consists of two types. The principal payload is the ATR Mark VII HEU fuel element and the secondary payload consists of loosely bundled ATR fuel element plates that have either been disassembled from, or never assembled to, an ATR fuel element.

The ATR fuel element basket (see Figure 5) and loose plate basket are fabricated from aluminum. Their purpose is to provide physical protection to the fuel element or loose plates during the fuel handling operations. The basket weights were minimized to accommodate operation by a single worker. The maximum ATR FFSC payload weight (basket plus fuel) is 50 lb.

The ATR FFSC facility footprint is minimized by the stacking feature built into the packaging. The packages are designed to be stacked in a 4-package wide by 3-package high configuration as shown in Figure 6. The Figure depicts the 12-pack of ATR FFSCs secured to the conveyance by use of straps. Shear continuity is provided between the packagings by use of 2 index lugs located on the top of each packaging and interfacing pockets on the bottom of the packagings (see Figure 7).

THE LICENSING DEMONSTRATION

A "license-by-test" philosophy was chosen for the new packaging. Certification testing consisted of structural tests only. Thermal performance was demonstrated by analysis. The structural tests consisted of four-foot normal condition of transport (NCT) free drops, 30-foot hypothetical accident condition (HAC) free drops, and 40-inch HAC puncture drops, as required by NRC regulations defined in 10 CFR 71. Since criticality safety is dependent on the integrity of the ATR FFSC fuel element, certification tests were conducted to demonstrate the structural performance of both the packaging and the fuel. Thus the testing was unusual in that the certification test package for the ATR fuel element payload contained a "live" ATR fuel element. The fuel element possessed the full inventory of fissile material but had small manufacturing flaws that rendered it unsuitable for reactor use.

The test program would have been much simpler by using a prototypic, non-fissile fuel element, but the material properties of the actual uranium-aluminum alloy under minimum-temperature impact (considering that brittle fracture of the fuel element was the most likely form of failure) were not known with sufficient certainty to support a licensing application. The considerable costs and schedule delays associated with a material property test program made the use of a fissile payload the preferable alternative. A typical cross section of the ATR fuel element is shown in Figure 8.

Certification testing was conducted at the Sandia National Laboratories (SNL) in Albuquerque, NM. Sandia provided the material security, fuel handling, and radiological control procedures and personnel required for the fissile payload, including a controlled area where the post-test disassembly of the test article could be performed.

The goals of the test program were as follows:

- Demonstrate the integrity of the ATR fuel element under minimum temperature (-20 ºF) conditions and worst-case free drop impacts, to ensure a criticality-safe post-accident geometry
- Demonstrate the functional integrity of the insulation wrapped around the central packaging tube, to ensure protection against melting of the aluminum-based fuel in the HAC fire event

- Demonstrate the integrity of the packaging and closure to ensure retention of the ATR fuel element within the packaging.

Two certification test units were used, one containing the loose plate basket (non-fissile) payload, and one containing a prototypic ATR (fissile) fuel element payload. A total of one, NCT four-foot drop, ten, HAC 30-foot drops, and three HAC puncture drops were performed on the two packages, including two HAC free drops at a temperature of -20 ºF.

The package remained intact throughout the test series. The 30-foot free drop on the closure end of the package deformed the closure end slightly as shown in Figure 9. The closure remained in the locked position and could not be opened. It was necessary to cut the ends from the package to remove the fuel. The packaging insulation remained intact, both on the sides and on the ends. The ends of the fuel assembly sustained some localized and expected damage but the overall fuel (fissile region) geometry remained essentially undamaged as shown in Figure 10. These results (as augmented by thermal analysis) demonstrate that the ATR fuel elements will be retained within the new ATR FFSC packaging, and that they will retain a safe criticality geometry in the worst case impacts and thermal conditions. The packaging thus met all of the requirements of 10 CFR 71.

CONCLUSIONS

A new package has been designed to carry ATR fuel elements. The packaging is designated Type AF and has the capacity of one fuel element. It is resistant to handling damage, conserves floor space, and can be used by a single operator. Because the package criticality control depends on the fuel element integrity, the certification testing included a “live” test payload containing fissile material. Although this approach brought added testing costs, it clearly demonstrated the robustness of the ATR fuel element and will likely bring long term savings in cost and schedule.

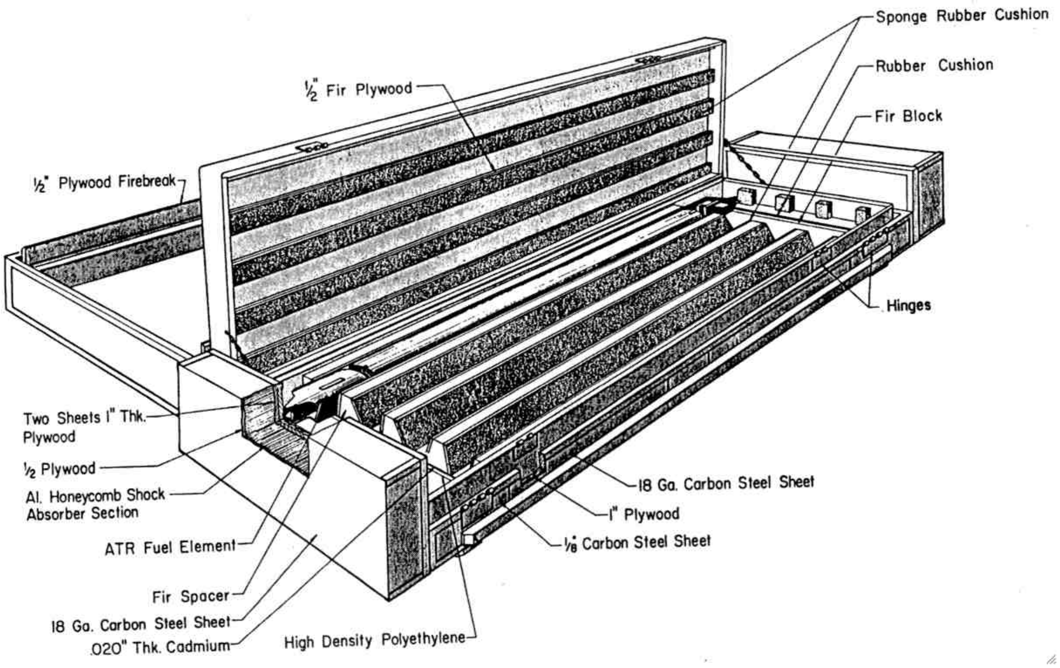

Figure 1 - ATR FFSC, USA/9099/B(U)F-85

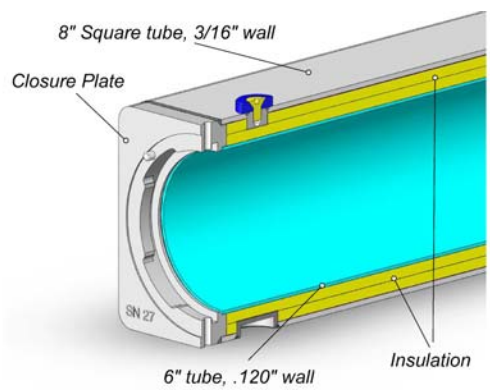

Figure 2
Sectional View, Package Closure End

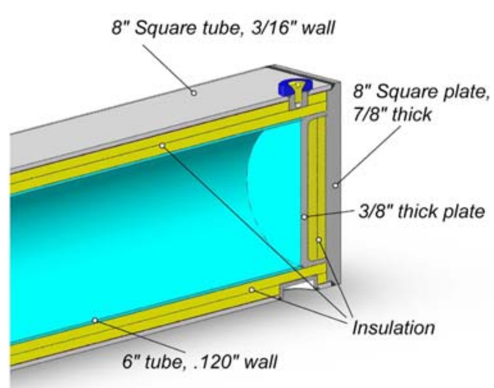

Figure 3
Sectional View, Package Bottom End

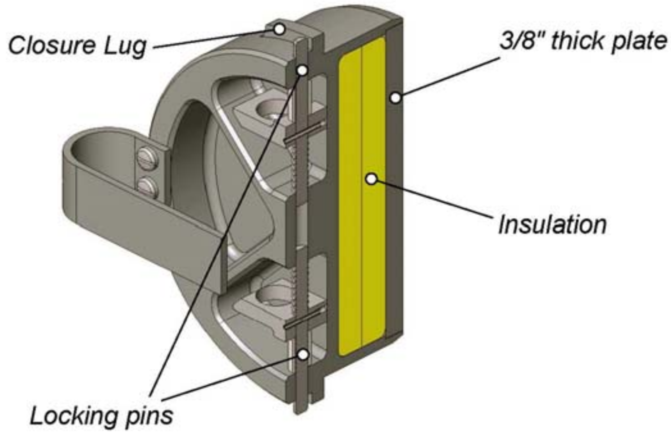

Figure 4 – Closure Section View

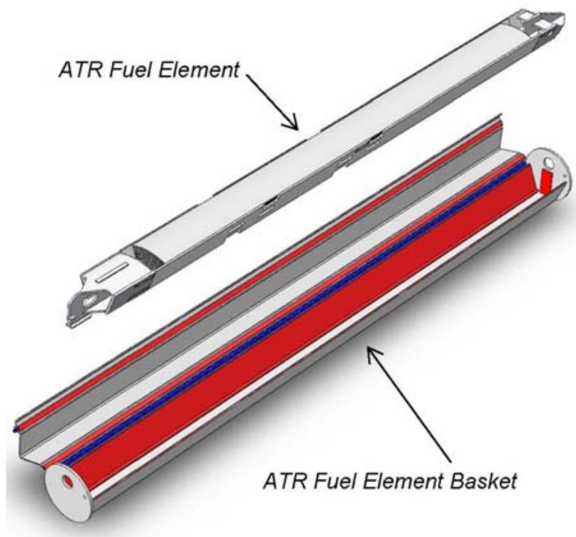

Figure 5 – ATR Fuel Element Basket

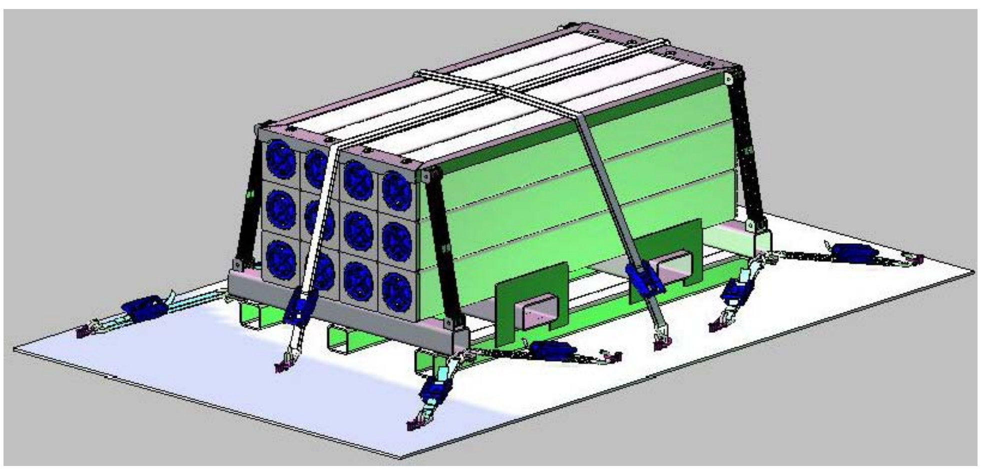

Figure 6 – ATR FFSC 4 × 3 Shipping Array

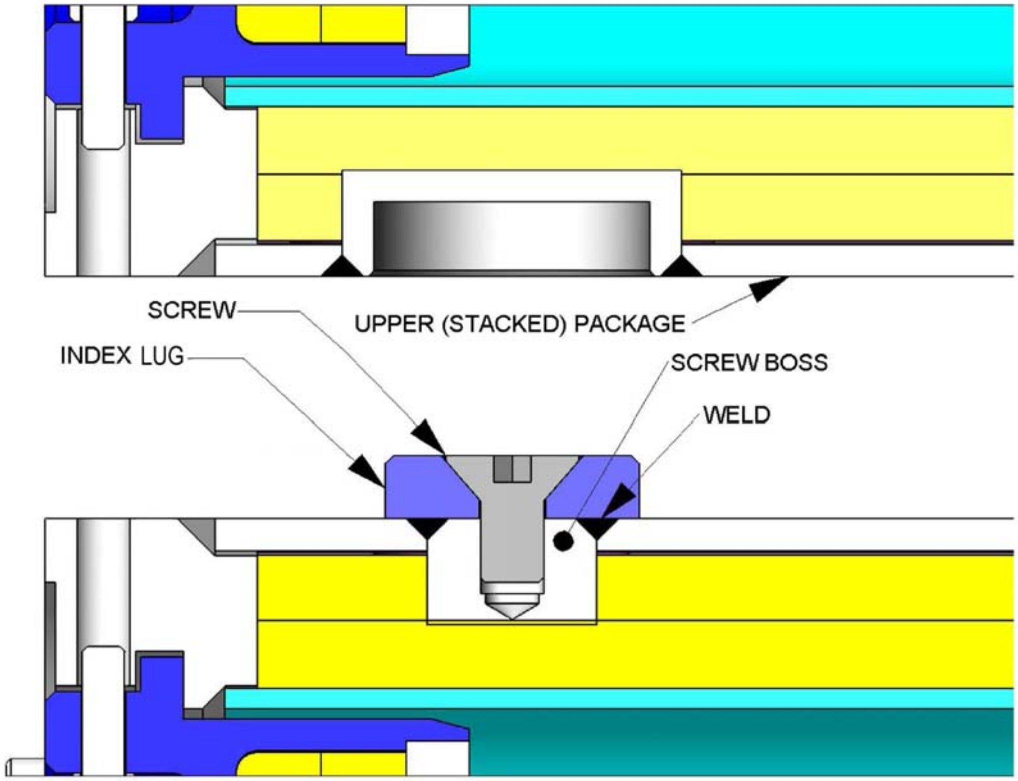

Figure 7 – Stacking Feature

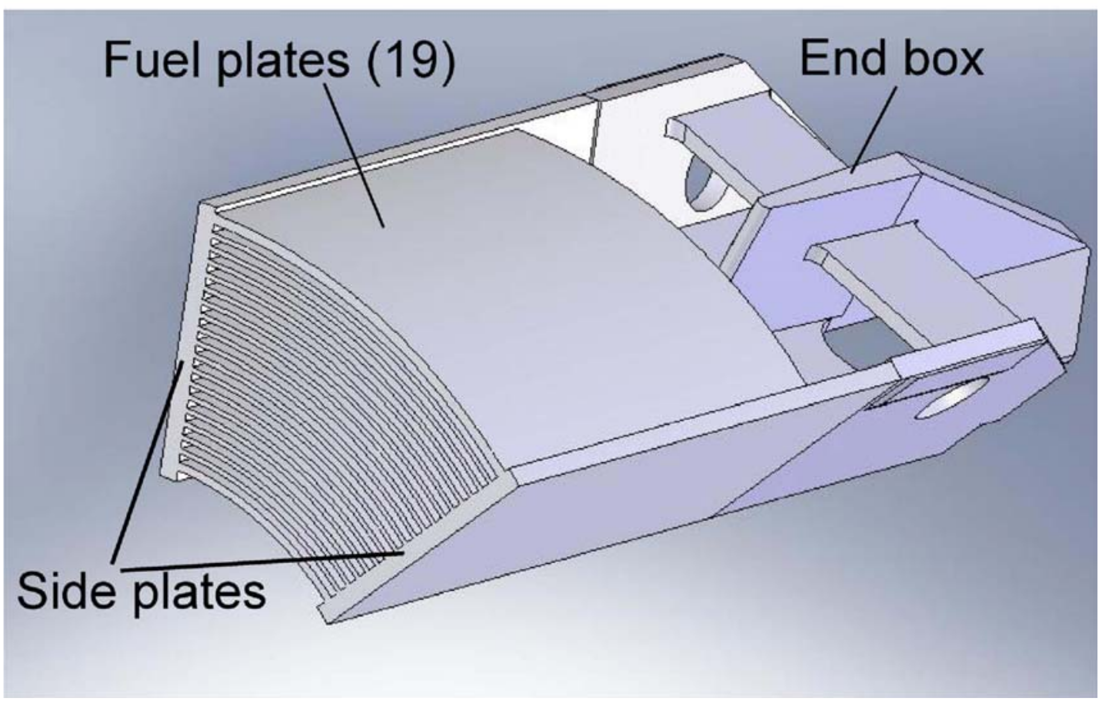

Figure 8 – Typical Cross Section of the ATR Fuel Element

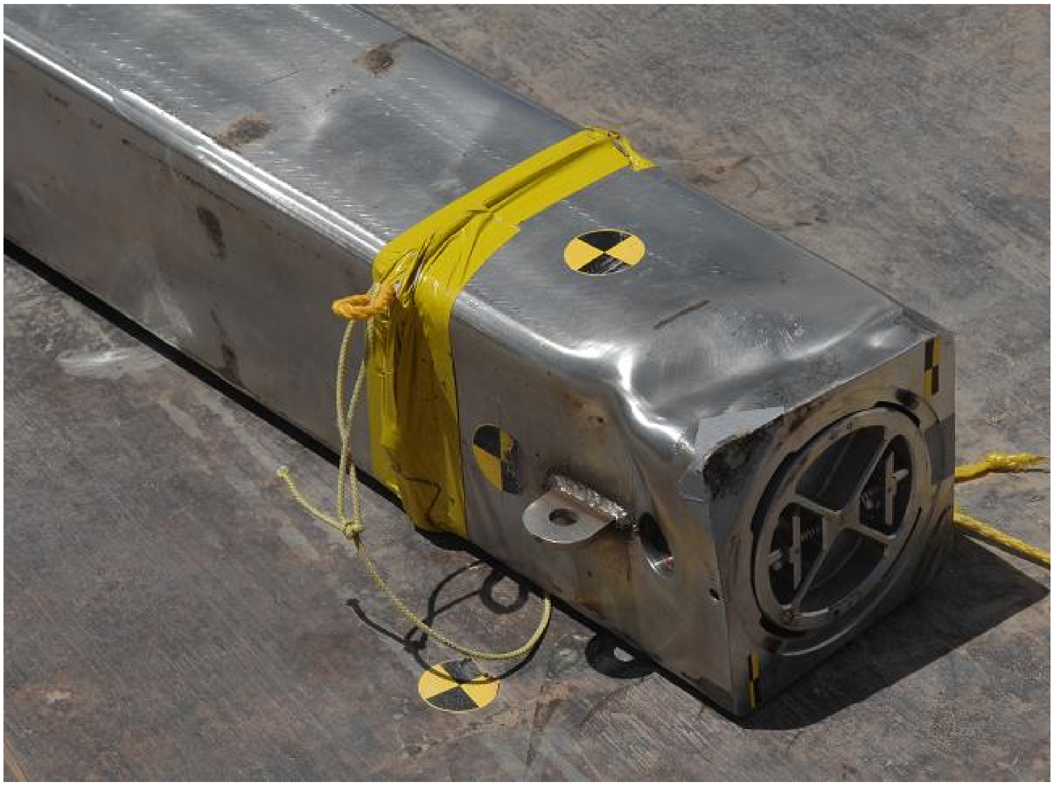

Figure 9 – Damage Following the 30-foot C.G.-Over-Corner Free Drop

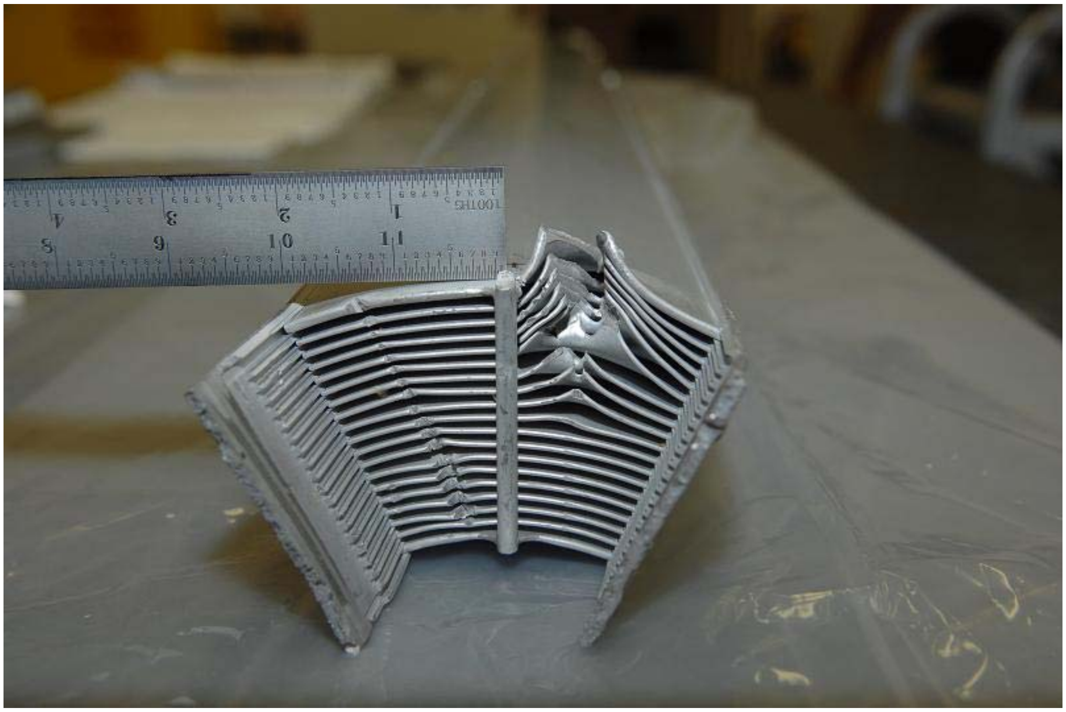

Figure 10 – Damage to ATR Fuel Element Following All Testing