Transport of LEU Research Reactor Fuel Elements in the ATR FFSC Package

Pre-Application Meeting

Orano Federal Services, LLC
under contract to
Battelle Energy Alliance, LLC

Agenda

- Introductions
- Purpose
- Review of ATR FFSC Packaging
- Discussion of new payloads and Fuel Handling Enclosures
- Safety Analysis
- Schedule

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Introductions

- Phil Noss, Licensing Manager, Orano Federal Services
- Eric Woolstenhulme, INL Program Manager
- Larry Gelder, Docket Manager, DOE Packaging Certification Program
- Michael McAnulty, DOE-Idaho
- Don Darrington, INL Packaging &Transportation
- Rich Smith, Project Manager, Orano Federal Services
- Brian Waud, DOE-NNSA M3
- Scott Ravenhill, DOE-NNSA M3
- Brett Cox, DOE-NNSA M3
- Kerry Dunn, SRNL USHPRR Program
- Mike Cercy, SRNL USHPRR Program

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Purpose

- **The U.S High Performance Research Reactor (USHPRR) Project (under NNSA's Convert Program) is working to convert the 5 remaining USHPRRs from Highly Enriched Uranium (HEU) fuel to Low Enriched Uranium (LEU) fuel.**
  - **The Project is developing LEU fuel element designs using U-10Mo monolithic fuel plates, and**
  - **Will need to ship prototypic, full-size, U-10Mo reactor fuel elements and associated Design Demonstration Elements (DDE)**
- **The ATR FFSC package is certified to transport plate-type research reactor fuels, loose plates, and fuel foils**
- **The ATR FFSC has been, and will continue to be, the shipping container of choice for these payloads**

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Review of ATR FFSC Packaging

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ATR FFSC Packaging

- The ATR FFSC packaging holds CoC USA/9330/AF-96 since 2008
- Certificate held by DOE-EM
- It was developed to transport a single, unirradiated ATR fuel element from the fuel manufacturer to the ATR reactor
- Since then, six additional plate-type research reactor fuel elements and experiments have been added
- All payloads have a Type A fissile quantity, and most are High Enriched Uranium (HEU) material
- Core material may be UAl_x, or U_3Si_2
- CSI varies between 4.0 and 25.0

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ATR FFSC Packaging

- **Outer dimensions: 8 inches wide × 8 inches tall × 72.5 inches long**
- **Inside dimensions: Cylindrical cavity 5.76 inches in diameter, 67.88 inches long**
- **Weight:**
  - **290 lb package gross weight**
  - **50 lb maximum payload weight (including fuel handling enclosure)**
- **All structural materials of packaging are Type 304 stainless steel**
- **Insulation is ceramic fiber**

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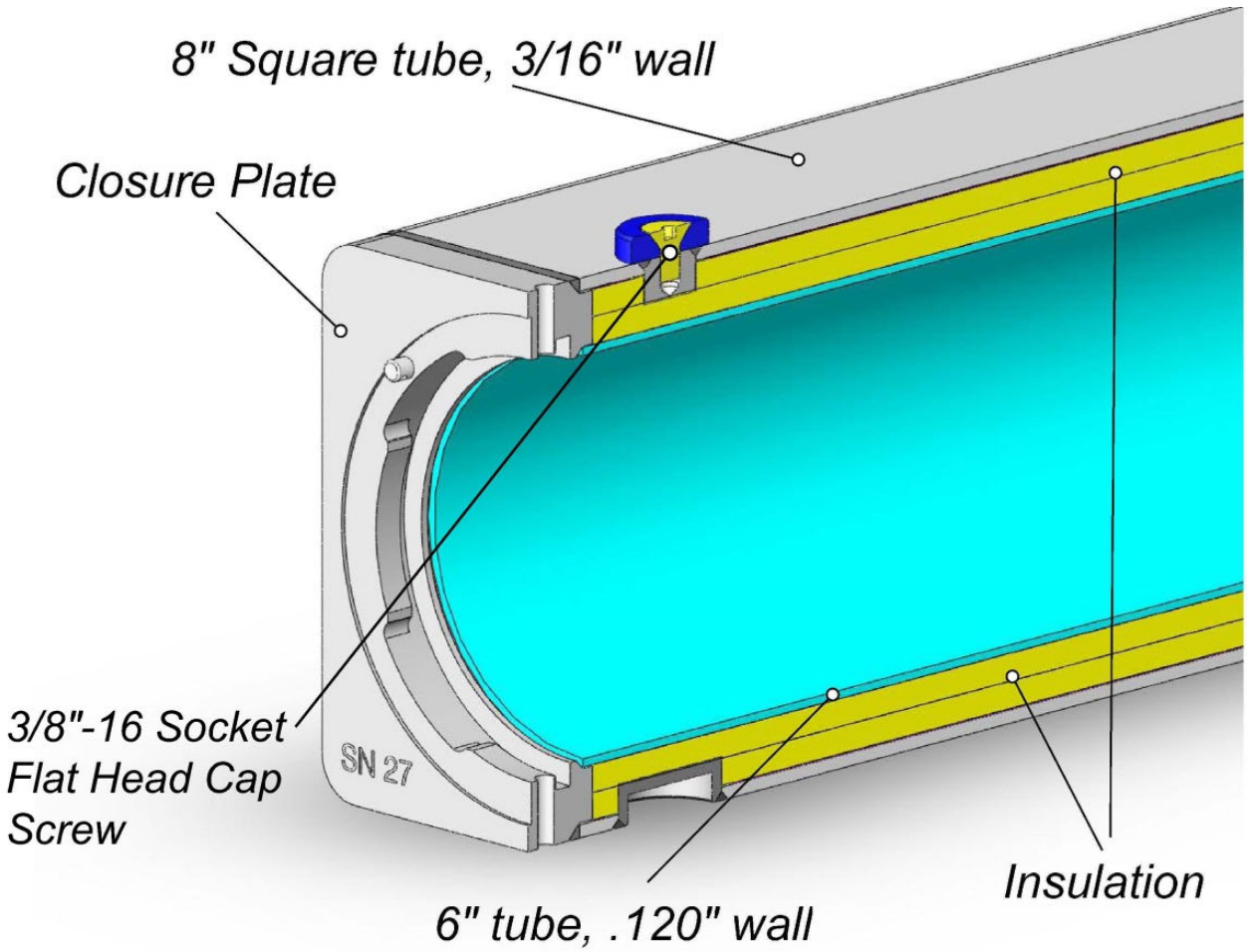
ATR FFSC Packaging



Open End

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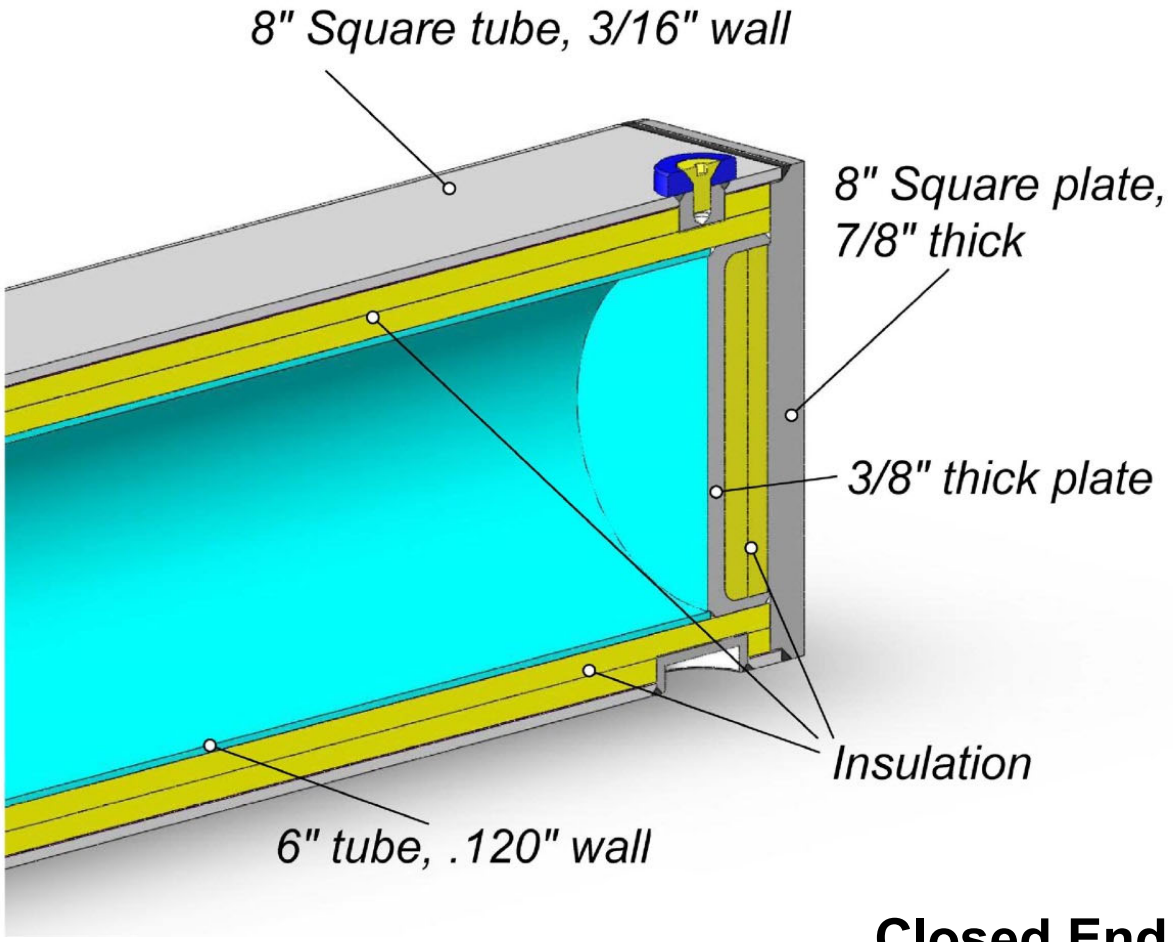
ATR FFSC Packaging



Closed End

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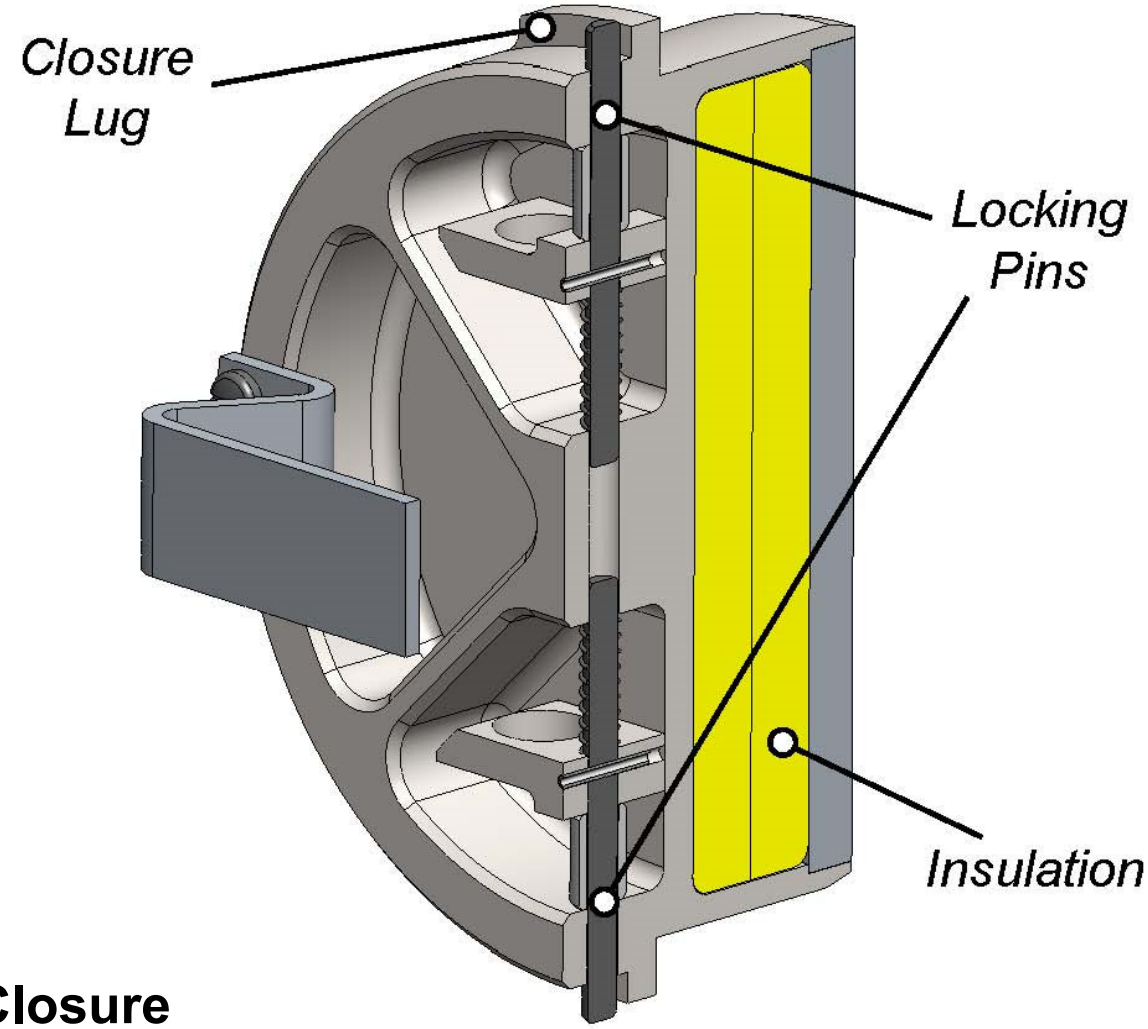
ATR FFSC Packaging



Bayonet Closure

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ATR FFSC Packaging

- All fuel elements or loose plates located in fuel handling enclosures (FHE)
- FHEs provide convenience and investment protection, do not have a safety function
- Two types of FHE currently used: sheet metal weldment (ATR fuel) and machined from billet (all others)
- All current FHE are made from aluminum and are not relied upon for criticality control

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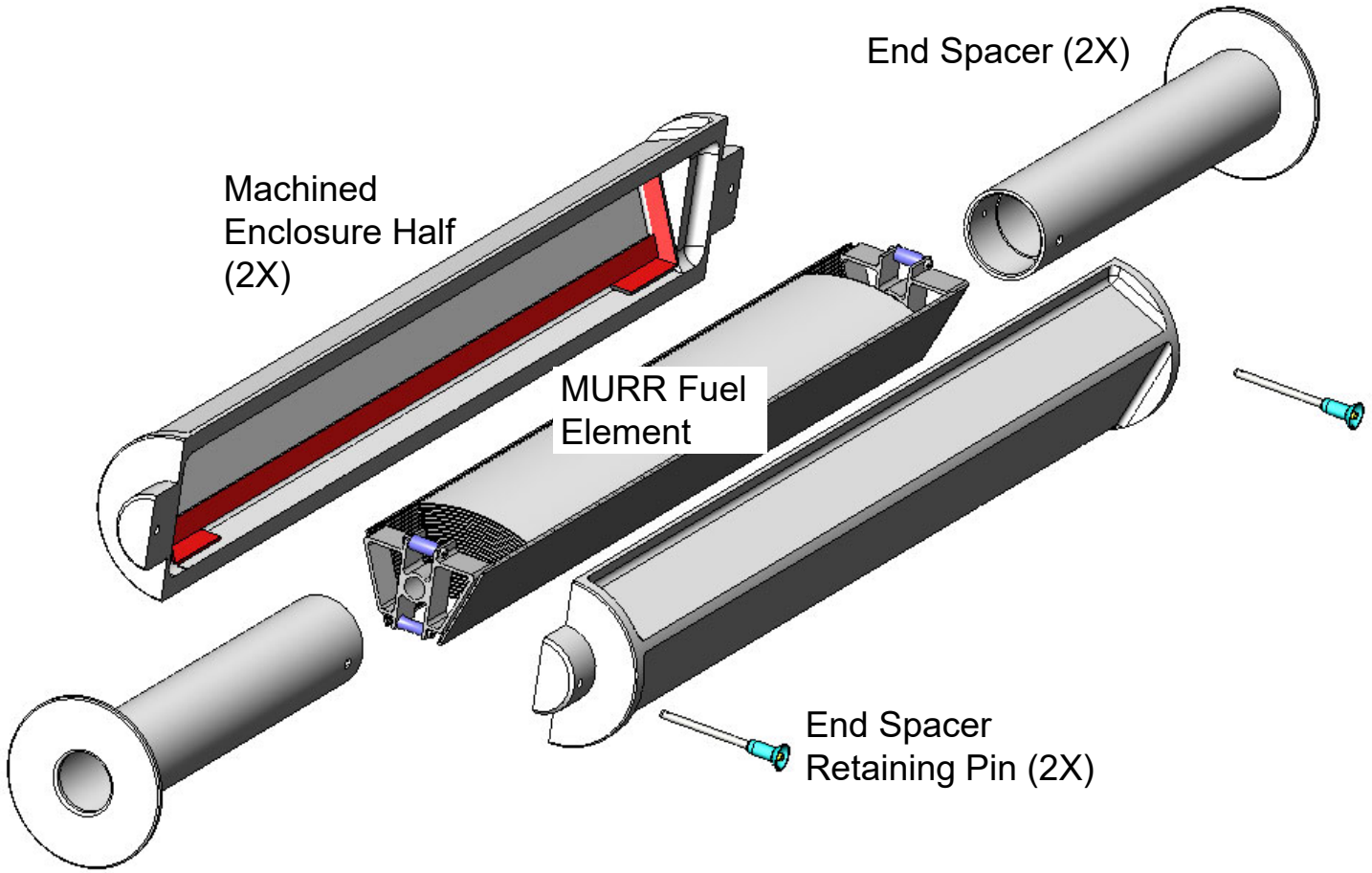
ATR FFSC Packaging



Example FHE: MURR

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LEU Fuel Elements and Fuel Handling Enclosures

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LEU Fuel Elements

- **Approval is being sought for full size prototype LEU fuel elements and Design Demonstration Elements (DDE)**
- **DDEs are similar to prototypic elements, and include prototypic fuel plates**
  - **DDE fissile mass and element weight is bounded by the associated LEU prototype element (i.e., MITR DDE bounded by MITR prototype)**
  - **DDE end fittings are different from prototypic element, permitting in-situ measurements to be taken**
  - **Only one DDE of each type will be shipped**
- **New LEU payloads are:**
  - **ATR full size LEU prototype element**
  - **MITR full size LEU prototype element and MITR DDE**
  - **MURR full size LEU prototype element and MURR DDE**
  - **NBSR DDE (only)**

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LEU Fuel Elements

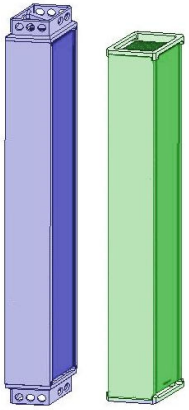
ATR LEU

Blue = LEU Elements (Same image would apply to HEU elements)

Green = LEU DDE

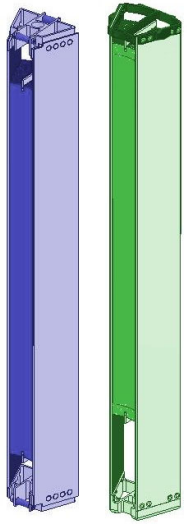
MITR LEU

MITR DDE

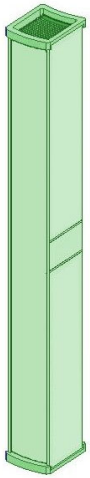


MURR LEU

MURR DDE



NBSR DDE



Balsa FHE

MITR FHE

Lightweight MURR FHE

Cardboard Blocking

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LEU Fuel Elements

- **All new payloads are enriched up to 20% U-235**
- **U-235 loading is between 1.4 times (ATR) and 2.1 times (MURR & MITR) more than the HEU element**
- **Core "meat" material is U-10Mo alloy**
- **Fuel cladding and element end fittings are from same aluminum alloys as for HEU elements in current use**

Fuel Type	U-235 mass, g	FHE Type
ATR	1,681	Balsa
MITR & DDE	1,660	Standard MITR FHE
MURR & DDE	1,070	Lightweight version of standard MURR FHE
NSBR DDE	460	Blocked with disposable material

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New Fuel Handling Enclosures

- **Because LEU fuel elements are heavier than HEU elements, two new FHEs are required**
- **New FHEs are lightweight, thus achieving the same total weight as for HEU (Fuel element + FHE = 50 lb max)**
- **Like existing FHEs, new FHEs are not relied upon for criticality control**
- **MITR LEU fuel and DDE with the existing MITR FHE weigh less than 50 lb, so no change to the MITR FHE is necessary**

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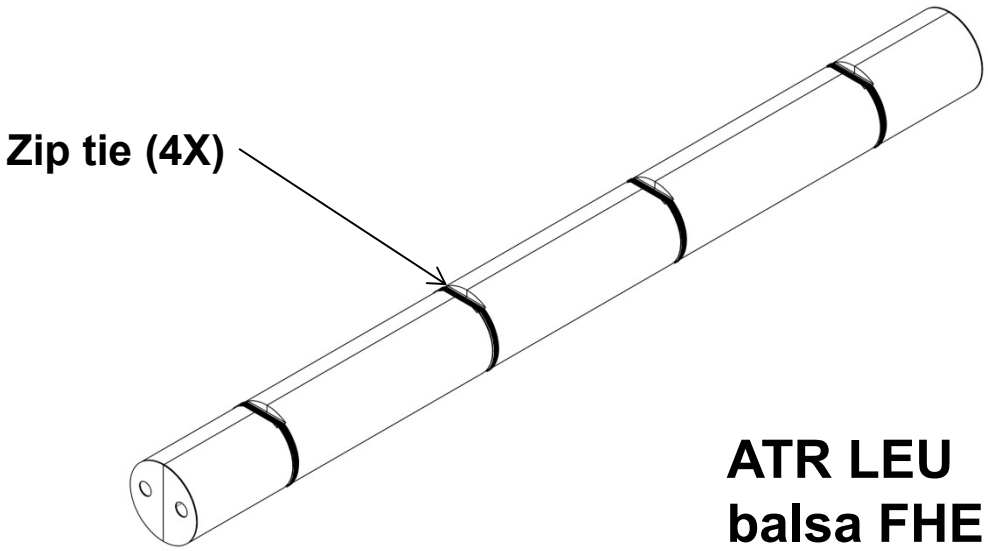
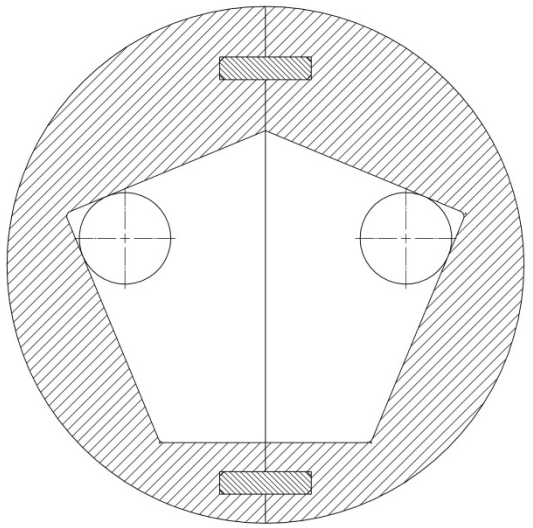
New Fuel Handling Enclosures

- **For ATR LEU fuel element, new balsa wood FHE has been developed**
- **Balsa FHE will have new SAR drawing**



ATR LEU balsa FHE



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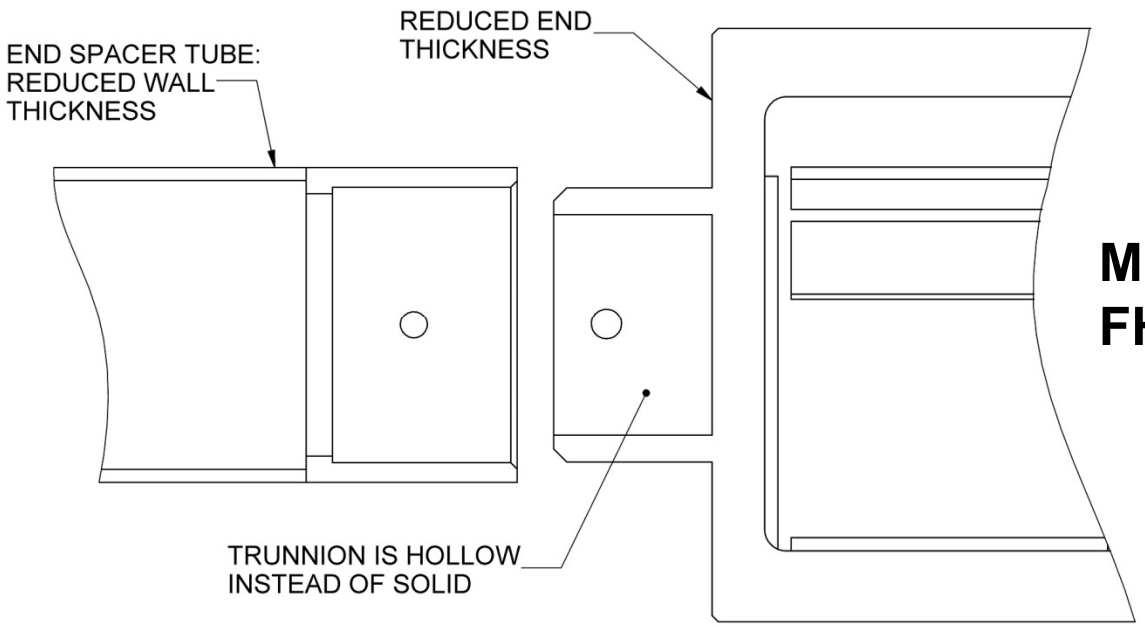
New Fuel Handling Enclosures

- **For MURR LEU fuel elements and DDE, a reduced-weight FHE has been developed which removes some unneeded thickness from the existing MURR FHE**



MURR Lightweight FHE

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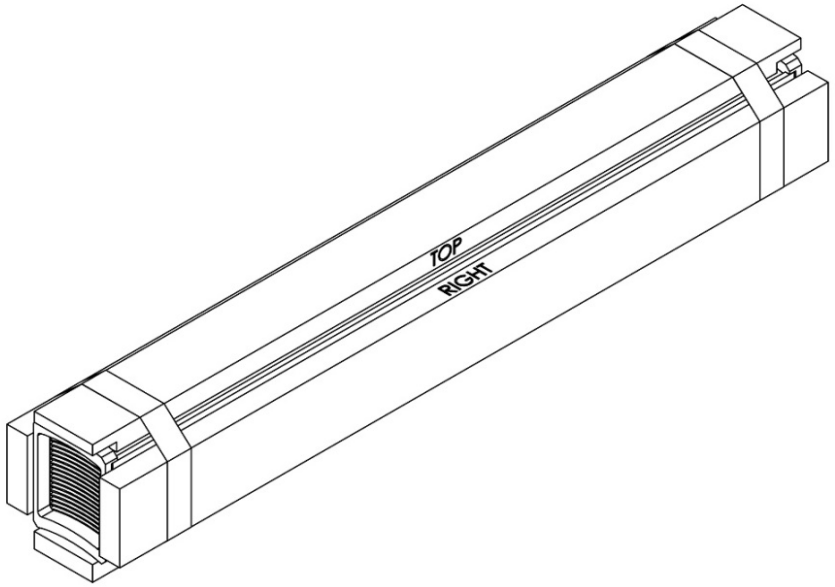
New Fuel Handling Enclosures

- **Since only one NBSR DDE will be shipped, and the full size NBSR fuel element does not fit into the ATR FFSC, an engineered FHE has not been developed**
- **The NBSR DDE will be blocked for property protection using cardboard**
- **Quantity of cardboard will be less than 4 kg (per existing SAR limit)**

(Example of NBSR DDE blocking)



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Safety Analysis Report

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Criticality Evaluation

- **Each fuel type evaluated independently, but methodology is very similar**
  - **Assumptions, conservatisms, and simplifications consistent with existing analyses**
  - **Fuel elements and DDEs of same type bounded by same models (MITR DDE bounded by MITR LEU element, MURR DDE bounded by MURR LEU element)**

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Criticality Evaluation

- **General Process**
  - **Fuel mass maximized (beyond tolerances), non-fuel material minimized**
  - **All available space filled with variable-density moderator**
    - **Inner cavity for NCT and HAC, outer shell for HAC only**
    - **Moderation between fuel plates varied independently to simulate bag**
  - **Independent movement of individual plates under HAC**
    - **MITR and MURR FHEs (aluminum) not modeled but credit taken for restricting movement of fuel plates as per existing HEU analysis**
    - **ATR (balsa) and NBSR (cardboard) not modeled or credited**
  - **Possible moderating materials accounted for**
    - **Up to 200 g polyethylene, neoprene is FHE-dependent**

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Criticality Evaluation

- **Air transport analysis updated to account for LEU fuel, balsa or cardboard packaging**
- **USL calculation performed using Whisper-1.1**
  - **Distributed as part of MCNP6.2, library of ~1,000 benchmarks**
  - **Utilizes sensitivity/uncertainty (S/U) techniques to select benchmarks similar to application**
  - **Sufficient number of very highly correlated ($c_k \geq 0.90$) and moderately correlated ($c_k \geq 0.80$) systems found for each application (i.e. fuel type)**
  - **Resulting USLs are consistent with existing ATR FFSC payloads**

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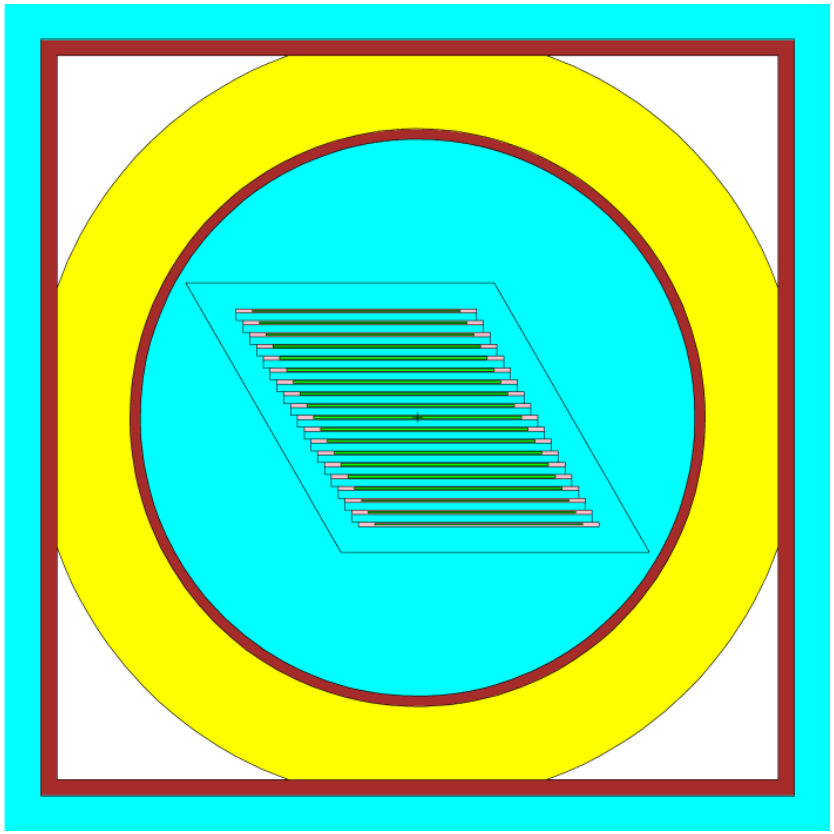
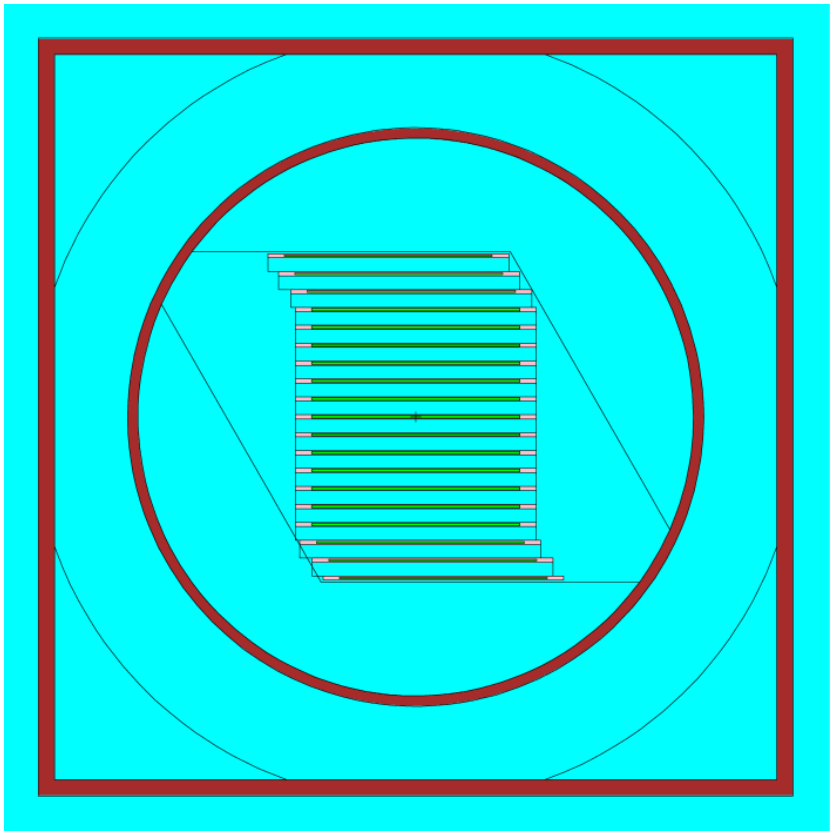
Criticality Evaluation

Example Configuration: MITR



NCT



HAC

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Criticality Evaluation

- **CSI of 6.25 for ATR LEU, 4.0 for all other LEU payloads**
- **Results below for k_{safe} ($k_{MCNP} + 2\sigma$)**

	ATR LEU	MURR LEU & DDE	MIT LEU & DDE	NBSR DDE
Normal Conditions of Transport (NCT)				
Single Unit Maximum	0.42385	0.5063	0.42693	0.39137
Array Maximum	0.77809 (7x7)	0.86146 (8x8)	0.68613 (9x9)	0.65257 (9x9)
Hypothetical Accident Conditions (HAC)				
Single Unit Maximum	0.58853	0.58572	0.52045	0.50968
Array Maximum	0.87986 (4x4)	0.86625 (5x5)	0.72735 (5x5)	0.74897 (5x5)
Upper Subcritical Limit (USL)				
	0.92312	0.92071	0.92288	0.92348

- **Air Transport: k_{safe} = 0.71171, USL = 0.90868**

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Thermal Evaluation

- The effect of the HAC fire on the balsa wood is considered in the thermal analysis
- Analysis of balsa follows the existing evaluation for gases evolved from neoprene and polyethylene
- Balsa decomposes from fire heat, but due to limited oxygen within the package, combustion does not occur
- Pressure increase is calculated and is negligible

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Structural Evaluation

- **Payload bounding weight is not changed: 50 lb for fuel element plus FHE**
- **Fuel element plates will remain intact after all HAC (same as HEU)**
- **Fuel plates assumed to break free of side combs and configure in worst case separation for criticality evaluation (same as HEU)**
- **Balsa FHE (ATR LEU) and cardboard blocking (NBSR DDE) are not credited in the criticality evaluation**
- **No structural evaluation is necessary because:**
  - **Packaging is not changed**
  - **Payload structure type (plate fuel) and bounding weight is not changed**
  - **Conservative assumptions used for post-HAC configuration of plates**

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Safety Analysis Report

- **Updates primarily to Chapter 1 (Introduction) and Chapter 6 (Criticality Evaluation)**
- **Updates will also occur in Chapter 3 (Thermal Evaluation) and Chapter 7 (Package Operations)**
- **New drawings supplied for the balsa FHE and MURR lightweight FHE**
- **Reference to "ATR U-Mo Demonstration Element" will be removed throughout, as this element has never been made and is replaced by the ATR full size prototype element**

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Schedule

- **Safety Analysis Report scheduled to be delivered to NRC in mid-May, 2021**
- **Certificate of Compliance is requested no later than December 24, 2021**

Discussion

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