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Fuel Specification for Uranium Monocarbide FAST Fuel Specimens

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Specification

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REVISION LOG

Rev.	Date	Affected Pages	Revision Description
0	04/26/22	All	New issue

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1. PURPOSE

This specification outlines the fabrication requirements for kernel compact uranium monocarbide (UC) fuel to be fabricated at General Atomics (GA). The UC fuel will be irradiated in the Advanced Test Reactor (ATR) using the Irradiation System for High-Throughput Acquisition (ISHA-1). The primary objective of the ISHA-1 capsule design is to deliver to Idaho National Lab (INL) a semi-universal drop-in capsule that can facilitate the irradiation of both fissile and structural materials in a variety of ATR positions. This irradiation experiment will support the need for development of Accelerated Fuel Qualification (AFQ) methods.

2. SCOPE

This specification outlines the requirements for the fuel specimen being fabricated at GA to be used in the ISHA irradiation experiment. UC fuel will be irradiated in the ATR. This document only applies to the fuel specimen as fabricated at GA and shipped to INL. A separate Fuel Qualification Plan will govern the qualification of the fuel specimens upon receipt at INL.

At a minimum, requirements in this specification must be met for the fuel specimens to be candidates for irradiation testing in ATR.

3. PROCESS DESCRIPTION

The UC fuel specimens will be qualified for ATR irradiation upon receipt at INL in accordance with a Fuel Qualification Plan. However, a minimum set of information is required from GA to support fuel specimen qualification.

Kernel compact pellet specimens are to be fabricated using a sol-gel process. Resulting gel will be hot pressed to the required pellet dimensions and to approximately 75% density. Each sol-gel batch used to fabricate pellets will require analysis. Under the purview of the Qualification Plan, some of these pellets will be destructively analyzed to verify chemical and isotopic composition. Adequate documentation and process documents shall be provided as evidence that all pellets within a batch were processed using identical pressing and sintering processes. Variance among individual pellet processing after the sol-gel process may result in the need for additional pellet inspection and analyses.

Chemical analyses of all fuel specimen constituents are required, and traceability throughout the process must be maintained in order for feedstock certifications to be made applicable to the final fuel specimens. Evidence must be provided demonstrating traceability of constituents throughout the fabrication process; this can be through the use of travelers or some other mechanism which documents the specimen processing.

4. DESIGN REQUIREMENTS

4.1 Design

The fuel specimens shall strictly comply with the dimensions of INL Drawing 823011. Any deviation requires written approval from INL.

4.2 Enrichment

The nominal enrichment shall be per Appendix A.

4.3 Chemistry

The fuel specimens shall be composed of enriched uranium monocarbide. Uranium and carbon content specifications are stated in Appendix A. Composition and isotopic analysis shall be performed on a per batch basis.

Allowable impurity levels are defined in Appendix B and measured per ASTM C1287 *Test Methods for Determination of Impurities in Nuclear Grade Uranium Compounds by Inductively Coupled Plasma Mass Spectrometry.* If not listed, the impurity shall be less than 1000 ppm. Total impurities shall be less than 0.5 wt% or 5000 ppm.

4.4 Dimensions

All pellets shall conform to the requirements in INL Drawing 823011. 100% dimensional inspection is required. Inspection requirements include dimensional, density, impurity and visual.

4.5 Density

Fuel pellets shall be 75% ± 5.0% of theoretical density. Theoretical density is 13.63 g/cc. Density may be calculated using any standard calibrated technique (ex. geometric calculation, pycnometry, Archimedes method).

Inspection of 100% of fuel pellets is required.

4.6 Pellet Quantity

A minimum of 30 pellets shall be provided unless otherwise agreed to by project management.

5. QUALITY ASSURANCE

5.1 General

Written procedures should be in place to govern activities associated with the fabrication of the fuel specimens and shall be made available to INL for review if requested. All measurements dictated within the scope of this specification must be performed by qualified personnel, using calibrated instruments. Calibration standards used must be traceable to NIST or an equivalent national standard.

5.2 Reporting Requirements

This minimum set of information is required to be transmitted from GA to INL either with or prior to the fuel specimen shipment.

As applicable, all inspections and reports must include, at a minimum the activity performer or inspector, item being inspected, date of inspection, type of observation, M&TE information, and results or acceptability.

- Inspection reports for dimensional inspections
- Inspection reports for density inspections
- Enrichment information
- Traceability information for fuel specimens

Process documentation which ties the final, as-fabricated, fuel specimen to the parent feedstock materials is required. This may be accomplished via use of unique identifiers of parent materials such as lot numbers, batch numbers, or other identifier, as traced through the entire fabrication process, and resulting in the final fuel specimen.

5.3 Records

During fabrication, all process steps and inspections shall be tracked and documented in accordance with a Records Management Process.

Individual detailed records must be maintained in accordance with this Records Management program. The information described within this Specification must be transmitted to INL in support of qualifying the fuel specimen.

6. VERIFICATIONS AND INSPECTIONS

Unless otherwise noted, these criteria and inspections apply individually to all fuel specimens.

6.1 Fuel Specimen Materials

All constituents that comprise the fuel specimen in its final, as-fabricated, condition must be known. Evidence of fuel pellet composition is required. Certification and analysis information on the original materials used for UC pellet production must be provided.

7. FUEL SPECIMEN SHIPPING

NOTE: *Any radiological or nuclear material to be shipped to INL requires prior authorization from INL Safeguards.*

For INL to receive nuclear material, INL Form 472.65 must be submitted to INL Safeguards personnel a minimum of 2 weeks prior to the requested shipping date.

MFC is on a 4-10 schedule, with Monday through Thursday as working days. Fuel must be shipped such that it arrives at MFC on a Monday through Thursday.

Additional information beyond what is transmitted via INL Form 472.65 is required prior to shipping the fuel specimen(s). This information includes:

1. Itemized list of material to be shipped must be transmitted in conjunction with the Safeguards authorization form. For each item, this list must include material gross weight, uranium element weight, enrichment, ^{235}U weight, and item identifier.

2. Specimen packaging configuration and shipping container information must be provided. Any images that can be provided will help ensure no damage occurs to specimens during unpacking.

3. Radiological conditions must be reported. This includes dose rate of the specimens themselves, along with the dose rate of the shipping container. Smearable contamination levels of the fuel specimens themselves, the inner package material, and the outer package must be reported.

4. The container identifier and TID must be reported.

5. Any special handling or unpackaging requirements must be noted.

Shipping requirements as described within this Specification are INL specific requirements and are not a guide on how to ship nuclear material. These requirements do not supersede those of any regulatory body such as the NRC, DOE, DOT, or any other agencies.

APPENDIX A

Fuel Pellet Specifications

Characteristic	**Acceptance Criteria**
Enrichment	2.27 ± 0.1 weight%
Uranium Content	95.2 ± 0.5 weight %
Carbon Content	5.25 ± 0.5 weight%
Impurities	Per section 4.3
Dimensions a. Pellet length b. Pellet Diameter c. Perpendicularity	 a. Per drawing 823011 b. Per drawing 823011 c. Per PI discretion
Density	75% ± 5.0% TD

APPENDIX B

Allowable Impurity Levels

Element	Maximum ppm (U basis)
Ag	1.0
Al	500.0
B	0.5
Ca	100.0
Cd	0.5
Co	6.0
Cr	250.0
Cu	500.0
Dy	0.5
Eu	0.5
Er	16.0
Fe	250.0
Gd	1.0
Hf	<26
Mg	100.0
Mn	500.0
Mo	100.0
Ni	250.0
O	500.0
Pb	20.0
Sm	2.0
Sn	25.0
Ti	40.0
Th	10.0
V	1.0
W	1000
Zn	20.0