INL/EXT-14-31986

Fabrication Control Plan for ORNL ATF Test Specimens to be Irradiated in the ATR

Kevin G. Field, Richard Howard, Michael Teague

June 2015

The INL is a U.S. Department of Energy National Laboratory
operated by Battelle Energy Alliance

INL/EXT-14-31986

Fabrication Control Plan for ORNL ATF Test Specimens to be Irradiated in the ATR

Kevin G. Field, Richard Howard, Michael Teague

June 2015

Idaho National Laboratory

Idaho Falls, Idaho 83415

http://www.inl.gov

Prepared for the
U.S. Department of Energy
Office of Nuclear Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

PLN-4655
Revision: 0
Effective Date: TBD

Fabrication Control Plan

Project No. 31418

Fabrication Control Plan for ORNL ATF Test Specimens to be Irradiated in the ATR

Fuel Cycle Research & Development

Advanced Fuels Campaign

Authors

Kevin G. Field – ORNL
Richard Howard – ORNL
Michael Teague - INL

Prepared for

U. S. Department of Energy
Office of Nuclear Energy

June 2014

Fabrication Control Plan for ORNL ATF Test Specimens to be Irradiated in the ATR

PLN-4655

Project File No. 31418

Approved by

6/10/2014

Heather Chichester
Irradiation Testing Technical Lead, Advanced Fuels Campaign

6/10/2014

Kristine Barrett
ATR Irradiation Testing Experiment Manager, Advanced Fuels Campaign

6/12/2014

Kevin G. Field
ORNL ATF Irradiation Testing Lead

6/12/2014

Richard Howard
ORNL ATF Fabrication and Experimental Design Lead

INTENTIONALLY BLANK PAGE

REVISION LOG

Rev.	Date	Affected Pages	Revision Description
0			New issue. See eCR 620484

INTENTIONALLY BLANK

CONTENTS

TABLES

ACRONYMS

AFC	Advanced Fuel Cycle
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATR	Advanced Test Reactor
B&PVC	Boiler and Pressure Vessel Code
CMM	Coordinate-Measuring Machine
ECAR	Experiment Calculations and Analysis Report
EDM	Electrical Discharge Machining
EFF	Experimental Fuels Facility
EM	Experiment Manager
FCRD	Fuel Cycle Research and Development
GE	General Electric
GRC	General Electric - Global Research Center
GNF	General Electric - Global Nuclear Fuels
GTAW	Gas Tungsten Arc Welding
INL	Idaho National Laboratory
IRC	INL Research Center
LT	Helium Leak Check
MFC	Materials and Fuels Complex
NCR	Nonconformance Report
NDE	Non-Destructive Examination
OA	Outboard-A
PT	Liquid Penetrant Examination
QA	Quality Assurance
QE	Quality Engineer
QI	Quality Inspector
QL	Quality Level
QLD	Quality Level Determination
RE	Responsible Engineer
RT	Radiographic Examination
TFR	Technical and Functional Requirements
VT	Visual Examination
WP	Work Package

1. PURPOSE

The purpose of this fabrication plan is (1) to summarize the design of a set of rodlets that will be fabricated and then irradiated in the Advanced Test Reactor (ATR) and (2) provide requirements for fabrication and acceptance criteria for inspections of the Light Water Reactor (LWR) – Accident Tolerant Fuels (ATF) rodlet components. The functional and operational (F&OR) requirements for the ATF program are identified in the ATF Test Plan [Reference 1]. The scope of this document only covers fabrication and inspections of rodlet components detailed in drawings 604496 and 604497. It does not cover the assembly of these items to form a completed test irradiation assembly or the inspection of the final assembly, which will be included in a separate INL final test assembly specification/inspection document. The controls support the requirements that the test irradiations must be performed safely and that subsequent examinations must provide valid results.

The primary objective of this test is to determine the behavior of fuel material under neutron irradiation in conditions that could be relevant for a typical commercial fuel bundle. One of the main objectives is to determine the compatibility between the fuel and the proposed metallic claddings under neutron irradiation. A second objective would be to determine the mechanical and physical behavior of the metallic cladding after irradiation, including the rodlet endcap weld performance and durability and pellet/clad mechanical interaction. In particular, it is understood that the cladding welds are considered "development" welds and the potential for weld failure is possible during irradiation testing.

2. BACKGROUND/ SCOPE OF WORK

It is planned to test two rodlets each of ORNL ATF FeCrAl clad to three different burn-ups resulting in 6 total rodlets being fabricated. The nominal composition of the clad material for the rodlets is Fe-13Cr-5.2Al-2Mo-0.2Si-1Nb-0.05Y. The rodlet will utilize commercial Westinghouse UO_2 fuel pellets with prototypical dish and chamfer. The fuel has been enriched to a nominal 4.95%. Details on the UO_2 fuel pellets can be found in Section 5.1. The desired nominal linear heat generate rate for the rodlets is 180-280 W/cm with a peak inside clad temperature (PICT) not exceeding 400 °C. Three burn-up values will be investigated: 10 GWd/MT, 30 GWd/MT, and 50 GWd/MT. Two test pins will be fielded for all burn-up conditions. Based on previous experience this will span a test cycle of 12-70 months. The 10 GWd/MT will provide an opportunity of early indication of the FeCrAl clad performance at low burn-up. A summary of the experimental test matrix is in Table 1

The rodlets will be fabricated according to INL drawing 604496 and 604497. The tubes and end caps for the rodlets will be fabricated by machining stock ORNL ATF FeCrAl clad (Fe-13Cr-5.2Al-2Mo-0.2Si-1Nb-0.05Y). The alloy stock material and certifications will be provided by ORNL to INL as part of the data package and can be found in Appendix D.

The fuel to be inserted in the six rodlets will be provided by Westinghouse. Westinghouse will ship the fuel to ORNL in the required dimensions for the insertion into the rodlets. The ORNL concepts will incorporate commercially available UO_2 pellets with a fixed OD of 0.322 in. (nominal). The exact dimensions of the UO_2 pellets to be fielded are in Section 5.6. Based on the design requirements in Table 1 and the fixed dimensions of the fuel to be utilized, the radial dimensions of the rodlet assembly have been fixed in drawing 604496 as shown in Figure 1. The justification of the radial dimensions and finalized drawings is based on the neutronic[11], thermal[12 & 13], and structural[14] analyses.

Table 1. Experiment Summary for ORNL ATF rodlets.

Fuel	Fuel Enrichment	Cladding	Desired Irradiation Conditions:			# of Rodlets
			PICT Desired/Max (°C)	LHGR (W/cm)	Burn up (GWd/MT)[1]	
Commercial UO_2	4.95%	Fe-13Cr-5.2Al-2Mo-0.2Si-1Nb-0.05Y	350/400	180-280	10	2
Commercial UO_2	4.95%	Fe-13Cr-5.2Al-2Mo-0.2Si-1Nb-0.05Y	350/400	180-280	30	2
Commercial UO_2	4.95%	Fe-13Cr-5.2Al-2Mo-0.2Si-1Nb-0.05Y	350/400	180-280	50	2

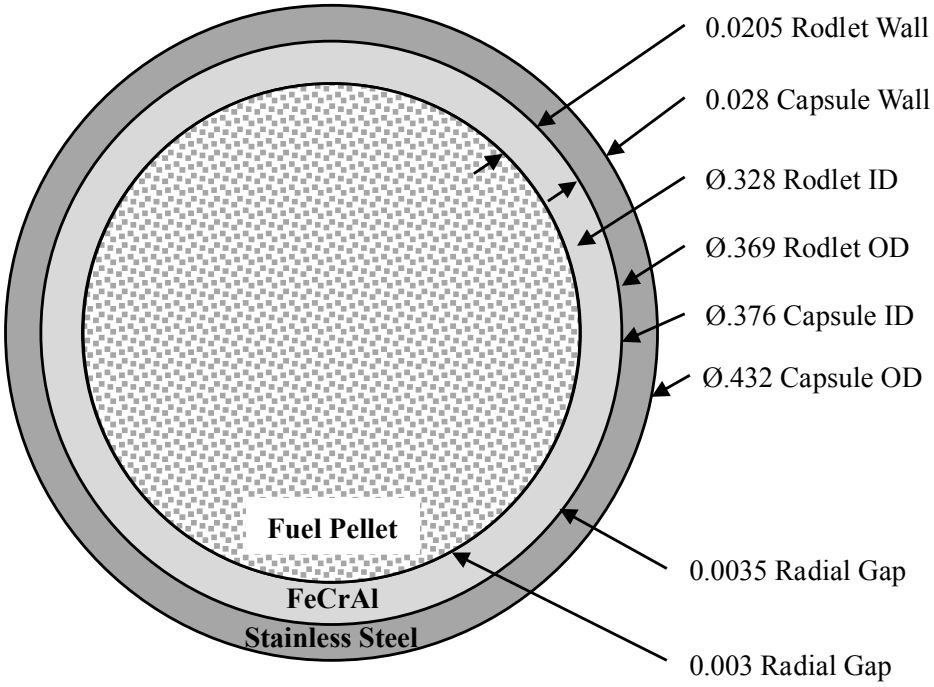


Figure 1: Pellet and fuel pin radial dimension. All units are in inches.

The rodlet design incorporates SiC discs at the top and bottom of each fuel stack with nominal dimensions of Ø.322 in. x 0.39 in (shown in drawing 604496). These discs serve to provide a thermal pathway for axial heat generation in the rodlet and provide another element for PIE investigations. High purity CVD-SiC (>99.999%) from Dow Chemical Co. will be used as base material for SiC components in drawing 604496. The final assembly of the rodlet per drawing 604496 will be performed at ORNL.

3. RESPONSIBILITIES, TRAINING, & QUALIFICATIONS

The major tasks in preparing and irradiating the rodlets are listed in Table 2. "Provider" indicates the organization responsible for performing the task, and "Recipient" indicates the organizations that will receive the material or information produced as a result of completing the task. In broad terms, ORNL is responsible for defining the pellet design, testing parameters, fabricating rodlet hardware, developing welding procedures, and assembling the rodlets. Westinghouse is responsible for providing special nuclear materials. INL is responsible for fabricating capsule hardware, developing welding procedure and for assembling the capsules, and irradiating the finalized test assembly.

Table 2. Tasks and Responsibilities.

Task #	Provider	Description	Recipient
1	ORNL	Provide rodlet design information	INL
2	ORNL	Provide pellet specification	Westinghouse
3	ORNL	Provide desired conditions for irradiation (LHGR, cladding temperature, and fuel temperature ranges)	INL
4	INL	INL will determine the U-235 enrichment and pellet/rodlet OD needed to meet test objectives	
5	Westinghouse	Fabricate pellets	ORNL
6	Westinghouse	Ship pellets to ORNL	ORNL
7	Westinghouse	Provide pellet manufacturing certificates	ORNL
8	ORNL	Provide cladding raw materials	ORNL
9	Dirats Laboratories	Perform chemical analysis on cladding materials	ORNL
10	ORNL	Fabricate Rodlet Parts	ORNL
11	ORNL	Provide plenum springs and end caps	ORNL
12	ORNL	Develop Welding Parameters/Procedures	INL
13	ORNL	Assemble rodlets	INL
14	ORNL	Report on rodlet assembly	INL
15	INL	Provide capsule components	INL
16	INL	Assemble capsules	INL
17	INL	Irradiate capsules/rodlets	INL
18	INL	Report on irradiation conditions	INL/ORNL

Table 3 includes a summary of responsibilities for verification, inspection and acceptance of ATF-1 rodlet components. The list in Table 3 is not all-inclusive for the fabrication process and roles may be delegated to qualified alternates as needed, per the Fabrication Work Package Manager discretion and Irradiation Testing Experiment Manager concurrence.

Table 3. Summary of responsibilities for verification, inspection, and acceptance of ATF-1 rodlet components.

TITLE	RESPONSIBILITIES
Experiment Manager (EM)	Overall responsibility for the irradiation experiment.
Fabrication Work Package Manager (WP mgr)	Responsible for assigning responsible engineers to supervise the fabrication process. Provide oversight and guidance for experiment fabrication and component inspections/verifications.
Responsible Engineer (RE)	Provide process supervision, guidance, and interface between WP manager, EM and Quality Inspectors/Engineers.
Quality Inspector (QI)	Perform inspection in accordance with inspection plans, work packages, and this PLN. Sign inspection checklists/reports and provide Green Tags as required.
Quality Engineer (QE)	Review & Validate quality documents.

For ORNL, training profiles, including required training for each position, are maintained for personnel who participate in the design, development, assembly, and test and inspection of the rodlets. Training activities shall be planned, accomplished, and documented in compliance to ORNL SBMS subject area, Training and Qualification of Staff and its subordinate procedures. The systems and processes described in these documents are intended to meet the requirements of the ANSI NQA-1-2008 standard and DOE Order 414.1D, to ensure the satisfactory knowledge and performance of personnel, that all necessary training and qualification/certification activities are completed prior to the commencement of the associated work activities, and to ensure that only the personnel who meet the explicit training and related requirements are permitted to perform each activity.

4. RECORDS MANAGEMENT

The records management system for ATF records generated at the INL is identified and described in the ATF Quality Implementation Plan (Reference 8).

The processes used to capture, control, and maintain records associated with ORNL's planned scope of work are implemented through the Requirements, Documents, and Records Management System's Records Management subject area which includes the following procedures:

- Establishing Records Program
- Identifying and Inventorying Records
- Scheduling Records
- Maintaining and Storing Active Records
- Transferring and Retrieving Inactive Records
- Destroying Records
- Training Records

5. FUEL COLUMN/PELLET REQUIREMENTS

5.1 Fuel Fabrication Process

The fuel fabrication process is those processes used commercially by Westinghouse.

5.2 Chemical Composition

UO_2 fuel pellet impurity limits shall be per ASTM C776-06 standard for sintered UO_2 pellets. The O/U ratio for the UO_2 pellets shall be 2.0-0.01/+0.02. The fuel shall have a nominal ^{235}U enrichment of 4.95 wt. %. The supplier has certified the chemical composition, density, and enrichment of the received pellets in report 2008015950[1] and 200801594[1].

5.3 Grinding

The sintered pellets are dry centerless ground to final dimensions.

5.4 Workmanship

The pellet surface will be free of abnormalities and loose powders or other foreign material.

5.5 Pellet Finish

All loaded pellets will be essentially free from abnormalities and surface imperfections. Surface imperfections are defined as: (1) chipping of the dished an[1]d flat ends, (2) chipping of the circumferential surface, (3) pits, (4) inclusions, (5) cracks in pellets surfaces, (6) end-capping/flaking, (7) non-clean up, and (8) grinding marks. Allowable imperfections are detailed in NFP 31029/PDPELE00, Rev. 56[1].

[1] [1]Denotes proprietary reports held on file at ORNL

5.6 Pellet Dimensions

Pellet dimensions shall comply with drawing PELE100[1]. The pellets shall have a dish and chamfer at both the top and bottom. Individual pellets will be identified by inclusion into single storage devices with proper markings prior to assembly. The dimensions with the Fuel OD are provided in Table 4.

Table 4: Fuel physical properties for ORNL rodlet. Average OD: 0.3221 and Average length: 0.3915 in.

Fuel I.D.	Length (in)	OD (in)	Mass (g)	Type
FR-102	0.4000	0.3224	5.5201	UO_2
FR-103	0.3913	0.3224	5.3953	UO_2
FR-104	0.3882	0.3217	5.3626	UO_2
FR-105	0.3965	0.3220	5.4822	UO_2
FR-106	0.3941	0.3220	5.4456	UO_2
FR-108	0.4035	0.3220	5.5763	UO_2
FR-109	0.3890	0.3220	5.3845	UO_2
FR-111	0.3878	0.3220	5.3703	UO_2
FR-113	0.3913	0.3220	5.4043	UO_2
FR-114	0.3957	0.3213	5.4845	UO_2
FR-116	0.3996	0.3213	5.5327	UO_2
FR-117	0.3988	0.3217	5.5234	UO_2
FR-118	0.3933	0.3217	5.4408	UO_2
FR-119	0.3925	0.3220	5.4207	UO_2
FR-120	0.3874	0.3224	5.3481	UO_2
FR-121	0.4004	0.3220	5.5154	UO_2
FR-124	0.3894	0.3224	5.3778	UO_2
FR-125	0.3988	0.3220	5.5121	UO_2
FR-127	0.3835	0.3224	5.2935	UO_2
FR-130	0.3890	0.3224	5.3731	UO_2
FR-132	0.3858	0.3217	5.3384	UO_2
FR-133	0.3724	0.3217	5.1406	UO_2
FR-134	0.3890	0.3220	5.3988	UO_2
FR-138	0.3846	0.3220	5.3182	UO_2
FR-140	0.3858	0.3224	5.3445	UO_2
FR-142	0.3870	0.3224	5.3639	UO_2
FR-143	0.3874	0.3224	5.3667	UO_2
FR-144	0.3724	0.3220	5.1424	UO_2
FR-145	0.4012	0.3220	5.5444	UO_2
FR-147	0.3890	0.3220	5.3933	UO_2
FR-149	0.3929	0.3224	5.448	UO_2
FR-152	0.3894	0.3224	5.3833	UO_2
FR-154	0.3941	0.3220	5.4536	UO_2
FR-155	0.3819	0.3220	5.2938	UO_2
FR-157	0.3906	0.3224	5.3874	UO_2
FR-158	0.3953	0.3220	5.4681	UO_2
FR-161	0.3949	0.3215	5.469	UO_2
FR-162	0.3909	0.3219	5.4218	UO_2
FR-164	0.4004	0.3219	5.5311	UO_2
FR-165	0.3850	0.3220	5.3312	UO_2
FR-167	0.4039	0.3220	5.5705	UO_2
FR-170	0.4008	0.3220	5.5427	UO_2

5.7 Pellet Density

Fuel pellets have a density of 95% (±1%) of theoretical density. Theoretical density for UO_2 is assumed to be 10.98 g/cm^3.

6. RODLET/CLADDING REQUIREMENTS

6.1 General

Requirements incumbent upon rodlet/cladding activities at ORNL, including those associated with procurement and internal control of materials, will be addressed through implementation of the ORNL QA plan entitled *Quality Assurance Plan and Interface Document for Fuel Cycle Technology Research and Development Activities Conducted at Oak Ridge National Laboratory*.

6.2 Rodlet Fabrication Process

Rodlets components per drawing 604497 will be fabricated at Materials Design using materials supplied by ORNL.

6.2.1 Rodlet Materials

Materials for rodlet components will be provided by ORNL. Materials include ORNL ATF FeCrAl clad and CVD SiC meeting the requirements provided in Table 5. ORNL will fabricate all rodlet parts from these materials.

Clad, endplugs, and SiC disc materials have been sampled and sent out for independent chemical analysis to validate that they meet the specified requirements. The resulting laboratory report and chemical analysis for FeCrAl and CVD-SiC are provided in Appendix D.

Stainless steel springs shown in drawing 604496 will be supplied by INL to ORNL for final assembly and material certifications and qualifications will be maintained by INL and added to the final data package.

Table 5. Cladding Chemical Requirements

Raw Material Identifier	FeCrAl	CVD-SiC
Element	**wt. %**	**wt. %**
Fe	Bal.	-
Cr	12.5-13.5	-
Al	5-5.4	-
Y	0.03-0.07	-
Mo	1.8-2.2	-
Nb	0.9-1.1	-
Si	0.15-0.25	69.0-70.0
C	<0.01	29.8-30.5
S	0.01	<0.005
Ni	-	<0.05
Mn	-	
P	-	
N	-	<0.005

6.2.2 Machining

Tube extrusion at elevated temperatures at ORNL together with gun drilling and machining will be utilized for making thin-wall tubing, followed by final machining to achieve the designed shape within the tolerance. The rodlet internals and end plug materials will be made from the same base material by using bar extrusion process, followed by machining to meet 604496 (-5 thru -8). Endplugs must be made as a matched set with each tube to ensure an interference fit between the endplug and tube.

Additionally, each set of endplugs are designed to be a tight fit with a matched capsule tube in order to ensure proper assembly. The OD of each rodlet endplug will be determined based on measurement of the matching capsule tube. Matched sets must be maintained together.

6.2.3 First Article Inspection

Inspection of the first article is required to ensure techniques utilized in the fabrication process are providing adequate parts. Significant changes to the fabrication process, change of equipment or machinist, or delays of more than 30 days between fabrication of parts will also require a first article inspection.

6.2.4 Rodlet Dimensional Inspections

Rodlet parts shall meet dimensional requirements specified in Drawing 604496 and Drawing 604497. Inspections shall be performed by a qualified ORNL precision dimensional inspector.

6.2.5 Items 1 & 2 – Rodlet Tube

6.2.5.1 Rodlet tube dimensional inspections shall be recorded on the RRD-JS-24 dimensional certification report included in Appendix A.

6.2.5.2 All equipment used to perform the metrology will accurately provide the level of precision required by drawings 604496 and 604497.

6.2.6 Items 5 thru 8 – Rodlet Endplugs

6.2.6.1 Endplug dimensional inspections shall be recorded on the RRD-JS-24 dimensional certification report included in Appendix A.

6.2.6.2 The endplug assembly requires a tight fit with the rodlet tube. Endplug/tube assemblies will be designated based on dimensional results to ensure appropriate fit up.

6.2.7 Rodlet Welding

ORNL will develop weld parameters to appropriately join the FeCrAl material with guidance from nationally recognized standards (American Welding Society [AWS], American Society of Mechanical Engineers [ASME] Boiler and Pressure Vessel Code [BPVC]) and provide all supporting documentation for performing the welding work to INL in accordance with NQA-1. ORNL will supply the following documentation in accordance with the INL fabrication requirements:

- Documentation detailing the weld joint and acceptance criteria for the weld that is supplied by the appropriate technical staff
- Any supporting documentation/test results to quantify the acceptance criteria (including non-destructive and destructive test results)
- Weld parameters documentation that describes the techniques and parameters required to perform the welding

Specific details for the testing, qualification, and weld procedure can be found in Appendix C of this document.

6.2.8 Cleaning of Rodlet Tube and Endplug Stock

- Initial cleaning of rodlet tubes and endplugs may be performed using ethanol, methanol, or deionized water.
- Acetone may be used after machining if alcohol is incapable of cleaning the part. After cleaning with acetone, the parts must then be cleaned with alcohol.
- Cleaning prior to welding shall be done using ethanol.
- Final cleaning shall be done using lint free cloths and ethanol.
- A report documenting the final cleaning procedure shall be completed for all parts. An example cleaning report form taken from RRD-JS-31 can be found in Appendix E.

6.2.9 Rodlet Identification

Each rodlet will be marked with a unique identifier as specified in Table 6.

Table 6: Rodlet identification scheme

Rodlet ID	ID on Bot Endplug	ID on Top Endplug	Fuel Designation	Bond Material	Weld Gas
FCA-L1	FCA-L1	O L1	FR-series	He	He
FCA-L2	FCA-L2	O L2	FR-series	He	He
FCA-L3	FCA-L3	O L3	FR-series	He	He
FCA-L4	FCA-L4	O L4	FR-series	He	He
FCA-L5	FCA-L5	O L5	FR-series	He	He
FCA-L6	FCA-L6	O L6	FR-series	He	He

7. QUALITY ASSURANCE DOCUMENTATION

7.1 Quality Acceptance of Materials

- For lead development team organizations that are on the INL Qualified Supplier List (QSL), it is expected that NQA-1 requirements identified in the ATF Quality Implementation Plan (QIP) will be disseminated to fellow development team members and appropriately flowed down to suppliers and collaborators by the lead development team organization using the INL Quality Requirements Checklist included in Appendix B of the QIP (Reference 8). Certified material test reports (CMTRs) and certificates of conformance (CoCs) from the lead development team organizations on the INL QSL will be accepted to attest material traceability, provided material identification is maintained.

- For lead development team organizations that are not on the INL QSL or cannot be designated as a qualified supplier per the INL QA program requirements, an application-focused quality evaluation will be performed to determine adequate execution of the requirements identified in the ATF QIP to meet NQA-1 compliance.

- In either case, an INL quality inspection plan will be developed by INL QE and the development team lead and/or principal researcher for acceptance of test materials at the INL. The Quality Requirements Checklist included in Appendix B of PLN-4608 will be used in conjunction with this fabrication control plan and the final experiment assembly specification (SPC) to support development of the inspection plan.

7.2 Quality Acceptance of Rodlet Assemblies

To facilitate quality acceptance of rodlet assemblies at INL, copies of material test reports, dimensional inspections, weld inspections and other fabrication documentation is required. Section 9 provides a comprehensive list of the required information.

8. SHIPPING

8.1 Authorization to Ship Fuel

Contact the INL Safeguards Representative and INL shipping logistics coordinator (see contact information below) a minimum of 2 weeks prior to shipping fuel to the INL to receive authorization to ship.

Shipping/receiving contact information at the INL:

Susan Case
Shipping Logistics Coordinator
(208) 520-6433 cell, (208) 526-2323 office
Susan.case@inl.gov

Terri Dixon
Safeguards Representative
MFC Complex
Terri.dixon@inl.gov
(208) 533-7945

At a minimum, the following information will be required in order for INL Safeguards to determine if the material to be shipped will be "recordable" or "non-recordable" per INL Safeguards procedures:

- Material Description including:
  - Total uranium weight
  - Total U-235 weight
  - % enrichment
- A radiological survey map, radiological readings, and qualified chemical composition details of the fuel will also be requested prior to receiving the fuel at INL.

Upon evaluation of the material description, the INL Safeguards Representative will determine the proper paperwork that will be needed to support the shipment. INL Safeguards organization will provide an "Authorization to Ship" upon review and acceptance of the contents to be received. The fuel pellet ownership will be transferred to the INL as government owned through the INL Safeguards and Security organization upon receipt at INL. As a DOE contractor, Battelle Energy Alliance is DOE/NRC 741 license-exempt (Ref. 10 CFR Part 70: Subpart B—Exemptions 70.11 "Persons using special nuclear material under certain Department of Energy and Nuclear Regulatory Commission contracts").

Documentation required for the shipment include:

- Analytical data on the fuel
- Fabrication data on the pellets (dimensions, wts, etc.)
- Drum ID's
- TID numbers

- Radiological readings and survey maps of the drums

INL will be responsible for shipping irradiated fuel capsules to MFC for PIE and ultimately disposition of the irradiated materials and fuel.

8.2 Shipping Container/Packaging

Contact the INL Shipping Logistics Coordinator for guidance on the shipping container and packaging requirements. The Materials and Fuels Complex requires all packages containing radioactive material to be secured with a tamper indicating device (TID) and that information be communicated prior to receipt.

9. Fuel Rodlet As-Built Data Package

The As-Built Data Package for ATF fuel pellets shall include the following items:

9.1 Fuel Materials

- Copies of reports for isotopic analysis of the fuel.
- Copies of reports for chemical analysis of the major constituents of the fuel.
- Copies of reports showing the levels of impurity elements as specified by the experimenter.

9.2 Rodlet Materials

- Chemical analysis reports/certifications from a qualified supplier for rodlet tube stock.
- Chemical analysis reports/certifications from a qualified supplier for SiC Spacers.
- Chemical analysis reports/certifications from a qualified supplier for endplug stock(s).
- Cleaning Reports for all components and final assemblies

9.3 Rodlet Weld Qualification Data

Details relating to weld qualification supplied shall include:

- Weld qualification reports detailing all welds, repairs, and testing shall be included in the data package.
- Weld qualification data sheets for the welder(s) performing the welds.

9.4 Rodlet Summary Data

The As-Built Data Package shall include:

- Helium leak test report of the sealed rodlet (performed at ORNL prior to shipping and INL after receipt and prior to loading in the capsule). The rodlets must have a leak rate of $<1x10^{-7}$ cc(He)/s in order to be acceptable.

- Radiographs of rodlet loading and condition of internal components (performed at ORNL prior to shipping and INL after receipt and prior to loading in the capsule).

- OPTIONAL radiographs of rodlet welds (performed at ORNL prior to shipping and OPTIONAL re-inspected by INL after receipt and prior to loading in the capsule per the discretion of the responsible engineer).

- Dimensional certification reports documenting geometric dimensional inspections called for in drawings for in 604496 and 604497 will be provided.

9.5 Rodlet Drawings

The As-Built Data Package shall include current fuel rodlet design drawings. All supporting documentation for the rodlet assembly will reference these current drawings.

9.6 Certification of Fuel Rodlets

Each fuel rodlet shall be accepted by the Responsible Engineer and a Quality Engineer indicating that the rodlet complies with fabrication specifications.

9.7 Non-conforming Fuel Rodlets

All fuel materials, components, and finished fuel test specimens (rodlets) that do not meet the drawing specifications and any additional specifications shall have a either a deviation or non-conformance report justifying acceptance.

10. REFERENCES

1. PLN-4444, “Plan for Irradiation Testing of Accident Tolerant Fuels in the ATR
2. “ATR ATF (Accident Tolerant Fuel) Experiment GE Fuel Rodlet End Caps and Tube Details”, DWG-604493, INL, 2014.
3. QLD, MSA-000203, “Fuel Cycle Research and Development (FCRD) Irradiation Experiment Test Specimens”
4. STD-7022, “Cleanliness Acceptance Levels for Nuclear or Non-Nuclear Service Components”
5. MCP-1451, “R&D Manufacturing Services Work Management Implementation”
6. MCP-13425, “NDE Personnel Certification”
7. MCP-13426, “Inspection and Test Personnel Certification”
8. PLN-4608, “Quality Implementation Plan for the Irradiation Testing of Accident Tolerant Fuels”
9. MCP-13022, “Quality Engineer Training Program”
10. FRM-416.22, INL Quality Accepted
11. ECAR-2538, “Beginning of Life Loading and Best Estimate Heat Generation Rates for the Accident Tolerant Fuels (ATF) Experiment,” 2014.

12. ECAR-2298, “Bounding Thermal-Hydraulic Analysis For ATF Fuels Irradiation Program,” 2014.
13. ECAR-2534, “Projected Temperatures For GE and ORNL Experiments,” 2014
14. ECAR-2495, “Structural Analysis Of ATF-1 GR/ORNL Rodlets ,” 2014

11. APPENDIXES

- Appendix A RRD-JS-24 Rev. 3
- Appendix B Fuel Inspection Report
- Appendix C Rodlet Weld Acceptance Criteria
- Appendix D Chemical Analysis of Base FeCrAl Alloy and SiC to be used for Fabrication
- Appendix E Cleanliness Report For Materials and Components

Appendix A
RRD-JS-24 Rev. 3

RESEARCH REACTORS DIVISION INSPECTION PLAN AND DIMENSIONAL CERTIFICATION REPORT

Page _1_ of _1_

JOB DESCRIPTION		JOB CONTROL NUMBER N/A	JOB SPECIFICATION JS-24	
PART NAME		DRAWING NUMBER	REV.	PART NUMBER
WORK REQUEST NO.	WORK ORDER NUMBER	MAT'L TYPE	HEAT NUMBER	SERIAL NUMBER(S)

METHOD OF RECORDING

Record dimensions in accordance with Job Specification requirements.

All entries must be made in ink or typed. **Record Temp. _____°F**

QC No.	INSPECTION RESULT	DRAWING REQUIREMENT	INSPECTION METHOD
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			

INSPECTION RESULTS	DISPOSITION OF NONCONFORMANCE(S)		INSPECTION METHOD APPROVAL
MEETS DRAWING REQUIREMENTS ☐ YES ☐ NO	NCR REQUIRED ☐YES ☐NO NCR NO.	PART(S) ACCEPTED FOR USE ☐ YES ☐ NO	INSPECTION SUPERVISOR DATE
DATE INSPECTOR	DATE TASK LEADER		QUALITY DEPARTMENT ** DATE
*DATE *INSPECTOR	DATE QUALITY DEPT.		

***Inspection equipment verified for accuracy prior to use and rechecked at end of shift.**
****Not required unless specified on QA Decal, Purchase Order or Work Request**
Form copied from RRD-JS-24, Rev. 3, Figure 2

RESEARCH REACTORS DIVISION INSPECTION PLAN AND DIMENSIONAL CERTIFICATION REPORT (cont.)

Page ___ of ___

PART NAME	DRAWING NUMBER	REV.	PART NUMBER	JOB CONTROL NUMBER

SERIAL NUMBER

QC No.								
1								
2								
3								
4								
5								
6								
7								
8								
9								
10								
11								
12								
13								
14								
15								
16								
17								
18								
19								
20								

Fig. 2B
RRD-JS-24

Form copied from RRD-JS-24, Rev. 3, Figure 2B

Appendix B
Fuel Inspection Report

FUEL ID: _____

Feature	Dimension	Measurement	Sat/ Unsat	Date
OD	.3219 ± .0006			
Length of Fuel	.400 ± .050			
Mass	NA		NA	
Inspector Signature:			Date:	

Responsible Engineer (Verification) _____ Date _____

Responsible Manager (Acceptance) _____ Date _____

Appendix C
Rodlet Weld Acceptance Criteria

OAK RIDGE NATIONAL LABORATORY

MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

1 Bethel Valley Rd.
M.S. 6051
P.O. Box 2008
Oak Ridge, TN 37831-6051
(865) 576-4867

Date: 04/10/2014

To: File

C: R. Miller

From: R. H. Howard

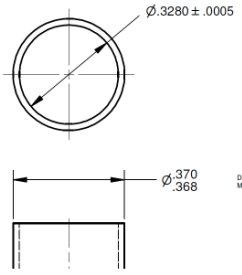
Subject: Failure Criteria for autogenously welded cap geometry for the FeCrAl ATF-1 rodlet campaign.

The rodlet components (cladding and end caps) are fabricated from an alumina- and chromia-forming iron (FeCrAl) alloy that is not currently described in the ASME Boiler and pressure vessel code. Material certifications must be supplied to identify the material.

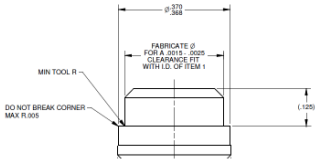
This memo establishes the acceptance criteria for the AWS B 2.1 weld procedure described in MPJFECRAL-1. Welded joints were destructively tested for the following conditions:

- Rodlet(s) must not fail or deform below the internal operating pressure limit of 1320 psig, which is outlined in correspondence with Michael Teague on 04/09/2014.
- Rodlet(s) will be taken to failure internal hydrostatic loading. This failure pressure must be higher than the internal operating pressure.
- FeCral Plate must be subjected to bend tests and tensile testing. The results of these tests must be documented and accompany MPJFECRAL-1.

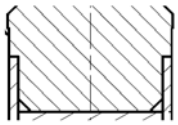
Visual inspection of all welds by qualified personnel is required as part of the acceptance criteria.



ITEM 1(CLAD)



ITEM 2 (CAP SOCKET)



ITEM 3 (SOCKETED WELD JOINT)

RHH

Appendix D
Chemical Analysis of Base FeCrAl Alloy and SiC to be used for Fabrication

DIRATS LABORATORIES

TEST REPORT

Report Number	**R581511**
Report Date	**26-Mar-2014**
Page	**1 of 2**
Client Order	**ALS14-0612**
Release	**ID: 1**

Yuki Yamamoto
UT-Battelle, LLC
ORNL Fuel Cycle & Isotopes Division
1 Bethel Valley Road
P.O. Box 2008
Oak Ridge, TN 37831-6083

EMAIL yamamotoy@ornl.gov

TEL 865-574-5153

FAX 865-241-0215

RECEIVED	1 Section Bar Stock appox. 1/2"Lg.
IDENTIFICATION	ID: 1 Name: C35MN5-B
MATERIAL	Fe-13Cr
TEST PER	Client Instructions
RETURN	Specimen

PROPERTIES AS SUPPLIED

Quantitative Analysis by ICP-OE

Al	5.08	%
B	6	ppm
Cr	13.02	%
Fe	78.68	%
Mo	1.99	%
Nb	0.97	%
P	<0.002	%
Si	0.21	%
Y	0.032	%

Quantitative Analysis by Combustion

C	0.003	%
S	3	ppm

41 AIRPORT ROAD P.O. BOX 39 WESTFIELD, MA 01086-0039 FAX 413-568-1453 413-568-1571

DIRATS LABORATORIES

TEST REPORT

Report Number R581511
Report Date 26-Mar-2014
Page 2 of 2

UT-Battelle, LLC
ORNL Fuel Cycle & Isotopes Division
Oak Ridge, TN 37831-6083

Quantitative Analysis by IGF

O	0.0028 %
N	0.0013 %

Disposition of Chemical Analysis

For Information

The < Symbol signifies not detected at the detectability limit indicated.

This document, including all Disclosures and Limitations, constitutes the entire report of all test services and results. These tests were performed in accordance with Client and Operations Manual requirements.

Signed by Eric E. Dirats, General Manager.

41 AIRPORT ROAD P.O. BOX 39 WESTFIELD, MA 01086-0039 FAX 413-568-1453 413-568-1571

DIRATS LABORATORIES

TEST REPORT

Report Number	R543925
Report Date	17-Feb-2012
Page	1 of 1
Client Order	4000110987
Release	Item 2, CVD SiC

Mike Brady
Lockheed Martin Energy Systems
1 Bethel Valley Road
P.O. Box 2008
Oak Ridge, TN 37831-6083

EMAIL bradymp@ornl.gov

TEL 865-574-5153

FAX 865-241-0215

RECEIVED	1 Test Sample approx. 1/4" x 1 1/2"lg.
IDENTIFICATION	CVD SiC Sample
MATERIAL	Silicon Carbide
TEST PER	Client Instructions

PROPERTIES AS SUPPLIED

Quantitative Analysis by ICP-OE

Si	69.80	%

Other Elements, by ICP-OE

Ni	0.01	%

Quantitative Analysis by Combustion

C	30.17	%
S	<0.001	%

Quantitative Analysis by IGF

O	0.003	%
N	<0.001	%

Disposition of Chemical Analysis

For Information

The < Symbol signifies not detected at the detectability limit indicated.

This document, including all Disclosures and Limitations, constitutes the entire report of all test services and results. These tests were performed in accordance with Client and Operations Manual requirements.

Signed by Eric E. Dirats, General Manager.

41 AIRPORT ROAD P.O. BOX 39 WESTFIELD, MA 01086-0039 FAX 413-568-1453 413-568-1571

Appendix E
Cleanliness Report For Materials and Components

APPENDIX A

CLEANLINESS REPORT FOR MATERIALS AND COMPONENTS

Job No. _____ Description _____

Drawing No. _____ Part No. _____

Cleaned in accordance with paragraph(s) _____

_____

_____

_____

_____

Component meets the cleanliness requirements stated above.

Item packaged for storage per RRD-JS-31, paragraph 4.8.2 or 4.8.3.

Final acceptance: _____ Date _____
Foreman in Charge

_____ Date _____
ORNL Quality Department

RRD-JS-31, REV. 0
Page 12 of 12