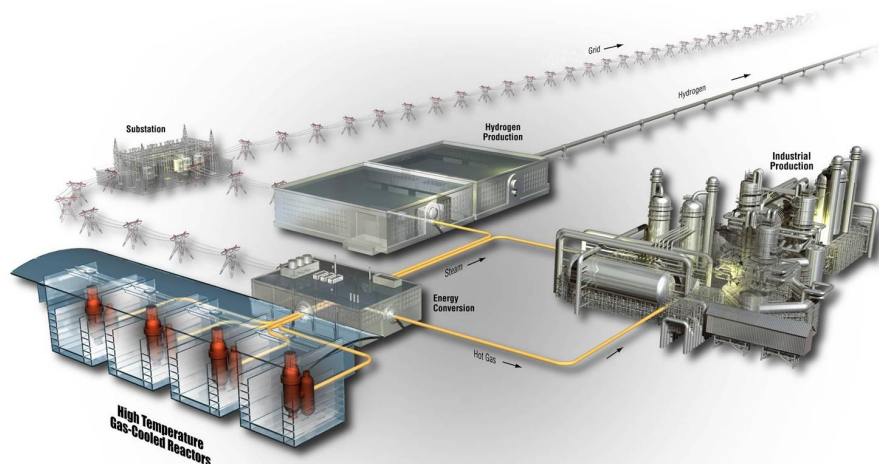


Plan

Project No. 29412, 23841

AGR-3/4 Compact 10-2 Examination Plan


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



Idaho National Laboratory

AGR-3/4 COMPACT 10-2 EXAMINATION PLAN	Identifier: PLN-6420 Revision: 0 Effective Date: 10/20/2021 <div style="text-align: right;">Page: ii of v</div>
INL ART Program	Plan <div style="float: right;">DCR Number: 691306</div>


Prepared by:



John D. Stempien
Fuels Post-Irradiation Examination Technical Lead

10/20/2021

Date




John D. Hunn
Oak Ridge National Laboratory Technical Lead

10/20/2021

Date

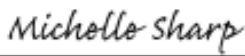
Approved by:



Paul A. Demkowicz
INL ART TRISO Fuel Technical Director

10/19/2021

Date



Michelle T. Sharp
INL ART Quality Assurance

10/18/2021

Date

AGR-3/4 COMPACT 10-2 EXAMINATION PLAN	Identifier:	PLN-6420
	Revision:	0
	Effective Date:	10/20/2021

Page: iii of v

REVISION LOG

[illegible]

Idaho National Laboratory

AGR-3/4 COMPACT 10-2 EXAMINATION PLAN	Identifier: PLN-6420 Revision: 0 Effective Date: 10/20/2021 <div style="text-align: right;">Page: iv of v</div>
--	---

CONTENTS

REVISION LOG.....	iii
ACRONYMS.....	v
1. INTRODUCTION.....	1
2. FUEL COMPACT DESCRIPTION.....	1
3. EXPERIMENTAL OBJECTIVES	1
4. SCOPE OF WORK	1
4.1 Radial Deconsolidation and Acid Leaching.....	1
4.2 Data Acquisition, Analysis, and Reporting.....	2
5. QUALITY ASSURANCE.....	2
6. REFERENCES.....	2

TABLE

Table 1. Identification and irradiation conditions for AGR-3/4 Compact 10-2.....	1
Table 2. Target sectioning dimension for radial deconsolidation.	2

Idaho National Laboratory

AGR-3/4 COMPACT 10-2 EXAMINATION PLAN	Identifier: PLN-6420 Revision: 0 Effective Date: 10/20/2021 <div style="text-align: right;">Page: v of v</div>
--	--

ACRONYMS

AGR	Advanced Gas Reactor
AGR-3/4	third and fourth AGR program irradiation experiments
DTF	designed-to-fail (coated particles)
FIMA	fissions per initial metal atom
INL	Idaho National Laboratory
LBL	leach-burn-leach
ORNL	Oak Ridge National Laboratory
PIE	post-irradiation examination
TAVA	time-average, volume-average (compact irradiation temperature)
TRISO	tristructural isotropic (coated particles)
UCO	uranium carbide and uranium dioxide (multiphase kernels)

AGR-3/4 COMPACT 10-2 EXAMINATION PLAN	Identifier: PLN-6420 Revision: 0 Effective Date: 10/20/2021 <div style="text-align: right;">Page 1 of 3</div>
--	---

1. INTRODUCTION

This plan describes the post-irradiation examination (PIE) activities to be performed by Oak Ridge National Laboratory (ORNL) on irradiated Compact 10-2 taken from the Advanced Gas Reactor (AGR) experiment, AGR-3/4. This work will be performed in accordance with the general objectives outlined in the AGR-3/4 PIE Plan¹ and guidance in the ORNL PIE Statement of Work.²

2. FUEL COMPACT DESCRIPTION

The fuel specimen contains tristructural isotropic (TRISO)-coated driver fuel particles with kernels containing mixed uranium carbide and uranium oxide (UCO), as well as 20 designed-to-fail (DTF) particles consisting of UCO kernels with ~20 μm thick, anisotropic, high-density pyrolytic carbon coatings that were expected to crack to expose the kernel during irradiation. The compact was irradiated in Capsule 10 of the AGR-3/4 test train in the northeast flux trap of the Advanced Test Reactor at Idaho National Laboratory (INL).³ Table 1 shows some identifiers and irradiation conditions for AGR-3/4 Compact 10-2.

Table 1. Identification and irradiation conditions for AGR-3/4 Compact 10-2.

Compact ID ^a	Container ID	Fabrication ID	Burnup ^b (% FIMA)	Fast Fluence ^b ($\times 10^{25}$ n/m ²)	TAVA (°C) ^c
AGR-3/4 10-2	AGR351	(LEU03-10T-07 DTF)-Z134	11.96	4.01	1213

^a. The X-Y naming convention denotes the location in the irradiation test train—Capsule-Level.¹

^b. Fissions per initial metal atom (FIMA) and fast neutron fluence ($E_n > 0.18$ MeV) are based on physics calculations.⁴

^c. Time-average, volume-average (TAVA) temperature is based on thermal calculations.⁵

3. EXPERIMENTAL OBJECTIVES

Radially deconsolidate the compact in a stepwise fashion and acid leach the particles and matrix debris from each discrete step using a leach-burn-leach (LBL) process, as described in Section 4.1, to measure the compact inventory of actinides and fission products not contained within intact silicon carbide layers.

4. SCOPE OF WORK

4.1 Radial Deconsolidation and Acid Leaching

The fuel compact will be electrolytically deconsolidated in 4–8M nitric acid to break up the matrix material and free the fuel particles (AGR-3/4 UCO compacts have ~1898 TRISO driver fuel particles and 20 DTF particles⁶). The deconsolidation will be done in four segments of roughly equal volumes as shown in Table 2. The first three segments will be radially deconsolidated by rotating the compact about the cylinder axis and collecting particles and matrix debris in three stages. The fourth segment will be deconsolidated by axially deconsolidating the remaining cylinder core, which is expected to contain all the DTF particles (most of which will not be intact). Actual section volumes will be determined by a combination of video and/or still imaging with image analysis software designed for this application.^{7,8}

The four sets of deconsolidated particles and matrix debris will be individually subjected to an LBL process as described in AGR-CHAR-DAM-37⁹. Particles and matrix debris will be transferred to a Soxhlet thimble, two 24-hour nitric acid leaches in a Soxhlet extractor performed, and the leachates analyzed for actinides and fission products. After these two preburn leaches, the particles and matrix debris from each segment will be “burned” in their respective Soxhlet thimbles by heating at 750°C in air to remove the exposed carbon. After the burn, the burned-back particles and residual ash in each Soxhlet

Idaho National Laboratory

AGR-3/4 COMPACT 10-2 EXAMINATION PLAN	Identifier:	PLN-6420	Page 2 of 3
	Revision:	0	
	Effective Date:	10/20/2021	

thimble will be subjected to two postburn 24-hour nitric acid leaches in a Soxhlet extractor. After these two postburn leaches, the burned-back particles will be washed, dried, and transferred to a storage vial.

Table 2. Target sectioning dimension for radial deconsolidation.

Compact section	Inner diameter (mm)	Outer diameter ^a (mm)	Section thickness (mm)	Section Volume ^b (cm ³)
Whole compact	0.000	12.141		1.44
1st section	10.514	12.141	0.813	0.36
2nd section	8.585	10.514	0.965	0.36
3rd section	6.071	8.585	1.257	0.36
Core section	0.000	6.071	3.035	0.36

^a Measured average diameter for irradiated Compact 10-2 was 12.141 mm.¹⁰

^b Measured average length used to compute the volume for irradiated Compact 10-2 was 12.4333 mm.¹⁰

4.2 Data Acquisition, Analysis, and Reporting

A compact PIE report will be prepared and will include a description of the experiments performed and all relevant data acquired. Overall data to be reported will include the following, as applicable:

- A compact fractional inventory of fission products released during irradiation, based on as-run inventory calculations⁴ and segmented in four radial segments as discussed in Section 4.1.

5. QUALITY ASSURANCE

Activities performed at ORNL shall be performed in accordance with applicable ORNL procedures and the ORNL Quality Assurance Plan for Nuclear Research and Development Activities¹¹ to meet the INL Quality Assurance requirements specified in Inter-Entity Work Order #150293.

6. REFERENCES

1. Demkowicz, P.A., 2017, *AGR-3/4 Phase 2 Post-Irradiation Examination Plan*, PLN-5382, INL/MIS-17-41954, Rev. 0, Idaho National Laboratory, May 2017.
2. Idaho National Laboratory, 2020, *Statement of Work for the AGR-3/4 PIE at Oak Ridge National Laboratory*, SOW-12084, INL/MIS-15-34327, Revision 6, April 2020.
3. Collin, B.P., 2016, *AGR-3/4 Irradiation Test Final As-Run Report*, INL/EXT-15-35550, Rev. 1, Idaho National Laboratory, May 2016.
4. Sterbentz, J.W., 2015, *JMOCUP As-Run Daily Physics Depletion Calculation for the AGR-3/4 TRISO Particle Experiment in ATR Northeast Flux Trap*, ECAR-2753, Rev. 1, Idaho National Laboratory, July 2015.
5. Hawkes, G.L., 2016, *AGR-3/4 Daily As-Run Thermal Analyses*, ECAR-2807, Rev. 1, Idaho National Laboratory, April 2016.

Idaho National Laboratory

AGR-3/4 COMPACT 10-2 EXAMINATION PLAN	Identifier: PLN-6420 Revision: 0 Effective Date: 10/20/2021 <div style="text-align: right;">Page 3 of 3</div>
--	---

-
6. Hunn, J.D., Trammell, M.P., and Montgomery, F.C., 2011, *Data Compilation for AGR-3/4 Designed-to-Fail (DTF) Fuel Compact Lot (LEU03-10T-OP2/LEU03-07DTF-OP1)-Z*, ORNL/TM-2011/124, Rev. 0, Oak Ridge National Laboratory, June 2011.
 7. Helmreich, G.W., Montgomery, F.C., and Hunn, J.D., 2015, *Development of a Radial Deconsolidation Method*, ORNL/TM-2015/699, Rev. 0, Oak Ridge National Laboratory, December 2015.
 8. Stempien, J.D., 2017, *Radial Deconsolidation and Leach-Burn-Leach of AGR-3/4 Compacts 3-3, 12-1, and 12-3*, INL/EXT-17-43182, Rev. 0, Idaho National Laboratory, September 2017.
 9. Montgomery, F.C., and Hunn, J.D., 2020, *Data Acquisition Method for Leach-Burn-Leach of Irradiated Fuel Compacts Using a Soxhlet Extractor in the 3525 Hot Cell*, AGR-CHAR-DAM-37, Rev. 4, Oak Ridge National Laboratory, February 2020.
 10. Stempien, J.D., Rice, F.J., Winston, P.L., and Harp, J.M., 2016, *AGR-3/4 Irradiation Test Train Disassembly and Component Metrology First Look Report*, INL/EXT-16-38005, Rev. 1, September 2016.
 11. Vance, M.C., 2018, QAP-ORNL-NR&D-01, *Quality Assurance Plan for Nuclear Research and Development Activities Conducted at the Oak Ridge National Laboratory*, Rev. 1, Oak Ridge National Laboratory, October 2018.