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The requirements pertaining to the irradiation phase of the AGR-1 experiment are presented. This document incorporates changes resulting from comments received concerning the AGR-1 Irradiation Test Specification, EDF-4731, Rev. 0.

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AGR-1 IRRADIATION TEST SPECIFICATION

1. Background

Several fuel and material irradiation experiments are planned for the Advanced Gas Reactor Fuel Development and Qualification Program which supports the development of the Next Generation Nuclear Plant (NGNP). The goals of these experiments are to provide irradiation performance data to support fuel process development, to qualify fuel for normal operating conditions, to support development and validation of fuel performance and fission product transport models and codes, and to provide irradiated fuel and materials for post irradiation examination (PIE) and safety testing. AGR-1 is the first in this series of planned experiments to test TRISO-coated, low enriched uranium (LEU) oxycarbide (UCO) fuel. This experiment is intended to serve as a shakedown test of a multi-cell capsule design to be used in subsequent irradiations and to test early variants of the fuel produced under this program.

2. Introduction

As defined in the AGR Technical Program Plan (Bell, 2003), the objectives of the AGR-1 experiment are:

1. To gain early experience with multi-cell capsule design, fabrication, and operation with the intent to reduce the probability of capsule or cell failure in subsequent irradiation test capsules.

2. To irradiate "early" fuel produced in a laboratory scale, small coater. Possibly, but not required, to also irradiate German reference fuel, unbonded particles and material samples.

3. To provide data that will support the development of an understanding of the relationship between fuel fabrication processes, fuel product properties, and irradiation performance.

However, the second AGR-1 objective has been refocused since the Technical Program Plan was written. Based on deliberations by the Technical Coordination Team (TCT), AGR-1 will now include only AGR baseline fuel and one or more variants of the baseline fuel produced under this Program.

The purpose of this document is to define the requirements for the irradiation phase of the AGR-1 experiment. How these requirements will be met and predictive fuel exposure histories will be presented in the AGR-1 Test Plan. Requirements pertaining to fuel fabrication, PIE, safety testing, and the irradiation test capsule design, fabrication and disassembly are or will be presented elsewhere.

This irradiation test specification incorporates changes that have resulted from comments received concerning the AGR-1 Irradiation Test Specification Rev. 0 (Maki, 2004). (Rev. 0 of this document superceded the Preliminary AGR-1 Irradiation Test Specification (Maki, 2003)). The current specification is presented in nine different sections. In Sections 3 through 8, requirements for the irradiation test capsule, irradiation test articles, irradiation test conditions, test operations, test measurements, and documentation are presented. The requirements are presented in terms of a specification, highlighted in italics, followed by a brief technical justification. At the end of each section, the specifications are assembled into a table for ease of use. References are listed in Section 9.

3. Test Capsule Requirements

- *The AGR-1 test capsule shall be a multi-cell, instrumented lead design.*
- *The capsule shall be designed for irradiation in one of the four large "B" holes of the Advanced Test Reactor (ATR) at the INEEL.*
- *The capsule shall contain up to six independent cells.*
- *Each cell shall be independently controlled for temperature and independently monitored for fission product gas release.*
- *Each cell shall have at least two thermocouples.*
- *Each cell shall have a sufficient number of neutron monitors to determine end of irradiation thermal and fast (E>0.18 MeV) neutron fluences at the measurement location.*
- *Other than the graphite holders[1] and sweep gas, no capsule component, such as thermocouples, gas lines, neutron monitors or pressure barriers, shall come in contact with the irradiation test articles.*
- *Test fuel compacts shall not make radial contact with each other but are allowed to make axial contact with each other.*

Test Capsule Technical Justification

A multi-cell, instrumented lead capsule that allows each cell to be independently controlled for temperature and monitored for fission product gas release provides flexibility in testing and gathering meaningful data from multiple fuel types during a single capsule irradiation. However, the test reactor's axial flux distribution and space considerations within the capsule, impose a practical limit of six independently controlled and monitored cells per capsule.

As stated in the AGR Technical Program Plan (Bell, 2003), Gas-Turbine Modular Helium Reactor (GT-MHR) design data provided the prerequisite design envelope for generation of the irradiation specifications. Preliminary INEEL physics calculations (Chang, 2002) have shown that the GT-MHR end of irradiation conditions (burnup of 26% FIMA and maximum fast neutron fluence of 5×10^{25} n/m^2) are best matched by the conditions obtained from irradiation in the large "B" holes of the ATR. In addition, the rate of burnup and fast fluence accumulation, or acceleration, in the large "B" holes is less than three times that expected in the GT-MHR. Past US and German experience indicates that by keeping the acceleration factor under three, an irradiation test is more prototypic of an actual reactor irradiation.

Each cell requires at least one thermocouple for thermal control, and in case of thermocouple failure, each cell should have at least one additional thermocouple to provide backup.

[1] The graphite may contain boron carbide for neutron flux tailoring purposes.

Fluences measured by the neutron monitors will be used to benchmark the analytical process used to determine compact burnups and fluences. These values will be compared to calculated results and possibly to other PIE measurements.

To prevent unwanted test article interactions and possible failures, no object or material other than specifically designed graphite test holders (the graphite may contain boron carbide for neutron flux tailoring purposes) and sweep gas should come into contact with the irradiation test articles. Fuel compacts should only be permitted to touch each other in the axial direction. This form of contact arises from stacking compacts one on top of another and simulates actual reactor use. Radial compact to compact contact is not allowed because this may lead to localized hot spots and possible deleterious particle to particle interactions.

Table 1. AGR-1 irradiation test capsule requirements.

Parameter	**Specification**
Capsule design	Multi-cell, instrumented lead
Location capsule to be sized and configured for	One of the four large "B" holes in the ATR at the INEEL
Number of independent cells	Up to and including six cells
Mode for temperature control and fission gas monitoring	Each cell independently controlled for temperature and monitored for fission gas release
Number of thermocouples per cell	At least two
Number of neutron monitors per cell	A sufficient number to determine end of irradiation thermal and fast (E>0.18 MeV) neutron fluences
Allowable material contact with test articles	Only specifically designed graphite test holders (where the graphite may contain boron carbide for flux tailoring purposes) and sweep gas may contact the test articles
Allowable fuel compact to fuel compact contact	Compact to compact contact only in the axial direction

4. Test Article Requirements

- *AGR-1 shall contain at least early production baseline fuel produced for the AGR Program.*

- *The AGR Program shall consider other test articles, as identified in the AGR Technical Program Plan, for inclusion in AGR-1.*

- *Each AGR-1 cell shall contain only one fuel variant or type.*

Test Article Technical Justification

The NGNP program has chosen the gas-turbine modular helium reactor (GT-MHR) fissile fuel particle design as the starting point for further development. Initial efforts have resulted in the development of the preliminary AGR fuel specification (Petti et al., 2003) and the AGR-1 specific fuel product specification (Shaber, 2004) that describes the baseline fuel requirements and the requirements for each fuel variant to be considered for irradiation in AGR-1. Nominal baseline AGR-1 fuel design parameters are listed in Table 2.

In addition to the AGR-1 baseline fuel, the AGR Technical Program Plan (Bell, 2003) had identified other potential test articles to be included in AGR-1. Based on deliberations by the Technical Coordination Team (TCT), those now under consideration include one or more variants of the baseline fuel. Baseline fuel variants may include particles produced according to a prescribed set of different processing parameters, such as coating temperature, coating deposition rate, carrier gas composition, and mode of deposition (i.e., interrupted as opposed to continuous coating). Potential candidate variants for irradiation are identified in the AGR-1 fuel product specification (Shaber, 2004). The choice of which variants to include in AGR-1 will be influenced by cost, schedule, availability and scientific significance.

Each AGR-1 cell shall contain only one fuel type or fuel variant. This ensures that the fission gas release measurements and possible particle failure indicators are attributed to an identifiable source.

Table 2. Nominal AGR-1 Fuel Design Parameters.

Design Parameter	Units	Nominal Value
Oxygen to uranium in kernel	atom ratio	1.50
Carbon to uranium in kernel	atom ratio	0.50
U-235 enrichment	weight %	19.80
Kernel diameter	μm	350
Buffer thickness	μm	100
IPyC thickness	μm	40
SiC thickness	μm	35
OPyC thickness	μm	40
Particle diameter	μm	780
Kernel density	Mg/m^3	≥ 10.50
Buffer density	Mg/m^3	0.95
IPyC density	Mg/m^3	1.90
SiC density	Mg/m^3	≥ 3.19
OPyC density	Mg/m^3	1.90
U-235 loading per particle	μg/particle	43.7
Total U loading per particle	μg/particle	221.6
Compact diameter	mm	12.34
Compact length	mm	25.4
Number particles per compact	N/A	4280
Particle packing	volume %	35
U-235 loading per compact	g/compact	0.19
Total U loading per compact	g/compact	0.95
Compact matrix density	Mg/m^3	1.74

Table 3. AGR-1 test article requirements.

Parameter	Specification
Minimum test articles	Baseline AGR-1 fuel
Optional test articles	One or more variants of the AGR-1 baseline fuel, as identified in the AGR-1 fuel product specification
Number of fuel types or variants per cell	One

5. Irradiation Test Condition Requirements

- *The instantaneous peak temperature for each cell shall be ≤ 1400 °C.*
- *The time average, peak temperature for each cell shall be ≤ 1250 °C.*
- *The time average, volume average temperature for each cell shall be 1150 + 30/-75 °C.*
- *The minimum compact average burnup for each fuel compact shall be > 14 % FIMA.*
- *The compact average burnup goal for the majority of the fuel compacts should be > 18 % FIMA.*
- *The maximum peak fast neutron fluence for each fuel compact shall be < 5 x 10^{25} n/m^2, E>0.18 MeV.*
- *The minimum peak fast neutron fluence for each fuel compact shall be > 1.5 x 10^{25} n/m^2, E>0.18 MeV.*
- *The instantaneous peak power per particle shall be ≤ 400 mW/particle.*

Irradiation Test Condition Technical Justification

The NGNP program has chosen the gas-turbine modular helium reactor (GT-MHR) design as the starting point for further reactor development. Therefore, GT-MHR design service conditions will initially serve as NGNP service conditions and provide a basis for the AGR-1 irradiation conditions.

For AGR-1, a time average, peak temperature of ≤ 1250 °C duplicates the expected maximum NGNP temperature. An instantaneous peak temperature specification of ≤ 1400 °C provides an operational limit to minimize over heating of the test fuel. The time average, volume average temperature of 1150 +30/-75 °C ensures a sufficiently high temperature without exceeding the time average peak temperature and the instantaneous peak temperature limits. Also, the time average, volume average temperature requirement limits the extent of possible palladium attack of the fuel's SiC layer that could be significant, for durations of two years or more, at temperatures near or above 1200 °C (Petti and Maki, 2004)

The specified minimum compact average burnup of > 14 % FIMA is established based on preliminary analysis of a three compact array, with each compact containing 35 volume % particles in the East large "B" hole of the ATR. The minimum burnup is that expected for the compacts at the very top and bottom of the capsule. Burnups for most of the compacts will be between 19 and 21% FIMA. These burnups are calculated to take about 2.5 calendar years to accumulate in accordance with the preliminary irradiation duration estimates in the Technical Program Plan (Bell, 2003). Extension of the irradiation to 3 calendar years would result in peak burnups of about 22% FIMA. These burnups are considered reasonable until NGNP design values become available.

No maximum compact average burnup is specified. This allows the Program flexibility in extending the irradiation, if desired, beyond the specified minimum burnups. However, the irradiation duration is still restrained by the peak fast neutron fluence requirement.

The specified AGR-1 peak fast neutron fluence of $< 5 \times 10^{25}$ n/m^2, E > 0.18 MeV, bounds the expected NGNP service conditions and would allow up to 3 calendar years of irradiation in the large "B" hole to achieve higher burnups if desired by the Program. A minimum peak fast neutron fluence requirement of $> 1.5 \times 10^{25}$ n/m^2, E > 0.18 MeV, ensures that the fuel pyrocarbon experiences the transition from creep-dominated strain to swelling-dominated strain (at 1250 °C).

The instantaneous peak power per particle requirement of ≤ 400 mW/particle is the same as the value adopted by General Atomics for the irradiation of their compacts in the HFR EU-2 experiment (Conrad et al., 2002). This specification limits the peak kernel temperature and the temperature gradient across the particle which reduces fission product diffusion and potential fission product/SiC interactions.

Table 4. AGR-1 fuel compact irradiation test conditions.

Parameter	**Specification**
Instantaneous peak temperature for each cell (°C)	≤ 1400
Time average, peak temperature for each cell (°C)	≤ 1250
Time average, volume average temperature for each cell (°C)	1150 +30/-75
Minimum compact average burnup (% FIMA)	> 14
Compact average burnup goal for majority of fuel compacts (% FIMA)	> 18
Peak fast neutron fluence (n/m^2, E > 0.18 MeV)	$< 5 \times 10^{25}$
Minimum peak fast neutron fluence (n/m^2, E > 0.18 MeV)	$> 1.5 \times 10^{25}$
Instantaneous peak power per particle (mW/particle)	≤ 400

6. Test Operation Requirements

- *Sweep gas shall consist of low neutron activation, inert gases.*
- *Each sweep gas supply cylinder shall have a gas purity of ≥ 99.99% by volume.*
- *Moisture content of the inlet sweep gas shall be measured at least once after each gas cylinder change on the inlet side of the capsule and shall be < 5 ppm H_2O at a dew point of –100 ± 2.5 °C.*

- *Sensitivity of the fission product monitoring system shall be able to detect every individual particle failure, up to and including the first 250 failures, from each identifiable cell.*

- *Transit time of the sweep gas from each cell to the fission product monitoring system shall be < 25 minutes.*

- *AGR-1 experiment operation shall be conducted in accordance with the approved ATR NQA-1Quality Assurance Program.*

Test Operation Technical Justification

Inert gas will be swept through each cell to provide temperature control and carry any released fission product gases to a detection system. Low neutron activation inert gases are specified for this sweep gas to minimize background activity in the fission product monitoring system. Historically, sweep gas has consisted of mixtures of helium and neon or helium and argon with purities ≥ 99.99% by volume for each gas. This level of purity limits the amount of contamination to the test articles and limits background activity. Also, moisture content of under 5 ppm H_2O within the sweep gas reduces possible reactions with the graphite contained in the test capsule.

As an indicator of fuel performance, the fission product monitoring system needs to be able to detect each particle failure and must have the ability to identify the cell where the failure had occurred. The limit value of 250 particle failures ($\sim 5 \times 10^{-3}$ failure fraction) is a compromise between detection sensitivity (which decreases as more particles fail) and programmatic need to identify the timing of each failure.

To limit the amount of decay from released, short-lived isotopes and to increase detectability, the transit time of the sweep gas from each cell to the fission product monitoring system is kept under 25 minutes.

The approved ATR NQA-1 Quality Assurance Program applies to AGR-1 experiment operation.

Table 5. AGR-1 operation requirements.

Parameter	**Specification**
Sweep gas composition	Low neutron activation, inert gases
Sweep gas purity	Each supply cylinder with sweep gas ≥ 99.99% by volume
Moisture content of inlet sweep gas on inlet side of capsule	< 5 ppm H_2O measured at least once after each gas cylinder change at a dew point of –100 ± 2.5 °C
Sensitivity of fission product monitoring system	Able to detect every individual particle failure from each cell, up to and including the first 250 failures, and able to identify in which cell each failure had occurred
Transit time of sweep gas	< 25 minutes from each cell to the fission product monitoring system
Experiment operation	Conducted in accordance with the approved ATR NQA-1 Quality Assurance Program

7. Test Measurement Requirements

- *Flow rate of each sweep gas constituent shall be measured with an accuracy of ± 2% and shall be recorded at least every hour during irradiation.*
- *Moisture content of the sweep gas shall be measured on the outlet side of the capsule at a dew point of –100 ± 2.5 °C and shall be recorded at least every hour during irradiation.*
- *Total radiation level of the sweep gas from each cell shall be measured and recorded continuously during irradiation.*
- *Concentrations of at least Kr-85m, Kr-87, Kr-88, Xe-131m, Xe-133, and Xe-135, shall be measured in the sweep gas from each cell and recorded at least daily during irradiation. If possible, the concentrations of Kr-89, Kr-90, Xe-135m, Xe-137, Xe-138, and Xe-139, should also be measured in the sweep gas from each cell and recorded at least daily during irradiation.*
- *Readings from each thermocouple shall be recorded at least every five minutes during irradiation and each thermocouple shall have an as-installed accuracy of ± 2% of reading.*
- *ATR lobe powers shall be provided by ATR Engineering within five working days of the end of each reactor cycle of irradiation.*
- *During abnormal events, the flow rate of each sweep gas constituent and the readings from each thermocouple shall be measured and recorded at least every minute.*
- *End of irradiation neutron fluences shall be determined from each neutron monitor with a monitor counting uncertainty within ± 10%.*
- *All test data shall be backed up and stored in separate facilities at least daily.*

Test Measurement Technical Justification

Measurement values for each sweep gas constituent flow rate, thermocouple readings, and reported ATR lobe powers are needed as input for thermal calculations. ATR lobe powers are also needed for physics calculations. The measurement values will be electronically processed through the ITV Gas System and are specified to be recorded at intervals deemed reasonable for their expected rate of change. During abnormal events, data will be recorded at least every minute to capture possible rapid data changes. Abnormal events are defined in the Technical and Functional Requirements documents (INEEL, 2003 a; and INEEL, 2003 b) and will be discussed in detail in the Experiment Safety Analysis Package (not yet completed).

Moisture content of the sweep gas, measured on the outlet side of the capsule, and compared to the inlet value, provides an indicator of capsule integrity. Past experience indicates that any water leak within the capsule will be detected by the outlet moisture monitor.

Continuously measuring and recording total radiation levels (as from an in-line ion chamber) of the sweep gas from each cell provides an indicator of particle failure. A failure is evident by a sharp rise and fall, or "spike", in the detected activity level. However, at sufficiently high radiation levels, the activity contribution (or spike) from a single particle failure cannot be resolved. Overall fuel performance is also indicated by release-to-birth (R/B) ratios of fission product gases released from the fuel. These R/B ratios are calculated from the measured concentrations of the isotopes in the sweep gas.

End of irradiation fluences measured by the neutron monitors and appropriately adjusted to prescribed energy levels, will be compared to physics calculations. The measured neutron fluences, together with other necessary input parameters, will be used to determine compact average burnups and will also be compared to physics calculations.

To avoid irretrievable loss of information, all test data will be backed up.

Table 6. AGR-1 measurement requirements.

Measurement	**Specified frequency of measurement recordings during irradiation**
Flow rate of each sweep gas constituent with an accuracy of ± 2%	At least every hour
Moisture content of sweep gas on outlet side of capsule at a dew point of –100 ± 2.5 °C	At least every hour
Total radiation level of the sweep gas from each cell	Continuously
Concentrations of at least Kr-85m, Kr-87, Kr-88, Xe-131m, Xe-133, and Xe-135 in the sweep gas from each cell. Optional isotopes to also measure include Kr-89, Kr-90, Xe-135m, Xe-137, Xe-138, and Xe-139	At least daily
Readings from each thermocouple with an as-installed accuracy of ± 2% of reading	At least every five minutes
ATR lobe powers	Provided by ATR Engineering within five working days of the end of each reactor operating cycle
Flow rate of each sweep gas constituent and readings from each thermocouple during abnormal events	At least every minute
Neutron fluence from each neutron monitor with a monitor counting uncertainty within ± 10%	At end of irradiation
Back up of all test data	At least daily in separate facilities

8. Documentation Requirements

- *Informal status reports highlighting experiment progress shall be distributed bi-weekly.*

- *As-run data reports shall be issued after 50% of projected test completion, after 75% of projected test completion, and then after the end of each reactor cycle to test completion.*

- *A Quick Look Irradiation Test Results report shall be issued within six weeks of test completion.*

- *A Final Irradiation Test Results report shall be issued within nine months of test completion.*

- *As-run data reports after 50% and 75% of projected test completion, and each test results report shall contain at least the following calculated values with their associated uncertainties:*

  Time-average peak temperature for each compact,
  Time-average, volume average temperature for each compact,
  Peak fast neutron fluence (E>0.18 MeV) for each compact,
  Average burnup for each compact,
  Compact-average power per particle for each compact,
  R/B values for at least Kr-85m, Kr-87, Kr-88, Xe-131m, Xe-133, and Xe-135 for each cell, and
  Estimated number of particle failures within each cell.

Documentation Technical Justification

The specified issuance of documents ensures timely and sufficient dissemination of test information.

Table 7. AGR-1 documentation requirements.

Document	**Specified issuance**
Informal status report highlighting experiment progress	Bi-weekly
As-run data report	After 50% of projected test completion, after 75% of projected test completion, and then after the end of each reactor cycle to test completion
Quick Look Irradiation Test Results report	Six weeks after test completion
Final Irradiation Test Results report	Nine months after test completion
Calculated values with associated uncertainties	**Documented in**
Time-average peak temperature for each compact, Time-average, volume average temperature for each compact, Peak fast neutron fluence (E>0.18 MeV) for each compact, Average burnup for each compact, Compact-average power per particle for each compact, R/B values for at least Kr-85m, Kr-87, Kr-88, Xe-131m, Xe-133, and Xe-135 for each cell, Estimated number of particle failures within each cell.	As-run data report after 50% of projected test completion, As-run data report after 75% of projected test completion, Quick Look Irradiation Test Results report, and Final Irradiation Test Results report

9. References

G.L. Bell, et al., "Technical Program Plan for the Advanced Gas Reactor Fuel Development and Qualification Program", ORNL/TM-2002/262, April 2003.

G.S. Chang, "Preliminary Physics Analysis of the German UO2 and GA UCO Fuel Test Assembly in North and South Large B Hole Positions", Memorandum GSC-PBMR-04-2002, August 2, 2002.

R. Conrad, K. Bakker, H. Nabielek, D. MacEachern, W. Scheffel and P. Guillermier, "Test Specification for Irradiation Experiment of GT-MHR Compacts in the HFR Petten Within HTR-TN", Technical Memorandum HFR/01/4679 Rev. 2, April 26, 2002.

INEEL, Technical and Function Requirements, "Advanced Gas Reactor AGR-1 Test Requirements for Irradiation in the Advanced Test Reactor (ATR)", Preliminary Draft TFR-249, September 2003 a.

INEEL, Technical and Function Requirements, "Advanced Gas Reactor Temperature and Off Gas Monitoring System for AGR-1", Preliminary Draft TFR-248, September 2003 b.

J.T. Maki, "AGR-1 Irradiation Test Specification", EDF-4731, Rev. 0, March 30, 2004.

J.T. Maki, "Preliminary AGR-1 Irradiation Test Specification", EDF-4187, Rev. 0, September 22, 2003.

D.A. Petti and J.T. Maki, "Irradiation Temperature for AGR-1", EDF-5016 Rev.0, June 28, 2004.

D.A. Petti, J.T. Maki, M.A. Ebner and G.K. Miller, "Preliminary AGR Fuel Specification", EDF-4198, September 22, 2003.

E. Shaber, "AGR-1 Fuel Product Specification and Characterization Guidance", EDF-4380 Rev. 1, March 18, 2004.