Potential Use of Advanced Test Reactor (ATR) and Transient Reactor Test facility (TREAT)

ATR: Integration with ATF-1 Test Series

The Advanced Fuels Campaign is currently performing irradiations of Accident Tolerant Fuel (ATF) concepts using drop-in capsules in ATR positions I-22 and I-23. The test train used in these small-I positions consists of 3 vertical channels, each of which can accommodate up to 7 capsules, providing space for up to 21 capsules in each of the two small-I positions. Japanese researchers could propose experiments using these ATR positions.

Assumptions and Constraints:

- Up to 7 capsule positions available beginning in Cycle 168A (approx. January 2020).
- External (safety) capsule of current ATF-1 design must be used, and internal (experimental) contents of capsule must meet same functional requirements of current capsule design (<650 W/cm internal heat generation; <800 psi internal gas pressure)
- Small-I positions are located in the ATR reflector region and have unperturbed fluxes that range from 2.2x1013 to 1.0x1014 n/cm2-s (thermal) and 8.0x1011 to 4.0x1012 n/cm2-s (fast), depending on the axial position of the capsule within the ATF-1 test train
- All experimental data and results would be made publicly available, unless other arrangements are made.

The ATF-1 capsule is made of 316SS and has an internal diameter of 0.376 in. (0.955 cm) and an internal length of 5.649 in. (14.348 cm), for a total internal volume of 0.627 in^3 (10.278 cm^3) available to accommodate test articles proposed and supplied by experimenters. See Appendix B for ATF-1 engineering drawing.

ATR Notes:

- The ATR Core Internal Change-out (major maintenance outage) is currently scheduled for March through December 2021 and no irradiation testing will be possible during this time. See Appendix C for ATR out year planning schedule.
- Proposals may be considered that include subsequent TREAT irradiation
- Limited (non-destructive) PIE testing following ATR specimen irradiation may be available without cost to GOJ

TREAT:

The Advanced Fuels Campaign has recently initiated transient testing operations using the TREAT reactor. A variety of versatile, reusable test trains are in various stages of development, fabrication, and testing in order to provide a diverse spectrum of options for TREAT users. See Attachments 1 and 2 for additional details on TREAT transient shapes and development of irradiation test devices for TREAT.

Two test trains will be available for use by the end of 2019.

- Design and commissioning of the first test train, designated as ATF-SETH (Separate Effects Test Holder) has recently been completed. The ATF-SETH module is designed to accommodate test articles up to and including the ATF-1 test capsules (described in previous section) and introduce them into TREAT to undergo a shaped transient prescribed by the user. A variety of transient shapes including short pulses through ramps are available. No special cooling is provided to the test train, so the experimental package will experience adiabatic conditions for the duration of the transient. Test samples can be driven to temperatures greater than 2000ºC using nuclear heating. During the transient, the test article is bathed in an inert atmosphere and begins the transient at 20°C. Instrumentation, including conventional thermocouples or fibers for pyrometry, and the fast neutron hodoscope (fuel motion monitoring system) can be included as part of the SETH module. See Attachment 3 for more details and drawings of ATF-SETH.
- Design and commissioning of the second test train, designated MARCH-SERTTA (Minimal Activation Reusable Capsule Holder – Static Environment Rodlet Transient Testing Apparatus) will be completed by the end of 2019. The MARCH-SERTTA module is an extension of the ATF-SETH module and will contain many of the same mechanical interfaces with TREAT and will use the same test sample type. However, this capsule will be filled with static water that can be preheated to ~200ºC and pressurized to 3.5 MPa prior to initiating the transient. Again, a variety of shaped transients can be prescribed and can be energetic enough to drive the fuel to melting. See Appendix D for drawing of MARCH-SERTTA

Although the test trains are currently only qualified to contain previously unirradiated fuel, provisions for use of pre-irradiated fuel samples in both devices are anticipated in 2021.

Beginning in 2020, one or more TREAT transients using the SETH and MARCH-SERTTA modules are anticipated to be performed each year. Japanese experimenters are invited to supply test specimens and propose transient prescriptions that could be included in the annual test series that makes use of the SETH and MARCH-SERTTA modules.

Support for Experiment Fabrication:

Coordination of Japanese experiments with the irradiation testing programs in both ATR and TREAT currently underway or planned by the Advanced Fuels Campaign should allow for standard capsule hardware, fabrication, and assembly to be provided free of charge. This applies only to capsule/test rig fabrication. Fabrication of test specimens may be available, contingent upon external funding (if possible using existing facilities and equipment with little or no modification needed), which could include:

	*Additional Cost
• Fabrication of materials test specimens	$100,000-300,000
• Fabrication of nuclear fuel test specimens	$500,000-1,000,000

Test specimens not fabricated at INL but supplied by Japanese institutions for inclusion in irradiation experiments, must meet the rigorous quality requirements established by Idaho National Laboratory and ATR/TREAT. The Japanese institution would be required to join the INL Qualified Suppliers List which will require an audit of the fabrication facility by a team of U.S. Quality Assurance specialists. In addition, the Japanese institution would be responsible for all costs and activities associated with transportation of test specimens fabricated in Japan to the INL for irradiation. The Japanese institution would also be responsible for all costs and activities associated with transportation of irradiated test specimens from INL back to Japan, if desired.

In addition to INL or Japan fabricating samples, irradiated materials in the NSUF Nuclear Fuels and Materials Library (NFML) can be made available to Japanese researchers. Access to the NFML can be gained through the NSUF website (https://nsuf.inl.gov) following a simple registration step. Requests for materials from the NSUF are reviewed for a number of aspects including, but not limited to, total number and type of material/samples requested, location of where samples will be studied (only locations within the United States are accepted), export control considerations, and programmatic needs. Requests for large sets of materials that would deplete the inventory for a particular type of material will not be accepted. Requesters are strongly encouraged to contact the NSUF office to discuss the availability of the materials of interest before including those materials in a proposal. Contact information for the NSUF office can be found on the NSUF website.

Support for Post-irradiation Examinations:

Coordination of Japanese experiments with the irradiation testing programs in both ATR and TREAT currently underway or planned by the Advanced Fuels Campaign should allow for basic post-irradiation examinations (PIE) to be provided. This could include:

- Shipment of experiments irradiated in ATR/TREAT to the PIE facility (HFEF)
- Neutron radiography
- Gamma ray spectroscopy

- Capsule disassembly (if required) and visual examinations
- Dimensional metrology
- Limited optical metallography/ceramography (not requiring development of new methods)

Additional post-irradiation examinations may be available, contingent upon external funding, which could include:

	*Additional Cost/Sample
• Burnup/transmutation measurements	$50,000-150,000
• Electron probe microanalysis (EPMA)	$200,000-500,000
• Electron microscopy (SEM/FIB/TEM)	$100,000-300,000
• Thermal property measurements (thermal diffusivity, specific heat)	$400,000-600,000

* Costs ranges indicated are for planning purposes only. Actual costs will be determined for each experiment after actual specimen type and composition as well as fabrication and/or PIE specifications have been provided by the experimenter.

List of Appendices:

Appendix A: Statement of Work Template for Proposals Requesting Access to U.S. Facilities

Appendix B: ATF-1 Engineering Drawing

Appendix C: ATR Out-Year Planning Schedule

Appendix D: MARCH-SERTTA Drawing

List of Attachments:

Attachment 1: *Transient Reactor Test Facility Advanced Transient Shapes*

Attachment 2: *Development of Irradiation Test Devices for Transient Testing*

Attachment 3: DRAFT *Core-to-Specimen Energy Coupling Results of the First Modern Fueled Experiments in TREAT (Note: since this is a draft document, consider it as "Information Only")*

Appendix A: Statement of Work Template for Proposals Requesting Access to U.S. Facilities

Project Objectives

Provide a concise description of the motivation, scientific and technical objectives and mission relevance. This can be adopted directly from the proposal narrative. Please note in your description whether there are any special requirements or unique challenges for your proposed experiment.

Experiment Description

Facilities Needed

1. Identify all U.S. testing facilities that may be needed to conduct experiment in its entirety. For the purposes of this solicitation, these facilities can include ATR, TREAT, fuel fabrication facilities and PIE facilities available at the Idaho National Laboratory.

Test Matrix

1. Provide a listing of the materials to be tested, including:
    a. material compositions
    b. number of samples
    c. geometry of test samples (with needed tolerances)
    d. planned application of material (such as structural material for x reactor, fuel and cladding for x reactor, core components for x reactor, experimental, instrumentation)
2. Identify whether test specimens will be fabricated in Japan and shipped to the US or fabricated at the Idaho National Laboratory
3. For test articles to be fabricated at the Idaho National Laboratory provide a description of test specimens to be fabricated and a detailed procedure for preparation of desired test article
4. Provide the source or supplier of materials that will be utilized to fabricate samples into the final desired geometry
5. For previously irradiated fuels and materials, identify:
    a. condition
    b. provenience/pedigree

c. radioactivity levels
d. isotopic content
e. material composition
f. configuration
g. ownership
h. other available information that will be needed in order to ship and/or prepare the fuel or material for examination

6. Identify whether irradiated material will be requested from the NSUF Nuclear Fuels and Materials Library. If yes, please specify which specimens will be requested and whether the applicant has contacted the NSUF office and received approval for use of these samples

Notes:

A. For irradiation tests, experiment feasibility will be strongly influenced by whether a specific material is allowed in ATR or TREAT and the ability to handle the samples during post-irradiation examination.
B. Proprietary materials processing methods do not have to be identified, however, any materials tested in-reactor will need material certifications identifying all measurable elemental constituents.
C. If material composition certifications are not provided from the material supplier, then material samples will have to be sent to an independent testing lab for elemental composition analysis, at the expense of the Japanese institution.

Testing Conditions & Capsule Design Concept

1. Indicate the desired testing conditions including:
   a. Flux (min/max)
   b. total fluence (min/max)
   c. neutron energy spectrum
      i. Include details on how this will be achieved (filtering, etc.).
   d. temperature (min/max)
   e. environmental requirements
2. Indicate the amount of testing parameter uncertainty that can be tolerated (e.g. +/- 50 degrees C).
3. Identify which test rig will be needed to support your experiment. For the purposes of this solicitation the available test rigs are ATF-1 for ATR testing and ATF-SETH and MARCH-SERTTA for TREAT testing. (see Appendix B, D and Attachment 2 for drawings)

For candidate proposals selected by GOJ and screened by DOE, this information will be reviewed by:

a) Reactor analysts to confirm desired testing conditions can be met and to determine which position(s) in the reactor will be suitable for the experiment.
b) Experiment managers to estimate the cost of experiment fabrication. Keep in mind that tighter tolerances on testing conditions may lead to the necessity for more in-pile instrumentation increasing cost and potentially reducing feasibility.

PIE plan

Provide a description of the post-irradiation examination activities needed to achieve the technical objectives. This plan can cover up to a period of three years.

a. Include all anticipated types of analysis and the number of samples that will need to be analyzed in each test.
b. Provide a prioritized list of specific samples to be analyzed, as workscope may be reduced if estimated PIE costs are exceeded.

Data Needs

Describe all of the data needed to support achievement of the technical objectives. This should include:

- analysts reports on experimental design and fabrication,
- as-run data
- PIE data
- what form the data will be needed and how should be stored and transmitted
- any required quality assurance requirements

Schedule

Provide a Gantt chart that indicates the approximate timeline for the experiment.

Reactor analysts will provide the estimated irradiation time to achieve desired fluence based on anticipated availability.

Roles and Responsibilities

Provide a description of the contribution from each PI or co-PI institution down to the individual person level where possible.

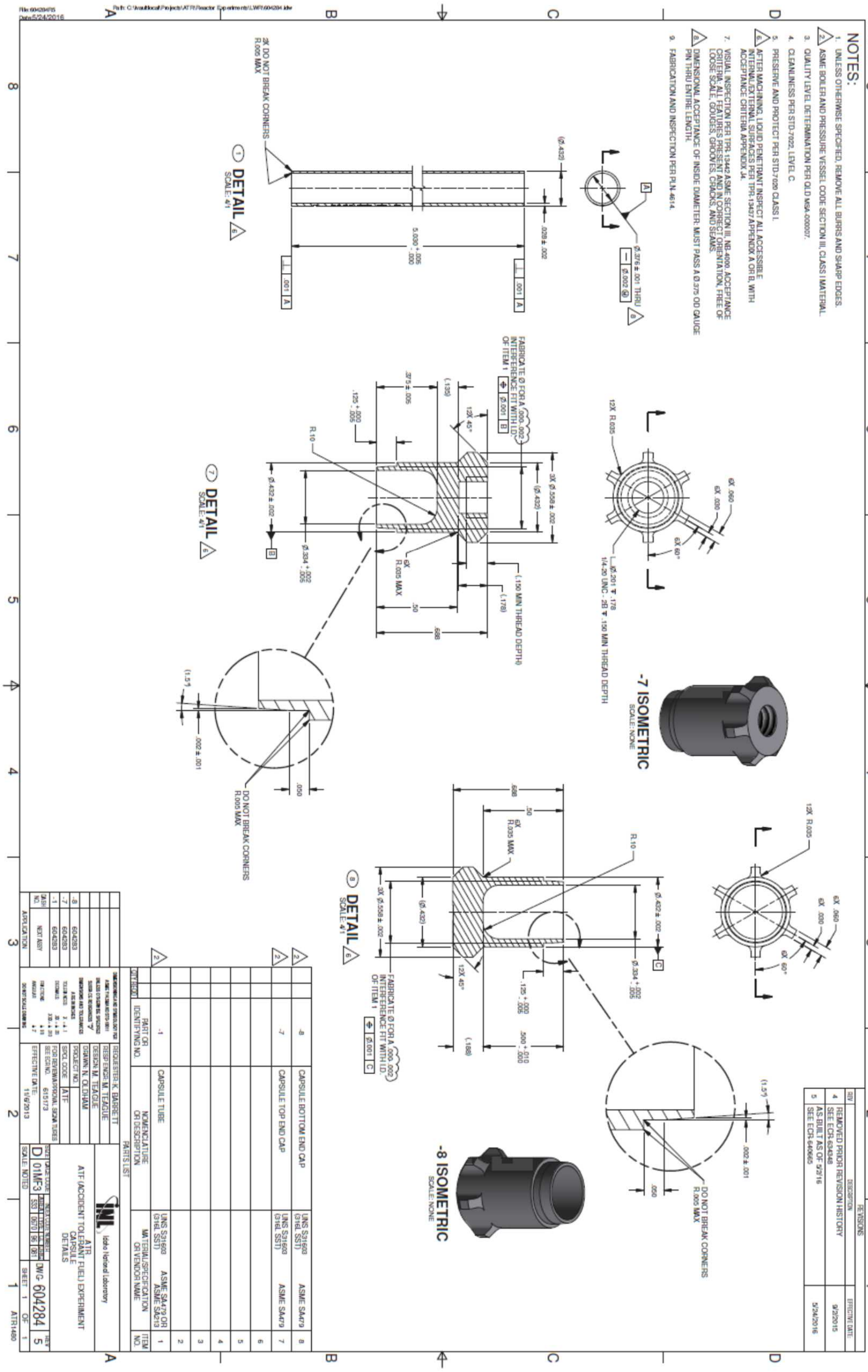
Project Risks and Mitigation Strategy

Identify major risks to timely accomplishment of project objectives and strategies of mitigating these risks.

Points of Contact

Provide at least one point of contact at the requesting Japanese institution who is proficient in the English language. For candidate proposals selected by GOJ and screened by DOE, this point of contact will interface with experts from Idaho National Laboratory to ensure that proposed experiments are feasible. For questions and information pertaining to the DOE feasibility review process, please contact the following technical experts at Idaho National Lab:
ATR Experiments – Christopher Murdock - Christopher.Murdock@inl.gov
TREAT Experiments – Doug Dempsey - douglas.dempsey@inl.gov.

Appendix B: ATF-1 Engineering Drawing



Appendix C: ATR Out-Year Planning Schedule (as of April 2019 and subject to change)

FY19 Out-Year Planning Schedule

CYCLE:	165A-1			165A-1 (Xe1 restart)			166A-1			166B-1			167A-1		
	Outage			Outage			Outage			Outage			Outage		
	PALM			PALM									PALM		
	EFPDs to CIC		341	EFPDs to CIC		339	EFPDs to CIC		327	EFPDs to CIC		268	EFPDs to CIC		208
	10/25/2018	Outage Scope Freeze Date[6]		12/9/2018	Outage Scope Freeze Date[6]		3/8/2019	Outage Scope Freeze Date[6]		6/8/2019	Outage Scope Freeze Date[6]		9/4/2019	Outage Scope Freeze Date[6]	
	Outage	Press Up[5]	EFPD	Outage	Press Up[5]	EFPD	Outage	Press Up[5]	EFPD	Outage	Press Up[5]	EFPD	[8]Outage	Press Up[5]	EFPD
Scheduled Duration (days):	36	7	2	70	7	12	26	7	59	21	7	60	26	7	7
Start:	1/17/2019	2/22/2019	3/1/2019	3/3/2019	5/12/2019	5/19/2019	5/31/2019	6/26/2019	7/3/2019	8/31/2019	9/21/2019	9/28/2019	11/27/2019	12/23/2019	12/30/2019
Finish:	2/22/2019	3/1/2019	3/3/2019	5/12/2019	5/19/2019	5/31/2019	6/26/2019	7/3/2019	8/31/2019	9/21/2019	9/28/2019	11/27/2019	12/23/2019	12/30/2019	1/6/2020

FY20 Out-Year Planning Schedule

CYCLE:	168A-1			168B-1			169A-1			170A-1		
	Outage			Outage			Outage			Outage		
							PALM					
	EFPDs to CIC		201	EFPDs to CIC		141	EFPDs to CIC		81	EFPDs to CIC		67
	10/14/2019	Outage Scope Freeze Date[6]		1/15/2020	Outage Scope Freeze Date[6]		4/12/2020	Outage Scope Freeze Date[6]		8/9/2020	Outage Scope Freeze Date[6]	
	Outage	Press Up[5]	EFPD	[12]Outage	Press Up[5]	EFPD	[12]Outage	Press Up[5]	EFPD	[12]Outage	Press Up[5]	[8]EFPD
Scheduled Duration (days):	26	7	60	21	7	60	98	7	14	26	7	60
Start:	1/6/2020	2/1/2020	2/8/2020	4/8/2020	4/29/2020	5/6/2020	7/5/2020	10/11/2020	10/18/2020	11/1/2020	11/27/2020	12/4/2020
Finish:	2/1/2020	2/8/2020	4/8/2020	4/29/2020	5/6/2020	7/5/2020	10/11/2020	10/18/2020	11/1/2020	11/27/2020	12/4/2020	2/2/2021

FY21 Out-Year Planning Schedule

CYCLE:	170B-1			171A-1		
	Cycle will likely be deleted			Outage		
				CIC		
	EFPDs to CIC		7			
	11/10/2020	Outage Scope Freeze Date[6]		12/20/2020	Outage Scope Freeze Date[6]	
	[12]Outage	Press Up[5]	EFPD	CIC	Press Up[5]	EFPD
Scheduled Duration (days):	26	7	7	274	3	59
Start:	2/2/2021	2/28/2021	3/7/2021	3/14/2021	12/13/2021	12/16/2021
Finish:	2/28/2021	3/7/2021	3/14/2021	12/13/2021	12/16/2021	2/13/2022

Appendix D: MARCH-SERTTA Drawing