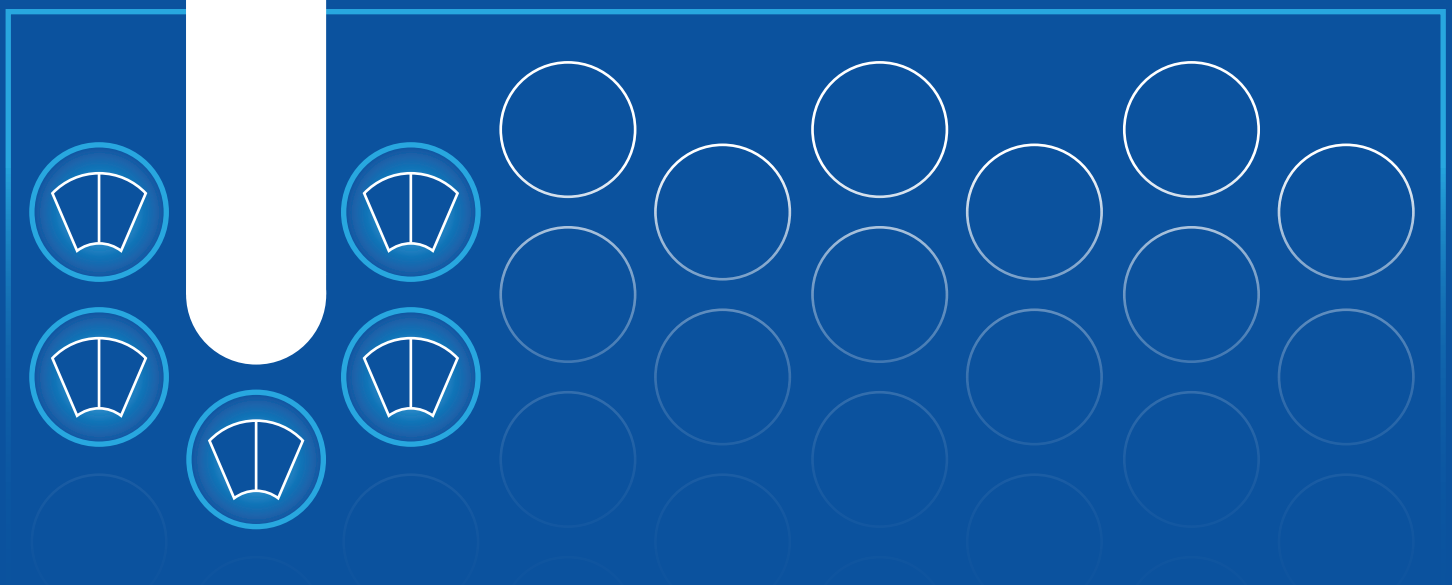
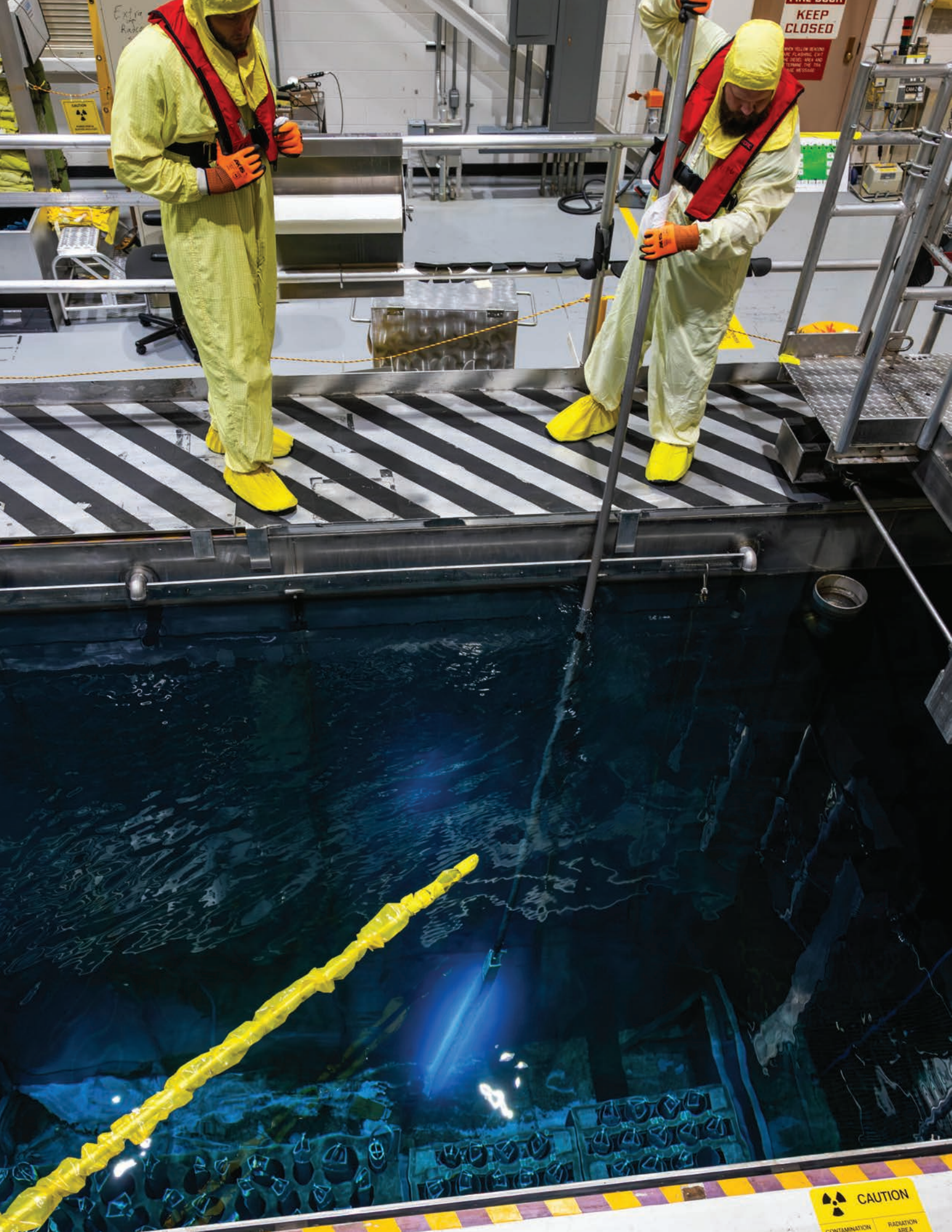
ATR | Advanced Test Reactor

Gamma Facility User Guide



Idaho National Laboratory


KEEP
CLOSED
CAUTION

CONTENTS

ATR canal operations staff rearrange fuel elements to tailor the dose rate within the Gamma Tube to the customer's specifications.

1 PURPOSE

This User Guide is intended for prospective research partners seeking high intensity gamma irradiation services for research. It provides a summary of the Gamma Facility capabilities and guidance to test sponsors on steps requires and the roles and responsibilities for conducting irradiations in the facility.

It also provides test sponsors with a brief discussion of each step involved in the process, typical order of events, and general methodology. The length of time to complete an experiment will vary depending on the complexity of the irradiation test (i.e., experiment design) and irradiation duration.

2 OBJECTIVES

The ATR Gamma Dry Tube #3 is approximately 20 feet long with a 5.25-inch internal diameter, installed in Fuel Storage Grid #36. Irradiated ATR fuel elements are placed in the canal fuel storage grid immediately adjacent to the gamma tube (see Figure 1). These fuel elements can be selected based on the required dose rate necessary for the experiment. The intensity of the gamma irradiation that can be achieved in the gamma facility will depend on the time since fuel removal from the ATR reactor and its proximity to the gamma tube.

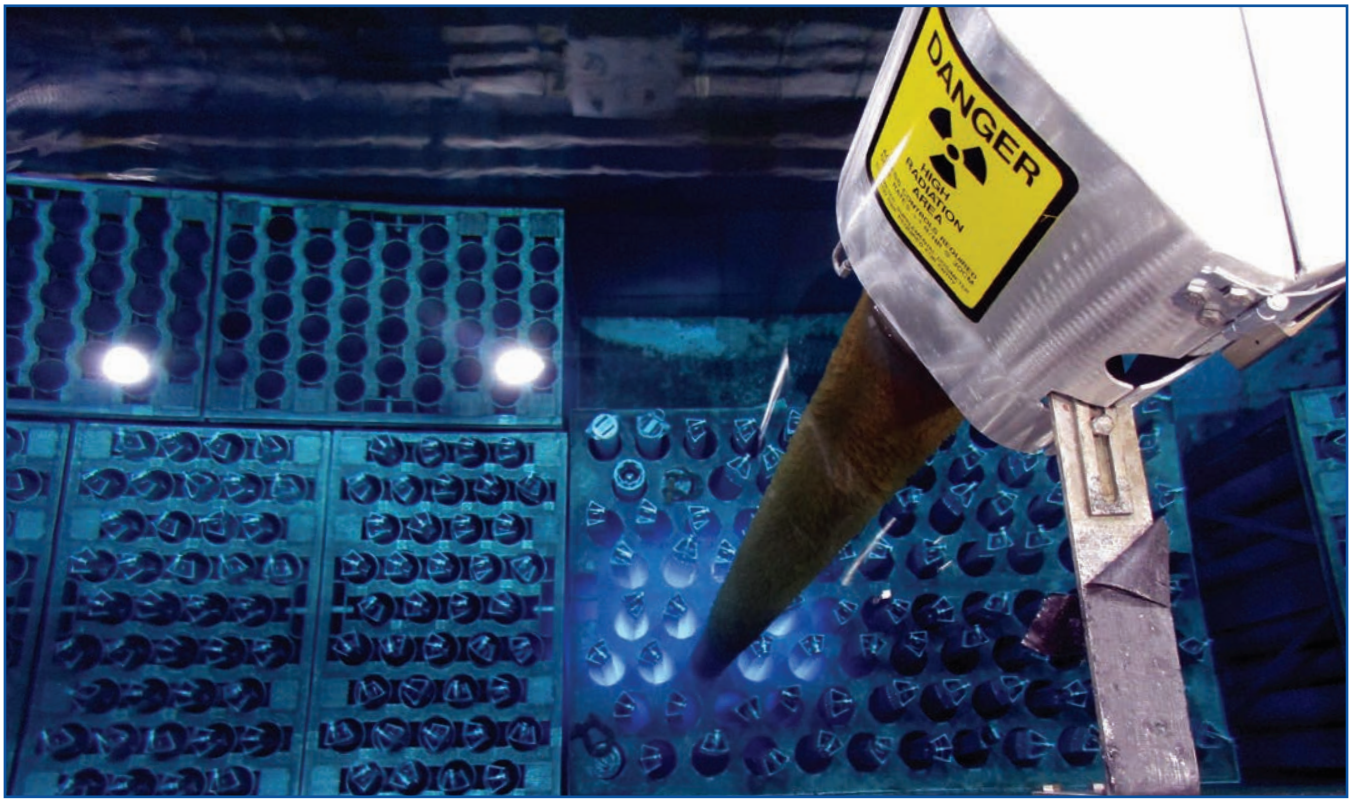


Figure 1. *The ATR Gamma Facility with freshly irradiated fuel.*

The lead filled shielded lid is slotted to accommodate instrumented leads. The slot creates a ½" square opening; however, cable bundles that are larger than this can typically be accommodated by other means (e.g., perching the lid). Measurement of the accumulated radiation exposure can be provided. This can be done in real-time or via measurements taken at the beginning and end of irradiation. The test may be removed/reinstalled to support intermediate measurements, as needed. If real-time or other in-situ radiation measurements are desired, the detector will be supplied by the test sponsor. The bottom 4 feet (fueled region) of the gamma tube provides the highest dose rates.

3 EXPERIMENT SHIPPING

Receipt at ATR and return to the sponsor will be based on the complexity of the experiment. Typically, experiments can be surveyed and returned to the test sponsor at the end of the irradiation.

4 EXPERIMENT DESIGN

All experiments must meet the established nuclear safety requirements for ATR. INL personnel are responsible to ensure that all ATR Gamma Facility insertion requirements are met. The weight of the experiment should be minimized and cannot exceed 31.5 pounds. Additionally, the experiment may not have any cryogenic liquids, explosive materials, or any unknown materials. Other design and nuclear safety requirements are addressed with support from ATR Experiment Engineering. See Appendix B for examples of safety requirements.

5 EXPERIMENT INFORMATION REQUIRED FROM TEST SPONSOR

The following is an outline of information that should be provided for each test. The required level of detail will vary depending on the complexity of the experiment and irradiation requirements. The test sponsor will work with ATR Experiment Engineering to determine what specific information is needed.

I GENERAL DESCRIPTION OF THE TEST TRAIN

Briefly describe the test train, including all samples and test handling hardware and instrumentation.

II PURPOSE OF THE IRRADIATION

Briefly discuss the purpose of the gamma irradiation and intended scope of the program.

III DETAILED TEST TRAIN PHYSICAL DESCRIPTION

This section should include the following information, as applicable:

1. Sketches or drawings showing dimensions and orientation of the test train.
2. List of all materials and quantities (grams) in the test train. (This includes specimen, cladding, container, etc.)
3. Calculations of the expected gamma heating in each of the materials in Item 2 above, if applicable.
4. Calculations of the resultant heat fluxes from Item 3 above, if applicable.

5 List chemical reaction rates (if any).

6 List nuclear reaction rates (if any).

7 Identify any corrosive materials (target or product).

8 List all gases produced (if any) by quantity and calculate maximum possible pressure.

9 Identify effects of water or moisture (due to canister flooding or leaking) on target materials or test train instrumentation.

10 Criticality evaluation if not enveloped by existing criticality analysis.

IV TEST TRAIN INSTRUMENTATION

1 List all instruments (if any) and date last calibrated, if applicable.

NOTE: Calibration should be traceable to a national standard.

2 Include test instrumentation operating instructions.

3 Wiring diagram of test train instrumentation, if applicable.

4 List utility requirements (if any).

V DESIRED GAMMA EXPOSURE

1 Desired dose rate and acceptable range for each target item.

2 Desired total dose and acceptable range for each target item.

3 Desired irradiation time.

4 Desired irradiation period, if applicable, and acceptable range for test duration.

5 Discuss sequence of insertions and removals as a function of exposure for each target item (capsules, holders, etc.).

6 List expected effects of gamma irradiations on the target and on the associated equipment (e.g., vessel walls, seal rings, hanger assembly, etc.).

VI SPECIAL OPERATING INSTRUCTIONS

List any special operating instructions required.

VII SPECIAL SAFETY PRECAUTIONS

1 List any special precautionary safety measures required in handling or irradiating the test train due to the nature of the target material or test configuration, or the product material or configuration.

2 List any special tools necessary for test train handling and assembly/disassembly (if required).

3 List any special precautions necessary for shipping, storage, and post irradiation disposition (include applicable license numbers, etc.).

6 INFORMATION FROM PREVIOUS EXPERIMENTS

- Since gamma radiation does not activate materials, the experiment may be returned to the sponsor with no additional controls following successful radiological surveys. Neutron flux is negligible.[1]
- The temperature in the gamma tube can reach up to 100°F. Test temperatures may exceed this depending on material composition, insulation, etc.
- Lubricants in the radiation field can rapidly degrade and turn "gummy" at significantly faster rate than would be expected in a normal environment. Most plastics also degrade and embrittle very rapidly.
- Insulation materials break down in the radiation field. A standard thermocouple wire insulation had completely disintegrated after ~250 million Rad such that there was essentially zero electrical insulation between bare thermocouple wires.
- Carbon steels tend to rust rapidly in the gamma tube.
- Peak dose rates of 5E6 Rad/hr may be achieved with freshly irradiated fuel. Dose rates will decrease by approximately 5% per day for several days with freshly irradiated fuel. After approximately 2 months of fuel decay, peak dose rates are around 1E6 Rad/hr. Average gamma energies also decrease with time.
- Dose measurements taken by the Radiation Measurements Laboratory (RML) are typically reported as Co-60 dose equivalent values.
- Sample dose rate measurements taken at different heights are shown in the graph below. This is representative of a typical gamma profile.

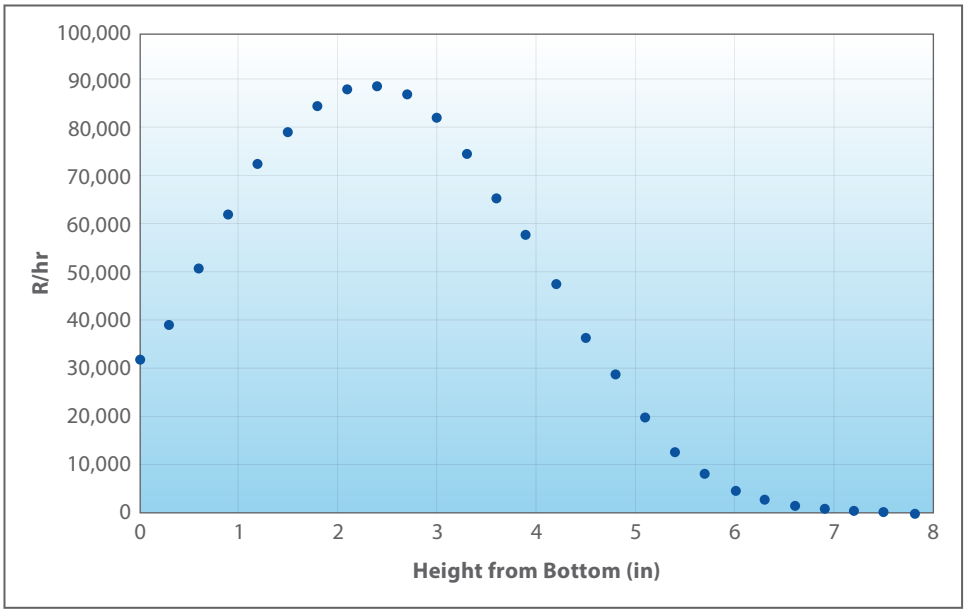


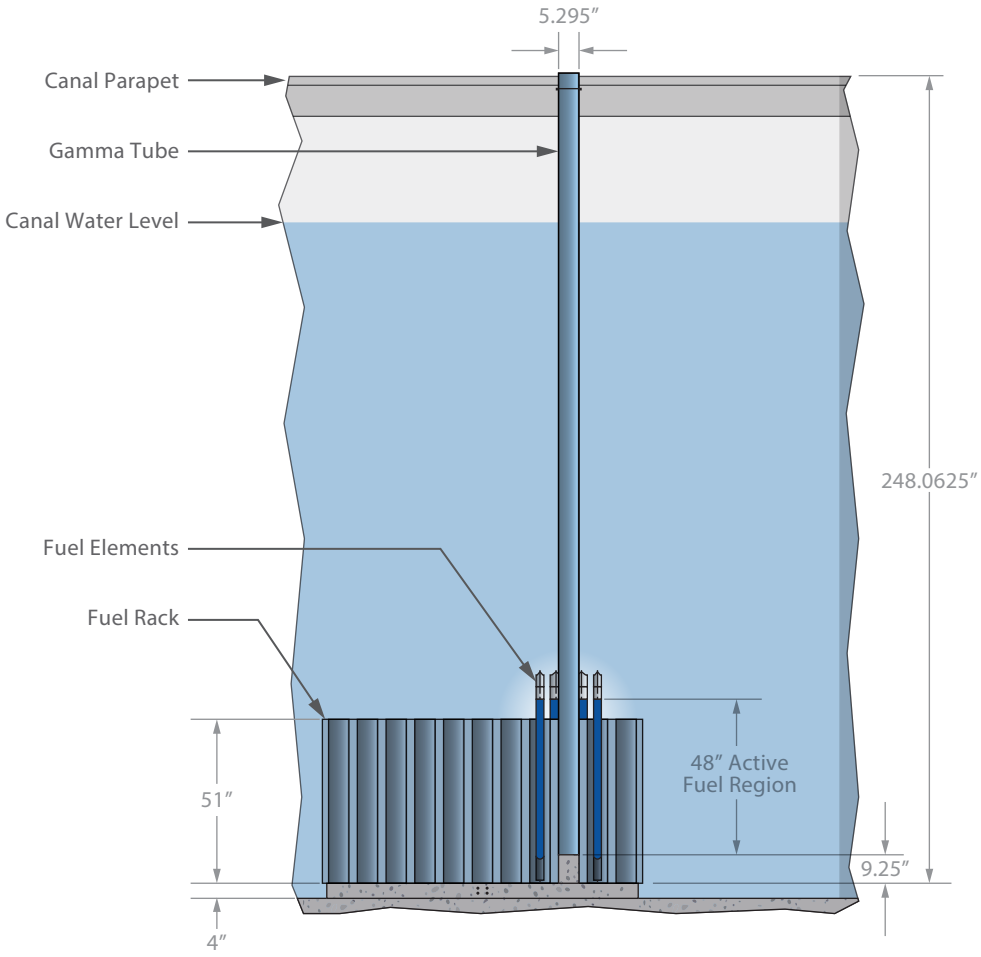
Figure 2. *Typical gamma exposure rate profile.*

7 REFERENCES

1 *Nigg, D.W., 2018, "Experimental Quantification of the Background Neutron Flux in the Advanced Test Reactor Fuel Storage Canal," INL-CON--18-50140, Idaho National Laboratory.*

APPENDIX A

DIMENSIONS AND LAYOUT



APPENDIX B

GENERIC SAFETY REQUIREMENTS CHECKLIST (EXAMPLE ONLY)

Experiment: _____

Estimated Start Date: _____

Total Estimated Irradiation Time: _____

NOTES:

1. This form is to be completed by qualified Experiment Safety Analysis (ESA) authors/reviewers.
2. This form is to be completed prior to each experiment receipt or reconfiguration.
3. If compliance to all requirements in a section cannot be shown, the experiment activity cannot be performed under the authority of the Generic Gamma ESA.

Experiment Documentation

List applicable experiment documents (i.e., Functional and Operational Requirements, supporting analyses) required to perform this checklist:

_____

_____

Experiment Description:

_____

_____

_____

Additional Analyses (if required):

_____

Initials

_____ 1. If the experiment contains materials which are incompatible with the reactor fuel element cladding, the reactor primary coolant, canal water coolant, or with the reactor PCS
_____ structural materials (e.g., mercury, gold, copper, silver, chlorides), then verify at least **ONE** of the following (SAR-153, 10.1.7.3.3):

- ☐ All incompatible materials are solid and insoluble.
- ☐ All incompatible materials are contained or encapsulated, and the container/capsule is not made with any materials that readily degrade in a gamma field.

Notes:_____

_____ 2. Verify the following materials are not included in the experiment.

- ☐ Unknown materials—No experiments shall be performed unless the material content,
_____ with the exception of trace constituents, is known.
- ☐ Explosive materials with an equivalent of ≥ 25 mg of TNT. (Explosive material is a solid or liquid that has an explosion hazard in water or steam [NRC 1973] and is used in a configuration that can detonate and produce a shock wave.)
- ☐ Cryogenic liquids. (SAR-153, 10.1.7.3.4)

_____ 3. Verify the following materials are not used in the experiment unless such usage is shown to be in compliance with the primary experiment safety analyses criterion in Section 10.1.7
_____ and the compliance analyses are completed prior to insertion in the reactor vessel or canal. (SAR-153, 10.1.7.3.5)

- ☐ Activation and fission products.
- ☐ Radiation sensitive materials (materials where alteration or degradation of mechanical properties due to radiation-induced decomposition and/or radiolytic generation of excessive gas pressure or explosive gas mixtures is a potential).
- ☐ Highly flammable or toxic materials, per se or as by-products of radiation sensitive materials.
- ☐ Reactive materials, which are defined as any solid or liquid that has a reactivity index of 2 in National Fire Protection Association Publication 704 (NFPA 704) or acceptable alternative, or has a disaster or fire hazard indicating detrimental reactions in water or steam.

_____ 4. Verify the following:

- ☐ The experiment instrumentation or control "leads" exiting the gamma tube and the
_____ control system have been evaluated per SD-11.1.46.
- ☐ The experiment does not require facility modifications per LWP-10500.
- ☐ The experiment contains no fissile or radioactive material and does not require any specific shielding or handling requirements.
- ☐ The experiment does not hold pressure greater than 235 psig and does not contain material that can generate pressure pulses greater than 430 psig.

Notes/ECAR: _____

☐ If experiment utilizes heaters, ensure analysis has been performed to show that no saturation (boiling) of canal water or that the outside wall of the Gamma Facility is maintained below 93°C, even if heaters fail high.

Notes/ECAR: _____

☐ Only experiments weighing ≤ 31.5 lb. are allowed since no mechanically assisted lifts are covered by this ESA. Notes: _____

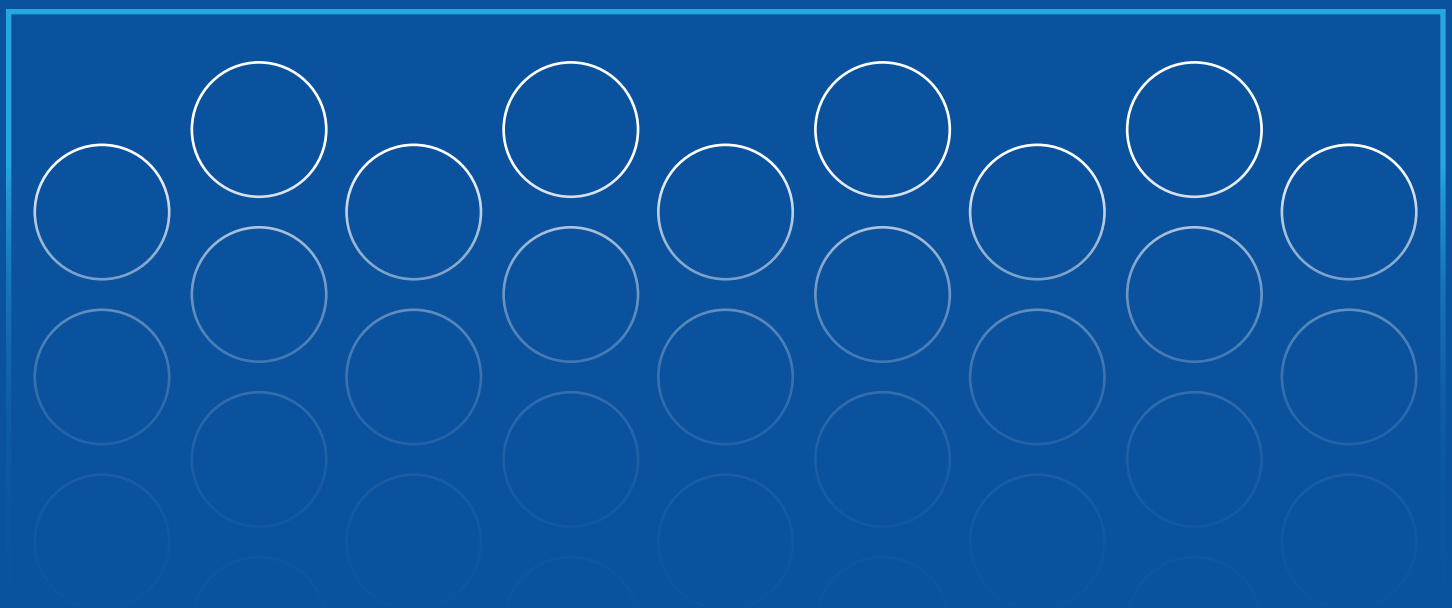
Review and Approval

_____ _____
Performer Date

_____ _____
Reviewer Date

_____ _____
SORC Date

_____ _____
Experiment Engineering Manager Date



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