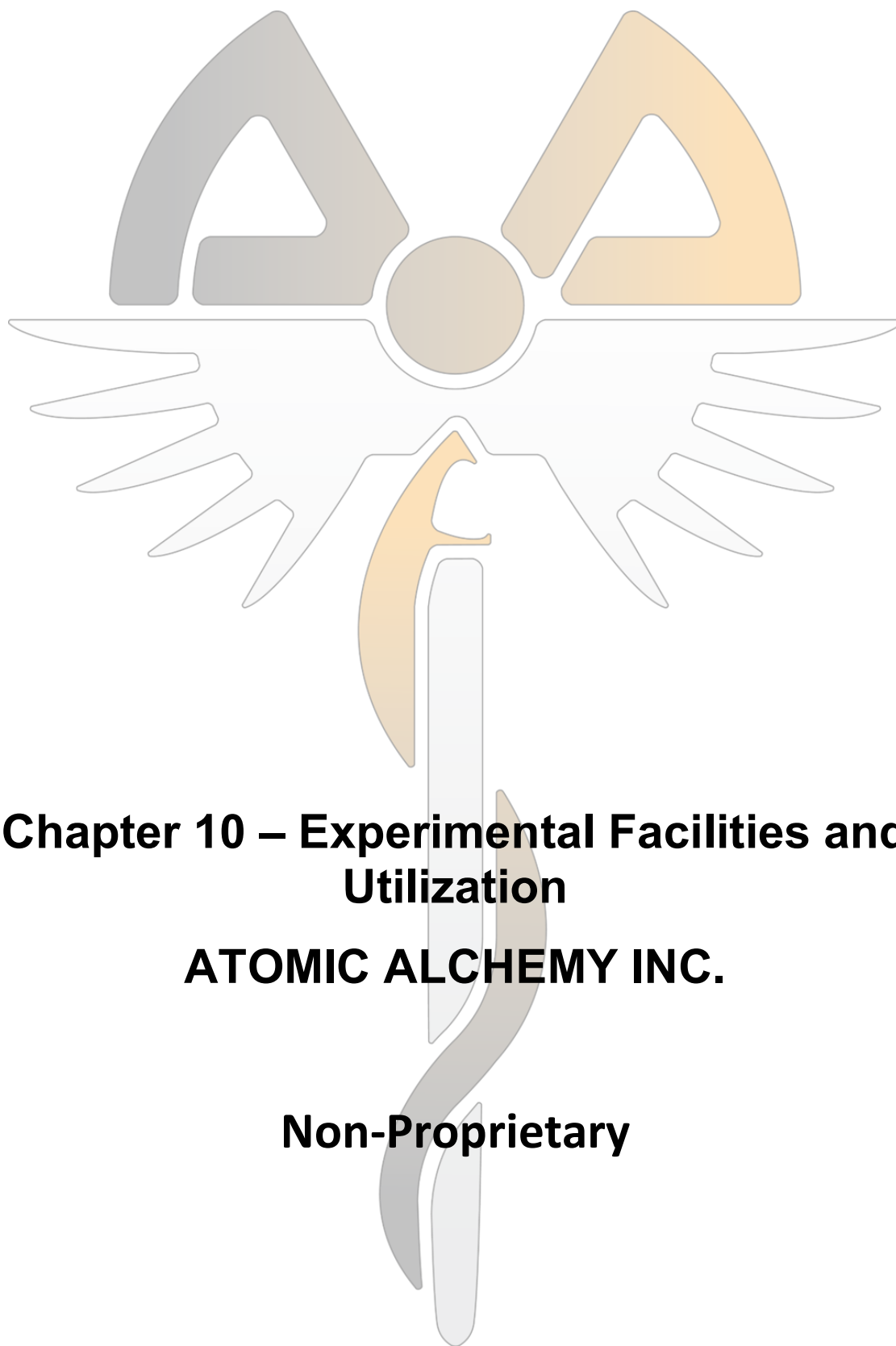




Chapter 10 – Experimental Facilities and Utilization

ATOMIC ALCHEMY INC.

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TERMS

ACRONYMS AND ABBREVIATIONS

Common acronyms, abbreviations, and units of measurements may not be included here as it is assumed the reader is familiar with their meaning.

AAI	Atomic Alchemy Inc.
ATR	Advanced Test Reactor
DANK	Deuterium-Augmented Nuclear Kinetics
LCOs	Limiting Conditions for Operation
NPUF	Non-power Production and Utilization Facility
NTD	neutron transmutation doping
PNSRC	Plant Nuclear Safety Review Committee
QAPD	Quality Assurance Program Description
RPF	radioisotope production facility
VIPR	Versatile Isotope Production Reactor



10 EXPERIMENTAL FACILITIES AND UTILIZATION

10.0 INTRODUCTION

This chapter discusses the design and intended use of the experimental facilities utilized by the Versatile Isotope Production Reactor (VIPR), along with an overview of the experimental programs.

Additional information regarding the experiment program can be found throughout Chapter 12 and Chapter 14, Appendix A, Section 3.8.

10.1 SUMMARY DESCRIPTION

The AAI VIPR has a variety of facilities, commonly known as experimental facilities at non-power reactors, to accomplish its primary mission of radioisotope production. These facilities include both in-core and in-reflector irradiation positions. These facilities have been optimized for thermal neutron flux. The AAI experimental facilities are further described in section 10.2. The most common radioisotope production activity that will occur in-core or in-reflector is the production of byproduct material via neutron capture (e.g., Yb-176 [n,y] Yb-177). The outermost ring of in-reflector positions will be primarily utilized for silicon neutron transmutation doping.

To facilitate irradiation and handling of materials in the experimental facilities, several variations of standardized capsules will be designed to confine target material in the VIPR reflector positions for transmutation to the desired isotope product. Capsules may also include ancillary features such as spacers, guides, handling fixtures, flux wires or plates, and thermocouples. Some capsules may not contain target material and instead serve as dummy capsules to meet specific capsule or reactor operational needs.

A capsule may also be placed inside a basket that is inserted into the experimental facility. Baskets may contain one or more capsules, including dummy capsules and spacers, and together the basket and its contents are referred to as an irradiation assembly. The terms capsule, target, and target capsule may be used interchangeably. Prior to irradiation they may be referred to as fresh capsules or targets; following irradiation they may be referred to as irradiated capsules or targets.

Every irradiation assembly will be designed and analyzed to ensure they are bounded by the approved safety envelope for insertion into a VIPR. Experimental facilities and irradiation assemblies will be designed to ensure they do not impact any safety-related function or engineered safety feature. Irradiation assembly or experimental facility failures are discussed in and bounded by the analysis in Chapter 13. Design and performance criteria for irradiation assemblies will be established to control their use. Examples of such criteria are physical, chemical, and nuclear/radiological compatibility between irradiation assemblies and all other interfaces such as reactor fuel, reactor structural and reflector materials, experimental facilities, reactor pool water, instrumentation, sensors, handling tools, etc.

AAI will develop and implement an experiment review process in accordance with Title 10 of the *Code of Federal Regulations* (CFR) 50.59, “Changes, tests and experiments” requirements and guidance per NRC Regulatory Guides (RGs) 2.2, “Development of Technical Specifications for Experiments in Research Reactors” and 2.8, “Guidance for Implementation of 10 CFR 50.59, ‘Changes, Tests and



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Experiments, ' At Non-Power Production or Utilization Facilities." Additionally, AAI will develop experiment-related Limiting Conditions for Operation (LCOs) to include in the AAI Technical Specifications which are addressed in Chapter 14 of this SAR. The LCOs will be further described in section 10.3.2 in the FSAR. AAI's administrative controls will be widely used to control experiments. Radiological protection and waste management programs are described in Chapter 11. AAI's Quality Assurance Program (QAP) is Chapter 12, Appendix. Target design, fabrication, inspection, acceptance, irradiation and processing operations, handling, shipping, and waste disposition, including applicable procedures, will be reviewed and approved in accordance with these programs to ensure that no operations involving experimental facilities will result in unacceptable radiological risk to workers, the public, the environment, or AAI structures, systems, or components. Approved target designs will be used for routine radioisotope production operations.

The standardized capsule design may be used to contain different target material to be irradiated, and new capsule designs may be required to meet specific customer needs. These will be considered new experiments which will require the same review and approval process. Over time, several approved production targets will be utilized for most operations. Operations and product quality experience gained over time will lead to improving the production target designs. All changes to target design and their associated procedures will be reviewed and approved in accordance with the Experiment Review Program prior to their use. Additional information AAI experiment review process is included in section 10.3 and throughout Chapter 12.

10.2 EXPERIMENTAL FACILITIES

10.2.1 In-Core Facilities

The AAI VIPR contains one flux trap at the center of the core, which is populated by a beryllium reflector block. This reflector block has []^{PROP,ECI} irradiation positions. Each of the irradiation positions within the flux trap have an individual cross-sectional area of []^{PROP,ECI}, shown in **Figure 10-1**. Forced Coolant from the reactor plenum passes upwards through the channels in this reflector block.



[]^{PROP,ECI}

Figure 10-1: Center reflector block with irradiation positions (dimensions in cm)

10.2.1.1 Component Description

The center reflector block is solid beryllium with irradiation positions optimized for neutron exposure. **Figure 10-1** includes the dimensions of the block.

10.2.1.2 Safety Evaluation

The center reflector block plays a significant role in the reactivity of the core. As such, it is secured in place via top grid plate and is not intended to move. There is no safety concern with this component, as it passively sits within the reactor core to serve its function as neutron reflector. The reflector will be periodically inspected to ensure that radiation-induced cracking is not occurring.

10.2.1.3 Instrumentation

There is no instrumentation associated with the beryllium block.

10.2.2 In-Reflector Facilities

The Deuterium-Augmented Nuclear Kinetics (DANK) tank serves as the heavy water reflector surrounding the reactor core. The DANK tank contains two sets of irradiation positions, differentiated by size and function as shown in **Figure 10-2** and **Figure 10-3**.



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[

] ^{PROP, ECI}

Figure 10-2: DANK tank with irradiation positions relative to the reactor coolant flow boundary



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[]^{PROP,ECI}

Figure 10-3: Isometric view of DANK tank with irradiation positions

There are two rings of inner reflector positions per VIPR core, each a cross-sectional area of []^{PROP,ECI} and with a total of []^{PROP,ECI} positions.

The third ring of irradiation positions near the outer edge of the tank primarily serves as silicon neutron transmutation doping facilities. There are []^{PROP,ECI} of these positions, each with a cross-sectional area of []^{PROP,ECI}.

Additional dimensions can be found in **Figure 10-4**. Forced coolant from the reactor coolant system does not pass through the irradiation positions in the DANK tank; these irradiation positions are cooled via natural convection, with water from the pool moving up through the bottom of the tank and through the channels.



[] PROP, ECI

Figure 10-4: DANK tank inner, outer, and NTD irradiation positions

10.2.2.1 Component Description

The DANK tank is an aluminum tank with irradiation positions optimized for neutron exposure. **Figure 10-4** presents the dimensions of the tank. The DANK tank is filled with heavy (deuterium) water and a blanket of helium gas. A plenum connects the tank to an auxiliary system with an ion exchange resin column which removes tritium gas produced by neutron-deuterium interactions and a chiller to regulate the water temperature. The auxiliary systems include a drainage tank to drain the bulk of the heavy water if necessary. Irradiation facilities allow a natural convective current from the pool to flow upwards and cool the facilities. The heavy water needs little to no replacement.

10.2.2.2 Safety Evaluation

A failure of the DANK tank, resulting in a loss of or mixing of deuterium in both the reactor pool and DANK tank, results in a net decrease in reactivity. Failure of the DANK tank or any of its auxiliary systems, detailed in Chapter 9, do not pose a challenge to nuclear safety. The primary concern with a boundary failure of the DANK tank is the potential release of tritium which is produced via neutron interaction with the deuterium during normal operation.

10.2.2.3 Instrumentation

Instrumentation for the operation of the DANK tank is part of the Facility Control System discussed in Chapter 7. There is no instrumentation associated with the irradiation facilities or the water channels in which the irradiation targets are placed.



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10.2.3 Gamma Irradiation Facility

10.2.3.1 Gamma Irradiation Facility Description

Similar to the gamma irradiation facility in the Advanced Test Reactor (ATR) Complex (Nigg 2018), AAI may utilize used fuel for the facilitation of gamma irradiation experiments. This will be accomplished in a nearly identical manner as ATR: A stainless steel dry tube is locked into place in a used fuel slot within the used fuel pool. A number of used fuel assemblies, which give off gamma radiation proportionally to how long the fuel has been removed from the core, are arranged around the dry tube. When the experiment has received the desired gamma fluence, the experiment is removed from the dry tube, or the tube itself is removed from the used fuel pool. The gamma irradiation facility is inside the used fuel pool as shown in **Figure 10-5** which is for reference only.

[]^{PROP,ECI}

Figure 10-5. Isometric view of the used fuel pool and gamma irradiation facility

10.2.3.2 Mechanical Design Basis

The gamma irradiation facility dry tube is made of stainless steel, which is compatible with the pool water and maintains its structural integrity. The top plug is made of a high-density material such as lead to provide adequate radiation shielding while the facility is being utilized.



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10.2.3.3 Safety Evaluation

As the gamma irradiation facility is located in the used fuel pool, it has no influence on reactivity of the reactor. Failure of the experimental facility, such as water leaking into the dry tube, will have no impact on the reactor. Because the dry tube simply occupies an existing space within the used fuel storage rack with its existing neutron absorber plates, failure of the experimental facility, such as water leaking into the dry tube, will have no impact on the vast subcriticality margin of the used fuel.

10.2.3.4 Instrumentation

To ensure the experiment is receiving the correct gamma dose rate or is within the bounds of other experiment parameters such as total fluence, instrumentation may be used to monitor progress. This instrumentation will reside at the side of the pool/pool top near the used fuel storage region where the dry tube is located. The instrumentation associated with this device does not interact or interfere with reactor instrumentation and controls in any way.

10.3 EXPERIMENT REVIEW

10.3.1 Summary Process

A summary of the experiment review process is included in section 10.1 above. Additional information is provided herein.

Review of AAI's experiments will be based on implementation of requirements in 10 CFR 50.59 and guidance from RGs 2.2 and 2.8. Reviews and approvals of all new and modified experiments will be performed by the AAI Independent Review Committee (IRC), as described in the AAI QAP, Section 2.1.3 and Chapter 12, Section 12.1.1. The Independent Review Committee's role is to confirm that experiments remain within the facility's safety and licensing basis, ensure hardware and procedural compatibility with reactor systems, and verify that appropriate controls are in place. The committee will follow documented procedures that allow for expedited reviews of routine or previously approved experiments, including the use of delegated authority where appropriate.

10.3.2 Proposed Limiting Conditions for Operations Technical Specifications

Proposed technical specifications regarding experiments are included in Chapter 14, Appendix A and will be further developed in the FSAR, utilizing R.G. 2.2 and R.G. 2.8.

10.4 REFERENCES

Nigg, David W., David T. Miller, and Kyle S. Beling. 2018. "Experimental Quantification of the Background Neutron Flux in the Advanced Test Reactor Fuel Storage Canal". United States.
<https://www.osti.gov/servlets/purl/1492835>.

Nuclear Regulatory Commission. 1996. NUREG-1537, Part 1, "Guidelines for Preparing and Reviewing Applications for the Licensing of Non-Power Reactors."