Chapter 14 Appendix A – Versatile Isotope Production Reactor Technical Specifications

ATOMIC ALCHEMY INC.

Non-Proprietary

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TABLE OF CONTENTS

LIST OF FIGURES

N/A

LIST OF TABLES

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.
CFR	*Code of Federal Regulations*
LSSS	limiting safety system settings
TS	Technical Specifications
VIPR	Versatile Isotope Production Reactor

1 INTRODUCTION

1.1 SCOPE

This document constitutes the Technical Specifications (TS) for the Versatile Isotope Production Reactor (VIPR) as required by Title 10 of the *Code of Federal Regulations* (CFR) 50.36, "Technical Specifications." This document includes the basis to support the selection and significance of the specifications. Each basis is included for information purposes only and is not part of the TS in that it does not constitute requirements or limitations which the licensee must meet in order to meet the specifications. These specifications are formatted to NUREG-1537 and ANSI/ANS 15.1-2007.

1.2 FORMAT

Content and section numbering follows the requirement set forth in section 1.2.2 of ANSI/ANS 15.1-2007, "The Development of Technical Specifications for Research Reactors."

1.3 DEFINITIONS

The following definitions are included to provide uniform interpretation of terms and phrases used per ANSI 15.1-2007.

Channel: the combination of sensor, line, amplifier, and output devices that are connected for the purpose of measuring the value of a parameter.

Channel calibration: an adjustment of the channel such that its output corresponds with acceptable accuracy to known values of the parameter that the channel measures. Calibration shall encompass the entire channel, including equipment actuation, alarm, or trip, and shall be deemed to include a channel test.

Channel check: a qualitative verification of acceptable performance by observation of channel behavior, or by comparison of the channel with other independent channels or systems measuring the same parameter.

Channel test: the introduction of a signal into the channel for verification that it is operable.

Confinement: an enclosure of the overall facility that is designed to limit the release of effluents between the enclosure and its external environment through controlled or defined pathways.

Containment: an enclosure of the facility designed to (1) be at a negative internal pressure to ensure in-leakage, (2) control the release of effluents to the environment, and (3) mitigate the consequences of certain analyzed accidents or events.

Core configuration: the core configuration includes the number, type or arrangement of fuel assemblies, reflector elements, and regulating/control/transient rods occupying the core grid.

Excess reactivity: the amount of reactivity that would exist if all reactivity control devices were moved to the maximum reactive condition from the point where the reactor is exactly critical (k_{eff}=1) at reference core conditions or at a specified set of conditions.

Experiment: any operation, hardware, or target (excluding devices such as detectors, foils, etc.) that is designed to investigate nonroutine reactor characteristics or that is intended for irradiation within the pool, on or in a beam port or irradiation facility. Hardware rigidly secured to a core or shield structure so as to be a part of its design to carry out experiments is not normally considered an experiment.

Facility-specific definitions**:** those definitions unique to a specific facility.

License**:** the written authorization, by the responsible authority, for an individual or organization to carry out the duties and responsibilities associated with a personnel position, material, or facility requiring licensing.

Measured value: The measured value is the value of a parameter as it appears on the output of a channel.

Movable experiment: A movable experiment is one where it is intended that all or part of the experiment may be moved in or near the core or into and out of the reactor while the reactor is operating.

Owner or operator: see licensee.

Operable: a component or system is capable of performing its intended function.

Operating: when a component or system is performing its intended function.

Permit: see license.

Protective action: the initiation of a signal or the operation of equipment within the reactor safety system in response to a parameter or condition of the reactor facility having reached a specified limit.

Reactivity worth of an experiment: the value of the reactivity change that results from the experiment being inserted into or removed from its intended position.

Reactor operating: the reactor is operating whenever it is not secured or shut down.

Reactor operator: an individual who is licensed to manipulate the controls of a reactor.

Reactor safety systems: those systems, including their associated input channels, that are designed to initiate automatic reactor protection or to provide information for initiation of manual protective action.

Reactor secured: A reactor is secured when

1) Either there is insufficient moderator available in the reactor to attain criticality or there is insufficient fissile material present in the reactor to attain criticality under optimum available conditions of moderation and reflection;
2) Or the following conditions exist:
   a) The minimum number of neutron absorbing control devices is fully inserted or other safety devices are in shutdown position, as required by technical specifications;
   b) The console key switch is in the off position, and the key is removed from the lock;
   c) No work is in progress involving core fuel, core structure, installed control rods, or control rod drives unless they are physically decoupled from the control rods;

d) No experiments are being moved or serviced that have, on movement, a reactivity worth exceeding the maximum value allowed for a single experiment, or one dollar, whichever is smaller.

Reactor shutdown: The reactor is shut down if it is subcritical by at least one dollar in the reference core condition with the reactivity worth of all installed experiments included.

Reference core condition: The condition of the core when it is at ambient temperature (cold) and the reactivity worth of xenon is negligible (<0.30 dollar).

Research reactor: A research reactor is defined as a device designed to support a self-sustaining neutron chain reaction for research, development, educational, training, or experimental purposes and that may have provisions for the production of radioisotopes.

Research reactor facility: Includes all areas within which the owner or operator directs authorized activities associated with the reactor.

Responsible authority: A governmental or other entity with the authority to issue licenses, charters, permits, or certificates.

Rod control: A control rod is a device fabricated from neutron-absorbing material or fuel, or both, that is used to establish neutron flux changes and to compensate for routine reactivity losses. A control rod can be coupled to its drive unit allowing it to perform a safety function when the coupling is disengaged.

Rod regulating: The regulating rod is a low worth control rod used primarily to maintain an intended power level that need not have scram capability and may have a fueled follower. Its position may be varied manually or by a servo-controller.

Scram time: Scram time is the elapsed time between the initiation of a scram signal and a specified movement of a control or safety device.

Secured experiment: A secured experiment is any experiment, experimental apparatus, or component of an experiment that is held in a stationary position relative to the reactor by mechanical means. The restraining forces must be substantially greater than those to which the experiment might be subjected by hydraulic, pneumatic, buoyant, or other forces that are normal to the operating environment of the experiment, or by forces that can arise as a result of credible malfunctions.

Senior reactor operator: An individual who is licensed to direct the activities of reactor operators. Such an individual is also a reactor operator.

Shall, should, and may: The word “shall” is used to denote a requirement; the word “should” is used to denote a recommendation; and the word “may” is used to denote permission, neither a requirement nor a recommendation.

Shutdown margin: Shutdown margin is the minimum shutdown reactivity necessary to provide confidence that the reactor can be made subcritical by means of the control and safety systems starting from any permissible operating condition and with the most reactive rod in the most reactive position, and the non-scrammable rods in their most reactive positions and that the reactor will remain subcritical without further operator action.

Supervisory reactor operator: See senior reactor operator.

True value: The true value is the actual value of a parameter.

Unscheduled shutdown: An unscheduled shutdown is defined as any unplanned shutdown of the reactor caused by actuation of the reactor safety system, operator error, equipment malfunction, or a manual shutdown in response to conditions that could adversely affect safe operation, not including shutdowns that occur during testing or checkout operations.

2 SAFETY LIMITS AND LIMITING SAFETY SYSTEM SETTINGS

2.1 SAFETY LIMITS

Applicability

This specification applies to the reactor fuel.

Objective

The objective of this specification is to define the maximum reactor fuel rod temperature that can be permitted to ensure that the integrity of the fuel cladding is maintained to guard against an uncontrolled release of radioactivity.

Specifications

a) The temperature of a fuel rod centerline shall not exceed 2804°C and decreasing 5°C per 10 GWD/MTU for any operating condition.

Basis

a) Well-established regulatory limits exist for fuel assemblies comprised of uranium dioxide with zircaloy-alloy cladding. Maintaining the integrity of the fuel cladding, preventing excessive oxidation, and preventing zirconium-water interactions requires that the cladding remain below the established cladding temperature limit of 1204°C (IAEA). Additionally, NUREG-0800 states that fuel is assumed to fail if centerline fuel melting occurs. Fuel integrity is maintained by ensuring that the uranium dioxide fuel does not reach this temperature.

2.2 LIMITING SAFETY SYSTEM SETTINGS

2.2.1 Forced Convection Flow

Applicability

This specification applies to the scram settings which prevent the safety limit from being reached or exceeded. The thermal hydraulic performance on the cooling capacity of the core is established from the thermal power, coolant mass flow rate, height of water above the core, and water temperature into the reactor core.

Objective

The objective of this specification is to assure that automatic protective action is initiated to prevent a safety limit from being exceeded.

Specifications

The limiting safety system settings (LSSS) for forced flow operating conditions are the following:

Table 2-1: Forced convection flow specifications

Parameter	Value	Unit
Power (Maximum)	16.80	MW
Coolant Mass Flow Rate (Minimum)	[ ]PROP	kg/s
Coolant Inlet Temperature (Maximum)	[ ]PROP	°C
Pool Level (Minimum)	[ ]PROP,ECI	m

Basis

PSAR Chapter 5.

The LSSS that are given in the Specification represent values of the interrelated variables which, if exceeded, shall result in automatic protective actions that will prevent safety limits from being exceeded during the most limiting anticipated transient. The safety margin that is provided between the LSSS and the safety limits also allows for the most adverse combination of instrument uncertainties associated with measuring the observable parameters.

The analysis presented in the Safety Analysis Report (SAR) for all credible accident scenarios indicate that if the interrelated variables were at their LSSS at the initiation of the transient, the safety limit would not be exceeded.

2.2.2 Natural Convection Flow

Applicability

This specification applies to the scram settings which prevent the safety limit from being reached or exceeded. The thermal hydraulic performance on the cooling capacity of the core is established from the thermal power, height of water above the core, and water temperature into the reactor core.

Objective

The objective is to assure that automatic protective action is initiated in order to prevent a safety limit from being exceeded.

Specifications

The LSSS for natural convection flow operating conditions are the following:

Table 2-2: Natural convection flow specifications

Parameter	Value	Unit
Power (Maximum)	500.00	kW
Coolant Inlet Temperature (Maximum)	[ ]PROP	°C
Pool Level (Minimum)	[ ]PROP,ECI	m

Basis

PSAR Chapter 5.

The LSSS represents values of the interrelated variables which, if exceeded, shall result in automatic protective actions that will prevent the safety limit from being exceeded.

The specifications given above assure that an adequate safety margin exists between the LSSS and the SL. The limit on reactor thermal power was chosen with the additional consideration related to bulk boiling at the outlet of the hot channel.

3 LIMITING CONDITIONS FOR OPERATIONS

3.1 REACTOR CORE PARAMETERS

3.1.1 Excess Reactivity

Applicability

This specification applies to all reactor core configurations during forced convection or natural convection flow operations.

Objective

The objective is to ensure that the reactor will be operated within the bounds of established safety analysis. The limit on excess reactivity ensures safe shutdown of the reactor in all operating conditions, preventing the loss of fuel integrity or uncontrolled release of radioactivity.

Specifications

The upper limit for allowed excess reactivity from all sources in all operating conditions is 11708 pcm (16.32 $).

Basis

PSAR Chapter 4.2.2

3.1.2 Shutdown Margin

Applicability

This specification applies to all reactor core configurations during forced convection or natural convection flow operations.

Objective

The objective is to ensure that the reactor will be operated within the bounds of established safety analysis. The shutdown margin ensures safe shutdown of the reactor in all operating conditions, preventing the loss of fuel integrity or uncontrolled release of radioactivity.

Specifications

The minimum shutdown margin is 400 pcm (0.56 $).

Basis

PSAR Chapter 4.2.2

3.1.3 Core Configurations

Applicability

This specification applies to all reactor core configurations during forced convection or natural convection flow operations.

Objective

The objective is to ensure that assumptions used in the specification of the individual reactivity coefficients and power defect are met, and that no conditions could lead to the loss of fuel integrity, uncontrolled release of reactivity, or potential exposures exceeding 10 CFR 20, ""Standards for Protections Against Radiation."

Specifications

Two VIPR core configurations are specified:

1. [ ][PROP,ECI] fuel assemblies installed in a square with 1 solid neutron reflector in the center and liquid neutron reflector tank located on the periphery. All [ ][PROP,ECI] fuel assemblies contain fresh fuel, with burnable poisons contained in 16 fuel pins each.
2. [ ][PROP,ECI] fuel assemblies installed in a square with 1 solid neutron reflector in the center and liquid neutron reflector tank located on the periphery. [ ][PROP,ECI] fuel assemblies contain fresh fuel, with burnable poisons contained in [ ][PROP,ECI] fuel pins each. [ ][PROP,ECI] fuel assemblies are reshuffled from the previous fuel cycle.

No vacancies in the VIPR core are permitted in any configuration.

No control rod assembly shall be removed from the core unless the reactor is subcritical by more than the worth of the most reactive control rod assembly.

No fuel shall be removed from the core unless the reactor is subcritical by more than the worth of the most reactive fuel assembly.

Basis

PSAR Chapter 4.5.1.2

3.1.4 Reactivity Coefficients

Applicability

This specification applies to all authorized VIPR core configurations during forced-convection and natural-convection operation.

Objective

The objective is to ensure reactivity feedback remains negative and consistent with the design analyses so that fuel integrity is preserved during anticipated operational occurrences and postulated accidents.

Specifications

- The fuel temperature coefficient of reactivity shall be non-positive over the analyzed operating range
- The moderator temperature coefficient of reactivity shall be less than or equal to the bounding value in Chapter 4, Table 4-10 (-6.09 pcm/°C).
- The moderator void coefficient shall be less than or equal to the bounding value established in Chapter 4, Table 4-10 (-153.61 pcm/$\%_{void}$).
- The net power defect (the integrated reactivity change between cold shutdown and hot full power, excluding xenon and samarium effects) shall be negative and of magnitude no less than the value determined in Chapter 4, Section 4.5.2.2 (-1174 pcm).
- The combined reactivity feedback shall remain negative under all steady-state operating conditions within the analyzed envelope.

The reactivity coefficients of the VIPR at the limiting core configuration (Section 3.1.3) are:

Table 3-1: Reactivity coefficients in the Limiting Configuration

Coefficient	Value
Fuel Temperature (pcm/°C)	-1.35
Moderator Temperature (pcm/°C)	-6.09
Moderator Void (pcm/$\%_{void}$)	-153.61
Power Defect (pcm)	-1,174

Basis

PSAR Chapter 4.5.2.2, 13

Chapter 4, Table 4-10 quantifies the fuel, moderator temperature, and moderator void coefficients at the beginning of the limiting cycle. Serpent simulations further define the power defect as the integrated reactivity change between cold shutdown and hot full power. At equilibrium, xenon-135 and samarium-149 contribute an additional approximately -3,082 pcm of negative reactivity, enhancing long-term stability. However, the limiting (least negative) defect is the thermal-only value at zero xenon, which governs startup and early transients and is therefore used in the Chapter 13 accident analyses. Accident evaluation in Chapter 13 demonstrates that this startup condition is the most limiting case and that these feedback values ensure conservative reactor response.

3.1.5 Fuel Parameters

Applicability

This specification applies to the fuel in all reactor core configurations.

Objective

The objective is to ensure that the fuel will not exceed safety limits in any operating conditions.

Specifications

The VIPR will not be operated with damaged fuel, except if necessary to locate such fuel. Fuel with parameters beyond limits addressed in the FSAR for the following categories is considered damaged:

- Longitudinal growth/Bowing/Bending.
- Detected fission products.

Fuel will be visually inspected on intervals specified in Section ?, following the manufacturers' recommendations for detecting deterioration.

Burnup in the fuel will not exceed a limit specified in GWd/MTU and addressed in the FSAR.

Basis

PSAR Chapter 4.2.1

3.2 REACTOR CONTROL AND SAFETY SYSTEMS

3.2.1 Control Rods

Applicability

This specification applies to the control rods in all reactor core configurations.

Objective

The objective is to ensure excess reactivity and shutdown margin specifications can be met in all operating conditions.

Specifications

The VIPR core has 4 control rod assemblies. All control rod assemblies are required to be operable.

The maximum scram time for the control rod assemblies is less than 1 second.

Basis

PSAR Chapter 4.2.2

3.2.2 Maximum Reactivity Insertion Rate

Applicability

This specification applies to the control rods in all reactor core configurations.

Objective

The objective is to limit the rate of positive reactivity insertion in order to sufficiently limit the consequences of any reactor transient and other applicable accident scenarios.

Specifications

The maximum speed at which the control rods can be withdrawn is 0.17 cm/s, corresponding to a maximum reactivity insertion rate of 69 pcm/s (0.10 $/s) should all control rod assemblies be simultaneously withdrawn through the region of highest neutron flux.

Simultaneous or ganged withdrawal of control rod assemblies is not permitted.

Basis

PSAR Chapter 4.2.2

3.2.3 Scram Channels

Applicability

This specification applies to the reactor safety system channels.

Objective

The objective is to require the minimum number of reactor safety system channels which must be operable during reactor operation.

Specifications

These safety system channels will be specified in the FSAR. Measuring channels may include:

- Startup Power Level
- Safety Power Level
- Linear Power Level
- Log N Power Level
- Flow Monitoring
- Primary Coolant Flow
- Pool Water Temperature
- Pool Water Level

- Manual SCRAM Button
- Reactor Key Switch
- SCRAM Logic Unit Ground Fault SCRAM
- Over-the-Pool Radiation Monitor
- Seismic Disturbance

Basis

PSAR Chapter 4.2.2, PSAR Chapter 4.5, PSAR Chapter 4.6, PSAR Chapter 13.

3.2.4 Interlocks

Applicability

This specification applies to the reactor control system.

Objective

To stipulate the minimum number of interlocks available to inhibit control rod withdrawal.

Specifications

Specifications for interlocks will be detailed in the FSAR.

Basis

PSAR Chapter 4.2.2, PSAR Chapter 4.5, PSAR Chapter 7.4.3.3.

3.2.5 Backup Shutdown Mechanisms

Applicability

This specification applies to the Deuterium Augmented Neutron Kinetics (DANK) tank in all reactor core configurations.

Objective

The objective is to ensure excess reactivity and shutdown margin specifications can be met in all operating conditions.

The VIPR uses both control rod assemblies and the draining of heavy water from the DANK tank for shutdown from conditions of maximum excess reactivity. When the excess reactivity of the VIPR in the reference core condition is sufficiently low that the minimum shutdown margin can be met by the control rod assemblies alone, and without the most reactive control rod (the “one stuck rod” criterion) assembly, the ability to drain heavy water from the DANK tank is not required.

Specifications

The upper limit for allowed excess reactivity from all sources in all operating conditions, without the ability to rapidly drain heavy water from the DANK tank, is 7022 pcm (9.79 $).

Basis

PSAR Chapter 4.2.2

3.2.6 Beryllium Reflector

Applicability

This specification applies to the beryllium reflector.

Objective

To stipulate the minimum replacement interval to inhibit poor reflector performance.

Specifications

Specifications for the beryllium reflector replacement interval will be detailed in the FSAR.

Basis

PSAR Chapter 4.2.3.3.

3.2.7 Bypassing Channels

Applicability

This specification applies to the interlocks in **Table** 3-5.

Objective

The objective is to indicate the conditions in which an interlock may be bypassed.

Specifications

Specifications for bypasses will be detailed in the FSAR.

Basis

PSAR Chapter 7.5.6.2, PSAR Chapter 7.5.6.3, PSAR Chapter 7.5.13.3.

3.3 COOLANT SYSTEMS

3.3.1 Shutdown Cooling Requirements

Applicability

This specification applies to the Primary Coolant System requirements needed to safely shutdown the reactor core.

Objective

The objective is to actively cool the reactor with forced convection until the decay heat from the reactor is at a safe level the natural convection will sufficiently cool the reactor.

Specifications

The reactor core is actively cooled during the shutdown sequence until the decay heat is managed by natural convection. The shutdown cooling requirements are dependent on the decay heat and time until the cooling is transitioned to natural convection.

Table 3-2: Shutdown cooling specifications

Shutdown Cooling Requirements	Value	Unit
Decay Heat	500.0	kW
Forced Convection Time	900.0	s

Basis

PSAR Chapter 4.6.3.2, PSAR Chapter 5.1

3.3.2 Isolation Valves

There are isolation valves in the primary coolant system that prevent coolant leaving the reactor core pool. These valves are not used during the operational needs of the reactor coolant system but serve as a precaution to prevent LOCA conditions in the reactor core.

3.3.3 Coolant Level Limits

Applicability

This specification applies to the water level above the active region of the core.

Objective

The objective is to sufficiently limit the radiation exposure at the top of the pool and maintain sufficient pressure for natural circulation when the core is shutdown.

Specifications

The minimum coolant level is the greater of the values required to provide sufficient shielding from radiation above the VIPR core and pressure for forced and natural convection flow. Values are given relative to the top of the active fuel region in the VIPR core:

Table 3-3: Minimum coolant level

Minimum Coolant Level Above Active Fuel	Value	Unit
Radiation Shielding	[ ]PROP,ECI	m
Coolant Height Above the Core	[ ]PROP,ECI	m

Basis

PSAR Chapter 4.4, PSAR Chapter 4.6.3.2, PSAR Chapter 5.2.3.1.

3.3.4 Leak Detection

Applicability

This specification applies to the coolant in the reactor coolant system and the allowable leak rate and monitoring systems.

Objective

The objective is to maintain coolant in the reactor coolant system and detect all leaks to limit the loss of coolant in the least amount of time.

Specifications

Specifications for leak detection will be addressed in the FSAR.

Basis

PSAR Chapter 5.2.5

3.3.5 Fission Product Activity Detection

Applicability

This specification applies to the detection of fission products in the coolant and reactor room atmosphere during forced convection or natural convection flow operations.

Objective

The objective is to promptly detect and identify fission products escaping from the fuel barrier.

Specifications

Fission products escaping the fuel barrier will be promptly detected by a continuous air monitor (CAM) located in the reactor room which can initiate a reactor scram, isolate the reactor room, or alarm, as appropriate.

Fission products will be distinguished from other airborne radioactivity by identification of fission product radionuclides through radiation spectroscopy.

Basis

NUREG-1537, Part 1, Appendix 14.1 Section 3.3.5

3.3.6 Hydrogen Concentration Limits

Not applicable to the operation of the VIPR; no significant risk from any isotope of hydrogen to personnel or the facility has been identified.

3.3.7 Emergency Core Cooling Systems

The VIPR core and pool is designed to prevent a total loss of coolant. There is no emergency core cooling system.

3.3.8 Primary and Secondary Coolant Activity Limits

Applicability

This specification applies to the activity allowed in the primary and secondary coolant.

Objective

The objective is to ensure that primary coolant quality be maintained to acceptable values to limit damage to the coolant system, corrosion, and exposure from radioactivity.

Specifications

The reactor shall not be operated unless the primary and secondary coolant meet limits which will be addressed in the FSAR.

Basis

PSAR Chapter 5.2.6

3.3.9 Primary Coolant Water Chemistry Limits

Applicability

This specification applies to the water quality of the primary coolant.

Objective

The objective is to ensure that primary coolant quality be maintained to acceptable values to reduce the potential for corrosion and limit the buildup of activated contaminants in the primary piping and pool.

Specifications

The reactor shall not be operated unless the pool water meets the following limits:

Table 3-4: Primary coolant water chemistry limits

Parameter	Value	Unit
Electric Conductivity (Maximum)	5	µS/cm
Potential Hydrogen (pH) (Maximum)	7.5	
Potential Hydrogen (pH) (Minimum)	5.5	

Basis

PSAR Chapter 5.4

The limits on resistivity are based on reducing the potential for corrosion in the primary piping or pool liner and to reduce the potential for activated contaminants in the system.

3.4 CONFINEMENT

3.4.1 Operations that Require Confinement

Applicability

This specification applies to the reactor confinement during forced convection or natural convection flow operations and in accident conditions.

Objective

The objective is to mitigate the release of radioactive particulates and gases produced during operation of the VIPR and in accident conditions.

Specifications

The VIPR will be housed in a confinement which will be operable before and during operation and after shutdown.

Confinement will be required during the following operations:

- Reactor operation
- Movement of irradiated fuel or fueled experiments outside of containers, systems, or storage areas
- Core or control rod work that could cause a change in reactivity of more than 1.00 $.
- Movement of experiments that could cause a change of total worth of more than 1.00 $.

Basis

NUREG-1537, Part 1, Appendix 14.1 Section 3.4

ANSI/ANS 15.1 Section 3.4.1

3.4.2 Equipment to Achieve Confinement

Applicability

This specification applies to the equipment required to achieve confinement during forced convection or natural convection flow operations and in accident conditions.

Objective

The objective is to mitigate the release of radioactive particulates, gases, and other effluents produced during operation of the VIPR and in accident conditions.

Specifications

The reactor confinement consists of the following:

- Reactor room structure, including walls and doors
- Ventilation systems, including fans, filters, isolation valves, and dampers
- Facility exhaust stack.

Exhaust rates from the reactor room for operating and accident conditions will be addressed in the FSAR.

To maintain a lower air pressure in the reactor room, the building leak rate under all conditions will be less than or equal to a limit which will be addressed in the FSAR.

Basis

NUREG-1537, Part 1, Appendix 14.1 Section 3.4

ANSI/ANS 15.1 Section 3.4.2

3.5 VENTILATION SYSTEMS

3.5.1 Normal Operation

Applicability

This specification applies to the equipment required to achieve confinement during forced convection or natural convection flow operations.

Objective

The objective is to mitigate the release of radioactive particulates, gases, and other effluents produced during operation of the VIPR.

Specifications

To maintain a lower air pressure in the reactor room than adjacent spaces, ventilation, and exhaust flow rates from the reactor room during operating conditions will be maintained greater than a limit which will be addressed in the FSAR. Air in the reactor room will not be distributed to other occupied spaces within the facility.

The facility exhaust stack location and release point elevation will be addressed in the FSAR.

Ventilation system vents and dampers will automatically failsafe closed.

The minimum number of fans, filters, and isolation valves required to be operating during operating conditions will be addressed in the FSAR.

Basis

NUREG-1537, Part 1, Appendix 14.1 Section 3.5

ANSI/ANS 15.1 Section 3.5

3.5.2 Emergency Operation

Applicability

This specification applies to the equipment required to achieve confinement in accident conditions.

Objective

The objective is to mitigate the release of radioactive particulates, gases, and other effluents produced in accident conditions.

Specifications

To maintain a lower air pressure in the reactor room than adjacent spaces, ventilation, and exhaust flow rates from the reactor room during operating conditions will be no less than a value specified in the FSAR. Air in the reactor room will not be distributed to other occupied spaces within the facility.

The facility exhaust stack will have a location and release point elevation specified in the FSAR.

Ventilation system vents and dampers will automatically failsafe closed.

The minimum number of fans, filters, and isolation valves required to be operating during accident conditions will be addressed in the FSAR.

Basis

NUREG-1537, Part 1, Appendix 14.1 Section 3.5

ANSI/ANS 15.1 Section 3.5

3.6 EMERGENCY POWER

3.6.1 Diesel Emergency Power

Applicability

This specification applies to the diesel emergency electrical power system.

Objective

The objective of this specification is to assure adequate emergency electrical power in the event of normal electrical power failure.

Specifications

The following design features apply to the facility emergency electrical power system:

The AAI facility shall have an emergency power generator capable of providing emergency electrical power to the facility ventilation exhaust system, reactor instrumentation, select radiation monitors, physical security control, and communication systems.

Basis

The emergency electrical power system is described in Section 8.3 of the SAR. Specification 3.6 assures that a system exists to provide the necessary electrical power to monitor the reactor systems and assure personnel safety in the event of a normal power failure to the reactor facility.

3.6.2 Battery Emergency Power

Applicability

This specification applies to the uninterruptible power supply for the emergency electrical power system.

Objective

The objective of this specification is to assure adequate emergency electrical power in the event of normal electrical power failure.

Specifications

The following design features apply to the facility emergency electrical power system:

The AAI facility shall have an uninterruptible power supply as part of the emergency power system capable of providing emergency electrical power to select facility systems and components.

Basis

Chapter 8, Section 8.3.

3.7 RADIATION MONITORING SYSTEMS AND EFFLUENTS

3.7.1 Monitoring Systems

Applicability

This specification applies to radiation monitoring information which must be available during reactor operation and the release of gaseous and particulate activity from the facility ventilation exhaust stack.

Objective

The objective is to ensure that sufficient radiation monitoring information is available during reactor operations and exposure to the public resulting from the radioactivity released from the reactor facility to the unrestricted environment will not exceed the limits of 10 CFR 20.

Specifications

The location, number, function, and setpoint of the required radiation monitors, and the type(s) of radiation detected, are described as follows:

Table 3-5: Monitoring systems specifications

Channel	Minimum Required	Radiation Detected	Function	Setpoint
Area Radiation Monitor	4	Alpha Beta Gamma	Alarm Door Interlock	Specification to be addressed in the FSAR
Reactor Bridge	4	Alpha Beta Gamma	Alarm Door Interlock Reactor Scram	Specification to be addressed in the FSAR
Stack Monitor	1	Alpha Beta Gamma	Alarm	Specification to be addressed in the FSAR
Environmental Monitor	1	Alpha Beta Gamma	Alarm	Specification to be addressed in the FSAR

Monitors that become inoperable will be replaced by substitute monitors that perform the same function to allow continued reactor operations. If the inoperable monitor is displayed in the control room, the operator on duty will also be able to observe the temporary monitor.

All radioactive gas and particulate air monitors will be operable and calibrated, unless replaced by a substitute monitor, during reactor operations. Air monitors will record outputs for long-term records to document the concentration and total quantity of radioactive effluents.

An environmental monitor located at the site boundary will verify that the potential maximum dose in the unrestricted environment is below analyzed values in potential accident scenarios and during normal operations.

Basis

NUREG-1537, Part 1, Appendix 14.1 Section 3.7.1.

PSAR Chapters 7 and 11.

3.7.2 Effluents

Applicability

This specification applies to the release of gaseous and particulate activity from the facility ventilation exhaust stack.

Objective

The objective is to ensure that exposure to the public resulting from the radioactivity released from the reactor facility to the unrestricted environment will not exceed the limits of 10 CFR 20.

Specifications

The maximum discharge rate through the facility exhaust stack will not exceed the following:

Table 3-6: Maximum discharge rates

Radionuclide	Maximum Annual Average Concentration	Maximum Instantaneous Release Concentration
Particulates and Halogens with Half-Lives Greater Than 8 Days	AEC	AEC
All Other Radionuclides	Specification will be addressed in the FSAR	Specification will be addressed in the FSAR

Air Effluent Concentration (AEC) values are taken from 10 CFR 20, Appendix B, Table 2, Column 1.

Basis

NUREG-1537, Part 1, Appendix 14.1 Section 3.7.1

10 CFR 20, Appendix B

3.8 EXPERIMENTS

3.8.1 Reactivity Limits

Applicability

This specification applies to all movable, unsecured, and secured experiments located in the core during forced convection or natural convection flow operations.

Objective

The objective is the avoidance of inadvertent prompt criticality if an experiment should fail, and to limit the excess reactivity that may be inserted into the core.

Specifications

Reactivity limits for movable, unsecured, and secured experiments are:

Table 3-7: Reactivity limits

Experiment Type	Value	Unit
Movable/Unsecured	Specification will be addressed in the FSAR	$
Secured	Specification will be addressed in the FSAR	$
Sum of All Absolute Worths	Specification will be addressed in the FSAR	$

The VIPR must be shut down during the changing or moving of any secured experiment.

Basis

NUREG-1537, Part 1, Appendix 14.1 Section 3.8.1

3.8.2 Materials

Applicability

This specification applies to all movable, unsecured, and secured experiments located in the core during forced convection or natural convection flow operations.

Objective

The objective is to limit the quantities of radioactive material that could be released if an experiment should fail, and to reduce the likelihood of an experiment failing.

Specifications

The maximum thermal power allowed will be determined for each experiment in each planned position to ensure adequate cooling to prevent failure.

Experiment materials will be analyzed and limited according to the following:

- The radioactive material content, including fission products, of any experiment will be limited so that the complete release of all gaseous, particulate, or volatile components will not result in doses to persons in excess of 10% of the equivalent annual doses stated in 10 CFR 20 in the length of time required to evacuate the restricted area.
- Trace elements or impurities whose activation may represent the dominant radiological hazard will be identified.
- Nuclides possessing high thermal neutron absorption cross sections will be identified and limited to control reactivity and thermal effects within the specified limitations.

- Explosive materials will be limited in experiments to amounts less than or equal to 25 milligrams of TNT equivalent. Prior analyses of encapsulations will ensure no reactor damage in the event of detonation.
- Materials which are chemically incompatible with the reactor system from the viewpoint of corrosion will be subject to special scrutiny and control.
- Radiation effects on experiment materials, including alteration or degradation of mechanical properties or radiolytic generation of excessive gas pressure or explosive gas mixtures, will be evaluated.
- Quantities of highly flammable or toxic materials will be limited.
- Cryogenic liquids will not be included in any experiment unless such usage is reviewed and approved by the NRC.
- No experiments will contain unknown material content, excepting trace elements and impurities.

Double encapsulation of materials will be required if:

- An experiment contains corrosive materials.
- The failure of an experiment would result in doses to persons in excess of 10% of the equivalent annual doses stated in 10 CFR 20 in the length of time required to evacuate the restricted area.
- The failure of an experiment would result in an industrial hazard that could affect safe reactor operation.

Basis

NUREG-1537, Part 1, Appendix 14.1 Section 3.8.2

ANSI/ANS 15.1 Section 3.8

RG 2.2

PSAR Chapter 13

3.8.3 Failure and Malfunctions

Applicability

This specification applies to all movable, unsecured, and secured experiments located in the core during forced convection or natural convection flow operations.

Objective

The objective is to limit the quantities of radioactive material that could be released if an experiment should fail.

Specifications

The failure and malfunction of an experiment will be considered in the experiment safety review on a case-by-case basis.

Basis

NUREG-1537, Part 1, Appendix 14.1 Section 3.8.3

PSAR Chapter 13

3.8.4 Irradiation Targets Containing Uranium

Applicability

This specification applies to all irradiation targets containing uranium that are inserted into the reactor core or irradiation facilities.

Objective

The objective is to limit the amount of fissile material in individual targets to ensure that reactivity effects remain negligible, postulated experiment failures are bounded by the accident analyses in Chapter 13, and radiological doses remain within the limits of 10 CFR Part 20.

Specification

- Targets containing uranium shall be fabricated with enrichment less than 20 percent U-235.
- The total quantity of U-235 in any single target capsule shall not exceed 100 milligrams.
- All targets shall be doubly encapsulated or otherwise designed to prevent release of material under normal handling and irradiation conditions.
- If an irradiation target is discovered or suspected to exceed these limits, reactor operation shall not be initiated (or shall be suspended if underway) until the target is removed or brought into compliance.

Basis

Control of experiment materials is required under 10 CFR 50.36 to be reflected in facility Technical Specifications. Consistent with ANSI/ANS-15.1 Section 3.8, limitations on uranium-bearing targets ensure that experiments do not challenge the reactor safety basis. Limiting the enrichment to less than 20 percent U-235 meets the requirements of 10 CFR 50.64, “Limitations on the use of highly enriched uranium (HEU) in domestic non-power reactors” regarding the use of highly enriched uranium in research reactors. The 100-mg limit ensures that the reactivity and source term associated with any single target remain negligible relative to core reactivity and accident source terms. The maximum credible accident analysis described in Chapter 13 demonstrates that failure of such a target does not result in offsite or worker doses in excess of the limits of 10 CFR 20.1201 and 20.1301.

3.9 FACILITY-SPECIFIC LCOS

Facility-specific LCOS may be identified and defined in the FSAR as appropriate.

4 SURVEILLANCE REQUIREMENTS

Surveillance requirements will be provided in the technical specifications and follow the formatting of ANSI/ANS-15.1-2007. The following topics, per the guidance, are likely to have surveillance requirements:

- Reactor Core Parameters
- Reactor Control and Safety Systems
- Coolant Systems
- Confinement
- Ventilation Systems
- Emergency Electrical Power Systems
    - Diesels and Other Devices
    - Emergency Batteries
- Radiation Monitoring Systems and Effluents
    - Monitoring Systems
    - Effluents
- Experiments
- Facility-Specific Surveillance

5 DESIGN FEATURES

5.1 SITE AND FACILITY DESCRIPTION

Applicability

This specification applies to the site of the AAI‘s facility.

Objective

The objective of this specification is to identify the location and specify the bounds of the AAI facility.

Specifications

Chapter 2 provides details of a proposed site. The final specifications of the chosen location of the facility and site boundaries will be detailed in the FSAR.

Basis

PSAR Chapter 2.1.1

5.2 REACTOR COOLANT SYSTEM

Applicability

This specification applies to the reactor coolant systems.

Objective

The objective of this specification is to assure proper cooling for safe operation.

Specifications

Full specifications of the reactor pool and primary and secondary cooling loops will be detailed in the FSAR.

Basis

PSAR Chapter 5.2.3, PSAR Chapter 5.3.1.

5.3 REACTOR CORE AND FUEL

Applicability

This specification applies to the reactor core and fuel assemblies.

Objective

The objective is to specify design features of the reactor core and fuel and allowable fuel configurations.

Specifications

Full specifications of allowable core and fuel configurations will be detailed in the FSAR.

Basis

PSAR Chapter 4.2, PSAR Chapter 4.5, PSAR Chapter 4.6

5.4 FISSIONABLE MATERIAL STORAGE

Applicability

This specification applies to the storage of reactor fuel at time when it is not in the reactor core.

Objective

The objective of this specification is to assure that fuel which is stored shall not become critical and will not reach an unsafe temperature.

Specifications

The following design features apply to fuel storage:

a) All fuel assemblies, fueled devices, or SNM outside the reactor core shall be stored in a geometrical array where the value of k_{eff} is less than 0.9 under all conditions of moderation and reflection.

b) Irradiated fuel assemblies or fueled devices shall be stored in an array which will permit sufficient natural convection cooling such that the temperature of the fuel assembly or fueled device will not exceed its design values.

Basis

ANSI/ANS-15.1-2007. The limits imposed by Specifications 5.4a and 5.4b are conservative and assure safe fuel and SNM storage.

6 ADMINISTRATIVE CONTROLS

Administrative controls will be provided in the technical specifications.

Examples of the proposed subjects of administrative controls are provided below:

Procedures

Written procedures shall be established, implemented, and maintained covering activities described in the following Programs.

Programs

- Quality Assurance Programs:
    - Training and Qualification
    - Engineering (Design Control)
    - Procurement
    - Documents Management
    - Item Control and Material Accountability
    - Control of Special Processes
    - Inspection
    - Test Control
    - Control of Measuring and Test Equipment
    - Handling, Storage, and Shipping
    - Inspection, Test, and Operating Status
    - Commitments, Issues, and Performance Management and Reporting
    - Records Management
    - Audits and Assessments
    - Experiments
    - Conduct of Operations
- Safety Authorization Bases Review (10 CFR 50.59 Review)
- Criticality Safety
- Fire Protection
- Radiation Protection
    - ALARA
    - Environmental Monitoring
    - Respiratory Protection
    - Radioactive Waste Management
- Chemical Control
- Security
- Emergency
- Maintenance

7 REFERENCES

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

American Nuclear Society. 2018. ANSI/ANS-15.1-2007 (R2018), "The Development of Technical Specifications for Research Reactors."

International Atomic Energy Agency (IAEA). 1999-2005. Final Report of a Coordinated Research Project, "Thermophysical properties database of materials for light water reactors and heavy water reactors." IAEA-TECDOC-1496. https://www-pub.iaea.org/MTCD/Publications/PDF/te_1496_web.pdf.