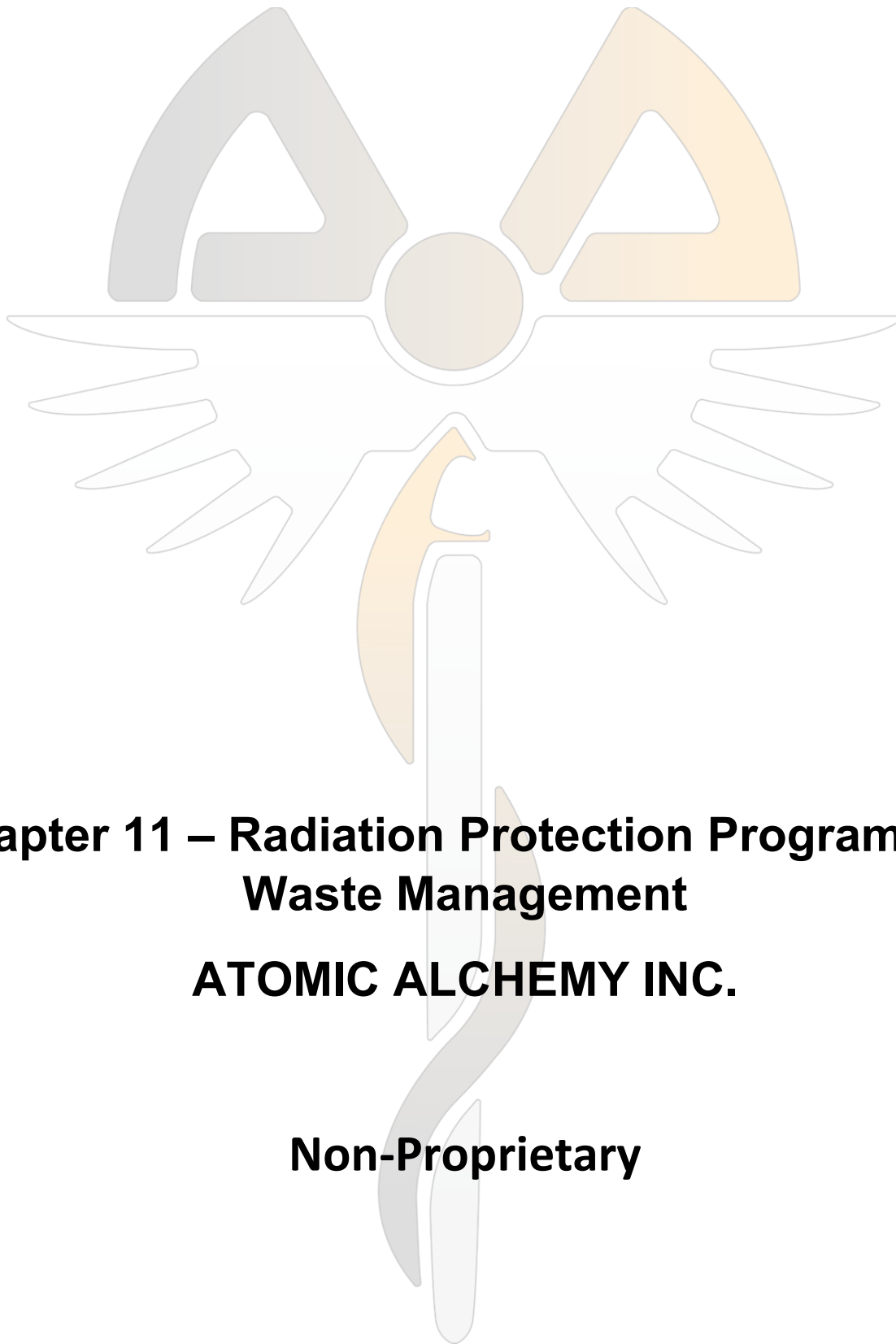




Chapter 11 – Radiation Protection Program and Waste Management

ATOMIC ALCHEMY INC.

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CHAPTER 11

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TERMS

ABBREVIATIONS AND ACRONYMS

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.
ALI	annual limit on intake
CAM	continuous air monitor
CAS	criticality alarm system
CFR	<i>Code of Federal Regulations</i>
DAC	derived air concentration
DQO	data quality objective
IRC	Independent Review Committee
LLW	low-level radioactive waste
MURR	Missouri University Research Reactor
NPUF	Non-power Production and Utilization Facility
NSS	N-16 Suppression System
PCS	primary coolant system
PPE	personal protective equipment
RAM	radiation area monitor
REMP	Radiological Environmental Monitoring Program
RSO	Radiation Safety Officer
RPP	Radiation Protection Program
RWMP	Radioactive Waste Management Program
RWP	radiation work permit
SMS	stack monitoring system
TEDE	total effective dose equivalent(s)
TLD	thermo-luminescent dosimeters
VIPR	Versatile Isotope Production Reactor
WAC	waste acceptance criteria



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11 RADIATION PROTECTION PROGRAM AND WASTE MANAGEMENT

11.0 INTRODUCTION

This chapter describes the Atomic Alchemy Inc. (AAI) programs for Radiation Protection and Waste Management, which contain provisions for protecting the safety and health of workers, the public, and the environment. These programs will be developed in accordance with applicable Nuclear Regulatory Commission regulations and guidance, commensurate with the scope and extent of the activities to be conducted at the Mietner-1 facility. AAI utilizes a graded approach to implement requirements and guidance, as appropriate.

This chapter was developed utilizing NRC regulations and guidance, and NRC-approved Safety Analysis Reports (SARs) from other Non-power Production and Utilization Facilities (NPUFs) or radioisotope manufacturing facilities, e.g., SHINE Medical Technologies, the NCSU PULSTAR, Missouri University Research Reactor (MURR).

11.1 RADIATION PROTECTION

This section describes AAI's Radiation Protection Program (RPP) and how it ensures compliance with the regulatory requirements of Title 10 of the *Code of Federal Regulation* (CFR) Part 20, "Standards for Protections Against Radiation" and the confinement principal design criteria identified in Chapter 3. The RPP applies to

- design of the AAI's facility,
- operations involving radiation,
- planning and procedures, and
- instrumentation, techniques, and practices employed to verify compliance with the radiation dose limits and other applicable requirements specified in the regulations.

The RPP incorporates the occupational and public dose limits of 10 CFR Part 20, Subpart C, and ensures that exposures are maintained as low as reasonably achievable (ALARA) as required by 10 CFR Part 20, Section 1101, "Radiation protection programs." Facility design features supporting these objectives include confinement, shielding, ventilation and effluent monitoring, access controls, and radiation monitoring instrumentation. Plans and the bases used to develop AAI procedures for assessing and controlling radioactive and other hazardous wastes and the ALARA Program are included.

Responsibilities of the AAI health physics organization at the facility are described. All radiation sources and radioactive materials produced in the reactor and possessed or used within the reactor facility under the authorization of the facility license are described in this SAR. Program details are described in the sections that follow.



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11.1.1 Radiation Sources

This section describes radiation sources that are monitored and controlled by the AAI RPP and Radioactive Waste Management Program (RWMP). These are categorized as airborne (i.e., gas), liquid, or solid as discussed in the sections that follow and summarized in **Table 11-1**.

Reasonably conservative estimates are made of the quantity and types of radioactive and other hazardous wastes expected to result from the AAI facility's operations and use, based on previous or other similar NPUF experience. To the extent currently known, sources and waste information presented herein include physical and chemical form, amounts, use, storage conditions, and locations for sources and wastes. In occupied or accessible areas, conservative estimates of external radiation fields are provided. An estimate of the maximum annual dose and collective doses to workers and the public are also provided for major and repetitive activities involving radiation. Requirements of Subpart C of 10 CFR Part 20 (20.1201-20.1208), which contain regulations for occupational dose limits, and Subpart D of 10 CFR Part 20 (20.1301-20.1302), which contain regulations for radiation dose limits for individual members of the public, will be met for applicable AAI facilities and operations, as demonstrated herein. AAI will utilize ALARA principles in its facility design and operations.

License conditions and technical specifications concerning material possession limits, enrichment, material forms, and source strengths, will be further developed and analyzed in this chapter and others as indicated.

Information not currently known, as specifically indicated in the subsections that follow, will be provided in the FSAR.

11.1.1.1 Airborne Radiation Sources

This subsection describes airborne radiation sources for the AAI Versatile Isotope Production Reactor (VIPR), estimated releases, dose rates, and resulting doses (i.e., exposures) from normal operating conditions for airborne radioactive sources. Also discussed are the models and key assumptions used by AAI for calculating dose rates and doses.

The primary coolant system (PCS) is the most significant source of airborne radioactivity in the AAI facility, due to the activation of particulates and gases entrained in the reactor coolant, and the coolant itself, as it passes through the VIPR. The principal airborne radionuclides expected during normal operation of the VIPR are N-16, Ar-41, and H-3. Additional radionuclides may be produced; however, their concentrations are expected to be negligible relative to these primary contributors and will remain well below the effluent concentration limits of 10 CFR Part 20, Appendix B.

11.1.1.1.1 Nitrogen-16

N-16 is produced from the irradiation of O-16, which is present in the water of the PCS, by high energy neutrons. N-16 is only produced within close proximity to the VIPR core, where neutron energies are high enough to facilitate the (n,p) nuclear reaction.



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During normal operation of the VIPR, N-16 is produced in gaseous form and conveyed towards the reactor pool surface by the forced upward flow of the coolant. The concentration of N-16 activity in the air of the reactor area is calculated according to the following sets of coupled rate equations and data. **Table 11-5** in Appendix A provides specific input values, calculations and results.

Microscopic cross sections for the (n,p) reaction in O-16 were obtained from the ENDF/B-VIII.0 nuclear reaction data library for energies above 10 MeV. The average neutron fluxes in the core water volume and within energy bins corresponding to the obtained cross section data were determined through stochastic simulations in the Serpent 2 VIPR model, which is discussed in Chapter 4. The coolant inlet flow velocity to the core, used to determine the residence time in the core and rise time to the pool surface, was determined through simulations in the RELAP5 VIPR model.

The estimated N-16 activity concentration in the air of the reactor region of the AAI facility is []^{PROP} which is greater than the maximum allowed value, $1.70 \times 10^{-7} \mu\text{Ci}/\text{cm}^3$, for the derived air concentration (DAC) of unlisted radionuclides given in 10 CFR Part 20, Appendix B, Table 1. The calculated concentration is conservative in its assumptions of the pool depth at its limiting safety system setting; the coolant flow rate at its maximum value; and no friction, expansion, or turbulence effects delaying the arrival of N-16 at the pool surface.

The coolant rise time to the pool surface resulting in an activity concentration equal to the DAC is 124.45 s. For times equal to or greater than this, sufficient radioactive decay of the produced N-16 will occur to reduce its concentration to acceptable levels. The N-16 suppression system (NSS) will be designed to introduce, at minimum, this delay in the arrival of irradiated coolant at the reactor pool surface.

Although a lower coolant flow rate and corresponding coolant velocity results in a longer residence time and increased N-16 activity concentration in the core, the determining factor in the air concentration of N-16 activity is the rise time to the pool surface. A lower coolant velocity increases the rise time, allowing for more N-16 decay before its release to the air of the reactor area. This decay in turn results in concentrations below the DAC limit.

11.1.1.1.2 Argon-41

Ar-41 is produced by neutron activation of stable Ar-40, which is the principal isotopic component of argon and is present in air entrained in the water of the PCS.

Ar-41 is produced from the activation of stable argon isotopes contained in air entrained in the coolant; because the quantity of entrained air cannot be predicted, Ar-41 concentrations are scaled from those measured in comparable nuclear reactors. The Ar-41 concentration in the air of the reactor region of the AAI facility is estimated from values presented in the MURR SAR. The sampled average air concentration of Ar-41 in the reactor containment building was $2.8 \times 10^{-8} \mu\text{Ci}/\text{cm}^3$; this value was scaled by a factor of 6.4 to reflect the simultaneous operation of the maximum number of VIPR units, each at a greater power than the MURR, and a factor of 0.6 to account for differences in air volumes available for dilution. The resulting estimated average air concentration of Ar-41 in the AAI facility is []^{PROP}. This value is less than the maximum allowed value of $3 \times 10^{-6} \mu\text{Ci}/\text{cm}^3$ for the DAC given in Table 1 of Appendix B to 10 CFR Part 20, but greater than the



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unrestricted area concentration limit of $1 \times 10^{-8} \mu\text{Ci}/\text{cm}^3$ given in Table 2 of Appendix B to 10 CFR Part 20.

Using the same method by which the MURR SAR takes credit, any release of Ar-41 to the public would be brought below the unrestricted area concentration limit using filtering, stack dispersion, and other appropriate controls further discussed in the FSAR. As the MURR SAR states:

Utilization of this dilution credit is allowed by the NRC...It is important to note that only a small amount of dilution is required to reduce the Ar-41 concentration to a level that is well below the 10 CFR Part 20 limit of $1 \times 10^{-8} \mu\text{Ci}/\text{ml}$ for unrestricted areas. This is due in part to the fact that the Ar-41 concentration leaving the ventilation exhaust stack while the reactor is operating is approximately $2.42 \times 10^{-6} \mu\text{Ci}/\text{ml}$ at a flow rate of about 30,500 ft^3/min (864 m^3/min).

The MURR flow rates are on the order of the VIPR facility stack flow rates. Additionally, the predicted air concentration likely overestimates the actual value, as approximately 98% of the Ar-41 contributing to the sampled air concentration at the MURR is produced in systems which are not present in the VIPR (i.e., the pneumatic tube system, thermal column).

11.1.1.1.3 Hydrogen-3

H-3, or tritium, is produced from the irradiation of H-2, which is present in small quantities in the water of the PCS as an isotopic component of hydrogen. H-3 will be produced during all VIPR operations and, due to its long half-life, is expected to reach an equilibrium concentration throughout the water of the PCS. H-3 will be released to the air of the reactor area in liquid form as a component of water evaporated from the reactor pool surface. The concentration of H-3 activity in the air of the reactor area is calculated according to the sets of coupled rate equations and data presented in Appendix A, **Table 11-6**.

Microscopic cross sections for the (n,γ) reaction in H-2 were obtained from the ENDF/B-VIII.0 nuclear reaction data library for energies above 1×10^{-5} eV. The average neutron fluxes in the core water volume and within energy bins corresponding to the obtained cross section data were determined through stochastic simulations in the Serpent 2 VIPR model.

The estimated H-3 activity concentration in the air of the reactor region of the AAI facility is []^{PROP}. This value is less than the maximum allowed value of $2 \times 10^{-5} \mu\text{Ci}/\text{cm}^3$ for the DAC given in Table 1 of Appendix B to 10 CFR 20 as well as the unrestricted area concentration limit of $1 \times 10^{-7} \mu\text{Ci}/\text{cm}^3$ given in Table 2 of Appendix B to 10 CFR 20.

11.1.1.1.4 Dose Rate and Exposure

Dose rates were determined for individuals at the AAI facility boundary and at the location of the maximally exposed individual. Annual average χ/Q values at each location were used to account for plume dispersion and estimate the air concentrations of the considered radionuclides. The data used for the meteorological conditions assumed can be found in Chapter 2, Section 2.3.2.

χ/Q values were calculated by following the methodologies provided in Regulatory Guide (RG) 1.145, "Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants," Rev. 2, 2001 and, by reference, RG 1.111, "Methods for Estimating



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Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors," Rev. 1, 1977 and NOAA Tech Memo ERL-ARL-42.

Dose consequences were calculated according to:

$$D_{n,o} = A_n \times \frac{\chi}{Q}(x) \times (DDE_{n,o} + CEDE_{n,o} \times BR)$$

Equation 11-1. Combined dose consequences to a particular organ from internal and external exposure to a particular radionuclide

where $D_{n,o}$ is the dose to organ o from radionuclide n , A_n is the activity of radionuclide n released, χ/Q is the atmospheric dispersion value at the given receptor distance, $DDE_{n,o}$ is the deep dose equivalent for organ o from radionuclide n (or effective dose equivalent, EDE_n , from radionuclide n), $CEDE_{n,o}$ is the committed effective dose equivalent for organ o from radionuclide n , and BR is the breathing rate of the exposed individual. The total dose committed to each organ, and the total effective dose, was calculated by summing the individual contributions of all radionuclides.

Parameters used in the calculation of annual average χ/Q values are given in Appendix A, **Table 11-7**. Results of the χ/Q calculation and the resultant dose consequences from the considered radionuclides are given in Appendix A, **Table 11-8**. The total airborne dose at the site boundary and to the maximally exposed individual were estimated to be 2.59×10^{-1} mrem/y which is well below the annual limit of 10 mrem in 10 CFR 20.1101(d).

11.1.1.2 Liquid Radioactive Sources

The following paragraphs discuss the major contributors to AAI's liquid radioactive sources and estimated releases of liquid effluents.

The PCS is the primary source of liquid radioactivity in the AAI facility, due to the activation of particulates and gases entrained in the reactor coolant as it passes through the VIPR. Neutron activation of isotopes from structures and components in contact with the reactor coolant also produces liquid radioactive sources in the PCS. Coolant in the PCS is contained within the system to the maximum extent possible, with no anticipated liquid releases.

All potentially radioactive liquid waste will be sampled and managed in accordance with AAI's RWMP. Liquid wastes will be treated (e.g., sorption, solidification, etc.) to meet applicable disposal facility waste acceptance criteria (WAC) for solid waste. There are no direct release pathways to the environment from liquid waste.

H-3 is the most significant radioisotope expected to be present in the liquid of the PCS, produced through the mechanism discussed in Section 11.1.1.1.3. The calculated equilibrium concentration in the reactor pool is []^{PROP}, corresponding to an activity concentration of []^{PROP}.

Other radionuclides present in the liquid of the PCS are expected to be produced by neutron activation of trace impurities from corrosion of structures and components in contact with the reactor coolant. In particular:



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- Sodium-24 and aluminum-28 are produced by neutron activation of 304L stainless steel, which is the principal constituent of the reactor pool liner and other components.
- Silver-110m is produced by neutron activation in the VIPR control rods.
- Cobalt-60 is produced by multiple neutron activations in the stainless steel comprising several VIPR structures and components. Other activation products may include manganese-54, manganese-55, zinc-65, and iron-59.

Radionuclides in the PCS will be continuously filtered and removed from the system by the cleanup system to maintain activity concentrations at acceptable levels.

11.1.1.3 Solid Radioactive Sources

Solid radioactive sources include but are not limited to the types described in the following subsections and in **Table 11-1**. Any radioactive waste will be disposed of in compliance with applicable sections of 10 CFR Part 20, Part 61, "Licensing Requirements for Land Disposal of Radioactive Waste," Part 71, "Packaging and Transportation of Radioactive Material," and Department of Transportation regulations (49 CFR) for transporting radioactive material. Radioactive waste is further discussed in section 11.2.

11.1.1.3.1 Fuel (New, In-Core, and Irradiated)

New reactor fuel is stored in a storage rack in the reactor area of the AAI facility, as described in Chapter 9. New reactor fuel is not expected to present a radiation hazard, but the storage area is monitored for radiation as part of criticality control.

Reactor fuel in current use is installed in the VIPR core as described in Chapter 4; radiation shielding from the operating reactor is provided by the biological shielding as described in Chapter 4.

Irradiated reactor fuel (also referred to as "used fuel" or "spent fuel") is either stored temporarily in the reactor pools or in the designated used fuel storage pool. Shielding from decay radiation in each location is bounded by the discussion of the biological shielding for the operating VIPR given in Chapter 4. The maximum hypothetical accident analysis described in Chapter 13 involves irradiated fuel and provides anticipated source terms and radiation exposure resulting from damage to the fuel cladding.

11.1.1.3.2 Radioactive Material to be Used as Irradiation Targets for Manufacturing of Isotopes

Most irradiation targets used for isotope manufacturing will contain stable, nonradioactive materials. However, the manufacturing of certain isotopes requires the use of radioactive isotopes, such as []^{PROP} or []^{PROP}. All irradiation targets will be sealed. The materials containing these isotopes are stored in approved locations, which are shielded and monitored for radiation, until they are used or disposed, as applicable.

In accordance with 10 CFR 50.36, limits on the quantity and form of radioactive materials authorized for use as experiments are established in the facility Technical Specifications. Uranium-bearing targets will be restricted to low-enriched uranium with enrichment less than 20 percent U-235, and the quantity of U-235 per target capsule will not exceed 100 milligrams. All



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proposed irradiation targets will be evaluated under 10 CFR 50.59, “Changes, tests and experiments” to confirm that their use is bounded by the analyses in the SAR, including the maximum credible accident described in Chapter 13. The bounding accident involves catastrophic failure of a []^{PROP} target capsule. The resulting source terms and doses to workers and the site boundary are demonstrated to remain within the limits of 10 CFR 20.1201, “Occupational dose limits for adults” and 10 CFR 20.1301, “Dose limits for individual members of the public.” Use of highly enriched uranium is further constrained by the requirements of 10 CFR 50.64.

11.1.1.3.3 Calibration and Test Sources

A calibration neutron source is provided for startup of the VIPR, which is used to test reactor power monitors. This source is stored in the reactor pool and only removed for maintenance or other approved testing.

Test radioactive sources are provided for the testing and calibration of radiation detectors and monitors. These sources are low activity but are stored in an approved location, which is shielded and monitored for radiation.

11.1.1.3.4 Facility Components That Contain Activation Products

Components and equipment in proximity to the VIPR or other neutron sources in the AAI facility, such as tools, containers, and support structures, are irradiated and become activated. These materials are held for decay in the reactor pool, canal, or cask loading area prior to handling or disposal at a commercial waste disposal facility, as needed.

Table 11-1: Sources of radiation

Symbol	Parameter	Value	Unit
Airborne Radiation Sources			
$N_{N16,air}$	N-16 concentration in air above reactor pool	[] ^{PROP}	cm ⁻³
$A_{N16,air}$	N-16 activity concentration in air above reactor pool	[] ^{PROP}	μCi/cm ³
$A_{N16,NSS,air}$	N-16 activity max concentration in air above reactor pool with NSS	[] ^{PROP}	μCi/cm ³
$A_{Ar41,air}$	Ar-41 activity concentration in air above reactor pool (estimated from MURR levels)	[] ^{PROP}	μCi/cm ³
$N_{H3,air}$	H-3 concentration in air above reactor pool	[] ^{PROP}	cm ⁻³



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Symbol	Parameter	Value	Unit
$A_{H3,air}$	H-3 activity concentration in air above reactor pool	[] ^{PROP}	μCi/cm ³
Liquid Radiation Sources			
$N_{N16,core}$	N-16 concentration exiting VIPR core	[] ^{PROP}	cm ⁻³
$N_{N16,surface}$	N-16 concentration at reactor pool surface	[] ^{PROP}	cm ⁻³
$N_{H3,pool}$	H-3 concentration in reactor pool	[] ^{PROP}	cm ⁻³
$A_{H3,pool}$	H-3 concentration activity concentration in reactor pool	[] ^{PROP}	μCi/cm ³
Solid Radiation Sources			
UO ₂ LEU Fuel	New reactor fuel	As needed; external dose is negligible.	Assemblies
	Fuel in the core	[] ^{PROP,ECI}	Assemblies
	Used fuel storage pool maximum capacity	[] ^{PROP,ECI}	Assemblies
---	Radioactive material used as irradiation targets for isotope manufacturing (sealed)	See footnote ¹	Ci
---	Calibration, Test, and Startup Sources (sealed)	See descriptions in sections 11.1.1.3.3 and 11.1.1.3.4.	Ci
---	Facility Components That Contain Activation Products		Ci

11.1.2 Radiation Protection Program

This section describes AAI's RPP, which will be established, maintained, and implemented in accordance with 10 CFR Part 19, "Notices, Instructions and Reports to Workers: Inspection and Investigations" and Part 20, "Standards for Protection Against Radiation." The following subsections

¹ Because of the varied nature of experimental programs, the source strengths of irradiated experimental materials are not tabulated herein. AAI's experiment protocols require that detailed source data and various other physical parameters for each experiment are reviewed per 10 CFR 50.59, "Changes, Tests, and Experiments," prior to implementation. More details about AAI's experiment review processes are described in Chapters 10 and 12 of this PSAR. Additional details about irradiation target materials will be included in the FSAR or 10 CFR Parts 30 and 70 license.



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describe key elements, and as applicable, reference other chapters such as Chapter 12, Conduct of Operations, where the topic is further developed:

- Objectives of the RPP
- Organizational structure and responsibilities
- Procedures and document management (scope and implementation)
- Training
- Reviews
- Audits
- Continuous Improvement Program
- RPP Radiation Work Permits (RWP) and Other Radiation Controls
- Records management
- Technical Specifications

11.1.2.1.1 Objectives of the Radiation Protection Program (RPP)

The objectives of the RPP are to

- prevent acute radiation injuries (deterministic effects),
- limit the probability of stochastic effects by maintaining personnel and public exposures within regulatory limits and consistent with the ALARA principle, and
- minimize and control radioactive effluent releases to the environment.

The RPP incorporates the dose limits of 10 CFR Part 20, Subpart C, for workers, declared pregnant workers, and members of the public. The RPP incorporates the occupational and public dose limits of 10 CFR Part 20, Subpart C, and requires that exposures be maintained ALARA in accordance with 10 CFR 20.1101(b) "Radiation protection programs." The RPP does not establish numerical administrative dose limits below the regulatory requirements; instead, dose management is achieved through programmatic controls, RWPs, and continuous ALARA review. **Table 11-2** provides the applicable regulatory dose limits.

Table 11-2. Regulatory radiation exposure limits

Individual Category	Dose Quantity	Limit	Regulatory Basis
Adult Occupational Worker	Total effective dose equivalent (TEDE) to whole body	5 rem (0.05 Sv) per year	10 CFR 20.1201(a)(1)(i)
	Sum of deep-dose equivalent and committed dose equivalent to any organ or tissue other than eye lens	50 rem (0.5 Sv) per year	10 CFR 20.1201(a)(1)(ii)
	Eye dose equivalent (lens of eye)	15 rem (0.15 Sv) per year	10 CFR 20.1201(a)(2)(i)



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Individual Category	Dose Quantity	Limit	Regulatory Basis
	Shallow-dose equivalent to skin or extremities	50 rem (0.5 Sv) per year	10 CFR 20.1201(a)(2)(ii)
Declared Pregnant Worker	Dose to embryo/fetus (entire gestation period, sum of deep dose equivalent to woman and dose to embryo/fetus)	0.5 rem (5 mSv) per gestation period	10 CFR 20.1208
Member of the Public	TEDE	0.1 rem (1 mSv) per year	10 CFR 20.1301(a)(1)
	Dose in any unrestricted area (in any 1 hour)	0.002 rem (0.02 mSv)	10 CFR 20.1301(a)(2)
Minor (under 18 years of age)	10% of adult occupational dose limits	0.5 rem (5 mSv) TEDE per year	10 CFR 20.1207
Airborne Radioactivity	DAC	As specified in 10 CFR Part 20, Appendix B	10 CFR 20.1201(b), 20.1202

11.1.2.1.2 Organizational Structure and Responsibilities

Overall responsibility for the RPP rests with the AAI CEO who collaborates with the COO for the safe operation of the facility. The CEO delegates direct program implementation to the Radiation Safety Officer (RSO), supported by a radiological engineer and health physics technicians. The RSO and RPP staff have the independent authority to suspend or terminate operations presenting an undue radiological hazard. Radiation protection personnel are organizationally independent of reactor operations to preserve objectivity. The organizational structure is further described in Chapter 12.

11.1.2.1.3 RPP Scope and Implementation

The RPP applies to the

- design and operation of reactor systems and experimental facilities,
- associated laboratory use,
- operational planning and procedures, and
- radiological work activities in controlled areas.

The RPP establishes instrumentation, techniques, and practices necessary to demonstrate compliance with regulatory requirements and license conditions. Radiation sources addressed by the RPP include reactor operations, experimental irradiations, activated materials, and byproduct



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material produced or possessed under the operating license or separate materials licenses. Document control procedures described in the Quality Assurance Program ensure that all radiation protection implementing procedures are current, distributed, and adhered to.

11.1.2.1.4 RPP Training

Radiation protection training is provided through the AAI Training and Qualification Program (see Chapter 12). Training addresses the radiological hazards of the facility, applicable regulations, and protective procedures. Training will meet the requirements of 10 CFR 19.12, "Instructions to workers" and incorporate guidance from NRC RGs in Division 8, ANSI/ANS-15 series standards, and ASTM E1168-95, as appropriate. Training effectiveness is periodically evaluated and reinforced through requalification requirements.

11.1.2.1.5 RPP Audits

The Independent Review Committee (IRC), described in Chapter 12, reviews and audits matters pertinent to the RPP. At least one IRC member will have expertise in radiation protection.

In accordance with 10 CFR 20.1101(c) AAI will conduct an annual review of the RPP. The review will evaluate ALARA performance, operational practices, and compliance with program requirements. Results are documented and used to inform continuous improvement.

11.1.2.1.6 Continuous Improvement Program

The RPP is integrated with AAI's continuous improvement program. Incident evaluations, root cause analyses, and trending of operational experience at AAI and similar facilities are applied to strengthen radiological protection measures. Corrective actions are verified for effectiveness and incorporated into procedures and training.

11.1.2.1.7 RPP Radiation Work Permits (RWPs) and Other Radiation Controls

Work within radiologically controlled areas will be performed under RWPs. The RWPs will specify the scope of work, applicable survey results, protective measures, exposure control limits, and monitoring requirements. Facility RWPs require approval by the RSO and the facility shift supervisor and will remain valid only for a defined period. Controls are consistent with NRC RG 8.10, "Operating Philosophy for Maintaining Occupational Radiation Exposures as Low as is Reasonably Achievable," Rev. 2, 2016.

11.1.2.1.8 RPP Records Management

Records of radiation protection activities will be generated and retained in accordance with 10 CFR Part 20, Subpart L, and AAI's Records Management Program (see Chapter 12). Records include survey results, RWPs, personnel exposure records, effluent monitoring results, and program audits. Occupational dose records will be provided to individuals in accordance with 10 CFR 19.13, "Notifications and reports to individuals." In accordance with 10 CFR 20.2205, "Reports to individuals of exceeding dose limits" and 10 CFR 20.2206, "Reports of individual monitoring" AAI will provide annual reports to all monitored workers and will submit the required annual occupational radiation exposure reports (NRC Form 5) to the NRC REIRS database.



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11.1.2.1.9 RPP Technical Specifications

Technical specifications pertinent to radiation protection are presented in Chapter 14. These specifications ensure that the facility will be operated consistent with the assumptions of the RPP and the analyses supporting safe operation.

11.1.3 ALARA Program

This section describes AAI's ALARA Program for its facility as required by 10 CFR 20.1101. The objective of the program is to make every reasonable effort to maintain exposure to radiation as far below the dose limits of 10 CFR 20.1201 and 10 CFR 20.1301 as is practicable. The design and implementation of the AAI ALARA program will be consistent with applicable guidance provided in Regulatory Guides in Division 8, Occupational Health.

AAI's ALARA program will apply to facility staff, facility users, the general public, and the environment. The AAI ALARA program is implemented through facility design features, operating procedures, personnel training, exposure tracking, and periodic reviews and audits. The program includes objectives, goals, and criteria for minimizing occupational exposure and residual radioactivity. As discussed in Section 11.1.5, radiological zones will be established within the facility. The establishment of these zones supports the ALARA commitment by minimizing the spread of contamination and reducing exposure of personnel to radiation. The ALARA concept is incorporated into the design of the facility. Areas where on-site personnel spend significant amounts of time will be designed to maintain the lowest dose rates as reasonably achievable. Design goals include considerations to implement ALARA such as:

- Structure, system, and component layout
- Shielding (permanent and moveable)
- Ventilation (location, flows, pressure differences between rooms)
- Monitoring instruments
- Radiation source locations, including piping, ventilation, and streaming and shine
- Personnel locations and residence time during operations
- Use of personnel protective equipment, including respirators
- Options for remote operation vs. hands-on
- Reliability, redundancy, inspectability, and maintainability
- Decontamination and clean-up
- Ease of access during construction, operation, maintenance, inspection, and decommissioning activities

The RSO is responsible for implementing the ALARA program and ensuring that adequate resources are committed to make the program effective.



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11.1.4 Radiation Monitoring and Surveying

11.1.4.1 Radiation Monitoring

The following subsections describe AAI's radiation monitoring plans under its RPP. AAI will meet the requirements of 10 CFR 20, Subpart F, "Surveys and Monitoring."

11.1.4.1.1 Personal Monitors

Personnel who enter radiologically restricted areas (as defined in subsection 11.1.5.1) are required to wear personal monitoring devices. In addition, personnel are required to monitor themselves, with help from health physics personnel if needed, prior to exiting restricted areas which may have the potential for contamination.

11.1.4.1.2 Continuous Air Monitors

Continuous air monitors (CAMs) will provide indication of the airborne activity levels in the controlled and restricted areas of the facility. When deemed necessary, portable air samplers may be used to collect a sample on filter paper for subsequent analysis in the laboratory.

11.1.4.1.3 Continuous Noble Gases, Aerosols, and Iodine Effluent Monitoring

The following design requirements apply to the stack monitoring system (SMS) on the facility effluent stack:

- a) Continuous monitoring of radioactive stack releases, and
- b) Generation of real time data for control room display and recording.

The SMS provides continuous on-line sampling of releases of gaseous effluents from the facility to demonstrate that releases are within the regulatory limits.

11.1.4.1.4 Detection and Monitoring of Radioactivity in Liquid Systems and Liquid Effluents

All potentially radioactive liquid waste will be directed to a liquid waste storage and disposal preparation system located in isotope manufacturing area of the AAI facility, where it will be prepared (e.g., sorption, solidification, etc.) to meet applicable off-site commercial disposal facility WAC for solid waste.

Continuous monitoring of closed loop process cooling water systems to detect coolant leakage between primary and secondary circuits due to failure in heat exchanger and other system boundaries will be provided.

11.1.4.1.5 Radiation Area Monitors

Radiation area monitors (RAMs) will provide radiation monitoring and alarms to alert personnel and the control room of radiation levels that are above normal background levels.

11.1.4.1.6 Control Point Monitoring

Monitoring stations will be located at the access points for restricted areas. Monitors will be provided to detect radioactive contamination of personnel. Monitoring station locations will be



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evaluated and moved as necessary in response to changes in facility radiological conditions. Various types of personnel monitoring equipment will be used at the facility access points (e.g., "friskers", hand/foot monitors, and portal monitors). Monitoring stations will also include methods for small article monitoring for loose contamination to allow for the release of, or assist in the decontamination of, articles that are to be removed from the restricted areas.

Calibration of radiological monitoring equipment will be performed in accordance with written procedures and documented prior to the initial use of each monitor. Periodic checks will be performed in accordance with written procedures. Calibrations will be performed at least annually, or as otherwise specified by instrument suppliers.

Portal monitors, hand and foot monitors, and friskers will have the required sensitivity to detect contamination on personnel to ensure that radioactive materials do not spread to areas outside the restricted areas. Instruments are calibrated in accordance with the National Institute of Standards and Technology or equivalent.

11.1.4.1.7 Criticality Monitoring

Criticality monitoring in the AAI facility will be provided by the criticality alarm system (CAS), as described in Chapter 7.

11.1.4.2 Radiation Surveys

Radiation surveys will be conducted for two purposes: (1) to ascertain radiation levels, concentrations of radioactive materials, and potential radiological hazards that could be present in the facility; and (2) to detect releases of radioactive material from facility equipment and operations.

To assure compliance with the requirements of 10 CFR 20, Subparts C, F, L, and M, written procedures for the radiation survey and monitoring equipment will be used.

Radiation survey and monitoring equipment and procedures will be consistent with guidance provided in NRC RGs in Division 8, as listed in Section 11.4, and ANSI N323-1978, "Radiation Protection Instrumentation Test and Calibration," as practicable.

Radiation monitoring and surveying procedures will include program objectives, sampling protocol including frequency, data analysis methods, and required records and reporting requirements. Equipment selection will be based on the type of radiation being monitored. Procedures will be prepared for each of the instruments used and specify the frequency and method of calibration. Maintenance and calibration will be performed in accordance with applicable standards and manufacturers' recommendations.

11.1.4.3 Technical Specifications

AAI technical specifications are proposed in Chapter 14, Section 3.7. Those related to radiation monitoring and surveying are based on the requirements and implementation described herein.



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11.1.5 Radiation Exposure Control and Dosimetry

AAI plans for radiation exposure control by various physical and administrative measures.

11.1.5.1 Controlled Areas

The NRC defines a controlled area per 10 CFR 20.1003, “Definitions” as an area, outside of a restricted area but inside the site boundary, access to which can be limited by the licensee for any reason. AAI’s controlled area is the entire facility outside of the restricted area. Due to the presence of administrative and physical barriers, members of the public will not have direct access to the controlled area of the facility and must be processed by security and authorized by AAI management to enter the facility. Training for unescorted access to controlled and restricted areas will be provided to employees, contractors, and visitors in accordance with the requirements in 10 CFR Parts 19 and 20. This training is discussed in Section 12.1.4.4 in Chapter 12.

Facility visitors include personnel who are temporary, transient occupants of the controlled area. Non-radiological-worker employees, contractors, and visitors that work in or visit the AAI facility controlled areas are subject to the 10 CFR 20.1301 TEDE limits for the public.

Area monitoring will demonstrate compliance with public exposure limits for such personnel. Personnel that enter any restricted areas will be subject to radiation monitoring, commensurate with the radiation hazards for their respective work or visitation areas.

11.1.5.2 Restricted Areas

The NRC defines a restricted area per 10 CFR 20.1003 as an area, access to which is limited by the licensee for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials.

Radiological zones with varied definitions and span of control will be designated for the facility site and areas surrounding the facility site. The purpose of these zones is to (1) control the spread of contamination, (2) control personnel access to avoid unnecessary exposure of personnel to radiation, and (3) control access to radioactive sources present in the facility. Public access to radiological zones will be restricted as detailed herein and as directed by facility management. Areas where personnel spend substantial amounts of time will be designed to minimize the exposure received when routine tasks are performed, in accordance with the ALARA principle.

Access to and egress from a restricted area at the facility site is through a radiation protection control point. No control(s) will be established in a restricted area that would prevent rapid evacuation of personnel. Monitoring equipment is located at these control points. Most restricted areas of AAI’s facility will be located within a building. However, radioactive material may be temporarily stored outside of buildings, in which case a restricted area would be established with the controls described below.



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Areas defined below may exist within the restricted area of AAI's facility. These areas may be temporary or permanent. The specific facility boundaries for these areas will be denoted in the FSAR. The areas will be conspicuously posted in accordance with the requirements of 10 CFR 20 Subpart J, "Precautionary Procedures," to inform workers of the potential hazard in the area to aid in keeping exposures ALARA and minimizing the potential for the spread of contamination.

11.1.5.2.1 Radiation Area

A radiation area is an area accessible to individuals in which radiation levels could result in an individual receiving a dose equivalent more than 5 mrem (0.05 mSv) per hour at 30 cm (11.8 inches) from the radiation source or from any surface that the radiation penetrates.

11.1.5.2.2 High Radiation Area

A high radiation area is an area accessible to individuals in which radiation levels could result in an individual receiving a dose equivalent more than 100 mrem (1 mSv) per hour at 30 cm (11.8 inches) from the radiation source or from any surface that the radiation penetrates. Entryways to these areas will be locked except during periods when access is required, with positive control over each individual entry. A RWP will be required for entry and operations in these areas.

11.1.5.2.3 Very High Radiation Area

A very high radiation area is an area, accessible to individuals, in which radiation levels from radiation sources external to the body could result in an individual receiving an absorbed dose more than 500 rads (5 grays) per hour at 1 m from a radiation source or 1 m from any surface that the radiation penetrates. A RWP will be required for entry and operations in these areas. Entryways to these areas will be locked except during periods when access is required. Entry will require approval and monitoring throughout the operation and exit from the area. If an individual designated as a monitor must make the entry and performing the operation, then their designated, trained, and qualified alternate will be required to monitor the entry, operation, and exit from the area.

11.1.5.2.4 Airborne Radioactivity Area

An airborne radioactivity area is a room, enclosure, or area in which airborne radioactive materials, composed wholly or partly of licensed material, exist in concentrations:

- a) In excess of the DACs specified in Appendix B, to 10 CFR Part 20, or
- b) To such a degree that an individual present in the area without respiratory protective equipment could exceed, during the hours an individual is present in a week, an intake of 0.6 % of the annual limit on intake (ALI) or 12 DAC-hours. Note that entry into this area does not automatically require respirator use.

AAI will utilize, to the extent practicable, process or other engineering controls such as confinement, decontamination, and ventilation to control the concentration of airborne radioactivity and contamination on surfaces of SSCs. When it is not practical to apply process or other engineering controls to reduce the airborne concentrations of radioactive material below the



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threshold for an airborne radioactivity area, AAI will take additional steps to increase monitoring and limit intakes. These steps may include:

- Control of access
- Limitation of exposure times
- Use of respiratory protection equipment
- Other applicable controls

When utilizing an ALARA analysis to determine whether respiratory protection will be used, AAI may consider safety factors other than radiological factors, such as the impact of respirator use on workers' industrial health and safety.

11.1.5.2.5 Contamination Area

A contamination area is an area within the facility where removable contamination levels will be above 20 disintegrations per minute (dpm) per 100 square cm (0.33 Becquerel per 100 square cm) of alpha radioactivity, or 1,000 dpm per 100 square cm of beta/gamma radioactivity (16.7 Bq/100 square cm).

11.1.5.2.6 Radiation Area Map

A map showing the confinement building floor plan with restricted areas identified in accordance with the definitions of 10 CFR 20.1003 will be in the FSAR. The confinement boundary is designated as a restricted area. All areas outside confinement but within the facility site boundary are designated as controlled areas, access to which is administratively limited and subject to public dose limits in 10 CFR 20.1301. Beyond the site boundary is considered unrestricted area.

11.1.5.3 Unrestricted Areas

The NRC defines an unrestricted area per 10 CFR 20.1003 as an area for which access is neither limited nor controlled by the licensee. Beyond AAI's site boundary is considered an unrestricted area by AAI.² This area can be accessed by members of the public or by facility personnel. The unrestricted area is governed by the exposure limits in 10 CFR 20.1301. The TEDE to individual members of the public from licensed normal operations may not exceed 100 mrem (1 mSv) in a year (exclusive of background radiation and individual medical radioisotope exposures). The dose in any unrestricted area from external sources may not exceed 2 mrem (0.02 mSv) in any one hour.

AAI does not plan to store any radioactive material or waste in the unrestricted area. In a situation where this might become needed, material would be continuously monitored for security and ALARA purposes.

² The AAI site is located within the boundary of the Idaho National Laboratory (INL), owned by the Department of Energy (DOE). The entire DOE INL site is controlled and monitored to restrict public access, except as authorized for official business.



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11.1.5.4 Posting for Radiation Protection Awareness

The special radiological zones within the restricted will be clearly identified by physical means such as placarding or boundary marking in accordance with 10 CFR 20.1902, "Posting requirements." The radiation and contamination levels from the most recent survey will be clearly noted on each posting.

11.1.5.5 Protective Clothing and Equipment

Personnel working in areas that are classified as airborne radioactivity areas or contaminated areas must wear appropriate protective clothing. If the areas containing the surface contamination can be isolated from adjacent work areas via a barrier such that dispersible material is not likely to be transferred beyond the area of contamination, personnel working in the adjacent area will not be required to wear protective clothing. Areas requiring protective clothing will be posted at each of their entry points and a RWP will be required for entry and work in these areas. The radiological engineer is responsible for determining the need for protective clothing in each work area.

11.1.5.6 Personnel Monitoring for External Exposures

External exposures are received primarily from H-3 and Ar-41 (or from N-16 if the N-16 suppression system is inactive), as described in Section 11.1.1.1. The nuclides of radiological significance are identified in Section 11.1.1.1. Personnel whose duties require them to enter restricted areas will be required to wear individual external dosimetry devices that are sensitive to beta and gamma radiation. Personal dosimetry will be worn in a manner consistent with the manufacturer's directions. External dosimetry devices will be evaluated at least quarterly, or soon after participation in high-dose evolutions, to ascertain external exposures. Limits on radiation exposure are listed in Appendix A, **Table 11-8**.

Any time more than 25% of the annual limit is exceeded in any fiscal year quarter, the RSO will be informed and will inform operations managers. The RSO is responsible for determining the need for and recommending investigations or corrective actions to the responsible managers and the IRC.

11.1.5.7 Determination of Internal Exposures

AAI will adhere to 10 CFR 20.1204, "Determination of Internal Exposure," as described in Appendix B.

AAI will determine internal exposures in accordance with 10 CFR 20.1204 and 10 CFR 20.1502, "Conditions requiring individual monitoring of external and internal occupational dose." When required, suitable measurements of airborne concentrations, body burden, or excreta will be used to assess dose. In the absence of individual monitoring data, bioassay data or respiratory protection, inhalation may be conservatively assumed at ambient airborne concentrations.

Where specific information on radionuclide behaviors or material properties is available, AAI may use it to refine dose estimates or adjust DAC/ALI values, consistent with 10 CFR Part 20, Appendix B. For mixtures, dose will be calculated using fractional contributions or, if unknown, conservatively based on the most restrictive DAC, as appropriate.



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Committed dose will be estimated assuming intake of 1 ALI or 2,000 DAC-hours results in 5 rem CEDE, except when organ-specific limits apply. In such cases, stochastic ALIs listed in parentheses will be used to demonstrate compliance with 10 CFR 20.1201(a)(1)(ii). Assessments of Class Y material may be delayed up to 7 months for additional measurements unless earlier reporting is required by 10 CFR 20.2202, "Notification of incidents" or 10 CFR 20.2203, "Reports of exposures, radiation levels, and concentrations of radioactive material exceeding the constraints or limits."

11.1.5.8 Summation of External and Internal Doses

AAI will adhere to requirements in 10 CFR 20.1202 for summation of external and internal doses. These requirements address how doses from external and internal radioactive sources must be calculated, including intakes by inhalation, oral ingestion, and intake through wounds or absorption through skin.

AAI will consider NRC Regulatory Guides in Division 8, listed in the references section, for implementation of these requirements in its RPP and its Respiratory Protection Program, and respective procedures.

11.1.5.9 Radiation Protection Program-Related Facility Features

Designated areas within the AAI facility will be provided for use by workers (and visitors as applicable) necessary to carry-out the RPP. These areas, rooms, cabinets, containers, and equipment will be labeled appropriately, routinely surveyed, and maintained. Examples of the features in these areas include:

- Personnel decontamination area— this will be used to handle cases of accidental radioactive contamination. A hand washing sink and a shower will be provided for contamination removal.
- First aid stations, including eye wash
- Restrooms, clean sinks, clean showers, changing stalls, and individual lockers -- these will not be used for personnel decontamination
- Supplies for use in the RPP, such as decontamination equipment
- RPP equipment storage and issuance
- Radiation counting enclosures (e.g., shielded "caves", hoods, gloveboxes), equipment, and instrumentation
- RPP instrument calibrations
- Secured and monitored storage for sealed sources, calibration sources, and materials and equipment for in-core or in-target measurements of flux, temperature, pressure, etc.

Physical and administrative controls will be applied to control and appropriately manage these locations and items for possible sources of contamination, radiation, and waste.



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11.1.5.10 Technical Specifications

AAI technical specifications are proposed in Chapter 14. Those related to radiation exposure control and dosimetry are based on the requirements and implementation described herein.

11.1.6 Contamination Control

Contamination control is part of the RPP described in Section 11.1.2. General equipment and facility layout design considerations to prevent the spread of contamination to the facility and the environment, and to facilitate eventual decommissioning in accordance with 10 CFR 20.1406, “Minimization of contamination” include the features discussed in the following subsections.

11.1.6.1 Shielded Compartments, Hot Cells, Gloveboxes, and Hoods

Process equipment containing significant radioactive material is located within shielded rooms, hot cells, compartments, and/or containers. Process equipment and materials which do not require local operator interaction during a specific operation will be located in shielded areas to protect workers, equipment, and other materials as necessary to maintain exposures ALARA.

Where operator intervention is required during processing activities, applicable equipment will be in shielded hot areas and the operator will be provided with a means for remote viewing and manipulation of components such as hot cell shielded windows and master-slave manipulator arms.

These shielded compartments and shielded hot cells will be provided with sumps and hard piped drains (with leak detection) to facilitate confinement, isolation, and collection of potential liquid spills to minimize the spread of contamination to the facility and the environment. Additionally, these shielded compartments and shielded hot cells will be provided with closed ventilation systems which are operated at negative pressures with respect to the surrounding environment.

Where radioactive materials do not require thick shielding from gamma radiation, gloveboxes or hoods will be used which also will be operated at negative pressure with respect to the surrounding areas. These provide confinement of beta- and alpha-emitting radionuclides, while allowing workers to be able to manually handle materials and equipment inside the glovebox or hood through gloves and hood openings.

There could be cases in which a particular target, product, and/or process could require an inert environment, such as argon. In such cases positive pressure could be necessary for inert atmosphere gloveboxes to control constituents (e.g., limit oxygen and water concentrations). For positive pressure gloveboxes, other controls will be employed to ensure worker safety, such as contamination smears and decontamination of items being inserted or removed from gloveboxes and of the internal surfaces of the glovebox and installed components, local continuous air sampling, oxygen monitoring, etc.



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11.1.6.2 MPF Monitoring and Controlled Entry and Egress to Restricted Area

Potentially radioactive components, piping, and materials will be located within the restricted areas of the facility. Access to and egress from restricted areas will be strictly controlled via administrative procedures and passive confinement structure design.

Personnel access and egress is controlled. Prior to entry personnel must don appropriate personal protective equipment (PPE) to minimize the potential for physical contamination of the worker and the subsequent spread of contamination beyond the restricted area. This PPE is either removed and disposed of or monitored for contamination prior to release from the restricted area. Personnel must then pass through appropriate portal monitoring equipment prior to egressing from the restricted area.

Material removed from the restricted area (radiochemical products, material, tools, disposed equipment, various process, and maintenance consumables) will be appropriately packaged in pre-approved containers, inventoried, and monitored prior to release. Criteria for categorizing contaminated materials and equipment will be provided in the FSAR.

The restricted areas will be provided with fixed CAMs to detect the potential spread of airborne contamination within the restricted areas. Additionally, RAMs will be in place to detect potential increases in background radiation levels from gamma and neutron sources.

Health physics personnel will routinely perform radiation and contamination assessments of accessible areas in the restricted area. Special surveys will be performed, prior to entry, if access is required to normally unoccupied areas.

11.1.6.3 Piping, Tank, and Other Process Equipment Layouts

The use of embedded pipes and tanks will be minimized to the extent practicable, consistent with maintaining radiation doses ALARA, and with being able to access such features for inspection, maintenance, and repair or replacement as needed. These components will be designed, manufactured, and tested in accordance with national codes and standards. Pipes, tanks, and other components that could cause personnel exposure or unplanned release of materials to the surrounding facility locations and/or the environment will be seismically supported and include features for leak detection, as applicable. Additional information about these items is included in Chapters 9 and 10.

11.1.6.4 Administrative Controls

A variety of administrative controls will be used to control contamination. These include appropriate training and qualification of RPP personnel and operations personnel, use of approved, controlled procedures and RWPs, routine tracking of personnel, component, and location exposures, dose rates, and concentration levels, frequent decontamination and good housekeeping, frequent sampling and analyses to assess problematic areas or processes and to detect, understand, and control trends, information and lessons learned sharing among personnel, and a culture of questioning attitudes,



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situational awareness, and performance improvement. These various controls are further discussed in Section 11.1 and in Chapter 12.

11.1.6.5 Technical Specifications

AAI technical specifications are proposed in Chapter 14 and its appendix. Those related to contamination control are based on the requirements and implementation described herein.

11.1.7 Environmental Monitoring

This subsection addresses the AAI Radiological Environmental Monitoring Program (REMP) which is required by 10 CFR 20.1302, "Compliance with dose limits for individual members of the public." The AAI REMP will be used to verify the effectiveness of facility measures which are used to control the release of radioactive material and to verify that measurable concentrations of radioactive materials and levels of radiation are not higher than expected based on effluent measurements and modeling of the environmental exposure pathways. Methods for establishing and conducting environmental monitoring are provided in RG 4.1, "Radiological Environmental Monitoring for Nuclear Power Plants," Rev. 2, 2009 which refers to NUREG-1301, "Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Pressurized Water Reactors," for detailed guidance on conducting effluent and environmental monitoring. While these two guidance documents were written for nuclear power reactors, AAI is utilizing them as applicable for its REMP. Additionally, AAI is using guidance from the Environmental Protection Agency, "Guidance on Systematic Planning Using the Data Quality Objectives Process," in development of data quality objectives (DQO) for its REMP.

11.1.7.1 Effluent Release Pathways and Monitoring

Radioactive effluent releases from the AAI facility are limited to airborne pathways. Airborne effluents include noble gases, iodine and other halogens, particulates, and Ar-41. The DQO process indicates the following radiation exposure pathways could represent plausible public exposure scenarios:

- Direct radiation exposure pathway (monitored using thermo-luminescent dosimeters (TLDs))
- Airborne exposure pathway (monitored using continuous air samples)
- Ingestion exposure pathway

No radioactive liquids are planned to be released from the AAI facility. Radioactive liquid waste are managed as described in Section 11.2. Sanitary wastewater and storm water runoff are non-radioactive effluent streams; no radioactive discharges to these pathways are planned. Occasional samples from these discharge locations will be collected, tested, and trended to verify background radiation levels and to compare with pre-operational survey results. All liquid radioactive wastes generated onsite will be managed as low-level radioactive waste or mixed low level radioactive waste, not effluent, as described in Section 11.2.2.



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11.1.7.1.1 Direct Radiation Monitoring

Direct exposure to gamma and beta emitting radionuclides released through the stack of the AAI facility will be monitored and measured at receptor locations using TLDs. The TLDs will quantify direct radiation from radiation sources within the AAI buildings, from radioactivity in the airborne effluent, and from deposition of airborne radioactivity onto the ground. A description of planned TLD locations and the rationale for them are provided in **Table 11-3**. Table 3.12-1 of NUREG-1301 recommends 40 TLD locations, i.e., an inner ring and an outer ring of TLDs with one TLD in each ring at each of the 16 meteorological sectors and the balance of TLDs to be located at special interest areas. At least one TLD will serve as a control, i.e., located a significant distance from the facility and upwind from the prevailing wind such that it will represent a background dose. Considering the low power levels of the AAI VIPRs compared to nuclear power reactors and based on the dose calculations presented in section 11.1.1, AAI is planning on 13 TLD locations—8 on the outer ring of the site boundary, and 5 within the controlled area. At least one location will include a paired TLD so that data quality can be determined; these are listed in **Table 11-3**.

Background radiation will be subtracted from the routinely measured TLD results. The background radiation values will be those established during the baseline environmental survey prior to operations. While a control (background) TLD is deployed as part of the REMP, the control TLD is not used for background subtraction. This is due to the high variance (relative to the dose constraint) in background radiation caused by differences in terrestrial radiation, cosmic radiation, and seasonal variations. As such, the baseline survey ensures these variations are accounted for by collecting data at the specific location that will be used to monitor direct radiation under the REMP during the operational phase.

Table 11-3. AAI facility TLD and CAM locations for REMP evaluation

Item	Location	Rationale
TLDs 1-8	Outer site boundary at 8 different wind directions: N, NE, E, SE, S, SW, W, NW	Obtain data for 8 wind directions. TLD 6, SW (upwind from the prevailing wind) of the AAI facility
TLD 9	At an outdoor location approximately 50 feet from the outer restricted area boundary of the facility, closest to the Materials and Fuels Complex at INL.	Special interest point in the event of an accident at MFC.
TLD 10	At an outdoor location of the outer restricted area boundary location, 90 degrees clockwise from TLD 9.	Controlled area data point, along with TLDs 9, 11, and 12 to cover 4 main wind directions.
TLD 11	At an outdoor location of the outer restricted area boundary location, 90 degrees clockwise from TLD 10.	Controlled area data point, along with TLDs 9, 10, and 12 to cover 4 main wind directions.
TLD 12	At an outdoor location of the outer restricted area boundary location, 90 degrees clockwise from TLD 11.	Controlled area data point, along with TLDs 9, 10, and 11 to cover 4 main wind directions.
TLD 13	Same location as TLD-12.	Determine precision for TLD exposures.



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Item	Location	Rationale
CAM 1-4	Inside the site boundary in 4 different wind directions, same locations as for TLDs 9-12.	Obtain data from 4 wind directions.
CAM-5	At site boundary, upwind from prevailing wind; same location as TLD 6 (SW).	Obtain background estimate.
CAM-6	Same location as for CAM 1.	Determine precision for continuous air sampling.

11.1.7.1.2 Iodine and Particulate Monitoring for Releases via Airborne Pathway

Airborne effluent releases from the AAI facility will contribute to off-site doses. Air monitoring will detect iodine or particulate releases should they occur. These types of releases could result in exposure via inhalation, direct radiation (cloud immersion), and ingestion.

Airborne effluent streams from the AAI facility that have the potential to include radioactive iodine will be treated (e.g., using carbon filters) to remove the iodine. Some particulate activity (other than iodine) could also be released in airborne effluents; however, most of the off-site exposure due to airborne effluent releases would be associated with noble gas and radioactive iodine releases. See the source term discussion in Section 11.1.1.

The guidance provided in Table 3.12-1 of NUREG-1301 was used to establish locations for airborne sample acquisition, sampling frequency, and type of sample analysis. The continuous air samplers that will be used to obtain continuous air samples will include a radioiodine canister for I-131 analysis and a particulate sampler which will be analyzed for gross beta radioactivity and for quarterly isotopic analysis.

Four continuous air sampler locations will be located within the controlled area, near the “inner” TLD locations as described previously, in the north, south, east, and west direction sectors to ensure all directions are monitored. The north and east direction sectors (with respect to the AAI facility stack) have the highest calculated annual ground level deposition factor (D/Q) values. There is also a continuous air sampler reference station located a sufficient distance from the AAI facility to provide background information for airborne activity. A description of preliminary air sample locations and the rationale for them are provided in **Table 11-3**.

11.1.7.1.3 Ingestion Pathway (Biota Monitoring)

NUREG-1301 suggests sampling of various biological media to indirectly assess doses due to particulate and iodine ingestion. Because the AAI VIPRs are at much lower powers than nuclear power reactors, and because there are essentially no crop or animal food sources for humans within 5 miles from the AAI site, biota monitoring is not routinely included in the AAI REMP.

If results from REMP sampling were to increase beyond expected results, then a more comprehensive sampling campaign would be undertaken. The sampling campaign will be conducted under the DQO process thus ensuring appropriate types and numbers of samples are



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collected to best represent potential public doses based on radionuclides of concern in the environmental sample results.

11.1.7.1.4 Groundwater Monitoring

Onsite groundwater is currently monitored at the INL Site by multiple organizations to

- Satisfy specific CERCLA-related remedial action objectives and/or regulatory requirements contained in RODs, RCRA regulations, WLAPs, and DOE orders
- Determine the nature and extent of groundwater contamination during CERCLA remedial investigation/feasibility study activities
- Evaluate general groundwater conditions, contaminant fate, and transport on a regional and subregional scale (as performed by the USGS and WAG 10)

AAI will collaborate with INL on the topic of groundwater monitoring, and the appropriate details will be developed for the FSAR.

11.1.7.1.5 Preoperational Baseline Monitoring

As previously indicated, effluent releases from the AAI facility will be limited to releases via the airborne pathway. Environmental monitoring of the AAI facility includes the use of TLDs for monitoring direct radiation and continuous air sampler for detecting iodine and particulate activities in airborne effluents. Preconstruction and preoperational baseline surveys will be performed to obtain TLD readings at the 13 TLD locations and to obtain air sample radioactive iodine and particulate surveys at the five air sample locations described in **Table 11-3**. The baseline TLD readings and air sample survey results will represent background radiation values that will be used with operational surveys to establish the radiological impact of the AAI facility on the environment.

Additional biota sampling (e.g., soil, broad leafed plants, and meat) will only be conducted if there are significant quantities of iodine or particulates in other sample results. Since there is a possibility that biota sampling could be performed at some future date, biota sampling will be included in the preoperational baseline survey.

11.1.7.2 **Environmental Monitoring Program Procedures and Improvements**

Environmental surveys conducted in support of the REMP will be performed in accordance with written plans and procedures. Changes to the REMP or to environmental survey plans will be reviewed for adequacy and approved prior to implementation in accordance with AAI's Quality Assurance and Conduct of Operations Programs and procedures, as described in Chapter 12.

11.1.7.3 **REMP Reports**

A Radioactive Effluent Release Report and a Radiological Environmental Operating Report will be generated and recorded on an annual basis representing a one-year monitoring period per Section C, of RG 4.20, "Constraint on Releases of Airborne Radioactive Materials to the Environment for Licensees other than Power Reactors," Rev. 1, 2012. Reports to the NRC will be provided when required by



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regulation, including notification of any effluent release or environmental monitoring result that indicates an exceedance of applicable limits.

In accordance with Appendix A to NUREG-1301, a laboratory inter-comparison program will be utilized by AAI to crosscheck sample analysis results. The results of the inter-comparison crosscheck sample analyses will be included in the annual Radiological Environmental Operating Report.

Although biota monitoring is not planned, AAI will stay informed about future land use around its site via communications with the Department of Energy. Any planned changes from the current land use and potential additional environmental monitoring that might be conducted will be discussed in the annual Radiological Environmental Operating Report.

11.2 RADIOACTIVE WASTE MANAGEMENT

This section addresses radioactive waste management for AAI's facility. Several irradiation and processing steps create gaseous, liquid, and/or solid radioactive waste materials. The AAI RWMP, controls, disposal pathways that will be established to ensure the identification, classification, control, processing (as required), and packaging for transport and disposal for each anticipated radioactive waste stream generated by the AAI facility, are addressed herein. AAI is committed to comply with all applicable federal, state, regional, and local regulations, plus NRC guidance to the extent practicable, for managing its radioactive wastes to protect the health and safety of workers, the public, and the environment. Section 11.1 describes the RPP and procedures for controlling and assessing radioactive exposures associated with radioactive sources, including radioactive waste streams. This section consists of 3 main subsections that address

- 1) the RWMP,
- 2) radioactive waste controls, and
- 3) release of radioactive waste.

Both Sections 11.1 and this 11.2 include preliminary estimates for the types and quantities of radioactive waste, and exposures from waste source terms.

Information unknown at this time, plus applicable updates to the information provided in this Preliminary Safety Analysis Report (PSAR) will be included in the FSAR.

11.2.1 Radioactive Waste Management Program (RWMP)

11.2.1.1 RWMP Policy

AAI is committed to managing radioactive waste to protect the health and safety of workers, the public, and the environment, via its RWMP which requires:

- Designing and implementing the RWMP commensurate with the risks posed by radiological waste while being effective in protecting the health and safety of workers, the public, and the environment.



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- Maintaining flexibility in the RWMP to accommodate changing radioactive waste loads, changing regulatory requirements, changing environmental factors, and new technologies.
- Adhering to applicable regulatory requirements for waste including 10 CFR Part 20 Subpart K, Waste Disposal.
- Following applicable NRC guidance documents and related codes and standards for waste to the extent practicable.
- Minimizing waste generation, as specifically described below in Section 11.2.1.2.
- Maintaining occupational and public radiation exposures and releases to the environment from radioactive waste ALARA.
- Establishing and maintaining an organizational structure and qualified RWMP staff independent of the operating organization and staff with the authority and responsibility to interdict perceived unsafe or non-compliant waste management activities.
- Utilizing AAI Quality Assurance administrative programs and procedures where appropriate to implement the RWMP.
- Routinely assessing and auditing RWMP content, implementation, actual types and quantities of radioactive waste generated, actual doses compared to expected doses from waste management activities, and lessons learned to continually improve the program.

The RWMP is coordinated with the RPP. The following subsections describe elements of the RWMP, including:

- Waste minimization
- Responsibilities
- Training and Qualification
- Procedures
- Document and Record Management
- Reviews and Audits
- Technical Specifications

11.2.1.2 Radioactive Waste Minimization

AAI's RWMP will include specific considerations for minimization of radioactive waste and overall pollution prevention. Key features will include, as appropriate and practicable:

- Incorporation of radioactive waste minimization and pollution prevention design features, such as separate zones within the facility based on radiation and contamination levels, ventilation, filtration, and air flow, features to facilitate decontamination between operations, standard systems to minimize waste volumes and mass, or emissions, e.g., compaction, evaporation, solidification, resin columns, filters, scrubbers, etc.
- Administrative controls such as monitoring, surveying, sorting, mixing, area posting, reusing, recycling, etc.



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- Employee training and education on general environmental activities and hazards regarding the facility, operations, waste minimization requirements, goals, and accomplishments, and pollution prevention
- Responsibilities and authorities for waste minimization and pollution prevention
- Recognition of employees for efforts to improve environmental conditions

11.2.1.3 Responsibilities

11.2.1.3.1 Radiation Safety Officer (RSO)

The AAI CEO has delegated overall responsibility and authority for the RWMP to the RSO who is specifically responsible for:

- Providing technical input to SSC designs and operations relative to waste management considerations
- Developing and implementing RWMP procedures
- Routinely assessing the RWMP Policy, program description document, and implementing procedures to improve them as applicable based on reviews and audits, lessons learned from AAI and other NPUF operations, waste disposal facilities' acceptance criteria, and new technologies
- Developing and implementing corrective and preventive actions as needed for RWMP issues
- Developing and providing RWMP
- Maintaining sufficient trained and qualified staff to carry-out RWMP activities (staffing levels will be provided in the FSAR)
- Performing RWMP activities per approved procedures in coordination with facility operations personnel

11.2.1.3.2 Operations Manager

The operations manager is responsible for:

- Providing technical input to waste management-related SSC designs and operations relative to operations considerations
- Implementing the RWMP and procedures, as applicable
- Participating in self-assessments regarding the RWMP
- Ensuring that operation personnel obtain required RWMP training, as applicable
- Performing operations of RWMP equipment in the facility as needed



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11.2.1.4 Training and Qualification

Training and qualifications for RWMP activities will be developed and provided to appropriate AAI staff. The AAI Training and Qualification Program is further described in Chapter 12, Section 12.1.4.

11.2.1.5 Procedures

RWMP activities are conducted in accordance with approved procedures which are subject to AAI's Document Control Program. Facility operations procedures may call out RWMP procedures for activities that involve generation or management of radioactive wastes, and vice versa. Both the Operations Manager and the RSO reviews and concurrences are required in such cases. All new procedures and procedure changes will require reviews per 10 CFR 50.59, as described further in Chapter 12, Section 12.2. Procedures are generally described in more detail in Chapter 12, Section 12.3.

11.2.1.6 Documents and Records Management

RWMP documents and records are subject to AAI's Document and Record Management Programs which are described more in Chapter 12, Sections 12.3 and 12.6, and Appendix 12-B.

11.2.1.7 Reviews and Audits

Changes to the AAI RWMP Policy will be reviewed by the AAI IRC and approved by the CEO or COO. RWMP self-assessments will be conducted routinely by RPP and facility operations staff and management. Independent audits will be conducted, at a minimum, on an annual basis on the functional and safety elements and programmatic efforts to minimize generation of radioactive wastes. These audits will be led by either a qualified Quality Assurance or IRC staff member or manager or external contractor and will include audit team members knowledgeable in radioactive waste management regulations and practices. Results will be reported to management and supervisory staff. Audit results and reports will be managed in accordance with the AAI Issues Management Program, as applicable. Review, audit, action, and report processes and the IRC are further described in Chapter 12.

11.2.1.8 Technical Specifications

AAI technical specifications are proposed in Chapter 14. Those related to RWMP are based on the requirements and implementation described herein. See Chapter 14, Section 6 for administrative controls.

11.2.2 Radioactive Waste Controls

AAI's RWMP Section 11.2.1, describes policies, responsibilities, and various administrative controls for radioactive waste management. AAI's RWMP is integrated with its RPP described in Section 11.1, including ALARA. Chapter 4 addresses the reactor facility and operations, including brief descriptions regarding waste. It provides the principal bases for source terms, including waste, from which the included estimates are derived. Other NPUF SARs, as noted in Section 11.0, were also considered in



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estimating certain waste types, quantities, characteristics, and respective controls. This section is broken down to address other aspects of radioactive waste controls as follows:

- Definitions and types of waste generated
- Processes and locations from which wastes are generated
- Processes, systems, and components utilized to control wastes
- Quantity and characteristics of waste generated

References to other sections of this chapter and to other AAI SAR chapters are included as applicable.

11.2.2.1 Waste Definitions

AAI utilizes definitions from Title 10 and Title 40, "Domestic Licensing of Source Material" of the *Code of Federal Regulations*. They include:

- Spent (used) fuel includes the special nuclear material, byproduct material, source material, and other radioactive materials associated with fuel assemblies. When used in AAI documents, "used fuel" is intended to be synonymous with "spent nuclear fuel" (10 CFR 72.3).
- Low-Level Radioactive Waste (LLW) may be contact-handled or require remote handling if radiation levels at the container surface exceed 200 mrem/hr. This handling distinction is separate from classification. LLW is classified in accordance with 10 CFR 61.55(a)(2), "Waste Classification," as follows:
 - Class A waste is waste that is usually segregated from other waste classes at the disposal site. The physical form and characteristics of Class A waste must meet the minimum requirements set forth in 10 CFR 61.56, "Waste Characteristics", paragraph (a) for waste handling at the disposal site. If Class A waste also meets the stability requirements set forth in 10 CFR 61.56(b), it is not necessary to segregate the waste for disposal.
 - Class B waste is waste that must meet more rigorous requirements on waste form to ensure stability after disposal. The physical form and characteristics of Class B waste must meet both the minimum handling and stability requirements set forth in 10 CFR 61.56.
 - Class C waste is waste that not only must meet more rigorous requirements on waste form to ensure stability but also requires additional measures at the disposal facility to protect against inadvertent intrusion. The physical form and characteristics of Class C waste must meet both the minimum handling and stability requirements set forth in 10 CFR 61.56.
 - Greater than Class C waste means low-level radioactive waste that exceeds the concentration limits of radionuclides established for Class C waste (10 CFR 61.55(a)(2))
- The characteristics of hazardous constituents are ignitability, corrosivity, reactivity, and toxicity (10 CFR 61.2).
- Mixed LLW is hazardous waste as defined by EPA that is also contaminated with radioactive isotopes.



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For the sake of completeness in Section 11.2.2 and its subsections, the airborne (gaseous) effluents that are released from the stack as described in Section 11.1.1.1 are included in this discussion.

11.2.2.2 Processes and Locations from Which Wastes Are Generated

Section 11.1.1.1 of this chapter describes processes and locations for waste sources generated at the AAI reactor facility. A general list is provided below. Additional information about these processes and locations regarding waste management will be provided in the FSAR.

- Reactor Confinement Module
- Primary Coolant System
- Reactor Auxiliary Module
- Shipping and Receiving (potentially contaminated packages)

11.2.2.3 Processes, Systems, and Components to Control Wastes

The following processes, systems, and components generally listed below are in some respects utilized in the facility to limit the release of airborne (gaseous) effluents from the stack, and to minimize and control liquid and solid wastes. Additional information about these items is preliminarily described herein in various SAR locations as noted in parentheses and will be further detailed in terms of specific waste management functions in the FSAR.

- Cleanup system (Chapters 5, 9)
- Makeup water system (Chapters 5, 9)
- N-16 suppression system (Chapters 4, 5, 11)
- Reactor confinement and shielding (Chapters 3, 4, 6, 9)
- Ventilation (Chapters 3, 6, 9, 11)
 - Scrubbers
 - Filters
 - Stack
- Sampling (Chapters 9, 11)
- Waste processing/management
 - Waste processing (Chapters 9, 11)
 - Decontamination
 - Neutralization
 - Sorption (adsorption and absorption)
 - Evaporation
 - Compaction (manual in filtered glovebags)
 - Stabilization
 - Solidification
 - Encapsulation
 - Shipment packaging (Chapters 11, 19)



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- Low Specific Activity
- Type A
- Type B
- Disposal (Chapter 11, 19)

11.2.2.4 Quantity and Characteristics of Wastes

Several waste streams have been preliminarily identified, which are included in the source term discussions in Section 11.1.1 and are briefly described in other chapters of the SAR as indicated above.

Table 11-4 below summarizes each estimated waste source, physical form, radionuclide concentration, chemical composition, and annual quantity to be released or disposed.

Table 11-4. Estimated waste streams for normal operations.

Waste Source Description	Basis of Estimate	Waste Form	Annual Avg. Quantity Estimate	Quantity Units	Notes (All estimates to be refined in FSAR)
Used Fuel	See Chapters 4, 6	Solid (Used Fuel Assemblies)	[] ^{PROP,ECI}	Used Fuel Assemblies	Used fuel storage pool designed to hold [] ^{PROP,ECI} used VIPR fuel assemblies. • []^{PROP,ECI} assemblies/core • []^{PROP} yr core residence time ea. • 60 yr. facility life • 4 reactors
High Level Radioactive Waste	Not Applicable (NA)	NA	None	NA	NA
Transuranic Waste	NA	NA	None	NA	NA
GTCC Waste	NA	NA	None	NA	NA
Airborne (Gaseous Wastes)	See section 11.1.1.1.	Gaseous	Table 11-8	μCi/cm ³	Released concentrations in air
N-16			[] ^{PROP}	Ci/yr	Based on stack release rate of 20.08 m ³ /s
Ar-41			[] ^{PROP}		
H-3			[] ^{PROP}		
Coolant Cleanup Ion Exchange Resin from	Other NPUF SARs	Solid LLW Class B	1.4	m ³ /yr	NA



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Waste Source Description	Basis of Estimate	Waste Form	Annual Avg. Quantity Estimate	Quantity Units	Notes (All estimates to be refined in FSAR)
the cleanup system					
Decontamination Waste (rags, gloves, used PPE, etc.)	Other NPUF SARs, Experience in Isotope Manufacturing	Solid LLW Class A	12	m ³ /yr	Assume 1 m ³ per month

11.2.3 Release of Radioactive Waste

Release for the purposes of this subsection means that waste is packaged as required to meet the WAC of a licensed disposal facility. Packaging may comprise one or more of several operations, such as manual compaction of dry waste in filtered glovebags, solidification with an appropriate medium (e.g., Aquaset, Portland cement, grout, etc.), adsorption onto or absorption into a solid medium, interim storage for decay of short-lived radionuclides, extraction and consolidation of specific isotopes, and a small volume of high dose rate material is held for decay. Section 11.2.2 provides information on estimated quantities of wastes to be released (1) as airborne gaseous emissions to the air via the stack, and (2) as solid waste to a licensed disposal facility.

11.3 RESPIRATORY PROTECTION PROGRAM

AAI's Respiratory Protection Program fulfills the requirements of 10 CFR Part 20 Subpart H, "Respiratory Protection and Controls to Restrict Internal Exposure in Restricted Areas." This section is broken down into three subsections that coincide with the three sections in 10 CFR Part 20 Subpart H.

11.3.1 Use of Process and Other Engineering Controls

AAI intends to use process and engineered controls to control the concentration of radioactive materials in the air, pursuant to 10 CFR 20.1701, "Use of Process or Other Engineering Controls." These controls will include:

- Confinement (discussed in Chapter 4 for the AAI VIPRs)
- Decontamination (discussed in Section 11.1.5)
- Filtered ventilation (discussed primarily in Chapter 9)

11.3.2 Use of Other Controls

In the event it is not practical to apply the controls noted above to limit the occupational DAC of radioactive materials in the air to values below the concentrations values specified in 10 CFR Part 20 Appendix B, "Annual Limits on Intake (ALIs) and Derived Air Concentrations (DACs) of Radionuclides for



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Occupational Exposure; Effluent Concentrations; Concentrations for Release to Sewerage,” AAI will use other controls per 10 CFR 20.1702, “Use of Other Controls,” to maintain personnel exposures ALARA by increasing monitoring and limiting intakes via controlling access, limiting exposure times, using respiratory protection equipment, and/or other controls as available and applicable. If AAI performs an ALARA analysis to determine whether respirators should be used, non-radiological safety factors, e.g., potential heat stress, will also be considered in the overall analysis.

11.3.3 Use of Individual Respiratory Protection Equipment

In the event respiratory protection equipment is needed based on analysis of specific operations or maintenance activities being considered, AAI will implement a Respiratory Protection Program and requisite procedures to fulfill the requirements of 10 CFR 20.1703, “Use of Individual Respiratory Protection Equipment.” Elements of the program will include:

- Requirement to use only respiratory protection equipment that is tested and certified by the National Institute for Occupational Safety and Health
- Procedures for radiation monitoring and air sampling used to identify potential hazards, to permit proper equipment selection, and to estimate doses
- Procedures to evaluate actual intakes by use of surveys and bioassays, as necessary
- Respiratory Protection Program Training
- Requirements for physician-approved medical fitness for respirator use (initial and routine exams)
- Procedures for the use of respiratory protection equipment

11.4 REFERENCES

American Society for Testing and Materials (ASTM). 2008. ASTM E1168-95, “Radiological Protection Training for Nuclear Facility Workers.”

North Carolina State University, 2017. PULSTAR Reactor, “Updated Safety Analysis Report, License No. R-120.” Docket No. 50-297, (March 29). Raleigh, NC.

SHINE Medical Technologies, Inc. 2015. “Preliminary Safety Analysis Report.” (June 16). ADAMS Package Accession No. ML15175A274.

University of Missouri. 2006. Missouri University Research Reactor (MURR), “License Renewal Application Safety Analysis Report,” License No. R-103, Docket No. 50-186, (August 16, 2006). Columbia, MO.

11.5 APPENDICES

Appendix A: Airborne Radiation Source Dose Estimates



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Appendix B: Determination of Internal Exposures



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The dose for N-16 produced in the core and carried to the reactor air is calculated as follows:

$$\begin{aligned}\frac{\partial N_{N16,core}}{\partial t} &= \Sigma\phi - \lambda N_{N16,core} \\ N_{N16,core}(0) &= 0 \\ N_{N16,core} &= \frac{1}{\lambda} (1 - e^{-\lambda t_{core}}) \sum_i^N \phi_i \Sigma_i \\ N_{N16,core} &= \frac{1}{\lambda} (1 - e^{-\lambda h_{core}/v}) \sum_i^N \phi_i \Sigma_i\end{aligned}$$

Equation 11-2. N-16 concentration in the VIPR core

$$\begin{aligned}\frac{\partial N_{N16,surface}}{\partial t} &= -\lambda N_{N16,core} \\ N_{N16,surface}(0) &= N_{N16,core} \\ N_{N16,surface} &= N_{N16,core} e^{-\lambda t_{rise}} \\ N_{N16,surface} &= N_{N16,core} e^{-\lambda h_{pool}/v}\end{aligned}$$

Equation 11-3. N-16 Concentration at the pool surface

$$\begin{aligned}\frac{\partial N_{N16,air}}{\partial t} &= \frac{vA_{flow}}{V_{air}} N_{N16,surface} - \lambda N_{N16,air} - \frac{r_{exhaust}}{V_{air}} N_{N16,air} \\ \frac{\partial N_{N16,air}}{\partial t} &= 0 \\ N_{N16,air} &= \frac{vA_{flow}}{V_{air} \left(\lambda + \frac{r_{exhaust}}{V_{air}} \right)} N_{N16,surface}\end{aligned}$$

Equation 11-4. N-16 concentration in the confinement air

$$\begin{aligned}A_{N16,air} &= \lambda N_{N16,air} \\ A_{N16,air} &= \frac{\lambda v A_{flow}}{V_{air} \left(\lambda + \frac{r_{exhaust}}{V_{air}} \right)} N_{N16,surface}\end{aligned}$$

Equation 11-5. N-16 activity concentration in the confinement air



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Table 11-5: N-16 air concentration data

Symbol	Parameter	Value	Unit
$N_{N16,core}$	N-16 concentration exiting VIPR core	[] ^{PROP}	cm ⁻³
$N_{N16,surface}$	N-16 concentration at reactor pool surface	[] ^{PROP}	cm ⁻³
$N_{N16,air}$	N-16 concentration in air above reactor pool	[] ^{PROP}	cm ⁻³
$A_{N16,air}$	N-16 activity concentration in air above reactor pool	[] ^{PROP}	μCi/cm ³
Σ_i	Macroscopic reaction cross section in energy group i		cm ⁻¹
ϕ_i	Average core neutron flux in energy group i		cm ⁻² s ⁻¹
λ	N-16 radioactive decay constant	0.10	s ⁻¹
t_{core}	Coolant residence time in core	[] ^{PROP}	s
h_{core}	Effective core height	[] ^{PROP,ECI}	cm
v	Coolant velocity	[] ^{PROP}	cm/s
t_{rise}	Time for coolant flow to reach pool surface	[] ^{PROP}	s
h_{pool}	Reactor pool depth	[] ^{PROP,ECI}	cm
A_{flow}	VIPR core coolant flow area	[] ^{PROP}	cm ²
V_{air}	Reactor area air volume	[] ^{PROP}	cm ³
$r_{exhaust}$	Reactor area air exchange rate	[] ^{PROP}	cm ³ /s



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The concentration of H-3 activity in the air of the reactor area is calculated according to the following sets of coupled rate equations and data:

$$\frac{\partial N_{H3,pool}}{\partial t} = \Sigma\phi - \lambda N_{H3,pool} - \frac{r_{evaporation}}{V_{pool}} N_{H3,pool}$$

$$\frac{\partial N_{H3,pool}}{\partial t} = 0$$

$$N_{H3,pool} = \frac{1}{\lambda + \frac{r_{evaporation}}{V_{pool}}} \sum_i^N \phi_i \Sigma_i$$

Equation 11-6. H-3 concentration in the pool

$$N_{H3,air} = \frac{r_{evaporation}}{V_{pool}} N_{H3,pool}$$

Equation 11-7. H-3 concentration in the confinement air

$$A_{H3,air} = \lambda N_{H3,air}$$

$$A_{H3,air} = \frac{\lambda r_{evaporation}}{V_{pool}} N_{H3,pool}$$

Equation 11-8. H-3 activity concentration in the confinement air

Table 11-6: H-3 air concentration data

Symbol	Parameter	Value	Unit
$N_{H3,pool}$	H-3 concentration in reactor pool	[] ^{PROP}	cm ⁻³
$N_{H3,air}$	H-3 concentration in air above reactor pool	[] ^{PROP}	cm ⁻³
$A_{H3,air}$	H-3 activity concentration in air above reactor pool	[] ^{PROP}	μCi/cm ³
Σ_i	Macroscopic reaction cross section in energy group <i>i</i>		cm ⁻¹
ϕ_i	Average core neutron flux in energy group <i>i</i>		cm ⁻² s ⁻¹
λ	H-3 radioactive decay constant	1.78×10 ⁻⁹	s ⁻¹
$r_{evaporation}$	Water evaporation rate from reactor pool	1.66	cm ³ /s
V_{pool}	Reactor pool water volume	[] ^{PROP,ECI}	cm ³



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Parameters used in the calculation of annual average χ/Q values are given below in **Table 11-7**. Results of the χ/Q calculation and the resultant dose consequences from the considered radionuclides are given in the following table, **Table 11-8**.

Table 11-7: Parameters used in the offsite dose consequence assessment

Parameter		Value	Unit
Building and Exhaust Stack	Reactor Module Width	17	m
	Reactor Module Length	76	m
	Reactor Area Volume	2.92×10^9	cm^3
	Air Changes per Hour	4	h^{-1}
	Reactor Area Exhaust Rate	3.24×10^6	cm^3/s
	Reactor Module Height Above Grade	9	m
	Smallest Vertical-Plane Building Cross-Section	153	m^2
	Exhaust Stack Height	35	m
	Stack Inside Diameter	1	m
	Plume Vertical Exit Velocity	25.56	m/s
Receptor Distance	Site Boundary	150	m
Breathing Rate		2.30×10^{-4}	m^3/s



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Table 11-8: Results of offsite dose consequence assessments

Parameter		Value	Unit
χ/Q	Site Boundary Annual Average	7.42×10^{-5}	s/m^3
Released Air Concentration	N-16 ^a	[] ^{PROP}	$\mu\text{Ci/cm}^3$
	Ar-41	[] ^{PROP}	$\mu\text{Ci/cm}^3$
	H-3	[] ^{PROP}	$\mu\text{Ci/cm}^3$
DAC Limit	N-16	1.70×10^{-7}	$\mu\text{Ci/cm}^3$
	Ar-41	1×10^{-8}	$\mu\text{Ci/cm}^3$
	H-3	1×10^{-7}	$\mu\text{Ci/cm}^3$
Annual Dose (at Site Boundary)	N-16	2.41×10^{-2}	mrem/y
	Ar-41	2.35×10^{-1}	mrem/y
	H-3	1.55×10^{-5}	mrem/y
	Total	2.59×10^{-1}	mrem/y

^(a)N-16 air concentration assuming the NSS is operating to reduce the air concentration of the radioisotope within the facility to, at minimum, the DAC.



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AAI will adhere to 10 CFR 20.1204, "Determination of Internal Exposure" as follows:

- For purposes of assessing dose used to determine compliance with occupational dose equivalent limits, AAI will, when required by 10 CFR 20.1502, take suitable and timely measurements of one or more of the following:
 - Concentrations of radioactive materials in air in work areas
 - Quantities of radionuclides in the body
 - Quantities of radionuclides excreted from the body
- Unless respiratory protective equipment is used, as provided in 10 CFR 20.1703, or the assessment of intake is based on bioassays, AAI will assume that an individual inhales radioactive material at the airborne concentration in which the individual is present.
- When specific information on the physical and biochemical properties of the radionuclides taken into the body or the behavior of the material in an individual is known, AAI may:
 - Use that information to calculate the committed effective dose equivalent, and, if used, AAI will document that information in the individual's record dose record
 - Adjust the DAC or ALI values to reflect the actual physical and chemical characteristics of airborne radioactive material (e.g., aerosol size distribution or density)
 - Separately assess the contribution of fractional intakes of Class D, W, or Y compounds of a given radionuclide (see 10 CFR 20, Appendix B) to the committed effective dose equivalent
- If AAI chooses to assess intakes of Class Y material using the measurements given in 10 CFR 20.1204(a)(2) or (3), AAI may delay the recording and reporting of the assessments for periods up to 7 months, unless otherwise required by 10 CFR 20.2202 or 20.2203, in order to permit AAI to make additional measurements pertinent to the assessments.
- If the identity and concentration of each radionuclide in a mixture are known, the fraction of the DAC applicable to the mixture for use in calculating DAC hours must be either of the following:
 - The sum of the ratios of the concentration to the appropriate DAC value (e.g., D, W, Y) from 10 CFR 20, Appendix B for each radionuclide in the mixture
 - The ratio of the total concentration for radionuclides in the mixture to the most restrictive DAC value for any radionuclide in the mixture
- If the identity of each radionuclide in a mixture is known, but the concentration of one or more of the radionuclides in the mixture is not known, the DAC for the mixture must be the most restrictive DAC of any radionuclide in the mixture.



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- When a mixture of radionuclides in air exists, AAI may disregard certain radionuclides in the mixture if the following are true:
 - AAI uses the total activity of the mixture in demonstrating compliance with the dose limits in 10 CFR 20.1201 and in complying with the monitoring requirements in 10 CFR 20.1502(b)
 - The concentration of any radionuclide disregarded is less than 10% of its DAC
 - The sum of these percentages for all the radionuclides disregarded in the mixture does not exceed 30 %
- AAI may assume the following:
 - In order to calculate the committed effective dose equivalent, AAI may assume that the inhalation of one ALI, or an exposure of 2,000 DAC-hours, results in a committed effective dose equivalent of 5 rem (0.05 Sv) for radionuclides that have their ALIs or DACs based on the committed effective dose equivalent.
 - When the ALI (and the associated DAC) is determined by the non-stochastic organ dose limit of 50 rem (0.5 Sv), the intake of radionuclides that would result in a committed effective dose equivalent of 5 rem (0.05 Sv) (the stochastic ALI) is listed in parentheses in Table 1 of 10 CFR 20, Appendix B. In this case, AAI may, as a simplifying assumption, use the stochastic ALIs to determine committed effective dose equivalent. As such, AAI would also demonstrate compliance to 20.1201(a)(1)(ii)--sum of the deep-dose equivalent and the committed dose equivalent to any individual organ or tissue other than the lens of the eye less than 50 rem (0.5 Sv).