3.2 Radiation Protection

Design Description

The ABWR design provides radiation protection features to keep exposures for both plant personnel and the general public below allowable limits. This section applies to the radiological shielding and ventilation design of the Reactor Building, Turbine Building, Control Building, Service Building, and Radwaste Building.

The plant design provides radiation shielding for rooms, corridors and operating areas commensurate with their occupancy requirements. Shielded cubicles, labyrinth access and provisions for temporary shielding are used to reduce exposure. Under accident conditions, plant shielding designs permit operators to perform required safety functions in vital areas of the plant. A vital area is an area which will or may require occupancy to permit an operator to aid in the mitigation of or recovery from an accident. In addition to protection of operating personnel, the plant design provides radiation shielding to protect the general public.

Plant ventilation systems maintain concentrations of airborne radionuclides at levels consistent with personnel access requirements. In addition, airborne radioactivity monitoring is provided for those normally occupied areas of the plant in which there exists a significant potential (greater than 0.1 per year) for airborne contamination.

Inspections, Tests, Analyses and Acceptance Criteria

Tables 3.2a and 3.2b provide a definition of the inspections, tests, and/or analyses, together with associated acceptance criteria, which will be undertaken for the ABWR plant shielding, ventilation and airborne monitoring equipment.

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Figure 3.2a Reactor Building Radiation Zone Map for Full Power and Shutdown Operations, Section A-A

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Figure 3.2b Reactor Building Radiation Zone Map for Full Power and Shutdown Operations, Section B-B

Redacted Security-Sensitive Information

Figure 3.2c Reactor Building Radiation Zone Map for Full Power and Shutdown Operations, Floor B3F—Elevation –8200 mm

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Figure 3.2d Reactor Building Radiation Zone Map for Full Power and Shutdown Operations—Elevation –5100 mm

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Figure 3.2e Reactor Building Radiation Zone Map for Full Power and Shutdown Operations, Floor B2F—Elevation –1700 mm

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Figure 3.2f Reactor Building Radiation Zone Map for Full Power and Shutdown Operations—Elevation 1500 mm

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Figure 3.2g Reactor Building Radiation Zone Map for Full Power and Shutdown Operations, Floor B1F—Elevation 4800 mm

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Figure 3.2h Reactor Building Radiation Zone Map for Full Power and Shutdown Operations—Elevation 8500 mm

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Figure 3.2i Reactor Building Radiation Zone Map for Full Power and Shutdown Operations, Floor 1F—Elevation 12300 mm

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Figure 3.2j Reactor Building Radiation Zone Map for Full Power and Shutdown Operations, Floor 2F—Elevation 18100 mm

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Figure 3.2k Reactor Building Radiation Zone Map for Full Power and Shutdown Operations, Floor 3F—Elevation 23500 mm

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Figure 3.2l Reactor Building Radiation Zone Map for Full Power and Shutdown Operations—Elevation 27200 mm

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Figure 3.2m Reactor Building Radiation Zone Map for Full Power and Shutdown Operations, Floor 4F—Elevation 31700mm

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Figure 3.2n Reactor Building Radiation Zone Map for Full Power and Shutdown Operations—Elevations 34500 mm and 38200 mm

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Figure 3.2o Control Building Radiation Zone Map for Full Power Operations, Section A-A

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Figure 3.2p Control Building Radiation Zone Map for Full Power Operations, Section B-B

Redacted Security-Sensitive Information

Figure 3.2q Control Building Radiation Zone Map for Full Power Operation, Floor B4F—Elevation –8200 mm

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Figure 3.2r Control Building Radiation Zone Map for Full Power Operation, Floor B3F—Elevation –2150 mm

Redacted Security-Sensitive Information

Figure 3.2s Control Building Radiation Zone Map for Full Power Operation, Floor B2F—Elevation 3500 mm

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Figure 3.2t Control Building Radiation Zone Map for Full Power Operation, Floor B1F—Elevation 7900 mm

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Figure 3.2u Control Building Radiation Zone Map for Full Power Operation, Floor 1F—Elevation 12300 mm

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Figure 3.2v Control Building Radiation Zone Map for Full Power Operation, Floor 2F—Elevation 17150 mm

Table 3.2a Plant Shielding Design

Inspections, Tests, Analyses and Acceptance Criteria		
Design Commitment	**Inspections, Tests, Analyses**	**Acceptance Criteria**
1. The plant design shall provide radiation shielding for rooms, corridors and operating areas commensurate with their occupancy requirements.	1. An analysis of the expected radiation levels in each plant area will be performed to verify the adequacy of the shielding design. This analysis shall consider the following: a. Confirmatory calculations shall consider significant radiation sources (greater than 5% contribution) for an area. Radiation source strength in plant systems and components will be determined based upon an assumed source term of 3,700 MBq/s offgas release rate (after 30 minutes decay), a 11.1 MBq/gram-steam N-16 source term at the vessel exit nozzle, and a core inventory commensurate with a 4005 MW_t equilibrium core at 51.6 kW/liter. Source terms shall be adjusted for radiological decay and buildup of activated corrosion and wear products. b. Commonly accepted shielding codes, using nuclear properties derived from well known references (such as Vitamin C and ANSI/ANS-6.4) shall be used to model and evaluate plant radiation environments. (1) For non-complex geometries, point kernel shielding codes (such as QAD or GGG) shall be used.	1. Maximum expected radiation dose rates in each plant area (deep dose equivalent measured at 30 cm from the source of the radiation, not contact dose rates) are no greater than the dose rates specified for the following zones, based on the access requirements of that area for plant operation and maintenance. (see zone table below)

Zone	Dose Rate (μSv/h)	Access Requirements
A	≤6	Uncontrolled, unlimited access.
B	<10	Controlled, unlimited access.
C	<50	Controlled, limited access 20 h/week.
D	<250	Controlled, limited access 4 h/week.
E	<1000	Controlled, limited access 1 h/week.
F	≥1000	Restricted, infrequent access. Authorization required.

Table 3.2a Plant Shielding Design (Continued)

Inspections, Tests, Analyses and Acceptance Criteria		
Design Commitment	**Inspections, Tests, Analyses**	**Acceptance Criteria**
	(2) For complex geometries, more sophisticated two or three dimensional transport codes (such as DORT or TORT) shall be used.	Plant layout such that access to higher zones (areas with higher dose rates) is from lower zoned areas. Corridors and normal traffic areas are Zone C or less. Control rooms are Zone B or less. Radiation zones for the Reactor Building and Control Building are indicated in Figures 3.2a through 3.2v.
	c. A safety factor shall be applied based upon benchmark comparisons.	
2. The plant design shall provide shielded cubicles, labyrinth access, and space for temporary shielding to reduce radiation exposure from adjacent rooms.	2. Using the methods identified in (1) above, radiation levels present in rooms shall be evaluated for the contribution from adjacent rooms.	2. Shielding design of a room including any temporary shielding is such that radiation from adjacent rooms shall contribute no more than a small fraction (10% or less) of the dose rate or less than 0.6 μSv/h whichever is larger, in the room. For this purpose, the drywell shall be considered a room.
3. The plant radiation shielding design shall permit plant personnel to perform required safety functions in vital areas of the plant (including access and egress of these areas) under accident conditions.	3. An analysis of the expected high radiation levels in each area which will or may require occupancy to permit plant personnel to aid in the mitigation of or recovery from an accident (vital area) shall be performed to verify the adequacy of the plant shielding design. This analysis shall use calculational methods consistent with (1.b) above and a radiation source term (adjusted for radioactive decay) based on the following:	3. Under accident conditions, radiation shielding design allows access to occupancy and egress from areas required to maintain post-accident safety functions such that individual personnel radiation doses do not exceed 0.05 Sv to the whole body, or its equivalent, for the duration of the accident (based on the required frequency of access to each vital area).

Table 3.2a Plant Shielding Design (Continued)

Inspections, Tests, Analyses and Acceptance Criteria		
Design Commitment	**Inspections, Tests, Analyses**	**Acceptance Criteria**
3. (continued)	3. (continued) a. Liquid containing systems: 100% of the core equilibrium noble gas inventory, 50% of the core equilibrium halogen inventory and 1% of the equilibrium core inventory of the remaining radionuclides are assumed to be mixed in the reactor coolant and recirculation liquids recirculated by the Residual Heat Removal (RHR) System, the High Pressure Core Flooder (HPCF) System, and the Reactor Core Isolation Cooling (RCIC) System. b. Gas containing systems: 100% of the core equilibrium noble gas inventory and 25% of the core equilibrium halogen activity are assumed to be mixed in the containment atmosphere. For vapor containing systems (such as the main steam lines), these core inventory fractions are assumed to be contained in the reactor coolant vapor space.	3. (continued) For areas requiring continuous occupancy (such as the main control room, technical support center, and emergency operations support center), design dose rates shall not exceed 150 μSv/h (averaged over 30 days).
4. The plant design shall provide radiation shielding to protect the general public outside of the controlled area.	4. Using the methods identified in (1) above, the radiation dose to the maximally exposed member of the general public outside of the controlled area from direct and scattered radiation shine shall be determined.	4. As a result of normal operations, the radiation dose from direct and scattered radiation shine to the maximally exposed member of the public outside of the controlled area is equal to or less than 25 μSv/year.

Table 3.2b Ventilation and Airborne Monitoring

Inspections, Tests, Analyses and Acceptance Criteria

Design Commitment	Inspections, Tests, Analyses	Acceptance Criteria
1. Plant design shall provide for containment of airborne radioactive materials and the ventilation system will maintain concentrations of airborne radionuclides at levels consistent with personnel access needs.	1. Expected concentrations of airborne radioactive material shall be calculated by radionuclide for normal plant operations and anticipated operational occurrences for each equipment cubicle, corridor, and operating area requiring personnel access. Calculations shall consider:	1. Calculation of radioactive airborne concentration shall demonstrate that:
	a. Total ventilation flow rates for each area.	a. For normally occupied rooms and areas of the plant (i.e., those areas requiring routine access to operate and maintain the plant), equilibrium concentrations of airborne radionuclides will be a small fraction (10% or less) of the occupational concentration limits listed in 10CFR20 Appendix B, January 1994.
	b. Typical leakage characteristics for equipment located in each area.	b. For rooms that require infrequent access (such as for non-routine equipment maintenance), the ventilation system shall be capable of reducing radioactive airborne concentrations to (and maintaining them at) the occupational concentration limits listed in 10CFR20 Appendix B, January 1994,during the periods that occupancy is required.
	c. A radiation source term in each fluid system based upon an assumed offgas rate of 3,700 MBq/s (30 minute decay) appropriately adjusted for radiological decay and buildup of activated corrosion and wear products.	c. For rooms where access is not anticipated to perform scheduled maintenance or surveillance (such as the backwash receiving tank room), plant design shall provide containment and ventilation to reduce airborne contamination spread to other areas of lower contamination.

Table 3.2b Ventilation and Airborne Monitoring (Continued)

Inspections, Tests, Analyses and Acceptance Criteria		
Design Commitment	**Inspections, Tests, Analyses**	**Acceptance Criteria**
2. Airborne radioactivity monitoring shall be provided for those normally occupied areas of the plant in which there exists a significant potential for airborne contamination (greater than 0.1 per year). The airborne radioactivity system shall: a. Have the capability of detecting the time integrated concentrations of the most limiting internal dose particulate and iodine radionuclides in each area equivalent to the occupational concentration limits in 10CFR20, Appendix B, January 1994, for 10 hours. b. Provide a calibrated response, representative of the concentrations within the area (i.e., air sampling monitors in ventilation exhaust streams shall collect an isokinetic sample). c. Provide local audible alarms (visual alarms in high noise areas) with variable alarm setpoints, and readout/annunciation capability.	2. An analysis shall be performed to identify the plant areas that require airborne radioactivity monitoring.	2. Airborne radioactivity monitoring system shall be installed as defined in this certified design commitment.