12.3 Radiation Protection Design Features

12.3.1 Facility Design Features

Specific design features for maintaining personnel exposure as low as reasonably achievable (ALARA) are presented in this subsection. The design feature recommendations given in Regulatory Guide 8.8 are utilized to minimize exposures to personnel.

12.3.1.1 Plant Design Features for ALARA

The equipment and plant design features employed to maintain radiation exposures ALARA are based upon the design considerations of subsection 12.1.2 and are outlined in this subsection.

12.3.1.1.1 Common Equipment and Component Designs for ALARA

This subsection describes the design features utilized for several general classes of equipment or components. These classes of equipment are common to many of the plant systems; thus, the features employed for each system to maintain minimum exposures are similar and are presented by equipment class in the following paragraphs.

Reactor Vessel

The reactor vessel design includes an integrated head package which combines the head lifting rig, control and gray rod drive mechanism (CRDM/GRDM), lift columns, control rod drive mechanism cooling system and power and instrumentation cabling into an effective, one-package reactor vessel head design. Mounted directly on the reactor vessel head assembly, the system helps to minimize the time, manpower, and radiation exposure associated with head removal and replacement during refueling. Integral in the design is permanent shielding for reducing work area dose rates from the control rod drive mechanism drive shafts.

The combination thermocouple/incore detector system is not kept with head assembly during refueling, but instead remains with the upper internals. This allows the thermocouple/incore detector system to be shielded underwater in the refueling cavity during a majority of refueling operations, reducing dose rates around the head assembly.

The reactor vessel nozzle welds are designed to accommodate remote inspection with ultrasonic sensors. The nozzle area is tapered along the reinforced areas to provide a smooth transition, and pipe branch locations are selected to avoid interference from one branch to the next. Weld-to-pipe interfaces require a smooth, high quality finish.

Reactor Coolant Pumps

The sealless high-inertia reactor coolant pumps are designed to require infrequent maintenance and inspection. When maintenance or replacement is required, the pump can be removed and moved to a low radiation background work area using a specially provided pump removal cart.

Reactor Vessel Insulation

Insulation in the area of the reactor vessel nozzle welds is fabricated in sections with a thin reflective metallic sheet covering and quick disconnect clasps to facilitate removal of the insulation. Permanent identification markings of the sections of insulation are provided to accommodate rapid reinstallation.

Steam Generators

The steam generator incorporates many design features to facilitate maintenance and inspection in reduced radiation fields. The tube ends are designed to be flush with the tube sheet in the steam generator channel head to eliminate a potential crud trap. The steam generator manways (entrance to channel head) are sized for easy entrance and exit of workers with protective clothing, and to facilitate the installation and removal of tooling.

The specification of low cobalt tubing material for the AP1000 steam generator design is an important feature of the design; not only in terms of reduced exposure relative to the steam generator, but to the total plant radiation source term. The cobalt content has been substantially reduced to 0.015 weight percent for the AP1000 steam generator tubing.

The steam generator design includes a sludge control system/mud drum which is designed to reduce the need for sludge lancing, and reduces tube and tube support degradation. Steam generator tube support plates design and full depth tubesheet expansion of tubes reduce corrosion and occupational exposure.

Reactor Coolant Pipe Connections

To minimize crud buildup in branch lines, piping connections to the reactor coolant loops are located on or above the horizontal centerline of the pipe wherever practicable.

Filters

Cartridges and filter bags that accumulate radioactivity are removed with semi-remote tools. Adequate space is provided to allow removing, and transporting the cartridge to storage and packaging areas as described in Section 11.4.

Liquid systems containing radioactive filters are provided with remote or semi-remote filter handling systems for the removal of spent radioactive filter elements from their housings and for their transfer to temporary storage or for packaging and shipment from the site for burial. The process is accomplished in such a manner that exposure to personnel and the possibility of inadvertent radioactive release to the environment is minimized. The filter handling is designed to be simple, with a minimum of components susceptible to malfunction.

Demineralizers

Demineralizers for radioactive systems are designed so that spent resins can be remotely and hydraulically transferred to spent resin tanks prior to processing and so that fresh resin can be loaded into the demineralizer remotely. The demineralizers and piping include provisions for being flushed with demineralized water. The system design prevents inadvertent flushing of the resin into the purification loop through the demineralizer inlet.

Pumps

Air operated diaphragm, sealless pumps or pumps with mechanical seals are used in radioactive systems to reduce leakage and seal servicing time. Pumps and associated piping are arranged to provide adequate space for access to the pumps for servicing. Small pumps are installed in a manner which allows easy removal if necessary. Large pumps are selected with back pullout features that permit removal of the pump impeller or mechanical seals without disassembly of attached piping. Pumps in radioactive waste systems are provided with flanged connections for ease of removal.

Tanks and Sumps

Tanks are provided with sloped bottoms and bottom outlet connections. Overflow lines are directed to the waste collection system to control contamination within plant structures. Tanks containing radioactivity are fabricated from stainless steel, and sumps which can contain radioactive liquid are lined with stainless steel to facilitate decontamination.

Heat Exchangers

Vertical heat exchangers are designed so that the shell-to-tube sheet joint need not be broken for inspection. The shell and tube assembly can be lifted intact above the channel head to expose the tube ends for inspection and testing for leaks.

Heat exchangers are provided with corrosion-resistant tubes of stainless steel to reduce leakage. Impingement plates are provided and as necessary and tube side and shell side velocities are limited to minimize erosive effects. Wherever practicable, the radioactive fluid passes through the tube side of the heat exchanger.

Instruments

Instrument devices are located in low radiation zones away from radiation sources whenever practicable. Primary instrument devices, which for functional reasons are located in high radiation zones, are designed for easy removal to a lower radiation zone for calibration. Transmitters and readout devices are located in low radiation zones, such as corridors for servicing. Non-contact type instruments or self cleaning instruments are used whenever possible.

Some instruments in high radiation zones, such as thermocouples, are provided in duplicate to reduce access and service time required. In-containment instruments are located outside the secondary shield (area of lower radiation at power and shutdown) whenever practicable.

Integral radiation check sources for response verification for airborne radiation monitors and area radiation monitors are provided.

Chemical seals are provided on the instrument sensing lines on process piping, which may contain highly radioactive solids, to reduce the servicing time required to keep the lines free of solids.

Instrument and sensing line connections are located slightly above the pipe midplane wherever practicable to minimize radioactive crud buildup.

Valves

To minimize personnel exposures from valve operations, motor-operated, air-operated, or other remotely actuated valves are used where justified by the activity levels and frequency of use. Valves are located in valve galleries so that they are shielded separately from the major components. Long runs of exposed piping are minimized in valve galleries. In areas where manual valves are used on frequently operated process lines, either valve stem extenders or shielding is provided such that personnel need not enter a high radiation area for valve operation.

Wherever testing is required, valves of the bolted body-to-bonnet forging type are used to permit the use of ultrasonic testing in place of radiography. This facilitates inspection and maintenance time. Valves under 2 inches in diameter located in the piping carrying radioactive fluids in containment or carrying highly radioactive fluids outside containment are hermetically sealed (packless) valves to preclude radioactive releases to the environment. The design of large-bore valves includes live-loaded packing and graphite packing materials to reduce the potential for steam leakage.

When equipment in high radiation areas is operated infrequently, those valves associated with normal processing are provided with remote-manual operators or reach rods. Other valve operations are performed with equipment in the shutdown mode.

For valves located in radiation areas, provisions are made to drain adjacent radioactive components when maintenance is required. To the extent practicable, valves are not located at piping low points.

Manually operated valves in the filter and demineralizer modules required for normal operation and shutdown are equipped with reach rods extending through the shield plates. Personnel do not enter the module during spent resin or cartridge transfer operations. The modules are designed to reduce personnel exposure during maintenance of components within or adjacent to the modules and to protect personnel who operate the valves.

Piping

The piping in pipe chases is designed for 60 year design objective with consideration for corrosion and operating environment. Pipe bends are used instead of elbows where practicable to reduce potential crud traps. Welds are made smooth to prevent crud traps from forming. Butt welds are used to the extent practicable. When radioactive piping is routed through areas where routine maintenance is required, pipe chases or distance separation are provided to reduce the radiation contribution from these pipes to levels appropriate for the inspection or maintenance requirements. Piping containing radioactive material is routed to minimize radiation exposure to plant personnel.

Floor and Equipment Drains

Floor drains and sloped floors are provided for rooms or cubicles containing serviceable components which contain radioactive liquids. When practicable, shielded pipe chases are used for radioactive pipes. Floor coatings are specified which simplify cleanup of spills. If a radioactive drain line must pass through a plant area requiring personnel access, shielding or distance separation is provided as necessary to maintain radiation levels consistent with the required access.

Lighting

Wherever practicable, multiple electric lights are provided for rooms containing highly radioactive components so that the burnout of a single lamp does not require entry and immediate replacement of the defective lamp since sufficient illumination is still available. Incandescent lights are provided inside containment and in the fuel handling area. They require less time for servicing and, hence, the personnel exposure is reduced. The fluorescent lights which are used outside containment do not require frequent service due to the increased life of the tubes. Burned out lamps can be replaced when the radioactive system is drained and flushed.

Heating, Ventilation, and Air-Conditioning

The heating, ventilation, and air-conditioning (HVAC) system design facilitates replacement of the filter elements. Ventilation airflow is routed from areas of lower potential airborne contamination to areas of potentially higher contamination. In the radiologically-controlled area ventilation system (VAS) high airborne activity causes the exhaust air to be rerouted through HEPA and charcoal filters in the containment air filtration system (VFS).

Sample Stations

Proper shielding and ventilation are provided at the primary sample room to minimize personnel exposure during sampling. The counting room and laboratory facilities are described in Section 12.5. The use of concrete containing fly ash is prohibited for the counting room and laboratory areas.

Clean Services

Whenever practicable, clean services and equipment such as compressed air piping, clean water piping, ventilation ducts, and cable trays are not routed through radioactive pipeways.

Materials

Equipment specifications for components exposed to high temperature reactor coolant contain limitations on the cobalt content of the base metal as given in Table 12.3-1. The use of hard facing material with cobalt content such as stellite is limited to applications where its use is necessary for reliability considerations. Nickel-based alloys in the reactor coolant system (Co-58 is produced from activation of Ni-58) are similarly used only where component reliability may be compromised by the use of other materials. The major use of nickel-based alloys in the reactor coolant system is the inconel steam generator tubes.

General prohibitions on antimony and other low melting point metals are contained in subsection 6.1.1. In addition, the reactor coolant pump mechanical design criteria prohibits antimony completely from the reactor coolant pump and its bearings.

Single Integrated Gripper Mast Assembly Refueling Machine

To minimize the radiation exposure during refueling, a single integrated gripper mast assembly refueling machine is used. The machine permits removal and insertion of thimble plugs or rod control cluster assemblies while a fuel assembly is being handled by the refueling machine.

Improved Head Closure System

The head closure system is designed to minimize the reactor head stud tensioning time.

12.3.1.1.2 Common Facility and Layout Designs for ALARA

This subsection describes the design features utilized for standard plant process and layout situations. These features are employed in conjunction with the general equipment described in subsection 12.3.1.1.1 and include the features described in the following paragraphs.

Valve Modules

Selected valve modules are provided with shielded entrances for personnel protection. Floor drains are provided to control radioactive leakage. To facilitate decontamination, concrete surfaces are covered with a smooth surface coating which allows decontamination.

Piping

Pipes carrying radioactive materials are routed through controlled access areas properly zoned for that level of activity. Radioactive piping runs are analyzed to determine the potential radioactivity level and surface dose rate. Where it is necessary that radioactive piping be routed through corridors or other low radiation zone areas, shielded pipeways or distance separation are provided. Whenever practicable, valves and instruments are not placed in radioactive pipeways. Equipment compartments are used as pipeways for those pipes associated with equipment in the compartment.

When practicable, radioactive and nonradioactive piping are separated to minimize personnel exposure. Should maintenance be required, provision is made to isolate and drain radioactive piping and associated equipment.

Piping is designed to minimize low points and dead legs. Drains are provided on piping where low points and dead legs cannot be eliminated. In radioactive systems, the use of nonremovable backing rings in the piping joints is prohibited. Whenever practicable, branch lines having little or no flow during normal operation are connected above the horizontal midplane of the main pipe.

Piping which carries resin slurries is run vertically and horizontal runs carrying spent resin are sloped toward the spent resin tanks, as much as practicable. Large radius bends are utilized instead of elbows. Where sloped lines or large radius bends are impractical, adequate flush and drain capability is provided to prevent flow blockage and minimize crud traps.

The use of embedded pipes is minimized to the extent possible, consistent with maintaining radiation doses ALARA. To the extent possible, pipes are routed in accessible areas, such as dedicated pipe routing tunnels or pipe trenches, which provide good conditions for decommissioning.

Wall Penetrations

To minimize radiation streaming through wall penetrations, as many wall penetrations as practicable are located with offsets between the radioactive source and the normally accessible areas. If offsets are not practicable, penetrations are located as far as practicable above the floor elevation to reduce radiation exposure to personnel. If these two methods are not used, alternate means are employed, such as baffle shield walls or grouting the penetration annulus.

Contamination Control

Access control and traffic patterns are considered in the plant layout to reduce the spread of contamination. Equipment vents and drains from highly radioactive systems are piped directly to the collection system to minimize airborne and floor contamination. Welded piping systems are employed on radioactive systems to the maximum extent practicable to reduce system leakage and crud buildup at joints.

The number of passageways (doors) between the radiologically controlled area and the environment has been minimized. When such doors are incorporated, systems of drains and floor and exterior concrete sloping are used to prevent (potentially radioactive) fluid from the interior of the buildings from exiting the buildings, and also to prevent surface water from entering the buildings.

Decontamination of potentially contaminated areas and equipment within the plant is facilitated by the application of epoxy paints and suitable smooth-surface coatings to the concrete floors and walls. Sloping floors with floor drains are provided in potentially contaminated areas of the plant. In addition, radioactive and potentially radioactive drains are separated from nonradioactive drains.

In radiologically controlled areas where contamination is expected, radiation monitoring equipment is provided (Section 11.5). Those systems that become highly radioactive, such as the spent resin lines in the radwaste system, are provided with flush and drain connections.

Because of the potential for adsorption of contaminated fluids, the use of concrete block walls in the radiologically controlled areas of the plant is minimized. Where such walls are used, they are fully sealed at the ceiling or top of the block in order to prevent liquid incursion.

The role of the ventilation systems in minimizing the spread of airborne contamination is described in subsection 12.3.3.

Equipment Layout

In those systems where process equipment is a major radiation source; pumps, valves, and instruments are separated from the process component. This allows servicing and maintenance of these items in reduced radiation zones. Control panels are located in low radiation zones.

Major components such as tanks, demineralizers, and filters in radioactive systems are located in shielded compartments insofar as practical. Labyrinth shields or shielding doors are provided for compartments where radiation could stream or scatter to access areas and exceed the radiation zone dose limits for those areas. For potentially high radiation components (such as ion exchangers, filters and spent resin tanks), shielded compartments with hatch openings or removable shield walls are used. Equipment in nonradioactive systems that requires lubrication is located in low radiation zones. Wherever practicable, lubrication of equipment in high radiation areas is achieved with the use of tube-type extensions to reduce exposure during maintenance.

Exposure from routine in-plant inspection is controlled by locating, whenever practicable, inspection points in low-background radiation areas. Radioactive and nonradioactive systems are separated as far as practicable to limit radiation exposure from routine inspection of nonradioactive systems. For radioactive systems, emphasis is placed on adequate space and ease of motion in a properly shielded inspection area. Where longer times for routine inspection are required and permanent shielding is not feasible, space for portable shielding is provided.

Field Run Piping

Field run radioactive piping is minimized in the plant design. Radioactive process piping is routed dimensionally on orthographic drawings. Fabrication isometrics of radioactive process piping are reviewed to provide adequate shielding.

12.3.1.2 Radiation Zoning and Access Control

Access to areas inside the plant structures and plant yard area is regulated and controlled by posting of radiation signs, control of personnel, and use of alarms and locks (Section 12.5). During plant operation, access to radiologically restricted areas is through the access control area in the annex building.

Plant areas are categorized into radiation zones according to design basis radiation levels and anticipated personnel occupancy with consideration given toward maintaining personnel exposures ALARA and within the standards of 10 CFR 20. Rooms, corridors, and pipeways are evaluated for potential radiation sources during normal, shutdown, spent resin transfer, and emergency operations; for maintenance occupancy requirements; for general access requirements; and for material exposure limits to determine appropriate zoning. Each radiation zone defines the radiation level range expected in the zone. The radiation zone categories employed and zoning for each plant area under normal conditions is shown in Figure 12.3-1. The zoning for each plant area under accident conditions is shown in Figure 12.3-2. Radiation zones shown in the figures are based upon conservative design data. Actual in-plant zones and control of personnel access are based upon surveys conducted by the Combined License holder. Access control provisions for each plant area under normal expected conditions are shown in Figure 12.3-3. These provisions implement the requirements of 10 CFR 20 and utilize the alternative access control methods outlined in Regulatory Guide 8.38.

Based on actual operating plant data, ingress or egress of plant operating personnel to radiologically restricted areas is controlled and monitored as discussed in subsection 12.3.5 such that radiation levels and exposures are within the limits prescribed in 10 CFR 20.

Posting of radiation signs, control of personnel access, and use of alarms and locks are discussed in subsection 12.3.5.

12.3.2 Shielding

The bases for the nuclear radiation shielding and the shielding configurations are discussed in this subsection.

12.3.2.1 Design Objectives

The objective of the plant radiation shielding is to minimize personnel and population exposures, while maintaining a program of controlled personnel access to and occupancy of radiation areas. Radiation levels are within the requirements of 10 CFR 50 during design basis accidents and ALARA within the requirements of 10 CFR 20 during normal operation. Shielding and equipment layout and design are considered in providing confidence that exposures are kept ALARA during anticipated personnel activities in areas of the plant containing radioactive materials. Design recommendations given in Regulatory Guide 8.8 are utilized where practicable.

The nuclear radiation shielding is designed to provide personnel protection and is based on the following operating states:

- Normal, full-power operation
- Shutdown operation
- Spent resin transfer
- Emergency operations (for required access to safety-related equipment)

The shielding design objectives for the plant during these operating states are:

- Radiation exposure to plant operating personnel, contractors, administrators, visitors, and site boundary occupants is ALARA and within the limits of 10 CFR 20.

- Sufficient personnel access and occupancy time is provided to allow normal anticipated maintenance, inspection, and safety-related operations required for each plant equipment and instrumentation area.

- Reduce potential equipment neutron activation and mitigate the effects of radiation on materials.

- Provide sufficient shielding for the control room so that for design basis accidents (DBAs) the direct dose plus the inhalation dose (calculated in Chapter 15) does not exceed the limits of 10 CFR 50, Appendix A, General Design Criterion 19.

12.3.2.2 General Shielding Design

Systems containing radioactivity and other sources of radiation are identified for four plant conditions defined in subsection 12.3.2.1. Shielding is provided to attenuate direct radiation through walls and penetrations and scattered radiation to less than the upper limit of the radiation zone for each area shown in Figure 12.3-1. Design criteria for shield penetrations are consistent with the recommendations of Regulatory Guide 8.8 and are described in subsection 12.3.1.1.2.

Materials used in shielding typically include lead, steel, water, and concrete. The material used for most of the plant shielding is ordinary concrete with a bulk density of approximately 140 lb/ft^3. Whenever poured-in-place concrete has been replaced by concrete blocks, an equivalent shielding basis as determined by the density of the concrete block is selected. Steel is used as shielding in the chemical and volume control system and other modules, as well as around the reactor vessel flange at the floor of the refueling cavity. Water is used as the primary shield material for areas above the spent fuel storage area and refueling cavity during refueling operations.

12.3.2.2.1 Containment Shielding Design

During reactor operation, the shield building protects personnel occupying adjacent plant structures and yard areas from radiation originating in the reactor vessel and primary loop components. The concrete shield building wall and the reactor vessel and steam generator compartment shield walls reduce radiation levels outside the shield building to less than 0.25 mrem/hr from sources inside containment. The shield building completely surrounds the reactor coolant system components.

For design basis accidents, the shield building and the main control room shielding reduce the plant radiation intensities from fission products inside the containment to acceptable levels, as defined by 10 CFR 50, Appendix A, General Design Criterion 19, for the main control room. (See subsection 12.3.2.2.7.)

Where personnel locks and equipment hatches or penetrations pass through the shield building wall, additional shielding is provided to attenuate radiation to the level defined by the outside radiation zone during normal operation and shutdown, and to acceptable levels during design basis accidents as defined by General Design Criterion 19.

12.3.2.2.2 Containment Interior Shielding Design

During reactor operation, many areas inside the containment are Zone V or greater and are normally inaccessible. Shielding is provided to reduce dose rates to approximately 100 mrem/hr or less in areas of the containment that potentially require access at power. These are the Zone IV or lower areas shown in Figure 12.3-1.

The main sources of radiation are the reactor vessel and the primary loop components, consisting of the steam generators, pressurizer, reactor coolant pumps, and associated piping. The reactor vessel is shielded by the concrete primary shield and by the concrete secondary shield which also surrounds other primary loop components. Air cooling is provided to prevent overheating, dehydration, and degradation of the shielding and structural properties of the primary shield.

The primary shield is a large mass of reinforced concrete surrounding the reactor vessel. The primary shield meets the following objectives:

- In conjunction with the secondary shield, reduce the radiation level from sources within the reactor vessel and reactor coolant system to allow limited access to the containment during normal, full-power operation.

- After shutdown, limit the radiation level from sources within the reactor vessel, permit limited access to the reactor vessel and the reactor coolant system equipment.

- Limit neutron activation of component and structural materials.

The secondary shield is a structural module filled with concrete surrounding the reactor coolant system equipment, including piping, pumps, and steam generators. This shield protects personnel from the direct gamma radiation resulting from reactor coolant activation products and fission products carried away from the core by the reactor coolant. In addition, the secondary shield supplements the primary shield by attenuating neutron and gamma radiation escaping from the primary shield. The secondary shield is sized to allow limited access to the containment during full-power operation.

The reactor cavity has been designed so that the dose rates on the operating deck due to neutron streaming are less than 100 mrem/hr.

Components of the purification portion of the chemical and volume control system (CVS) in the containment are located in a shielded compartment. Shielding is provided for equipment in the purification system consistent with its postulated maximum activity (subsection 12.2.1) and with the access and zoning requirements of adjacent areas. This equipment includes the regenerative heat exchanger, the letdown heat exchanger, chemical and volume control system filters and demineralizers, and the letdown lines.

After shutdown, the containment is accessible for limited periods of time and access is controlled. Areas are surveyed to establish allowable working periods. Dose rates are expected to range from 0.5 to 1000 mrem/hr, depending on the location inside the containment (excluding reactor cavity). These dose rates result from residual fission products and neutron activation products (components and corrosion products) in the reactor coolant system.

Spent fuel is the primary source of radiation during refueling. Because of the high activity of the fission products contained in the spent fuel elements, extensive shielding is provided for areas surrounding the refueling cavity and the fuel transfer canal to limit the radiation levels to below zone levels specified for adjacent areas. Water provides the shielding over the spent fuel assemblies during fuel handling.

12.3.2.2.3 Auxiliary Building Shielding

During normal operations, the major components in the auxiliary building with potentially high radioactivity are those in liquid radwaste, gaseous radwaste, and spent resin handling systems. Shielding is provided consistent with the postulated maximum activity (See Sections 11.1, 11.2, 11.3, and 12.2) and with the access and zoning requirements of adjacent areas. (See Figure 12.3-1.)

Depending on the equipment in the compartments, the radiation zones vary. Corridors are generally shielded to allow Zone II access, and operator areas for valve modules are generally Zone II or III for access.

Concrete plugs are utilized to provide necessary access for equipment maintenance and spent filter cartridge replacement. Where necessary, labyrinth entrances with provisions for adequate ingress and egress for equipment maintenance and inspection are provided and are designed to be consistent with the access and zoning requirements of adjacent areas.

Following reactor shutdown, the normal residual heat removal (RNS) system pumps and heat exchangers are in operation to remove heat from the reactor coolant system. The radiation levels in the vicinity of this equipment temporarily reach Zone V or higher levels due to corrosion and fission products in the reactor coolant water. Shielding is provided to attenuate radiation from normal residual heat removal equipment during shutdown cooling operations to levels consistent with the radiation zoning requirements of adjacent areas.

12.3.2.2.4 Fuel Handling Area Shielding Design

The concrete shield walls surrounding the spent fuel cask loading and decontamination areas, and the shield walls surrounding the fuel transfer and storage areas are sufficiently thick to limit radiation levels outside the shield walls in accessible areas to Zone II. The building external walls are sufficient to shield external plant areas which are not controlled to Zone I.

Spent fuel removal and transfer operations are performed under borated water to provide radiation protection and maintain subcriticality. Minimum allowable water depths above active fuel in a fuel assembly during fuel handling are 8.75 feet in the reactor cavity and 8.75 feet in the fuel transfer canal and spent fuel pool. This limits the dose to personnel on the spent fuel pool handling machine to less than 2.5 mrem/hr for an assembly in a vertical position. Minimum water depth above the stored assemblies is about 26 feet, and for this depth the dose rate at the pool surface is insignificant. The concrete walls of the fuel transfer canal and spent fuel pool walls supplement the water shielding and limit the maximum radiation dose levels in working areas to less than 2.5 mrem/hr.

The spent fuel pit cooling system (SFS) shielding (Section 9.1) is based on the activity discussed in subsection 12.2.1 and the access and zoning requirements of adjacent areas. Equipment in the spent fuel pit cooling system to be shielded includes the spent fuel cooling system heat exchangers, pumps, piping, filters and demineralizers which may be contaminated with radioactive crud.

12.3.2.2.5 Radwaste Building Shielding Design

Shielding is provided as necessary for the waste storage areas in the radwaste building to meet the radiation zone and access requirements. Depending on the equipment in the compartments, the radiation zoning varies from Zone I through IV as shown on the radiation zone drawing of Figure 12.3-1. Temporary partitions and shield walls will be provided, as required, to supplement the permanent shield walls surrounding the waste accumulation and packaged waste storage rooms inside the radwaste building.

12.3.2.2.6 Turbine Building Shielding Design

The steam generator blowdown demineralizers are shielded to meet the radiation zone and access requirements. Radiation shielding is not required for other process equipment located in the turbine building. Space has been provided so that shielding may be added around the condensate polishing demineralizers if they become radioactive.

12.3.2.2.7 Control Room Shielding Design

The design basis loss-of-coolant accident dictates the shielding requirements for the control room. Consideration is given to shielding provided by the shield building structure. Shielding combined with other engineered safety features is provided to permit access and occupancy of the control room following a postulated loss-of-coolant accident, so that radiation doses are limited to five rem whole body from contributing modes of exposure for the duration of the accident, in accordance with General Design Criterion 19.

12.3.2.2.8 Miscellaneous Plant Areas and Plant Yard Areas

Sufficient shielding is provided for plant buildings containing radiation sources so that radiation levels at the outside surfaces of the buildings are maintained below Zone I levels. Plant yard areas that are frequently occupied by plant personnel are fully accessible during normal operation and shutdown. Tanks containing radioactive materials are not located in the yard.

12.3.2.2.9 Spent Fuel Transfer Canal and Tube Shielding

The spent fuel transfer tube is shielded to within adjacent area radiation zone limits. This is primarily achieved through the use of concrete and water. The only removable shielding consists of concrete or steel hatches which reduce radiation in accessible areas to within those levels prescribed in the normal operation radiation zone maps (Figure 12.3-1).

The spent fuel transfer tube is completely enclosed in concrete and there is no unshielded portion of the spent fuel transfer tube during the refueling operation. The only potential radiation streaming path associated with the tube shielding configuration is the 2 inch (5.08 cm) seismic gap between the fuel transfer tube shielding and the steel containment wall. Shielding of this gap is provided by a water-filled bladder. This "expansion gap" radiation shield provides effective reduction of the radiation fields during fuel transfer and accommodates relative movement between the containment and the concrete transfer tube shielding with no loss in shield integrity. A removable hatch in the shield configuration provides access for inspection of the fuel transfer tube welds. The opening of this hatch is administratively controlled and is treated as an entrance to a very high radiation area under 10 CFR 20. This hatch is in place during the spent fuel transfer operation.

12.3.2.3 Shielding Calculational Methods

The shielding thicknesses provided for compliance with plant radiation zoning and to minimize plant personnel exposure are based on maximum equipment activities under the plant operating conditions described in Chapter 11 and Section 12.2. The thickness of each shield wall surrounding radioactive equipment is determined by approximating as closely as practicable the actual geometry and physical condition of the source or sources. The isotopic concentrations are converted to energy group sources using data from standard references (References 1 through 6).

The geometric model assumed for shielding evaluation of most tanks, heat exchangers, filters, ion exchangers, and the containment is a finite cylindrical volume source. For shielding evaluation of piping, the geometric model is a finite shielded cylinder. In cases where radioactive materials are deposited on surfaces such as pipe, the latter is treated as an annular cylindrical surface source.

Computer codes based on point kernel and Monte Carlo methods are used to calculate gamma dose rates. Most dose rates for non-complex geometries are calculated with a point kernel code MicroShield 6.20 (Reference 22), which is a PC shielding code with a menu-guided user-interface. For complex geometries, Monte Carlo or discrete ordinate methods were used for radiation analysis. Some simplifications are made in the modeling, concerning non-active components connected to the sources, and shielding. As a rule, these simplifications result in conservative dose rate estimates, but do not significantly affect the overall evaluation of the radiological conditions in the containment. Non-homogenous sources, such as fuel assemblies, ion exchange resin beds are homogenized, where this does not underestimate the dose rates.

Complex geometries are modeled in MCNP code (Reference 21). Due to the need of larger computer and work resources MCNP is used only in those cases that cannot be calculated by methods based on line-of-sight attenuation such as point kernel method. Such cases may involve labyrinth structures, penetrations, dominance of scattered radiation etc.

For very simple geometries also analytical formulas using gamma energy yields of radioactive isotopes are used.

The source activity (Ci) and gamma ray source strengths (MeV/sec) are calculated using one of the following computer codes: ORIGEN (Reference 17), SOURCE2/ACCUM (Reference 12), or RADGAS3 (Reference 13). ACCUM (Reference 12) is an option within SOURCE2 that computes isotope accumulation for several time periods from a given flow of isotopes in curies per second. This accumulated activity may then be decayed for any number of decay times at which gamma energy spectra and isotope Curie activity are computed. The generation of daughter products is included during the accumulation and decay periods. FIPCO, CORA, and RADGAS3 compute isotopic activity in radioactive liquid and gaseous systems. The total activity in system lines or equipment is computed from the initial isotope flow, equipment accumulating (operating) time, and parameters which describe the physical accounts for instantaneous mixing or uniform flow and plateout of particulate daughter products. Isotope data is based on the Table of Isotopes (Reference 5) and ORIGEN library data (Reference 6).

The shielding thicknesses of walls and slabs are selected to reduce the aggregate computed radiation level from the contributing sources below the upper limit of the radiation zone specified for each plant area. The labyrinths are constructed so that the scattered dose rate, plus the transmitted dose rate through the shield wall from all contributing sources, is below the upper limit of the radiation zone specified for each plant area. Shielding requirements in each plant area are evaluated at the point of maximum radiation dose through any wall. In addition, for shielding design purposes the concrete density of 140 lb/ft^3 was assumed. Therefore, the actual anticipated radiation level in each plant area is less than this maximum dose and consequently less than the radiation zone upper limit.

Neutron radiation is calculated either with MCNP code or hand calculation methods combined to literature data on neutron attenuation (References 7 and 8).

12.3.3 Ventilation

The plant heating, ventilating, and air-conditioning systems are designed to provide a suitable environment for personnel and equipment during normal operation.

12.3.3.1 Design Objectives

The plant heating, ventilating, and air-conditioning systems for normal operation are designed to meet the requirements of 10 CFR 20 and 10 CFR 50.

12.3.3.2 Design Criteria

Design criteria for the plant HVAC systems include the following:

- During normal operation the average and maximum airborne radioactivity levels to which plant personnel are exposed in restricted areas of the plant are ALARA and within the limits specified in 10 CFR 20. The average and maximum airborne radioactivity levels in unrestricted areas of the plant during normal operation, are ALARA and within the limits of 10 CFR 20.

- During normal operations the dose from concentrations of airborne radioactive material in unrestricted areas beyond the site boundary is ALARA and within the limits specified in 10 CFR 20 and 10 CFR 50, Appendix I.

12.3.3.3 Design Features

To accomplish the design objectives and to conform to the design criteria, the following design features are incorporated wherever practicable.

12.3.3.3.1 Design Features to Minimize Airborne Radioactivity

- Access control and traffic patterns are considered in the plant layout to minimize the spread of contamination.

- Equipment vents and drains are piped directly to a collection device connected to the collection system. This is to minimize airborne contamination and to prevent contaminated fluid from flowing across the floor to a floor drain.

- Welded piping systems are employed on systems containing radioactive fluids to the maximum extent practicable. If welded piping systems are not employed, drip trays are provided at the points of potential leakage. Drains from drip trays are piped directly to the collection system.

- Suitable coatings are applied to the concrete floors and walls of potentially contaminated areas to facilitate decontamination.

- Design of equipment incorporates features that minimize the spread of radioactivity during maintenance operations. These features include flush and drain connections on pump casings for draining and flushing the pump prior to maintenance and flush connections on piping systems that could become highly radioactive.

12.3.3.3.2 Design Features to Control Airborne Radioactivity

- The airflow is directed from areas with lesser potential for contamination to areas with greater potential for contamination.

- In building compartments with a potential for contamination, the exhaust is designed for greater volumetric flow than is supplied to that area. This minimizes the amount of uncontrolled exfiltration from the area.

- Consideration is given to the potential disruption of normal airflow patterns by maintenance operations, and provisions are made in the design to prevent adverse airflow direction.

- The ventilation system design for radiologically controlled areas is discussed in subsections 9.4.3, 9.4.7, 9.4.8, and 9.4.11. The exhaust air from these areas is normally unfiltered except for the containment atmosphere which is filtered by the containment air filtration system exhaust filters. A description of these filter units is given in subsection 12.3.3.5.

- Air discharged from the containment is passed through high efficiency particulate air filters and charcoal adsorbers to remove particulates and halogens. Air exhausted from the auxiliary building, fuel handling area of the auxiliary building, and the annex building is monitored for high airborne activity. Means are provided to shut off supply air and divert exhaust air through high efficiency particulate air filters and charcoal adsorbers upon detection of high airborne activity. Alarms are provided in the main control room for these discharge flows and for flows from the radwaste building and the health physics/hot machine shop area. These alarms alert the operator of high radioactivity concentrations in the air. This minimizes the discharge of contaminants to the environment and in-plant exposures.

- Atmospheric tanks which contain radioactive materials are vented to the respective building ventilation system for release to the monitored plant vent.

12.3.3.3.3 Design Features to Minimize Personnel Exposure from HVAC Equipment

- The guidelines of Regulatory Guide 8.8 have been utilized, as practicable, in the design of the plant ventilation systems.

- Ventilation fans and filters are provided with adequate access space to permit servicing with minimum personnel radiation exposure. The HVAC system is designed to allow rapid replacement of components.

- Ventilation ducts are designed to minimize the buildup of radioactive contamination within the ducts.

- Ventilating air for radiologically controlled areas of the plant is a once-through design.

- Access to ventilation systems in potentially radioactive areas can result in operator exposure during maintenance, inspection, and testing. Equipment locations are selected to minimize personnel exposures. The outside air supply units and building exhaust system components are located in ventilation equipment rooms. These equipment rooms are accessible to the operators. Work space is provided around each unit for anticipated maintenance, testing, and inspection.

12.3.3.4 Design Description

The ventilation systems serving the following structures are considered to be potentially radioactive and are discussed in detail in Section 9.4.

- Containment building (See subsection 9.4.7)
- Auxiliary building (See subsection 9.4.3)
- Fuel handling area of the auxiliary building (See subsection 9.4.3)
- Annex building (See subsection 9.4.3)
- Radwaste building (See subsection 9.4.8)
- Health physics and hot machine shop (See subsection 9.4.11)

The main control room is considered to be a nonradioactive area. The associated ventilation system design is described in Section 6.4 and subsection 9.4.1.

Other structures contain insignificant sources of airborne radioactivity and are not addressed in this chapter.

12.3.3.5 Air Filtration Units

The guidance and recommendations of Regulatory Guide 1.140 concerning maintenance and inplace testing provisions for atmospheric cleanup systems, air filtration, and adsorption units are used as a guide in the design of the various ventilation systems. The extent to which Regulatory Guide 1.140 has been incorporated is discussed in subsection 1.9.1. Figure 12.3-3 shows the typical layout of an air filtration unit.

Provisions specifically included to minimize personnel exposures and to facilitate maintenance or inplace testing operations are as follows.

A. The loading of the filters and adsorbers with radioactive material during normal plant operation is a slow process. Therefore, in addition to monitoring for pressure drop, the filters are checked for radioactivity on a scheduled maintenance basis with portable equipment. The filter elements are replaced before the radioactivity level is of sufficient magnitude to create a personnel hazard. No shielding is provided since it is not required for the level of radioactivity accumulation during normal operation. In case of excessive radioactivity caused by a postulated accident, the filter is replaced before normal personnel access is resumed. It is not necessary for workers to handle filter units immediately after a design basis accident, so exposures can be minimized by allowing the short-lived isotopes to decay before changing the filter.

B. Active components of the atmospheric cleanup systems are designed for ease of removal.

C. Access to active components is direct from working platforms to simplify element handling. Ample space is provided on the platforms for accommodating safe personnel movement during replacement of components, including the use of necessary material handling equipment and inplace testing devices.

D. No filter bank is more than three filter cells high, where each filter cell is 2 feet by 2 feet. The access to the level or platform at which the filter is serviced is by stairs.

E. The clear space for access to filter banks and active components is a minimum of 20 inches by 50 inches.

F. The HEPA filter banks are designed with replaceable cells that are clamped in place against compression seals. The charcoal adsorbers are designed to be replaced with bulk charcoal using a vacuum transfer system. The filter housing is designed and tested to be airtight with bulkhead type doors that are closed against compression seals.

12.3.4 Area Radiation and Airborne Radioactivity Monitoring Instrumentation

For a description of the radiation monitoring system (RMS), refer to Section 11.5.

12.3.5 Combined License Information

12.3.5.1 Administrative Controls for Radiological Protection

The Combined License applicant will address the administrative controls for use of the design features provided to control access to radiologically restricted areas, including potentially very high radiation areas, such as the fuel transfer tube during refueling operations and to the reactor cavity.

12.3.5.2 Criteria and Methods for Radiological Protection

The Combined License applicant will address the criteria and methods for obtaining representative measurement of radiological conditions, including airborne radioactivity concentrations in work areas. The Combined License applicant will also address the use of portable instruments, and the associated training and procedures, to accurately determine the airborne iodine concentration in areas within the facility where plant personnel may be present during an accident.

12.3.5.3 Groundwater Monitoring Program

In accordance with Reference 23, the Combined License applicant will establish a groundwater monitoring program beyond the normal radioactive effluent monitoring program. If and as necessary to support this groundwater monitoring program, the Combined License applicant will install groundwater monitoring wells during the plant construction process. Areas of the site to be specifically considered in this groundwater monitoring program are as follows:

- West of the auxiliary building in the area of the fuel transfer canal
- West and south of the radwaste building
- East of the auxiliary building rail bay and the radwaste building truck doors

12.3.5.4 Record of Operational Events of Interest for Decommissioning

In accordance with Reference 23, the Combined License applicant will establish a program to ensure documentation of operational events deemed to be of interest for decommissioning, beyond that required by 10 CFR 50.75. This or another program will include remediation of any leaks that have the potential to contaminate groundwater.

12.3.6 References

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3. Bowman, W. W., and MacMurdo, K. W., "Radioactive Decay λ's Ordered by Energy and Nuclide," Atomic Data and Nuclear Data Tables, Academic Press, February 1970.

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5. Lederer, C. M., et al., Table of Isotopes, seventh edition, Lawrence Radiation Laboratory, University of California, April 1978.

6. Kee C.W., "A Revised Light Element Library for the ORIGEN Code," ORNL-TM-4896, Oak Ridge National Laboratory, May 1975.

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8. Courtney, J. C. (ed.) A Handbook of Radiation Shielding Data. ANS. 1975.

9. Engle, W. W., Jr., "A User's Manual for ANISN: A One Dimensional Discrete Ordinates Transport Code with Anisotropic Scattering," Report No. K-1693, Union Carbide Corporation, 1967.

10. Soltesz, R.G., et al., "Nuclear Rocket Shielding Methods, Modification, Updating and Input Data Preparation. vol. 5 - Two-Dimensional Discrete Ordinates Transport Technique," WANL-PR(ll)-034, vol 5, August 1970.

11. SHIELD-SG - Point Kernel Gamma Shielding Program, Bechtel Corporation.

12. SOURCE2 - Radioisotope Decay Program, Bechtel Corporation.

13. RADGAS3 - Gaseous Radwaste Program, Bechtel Corporation.

14. RSIC Computer Code Collection CCC-120, SPACETRAN-I/SPACETRAN-II - Dose from Cylindrical Surface.

15. ALBEDO - A Program to Calculate Reflected Dose Rates from Concrete Surfaces, Bechtel Corporation.

16. QAD-CG - Combinatorial Geometry Version of QAD-P5A, Bechtel Corporation.

17. RSIC Computer Code Collection CCC-371, ORIGEN 2.1 - Isotope Generation and Depletion Code-Matrix Exponential Method.

18. FIPCO-VI - A Computer Code for Calculating the Distribution of Fission Products in Reactor Systems, Westinghouse Electric Corporation.

19. Kang, S. and Sejvar, J., "The CORA-II Model of PWR Corrosion Product Transport," EPRI NP-4246, September 1995.

20. RSIC Computer Code Collection CCC-543, TORT-DORT - Two- and Three-Dimensional Discrete Ordinates Transport, Version 2.73.

21. RSIC Computer Code Collection CCC-200, Monte Carlo Neutron and Photon Transport Code System.

22. MicroShield, Version 6.20, User’s Manual, Grove Engineering Inc., 2005.

23. USNRC, "Minimization of Contamination," 10 CFR 20.1406.

Table 12.3-1

EQUIPMENT SPECIFICATION LIMITS FOR COBALT IMPURITY LEVELS

Region, Component or Application	Maximum Weight Percent of Cobalt
Inconel and stainless steel components in fuel assembly	0.05
Inconel tubing in steam generators	0.015
Components that are external to the active core, but in regions of high neutron flux. This typically includes: baffle plates, formers, lower and upper core plates, lower core barrel, and neutron panels or thermal shields	0.05
Surfaces in the steam generators other than the tubing	0.10
Other primary components and weld clad surfaces, except hard-facing and fasteners indicated below	0.05
Auxiliary heat exchangers exposed to reactor coolant	0.05
Bolting materials in reactor internals; other small components in region of high neutron flux	0.20
Bearing and hard-facing materials	Not limited (However low- or no-cobalt materials will be used, as available)
Auxiliary components such as valves piping instrumentation, tanks, and so on, including bolting materials in primary and auxiliary components	Not limited (Average ~ 0.20)
Welding material, except where used as weld cladding	Not limited (Average ~ 0.20)

LEGEND:

A. PLANT RADIATION ZONES:

DESIGNATION	MAXIMUM DESIGN DOSE RATE	DESCRIPTION
0	≤ 0.05 mRem/hr	NO RADIATION SOURCES; UNLIMITED GENERAL OCCUPANCY; OUTSIDE "CONTROLLED AREA"
I	≤ 0.25 mRem/hr	VERY LOW OR NO RADIATION SOURCES; INSIDE "CONTROLLED AREA" AND OUTSIDE "RESTRICTED AREA"
"RESTRICTED AREA" ZONES		
II	≤ 2.5 mRem/hr	LOW RADIATION SOURCES; UNLIMITED WORKER OCCUPANCY
III	≤ 15.0 mRem/hr	LOW-TO-MODERATE RADIATION SOURCES; LIMITED WORKER OCCUPANCY
IV	≤ 100 mRem/hr	MODERATE RADIATION SOURCES; LIMITED WORKER OCCUPANCY
V	≤ 1 Rem/hr	HIGH RADIATION SOURCES; LIMITED WORKER OCCUPANCY
VI	≤ 10 Rem/hr	SAME AS ZONE V ABOVE
VII	≤ 100 Rem/hr	SAME AS ZONE V ABOVE
VIII	≤ 500 Rad/hr	SAME AS ZONE V ABOVE
IX	> 500 Rad/hr	VERY HIGH RADIATION SOURCES; VERY LIMITED WORKER ACCESS

B. DRAWING SYMBOLS:

V / IV - UPPER RADIATION ZONE NUMERAL FOR FULL POWER OPERATION/ LOWER NUMERAL FOR 24 HOURS AFTER PLANT SHUTDOWN (IF DIFFERENT)

- RADIATION ZONE BOUNDARY

C. GENERAL DRAWING NOTES

1. ACCESS CONTROL REQUIREMENTS AND TRAFFIC PATTERNS ARE SHOWN IN SERIES 201 DRAWINGS.

2. DOSE RATES INSIDE CONTAINMENT DURING POWER OPERATION ARE SUBJECT TO SIGNIFICANT VARIABILITY OWING TO LOCALIZED NEUTRON STREAMING/SCATTERING EFFECTS. ACTUAL RADIATION FIELDS WILL BE DETERMINED FROM RADIATION SURVEYS AND ACCESS TO THE CONTAINMENT DURING POWER OPERATION WILL BE STRICTLY CONTROLLED.

Figure 12.3-1 (Sheet 1 of 16)

Radiation Zones, Normal Operation/Shutdown Legend

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Figure 12.3-1 (Sheet 2 of 16)

Site Radiation Zones, Normal Operations/Shutdown

Redacted Version, Withheld Under 10 CFR 2.390d

Figure 12.3-1 (Sheet 3 of 16)

Radiation Zones, Normal Operations/Shutdown
Nuclear Island, Elevation 66′-6″

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Figure 12.3-1 (Sheet 4 of 16)

**Radiation Zones, Normal Operations/Shutdown
Nuclear Island, Elevation 82′-6″**

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Figure 12.3-1 (Sheet 5 of 16)

Radiation Zones, Normal Operations/Shutdown
Nuclear Island, Elevation 96′-6″

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Figure 12.3-1 (Sheet 6 of 16)

Radiation Zones, Normal Operations/Shutdown
Nuclear Island, Elevation 100′-0″ & 107′-2″

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Figure 12.3-1 (Sheet 7 of 16)

Radiation Zones, Normal Operations/Shutdown Nuclear Island, Elevation 117′-6″

Redacted Version, Withheld Under 10 CFR 2.390d

Figure 12.3-1 (Sheet 8 of 16)

Radiation Zones, Normal Operations/Shutdown
Nuclear Island, Elevation 135′-3″

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Figure 12.3-1 (Sheet 9 of 16)

Radiation Zones, Normal Operations/Shutdown
Nuclear Island, Elevation 153′-0″ & 160′-0″

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Figure 12.3-1 (Sheet 10 of 16)

Radiation Zones, Normal Operations/Shutdown
Nuclear Island, Elevation 160′-6″ & 180′-0″

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Figure 12.3-1 (Sheet 11 of 16)

Radiation Zones, Normal Operations/Shutdown
Annex Building, Elevation 100′-0″ & 107′-2″

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Figure 12.3-1 (Sheet 12 of 16)

Radiation Zones, Normal Operations/Shutdown
Annex Building, Elevation 117′-6″ & 126′-3″

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Figure 12.3-1 (Sheet 13 of 16)

Radiation Zones, Normal Operations/Shutdown
Annex Building, Elevation 135′-3″, 146′-3″, 156′-0″ & 158′-0″

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Figure 12.3-1 (Sheet 14 of 16)

Radiation Zones, Normal Operations/Shutdown
Radwaste Building, Elevation 100′-0″

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Figure 12.3-1 (Sheet 15 of 16)

Radiation Zones, Normal Operations/Shutdown
Turbine Building, Elevation 100′-0″

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Figure 12.3-1 (Sheet 16 of 16)

**Radiation Zones, Normal Operations/Shutdown
Turbine Building, Elevation 117′-6″**

LEGEND:

A. POST-ACCIDENT RADIATION ZONES:

DESIGNATION	MAXIMUM DESIGN DOSE RATE	DESCRIPTION
0	≤ 0.05 mRem/hr	NO RADIATION SOURCES
I	≤ 0.25 mRem/hr	VERY LOW OR NO RADIATION SOURCES
II	≤ 2.5 mRem/hr	LOW RADIATION SOURCES
III	≤ 15.0 mRem/hr	LOW-TO-MODERATE RADIATION SOURCES
IV	≤ 100 mRem/hr	MODERATE RADIATION SOURCES
V	≤ 1 Rem/hr	HIGH RADIATION SOURCES
VI	≤ 10 Rem/hr	SAME AS ZONE V ABOVE
VII	≤ 100 Rem/hr	SAME AS ZONE V ABOVE
VIII	≤ 500 Rad/hr	SAME AS ZONE V ABOVE
IX	> 500 Rad/hr	VERY HIGH RADIATION SOURCES

B. DRAWING SYMBOLS:

VI	– RADIATION ZONE NUMERAL AT POST-ACCIDENT PEAK
ECS	DOMINANT POST-ACCIDENT RADIATION SOURCE(S)

– NON-RADIOACTIVE AREA BOUNDARY

– RADIOACTIVE AREA BOUNDARY

– ANNEX AREA BOUNDARY

– RADIATION ZONE BOUNDARY

– POST-ACCIDENT ACCESS ROUTE

C. POST-ACCIDENT SOURCES:

SYMBOL	POST-ACCIDENT RADIATION SOURCE
ECS	EXTERNAL CLOUD SHINE
NRA	NON-RADIOACTIVE AUXILIARY BUILDING AREA CLOUD
RAC	RADIOACTIVE AUXILIARY BUILDING AREA CLOUD
SCC	SHIELDED CONTAINMENT CLOUD
UCC	UNSHIELDED CONTAINMENT CLOUD
CPS	CONTAINMENT AND PENETRATION RADIATION STREAMING
AXC	ANNEX BUILDING AREA CLOUD
PAS	POST-ACCIDENT SAMPLE PIPING

D. GENERAL DRAWING NOTES:

1. ZONING IS BASED ON PEAK POST-ACCIDENT DOSE RATES IN THE DESIGNATED AREA.
2. INCLUDES CONTRIBUTIONS FROM POST-ACCIDENT CONTAINED AND AIRBRONE CLOUD SOURCES.

Figure 12.3-2 (Sheet 1 of 15)

Radiation Zones, Post-Accident Legend

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Figure 12.3-2 (Sheet 2 of 15)

Site Radiation Zones, Post-Accident

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Figure 12.3-2 (Sheet 3 of 15)

Radiation Zones, Post-Accident
Nuclear Island, Elevation 66′-6″

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Figure 12.3-2 (Sheet 4 of 15)

Radiation Zones, Post-Accident
Nuclear Island, Elevation 82′-6″

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Figure 12.3-2 (Sheet 5 of 15)

Radiation Zones, Post-Accident
Nuclear Island, Elevation 96′-6″

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Figure 12.3-2 (Sheet 6 of 15)

Radiation Zones, Post-Accident
Nuclear Island, Elevation 100′-0″ & 107′-2″

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Figure 12.3-2 (Sheet 7 of 15)

Radiation Zones, Post-Accident
Nuclear Island, Elevation 117′-6″

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Figure 12.3-2 (Sheet 8 of 15)

Radiation Zones, Post-Accident
Nuclear Island, Elevation 135′-3″

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Figure 12.3-2 (Sheet 9 of 15)

Radiation Zones, Post-Accident
Nuclear Island, Elevation 153′-0″ & 160′-6″

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Figure 12.3-2 (Sheet 10 of 15)

Radiation Zones, Post-Accident
Nuclear Island, Elevation 160′-6″ & 180′-0″

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Figure 12.3-2 (Sheet 11 of 15)

Radiation Zones, Post-Accident
Annex Building, Elevation 100′-0″ & 107′-2″

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Figure 12.3-2 (Sheet 12 of 15)

Radiation Zones, Post-Accident
Annex Building, Elevation 117′-6″ & 126′-3″

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Figure 12.3-2 (Sheet 13 of 15)

Radiation Zones, Post-Accident
Annex Building, Elevation 135′-3″, 146′-3″, 156′-0″ & 158′-0″

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Figure 12.3-2 (Sheet 14 of 15)

Radiation Zones, Post-Accident
Radwaste Building, Elevation 100′-0″

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Figure 12.3-2 (Sheet 15 of 15)

Radiation Zones, Post-Accident
Turbine Building, Elevation 100′-0″

LEGEND:

A. PLANT ACCESS CONTROL PROVISIONS:

AREA TYPE	DOSE RATE	SINGLE AREA	MULTIPLE AREAS
RADIATION AREA	> 5 mRem/hr		
HIGH RADIATION AREA	> 100 mRem/hr	BARRICADED OR ALARMED	BARRICADED OR ALARMED
HIGH RADIATION AREA	> 1 Rem/hr	LOCKED OR (IF OPEN AREA) BARRICADED WITH LOCAL ALARM	LOCKED OR BARRICADED WITH LOCKED COMMON ENTRY AND LOCAL CONTROL POINT
VERY HIGH RADIATION AREA	> 500 Rad/hr	LOCKED	LOCKED OR BARRICADED WITH LOCKED COMMON ENTRY, LOCAL CONTROL POINT AND SURVEILLANCE

B. DRAWING SYMBOLS:

➪ - PERSONNEL TRAFFIC PATTERN

▲ - ENTRANCE BARRICADE (e.g. ROPE, CHAIN, ETC.)

● - LOCKED ENTRANCE

C - LOCAL ACCESS CONTROL POINT

A - ALARM LOCATION

S - SURVEILLANCE POINT

- ACCESS CONTROL BARRIER (e.g. CHAIN LINK FENCE, ETC.)

- "RESTRICTED" AREA BOUNDARY

- "CONTROLLED" AREA BOUNDARY

C. GENERAL DRAWING NOTES:

1. ACCESS CONTROL PROVISIONS ARE BASED ON NORMAL EXPECTED RADIATION SOURCES.

Figure 12.3-3 (Sheet 1 of 16)

Radiological Access Controls Legend

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Figure 12.3-3 (Sheet 2 of 16)

Site Radiation Access Controls, Normal Operations/Shutdown

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Figure 12.3-3 (Sheet 3 of 16)

Radiological Access Controls, Normal Operations/Shutdown
Nuclear Island, Elevation 66′-6″

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Figure 12.3-3 (Sheet 4 of 16)

Radiological Access Controls, Normal Operations/Shutdown
Nuclear Island, Elevation 82′-6″

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Figure 12.3-3 (Sheet 5 of 16)

Radiological Access Controls, Normal Operations/Shutdown
Nuclear Island, Elevation 96′-6″

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Figure 12.3-3 (Sheet 6 of 16)

Radiological Access Controls, Normal Operations/Shutdown
Nuclear Island, Elevation 100′-0″ & 107′-2″

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Figure 12.3-3 (Sheet 7 of 16)

Radiological Access Controls, Normal Operations/Shutdown Nuclear Island, Elevation 117′-6″

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Figure 12.3-3 (Sheet 8 of 16)

Radiological Access Controls, Normal Operations/Shutdown
Nuclear Island, Elevation 135′-3″

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Figure 12.3-3 (Sheet 9 of 16)

Radiological Access Controls, Normal Operations/Shutdown
Nuclear Island, Elevation 153′-0″ & 160′-6″

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Figure 12.3-3 (Sheet 10 of 16)

**Radiological Access Controls, Normal Operations/Shutdown
Nuclear Island, Elevation 160′-6″ & 180′-0″**

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Figure 12.3-3 (Sheet 11 of 16)

Radiological Access Controls, Normal Operations/Shutdown
Annex Building, Elevation 100′-0″ & 107′-2″

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Figure 12.3-3 (Sheet 12 of 16)

Radiological Access Controls, Normal Operations/Shutdown
Annex Building, Elevation 117′-6″ & 126′-3″

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Figure 12.3-3 (Sheet 13 of 16)

Radiological Access Controls, Normal Operations/Shutdown
Annex Building Elevation 135′-3″, 146′-3″, 156′-0″ & 158′-0″

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Figure 12.3-3 (Sheet 14 of 16)

Radiological Access Controls, Normal Operations/Shutdown
Radwaste Building, Elevation 100′-0″

Redacted Version, Withheld Under 10 CFR 2.390d

Figure 12.3-3 (Sheet 15 of 16)

**Radiological Access Controls, Normal Operations/Shutdown
Turbine Building, Elevation 100′-0″**

Redacted Version, Withheld Under 10 CFR 2.390d

Figure 12.3-3 (Sheet 16 of 16)

**Radiological Access Controls, Normal Operations/Shutdown
Turbine Building, Elevation 117′-6″**