CHAPTER 12

RADIATION PROTECTION

12.1 Assuring that Occupational Radiation Exposures Are As-Low-As-Reasonably Achievable (ALARA)

12.1.1 Policy Considerations

The AP1000 plant is designed with administrative programs and procedures to maximize the incorporation of good engineering practices and lessons learned to accomplish ALARA objectives.

12.1.1.1 Design and Construction Policies

The ALARA policy is applied during the design of AP1000. The design is reviewed for ALARA considerations and updated and modified as experience from operating plants is applied. ALARA reviews include the plant design and integrated layout, considering shielding, ventilation, and monitoring instrument designs as they relate to traffic control, security, access control and health physics.

Similarly, routing of pipe containing radioactive fluids is reviewed as part of the design effort. This confirms that lines expected to contain significant radiation sources are adequately shielded and properly routed to minimize exposure of personnel.

Many of the engineers and supervisors assigned to the AP1000 design have performed similar design work or service work on other nuclear power plants. Through this experience, they have acquired knowledge of the radiation protection aspects which are applied to AP1000. Nuclear plant operating experience is incorporated through Nuclear Regulatory Commission (NRC) inspection and enforcement bulletins, information notices, and other documents. Independent reviews are conducted by the Electric Power Research Institute (EPRI) and Utility Steering Committee and its subcommittees. Knowledge of radiation protection and ALARA is applied to AP1000 design. This allows integration of experience and ALARA considerations from plant operators and plant designers and promotes incorporation of recent operating and service experience and lessons learned.

12.1.1.2 Operation Policies

The activities conducted by management personnel who have plant operational responsibility for radiation protection are addressed in subsection 12.1.3.

12.1.1.3 Compliance with 10 CFR 20 and Regulatory Guides 1.8, 8.8, and 8.10

Compliance of the design with 10 CFR 20 is confirmed by compliance of the design and operation of the facility within the guidelines of Regulatory Guides 1.8, 8.8, and 8.10. Compliance with Regulatory Guides 1.8, 8.8, and 8.10 is addressed as discussed in subsection 12.1.3.

The design of AP1000 meets the guidelines of Regulatory Guide 8.8, Sections C.2 and C.4, which address facility, equipment and instrumentation design features. Features of the plant that are examples of compliance with Regulatory Guide 8.8 are delineated in Section 12.3.

12.1.2 Design Considerations

Provisions and designs for maintaining personnel exposures ALARA are presented in the following paragraphs. The basic management philosophy guiding the AP1000 design effort so that radiation exposures are ALARA can be expressed as:

- Design structures, systems and components for reliability and maintainability, thereby effectively reducing the maintenance requirements on radioactive components.

- Design structures, systems and components to reduce the radiation fields, thereby allowing operation, maintenance and inspection activities to be performed in the minimum design radiation field.

- Design structures, systems and components to reduce access, repair and removal times, thereby effectively reducing the time spent in radiation fields during operation, maintenance, and inspection.

- Design structures, systems and components to accommodate remote and semi-remote operation, maintenance and inspection, thereby effectively reducing the time spent in radiation fields.

12.1.2.1 General Design Considerations for ALARA Exposures

General design considerations and methods to maintain in-plant radiation exposures ALARA consistent with the recommendations of Regulatory Guide 8.8 have two objectives:

- Minimizing the necessity for access to and personnel time spent in radiation areas

- Minimizing radiation levels in routinely occupied plant areas in the vicinity of plant equipment expected to require personnel attention

Equipment and facility layouts and designs are considered for maintaining exposures ALARA during plant operations, including:

- Normal operation
- Maintenance and repairs
- Refueling operations and fuel storage
- Inservice inspection and calibrations
- Radioactive waste handling and disposal
- Other anticipated operational occurrences
- Decommissioning

The actual design features are described in Section 12.3. Examples of features that assist in maintaining exposures ALARA include:

- Provision of features to allow maintenance of state-of-the-art reactor coolant chemistry conditions, such that corrosion and consequential source terms are minimized: these include pH control capability sufficient to meet current and evolving industry standards and the ability to add zinc to the primary coolant
- Provision of features to allow draining, flushing, and decontaminating equipment and piping
- Design of equipment to minimize the creation and buildup of radioactive material and to ease flushing of crud traps
- Provision of shielding for personnel protection during maintenance or repairs and during decommissioning
- Provision of means and adequate space for the use of movable shielding
- Separation of more highly radioactive equipment from less radioactive equipment and provision of separate shielded compartments for adjacent items of radioactive equipment
- Provision of shielded access hatches for installation and removal of plant components
- Provision of design features, such as the chemical and volume control system, to minimize crud buildup
- Provision for means and adequate space for the use of remote and robotic maintenance and inspection equipment
- Simplifying the plant design compared to previous pressurized water reactors with design approaches such as:
  - Elimination of boron recycle
  - Elimination of evaporators
  - Use of an extended fuel cycle
  - Reduction in components containing radioactive fluids
  - Clearly and deliberately separating clean areas from potentially radioactive ones

12.1.2.2 Equipment General Design Considerations for ALARA

Equipment design considerations to minimize the necessity for, and amount of, time spent in a radiation area generally include:

- Reliability, durability, constructibility, and design features of equipment, components, and materials to reduce or eliminate the need for repair or preventive maintenance.

- Servicing convenience for anticipated maintenance or potential repair, including ease of disassembly and modularization of components for replacement or removal to a lower radiation area for repair (For example, the passive residual heat removal heat exchanger is designed with extra tubes to allow for plugging of some tubes. Heat exchangers have drains to allow draining of the shell side water.)

- Provisions, where practicable, to remotely or mechanically operate, repair, service, monitor, or inspect equipment.

- Redundancy of equipment or components to reduce the need for immediate repair when radiation levels may be high and when there is no feasible method available to reduce radiation levels.

- Provisions for equipment to be operated from, and have its instrumentation and control in, accessible areas both during normal and abnormal operating conditions.

- Provisions for remote operation, draining and flushing of systems such as the chemical and volume control system.

- Past experience and lessons learned from servicing currently operating nuclear power plants.

Equipment design considerations directed toward minimizing radiation levels near equipment or components requiring personnel attention include:

- Selection of materials that minimize the creation of radioactive contamination.

- Provision of equipment and piping designs that minimize the accumulation of radioactive materials (for example, the use of seamless piping and minimizing the number of fittings reduces radiation accumulation at the seams and welds).

- Provisions for draining, flushing, or if necessary, remote cleaning or decontamination of equipment containing radioactive materials.

- Provision in the design for limiting leaks or controlling the fluid that does leak. This includes the use of high quality valves and valve packings, and the direction of leakage via drip pans and piping to sumps and floor drains.

- Provisions for isolating equipment from radioactive process fluids.

- Provisions for the chemical and volume control system; the spent fuel pit cleanup system; and the liquid radwaste cleanup system to limit radioactive isotope levels in the process water.

12.1.2.3 Facility Layout General Design Considerations for ALARA

Facility design considerations to minimize the amount of personnel time spent in a radiation area include the following:

- Locating equipment, instruments, and sampling stations that require routine maintenance, calibration, operation, or inspection, in a manner that promotes ease of access and minimum of required occupancy time in radiation areas

- Laying out plant areas to allow remote or mechanical operation, service, monitoring, or inspection of highly radioactive equipment

- Providing, where practicable, for transportation of equipment or components requiring service to a lower radiation area

Facility design considerations directed toward minimizing radiation levels in plant access areas and in the vicinity of equipment requiring personnel attention generally include the following:

- Separating radiation sources and occupied areas, where practicable (for example, pipes or ducts containing potentially highly radioactive fluids do not pass through occupied areas). Redundant components requiring periodic maintenance that are a source of radiation are located in separate compartments to allow maintenance of one component while the other component is in operation.

- Providing shielding to separate equipment such as demineralizers and filters from nonradioactive equipment to provide unrestricted maintenance on the nonradioactive equipment.

- Providing shielding between radiation sources and access and service areas.

- Providing labyrinth entrances to radioactive pump, equipment, and valve rooms. Adequate space is provided in labyrinth entrances for easy access. Highly radioactive passive components with minimal maintenance requirements are located in completely enclosed compartments and are provided with access via a shielded hatch or removable blocks.

- Separating equipment or components in service areas with permanent shielding, where appropriate.

- Providing means and adequate space for using movable shielding for sources within the service area, when required.

- Incorporating, within the plant layout, restrictions and control of access to the various radiation zones. Access to a given radiation zone generally does not require passing through a higher radiation zone. In the case of an abnormal occurrence or accident, the zone restrictions may change due to increased dose rates. Special access controls would be implemented at that time as discussed in subsection 12.1.3.

- Locating equipment, instruments, and sampling sites in the lowest practicable radiation zone.
- Providing control panels to permit remote operation of essential instrumentation and controls from the lowest radiation zone practicable.
- Providing means to control contamination or facilitate decontamination of potentially contaminated areas.
- Providing means for decontamination of service areas.
- Maintaining ventilation air flow patterns from areas of lower radioactivity to areas of higher radioactivity.
- Provide adequate lighting and support services (electrical power, compressed air, demineralized water, ventilation, and communications) at workstations.

12.1.2.4 Equipment and Facility Layout General Design Considerations for 10 CFR 20.1406

General equipment and facility layout design considerations to prevent the spread of contamination and to facilitate eventual decommissioning in accordance with 10 CFR 20.1406 include the features discussed in the following subsections.

12.1.2.4.1 Piping

The use of embedded pipes is minimized to the extent possible, consistent with maintaining radiation doses ALARA.

To the extent possible, radioactive piping is located inside the auxiliary building and the containment vessel. This minimizes the potential for leakage to the groundwater from piping or fittings. The few exceptions are as follows:

- Process piping to and from the radwaste building (which can be fully visually inspected from the radwaste building pipe trench to the auxiliary building wall).
- Drain lines from the radwaste building and annex building back to the auxiliary building. These lines are not normally water filled, and can also be fully visually inspected from the annex or radwaste building pipe trench to the auxiliary building wall.
- Piping associated with the waste monitor tanks in the radwaste building. These tanks contain processed water, and they are located within the curbed radwaste building, which drains to the liquid radwaste system.
- Monitored radwaste discharge pipeline as discussed below.

The monitored radwaste discharge pipeline is engineered to preclude leakage to the environment. This pipe is routed from the auxiliary building to the radwaste building (the short section of pipe between the two buildings is fully available for visual inspection as noted above) and then out of the radwaste building to the appropriate point for dilution and discharge. The exterior piping either incorporates a guard pipe, or is available for visual inspection. No valves, vacuum breakers, or other fittings are incorporated outside of buildings.

As discussed in subsections 11.1.2 and 11.1.3, operation with primary to secondary leakage would lead to limited radiological contamination of some secondary side systems. Liquid leakage from piping or components located in the turbine building will be collected by the waste water system and routed to a turbine building sump.

Outdoor piping between the condenser hotwell and the condensate storage tank is located above ground where liquid leakage can be detected.

12.1.2.4.2 Fuel Pool Design

The spent fuel pool and connected pools are designed to eliminate unidentified leakage to the groundwater as follows:

- The walls of these pools are constructed using modular construction techniques. This allows higher quality than traditional construction. The advanced welding techniques used minimize the potential for weld failures during operation, and allow for inspection to verify weld quality.
- The pools walls are made of 1/2-inch stainless steel plate, joined to one another with full penetration welds.
- The thickness of the wall plate and the use of full penetration welds prevents wall or weld damage from fuel handling operations, including tool manipulation and storage.
- The pools are equipped with leak chases at each weld. This leak detection system uses piping that is adequately sized to allow testing and to minimize the potential for blockage by encrustation of precipitates (boric acid), and facilitates removal of any such blockage.
- The pool leak detection system will be zoned to allow identification of the area of the pool liner which is leaking, even for very small leaks.
- To the extent possible, these pools are located entirely inside the auxiliary and containment building, so that any theoretical leakage from the tanks is into the building rather than having the potential for release to the environment. Specifically, for pools other than a portion of the fuel transfer canal, the concrete support structure of the pools may be inspected from rooms adjacent to or below (i.e., outside) the pool.

12.1.3 Combined License Information

Operational considerations of ALARA, as well as operational policies and continued compliance with 10 CFR 20 and Regulatory Guides 1.8, 8.8, and 8.10, will be addressed by the Combined License applicant. In addition, the Combined License applicant will address operational considerations of the Standard Review Plan to the level of detail provided in Regulatory

Guide 1.70. Regulatory Guides that will be addressed include: 8.2, 8.7, 8.9, 8.13, 8.15, 8.20, 8.25, 8.26, 8.27, 8.28, 8.29, 8.34, 8.35, 8.36, and 8.38.