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CONTROL OF ACCESS TO HIGH AND VERY HIGH RADIATION AREAS IN NUCLEAR POWER PLANTS

A. INTRODUCTION

In Section 20.1101, "Radiation Protection Programs," of Title 10, Part 20, of the *Code of Federal Regulations* (10 CFR Part 20), "Standards for Protection Against Radiation," the U.S. Nuclear Regulatory Commission (NRC) requires licensees to develop and implement a radiation protection program appropriate to the scope of licensed activities and potential hazards. To augment that requirement, 10 CFR 20.2102, "Records of Radiation Protection Programs," requires licensees to document those radiation protection programs. An important aspect of such programs at nuclear power plants is the institution of a system of controls that includes procedures, training, audits, and physical barriers to protect workers against unplanned exposures in high and very high radiation areas. Toward that end, specific requirements applicable to controlling access to high radiation areas are in 10 CFR 20.1601, and additional requirements to prevent unauthorized or inadvertent entry into very high radiation areas are in 10 CFR 20.1602. This regulatory guide describes methods that the NRC staff finds acceptable for implementing these requirements.

Appendix A to this guide contains recommended procedures for good operating practices for underwater diving operations in high and very high radiation areas. These practices have evolved, in part, from instances in which proper controls were not implemented. In addition, Appendix B summarizes past experience with very high and potentially very high radiation areas, so that pertinent historical information is readily accessible.

Any information collections mentioned in this regulatory guide are established as requirements in 10 CFR Part 20, which provides the regulatory basis for this guide. The Office of Management and Budget (OMB) has approved those information collection requirements under OMB control number 3150-0014. The NRC may neither conduct nor sponsor, and a person is not required to respond to, an information collection request or requirement unless the requesting document displays a currently valid OMB control number.

B. DISCUSSION

The provisions of 10 CFR 20.1601 and 20.1602 specify the requirements through which the NRC intends to prevent exposures in excess of regulatory limits at agency-licensed facilities. This guide complements those requirements by recommending a framework of graded radiation protection procedures to ensure that the controls for access to high and very high radiation areas at nuclear power plants are appropriate to the radiation hazards during both normal operations and abnormal operational occurrences.

Dose rates in areas of nuclear power plants that are accessible to individuals can vary over several orders of magnitude. High radiation areas, where personnel can receive doses in excess of the regulatory limits in a relatively short time, require special controls. Very high radiation areas require much stricter monitoring and controls, because failure to adequately implement effective radiological controls can result in radiation doses that pose a significant health risk.

For the purposes of this guide, a high radiation area is defined as an area, accessible to individuals, in which radiation levels could result in an individual receiving a deep dose equivalent in excess of 0.1 rem (1 mSv) in 1 hour at 30 centimeters (cm) (11.8 in.) from the radiation source or from any surface that the radiation penetrates. A very high radiation area means an area, accessible to individuals, in which radiation levels could result in an individual receiving an absorbed dose in excess of 500 rads [5 grays (Gy)] in 1 hour at 1 meter (3.3 ft) from a radiation source or any surface that the radiation penetrates. An accessible area is defined as one that can reasonably be occupied by a major portion of an individual's whole body, which is defined in 10 CFR 20.1003, "Definitions."

C. REGULATORY POSITION

1. Program Elements

In 10 CFR 20.1101, the NRC requires licensees to develop and implement a radiation protection program appropriate to the potential radiation hazards in the given facility. Because of the potential for exceeding regulatory limits in high and very high radiation areas, it is important that licensees have effective programs for controlling access to such areas. Past experience has shown that inadequate access controls have resulted in instances in which unauthorized personnel entered these areas.

Licensees' plant procedures and practices should include the following access control elements to ensure that personnel are protected in high and very high radiation areas.

1.1 *Management Control*

Facility management has the responsibility for developing, implementing, and enforcing access control procedures for high and very high radiation areas.

1.2 *Procedural Controls*

1.2.1 Access Control Procedures

Access control procedures for high and very high radiation areas should address at least the following areas:

(1) job planning

(2) radiation protection coverage

(3) survey techniques and frequencies

(4) training of workers

(5) prework briefing

(6) frequency for updating radiation work permits (RWPs) or their equivalent

(7) placement of measuring and alarming dosimeters

1.2.2 Administrative Procedures

Administrative procedures should address the management oversight and specific control measures needed for entry into high and very high radiation areas. The procedures should include the process for gaining entry to these areas, such as the control and distribution of keys.

1.2.3 Activities That Can Greatly Increase Radiation Levels

Procedures for activities that can greatly increase in-plant radiation levels (i.e., withdrawal of in-core detectors, thimble tubes, or transversing in-core probes from the reactor) should provide for notification of personnel who are likely to authorize or have access to affected areas.

1.2.4 Timely Surveys

Procedures should provide for timely surveys to identify and post with precautionary notices the areas and systems that may become high or very high radiation areas, especially when in-plant changes (e.g., spent fuel transfer operations) could alter ambient radiation levels.

1.2.5 Verification of Controls

Licensees should implement procedures to ensure that proper controls for restricting access to high and very high radiation areas are in place and verified at least weekly.

1.3 *Training*

The types of controls required for entry into high and very high radiation areas should be included in both initial and requalification training for radiation workers. Plant areas that are known to have a potential to become very high radiation areas should be specifically identified.

1.4 *Communications*

Good communication is essential among all departments concerned with entry into high and very high radiation areas to prevent excessive and unwarranted radiation exposures. This communication is especially important among personnel in known potential or existing very high radiation areas, such as reactor cavities, spent fuel transfer areas, spent fuel pools, and other reactor components and tanks. The access control program should include procedures and provisions for the use of equipment to ensure adequate communication. The group or department responsible for radiation protection should be notified prior to any entry into a very high radiation area.

1.5 *Physical Controls*

Physical barriers (such as chain link fencing or fabricated walls) may be used to prevent unauthorized personnel access to high and very high radiation areas. Barriers used to control access to high radiation areas should provide reasonable assurance that they secure the area against unauthorized access and cannot be easily circumvented. (That is, an individual who incorrectly assumes, for whatever reason, that he or she is authorized to enter the area, would be unlikely to disregard and/or circumvent the barrier.) A fence that is 2 meters (approximately 6 ft) high would normally be adequate to control access to a high radiation area at a nuclear power plant. To the extent practicable, physical barriers should completely enclose very high radiation areas in a manner that is sufficient to thwart[1] undetected circumvention of the barrier. That is, fencing around very high radiation areas should extend to the overhead and preclude anyone from climbing over the fencing. Entrances or access points to these areas should be controlled, as described in Regulatory Positions 2 through 4. Physical controls should be established that do not preclude personnel access to these areas when access is required to respond to emergencies.

Implicit in the definition of an entrance or access point to a high radiation area is that the opening (or portal) itself is accessible to personnel. Openings in physical barriers around a high radiation area are not required to be controlled as entrances if accessing them requires exceptional measures (unusual or extraordinary actions taken as a means to an end). Examples of areas that do not need to be controlled as entrances are the manway to a tank or vessel that has its cover bolted in place, or an opening in a shield wall that is physically difficult to access without a ladder or mobile platform.

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[1] Determined circumvention of a physical barrier, with wire cutters or other tools, cannot be prevented absolutely. Such instances should be addressed with appropriate disciplinary action.

An acceptable method of excluding personnel from areas with dose rates greater than 100 mrem (1 mSv) in 1 hour is to provide a substantial physical barrier (e.g., chain link fencing) that completely encloses the area and has no openings or portals. This type of control is commonly called "cocooning." Since these areas are not accessible, the 10 CFR Part 20 requirements for access control and posting of high and very high radiation areas do not apply. However, the requirements to instruct the worker on the radiological hazards in these areas are applicable, as specified in 10 CFR Part 19, "Notices, Instructions, and Reports to Workers: Inspection and Investigations."

Note that when an inaccessible high or very high radiation area is made accessible (e.g., a manway cover is removed, scaffolding is erected, or a diver is sent into the spent fuel pool) or a portal is created in a physical barrier (i.e., a cocoon is breached), the applicable controls for a high or very high radiation area must be provided.

Controls must be established to prevent personnel from being locked in a high radiation area [10 CFR 20.1601(d)]. For example, if chains and padlocks are used, the procedural controls must prevent the area from being locked with personnel inside. If doors are self-locking, personnel must be able to open them from the inside without a key.

1.6 *Shielding*

Temporary shielding (i.e., shielding that is not a permanent, unmovable part of the plant's systems or structures) may be used to ensure inaccessibility of a high, very high, or potentially very high radiation area. The following guidelines apply to shielding used for the purpose of controlling access:

(1) Blankets, bricks, or other portable shielding that could be moved by hand should be secured in place by lock-wire, ties, bolts, or other fasteners that would require a tool to remove. Block walls that are designed into the plant and also provide shielding, or shielded hatches, plugs, or covers that require a hoist or crane to move, are not considered removable by hand.

(2) The shielding or shielded access should be posted with an appropriate warning sign, such as "Warning, do not remove. High radiation levels may result," or "Danger, do not remove. Very high radiation levels may result."

(3) Local audible and visible alarming radiation monitors should be installed to alert personnel if temporary shielding, used to control access to the spent fuel transfer tube or other plant areas of greater than 100 rads/hour (1 Gy) is removed.

(4) The facility's routine radiological surveillance program should verify the effectiveness of the temporary shielding and/or (if appropriate) operability of the alarming radiation monitors.

2. High Radiation Areas

2.1 *Options for Access Control*

Of the options for access control provided in 10 CFR 20.1601(a), the procedure that is most widely used at nuclear power plants is keeping high radiation areas locked. Although licensees have the option to control high radiation areas with a control device to reduce radiation levels when an individual enters the area, or an alarm to alert the individual and his or her supervisor to an entry into a high radiation area, experience has shown that these options have limited practical application at nuclear power plants. In addition to the provisions of 10 CFR 20.1601(a), nuclear power plant licensees may apply for Commission approval of alternative methods for control under 10 CFR 20.1601(c). (See Regulatory Position 2.4 below.)

2.2 *Positive Access Control*

The provisions of 10 CFR 20.1601(a)(3) require positive control over each individual entry when access is required to a high radiation area that is normally locked. A large facility such as a nuclear power plant can institute appropriate positive access controls through the use of RWPs or an equivalent program. Such a system ensures appropriate supervision through specific procedures that establish requirements for control and delegate responsibility to qualified individuals. Procedures for establishing positive control over each entry should provide for the following:

(1) Surveys should be conducted to identify the radiation hazards in the area, and the survey results should be documented.

(2) An appropriate level of supervision should determine that exposure of the individual to the hazards is warranted.

(3) The nature and extent of the radiation hazards should be communicated to each individual entering the area.

(4) Protective measures (e.g., shielding, time limits, protective clothing, monitoring) should be used to protect the individual from excessive or unnecessary radiation exposure.

(5) Only authorized individuals should be permitted to enter the high radiation area, with all entries and exits documented.

2.3 *Direct or Electronic Surveillance*

The provisions of 10 CFR 20.1601(b) identify direct or electronic surveillance as a substitute for the controls required in 10 CFR 20.1601(a). As a minimum, the direct or electronic surveillance should have the following capabilities:

(1) Detect attempted unauthorized entry.

(2) Warn individuals that their attempted entry is unauthorized.

(3) Alert the proper authority about an unauthorized entry, so that action can be taken to correct the situation.

2.4 *Alternative Methods for Access Control*

In some instances, the requirements of 10 CFR 20.1601(a) for access to high radiation areas may unnecessarily restrict plant operations. According to 10 CFR 20.1601(c), licensees may apply for Commission approval to use alternative methods for controlling access to high radiation areas. The NRC staff considers the following method acceptable for use as an alternative to the requirements in 10 CFR 20.1601(a) for the control of access to high radiation areas.

Each high radiation area, as defined in 10 CFR Part 20, should be barricaded[2] and conspicuously posted as a high radiation area, and entrance thereto should be controlled by requiring issuance of an RWP or equivalent. Individuals trained and qualified in radiation protection procedures (e.g., a health physics technician) or personnel continuously escorted by such individuals may be exempted from this RWP requirement while performing their assigned duties in high radiation areas where radiation doses could be received that are equal to or less than 1.0 rem (0.01 Sv) in 1 hour [measured at 30 centimeters (11.8 in.) from any source of radiation] provided that they are otherwise following plant radiation protection procedures, or a general radiation protection RWP, for entry into such high radiation areas. Any individual or group of individuals permitted to enter such areas should be provided with or accompanied by one or more of the following:

(1) a radiation monitoring device that continuously indicates the radiation dose rate in the area

(2) a radiation monitoring device that continuously integrates the radiation dose rate in the area and alarms when a preset integrated dose is received; entry into such areas with this monitoring device may be made after the dose rates in the area have been determined and personnel have been made knowledgeable of them

(3) an individual qualified in radiation protection procedures with a radiation dose rate monitoring device; this individual is responsible for providing positive radiation protection control over the activities within the area and should perform periodic radiation surveillance at the frequency specified in the radiation protection procedures or the applicable RWP

In addition, areas that are accessible to personnel and that have radiation levels greater than 1.0 rem (0.01 Sv) [but less than 500 rads (5 Gy) at 1 meter (3.3 ft)] in 1 hour at 30 cm (11.8 in.) from the radiation source, or from any surface penetrated by the radiation, should be provided with locked doors to prevent unauthorized entry, and the keys should be maintained under the administrative control of the shift supervisor on duty or health physics supervisor. Doors should remain locked except during periods of access by personnel under an approved RWP that specifies the dose rates in the immediate work areas and the maximum allowable stay time for individuals in that area. In lieu of a stay time specification on the RWP, direct or remote continuous surveillance (such as closed circuit TV cameras) may be made by personnel qualified in radiation protection procedures to provide positive exposure control over the activities being performed within the area.

Individual high radiation areas that are accessible to personnel, which could result in radiation doses greater than 1.0 rem (0.01 Sv) in 1 hour, and that are within large areas where no enclosure exists to enable locking and where no enclosure can be reasonably constructed around the individual area should be barricaded and conspicuously posted. A flashing light should be activated as a warning device whenever the dose rate in such an area exceeds or is expected to exceed 1.0 rem (0.01 Sv) in 1 hour at 30 cm (11.8 in.) from the radiation source or from any surface penetrated by the radiation.

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[2] A barricade can be a rope, ribbon, or other firmly secured, conspicuous obstacle that (by itself or used with physical barriers such as existing walls or hand railings) completely surrounds the area and obstructs entry.

2.5 *Controls for High Radiation Areas (Control Points and Barriers)*

Controls (e.g., locked doors, access control, and posting) for high radiation areas may be established at locations beyond the immediate boundaries of the high radiation areas to take advantage of natural or existing barriers. The use of one locked door, or one control point where positive control over personnel entry is exercised, to establish control over multiple high radiation areas is acceptable, provided that the following conditions are met:

(1) The individual high radiation areas are barricaded and posted separately to identify the actual areas of concern.[3]

(2) Control points are established sufficiently close to the high radiation areas that adequate supervision of access to the areas can be ensured.

(3) The required protective measures and other requirements for entering the high radiation areas (e.g., dosimetry, monitoring) are enforced at the control point.[4]

2.6 *Controls of Keys to High Radiation Areas*

The shift supervisor or radiation protection manager (or their respective designees) should administratively control the issuance of keys to, and return of keys by, personnel requiring access to high radiation areas.

3. Very High Radiation Areas

Because of the potential danger of life-threatening overexposures to individuals, extremely tight control must be maintained over any entry to very high radiation areas. According to 10 CFR 20.1602, licensees must institute additional measures to ensure that an individual is not able to gain unauthorized or inadvertent access to very high radiation areas. To the extent possible, entry should be forbidden unless there is a sound operational or safety reason for entering. Special consideration should be given to areas that become very high radiation areas when the plant changes operational modes, such as shutdowns or startups.

3.1 *Entrances*

Entrances to very high radiation areas should be kept locked except during periods when access to the areas is required. (See 10 CFR 20.1601(a)(3).) Posting of very high radiation areas is required by 10 CFR 20.1902, "Posting Requirements."

Multiple very high radiation areas may be controlled with one locked entrance to take advantage of natural or existing barriers. For example, several very high radiation areas inside the reactor containment, with the reactor at power, may be controlled by locking the containment access port. However, each very high radiation area within these areas should also be conspicuously posted and barricaded separately. Controls for personnel access to very high radiation areas should be established at the locked entrance.

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3 Relatively small areas with several discrete high radiation areas (i.e., near several valves or components) do not require separate barricades and posting for each if the whole room (or area) is considered a high radiation area.

4 Protective measures for access to an area that is not posted and barricaded as a high radiation area, but is within a room or area controlled as a high radiation area, may be relaxed commensurate with the radiological hazards existing in the area.

Authorized entries to very high radiation areas may be monitored by continuous direct electronic surveillance. Unauthorized entries to very high radiation areas inside a pressurized-water reactor (PWR) containment at power can be controlled by locking containment access. However, during authorized entry of the containment at power, electronic surveillance is an acceptable method to ensure that unauthorized entries do not occur into posted and barricaded very high radiation areas within the containment.

3.2 *Control of Keys to Very High Radiation Areas*

The following procedures should govern the administrative control of keys to very high radiation areas:

(1) Procedures should be established so that (a) requirements for issuance of keys to very high radiation areas are stricter than those for keys to high radiation areas, and (b) the responsible operations and radiation protection supervisors are notified before personnel enter very high or potentially very high radiation areas.

(2) A key for access to a very high radiation area should unlock only that area. Master keys that unlock more than one area may be established for use during emergency situations, provided that their distribution is limited and they are not used for normal personnel access.

3.3 *Radiation Work Permits*

Entries to very high radiation areas should be controlled by issuance of a specific RWP or equivalent. General, standing, or blanket RWPs should not be used to control entries to very high radiation areas.

3.4 *Radiation Protection Technician*

A person entering a very high radiation area should be accompanied to the entryway to that area by a radiation protection technician who can determine the radiation exposure conditions at the time of entry and render assistance if necessary.

4. Special Areas

Special hazards may arise in areas that usually are not very hazardous but have the potential to become very high radiation areas during certain normal plant operations. For example, a PWR reactor cavity sump can change from a radiation area to a very high radiation area as a result of withdrawal of the retractable in-core detector thimble tubes. (See Appendix B.)

4.1 *Administrative Procedures*

Administrative procedures should be established to identify these "special" plant areas and ensure that appropriate control measures for potentially very high radiation areas are implemented prior to starting any operation that could create very high radiation areas.

4.2 *Spent Fuel Pools, Reactor Vessels, and Refueling Cavities*

Because of high radioactivity levels from activation and contamination, materials in the spent fuel pools, reactor vessel, and refueling cavities could create a very high radiation area when unshielded. These materials are normally covered with more than 3 meters (10 ft) of water and are inaccessible to personnel performing duties above the pool surface. (Diving operations can make the high and very high radiation areas in the pools accessible. See Regulatory Position 4.3, below, for guidance on access control of divers.) Therefore, these pool areas do not have to be controlled as high or very high radiation areas solely because of the materials in them, provided that the following criteria are fulfilled:

(1) Control measures are implemented to ensure that activated materials are not raised above or brought near the surface of the pool water.

(2) All drain line attachments, system interconnections, and valve lineups are properly reviewed to prevent accidental drainage of the water.

(3) Controls for preventing accidental water loss and drops in water levels that may create high and very high radiation areas are incorporated into plant procedures.

4.3 *Procedures for Diving*

Written procedures for any diving operations into pools, tanks, or cavities, or for access to plant components that contain or may contain highly radioactive materials, should be established to ensure proper radiological controls.

Underwater divers are commonly used for inspections and maintenance in reactor cavities and spent fuel pools. These underwater operations require careful planning, proper work methods, and specific procedures because of the potential for significant exposures from irradiated fuel elements and irradiated reactor components and structures that act as high-level radiation sources.

Appendix A discusses some radiological considerations that should be incorporated into plant procedures for diving operations.

4.4 *Potential Very High Radiation Areas*

Areas of the plant that are known to have a high potential for becoming very high radiation areas during certain operational occurrences should be controlled to provide for ready evacuation of the area. An example would be the upper drywell in a boiling-water reactor (BWR) if an activated fuel bundle is dropped during fuel handling.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC staff's plans for using this regulatory guide. No backfitting is intended in connection with the issuance of this guide.

Except in those cases in which an applicant or licensee proposes or has previously established an acceptable alternative method for complying with specified portions of the NRC's regulations, the methods to be described in the active guide will reflect public comments and will be used in evaluating (1) submittals in connection with applications for new licenses, license renewals, and license amendments, and (2) compliance with 10 CFR Part 20 on control of access to high and very high radiation areas in nuclear power plants.

REGULATORY ANALYSIS

The NRC staff did not prepare a regulatory analysis for this revised guide because this revision simply clarifies terminology, without changing the NRC's regulatory position. The staff also did not prepare a separate regulatory analysis for the initial issuance of Regulatory Guide 8.38 in June 1993. The regulatory analysis prepared for 10 CFR Part 20, "Standards for Protection Against Radiation" (56 FR 23360), also provides the regulatory basis for this guide and examines the costs and benefits of the rule as implemented by the guide. A copy of the "Regulatory Analysis for the Revision of 10 CFR Part 20" (PNL-6712, dated November 1988), is available (as an enclosure to 10 CFR Part 20) for inspection and copying for a fee at the NRC's Public Document Room, located at 11555 Rockville Pike, Rockville, Maryland.

APPENDIX A

PROCEDURES FOR DIVING OPERATIONS IN HIGH AND VERY HIGH RADIATION AREAS

(1) A special radiation work permit (RWP), or equivalent, should be written to provide detailed requirements for the work.

(2) Diving operations should be continuously observed by qualified radiation protection personnel who have stop-work authority. Clear management guidance on when to exercise this control function should be included in radiation protection and diving procedures. (See the additional discussion on diving in Appendix B.)

(3) The locations of the fuel assemblies and other irradiated objects that produce dose rates greater than 1 rem (0.01 Sv) per hour at their surface should be documented and made known to the divers.

(4) Radiation surveys of diving areas should be conducted before all diving operations. Those prework surveys should be conducted using two independent radiation survey instruments. The diver may also perform confirmatory surveys of the work area, provided that the diver is properly trained to perform such surveys. If irradiated fuel or other highly radioactive objects are moved, an underwater survey should be conducted before any diving operation resumes. A survey map of the diving area should be prepared and updated to reflect the current status.

(5) When practical, physical barriers should be provided to prevent divers from accessing irradiated fuel elements and other high radiation items or areas. Each diver should be equipped with a safety line and continuous voice communication with surface personnel. Emergency procedures for diver rescue should be provided and understood by everyone involved in the diving operation.

(6) Divers should be equipped with a calibrated dosimeter that will function and provide an alarm underwater. This dosimeter should be checked for operability each day before diving operations begin. Each diver should also be equipped with a remote-readout radiation detector that is continuously monitored by radiation protection personnel.

APPENDIX B

EXPERIENCE WITH VERY HIGH AND POTENTIALLY VERY HIGH RADIATION AREAS

The following NRC documents provide information concerning past incidents in high and very high radiation areas and discuss means for preventing their recurrence. They are listed here so that pertinent historical information is readily accessible:

- IE Circular 76-03, "Radiation Exposures in Reactor Cavities," September 10, 1976, http://www.nrc.gov/reading-rm/doc-collections/gen-comm/circulars/1976/cr76003.html.
- IE Bulletin 78-08, "Radiation Levels from Fuel Element Transfer Tubes," June 12, 1978, http://www.nrc.gov/reading-rm/doc-collections/gen-comm/bulletins/1978/bl78008.html.
- IE Bulletin 84-03, "Refueling Cavity Water Seal," August 24, 1984, http://www.nrc.gov/reading-rm/doc-collections/gen-comm/bulletins/1984/bl84003.html.
- Information Notice 82-31, "Overexposure of Diver During Work in Fuel Storage Pool," July 28, 1982, http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1982/in82031.html.
- Information Notice 82-51, "Overexposures in PWR Cavities," December 21, 1982, http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1982/in82051.html.
- Information Notice 84-19, "Two Events Involving Unauthorized Entries into PWR Reactor Cavities," March 21, 1984, http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1984/in84019.html.
- Information Notice 84-61, "Overexposure of Diver in Pressurized-Water Reactor (PWR) Refueling Cavity," August 8, 1984, http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1984/in84061.html.
- Information Notice 84-93, "Potential for Loss of Water from the Refueling Cavity," December 17, 1984, http://www.nrc.gov/reading-rm/doc-collections/gen-comm/ info-notices/1984/in84093.html.
- Information Notice 86-107, "Entry into PWR Cavity with Retractable Incore Detector Thimbles Withdrawn," December 29, 1986, http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1986/in86107.html.
- Information Notice 87-13, "Potential for High Radiation Fields Following Loss of Water from Fuel Pool," February 24, 1987, http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1987/in87013.html.
- Information Notice 88-63 and its supplements, "High Radiation Hazards from Irradiated Incore Detectors and Cables," August 15, 1988, http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1988/in88063.html.

- Information Notice 88-79, "Misuse of Flashing Lights for High Radiation Area Controls," October 7, 1988, http://www.nrc.gov/reading-rm/doc-collections/gen-comm/ info-notices/1988/in88079.html.

- Information Notice 90-33, "Sources of Unexpected Occupational Radiation Exposure at Spent Fuel Storage Pools," May 9, 1990, http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1990/in90033.html.

- Information Notice 95-56, "Shielding Deficiency in Spent Fuel Transfer Canal at a Boiling-Water Reactor," December 11, 1995, http://www.nrc.gov/reading-rm/doc-collections/gen-comm/info-notices/1995/in95056.html.

- Information Notice 96-25, "Traversing In-Core Probe Overwithdrawn at LaSalle County Station, Unit 1," April 30, 1996, http://www.nrc.gov/reading-rm/doc-collections/gen-comm/ info-notices/1996/in96025.html.

- Information Notice 97-68, "Loss of Control of Diver in a Spent Fuel Storage Pool," September 3, 1997, http://www.nrc.gov/reading-rm/doc-collections/gen-comm/ info-notices/1997/in97068.html.

These documents are available electronically through the NRC's public Web site (as indicated above). They are also available for inspection and copying for a fee from the NRC's Public Document Room, located at 11555 Rockville Pike, Rockville, Maryland. The PDR's mailing address is USNRC PDR, Washington, DC 20555-0001. The PDR can also be reached by telephone at (301) 415-4737 or (800) 397-4205, by fax at (301) 415-3548, and by email to PDR@nrc.gov.

In addition, in January 1983, the Electric Power Research Institute, Nuclear Safety Analysis Center (NSAC), published a report, entitled "Residual Heat Removal Experience Review and Safety Analysis: Pressurized Water Reactors" (NSAC-052), which provides additional information on past incidents.

Some of the areas mentioned in the above documents have the potential to become high and very high radiation areas during certain periods of operation (most frequently during refueling outages). Table B-1 lists potential radiation fields for certain operations; these are general ranges, and actual numbers may be higher or lower because of plant-specific factors.

Table B-1

Potential Radiation Fields	General Exposure Ranges
Spent fuel transfer tube	10,000-50,000 rads/hr (100–500 Gy/hr) [a]
Letdown IX/filter	1,000–10,000 rads/hr (10–100 Gy/hr)
Spent fuel (in pool)	100,000–1,000,000 rads/hr (1,000–10,000 Gy/hr)
Radwaste resin tank	5,000 rads/hr (50 Gy/hr)
Traversing in-core probe detectors (TIPS) and cables, source and intermediate range monitor detectors and cables (SRMs, IRMs) [b]	1–100,000 rads/hr (0.01–1,000 Gy/hr)
Reactor cavity with thimbles withdrawn	200–2,000 rads/hr (2–20 Gy/hr)
Thimbles	50,000 rads/hr (500 Gy/hr)
Reactor cavity (in-core)	>1,000 rads/hr (>10 Gy/hr)
Steam generator channel head [c]	10–40 rads/hr (0.1–0.4 Gy/hr)

Without proper controls and monitoring, personnel entering these areas when the indicated radiation fields are present could receive radiation exposures with severe or life-threatening consequences.

A study of the above documents indicates generic reasons for repeated incidents. In general, improper entry into these areas results from a lack of awareness, indicating insufficient training and administrative controls. Some of the causes are discussed below.

Entry Into Reactor Cavities When In-Core Detectors Are Withdrawn

During refueling or maintenance, the retractable in-core detectors and associated thimble tubes are sometimes withdrawn from the reactor. While in the reactor core, parts of the detector system (such as the thimble tubes) become highly radioactive. These parts can create radiation fields within the reactor cavity where annual occupational dose limits can be exceeded within a few seconds. These extremely hazardous areas can present life-threatening radiation situations in which acute exposures, sufficient to cause serious radiation injury, are possible after just a few minutes of exposure. This hazard is compounded by limited visibility and access to equipment within the reactor cavity. The cavity is also a hostile physical environment in which accidents and mishaps can occur.

In the vicinity of the thimbles, general area dose rates can be greater than 2,000 rads per hour (20 Gy per hour), with dose rates at the surface of the guide tubes as high as 20,000–40,000 rads per hour (200–400 Gy per hour). Acute exposures to these high dose rates are sufficient to cause clinical radiation injury effects (or possibly death) within just a few minutes [e.g., 2,000 rads/hr or 30 rads/min (20 Gy/hr or 0.3 Gy/min)]. (See Figure B-1.)

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[a] This is the dose rate during spent fuel transfer.

[b] These doses vary considerably depending on the time after withdrawal from the core. Immediately upon withdrawal, a dose rate of >10,000 rads/hr (100 Gy/hr) may be experienced, while decay can reduce the contact dose rates to 1–10 rads/hr (0.01–0.1 Gy/hr) after about 3 days.

[c] Although this is not a very high radiation area, it is important because it is frequently accessed by personnel.

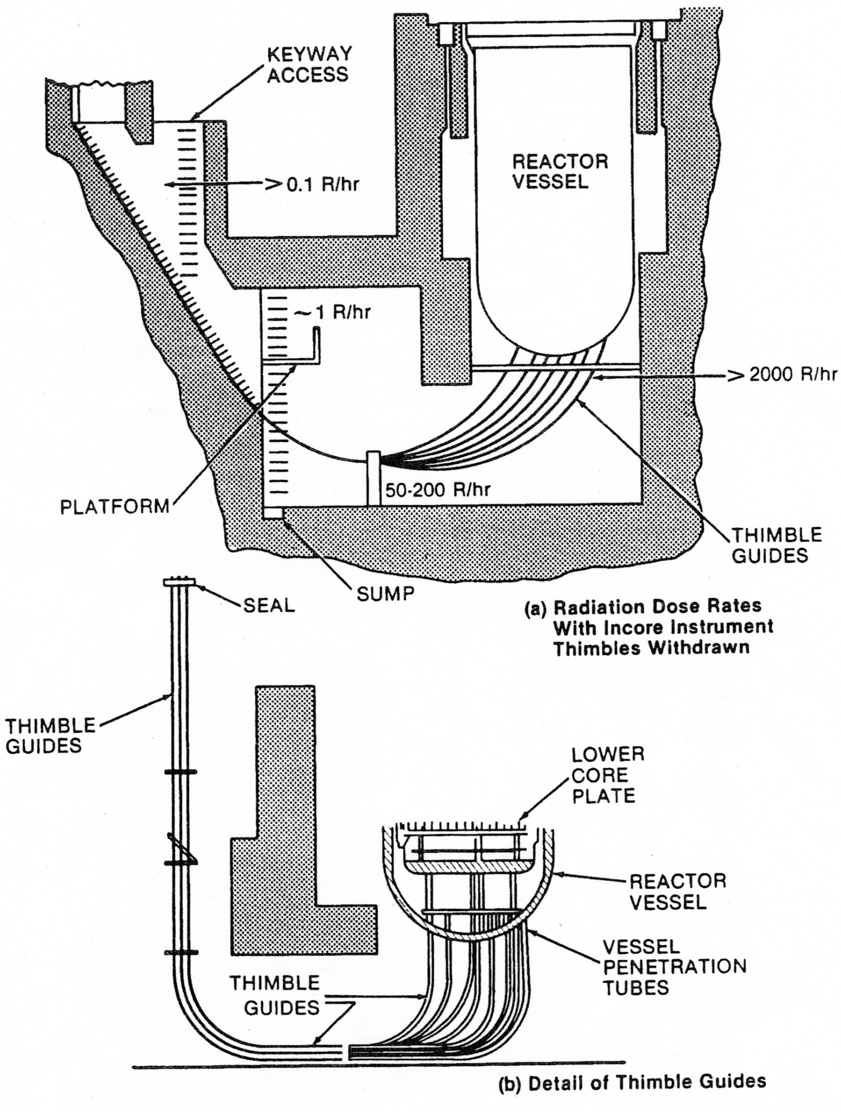
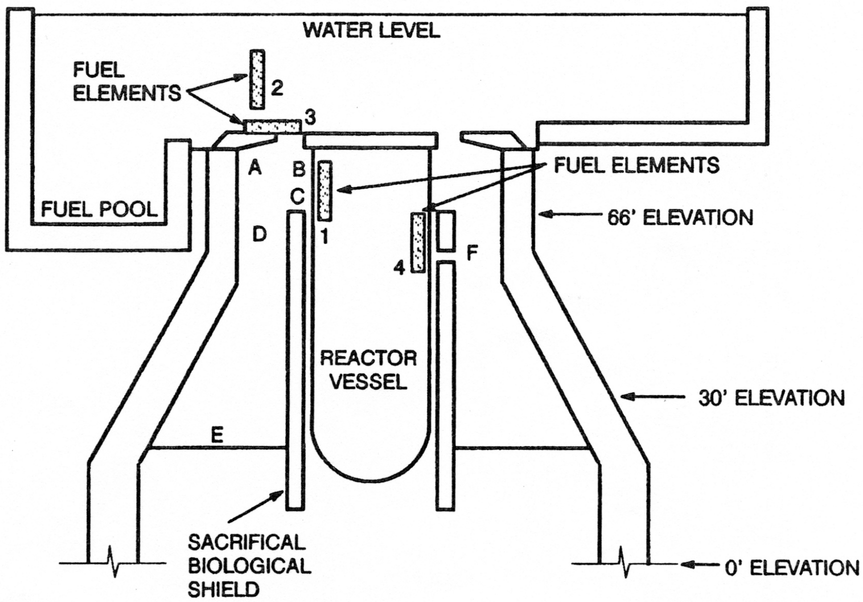


Figure B–1 Pressurized Water Reactor Cavity

In the past, personnel from the operations departments at several plants have entered the reactor cavity without radiation work permits, adequate surveys, or knowledge of the condition of the retractable in-core detectors and their thimble tubes. Personnel have bypassed the lock systems and ignored posted warning signs regarding the special conditions required for entry. These personnel have included managers, shift engineers, shift supervisors, reactor operators, and health physics technicians. These incidents have resulted in overexposures exceeding the NRC's established regulatory limits and several near overexposures.

Fuel Movement in BWR Drywells

During certain spent fuel handling operations, very high dose rates can exist in BWR drywells. All drywell containment types (Mark I, II, and III) lack complete shielding. Fuel handling must be controlled to prevent potentially fatal exposure to drywell workers from mishaps with irradiated fuel. Unshielded irradiated fuel can create radiation fields of 10^4 to 10^6 rads per hour (10^2 to 10^4 Gy per hour) at a distance of 30.5 cm (1 ft). Figure B-2 shows dose rates in several drywell areas resulting from spent fuel in various configurations.



Dose Rates During Refueling
(R/hr without/with moveable shield)

Location	Fuel Position			
	1	2	3	4
A	–/–	30/0.3	8×10^4/15	–/–
B[1]	10/–	–/–	–/–	–/–
C[2]	50/–	–/–	–/–	–/–
D	–/–	$3/3\times10^{-2}$	2×10^3/1.5	–/–
E	–/–	$0.13/1\times10^{-4}$	5×10^2/0.15	–/–
F	–/–	–/–	–/–	3/–

Foot Note: 1. Measured 2 ft. from reactor vessel
2. Measured on contact with reactor vessel

Figure B-2 Dose Rates in BWR Drywell During Spent Fuel Transfer

The NRC has conducted reviews of the radiological controls for BWR drywells during spent fuel movement, which included licensees' use of temporary shielding for spent fuel transfer to the storage pool (see Figure B-3), operational considerations (e.g., restricting access to the upper drywell or evacuation procedures for the drywell during fuel movement), and employee training. These reviews identified the following conditions:

(1) Personnel were not aware of the hazards to a worker in the drywell resulting from a dropped spent fuel element.

(2) Personnel were not aware of the special shielding requirements.

(3) Radiological controls, procedures, and personnel training needed improvement.

(4) There was a lack of communication between fuel operations and personnel at radiological control points.

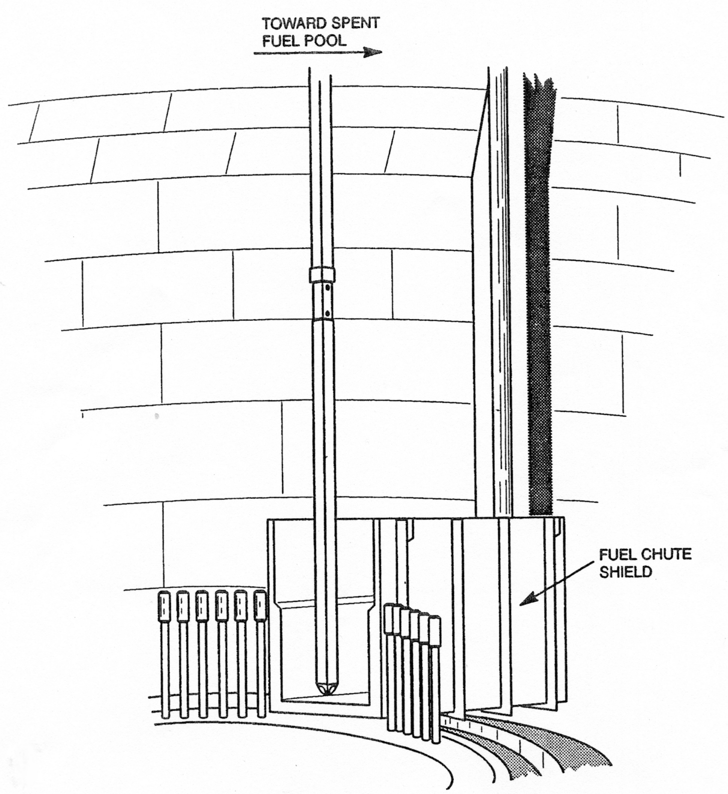


Figure B-3 Portable Radiation Shield

Divers in the Spent Fuel Pool and Reactor Cavity

Divers are used for an increasing number of maintenance and inspection tasks. The operations these individuals perform require careful and thorough planning. The use of proper underwater work techniques can result in substantial time savings and reductions in radiation doses.

The gear that divers wear makes their out-of-water movements awkward and makes seeing and hearing more difficult, thereby hindering communications. Control of a diver's location in the pool is important to keep the diver away from areas of high radiation levels.

Careful planning and execution of divers' work in the spent fuel pool, reactor cavity, and reactor vessel and piping are extremely important, as a single spent fuel element can create radiation fields of 10^4 and 10^6 rads per hour (10^2 and 10^4 Gy per hour) at close proximity. Other irradiated objects in the pool or cavity can produce dose rates from ten to hundreds of rads per hour.

Past experience shows that surveys and radiation work permits have sometimes been inadequate for the special nature of the divers' work environment. Continuous-readout dosimeters and dose rate survey instruments have not been widely used. Dosimeters with alarms have failed for lack of proper controls and checks of instruments. Dose rate monitoring devices that warn of unexpected changes in dose rates in the work area have not been used. Procedures detailing special precautions for diving operations in these areas have also been inadequate in some cases. Visibility, lighting, and performance of underwater survey instrumentation in the fuel pool have been poor.

Loss of Water from the Fuel Pool, Fuel Transfer Canal, and Reactor Cavity

Complete or partial loss of water from the spent fuel pool, fuel transfer canal, or reactor cavity can result in very high radiation areas. In some instances, a refueling cavity water pneumatic seal and a transfer canal pneumatic seal have failed, causing a rapid drop in the water level in the spent fuel pool. These large water losses can expose spent fuel in the fuel pool or uncover other highly radioactive objects in the fuel pool (such as irradiated control rod blades and neutron detectors) within a few minutes. These large water losses could also result in high radiation levels from components that have been suspended at insufficient depth in the spent fuel pool.

Other mechanisms that can cause water losses in the spent fuel pool, fuel transfer canal, and reactor cavity include certain misalignments of valves in the residual heat removal system while the reactor is in the shutdown cooling mode (assuming shutdown cooling is in use when the cavity is filled), leaking steam generator nozzle dams, and slow-draining lines attached to the refueling cavity.

Resin Tanks, Systems, and Chemical Decontamination

Resin tanks may accumulate large inventories of radionuclides from the processing of various coolants or wastes. Resins may flow through piping in the reactor facilities because of improper valve lineups, malfunctions, etc., and may result in new high radiation areas.

Chemical decontamination of systems may result in movement of large quantities of radioactive materials. Activities in these areas must be carefully observed because of the potential for the areas to become very high radiation areas.

Other Very High Radiation Areas

Portions of the reactor piping (such as valves and loops) may become collection points for radionuclides over time. Activities in these areas must be carefully observed because of the potential for the areas to become very high radiation areas.