UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, D.C. 20555-0001

September 3, 1997

NRC INFORMATION NOTICE 97-68: LOSS OF CONTROL OF DIVER IN A SPENT FUEL STORAGE POOL

Addressees

Holders of a facility license or construction permit issued for a power reactor pursuant to 10 CFR Part 50.

Purpose

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice to inform addressees of inadequacies in licensee control of work in a spent fuel storage pool at a power reactor facility which resulted in a diver getting close to very high radiation fields emanating from recently discharged spent fuel. It is expected that recipients will review the information in this notice for applicability to their facilities and consider actions, as appropriate, to avoid similar problems. However, suggestions contained in this information notice are not NRC requirements; therefore, no specific action or written response is required.

Description of Circumstances

On April 3, 1997, the Calvert Cliffs Unit 2 facility, owned and operated by Baltimore Gas and Electric Company (the licensee), was in Mode 6 with reactor defueling on hold because of a malfunction of the Unit 2 fuel transfer system. The fourth in a series of diving activities to effect repairs to the fuel transfer system was conducted in the spent fuel pool. Previous dives had been made in the refueling cavity to repair the system. The diver entered the spent fuel pool at about 9:00 a.m. to commence work on an upender limit switch at the south end of the fuel transfer area, the only surveyed and authorized work area. The fuel transfer area runs the length of the west side of the Unit 2 spent fuel pool. No wall or shield (other than the pool water) separates the area from the fuel storage racks on the east side.

As with the previous dives, normal diving controls were specified by a licensee-approved procedure and a job-specific radiation work permit. Multiple thermoluminescence dosimeters (TLDs) were attached to the diver's wrists, head, chest, back, and thighs and feet. Monitoring of the diver's dose was provided in real time with teledosimetry devices attached to his wrists, thighs (above knee), chest, and back. The diver was also provided with two radiation detector probes attached to a shaft approximately 76 cm (30 in) long for the purpose of surveying his immediate vicinity. Each teledosimetry device was set to alarm at the surface monitoring station on detecting an integrated dose of 1.0 mSv (100 mrem) or a dose rate of 8.95 mSv/hr (895 mrem/hr). Radiation protection (RP) technicians continuously

monitored the instrument readouts, and relayed the information through an intercom to the diver who had no local indication of monitor readings or alarms. Unlike previous dives into the refueling cavity which employed underwater closed-circuit television (video) to visually monitor the diver, a technician at the pool surface was assigned to observe the diver through a floating window box during the fourth dive.

Following the repair of the limit switch, the diver asked for some materials that he needed to complete the work. While he was waiting for the materials to be lowered, the diver told the support team that he wanted to inspect a kink in the upender cable. He was referring to a cable kink at the north end of the pool. However, the RP technicians assumed that the diver was referring to the cable in the authorized work area. Accordingly, the health physicist (HP) technician approved the request, and the diver headed toward the north end of the pool. At the north edge of the authorized work zone, the diver inflated his diving suit, ascended and hovered above the pool floor to inspect cabling. He then vented his suit, descended to the pool floor and continued toward the north leaving the authorized area. The observer at the surface did not detect the diver's unauthorized entry into the north end of the fuel transfer area because the vented air bubbles ascending through the pool water obscured his view of the diver. The observer subsequently was distracted with other duties and never regained visual contact with diver. Therefore, the dive tender continued to provide cable and breathing air line to the diver unchallenged.

Near the north end of the transfer system, the diver stopped to survey a pipe on the west wall of the pool that he did not recognize. During the survey, the monitors on the diver's right and left wrists alarmed and increased to 90 mGy/hr (9 rad/hr) and 23 mGy/hr (2.3 rad/hr) respectively. The RP technicians instructed the diver to retreat to a lower dose area. The RP technician was not aware that the diver had actually encountered the radiation field from recently off-loaded spent fuel located in the racks on the east side of the transfer area. Still believing that the diver was at the south end of the pool, the RP technician instructed the diver to survey the area to locate the source of the unexpected radiation. When the survey meter readout increased to 30 mSv/hr (3 rem/hr), the dive was suspended. Only after the diver surfaced, did the RP personnel realize that the diver had actually been in the north end of the pool. The subsequent assessment of the event revealed that the diver crossed about 4.6 meters (15 feet) of unsurveyed fuel transfer area floor and came within a few feet of radiation dose rates ranging from 120 to 200 Gy/hr (12,000 to 20,000 rad/hr).

The diver's TLDs were subsequently processed, but not before he was allowed to re-enter the radiation control area (RCA) to support another diving operation as a standby safety diver. The licensee allowed the re-entry to the RCA prior to dosimetry processing based on a preliminary assessment that the teledosimetry readings indicated that the diver received no significant radiation exposure.

Following TLD processing, the licensee calculated a maximum dose to the extremities (right knuckles) of 8.85 mSv (885 mrem) based on a wrist TLD badge shallow dose equivalent result of 4.24 mSv (424 mrem). The licensee also calculated a dose of 2.7 mSv (270 mrem) to the highest exposed portion of the whole body (arm above the elbow) as compared to a

maximum TLD reading on the head of 1.37 mSv (137 mrem). The maximum dose to the lower extremity (ankle) was 0.021 mSv (21 mrem) shallow dose equivalent.

Discussion

The NRC has noted several deficiencies in the preplanning and controls implemented to support the April 3, 1997, diving operations at Calvert Cliffs. These include:

1. The scope of work was not clearly understood by all parties involved.

   During the formal pre-job briefing, on the morning of the dive, it was noted that the scope of work included an inspection of the cable kink at the north end of the transfer mechanism "if radiological conditions permitted." The RP personnel in attendance were not sure if the radiation survey made to support the dive covered the north end of the pool. After the briefing, the RP supervisor determined that the survey was limited to the south end of the fuel transfer area and informed the dive engineering support personnel that work in the north of the pool was not authorized. No one gave this information to the diver or the dive tender.

2. The diver was given inadequate instructions about the location and magnitude of the radiation sources accessible to him.

   A second communications failure took place at the dive site when the RP technician briefed the diver on the radiation levels in the work area. A map indicating the results of the radiation survey was shown to the diver. However, this map was an enlarged view of the south end of the transfer area. Due to a lack of perspective, the diver believed he was being shown the radiation levels in the entire pool. This mis-communication reinforced the diver's incorrect understanding of the scope of the authorized work.

3. Positive control over the diver in the pool was inadequate.

   Guidance on effective access control over divers in the spent fuel pool is given in Regulatory Guide (RG) 8.38, "Control of Access to High and Very High Radiation Areas in Nuclear Power Plants," and in such industry standards as the Electric Power Research Institute's (EPRI's) "Underwater Maintenance Guide" (EPRI NP-7088-R2). Appendix A to RG 8.38 discusses six areas of concern where control needs to be exercised over diving operations. This list is a compilation of the result of lessons learned from previous diving events at nuclear power plants. The licensee failed to implement effective controls in five of these six areas.

   At the time visual contact with the diver was lost, the licensee had, in effect, lost control of the dive. As stated in Section 1.5.4 of the EPRI guide, visual contact should be maintained throughout the entire dive to be sure of the

diver's location and proximity to all known underwater radiation sources. The licensee failed to recognize the significance of maintaining visual contact with the diver. The inattentiveness and lack of a questioning attitude by the dive support personnel contributed significantly to the loss of control.

The licensee's investigation of this event determined that several of the people involved did not clearly understand the scope of their responsibilities for the planning and conduct of the diving operation. One of the root causes identified was the practice at Calvert Cliffs of providing management expectations on how a task is to be performed in documents other than the formal job procedure. For example, the licensee found that the individual assigned to observe the diver did not understand that he was to continuously observe the diver and thought that this task was optional since it was not stated in the procedure. The requirement to maintain visual contact with the diver was in an RP Job Coverage Standard instead of in a formal procedure. The licensee is revising plant procedures so that they will contain all critical steps needed to exercise adequate controls over on-site work.

4. Licensee failed to adequately evaluate the diver's exposure status before authorizing additional work in the RCA.

Given the complexity of the diving environment, the licensee's assessment of the diver's dose based on the teledosimetry readings was not sufficiently comprehensive. Teledosimetry located on the diver's thigh is not adequate to determine whether an overexposure to the diver's extremity occurred during this event. The diver could have received a high dose to his feet while walking across the unsurveyed section of the pool floor without exceeding the alarm setpoint on the thigh monitors because of the shielding provided by the pool water. In addition, the estimate of the whole body dose did not consider the possibility of exposure to neutron radiation since the detectors were not sensitive to neutrons. Subcritical spent fuel is a significant neutron source due to alpha-n reactions and spontaneous fission of curium in the fuel. In response to the NRC inspector's questions, the licensee subsequently determined that the diver would have to be within 0.6 meters (2 feet) of the fuel for neutrons to be a factor. The TLD readings verified that the diver received no measurable neutron dose.

Although it appears that the radiation doses received by the diver did not exceed the dose limits given in 10 CFR Part 20, the breakdowns noted above resulted in the diver being able to gain access to a very high radiation area contrary to the requirements of 10 CFR 20.1602. During normal operations spent fuel pools are neither high nor very high radiation areas since the radioactive sources in them are usually covered by at least 3.3 meters (10 feet) of water and are thus considered inaccessible to personnel (see Regulatory Position 4.2 in RG 8.38). However, consistent with Regulatory Position 1.5 in RG 8.38, once an inaccessible area is made accessible, in this case by conducting diving operations, the applicable controls for a high or very high radiation area must be provided. This includes the access control

requirements of 10 CFR 20.1601 and 20.1602 as well as appropriate posting at the entrance to the area consistent with the requirements of 10 CFR 20.1902.

The combination of an extremely intense radiation source and the very steep dose gradients that can be encountered as a diver moves through his shielding (water), make diving in areas where irradiated fuel can be accessed a uniquely hazardous operation. Had the circumstances of this event been only slightly altered, the diver could have been exposed to much higher dose rates. Even with continuous teledosimetry monitoring, it is possible for a diver to inadvertently enter a radiation field and receive a serious radiation dose, in a matter of seconds. Establishing and maintaining proper effective controls is critical to worker safety.

Related NRC Communications and Correspondence

The following related communications and correspondence are noted:

- NRC Information Notice 82-31, "Overexposure of Diver During Work in Fuel Storage Pool," July 28, 1982
- NRC Information Notice 84-61, "Overexposure of Diver in Pressurized Water Reactor (PWR) Refueling Cavity," August 8, 1984
- NRC Regulatory Guide 8.38, "Control of Access to High and Very High Radiation Areas in Nuclear Power Plants," June 1993, Appendix A, "Procedure for Diving Operations in High and Very High Radiation Areas"
- NRC Inspection Reports 50-317/97-02 and 50-318/97-02, May 29, 1997
- NRC Enforcement Action EA97-192 dated August 11, 1997

This information notice does not require any specific action or written response. If you have any questions about the information in this notice, please contact one of the technical contacts listed below.

JWRoe

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Information Notice No.	Subject	Date of Issuance	Issued to
97-67	Failure to Satisfy Requirements for Significant Manipulations of the Controls for Power Reactor Operator Licensing	08/21/97	All holders of OLs for nuclear power reactors except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor vessel
97-66	Failure to Provide Special Lenses for Operators Using Respirator or Self-Contained Breathing Apparatus During Emergency Operations	08/20/97	All holders of operating licenses or construction permits for nuclear power and non-power reactors and all licensed reactor operators and senior operators
97-65	Failures of High-Dose-Rate (HDR) Remote After-loading Device Source Guide Tubes, Catheters, and Applicators	08/15/97	All high-dose-rate (HDR) remote afterloader licensees
97-64	Potential Problems Associated with Loss of Electrical Power in Certain Teletherapy Units	08/13/97	All U.S. Nuclear Regulatory Commission medical teletherapy licensees
97-63	Status of NRC Staff's Review of BWRVIP-05	08/07/97	All holders of OLs or CPs for boiling water reactors
97-62	Unrecognized Reactivity Addition During Plant Shutdown	08/06/97	All holders of OLs or CPs for nuclear power reactors

OL = Operating License
CP = Construction Permit

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DATE	07/24/97		07/25/97		07/ /97		07/ /97	

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access control requirements of 10 CFR 20.1601 and 20.1602 as well as appropriate posting at the entrance to the area consistent with the requirements of 10 CFR 20.1902.

The combination of an extremely intense radiation source and the very steep dose gradients that can be encountered as a diver moves through his shielding (water), make diving in areas where irradiated fuel can be accessed a uniquely hazardous operation. Had the circumstances of this event been only slightly altered, the diver could have been exposed to much higher dose rates. Even with continuous teledosimetry monitoring, it is possible for a diver to inadvertently enter a radiation field and be overexposed, or worse, in a matter of seconds. Establishing and maintaining proper effective controls is critical to worker safety.

Related NRC Communications and Correspondence

The following related communications and correspondence are noted:

- NRC Information Notice 82-31, "Overexposure of Diver During Work in Fuel Storage Pool," July 28, 1982

- NRC Information Notice 84-61, "Overexposure of Diver in Pressurized Water Reactor (PWR) Refueling Cavity," August 8, 1984

- NRC Regulatory Guide 8.38, "Control of Access to High and Very High Radiation Areas in Nuclear Power Plants," June 1993, Appendix A, Procedure for Diving Operations in High and Very High Radiation Areas

- NRC Inspection Reports 50-317/97-02 and 50-318/97-02, May 29, 1997

This information notice does not require any specific action or written response. If you have any questions about the information in this notice, please contact one of the technical contacts listed below.

Mary Lee Slosson, Acting Director
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