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

May 25, 1993

NRC INFORMATION NOTICE 93-39: RADIATION BEAMS FROM POWER REACTOR BIOLOGICAL SHIELDS

Addresses

All holders of operating licenses or construction permits for nuclear power reactors.

Purpose

This information notice is to alert addressees to narrow, intense beams of radiation that can stream into accessible areas of a drywell through penetrations in the biological shield of a boiling-water reactor (BWR), potentially causing personnel exposures above regulatory limits and exposing environmentally qualified (EQ) equipment located in a drywell to high levels of radiation. It is expected that recipients will review the information 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

During startup of the Philadelphia Electric Company (the licensee) Limerick Generating Station, Unit 1, on July 7, 1992, operators could not properly operate a main steamline sample-flow isolation valve (HV-041-1F084) from the control room. Members of the licensee Operations Group determined that the valve was an inboard primary containment isolation valve and generated an action request to troubleshoot the valve. The valve is on the 303-foot elevation of the drywell (at an azimuth of 280 degrees). The electrical junction box for the valve is on the 296-foot elevation at about the same azimuth in the drywell and is directly across from the reactor water-level instrument-line penetration in the biological shield.

The licensee revised an existing radiation work permit, originally prepared for the inspection of systems in the Unit 1 drywell, to include trouble-shooting of the valve. The licensee stated that it routinely performs such inspections during startup from a refueling outage.

From July 7 through 9, 1992, six separate work crews performed troubleshooting and repair work in the drywell with the reactor operating at a maximum of about 10 percent of its rated power.

During the first and second entries into the drywell on July 7 and 8, 1992, personnel worked only on the 303-foot elevation of the drywell, where

radiation levels were generally low and where there were no biological shield penetrations in the immediate work area. However, during the third and fourth entries on July 8 and 9, 1992, personnel went to the 296-foot elevation and either passed in front of or worked in sight of the reactor water-level instrument-line penetration (Figures 1, 2, and 3)[1]. Unknown to those working on this elevation, a narrow, intense, beam of radiation passed from reactor water-level instrumentation penetration N16-D directly across the drywell, striking the inner drywell wall in the immediate vicinity of the work area. The diameter of the beam ranged from about 0.15 meter [0.5 foot] at the penetration to 0.3 to 0.6 meter [1 to 2 feet] at the drywell wall. The NRC determined that licensee radiological controls personnel did not know that the third work crew had gone to the 296-foot elevation. Although a radiological controls technician (RCT) accompanied the fourth work crew, the beam was not detected during this entry.

During the fifth entry, on July 9, 1992, the work crew, accompanied by a radiological controls technician, entered the 296-foot elevation and worked in sight of penetration N16-D. While working, one worker's dosimeter alarmed; apparently, the beam struck the dosimeter. The RCT conducted a radiation survey, detected the beam, and immediately evacuated the work area.

The licensee detailed survey found, at the extremity of the work area, radiation levels of about 30 mSv per hour [3 rem per hour] (gamma); and, at the point where the beam emerged from the penetration, levels of about 1500 mSv per hour [150 rem per hour] (gamma) and greater than 50 mSv per hour [5 rem per hour] (neutron). Radiation dose rates in the work area, readily accessible to personnel, and attributable to the beam, ranged from about 30 to about 250 mSv per hour [about 3 to about 25 rem per hour] (gamma) while the maximum general area radiation dose rates were 10 mSv per hour [1 rem per hour] (gamma) and 5 mSv per hour [500 millirem per hour] (neutron). These last maximum general area dose rates were used as the basis for radiation work permit requirements for work in the area. Figures 1, 2, and 3 show the location of the penetration, the approximate path of the beam, and the work location on the 296-foot elevation of the Unit 1 drywell. After the licensee detected the beam and reviewed the situation, a sixth work crew entered the 296-foot elevation to restore electrical connections to the isolation valve while remaining out of the path of the beam.

Specific licensee actions in response to this event are described in Attachment 4.

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[1] From the Philadelphia Electric Company's presentation to the NRC October 14, 1992

Discussion

Upon reviewing this event, the NRC concluded that a significant potential existed for personnel to receive exposures in excess of regulatory limits on the 296-foot elevation of the drywell. This conclusion is based on the following: (1) personnel entered an area (the 296-foot elevation where the beam was later found) without the knowledge of radiological controls personnel; (2) the licensee failed to detect the beam using its normal radiation survey procedures and techniques; and (3) the licensee did not anticipate such beams. The NRC also found that such beams may exist at other facilities, particularly at BWRs.

The Limerick event indicates that licensees may not be adequately considering the effects of radiation beams with respect to environmental qualification of equipment exposed to such beams. The NRC established environmental design criteria to ensure that all safety-related equipment is capable of performing its safety function or remaining in a safe mode under all conditions postulated to occur during its installed life. These criteria are incorporated into requirements such as Section 10 CFR 50.49 of Title 10 of the Code of Federal Regulations (10 CFR Part 50).

Worker entry into a BWR drywell or pressurized-water reactor containment at power involves a challenging environment for radiological controls and monitoring. These include (1) the possibility of high levels of airborne radioactivity, (2) high gamma and neutron radiation dose rates, (3) the potential for large radiation dose rate gradients, including relatively small, intense beams of radiation, which may change location as rod positions change, and (4) the difficulty of detecting and characterizing small beams of radiation, using routine survey procedures and instruments. If appropriate radiation surveys inside containment at power have not been performed during a previous reactor startup, the potential exists for significant undetected and uncharacterized radiation dose rates from radiation beams. Each of these factors presents significant personnel exposure control problems.

This information notice requires no 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 or the appropriate Office of Nuclear Reactor Regulation (NRR) project manager.

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Office of Nuclear Reactor Regulation

Technical contacts: R. L. Nimitz, RI
(215) 337-5267

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Attachments:
1. Figure 1, "Limerick Generating Station Unit 1 Drywell"
2. Figure 2, "Limerick Generating Station, Unit 1, Drywell 296' Elevation Survey Data"
3. Figure 3, "Limerick Generating Station, Unit 1, Section Along Azimuth 280°"
4. Licensee Actions
5. List of Recently Issued Information Notices

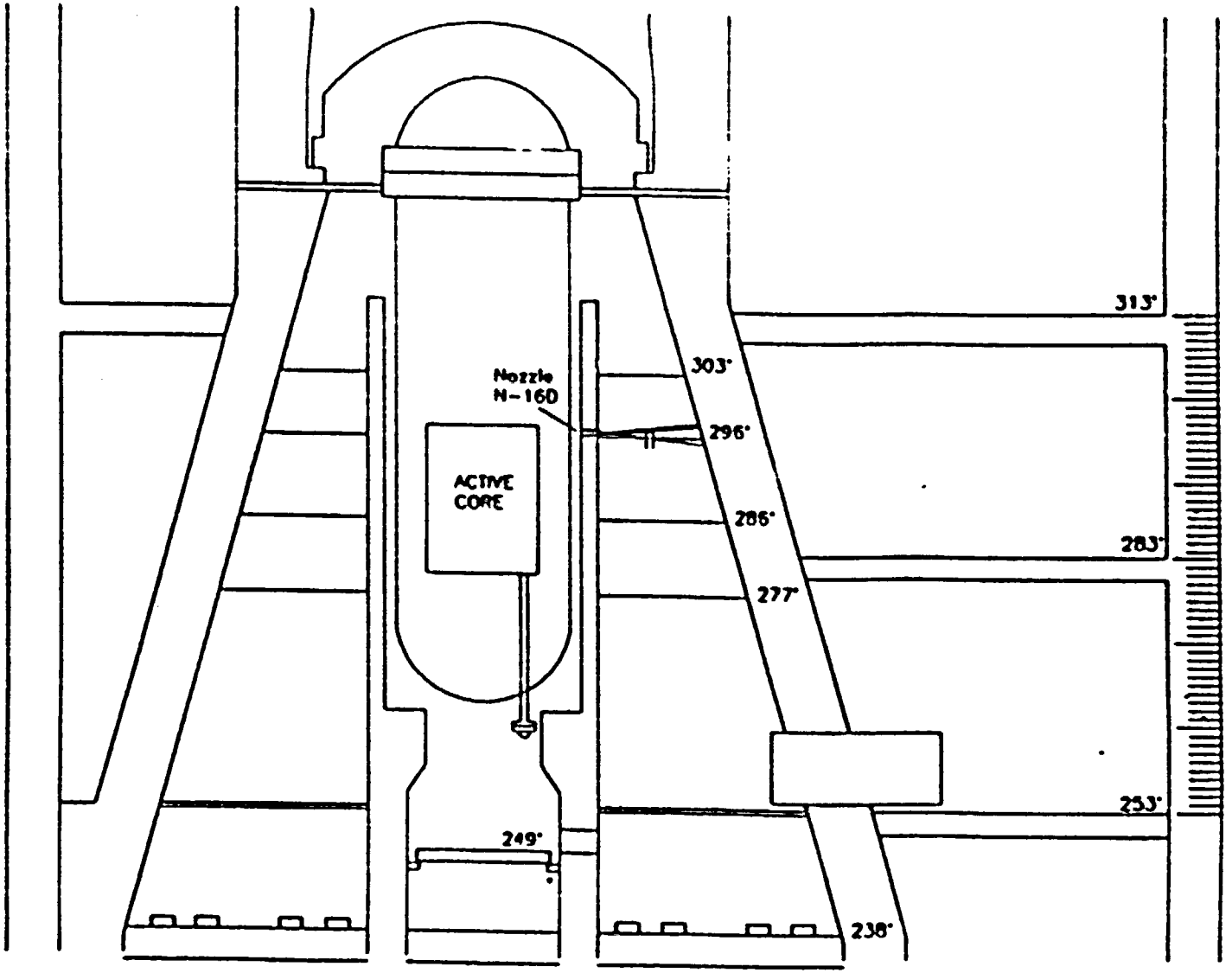

Figure 1: Limerick Generating Station Unit 1 Drywell

Source: Philadelphia Electric Company's Briefing of NRC, 10/14/92

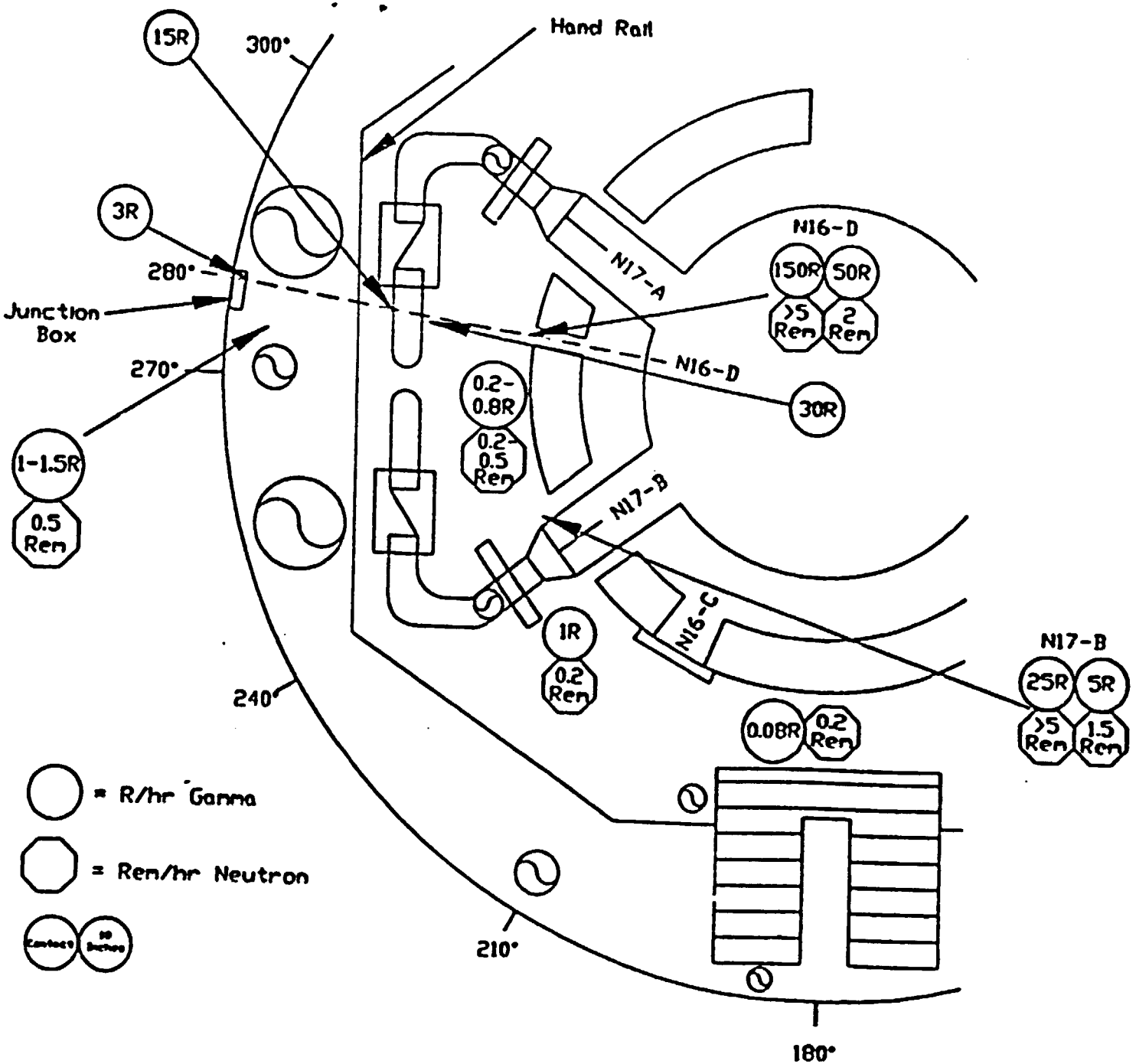

Figure 2: Limerick Generating Station Unit 1 Drywell 296' Elevation Survey Data

Source: Philadelphia Electric Company's Briefing of NRC, 10/14/92

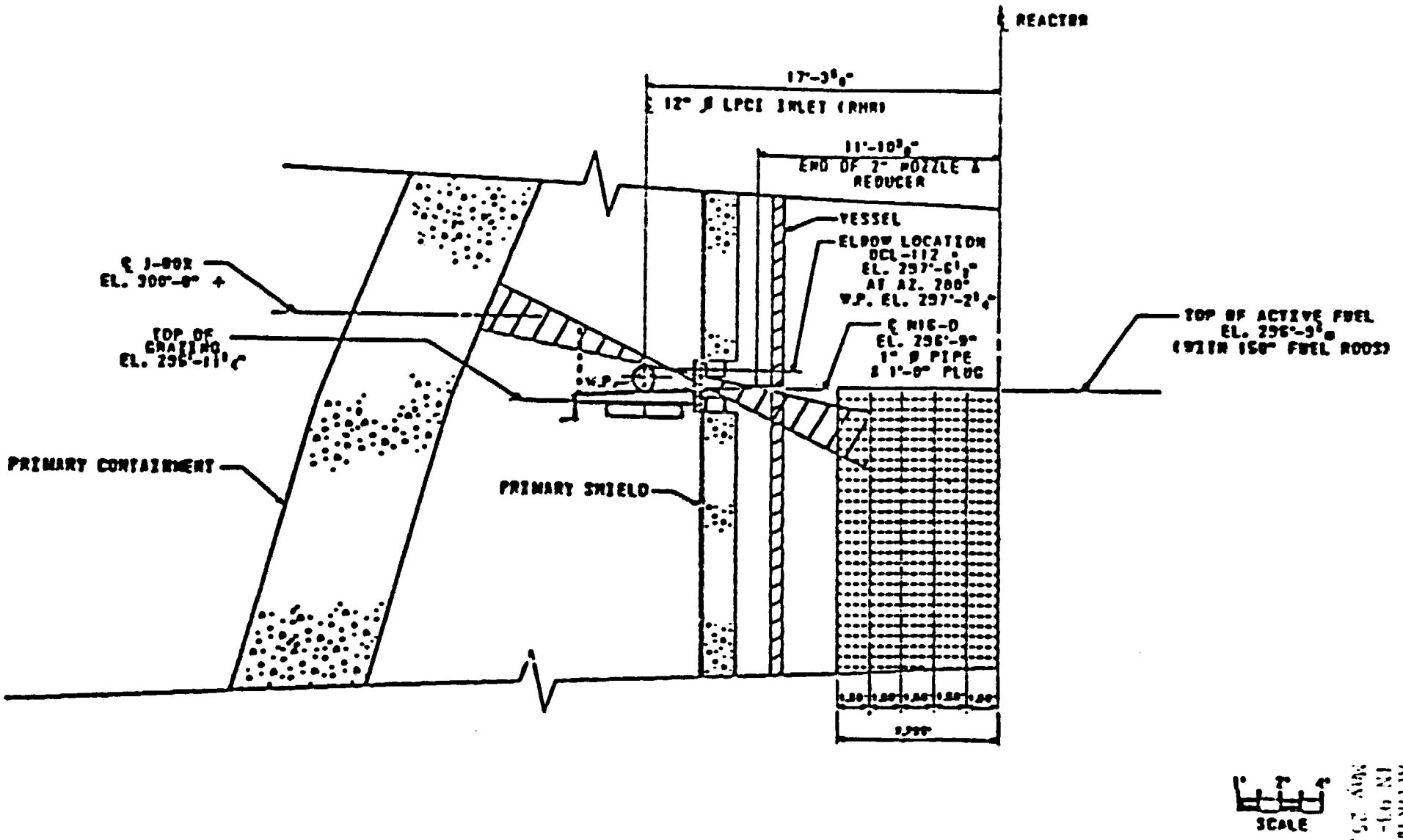

Figure 3: Limerick Generating Station Unit 1 Drywell
Section Along Azimuth 280°

Source: Philadelphia Electric Company's Briefing of NRC, 10/14/92

LICENSEE ACTIONS

After detecting and characterizing the beam, the licensee took the following corrective actions:

1. Immediately evacuated the area and had radiation protection supervisors and station managers evaluate the situation.

2. Prevented personnel from entering the beam path.

3. Sent personnel dosimeters for evaluation and performed dose assessments.

4. Studied each individual's activities in the drywell to determine individual exposures and which individuals may have been exposed to the beam. The licensee believes that the maximum individual exposure from the beam was about 300 millirem and that no one's radiation exposure exceeded regulatory limits.

5. Prepared a radiological occurrence report.

6. Had its Independent Safety Engineering Group (ISEG) perform a root-cause and barrier analysis of the event. The Group recommended that the licensee review EQ concerns. The licensee concluded that reactor power did not increase while personnel were in the drywell.

7. Had the ISEG evaluate the event during which it found that:

   - the beam should have been anticipated,

   - the beam probably resulted from the unique geometric arrangement of the low-pressure coolant injection (LPCI) piping, the shield penetration, and the core peak axial power location, and that

   - moving the rods downward to increase reactor power caused the location of peak axial power to move downward in the core, increasing the angle of the beam uoward and causing the beam to pass over the top of a LPCI line, located in front of the penetration, and into the work area (see Figure 3). (Although operators changed the reactor power level between entries, power level changes were controlled so that no changes occurred while personnel were in the drywell.)

8. Had the ISEG review the potential for beams at other biological shield penetrations. The ISEG:

   - concluded that, owing to the unusual circumstances, the subject penetration was the worst case for occupational radiation protection, and

- found that the recirculation inlet nozzle penetration had the highest associated radiation dose rates for EQ considerations. (The dose rates at this latter penetration were used for bounding EQ calculations).

9. Confirmed previous EQ evaluations but found that more detailed reviews were needed.

10. Compared measured dose rates as a function of distance from penetration N16-D with dose rates calculated earlier by the architect-engineer, establishing that the measured dose rates associated with the penetration did not decrease as rapidly as indicated by the calculations.

11. The licensee planned to complete the following long-term corrective actions:

- Prepare a special procedure for drywell entries at power.
- Require a higher level of station management approval for work in the drywell at power.
- Prepare special guidance on survey techniques and instruments for surveying penetrations in the biological shield.
- Emphasize work-area boundaries in preparing radiation work permits, performing ALARA reviews, and performing pre-job briefings.
- Emphasize the need for the control of reactor power levels during work in the drywell.
- Increase health physics coverage during at-power entries to the drywell.
- Improve shielding, access control, or both, for high-radiation areas resulting from radiation beams.
- Include review of this event in the training of health physics, operations, and radiation workers.

LIST OF RECENTLY ISSUED NRC INFORMATION NOTICES

Information Notice No.	Subject	Date of Issuance	Issued to
93-38	Inadequate Testing of Engineered Safety Features Actuation System	05/24/93	All holders of OLs or CPs for nuclear power reactors.
93-37	Eyebolts with Indeterminate Properties Installed in Limitorque Valve Operator Housing Covers	05/19/93	All holders of OLs or CPs for nuclear power reactors.
93-36	Notifications, Reports, and Records of Misadministrations	05/07/93	All U.S. Nuclear Regulatory Commission medical licensees.
93-35	Insights from Common-Cause Failure Events	05/12/93	All holders of OLs or CPs for nuclear power plants (NPPs).
93-34, Supp. 1	Potential for Loss of Emergency Cooling Function Due to A Combination of Operational and Post-Loca Debris in Containment	05/06/93	All holders of OLs or CPs for nuclear power reactors.
93-34	Potential for Loss of Emergency Cooling Function Due to A Combination of Operational and Post-Loca Debris in Containment	04/26/93	All holders of OLs or CPs for nuclear power reactors.
93-33	Potential Deficiency of Certain Class 1E Instrumentation and Control Cables	04/28/93	All holders of OLs or CPs for nuclear power reactors.

OL = Operating License
CP = Construction Permit