UNITED STATES
NUCLEAR REGULATORY COMMISSION
OFFICE OF NUCLEAR REACTOR REGULATION
WASHINGTON, DC 20555-001

January 31, 2011

NRC INFORMATION NOTICE 2011-02: OPERATOR PERFORMANCE ISSUES INVOLVING REACTIVITY MANAGEMENT AT NUCLEAR POWER PLANTS

ADDRESSEES

All holders of operating licenses for nuclear power reactors under the provisions of Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," except those who have permanently ceased operations and have certified that fuel has been permanently removed from the reactor.

PURPOSE

The U.S. Nuclear Regulatory Commission (NRC) is issuing this information notice (IN) to inform addressees of events involving deficiencies with reactivity management planning and implementation. The NRC expects recipients to review the information for applicability to their facilities and to consider actions, as appropriate, to avoid similar problems. Suggestions contained in this IN are not NRC requirements; therefore, no specific action or written response is required.

DESCRIPTION OF CIRCUMSTANCES

Callaway Plant

During a Callaway Plant shutdown in October 2003, the control room operators did not effectively control core reactivity during low-power operations. The event began on the morning of October 20, 2003, when the Callaway Plant experienced an inverter failure on a safety-related bus that put the unit in a 24-hour technical specification action to restore the inverter or be in Mode 3 (hot standby) within the next 6 hours. The next morning, because the inverter had not yet been restored, operators initiated a plant shutdown at approximately 10 percent per hour. With the main turbine on line and with turbine bypass valves closed, operators attempted to stabilize the plant at approximately 8-percent power. Per procedure, operators opened the turbine drain valves, which increased main steam flow, reducing reactor coolant temperature and adding positive reactivity. At the same time, negative reactivity was being inserted by xenon buildup, decreasing reactor power. The net effect was that reactor coolant temperature decreased by approximately 10 degrees Fahrenheit over a half-hour period. Operators did not withdraw control rods or dilute boron concentration to stabilize reactor power or reactor coolant temperature. As a result of the lowering reactor coolant temperature, pressurizer level lowered enough to cause letdown to isolate. In addition, reactor coolant temperature decreased below the technical specification required minimum temperature while critical for several minutes. In response to the lowering reactor coolant temperature, the operators manually tripped the main turbine with power at approximately 5 percent. Upon tripping the main turbine, the turbine bypass valves controlled steam pressure, causing reactor coolant temperature and pressurizer level to return to normal. Tripping the main turbine reduced main steam flow, increasing reactor coolant temperature and adding negative reactivity, which together with the addition of negative reactivity by xenon buildup, caused the reactor to become subcritical. Operators did not insert the control rods until almost 2 hours after the reactor became subcritical.

A subsequent review of this plant shutdown found that control room operators did not effectively control reactivity to maintain the reactor in the desired condition during low-power operations by properly anticipating, controlling, and responding to changing plant parameters. Operators did not use control rods or boron concentration—two means that operators can use to directly control the amount and timing of reactivity changes—to adjust for reactivity changes by xenon buildup and reactor coolant temperature changes. Specifically, reactivity was not effectively controlled in that (1) operators did not sufficiently anticipate and compensate for xenon buildup when they attempted to stabilize and hold the plant at approximately 8 percent power which caused reactor coolant temperature to continue to decrease below the technical specification required minimum temperature for criticality; (2) operators did not shut down the reactor in a deliberate manner (e.g., by inserting control rod banks), but rather the reactor became subcritical by xenon buildup and by the increase in reactor coolant temperature resulting from the operators manually tripping the main turbine; and, (3) operators did not insert control rods for nearly 2 hours after the reactor became subcritical. Fully inserting control rods provides assurance that the reactor remains shut down (regardless of reactor coolant temperature or xenon concentration). Notwithstanding, the NRC determined the delay in completing the shutdown by inserting the control rods did not result in an unsafe reactor condition.

Operator performance in not effectively controlling reactivity was attributable, in part, to weaknesses with management oversight, training, and procedural guidance. The pre-evolution practice session using the simulator did not cover plant operations below 10-percent power and did not include operation after the point where the operators tripped the main turbine. The reactivity management plan did not address the possibility that the expected reactivity change from tripping the main turbine together with the xenon buildup could cause the reactor to become subcritical. The licensee's initial post-shutdown review did not identify and evaluate the atypical manner that the reactor became subcritical. This omission delayed application of the lessons learned to operator qualification and requalification training and significantly delayed procedure changes to address weaknesses in operator control of reactivity during low-power operation. This event is also discussed in "Callaway Plant—NRC Integrated Inspection Report 05000483/2007003," dated August 2, 2007, which can be found on the NRC's public Web site in the Agencywide Documents Access and Management System (ADAMS) under Accession No. ML072140876.

River Bend Station

On March 8, 2008, with River Bend Station at 25-percent power, control room operators were withdrawing control rods to increase reactor power. The operating procedure for plant startup directs operators to withdraw control rods using a withdrawal sequence specified in a reactivity control plan that is provided to them by licensee reactor engineering. However, the dedicated reactor operator at the controls stated an incorrect target position when reading aloud a rod movement step in the reactivity control plan. As a result, this operator individually withdrew six consecutive rods to position 24 rather than the target position 20 specified in the reactivity control plan. The dedicated peer-check reactor operator did not identify that the stated target position was incorrect because he could not readily see the reactivity control plan that was resting on the lap of the reactor operator at the controls. The operator at the controls halted the withdrawal of the seventh rod at position 18 after the dedicated peer-check reactor operator identified the error. The licensee determined that the reactor operator at the controls and the peer-checker did not follow the procedures to prevent human performance errors and that the senior reactor operator did not maintain effective oversight of the activity. Additional information is available in "River Bend Station—NRC Integrated Inspection Report 05000458/2008002," dated May 9, 2008 (ADAMS Accession No. ML081300838).

Diablo Canyon Power Plant, Unit 2

In August 2009, Diablo Canyon Power Plant Unit 2 was shut down in order to troubleshoot and repair a main transformer bushing. In preparation for the shutdown, the control room operators performed simulator training on a ramp downpower using a draft copy of a ramp plan provided via e-mail by reactor engineering. Before the actual shutdown, a revised ramp plan was provided by reactor engineering, approved by the operations manager, and issued in the shift orders. This revised ramp plan was also e-mailed to all shift members. The oncoming shift foreman and shift manager did not review the approved ramp plan located in the shift orders nor did they review the ramp plan as part of the reactivity brief. Operators began the ramp downpower using the original (unapproved) draft ramp plan. After the first 2 hours of the downpower, the control room operator questioned plant conditions that were inconsistent with the simulator scenario and contacted the reactor engineer. The reactor engineer provided a copy of the approved ramp plan. No reactivity manipulations outside of the approved plan had been made. Operators continued the downpower using the approved ramp plan.

The licensee performed an apparent cause evaluation and determined that the shift foreman did not validate that the ramp plan in use was the same as the one that the operations manager had approved. Licensee corrective actions included revising existing procedures to require validation of the ramp plan by the shift foreman and shift manager during the reactivity briefing. This event is also discussed in "Diablo Canyon Power Plant—NRC Integrated Inspection Report 05000275/2009005 and 05000323/2009005," dated February 3, 2010 (ADAMS Accession No. ML100341199).

Arkansas Nuclear One

On April 25, 2010, following the completion of a refueling outage, Arkansas Nuclear One, Unit 1 was at approximately 20-percent reactor power determined by heat balance (approximately 30-percent reactor power indicated on nuclear instrumentation (NI)) and holding to allow instrumentation and controls (I&C) technicians to calibrate the NI, which involves adjusting the gain on the NI excore detectors so that NI indicated reactor power level matches the reactor power determined by heat balance. To prevent the integrated control system (ICS) from automatically moving control rods in response to the changing input of NI reactor power level from the gain adjustment, the calibration procedure first directs a control room operator to place the control rod station in manual. The I&C technician who was implementing the procedure stated to a control room operator, "We are ready to place ICS to manual." The control room operator responded, "ICS is in manual." However, this exchange did not result in the operator placing the control rod station in manual and it remained in automatic. When I&C technicians subsequently adjusted the gain on the NIs, control rods automatically withdrew for approximately 38 seconds and resulted in an automatic reactor trip because of high reactor power (49.55 percent NI indicated reactor power) and high RCS pressure. The rapid event succession did not afford operators time to complete diagnosis of the rod withdrawal and initiate manual corrective action.

The causes of the event included failure to follow the NI calibration procedure, miscommunication between the I&C technician and the reactor operator, failure to conduct a pre-job brief, and lack of supervisory oversight. Additional information is available in "Arkansas Nuclear One—NRC Integrated Inspection Report 05000313/2010003 and 05000368/2010003," dated August 5, 2010 (ADAMS Accession No. ML102180209).

BACKGROUND

The following are related NRC generic communications:

- NRC IN 92-39, "Unplanned Return to Criticality during Reactor Shutdown," dated May 13, 1992, discussed events involving unplanned returns to criticality caused by the cooldown of the reactor coolant system during reactor shutdowns (ADAMS Accession No. ML031200314).

- NRC IN 96-69, "Operator Actions Affecting Reactivity," dated December 20, 1996, highlighted several events in which poor command and control during reactivity evolutions have led to unanticipated and unintended plant conditions (ADAMS Accession No. ML031050475).

- NRC IN 97-62, "Unrecognized Reactivity Addition During Plant Shutdown," dated August 6, 1997, discussed an incident in which a reactor operator inserted control rods to bring the reactor subcritical and then promptly withdrew the rods in order to take the reactor to the critical (ADAMS Accession No. ML031050177).

DISCUSSION

One of the most important responsibilities of an on-duty licensed reactor operator and senior reactor operator is reactivity management in order to maintain the reactor in the desired condition, consistent with plant technical specifications, by properly anticipating, controlling, and responding to changing plant parameters. Reactivity management involves establishing and implementing procedures for operators to use in determining the effects on reactivity of plant changes, and to operate the controls associated with plant equipment that could affect reactivity. Before conducting planned evolutions involving reactivity changes (e.g., power decreases and increases), although there is no specific NRC requirement to do so, many licensee reactor engineering staffs prepare a reactivity management plan that helps control room operators maintain the reactor in the desired condition by providing expected plant responses and expected alarms. Required training is expected to give licensed operators an understanding of facility operating characteristics during steady-state and transient conditions, including causes and effects of temperature, pressure, coolant chemistry, and load changes, as well as, operating limitations and their bases. Licensee post-transient reviews are important for determining the cause of transients or unexpected plant responses and for taking corrective actions, such as procedure changes and training, to prevent recurrence.

During one of the events discussed above, after the reactor became subcritical through xenon buildup and a reactor coolant temperature increase, operators delayed inserting control rods for nearly 2 hours. NRC IN 92-39 discusses an event in which, after the operators brought the reactor subcritical by inserting control rods, an inadvertent unplanned return to criticality occurred because operators delayed actions to continue inserting control rods while changing shifts. Although not specifically required, licensees may consider revising procedures and training operators so that, after the reactor becomes subcritical, the operators will proceed without delay to insert control rods or add boron to ensure the reactor remains shut down.

CONTACT

This IN requires no specific action or written response. Please direct any questions about this matter to the technical contact listed below or to the appropriate Office of Nuclear Reactor Regulation project manager.

/RA/ by TMcGinty for

Thomas B. Blount, Acting Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Technical Contact: Geoffrey Miller
817-860-8141
geoffrey.miller@nrc.gov

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