Operating Experience Note

No. 007 October 24, 2014

Operating Experience Insights

* Effectiveness of Heavy Lift Measures and Contractor Control
* Control of Modifications
* SG Nozzle Dam Air Supply Contingencies
* Effectiveness of Simulator Training
* Verification and Maintenance of Flood Mitigation Measures

Event Review: Arkansas Nuclear One Heavy Lift Equipment Collapse

Plant Description:

Arkansas Nuclear One (ANO) is a two-unit site located in London, Arkansas within the NRC Region IV area of responsibility. ANO Unit 1 is a Babcock and Wilcox pressurized water reactor with a dry-ambient pressure containment. ANO Unit 1's original operating license was issued in May 1974, and the plant is licensed to 2,568-MWt. ANO Unit 2 is a Combustion Engineering pressurized water reactor with a dry-ambient pressure containment. ANO Unit 2's original operating license was issued in September 1978, and the plant is licensed to 3,026-MWt. Both units at the ANO site have completed the NRC's license renewal process.

Initial Conditions:

On March 31, 2013, ANO Unit 1 had been shut down in a refueling outage for one week. The reactor vessel head was removed, fuel was in the reactor vessel, and the refueling cavity was filled to a water level of approximately 23-ft (7-m) above the reactor vessel flange. Two trains of decay heat removal were in service and both emergency diesel generators (EDG) were operable.

ANO Unit 2 was operating at 100 percent power with no technical specification limitations in effect.

Event Summary:

One of ANO Unit 1's refueling outage activities was the replacement of its main generator stator as part of a plan to modernize the station's main generator. The plant operator hired a contractor to lead the modernization, and this contractor further sub-contracted with another company to carry out the heavy lift operations associated with the project. On the morning of March 31, 2013, the temporary heavy lift assembly being used for the main generator stator replacement collapsed while lifting the stator. The stator weighed approximately 524-tons (475-metric tons). One contract worker was killed and several others were injured as a result of the collapse.

The impact of the stator falling caused the main floor of the turbine building to deflect downward, causing damage to electrical switchgear equipment on the level below, which resulted in a loss of offsite power (LOOP) to ANO Unit 1.

EDGs started and loaded as designed to restore power to affected ANO Unit 1 safety busses. ANO Unit 1 EDGs continued to supply safety busses for about six days until offsite power was restored using a temporary source. The impact of the collapsing equipment also ruptured an 8-inch (20-centimeter) main supply line for firefighting water, resulting in a substantial amount of water being released into the turbine building.

The impact of the dropped stator caused an automatic reactor trip of ANO Unit 2. The trip was attributed to extensive vibration inducing a relay to trip in the 'B' reactor coolant pump circuitry. Vibration-induced relay activation had been previously documented at ANO. The plant operator previously noted this condition in Westinghouse "Type ITH" instantaneous over-current relays that were used as motor differential relays. Following the reactor trip on Unit 2, the 'A' main feedwater (MFW) regulating valve failed to indicate fully closed. In response, operating personnel tripped the running MFW pump and initiated emergency feedwater cooling. The plant operator later identified that an incorrectly performed maintenance action, completed several months before the collapse, had caused the discrepancy in the MFW regulating valve indication.

Water from the ruptured firefighting pipe wetted nonvital electrical equipment and resulted in a lock out of one of the ANO Unit 2 offsite power supplies. This partial -LOOP complicated the response at ANO Unit 2 by causing a loss of power to the running reactor coolant pumps; resulting in a loss of forced cooling flow through the ANO Unit 2 reactor coolant system. In response, ANO Unit 2 operators conducted a natural circulation cooldown of the plant. This was the first time these operators had performed a natural circulation cooldown outside of simulator training events.

ANO Unit 2 returned to operation about one month after this event following repairs to the turbine building wall and affected switchgear. Unit 1 restarted about four months after the event following significant repairs to the turbine building and offsite power connections, as well as implementation of measures to address the causes of the event.

Chronology/Highlights of Operator Actions:

A detailed chronology is available in Attachment 2 to "Arkansas Nuclear One – NRC Augmented Inspection Team Report 05000313/2013011 and 06000368/2013011," dated June 7, 2013 (Agencywide Documents Access and Management System [ADAMS] Accession Number ML13158A242).

Cause Evaluation:

The direct cause of the event was a failure of the north tower of the temporary heavy lift assembly. The plant operator confirmed that the north tower failed through buckling by visual examination, finite element analysis of the lift assembly, and examination of video of the event. The ANO plant operator determined

the root cause of the event to be an inadequate design by the heavy lift sub-contractor coupled with a failure to perform a load test of the special lift assembly.

A similar assembly had been used for identical applications at other sites, and the sub-contractor, contractor, and the plant operator accepted this experience in lieu of performing the load test required by station procedures and industry standards. In fact, the temporary assembly used at ANO differed slightly from the assembly that had been used successfully elsewhere. An inaccurate assumption made by a sub-contractor masked the fact that the north tower would not actually be able to bear the load of the stator lift. This error went unnoticed during reviews by the sub-contractor or the contractor. The NRC inspection found that the plant operator did not provide a sufficient level of oversight for the lift assembly design and load-testing process, and did not ensure that appropriately qualified personnel performed the necessary independent reviews of the design calculations required by site procedures.

A non-proprietary version of the plant operator's root cause analysis is available through the NRC public website (ADAMS Accession No. ML13213A270). Additionally, in accordance with policies associated with NRC enforcement actions, the plant operator submitted a response to the Notice of Violation associated with this event. The response includes an explanation of the root causes and actions taken by the plant operator to prevent recurrence (ADAMS Accession No. ML14199A412).

Risk Analysis:

The NRC's risk evaluation of this event is available in Attachment 2 (for ANO Unit 1) and Attachment 3 (for ANO Unit 2) of "Arkansas Nuclear One – NRC Augmented Inspection Team Follow-Up Inspection Report 05000313/2013012 and 05000368/2013012; Preliminary Red and Yellow Findings," dated March 24, 2014 (ADAMS Accession No. ML14083A409). The NRC published a corrected risk evaluation on April 10, 2014 (ADAMS Accession No. ML14101A219). Both documents can be accessed at ML14101A214.

Regulatory Response:

The NRC performed several inspections in response to this event. During the inspections the NRC reviewed the sequence of events, the operator and plant response, cause analyses and other aspects to identify deficiencies that resulted in the event and to evaluate the adequacy of the plant operator's immediate and long-term response to the event. The NRC identified several inspection findings of varying safety significance during the inspections. NRC inspectors issued a Yellow inspection finding to each unit at the ANO site—Yellow is the second most severe level of finding available through the NRC's Reactor Oversight Process. In part as a result of these two findings, the NRC increased its oversight and inspection efforts at ANO. These additional inspections are focused on providing assurance of the adequacy of licensee efforts to identify the root cause,

extent of condition, safety culture aspects, and corrective actions associated with the event.

The U.S. Department of Labor Occupational Safety and Health Administration (OSHA) performed inspections of the ANO plant operator and three contractors involved in the event. OSHA identified several safety violations associated with this event and provided citations to the ANO plant operator and contractors. Further information about this event can be found through the OSHA website (www.osha.gov).

The significant amount of firefighting water released following the collapse of the lifting equipment challenged the effectiveness of ANO Unit 1 and Unit 2's internal flood mitigation measures, and extent of condition reviews revealed multiple deficiencies in flood barriers. On September 9, 2014, the NRC published the results of an inspection into ANO's flood mitigation deficiencies (ADAMS Accession No. ML14253A122). In that inspection report the NRC identified an apparent violation and preliminary finding associated with degraded flood barriers at ANO Unit 1 and Unit 2. Examples of the deficiencies included over 100 unsealed or degraded penetrations, un-isolable floor drains, and open ventilation ductwork. The NRC process for finalizing these issues is still in progress as of the date of this report. The final results of these issues will be made available through the NRC public website (www.nrc.gov).

Operating Experience Insights:

Effectiveness of Measures Prior to Heavy Lift/Control of Contractor Activities: Prior to the heavy lift, the plant operator focused on ensuring that the hoisting equipment did not overload existing plant structures rather than verifying the adequacy of the lift equipment itself. As a consequence, the plant operator did not perform an adequate review of the heavy lift sub-contractor's calculations associated with the design of the heavy lift assembly. The contractor and sub-contractor stated that the heavy lift equipment had been used in another application to lift equipment at least as heavy as the ANO Unit 1 stator and used this information to justify waiving the requirement to perform a load test. NRC inspectors later found that the lift assembly design included an incorrect assumption, and the component that failed was not designed to support the stator load.

Control of Modifications: In 1999, the plant operator installed a fire pump that could be used temporarily during outages and other times when permanent fire pumps were out of service. The temporary fire pump was powered from a different power source than the permanent electric fire pump. When the stator drop event occurred in March 2013, the temporary fire pump was in service. When the firefighting water pipe ruptured, the backup diesel-driven fire pump started on low header pressure; but the permanent electric pump did not start because of a loss of offsite power. Operators turned off the diesel-driven pump to stop flow through the ruptured firefighting water pipe; however, they did not turn the temporary fire pump off. Continued temporary fire pump operation pushed a high volume of water through the rupture for an additional 30-minutes before operators turned off the pump. Follow-on inspection efforts revealed that procedural controls associated with the temporary fire pump were inadequate because they did not direct

operators to turn the pump off in the event of a fire system leak or rupture.

Steam Generator Nozzle Dam Air Supply Contingencies: Prior to the stator drop, the plant operator installed steam generator nozzle dams to facilitate maintenance inside the steam generator while maintaining reactor coolant system inventory. The nozzle dams consist of a rigid plug and two inflatable dams that are installed in the reactor coolant system piping at the steam generators. The inflatable nozzle dams were supplied from two electric air compressors that were powered from two different non-safety electric power supplies. The instrument air system was designated as the backup air source for the nozzle dams. The dams were designed so that if the inflatable seals became depressurized, the rigid seal would limit leakage to about two gallons per minute. Following the stator drop event, the air compressors that serviced the nozzle dams lost power and the instrument air system was not available; leaving the nozzle dams without an air source. Leakage through check valves in the air supply lines resulted in the nozzle dam pressure reducing to a point where leakage was noted. Operators eventually restored nozzle dam pressure using nitrogen bottles. The NRC determined that the option to use nitrogen bottles as a backup source of pressurizing the nozzle dams was removed from the nozzle dam procedure in 2010 based on the operational convenience of not staging the bottles in containment. Although this change was consistent with industry practice, NRC inspectors determined this procedure change to be non-conservative in nature.

Effectiveness of Simulator Training: As a result of a partial LOOP, ANO Unit 2 experienced a loss of forced circulation through the reactor coolant system. Operator response was complicated by the concurrent loss of instrument air header pressure; rendering letdown, normal pressurizer spray and steam dump bypass control unavailable. ANO Unit 2 operators established auxiliary pressurizer spray and turned off pressurizer heaters to reduce reactor coolant system pressure and avoid lifting pressurizer safety relief valves. The operators then conducted a reactor plant cooldown using natural circulation. Operator performance at ANO Unit 2 provides an example of the value of simulator training to the nuclear industry. This was the first time these operators had performed a natural circulation cooldown outside of simulator training events. NRC inspectors determined that ANO Unit 2 operator actions were appropriate.

Verification and Maintenance of Flood Mitigation Measures: The release of firefighting water during this event revealed deficiencies in the ANO site's flood mitigation measures. After completing extent-of-condition reviews for the stator drop event and walkdowns associated with NRC-led actions in response to Fukushima, the plant operator identified more deficiencies involving flood mitigation measures. The causes for the degraded flood barriers included inadequate design, construction, and maintenance of certain flood barriers; examples included over 100 unsealed or degraded penetrations, un-isolable floor drains, and open ventilation ductwork. These deficiencies would impact plant performance in response to internal and external flooding events. The NRC is still in the process of finalizing the safety-significance of the findings associated with these deficiencies. However, these discoveries highlight the importance of accurately classifying plant equipment and structures for monitoring and maintenance and verifying that plant equipment and structures are capable of fulfilling safety-related functions as reflected in design documentation and safety analyses.