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U. S. Nuclear Regulatory Commission
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Braidwood Station, Units 1 and 2
Facility Operating License Nos. NPF-72 and NPF-77
NRC Docket Nos. STN 50-456 and STN 50-457

Byron Station, Units 1 and 2
Facility Operating License Nos. NPF-37 and NPF-66
NRC Docket Nos. STN 50-454 and STN 50-455

Subject: Byron Station, Unit 1 Licensed Thermal Power Limit Verification

References:
(1) Letter from J. A. Zwolinski (U.S. NRC) to J. L. Skolds (Exelon Generation Company, LLC), "Licensed Thermal Power – Byron Station, Unit 1," dated January 22, 2003

(2) Letter from K. R. Jury (Exelon Generation Company, LLC) to the U.S. NRC, "Byron Station, Unit 1, Licensed Thermal Power Limit Verification," dated February 5, 2003

(3) Letter from G. F. Dick (U.S. NRC) to J. L. Skolds (Exelon Generation Company, LLC), "Licensed Thermal Power, Byron Station, Unit 1 – Request for Additional Information," dated July 8, 2003

(4) Letter from K. R. Jury (Exelon Generation Company, LLC) to the U.S. NRC, "Byron Station, Unit 1, Licensed Thermal Power Limit Verification," dated August 15, 2003

In Reference 1, the NRC notified Exelon Generation Company, LLC (EGC) that due to a number of plant performance indications and observations, the NRC is concerned that Byron Station, Unit 1 may be operating above its licensed thermal power limit. In this letter, the NRC requested that EGC provide assurance that Byron Station, Unit 1 is operating within its licensed thermal power limit. EGC provided the requested information to the NRC in Reference 2.

During the review of Reference 2, the NRC determined that additional information would be needed to fully resolve the issue of whether Byron Station, Unit 1 is operating above its licensed thermal power limit. Subsequently, the NRC issued a request for additional information in Reference 3. The requested information was provided in Reference 4.

The EGC response to Question 2.3 of Reference 4 outlined plans to conduct additional testing and validation of the accuracy of feedwater (FW) flow as measured by the ultrasonic flow meters (UFMs). The test plan was initiated to identify the reasons for the megawatt-electric differences between Byron and Braidwood Stations. It included the use of an additional UFM on the common FW header to check both the venturi flow sum and the existing UFM flow sum on Byron Station, Unit 1 and Braidwood Station, Unit 1. The test plan also included use of the additional UFM during the coastdown prior to the Byron Station, Unit 1 refueling outage in the Fall 2003 to observe the effect of changing power on the UFM correction factor (CF). The results of the completed testing are provided below.

Test Results

In May 2003, as a result of an EGC initiative to resolve Byron Station and Braidwood Station megawatt electric discrepancies, a UFM and associated instrumentation were installed on the FW common header at Braidwood Station, Unit 1 to compare the flow in the common header to the sum of the flows in the four FW loops. The results of this test indicated the independent measurements yielded results with a relative difference of 0.021% that was well within the expected uncertainties. Additional data gathering equipment was installed on Byron Station, Unit 1 in May 2003, with modem access to permit the UFM vendor to continuously retrieve and trend Unit 1 UFM data remotely. Plant data (i.e., venturi flows, FW temperature, etc.) was also collected to allow comparison to the UFM data. An additional UFM and associated instrumentation were installed on the FW common header at Byron Station, Unit 1 on August 20, 2003. The purpose of this activity was to compare the flow in the common header to the sum of the flows in the four individual FW lines at the 5.0% uprated power condition and to collect continuous data during the coast down into the planned Byron Station, Fall 2003 refueling outage to determine whether there was a change in CF with power level.

The results at full uprated power operation for the Byron Station, Unit 1 common header test identified that the difference between the sum of the UFM measurements in the four FW loops and the common header was outside the acceptable statistical limits of the UFM (i.e., a difference of 1.572% mass flow rate compared to a maximum allowable statistical limit of 0.70% mass flow rate). The UFM vendor review of this issue led to a preliminary conclusion that the inconsistent measurements in the four FW loops were being driven by a variable affecting the ultrasonic flow signals, and ultimately the calculated time delay measured by the UFM electronics. The variability in the time delay measurement was determined to potentially be the result of ultrasonic signal noise contamination. A review of the UFM installations at Byron Station, Units 1 and 2 and Braidwood Station, Units 1 and 2 indicated the presence of ultrasonic signal noise contamination on several, but not all of the individual FW line measurements. The ultrasonic signal noise contamination was absent from the installed FW common header locations at Byron Station, Unit 1 and Braidwood Station, Unit 1. Based on discussions with the UFM vendor on August 28 and August 29, 2003, Byron Station management made a decision to return the UFM CFs to

1.0 on both units, pending resolution of the issue. This action returned the plant power level to that measured by the FW venturis only.

Upon investigation by site and vendor personnel, it was determined that signal noise affected the flow velocity calculations, which in turn affected the determination of the CFs. With the noise contaminated CFs inputted into the calorimetric calculation, a non-conservative or lower power measurement resulted. When reactor power was adjusted to match the calorimetric calculation, an overpower condition was created. It was subsequently determined that the worst case overpower condition for Byron Station, Unit 1 was 101.64% reactor power and 100.42% reactor power for Byron Station, Unit 2.

This event is detailed in Licensee Event Report (LER) 454-2003-003-00, "Licensed Maximum Power Level Exceeded Due to Inaccuracies in Feedwater Ultrasonic Flow Measurements Caused by Signal Noise Contamination," dated September 29, 2003. The LER provides further information regarding the description of the event, cause of the event, safety analysis review and corrective actions.

A similar LER (i.e., LER 457-2003-002-00, "Licensed Maximum Power Level Exceeded Due to Inaccuracies in Feedwater Ultrasonic Flow Measurements Caused by Signal Noise Contamination," dated September 30, 2003) was submitted for Braidwood Station. This LER again provides further information regarding the description of the event, cause of the event, safety consequences and corrective actions. As noted in this LER, Braidwood Station, Unit 1 was determined (at that time) not to have exceeded 100% reactor power; however, power level on Braidwood Station, Unit 2 was reduced as the worst case overpower condition for Unit 2 was determined to be 100.39% reactor power. Subsequently, the UFM CFs on both Braidwood Station units were conservatively returned to 1.0.

Initial Root Cause

Numerous causes for the apparent noise were considered and investigated. A detailed evaluation by a root cause team consisting of site, corporate and UFM vendor personnel determined that the root cause was noise contamination of the UFM signal caused by acoustic resonant response of the FW piping system. Potential resonant frequencies were predicted using several theoretical methods. Dynamic pressure measurements were taken on each of the four Byron Station, Unit 2 FW lines at a low point drain located near the flow measurement venturi. Analysis of the dynamic pressure data showed agreement between the theoretical methods and actual plant response and suggested that the principal resonance is most probably occurring in the piping between the FW regulating valve and the steam generator. Data analysis also supported the existence of a low frequency resonant system response consistent with the noise frequencies and reflected the magnitude of noise differences in the four FW loops. It is assumed this condition has existed since the UFMs were put in service at Braidwood Station in June 1999 and Byron Station in May 2000.

A step in the test plan to collect data on the four individual branch line UFMs to observe the effect of changing power level on the UFM system CF was not completed in light of the identified signal noise. This data, however, was collected on the common FW header

UFM during a power reduction from 100% to 80% for turbine throttle valve/governor valve testing on Byron Station, Unit 2 in September 2003. This data confirmed the consistency of the CF.

A root cause report addressing the overpower issue at Byron Station, Units 1 and 2 and Braidwood Station, Unit 2, was completed on September 26, 2003. This report was reviewed by an independent third party who concurred with the EGC conclusions.

Additional Testing and Results

Based on the identification of the UFM signal noise contamination in August 2003, the original testing plans, as noted in Reference 4, to complete a six-month continuous data run and associated analysis with third party review were not completed.

Additional project plans were developed to permanently install common FW header UFMs at all units at Byron and Braidwood Stations. Corrective actions as identified in the root cause report were required to be implemented as part of the installation that included testing to confirm the common FW header UFMs were free of signal noise contamination.

In addition, a highly accurate tracer test was added as a requirement prior to UFM implementation to validate the FW mass flow rate as measured by the UFM system. The FW mass flow rate as measured by the venturis would also be compared to the tracer test measurement. The tracer substance, radioactive sodium (i.e., Na-24), was in the form of dry sodium carbonate (Na_2CO_3). A solution with tracer concentration was injected into the flow under investigation at a constant flow rate. After a certain distance, the tracer was assumed to be homogeneously mixed across the pipe cross section due to turbulent mixing effects and the unknown mass flow rate was determined from measurements of the resulting concentration down stream in the pipe.

In the Byron Station, Unit 1 and 2 FW systems, the tracer was injected immediately after the outlet of one of the final FW heaters (i.e., the 1(2)7A FW heaters) to take advantage of the turbulence created at the intersection of the 1(2)7A and 1(2)7B FW heaters outlet lines. Mixing was accomplished in the main FW header line before the first of the steam generator loop lines branches off. The FW pressure sensing lines in one of the four steam generator FW branch lines served as the downstream points for tracer sampling. Existing sample points in the chemical sample system were used for the evaluation of the system background activity. The background activity sample points were located at the header pipe on the suction side of the FW pumps.

The tracer tests were performed on both Byron Station units on February 6, 2004. Both units were operated at steady state conditions at approximately 100% power. FW flow data was simultaneously taken from the main FW header UFM and from the installed FW flow venturis during the tracer test for direct FW flow comparison.

UFM measurements utilize many flow data points that are compiled into a statistical average. The 24-minute tracer time period was not of sufficient length to gather enough UFM data points to obtain an accurate UFM flow measurement. The UFM measurements were taken over a time period that started two hours prior and finished two hours following the tracer sampling time period. The plant power level was stable during this time period in accordance with test criteria, and the flow measurements were representative of the flow during the tracer test time periods. Because this normalized time period was used, the corresponding plant FW venturi flow rate, final FW temperature, and final FW pressure were used to calculate the reported CF.

During preparation for the tracer test, while the FW high-pressure heaters were bypassed, the UFM CF varied unexpectedly. This issue was identified while installing the tracer injection taps at both Byron Station and Braidwood Station. Based on this new issue, implementation of the UFMs was put on hold at Byron and Braidwood Stations. To help understand the cause for the CF variability, it was decided to continue with tracer testing but to only perform testing at Byron Station, Units 1 and 2.

When analyzing the results of the tracer test, the UFM, venturi, and tracer measurements of FW flow were compared using the methodology specified in American Society of Mechanical Engineers, Performance Test Code (ASME PTC) 19.1, “Test Uncertainty,” which minimizes overall uncertainty including tracer bias.

Byron Station Feedwater Flow Comparison Test Results

Unit 1 Tracer to Venturi Comparison

The tracer test nominal FW flow measurement was +0.63% above the nominal indicated venturi flow. The upper 95% confidence limit is +0.65% using nominal tracer and FW flow measurements with their associated uncertainties. These results validated the Unit 1 venturi flow measurement accuracy using the tracer test.

Unit 1 Tracer to UFM Comparison

The tracer test nominal FW flow measurement was +2.4% above the nominal indicated UFM flow. The upper 95% confidence limit is +0.61% using nominal tracer and UFM FW flow measurements and their associated uncertainties. These results did not validate the Unit 1 common FW header UFM using the tracer test.

Unit 2 Tracer to Venturi Comparison

The tracer test nominal FW flow measurement was +0.21% above the nominal indicated venturi flow. The upper 95% confidence limit is +0.64% using nominal tracer and FW flow measurements with their associated uncertainties. These results validated the Unit 2 venturi flow measurement accuracy using the tracer test.

Unit 2 Tracer to UFM comparison

The tracer test nominal FW flow measurement was +1.2% above the nominal indicated UFM flow. The upper 95% confidence limit is +0.63% using nominal tracer and UFM FW flow measurements and their associated uncertainties. These results did not validate the Unit 2 common FW header UFM using the tracer test.

Conclusion

The tracer test results for Byron Station, Units 1 and 2 validated the venturi flow measurement accuracy because the nominal values for the tracer and the venturi agreed within their uncertainty bands. The tracer test results did not validate the UFM accuracy because the tracer and UFM nominal values did not overlap within their uncertainty bands.

Given the tracer test results from Byron Station, Units 1 and 2, and the undetermined cause for the UFM CF changes coincident with FW system configuration changes, implementation of the UFMs for FW flow measurement correction has been suspended at Byron and Braidwood Stations. Based on the results of studies currently underway by the UFM vendor to identify the causes for the anomalies in UFM performance, and appropriate corrective actions to ensure UFM reliability, EGC will determine whether to utilize the UFMs as an input to the calorimetric calculation in the future. EGC will maintain an open dialogue with the NRC regarding future use of the UFM technology.

Based on the results of the tracer tests, the previous LERs for Byron Station and Braidwood Station were updated. The originally reported worst-case overpower conditions on Byron Station, Units 1 and 2 (i.e., reported in LER 454-2003-003-00 dated September 29, 2003); and Braidwood Station, Unit 2 (i.e., reported in LER 457-2003-002-00, dated September 30, 2003) were based on the premise that the UFM system on the common main FW header was providing accurate flow measurements. The tracer test on Byron Station, Unit 1 and Unit 2 validated the accuracy of the venturi flow measurement; therefore, the worst-case overpower is now based on the maximum UFM correction factor applied to the venturi flow measurement. It was assumed that similar test results would be obtained on both Braidwood units.

Byron Station issued supplemental LER 454-2003-003-01, "Licensed Maximum Power Level Exceeded Due to Inaccuracies in Feedwater Ultrasonic Flow Measurements," dated March 31, 2004. In this LER, the reported overpower values for Units 1 and 2 were revised to 2.62% and 1.88%, respectively. Braidwood Station issued LER 456-2004-001-00, "Licensed Maximum Power Level Exceeded Due to Inaccuracies in Feedwater Ultrasonic Flow Measurements," dated March 30, 2004. In the letter transmitting this LER to the NRC, (i.e., letter from Thomas P. Joyce (Exelon Generation Company, LLC) to the NRC, “Submittal of Licensee Event Report Number 2004-001-00, ‘Licensed Maximum Power Level Exceeded Due to Inaccuracies in Feedwater Ultrasonic Flow Measurements,’") dated March 30, 2004, Braidwood Station withdrew LER 457-2003-002-00, as it only identified an overpower condition for Braidwood Station, Unit 2. LER 2004-001-00 revised the Unit 2 overpower value to 1.21% and indicated that Unit 1 also exceeded the licensed thermal power level by 1.07%.

Should you have any questions related to this letter, please contact J. A. Bauer at (630) 657-2801.

Respectfully,

Kenneth A. Ainger
Manager, Licensing