Nuclear Safety Advisory Letter

Westinghouse Electric Company

This is a notification of a recently identified potential safety issue pertaining to basic components supplied by Westinghouse. This information is being provided so that you can conduct a review of this issue to determine if any action is required.
P.O. Box 355, Pittsburgh, PA 15230

Subject: **CROSSFLOW Ultrasonic Flow Measurement System Flow Signal Interference Issues**	Number: **NSAL-03-12**
Basic Component: CROSSFLOW Ultrasonic Flow Measurement System	Date: 12/05/2003
Affected Plants: See attached list	
Substantial Safety Hazard or Failure to Comply Pursuant to 10 CFR 21.21(a)	Yes ☐ No ☒
Transfer of Information Pursuant to 10 CFR 21.21(b)	Yes ☐
Advisory Information Pursuant to 10 CFR 21.21(d)(2)	Yes ☐
References: See attached list.	

SUMMARY

The CROSSFLOW Ultrasonic Flow Measurement System is used to calibrate the feedwater flow measurement instrumentation (e.g., venturi flow meter) at nuclear power plants. The CROSSFLOW technology and methodology is documented in CENPD-397-P-A, Rev. 01 (Reference 1) and was approved by the Nuclear Regulatory Commission (NRC) on March 20, 2000 (Reference 2), for improved feedwater flow measurement accuracy. By employing CROSSFLOW, a plant can recapture lost power due to feedwater flow instrumentation inaccuracies and/or, subject to NRC approval, can increase plant thermal output by taking credit for the reduction in the uncertainty of the secondary heat balance measurement (i.e., an Appendix K or measurement uncertainty recapture power uprate).

This NSAL discusses the status of a flow signal interference issue that has the potential to adversely affect the feedwater flow measurement. The signal interference (contamination) issue was previously discussed in Technical Bulletin, TB-03-6, "CROSSFLOW Ultrasonic Flow Measurement System Signal Issues" (Reference 3). The following discussion also provides operational guidance that should be used to ensure that the CROSSFLOW system is properly implemented and performs within acceptable limits, and therefore, that the system will provide flow measurement accuracy consistent with its plant specific application.

Additional information, if required, may be obtained from Rhonda Doney. Telephone (860) 731-6707.

Originator:(s)

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ISSUE DESCRIPTION

As a result of an investigation of CROSSFLOW performance at the Byron and Braidwood nuclear power stations, Westinghouse Electric Company LLC (Westinghouse) and its CROSSFLOW partner the Advanced Measurement Analysis Group, Inc. (AMAG) identified a potential interference (contamination) of the flow signals used to determine feedwater flow rate. Specifically, it appears that plant mechanical equipment in the feedwater system in combination with the unique plant specific acoustic response characteristics of the piping system has the potential to cause flow signal interference that can lead to an incorrect and potentially non-conservative determination of the venturi flow correction factor, C_f.

The presence of flow signal interference or correlated noise can result in a bias (shift) in the CROSSFLOW time-delay measurement. The interference can either increase or decrease the true time-delay measurement, which is the time that it takes for the eddies within the fluid to pass between the two ultrasonic beams. When the time-delay is biased high, the flow measurement is biased low (non-conservative direction with respect to assessment of plant power level) and when the time-delay is biased low, the flow measurement is biased high (conservative direction with respect to assessment of plant power level).

TECHNICAL EVALUATION

This issue has undergone extensive scrutiny. All users should continue to ensure their application stays within its plant specific CROSSFLOW operation acceptance limits. The following paragraphs provide further information and guidance on various aspects of CROSSFLOW operation that will assure systems continue to perform as expected and intended.

Correction of Plant Flow Instrumentation or Venturi Flow Correction Factor (C_f)

The correction factor, C_f, is defined as the ratio of the CROSSFLOW determined flow value (F_{UFM}) to the corresponding venturi determined flow value (F_V) for the same time period (i.e., $C_f = F_{UFM}/F_V$). Since C_f is the ratio of F_{UFM} and F_V, a fluctuation in C_f can result from either 1) a change in the CROSSFLOW system, which manifests itself as a change in F_{UFM} or, 2) a change in plant conditions, which manifest themselves as a change in F_V. If the fluctuation in plant flow, F_V, is low (which is typical), there is little or no contribution to C_f fluctuation from the plant. In this situation, C_f varies primarily as a function of F_{UFM} which is expected to be less than a buffered average of ~±0.3%, although the explicit value is plant specific. CROSSFLOW software monitors the acceptability of both C_f and F_{UFM} and identifies when the system is generating a measurement that does not meet the plant specific acceptance limits specified in the measurement uncertainty calculation. Consequently, if F_{UFM} is operating within expected limits, and C_f is varying beyond the plant specific acceptance limit, the variation is originating not from CROSSFLOW but from a change in plant conditions. For example, it could be an early indication of changing plant conditions such as plant instrumentation drift, fouling, etc. The plant specific limits on C_f variation are set by the Utility which identifies what actions are required if the calculated C_f is outside acceptance limits.

For a given installation, the overall integrity of the CROSSFLOW generated F_{UFM} is monitored by collecting adequate data points to satisfy the required plant specific uncertainty limit as documented in the associated CROSSFLOW measurement uncertainty calculation. This measurement varies as a function of the normal fluctuation in measured time delay, which is a function of the inherently random nature of the turbulent flow. An unexplained increase in the standard deviation or rejection rate of the collected data could be a precursor to an issue that has the potential to affect F_{UFM}. The expected fluctuation in the F_{UFM} buffered value is based on plant specific flow measurement characteristics and is typically less than ~±0.3%.

CROSSFLOW Initial Installation Procedure

At the time of CROSSFLOW system initial installation, a frequency spectrum analysis is now performed to ensure that the system is free of plant specific signal interference. Once the integrity of the signal is verified, variations in the time-delay readings caused by flow fluctuations are recorded. This information is used to establish plant specific uncertainty limits for F_{UFM}. Therefore, as long as F_{UFM} remains within acceptance limits, the uncertainty analysis used to establish the overall accuracy of the CROSSFLOW meter is bounded.

CROSSFLOW Normal Operation (Manual and Automatic Modes)

Based on the installation baseline information, each Utility should review their current operating procedures for monitoring F_{UFM}, and C_f, to ensure that they appropriately identify when these limits are being approached or exceeded. If these limits are exceeded, procedures should be available to determine if the value of C_f is valid (i.e., is acceptable for use), by using other corroborating plant parameters or plant specific operating history.

Further, since the CROSSFLOW system was designed to improve feedwater flow measurement accuracy and thereby recover only modest amounts of power (e.g., as associated with venturi fouling), if the cumulative change in C_f ever equals or exceeds the plant specific upper or lower maximum operational limits, the CROSSFLOW system should be taken out-of-service or a power penalty applied until the cause of the excursion is identified and addressed. The upper and lower maximum operational limits, which are established by the Utility, are based on plant specific historical instrumentation drift and fouling characteristics.

In addition, evaluations of C_f acceptability should be performed if the following plant conditions occur:

- Plant power uprates are implemented.
- Feedwater system modifications are made that have the potential to affect the flow characteristics at the CROSSFLOW meter location (e.g., changes in feedwater regulating valve internals, piping modifications, steam generator replacement, etc.).
- A variation in C_f that is outside the established plant specific acceptance limits and which cannot be attributed to a known change in plant conditions (e.g., a fouling or defouling event).

In each case, it should be confirmed that changes such as these have not introduced signal interference with the CROSSFLOW system. This can be done by performing a frequency spectrum analysis. If a potential interference issue is identified, the CROSSFLOW system should be taken out-of-service or a power penalty applied until the affect of the interference is addressed.

Point-In-Time Calibration

Occasionally, utilities have requested that Westinghouse/AMAG perform an independent CROSSFLOW feedwater flow measurement for the purpose of a point-in-time venturi calibration. That is, there is no permanent CROSSFLOW meter installation in the plant. Westinghouse/AMAG bring in the necessary CROSSFLOW equipment, determine the appropriate venturi flow correction factor (C_f) and then remove the equipment following the point-in-time calibration. Since CROSSFLOW is not actively monitoring flow conditions which could impact the continued acceptability of the C_f, it is the responsibility of the Utility to have procedures in place to ensure that continued use of the C_f is justified. This procedure should outline the required steps to be followed to ensure that any change in the C_f will be identified and the appropriate actions taken to preclude an overpower condition as a result of unjustified changes. Because CROSSFLOW is not actively monitoring flow conditions, it is necessary for the Utility to rely on other plant parameters to detect a change and to adjust the C_f, if warranted, for the feedwater venturi flow.

CROSSFLOW Manual Operation

When the CROSSFLOW system is continuously operating in the manual mode, C_f is calculated by taking the average of a number of CROSSFLOW readings and dividing it by the average of the corresponding venturi readings over the same time period. The collected CROSSFLOW data with nominal input temperature and pressure should be corrected for the actual plant average temperature and pressure for the data collection period. The resulting C_f is then entered into the plant computer, where subsequent venturi readings are multiplied by this C_f prior to being used in the core thermal power calculation. The appropriate number of readings in manual mode is a function of plant specific flow characteristics. Guidelines for data collection are documented in the plant specific CROSSFLOW measurement uncertainty calculation provided to each user.

CROSSFLOW Automatic Operation

When the CROSSFLOW system is continuously operating and is interfaced with the plant computer, C_f is continually generated by taking the ratio of the instantaneous CROSSFLOW readings and dividing them by the corresponding venturi readings to calculate an instantaneous correction factor. In this mode of operation, the instantaneous C_f is entered into a moving average buffer and the value of the moving average buffer is then passed to the plant computer. Checks are made to ensure that the accuracy of F_{UFM} is better than or equal to the accuracy of the meter as defined by the plant specific quality assured uncertainty calculation. This ensures for example, that the justification for the Appendix K power uprate through improved feedwater flow measurement accuracy remains valid. In the Automatic mode there are several checks in the process of monitoring F_{UFM}, and calculating the C_f, with associated alarms. Further details about the checks that monitor the communication stream with the plant computer and the algorithm used for calculating C_f and associated alarms are provided in the plant specific Software Requirements Specification documents prepared jointly by Westinghouse/AMAG and the Utility.

SAFETY SIGNIFICANCE

Westinghouse has determined that this issue does not represent a substantial safety hazard. Evaluations of safety analyses for which Westinghouse holds the analysis of record (AOR) were performed for the overpower condition at Byron Units 1 and 2 and Braidwood Unit 2. The overall conclusion was that the applicable regulatory acceptance criteria were met for all of the UFSAR Chapters 6 and 15 events evaluated. Considering the margins available in the system designs and safety analyses, had the CROSSFLOW signal contamination gone undetected, and the plant continued to operate at the same overpower condition, it is expected that the applicable regulatory acceptance criteria would continue to be met.

Regarding generic aspects of this issue, CROSSFLOW is not expected to produce power uprates that reach into the Stretch Power range and certainly not into the Extended Power uprate range. Power increases using CROSSFLOW have been less than 3%; when combining recovery of lost power (e.g., due to venturi inaccuracies) with an Appendix K power uprate. A power increase of this magnitude does not approach the percent increase associated with a Stretch Power uprate (~7%), consequently, it is unlikely to significantly challenge NSSS systems, structures and components. Further, CROSSFLOW operation does not result in automatic power increases. Operator intervention and appropriate licensee procedural controls are required prior to plant power level being changed.

In consideration of the above, while a condition that results in overpower operation violates the operating license, there is reasonable assurance of safe operation with respect to the CROSSFLOW signal interference issue. Thus, even if uncorrected, the condition does not represent a substantial safety hazard.

NRC AWARENESS

The NRC is aware of this issue. Exelon filed two Licensee Event Reports (References 4 and 5) regarding exceeding licensed power levels and also had a meeting with NRC Region 3 staff on September 18, 2003. Additionally, Westinghouse held a telephone conference call with NRC Headquarters staff members on August 28, 2003 to informally advise them of the signal contamination issue. The NRC was also informally provided a list of CROSSFLOW users and a copy of Westinghouse Technical Bulletin TB-03-6 (Reference 3). Finally, a meeting was held between Westinghouse, AMAG, Exelon, and the NRC on September 26, 2003 at NRC headquarters in which the NRC staff was briefed in detail about the signal contamination issue. In addition, Westinghouse responded to NRC requests for additional information that arose during the course of the meeting. One of the actions from this meeting was that Westinghouse provide more specific CROSSFLOW system operational guidance, with respect to the signal contamination issue, in an NSAL distributed to all CROSSFLOW users. This guidance is provided below and will be incorporated along with other operational guidance in an upcoming revision to the CROSSFLOW Users Manual.

RECOMMENDED ACTIONS

The following actions are recommended in order to maintain system uncertainty certification.

1. Westinghouse/AMAG recommends that CROSSFLOW system operators attend and complete the training course provided with the CROSSFLOW installation. Additional training can be provided upon request. This action ensures that personnel operating the system will be certified by Westinghouse/AMAG as having a comprehensive understanding of CROSSFLOW functionality, including acceptable ranges of operation and what actions should be taken if system performance deviates from acceptable norms.

2. Going forward, Westinghouse/AMAG will perform a baseline frequency spectrum analysis at the time of installation. This baseline frequency spectrum analysis will be provided to Utility customers and also retained by Westinghouse as a quality record along with other installation parameters. This action ensures that the system is free of interference and provides a record for comparison to potential future frequency spectrum analyses. Westinghouse/AMAG have completed a review of frequency spectrum records, or have obtained new records, for all Utilities currently using CROSSFLOW to adjust plant power. No other plants were found to be affected by the signal interference issue.

3. Westinghouse/AMAG recommends that the performance of the CROSSFLOW system be re-evaluated whenever a modification is made to the feedwater system that has the potential to affect the flow characteristics and/or a power uprate is implemented. This action ensures that interference is not unknowingly introduced which could adversely affect subsequent CROSSFLOW performance.

4. CROSSFLOW system users should continue to ensure their application stays within its plant specific acceptance limits using the guidance provided in the Technical Evaluation above and the information (e.g. Users manual, uncertainty calculations, etc) provided with the CROSSFLOW system. Utilities should also verify that operating procedures have been updated to reflect these recommendations.

REFERENCES

1. CENPD-397-P-A, Rev. 01, "Improved Flow Measurement Accuracy Using CROSSFLOW Ultrasonic Flow Measurement Technology", May 2000

2. Letter, S. A. Richards (NRC) to I. C. Rickard (ABB-CE), "Acceptance for Referencing of CENPD-397-P, Rev. 01-P, 'Improved Flow Measurement Accuracy Using CROSSFLOW Ultrasonic Flow Measurement Technology' (TAC No. MA6452)", March 20, 2000

3. TB-03-6, "CROSSFLOW Ultrasonic Flow Measurement System Signal Issues", September 5, 2003

4. Letter, M. J. Pacilio (Exelon/Braidwood) to USNRC Document Control Desk, "Submittal of Licensee Event Report Number 2003-002-00, 'Licensed Maximum Power Level Exceeded Due to Inaccuracies in Feedwater Ultrasonic Flow Measurements Caused by Signal Noise Contamination'", BW030080, September 30, 2003

5. Letter, S. E. Kuczynski (Exelon/Byron) to USNRC Document Control Desk, "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'", Byron 2003-0092, September 29, 2003

CROSSFLOW Installation Summary - U.S.	
Braidwood Units 1 & 2	Hope Creek Unit 1
Byron Units 1 & 2	Kewaunee
Calvert Cliffs Units 1 & 2	La Salle Units 1 & 2
Clinton	Monticello
Diablo Canyon Units 1 & 2	Palisades
Dresden Units 2 & 3	Pilgrim
Duane Arnold	Salem Units 1 & 2
Fermi	San Onofre Units 2 & 3
Ft. Calhoun	South Texas Units 1 & 2
Hatch Units 1 & 2	Vermont Yankee

CROSSFLOW Installation Summary - International Units
Brazil
Angra Unit 1
Japan
Genkai Units 1 - 4
Sendai Units 1 & 2
Spain
Almaraz Units 1 & 2
Sweden
Ringhals Unit 3