APP C 89

From: Warren Lyon
To: John Nakoski
Date: Wed, Nov 1, 2006 12:59 PM
Subject: CROSSFLOW

John - No problem with your changes. I've also incorporated Tim's changes to delete our summary of the nonconcurrence in the beginning and at the end and to modify the first part of item 7 to provide a specific reference to the Westinghouse conclusion. (I deleted one of the examples because it was taking me too much time to find the reference.)

CC: Timothy Collins

M-11

Pages 2 through 17 redacted for the following reasons:

- -

Exemption 5

Attachment

OK for Release

October , 2006

MEMORANDUM TO: Ho Nieh, Deputy Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

FROM: Thomas O. Martin, Director,
Division of Safety Systems
Office of Nuclear Reactor Regulation

SUBJECT: NRC STAFF ASSESSMENT OF THE WESTINGHOUSE / ADVANCE MEASUREMENT AND ANALYSIS GROUP (W/AMAG) CROSSFLOW ULTRASONIC FLOWMETER (UFM)

Reference: "Improved Flow Measurement Accuracy Using Crossflow Ultrasonic Flow Measurement Technology," ABB Combustion Engineering, CENPD-397-P-A, ML052070504, May 31, 2000. (Proprietary)

We have completed our reassessment of the CROSSFLOW UFM topical report. The NRC staff finds that (1) the use of CROSSFLOW calibration derived from the laboratory testing described in the topical report and other documentation is not acceptable; (2) the use of in-situ (in-plant) calibration, as currently described in the topical report, is not sufficiently detailed to serve as a basis for future licensing submittals; (3) the ranges of flows and plant configurations that define where CROSSFLOW can be used, as currently described in the topical report, were not adequately described; and (4) as currently described in the topical report, the description of the installation and use of CROSSFLOW was not consistent with the actual calibration and commissioning practices necessary to establish reasonable assurance that CROSSFLOW would function as expected within the claimed uncertainty. Accordingly, pending a revision to the topical report that demonstrates the adequacy of the CROSSFLOW UFM, the previously approved CENPD-397-P topical report is not acceptable as a basis for future licensing actions using CROSSFLOW to determine feedwater flow rate and NRC staff approval of the topical report should be withdrawn.

We recommend that you transmit the enclosed letter to Westinghouse to inform them of our findings.

CONTACT: Warren Lyon
301-415-2897

Enclosure: As stated

October , 2006

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Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

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ACCESSION NUMBER:

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DATE	9/ 20 /06	9/ 20 /06	9/ 20 /06	10/ 13 /06	9/ 21 /06	9/ /06

*With comments that have been addressed in this report revision.
C:\temp\gwprint\Marinos Non-Currence Rev 4.wpd

Mr. J. A. Gresham, Manager
Regulatory Compliance and Plant Licensing
Westinghouse Electric Company LLC
P.O. Box 355
Pittsburgh, PA 15230-0355

SUBJECT: WITHDRAWAL OF STAFF ACCEPTANCE FOR REFERENCING OF CENPD-397-P, REVISION-01-P, IMPROVED FLOW MEASUREMENT ACCURACY USING CROSSFLOW ULTRASONIC FLOW MEASUREMENT TECHNOLOGY"

REFERENCE: Letter from S. Richards (NRC) to Ian Rickard (ABB-CE) dated March 20, 2000 "ACCEPTANCE FOR REFERENCING OF CENPD-397-P, REVISION-01-P, IMPROVED FLOW MEASUREMENT ACCURACY USING CROSSFLOW ULTRASONIC FLOW MEASUREMENT TECHNOLOGY" (TAC NO. MC6452)

Dear Mr. Gresham:

The referenced letter provided NRC acceptance of topical report CENPD-397-P, Revision-01-P, for referencing in licensing submittals. The subject of the topical report was the use of the CROSSFLOW ultrasonic flow meter (UFM) to measure feedwater flow with a measurement uncertainty of ±0.5% with a 95% confidence. Based on the information reviewed at the time, the staff concluded that the CROSSFLOW UFM could achieve the accuracy stated in the topical report.

Operating experience at plants using the CROSSFLOW UFM for feedwater flow measurements has identified significant issues with regard to the ability of plants to achieve the desired measurement uncertainty using the theory, guidelines, and methods described in the topical report. As you are aware, licensees have reported operating at power levels in excess of their licensed limits as a result of using the CROSSFLOW UFM. This experience led to the formation of an NRC task force. The task force evaluated the operating experience and concluded that CROSSFLOW accuracy is questionable and that CROSSFLOW's response is sensitive to plant configuration. Additional issues for CROSSFLOW users to address were also identified. Following the task force findings, the staff undertook a reassessment of the acceptability of the reference topical report for continued use in licensing applications.

The staff's reassessment took into account the original topical report information as well as additional information that has come to light as part of the operating experience reviews. The staff considered the theoretical basis for the UFM, the experimental data supporting the claimed uncertainty, and the installation and calibration requirements included in the implementation guidelines, as well as supporting analysis. The staff concluded that the topical report does not provide a sufficient theoretical or experimental basis to generically disposition the issues that have been manifested in the staff's operating experience reviews or to prevent the occurrence of future overpower conditions that could result from feedwater flow measurement errors in excess of the limits indicated in the topical report.

Based on the issues described in the enclosed safety evaluation, the NRC staff is withdrawing its approval of topical report CENPD-397-P, Revision-01-P, for future licensing applications. As a consequence, this topical report is not acceptable as the basis for applying CROSSFLOW to improve the uncertainty of feedwater flow measurements for either measurement uncertainty power uprates or power recovery purposes. The impact to those licensees currently using CROSSFLOW for power uprates explicitly approved by the NRC staff or for power recovery applications under the provisions of 10 CFR 50.59 will be addressed separately.

If you have any questions regarding this matter, please contact Mr. Jon Thompson of my staff at (301) 415-1119.

Sincerely,

Ho Nieh, Deputy Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Enclosure: As stated

SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION
WESTINGHOUSE ELECTRIC COMPANY LLC
ADVANCED MEASUREMENT AND ANALYSIS GROUP
CROSSFLOW ULTRASONIC FLOW MEASUREMENT TECHNOLOGY
TAC NO. MC6424

1.0 INTRODUCTION

CROSSFLOW is an ultrasonic flow meter (UFM) marketed by Westinghouse Electric Company LLC / Advance Measurement and Analysis Group (W/AMAG). It is claimed to provide better accuracy than the venturis that have typically been used for measuring feedwater flow rate in nuclear power plants. Feedwater flow rate is an important input parameter in establishing the plant's operating power level. The operating power limit is defined in the plant's operating license. Use of CROSSFLOW was described in topical report CENPD-397-P, Rev. 01 (Reference 1). Based on the information reviewed at the time, the NRC staff concluded that CROSSFLOW could achieve the accuracy stated in the topical report. The NRC approved CENPD-397-P in Reference 2.

CROSSFLOW is used (1) to compensate for fouling in venturis that could lead to operation at less than licensed thermal power and, (2) in conjunction with license amendments to operate at higher power levels. The former application, generally known as power recovery, has been implemented under 10 CFR 50.59 which does not require NRC staff review. The latter application, referred to as a measurement uncertainty recapture power uprate, requires a license amendment request (LAR) under 10 CFR 50.90 and 50.92 since an increase in licensed thermal power is involved. Under both applications, the CROSSFLOW device is used to determine a correction factor for the venturis installed in the plant that provide the input for the determination of thermal power.

CROSSFLOW was placed in use at Braidwood in June 1999, and at Byron in May 2000. In August 2003, operation at these plants was reported in excess of licensed thermal power due to use of CROSSFLOW. In March 2004 the reported overpower operation was 1.07 and 1.21 percent for Braidwood Units 1 and 2, respectively, and to 2.62 and 1.88 percent for the Byron units. The overall effect was operation for several years in excess of licensed thermal power.

This experience led to formation of an NRC task group to assess the implications of the Byron and Braidwood overpower events. The task group reported that CROSSFLOW (1) is sensitive to the plant configuration, (2) has not provided the intended accuracy at some facilities, and (3) has demonstrated questionable accuracy at some facilities. Consequently, it was recommended that users should demonstrate that the devices are providing the claimed accuracy in order to ensure compliance with the licensed power level (Reference 3). This reporting led to an NRC staff followup that considered CENPD-397-P-A information, the theoretical basis for CROSSFLOW, experimental data supporting the claimed uncertainty, installation and calibration requirements, supporting analyses, and operating experience. The NRC staff followup included study of more than three dozen documents that were not included in the task group evaluation (including information from 9 documents received from W/AMAG in late May and early June, 2006), independent theoretical evaluations, consultation with the NRC's Office of Research, trips to Alden Laboratories and Calvert Cliffs, and approximately eight days of meetings with W/AMAG.

Enclosure

Additional potential or actual overpower situations were found during the followup evaluation that was initiated after the Byron and Braidwood experience. For example, the Ft. Calhoun licensee had to revise its power uprate LAR as it attempted to establish that CROSSFLOW could meet the claimed accuracy. Calvert Cliffs Units 1 and 2 were found to be overpowered from July 2003 until September 2005, during the time the licensee was attempting to establish that CROSSFLOW would operate with the claimed uncertainty for a power uprate.

2.0 REGULATORY EVALUATION

10 CFR 50.36 requires all nuclear power plants to have technical specifications that provide operating limits such as the licensed thermal power level. The plant thermal power limit is specified in the operating license. Appendix K to 10 CFR Part 50 states that for analysis of loss-of-coolant accidents licensees must assume "that the reactor has been operating continuously at a power level at least 1.02 times the licensed power level (to allow for instrumentation error).... An assumed power level lower than the level specified in this paragraph (but not less than the licensed power level) may be used provided the proposed alternative value has been demonstrated to account for uncertainties due to power level instrumentation error."

CENPD-397-P-A provides the regulatory basis for using CROSSFLOW under 10 CFR 50.59, 10 CFR 50.90, and 10 CFR 50.92. All 10 CFR 50.90 license amendment requests for use of CROSSFLOW and the applicable W/AMAG generic communications that apply to CROSSFLOW for either power recovery or power uprate incorporate topical report CENPD-397-P Rev. 01 by reference or use it as part of the justification for the application.

The key consideration in the NRC staff's original evaluation of CENPD-397-P Rev. 01 was the ability of CROSSFLOW to achieve a flow measurement uncertainty of ±0.5 percent or better at the 95 percent confidence interval. The NRC staff's evaluation noted that actual uncertainties would be determined on a plant specific basis by using guidelines and equations provided in the topical report. Since its original evaluation, the NRC staff concluded that the desired level of measurement uncertainty is achievable only when the plant specific operating conditions and flow uncertainty parameters strictly follow the guidelines in the topical report.

In Reference 2, the NRC staff stated:

> Should our criteria or regulations change so that our conclusions as to the acceptability of the report are invalidated, ABB-CE and/or the applicants referencing the topical report will be expected to revise and resubmit their respective documentation, or submit justification for the continued applicability of the topical report without revision of their respective documentation.

The adequacy of CENPD-397-P, Rev. 01, to reasonably assure that the claimed CROSSFLOW uncertainty is achieved and the NRC assessment of information obtained since approval of CENPD-397-P, Rev. 01, are the principal focus of this safety evaluation.

3.0 TECHNICAL EVALUATION

3.1 CROSSFLOW Laboratory Calibration Methodology

The primary method for calibrating CROSSFLOW devices described in CENPD-397-P-A, Rev. 1, was to rely on the velocity profile correction factor (C_0) determined from a literature representation based upon fully developed flow and laboratory data for relatively long sections of piping. Originally, the C_0 was described as applicable to a fully developed flow location but it was later modified to mean a standard installation. CROSSFLOW was tested at a laboratory facility where the bulk fluid flow rate was measured with precision laboratory equipment and a number of individual CROSSFLOW measurements of fluid velocities were obtained for a constant bulk fluid flow rate. The individual CROSSFLOW measurements were averaged to obtain an average indicated fluid velocity. Using the average indicated fluid velocity, the bulk fluid flow rate was calculated by CROSSFLOW. With this information, the relation between the bulk fluid flow rate measured with the precision laboratory equipment and the CROSSFLOW calculated bulk fluid flow rate was defined for the fluid dynamic conditions maintained during the experiment. The relation is the ratio of the bulk fluid flow rate to the CROSSFLOW calculated flow rate and is defined as C_0, the velocity profile correction factor. By running laboratory tests under different constant bulk flow rate conditions, W/AMAG was able to define a C_0 that provided a velocity profile correction factor at a claimed uncertainty under laboratory controlled conditions. Using the laboratory data, W/AMAG developed small corrections for two constants in a specific correlation related to fully developed turbulent flow to support use of CROSSFLOW. The modified correlation was used to calculate the velocity profile correction factor in the plants when fully developed flow was believed to exist. Additional velocity profile correction factors were provided using laboratory data for such conditions as the distance from an upstream elbow.

Based on operating experience (i.e., Byron, Braidwood, Ft. Calhoun, and Calvert Cliffs), the NRC staff questioned whether the use of the laboratory determined velocity profile correction factors for installation in a plant provided reasonable assurance that the claimed uncertainties could be achieved, and the plants would operate within their licensed thermal power limits. To assess this premise, the NRC staff examined the empirical and theoretical basis upon which W/AMAG claimed CROSSFLOW functioned.

The theory of the CROSSFLOW device is that it measures the transit time of a unique eddy identified with ultrasonic signals along the pipe centerline. A premise of the CROSSFLOW technology is that when the device is installed in the right location on the pipe the measured change in the ultrasonic signal identifies a unique fluid condition. This unique fluid condition moves down the feedwater pipe and can be identified at another location a known distance from the first location. When a measurement that matches the measurement from the first location is found, the premise is that it is the same unique fluid condition and CROSSFLOW computes the fluid flow rate based on the time it took the unique fluid condition identified at the first location to travel to the second location. A large number of individual measurements over a pre-determined time are averaged to obtain a flow rate indication.

This premise relies upon two assumptions:

1. the eddy patterns detected at the upstream location are sufficiently unique and stable, and the detection equipment and algorithm are sufficiently sensitive, that a downstream pattern will be reliably associated with the correct upstream patterns, and

2. the flow velocity profile at the installed location is sufficiently similar to the profile upon which the CROSSFLOW calibration was based.

If the eddy patterns detected at the downstream location are not associated with the correct upstream patterns, then the eddy velocity measurements may be incorrect.

If the flow profile at the installed location differs from the flow profile upon which the CROSSFLOW calibration factors were established, then the relationship between the measured eddy pattern velocities and the volumetric flowrate will not be as assumed. The shape of the flow profile determines the average axial velocity, and if the shape is not as assumed, then the resulting average axial velocity will be incorrectly inferred.

Under fully developed flow conditions for a constant bulk fluid velocity, it is reasonable to accept the premise that the unique fluid condition identified at one location in the pipe can be identified at another location in the pipe provided pipe surface conditions and dimensions are constant. W/AMAG provided a basis for CROSSFLOW that relied on a combination of turbulent flow theory and empirical data in CENPD-397-P, Rev. 1. In the original review of CENPD-397-P, the NRC staff considered that a fully developed flow fluid dynamic condition existed at the location where CROSSFLOW was installed. The empirical data included with the topical report was provided to support the development of the velocity profile correction factor, C_0, for the standard installation. Additional correction factors were also provided for non-standard installation based on laboratory testing. Using this information, the NRC staff originally concluded that if the conditions described in the topical report were met, CROSSFLOW could achieve the claimed uncertainties. However, upon subsequent review by the NRC staff, it was recognized that at commercial power plants, feedwater pipe runs of the length needed to establish fully developed flow conditions, a condition upon which C_0 for the system was based, were not likely to exist. As such, part of the foundation necessary to apply the laboratory determined velocity profile correction factors was undermined.

In discussions with the NRC staff after some of the operating experience events, W/AMAG introduced the concept of "stable flow."[5] Stable flow was based on finding a location on the pipe where the CROSSFLOW measurements were judged to be constant when the device was moved axially along the pipe and was rotated about the pipe (i.e., "stable flow" is a function of the instrument response, not just the fluid condition). At this location, W/AMAG indicated that stable flow and fully developed flow were identical for the purposes of CROSSFLOW applications. In other words, insofar as CROSSFLOW is concerned, the velocity profile at the stable flow location would not change for a constant flow rate. With a stable velocity profile the premise that the unique fluid condition identified at the first CROSSFLOW measurement point could be identified at the second measurement point would continue to apply. As such, the

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[5]The stable flow concept was not identified in Reference 1. The term was first used in communications with the NRC several years later.

calibration would remain valid and CROSSFLOW would provide a representative flow rate. If the concept of stable flow was demonstrated to be acceptable, the theoretical and empirical basis for using the laboratory determined C_0 could be re-established.

Operating experience however has shown that under actual plant conditions the use of the CROSSFLOW device, relying on the laboratory determined velocity profile correction factors, have resulted in plants operating above their rated thermal power. NRC staff review concluded that this was due, in some cases, to installation of the CROSSFLOW device at a location consistent with the requirements of CENPD-397-P-A and the definition of stable flow provided by W/AMAG, but where swirl was determined to be present in the fluid flow and the laboratory determined velocity profile correction factors were incorrect. In other cases, noise contaminated the CROSSFLOW signal and affected the transit time determined by CROSSFLOW. As a result, in some cases CROSSFLOW indicated that the feedwater flow was lower than actual and a correction was made to the venturis allowing the actual feedwater flow to be inappropriately increased, thereby resulting in an increase in the reactor thermal power that exceeded the licensed limit. Based on the fact that there were instances where CROSSFLOW was installed at a location where W/AMAG believed the installation was adequate (there was stable flow) and the plants operated above their rated thermal power levels, the NRC staff concluded that as defined and implemented, stable flow was not demonstrated to be equivalent to fully developed flow. As such, the NRC staff concluded that the basis provided by W/AMAG in CENPD-397-P, Rev. 1, to support the application of the laboratory determined velocity profile correction factors for CROSSFLOW devices installed at commercial power reactors was no longer valid.

3.2 CROSSFLOW In-situ Calibration Methodologies

In-situ testing of CROSSFLOW could be conducted that results in an installation specific velocity profile correction factor being determined. This approach to calibration could eliminate the NRC staff's concerns with using the laboratory determined velocity profile correction factor. To be acceptable to the NRC staff, the in-situ testing would require a methodology that is traceable to a national consensus standard, the uncertainties associated with the testing methodology would need to be factored into the claimed CROSSFLOW uncertainty, and uncertainties associated with the fluid dynamic conditions experienced at the location where CROSSFLOW is installed would have to be accounted for.

Several methods to accomplish in-situ calibration were proposed by W/AMAG either in CENPD-397-P, Rev. 1, or in supplemental information they provided. One method, discussed in CENPD-397-P, Rev. 1, was to use a CROSSFLOW installed at a location on the feedwater pipe where fully developed flow (or stable flow) was believed to exist to calibrate a different CROSSFLOW device in a different feedwater pipe. In this method, it was assumed that the velocity profile correction factor for the CROSSFLOW installed at the stable flow location was the velocity profile correction factor obtained from the laboratory testing. Then a separate velocity profile correction factor was developed for the CROSSFLOW in other feedwater pipes based on a comparison to the CROSSFLOW readings at the stable flow location. As previously discussed, the NRC staff has concluded that applying the velocity profile correction factor from the laboratory to the plant is not acceptable. Similar to transferring the laboratory velocity profile correction factor to plant use, the NRC staff concluded that this method relies on theoretical and empirical bases that have not been demonstrated to provide reasonable assurance that the claimed uncertainties can be achieved. Further, this practice has been demonstrated to be incorrect on the basis of other in-situ calibration data. As such, the calibration practice of using one CROSSFLOW installed at a stable flow location to calibrate another CROSSFLOW in another pipe is not acceptable to the NRC staff.

Another method of calibrating CROSSFLOW described by W/AMAG was chemical tracer testing. Based on the NRC staff review of the information provided by W/AMAG, chemical tracer testing for in-situ calibrations was traceable to recognized national standards. Using a tracer test, W/AMAG could determine a velocity profile correction factor for CROSSFLOW for the fluid dynamic conditions maintained during the calibration process. However, it was not demonstrated that the uncertainties associated with the use of chemical tracer testing were adequately addressed. For example, the data provided to the NRC staff regarding one set of chemical tracer tests indicated that they exhibited a sensitivity approximately equal to the claimed CROSSFLOW uncertainty. This sensitivity was not considered in determining the CROSSFLOW uncertainty. The NRC staff concluded that when properly implemented chemical tracer tests can be used to calibrate CROSSFLOW, however, W/AMAG has not demonstrated that this can be done to the level of uncertainty necessary to support the uncertainties claimed for CROSSFLOW in CENPD-397-P-A.

Recently cleaned and calibrated venturis could be used to develop a velocity profile correction factor for an installed CROSSFLOW device. Use of venturis for this application should be conducted consistent with the American Society of Mechanical Engineers (ASME) Code. Included within the ASME Code requirements are limitations on swirl in the fluid during calibration. Provided that the ASME Code requirements are followed, the NRC staff expects that the effect of swirl on the calibration of the venturi should be limited and the subsequent effect on the calibration of the CROSSFLOW device should likewise be limited. Based on the review of the information provided by W/AMAG, the staff determined that recently cleaned and calibrated venturis can be used to develop installation-specific velocity profile correction factors, provided that the calibration is conducted in accordance with the ASME Code requirements and uncertainties associated with the venturi calibration are addressed in the calibration of the CROSSFLOW device.

As with any instrument being calibrated, CROSSFLOW needs to be calibrated for the conditions under which it will be used. This includes the fluid dynamic conditions that could contribute to the overall instrument uncertainty. Because CROSSFLOW relies on the identification of a unique fluid dynamic condition being identified by an ultrasonic signal at two points in the feedwater piping a known distance apart, factors that could affect either the fluid velocity profile (a representation of the fluid dynamic condition) or the ultrasonic signal directly need to be assessed in the calibration. Some factors that routinely occur in a nuclear power plant that can affect these conditions include:

1. Feedwater flow rate
2. Valve positions and valve wear or replacement
3. Feedwater heater configuration
4. Feedwater pump operation, wear, and replacement
5. Feedwater pipe fouling, defouling, and other changes that affect pipe roughness
6. Acoustic noise (from pipe vibration, operating equipment, etc.)

In performing any CROSSFLOW calibration, these factors, and others that may exist for a specific installation, need to be assessed in determining the overall instrument uncertainty that can be achieved during calibration. The calibration method must describe the process for addressing those factors that can have an influence on the device uncertainty. W/AMAG has described its installation and commissioning process to the NRC staff. However, CENPD-397-P, Rev. 1, does not describe the installation and commissioning process in sufficient detail to reasonably demonstrate how the kind of in-plant factors mentioned above were addressed in the calibration process. Further discussion on the installation and commissioning of CROSSFLOW at a stable flow location is provided in Section 3.3 of this safety evaluation.

The NRC staff concluded that some of the methods described by W/AMAG for in-situ calibration would address the concerns with using the laboratory determined velocity profile correction factors to calibrate CROSSFLOW. However, CENPD-397-P, Rev. 1, does not provide sufficient information for the NRC staff to conclude that following the topical report's requirements provides reasonable assurance that in-situ calibration will be conducted to national consensus standards, adequately account for the uncertainties associated with the in-situ calibration methodology, nor account for uncertainties associated with the fluid dynamic conditions encountered at the CROSSFLOW installation location during plant operation.

3.3 CROSSFLOW Installation and Commissioning

In the installation process described by W/AMAG, a stable flow location was determined, in part, by holding power and feedwater flow rate reasonably constant, then moving CROSSFLOW axially and radially on the feedwater piping until a location was found where it was deemed that movement does not indicate a flow rate change. As part of the commissioning process, this is repeated at different power levels and feedwater system configurations to identify a location where the CROSSFLOW readings are relatively unaffected by changing the location axially or radially on the feedwater piping and the CROSSFLOW readings can be used. In theory, using this approach a licensee could identify a location where CROSSFLOW could be calibrated for a narrow range of power levels, feedwater flow rates, and plant configurations for which a single velocity profile correction factor could be defined that would result in a conservative determination of feedwater flow rate. The NRC staff's review of operating experience indicates that implementation of this approach has not always resulted in an installation location that supports the use of CROSSFLOW for improved feedwater flow measurements to the uncertainties intended to be achieved.

In addition, the NRC staff's review of the information provided on how a stable flow location was determined also found inappropriate statistical bounds were applied, sufficient data were not collected, and claimed test laboratory uncertainties were inappropriately applied. For example, W/AMAG stated that one test for determining that a stable flow condition exists was that the same flow indication exists for different axial locations and angular orientations when the indicated CROSSFLOW measurements were within the claimed uncertainty of the CROSSFLOW device. This test ignores the fact that each of the CROSSFLOW measurements have an associated uncertainty and that a statistically valid number of samples need to be obtained at that location to have reasonable assurance that a representative measurement for comparison to another location (or orientation) is determined (convergence is achieved for the measured flow rate). Further, in some cases, NRC staff examination of the few data points that W/AMAG claimed established convergence actually showed trends still existed. Based on these concerns, the NRC staff concluded that the process described in CENPD-397-P-A for determining a fully developed flow (or stable flow) location were not sufficient to support the claimed uncertainty.

3.4 Post-Installation Monitoring and Calibration

W/AMAG uses online monitoring of a large number of CROSSFLOW parameters, system diagnostic alarms, and, when judged necessary, by examining other plant parameters and measurements that provide insight into feedwater flow rate and thermal power to assess whether the velocity profile correction factor remains acceptable and if CROSSFLOW is performing as expected. The NRC staff's review determined that W/AMAG did not demonstrate that the CROSSFLOW system online monitoring was sufficient to support the claimed uncertainty.

Based on its review of documentation provided by W/AMAG after the NRC staff approved the topical report, the NRC staff determined that the velocity profile correction factor could vary by about as much as the claimed CROSSFLOW uncertainty before an alarm is initiated. Also, the licensee can adust the alarm setpoints based on its judgment regarding the cause of changes to the venturi correction factor. Further, the theoretical and empirical bases provided by W/AMAG did not provide a description of the fundamental fluid dynamics aspects of CROSSFLOW that would allow the NRC staff to conclude that the monitoring being performed was adequate on its own. Nor did W/AMAG provide justification demonstrating that changes in indicated flow rate determined by CROSSFLOW were the result of a change in the bulk fluid flow rate, not a change in the velocity profile correction factor due to changes in the fluid dynamic conditions (velocity profile) at the device location. The NRC staff concluded that other plant parameters or measurements were needed to supplement the online monitoring to make this determination.

W/AMAG describes, in general, its approach for using other plant parameters and measurements to assess the performance of CROSSFLOW. The NRC staff has concerns with the use of other plant parameters for assessing whether the calibration of CROSSFLOW has changed. Other plant parameters have larger uncertainties than claimed for CROSSFLOW and this adds to the difficulty in assessing CROSSFLOW performance. W/AMAG has not provided a statistically valid approach for applying the other parameters to substantiate that CROSSFLOW is operating as expected and to provide early detection of problems in its operation. Based on these issues, the NRC staff concluded that W/AMAG has not demonstrated that the use of other plant parameters provides assurance that the CROSSFLOW calibration remains effective after the initial calibration to the uncertainties claimed.

Finally, while CENPD-397-P, Rev. 1, discussed using other plant parameters to monitor CROSSFLOW performance, the level of detail was not sufficient for the NRC staff to conclude that it provided reasonable assurance that changes in CROSSFLOW readings could be shown to be from changes in the feedwater flow rate, rather than a change in the velocity profile correction factor.

4.0 CONCLUSION

The NRC staff considers that the commissioning of CROSSFLOW as described in CENPD-397-P, Rev. 1 is not valid based on experience of calibration problems with use of CROSSFLOW, the fact that neither fully developed or stable flow have been adequately demonstrated to exist in plant feedwater systems over the range of flows and plant configurations assumed, the lack of adequate consideration and operational restrictions for a variety of factors that could impact the flow profile and its ultrasonic measurement, and the absence of a sound technical basis for the transferability of the calibration data from a laboratory environment to a plant environment.

Specific weaknesses in the topical report include:

1. The assumption that laboratory calibration results are transferrable to an in-plant configuration without additional in-plant calibration.

2. The lack of periodic in-plant calibration using an instrument traceable to a national standard.

3. The lack of specific restrictions over a range of flows and plant configurations that define where the CROSSFLOW calibration can be considered valid. Such restrictions could address, in part, a variety of factors that impact ultrasonic flow measurement, including changing valve positions, feedwater heater configuration, feedwater pump configuration, and acoustic noise.

4. Inadequate description of the installation and use of CROSSFLOW consistent with the actual calibration and commissioning practices.

Based on the operating experience that has demonstrated that installation of CROSSFLOW using the guidance and recommendations of CENPD-397-P, Rev. 1, are not sufficient to assure that the claimed uncertainty can be achieved, the NRC staff finds that (1) the existing previously approved CENPD-397-P topical report is not acceptable as a basis for future licensing actions using CROSSFLOW to determine feedwater flow rate, and (2) a basis has not been established for such use that acceptably addresses the issues discussed in this safety evaluation.

Consequently, the NRC staff is withdrawing approval of CENPD-397-P, Rev. 1, for use as the technical basis for future licensing actions.

5.0 REFERENCES

1. "Improved Flow Measurement Accuracy Using Crossflow Ultrasonic Flow Measurement Technology," CE Nuclear Power LLC, CENPD-397-P-A, ML052070504, May 31, 2000. (Proprietary)

2. Richards, Stuart A., "Acceptance for Referencing of CENPD-397-P, Revision-01-P, 'Improved Flow Measurement Accuracy Using Crossflow Ultrasonic Flow Measurement Technology' (TAC No. MA6452)," Letter to ABB Combustion Engineering from NRC, ML003694197, March 20, 2000.

3. Dembek, Stephen, "Proprietary Version of the Final Report of the Ultrasonic Flow Meter Allegation Task Group Regarding the Westinghouse/AMAG Crossflow Ultrasonic Flow Meter," NRC letter to Westinghouse Electric Company, June 22, 2004.