September 26, 2007

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

SUBJECT: FINAL SAFETY EVALUATION FOR SUSPENSION OF U.S. NUCLEAR REGULATORY COMMISSION (NRC) ACCEPTANCE FOR REFERENCING OF WESTINGHOUSE ELECTRIC COMPANY (WESTINGHOUSE) TOPICAL REPORT (TR) CENPD-397-P, REVISION-01-P, "IMPROVED FLOW MEASUREMENT ACCURACY USING CROSSFLOW ULTRASONIC FLOW MEASUREMENT TECHNOLOGY" (TAC NO. MD3857)

Dear Mr. Gresham:

By letter dated January 6, 2000 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML003672804) and supplemented by letters dated January 25 (ADAMS Accession No. ML003677941), March 8 (ADAMS Accession No. ML052070504), and March 13, 2000 (ADAMS Accession No. ML010360396), ABB Combustion Engineering Nuclear Power, Inc (ABB-CE, which is now incorporated into Westinghouse) submitted TR CENPD-397-P, Revision-01-P, "Improved Flow Measurement Accuracy Using CROSSFLOW Ultrasonic Flow Measurement Technology," to the NRC staff for review. Subsequently, by letter dated March 20, 2000, the NRC staff approved this TR (ADAMS Accession No. ML003694197). Since that time, the NRC staff has found it necessary to reassess the adequacy of this TR and has determined that the staff's previous approval of this TR should be suspended. Enclosed is a copy of the NRC staff's final safety evaluation (SE) for the TR which provides the basis for this determination.

The subject of TR CENPD-397-P, Revision-01-P, is the use of the CROSSFLOW Ultrasonic Flow Meter (UFM) to measure feedwater flow with a measurement uncertainty of +/- 0.5 percent with a 95 percent confidence. Subsequent to the NRC staff's approval of TR CENPD-397-P, Revision-01-P, operating experience at some plants using the CROSSFLOW UFM for feedwater flow measurements revealed problems regarding the ability to achieve the desired measurement uncertainty using the theory, guidelines, and methods described in the TR.

As you are aware, some licensees have reported operating at power levels in excess of their licensed limits as a result of using the CROSSFLOW UFM. This operating experience and other information led to the formation of an NRC staff task group. The task group evaluation concluded that CROSSFLOW accuracy is questionable and that CROSSFLOW's indicated flow rate is sensitive to plant configuration. Additional issues for CROSSFLOW users to address were also identified. Following the task group findings, the NRC staff undertook a reassessment of the acceptability of the subject TR.

The NRC staff's reassessment took into account the original TR information as well as additional information that has come to light as part of the NRC staff and industry representative reviews of operating experience. The NRC staff considered the theoretical basis for the UFM, the experimental data supporting the claimed uncertainty, the installation and calibration requirements included in the implementation guidelines, and the supporting analysis. The TR does not provide a sufficient theoretical or experimental basis to generically disposition the issues that have been identified in the NRC staff's operating experience reviews. The NRC staff concludes that the previously approved TR does not assure that the CROSSFLOW UFM would function as expected within the claimed uncertainty. As a result, use of the CROSSFLOW UFM may result in a feedwater flow rate and a power level that is greater than the values used in the accident analyses.

The NRC staff's experience with reviewing postulated loss-of-coolant accident (LOCA) and non-LOCA events at higher power levels is that the consequences of these events are only slightly affected by the small variations in power level that could result from the increase in feedwater flow rate uncertainty. The small effect on consequences and, therefore, low safety significance, is due to the margins between the results of the analyses and the acceptance criteria, and conservatisms assumed in the licensing basis accident and transient analyses. For example, Appendix K to 10 CFR Part 50 requires specified features in an evaluation model. Many of the features are required to have conservative bounds that are individually applied for conditions anticipated to predict the highest peak clad temperature. Often, no consideration is given to the likelihood of each bound occurring at the same time.

Pursuant to Section 2.390 of Title 10 of the Code of Federal Regulations (10 CFR), the NRC staff previously sent a draft SE to you by letter of March 13, 2007 (ADAMS Accession No. ML063330245) to confirm that the draft SE did not contain proprietary information. That letter also provided Westinghouse the opportunity to identify any factual errors in the draft SE. Westinghouse confirmed that the draft SE did not contain any proprietary information by letter dated April 12, 2007 (ADAMS Accession No. ML071430308). In the April 12, 2007, letter, Westinghouse also provided comments in response to the NRC staff's request to identify any factual errors. These comments and the NRC staff's dispositions were discussed in a public meeting on May 1, 2007 (ADAMS Package No. ML071280813) and are reflected in this letter and the final SE that is enclosed with this letter. In addition, the NRC staff's disposition of specific Westinghouse comments on the draft SE are discussed in the attachment to the final SE. The NRC staff has also made additional changes to the draft SE that were recommended following further independent review by NRC staff members who were not previously involved in CROSSFLOW assessment.

By letter dated June 4, 2007, Westinghouse requested that the NRC staff consider an alternative to complete suspension of the approval for TR CENPD-397-P, Revision-01-P which involved suspending certain subsections of the TR (ADAMS Accession No. ML071580119). By letter dated July 11, 2007, the NRC staff indicated that it would consider that request as part of the NRC staff's deliberations regarding TR CENPD-397-P (ADAMS Accession No. ML071910417). This request was duly examined and evaluated. However, the nature and extent of the conclusions identified in the final SE are such that partial suspension of the TR is not considered a viable option by the NRC staff.

Therefore, on the basis of the issues described in the enclosed final SE, the NRC staff is suspending its approval of TR CENPD-397-P, Revision-01-P, for new and future use of the CROSSFLOW UFM until the issues identified herein and in the enclosed SE have been resolved. Accordingly, the NRC staff will not approve any pending or future license amendment requests (LARs) for measurement uncertainty recapture (MUR) power uprates using the CROSSFLOW UFM that rely on the NRC staff's previous approval of the TR, without additional justification that is acceptable to the NRC staff. The NRC staff will inform individual licensees that have submitted LARs for MUR power uprates using the CROSSFLOW UFM of the status of their submittals given that the NRC staff's approval of the TR has been suspended. Additionally, licensees should no longer consider the TR "approved by NRC for the intended application" under Title 10 of the *Code of Federal Regulations* (10 CFR) 50.59(a)(2)(ii) in future 10 CFR 50.59 evaluations of changes to support power recovery.

As a result of the NRC staff's suspension of its approval of TR CENPD-397-P, Revision-01-P, licensees of plants that rely on the TR for previously approved MUR power uprates or for previously conducted 10 CFR 50.59 evaluations to support power recovery are expected to review this new information for applicability to their facilities and consider actions, as appropriate, to assure operation in compliance with the licensing basis for their plants. Licensees that currently rely on the TR are expected to ensure that the CROSSFLOW UFM continues to function consistent with all requirements and the plant's licensing bases (e.g., 10 CFR 50.46, Appendix K to 10 CFR Part 50, and the plant's licensed maximum rated thermal power). Additionally, the NRC staff expects licensees to address and, if necessary, correct identified deficiencies at their plants and comply with applicable reporting requirements. The NRC staff plans to issue a generic communication that will address the NRC staff's expectations for licensees that currently rely on the TR for previously approved MUR power uprates or for previously conducted 10 CFR 50.59 evaluations to support power recovery.

Please contact Mr. Jon Thompson of my staff at (301) 415-1119, if you have additional questions regarding this matter.

Sincerely,

/RA/

Michael J. Case, Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 700

Enclosure: Final SE

cc w/encl:
Mr. Gordon Bischoff, Manager
Owners Group Program Management Office
Westinghouse Electric Company
P.O. Box 355
Pittsburgh, PA 15230-0355

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Michael J. Case, Director
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Project No. 700
Enclosure: Final SE
cc w/encl:
Mr. Gordon Bischoff, Manager
Owners Group Program Management Office
Westinghouse Electric Company
P.O. Box 355
Pittsburgh, PA 15230-0355

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ADAMS ACCESSION NO.: ML071650263 **NRR-043**

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FINAL SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

TOPICAL REPORT CENPD-397-P, REVISION-01-P

"IMPROVED FLOW MEASUREMENT ACCURACY USING CROSSFLOW

ULTRASONIC FLOW MEASUREMENT TECHNOLOGY"

WESTINGHOUSE ELECTRIC COMPANY

PROJECT NO. 700

1.0 INTRODUCTION AND BACKGROUND

CROSSFLOW is an ultrasonic flow meter (UFM) originally marketed by ABB Combustion Engineering Nuclear Power, Inc. (ABB-CE, which is now incorporated into Westinghouse Electric Company LLC, (Westinghouse)) now Westinghouse, Advanced Measurement and Analysis Group (W/AMAG). It is claimed that CROSSFLOW provides better accuracy than the venturi flow meters 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 (TR) CENPD-397-P, Revision-01-P (Reference 1). Based on the information reviewed at the time, the NRC staff had previously concluded that CROSSFLOW could achieve the accuracy stated in the TR. The NRC staff, therefore, approved TR CENPD-397-P, Revision-01-P, by letter dated March 20, 2000 (Reference 2).

CROSSFLOW is used (1) to compensate for fouling in venturi flow meters 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 Section 50.59 of Title 10 of the *Code of Federal Regulations* (10 CFR) which does not require prior NRC staff review and approval. The latter application, referred to as a measurement uncertainty recapture (MUR) power uprate, requires a license amendment request (LAR) under 10 CFR 50.90 and 50.92, since a change to the license is involved. Under both applications, the CROSSFLOW device is used to determine a correction factor for the venturi flow meters installed in the plant that provide the input for the determination of thermal power.

CROSSFLOW was placed in use at Braidwood Generating Station (Braidwood) in June 1999 and at Byron Generating Station (Byron) in May 2000. In August 2003, operation at these plants was reported in excess of licensed thermal power due to the 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 2.62 and 1.88 percent for the Byron units. The overall effect was operation for several years in excess of licensed thermal power.

ENCLOSURE

This operating experience and other information led to the formation of an NRC staff task group to assess the implications of the Byron and Braidwood overpower events. The NRC staff task group concluded 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. The NRC staff task group also found that use of CROSSFLOW does not represent a significant safety concern because of the large margins and conservatisms assumed in the licensing basis accident and transient analyses. Consequently, it was recommended that users should demonstrate that the devices are providing the claimed accuracy in order to assure compliance with the licensed power level (Reference 3). The issues identified by the task group led to the NRC staff re-evaluating TR CENPD-397-P, Revision-01-P, 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 review of more than three dozen documents that were not included in the NRC staff task group evaluation (including information from nine documents received from W/AMAG in late May and early June 2006), independent theoretical evaluations, consultation with the NRC's Office of Nuclear Regulatory Research, trips to Alden Laboratories and Calvert Cliffs Nuclear Power Plant (Calvert Cliffs), approximately eight days of meetings with W/AMAG, and an additional review during the first half of 2007 by qualified NRC staff members who were not previously involved in the CROSSFLOW review.

Additional actual or potential overpower situations were identified during the NRC staff and industry evaluations that were initiated after the Byron and Braidwood experience. For example, the licensee for Calvert Cliffs Units 1 and 2 found that those units were overpowered from July 2003 until September 2005 due to reliance on CROSSFLOW for power recovery, during the time the licensee was attempting to establish that CROSSFLOW would operate with the claimed uncertainty for a power uprate. In addition, although it was never operated in an overpower condition, the Fort Calhoun Station (Ft. Calhoun) licensee had to revise the initial power uprate LAR and then submit another LAR to go back to the pre-MUR-uprate power level, in its attempt to establish that CROSSFLOW could meet the claimed accuracy.

2.0 REGULATORY EVALUATION

The regulations in 10 CFR 50.36 require 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. Section I.A of Appendix K to 10 CFR Part 50 states that for analysis of loss-of-coolant accidents (LOCAs) 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."

TR CENPD-397-P 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 LARs that use CROSSFLOW, and the applicable W/AMAG generic communications that apply to CROSSFLOW for either power recovery or power uprate, incorporate TR CENPD-397-P, Revision-01-P, by reference, or use it as part of the justification for the application.

The key consideration in the NRC staff's original evaluation of TR CENPD-397-P, Revision-01-P, was the ability of CROSSFLOW to achieve a flow measurement uncertainty of ± 0.5 percent, or better, at the 95 percent confidence interval because the claimed uncertainty was to be used in place of the two percent value required by 10 CFR Part 50, Appendix K. 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 TR. Since its original evaluation on March 20, 2000, the NRC staff determined that the desired level of measurement uncertainty is not assured when the plant specific operating conditions and flow uncertainty parameters strictly follow the guidelines in the TR.

In the cover letter of 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 principal focus of this safety evaluation is to re-evaluate the adequacy of TR CENPD-397-P, Revision-01-P, to determine whether the claimed CROSSFLOW uncertainty is achieved.

3.0 TECHNICAL EVALUATION

3.1 CROSSFLOW Laboratory Calibration Methodology

The primary method for calibrating CROSSFLOW devices described in TR CENPD-397-P, Revision-01-P, 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 apply to 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. 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 reviews of test information, independent assessments, and 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 that 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 that CROSSFLOW functioned.

The theory of the CROSSFLOW device is that it measures the transit time of a unique eddy identified with ultrasonic signals between two axial pipe locations. 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, it is assumed to be 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 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 TR CENPD-397-P, Revision-01-P. As part of the original review of TR 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 TR were provided to support the development of the C_0 value for the standard installation. Additional correction factors were also provided for non-standard installations based on laboratory testing. Using this information, the NRC staff originally concluded that if the conditions described in the TR were met, then CROSSFLOW could achieve the claimed uncertainties. However, upon subsequent review by the NRC staff, it was determined that 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 at commercial power plants. As such, part of the foundation necessary to apply the laboratory-determined velocity profile correction factors was undermined. Further, the NRC staff concluded that (1) the TR description of the transfer of laboratory test data to the in-plant installations and operating conditions was based in part on an unacceptable statistical and technical rationale, (2) the laboratory test data are statistically inadequate and do not sufficiently converge to acceptably support some of the claimed additional velocity profile correction factors, (3) in some cases, the laboratory tests did not adequately simulate the in-plant configurations, and (4) the laboratory tests have not been established to be consistent with claimed conservatisms.

In discussions with the NRC staff after some of the operating experience events, W/AMAG introduced the concept of "stable flow." (The stable flow concept was not identified in Reference 1. The term was first used in communications with the NRC staff several years later). 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 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, has resulted in some plants operating above their rated thermal power. The 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 TR CENPD-397-P 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. As such, the NRC staff concluded that the basis provided by W/AMAG in TR CENPD-397-P, Revision-01-P, to support the application of the laboratory-determined velocity profile correction factors for CROSSFLOW devices installed at commercial power reactors could no longer be considered to be reliable.

3.2 CROSSFLOW In-Plant Calibration Methodologies

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

CROSSFLOW is installed. Further, if CROSSFLOW is installed where calibration is sensitive to location, then the calibration change and uncertainty due to changes in flow profile may be greater than for an installation that is insensitive to location.

Several methods to accomplish in-plant calibration were proposed by W/AMAG either in TR CENPD-397-P, Revision-01-P, or in supplemental information that it provided. One method, discussed in TR CENPD-397-P, Revision-01-P, 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, derived using the laboratory data, to plants has not been demonstrated to be acceptable. Therefore, a CROSSFLOW value, with a calibration based solely on laboratory testing, cannot be used as a calibration standard following its installation in a feedwater pipe. Further, use of a calibration standard in one pipe to calibrate a CROSSFLOW in another pipe has been demonstrated to be incorrect on the basis of in-plant calibration data. As such, the calibration practice of using one CROSSFLOW, installed at a stable flow location, to calibrate another CROSSFLOW measurement 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-plant 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 chemical tracer tests, when properly implemented, can be used to calibrate CROSSFLOW. However, W/AMAG has not demonstrated that chemical tracer test uncertainty is sufficiently small to support the uncertainties claimed for CROSSFLOW in TR CENPD-397-P.

Information provided by W/AMAG indicates that recently cleaned and calibrated venturi flow meters could be used to develop a velocity profile correction factor for an installed CROSSFLOW device, if used 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. In addition, uncertainties associated with the venturi calibration must be addressed in the calibration of the CROSSFLOW device. However, the venturi test data reviewed by the NRC staff have not been established to meet the ASME Code and calibration requirements.

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, and
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 to the NRC staff its commissioning process (the W/AMAG process of installing and testing the CROSSFLOW to establish it is operating as claimed). However, TR CENPD-397-P, Revision-01-P, 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-plant calibration would address the concerns with using the laboratory-determined velocity profile correction factors to calibrate CROSSFLOW. However, TR CENPD-397-P, Revision-01-P, does not provide sufficient information for the NRC staff to conclude that following the TR's requirements provides reasonable assurance that in-plant calibration would be conducted to national consensus standards and would adequately account for the uncertainties associated with the in-plant calibration methodology, nor does it 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 circumferentially 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 circumferentially on the feedwater piping and the CROSSFLOW readings can be used. In theory, using this approach a licensee may be able to 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 regarding how a stable flow location was determined also found that 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 circumferential 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 has 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 TR CENPD-397-P 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, other plant parameters and measurements are examined to 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 TR, 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 adjust 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, rather than 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. However, the use of other plant parameters for assessing whether the calibration of CROSSFLOW has changed has not been demonstrated to be acceptable. 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 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 has 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.

4.0 CONCLUSION

The NRC staff considers that the commissioning of CROSSFLOW as described in TR CENPD-397-P, Revision-01-P is not valid based on calibration problems experienced 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 transfer of the calibration data from a laboratory environment to a plant environment.

Specific weaknesses in the TR that should be addressed for use of CROSSFLOW to determine feedwater flow rate in nuclear power plants include:

1. The assumption that laboratory calibration results are transferrable to an in-plant configuration without additional in-plant calibration. If a laboratory calibration methodology is used for the CROSSFLOW installation, then a complete uncertainty evaluation must be supplied that includes the uncertainties associated with transfer from the laboratory calibration to the in-plant installation. The entire process must be traceable to accepted national standards. If an in-plant calibration is used to eliminate this assumption, then a complete uncertainty evaluation that includes substantiation of traceability to accepted national standards must be supplied.

2. The treatment of the impact of acoustic noise on CROSSFLOW and the ability to detect and remove the effects, including determination of residual uncertainty. This must be evaluated for the initial calibration and for initial and long term operation.

3. The lack of periodic in-plant calibration using an instrument traceable to a national standard and assurance that CROSSFLOW operation remains within the claimed uncertainty. A complete, in-depth, evaluation of the process of obtaining continued assurance that CROSSFLOW operation remains within the claimed uncertainty must be supplied. This must include a valid process of comparing CROSSFLOW flowrate indication with the flowrate determined from other available plant parameters.

4. 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.

5. Inadequate description of the installation and use of CROSSFLOW consistent with the actual calibration and commissioning practices. The process, procedures, and training used to enable CROSSFLOW users to understand system operation, including diagnostics, must be sufficiently described to establish a basis that ensures CROSSFLOW will be operated within the specified uncertainty.

Based on the operating experience that has demonstrated that installation of CROSSFLOW using the guidance and recommendations of TR CENPD-397-P, Revision-01-P, 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, Revision-01-P, TR is not acceptable as a basis for new and future use of CROSSFLOW to determine feedwater flow rate for MUR power uprate license amendment requests or for 10 CFR 50.59 evaluations to support power recovery, and (2) a basis has not been established that acceptably addresses the issues discussed in this safety evaluation.

Therefore, the NRC staff is suspending its approval of TR CENPD-397-P, Revision-01-P, for new and future use of the CROSSFLOW UFM until the issues discussed in this safety evaluation have been resolved. Accordingly, the NRC staff will not approve any LARs for MUR power uprates using the CROSSFLOW UFM that rely on the NRC staff's previous approval of the TR without additional justification that is acceptable to the NRC staff. The NRC staff will inform individual licensees that have submittals of LARs pending review for MUR power uprates using the CROSSFLOW UFM of the status of their submittals given that the NRC staff's approval of the TR has been suspended. Additionally, licensees should no longer consider the TR "approved by NRC for the intended application" under 10 CFR 50.59(a)(2)(ii) in future 10 CFR 50.59 evaluations of changes to support power recovery.

As a result of the NRC staff's suspension of its approval of TR CENPD-397-P, Revision-01-P, licensees of plants that rely on the TR for previously approved MUR power uprates, or for previously conducted 10 CFR 50.59 evaluations to support power recovery, are expected to review this new information for applicability to their facilities and consider actions, as appropriate, to assure operation in compliance with the licensing basis for their plants. Licensees that currently rely on the TR are expected to ensure that the CROSSFLOW UFM continues to function consistent with all requirements and the plant's licensing bases (e.g., 10 CFR 50.46, Appendix K to 10 CFR Part 50, and the plant's licensed maximum rated thermal power). Additionally, the NRC staff expects licensees to address and, if necessary, correct identified deficiencies at their plants and comply with applicable reporting requirements. The NRC staff plans to issue a generic communication that will address the NRC staff's expectations for licensees that currently rely on the TR for previously approved MUR power uprates or for previously conducted 10 CFR 50.59 evaluations to support power recovery.

5.0 REFERENCES

1. "Improved Flow Measurement Accuracy Using Crossflow Ultrasonic Flow Measurement Technology," CE Nuclear Power LLC, CENPD-397-P (ADAMS Accession No. 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, (ADAMS Accession No. ML003694197), March 20, 2000.

3. Dembek, Stephen, “Non-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, (ADAMS Accession No. ML041770229), July 1, 2004.

Attachment: Resolution of Comments

Principal Contributor: Warren C. Lyon

Date: September 26, 2007

RESOLUTION OF COMMENTS ON DRAFT SAFETY EVALUATION (SE) FOR

TOPICAL REPORT (TR) CENPD-397-P, REVISION 01-P,

"IMPROVED FLOW MEASUREMENT ACCURACY USING CROSSFLOW

ULTRASONIC FLOW MEASUREMENT TECHNOLOGY"

(Changes that affect the draft letter to Westinghouse Electric Company LLC, Advance Measurement and Analysis Group (W/AMAG) or the draft SE are shown by a margin notation or strikeout).

1 **W/AMAG Comment (General)**: W/AMAG has reviewed the draft SE and has not found it to contain any information considered to be proprietary in nature.

2 **W/AMAG Comment (General)**: The draft SE generally improperly treats all CROSSFLOW users the same based on the problems exhibited by only the few plants the NRC identified in the draft SE. To the best of our knowledge, the NRC has never reviewed the operating data nor inspected any other CROSSFLOW acceptability.

NRC Staff Response: The NRC staff reviewed all of the information that was submitted by W/AMAG and the Calvert Cliffs and Ft. Calhoun licensees. Further, the NRC staff traveled to Alden Laboratories and to Calvert Cliffs, conducted interviews with approximately two dozen personnel regarding the Byron and Braidwood overpower conditions, spent approximately eight days in meetings with W/AMAG (meetings where licensee personnel typically participated) and conducted independent analyses. The information obtained was sufficient to support the NRC staff conclusions regarding CROSSFLOW.

3 **W/AMAG Comment (General)**: The draft SE focuses excessively on the CROSSFLOW technology rather than the actual cause of the problems which were due to application errors. The human error problems included inadequate TR documentation as to certain points, inadequate installation and commissioning practices, and weak licensee operation practices at a few plants. That is, the technology is sound but there have been shortcomings in its application.

NRC Staff Response: The NRC staff has determined that W/AMAG has not demonstrated that the CROSSFLOW technology is sound. The NRC staff reviewed all aspects of the available information and conducted additional analyses to develop insights that were not directly available. The NRC staff found that there were issues related to CROSSFLOW testing, calibration, and use. These issues have not been properly identified or resolved by W/AMAG or the licensees. A few examples of these issues are as follows:

- By letter dated March 6, 2006, Constellation Energy Generation Group described using a CROSSFLOW meter in one feedwater pipe to calibrate CROSSFLOW meters in other feedwater pipes. The differences between the CROSSFLOW meter calibrations and the chemical tracer calibrations were 0.61, -0.50, and 0.12 percent. Since chemical tracer calibration was considered more accurate, this identified an unanticipated CROSSFLOW error.

The Constellation Energy Generation Group letter of March 6, 2006, concluded that "the wide variation in the results indicates that the Loop 12 calibration could not be used for the remaining three loops, contrary to the results from the cold laboratory testing." The NRC staff notes that Westinghouse considered that the installation of CROSSFLOW for these in-plant conditions and configurations was consistent with the previous testing, calibration, and use of CROSSFLOW from the time CROSSFLOW was installed at the plant until an anomaly was discovered that led to the use of chemical tracer testing. The changes (proprietary in nature) made as a result of this experience in using CROSSFLOW to calibrate other CROSSFLOW meters are described on Pages 17 and 18 of Westinghouse's letter of June 2, 2006 (Agencywide Documents Access and Management System (ADAMS) No. ML061580091).

- The application of laboratory test calibrations to plant applications has not demonstrated attainment of the claimed uncertainties. This situation occurs for both the basic calibration coefficient that was originally developed for fully developed flow, and for calibration coefficients developed to account for piping configuration changes that affect the flow profile.

- Data (proprietary in nature) have not consistently supported the claimed change in calibration coefficient with pipe roughness.

4 **W/AMAG Comment (General):** The draft SE states that all of the supplemental materials provided by W/AMAG was reviewed. However, within the draft SE discussion none of the supplemental material is referenced nor is there any discussion as to why the NRC staff was not satisfied with that material in response to their concerns and questions about CROSSFLOW technology and its application. Consequently, it is not possible for W/AMAG and the CROSSFLOW users to chart a course forward to resolve NRC staff concerns. In order to obtain this information, W/AMAG requests that the NRC staff provide a detailed explanation that could then be used to resolve the open issues.

NRC Staff Response: The NRC staff has reviewed all of the supplemental material provided by W/AMAG and others, and considered all of that information in the development of the SE. In addition, the NRC staff met with Westinghouse on September 18, 2007, to discuss additional review material developed by the NRC staff that was of a proprietary nature. While that information was considered by the NRC staff, the NRC staff agrees that the draft SE does not extensively cite this material in reaching and explaining its conclusions. However, sufficient detail is provided in the SE to support and explain the NRC staff's conclusions.

5 **W/AMAG Comment (Cover Letter page 1, lines 43-46):** The statement, "Subsequently, operating experience at plants using the CROSSFLOW UFM for feedwater flow measurements has revealed problems regarding the ability of plants to achieve the desired measurement uncertainty using the theory, guidelines, and methods described in the TR," in the draft SE is misleading; not all plants experienced performance problems, only the few plants the NRC has identified in the draft SE and with which W/AMAG agrees. The statement in the draft SE also is misleading because

it implies that issues have been identified with respect to the CROSSFLOW technology rather than the actual cause of the problems identified by the NRC which were due to plant-specific application errors.

NRC Staff Response: The statement in the letter is accurate. However, the NRC staff agrees that the statement could be misleading. Therefore, the statement will be reworded as follows: "Subsequently, operating experience at some plants using the CROSSFLOW UFM for feedwater flow measurements has revealed problems regarding the ability of plants to achieve the desired measurement uncertainty using the theory, guidelines, and methods described in the TR." However, the NRC staff does not agree with the remainder of the W/AMAG comment (i.e., that CROSSFLOW technology issues were not identified) since fundamental issues have been identified with respect to the testing, calibration, and use of CROSSFLOW (see the NRC staff response to W/AMAG Comment 3).

6 **W/AMAG Comment (Cover Letter page 1, lines 48-49)**: The statement, "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," in the draft SE is misleading; not all plants experienced performance problems, only the few plants the NRC has identified in the SE and with which W/AMAG agree. The statement in the draft SE also is misleading because it implies that issues have been identified with respect to the CROSSFLOW technology rather than the actual cause of the problems identified by the NRC which were due to plant-specific application errors.

NRC Staff Response: The statement in the letter will be modified by adding the word "some" before the word "licensees" in order to provide greater clarity. The NRC staff does not agree with the remainder of the W/AMAG comment since fundamental issues have been identified with respect to the testing, calibration, and use of CROSSFLOW (see the NRC staff response to W/AMAG Comment 3).

7 **W/AMAG Comment (Cover Letter page 2, lines 50-52)**: The statement, "The task group evaluated the operating experience and concluded that CROSSFLOW accuracy is questionable and that CROSSFLOW's indicated flow rate is sensitive to plant configuration," in the draft SE is misleading; not all plants experienced performance problems, only the few plants the NRC has identified in the SE and with which W/AMAG agrees. The task group evaluated the operating experience of licensees prior to the observations at Calvert Cliffs [in 2005]. Further, it is noted that the evaluation of the operating experience at Ft. Calhoun was preliminary; the utility was still evaluating CROSSFLOW for commissioning concurrent with the task group review. The task group would therefore not have been able to reach conclusions about the accuracy of CROSSFLOW at facilities, other than at Byron/Braidwood. The statement in the draft SE also is misleading because it implies that issues have been identified with respect to the CROSSFLOW technology rather than the actual cause of the problems identified by the NRC which were due to plant-specific application errors.

NRC Staff Response: The statement is an accurate description of the task group conclusion but could be construed to be misleading. It will be changed as follows: "The task group ~~evaluated the operating experience and~~ evaluation concluded that CROSSFLOW accuracy is questionable and that CROSSFLOW's indicated flow rate is sensitive to plant configuration."

8 **W/AMAG Comment (draft SE page 1, lines 209-214)**: As written, the statement, "CROSSFLOW was placed in use at Braidwood Generating Station (Braidwood) in June 1999 and at Byron Generating Station (Byron) in May 2000. In August 2003, operation at these plants was reported in excess of licensed thermal power due to the 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 2.62 and 1.88 percent for the Byron units. The overall effect was operation for several years in excess of licensed thermal power," is misleading. The NRC improperly directs criticism for the duration of the overpower condition to CROSSFLOW and ignores other relevant factors. Although the Byron/Braidwood plant- specific implementations of CROSSFLOW resulted in the licensee exceeding their licensed thermal power level, the duration of time that the overpower condition went undiscovered was not due to CROSSFLOW. Other plant parameters and rigorous use of a plants' thermal kit allow the thermal performance engineer to judge whether multiple indications are consistent or whether a more detailed investigation of thermal performance is warranted. W/AMAG has communicated guidance and recommendations to perform such comparisons of CROSSFLOW with plant performance parameters in order to identify any potential overpower condition to exist.

NRC Staff Response: The SE statement is accurate. The licensees initially claimed that CROSSFLOW was accurate and that the other indications did not contradict CROSSFLOW. W/AMAG was involved at this time and did not contradict the licensee claims. When the NRC staff became involved, W/AMAG increased its involvement and undertook an extensive series of tests and evaluations before W/AMAG was able to identify the major contributors to CROSSFLOW error. Issues related to these contributors have not been fully resolved.

9 **W/AMAG Comment (draft SE pages 1-2, lines 216-220)**: As written, the statement, "This operating experience and other information led to the formation of an NRC task group to assess the implications of the Byron and Braidwood overpower events. The NRC task group concluded 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," is factually incorrect. W/AMAG agrees that the task group report states that accuracy questions have arisen in some other plant installations. The statement, however, does not appear to have any foundation in fact. Other than operating experience subsequent to the completion of the task group report, W/AMAG is not aware of any other plants experiencing performance issues that the task group had reviewed.

NRC Staff Response: The SE statement is an accurate description of the task group formation and its conclusions. Further, the statement is fully supported by the NRC staff's review accomplished since the task group issued its report.

10 **W/AMAG Comment (draft SE page 2, lines 234-242)**: As written, the statement, "Additional potential, or actual, overpower situations were identified during the NRC and industry evaluations that were initiated after the Byron and Braidwood experience. For example, the Fort Calhoun Station (Ft. Calhoun) licensee had to revise the initial power uprate LAR and then submit another LAR to go back to the pre-MUR-uprate power level, in its attempt to establish that CROSSFLOW could meet the claimed accuracy. In addition, the licensee for Calvert Cliffs Units 1 and 2 found that those units were overpowered from July 2003 until September 2005 due to reliance on CROSSFLOW for power recovery, during the time the licensee was attempting to establish that CROSSFLOW would operate with the claimed uncertainty for a power uprate," is misleading. Ft. Calhoun was not a potential overpower nor actual overpower event. The Ft. Calhoun meter never completed the commissioning process and thus was never put it into active service. Additional performance issues were identified during the NRC and industry evaluations that were initiated after the Byron and Braidwood experience. For example, Ft. Calhoun licensee could not implement its NRC-approved MUR power uprate because of performance issues identified during the commissioning phase of the CROSSFLOW system installation. The Ft. Calhoun CROSSFLOW system was never declared operable and the plant was never overpowered as a result of CROSSFLOW use. Further, it was the CROSSFLOW system diagnostics that identified the subject performance issues. Although the Calvert Cliffs Units 1 and 2 plant specific implementations of CROSSFLOW resulted in the licensee exceeding their licensed thermal power level, the duration of time that the overpower condition went undiscovered was not due to CROSSFLOW. Other plant parameters and rigorous use of a plants' thermal kit allow the thermal performance engineer to judge whether multiple indications are consistent or whether a more detailed investigation of thermal performance is warranted. W/AMAG has communicated guidance and recommendations to perform such comparisons of CROSSFLOW with plant performance parameters in order to identify any potential overpower condition to exist.

NRC Staff Response: The SE statements are accurate but the NRC staff agreed during the meeting on May 1, 2007, that coverage of the subjects could be improved. The statement is rewritten as follows:

Additional actual or potential overpower situations were identified during the NRC staff and industry evaluations that were initiated after the Byron and Braidwood experience. For example, the licensee for Calvert Cliffs Units 1 and 2 found that those units were overpowered from July 2003 until September 2005 due to reliance on CROSSFLOW for power recovery, during the time the licensee was attempting to establish that CROSSFLOW would operate with the claimed uncertainty for a power uprate. In addition, although it was never operated in an overpower condition, the Fort Calhoun Station (Ft. Calhoun) licensee had to revise the initial power uprate LAR and then submit another LAR to go back to the pre-MUR-uprate power level, in its attempt to establish that CROSSFLOW could meet the claimed accuracy.

11 **W/AMAG Comment (draft SE pages 2-3, lines 266-269)**: As written, the statement, "Since its original evaluation on March 20, 2000, the NRC staff determined that the desired level of measurement uncertainty is not assured when the plant specific operating conditions and flow uncertainty parameters strictly follow the guidelines in the

TR," is factually incorrect. The statement implies all CROSSFLOW installations are operating incorrectly which is not factual. The potential that the measurement uncertainty is not achieved does exist, however, because experience has shown that the TR could be more complete including certain specificity with respect [to] technical content, implementation procedures and operating guidelines. The fact is that utilities and W/AMAG are not relying solely on the requirements in the TR; other actions, as specified in vendor communications, implementation procedures, and operating guidelines specify the additional steps that need to be taken to assure that the desired measurement uncertainty is achieved. Furthermore, W/AMAG has already identified and acknowledged that it is amenable to a TR revision to include technical clarifications and additional requirements. This was presented to NRC staff in early 2006.

NRC Staff Response: The SE statement is backed up by the NRC staff's evaluation and is accurate.

12 **W/AMAG Comment (draft SE page 3, lines 310-313):** As written, the statement, "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 that the plants would operate within their licensed thermal power limits," is factually incorrect. Ft. Calhoun was never overpowered and indeed was never commissioned nor put into service. Furthermore, the laboratory-determined velocity profile correction factor was never an issue at Ft. Calhoun. The statement in the draft SE also is misleading because it implies that issues have been identified with respect to the CROSSFLOW technology rather than the actual cause of the problems identified by the NRC which were due to plant-specific application errors.

NRC Staff Response: See Items 10 and 11. Further, the NRC staff questions the accuracy of the laboratory-determined velocity profile correction factor and its application to the Ft. Calhoun feedwater system. Nevertheless, as a result of the May 1, 2007, meeting discussion, the NRC staff believes the SE discussion can be improved. Consequently, the statement is replaced by the following:

Based on review of test information, independent assessments, and 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 that the plants would operate within their licensed thermal power limits.

13 **W/AMAG Comment (draft SE page 5, lines 389-391)**: As written, the statement, "In other cases, noise contaminated the CROSSFLOW signal and affected the transit time determined by CROSSFLOW," is factually incorrect. In context, this sentence implies correlated noise affects the velocity profile correction factor. This is incorrect; noise only introduces a bias in the CROSSFLOW measurement which can be corrected. However, it is true that if this bias remains uncorrected the transit time determined by CROSSFLOW could be incorrect depending on the intensity of the noise.

NRC Staff Response: The SE statement is correct. Noise has caused erroneous CROSSFLOW indicated flow rates at both nuclear power plants and at test facilities.

14 **W/AMAG Comment (draft SE page 5, lines 394-398)**: As written, the statement, "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," is factually incorrect. W/AMAG agrees that stable flow is not equivalent to a fully-developed flow condition. However, W/AMAG disagrees with the statement, as written that because the plants operated above their rated thermal power, this was due to the fact that stable flow and fully-developed flow are not equivalent. There are other factors independent of how CROSSFLOW response in stable and fully-developed flow compares that could cause a measurement bias, such as correlated noise that has nothing to do with the flow profile condition.

NRC Staff Response: The NRC staff agrees that there are other factors independent of how CROSSFLOW response in stable and fully-developed flow compares that could cause a measurement bias, such as correlated noise that has nothing to do with the flow profile condition. However, while the SE statement is correct, it is unnecessary to support the NRC staff's conclusion. The statement is deleted: ~~"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."~~

15 **W/AMAG Comment (draft SE page 8, lines 524-526)**: W/AMAG needs more information regarding the statement, "Further, in some cases, NRC staff examination of the few data points that W/AMAG claimed established convergence actually showed trends still existed," about what data points are referred to in order to assess the factual accuracy of this statement.

NRC Staff Response: The SE statement is correct. The NRC staff agrees that the draft SE does not provide all of the detailed information that supports its conclusions. However, sufficient detail is provided in the SE to support and explain the NRC staff's conclusions (see also the NRC staff response to W/AMAG comment 4).

16 **W/AMAG Comment (draft SE page 8, lines 540-544)**: As written, the statement, "Based on its review of documentation provided by W/AMAG after the NRC staff approved the TR, 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 adjust the alarm setpoints based on its judgment regarding the cause of changes to the venturi correction factor," is factually incorrect. It appears that the [NRC] staff is confusing the velocity profile correction factor, C_0, with the venturi flow correction factor, C_f. It is not the velocity profile correction factor that varies, but rather the venturi flow correction factor. The velocity profile correction factor is nearly a constant at plant operating conditions. The acceptability band on the venturi

flow correction factor can vary depending on the amount of venturi fouling a plant may experience. The licensee is allowed to shift the alarm band to compensate for the downward drift resulting from venturi fouling.

NRC Staff Response: The NRC staff understands that C_f, is the ratio of the flow rate determined by CROSSFLOW divided by the flow rate determined by the venturi. Further, the flow rate indicated by CROSSFLOW is directly a function of C_0. A change in either of the indicated flow rates will affect the ratio, C_f. Contrary to the W/AMAG comment, there is clear evidence that C_0 may change and may not be constant at operating conditions. Thus, the issue involves whether the CROSSFLOW indication is consistent and this has not been verified to be the case. The SE statement is correct.

17 **W/AMAG Comment (draft SE pages 8-9, lines 554-559)**: As written, the statement, "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 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," is factually incorrect. The use of other plant parameters to corroborate CROSSFLOW performance and the viability of the calibration to remain valid is based on observations of change. The change in other plant parameters has a much smaller uncertainty than the absolute uncertainty of those parameters and, therefore, can be used to validate the calibration of CROSSFLOW.

NRC Staff Response: The NRC staff agrees that change in plant parameters is expected to have a smaller uncertainty than absolute uncertainty but notes that W/AMAG has not provided a description of a viable treatment of uncertainty for either case. Further, the W/AMAG statement that other plant parameters "can be used to validate the calibration of CROSSFLOW" has not been established with respect to the claimed CROSSFLOW uncertainties. The SE statement is correct.