# Enclosure 3 to WOG-04-622

# Westinghouse Owners Group CROSSFLOW Task Force

## Non-Proprietary White Paper

## Assurance that CROSSFLOW Technology, Installation, and Operation Maintain Design and Licensing Basis

**December, 2004**



T-2

# Assurance that CROSSFLOW Technology, Installation and Operation Maintain Design and Licensing Bases

## Executive Summary

Inadequate installation practices led to the use erroneous feedwater flow determinations by Ultrasonic Flow Measurement (UFM) systems at some operating plants and, when used, caused the plants to exceed licensed power. Similar problems have been found at other plants preparing to operate their systems. Although not safety issues, these events raised several concerns in the industry regarding the cause(s) of the problems and how utilities using UFMs could demonstrate defense-in-depth to avoid using incorrect feedwater flow measurements. This document presents information specific to the actions taken to understand and correct inadequate installation practices for CROSSFLOW UFM systems and to verify and use only correct feedwater flow measurements.

Utility members of the Westinghouse Owners Group (WOG) using CROSSFLOW systems have formed a Task Force (CTF) whose purpose is to support and participate in the issue resolution activities and, going forward, to benefit from effective communication of relevant operating experience. These utilities, along with support from Westinghouse Electric Co., LLC (Westinghouse), its technology partner and the CROSSFLOW system vendor, the Advanced Measurement and Analysis Group, Inc. (AMAG), have undertaken a comprehensive program to understand and resolve the installation practices that led to the determination of incorrect feedwater flow measurements. This program provides assurance that the CROSSFLOW technology remains valid, that the installation and use of CROSSFLOW systems are consistent with the design and licensing basis, and that lessons-learned and operating experience are widely and effectively communicated.

This document is presented in three sections that describe:

- CROSSFLOW Technical Basis, Licensing Basis and Independent Verification of Accuracy
- CROSSFLOW Installation and Application Consistent With the Design and Licensing Basis, and
- Operational Considerations to Assure that the Design and Licensing Basis are Maintained

The CROSSFLOW technical and licensing basis remains, as documented in the CROSSFLOW Topical Report (CENPD-397-P-A, Rev. 1) which includes the Nuclear Regulatory Commission (NRC) Safety Evaluation (SE). A number of laboratory tests are in progress at this time whose goal is to further enhance the existing CROSSFLOW technical and licensing basis, including verification of techniques to develop flow profile correction factors in low Reynolds number laboratory conditions and to verify methods to remediate acoustic signal contamination from interfering with measurement accuracy. Independent corroboration of CROSSFLOW performance has been accomplished through detailed comparisons of CROSSFLOW and ASME flow section measurements and on-going plant specific corroboration includes the use of several independent plant parameter measurements (e.g., 1$^{st}$ stage HP turbine pressure, valve position, feedwater heater temperature).

Confirmation that existing CROSSFLOW systems are installed consistent with the design and licensing bases has been accomplished through a comprehensive review of

currently installed systems. This re-validation activity included a detailed review of meter installation locations meeting the design criteria relative to feedwater piping layouts and each plant has verified operation consistent with the assumptions used for the uncertainty calculations at the time of CROSSFLOW commissioning. Westinghouse has communicated the current baseline validation review status to the NRC. Operational considerations to assure that CROSSFLOW application is consistent with design and licensing bases include comparison of measurements with other plant parameters, use of in-situ CROSSFLOW measurements, and adherence of the application to stated plant specific operating limits, interface, surveillance and maintenance requirements. Improvements are under development for the achievement of better accuracy, such as more rigorous testing for, and eliminating as necessary, any effects from acoustic signal contamination. These new and improved methods will be available for implementation in all CROSSFLOW installations.

CROSSFLOW users are provided with comprehensive source documents that include guidance and specific instructions on operations, maintenance, troubleshooting, alarms, acceptance limits, surveillance and trending. In addition, the WOG CTF is developing a User Guideline that will include up-to-date information on CROSSFLOW technology, use and application, operations experience, operations management and references to the applicable source documents.

## 1.0 Purpose

This document provides information on the CROSSFLOW Ultrasonic Flow Measurement (UFM) System technology verification, application and control to preclude its use in situations that could cause plants to exceed their licensed power level. It is also expected that this information will support the NRC with closure of several findings regarding CROSSFLOW that were reported by the Ultrasonic Flow Meter (UFM) Task Group (Reference 1). This document is presented in three sections that provide a description of:

- CROSSFLOW Technical Basis, Licensing Basis and Independent Verification of Accuracy
- CROSSFLOW Installation and Application Consistent With the Design and Licensing Basis, and
- Operational Considerations to Assure that the Design and Licensing Basis are Maintained

This document describes how lessons learned from the evaluation of recent CROSSFLOW issues are being used to enhance the installation baseline for current as well as future CROSSFLOW users. The document also describes how the accuracy of CROSSFLOW measurements are substantiated by independent data sources and how the rigor and defense-in-depth of procedures from which plant operations are managed minimize the potential for use of any inappropriate measurements to minimize the potential for plants exceeding licensed power levels.

## 1.1 Introduction

Four operating plants inadvertently used the erroneous feedwater flow measurements in a manner that resulted in plant power exceeding their licensed power levels. Another plant preparing to use CROSSFLOW was unable to complete the commissioning process upon discovery that their measurements were effected by signal contamination. As a result, this plant had to withdraw a license amendment request to use CROSSFLOW for an Appendix K Margin Uncertainty Recapture (MUR) power uprate and delay their re-submittal until the measurement problems are resolved. These occurrences, and similar problems experienced by utilities using UFM systems offered by another vendor raised concerns by the NRC and by the Institute for Nuclear Power Operations (INPO). While these occurrences of not recognizing and using erroneous feedwater flow measurements are not safety significant, it was concluded by Westinghouse / AMAG that additional work would be undertaken in the verification and validation of CROSSFLOW installations and operation in order to demonstrate reasonable assurance that plants using CROSSFLOW would not exceed their licensed power level.

The cause(s) of the creation and use of erroneous CROSSFLOW feedwater flow measurements is the subject of a comprehensive investigation by Westinghouse / AMAG . Two Technical Bulletins (TBs) and a Nuclear Safety Advisory Letter (NSAL) have been issued to alert CROSSFLOW users about these issues and how to monitor their CROSSFLOW systems for changes that fall outside of the acceptable operating range and to use the systems in accordance with the assumptions

for which the systems were originally installed and commissioned. The apparent causes of the erroneous flow measurements were due to inadequate installation practices that did not recognize either the influence of hydraulic effects from feedwater piping configurations that were not accounted for and/or acoustic signal contamination effects that were not identified and corrected. An installation procedure revision has already been implemented to increase the degree of rigor required in the installation process. In addition, ongoing testing and analysis are expected to fully determine the cause(s) and define the appropriate corrective action(s) that can be applied at the specific plants effected as well as provide lessons learned that can enhance the installation baselines and operation of all CROSSFLOW systems.

The longstanding CROSSFLOW Users Group (est. August 2000) was migrated to a CROSSFLOW Task Force (CTF) under the Westinghouse Owners Group (WOG) in May 2004 to take advantage of an existing and proven infrastructure. Through the WOG, a more effective forum for Westinghouse / AMAG to communicate their findings to CROSSFLOW users and for user experience and observations to be communicated to Westinghouse / AMAG was established.

The information presented in this report summarizes the joint undertaking of activities in the following key areas relative to CROSSFLOW:

- The validation process used to ensure that plant specific CROSSFLOW installations are consistent with the design and licensing basis.
- How independent data sources were used to verify CROSSFLOW accuracy.
- Rigor in operating procedures to clearly recognize and minimize use of erroneous CROSSFLOW data.
- Verification of method(s) to detect and remediate acoustic signal contamination.
- Analysis of piping configurations to quantify effects on flow profile shape, stability and the need for attaining plant-specific flow profile corrections.
- Improved rigor of hydraulic laboratory test equipment, procedures for attaining correction factors, based on plant-specific piping configurations, as required.
- Activities of the WOG CTF to support improved communication of lessons learned.

## 2.0 CROSSFLOW Technical Basis, Licensing Basis and Verification of Accuracy

### 2.1 CROSSFLOW Technology and Licensing Basis

The technology basis for CROSSFLOW is described in the CROSSFLOW Topical Report, CENPD-397-P-A, Revision 1 (Reference 2). This report also contains the NRC SE approving use of the CROSSFLOW system for support of Appendix K MUR power uprates.

The CROSSFLOW system is based on the recognition of turbulent flow eddy patterns that exist in the flowstream and measuring the time it takes for the eddies to pass through a known distance. The flow profile can effect the feedwater flow determination due to perturbations created by flow through the feedwater piping (e.g., elbows, T-fittings, Y-fittings, valves, etc.) upstream of the point of CROSSFLOW installation

location. Some upstream piping configurations can create rotational flow known as 'swirl' that has a predictable effect on the eddy patterns. [

]$^{a,c}$ Corrections for swirl are accomplished by constructing a plant specific scale model of the pipe configuration in a hydraulic test facility and taking CROSSFLOW measurements to compare to measurements without the influence of flow swirl through the configuration. Alternatively, in-situ calibration provides another method to correct for the influence of swirl.

Acoustic effects introduced from plant equipment (e.g., piping vibrations, pumps, regulating valves, etc.) are determined from a frequency spectrum scan (FSS) and its subsequent analysis. If signal contamination is present, at a level that can affect the meter, it can be removed from the CROSSFLOW signal by use of an appropriate filtering technique. The removal of signal contamination eliminates the potential for bias in the CROSSFLOW feedwater flow determination.

The investigation into the CROSSFLOW performance issues has not uncovered any information that invalidates CROSSFLOW's underlying cross-correlation technology, its design basis implementation or its licensing basis. The investigation into the installation and use of CROSSFLOW at these plants and, in conjunction with feedback of operating plant experience from other CROSSFLOW users, resulted in Westinghouse issuing the following vendor notices:

- Technical Bulletin TB- 03-6, , "CROSSFLOW Ultrasonic Flow Measurement System Flow Issues" September 5, 2003
- Nuclear Safety Advisory Letter NASL-03-12, "CROSSFLOW Ultrasonic Flow Measurement System Flow Signal Interference Issues" December 5, 2003
- Technical Bulletin TB-04-4, "Information Regarding Recent CROSSFLOW Measurement System Performance Observations" February 12, 2004

These notices informed CROSSFLOW users of the performance issues and provided recommendations for assessing the acceptability of continued CROSSFLOW operation on a plant specific basis. The conclusion to date is that CROSSFLOW technology supports operation within the intended accuracy as described in CENPD-397-P-A, Rev. 1 (Reference 2) provided that plant conditions are consistent with assumptions in the plant specific uncertainty analysis.

In order to ensure that the design and licensing bases are maintained in the implementation of CROSSFLOW the sensitivity to operating plant changes has been and continues to be carefully evaluated. The potential issues addressed in the Technical Bulletins and the Nuclear Safety Advisory Letter is the subject of efforts being performed by Westinghouse / AMAG, and the utilities, including the activities of the WOG CTF.

An important aspect of the technology is correction of flow profiles that are different than those experienced during plant specific baseline installation. This is evaluated by one or

a combination of methods including in-situ calibration, hydraulic scale model testing and computational fluid dynamics (CFD) analysis. The test program currently underway (described in more detail later in this report) is intended to supplement existing information and enhance the rigor of the hydraulic scale model testing and the means for detecting and remediating correlated noise (i.e., acoustic signal contamination).

### 2.2 Providing reasonable assurance of proper CROSSFLOW installation/application (e.g., use of corroborating information)

CROSSFLOW operates in an environment in which other plant parameters can provide reasonable corroboration of its results. Although not an all inclusive list, some examples are:

- Secondary Plant Feedwater Flow Venturis
- ASME Flow Elements or Sections (where present)
- Secondary Plant Power-Dependent Parameters
- In-Situ Comparison With an Additional CROSSFLOW Meter
- Comparison with turbine vendor heat balance.

The WOG CTF recently provided the NRC a detailed comparison of ASME flow element / section data to CROSSFLOW data obtained at the Kewaunee station (Reference 3). Although ASME flow element / section and other plant instrumentation may not be as accurate as CROSSFLOW, a statistical comparison of independent data provides a means to reasonably substantiate the CROSSFLOW design and licensing basis. In WCAP-15689-P, Rev. 1 (Reference 4), Westinghouse provided a number of flow measurement comparisons between CROSSFLOW and plant venturi instruments that had been recently calibrated, de-fouled or independently verified from chemical tracer tests. These comparisons provide reasonable assurance of the design and licensing basis of the CROSSFLOW system.

Secondary plant power dependent parameters can also be used to provide reasonable assurance that CROSSFLOW has been installed properly and that it continues to perform properly and in a manner that is consistent with other plant parameter indications. These parameters can be used as independent reasonableness checks or combined in a statistical manner to compare with the CROSSFLOW measurement. The statistical methods can also be developed into an independent check on the UFM measured flow. For example, trending of several independent parameters can lead to early detection if one parameter is drifting.

If the CROSSFLOW measurements are beyond designated plant specific setpoints, the operator has information available to indicate that intervention is required and is provided an opportunity for corroboration against other power dependant parameters. For plants whose CROSSFLOW system is linked to the plant computer, operators receive an alarm in the Control Room. Attention to CROSSFLOW computer information displays is required to fully assess the condition. Depending on the nature of the condition the plant computer (when so linked) can automatically take the CROSSFLOW system offline or a determination can be made if there is an unusual plant transient that could have impacted CROSSFLOW in which case the CROSSFLOW system can be manually taken offline until the reason for the alert is understood and corrected if

necessary. For CROSSFLOW systems not linked to the plant computer, a manual calculation can be performed at the CROSSFLOW computer through comparison of the CROSSFLOW measured data and plant data and CROSSFLOW measurement performance checks provided directly on the local CROSSFLOW computer screen (e.g., standard deviation, data rejection rate, etc.).

Although not an all inclusive list, examples of independent parameters that can be used to corroborate changes in measured feedwater flow are provided in the following table:

| Problem | Symptom | Confirm |
|---|---|---|
| Measured FW flow lower than actual | Higher than expected MWe generation | - Higher 1st stage pressure<br>- Higher HP exhaust pressure<br>-Throttle valve further open<br>- Higher final FW temperature<br>- Increased FW pump driver amps or steam flow |
| Measured FW flow higher than actual | Lower than expected MWe generation | - Lower 1st stage pressure<br>- Lower HP exhaust pressure<br>-Throttle valve further closed<br>- Lower final FW temperature<br>- Decreased FW pump driver amps or steam flow |

Guidance for the actions described above will be included in a User Guideline that the CTF is developing (see Section 4.6).

## 2.3 Current On-going Activities to Strengthen the Approach to Plant Specific Scale Model Testing

**Velocity Profile Correction Factor Test**

Tests are currently being conducted at the National Research Council Canadian Hydraulic Center (NRC-CHC) in Ottawa, Canada and the Alden Research Laboratory (ARL) in Worchester, Massachusetts. The purpose of these tests is to enhance the hydraulic scale model test methodology for determination of a velocity profile correction factor for atypical feedwater system piping geometries. The NRC-CHC test series has been completed and testing has now moved to the ARL facility. Specific improvements are anticipated in the following areas:

[

]a,c

[

]a,c

Westinghouse / AMAG plans to share the results of these tests with the NRC once completed and the final test reports are written.

## 2.4 Computational Fluid Dynamics (CFD)

**Screening tool for evaluating the need for a scale model test**

[

]a,c

[

]a,c

## 3.0 Validation of CROSSFLOW Installation and Application Consistent With Design and Licensing Basis

### 3.1 CROSSFLOW Baseline Installation Criteria

CENPD-397-P-A, Rev. 1 (Reference 2), and CROSSFLOW Project Process Procedure, PP-PS-04-3 Rev. 01 (Reference 5) provide the technical basis by which CROSSFLOW is installed. In addition, the procedure identifies the required plant information necessary to identify, evaluate and validate potential installation locations. The CROSSFLOW System Field Installation Procedure, AMAG_INS_FS_001 (Reference 6) provides details of the meter's physical hardware installation process and the measurements taken during the CROSSFLOW system installation and validation process. The following guidelines are used during this evaluation:

[

]a, c

[

]a,c

### 3.2 *Current Installations*

**Checked for Signal Contamination**

Each plant with an operating CROSSFLOW system has had a frequency spectrum scan (FSS) and analysis for signal contamination performed. The analysis consisted of reviewing the FSS acquired through the AMAG DIAGNOSE software. The FSS was then reviewed by AMAG personnel to determine if the FSS indicated the existence of correlated noise that would cause the CROSSFLOW meter to provide biased results. All plants, except those in which the performance issues were identified, were found to be free of adverse signal contamination.

**Re-Validation of Current Installations**

The lessons learned from recent CROSSFLOW issues led to a comprehensive review of domestic and international installations (in progress) by Westinghouse / AMAG and CROSSFLOW users to assure that the installations meet the baseline engineering installation criteria. Westinghouse reported the results to date from this baseline re-validation effort in an October 19, 2004 letter to the NRC (Reference 7).

[

]a,c

[

]a,c

Westinghouse / AMAG have issued draft re-validation reports for each domestic CROSSFLOW installation that is, or is preparing to operate and have provided those draft reports to the individual utilities for review and comment. In a June 18, 2004 letter to the NRC (Reference 8), Westinghouse / AMAG expressed confidence that reasonable assurance existed that current CROSSFLOW installations were performing properly and within the design and licensing bases. Following the technical portion of the current re-validation activity, Westinghouse / AMAG found that, with the exception of three installations that require further validation work, this assurance is maintained. Two of the three CROSSFLOW installations that require further validation work are not currently operating and have undertaken programs to address the re-validation questions before they are returned to service. The CROSSFLOW system at the third installation is currently operating, however, the utility has confirmed that the plant is being operated well below its licensed thermal power limit, due to other unrelated constraints. As noted in Reference 7, Westinghouse / AMAG have re-enforced the recommendations in the CROSSFLOW related Technical Bulletins and Nuclear Safety Advisory Letter with the utility that is currently operating their CROSSFLOW system, for which further validation work is needed.

Each re-validation report includes a re-statement of the plant assumptions that applied to the plant specific CROSSFLOW uncertainty calculation. The utilities were requested to verify, using their in-house processes, that they were operating their plants within the parameters established in the uncertainty calculation and after consideration of the vendor notification recommendations. A positive affirmation that this had been accomplished by each participating WOG CTF utility was provided in a June 8, 2004 WOG letter to the NRC (Reference 9).

### 3.3 Improved Installation Procedures for Future Applications

**Revised installation process procedure to incorporate new information and lessons learned.**

Section 3.2 discusses an enhancement to the CROSSFLOW installation procedures based on lessons learned from recent performance issues. Such enhancements will be captured in these and other procedures, as appropriate, on an on-going basis to ensure that operating experience is routinely considered in future applications. In addition, if there are lessons learned from operating experience that are pertinent to current operations, this information will be communicated at WOG CTF meetings and documented in CROSSFLOW notices, as appropriate. Currently, the WOG CTF is proving to be an effective forum for communications among users, the NRC and industry organizations such as the Institute for Nuclear Power Operations (INPO).

**Developing new software to detect and alert users to signal contamination**

[

]$^{a,c}$

**Lessons learned may be applied to current installations**

The following is a list of items affected by lessons learned over the last several months:

[

]a,c

## 4.0 Operational Considerations to assure that Design and Licensing Bases are Maintained

### 4.1 Troubleshooting

CROSSFLOW Troubleshooting and Maintenance instructions can be found in detail in the System User's Manual.

A System User's Manual is provided to enable the user to provide basic troubleshooting of the CROSSFLOW system. Troubleshooting instructions include system descriptive information and diagrams, sequenced troubleshooting guidelines, and problem statements and resolutions. These guidelines provide the user with the initial troubleshooting steps. More difficult problems are referred to the appropriate Westinghouse / AMAG representatives. Troubleshooting is also emphasized in the CROSSFLOW training classes. During the class, troubleshooting operations are reviewed with the participants and corrective actions are discussed which include access to the necessary software screens, the self checks that the system provides the user

and access to AMAG specialists to address questions. It is necessary for the user to be fully aware of the limitations of the CROSSFLOW system and when to seek assistance. Vendor support is readily available to utilities to aid in diagnosing system problems.

Included in the vendor notifications, discussed previously, are recommendations that users be cognizant of other plant instrumentation that can indicate a potential problem with CROSSFLOW. Any anomalous trends should be researched and, as necessary, brought to the attention of Westinghouse / AMAG if it is suspected that the system is outside of its design parameters. If such a situation cannot be resolved, the CROSSFLOW system should be taken out of service until the problem is corrected. [

]$^{a,c}$

## 4.2 System/Data Monitoring and Maintenance

As discussed previously, it is important to monitor and trend CROSSFLOW output and compare it with other system parameters that can indicate inconsistencies in parameter trends.

Plant-specific maintenance, calibration and surveillance actions are included in the CROSSFLOW system documents that are provided to each user. The list below provides examples of typical system maintenance, calibration and data monitoring activities. This is not all-inclusive list and may not apply to plant specific installations and use, as stated:

[

]$^{a,c}$

[

]a,c

## 4.3 Alarm limits

The WOG CTF CROSSFLOW User Guideline that is being developed (see Section 4.6) will provide recommendations to CROSSFLOW users on CROSSFLOW system alarms, both critical and non-critical, and the actions to take upon receipt. Various utilities already incorporate the vendor alarm recommendations into their plant procedures. Utility experience with respect to alarms and procedures will be captured in the user guideline.

## 4.4 Changing system alignments

Normally the feedwater system components are aligned for near 100% power operations when the CROSSFLOW system is initially installed and commissioned. This alignment is documented in the uncertainty calculation for newly commissioned plants. The re-validation activity discussed above for existing installations documented the conditions for which the CROSSFLOW uncertainty calculation remains valid. Westinghouse / AMAG guidance provided in these reports, and consistent with communications in the recent vendor notices, states that any deviation from the assumptions that support the uncertainty calculations may affect the operation of the CROSSFLOW meter.

The CROSSFLOW system should not be used in other configurations without additional monitoring of the plant and the CROSSFLOW system to ensure the response is consistent with the design basis installation measurements. These configuration changes can be in the form of significant reactor power reductions (e.g., ≥5%), alignment alterations (e.g., feedwater heater bypass) or component changes (e.g., rotation of feedwater pump combinations, component maintenance or replacement). CROSSFLOW and other plant parameters should be monitored to obtain reasonable assurance that there are no adverse effects introduced due to configuration changes.

## 4.5 Frequency spectrum checks (initial and periodic follow-ups)

Each plant was checked at the time of installation or rechecked during the re-validation of the installation baseline if the original records were unavailable to assure that the FSS

did not indicate an adverse noise signature. Noise can be present or be introduced to the system as a result of piping / system vibration, through equipment changes, including wear, and changes in response to piping configuration, valve, alignment, or other system modifications. The WOG CTF CROSSFLOW User Guideline will provide utility guidance that periodic FSSs for signal contamination be performed to assure that external noise is not being introduced that could bias CROSSFLOW results.

This guidance will recommend that changes to the feedwater pumps, including maintenance that could impact the noise signature, changes to the valves including major position changes and intrusions into the feedwater system for inspection or modification be considered for performance of new FSSs. A new FSS should be performed following any of the changes noted above, or at other intervals consistent with vendor recommendations. FSS records should be retained for comparison to previous scans to help determine if there have been any significant changes.

### 4.6 Considerations to be a major focus and an integral part of the WOG CROSSFLOW User Guideline

The WOG is currently preparing a comprehensive User Guideline to assist the operator or systems engineer to evaluate, diagnose, trend and use the output from CROSSFLOW. The intent of the guidelines are to 1) assist the utility in evaluating it's current operating procedure(s) or to develop enhanced procedures, 2) provide a consistent industry process of data evaluation and 3) to assure that industry events are considered and included in each plant's operating procedures.

The following is an initial outline of subject material that is being considered for the User Guideline. Depending on the CROSSFLOW system at each plant and the potential interface with the plant computer, the implementation of the Guideline will vary from plant to plant.

| Outline of WOG CROSSFLOW Task Force User Guideline |
| --- |
| |
| |
| |
| |

a, b

| Outline of WOG CROSSFLOW Task Force User Guideline |
| --- |
| |
| |
| |
| |

a, b

## 4.0 References

1. Letter, S. Dembek (NRC) to J. A. Gresham (Westinghouse), "Non-Proprietary Version of the Final Report of the Ultrasonic Flow Meter Allegation Task Group Regarding the Westinghouse / AMAG CROSSFLOW Ultrasonic Flow Meter", July 1, 2004
2. "Improved Flow Measurement Accuracy Using CROSSFLOW Ultrasonic Flow Measurement Technology", CENPD-397-P-A Revision 1, May 2000
3. "Comparison of CROSSFLOW and ASME Flow Section Feedwater Flow Measurement at Kewaunee Nuclear Power Plant", WOG-04-541, Letter to NRC dated 10/20/04
4. "Evaluation Of Transit Time And Cross Correlation Ultrasonic Flow Measurement Experience With Nuclear Plant Feedwater Flow Measurement", WCAP-15689-P, Rev. 1, September 2002
5. CROSSFLOW Project Process Procedure, PS-04-3 Rev. 01, September 2004

6. CROSSFLOW System Field Installation Procedure, AMAG_INS_FS_001, June 2004
7. UFM Technology Update, LTR-NRC-04-61, letter to NRC, October 19, 2004
8. Westinghouse Conclusions Regarding Recent CROSSFLOW Ultrasonic Flow Measurement System Performance Events, LTR-NRC-04-37, letter to NRC dated June 18, 2004
9. "Westinghouse Owners Group, CROSSFLOW Task Force: Feedback Regarding Westinghouse Technical Bulletin, TB-04-4", WOG-04-310, Letter to NRC dated June 8, 2004
10. AMAG-REP-EN-043-00, Rev. 0, "Estimation/Cancellation of Correlated Noise Bias on CROSSFLOW Time Delay Measurements", September 2004