CROSSFLOW Ultrasonic Flow Measurement System NRC Status Meeting

March 29, 2006

CROSSFLOW Status Meeting (3/29/06)

- **Agenda**
  - Objectives
  - Background
  - NRC LAR and RAI Status
  - Discussion of Westinghouse/AMAG Activities
  - Summary

CROSSFLOW Status Meeting (3/29/06)

- **Objectives**
  - To discuss the responses to the NRC Requests for Additional Information on CROSSFLOW.
  - To provide an update on Calvert Cliffs and Ft. Calhoun LAR activities.
  - To update the NRC on the status of various CROSSFLOW activities and the conclusions drawn.
  - To reach agreement on acceptable approaches for resolution of outstanding CROSSFLOW issues.

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- **Background**
  - There have been several performance issues during operation and start-up
    - For all Appendix K applications, the specific issues found were during the commissioning process and not during operation.
    - NRC and Westinghouse/AMAG agree that these issues are plant-specific and have regulatory compliance implications.
  - Westinghouse/AMAG implemented a comprehensive Generic Action Plan (GAP) to investigate the performance issues and identify corrective actions.
  - Guidance has been issued to CROSSFLOW users to address operating experience via Westinghouse Technical Bulletins, NSALs and the Pressurized Water Reactor Owners Group (PWROG, formerly WOG) CROSSFLOW Task Force (CTF).
  - PWROG CTF was formed to work with Westinghouse/AMAG and to foster sharing of operational experience (good practices as well as problems).

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- **CROSSFLOW Licensing Basis**
  - Establish plant baseline
    - Installation procedures provide rigorous approach for establishing installation baseline.
  - System operation – alarms and diagnostics
    - Continuous monitoring of system performance.
    - System is designed to recognize unacceptable performance and alert users through system alarms.
  - Periodic surveillance and maintenance
    - Provided in vendor documentation and summarized in PWROG CTF guidelines.
  - Operating plant experience continues to demonstrate performance of CROSSFLOW, consistent with the design and licensing basis.

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Discussion of Current Licensing Actions

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- **Current Licensing Actions**
  - Westinghouse/AMAG CROSSFLOW X-Beam Topical Report (WCAP-16163-P)
  - Calvert Cliffs Units 1 and 2 (CCNPP) Measurement Uncertainty Recapture (MUR) Power Uprate
  - Ft. Calhoun Station (FCS) MUR Power Uprate

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- **Current Licensing Actions (continued)**
  - Westinghouse/AMAG CROSSFLOW X-Beam Topical Report (WCAP-16163-P, Rev. 0)
    - Responses to first round RAIs from NRC Instrumentation & Controls Branch answers have been incorporated in draft Rev. 1 (provided to NRC informally).
    - Responses to second round RAIs from NRC Reactor Systems Branch provided March 17, 2006 (LTR-NRC-06-11).

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- **Current Licensing Actions (continued)**
  - Calvert Cliffs MUR Submittal
    - Calvert Cliffs specific RAIs submitted to NRC March 3, 2006.
    - Determined meters do not satisfy criteria for standard installation.
    - Perform CROSSFLOW calibration based on tracer tests.
    - Redo uncertainty analyses based on tracer calibration.
    - Update LAR submittal to include discussion of tracer calibration.
    - Submit supplemental LAR information to NRC.

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- **Current Licensing Actions (continued)**
  - Ft. Calhoun MUR Submittal
    - Ft. Calhoun specific RAIs submitted to NRC March 15, 2006.
    - Determined meters satisfy criteria for standard installation.
      - Computational Fluid Dynamics (CFD) analysis was used to provide an indication that stable flow exists at the chosen installation location.
      - A second CROSSFLOW meter in series with primary meter confirmed the existence of stable flow.
    - CROSSFLOW measurements were validated based on comparison to venturi and corroborated using EnergiTools™.
      - The venturi calibrated during outage immediately prior to validation.
      - The venturi does not have a history of fouling upon unit start-up
      - The venturi is installed in accordance with ASME standards
    - The LAR submittal and RAI responses include additional information regarding the venturi validation and EnergiTools™ corroboration.

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Nuclear Regulatory Commission

Requests for Additional Information

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- **NRC issued three Requests for Additional Information (RAIs)**
  - Calvert Cliffs Units 1 and 2 (CCNPP)
    - Three RAIs
  - Ft. Calhoun Station (FCS)
    - Three RAIs
  - Westinghouse/AMAG CROSSFLOW Generic
    - Nine RAIs and one White Paper.

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Responses to NRC RAIs

Calvert Cliffs Units 1 and 2 Specific

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- **The Calvert Cliffs RAI response has been submitted to the NRC.**
  - CCNPP Letter, J. A. Spina (CCNPP) to USNRC Document Control Desk, "Request for Additional Information Regarding Measurement Uncertainty Recapture Power Uprate (TAC Nos. MC6210 and MC6211)", March 3, 2006.

Request for Additional Information	Response
1. Please provide a summary of the computational fluid dynamics (CFD) analyses and follow-up testing that have been accomplished and the findings of each analysis. In the case of follow-up testing, please provide the unrecalibrated AMAG-indicated flow rates for each of the installed instruments (CROSSFLOW and/or X-Beam), the flow rates determined using tracer testing, and from the venturis obtained during follow-up testing.	• A detailed summary of the flow measurement comparisons (chemical tracer to venturi to CROSSFLOW) are provided. • The results and interpretation of the Computational Fluid Dynamics (CFD) model analyses are provided.

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Request for Additional Information	Response
2. Please provide a description of the tracer testing procedures to be used. Include a discussion of how the tracer testing is traceable to national standards, controls in place to assure the procedures are properly conducted, the accuracy of the tracer testing, and how the uncertainties associated with the tracer testing are factored into the overall uncertainty of the CROSSFLOW system accuracy.	• A detailed summary description of chemical tracer testing theory and the Westinghouse ChemTrac™ process are provided. This information addresses the traceability to national standards, process controls, accuracy and factoring the uncertainty into the overall CROSSFLOW uncertainty.

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Request for Additional Information	Response
3. Please provide a description of any periodic testing to be performed that will verify the CROSSFLOW systems remain calibrated over the range of operating conditions and changes in flow that may occur over time due to degradation of, modification to, and/or operational changes in the main feedwater system.	• The response includes a detailed summary of: – Historical stability data of CROSSFLOW compared to venturi measurements. – CROSSFLOW alarm conditions (deviation of data from nominal quality setpoints) possible causes, and operator responses and investigations. – Determining any power dependency corrections for the CROSSFLOW system.

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- Assessment of CROSSFLOW Uncertainty When Using In-Situ Tracer Calibration for Non-Standard Installation Locations

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CROSSFLOW Status Meeting (3/29/06)

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Responses to NRC RAIs

Ft. Calhoun Specific

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- **The Ft. Calhoun RAI response has been submitted to the NRC.**
  - OPPD e-mail, T. C. Matthews (OPPD) to A. Wang (USNRC PM for OPPD), March 15, 2006.

Request for Additional Information	Draft Response
1. Please provide the technical basis for determining the location for installing the CROSSFLOW ultrasonic flow meters. If performed, include the computational fluid dynamic (CFD) analysis in your technical basis. Also, provide a discussion of any in-situ testing that has been performed. In the case of in situ testing, please provide the unrecalibrated AMAG-indicated flow rates for each of the installed instruments (CROSSFLOW and/or X-Beam), the flow rates from the in-situ testing, and from the venturis obtained during in-situ testing.	• A summary of activities and pre-commissioning testing to determine a suitable location for the CROSSFLOW meters is provided. • The results and interpretation of the Computational Fluid Dynamics (CFD) model analyses are provided. • A description of the corroboration process is provided.

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Request for Additional Information	Draft Response
2. If being conducted, please provide a description of in-situ testing procedures to be used. Include a discussion of how the in-situ testing is traceable to national standards, controls in place to assure the procedures are properly conducted, the accuracy of the in-situ testing, and how the uncertainties associated with the in-situ testing are factored into the overall uncertainty of the CROSSFLOW system accuracy.	• A description of the in-situ comparison of CROSSFLOW with the recently calibrated venturi measurements and the uncertainties is provided.

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Request for Additional Information	Draft Response
3. Please provide a description of any periodic testing to be performed that will verify the CROSSFLOW system remains calibrated over the range of operating conditions and changes in flow that may occur over time due to degradation of, modification to, and/or operational changes in the main feedwater system.	• A description of the verification activities to assure the calibration conditions are maintained is provided. • Activities are consistent with recommendations in the PWROG CROSSFLOW Task Force User Guidelines.

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Responses to NRC RAIs

Westinghouse/AMAG CROSSFLOW Generic

CROSSFLOW Status Meeting (3/29/06)

- **The Westinghouse/AMAG RAI response has been submitted to the NRC.**
  - Westinghouse Letter, J. A. Gresham (Westinghouse) to USNRC Document Control Desk, "Response to NRC Request for Additional Information Regarding the CROSSFLOW Ultrasonic Flow Measurement System (Proprietary)", LTR-NRC-06-11, March 17, 2006.
    - Responses are to the nine RAIs.
    - Comments on White Paper to be provided.

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Request for Additional Information	Response
1. "CROSSFLOW System/Theory & Application," Slides from NRC Meeting with Westinghouse (W) and AMAG, October 3, 2005. (Proprietary) provided data from nine tests at Everest Laboratory. We calculated that the average C_o was 1.00067 and the 2σ was 0.258%. a. Are we correct in assuming that the CROSSFLOW instrument used in these tests was recalibrated to an average C_o of one on the basis of the nine tests? If not, then are we correct in assuming that the C_o was determined from the Alden-derived equation that fitted the two coefficients? Please provide the unrecalibrated AMAG flow rates for the nine tests. b. Please explain how the 0.258% uncertainty is factored into overall AMAG uncertainty with respect to both testing and in plant installations. c. We would like to use these and other data to assess the straight line fit you used to obtain the two coefficients in your straight line equation but are unable to do so because you did not provide the unrecalibrated AMAG-indicated flow rates when tabulating the test-determined flow rates and Reynolds numbers. Please do so.	• The NRC evaluations are clarified in the response. – Not the C_o values but the comparison coefficients. – Not the uncertainty but the comparison differences. • The requested data are provided.

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Request for Additional Information	Response
2. CENPD-397-P-A Rev. 01 on Page 5-11 stated that [ ]a, c Please provide the data in a format similar to the data you provided for determination of the [ ]a, c and provide a summary of how the data were applied.	• Detailed summary of how the data were applied is provided. – ARL tests; straight pipe and 90° elbow results. – Comparisons to Ontario Hydro results. – Regression analyses, uncertainties and relation to use of the Alden test data at plant conditions. • The requested data are provided.

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Request for Additional Information	Response
3. The CENPD also makes a commitment on Page 5-11 [ ]a, c Please provide a list of the CFD analyses and follow-up testing that have been accomplished and summarize the findings of each analysis. In the case of follow-up testing, please provide the unrecalibrated AMAG-indicated flow rates.	• Details of CFD analyses for three different plant applications are provided (Calvert Cliffs Units 1 and 2, Ft. Calhoun, Oskarshamn Unit 3).
4. We have been provided with the figures "Verification of the Alden Calibration Curve at Higher Reynolds Number" in numerous references but we have not been supplied with the data illustrated on the figures and we cannot read the figure to sufficient accuracy to assess the data. Please provide the data for each point of Profile Correction Factor as a function of Re and of frictional velocity ratio.	• The requested data are provided. • Alternate extrapolation uncertainty evaluation report [ ]a, c is provided.

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Request for Additional Information	Response
5. Many of the comparisons, such as in Slides 13, 14, 16, and 17 provided to us on October 6, 2005, in "CROSSFLOW Fully Developed Flow/Stable Flow," are in graphical form. Graphical comparisons are not sufficient when uncertainties of a fraction of a percent are involved. To be useful in justifying your uncertainty conclusions, we must either have sufficient data so that we can calculate uncertainties or you must provide them. And Slide 12 provides a comparison of [ ]a, c	• The requested data are provided. • Clarified that Slide 12* depicts the CI results from all data.

* Refers to a specific presentation slide used during the Westinghouse/AMAG/NRC meeting to discuss CROSSFLOW technology, October 2005.

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Request for Additional Information	Response
6. An uncertainty is introduced by the AMAG self-assessment that allows continued operation within an indicated band. How is this uncertainty factored into the overall AMAG uncertainty?	• A detailed summary description of the relation of the operating band and the uncertainty contribution is provided.
7. "CROSSFLOW Standard and Nonstandard Installation," Slides from NRC Meeting with W/AMAG, October 6, 2005, Slide 10 provides a graph labeled "Delta between FPCF and 90E." Are we correct in believing this is for behavior downstream of a single 90° elbow?	• Provided clarification to the interpretation of the information in Slide 10*. • Provided a summary description of the method used to derive a correction to the velocity profile correction factor, C_o, for complex piping configurations.

* **Refers to a specific presentation slide used during the Westinghouse/AMAG/NRC meeting to discuss CROSSFLOW technology, October 2005.**

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Request for Additional Information	Response
8. [ ]a, c Please address this. Include the contribution to uncertainty.	[ ]a, c

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Request for Additional Information	Response
9. Please provide a table that lists every uncertainty associated with the feedwater flow rate determined by AMAG and provide either plant-specific uncertainties from one plant or typical uncertainties for each item for two conditions: [ ]a, c	[ ]a, c

CROSSFLOW Status Meeting (3/29/06)

- Yuri Orechwa White Paper Conclusions:

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CROSSFLOW Status Meeting (3/29/06)

- Response to Yuri Orechwa White Paper:

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CROSSFLOW Status Meeting (3/29/06)

- Response to Yuri Orechwa White Paper:

a, c

Westinghouse

CROSSFLOW Status Meeting (3/29/06)

- Response to Yuri Orechwa White Paper:

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Westinghouse

CROSSFLOW Status Meeting (3/29/06)

- **RAI Response Summary**
  - Westinghouse/AMAG, CCNPP and OPPD believe that the information provided in response to the NRC RAIs should fully address the outstanding Staff issues and allow closure of the three pending licensing actions (two LARs and X-Beam topical report).
    - Westinghouse further believes that the Staff should be able to reach closure on the two LARs independent of the X-Beam topical report since neither plant is crediting the use of X-Beam in its LAR submittal.
  - Should the staff have further questions resulting from the RAI responses, Westinghouse/AMAG, CCNPP and OPPD are available to meet or discuss via telephone with the Staff at any time in order to expeditiously reach final closure on these licensing actions.

Westinghouse/AMAG Activities

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- **As part of GAP, several test programs were undertaken.**
  - National Research Council Laboratory (NRCL), Ottawa, Canada
  - Alden Research Laboratory (ARL), Holden, MA
  - Wyle Laboratories, Huntsville, AL (in progress)
  - Applied Research Laboratory – Pennsylvania State University (ARL/PSU), State College, PA (in progress)
- **In general, the overall purpose of the GAP test programs has been to improve and validate methodologies for extrapolating from low temperature, low Reynolds Number (Re) laboratory conditions (i.e., a cold laboratory) to plant operating conditions using the benchmark approach for non-standard piping configurations.**

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- **Conclusions from CROSSFLOW Performance Testing**
  - Demonstrating UFM performance in an operating plant using a laboratory environment is challenging.
  - Signal contamination (noise) has an effect; mitigation methods have been developed and employed.
  - Full scale testing with a highly accurate flow reference (e.g., weigh tank) would ideally demonstrate CROSSFLOW performance.
    - Suitable test facilities that could minimize scaling effects and provide a highly accurate flow reference are not presently available.

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CROSSFLOW Status Meeting (3/29/06)

- Installation/Commissioning

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CROSSFLOW Status Meeting (3/29/06)

- Installation/Commissioning (continued)

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CROSSFLOW Status Meeting (3/29/06)

- Installation/Commissioning (continued)

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CROSSFLOW Status Meeting (3/29/06)

- Application of Alternate In-Situ High Precision Flow Measurement Techniques

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CROSSFLOW Status Meeting (3/29/06)

- Application of Alternate In-Situ High Precision Flow Measurement Techniques (continued)

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Westinghouse

CROSSFLOW Status Meeting (3/29/06)

- **Existing Commissioned CROSSFLOW Installations**
  - CROSSFLOW systems include comprehensive diagnostics and self-checking to alert the user of off normal conditions.
  - The PWROG CTF participants have confirmed that their installations satisfy the recommendations made in TB-04-4.
  - Baseline Validation Reports (BVRs) for all but three domestic installations showed compliance with installation and operation requirements.
    - Plant A has since corrected its compliance issues.
    - Plant B is under investigation by utility and Westinghouse/AMAG.
    - Plant C is currently operating well below licensed power rating.
  - Comparisons of CROSSFLOW with alternate high precision operating plant benchmark flow data demonstrates that the CROSSFLOW uncertainty is consistent with CENPD-397-P-A, Rev. 1.

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- **Existing Commissioned CROSSFLOW Installations (continued)**
  - Use of Corroborating Information
    - Corroborating information is used to trend and periodically monitor CROSSFLOW meter performance following commissioning as part of normal operations.
    - Westinghouse/AMAG provided guidance to CROSSFLOW Users that use of corroborating plant performance parameters or plant specific operating history could be used to obtain reasonable assurance that the system was operating as designed.
      - TB-04-4, "Information Regarding Recent CROSSFLOW Ultrasonic Flow Measurement System Performance Observations", February 12, 2004
    - The PWROG CTF adopted this guidance in the CROSSFLOW User Guidelines (WCAP-16437-P). Section 4.6.1.1 notes:

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- **Existing Commissioned CROSSFLOW Installations (continued)**
  - Use of Corroborating Information (continued)
    - Utility thermal performance engineers (TPEs) routinely monitor the performance of the BOP power production cycle.
      - The EPRI P^2EP program discusses in detail the elements of building and maintaining a good thermal performance program.
    - TPEs use simple spreadsheets or proprietary software (e.g., EnergiTools™, PEPSE) to monitor and assess the BOP power production cycle.
    - For the most part, the proprietary software examines the same parameters that would be useful in evaluation of corroborating information for trending analysis relative to assessing CROSSFLOW performance.

CROSSFLOW Status Meeting (3/29/06)

- **Topical Report Update**
  - Content Update
    - Remove outdated material not affecting current CROSSFLOW users.
      - For example, old transducer and mounting bracket designs.
    - Clarify statements based on operating experience and new information gleaned from testing.
      - For example, installation criteria.
    - Incorporate new information not previously in the topical report or not discussed in detail.
      - For example, alternate means of in-situ calibration, noise remediation.
    - Integrate information scattered among several topical reports or other documents into one replacement topical report.
    - Other new information not currently captured in a topical report.
  - The new WCAP will be developed by subsuming information from CENPD-397-P-A, Rev. 1, WCAP-15689-P and WCAP-16163-P.

CROSSFLOW Status Meeting (3/29/06)

- **Summary**
  - NRC is being provided with additional information to support the Calvert Cliffs and Ft. Calhoun LARs as well as to update the generic CROSSFLOW licensing documentation.
    - Plant specific information is being provided to the NRC to enable completion of the LARs for Ft. Calhoun and Calvert Cliffs.
    - We are confident that Calvert Cliffs and Ft. Calhoun CROSSFLOW installations are being implemented appropriately and successfully.
    - A revised CROSSFLOW topical report will be submitted to the NRC to describe the current state-of-the-art for meter installation and operation and will apply to both the standard and X-Beam designs.
  - A more rigorous CROSSFLOW installation process has been implemented to confirm whether the meter is in a standard or non-standard location and for establishing the installation baseline.