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# Discussion of the CROSSFLOW™ Ultrasonic Flow Measurement System Topical Report Safety Evaluation

Westinghouse / NRC Staff Meeting  
NRC Offices  
Rockville, MD

May 1, 2007

# CROSSFLOW Topical Report Safety Evaluation

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## Agenda

- ◆ Background and Summary
- ◆ Meeting Goals
- ◆ Westinghouse / AMAG Perspective
- ◆ Review of Comments on Draft SE
- ◆ Going Forward Plan
- ◆ Conclusion

# CROSSFLOW Topical Report Safety Evaluation

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- **Background and Summary**

- ◆ CROSSFLOW is a cross-correlation ultrasonic flow meter (UFM) marketed by Westinghouse Electric Company LLC and the Advanced Measurement and Analysis Group, Inc. (W / AMAG).
- ◆ The principal application of CROSSFLOW is for feedwater flow measurement with improved accuracy compared with venturi instruments.
- ◆ CROSSFLOW system and operation is described in Topical Report (TR) CENPD-397-P-A, Rev. 01-P, “*Improved Flow Measurement Accuracy Using CROSSFLOW Ultrasonic Flow Measurement Technology*”.
- ◆ NRC approved the TR on March 20, 2000.
- ◆ Observations of measurement discrepancies in 2003 - 2005 led to an NRC review of CROSSFLOW.

# CROSSFLOW Topical Report Safety Evaluation

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- **Background and Summary (continued)**

- ◆ W / AMAG and utility users have met with and provided a significant amount of information to NRC to support the CROSSFLOW review.
- ◆ The last face-to-face meeting with NRC was in April 2006 and the last detailed information submittals were in May-June 2006 (list provided in LTR-NRC-06-39).
- ◆ As a result of NRC's review, a new [draft] Safety Evaluation on CROSSFLOW was issued on March 13, 2007, identifying NRC's concerns and suspending the TR approval for new and future CROSSFLOW applications.
- ◆ Westinghouse requested this meeting to discuss the draft SE and how to meet NRC expectations, going forward.

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- **Meeting Goals**

- ◆ Discuss W / AMAG comments regarding proprietary content and factual accuracy of CROSSFLOW TR draft SE.
- ◆ Obtain NRC feedback regarding the comments provided for use in creating the final SE.
- ◆ Discuss the process for W / AMAG to gain an in-depth understanding of NRC concerns enumerated in the draft SE that were presented at a higher level.

# CROSSFLOW Topical Report Safety Evaluation

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- **Westinghouse / AMAG Perspective**

- ◆ The CROSSFLOW cross-correlation approach is fully capable of measuring feedwater flowrates within the uncertainty stated in the TR when properly installed and operated (see LTR-NRC-06-37).
- ◆ W/AMAG had previously identified to NRC staff that information in the TR needs to be supplemented to address the same gaps the NRC has identified (see LTR-NRC-06-13, LTR-NRC-06-33). Information previously communicated to all CROSSFLOW users supplements the TR in how CROSSFLOW performance is evaluated in plant applications to determine if the TR calibration can be used and to identify any specific restrictions.
- ◆ Problems experienced are the result of previous lax implementation practices and are not indicative of a problem with CROSSFLOW's underlying technology, nor with current practices.
- ◆ The NRC review has not included information from properly implemented CROSSFLOW applications which should be considered prior to issuance of a generic communication.

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- **Westinghouse / AMAG Perspective (continued)**

- ◆ W / AMAG strongly suggest that there is no need to completely suspend the original CROSSFLOW TR acceptance.
  - The NRC can simply disallow use of that portion of the implementation approach in which they have concerns that need to be resolved.
  - The TR acceptably can be maintained for new and future CROSSFLOW installations based on the use of in-situ calibrations using independent instruments of suitable accuracy. Resolution of open concerns can then be resolved off of the critical path.

# CROSSFLOW Topical Report Safety Evaluation

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- **Review of March 13, 2007 Draft Safety Evaluation Letter**
  - ◆ W / AMAG reviewed the draft SE and have provided (LTR-NRC-07-22) the NRC requested feedback:
    - The draft SE does not contain any proprietary information.
    - The draft SE does contain some factual inaccuracies that W / AMAG recommend be corrected prior to issuance. W / AMAG have also identified statements in the draft SE that we believe to be misleading.

# CROSSFLOW Topical Report Safety Evaluation

- **Review of March 13, 2007 Suspension Letter (continued)**

| <b><u>W</u> / AMAG Feedback on CROSSFLOW TR Draft Safety Evaluation</b> |             |             |                           |   |
|---|-------------|-------------|---------------------------|---|
| <b>Item</b>   | <b>Page</b> | <b>Line</b> | <b>Draft SE Statement</b> | <b>Westinghouse/AMAG Comment</b>  |
| 1.  | General     |             |                           | <i>W / AMAG have reviewed the draft SE and have not found it to contain any information considered to be proprietary in nature.</i>   |
| 2.  | General     |             |                           | <i>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 installation for operational acceptability.</i>   |
| 3.  | General     |             |                           | <i>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.</i> |

# CROSSFLOW Topical Report Safety Evaluation

- **Review of March 13, 2007 Suspension Letter (continued)**

| <b>W / AMAG Feedback on CROSSFLOW TR Draft Safety Evaluation</b> |             |             |                           |   |
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| <b>Item</b>  | <b>Page</b> | <b>Line</b> | <b>Draft SE Statement</b> | <b>Westinghouse/AMAG Comment</b>  |
| 4.   | General     |             |                           | <p><i>The draft SE states that all of the supplemental materials provided by W / AMAG were reviewed. However, within the draft SE discussion none of the supplemental material is referenced nor is there any discussion as to why the NRC 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 concerns. In order to obtain this information, W / AMAG requests that the NRC provide a detailed explanation that could then be used to resolve the open issues.</i></p> |

# CROSSFLOW Topical Report Safety Evaluation

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- **Review of March 13, 2007 Suspension Letter (continued)**

| <b>W / AMAG Feedback on CROSSFLOW TR Draft Safety Evaluation</b> |                |             |  |  |
|--|----------------|-------------|--|--|
| <b>Item</b>  | <b>Page</b>    | <b>Line</b> | <b>Draft SE Statement</b>  | <b>Westinghouse/AMAG Comment</b>   |
| 5.   | Cvr Ltr<br>P 1 | 43-46       | “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.” | <i>The statement 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 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.</i> |

# CROSSFLOW Topical Report Safety Evaluation

- **Review of March 13, 2007 Suspension Letter (continued)**

| <b>W / AMAG Feedback on CROSSFLOW TR Draft Safety Evaluation</b> |                |             |  |  |
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| <b>Item</b>  | <b>Page</b>    | <b>Line</b> | <b>Draft SE Statement</b>  | <b>Westinghouse/AMAG Comment</b>   |
| 6.   | Cvr Ltr<br>P 1 | 48-49       | “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.” | <i>The statement 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.</i> |

# CROSSFLOW Topical Report Safety Evaluation

- Review of March 13, 2007 Suspension Letter (continued)**

| <b>W / AMAG Feedback on CROSSFLOW TR Draft Safety Evaluation</b> |                |             |   |  |
|--|----------------|-------------|---|--|
| <b>Item</b>  | <b>Page</b>    | <b>Line</b> | <b>Draft SE Statement</b>   | <b>Westinghouse/AMAG Comment</b>   |
| 7.   | Cvr Ltr<br>P 2 | 50-52       | “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.” | <i>The statement 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 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.</i> |

# CROSSFLOW Topical Report Safety Evaluation

## ● Review of March 13, 2007 Suspension Letter (continued)

| <b>W / AMAG Feedback on CROSSFLOW TR Draft Safety Evaluation</b> |             |             |  |  |
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| <b>Item</b>  | <b>Page</b> | <b>Line</b> | <b>Draft SE Statement</b>  | <b>Westinghouse/AMAG Comment</b>   |
| 8.   | DSE<br>P 1  | 209-214     | <p>“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.”</p> | <p><i>As written, this statement 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 have communicated guidance and recommendations to perform such comparisons of CROSSFLOW with plant performance parameters in order to identify any potential overpower condition to exist.</i></p> |

# CROSSFLOW Topical Report Safety Evaluation

## ● Review of March 13, 2007 Suspension Letter (continued)

| <b>W / AMAG Feedback on CROSSFLOW TR Draft Safety Evaluation</b> |              |             |  |  |
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| 9.   | DSE<br>P 1-2 | 216-220     | “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.” | <i>As written, this statement is factually incorrect. W / AMAG agree that the task group report states that accuracy questions have arisen in some other plant installations. This 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 are not aware of any other plants experiencing performance issues that the task group had reviewed.</i> |

# CROSSFLOW Topical Report Safety Evaluation

## ● Review of March 13, 2007 Suspension Letter (continued)

| <b>W / AMAG Feedback on CROSSFLOW TR Draft Safety Evaluation</b> |             |             |   |  |
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| <b>Item</b>  | <b>Page</b> | <b>Line</b> | <b>Draft SE Statement</b>   | <b>Westinghouse/AMAG Comment</b>   |
| 10.  | DSE<br>P 2  | 234-242     | <p>“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.”</p> | <p><i>As written, this statement 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 into active service.</i></p> <p><i>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.</i></p> <p><i>(continued on next page)</i></p> |

# CROSSFLOW Topical Report Safety Evaluation

- Review of March 13, 2007 Suspension Letter (continued)**

| <b>W / AMAG Feedback on CROSSFLOW TR Draft Safety Evaluation</b> |             |             |                           |   |
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| 10.  | DSE<br>P 2  | 234-242     |                           | <p><i>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 have communicated guidance and recommendations to perform such comparisons of CROSSFLOW with plant performance parameters in order to identify any potential overpower condition to exist.</i></p> |

# CROSSFLOW Topical Report Safety Evaluation

## ● Review of March 13, 2007 Suspension Letter (continued)

| <b>W / AMAG Feedback on CROSSFLOW TR Draft Safety Evaluation</b> |              |             |   |  |
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| 11.  | DSE<br>P 2-3 | 266-269     | “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.” | <i>As written, this statement 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 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 have already identified and acknowledged that we are amenable to a TR revision to include technical clarifications and additional requirements. This was presented to NRC staff in early 2006.</i> |

# CROSSFLOW Topical Report Safety Evaluation

- **Review of March 13, 2007 Suspension Letter (continued)**

| <b>W / AMAG Feedback on CROSSFLOW TR Draft Safety Evaluation</b> |             |             |   |  |
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| 12.  | DSE<br>P 3  | 310-313     | “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.” | <i>As written, this statement 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.</i> |

# CROSSFLOW Topical Report Safety Evaluation

- **Review of March 13, 2007 Suspension Letter (continued)**

| <b>W / AMAG Feedback on CROSSFLOW TR Draft Safety Evaluation</b> |             |             |  |  |
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| 13.  | DSE<br>P 5  | 389-391     | “In other cases, noise contaminated the CROSSFLOW signal and affected the transit time determined by CROSSFLOW.” | <i>As written, this statement 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.</i> |

# CROSSFLOW Topical Report Safety Evaluation

## ● Review of March 13, 2007 Suspension Letter (continued)

| <b>W / AMAG Feedback on CROSSFLOW TR Draft Safety Evaluation</b> |             |             |  |   |
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| 14.  | DSE<br>P5   | 394-398     | “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.” | <i>As written, this statement is factually incorrect. W / AMAG agree that stable flow is not equivalent to a fully developed flow condition. However, W / AMAG disagree 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.</i> |
| 15.  | DSE<br>P8   | 524-526     | “Further, in some cases, NRC staff examination of the few data points that W/AMAG claimed established convergence actually showed trends still existed.”   | <i>W / AMAG need more information about what data points are referred to in order to assess the factual accuracy of this statement.</i>   |

# CROSSFLOW Topical Report Safety Evaluation

- **Review of March 13, 2007 Suspension Letter (continued)**

| <b>W / AMAG Feedback on CROSSFLOW TR Draft Safety Evaluation</b> |             |             |  |  |
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| 16.  | DSE<br>P8   | 540-544     | <p>“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.”</p> | <p><i>As written, this statement is factually incorrect. It appears that the staff is confusing the velocity profile correction factor, <math>C_v</math>, with the venturi flow correction factor, <math>C_f</math>. 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.</i></p> |

# CROSSFLOW Topical Report Safety Evaluation

- Review of March 13, 2007 Suspension Letter (continued)**

| <b>W / AMAG Feedback on CROSSFLOW TR Draft Safety Evaluation</b> |              |             |   |   |
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| 17.  | DSE<br>P 8-9 | 554-559     | “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.” | <i>As written, this statement 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.</i> |

# CROSSFLOW Topical Report Safety Evaluation

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## ● **Going Forward Plan**

- ◆ Assist Calvert Cliffs and Ft. Calhoun with existing LARs for MUR power uprates on a plant-specific basis.
- ◆ Obtain a thorough understanding of technical details of each NRC concern.
  - Detail of NRC concerns, including feedback on information W / AMAG submitted in Spring 2006 are requested to be provided in writing to avoid any misunderstanding.
- ◆ Discuss technical details of each NRC concern with review staff.
  - Establish dates / scope for face-to-face meetings.
  - Establish definitive and documented acceptance criteria for satisfying each concern.
  - Discuss and agree on W / AMAG approach for satisfying each concern, including but not limited to, vendor and utility scope, schedule, and follow-up activities.
- ◆ Update CROSSFLOW documentation so as to resolve open issues.
  - TR will likely not be updated but revised documentation packages will be submitted on a plant specific basis.

# CROSSFLOW Topical Report Safety Evaluation

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## ● **Summary / Conclusion**

- ◆ W / AMAG have provided the NRC requested feedback on the CROSSFLOW draft SE (see LTR-NRC-07-22, dated April 12, 2007)
- ◆ The CROSSFLOW UFM is fully capable of measuring feedwater flowrates within the uncertainty stated in the TR when properly installed and operated
- ◆ W/AMAG had previously identified to NRC staff that information in the TR has been supplemented for users to assure effective CROSSFLOW operation in plant applications.
  - Communication of the additional requirements, learned subsequent to the TR publication, have been made to utility users
  - Integrating supplemental CROSSFLOW documentation into the licensing basis will address gaps that have been identified.
- ◆ W/AMAG look forward to further interaction with NRC staff to resolve the review issues.