From: Evangelos Marinos
To: Jim Dyer
Date: Tue, Nov 30, 2004 2:02 PM
Subject: Allegation Closure Letter on Crossflow UFMs

Jim,

Last February I felt compelled to respond to the preliminary conclusions presented to the Executive Team, by the Task Group on their findings regarding the Crossflow instrument. The task Group recommended derating all the plants that use the Crossflow instrument and substantiation of the allegations made by Caldon.

At this time I again feel compelled to respond to the course of action being proposed for addressing the Caldon allegations.

Over the last nearly two years DE/EEIB has seen different versions of the allegations presented by DIPM for our review or concurrence for disposition of the allegations. To my knowledge, as procedures require, none of them have been properly characterized and agreed to by the alleger, per Management of Allegation Directive 8.8. The last characterization we have seen is attached.

None the less based on the characterization presented in the attached e-mail from Chris Grimes, neither allegation can be substantiated on the basis of the information collected from the use of the Crossflow instrument in power uprates that the staff has responsibility for review. My reasons are stated below:

1. Regarding Allegation NRR-2003-A-0003 there has been no information of overpower conditions in any plant that we have formally reviewed and approved for power uprate. In fact this allegation was raised against the application of Crossflow instruments at San Onofre, where it was determined that the pipe roughness assumed in the estimated calculation during commissioning was in error and was corrected. The instrument has been performing as expected with power uprate. This was an installation specific issue accounted for in our review. The task Group report does not acknowledge the San Onofre case.

The Task Group's reference of the Ft. Calhoun as a case of overpower is in error. Ft. Calhoun has not commissioned the instrument. We have repeatedly reported that the stipulations, in each application specific SER, are that prior to declaring the instrument operational at the accuracy level for the plant, the licensee must prove the instrument performance at the desired location.

Ft. Calhoun prudently tested the instrument at the desired location but could not match its performance with that of the venturi loop that was being checked against, when different pump or valve alignments were being introduced. Therefore, no overpower conditions existed at Ft. Calhoun that could place into question the integrity of the instrument.

To grant, therefore, substantiation of the allegation from this alleger, who tries to gain market advantage is unsupportable. Particularly since the instrument supplied by this alleger for power uprates does not provide the same assurance that it will perform as expected by independently checking the instrument against a known standard, such as the venturi loop, during implementation.

With regard to Byron/Braidwood power recovery use of the Crossflow, the staff had no role in the implementation of the instrument. The overpower occurred because bounding alarms were not placed on the instrument to limit its venturi correction factor value within the uncertainty level of the instrument. So when pump or valve alignments were changing and signal contamination was being introduced, altering the correction factors to the venturi, the licensee allowed the condition to exist.

As we have repeatedly reported, the Byron/Braidwood misapplication of the instrument can not exist in the formally licensed applications for power uprates. In those applications the venturi correction factor is required to be fixed, at the value determined during commissioning with a specific pump/valve alignment,

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bounded by the instrument uncertainly, and be alarmed.

The confidence, that the instrument is conservatively applied, is derived from its comparison to the venturi loop that is not subject to signal contamination from any plant configuration changes such as pump/valve realignments.

It is curious that we are now providing a patina of credibility to this allegation, by sighting the unrelated events of Byron/Braidwood and Ft. Calhoun, which were not identified in the allegation. These events occurred after the allegation was received. This alleger has for years been attempting to undermine the credibility of the agency with their claims against the Crossflow instrument. DIPM should have closed this unsubstantiated allegation, as advised by DE/EEIB, long before these events provided this patina of credibility.

2. Regarding Allegation NRR-2003-A-0007 the Caldon ER-262 report was intended to address Caldon's spool type (LEFM- Check) instrument sensitivity to the swirl phenomenon, not previously recognized and accounted for in the formally licensed applications of their instrument. In fact, alarms were activated at plants we previously approved for use of the LEFM. Further review, however, by Caldon, of the effects of swirl on their not licensed clamp-on type instrument, currently used in power recovery applications, indicated similar or higher sensitivity for potential overpower.

Our review of the Caldon ER-262 report concluded that the swirl phenomenon when occurs, after the spool-type (Check) instrument is installed for power uprates, its effects would be recognized much like the Crossflow instrument would recognize signal contamination, by alarms placed of the fixed value of instrument reading. Therefore, no overpower would result from this phenomenon unless the alarm is ignored and the instrument is reset to a different value, in violation of procedures.

We further concluded , however, that swirl has no effect on the Crossflow instrument simply because the instrument is insensitive to radial velocity components, unlike the transit time instruments supplied by Caldon. A simple vector analysis would demonstrate that. Since the Crossflow instrument is perpendicular to the flow, the radial component of velocity is not present. Even if this phenomenon could influence the Crossflow instrument it would be recognized by the alarms and would be treated like any other signal contamination that must be addressed by the operators.

The details of our conclusion regarding the insensitivity of the Crossflow instrument to swirls could not be presented in the SER because Westinghouse considers the treatment of this issue as proprietary.

CC: Brian Sheron; Bruce Boger; Christopher Grimes; Ellis Merschoff; Jared Wermiel; Jose Calvo; Richard Barrett; Richard Borchardt; Suzanne Black

From: Christopher Grimes
To: Jared Wermiel; Jose Calvo; Theodore Quay
Date: 11/26/04 3:32PM
Subject: UFM End Game Briefing Notes

Based on the feedback from our 11/3/04 end game meeting, I assembled the attached notes to brief Jim & Brian on my recommendations for closure. I've scheduled the briefing for Wednesday afternoon, Dec 1, at 3:00. I'd expect to conduct the briefing, assisted by George Dick (or his designee) to keep notes. Please let me know who you want to participate in the briefing. Thanks

CC: Brian Benney; Bruce Boger; Clifford Doutt; Evangelos Marinos; Gene Suh; George Dick; Ghani Zigh; Gregory Cwalina; Herbert Berkow; Iqbal Ahmed; James Lyons; Jennifer Uhle; Michael Case; Michael Johnson; Richard Barrett; Stephen Alexander; Suzanne Black; Tad Marsh; Warren Lyon; Yuri Orechwa

UFM End Game

December 1, 2004

Success: Specific actions to (1) decide whether and how to substantiate or deny the Crossflow accuracy allegations; (2) complete an appropriate generic communication regarding UFM accuracy expectations, regarding power level measures to demonstrate compliance with the licensed power level; and (3) establish an appropriate review standard for topical reports and license amendments seeking approval of specific methods for power level measurement accuracy.

Proposed Actions:

Allegation NRR-2003-A-0003: *(1) Power uprates and power recovery at certain plants have been based on Crossflow accuracy that is not supported and even contradicted by published data. Affected licensees may have operated above their licensed power level. (2) Uprates have been granted based on Crossflow accuracy of ± 0.5%; published data indicate feedflow errors of as much as 1-3%.*

- Partially substantiate both parts of the allegation, to the extent that the UFM Task Group identified issues associated with plant-specific installations, Westinghouse notified licensees of these issues in Technical Bulletins and a Safety Advisory Letter, and licensees have taken actions to ensure that the accuracy of the Crossflow instrumentation is achieving the desired accuracy.

- Clarify the response letter to describe "closure" as the ongoing efforts of the NRC to decide on the appropriate generic communication to share the results of the UFM Task Group findings and follow-up with appropriate inspection verification.

Allegation NRR-2003-A-0007: *WCAP-15689 (non-proprietary) contains incorrect and misleading statements which caused the NRC staff to issue an SER which is in error.*

- Partially substantiate the allegation, to the extent that the staff's SER was in error because there was insufficient information presented in the WCAP to conclude that "*(Crossflow) flowmeter is not as sensitive to upstream flow perturbations as a clamp-on transit-time flowmeter (External LEFM). As such, the concerns identified in ER-262 [the Caldon topical on flow profile effects] are not applicable to "Crossflow" ultrasonic flowmeter measurements.* " The phrase "not as sensitive" is too subjective to defend, and not appropriate for an SER intended for licensees to reference.

- Determine whether either Caldon (ER-262) or Westinghouse (WCAP-15689-P/NP Rev 0 and Rev 1) issued "approved" versions of their topical attaching the Jan 28, 2003 SER; determine the most efficient way to correct the SER conclusion and establish an appropriate "approval" basis for referencing [see WCAP-16163 below].

- Clarify the response letter to describe "closure" as a future action to correct the approval basis for both the Crossflow (Westinghouse) and LEFM (Caldon) flowmeters, based on the nature and extent of the actions licensees rely on to ensure operation within the licensed power level. This future action will depend on the generic communication, described below, gathering this information.

Generic Communication: Considering the time that has lapsed in the development of a proposed bulletin and the extent of public feedback, a bulletin is not the appropriate generic communication. In order to bring closure to this issue, a generic communication requiring an affirmative response from the licensees is warranted. SRXB agreed to draft a generic letter that would simply ask licensees to respond with a description of the actions taken to address power level measurement uncertainty and data relied on to ensure the claimed accuracy of the measurement has been achieved. Follow-up with a TI to verify power level measurement accuracy for the most susceptible.

WCAP-16163 "X-Beam" UFM: By letter dated Feb 2, 2004, Westinghouse submitted this topical report requesting approval for referencing to achieve accuracy in the range of 0.3 to 0.45%. The 10/21/04 EEIB draft SER approves the topical by referencing the approval basis for CENPD-397-P (the Mar 2000 Crossflow SER).

- Inform Westinghouse that the review of this topical will be rescheduled after we determine the generic communication to address the UFM experience, which we would expect to provide a description of the licensees' actions to verify the installed accuracy of the Crossflow devices [the Westinghouse 10/19/04 letter states: *WOG CTF* [Crossflow Task Force] *will continue to keep the NRC informed regarding ongoing progress and the ultimate conclusions drawn once all investigative activities and evaluations are completed.*

- Use the responses to the generic letter to establish a appropriate technical basis for approving UFM topical reports, which would include the verification methods that could be included as conditions for referencing the "approved" topical reports. Thereafter, issued corrected SERs for Westinghouse Crossflow (CENPD-397 & WCAP-15689) and Caldon (ER-262). Use this evaluation basis to complete the WCAP-16163 topical.

Historical Notes:

1/15/99 SER for Caldon ER80P: *Based on the above, the staff finds that feedwater flow measurement using the LEFM can provide a thermal power measurement that will remain bounding within an uncertainty of ±1% of rated thermal power.*

3/15/00 SER for CENPD-397-P (now WCAP-15689): *This level of accuracy* [0.5% or better with 95% confidence] *is achievable only when the plant-specific operating conditions and flow uncertainty parameters strictly follow the guidelines in the Crossflow UFM topical report. ... the report is generically suitable for reference by utilities employing the Crossflow UFM to pursue plant operation at a higher power level, within the limitations of the license.*

6/18/04 Westinghouse letter: ... *we have concluded that the information previously submitted remains valid for those conditions in which the CROSSFLOW meter was designed to function. In the process of assessing these events and reaching these conclusions, Westinghouse issued several vendor notices:*

1. *Technical Bulletin, TB-03-6, "CROSSFLOW Ultrasonic Measurement System Signal Issues," September 5, 2003*
2. *Nuclear Safety Advisory Letter, NSAL-03-12, "CROSSFLOW Ultrasonic Flow Measurement System Flow Signal Interference Issues," December 5, 2003.*
3. *Technical Bulletin, TB-04-4, "Information Regarding Recent CROSSFLOW Ultrasonic*

Flow Measurement System Performance Observations," February 12, 2004.

6/18/04 INPO SER 3-04: *Although UFM technology has been in use for many years, few events were reported between 1991 and 1999. An increasing trend in the number of overpower events related to UFM began in 2000, with 14 events occurring between 2000 and 2003. This resulted primarily because UFM systems allowed operation closer to design limits for core thermal power.* Lessons learned: signal noise, transducer problems, operational considerations, and management considerations.

7/1/04 NRC letter to Westinghouse, UFM Task Group report on Crossflow: The Task Group anticipates that W will provide the staff with action plan results that may lead to a supplement to the approved topical report for the AMAG instrument and a supplement to the staff's safety evaluation report. ... Issue a generic communication (bulletin) to all licensees who rely upon information obtained from AMAG UFMs which requires that information be provided to demonstrate that the device is providing the intended accuracy consistent with the plant license.

7/1/04 Public meeting description of a draft bulletin that would require ... *The subject addressees that are using or have used measurements of W/AMAG Crossflow, Caldon LEFMs (strap-on or spool piece design), or any other UFM, for a one-time check of venturi calibration or power recovery or MUR power uprate, are requested to address the overpower concern identified above, confirm that this(these) plant(s) is (are) operated at or below the licensed thermal power level and within the safety limits and limiting conditions for operation, and provide the basis for this confirmation.* ***Licensees may confirm UFM accuracy by comparing the instrument performance in operating plant conditions against measurement values of a fully clean ASME flow nozzle of known accuracy or any other standard test of known accuracy and submit the test results for staff review with the required response.*** *If such confirmation can not be provided, the licensees shall describe what actions will be taken to ensure operation within the licensed thermal power level and within the safety limits and limiting conditions for operation. ¶ In accordance with 10 CFR 50.54(f), in order to determine whether a facility license should be modified, suspended, or revoked, or whether other action should be taken, an addressee is required to ... [w]ithin 30 days of the date of this bulletin, an addressee is required to submit a written response if they are unable to provide the requested information or they can not meet the requested completion date. The addressee must address in its response any alternative course of action that it proposes to take, including the basis for the acceptability of the proposed alternative course of action.*

7/8/04 ACRS meeting: *But it's like driving 61 mph in a 60 mph speed limit. There's no real danger to anybody, but you're still illegal ... I think that we* [ACRS] *should develop a thought process of our own to decide what ... is our position ... when the time comes for us to respond.*

8/4/04 Merschoff email: *Can I assume that our central point now would be the effect of elbows, valves, and specific pump alignments on the in situ application? If yes, how can we accept anything less than testing every plant, or do we think that a sample of plants will show the effect of vortice shedding is not important in fully developed turbulent flow. Has the vendor made that argument?*

9/17/04 Public Meeting: WOG => re-evaluating plant specific installations "in light of revised installation procedures and lessons learned," enhanced hydraulic model test methodology in progress (Dec 2004) and revised software for signal contamination in progress (Fall 2004). *The severity level for the potential NRC generic correspondence should consider information already accumulated by the NRC through notices, as well as vendor and public meetings,*

oversight by industry groups such as INPO, the safety significance and the level of commitment by the utilities/vendors to resolve the concerns and share information. Caldon => ASME nozzles are expensive and hard to install, and unwarranted for LEFM Check Plus.

ASME Performance Test Codes: The staff's SER references PTC 19.1 for *Test Uncertainty* (for instrument measurements), Caldon referenced PTC 18, *Hydraulic Turbines and Pumpt-Turbines* (for flow measurement instruments and evaluation of errors), and PGE referred to PTC-6, *Guidance for Evaluation of Measurement Uncertainty in Performance Tests of Steam Turbines* (for the calibration methods to use ASME flow nozzles to calibrate their Crossflow instruments).

10/7/04 Orechwa evaluation of thermal power prediction for three flow meters: *Specific implementation at a plant my* [may] *have deficiencies which could be inconsistent with these conclusions. ... The basic (pre-calibration) computational algorithm of a chordal instrument will give a result with a higher accuracy than one achieved with the venturi and especially one with the crossflow instrument.*

10/19/04 Westinghouse letter: [We] *have re-enforced the recommendations in CROSSFLOW Technical Bulletins and a Nuclear Safety Advisory Letter with the utility that is currently operating their CROSSFLOW system, for which further validation work is needed. ... and now WOG CTF will continue to keep the NRC informed regarding ongoing progress and the ultimate conclusions drawn once all investigative activities and evaluations are completed.*

From: Stephen Alexander
To: Dale Thatcher; Evangelos Marinos; Gregory Cwalina; Iqbal Ahmed; Jose Calvo; Steven Arndt; Theodore Quay
Date: Mon, Sep 22, 2003 4:47 PM
Subject: 2003-0003 CI Concerns Compilation

Reference documents received from CI:
ER-262 (NP)

Apparent Contradictions and Errors in NRC Review of Caldon Engineering Report ER-262 (P)

ER-356, Rev 0, Evidence Summary of Crossflow Calibration Errors in the Field-Case Studies (P)

Caldon/NRC Meeting Regarding January 28, 2003, SER, Rev P, April 27, 2003 (Proposed Staff Meeting Notes) (P)

PR399, Rev 8, Caldon/NRC Meeting to Discuss January 28, 2003, SER Proposed Staff Meeting Slides, March 2003 (P)

ER-365, Rev 0 and Rev 1, June 2003, A Tabulation of Errors and Misleading Statements in WCAP 15689, *Evaluation of Transit Time and Cross Correlation Ultrasonic Flow Measurement Experience with Nuclear Plant Feedwater Flow Measurement, Rev 1, September 2002* (P)

Additional Questions Raised by public documents (including TB-03-6) related to the feed flow issue at Byron and Brazilwood.

The following is a distillation of the principal concerns expressed in the above documents and in conversations with the CI. Refer to the cited documents if more detail is desired.

1. The discrepancies in indicated feedwater flow between SONGS-2 and 3 may be due in part to some kind of bias or systematic error in the Crossflow equipment coupled with the random uncertainty that WEC/AMAG have not accounted for and that the equipment is not able to detect and compensate for.

2. The calibration of the Crossflow UFM at ARL that was used to create the VPCF calibration curve is a four-point least-squares fit, with the highest value being at Re=7E6 (approx), yet the ARL stated uncertainty of 0.25% is carried as the uncertainty of that curve without additional uncertainty for extrapolation to bounding plant flow conditions with Reynolds numbers around 30E6. WEC goes on to assert in CENPD-397-NP-A, Rev. 1, Section 4.2, "Profile Validation at Higher Reynolds Numbers," and Section 4.3, "Conclusions," that the calibration can be extrapolated to the higher Reynolds numbers found in plants, and that the uncertainty need only be that of the original ARL uncertainty, by citing standard practice for venturis. However, cross-correlation meters do not have the same physics or operational history as venturis. Further, in the case of venturis, the individual meters are calibrated and then the calibration is extrapolated to the operating conditions, but with the Crossflow UFM, the calibration curve was developed with one meter and it was then generalized for all of the meters.

3. The VPCF calibration curve is based on the performance of a particular single Crossflow UFM. There is inadequate justification of the applicability of this instrument response curve to all other Crossflow UFMs with zero additional uncertainty being carried to bound the effects of all the credible differences. Since there are no conclusive, repeatable comparisons with the performance of other Crossflow UFMs under the same laboratory conditions, and against NIST-traceable standards, or even against other independent instruments that are inherently more accurate than (or even as accurate as) the Crossflow UFM, how can identical, repeatable performance be assumed (noting exceptions taken to the plant confirmatory data)?

4. The calibration curve is based on the performance of a Crossflow UFM under a set of laboratory

conditions. In order to demonstrate applicability of that testing to all other conditions that may be encountered in actual plant installations, all the credible differences would need to be accounted for. The Crossflow UFM total uncertainty would be expected to account for some kinds of credible differences by adding uncertainty in the correction factors for electronics, limited piping configuration variance based on laboratory testing, transducer spacing, time delay measurement, and the accuracy of flow area determination. How are these correction factors extrapolated to plant Reynolds numbers without carrying additional uncertainty such that they can be assured to bound the effects of all the credible differences under actual plant conditions when they were determined in the laboratory? The effects of specific plant conditions, such as flow velocity or upstream perturbations need to be modeled or measured and correction factors developed. The correction factors are applied, but the uncertainties of the corrections are not included, only the uncertainty of the original calibration. Without these uncertainties being evaluated and accounted for, the calibration is only traceable to the particular instrument calibrated in the certified laboratory and for the conditions examined at that laboratory.

5. The other way that the effects on flow of different plant conditions are addressed is to determine in the laboratory, where they can be measured to an accuracy greater than the claimed UFM accuracy, what the bounding conditions are and the limitations on these effects. Then install the UFM in locations beyond the reach of those effects. When the UFM cannot be installed beyond the reach of accuracy degrading effects, the so-called "in-situ" calibrations are performed. It is recognized that when this practice is employed, the uncertainties of the individual UFMs are combined using the RSS method. However, again it appears that the accuracy of one Crossflow UFM is being confirmed by the accuracy of others, and there is inadequate traceability under those conditions to standards that are even as accurate as the instrument being calibrated. In addition, WEC/AMAG have determined that 15 diameters was the point at which the velocity profile correction factor is no longer a function of upstream disturbances. This was reportedly done using a 90-degree planar bend. How are more complicated piping configurations accounted for such as one or two non-planar bends?

5. The eight (8) plant confirmatory data has significant data scatter, but the uncertainty bounds are not given. They were taken over a range of Reynolds numbers from 11,000,000 up to 25,000,000 at different plants with different instruments whose accuracy was determined with varying degrees of rigor. For example, the highest value at Re=25E6 was taken from a recently calibrated venturi, while others around 20,000,000 for example were taken with "defouled" venturis. The fact that a few diverse raw data points happen to agree within some given value to the VPCF curve value for the corresponding Reynolds number during a given plant test does not mean they necessarily and repeatably agree, but only that there exist some data that happen to agree. Where there is relatively close agreement, it could simply be a fortunate superposition of errors. This sort of comparison is not valid empirically. It does not prove that the curve is accurate under all conditions to the claimed +/-0.25% (the ARL uncertainty). This is because (1) the uncertainty of the comparison instruments has not been taken into account, (2) that uncertainty, when taken into account, will be, at best, 0.6% when, as prescribed in ASME Std PTC-6, the flow nozzle (and presumably the same DP cell as well) is cleaned, calibrated at the lab, reinstalled, tested promptly, and then sent back to the lab for re-checking the calibration. Not all these provisions were met in all the tests. Therefore, using these data for confirmation of claimed accuracy of the VPCF calibration curve is trying to demonstrate an accuracy of 0.25% by comparison to a few data from instruments of lesser accuracy, i.e., 0.6% at best at plant-comparable Reynolds numbers. Other data of ostensibly higher accuracy, again was a lower Reynolds number (e.g., tracer data at Re=11E6). Finally, there is an insufficient number of comparable raw data points to perform a meaningful statistical analysis.

6. The laboratory testing to determine the VPCF used long, straight, very smooth (plastic) pipe to minimize hydraulic anomalies, especially pipe wall roughness, to achieve classic "fully developed" flow. The corresponding flow velocity distribution or profile has a finite amount of curvature that, according to theory is a function of Reynolds number. This forms the fundamental characteristic programmed response of the Crossflow UFM to flow of varying Reynolds number. However, aside from the metrology concerns about the accuracy and repeatability of this curve, there is data [obtained by the CI] that indicates that there can be distortions to the flow velocity profile that (1) are flatter than classic fully developed flow (non-conservative), (2) asymmetrical, (3) that persist out to at least 45 L/D, (4) that change over time, independent of changes in plant configuration or readily recognizable events (Note: I

think WEC has addressed this specific one to some extent). One of the principle phenomenon of concern is swirl which can create tangential velocity vectors with magnitudes as much as 20% of the axial velocity and can vary significantly over time. It is not clear from the WEC/AMAG documents how the Crossflow UFM can adequately detect and properly correct for all those conditions that appear to be outside its design basis. What data does WEC/AMAG have that support the assumption that their smooth pipe assumption is always conservative? Has WEC/AMAG done any experiments to see for themselves if this can occur?

7. We have been following the Byron and Braidwood feed flow issue. We brought up the question of unaccounted for error sources from noise in TP 28 (2000) and again in ER-365. It is not clear from existing WEC documentation (including recent information pertaining to Byron and Braidwood) how the Crossflow UFM, even when operated in accordance with WEC guidelines, can recognize accoustic anomalies (noise or "signal contamination") that may develop over time and that may bias it and degrade its accuracy.

Note that due to various circumstances, EEIB has lost three of the nine working days alloted to the proprietary review by the ARB. If EEIB cannot complete this review within the six days left beginning, Tuesday, September 23, until the ARB-approved due date of September 30, we will need to take other steps to regain the schedule. We may ask the CI to complete the review to confirm completeness and accuracy of the distillation of concerns in a shorter time than its alloted "one week" in order to catch up to the schedule for review and closeout of this allegation.