CAMERON

Measurement Systems

Caldon® Ultrasonics

Engineering Report: ER-157(NP-A) Rev. 8 & Rev.8Errata

Supplement to Caldon Topical Report ER-80P: Basis for Power Uprates with an LEFM Check or an LEFM CheckPlus System

Prepared by: Herb Estrada
Reviewed by: Don Augenstein

May 2008

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

August 16, 2010

Mr. Ernest Hauser, Director of Sales
Cameron
Caldon Ultrasonic Technology Center
1000 McClaren Woods Drive
Coraoplis, PA 15108

SUBJECT: FINAL SAFETY EVALUATION FOR CAMERON MEASUREMENT SYSTEMS ENGINEERING REPORT ER-157P, REVISION 8, "CALDON ULTRASONICS ENGINEERING REPORT ER-157P, 'SUPPLEMENT TO TOPICAL REPORT ER-80P: BASIS FOR A POWER UPRATE WITH THE LEFM CHECK OR CHECKPLUS SYSTEM'," (TAC NO. ME1321)

Dear Mr. Hauser:

By letter dated May 11, 2009 (Agencywide Documents Access and Management System (ADAMS) Accession No. ML091340322), Cameron Measurement Systems (Cameron/Caldon) submitted for U.S. Nuclear Regulatory Commission (NRC) staff review Topical Report (TR) Engineering Report ER-157P, Revision 8, "Caldon Ultrasonics Engineering Report ER-157P, 'Supplement to Topical Report ER-80P: Basis for a Power Uprate with the LEFM Check or CheckPlus System'." By letter dated May 24, 2010, an NRC draft safety evaluation (SE) regarding our approval of TR Engineering Report ER-157P, Revision 8, "Caldon Ultrasonics Engineering Report ER-157P, 'Supplement to Topical Report ER-80P: Basis for a Power Uprate with the LEFM Check or CheckPlus System'," was provided for your review and comments. By letter dated June 11, 2010 (ADAMS Accession No. ML101690084), Cameron/Caldon indicated that ER-157P, Revision 8, does not contain any proprietary information. The NRC staff's disposition of Cameron/Caldon's comments on the draft SE are discussed in Enclosure 2 to this letter.

The NRC staff has found that Engineering Report ER-157P, Revision 8, is acceptable for referencing in licensing applications for a measurement uncertainty recapture application for power uprate using the leading edge flow meter (LEFM) Check or LEFM CheckPlus system for feedwater flow and temperature measurements to the extent specified and under the limitations delineated in the TR and in the enclosed final SE. The final SE defines the basis for our acceptance of the TR.

Our acceptance applies only to material provided in the subject TR. We do not intend to repeat our review of the acceptable material described in the TR. When the TR appears as a reference in license applications, our review will ensure that the material presented applies to the specific plant involved. License amendment requests that deviate from this TR will be subject to a plant-specific review in accordance with applicable review standards.

In accordance with the guidance provided on the NRC website, we request that Cameron/Caldon publish the accepted version of this TR within three months of receipt of this letter. The accepted version shall incorporate this letter and the enclosed final SE after the title page. Also, it must contain historical review information, including NRC requests for additional information and your responses. The accepted versions shall include an "-A" (designating accepted) following the TR identification symbol.

As an alternative to including the RAIs and RAI responses behind the title page, if changes to the TR were provided to the NRC staff to support the resolution of RAI responses, and the NRC staff reviewed and approved those changes as described in the RAI responses, there are two ways that the accepted version can capture the RAIs:

1. The RAIs and RAI responses can be included as an Appendix to the accepted version.
2. The RAIs and RAI responses can be captured in the form of a table (inserted after the final SE) which summarizes the changes as shown in the approved version of the TR. The table should reference the specific RAIs and RAI responses which resulted in any changes, as shown in the accepted version of the TR.

If future changes to the NRC's regulatory requirements affect the acceptability of this TR, Cameron/Caldon and/or licensees referencing it will be expected to revise the TR appropriately, or justify its continued applicability for subsequent referencing.

Sincerely,

Thomas B Blount

Thomas B. Blount, Deputy Director
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Project No. 700

Enclosures:
1. Final SE
2. Resolution of comments

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

FINAL SAFETY EVALUATION BY THE OFFICE OF NUCLEAR REACTOR REGULATION

ENGINEERING REPORT ER-157P TOPICAL REPORT, REVISION 8,

"SUPPLEMENT TO TOPICAL REPORT ER-80P: BASIS FOR A POWER UPRATE WITH THE LEFM CHECK OR CHECKPLUS SYSTEM"

CAMERON MEASUREMENT SYSTEMS

PROJECT NO. 1370

1.0 INTRODUCTION AND BACKGROUND

Caldon, Inc., submitted an engineering report (ER), ER-80P topical report (TR) (Reference 1), in March 1997, that describes the Leading Edge Flow Meter (LEFM), includes calculations of power measurement uncertainty using a Caldon, Inc., LEFM Check system in a typical two-loop pressurized-water reactor or a two-feedwater-line boiling-water reactor, and provides guidance for determining plant-specific power calorimetric uncertainties. The U.S. Nuclear Regulatory Commission (NRC) staff approved this TR for an exemption to the 2 percent uncertainty requirement in Appendix K to 10 CFR Part 50 and approved a 1 percent power uprate for using the LEFM (Reference 2). Following publication of the amendment to Appendix K that allowed for an uncertainty less than 2 percent, the NRC staff approved ER-160P TR (Reference 3) for up to a 1.4 percent power uprate (Reference 4). Subsequently, the NRC staff approved ER-157P, Revision 5, TR, (Reference 5) for up to a 1.7 percent power uprate using the Caldon, Inc., LEFM CheckPlus system (Reference 6). Since that time, Caldon, Inc., more recently as a part of Cameron Measurement Systems (Cameron/Caldon), has submitted updates and plant-specific documentation describing application of the Check and the CheckPlus ultrasonic flow meter (UFM) instrumentation.

The subject of this safety evaluation (SE), ER-157P, Revision 8, TR, (Reference 8), is the most recent Cameron/Caldon TR submitted to NRC for review and supersedes ER-157P, Revision 8, submitted "for information only" in June 2008 (Reference 7). ER-157P, Revision 8, TR (Reference 8), supplements the previous documents and characterizes both the Check and the CheckPlus LEFMs, summarizes LEFM field experience through 2007, provides more detail pertaining to coherent noise effects, and addresses transducer replacement uncertainty. Together, ER-80P TR and ER-157P, Revision 8, TR, including applicable references in ER-157P, Revision 8, TR, provides an acceptable generic basis for a measurement uncertainty recapture (MUR) power uprate subject to items identified in the remainder of this SE.

In Reference 8, Cameron/Caldon requested NRC review of ER-157P, Revision 8, TR. In conducting its review, the NRC staff considered the information provided in the above references, guidance from Regulatory Issue Summary 2002-03 (Reference 9), and the results from previously reviewed licensee MUR requests. Several items were found that potentially affected Revision 8 and Cameron/Caldon proposed another item during the review that could affect future licensee requests that referenced Revision 8. The NRC staff found that revision of this TR was not necessary to cover these items and that covering them in the SE as discussed below was an acceptable method to address them.

In general, the CheckPlus is more accurate and less susceptible to flow disturbances than the Check, and in several areas, as identified in this SE, the NRC staff's evaluation is limited to the CheckPlus and may not be applied to the Check.

Nuclear power plants are licensed to operate at a specified core thermal power, and the uncertainty of the calculated values of this thermal power is a significant input into the probability of the plant exceeding the power levels assumed in the design-basis transient and accident analyses. In this regard, Appendix K, "ECCS Evaluation Models," to Title 10 of the *Code of Federal Regulations* (10 CFR) Part 50, "Domestic Licensing of Production and Utilization Facilities," originally required loss-of-coolant accident (LOCA) and emergency core cooling system analyses to assume that the reactor had been operating continuously at a power level at least 102.0 percent of the licensed thermal power to allow for uncertainties, such as instrument error. To reduce an unnecessarily burdensome regulatory requirement and to avoid unnecessary exemption requests, the Commission published a revised rule in the *Federal Register* (65 FR 34913; June 1, 2000). This rule amended the requirement in Appendix K to allow licensees the option of justifying a smaller margin for power measurement uncertainty by using more accurate instrumentation to calculate the reactor thermal power or of maintaining the current margin of 2 percent power.

The neutron flux instrumentation continuously indicates the reactor core thermal power; this instrumentation must be periodically calibrated to accommodate the effects of fuel burnup, flux pattern changes, and instrumentation setpoint drift. The reactor core thermal power generated by a nuclear power plant is determined by steam plant calorimetry, which is the process of performing a heat balance around the nuclear steam supply system (called a calorimetric). The accuracy of this calculation depends primarily upon the accuracy of feedwater flow rate and feedwater net temperature measurements. As such, an accurate measurement of feedwater flow rate and temperature is necessary for an accurate calibration of the nuclear instrumentation. Of the two parameters, flow rate and temperature, the most important in terms of calibration sensitivity is the feedwater flow rate.

The originally installed instruments for measuring feedwater flow rate in nuclear power plants were usually a venturi or a flow nozzle, each of which generates a differential pressure proportional to the square of the feedwater velocity in the pipe. Of the two, the venturi was the most widely used because of relatively low head loss. However, venturi fouling and, to a lesser extent flow nozzle fouling, the transmitter, and the analog-to-digital converter introduce errors in the flow rate measurement.

Because of the desire to reduce flow instrumentation uncertainty to enable operation of the plant at a higher power, while remaining within the licensed rating, the industry assessed alternate flow rate measurement techniques and found that UFMs are a viable alternative. UFMs are computer-controlled electronic transducers that do not have differential pressure elements that are susceptible to fouling. Caldon developed a UFM called a "leading edge flow meter" and named it the LEFM Check system, and then it developed the LEFM CheckPlus system. An LEFM CheckPlus system, which consists essentially of two LEFM Check systems, provides a more accurate feedwater flow measurement than that of the LEFM Check system. Both of these UFMs have demonstrated better measurement accuracies than the differential pressure type instruments and provide on-line verification to ensure that the UFM is operating within its uncertainty bounds.

2.0 REGULATORY EVALUATION

Appendix K of Section 50 and 50.46 of 10 CFR originally required licensees to base their LOCA analysis on an assumed power level of at least 102 percent of the licensed thermal power level to account for power measurement uncertainty. On June 1, 2000, the NRC published a final rule in the *Federal Register* (65 FR 34913) that allows licensees to justify a smaller margin for power measurement uncertainty. Approximately three-fourths (or greater) of the power measurement uncertainty is due to measurement of feedwater flow rate. Consequently, if a licensee proposes to install a flow rate metering system that has a smaller uncertainty than associated with an existing two percent uncertainty installation, the licensee may apply for an amendment to operate at a power level higher than the previously licensed power on the basis of the use of a flow rate metering system that has a reduced uncertainty.

The Cameron/Caldon LEFM that is addressed in the subject TR (Reference 8) is typically claimed to allow an uncertainty reduction from 2 percent to less that 0.4 percent. Consequently, the NRC staff evaluated the TR and associated documentation with respect to such items as the following:

1. Consistency with the guidelines in NRC Regulatory Issue Summary, 2002-03, "Guidance on the Content of Measurement Uncertainty Recapture Power Uprate Applications" (Reference 9).

2. Substantiation that flatness ratio, defined as the ratio of the measured average axial velocity at the outside chords to the average axial velocity at the inside chords, can be correlated to the UFM correction factor or calibration coefficient to address Reynolds number differences between the Alden Laboratory test and in-plant conditions if the flow profile is not significantly distorted by upsteam piping components, such as elbows located within a few pipe diameters of the LEFM. Where significant distortion occurs, as can be determined from Alden Laboratory test results, then a Reynolds number extrapolation is necessary and acceptable.

3. Acceptability of the theoretical description of the LEFM and its operation.

4. Substantiation that the uncalibrated CheckPlus is typically within a fraction of a percent of the flow rate measured at Alden research Laboratory.

5. Substantiation that the CheckPlus is typically relatively unaffected by flow profile distortion and swirl and, further, that the CheckPlus will provide an approximation of the flow profile.

6. Substantiation that downstream geometry does not have a significant influence on CheckPlus calibration.

The NRC staff finds that the hydraulic aspects of the Check and CheckPlus systems have been accurately described in applicable documentation and that there is a firm theoretical and operational understanding of behavior. With one exception, there is no further need to re-examine the hydraulic bases for use of the CheckPlus systems in nuclear power plant feedwater applications. The exception, which should be addressed on a plant-specific basis, occurs if there is an upstream tubular flow straightener.

The Check system is more sensitive to flow profile perturbations caused by upstream and potentially by downstream hardware configuration changes than the CheckPlus, as addressed in this SE. The effect of such changes must be addressed on a plant-specific basis, if the Check system is proposed for use in that plant.

3.0 TECHNICAL EVALUATION

3.1 Engineering Report ER-157P

3.1.1 Ultrasonic Flow Meter Design and Characteristics[1]

To determine volumetric flow rate, the Cameron/Caldon UFM transmits an acoustic pulse along a selected path and records the arrival of the pulse at the receiver. Another pulse is transmitted in the opposite direction and the time for that pulse is recorded. Since the speed of an acoustic pulse will increase in the direction of flow and will decrease when transmitted against the flow, the difference in the upstream and downstream transit times for the acoustic pulse provides information on flow velocity. Once the difference in travel times is determined, the average velocity of the fluid along the acoustic path can be determined. Therefore, the difference in transit time is proportional to the average velocity of the fluid along the acoustic path.

Cameron/Caldon provides an array of ultrasonic transducers installed in a spool piece, 16 transducers to determine average velocity in each of 8 paths in the CheckPlus, housed in fixtures on a spool piece. The transducers are arranged such that they form parallel and precisely defined acoustic paths. Using the resulting time measurements and the known path lengths, the average fluid velocity along each path length is determined. Using Gaussian quadrature integration, the velocities measured along the acoustic paths are combined to determine the average volumetric flow rate through the flow meter cross section. The chordal placement is intended to provide an accurate numerical integration of the axial flow velocity along the chordal paths. Note that this process assumes a continuous velocity profile in the flow area perpendicular to the spool piece axis. Although the velocity profile can be distorted, the distortion cannot be such that the Gaussian quadrature process no longer provides an acceptable mathematical fit to the profile, such as may occur if the profile has discontinuities.

To obtain the actual average flow velocity a meter factor is applied to the integrated average flow velocity indicated by the UFM. The meter factor for the Cameron/Caldon UFMs is determined through meter testing at the Alden Laboratory and is equal to the true area averaged flow velocity divided by the flow velocity averaged along the meter paths to correlate the meter readings to the average velocity and hence to the average meter volumetric flow. The mass flow rate is found by multiplying the spool area by the average flow velocity and density. The mean fluid density may be obtained using the measured pressure and the derived mean fluid temperature as an input to a table of thermodynamic properties of water. Typically, an uncalibrated CheckPlus will agree with Alden Laboratory tests results to less than 0.5 percent.

[1] Reference 11 provides a concise, easily understood description of the Cameron UFM.

Use of a spool piece and chordal paths improves the dimensional uncertainties including the time measurement of the ultrasonic signal and enables the placement of the chordal paths at precise locations generally not possible with an externally mounted UFM. This allows a chordal UFM to integrate along off-diameter paths to more efficiently sample the flow cross section. In addition, a spool piece has the benefit that it can be directly calibrated in a flow facility, improving measurement uncertainty compared to externally mounted UFMs that were historically installed in nuclear power plant feedwater lines.

The instrument design and general operation are summarized in References 7 and 11 and are acceptably addressed and approved in References 1 - 6 and 12, in addition to many plant-specific publications such as Reference 13. Plant-specific operation considerations must be addressed by the applicant.

3.1.2 Calibration and In-Plant Testing

Calibration testing at a qualified test facility and at the plant involves traceability to a national standard, facility uncertainty, and facility operation. Alden Research Laboratory is an independent supplier of National Institute of Standards and Technology (NIST) traceable Flow Meter Calibration Services. The NRC staff audited testing at Alden Laboratory as reported in References 14 and 15 and verified Alden's traceability to NIST. The NRC staff's audit also found that Alden's processes and operation were consistent with the claimed facility uncertainties. These references provide an acceptable basis for concluding that the Alden Research laboratory meets the stated testing criteria.

The Check and CheckPlus UFMs have an ability to provide the flow distribution/velocity profile as a function of radius and angular position in the spool piece and the demonstrated insensitivity to changes in operation associated with transfer changes and plant changes.

However, that transfer traceability requires acceptable simulation of the plant geometry in the test facility and some changes, such as location of a flow straightener immediately upstream of the UFM, can introduce errors that must be addressed. Methods to address such issues include a sufficiently broad range of test conditions to bracket the effects.

Test fidelity, such as test versus planned plant configuration, test variations to address configuration differences and potential effects of operation on flow profile and calibration, should be addressed on a plant-specific basis. The applicant requests must provide a comparison of the test and plant piping configurations with an evaluation of the effect of any differences that could affect the UFM calibration. Further, sufficient variations in test configurations must be tested to reasonably establish that test-to-plant differences have been bracketed in the determination of UFM calibration and uncertainty. Historically, calibration testing has acceptably covered upstream effects due to differences between the test and in-plant configurations by applying a wide variation of configurations during testing to distort the flow profile. This had not been done to address downstream effects under the assumption that such effects would not propagate upstream far enough to perturb the UFM signals. Although these subjects are not addressed in Revision 8, they are addressed in this safety evaluation, because the results are applicable to use of ER-157P, Revision 8. These subjects are addressed in Sections 3.2.1 and 3.2.2, respectively.

3.1.3 In-Plant Operation

Each applicant must conduct an in-depth evaluation of the UFM following installation at its plant that includes consideration of any differences between the test and in-plant results and must prepare a report that describes the results of the evaluation. This should address such items as calibration traceability, potential loss of calibration, and cross-checks with other plant parameters during operation to reasonably ensure consistency between thermal power calculations based upon the LEFM and other plant parameters.

3.1.4 Operation with a Failed Component

Revision 8 of ER-157P states that "The redundancy inherent in the two measurement planes of an LEFM CheckPlus also makes this system more resistant to component failures" when compared to the Check. "For any single component failure, continued operation at a power greater than that prior to the uprate can be justified with a CheckPlus system ... since the system with the failure is no less than an LEFM Check." Licensees referencing ER-157P, Revision 8, must ensure compliance with limitations and conditions discussed in Section 4.0.

3.1.5 Spool Piece Dimensional Effects on UFM Response

Appendix A of ER-157P, Revision 8, addresses the effect of variation in such spool piece dimensions as as-built internal diameter and sonic path lengths, path angles, and path spacings. The described processes for addressing these effects are acceptable.

3.1.6 Transducer Installation Sensitivity

Transducers are typically removed after Alden Laboratory testing to avoid damage during shipping the spool piece to the plant and are later re-installed. Further, transducers may be replaced following failure or deterioration during operation. Replacement potentially introduces a change in position within the transducer housing that could affect the chordal acoustic path. Appendix D of the ER-157P, Revision 8, TR addresses replacement sensitivity by describing tests performed at the Cameron/Caldon Ultrasonics flow loop and provides a comparison of test results to analyses of potential placement variations that shows that the test results are bounded by predicted behavior. One would expect an uncertainty, associated with the test loop, even if nothing was changed. This is not addressed in this TR. Rather, all of the test uncertainty is conservatively assumed to be due to transducer replacement. Further, as stated, the analyses predict a larger uncertainty than obtained during testing, and the analysis uncertainty is used for transducer replacement uncertainty. The NRC staff considers this approach to be sufficient to cover the inability of the test loop to achieve flow rates, comparable to those obtained in plant installations, and to cover any analysis uncertainty associated with applications with pipe diameters that differ from the tests. Therefore, the NRC staff finds that transducer replacement has been acceptably addressed and the ER-157P process for determining transducer replacement uncertainty is acceptable.

3.1.7 The Effects of Random and Coherent Noise on Leading Edge Flow Meter CheckPlus Systems

Appendix C of the ER-157P, Revision 8, TR provides a proprietary methodology for the test- and plant-specific calculation of the contribution of noise to the CheckPlus uncertainty. The

NRC staff has reviewed this methodology and finds it acceptable for the applicants to use this methodology in their MUR requests.

3.2 Items Not Addressed in ER-157P topical report

3.2.1 Evaluation of the Effect of Downstream Piping Configurations on Calibration

Typically, the effects of downstream equipment need not be considered for typical LEFM installations. The turbulent flow regimes that exist when the plant is near full power result in limited upstream flow profile perturbation from the downstream piping. In some cases, however, an installation may contain piping elbows or other hardware located immediately downstream of the end of the UFM spool piece. This was the case, for example, with a Calvert Cliffs Nuclear Power Plant application that the NRC found acceptable (References 16 and 17). In that installation, the spool piece exit is 15 inches from the downstream elbow and the chordal paths are 2.7 diameters upstream of the entrance to the piping bend.

In the Reference 16 supplemental letter, the Calvert Cliffs Nuclear Power Plant Inc., the licensee, explained why the close proximity of a downstream piping difference between in-situ and laboratory installations still results in an acceptable calibration testing configuration. In addition, the licensee indicated that previous UFM calibrations and installations had confirmed that pipe bends in downstream locations closer than the Calvert Cliffs Nuclear Power Plant in-situ installations had an insignificant effect on the meter factor. Based on the installation location of the Calvert Cliffs Nuclear Power Plant flow meters, and on experience with other flowmeters installed upstream of piping bends, the NRC staff found that the licensee's laboratory calibration was sufficiently fabricated to provide meaningful data based on the modeling of piping geometry upstream of the UFM.

Consequently, an applicant with a comparable geometry can reference the above finding in Section 3.2.1 to support a conclusion that downstream geometry does not have a significant influence on CheckPlus calibration. However, CheckPlus test results do not apply to a Check and downstream effects with use of a CheckPlus with disabled components that make the CheckPlus comparable to a Check must be addressed. The NRC staff states that conducting applicable Alden Laboratory tests is an acceptable method.

3.2.2 Evaluation of the Effect of Upstream Flow Straighteners on CheckPlus Calibration

A previously undocumented effect of upstream tubular flow straighteners on CheckPlus calibration was discovered during Alden Laboratory testing while NRC staff members were at the site on August 24, 2009, that, to the NRC staff's knowledge, did not apply to any previous CheckPlus installations. As a follow-up, additional tests were conducted with several flow straighteners and two different pipe/spool piece diameters to enhance the statistical data basis and to develop an understanding of the interaction between flow straighteners and the CheckPlus. The results are provided in the proprietary Reference 18.

Cameron concluded that two additional meter factor uncertainty elements are necessary if a CheckPlus is installed downstream of a tubular flow straightener and provided uncertainty values derived from the test results. The data also provide insights into the unique flow profile characteristics downstream of tubular flow straighteners and a qualitative understanding of why the flow profile perturbations may affect the CheckPlus calibration.

Cameron determined that the two uncertainty elements are uncorrelated and therefore combined them as the root sum squared to provide a quantitative uncertainty. The NRC staff judges that the Cameron approach is valid, but is concerned that the characteristics of existing tubular flow straighteners in power plants may not be adequately represented by the samples tested in the laboratory. Any applicant that requests an MUR with the upstream flow straightener configuration discussed in Section 3.2.2 should provide justification for claimed CheckPlus uncertainty that extends the justification provided in Reference 17. Since the Reference 17 evaluation does not apply to the Check, a comparable evaluation must be accomplished if a Check is to be installed downstream of a tubular flow straightener.

3.2.3 Resolution of the Processing of Large Contributors to Uncertainty

Table A-1 of ER-157P, Revision 8, TR tabulates the 22 representative thermal power uncertainties that contribute to a total uncertainty of 0.54 percent and 0.396 percent for the Check and CheckPlus, respectively. Most of the contributors are less than 0.1 percent, but the listed profile factor and steam enthalpy are significantly larger. This is inconsistent with Footnote 1 of the table, which states that "if the root sum square of individual uncertainties is to represent the total system uncertainty accurately, the contributing individual uncertainties must be roughly comparable in magnitude." The footnote continues with the statement that "although the profile factor uncertainty is dominant in the table, it is made up of several components" and "none of the components is correlated." A separate table lists the contributors to the profile factor. For the Check, these are within a factor of two of each other. For the CheckPlus, they vary in the second significant figure and are almost identical.

With respect to the steam enthalpy, and in particular its moisture content, Reference 18 states that some licensees may have the results of an in-plant test where the moisture uncertainty is made up of a number of small contributors. This may alleviate the issue. However, this does not address cases where (1) in-plant data are not available or (2) the ER-157P, Revision 8, TR issue where significant moisture is assumed to be equal to a typical steam supplier's guarantee for some early water reactor designs with an uncertainty that is also typical of some early designs. ER-157P, Revision 8, TR also presents an alternative analysis where zero moisture is assumed. Some modern separators and dryers deliver steam with a moisture content in the 0.05 percent range, and these licensees often assume a zero moisture content that is conservative since the calculated power will be greater than actual power for such cases. No uncertainty is necessary, if there is no moisture.

To address the case where significant moisture uncertainty remains, Reference 18 discusses an analysis, in which the uncertainty in thermal power (due to measurement of all variables excluding moisture) is assumed to be normally distributed with two standard deviations of 0.3357 percent, essentially the aggregate uncertainty of all contributors excluding moisture for the CheckPlus system. The contribution of the uncertainty due to moisture content is then calculated by multiplying a second, uniformly distributed random number times the uncertainty band assumed in Table A-1 and Monte Carlo calculations of total power uncertainty are obtained. The results are summarized in Reference 18, Figure 1. The author "concluded that licensees assuming large uncertainties in steam moisture content should have an engineering basis for the distribution of the uncertainties or, alternatively, should ensure that their calculations provide margin sufficient to cover the differences shown in Figure 1." Therefore, the NRC staff finds that the uncertainty issue is acceptably resolved.

3.2.4 Proposed Content of Measurement Uprate Requests

The NRC staff's SE for the approved ER-80P TR (Reference 2) provides four criteria that the licensee should address:

1. Discuss maintenance and calibration procedures that will be implemented with the incorporation of the LEFM, including processes and contingencies for inoperable LEFM instrumentation and the effect on thermal power measurements and plant operation.

2. For plants that currently have LEFMs installed, provide an evaluation of the operational and maintenance history of the installed instrumentation and confirmation that the installed instrumentation is representative of the LEFM system and bounds the analyses and assumptions set forth in TR ER-80P.

3. Confirm that the methodology used to calculate the uncertainty of the LEFM in comparison to the current feedwater instrumentation is based on accepted plant setpoint methodology (with regard to the development of instrument uncertainty). If an alternative approach is used, the application should be justified and applied to both venturi and ultrasonic flow measurement instrumentation installations for comparison.

4. Licensees for plant installations where the ultrasonic meter (including LEFM) was not installed with flow elements calibrated to a site specific piping configuration (flow profiles and meter factors not representative of the plant specific installation), should provide additional justification for use. This justification should show that the meter installation is either independent of the plant specific flow profile for the stated accuracy, or that the installation can be shown to be equivalent to known calibrations and plant configurations for the specific installation including the propagation of flow profile effects at higher Reynolds numbers. Additionally, for previously installed calibrated elements, the licensee should confirm that the piping configuration remains bounding for the original LEFM installation and calibration assumptions.

These criteria are to be addressed by applicants as part of their MUR request.

Item 4 allows for installation of a previously calibrated UFM where the calibration was performed at lower Reynolds numbers if acceptable justification is provided. Cameron/Caldon has always obtained a pre-installation calibration of each CheckPlus UFM at Alden Laboratory before installing the UFM and has acceptably addressed propagation of flow profile effects at the higher Reynolds numbers that exist in the licensee's nuclear power plants. Cameron/Caldon then conducts additional confirmatory in-plant tests following installation as part of the final acceptance / commissioning process that provides the final positive confirmation that actual performance in the field meets the uncertainty bounds established for the instrumentation.

Item 4 also allows for installation without a pre-installation calibration.[2] Consequently, there is a background of NRC staff actions to support submission of an MUR request in which all of the

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[2] Another UFM vendor encountered calibration errors when it did so and NRC suspended its approval due, in part, to errors introduced by this approach (Reference 21). The NRC staff notes, however, that the CheckPlus has features that would have prevented these errors if acceptably addressed prior to and following installation.

data necessary to support the final installation and operation have not been obtained. This background includes both pre-installation and post-installation testing.

During a closed meeting with the NRC staff (Reference 19) on September 15, 2009, Cameron/Caldon stated that there may be situations, when test scheduling could not be arranged to be consistent with licensee's plans of implementing an uprate and, if the tests had to be completed before the licensee could submit the MUR Requested Licensing Action (RLA), it may cause up to a two year delay in uprate implementation due to the need for an outage to accomplish the implementation. Consequently, Cameron/Caldon discussed the possibility that certain licensees may seek to submit their MUR RLAs, using bounding uncertainty parameters in a Revision 0, of the MUR RLA submittal, while the flow meter is being tested in the laboratory. In these cases, the requesting licensee would commit to provide a Revision 1, MUR RLA submittal that would confirm that the laboratory testing demonstrates that the Revision 0, uncertainties selected by the licensee are indeed bounding of the flow meter's performance. This process would be referred to as a "Conditional MUR Application," defined as RLA seeking a MUR uprate that uses the bounding flow measurement uncertainty value and is submitted for NRC review while confirmatory testing is being performed (Reference 22).

This constitutes an application based on a laboratory test that has yet to be performed or completed. Based on a narrow read of LIC-109 (Reference 21), a project manager (PM) could deem such a request unacceptable. This PM's action might be consistent with the intent of LIC-109, because it eliminates the uncertainty that a licensee could be unable to meet its commitment due to either unsuccessful testing or delays in the testing process.

Appendix B of LIC-109, Revision 1, states that the PM should "determine whether the request for licensing action (RLA) commits to submit required information at a later date... If the licensee or applicant identifies a calculation or other information that is needed, but has yet to be performed or completed, the RLA is unlikely to be acceptable for review." This is the "Promised Information" criterion. Note that no UFM could be installed if the letter of this statement is followed, because final commissioning and actual use of the UFM requires in-plant testing that is conducted after NRC approval of the licensing amendment request has been obtained (Reference 21).

In Reference 22, Cameron/Caldon addressed the likelihood that testing would fail to confirm the bounding uncertainty parameters. They showed that the meter factor uncertainty was 0.22 percent on the basis of over 94 CheckPlus UFMs subjected to over 2045 calibration tests of over 409 test configurations, with a higher uncertainty of about 0.32 percent for a single meter that was less than 10 pipe diameters downstream of a tubular flow straightener. Typically, the differences between bounding Revision 0, and post-test Revision 1, analyses have been between 0.02 and 0.03 percent. Consequently, licensee Revision 0, submittals would typically contain an additional 0.02 to 0.03 percent margin over the expected Revision 1, calibration results to reduce the likelihood of a failure to confirm the submitted MUR Revision 0, request.

Reference 22 also provided typical schedules to illustrate the impact of a test schedule conflict and the possibility of basing the MUR on a Revision 0, submittal, and provided cost/benefit information. Cameron/Caldon stated that the NRC would be reducing unnecessary regulatory burden by accepting and reviewing a Conditional MUR Application. However, the criterion 4 applies to an applicant as opposed to the vendor request associated with the Cameron/Caldon proposal. Furthermore, this approach would be a deviation from the historic review process, where test results are provided at the time of the initial MUR request and may conflict with LIC-109, Revision 1. The NRC staff has concluded that such a request is a process deviation and cannot be approved at this time on a generic basis. Therefore, NRC staff determined that no update to LIC-109, Revision1, is needed, because it adequately addresses the current process of the MUR RLA submittals.

4.0 LIMITATIONS AND CONDITIONS

Revision 8 of ER-157P, states that "The redundancy inherent in the two measurement planes of an LEFM CheckPlus also makes this system more resistant to component failures" when compared to the Check. "For any single component failure, continued operation at a power greater than that prior to the uprate can be justified with a CheckPlus system ... since the system with the failure is no less than an LEFM Check." Licensees referencing ER-157P, Revision 8, must ensure compliance with the following limitations and conditions:

1. Continued operation at the pre-failure power level for a pre-determined time and the decrease in power that must occur following that time are plant-specific and must be acceptably justified.

2. The only mechanical difference that potentially affects the quoted statement is that the CheckPlus has 16 transducer housing interfaces with the flowing water, whereas the LEFM Check has 8. Consequently, a CheckPlus operating with a single failure that is assumed to disable one plain of transducers is not identical to an LEFM Check. Although the effect on hydraulic behavior is expected to be negligible, this must be acceptably quantified if a licensee wishes to operate as stated. An acceptable quantification method is to establish the effect in an acceptable test configuration such as can be accomplished at the Alden Laboratory.

5.0 CONCLUSION

Based on the review of ER-157P, Revision 8, TR the NRC staff finds that licensees can reference this TR in their applications for MUR power uprates and that their plant-specific measurement uncertainty analyses may follow the example of ER-157P, Revision 8, TR for the LEFM Check or LEFM CheckPlus system subject to the following qualifications as discussed in this SE:

1. Continued operation at the pre-failure power level for a pre-determined time and the decrease in power that must occur following that time are plant-specific and must be acceptably justified.

2. A CheckPlus operating with a single failure is not identical to an LEFM Check. Although the effect on hydraulic behavior is expected to be negligible, this must be acceptably quantified if a licensee wishes to operate using the degraded CheckPlus at an increased uncertainty.

3. An applicant with a comparable geometry can reference the above Section 3.2.1 finding to support a conclusion that downstream geometry does not have a significant influence on CheckPlus calibration. However, CheckPlus test results do not apply to a Check and downstream effects with use of a CheckPlus with disabled components that make the

CheckPlus comparable to a Check must be addressed. An acceptable method is to conduct applicable Alden Laboratory tests.

4. An applicant that requests a MUR with the upstream flow straightener configuration discussed in Section 3.2.2 should provide justification for claimed CheckPlus uncertainty that extends the justification provided in Reference 17. Since the Reference 17 evaluation does not apply to the Check, a comparable evaluation must be accomplished if a Check is to be installed downstream of a tubular flow straightener.

5. An applicant assuming large uncertainties in steam moisture content should have an engineering basis for the distribution of the uncertainties or, alternatively, should ensure that their calculations provide margin sufficient to cover the differences shown in Figure 1 of Reference 18.

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Principle Contributors: Warren Lyon (NRR/DSS/SRXB)
Pong Chung (NRR/DE/EICB)

Date: August 16, 2010

CAMERON

Measurement Systems

Engineering Report No. ER-157(NP-A), Rev. 8 & Rev. 8Errata
May 2008

Rev. 8 Errata

1.0 Main Body (Non-proprietary)

1. Page 4: Change the first sentence to read:
   "An LEFM CheckPlus system is illustrated in Figure 2."

2. Page 6, first paragraph after bulleted list, second sentence, add a foot note after "component failure*" as follows:
   "* A component failure is defined as a failure of any single subassembly of the LEFM measurement system, such as a power supply, a transducer, an acoustic processor (transmitter/receiver), or a (digital) processor."

3. Page 6, first paragraph after bulleted list, third sentence, insert the word "component" between "single" and "failure".

4. Page 6, second paragraph after bulleted list, first sentence, change "principle" to "principal".

5. Page 6, second paragraph after bulleted list, last sentence, insert the word "component" between "single" and "failure".

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Engineering Report: ER-157(NP-A) Revision 8 & Rev. 8Errata

Supplement to Caldon Topical Report ER-80P: Basis for Power Uprates with an LEFM Check or an LEFM CheckPlus System

Table of Contents

1. Background and Purpose

In the June 2000 Federal Register, the NRC published the final rule amending 10CFR50 Appendix K to permit power increases based on improvements in accuracy of the instrumentation used to measure thermal power. A previously submitted Topical Report, ER 80P, described the principles and performance characteristics of a Caldon feedwater measurement system, the LEFM Check, that, because of its superior flow measurement accuracy, can be used for such uprates. The analyses documented in ER 80P were performed in 1997, well in advance of the rulemaking and also in advance of the delivery of a system. ER 80P used as a basis for its "typical" analysis a 2-loop PWR and a 2-feedwater line BWR. It also employed performance data of earlier Model LEFM Systems; in early 1997 when ER 80P was submitted, prototype hardware for LEFM Check was being built. The magnitude of the uprate postulated in ER 80P was conservatively set at 1%. NRC reviewed and accepted ER 80P in connection with a 1% uprate of both units at a pressurized water reactor plant.[1]

In May, 2000 Caldon issued a supplement to ER 80P[2], ER 160P, that assesses, for a 1.4% power uprate, the margin between the uprate power and the power at which the Appendix K safety analyses were performed. ER 160P was reviewed and accepted by NRC, in connection with a 1.4% power uprate of a single unit PWR plant.[3] The information in ER 160P remains bounding for the performance of LEFM Check systems. Accordingly, licensees using the LEFM Check system may continue to reference this document when applying for uprates in the 1.4% range.

This document supplements ER 80P and ER 160P in several respects:

- It describes a second Caldon system, the LEFM CheckPlus, that is more accurate than the LEFM Check. Licensees who wish to take advantage of the superior accuracy of the LEFM Check Plus in selecting the amount of a power uprate will reference ER-157P.
- It characterizes the performance of both the LEFM Check and CheckPlus systems using representative calibration data for systems now in operation as well as measured data from these systems. As a result, the performance of the LEFM Check system calculated herein is slightly better than that of ER 160P. Licensees using an LEFM Check system and applying for an uprate greater than 1.4% may choose to reference ER-157P.
- It assesses the margin between the uprate power and the power at which safety analyses are performed for uprates of 1.4% and 1.7%. Uprates with LEFM Check and LEFM CheckPlus Systems will lie between these values.
- It updates, through 1999, LER data on overpower incidents previously included in ER 160P. It also briefly summarizes field experience, through 2007, with LEFM Check and CheckPlus systems.
- It includes two new appendices, C and D, not included in earlier revisions of this document. Specifically, Appendix C contains a more detailed description of how coherent noise affects the accuracy of the transit time measurements than was included in prior revisions. Appendix D describes and quantifies an uncertainty not explicitly included in ER-80P and earlier

[1] Reference 4 (section 5 of this report): NRC SER dated March 8, 1999
[2] Reference 5
[3] Reference 6: NRC Safety Evaluation related to Amendment 31 Operating License NPF-390, Docket number 50-390

revisions of this document: the uncertainty owing to the potential change in the location of the acoustic path(s) when (one or more) transducers are replaced.

Much of the information contained in ER 80P remains applicable and is necessary to a full understanding of the material presented in this document. In particular, it may be necessary to consult Appendices A, B, C, D, and F* of ER 80 P for a complete understanding of the material herein. It should be pointed out that the analysis of the sensitivity of LEFM Check and CheckPlus systems to hydraulic configurations, treated in Appendix F of ER-80P, has been supplemented for a broad spectrum of system installations in Reference 7. This reference provides hydraulic profile and calibration coefficient data obtained in the calibration laboratory as well as profile data for the final installations. It may serve as useful background in understanding the insensitivity of Check and CheckPlus systems to upstream hydraulics and to variations over time of the hydraulics

An updated version of Appendix E of ER 80P, a detailed accounting of the uncertainties in a power measurement using an LEFM Check or an LEFM CheckPlus, is provided as Appendix A to this document. This appendix has also been revised to reflect the changes in the analyses outlined above.

2. System Descriptions

The characteristics and design features of the LEFM Check are described in detail in ER 80P. A very brief recapitulation is provided here. Figure 1 is a diagram of an LEFM Check employing one flow measuring spool piece (for the measurement of total feedwater flow). The eight transducer assemblies that form the four acoustic paths of an LEFM Check are shown in the diagram. As described in Appendix B of ER 80P, the LEFM Check measures the transit times of pulses of ultrasonic energy traveling these paths, both with the flow and against it. From these measurements it forms four path length-fluid velocity products, which it numerically integrates to determine volumetric flow. It also measures sound velocity along the four acoustic paths, which it uses, along with a feedwater pressure input, to determine fluid temperature and density.

* These ER 80P Appendices cover the following subjects:
A Uncertainties in existing [conventional] calorimetric instrumentation (including thermodynamic sensitivity coefficients also applicable to the LEFM analyses of this document)
B The general principles of chordal LEFMs.
C The LEFM water temperature algorithm
D Identifying and Bounding the uncertainties in LEFM flow and temperature measurements
F A survey of hydraulic performance of chordal LEFMs.

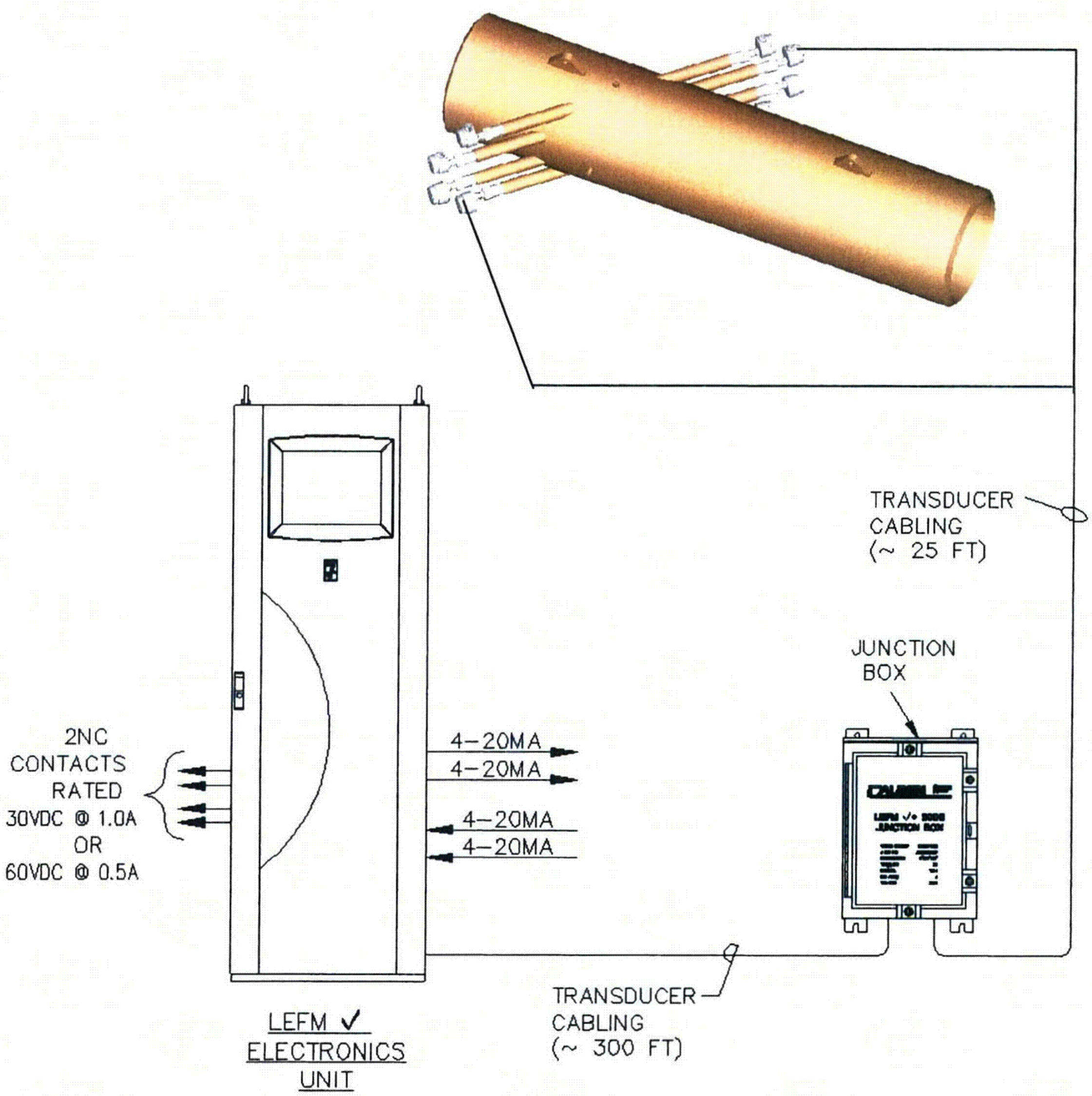

Figure 1: Diagram of a One Loop LEFM Check System

An LEFM CheckPlus System, illustrated in Figure 2, consists essentially of two LEFM Check systems, both hydraulically and electronically. The electronics for the two subsystems, while electrically separated, are housed in a single cabinet, as shown in the figure.

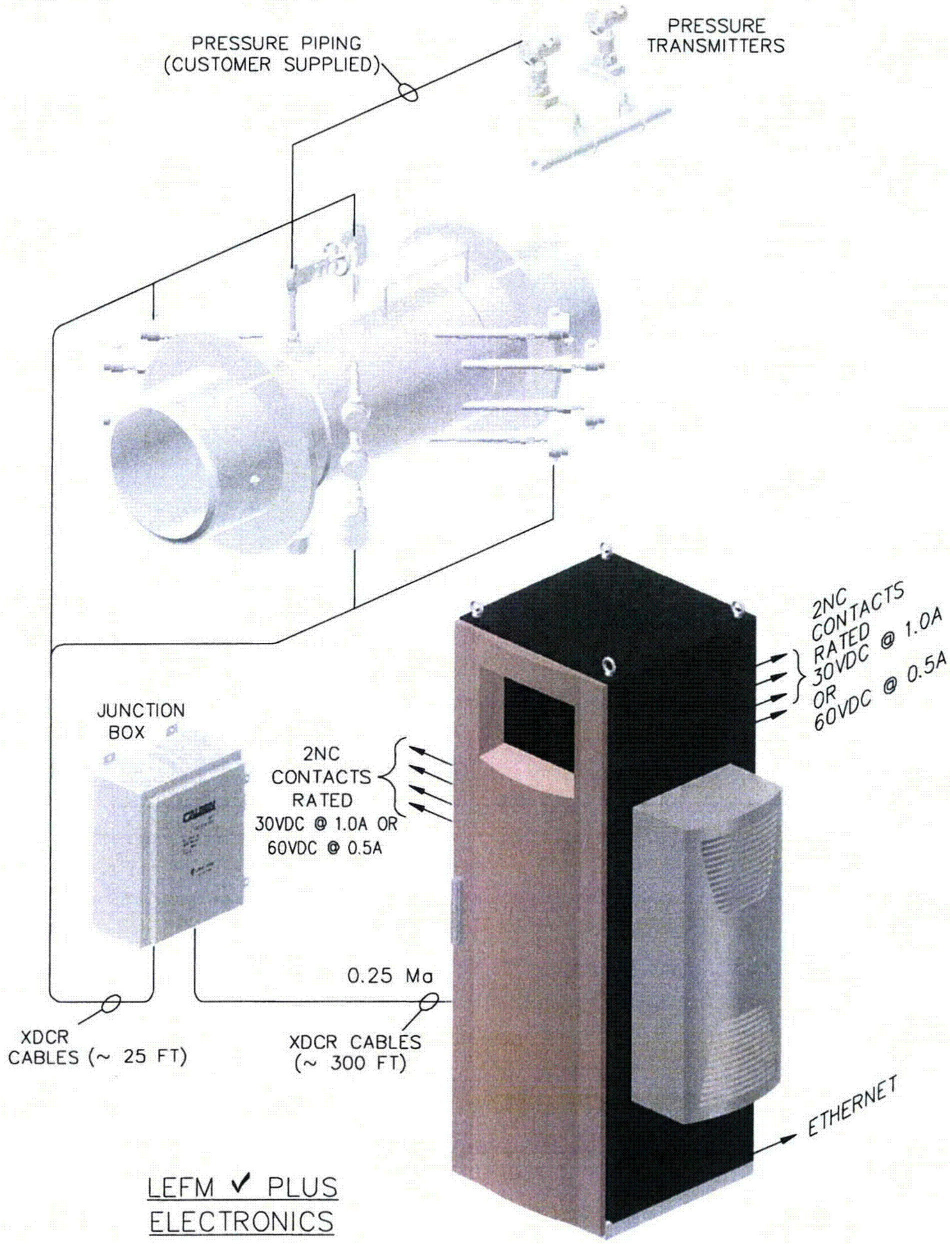

Figure 2: Diagram of a One Loop LEFM CheckPlus System

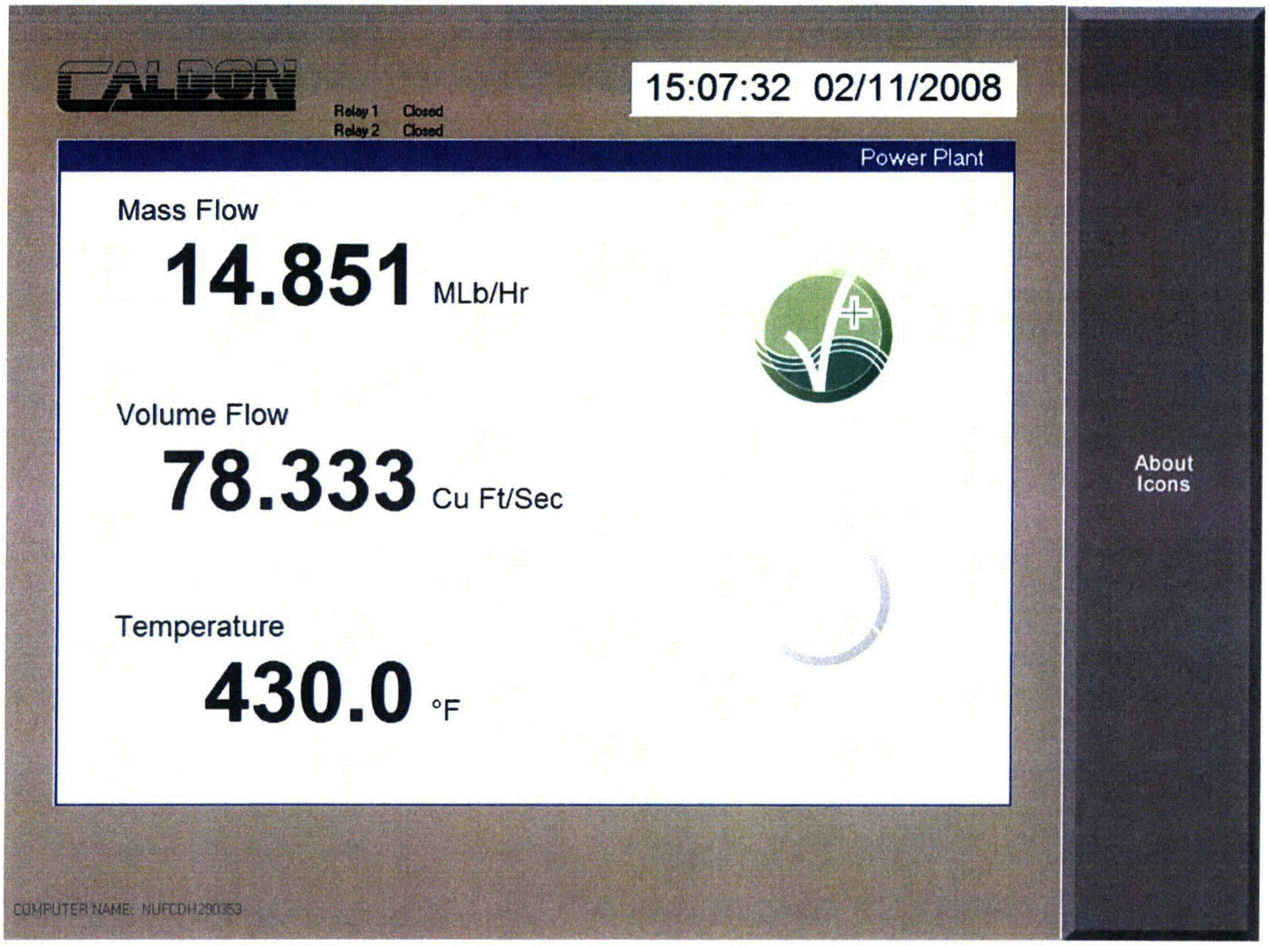

Figure 3: LEFM CheckPlus Main Display

Figure 3 shows the main display screen for the LEFM CheckPlus system. The status of the LEFM system is displayed on this screen by the "check" and "wrench" icons. If the system is in Normal (fully functional and meeting its design basis accuracy requirements), the check is green and the wrench is gray. If maintenance is necessary, but the system can still operate in a reduced accuracy mode, the wrench will turn to yellow. If the auto checking features of the LEFM determine that its functionality cannot be assured, the "check" icon will turn red.

An LEFM CheckPlus will provide a more accurate measurement of feedwater flow than will an LEFM Check system. This advantage arises from two features of the CheckPlus System:

- As can be seen in Figure 2, the 8 acoustic paths of the CheckPlus form two measurement planes, 90 ° apart. The velocity measured by an acoustic path in one of these planes consists of the vector sum of the axial fluid velocity as projected onto the path and any transverse component of fluid velocity, also as projected onto the path. When the net velocity measured by this acoustic path is averaged with the velocity measured by its companion path in the second plane, the transverse components of the fluid velocity will cancel, so that the average reflects the contribution of the axial velocity only. Thus the numerical integration of the 4 pairs of averaged axial velocities measured by an LEFM CheckPlus is inherently a more

accurate computation of the volumetric flow than can be obtained from a single plane of 4 acoustic paths[4]
- Because there are twice as many paths, errors due to some of the uncertainties in transit time measurements and path length are reduced. For example, to ensure independence, the two measurement planes of a CheckPlus employ independent clocks. As a result the aggregate clock error is smaller

The redundancy inherent in the two measurement planes of an LEFM CheckPlus also makes this system more resistant to component failures. For any single component failure, continued operation at a power greater than that prior to the uprate can be justified with a CheckPlus system, whereas with an LEFM Check, a failure will generally require a reduction in power to a level consistent with the accuracy of the system following the failure, typically the pre-uprate power. The power level that can be justified in the event of a single failure in an LEFM CheckPlus system is installation specific. Qualitatively, justification of a power level 1.4% above the pre-uprate power might be expected, since the system with the failure is no less than an LEFM Check.

The principle uncertainty element in an 8 path system operating with only 4 paths in service arises because of the potential for uncentered swirl to change in service. This potential is limited in LEFM Check systems by the choice of hydraulic locations. It is not necessarily limited for potential hydraulic locations for LEFM CheckPlus systems. Consequently this hydraulic uncertainty must be treated on a case basis for licensees choosing to operate at a power above the pre-uprate power following any single failure in a CheckPlus system.

A power uprate can be obtained based on improved accuracy of the instrumentation used to measure thermal power, in accordance with the 10CFR50 Appendix K rule change described in Section 1 above. The LEFM Check and LEFM CheckPlus are instrument systems that will support such uprates. Both provide measurements of feedwater mass flow and temperature leading to an uncertainty in thermal power significantly better than current instrumentation[5]. Table A-1 of Appendix A of this document tabulates the uncertainties in the thermal power computation for a representative BWR or PWR using feedwater flow and temperature measurements by a single meter, either an LEFM Check or an LEFM CheckPlus. The bases for all of the entries in this table and how these entries are combined are also found in Appendix A. The appendix demonstrates that a thermal power measurement using the LEFM Check can provide an overall accuracy of better than ±0.6%, 95% confidence level (± 0.49% to 0.54%[6]). The LEFM CheckPlus system can support power measurement accuracies approaching ±0.3%, 95% confidence level (± 0.336% to 0.396% for the system discussed in the appendix).

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[4] It should be noted that in hydraulic configurations where transverse flow components are small, an LEFM Check can produce equally accurate results. However, the calibration of a CheckPlus is in general less sensitive to the specifics of a hydraulic configuration than is that of an LEFM Check.

[5] Appendix A of ER 80P calculates an uncertainty of ± 1.4% (95% confidence level) for a 2 loop installation using typical conventional flow and temperature instruments.

[6] The range is due to differences in the accuracy with which steam enthalpy is determined. See Table A-1, Appendix A.

Figure 4: Calibration Test of an LEFM Check Spool (Looking Upstream)

Figure 5: Calibration Test of an LEFM CheckPlus Spool (Looking Downstream)

It should again be emphasized that the figures of Table A-1 of Appendix A are typical bounding values. Each licensee will commit to computing their bounding values and will submit, as part of his uprate package, an accounting of the uncertainties applicable to his plant. In any case, the licensee will maintain, as part of his design basis, LEFM calibration and other data justifying the amount of the uprate requested in his license amendment application.

Some installations will employ multiple LEFM Check or CheckPlus systems to measure flow in the individual feeds to steam generators (for PWRs) or to each reactor vessel feedwater nozzle (for BWRs). Such systems may have slightly better performance than the systems of Table A-1 of Appendix A. When individual loop flow measurement errors are randomly combined, the net measurement error will likely be smaller.

3. Probabilistic Basis for Power Uprate

To assess the increase in thermal power rating appropriate to the use of LEFM systems, this discussion will interpret the data of Appendix A on a probabilistic basis. When the ASME developed standards for the measurement of steam turbine heat rate in power plants, they performed a series of Monte Carlo analyses which demonstrated that, if the uncertainty elements of a measurement system are calculated on a 2 standard deviation basis, the uncertainty in the overall measurement is characterized by a normal distribution with 2 standard deviations equal to the root sum square of appropriately weighted individual elements (Reference 1). This result held even when the uncertainties of individual elements were not normally distributed. For example, a particular element might be characterized by a "roulette wheel" distribution (a flat or uniform distribution) between defined uncertainty bounds. That the overall uncertainty was characterized by a normal distribution conclusion was subject only to one condition: that no single element dominated the calculation of the overall uncertainty.

The individual entries of Table A-1 of Appendix A meet this condition. The profile factor uncertainties of the LEFM Check and LEFM CheckPlus appear dominant, but are, in fact, made up of several elements, none of which is dominant (see the discussion in Appendix A). Therefore, the overall LEFM Check and LEFM CheckPlus uncertainties described in Appendix A and summarized in the preceding section will be normally distributed. Furthermore, the sensitivity of the results to the nature of the elemental uncertainty distribution has been investigated in ER 80P, Appendix G. This investigation also shows that the distribution of the total uncertainty is likely to be normal whether the contributors are each normally distributed or distributed uniformly between limits.

Appendix A implies an uncertainty probability distribution wherein one standard deviation of the LEFM Check uncertainty is likely to be less than ±0.3% full power (since two standard deviations are less than ± 0.6%). Table 1 below, shows that, with a distribution characterized by this standard deviation, there is essentially no chance (less than one in 3 million) that an operator using the LEFM Check to determine thermal power will exceed a power level 1.5% above that to which he is controlling. For the LEFM CheckPlus distribution, one standard deviation is likely to be a little greater than ±0.15% full power. From Table 1, there is essentially no chance that an operator using the LEFM CheckPlus will exceed a power level 0.75% above that to which he is controlling.

For comparison purposes Table 2 tabulates odds for a conventional (nozzle based) power determination having an uncertainty distribution with one standard deviation of 1% in accordance with the original Appendix K allowance of 2% (two standard deviations) for instrument uncertainty. As compared to the 10CFR50 Appendix K base case, the reduction in the probability of overpower incidents with LEFM Check and CheckPlus systems, even at uprated power levels, is obvious from the Table.

Number of Standard Deviations	Venturi Nozzle Bounds	LEFM Check Bounds	LEFM CheckPlus Bounds	Probability of Operation Within Bounds	Odds of Exceeding Bounds on the High Side
1	1.0%	0.3%	0.15%	68%	1/6.3
2	2.0%	0.6%	0.3%	95.4%	1/44
3	3.0%	0.9%	0.45%	99.7%	1/741
4	4.0%	1.2%	0.6%	99.994%	1/32,300
5	5.0%	1.5%	0.75%	99.99994%	1/3.3 million

Table 1.
Probabilities and Odds Associated With Assumed Nozzle and LEFM Uncertainty Bounds[7]

To clarify the basis for a power increase with use of the LEFM Check or LEFM CheckPlus, the results of Table 1 are shown graphically in Figures 6, 7, and 8. All three figures show power level (as a percent of the pre-uprate 100% power) along the "x" axis, and probability data along the "y" axis. All three figures illustrate three cases:

1. Operation at the current 100% power level with the current instrumentation providing a 2% power determination uncertainty,
2. Operation at a 1.4% power increase with an LEFM Check providing a ± 0.6% power determination uncertainty, and
3. Operation at a 1.7% power increase with an LEFM CheckPlus providing a ± 0.3% power determination uncertainty.

Figure 6 shows the probable operating ranges for each of the three cases. As expected, the curves peak at the power level where operation is intended, and fall off symmetrically on either side of the peak. Of greater interest from the standpoint of operating safety is the probability that any given power level will be exceeded, as shown in Figure 7. As Figure 7 shows, the probability of exceeding a given power level is 100%, or a sure thing, just prior to the intended power level. The probability for each of the three cases equalizes at 102% power, which is the power level at which most plants' safety systems are analyzed for acceptable performance.

Figure 8 presents the same data as Figure 7, but focuses in the vicinity of 102% power where the probability curves for the LEFM Check, the LEFM CheckPlus, and current instrumentation intersect. Though the intended operating point is higher for both the LEFM Check and LEFM CheckPlus systems due to the power increase, the probability of exceeding 102% power is the same for all three instruments. In other words, the probability of exceeding the analyzed power level of 102% is the same for the current instrumentation operating at 100%, for the LEFM Check operating at 101.4% and for the LEFM CheckPlus operating at 101.7%.

[7] The probabilities and odds of Table 1 are computed in Appendix B to this document.

Figure 8 also shows another advantage of more accurate power measurements. As power measurement precision increases, the chance of a significant overpower incident decreases. For example, a plant equipped with flow nozzles, intending to operate at 100% of its licensed power, has about a 1 in 100 chance of exceeding 102.3%. On the other hand, the same plant, equipped with the LEFM CheckPlus, and intending to operate at 101.7% of its (previous) licensed power, has less than a 1 in 30,000 chance of exceeding 102.3%. (These odds are based on Table 1. It is not possible to read a probability this low on Figure 8).

There are two assumptions critical to the preceding discussion of thermal power margin. The first is the necessity of an uncertainty distribution that is normal, which has been discussed and, based on the ASME studies and Appendix G of ER 80P, is satisfied. The second is that Table 1 and Appendix A *actually describe* the performance of the instruments in service. Verification that the LEFM systems are operating within their design bounds is provided continuously, on-line, as discussed in detail in ER 80P. But there is no comparable on-line assurance that current nozzle-based instrumentation is operating within its design bounds. This is the basis for the conclusion that power uprates with LEFM systems increase safety.

4. Benefits of On-Line Verification

To illustrate the benefits of on-line verification, Figure 9 shows the results of a survey of sustained overpower events reported in Licensee Event Reports from 1981 through 1999 (Reference 3). The 61 identified events have been categorized by cause in order to examine whether they would have been preventable with the on-line verification capabilities of LEFM systems.

Figure 9 shows that the LEFM systems with on-line verification would have prevented all significant sustained overpower events. Looking at the extremes, five cases have been reported in Licensee Event Reports where steady state overpower has occurred in an amount not consistent with the probability predictions implied by Table 1; i.e., operation at 2% or more beyond the licensed power level. The causes for these events are summarized in Table 2.

LER Number	Reported Power Excursion	Reported Duration	Reported Cause of Event
82-002	2.7%	46 days	Differential pressure transmitter found out of tolerance.
87-069	2.1%	2 days	Procedural - nuclear instruments interval and deadband error allowed beyond limit.
88-035	2%-3%	10 days	Hole in venturi pressure tap.
91-012	2.09%	5 years	Core power calculation error; improper density compensation.
94-002	2.6%	8 months	Perimeter bypass flow of venturi feed nozzles.

Table 2 Sustained Overpower Events Above 102% and Their Causes

In three of these cases, the sustained overpower event was the result of the instrumentation system (transmitters or nozzles) failing to operate as designed. The other two cases were due to procedural errors and improper density compensation. The common link in all of these cases is that there was no indication of a problem until an independent means of measurement or calculation was employed. There is currently no indication available to the operators for the accuracy of the thermal power measurement. All of these cases would have been prevented by use of LEFM systems, because LEFM systems incorporate on-line verification features and real-time control room displays that prevent occurrences of subtle failures by providing operators with continuous information about the measurement and about the accuracy of the measurement.

It is the LEFM's ability to confirm on-line that it is performing within its accuracy bounds, as well as its high accuracy, that justifies a power uprate with its use. In addition to providing for a power uprate, LEFM systems will assure that the probability of exceeding the analyzed power level (i.e., 1.02 times the current licensed rating) by as little as 0.5% is negligibly small.

That the self-checking capabilities of LEFM Check and CheckPlus systems do in fact prevent overpower incidents has been demonstrated by operating experience obtained subsequent to the publication of the original revision of this report. In the industry as a whole, overpower incidents have continued to occur at rates roughly comparable to those documented in Reference 3. These incidents have occurred in plants using conventional instrumentation and in plants using externally mounted ultrasonic flow measurement systems. But, as of this writing, in 150 plant years of operation of 36 plants using Check and CheckPlus systems not a single overpower incident has occurred.

5. Using the LEFM to Control Thermal Power

With the existing instrumentation, for each feedwater flow measurement, the differential pressure transmitters provide an output proportional to the differential pressure across the flow nozzle. Resistance thermometers (or thermocouples) measure the feedwater temperature. Typically, these outputs are supplied to the plant computer where the feedwater mass flow and enthalpy are calculated with the aid of synthesized ASME steam tables. The thermal power is then calculated, also by the plant computer.

It is anticipated that a licensee will make use of LEFM mass flow and temperature measurements by directly substituting the LEFM indications for the nozzle-based mass flow indication and the RTD temperature indications in the plant computer. The plant computer would then calculate feedwater enthalpy and thermal power as it does now. As an alternative, the calorimetric power can be manually calculated, using LEFM indications and following a prescribed procedure.

While this discussion is focused on operation at full power, it should be noted that LEFM systems provide accurate flow and temperature indications from synchronization to full power. The LEFM Check or LEFM CheckPlus may be used for thermal power determinations following synchronization at 10% to 15% power (when feedwater heating commences) and up to full power, with an accuracy better than the present instrumentation. [The LEFM provides a valid and accurate volumetric flow indication down to zero flow. An optional RTD incorporated in the LEFM will provide valid mass flow and temperature indications below synchronization power, down to zero mass flow with feedwater temperatures to 32°F.]

In order to maintain control of thermal power at 100 percent power, a real-time display of thermal power as calculated using the LEFM will be available in the main control room for the reactor operator's use. The operator will use this display to maintain reactor power at or below the licensed thermal rating, with a tolerance in accordance with current plant practice. A clear indication of the validity of the thermal power measurement, as determined by LEFM diagnostics, will also be present, at a location close to the thermal power display. This indication will be provided by the LEFM's on-line verification system, which is discussed in detail in ER 80P.

6. References

1. ANSI/ASME Power Test Code PTC 19.1 – 1985, Part 1 Measurement Uncertainty, Reaffirmed 1990.
2. Caldon Topical Report ER-80P, "Improving Thermal Power Accuracy and Plant Safety While Increasing Operating Power Level Using the LEFM Check System", Rev. 0.
3. Regan, J., "Operation Near 100% Rated Thermal Power: Historical Licensee Event Reports", Proceedings of the 1999 ANS Winter Meeting, November 1999.
4. NRC SER dated March 8 1999, "Safety Evaluation by the Office of Nuclear Reactor Regulation Topical Report ER-80P, 'Improving Thermal Power Accuracy and Plant Safety While Increasing Operating Power Level Using the LEFM System', Comanche Peak Steam Electric Station, Units 1 and 2 Docket Nos. 50-445 and 50-446".
5. Caldon Engineering Report ER 160P, "Supplement to Topical Report ER 80P: Basis for a Power Uprate with the LEFM System", May 2000
6. NRC Safety Evaluation related to Amendment 31 Operating License NPF-390, Docket number 50-390, January 2001
7. Caldon Engineering Report ER-486 Rev 0, "Representative Calibration Data for LEFM Check and CheckPlus Flow Elements", March 2005

Figure 6. Probable Operating Ranges For LEFM Systems at Increased Power Levels

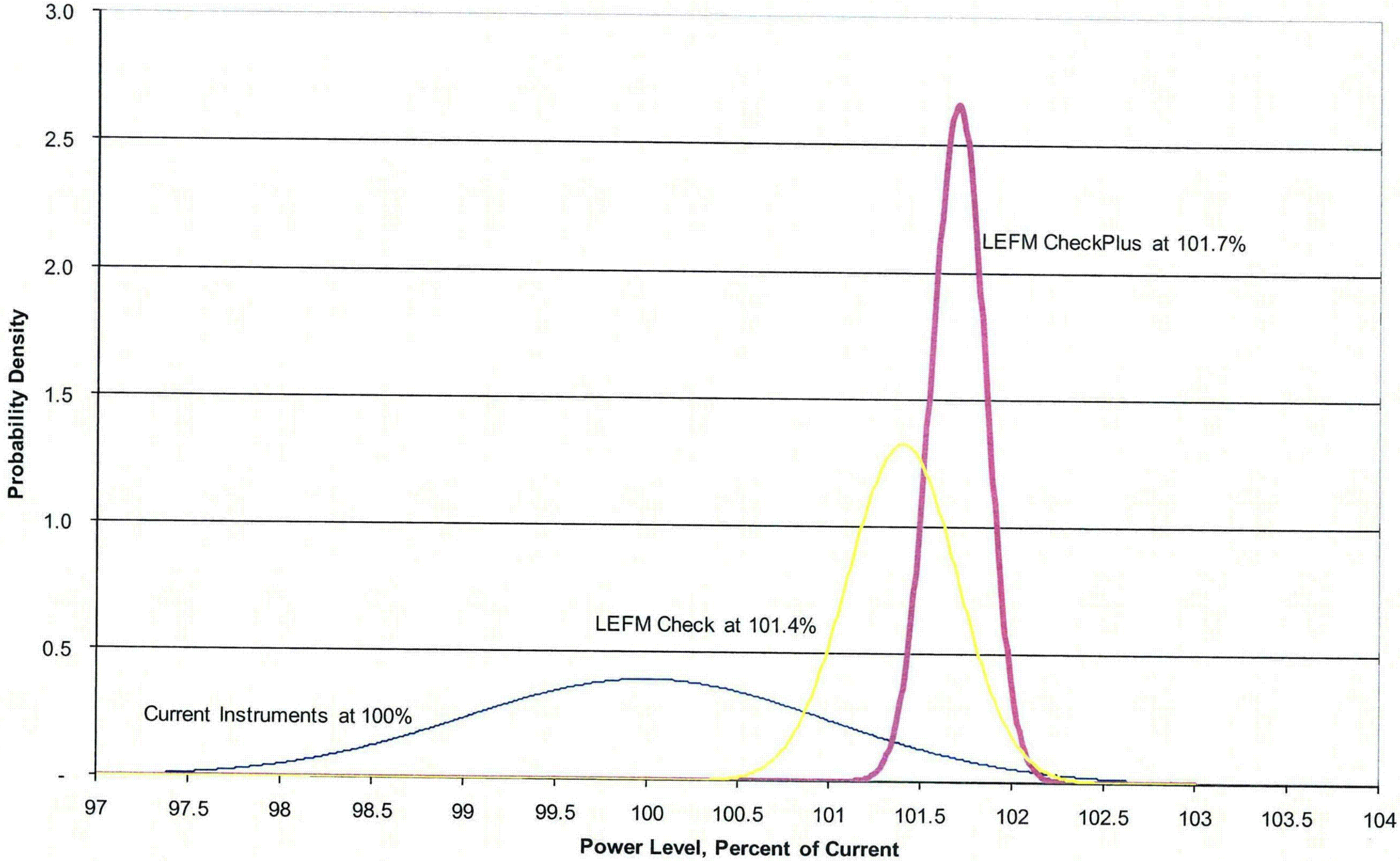


Figure 7. Probability of Exceeding Power Levels With LEFM Systems And Increased Power

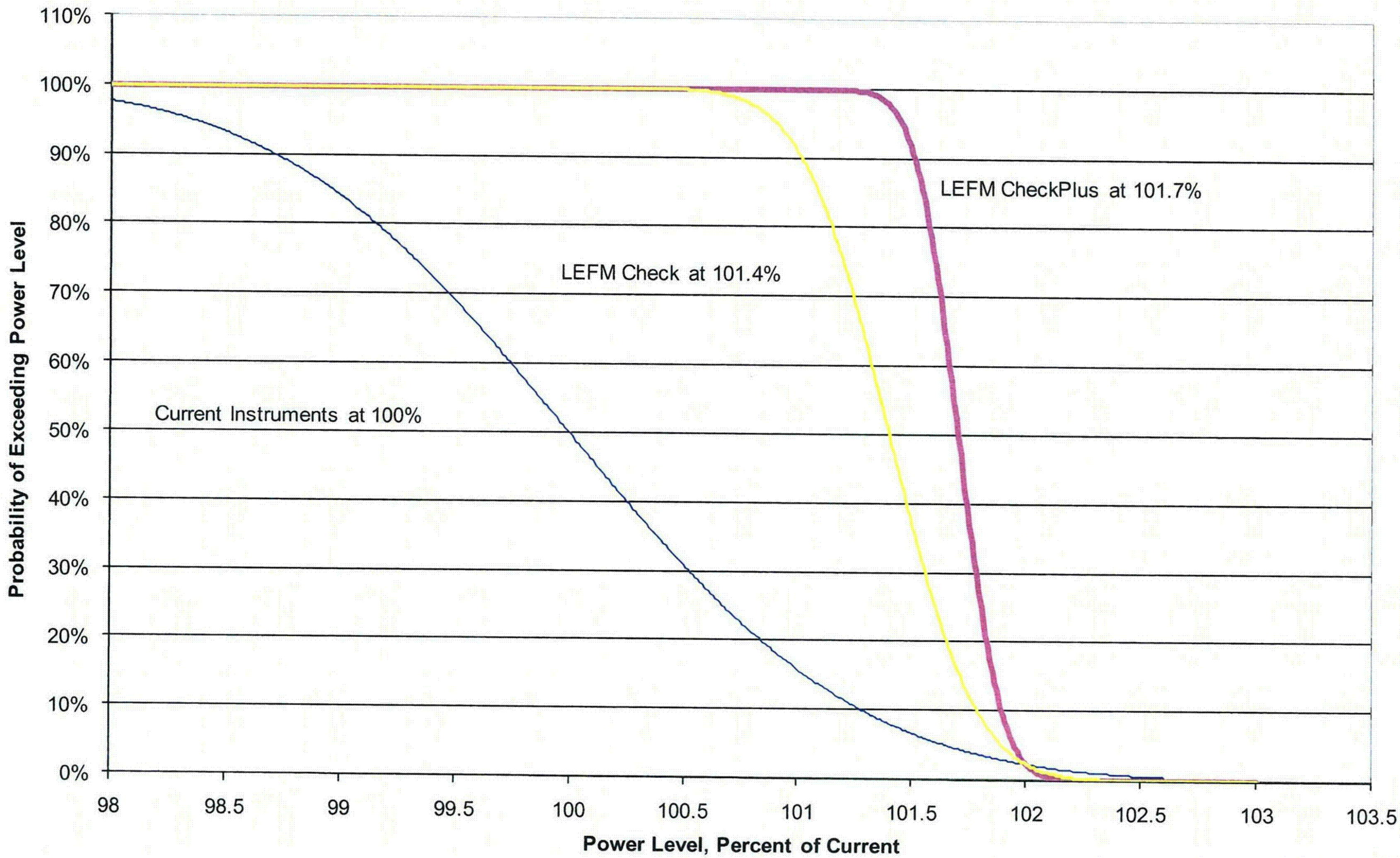


Figure 8. Probability of Exceeding Power Level in the Vicinity of 102% Power

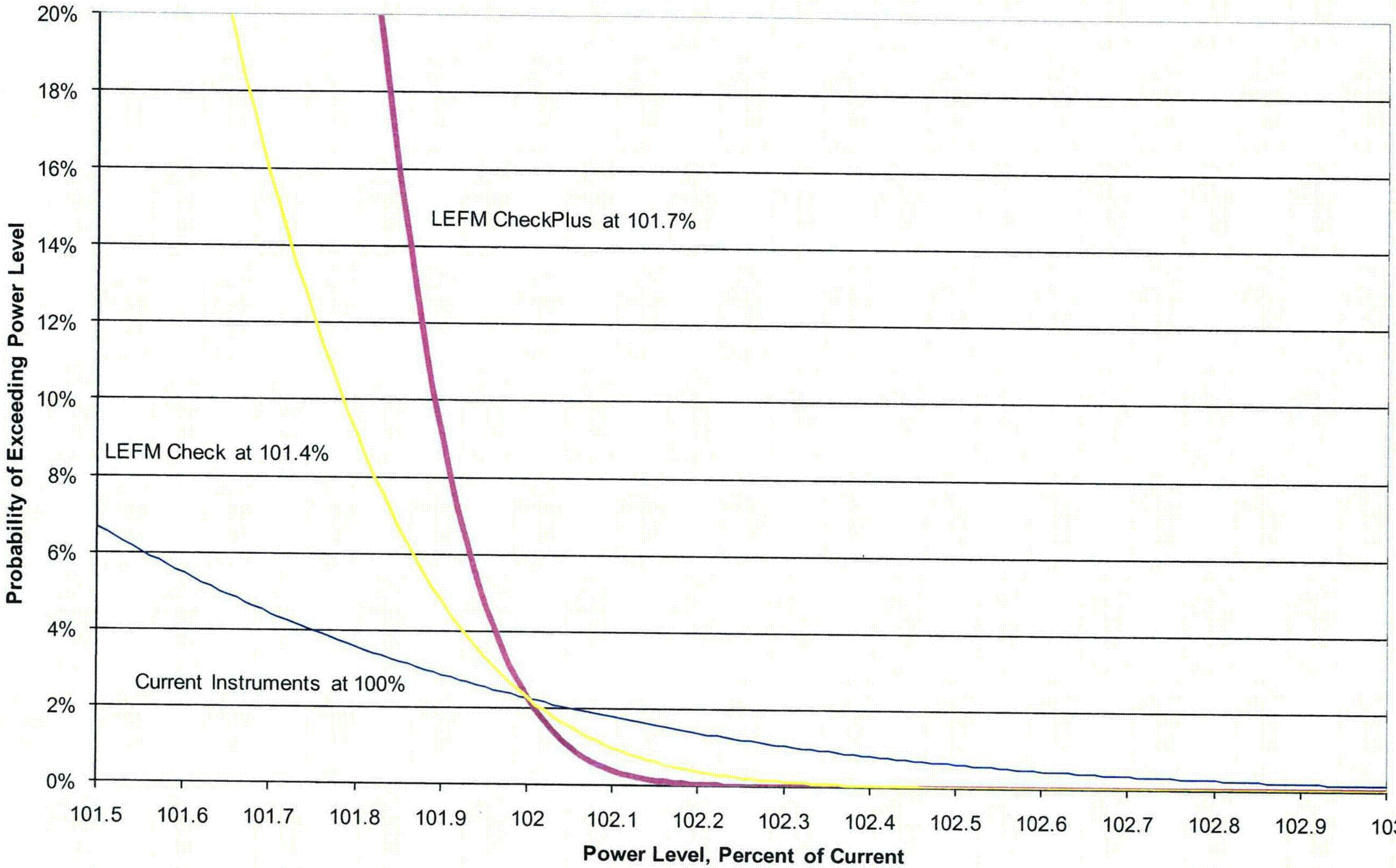
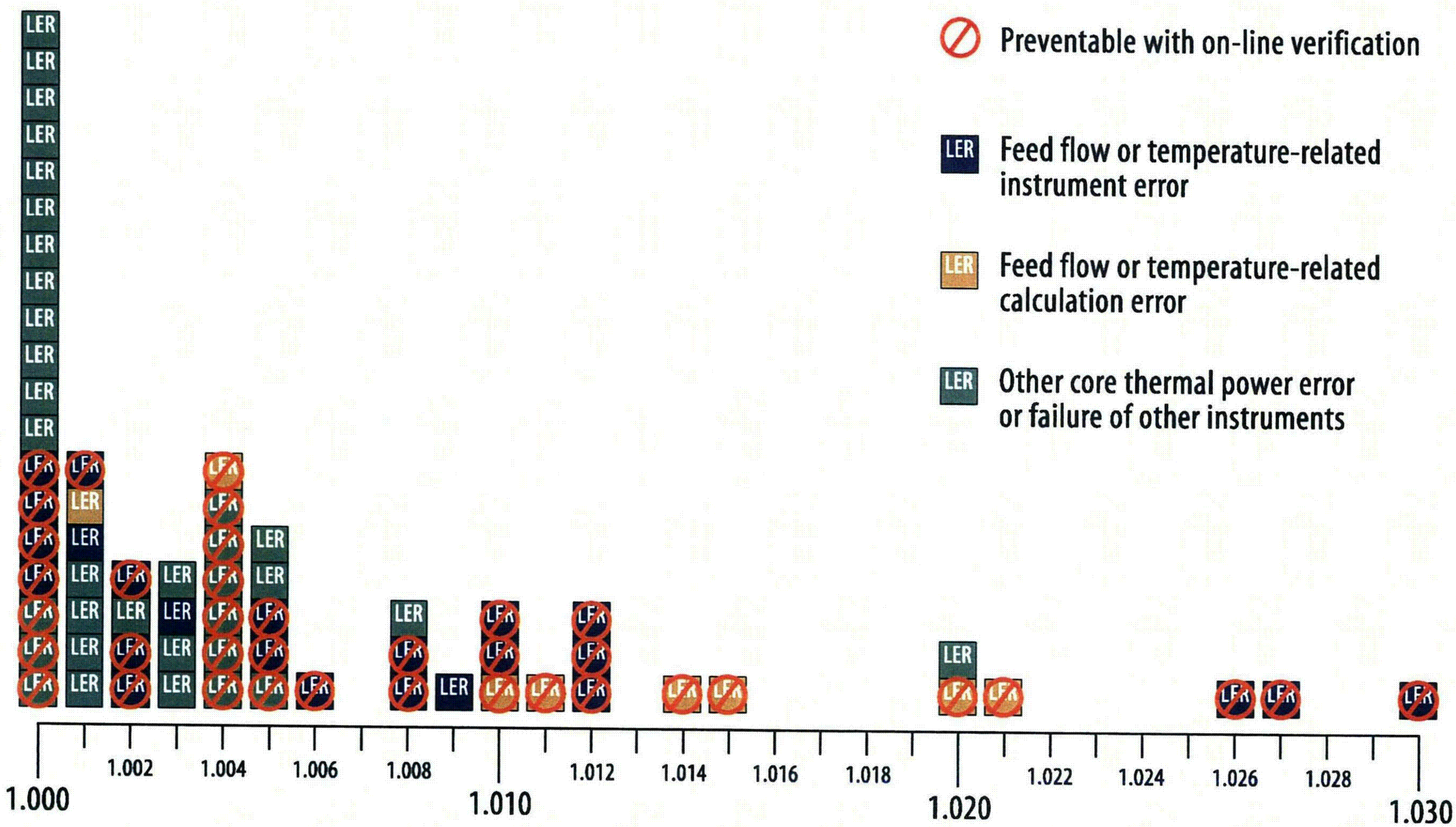


Figure 9. Results of LER Survey 1982-1999



APPENDIX A

BASIS FOR UNCERTAINTIES IN DETERMINING THERMAL POWER WITH THE LEFM CHECK AND LEFM CHECKPLUS FLOW AND TEMPERATURE MEASUREMENTS

Cameron considers Appendix A to be proprietary in its entirety as it consists of Trade Secret/ Confidential Commercial Information.

APPENDIX B

ESTIMATES OF THE PROBABILITY OF EXCEEDING POWER MARGINS OF UP TO FIVE STANDARD DEVIATIONS

APPENDIX B to Cameron ER-157(NP-A)

ESTIMATES OF THE PROBABILITY OF EXCEEDING POWER MARGINS OF UP TO FIVE STANDARD DEVIATIONS

Purpose:

The purposes of this appendix are to:

a) Quantify the effect of turbulence on the two standard deviation uncertainty bands of current calorimetric instrumentation as well as calorimetric instrumentation utilizing the chordal LEFM Check or LEFM CheckPlus system and,
b) Estimate the probabilities of exceeding power levels one, two, three, four and five standard deviations above the power levels measured by instruments characterized in (a) above.

Assumptions:

1. The impact of turbulence on existing instrumentation will be assumed comparable to that calculated for the LEFM Check in Appendix A under Item 7 subsection b, "Setting the Sample Size". In that subsection, the observational uncertainty due to turbulence was calculated to be ± 0.05% (2σ).

2. The 95% confidence limits for a set of instruments are assumed to define an error probability distributed normally about the true value of the measured variable with two standard deviations equal to the 95% confidence limits. The possibility of error distributions other than normal and the implications of such distributions on overall error probability are discussed in Reference 2.

3. The aggregate power measurement uncertainties of current instrumentation and the LEFM Check and LEFM CheckPlus are made up of numerous small contributing elements. Errors characterizing these elements may not always be normally distributed; however, for initial probability estimates, it will be assumed that, when the error elements aggregate, the resulting error distribution is normally distributed.

Discussion

1. As noted in Reference 4 Appendix K of 10CFR50 allocates a 2% margin to cover the uncertainties in thermal power measurements with conventional instrumentation. For purposes of comparison with LEFM performances, this figure will be taken as the 95% confidence limit for such instruments. One standard deviation of the error distribution for this instrument set is therefore 1%.

2. The effect of turbulence on the power measurement, in the case of the LEFM Check or LEFM CheckPlus, is to add an uncertainty of ± 0.05% as the root sum square to the

instrument uncertainty. The uncertainty caused by turbulence is controlled, in the case of an LEFM, by selecting a sample size such that two standard deviations of the mean flow measurement do not exceed ± 0.05% (See Appendix A, Item 7b). A similar procedure can be followed in processing the analog output of a nozzle instrument; a sample period can be selected to limit the uncertainty in the mean of the flow data to ± 0.05%. Assuming that this procedure is followed, the effective value of 2 standard deviations of the power determination with current instrumentation, <u>including</u> the effects of turbulence, is

$$2\ SD_{eff} = \sqrt{[\ (2)^2 + (0.05)^2\ ]} \cong \pm 2\%$$

a) Based on the calculations of Appendix A, an upper bound for the 95% confidence limit for a power determination with a single LEFM Check Installation is ± 0.54%. For the LEFM CheckPlus system a lower bound is ± 0.34%. Accordingly, the effective values for two standard deviations of the LEFM Check and CheckPlus power determinations including turbulence are:

LEFM Check $\quad 2\ SD_{eff} = [(0.54)^2 + (0.05)^2]^{1/2} = \pm 0.54\%$

LEFM CheckPlus $\quad 2\ SD_{eff} = [(0.34)^2 + (0.05)^2]^{1/2} = \pm 0.34\%$

For the comparisons of this appendix, rounded values that bracket the uncertainties of power determination of both systems will be employed. For the LEFM Check System, an upper bound of ± 0.6% for two standard deviations will be used; for the LEFM CheckPlus a lower bound of ± 0.3% will be used.

4. Values for the error probabilities for various uncertainty bands expressed in terms of standard deviations are tabulated in Table B-1, below. The Table is based on data interpolated or extrapolated from Eshbach's *Handbook of Engineering Fundamentals,* referenced in the Table. For example, from Table B-1, the probability that the true value of the measured variable will lie within 2 standard deviations of the true value is 0.95446. Accordingly, the probability of the true power level <u>exceeding</u> that indicated by a set of instruments by two standard deviations, P(+2SD), is 1/2 of the difference between 1.00000 and 0.95446 (one half, since the probability of <u>exceeding</u> 2 standard deviations <u>only</u> is being calculated).

$$P\ (+2\ SD) = 1/2\ (1.00000 - 0.95446) = 0.02277 \cong 2.3\%.$$

The probabilities of exceeding the indicated power level by one, three, four and five standard deviations are also tabulated in Table B-1 for current power level instrumentation, as characterized in column 2 ("Error Band Nozzle or Venturi") and for power determinations using the LEFM Check (column 3) and LEFM CheckPlus (column 4). The probabilities of exceeding the various bands are expressed both in decimal and reciprocal (odds) formats.

Table B-1
Probability Tabulations

Based on Table I, Eshbach, *Handbook of Engineering Fundamentals*, Part 2, Section 61, "The Probable Error", First Edition, John Wiley and Sons

Number of Standard Deviations σ	Error Band Nozzle or Venturi	Error Band LEFM Check	Error Band LEFM CheckPlus	h a * = $\sigma / \sqrt{2}$	P *	P_{exc}= 1/2 (1.00000-P)	1/ P_{exc}
1.0	0.7%	0.3%	0.15%	0.707	0.68261	0.1587	1/6.3
2.0	1.4%	0.6%	0.3%	1.414	0.95446	0.0228	1/44
3.0	2.1%	0.9%	0.45%	2.121	0.99730	$1.35*10^{-3}$	1/741
4.0	2.8%	1.2%	0.6%	2.828	0.999938	$3.1*10^{-5}$	1/32,300
5.0	3.5%	1.5%	0.75%	3.536	0.9999994	$3 *10^{-7}$	1/3.3 million

* P is tabulated in Table I of the *Eshbach* as a function of "h a", where "h a" is as defined in the Table above. Values of P for 1 through 4 sigma have been obtained by interpolating the values of probability given as a function of "h a" in the referenced table. The value for five sigma is based on a straight line log extrapolation of (1 - P_{exc}).

5. The probability computations above rest on two key assumptions:

   (a) that the computed uncertainty bands characterize the actual performance of the instruments in service, and
   (b) that the elemental uncertainty bands which, together, determine the overall uncertainty band are themselves normally distributed.

   Assumption (a) generates a requirement to be able to confirm instrument performance on-line. The capability of an LEFM Check or LEFM CheckPlus system to fulfill this requirement is discussed in Reference 2.

   As for assumption (b), many LEFM elemental uncertainties are normally distributed about the measured value for that element, since the contributors to the uncertainty tend to be random in nature, and any known biases are corrected. However, some elemental errors are likely to be uniformly distributed. To analyze the potential impact of uniform error distributions on overall LEFM Check uncertainty, results of exploratory *Monte Carlo* analyses of synthetic measurement systems whose elements are characterized by random and uniform error distributions are presented in Reference 2. The key conclusion from this work is that the probabilities tabulated in Table B-1 are valid, regardless of the specifics of the error distributions of the individual elements of the measurement systems.

APPENDIX C

The Effects of Random and Coherent Noise on LEFM CheckPlus Systems

Cameron considers Appendix C to be proprietary in its entirety as it consists of Trade Secret/ Confidential Commercial Information.

APPENDIX D

ENGINEERING REPORT ER-551
(Non-Proprietary Version)

Caldon® Ultrasonics

Engineering Report: ER-551NP Rev. 3

LEFM✓ + Transducer Installation Sensitivity

Prepared by: Don Augenstein
Checked by: Matthew Mihalcin mpm
Reviewed by: Matthew Mihalcin mpm

June 2008

ER-551NP Rev. 3
June 2008

Engineering Report: ER-551NP Revision 3

LEFM✓+ Transducer Installation Sensitivity

Table of Contents

Engineering Report: ER-551P Rev. 3, LEFM✓+ Transducer Installation

1.0 SCOPE

This report summarizes and analyzes the flow measurement sensitivity of the LEFM✓+ flowmeter to transducer installation. The transducer replacement sensitivity tests were performed on an 18 inch (15 inch ID) LEFM✓+ flowmeter. The test objective was to measure and quantify the LEFM✓+ flowmeter sensitivity to transducer installation. The test was performed at the Caldon Ultrasonics flow loop.

The analysis addresses the uncertainties associated with replacing transducers that meet all acceptance criteria (e.g., SNR both coherent and random) and have been coupled properly (e.g, transducer couplant is properly compressed across the entire face of the transducer).

2.0 PURPOSE/BACKGROUND

The NRC requested that Caldon investigate the effects of changing acoustic transducers of an LEFM✓+ flow measurement system.

3.0 SUMMARY

3.1 Calibration Standard

The test was performed at the Caldon Ultrasonics flow loop (nominal maximum flow of 5700 gpm). The Caldon Ultrasonics flow loop has one 150 HP Variable Speed Pump whose maximum flow is ~ 5700 gpm. The Caldon Ultrasonics flow loop is design for the full flow range of an 8 inch meter. Given the flow loop's maximum flow is only ~20% of the 18 inch LEFM✓+ flowmeter's range, the test were only run at the maximum obtainable flow of ~5700 gpm.

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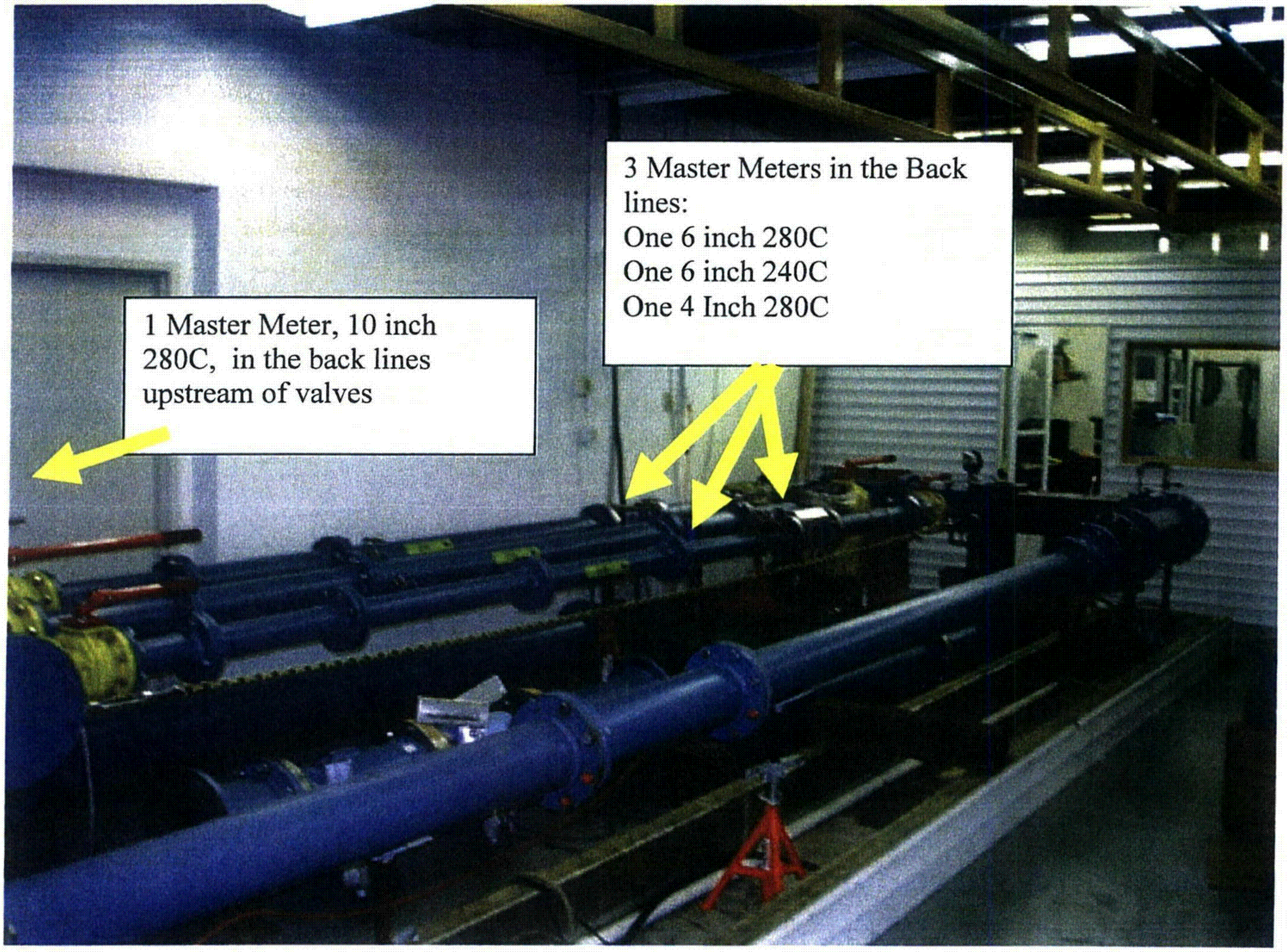

Figure 1: Caldon Ultrasonics Flow Calibration Laboratory

The flow loop and its operations are defined under Caldon MPS121 procedures. The Caldon Ultrasonics flow loop used a propylene-glycol/water mixture ~ 50%/50%. Secondary standards (e.g., master meters) were used as the standard. The master meter standard was selected since the primary standard method is limited to ~2900 gpm. Since the objective was to measure repeatability/reproducibility of the meter factor after transducer replacements, the master meter method produced the best test uncertainty.

The LEFM✓ + flowmeter was an 18 inch meter (ID of 15 inches) with 16 inch 150#flanges. It was installed downstream of a 10x12 inch reducer/expander and a 12x16 inch reducer/expander.

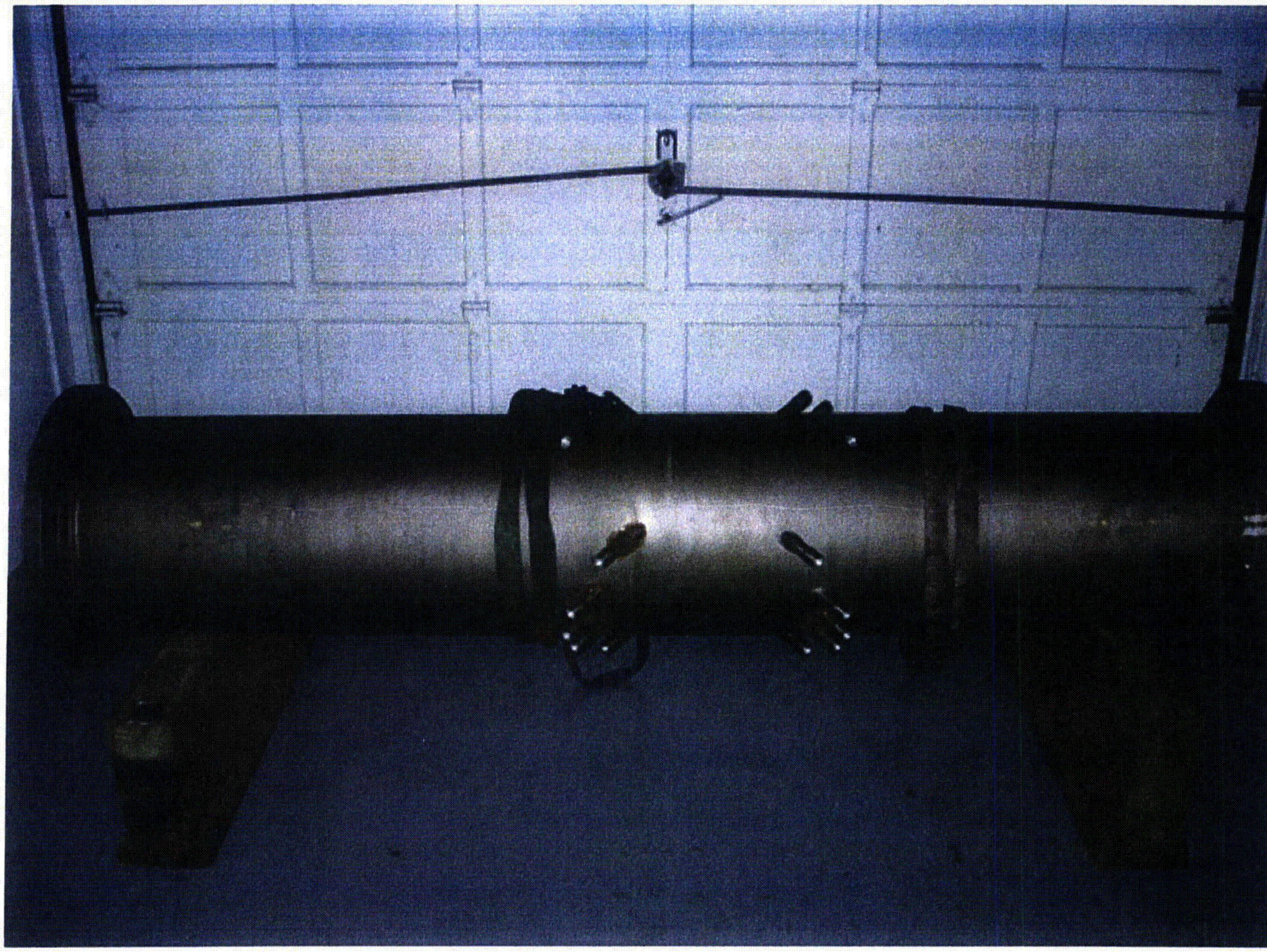

Figure 2: 18 Inch LEFM✓+ Flowmeter – Transducers, Transducer Adapter Rods and J-Boxes Removed

3.2 Transducer Replacement Test Procedure

The test procedure was as follows:

1. Install transducers with zero-flow conditions according to the Table 1
2.
3. Set flow rate
4.

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	Path (Transducers in Paris - Up/Dn)							
Test	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**
1	A	B	C	D	E	F	G	H
2	K	A	B	C	D	E	F	G
3	J	K	A	B	C	D	E	F
4	H	J	K	A	B	C	D	E
5	G	H	J	K	A	B	C	D
6	F	G	H	J	K	A	B	C
7	E	F	G	H	J	K	A	B
8	D	E	F	G	H	J	K	A
9	C	D	E	F	G	H	J	K

Table 1: Location of Transducer Pairs

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3.3 Summary: Transducer Change-Out Sensitivity

Transducer pair replacement test showed:

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4.0 CALIBRATION RESULTS

The following table summarizes the sensitivity of meter factor for the LEFM✓+[2] meter under test to transducer installation.

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Table 2: Sensitivity in Meter Factor Due to Transducer Installation

Note: Per Path Sensitivity is the 95% Confidence value divided by the sqrt(8). This weights all paths equally.

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[2] This an 8 path meter. Since the paths are treated randomly, a four path meter (e.g., LEFMCheck) would have a meter factor uncertainty of sqrt(2) times higher – since it has half of the paths.

The following table shows the average path zero flow Delta T observed with each configuration. (Note: All units in the following table are nanoseconds, ns.)

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Table 3: Sensitivity in Delta T Due to Transducer Installation

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The following table gives the variability in path coupling for the tests. (Note: All units in the following table are decibels, dB).

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Table 4: Variability in Path Gain Due to Transducer Installation

Note: Inside paths are paths 2, 3, 6, and 7. Outside paths are paths 1,4, 5, and 8

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5.0 UNCERTAINTY ASSESSMENT - TRANSDUCER REPLACEMENT SENSITIVITY

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Table 5: Uncertainty Assessment

5.1 Transducer Alignment Sensitivity

There are two ways that transducers misalignment can impact the flow measurement:

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5.1.1 Acoustic Angle

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Table 7: Error Uncertainty due to Variation in Chord Location

As shown in Table 7, the velocity integration is insensitive to transducer misalignment.

5.2 Transducer Alignment Sensitivity Extended to Other Size Meters

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Confidential
Commercial
Information

Measurement Systems

Caldon® Ultrasonics Technology Center
1000 McClaren Woods Drive
Coraopolis, PA 15108
Tel 724-273-9300
Fax 724-273-9301
www.c-a-m.com

CAMERON

October 15, 2010
CAW 10-07

Document Control Desk
U. S. Nuclear Regulatory Commission
Washington, DC 20555

APPLICATION FOR WITHHOLDING PROPRIETARY INFORMATION FROM PUBLIC DISCLOSURE

Subject: Caldon® Ultrasonics Engineering Report: ER-157P-A Rev. 8 and Rev. 8Errata "Supplement to Caldon Topical Report ER-80P: Basis for Power Uprates with an LEFM Check or CheckPlus System"

Gentlemen:

This application for withholding is submitted by Cameron International Corporation, a Delaware Corporation (herein called "Cameron") on behalf of its operating unit, Caldon Ultrasonics Technology Center, pursuant to the provisions of paragraph (b)(1) of Section 2.390 of the Commission's regulations. It contains trade secrets and/or commercial information proprietary to Cameron and customarily held in confidence.

The proprietary information for which withholding is being requested is identified in the subject submittal. In conformance with 10 CFR Section 2.390, Affidavit CAW 10-07 accompanies this application for withholding setting forth the basis on which the identified proprietary information may be withheld from public disclosure.

Accordingly, it is respectfully requested that the subject information, which is proprietary to Cameron, be withheld from public disclosure in accordance with 10 CFR Section 2.390 of the Commission's regulations.

Correspondence with respect to this application for withholding or the accompanying affidavit should reference CAW 10-07 and should be addressed to the undersigned.

Very truly yours,

CR Hastings

Calvin R. Hastings
General Manager

Enclosures (Only upon separation of the enclosed confidential material should this letter and affidavit be released.)

October 15, 2010
CAW 10-07

AFFIDAVIT

COMMONWEALTH OF PENNSYLVANIA:

ss

COUNTY OF ALLEGHENY:

Before me, the undersigned authority, personally appeared Calvin R. Hastings, who, being by me duly sworn according to law, deposes and says that he is authorized to execute this Affidavit on behalf of Cameron International Corporation, a Delaware Corporation (herein called "Cameron") on behalf of its operating unit, Caldon Ultrasonics Technology Center, and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

CR Hastings
Calvin R. Hastings
General Manager

Sworn to and subscribed before me

this 18th day of

October, 2010

Joann B Thomas
Notary Public

COMMONWEALTH OF PENNSYLVANIA
Notarial Seal
Joann B. Thomas, Notary Public
Findlay Twp., Allegheny County
My Commission Expires July 28, 2011
Member, Penn... ...iation of Notaries

1. I am the General Manager of Caldon Ultrasonics Technology Center, and as such, I have been specifically delegated the function of reviewing the proprietary information sought to be withheld from public disclosure in connection with nuclear power plant licensing and rulemaking proceedings, and am authorized to apply for its withholding on behalf of Cameron.

2. I am making this Affidavit in conformance with the provisions of 10CFR Section 2.390 of the Commission's regulations and in conjunction with the Cameron application for withholding accompanying this Affidavit.

3. I have personal knowledge of the criteria and procedures utilized by Cameron in designating information as a trade secret, privileged or as confidential commercial or financial information. The material and information provided herewith is so designated by Cameron, in accordance with those criteria and procedures, for the reasons set forth below.

4. Pursuant to the provisions of paragraph (b) (4) of Section 2.390 of the Commission's regulations, the following is furnished for consideration by the Commission in determining whether the information sought to be withheld from public disclosure should be withheld.

   (i) The information sought to be withheld from public disclosure is owned and has been held in confidence by Cameron.

   (ii) The information is of a type customarily held in confidence by Cameron and not customarily disclosed to the public. Cameron has a rational basis for determining the types of information customarily held in confidence by it and, in that connection utilizes a system to determine when and whether to hold certain types of information in confidence. The application of that system and the substance of that system constitutes Cameron policy and provides the rational basis required. Furthermore, the information is submitted voluntarily and need not rely on the evaluation of any rational basis.

Under that system, information is held in confidence if it falls in one or more of several types, the release of which might result in the loss of an existing or potential advantage, as follows:

(a) The information reveals the distinguishing aspects of a process (or component, structure, tool, method, etc.) where prevention of its use by any of Cameron's competitors without license from Cameron constitutes a competitive economic advantage over other companies.

(b) It consists of supporting data, including test data, relative to a process (or component, structure, tool, method, etc.), the application of which data secures a competitive economic advantage, e.g., by optimization or improved marketability.

(c) Its use by a competitor would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, and assurance of quality, or licensing a similar product.

(d) It reveals cost or price information, production capacities, budget levels, or commercial strategies of Cameron, its customer or suppliers.

(e) It reveals aspects of past, present or future Cameron or customer funded development plans and programs of potential customer value to Cameron.

(f) It contains patentable ideas, for which patent protection may be desirable.

There are sound policy reasons behind the Cameron system, which include the following:

(a) The use of such information by Cameron gives Cameron a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Cameron competitive position.

(b) It is information that is marketable in many ways. The extent to which such information is available to competitors diminishes the Cameron ability to sell products or services involving the use of the information.

(c) Use by our competitor would put Cameron at a competitive disadvantage by reducing his expenditure of resources at our expense.

(d) Each component of proprietary information pertinent to a particular competitive advantage is potentially as valuable as the total competitive advantage. If competitors acquire components of proprietary information, any one component may be the key to the entire puzzle, thereby depriving Cameron of a competitive advantage.

(e) Unrestricted disclosure would jeopardize the position of prominence of Cameron in the world market, and thereby give a market advantage to the competition of those countries.

(f) The Cameron capacity to invest corporate assets in research and development depends upon the success in obtaining and maintaining a competitive advantage.

(iii) The information is being transmitted to the Commission in confidence, and, under the provisions of 10CFR Section 2. 390, it is to be received in confidence by the Commission.

(iv) The information sought to be protected is not available in public sources or available information has not been previously employed in the same manner or method to the best of our knowledge and belief.

(v) The proprietary information sought to be withheld in the enclosed submittal titled "Caldon® Ultrasonics Engineering Report: ER-157P-A Rev. 8 and Rev. 8Errata - Supplement to Caldon Topical Report ER-80P Basis for Power Uprates with an LEFM Check or an LEFM CheckPlus System" is designated therein in accordance with 10 CFR §§ 2.390(b)(1)(i)(A,B), with the reason(s) for confidential treatment noted in the submittal and further described in this affidavit can be found in Rev. 8Errata pages 1-3, Appendix A in its entirety, Appendix C in its entirety, and Appendix D pages 2 & 4-12.

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Cameron because it would enhance the ability of competitors to provide similar flow and temperature measurement systems and licensing defense services for commercial power reactors without commensurate expenses. Also, public disclosure of the information would enable others to use the information to meet NRC requirements for licensing documentation without the right to use the information.

The development of the technology described in part by the information is the result of applying the results of many years of experience in an intensive Cameron effort and the expenditure of a considerable sum of money.

In order for competitors of Cameron to duplicate this information, similar products would have to be developed, similar technical programs would have to be performed, and a significant manpower effort, having the requisite talent and experience, would have to be expended for developing analytical methods and receiving NRC approval for those methods.

Further the deponent sayeth not.