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CALDON, INC.

ENGINEERING REPORT-157N

**Supplement to Topical Report ER-80N:
Basis for a Power Uprate
With the LEFM[✓]™ or LEFM CheckPlus™ System**

Revision 1

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Reviewed By: Herb Estrada, Jr.**

PROPRIETARY

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**Supplement to Caldon Topical Report ER-80N:
Basis For A Power Uprate
With The LEFM✓ Or LEFMCheckPlus**

1. Purpose and Background

On May 3, 2000, the NRC approved a rule change amending 10CFR50 Appendix K to permit power increases based on improvements in accuracy of the instrumentation used to measure thermal power. These power increases, referred to as "Appendix K Uprates", are relatively small increases on the order of 1% to 1.7%, depending on the demonstrated instrument accuracy. The purpose of this supplement is to provide a basis for these uprates using Caldon's LEFM✓ or LEFM CheckPlus systems to measure thermal power.

1. Probabilistic Basis for Power Uprate

A power uprate can be obtained based on improved accuracy of the instrumentation used to measure thermal power, in accordance with the Appendix K rule change described above. As shown in Tables 1 and 2, the LEFM✓ and LEFM CheckPlus provide measurements of feedwater mass flow and temperature leading to an uncertainty in thermal power significantly better than the 1.4% associated with the current instrumentation. The LEFM✓ measures thermal power to within $\pm 0.6\%$, and the LEFM CheckPlus can measure it to within $\pm 0.3\%$. To assess the increase in thermal power rating appropriate to the use of the LEFM✓, this discussion will interpret the meaning of the data of Tables 1 and 2 on a probabilistic basis.

When they developed standards for the measurement of steam turbine heat rate in power plants, the ASME 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 that results 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" (flat) distribution between defined uncertainty bounds. It was subject only to one condition: that no single element dominate the calculation of the overall uncertainty.

While it is not obvious, the tabulations in Tables 1 and 2 meet this condition. The profile factor uncertainty of the LEFM✓ and LEFM CheckPlus in Table 1 appears dominant, but is, in fact, made up of four elements, none of which is dominant. Similarly, the instrumentation allowance in Table 2 appears dominant, but is in fact made up of numerous elements in several instruments. Therefore, the overall uncertainties described in Tables 1 and 2 are likely to be normally distributed. Furthermore, the sensitivity of the results to the nature of the elemental uncertainty distribution has been investigated as described in Reference 2. This investigation shows that the distribution of the total uncertainty is likely to be normal whether the contributors are each normally distributed or distributed in roulette wheel fashion.

Table 1 implies a distribution wherein one standard deviation of LEFM✓ uncertainty is about $\pm 0.3\%$ full power, and for the LEFM CheckPlus about $\pm 0.15\%$ full power. As shown in Table 3, with these distributions there is essentially no chance (less than one in 3 million) that an operator using the LEFM✓ to determine thermal power will exceed a power level 1.5% above that to which he is controlling. Likewise, 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. Here the odds have been computed on the basis of 5 standard deviations (Appendix to this Supplement). Similarly, Table 2 implies a normal distribution of nozzle-based uncertainty with one standard deviation of $\pm 0.7\%$. As shown in Table 3, the odds of exceeding a power 3.5% above that indicated by the current instrumentation are similarly small. The one sigma value of 0.7% assumed for uncertainty of venturi-based power measurement is regarded by the NRC as representative of the low end of the scale for venturi-based uncertainty. Specifically, the NRC states, "Generally, the single loop uncertainty for thermal power appears to range from 1.8% to over 3% of power when using a venturi to measure feedwater flow based on a review of various Westinghouse PWR plants" (Reference 4).

Table 3. Probabilities and Odds Associated With Nozzle and LEFM Uncertainty Bounds

Number of Standard Deviations	Venturi Nozzle Bounds (±)	LEFM✓ Bounds (±)	LEFM CheckPlus Bounds (±)	Probability of Operation Within Bounds	Odds of Exceeding Bounds on the High Side
1	0.7%	0.3%	0.15%	68%	1/6.3
2	1.4%	0.6%	0.3%	95.4%	1/44
3	2.1%	0.9%	0.45%	99.7%	1/741
4	2.8%	1.2%	0.6%	99.994%	1/32,300
5	3.5%	1.5%	0.75%	99.99994%	1/3.3 million

To clarify the basis for a power increase with use of the LEFM✓ or LEFM CheckPlus, the results of Table 3 are shown graphically in Figures 1 through 3. 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 with the current instrumentation at the current 100% power level,
2. Operation with the LEFM✓ at a 1.4% power increase, and
3. Operation with the LEFM CheckPlus at a 1.7% power increase.

Figure 1 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 2. As Figure 2 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 proper performance. Figure 3 presents the same data as Figure 2, but focuses in the vicinity of 102% power where the probability curves for the LEFM✓, LEFM CheckPlus, and current instrumentation intersect. Though the intended operating point is higher for both the LEFM✓ 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✓ operating at 101.4% and for the LEFM CheckPlus operating at 101.7%.

Figure 3 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 3. It is not possible to read a probability this low on Figure 3).

There are two assumptions critical to the preceding discussion of thermal power margin. First, the necessity of an uncertainty distribution that is normal has been discussed and, based on the ASME studies and the Appendix, is satisfied. The second is that Tables 1 and 2 *actually describe* the performance of the instruments in service. Verification that the LEFM systems are operating within their design bounds is provided continuously, as mentioned above and discussed in detail in Reference 2. 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 increases with LEFM systems increase safety.

3. Benefits of On-Line Verification

To illustrate the benefits of on-line verification, Figure 4 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 4 illustrates 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 3; i.e., operation at 2% or more beyond the licensed power level. The causes for these events are summarized in Table 4.

Table 4. Sustained Overpower Events Above 102% and Their Causes

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.

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 case 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 failure by providing operators 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.

4. 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 density 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 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✓ 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.

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. The thermal power display will also be present, in the same location as the thermal power value, a clear indication of the validity of the thermal power measurement, as determined by LEFM diagnostics. This indication will be provided by the LEFM's on-line verification system, which is discussed in detail in Reference 2.

5. 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 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"

Appendix is Proprietary to Caldon in its Entirety



July 11, 2000
CAW 00-03

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**APPLICATION FOR WITHHOLDING PROPRIETARY
INFORMATION FROM PUBLIC DISCLOSURE**

Subject: Caldon ER-157P, "Engineering Report – 157P: Supplement to Topical Report ER-80P: Basis for a Power Uprate With the LEFM[✓]™ or LEFM CheckPlus™ System", Rev. 1 enclosure – PP&L Letter, PLA-5213, "Submittal of Supplement Engineering Report –157P to Topical Report ER-80P in Support of A Plant Power Uprate Technical Specification Change Request".

Gentlemen:

This application for withholding is submitted by Caldon, Inc. ("Caldon") pursuant to the provisions of paragraph (b)(1) of Section 2.790 of the Commission's regulations. It contains commercial strategic information proprietary to Caldon 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 2.790, Affidavit CAW-00-03 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 Caldon, be withheld from public disclosure in accordance with 10 CFR Section 2.790 of the Commission's regulations.

Correspondence with respect to this application for withholding or the accompanying affidavit should reference CAW-00-03 and should be addressed to the undersigned.

Very truly yours,

Calvin R. Hastings
President and CEO

Enclosures

July 11, 2000
CAW-00-03

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 Caldon, Inc. ("Caldon") and that the averments of fact set forth in this Affidavit are true and correct to the best of his knowledge, information, and belief:

Calvin R. Hastings

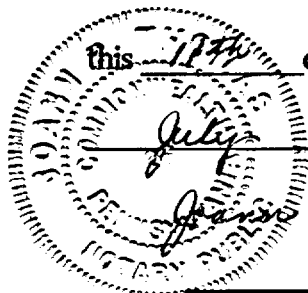
Calvin R. Hastings,
President and CEO
Caldon, Inc.

Sworn to and subscribed before me

this 11th day of

July, 2000

Joann B. Thomas



Notarial Seal
Joann B. Thomas, Notary Public
Pittsburgh, Allegheny County
My Commission Expires July 28, 2003
Member, Pennsylvania Association of Notaries

1. I am the President and CEO of Caldon, Inc. 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 Caldon.

2. I am making this Affidavit in conformance with the provisions of 10CFR Section 2.790 of the Commission's regulations and in conjunction with the Caldon application for withholding accompanying this Affidavit.

3. I have personal knowledge of the criteria and procedures utilized by Caldon in designating information as a trade secret, privileged or as confidential commercial or financial information.

4. Pursuant to the provisions of paragraph (b) (4) of Section 2.790 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 Caldon.

 - (ii) The information is of a type customarily held in confidence by Caldon and not customarily disclosed to the public. Caldon 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 Caldon policy and provides the rational basis required.

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 Caldon's competitors without license from Caldon 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 Caldon, its customer or suppliers.
- (e) It reveals aspects of past, present or future Caldon or customer funded development plans and programs of potential customer value to Caldon.
- (f) It contains patentable ideas, for which patent protection may be desirable.

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

- (a) The use of such information by Caldon gives Caldon a competitive advantage over its competitors. It is, therefore, withheld from disclosure to protect the Caldon competitive position.
- (b) It is information that is marketable in many ways. The extent to which such information is available to competitors diminishes the Caldon ability to sell products or services involving the use of the information.

- (c) Use by our competitor would put Caldon 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 Caldon of a competitive advantage.
 - (e) Unrestricted disclosure would jeopardize the position of prominence of Caldon in the world market, and thereby give a market advantage to the competition of those countries.
 - (f) The Caldon 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 2.790, 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 this submittal is that which is appropriately marked in the enclosure (Caldon ER-157P) to PP&L Susquehanna LLC letter PLA-5213 dated July 13, 2000 from R. G. Byram to the NRC Document Control Desk, "Submittal of Supplement Engineering Report – 157P to Topical Report ER-80P in Support of a Plant Power Uprate Technical Specification Change Request". This information is submitted for use by the NRC Staff and is expected to be applicable in other license submittals for justification of the use of Ultrasonic Flow Measurement Instrumentation to increase reactor plants' thermal power.

Public disclosure of this proprietary information is likely to cause substantial harm to the competitive position of Caldon 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 Caldon effort and the expenditure of a considerable sum of money.

In order for competitors of Caldon 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.