ATTACHMENT 1

**Cameron Measurement Systems/Caldon Ultrasonics Engineering Report:
ER-1059 Rev 1, "Bounding Uncertainty Analysis for Thermal Power
Determination at South
Texas Project Units 1 and 2 Using the
LEFM CheckPlus System" (Non-Proprietary)**

CAMERON

Measurement Systems

Caldon Ultrasonics

Engineering Report: ER-1059 Rev. 1

BOUNDING UNCERTAINTY ANALYSIS FOR THERMAL POWER DETERMINATION AT SOUTH TEXAS PROJECT UNITS 1 and 2 USING THE LEFM✓+ SYSTEM

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BOUNDING UNCERTAINTY ANALYSIS FOR THERMAL POWER DETERMINATION AT SOUTH TEXAS NUCLEAR PROJECT UNITS 1 AND 2 USING THE LEFM✓+ SYSTEM

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1.0 INTRODUCTION

The LEFM✓ and LEFM✓+[1] are advanced ultrasonic systems that accurately determine the volume flow and temperature of feedwater in nuclear power plants. Using a feedwater pressure signal input to the LEFM✓ and LEFM✓+: mass flow can be determined and, along with the temperature output are used along with plant data to compute reactor core thermal power. The technology underlying the LEFM✓ ultrasonic instruments and the factors affecting their performance are described in a topical report, Reference 1, and a supplement to this topical report, Reference 2. The LEFM✓+, which is made of two LEFM✓ subsystems, is described in another supplement to the topical report, Reference 3. The exact amount of the uprate allowable under a revision to 10CFR50 Appendix K depends not only on the accuracy of the LEFM✓+ instrument, but also on the uncertainties in other inputs to the thermal power calculation.

It is the purpose of this document to provide an analysis of the uncertainty contribution of the LEFM✓+ System [ ] to the overall thermal power uncertainty of South Texas Nuclear Generating Station Units 1 and 2 (Appendix B).

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The uncertainties in mass flow and feedwater temperature are also used in the calculation of the overall thermal power uncertainty (Appendix B). [ ] A detailed discussion of the methodology for combining these terms is described in Reference 3.

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This analysis is a preliminary bounding analysis for the South Texas Nuclear Generating Station Units 1 and 2. This revision utilizes nominal dimensions for the spool piece and nominal values for full power mass flow, final feed temperature, and steam conditions. [ ] The commissioning tests for the LEFM✓+, to be performed following its installation in the plant, will confirm that in fact, the time measurement uncertainties are within the bounding values used in the analysis.

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[ ]

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2.0 SUMMARY

For South Texas Nuclear Project Units 1 and 2, Revision 1 results are as follows:

1. The mass flow uncertainty approach is documented in Reference 3. The uncertainty in the LEFM✓+'s mass flow of feedwater is as follows:
   - Fully Functional LEFM✓+ system mass flow uncertainty is [ ]
   - Maintenance Mode LEFM✓+ system mass flow uncertainty is [ ]

   [ ]

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2. The uncertainty in the LEFM✓+ feedwater temperature is as follows:
   - Fully Functional LEFM✓+ system temperature uncertainty is [ ]
   - Maintenance Mode LEFM✓+ system the uncertainty is [ ]

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3. The total thermal power uncertainty approach is documented in Reference 3 and Appendix B of this document. The total uncertainty in the determination of thermal power uses the LEFM✓+ system parameters and plant specific parameters, i.e., heat gain/losses, etc.; however, the uncertainty values below do not include the plant specific parameters.
   - Thermal power uncertainty using a Fully Functional LEFM✓+ system is [ ]
   - Thermal power uncertainty using a Maintenance Mode LEFM✓+ system is [ ]

   [ ]

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3.0 APPROACH

All errors and biases are calculated and combined according to the procedures defined in Reference 4 and Reference 5 in order to determine the 95% confidence and probability value. The approach to determine the uncertainty, consistent with determining set points, is to combine the random and bias terms by the means of the RSS approach provided that all the terms are independent, zero-centered and normally distributed.

Reference 4 defines the contributions of individual error elements through the use of sensitivity coefficients defined as follows:

A calculated variable P is determined by algorithm f, from measured variables X, Y, and Z.

$$P = f(X, Y, Z)$$

The error, or uncertainty in P, dP, is given by:

$$dP = \left.\frac{\partial f}{\partial X}\right|_{YZ} dX + \left.\frac{\partial f}{\partial Y}\right|_{XZ} dY + \left.\frac{\partial f}{\partial Z}\right|_{XY} dZ$$

As noted above, P is the determined variable--in this case, reactor power or mass flow-- which is calculated via measured variables X, Y, and Z using an algorithm f (X, Y, Z). The uncertainty or error in P, dP, is determined on a per unit basis as follows:

$$\frac{dP}{P} = \left\{\left.\frac{X}{P}\frac{\partial f}{\partial X}\right|_{YZ}\right\}\frac{dX}{X} + \left\{\left.\frac{Y}{P}\frac{\partial f}{\partial Y}\right|_{XZ}\right\}\frac{dY}{Y} + \left\{\left.\frac{Z}{P}\frac{\partial f}{\partial Z}\right|_{XY}\right\}\frac{dZ}{Z}$$

where the terms in brackets are referred to as the sensitivity coefficients.

If the errors or biases in individual elements (*dX/X, dY/Y, and dZ/Z* in the above equation) are all caused by a common (systematic) boundary condition (for example ambient temperature) the total error dP/P is found by summing the three terms in the above equation. If, as is more often the case, the errors in X, Y, and Z are independent of each other, then Reference 4 and 5 recommends and probability theory requires that the total uncertainty be determined by the root sum square as follows (for 95% confidence and probability):

$$\frac{dP}{P} = \sqrt{\left[\left(\left\{\left.\frac{X}{P}\frac{\partial f}{\partial X}\right|_{YZ}\right\}\frac{dX}{X}\right)^2 + \left(\left\{\left.\frac{Y}{P}\frac{\partial f}{\partial Y}\right|_{XZ}\right\}\frac{dY}{Y}\right)^2 + \left(\left\{\left.\frac{Z}{P}\frac{\partial f}{\partial Z}\right|_{XY}\frac{dZ}{Z}\right)^2\right]}$$

Obviously, if some errors in individual elements are caused by a combination of boundary conditions, some independent and some related (i.e., systematic) then a combination of the two procedures is appropriate.

4.0 OVERVIEW

The analyses that support the calculation of LEFM✓+ uncertainties are contained in the appendices to this document. The function of each appendix is outlined below.

Appendix A.1, LEFM✓+ Inputs

This appendix tabulates dimensional and other inputs to the LEFM✓+. [

] which is used by the LEFM✓+ for the computation of mass flow and temperature.

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Appendix A.2, LEFM✓+ Uncertainty Items Calculations

This appendix calculates the uncertainties in mass flow and temperature as computed by the LEFM✓+ using the methodology described in Appendix E of Reference 1 and Appendix A of Reference 3[3], with uncertainties in the elements of these measurements bounded as described in both references[4]. The spreadsheet calculations draw on the data of Appendix A.1 for dimensional information. [

]

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These uncertainties are an important factor in establishing the overall uncertainty of the LEFM✓+.

Revision 1 of this analysis utilizes the bounding values of Reference 3 for all uncertainty elements[5] in the computation of plant specific uncertainties. Revision 2 of this appendix will utilize the results of the calibration test for the plant spool piece(s) for the uncertainty in the meter factor (calibration coefficient). The engineering report for the spool piece calibration test will be included as Appendix A.3 to Revision 2 of this report.

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[3] Reference 3 (ER 157P-A) develops the uncertainties for the LEFM✓+ system. Because this system uses two measurement planes, the structure of its uncertainties differs somewhat that of an LEFM✓.

[4] Reference 3 (ER 157P-A) revised some of the time measurement uncertainty bounds. The revised bounds are a conservative projection of actual performance of the LEFM hardware. ER 80P used bounds that were based on a conservative projection of theoretical performance.

[

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Appendix A.3, Meter Factor (Calibration) Uncertainties

This report documents the meter factor bounding uncertainty analysis for South Texas Project (STP) Units 1 and 2. Once the actual flow elements STP are made and calibrated, the actual calibration data and parametric tests will be used to compute a meter factor uncertainty for each unit.

The calibration test report for the spool piece(s) establishes the overall uncertainty in the meter factor of the LEFM✓+. [

]

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This report's approach is to use the body of calibration and parametric testing that Cameron has performed on 195 nuclear power plant flow meters.

Cameron will use the most conservative approach to compute a bounding uncertainty in the meter factor as applied to STP. Further, additional conservatisms are used such that the uncertainty can be considered to be bounding.

Appendix A.4, [ ]

[ ]

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Appendix A.5, [ ]

[ ]

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Appendix B, Total Thermal Power Uncertainty due to the LEFM ✓+

The total thermal power uncertainty due to the LEFM✓+ is calculated in this appendix, using the results of Appendix A.2, A.4 and A.5. Plant supplied steam conditions (which enter into the computation of errors due to feedwater temperature) are used for this computation. This appendix also computes the fraction of the uncertainty in feedwater temperature that is systematically related to the mass flow uncertainty.

5.0 REFERENCES

1) Cameron Topical Report ER-80P, "Improving Thermal Power Accuracy and Plant Safety While Increasing Operating Power Level Using the LEFM Check System", Rev. 0

2) Cameron Engineering Report ER-160P, "Supplement to Topical Report ER 80P: Basis for a Power Uprate with the LEFM System", May 2000

3) Cameron Engineering Report ER-157(P-A), "Supplement to Cameron Topical Report ER-80P: Basis for Power Uprates with an LEFM Check or an LEFM CheckPlus", dated May 2008, Revision 8 and Revision 8 Errata

4) ASME PTC 19.1-1985, Measurement Uncertainty

5) ISA-RP67.04.02-2000, Methodologies for the Determination of Set Points for Nuclear Safety-Related Instrumentation

Appendix A

Appendix A.1, LEFM✓+ Inputs

Appendix A.2, LEFM✓+ Uncertainty Items/Calculations

Appendix A.3, Meter Factor Calculation and Accuracy Assessment

Appendix A.4, [ ]

Appendix A.5, [ ]

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Appendix A.1

LEFM✓+ Inputs

No attachment to follow as Appendix is Proprietary in its Entirety

BWH

Appendix A.2

LEFM✓+ Uncertainty Items/Calculations

No attachment to follow as Appendix is Proprietary in its Entirety

EMH

Appendix A.3

LEFM✓+ Meter Factor Calculation and Accuracy Assessment

The meter factor report for Unit 1 and 2 is ER-1060 Rev 1.

Appendix A.4

[ ]

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No attachment to follow as Appendix is Proprietary in its Entirety

BmH

Appendix A.5

[ ]

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No attachment to follow as Appendix is Proprietary in its Entirety

BMH

Appendix B

Total Thermal Power and Mass Flow Uncertainty using the LEFM✓+ System

No attachment to follow as Appendix is Proprietary in its Entirety

EMH