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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"

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1.0 INTRODUCTION

By letters dated July 17(TXX-98180) and December 17, 1998 (TXX-98274), Texas Utilities Electric Company (TU Electric /the licensee) submitted Caldon Topical Report ER-80P, "Improving Thermal Power Accuracy and Plant Safety While Increasing Operating Power Level Using the LEFM System." The staff review of this topical report was limited to an evaluation of ultrasonic flow meters (specifically, in-line, multipath, transit time) replacing conventional venturi based feedwater flow measurement.

2.0 BACKGROUND

Typically, a plant will calculate reactor thermal power by the performance of a secondary side heat balance. The purpose of this calculation is to provide a means to confirm the calibration of the neutron flux instrumentation and to verify that the plant is operating within TS licensed power per the operating license.

The vendor, Caldon, states that the leading edge flow meter (LEFM) system addressed by Topical Report ER-80P is an updated ultrasonic flowmeter capable of improving the accuracy of thermal power measurement in nuclear power plants. Topical Report ER-80P also states that overall safety is improved since the LEFM includes on-line verification of the accuracy of feedwater flow and temperature measurements used in the calculation of thermal power. Caldon states that the LEFM provides the ability to ensure that instrument performance is consistent with design bases assumptions by confirming instrumentation parameters on-line. The vendor also claims a substantial increase in overall accuracy of the feedwater flow measurement for the LEFM system.

With the improvements in feedwater flow measurement indicated in Topical Report ER-80P, it could be possible for a plant to operate at increased thermal power levels while maintaining current licensed safety analysis assumptions. Specifically, Topical Report ER-80P proposes that licensee thermal power levels may be increased by up to 1% without re-analysis. The justification for a power uprate is based on the improved accuracy of thermal power

ENCLOSURE

measurement such that the resulting measurement uncertainties maintain the 10 CFR Part 50 Appendix K 1.02% initial power assumption for design basis accident analysis. In other words, the vendor states that a plant utilizing the LEFM system may operate at an increased thermal power level of 101% with a probability of exceeding 102% thermal power equal to plants running at 100% thermal power using traditional feedwater flow instrumentation. This is premised on the assumption that no additional uncertainties beyond those included in Topical Report ER-80P are assumed to be included in the Appendix K 102% thermal power margin requirement (accident analysis assumptions, for example). The review of applicable uncertainties included in the 10 CFR Part 50, Appendix K 1.02% initial power assumption is not addressed in this safety evaluation.

The flowmeter manufactured by Caldon and the subject of Topical Report ER-80P is an ultra-sonic flow meter utilizing time-of-flight (transit time or counter propagating) methodology. Additionally the LEFM manufactured by Caldon uses multiple chordal paths with the transducers mounted in-line within a spool piece. This construction, as stated by the topical report, provides better definition of the flow profile and more accurately defines dimensional parameters (path length, path angle, and pipe diameter) thereby improving the accuracy of the LEFM with respect to other ultrasonic meter types such as a clamp-on transit time flow meter.

An additional feature of the Caldon LEFM and time-of-flight ultrasonic meters in general is that not only will the meter determine fluid velocity, it also establishes the speed of sound through the fluid. This information can then be used to determine fluid temperature if the relationship of the fluid property to the speed of sound is known. Temperature measurement is also proposed to be incorporated as part of the plant thermal power calculation replacing the conventional RTD temperature measurement currently used for this purpose.

Licensees also use ultrasonic meters, including the LEFM, for correction of feedwater flow venturi readings. The LEFM is used to correct the feedwater venturi indication for the effects of water corrosion and fouling in the throat of the venturi as it occurs over a fuel cycle. The corrected feedwater flow readings are used in the calibration of power range instruments, to calculate reactor coolant system flow, and as inputs for the Over Temperature Delta Temperature and Over Power Delta Temperature setpoints.

3.0 EVALUATION

The requirements and methodology for the reactor thermal power calculation are evaluated to determine the effect of improved feedwater flow measurement on the uncertainty of reactor thermal power. A review of reactor thermal power sensitivities shows that feedwater flow measurement is a significant contributor to the overall thermal power uncertainty. However, it also shows that feedwater enthalpy is a significant uncertainty contributor as well.

A comparison of the uncertainties attributed to measuring feedwater flow with a feedwater venturi vs an ultra sonic flow meter can be made to determine the overall improvement in feedwater flow uncertainty and ultimately reactor thermal power uncertainty. Since the measurement uncertainty of a feedwater venturi based system is well documented, this evaluation will concentrate on the capabilities of an ultrasonic flow instrument based system.

The use of an ultrasonic flow meter is not new as evidenced by the installation of ultrasonic meters (including the Caldon LEFM) in plants since the 1970's to measure reactor coolant primary loop and feedwater flows. Ultrasonic flow meters are installed either as clamp on devices or are installed in a flowmeter body in-line with the pipe. Although there are variations in ultrasonic flowmeters, there are basically two different types: time of flight and Doppler. Both meter types are used for fluids, with the Doppler style relying on particulate in the fluid for signal reflection. The Caldon LEFM ultrasonic flow meter is a time-of-flight device (counter propagating) mounted in-line within the pipe via a spool piece. The construction of a time-of-flight meter includes a transducer located upstream of another with the acoustic wave (pulse) launched between the transducers at an angle to the pipe axis (chordal). The time-of-flight meter utilizes the fact that the speed of an acoustic wave will increase in the direction of flow and will decrease when propagated against the flow. The result is a difference in transit time for the acoustic wave when transmitted along a selected acoustic path in both the upstream and downstream direction. By measuring the time difference, the fluid velocity along the acoustic path in the pipe can be calculated. To determine the fluid velocity in the pipe, the axial fluid velocity must be determined. This is done by determination of the angle of the acoustic path to the pipe axis. To determine volumetric flowrate the velocity is then integrated over the pipe cross section. Additionally, since a time-of-flight meter determines the speed of sound of the fluid, other fluid parameters can be measured such as temperature. The volumetric flow is then multiplied by the density of the fluid to find mass flow.

Topical Report ER-80P provides a discussion of the thermal power measurement uncertainties using current instrumentation (venturi and RTDs for example). By using an ultrasonic flow meter, the uncertainties related to flow nozzles and temperature measurement in current instrumentation are displaced by those of the ultrasonic flow meter. Typical measurement/uncertainties for venturi feedwater flow measurement are:

1. Venturi thermal expansion coefficient
2. Venturi flow coefficient
3. Enthalpy (temperature, pressure)
4. Instrumentation (differential pressure instrument calibration, readout, drift)

With the use of an ultrasonic flow meter the thermal power measurements/uncertainties are essentially the same, i.e., element dimensional accuracy, dimensional stability, temperature effects, pressure, and hydraulic profiles. The basic difference is that the sensitivity to each error contribution varies depending on the meter type. Caldon states that the one loop uncertainty for a venturi based thermal power measurement in a PWR or BWR is typically 1.67% of power. A review of various nuclear plants shows the uncertainties stated for loop power by Caldon are in the lower range of the typical values noted. Generally, the single loop uncertainty for thermal power appears to range from 1.8% to over 3.0% of power when using a venturi to measure feedwater flow based on a review of various Westinghouse PWR plants. As stated in Topical Report ER-80P, the single loop uncertainty of the LEFM for feedwater flow measurement is ±.48% of flow for a total rated thermal power uncertainty of ±.61%.

To provide an improved perspective on the accuracy of ultrasonic flow meters, the staff investigated various available systems and the accuracy attributed to each. Generally, ultrasonic flow meters of the clamp on type (time of flight) have not achieved the accuracy to support the uncertainties in Topical Report ER-80P at this time. A staff review of ultrasonic flow meters of the transit time multipath, chordal, in-line mounted type such as the Caldon LEFM indicate they can achieve the accuracies stated in Topical Report ER-80P. Ultrasonic flow meters have shown significant improvement in recent years with calibration lab test results showing accuracies better than .2% of flow (straight pipe, fully developed flow) and commercially available systems claiming .5% of flow (including the Caldon LEFM). The advantage of the in-line spool piece approach is that the critical dimensions of the pipe diameter, path lengths, path angle and transducer installation can be more precisely controlled thus reducing the uncertainty of these parameters in comparison to other ultrasonic meter installation approaches (clamp on). Additionally, industry testing has shown that a transit time in-line multipath ultrasonic flow meter can provide an improved characterization of the flow profile and thereby provide additional meter accuracy.

The documentation included in Topical Report ER-80P to support the improved flow measurement accuracy for the Caldon LEFM fell into four categories as follows:

1. The LEFM, as configured and applied as described in the topical report, will provide substantially more accurate calorimetric measurement.

2. Meter parameters are verifiable on-line.

3. The combination of the above two factors reduces the probability of overpower in excess of that analyzed in a current, typical plant licensing basis even though the plant covered by that basis is proposing to operate at a power level 1% greater than its current license power limit.

4. Test results support meter accuracy of better than .5% of flow.

While the staff review could not directly confirm the accuracy of the LEFM as installed in the field, it is apparent that technology exists such that a transit time multipath, chordal, in-line mounted ultrasonic flow meter such as the LEFM can achieve an accuracy of .5% of flow. A key element in achieving this accuracy with an ultrasonic flow meter (including a multipath chordal meter) is an extremely accurate representation of the flow profile in a piping configuration that represents the plant specific installation. Temperature is also a factor since the speed of sound in the fluid is a function of temperature. For the LEFM, the calibration of the spool piece in a piping configuration representative of the actual plant specific piping arrangement is important for the instrument to maintain laboratory calibration and achieve the stated accuracy in a plant specific installation.

The staff agrees that an ultrasonic flowmeter of the type described in the Topical Report ER-80P (the Caldon LEFM) has the potential to improve feedwater flow measurement accuracy and ultimately provide an improved thermal power measurement. Based on testing documented in Topical Report ER-80P, the staff finds that the LEFM installation can provide improved feedwater flow measurement accuracy in support of a 1% power uprate, i.e., calibrated spool piece including a meter factor based on plant specific piping configurations and flow profile.

Topical Report ER-80P states that the calibration of the LEFM is verifiable on-line. The staff notes that although the calibration is stated as verifiable on-line there is no in-situ calibration accomplished in the conventional sense or as defined in the plant technical specifications. However, the on-line diagnostics do provide information that verify that the parameters of the LEFM are within acceptable limits. Therefore, the meter accuracy is considered unchanged. This is an improvement over a conventional venturi based flow measurement system in that the meter parameters can be verified throughout a fuel cycle.

In addition to the guidelines outlined in Topical Report ER-80P, as described in the TU submittal, the following criteria should be addressed by licensees incorporating Topical Report ER-80P in their plant licensing bases:

1. The licensee should discuss the maintenance and calibration procedures that will be implemented with the incorporation of the LEFM. These procedures should include processes and contingencies for inoperable LEFM instrumentation and the effect on thermal power measurement and plant operation.

2. For plants that currently have LEFMs installed, the licensee should provide an evaluation of the operational and maintenance history of the installed installation and confirm that the installed instrumentation is representative of the LEFM system and bounds the analysis and assumptions set forth in Topical Report ER-80P.

3. The licensee should 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 methodology 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.

4.0 CONCLUSION

Based on its review of Topical Report ER-80P, the staff concludes that a transit time multipath, in-line mounted ultrasonic flow meter, such as the LEFM, is capable of providing improved thermal power measurement capability through improved feedwater flow measurement accuracy. The staff review of the LEFM confirmed that the measurement of reactor thermal power and related surveillance are consistent with the plant analysis assumptions and the associated uncertainties in the analysis, provided the calibration, installation and maintenance as outlined in Topical Report ER-80P and included in this safety evaluation are followed. Based on the above the staff finds that feedwater flow measurement using the LEFM can provide a thermal power measurement that will remain bounding within an uncertainty of ±1% of rated thermal power. This is premised on the assumption that no additional uncertainties beyond those included in Topical Report ER-80P are assumed to be included in the 10 CFR Part 50,

Appendix K 102% thermal power margin requirement. The staff also finds that the methodology used to determine thermal power uncertainties should be the same as that used to determine current plant thermal power instrumentation uncertainty (venturi) when comparisons in improved thermal power measurement uncertainty is claimed. The staff, therefore, concludes that the use of the LEFM ultrasonic flow meter as described in ER-80P is acceptable.

5.0 REFERENCES

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