Enclosure 2

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TECHNICAL EVALUATION: THE CORE THERMAL LIMIT PROTECTION FUNCTION SETPOINT METHODOLOGY FOR SEABROOK STATION YAEC-1854P FOR YANKEE ATOMIC ELECTRIC COMPANY

P.B. Abramson
H. Komoriya

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International Technical Services, Inc.
420 Lexington Avenue
New York, NY 10170

9406160148 XA

TECHNICAL EVALUATION OF THE CORE THERMAL LIMIT PROTECTION FUNCTION SETPOINT METHODOLOGY FOR SEABROOK TOPICAL REPORT YAEC-1854P FOR THE YANKEE ATOMIC ELECTRIC COMPANY

1.0 INTRODUCTION

YAEC-1854P, dated October 1992 (Ref. 1), was submitted by Yankee Atomic Electric Company (YAEC) for NRC review and approval. Additional information was submitted on May 12, 1994 (Ref. 2). This topical report and the supplemental submittal document YAEC's development of their methodology for determining core thermal limit protection function setpoints for Seabrook Station.

By the use of the proposed methodology, YAEC expects to reduce uncertainty in the quantification of available margin to the LOCA limits in the current methodology. In the proposed methodology, the use of the Fixed Incore Detector System (FIDS) is expected to result in direct continuous monitoring of the actual core power distribution with respect to LOCA limits while in the current methodology, worst case core power distributions are inferred from the excore detector to assure that the they remain within the envelope of acceptable distributions predetermined by analysis. Using a direct surveillance of power distribution to monitor compliance with LOCA limits is expected to result in a reduction in uncertainty which allows the axial flux difference limiting conditions for operation (LCO) band to be relaxed beyond that specified by the currently approved Constant Axial Offset Control (CAOC) philosophy, since the band can be defined by less restrictive axial power distribution constraints.

The proposed methodology described in the submittals is based upon the previously NRC approved setpoint methodology for the Maine Yankee plant. The submittals provide descriptions of adaptations to Seabrook application, necessitated by the plant design differences, made to the approved methodology. Other changes are introduced into the proposed methodology due to the fact that YAEC intends to use YAEC's NRC approved DNB methodology using the Revised Thermal Design Procedure (RTDP) and the WRB-1 critical heat flux (CHF) correlation. The use of the WRB-1/RTDP methodology in place of the W-3/deterministic approach results in a gain of considerable margin in the setpoints providing flexibility in operation.

The purpose of this review, therefore, based upon a review of the submitted materials (Refs. 1, 2), is twofold: (1) to determine acceptability of extension of the existing NRC approved power distribution methodology for

Maine Yankee together with use of the RTDP methodology with WRB-1 to incorporate features of Seabrook plant designs, and (2) to evaluate appropriateness of its application to determine setpoints for Seabrook.

2.0 SUMMARY OF TOPICAL REPORT

The topical report YAEC-1854P and its associated submittal document descriptions of YAEC's core thermal limit protection function setpoint methodology for Seabrook using CASMO-3/SIMULATE-3/TABLES as well as the RETRAN, VIPRE and CHIC-KIN computer codes. The proposed methodology was adapted from NRC approved methodology developed for use with Maine Yankee setpoint determination.

The similarity and differences of the functionality of comparable features of the Seabrook and Maine Yankee protection systems is discussed in detail in support of validating the extension of the approved Maine Yankee methodology to Seabrook application. Methods of determining the axial flux difference LCO band are also discussed.

The supplemental material (Ref. 2) provides descriptions of and approach to qualification of setpoints used with the RETRAN analysis.

2.1 Core Thermal Limit Protection Functions

YAEC demonstrated, in order to show that extension of the approved methodology to Seabrook could be easily made, that both Maine Yankee and Seabrook were designed with functionally similar protection functions: (1) fuel centerline melt protection; (2) prevention of DNB; and (3) control of axial power distribution during normal operation and prevention of DNB during coolant flow reduction.

In addition, YAEC provided a table summarizing the acceptable core thermal design limits for Seabrook and Maine Yankee. These limits included a power generation limit, limits on MDNBR and the hot leg subcooling margin. A limit regarding thermohydrodynamic flow instability in Maine Yankee has been previously analyzed by Westinghouse to be irrelevant for Seabrook. Therefore comparable void fraction limits are not applicable.

2.1.1 Similarities between Maine Yankee and Seabrook Systems

(1) Centerline Melt Protection

Protection against centerline melt is provided at Maine Yankee by a combination of the Variable Overpower Reactor Trip (VOPT) and Symmetric Offset Trip Setpoints (SOTS) in terms of axial power distribution versus power. At Seabrook, the Overpower-DT (OPDT) trip setpoint defines a trip envelop in terms of axial power distribution versus power level.

(2) Prevention of DNB

The reactor protection systems at both plants monitor core power level, core axial power distribution, reactor coolant flowrate and coolant pressure and

temperature. At Maine Yankee, the Thermal Margin/Low Pressure (TM/LP) trip system provide protection against DNB. The Low Reactor Coolant Flow trip assures that the DNB limits are not violated by reduction in coolant flowrate. At Seabrook the Overtemperature DT (OTDT) trip system monitors core power level, pressurizer pressure, excore axial flux difference and coolant loop average temperature. The Low Reactor Coolant Flow and RCP undervoltage and underfrequency trips assure against DNB due to coolant flowrate reduction.

(3) Axial Power Distribution LCO Band and Reactor Coolant Flow Trips

Centerline melt and DNB trip functions do not explicitly provide protection for two types of anticipated operational occurrences (AOOs): (1) reduction in reactor coolant flowrate; and (2) control rod misalignment. For these AOO protection is provided by the low reactor coolant flow trips and Technical Specification limits on axial power distribution. This is because centerline melt and DNB trip functions do not monitor reactor coolant flowrate, radial power peaking or control rod position.

At each plant, core power distributions are limited by the axial power distribution LCO to provide protection during a control rod misalignment or flow reduction AOO. The approved methodology for Maine Yankee included a process for assessing the adequacy of the axial power distribution LCO and low reactor coolant flow trip with respect to those AOOs not protected by the other trip systems. The methodology was extended to analyze these events for Seabrook.

2.1.2 Differences between the Main Yankee and Seabrook Systems

Due to three key differences in the protection system functions between these plants, modifications of the approved Maine Yankee method was necessary before its application to Seabrook. Each of the following will be discussed separately in detail in Section 3.1:

(1) The methodology was modified to accommodate effects of overpower events from reduced power at Seabrook, since Seabrook's OPDT trip setpoint is "fixed" at the maximum overpower value while the Maine Yankee VOPT setpoint is variable with respect to power level.

(2) Because the Maine Yankee TM/LP trip automatically adjusts the trip setpoint at reduced power level while the Seabrook OTDT trip function does not, a modification was made to address overpower events from reduced power.

(3) Operation with automatic rod control is allowed at Seabrook while the Maine Yankee Tech Specs prohibit operation with the control banks in automatic control mode. Therefore, consideration of automatic control rod motion in certain transient situations was included in the proposed methodology for Seabrook.

3.0 EVALUATION

3.1 Setpoint Methodology for Seabrook

The setpoint methodology consists of static and dynamic components. The static portion of the Seabrook setpoint methodology is depicted in a flowchart provided in Reference 2. Certain aspects of the dynamic components are currently and will continue to be provided by Westinghouse. YAEC will perform a check to assure that when all are combined, the methodology remains bounding and acceptable.

In both OPDT and OTDT setpoint evaluation, the core thermal-hydraulic methodology is based upon use of the VIPRE-01 computer code and the revised thermal design procedure, together with a Westinghouse developed statistical uncertainty methodology for computation of DNBR previously approved by the NRC.

Detailed discussion is provided below.

3.1.1 Overpower DT Trip Setpoints

The OPDT trip equation is based upon an assumption that coolant loop temperatures remain subcooled so that the indicated coolant loop delta-T is proportional to core power level. Therefore, by using measured coolant delta T, the OPDT trip indirectly monitors the core power level. The derivation of the trip setpoints is designed to assure that coolant loop temperatures are always subcooled prior to reaching the trip setpoints.

The expression for the OPDT trip setpoint for fuel centerline melt protection is composed of two parts: (1) the base thermal overpower trip setpoint equation consisting of three terms; and (2) the trip setpoint reset function, F_2 (delta-I), which automatically reduces the setpoint when core axial power distribution is skewed to high values of axial flux difference.

The OPDT base overpower trip setpoint corresponds to the VOPT at Maine Yankee and the OPDT F_2 (delta-I) function corresponds to the SOTS at Maine Yankee.

Uncertainties associated with each phase of setpoint determination are summarized in Tables 2-1 through 2-4 of Reference 2.

3.1.1.1 Determination of Base OPDT Setpoint Equation

The base OPDT setpoint equation is a function of coolant loop delta-T. Two of the three terms in the base equation compute the delta-T trip setpoint corresponding to the selected maximum overpower value for the measured coolant loop Tave. The third term provides dynamic compensation of this trip setpoint whenever Tave is increasing and is designed to compensate for the lag in temperature measurements relative to core power level changes during fast transients due to fluid transport, RTD response lag, and instrument processing delays. The method of deriving the two static terms accounts for the effects on the proportionality of coolant loop delta-T to core power level for variations in both temperature and pressure.

The coefficients of the two static terms are computed by fitting a curve defined by the locus of the points of intersection of lines of indicated coolant loop delta-T at maximum overpower values, a vendor specified value, with corresponding DNB limit lines for the range of pressures between the high and low pressure trips using the reference power distribution. Selection of the reference power distribution is discussed in Reference 2.

3.1.1.2 Determination of the Trip Setpoint Reset Function

The base OPDT equation defines protection for operation in the reference power distribution range assuming little axial flux difference. However, when there are high values of axial flux differences, the setpoints must be automatically reduced.

The allowable trip setpoint envelope, defined by the F_2 function, is obtained from a set of data in terms of power level versus axial power shape index (delta-I). The maximum allowed overpower line, a Westinghouse specified value, is drawn near the top so that most of the central points are above this line and form the top of the "tent" shape defined for this function. The function coefficients are computed to define the bounding lines which form the sides of the tent. The function defined by the tent shape is expressed in terms of a required percent reduction of the selected base overpower trip setpoint.

3.1.2 Overtemperature DT Trip Setpoints

The derivation of OTDT trip setpoints is designed to assure protection against violation of the thermal-hydraulic core design limits (hot leg saturation limit and DNB limits).

The functional representation of the OTDT trip setpoint is similar to the OPDT setpoint equation. It consists of a base equation as a function of coolant pressure and temperature and excore axial flux difference expressed by a sum of three terms. One of these terms represents the dynamic compensation of the OTDT setpoint. The base equation is modified by the F_1 (delta-I) function which reduced the setpoint for more adverse core axial power distributions than that assumed in the reference power distribution.

For evaluation of the OTDT trip setpoints, a series of steps are followed: (1) Identification of limiting flyspeck power distributions; (2) Generation of the thermal limit lines; (3) Generation of hot leg saturation limit lines; (4) generation of MSSV limit line.

3.1.2.1 Identification of Limiting Flyspeck Power Distributions

The first step in evaluation of the relative thermal margin is to identify the set of limiting power distributions for a particular core design. Limiting power distributions are identified for each control bank insertion. This is done by a search of each Flyspeck power distribution to find the hot channel location. VIPRE is used to determine the unique minimum value of core power for each distribution at which the DNB design limits would be

reached at the core hot channel location.

The manner in which the methodology deals with the reduced power cases is identical to that for the OPDT trip setpoint determination.

3.1.2.2 Generation of Limit Lines

(1) Thermal Limit Lines (TLLs)

Since protection must be provided over the full range of thermal/hydraulic (T/H) conditions which may be encountered during normal operation and AOOs, the variation in allowable core power level over the range of potential T/H conditions must be considered in order to derive appropriate setpoints. A series of DNB calculations were performed by iterating on core inlet temperature as a variable, to generate the thermal limit lines over a range of potential T/H conditions during normal operation and or AOOs.

The pressure range is bounded by the high and lo-lo pressurizer pressure trip setpoints. The core inlet temperature is bounded by: (1) the saturation temperature associated with the secondary system design pressure; and (2) the temperature at which the low PZR pressure setpoint reaches the base OPDT setpoint.

(2) Hot Leg Saturation Limit Lines

The basic assumption underlying the derivation of the OPDT and OTDT trips is that coolant loop delta-T is proportional to core power provided that the coolant temperature is subcooled. Thus, in order for these trips to be valid, operation must be restricted to maintain subcooled conditions in the hot legs.

Hot leg saturation limit lines are computed using the steady state heat balance approach used in the approved methodology for Maine Yankee, i.e., the same equation is used to compute core power as a function of core inlet temperature for each pressure condition. Computed data are later translated to coolant loop delta-T versus loop Tave, since these are monitored by the OPDT and OTDT trips at Seabrook.

The Hot Leg Saturation Limit lines are bounded by the base OPDT reactor trip setpoint and the main steam safety valve (MSSV) limit line.

(3) MSSV Limit Lines

Once the steam pressure increases to the point of actuating the MSSV, the steam pressure (therefore the saturation temperature) in the steam generator will remain relatively fixed. The MSSV limit line defines the physical upper limit of Tave as a function of coolant loop delta-T.

The derivation of the lines follows the same equation used in the approved methodology.

3.1.2.3 Determination of the Base OTDT Setpoint Equation

The base OTDT trip equation coefficient settings are derived to bound the TLL data for a particular reference power distribution.

The constant coefficients (K_1, K_2 and K_3) are selected to result in a conservative fit of the reference set of thermal limit lines bounded by (1) high and lo-lo pressurizer pressure trip setpoints, (2) OTDT trip setpoint, (3) lo-lo pressurizer pressure trip setpoint, and (4) the MSSV limit line.

The definition and derivation of these coefficients are provided in References 1 and 2.

3.1.2.4 Compensation for Increased Radial Peaking

In order to provide protection against a change in DNB margin due to an increase in radial power peaking at reduced power level, a method was developed to incorporate this effect into the process of determining the base OTDT setpoint equation coefficients.

3.1.2.5 Axial Power Distribution Compensation

The F_1(delta-I) function is derived analogously to the derivation of the F function for OPDT setpoints to adjust for cycle-specific power distributions where the combination of the peaking and axial power shape are more limiting than those included in the set of reference power distributions used to derive the base OTDT trip.

3.1.3 Evaluation of OPDT and OTDT Trip Dynamic Compensation

In order to demonstrate the trip setpoint performance, YAEC selected for analysis transients based upon rapidity of changes in the conditions which influence margin to the DNB thermal design limits. The selected transients are listed in Table 3-2 of Reference 1.

YAEC provided a description of the approach taken to verify adequacy of the dynamic compensation in OPDT and OTDT trip setpoints. Simulation was performed using RETRAN assuming bounding initial conditions and times in core life. Appropriate reduction was made to the K_1 and K_4 setpoint coefficients according to the predicted results.

3.1.4 Axial Flux Difference LCO Band

Normal operation is restricted to remain within an axial power distribution control band (the delta-I LCO band) within which the worst case allowed power distribution has been demonstrated to possess sufficient initial margin to the core thermal design limits.

Through an iterative process, a LCO band is determined. First a transient requiring initial overpower margin is evaluated to define the allowable delta-I LCO band. Then the other events are evaluated to assure that the

initial margin of the limiting power distribution within the band is acceptable. If not, the band is narrowed until the allowable initial power distribution possesses acceptable initial overpower margin for all events. YAEC stated that a similar process is used to validate an existing delta-I LCO band for a particular reload cycle.

Several AOOs result in rapid changes in core power distribution and or core thermal-hydraulic conditions which significantly reduce the available margin to the core thermal design limits, but which are either not detected by the OPDT or OTDT trips or would not be detected quickly enough to prevent violation of the limits. These are loss of forced flow events and misaligned RCCAs.

The initial delta-I LCO band determination is based upon the complete loss of flow event for Seabrook and then redefined to accommodate requirements of single and multiple RCCA drops and static RCCA misalignment events. A check is made to assure that other transients not protected by the OPDT or OTDT are protected by the resulting delta-I LCO band.

3.1.4.1 Evaluation of AOOs with Rod Control in Automatic

In the approved methodology for Maine Yankee, there was no necessity to address AOOs with rod control in automatic operation since this mode is prohibited at Maine Yankee. However, since it is allowed at Seabrook, YAEC developed a method to evaluate the adequacy of the axial power distribution LCO band for the events in which automatic control bank motion may result in reduced margin to core thermal design limit.

YAEC provided qualitative justification with respect to the adequacy of the proposed trip methodology regarding the effects of automatic rod motion for: (1) inadvertent dilution and boration events; (2) excess load and RCCA Bank Withdrawal events; and (3) loss of flow events. These are not considered to be severe enough to cause a power distribution outside of the set of limiting power distributions considered in developing the OPDT or OTDT trip setpoint.

3.1.4.2 Single and Multiple RCCA Drops and Static RCCA Misalignment Events

Misalignment of RCCAs can result in radial/azimuthal power distribution perturbation with reduction in available margin to core thermal design limits not detected by either the OPDT or OTDT trip functions. Hence YAEC developed a method so that the final delta-I LCO band would remain conservatively limiting.

Misaligned RCCA Margin Evaluation

Evaluation of rod drops with rod control in manual operation follows the approved method. An adjustment to the approved methodology is made to accommodate conditions in which the rod control system in automatic mode.

With the control rod bank in automatic mode, the possibility exists for core power level to overshoot the initial pre-drop power level. Thus, in addition to the increase in power peaking which results from the dropped rod(s), the

potential power overshoot must be quantified to determine whether the proposed delta-I LCO band assures availability of sufficient initial margin.

A multi-step process was proposed by YAEC to evaluate acceptability of the proposed Seabrook delta-I band with AUTOMATIC rod control to the RCCA drop event.

A combination of worth, peaking and tilt factors which represent a conservative bounding set was determined by the use of (1) bounding rod drop combinations versus peaking and (2) minimum excore detector signal versus the worth. Combining these two results in a combination of limiting dropped rod worth, increase in peaking, and minimum excore tilt factor that are as or more limiting than the actual combination of these parameters predicted by SIMULATE-3 for a particular dropped rod combination. Calculations continue iteratively until an acceptable set is found, or otherwise the band is reduced until a set can be found.

3.1.4.3 Other Events Affected by Initial Power Distribution

Non-AOO design basis accidents such as Locked RCP Rotor, Single RCCA Withdrawal and RCCA Ejection are analyzed to assure that the delta-I LCO band would adequately bound the consequences of these accidents which are influenced by initial core power distribution.

For these transients, a limiting scenario is used to determine the estimated potential percent of fuel clad failure. The delta-I LCO band is adjusted if the offsite dose computed for the maximum percent fuel failure predicted for any of the limiting initial power distributions allowed by the delta-I LCO band and FIDS LOCA-limiting monitoring is not within the current assumed value for this event.

3.2 Analytical Methods

Eight computer codes are used in computation for the Seabrook setpoint methodology. All of these codes have received NRC approval for the range of the intended application proposed in this methodology.

YAEC described incorporation of Seabrook OPDT and OTDT trip setpoints in the RETRAN analysis through the use of RETRAN control blocks. Only the base equations for these trips are modeled. The F functions, if necessary, are used to bias the trips since the values would be known prior to analysis performance and are not dependant on system parameters computed by RETRAN.

Description of qualification of static and dynamic OPDT and OTDT trip functions as modelled using RETRAN was provided in Reference 2.

4.0 CONCLUSIONS

We reviewed the subject topical report and YAEC responses to the NRC request for additional information, documenting the description of the proposed setpoint methodology for Seabrook based upon the NRC approved YAEC developed setpoint methodology for Maine Yankee, with modifications necessary for

adaption to accommodate the plant protection system function differences between the two plants and to accommodate the effects of automatic control rod motion at Seabrook.

The algorithms used to compute the coefficients of terms in the OPDT and OTDT setpoints and to define the reset functions to reduce the setpoint envelope for skewed power distributions and overpower excursions were reviewed and found to be acceptable. Similarly the methods used to determine an expanded axial flux difference Limiting Condition for Operation (LCO) band were reviewed and found to be acceptable.

However, it should be emphasized that what was reviewed in connection with Seabrook trip setpoint methodology is the process of determining the trip setpoints and not the actual setpoints.

Therefore, regarding the use of YAEC's setpoint methodology for Seabrook Station, since setpoints are technical specification items, and with integration of the RTDP/WRB-1 DNB methodology setpoints for Seabrook are expected to be significantly changed, the individual trip setpoints with appropriate coefficients and associated changes which may result from changes in setpoints must be reviewed to assure that reload licensing transient analysis are still bounding with new setpoints.

5.0 REFERENCES

1. "Core Thermal Limit Protection Function Setpoint Methodology for Seabrook," YAEC-1854P, October 1992.

2. Letter from T.C. Feigenbaum (NAES) to USNRC, "Response to Request for Additional Information (TAC M86959)," May 12, 1994.

3. "Maine Yankee Reactor Protection System Setpoint Methodology," YAEC-1110, September 1976.

4. "Setpoint Methodology Overview for Seabrook Station YAEC-1854P," an NRC/YAEC meeting handout, 4/28/93.