ULNRC-2196

ATTACHMENT 6

SETPOINT CALCULATIONS

FOR

RTD BYPASS ELIMINATION

(NON-PROPRIETARY VERSION)

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1.0 EVALUATION OF OTDT RESPONSE TIME

1.1. Background and Introduction

The Overtemperature Delta-T (OTDT) reactor trip function provides the primary protection against departure from nucleate boiling (DNB) during postulated transients in Westinghouse reactors. The OTDT protection function will trip the reactor when the compensated Delta-T in any two channels exceeds the setpoint. The setpoint for each channel is a continuously calculated setpoint. The Delta-T that is compared to the OTDT setpoint is calculated from the RTDs which measure the hot and cold leg temperatures. The response of the OTDT protection function is dependent on the system used to measure hot and cold leg temperatures. The current plant configuration consists of a bypass loop with the RTDs mounted in the manifold in the bypass loop. Due to maintenance and ALARA concerns, the bypass loop is being removed and the RTDs are being mounted in thermowells which are mounted directly into the hot and cold legs.

The Overpower Delta-T (OPDT) reactor trip function provides backup protection against excessive power (fuel rod integrity protection). No credit is taken for OPDT trips in the Callaway FSAR Chapter 15 accident analyses.

The total time response of the OTDT trip assumed in the safety analyses which form the licensing basis for Callaway is currently 8.0 seconds. However, the Callaway Technical Specifications reflect the testable loop response time for the existing system (6.0 seconds), consistent with the definition of REACTOR TRIP SYSTEM RESPONSE TIME as "the time interval from when the monitored parameter exceeds its Trip Setpoint at the channel sensor until loss of stationary gripper coil voltage." The proposed system will have a total system time response shown below:

	Proposed System (sec)
Direct Immersion RTD	N/A
Combined RTD/Thermowell	4.75
Electronics Delay (7300 cabinets, SSPS, reactor trip breakers)	1.16
Total Testable Response Time	5.91
Scoop and Bypass Loop Delay and Thermal Lag (non-testable)	0.25
Total System Response Time	6.16

The time response is modeled in two parts. The first part is a first order lag (i.e., thermal lags and RTD response) and the second part is a pure delay (i.e., electronics delay).

The appropriate breakdown of the total system time response in terms of first order lag and pure delay is as follows:

	Proposed System	Values Assumed In FSAR Ch. 15 Analyses
First Order Lag	5.0	6.0
Pure Delay	1.16	2.0
Total System Response Time	6.16	8.0

Depending on the transient and the OTDT equation, a first order lag can result in later rod motion than a pure delay of the same magnitude. But in the case of Callaway, the assumptions made in the existing safety analysis do bound the proposed system. Because of the above, no changes are required to the Technical Specification response times.

Superheat Analysis for Equipment Qualification

In addition to the FSAR analyses, OTDT is also credited in WCAP-10961-P, "Steamline Break Mass/Energy Releases for Equipment Environmental Qualification Outside Containment." This analysis was performed by the Westinghouse Owner's Group. The OTDT time response in this analysis used the same conservative assumptions with respect to the OTDT response time as used for the Callaway FSAR accident analyses. The OTDT time response breakdown which was modeled for the Superheat Analysis consisted of a 2.0 second pure delay and a 6.0 second first-order lag. This modeling conservatively bounds both the existing system and the proposed system. Thus, the results of the Superheat Analysis performed for Callaway remain valid.

2.0 HOT LEG TEMPERATURE STREAMING UNCERTAINTY

The setpoint calculations incorporate an uncertainty to account for the difference between the actual hot leg temperature and the measured hot leg temperature caused by the incomplete mixing of coolant leaving regions of the reactor core at different temperatures. This uncertainty is made up of two parts--a temperature streaming uncertainty and a scoop mixing bias. The temperature streaming uncertainty is unchanged from the previous calculations and is based on an analysis of test data from other Westinghouse plants and calculations to evaluate the impact of numerous possible hot leg temperature distributions on the temperature measurement accuracy. The proposed design introduces a scoop mixing bias as discussed in Section 3.4 of Attachment 1. The magnitude of this bias has been quantified using test data from the Salem plant. The scoop bias used in the setpoint calculations is conservatively established as - 0.27°F in the hot leg with no bias in the cold leg.

3.0 CALCULATIONS

To determine the impact of the removal of the RTD bypass piping and manifolds on the Callaway temperature-related control and protection functions, Union Electric performed instrument uncertainty calculations which utilized the latest available information on plant installed instrumentation and the Combustion Engineering scoop/thermowell design. As a direct result of this work, it can be concluded that the Rod Control System will operate within assumed tolerances, and that the temperature-related protection functions (i.e., Overtemperature Delta-T, Overpower Delta-T, SG Water Level Trip Time Delay (TTD) Power 1&2, and Loss of Flow reactor trips) will maintain their current Technical Specification Nominal Trip Setpoints. Changes to the Technical Specification Z, S, and Allowable Values for Overpower Delta-T and SG Water Level TTD Power 1&2 will be requested.

To perform these calculations, Union Electric used the same methodology which was used to calculate Callaway's existing setpoints. This methodology calculates all of the various uncertainties and values pertaining to a reactor trip.

However, there have been some changes to the input uncertainties and the calculational methodology to reflect the use of multiple thermowell-mounted RTDs and the removal of the RTD bypass piping. These modifications are explained below.

3.1. SENSOR ERRORS

3.1.1. SENSOR CALIBRATION ACCURACY (SCA)

The existing Callaway setpoint methodology uses a value of [ ]$^{+a,c}$ for SCA reflecting [ ]$^{+a,c}$.

Thus, any RTD used at Callaway must have an SCA equal to or better than this [ ]$^{+a,c}$. The value of sensor calibration accuracy for the proposed dual element RTD is $\pm$0.3°F, which satisfies the above condition and permits continued use of [ ]$^{+a,c}$ for SCA.

3.1.2. SENSOR DRIFT (SD)

The existing Callaway setpoint methodology uses a value of [ ]$^{+a,c}$ for SD reflecting [ ]$^{+a,c}$. The sensor drift for the proposed dual element RTD is $\pm$1°F over 5 years. Assuming drift is linear and a calibration interval of 24 months, a value for anticipated drift of $\pm$0.4°F is obtained. This value is also enveloped by the value assumed in the existing methodology and therefore permits the continued use of [ ]$^{+a,c}$ for SD.

3.1.3. CALCULATION OF SENSOR ERRORS

In the existing system only one RTD is used to measure temperature in the hot and cold legs, respectively. Since the RTDs are independent, their combined uncertainty for Delta-T was calculated using the square-root-sum-of-squares method. Simple arithmetic averaging was used for T-AVG. Therefore, the following equations were used in calculating error for Delta-T and T-AVG:

Delta-T Sensor Error =

[ ]$^{+a,c}$ (1)

T-AVG Sensor Error =

[ ]$^{+a,c}$ (2)

The proposed design incorporates three RTDs in the hot legs. The cold legs will use one RTD. New equations were used in the updated methodology to calculate the Delta-T and T-AVG errors.

These new equations modify the way the sensor errors are calculated for T-Hot. Since independent, identical RTDs are used, the error for T-Hot is given by:

T-Hot Sensor Error =

$$[((SCA_H + SD_H)^2 + (SCA_H + SD_H)^2 + (SCA_H + SD_H)^2)^{1/2}/3] \quad (3)$$

$$= (SCA_H + SD_H)/\sqrt{3} \quad (4)$$

Substituting Equation 4 into Equations 1 and 2 for the T-Hot terms, we obtain:

Delta-T Sensor Error =

$[\qquad]^{+a,c}$ (5)

T-AVG Sensor Error =

$[\qquad]^{+a,c}$ (6)

As one can see, the new sensor error is smaller because of the added factor of $\sqrt{3}$ in the denominator of the hot leg term due to the averaging of the hot leg RTDs.

3.2. RACK ERRORS

3.2.1. RACK CONFIGURATION

Only minor modifications are needed to be made to the 7300 cabinets to accommodate the proposed design. In the present design, the T-Hot signal is obtained from a single R/E converter (NRA card). In the proposed design, three R/E converters (one for each hot leg RTD) feed a summing amplifier (NSA card). The output of this summing amplifier is T-Hot. All other rack components are unaffected.

3.2.2. PRESENT RACK CALCULATIONAL METHOD

The present setpoint methodology uses a value of $[\quad]^{+a,c}$ for the calibration accuracy of the R/E converters with a value of $[\quad]^{+a,c}$ for M&TE. Similar to the sensor errors, the Delta-T and T-AVG errors due to the R/E converters are calculated by the following equations:

Delta-T R/E Converter Error =

$[\qquad]^{+a,c}$ (7)

T-AVG R/E Converter Error =

$[\qquad]^{+a,c}$ (8)

3.2.3. PROPOSED RACK CALCULATIONAL METHOD

The proposed design will reflect the use of three R/E converters and a summing amplifier in the hot leg temperature loops.

Since 3 R/E converters are employed, the error due to these cards is given by:

$$[(RCA^{H}\ R/E + M\&TE)/\sqrt{3}] \quad (9)$$

Adding the contribution of the independent summing amplifier, one obtains the total error associated with this segment of the rack:

$$[(RCA^{H} + M\&TE)/\sqrt{3} + RCA_{sum}] \quad (10)$$

Substituting Equation 10 into Equations 7 and 8 for the T-Hot terms we obtain:

Delta-T R/E Converter Error =

$$[\qquad]^{+a,c} \quad (11)$$

T-AVG R/E Converter Error =

$$[\qquad]^{+a,c} \quad (12)$$

3.2.4. INPUT UNCERTAINTIES

The manufacturer's accuracy for the NRA and NSA cards are [ ]$^{+a,c}$ and [ ]$^{+a,c}$, respectively. For the purposes of this calculation, the conservative values for the R/E converter accuracy and summing amplifier accuracy are [ ]$^{+a,c}$ and [ ]$^{+a,c}$, respectively.

3.2.5. RACK UNCERTAINTIES

As a result of these changes, the existing values for the rack calibration accuracy due to R/E converters are unaffected. The reduction in the T-Hot uncertainty due to averaging is offset by the addition of the summing amplifier allowance. Since no additional changes are made to the 7300 racks and all cards are made by the same manufacturer, the assumptions made for the remaining rack accuracy and rack drift remain valid. Therefore, the values for these allowances used in the setpoint methodology remain the same.

3.3. BARTON BIAS

In the present setpoint methodology, a bias is included to offset excessive errors at normal temperatures (Barton thermal non-repeatability). Since this problem affected some transmitters manufactured prior to 1984, it was included in

our existing instrument error calculations. Since that time, the pressurizer pressure transmitters have been replaced with transmitters from a different manufacturer. The turbine impulse pressure transmitters have been modified to eliminate the problem. Therefore, this bias value is being eliminated in the uncertainty calculations for the proposed system.

3.4. PROCESS MEASUREMENT ACCURACY (PMA)

Process Measurement Accuracy is used to account for errors due to [ ]$^{+a,c}$. As discussed earlier, this allowance has two parts. In the present setpoint calculations, a value of [ ]$^{+a,c}$ is used for PMA. For the proposed system, a value of [ ]$^{+a,c}$ with a -0.27°F bias will be employed.

3.5. MODEL CHANGES

3.5.1. OVERTEMPERATURE DELTA-T

Based on the above, a new model for Overtemperature Delta-T was constructed with the following features:

a) Addition of the scoop mixing bias in the PMA term for the Delta-T channel.

b) SCA and SD terms for multiple RTDs are calculated per Section 3.1.3 of this report for both the Delta-T and T-AVG channels.

c) Uncertainties for multiple R/E converters are calculated per Section 3.2.3 of this report.

d) Barton thermal non-repeatibility bias is eliminated.

3.5.2. OVERPOWER DELTA-T

The Overpower Delta-T was modified in the following fashion:

a) Addition of the scoop mixing bias in the PMA term.

b) SCA and SD terms for multiple RTDs are calculated per Section 3.1.3 of this report.

c) Uncertainties for multiple R/E converters are calculated per Section 3.2.3 of this report.

3.5.3. SG LOW-LOW WATER LEVEL (TTD POWER 1&2 INTERLOCKS)

The Power 1 & 2 setpoints were modified in the following fashion:

a) Addition of the scoop mixing bias in the PMA term.

b) SCA and SD terms for multiple RTDs are calculated per Section 3.1.3 of this report.

c) Uncertainties for multiple R/E converters are calculated per Section 3.2.3 of this report.

3.5.4. ROD CONTROL SYSTEM ACCURACY

The Rod Control System Accuracy was modified in the following fashion:

a) Addition of the scoop mixing bias in the T-AVG PMA term.

b) SCA and SD terms for multiple RTDs are calculated per Section 3.1.3 of this report.

c) Uncertainties for multiple R/E converters are calculated per Section 3.2.3 of this report.

d) Barton thermal non-repeatibility bias is eliminated in the turbine impulse pressure channels (AC-PT-0505 and -0506).

3.5.5. FEEDWATER AND STEAM FLOW CALORIMETRICS

Both the Feedwater and Steam Flow Calorimetric calculations were reviewed. There is no impact on these calculations since they involve only secondary side parameters.

3.5.6. RCS FLOW UNCERTAINTY

The calculations regarding the RCS flow uncertainty were reviewed. Although allowances for errors in T-Hot and T-Cold are included in the precision calorimetric, the results are not affected. There is no PMA term in this calculation, therefore, the new scoop design has no impact. The values used for SD and SCA in this calculation also envelop the values used in the proposed system for these allowances. The new design which uses 3 hot leg RTDs actually lowers these values for these channels. Thus, the results of the precision calorimetric are not changed. Since the value for the precision calorimetric is later used in the RCS low flow calculation, and that value is unaffected, the result of the RCS low flow calculation remains valid.

The following tables contain the details concerning the protection and rod control function calculations. This information is presented in a format similar to that used by Westinghouse in the earlier setpoint studies.

In addition to the changes listed above, these tables incorporate, as required, a change which modifies the Delta-T gain to reflect the actual 100% Delta-T now at Callaway. This change increases error allowances slightly (i.e. 100% Delta-T span now equates to 86.01°F and 150% rated thermal power).

4.0 Conclusions

The above evaluations performed for an OTDT response time breakdown consisting of a 1.16 second pure delay and a 5.0 second first-order lag demonstrate that the DNBR design limit will continue to be met for those accidients analyzed in the Callaway FSAR that rely on OTDT for protection. Therefore, the conclusions of the FSAR remain valid. This is due to the fact that the present first-order lag and pure delay values assumed in the FSAR accident and WCAP-10961-P analyses envelop the proposed system.

In regard to control and protection functions, the rod control system will operate within its assumed tolerances. Overtemperature Delta-T, Overpower Delta-T, SG Low-Low Water Level TTD Power 1&2 will maintain their current Technical Specification Nominal Trip Setpoints. Changes to Allowable Value and related Z and S parameters will be required; however, for Overpower Delta-T and SG Water Level TTD Power 1 & 2. The power calorimetric and low flow trip are not affected.

OVERTEMPERATURE DELTA T

PARAMETER		ALLOWANCE
PROCESS MEASUREMENT ACCURACY (PMA)	[ ] +a,c	[ ] +a,c
PRIMARY ELEMENT ACCURACY (PEA)		
SENSOR CALIBRATION ACCURACY (SCA)	[ ] +a,c	
SENSOR PRESSURE EFFECTS (SPE)		
SENSOR TEMPERATURE EFFECTS (STE)	[ ] +a,c	
SENSOR DRIFT (SD)	[ ] +a,c	
RACK CALIBRATION ACCURACY (RCA)	[ ] +a,c	

RACK TOTALS

DELTA T
T-AVG
PRESSURE
DELTA I

RACK COMPARATOR SETTING ACCURACY (RCSA)

A. DELTA-T
B. T-AVG

RACK TEMPERATURE EFFECTS (RTE)

A. DELTA-T

RACK DRIFT (RD)

A. DELTA-T
B. T-AVG

SEISMIC ALLOWANCE (SA)

A. DELTA I

[ ]+a,c

NUMBER OF HOT LEG RTDs 3

[ ]+a,c
S= 2.89 S (TEMP)= 1.65 S(PRES)= 1.24
Z= 5.9
[ ]+a,c TA= 9.33 [ ]+a,c
[ ]+a,c

NOMINAL SETPOINT = 1.15 (K1)
ALLOWABLE VALUE = 2.97

OVERPOWER DELTA T

PARAMETER		ALLOWANCE
PROCESS MEASUREMENT ACCURACY (PMA)	[ ]+a,c	[ ]+a,c
PRIMARY ELEMENT ACCURACY (PEA)		
SENSOR CALIBRATION ACCURACY (SCA)	[ ]+a,c	
SENSOR PRESSURE EFFECTS (SPE)		
SENSOR TEMPERATURE EFFECTS (STE)		
SENSOR DRIFT (SD)	[ ]+a,c	
RACK CALIBRATION ACCURACY (RCA)	[ ]+a,c	
RACK TOTALS		
DELTA T		
T-AVG		
RACK COMPARATOR SETTING ACCURACY (RCSA)		
A. DELTA-T		
B. T-AVG		
RACK TEMPERATURE EFFECTS (RTE)		
A. DELTA-T		
RACK DRIFT (RD)		
A. DELTA-T		
B. T-AVG		

NUMBER OF HOT LEG RTDs 3

[ ]+a,c
S= 1.65
Z= 1.9
[=]+a,c TA= 5.67 [ ]a,c
[ ]+a,c

NOMINAL SETPOINT= 1.08 (K4)
ALLOWABLE VALUE= 3.07

DELTA-T (POWER-1 & POWER-2)

PARAMETER		ALLOWANCE	
PROCESS MEASUREMENT ACCURACY (PMA) [ ]	+a,c	[	+a,c
PRIMARY ELEMENT ACCURACY (PEA)			
SENSOR CALIBRATION ACCURACY (SCA) [ ]	+a,c		
SENSOR PRESSURE EFFECTS (SPE)			
SENSOR TEMPERATURE EFFECTS (STE)			
SENSOR DRIFT (SD) [ ]	+a,c		
RACK CALIBRATION ACCURACY (RCA) [RACK ACCURACY]	+a,c		
RACK COMPARATOR SETTING ACCURACY (RCSA) A. DELTA-T			
RACK TEMPERATURE EFFECTS (RTE) A. DELTA-T			
RACK DRIFT (RD) A. DELTA-T			
ENVIRONMENTAL ALLOWANCE (EA) [ ]	+a,c	]	

```
NUMBER OF HOT LEG RTDs              3
       [          ]+a,c
       S=      1.65
       Z=      2.72
   [   =          ]+a,c   TA=     6 [                  ]+a,c
  [                                                          ]+a,c

NOMINAL SETPOINT = 10 AND 20 % RATED THERMAL POWER
ALLOWABLE  VALUE = NOMINAL SETPOINT PLUS  2.6  %SPAN   =
                                  13.9  % RATED THERMAL POWER
                                & 23.9  % RATED THERMAL POWER
```

ROD CONTROL SYSTEM ACCURACY

PARAMETER	ALLOWANCE
PROCESS MEASUREMENT ACCURACY (PMA) +a,c	+a,c
PRIMARY ELEMENT ACCURACY (PEA)	
SENSOR CALIBRATION ACCURACY (SCA) +a,c	
SENSOR PRESSURE EFFECTS (SPE)	
SENSOR TEMPERATURE EFFECTS (STE)	
SENSOR DRIFT (SD) +a,c	
RACK CALIBRATION ACCURACY (RCA) +a,c	
RACK TOTALS	
T-AVG	
TURBINE IMPULSE PRESSURE	
CONTROLLER ACCURACY (CA)	
A. T-AVG	
B. TURBINE IMPULSE PRESSURE	

RACK TEMPERATURE EFFECTS (RTE)		[ ] +a,c
A. T-AVG		
RACK DRIFT (RD)		
A. T-AVG		
B. TURBINE IMPULSE PRESSURE		
BIAS VALUE	(HOT LEG SCOOP STREAMING) 0.27°F HOT LEG; 0°F COLD LEG	0.14
CONTROLLER DEADBAND	1.5 DEGREES F.	0.87

NUMBER OF HOT LEG RTDs 3

ELECTRONICS CSA= [ ] +a,c
ELECTRONICS SIGMA=
CONTROLLER SIGMA=
CONTROLLER CSA=
BIAS VALUE=

ATTACHMENT 7

LIST OF ACRONYMS

FOR

RTD BYPASS ELIMINATION

GENERAL TERMS

AFW	Auxiliary Feedwater
ALARA	As Low As Reasonably Achievable
ANS	American Nuclear Society
ASME B&PV CODE	American Society of Mechanical Engineers Boiler and Pressure Vessel Code
B/P	Bypass Piping
CE	Combustion Engineering
CVCS	Chemical and Volume Control System
DNBR	Departure from Nucleate Boiling Ratio
EDM	Electrical Discharge Machining
ESFAS	Engineered Safety Feature Actuation System
FR-XLPE	Flame Retardant Cross-Linked Polyethylene
FSAR	Final Safety Analysis Report
IEEE	Institute of Electrical and Electronics Engineers
ITDP	Improved Thermal Design Procedure
LCSR	Loop Current Step Response
LOCA	Loss of Coolant Accident
NBS	National Bureau of Standards
NEMA	National Electrical Manufacturers Association
OBE	Operating Basis Earthquake
OPDT	Overpower Delta-T
OTDT	Overtemperature Delta-T
PORV	Power Operated Relief Valve
RCCA	Rod Cluster Control Assembly
RCP	Reactor Coolant Pump
RCPB	Reactor Coolant Pressure Boundary
RCS	Reactor Coolant System
R/E	Resistance to Voltage
RPS	Reactor Protection System
RTD	Resistance Temperature Detector
SBLOCA	Small Break LOCA
SSE	Safe Shutdown Earthquake
SST	Stainless Steel
T-AVG	Average RCS Temperature
T-HAVG	Average Hot Leg Temperature
TS	Technical Specifications
TTD	Trip Time Delay

7300 CARDS

NLP	Loop Power Supply (used for isolation)
NMT	Master Test
NRA	RTD Amplifier (also referred to as R/E Converter)
NSA	Summing Amplifier
NTC	Temperature Channel Test

SETPOINT TERMS

M&TE	Measurement and Test Equipment
PMA	Process Measurement Accuracy
RCA	Rack Calibration Accuracy
SCA	Sensor Calibration Accuracy
SD	Sensor Drift
SQSS	Square Root of the Sum of the Squares