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Your ref: Docket No. 52-006
Our ref: DCP_NRC_002598

August 19, 2009

Subject: AP1000 Response to Proposed Open Item (Chapter 16)

Westinghouse is submitting a response to the NRC open item (OI) on Chapter 16. This proposed open item response is submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in this response is generic and is expected to apply to all COL applications referencing the AP1000 Design Certification and the AP1000 Design Certification Amendment Application.

Enclosure 1 provides the response for the following proposed Open Item(s):

OI-SRP16-CTSB-42

Questions or requests for additional information related to the content and preparation of this response should be directed to Westinghouse. Please send copies of such questions or requests to the prospective applicants for combined licenses referencing the AP1000 Design Certification. A representative for each applicant is included on the cc: list of this letter.

Very truly yours,

Robert Sisk, Manager
Licensing and Customer Interface
Regulatory Affairs and Standardization

/Enclosure

1. Response to Proposed Open Item (Chapter 16)

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ENCLOSURE 1

AP1000 Response to Proposed Open Item (Chapter 16)

AP1000 DCD SER Open Item REVIEW

Open Item Resolution

RAI Response Number: **OI-SRP16-CTSB-42**
Revision: 0

Question:

In DCD TS 3.3.1, Table 3.3.1-1, equations for overtemperature ΔT (Note 1) and overpower ΔT (Note 2) are provided. The staff previously requested, in RAI-SRP16-CTSB-42, that the applicant provide the technical bases and derivation of the revised overtemperature ΔT and overpower ΔT reactor trip setpoint equations presented in Revision 16, and provide a reference to a document approved by the staff for the basis of the revised equations, or submit the basis for the revised equations to the staff for further review. The response provided for RAI-SRP16-CTSB-42 via submittal ML083290461 did not fully address the staff's request. WCAP-8745-P-A, previously reviewed and approved by the staff, provided the bases for the overtemperature ΔT and overpower ΔT setpoint equations presented in Revision 15 of the DCD. The revised equations presented in DCD Revision 16 for these reactor trip functions differ from those previously submitted in Revision 15 of DCD 7.2.1.1.3 and Technical Specification Table 3.3.1-1, Note 1.

Based on this the staff believes that the applicant should document either by submitting a revision to WCAP-8745-P-A, submitting a revision to the DCD, or by submitting an equivalent topical document to be referenced appropriately in the DCD and Technical Specifications Section 5.6.5 per Generic letter 88-16. The submittal should document the bases for the revised equations; the bases for development of the tables of allowable core thermal power as a function of core inlet temperature at various pressures for the overtemperature ΔT trip equation; the bases for the determination of the preset bias K_4 in the overpower ΔT trip equation; and the bases for the constants and bracketed values that appear in the revised equations presented in Revision 16.

Westinghouse Response:

Westinghouse has prepared a Technical Report APP-GW-GLR-137, Rev. 0, to provide the information and references requested. APP-GW-GLR-137 is transmitted under separate cover. (see DCP_NRC_002597 dated August 19, 2009).

Design Control Document (DCD) Revision:

Changes to the following sections of DCD Rev 17 are proposed in this response for consistency and appropriate reference to APP-GW-GLR-137:

Section 7.2.1.1.3
Section 7.2.4
Table 16.3.3.1, Note 1 and 2

Section 16.5.6.5
Section 16 B 2.1.1
Section 16 B 3.3.1

Modify DCD Section 7.2.1.1.3 as shown:

7.2.1.1.3 Core Heat Removal Trips

Overtemperature ΔT Reactor Trip

The overtemperature ΔT trip provides core protection to prevent departure from nucleate boiling for combinations of pressure, power, coolant temperature, and axial power distribution. The protection is provided if the transient is slow with respect to piping transient delays from the core to the temperature detectors and pressure is within the range between the high and low pressure reactor trips. This setpoint includes corrections for changes in density and heat capacity of water with temperature and dynamic compensation for piping delays from the core to the loop temperature detectors. With normal axial power distribution, this reactor trip limit is always below the core safety limit. If axial peaks are greater than design, as indicated by the difference between upper and lower power range nuclear detectors, the reactor trip limit is automatically reduced. Two hot leg temperature measurements per loop are combined with individual cold leg temperature measurements to form four ΔT power signals, $q_{\Delta T}$.

The ΔT power signal, $q_{\Delta T}$, is the calculated core power based on the properties of compressed water at the measured hot leg T_H, cold leg temperature, T_C, and pressurizer pressure, P_{PZR}:

$q_{\Delta T}$ = $f(T_H, T_C, P_{PZR})$

$q_{\Delta T}$ = $\rho(T_C, P_{PZR})[h(T_H, P_{PZR}) - h(T_C, P_{PZR}) \underline{- C}]/\Delta T°$

Where:

T_C = $(1 + \tau_1 s)/[(1 + \tau_2 s)\underline{(1 + \tau_3 s)}]T_{COLD}$, where T_{COLD} is the measured cold leg temperature (lead/lag compensation <u>with time constants τ_1, τ_2, and τ_3</u> applied to compensate for cold leg-to-core transit time)

T_H = $(1 + \tau_4 s)/[(1 + \tau_5 s)\underline{(1 + \tau_6 s)}]T_{HOT}$, where T_{HOT} is the measured hot leg temperature (lead/lag compensation <u>with time constants τ_4, τ_5, and τ_6</u> applied to compensate for core-to-hot leg transit time)

$\rho(T_C, P_{PZR})$ = density of water at cold leg temperature T_C and pressure P_{PZR}

$h(T, P_{PZR})$	=	enthalpy of water at the specified temperature (T_H or T_C) and pressure P_{PZR}
$\Delta T°$	=	a conversion factor, such that the value of $q_{\Delta T}$ is 100 percent at normal rated thermal power
<u>C</u>	<u>=</u>	<u>A bias coefficient that permits zeroing $q_{\Delta T}$ at zero power (to compensate for small errors in RTD calibration)</u>
s	=	Laplace transform operator

The ΔT setpoint for the overtemperature trip is continuously calculated (with one set of temperature measurements per loop) by interpolating from tabulated core safety limits, with correction (if needed) for adverse axial power distribution.

$$OT\Delta T_{SP} = OT\Delta T^{\circ}_{SP} - f_1(\Delta I)$$

Where:

$f_1(\Delta I)$	=	the penalty associated with an adverse axial power distribution
$OT\Delta T^{\circ}_{SP}$	=	the core DNB thermal design limit with design axial power distribution
$OT\Delta T^{\circ}_{SP}$	=	$f(P_{PZR}$, TC). The function f(P,T) is determined by interpolation from specified tables of allowable core thermal power as a function of core inlet temperature at various pressures.

P_{PZR} and T_C, pressurizer pressure and cold leg temperature, are as defined previously.
A reactor trip is initiated if $q_{\Delta T} \geq OT\Delta T_{SP}$ in two of the four divisions.

Two separate ionization chambers supply the upper and lower flux signal for each overtemperature ΔT channel.

Increases in ΔI beyond a predefined deadband results in a decrease in trip setpoint.

The required single pressurizer pressure parameter per loop is obtained from four separate sensors connected to pressure taps at the top of the pressurizer.

Figure 7.2-1, sheet 5, shows the logic for the overtemperature ΔT trip function.

<u>A more detailed description of the Overtemperature ΔT reactor trip is provided in Reference 5.</u>

Overpower ΔT Trip

The **O**verpower ΔT reactor trip provides confidence of fuel integrity during overpower conditions, limits the required range for overtemperature ΔT protection, and provides a backup to the power range high neutron flux trip.

A reactor trip is initiated if the ΔT power signal $q_{\Delta T}$ exceeds the setpoint in two of the four divisions; that is, if:

$$q_{\Delta T} \geq OP\Delta T_{SP} = \underline{C_{OP}°} - f_2(\Delta I),$$

Where:

$q_{\Delta T}$ is the same ΔT power signal used for the Overtemperature ΔT reactor trip

$\underline{C_{OP}°}$	=	A preset bias
$F_2(\Delta I)$	=	A function of the neutron flux difference between upper and lower ionization chamber flux signals (to correct, if necessary, for an adverse axial flux shape)

Increases in ΔI beyond a predefined deadband result in a decrease in trip setpoint.

The source of temperature and neutron flux information is identical to that of the overtemperature ΔT trip, and the resultant ΔT setpoint is compared to the same measured ΔT power signal. Figure 7.2-1, sheet 5, shows the logic for this trip function.

<u>A more detailed description of the Overpower ΔT reactor trip is provided in Reference 5.</u>

Modify DCD Section 7.2.4 as shown:

7.2.4 References

1. WCAP-16438-P (Proprietary), WCAP-16438-NP (Non-Proprietary), "FMEA of AP1000 Protection and Safety Monitoring System," Revision 2.

2. WCAP-15776, "Safety Criteria for the AP1000 Instrument and Control Systems," April 2002.

3. WCAP-16097-P-A (Proprietary) and WCAP-16097-NP-A (Non-Proprietary), Appendix 3, Rev. 0, "Common Qualified Platform, Digital Plant Protection System," May 2003.

4. WCAP-16592-P (Proprietary), WCAP-16592-NP (Non-Proprietary), "Software Hazards Analysis of AP1000 Protection and Safety Monitoring System," Revision 1.

5. **APP-GW-GLR-137, "Bases of Digital Overpower and Overtemperature Reactor Trips," Rev. 0**

Revise Note 1 and 2 of DCD Table 16.3.3.1 as follows:

Note 1: Overtemperature ΔT

The ΔT power signal, $q_{\Delta T}$, shall not be less than the measured reactor thermal power by more than 1% of RTP, where the ΔT power signal, $q_{\Delta T}$, is computed as

$$q_{\Delta T} = \rho\,(T_C, P_{PZR})\,[h\,(T_H, P_{PZR}) - h\,(T_C, P_{PZR}) - C]/\Delta T^\circ$$

where:

T_C = $[(1 + \tau_1 s)/[(1 + \tau_2 s)(1 + \tau_3 s)]\, T_{COLD}$, where T_{COLD} is the measured cold leg temperature, °F, with lead/lag compensation applied to compensate for cold leg-to-core transit time and sensor response tme

T_H = $[(1 + \tau_4 s)/[(1 + \tau_5 s)(1 + \tau_6 s)]\, T_{HOT}$, where T_{HOT} is the measured hot leg temperature, °F, with lead/lag compensation applied to compensate for core-to-hot leg transit time and sensor response time

$\tau_1 \cancel{\geq} = [*]$ sec $\tau_2 \cancel{\leq} = [*]$ sec $\tau_3 = [*]$ sec
$\tau_4 \cancel{\geq} = [*]$ sec $\tau_5 \cancel{\leq} = [*]$ sec $\tau_6 = [*]$ sec

$\rho\,(T_C, P_{PZR})$ = density of water at the measured cold leg temperature in the cold leg (T_C), °F, and measured pressurizer pressure, P_{PZR}, psia

$h\,(T, P_{PZR})$ = enthalpy of water at the specified measured temperature (T_H or T_C) and measured pressurizer pressure, P_{PZR}, psia

ΔT° = a conversion factor, such that the value of $q_{\Delta T}$ is 100 percent at normal rated thermal power

C = a bias coefficient that permits zeroing $q_{\Delta T}$ at zero power (to compensate for small errors in RTD calibration)

s = Laplace transform operator

And the Overtemperature ΔT setpoint shall not exceed the following nominal Trip Setpoint by more than 0.2% of RTP for T_{HOT}; 0.2% of RTP for T_{COLD}; 0.06% of RTP for pressure; and 0.14% of RTP for ΔI.

$$OT\Delta T_{SP} = OT\Delta T^{\circ}_{SP} - f_1(\Delta I)$$

and trip if $[OT\Delta T_{SP} - q_{\Delta T})][(1 + \tau_{10}s)/[(1 + \tau_{11}s)(1 + \tau_{12}s)] < 0$

where:

$OT\Delta T^{\circ}_{SP}$ = f ($P_{\cancel{PZR}}$, T_C), determined by interpolation from tables [*] of allowable core thermal power as a function of core inlet temperature at various pressures, where P_P is the minimum of $[P_{PZR}(1 + \tau_{21}s)/(1 + \tau_{22}s)$ and $P_{PZR}]$.

P_{PZR} and T_C pressurizer pressure and cold leg temperature, are as defined above

$\tau_{10} = \geq$[*], $\tau_{11} \leq$[*], $\tau_{12} = \leq$[*]

$\tau_{21} = \geq$[*], $\tau_{22} \leq$[*],

$f_1(\Delta I)$ = [*] {[*] + ($q_t - q_b$)]when $q_t - q_b \leq$-[*]% RTP

0% of RTP when -[*]% RTP < $q_t - q_b \leq$[*]% RTP

-[*] {($q_t - q_b$) – [*]} when $q_t - q_b$ > [*]% RTP

where q_t and q_b are percent RTP in the upper and lower halves of the core respectively,

and $q_t + q_b$ is the total THERMAL POWER in percent RTP.

*These values denoted with [*] are specified in the COLR.

Note 2: Overpower ΔT

The Overpower ΔT setpoint shall not exceed the following nominal Trip Setpoint by more than 0.2% of RTP for T_{HOT}; and 0.2% of RTP for T_{COLD}.

$OP\Delta T_{SP} = [\cancel{K_4}C_{OP}^{\circ} - f_2(\Delta I)$

And trip if [OPΔTSP –qΔT][(1 + τ_7s)/[(1 + τ_8s)(1 + τ_9s)] < 0

Where:

$\cancel{K_4 C_{OP}^{\circ}} \leq$[*]

$f_2(\Delta I)$ = [*]

$\tau_7 \geq$[*], $\tau_8 \leq$[*], $\tau_9 \leq$[*]

*These values denoted with [*] are specified in the COLR.

Add the following reference to DCD Section 16.5.6.5.b.

6. APP-GW-GLR-137, "Bases for Digital Overpower and Overtemperature (OPΔT/OTΔT) Reactor Trips", Rev. 0

   (Methodology for Specification 2.1.1 – Reactor Core Safety Limits, and 3.3.1 – Reactor Trip System (RTD) Instrumentation)

Modify DCD Section 16 B 2.1.1 as follows:

Page B 2.1.1-2:

SAFETY LIMITS

The figure provided in the COLR shows the loci of points of THERMAL POWER, RCS pressure, and cold leg temperature for which the minimum DNBR is not less than the safety analysis limit, that fuel centerline temperature remains below melting, ~~that the average enthalpy in the hot leg is less than or equal to the enthalpy of saturated liquid,~~ or that the exit quality is within the limits defined by the DNBR correlation.

Page B 2.1.1-3

SAFETY LIMITS (continued)

The reactor core SLs are used to define the various RPS functions such that the above criteria are satisfied during steady state operation, normal operational transients, and anticipated operational occurrences (AOOs). To ensure that the RPS precludes the violation of the above criteria, additional criteria are applied to the Overtemperature and Overpower ΔT reactor trip functions. That is, it must be demonstrated that ~~the average enthalpy in the hot leg is less than or equal to the saturation enthalpy and~~ the core exit quality is within the limits defined by the DNBR correlation and that the Overtemperature and Overpower ΔT reactor trip protection functions continue to provide protection if local hot leg streams approach saturation temperature. Appropriate functioning of the RPS ensures that for variations in the THERMAL POWER, RCS Pressure, RCS cold leg temperature, RCS flow rate, and ΔI that the reactor core SLs will be satisfied during steady state operation, normal operational transients, and AOOs.

Modify DCD Section 16 B 3.3.1 as follows:

Page B 3.3.1-14:

- axial power distribution – the Trip Setpoint is varied to account for imbalances in the axial power distribution as detected by the PMS upper and lower power range detectors. If axial peaks are greater than the design limit, as indicated by the difference between the upper and lower PMS power range detectors, the Trip Setpoint is reduced in accordance with Note 1 of Table 3.3.1-1.

Dynamic compensation of the ΔT power signal is included for system piping delays from the core to the temperature measurement system. The Overtemperature ΔT trip Function is calculated for each loop as described in Note 1 of Table 3.3.1-1. **<u>A detailed description of this trip is provided in Reference 11.</u>** This Function also provides a signal to generate a turbine runback prior to reaching the Trip Setpoint. A turbine runback will reduce turbine power and reactor power. A reduction in power will normally alleviate the Overtemperature ΔT condition and may prevent a reactor trip. No credit is taken in the safety analyses for the turbine runback.

Page B 3.3.1-15:

- Axial power distribution – the Trip Setpoint is varied to account for imbalances in the axial power distribution as detected by the PMS upper and lower power range detectors. If axial peaks are greater than the design limit, as indicated by the difference between the upper and lower PMS power range detectors, the Trip Setpoint is reduced in accordance with Note 2 of Table 3.3.1-1.

The Overpower ΔT trip Function is calculated for each loop as per Note 2 of Table 3.3.1-1. **<u>A detailed description of this trip is provided in Reference 11.</u>** The Trip Setpoint reflects the inclusion of both steady state and adverse environmental instrument uncertainties as the detectors provide protection for a steam line break and may be in a harsh environment. Note that this Function also provides a signal to generate a turbine runback prior to reaching the Trip Setpoint. A turbine runback reduces turbine power and reactor power. A reduction in power normally alleviates the Overpower ΔT condition and may prevent a reactor trip.

Page B 3.3.1-45:

REFERENCES

1. Chapter 6.0, "Engineered Safety Features."
2. Chapter 7.0, "Instrumentation and Controls."
3. Chapter 15.0, "Accident Analysis."
4. WCAP-16361-P, "Westinghouse Setpoint Methodology for Protection Systems – AP1000," May 2006 (proprietary).
5. Institute of Electrical and Electronic Engineers, IEEE-603-1991, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations," June 27, 1991.
6. 10 CFR 50.49, "Environmental Qualifications of Electric Equipment Important to Safety for Nuclear Power Plants."
7. APP-GW-GSC-020, "Technical Specification Completion Time and Surveillance Frequency Justification."
8. NRC Generic Letter No. 83-27, Surveillance Intervals in Standard Technical Specifications.
9. ESBU-TB-97-01, Westinghouse Technical Bulletin, "Digital Process Rack Operability Determination Criteria," May 1, 1997.
10. WCAP-13632-P-A (Proprietary) and WCAP-13787-A (Non-Proprietary), Revision 2, "Elimination of Pressure Sensor Response Time Testing Requirements," January 1996.
11. **APP-GW-GLR-137, "Bases of Digital Overpower and Overtemperature Delta-T (OPΔT/OPΔT) Reactor Trips**