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Your ref: Docket No. 52-006
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January 22, 2010

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

Westinghouse is submitting the following responses to the NRC open item (OI) on Chapter 16. These proposed open item response are submitted in support of the AP1000 Design Certification Amendment Application (Docket No. 52-006). The information included in these responses 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 R1

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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NRO

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ENCLOSURE 1

AP1000 Response to Proposed Open Item (Chapter 16)

AP1000 TECHNICAL REPORT REVIEW

Response to Request For Additional Information (RAI)

RAI Response Number: OI-SRP16-CTSB-42
Revision: 1

Question:

Request for Additional Information Related to Information in APP-GW-GLR-137

Based upon information contained within the AP1000 Standard Combined License Technical Report, APP-GW-GLR-137, "Bases of Digital Overpower and Overtemperature Delta-T (OPΔT/OTΔT) Reactor Trips," several topics require further explanation. Those areas of information requiring further understanding are captured below:

1.) Within Section 1.0, "Introduction and Summary", the text states that due to the digital design of the Protection and Safety Monitoring System (PMS) it allows an individual RTD to "vote" for a trip if it approached saturation. This eliminates the need to assign uncertainties to the variation between local RTD temperature and bulk hot leg T_H fluid temperature.

How does that action meet the single failure criteria of 10 CFR 50.55a(h)?

2.) Within Section 3.0, Description of Digital OPΔT and OTΔT Reactor Trips, T_H Signal Development, Sub-Section 2, "Streaming Bias" it discusses the bias applied to the $T_{HOT-LOCAL}$ signal such that it provides a best-estimate for the "mixed mean hot leg temperature.

Specifically, how does the bias applied to the $T_{HOT-LOCAL}$ signal lead to approximation of the mixed mean hot leg temperature? Also, why are the errors insignificant contributors to the uncertainty in either the ΔT power signal ($q_{\square T}$) or the OPΔT/OTΔT setpoints?

3.) Within Section 3.0, Description of Digital OPΔT and OTΔT Reactor Trips, T_H Signal Development, Sub-Section 4, "Redundant Sensor Algorithm (RSA)", the discussion of T_H streaming informs the reader about the logic used if either one or more than one $T_{HOT-LOCAL}$ signals indicate an approach to saturation temperature and the potential for the signal to go to the TRIP state.

Is this topic discussed in Chapter 7 of the DCD? If so, state specifically where and if not, explain why not.

4.) Within Section 3.0, Description of OPΔT and OTΔT Reactor Trips, T_H Signal Development Sub-Section 5, "Weighted Average", the text discussed how weighting factors may be applied or presumably adjusted based on operating experience and other factors. However, the text also discusses that these weighting factors may be adjusted automatically. Describe how the weighting factors are automatically adjusted in these trip functions. Explain how the automatic adjustment of setpoints or weighting factors would not violate 10 CFR 50 Appendix B, Criterion III, Design Control.

5.) Within Section 3.0, Description of OPΔT and OTΔT Reactor Trips, T_C Signal Development Item 3, a discussion dealing with a preset tolerance of expected temperature being utilized for downstream calculations and if a value falls outside of the preset tolerance then the T_{COLD} signal is flagged for BAD quality.

How does the system respond after the signal is flagged as bad quality?

6.) Within Section 3.0, Description of OPΔT and OTΔT Reactor Trips, Development of the Digital OPΔT Margin to Trip Sub-Section, the text discusses how a reactor trip is initiated if the value becomes negative, but no discussion is offered on how this affects the PMS.

Specifically, is the OPΔT Margin to Trip signal simply an explanation of the methodology utilized to generate an OPΔT trip signal? If so, does this signal perform any other functions (e.g. indications or alarm functions)?

7.) Regarding equations shown in Section 3, the time constants that are common between the equations presented in this topical report and those presented in Appendix A of Ref. 1, WCAP-8745-P-A, "Design Bases for the Thermal Overpower ΔT and Thermal Overtemperature ΔT Trip Functions," are unchanged in their inherent meaning, however it is discussed that the way in which the dynamic response equations are developed has changed. Additionally, the number of time constants in the updated methodology has increased (e.g. there are now three terms in the overall lead/lag term as opposed to two in the previously accepted methodology). Also, in Section 1, it is stated that "direct use of T_{hot} and T_{cold} instead of T_{avg} and ΔT also simplifies the dynamic compensation for instrument delays and fluid transport time," but this is not shown or discussed further.

Regarding the time constants that function within various OPΔT and OTΔT algorithms, where is the discussion of the application of these constants within the safety analysis of record for the AP1000 plant? What is the definition of each time constant? Also, how exactly are these time constants calculated; meaning how are the given input parameters converted, complied, or otherwise altered or added into the function to produce the resultant, function-based output signal?

8.) In the OTΔT trip function, the ΔT power signal, $q_{\Delta T}$, is adjusted by a bias coefficient C to compensate for small error in RTD calibration, and a conversion factor ΔT_o to normalize $q_{\Delta T}$ to 100% at rated thermal power. Describe how these two constants are determined and implemented in the OTΔT trip function, and how often they have to be adjusted during plant operation.

9.) Provide the value of the limiting time constants to be given in the safety analysis of record referenced by the corresponding technical specifications given in DCD Tier 2 Chapter 16, Table 3.3.1-1 Notes 1 and 2. Also, provide the time constants to be used for the reference cycle if they are different than those given in the safety analysis of record.

10.) How does the old analog dynamic response model compare with the new model that does not use T_{avg} and ΔT and employs digital instrumentation? Provide a comparative example to demonstrate.

11.) Have the Chapter 15 design basis events which take credit of the OTΔT and OPΔT reactor trip functions been re-analyzed with the revised digital-based OTΔT and OPΔT reactor trip functions? Are the analyses of record of these events in the AP1000 DCD based on the revised OTΔT and OPΔT functions? If not, what are the justifications for the validity of the DCD analyses for the affected events?

12.) Time constants have been added in the dynamic compensation equations given in the topical report that are not seen in corresponding logic diagrams in the DCD. Specifically, DCD Tier 2 Figure 7.2-1 (Sheet 5) should be updated to include all time constants as appropriate.

13.) Ensure that the AP1000 DCD Tech Specs and associated Tech Spec Bases are updated to reflect the information in Technical Report APP-GW-GLR-137, as clarified by the RAI responses.

Westinghouse Response:

Response to 1: This action is explained more fully in item 3 of Section 3 of APP-GW-GLR-137. The approach to saturation temperature of a single RTD within a division only means that it is excluded from the average hot leg temperature signal for that division. The action is taken independently within each of the four divisions. The two-of-four voting logic by divisions is not impacted by one (or more) RTDs approaching saturation, so the single failure criterion is not impacted.

Response to 2: The term "bias" may be misleading here. To minimize confusion, we are modifying the wording in APP-GW-GLR-137 to use the word "correction" rather than "bias" for this feature. In any case, the ΔT power signal is proportional to power, and is calibrated to agree with the measured thermal power. Since the signal is checked frequently against the thermal power, and adjusted when needed, it is not sensitive to difference (error) between the actual mixed mean hot leg temperature and the presumed average hot leg temperature to which the individual hot leg RTD signals are corrected. Hot leg temperature is not an input to either the OPΔT or the OTΔT setpoints, so they are not impacted by such an error.

Response to 3: This feature, and other digital OPΔT/OTΔT design features are incorporated by reference to APP-GW-GLR-137 (see the accompanying DCD Rev 17 markup submitted with the report via DCP_NRC_002598 of August 19 2009, enclosing the response to OI-SRP16-CTSB-42.)

Response to 4: The sentence in Rev 0 of the report states, "The weighting factors are automatically re-adjusted (so they continue to sum to 1.000 for active channels) in the event that one $T_{HOT\text{-}LOCAL}$ signal is given a BAD quality or fails the RSA check." The wording of the sentence inaccurately implies that the individual weighting factors are changed, when in fact only the relative weights of the individual temperatures are changed. The actual formula is

$$T_H = \left[\Sigma\left(W_i T_{Hi}\right)\right] / \left[\Sigma\left(W_i\right)\right]$$, where T_{Hi} is the signal from the ith RTD (i=1 to 3)

The individual weighting factors, W_i, are not changed when an RTD is dropped from the average. Only the sum of the weighting factors, $\Sigma(W_i)$, changes.

To clarify this point, we are modifying the sentence in APP-GW-GLR-137 and adding the equation above.

Response to 5: A BAD quality for the group T_{COLD} signal will cause an alarm in the Main Control Room (MCR) to alert operators to investigate the cause and take appropriate action. The response of the bistables to a BAD T_{COLD} signal in that division depends upon the numeric value of the signal (the last input value of the signal that could be interpreted) and whether the individual signals were detected as "bad sensor input" (i.e., out-of-range). For example, if both are offscale low, then no trip occurs (since cold shutdown is a normal state); but if both are offscale high, the division votes for a reactor trip. Other cases depend on the numeric value of the signal and whether the analog to digital converter detected a bad sensor input value.

Response to 6: The PMS trip occurs on the margin to trip (i.e., the $Margin_{OP\Delta T}$ signal is the input to the trip bistable). The margin to trip signal also goes to the Main Control Room for alarm and display; is hardwired to the plant control system; and is put on the data highway for other systems. Also, please note that lead/lag compensation can be applied to the margin to trip signal to compensate for reactor trip delays if desired.

Response to 7: The discussion of the time constants is incorporated in the DCD Chapter 7 by reference to the technical report, APP-GW-GLR-137, in the markup to DCD Rev 17 submitted concurrently with the technical report (see reference in response to Question 3). The time constants are calculated as described in the technical report.

Two lag terms (rather than one) are used in the digital function because they provide better filtering for high frequency noise with little impact on low frequency noise (for which the response is approximately the same as for a first-order lag with the same total time constant).

The lag terms are selected as a compromise between noise filtering (large values) and fast response (small values). The net lead (lead time constant minus the sum of lag time constants is selected to provide the dynamic compensation required, as described in APP-GW-GLR-137 for T_C and T_H in the section on "Development of the ΔT Power Signal", and in the sections on development of the OPΔT and OTΔT margins to trip signals for τ_7 through τ_{12}.

Specific values of the lead and lag terms are determined by the safety analysis; i.e., whatever values were used in the safety analysis to verify the adequacy of the protection system are the values to be set in the plant.

Response to 8: The ΔT power signal, $q_{\Delta T}$, should be checked prior to plant startup and the bias coefficient, C, adjusted such that $q_{\Delta T}$ is zero at hot zero power. This is part of the channel calibration required every 24 months by SR 3.3.1.9. The conversion factor, ΔT_o, is essentially a gain adjustment and will be adjusted whenever necessary to comply with SR 3.3.1.3. SR 3.3.1.3 requires that the ΔT power signal be compared every 24 hours with the measured thermal power and adjusted if needed, comparable to the SR 3.3.1.2 requirement for the neutron flux power range signal.

Questions 9, 10, and 11 are combined for a single response

Response: The adequacy of the digital OTΔT and OPΔT trip functions has been confirmed. Although the Chapter 15 analyses in DCD Rev 17 were generated prior to adoption of the digital OPΔT/OTΔT reactor trip, analyses were done to confirm that the digital function could emulate the analog trip without loss of safety margin. Results of those analyses were provided in the response to RAI-TR36-012 Rev 1 (submitted Oct 4, 2007, Project Number 740, providing quantitative analyses for Technical Report 36, APP-GW-GLR-016, Pressurizer Configuration Design Change), As stated in item 4 (Uncontrolled RCCA Withdrawal at Power) of the response to question 1 in that document:

> "Quantitative analyses of the RCCA bank withdrawal event were performed using the updated AP1000 configuration. . . The new analyses incorporated the reconfigured Overtemperature ΔT (OTDT) reactor trip function (see Reference 2). . . As the OTDT reactor trip function was configured originally on the AP1000 and on operating Westinghouse plants, a conservative linear relationship is used in setting the setpoints of the trip function. With the improved digital OTDT trip function, setpoints can be selected to match the non-linear characteristics of the core thermal limits. For this analysis, OTDT setpoints were chosen to give the same trip characteristics as the original OTDT function. Differences can be seen in the analysis results for cases that trip on OTDT, but these are principally due to the refined dynamic compensation (filters, lead/lag functions) used with the new OTDT reactor trip."

Table 4-1 and Figures 4-1 through 4-12 show the response to the original analog trip functions and the revised digital trips. As noted above, the digital design can duplicate the steady-state trip limits with negligible difference, but the dynamic compensation can only be approximated since the analog applies lead/lag compensation to the Tavg and ΔT signals, and the digital applies compensation to the T_{HOT} and T_{COLD} signals. The dynamic terms used for the analog and digital systems were as follows:

1. **Analog OPΔT/OTΔT Reactor Trip ("Original AP1000")**

Tavg & ΔT Measurement lag (RTD-Thermowell Time Constant)	5.5 sec
Lead/Lag on Tag for OTDT Reactor Trip	33/4 sec
Lead/Lag on ΔT signal	0/0 sec

2. **Digital OPΔT/OTΔT Reactor Trip ("Updated AP1000")**

Thot & Tcold Measurement Lag (RTD-Thermowell Time constant)	4.0 sec
Thot Lead/Lag,lag	13/4,0 sec
Tcold Lead/Lag,lag	6/3,0 sec
Lead/Lag,lag on OTDT Margin to Trip	0/0,0

For both the analog and digital trips, A 2.0 second reactor trip time delay was assumed for both the analog and digital trips.

The figures from the response to RAI-TR36-012 will be put in the DCD as part of the markup from Rev 17 to Rev 18 such that the DCD chapter 15 analyses will reflect the digital design.

Response to 12: See attached Figure 7.2-1 (Sheet 5 of 20) for change to Figure to make it consistent with the terminology provided in topical report.

Response to 13: The requested DCD revisions are being made as part of the responses to RAI-TR36-012, RAI-SRP16.0-CTSB-42, and this Open Item response and will be included in DCD Rev. 18.

Design Control Document (DCD) Revision:

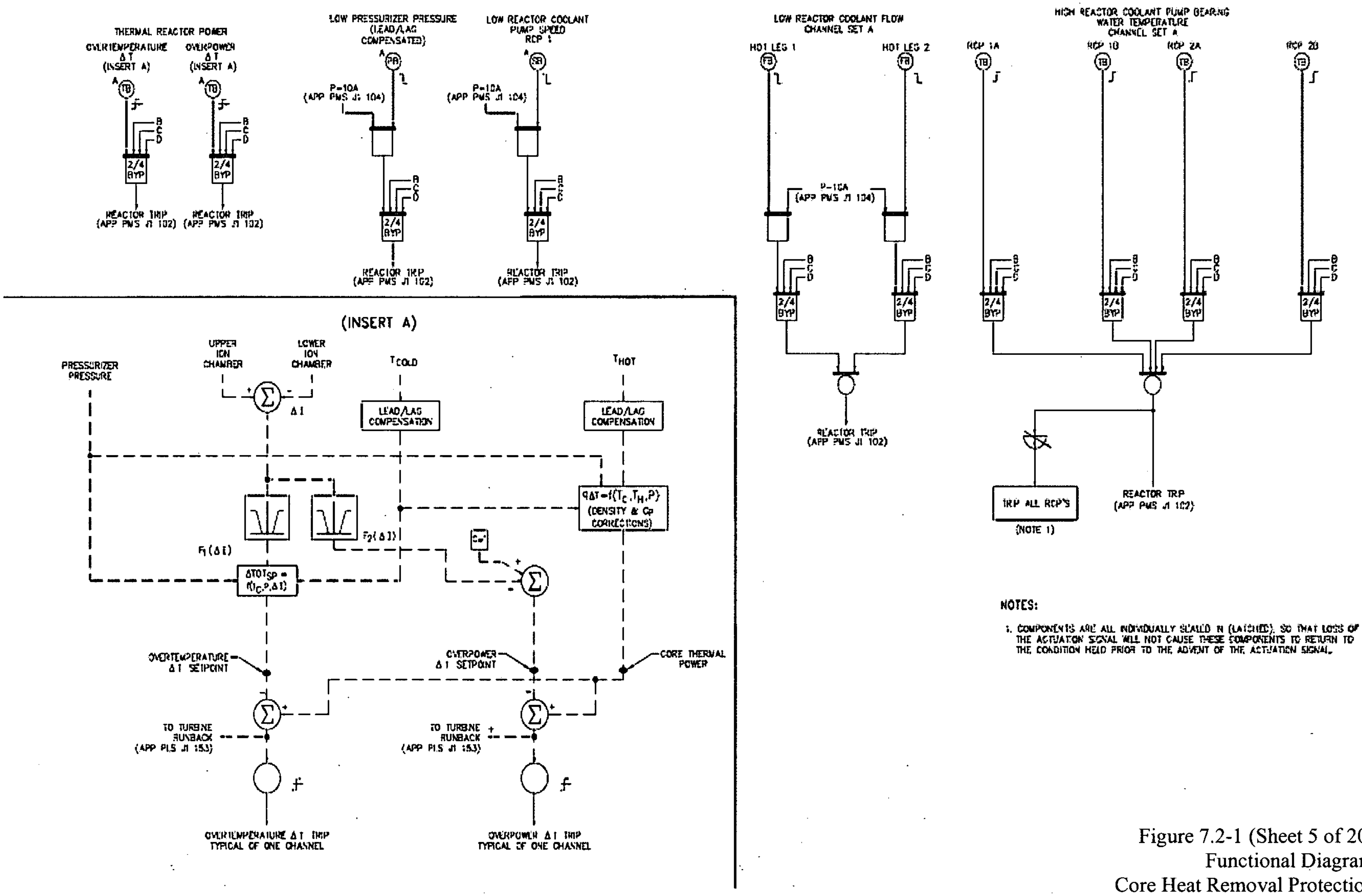

Figure 7.2-1 (Sheet 5 of 20)
Functional Diagram
Core Heat Removal Protection
and Reactor Coolant Pump Trip

PRA Revision:

None

Technical Report (TR) Revision:

None