WCAP-15234-S1

# RETRAN-02 Modeling and Qualification For Westinghouse Pressurized Water Reactors Non-LOCA Safety Analyses

## Supplement 1-Thick Metal Mass Heat Transfer Model and NOTRUMP-Based Steam Generator Mass Calculation Method

December 2002

## 1.0 Introduction / Purpose

The current RETRAN methodology, as described in Reference 1, includes several assumptions that are unnecessarily conservative for the analyses of long-term heatup events, such as Loss of Normal Feedwater (LONF), Loss of Non-Emergency AC Power (LOAC) and Feedwater Line Break (FLB) events.

One unnecessarily conservative assumption is the neglecting of coolant-to-metal heat transfer. This assumption is conservative in that it maximizes primary side coolant temperature changes. However, this level of conservatism is considered unnecessary. Therefore, Westinghouse has developed an enhanced thick-metal model to be used in the RETRAN analysis of selected heat-up events, such as the Loss of Normal Feedwater, Loss of Non-Emergency AC Power and Feedwater Line Break events. The enhanced RETRAN thick-metal model is based on the approved LOFTRAN thick-metal model, documented in WCAP-7907-S1-P (Reference 2). This model is described in detail in Section 2.

Conditions in the current RETRAN steam generator (SG) model are also unnecessarily conservative as themodel under-predicts the steam generator mass. Therefore, an existing method in which more realistic but conservative steam generator masses are calculated is employed. This method is based on a detailed, plant-specific steam generator model, generated using the NOTRUMP computer code. This model is described in detail in Section 3.

This report will justify the use of the enhanced thick-metal model and the NOTRUMP based steam generator mass calculations in the analyses of selected heat-up transients, such as the LONF, LOAC and FLB events.

## 2.0 Enhanced RETRAN Thick-Metal Heat Transfer Model

Heat transfer to and from metal in the reactor coolant system (RCS) is ignored in the majority of the non-LOCA RETRAN analyses (Reference 1). This is conservative in that it minimizes the primary system heat capacity and thus accentuates RCS temperature changes. One exception is in the computation of mass and energy release following a steam line break in which neglecting the heat transfer between the RCS metal and the coolant would be non-conservative. For steam line break mass and energy release calculations performed with RETRAN, Westinghouse applies a simplified thick-metal mass heat transfer model that conservatively over-predicts the heat transfer from the thick-metal to the reactor coolant fluid.

In transients with a relatively large yet slow increase in RCS temperature, such as a loss of normal feedwater event, there would be a substantial amount of heat absorbed in the RCS thick-metal mass. While it is conservative to ignore this effect in heat-up transients, this conservatism is considered unnecessary. To credit the heat absorption characteristics of RCS thick-metal masses, the simplified thick-metal mass heat transfer model used in the steam line break mass and energy release calculations is inappropriate because it would overestimate the heat transfer to the thick-metal.

Therefore, a more enhanced RETRAN thick-metal mass heat transfer model has been developed for use in the long-term heatup events, such as loss of normal feedwater. This model is based on the enhanced LOFTRAN model described in WCAP-7907-S1-P (Reference 2), which was approved by the Nuclear Regulatory Commission (NRC) via the Safety Evaluation Report (SER) of Reference 3 for use in the analysis of feedwater line break. [ ] a,c

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] It is expected that the net effect of these two differences will effectively be similar in magnitude and not as large as the overall effect of modeling of the thick-metal mass. Therefore, the results from the RETRAN thick-metal model are expected to be comparable to the results from the LOFTRAN thick-metal model for transients with a relatively large yet, slow increase in RCS temperature despite these differences in the methodology. Figure 2-3 and Figure 2-4 compare the pressurizer water volume and [ ] a,c temperature, respectively, in the LOAC event using the enhanced RETRAN thick-metal model to the same parameters obtained when using the previously approved RETRAN model (Reference 1). As in the LOFTRAN thick-metal model, each parameter in the enhanced RETRAN model follows the same trend, just slightly less conservative, as the approved RETRAN model (Reference 1) parameter.

The enhanced RETRAN thick-metal model remains conservative with respect to actual plant conditions in that not all of the coolant-to-metal heat transfer regions are modeled. [ a,c

a,c

**Figure 2-1:Reactor Coolant System Nodalization**

a,c

**Figure 2-2:Reactor Pressure Vessel Nodalization**

a,c

[ ]

**Figure 2-3:Comparison of Pressurizer Water Volumes for LOAC**

a,c

**Figure 2-4:Comparison of [ ] Temperatures** a,c

# 3.0 Steam Generator Secondary-Side Mass Calculation Method

## 3.1 Background

As noted in the US Nuclear Regulatory Commission (NRC) Safety Evaluation Report (SER) for the Westinghouse RETRAN model (see Reference 1), the Westinghouse-developed RETRAN steam generator model conservatively under-predicts secondary-side steam generator water mass. Although low steam generator water masses are conservative for the analyses of many transients, the steam generator masses associated with the Westinghouse-developed RETRAN steam generator models are considered to be overly conservative. As such, Westinghouse has utilized the NOTRUMP steam generator thermal-hydraulic computer code to calculate more realistic but conservative secondary-side steam generator water masses. These masses will be applied in RETRAN analyses of secondary-side transients such as loss of normal feedwater and feedwater line break to define the amount of water mass in the steam generators at the time a low steam generator level reactor trip is reached. Note that the application of these steam generator masses in the RETRAN analyses is similar to the method currently employed in the analyses of secondary-side transients using the LOFTRAN computer code.

## 3.2 NOTRUMP Code

The NOTRUMP computer code is a one-dimensional nodal network code used for the analysis of thermal-hydraulic transients. Although primarily used for small break LOCA analyses, the NOTRUMP computer code has also been used for steam generator simulations, as presented in WCAP-9230, "Report on the Consequences of a Postulated Main Feedline Rupture" (see Reference 4). This WCAP was submitted to the NRC as the licensing basis for the Westinghouse methodology for analyzing feedwater line break accidents. WCAP-9230 was submitted to the NRC with, and makes reference to, WCAP-9236, "NOTRUMP, A Nodal Transient Steam Generator and General Network Code" (Reference 5), and has since been approved by the NRC on many plant-specific licensing applications as an acceptable methodology for analyzing feedwater line break transients.

a,c

a,c

[ ]

Nodalization of the plant-specific Westinghouse NOTRUMP steam generator model is presented in Figures 3-1 to 3-3, with a description of the fluid node composition provided in Table 3-1. A comparison of the NOTRUMP calculation results to the thermal-hydraulic design code results is presented in Table 3-2.

a,c

**Figure 3-1: Secondary-Side Fluid Nodes and Flow Links**

a,c

**Figure 3-2: Primary-Side Fluid Nodes and Flow Links**

a,c

**Figure 3-3: Metal Nodes and Heat Links for Primary- and Secondary-Sides**

**Table 3-1: Fluid Node Composition**

a,c

a,c

### Table 3-2: Steady-State Model Results Comparison

a,c

### 3.3 Application of NOTRUMP Masses to RETRAN Calculations

The Westinghouse RETRAN feedring steam generator model, presented in Figure 3.6-2 of WCAP-14882-P-A (Reference 1), is shown in Figure 3-4. [ ] a,c

The NOTRUMP and RETRAN steam generator transient responses of key steam generator parameters on both the primary-side and secondary-side, including secondary-side mass, to a loss of feedwater event are compared in Figures 3-5 to 3-10.

a,c

**Figure 3-4: Westinghouse RETRAN Feedring Steam Generator Nodalization**

a,c

**Figure 3-5: Primary-Side Mass Flow Rate for LOAC**

a,c

Figure 3-6: Primary-Side Pressure for LOAC

a,c

**Figure 3-7: Primary-Side Enthalpy for LOAC**

a,c

**Figure 3-8: Secondary-Side Feedwater Mass Flow Rate for LOAC**

a,c

Figure 3-9: Secondary-Side Steam Mass Flow Rate for LOAC

a,c

**Figure 3-10: Secondary-Side Total SG Mass for LOAC**

## 4.0 Conclusions

An enhanced RETRAN thick-metal model and detailed NOTRUMP-based steam generator mass calculation method have been developed for use in the RETRAN analyses of selected heat-up transients, such as the Loss of Normal Feedwater, Loss of Non-Emergency AC Power and Feedwater Line Break events. In each case, unnecessary conservatisms (i.e., the models are more realistic) have been removed in the assumptions used in the current RETRAN methodology for the analysis of these long-term heat-up events, as described in Reference 1.

The enhanced RETRAN thick-metal model was developed to credit energy absorbed by the RCS piping due to coolant-to-metal heat transfer. The enhanced RETRAN thick-metal model is described and justified in Section 2 for use in long-term heat-up events. As described in Section 2, the model is more realistic than current methodology, yet conservative as not all components of the RCS are modeled as thick-metal.

The use of a more detailed, steam generator model in the RETRAN analyses of long-term heat-up events is described and justified in Section 3. The steam generator model utilizes the NOTRUMP computer code to calculate more realistic but conservative steam generator masses.

## 5.0 References


1. WCAP-14882-P-A (Proprietary) and WCAP-15234-A (Non-Proprietary), "RETRAN-02 Modeling and Qualification for Westinghouse Pressurized Water Reactor Non-LOCA Safety Analyses," April 1999.

2. WCAP-7907-S1-P, Revision 1 (Proprietary) and WCAP-7907-S1-NP, Revision 1 (Non-Proprietary) "LOFTRAN Code Description Supplement 1 – LOFTRAN Thick Metal Mass Heat Transfer Models," January 2001.

3. Safety Evaluation by the Office of Nuclear Reactor Regulation Related to Amendment No. 119 to Facility Operating License No. NPF-37, Amendment No. 119 to Facility Operating License No. NPF-66, Amendment No. 113 to Facility Operating License No. NPF-72, and Amendment No. 113 to Facility Operating License No. NPF-77 – EXELON Generation Company, LLC – Byron Station Unit Nos. 1 and 2, Braidwood Station Unit Nos. 1 and 2, Docket Nos. STN 50-454, STN 50-455, STN 50-456 and STN 50-457.

4. WCAP-9230, "Report on the Consequences of a Postulated Main Feedline Rupture," G. E. Lang and J. P. Cunningham, January 1978.

5. WCAP-9236, "NOTRUMP, A Nodal Transient Steam Generator and General Network Code," P. E. Meyer and G. K. Frick, February 1978.

# Attachment 7

# WCAP-14882-S1-P