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OTSG Modeling for the Analysis of the TMI Incident* BNL-NUREG-27185

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The IRT code is a reactor plant systems code for the analysis of pressurized water reactor (PWR) transients that is being modified by Brookhaven National Laboratory for the Nuclear Regulatory Commission. A significant modification that has recently been implemented is a model for a once-through steam generator (OTSG) to enable simulation of Babcock & Wilcox (B&W) reactor transients. This paper describes the new OTSG modeling and presents the results of an analysis of the initial phase of the TMI incident using this model.

The IRT code is based on a homogeneous equilibrium model and is applicable to a wide variety of PWR non-LOCA transients. The OTSG model that has been implemented is based on assumptions similar to the assumptions of the IRT primary system modeling. Referring to Figure 1, the steam generator secondary side is divided into N+1 control volumes with the Nth volume representing the upper annular space connecting the secondary side to the steam line. (The total number of volumes is currently fixed at 12). The (N+1)th volume is used to represent the downcomer and includes a provision for the addition of normal feedwater. For each of the secondary side volumes, excluding those representing the annular steam space and the downcomer, there are corresponding primary side and tube metal volumes that are used for the calculation of the steam generator heat transfer rate. Between one of the secondary side nodes and the

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downcomer, there is a path (to represent the aspirator) through which a fraction of the steam in the tube region is recirculated to the downcomer to preheat the feedwater to approximately saturated conditions. The pressure in the primary system steam generator volumes is assumed uniform spatially as calculated by the original IRT equations. The secondary side pressure is also spatially uniform and is calculated from the conservation of mass and energy equations and the equation of state. The flow from the downcomer to the secondary tube region is strongly dependent on friction and the difference in gravity head between the downcomer and boiling region and is obtained by solving the momentum equation (assuming a uniform secondary side pressure).

The boundary conditions for the primary side volumes include coolant enthalpy and flow rate at the primary side steam generator inlet. These parameters are obtained from the IRT primary system calculation. The secondary side boundary conditions include the feedwater flow rate and enthalpy; the steam flow removed from the secondary side is either user specified or calculated from the OTSG model secondary side control system.

Each of the steam generator tube nodes is assumed to be at a uniform temperature at the centerline of the tube wall. The secondary side surface wall temperature, required in calculating the heat transfer coefficient, is estimated from the average tube temperature by accounting for the tube internal heat transfer resistance. The primary and secondary side heat transfer coefficients are determined based on the thermal-hydraulic conditions prevailing in each control volume. The heat transfer modes available include forced convection, subcooled and nucleate boiling, transition boiling, stable film boiling and single phase steam flow. In addition, correlations for the onset of boiling and critical heat flux are provided.

The initial phase of the TMI incident has been analyzed with the new IRT OTSG model and the results are shown in Figure 2 which shows a comparison of the calculated system pressure transient with the available data. Comparison of other system parameters (pressurizer level, primary system temperatures, and steam generator heat transfer rate) show equally good agreement. These results and further analyses will be used to establish the IRT OTSG model.

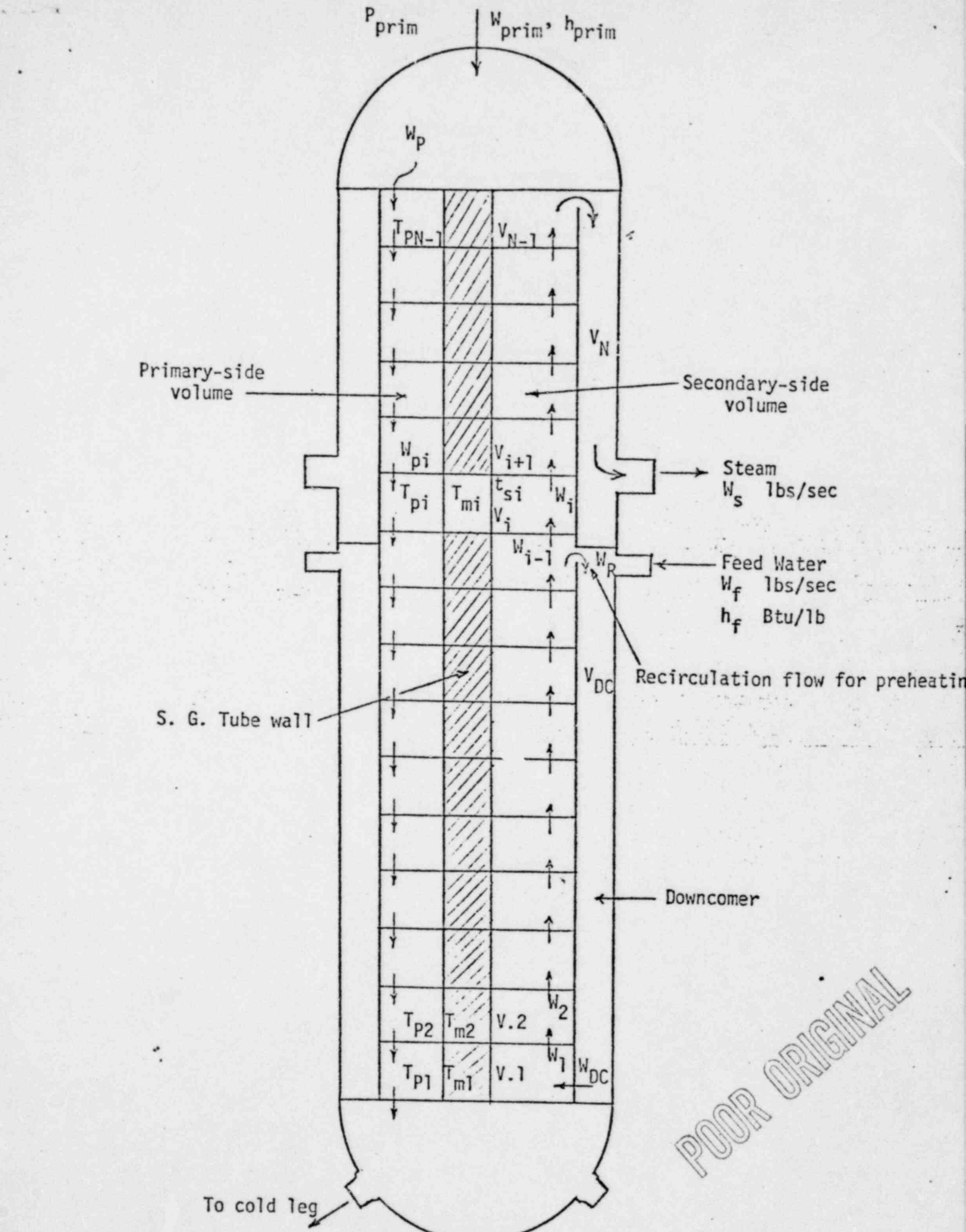
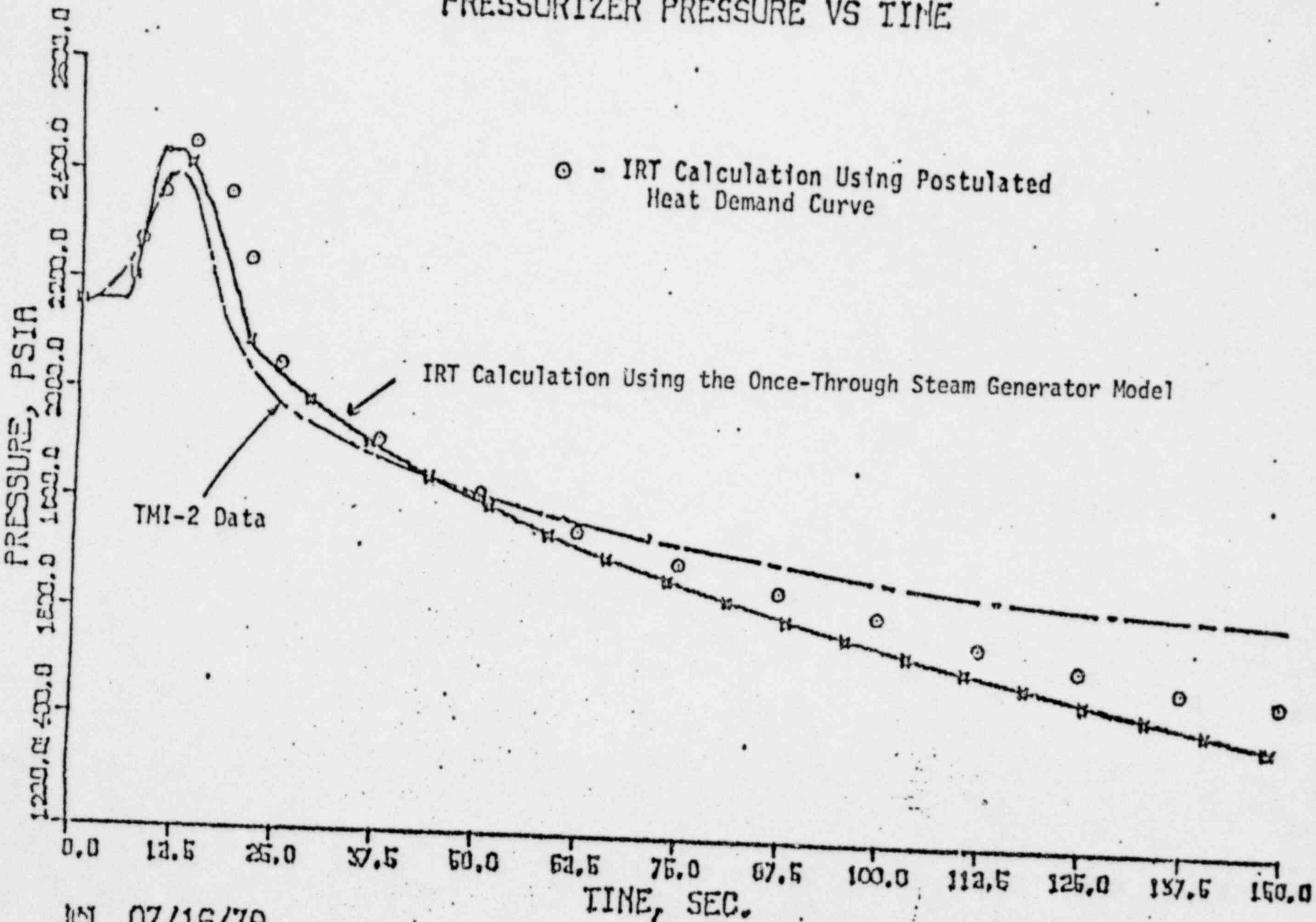

P_{prim}
W_{prim}, h_{prim}
W_p
T_{PN-1}
V_{N-1}
V_N
Primary-side volume
Secondary-side volume
W_{pi}
V_{i+1}
Steam
W_s lbs/sec
T_{pi}
T_{mi}
t_{si}
V_i
W_i
W_{i-1}
W_R
Feed Water
W_f lbs/sec
h_f Btu/lb
V_{DC}
Recirculation flow for preheatin
S. G. Tube wall
Downcomer
W_2
T_{P2}
T_{m2}
V.2
W_1
W_{DC}
T_{P1}
T_{m1}
V.1
To cold leg

FIGURE 1

FIGURE 2: TMI LOSS OF FEEDWATER TRANSIENT

PRESSURIZER PRESSURE VS TIME



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