Quad Cities and Dresden Main Steam Line Break Analysis with TRACG Model

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1. INTRODUCTION AND SUMMARY

The Main Steam Line Break (MSLB) Accident event results in the most limiting reactor vessel depressurization. This event also yields the largest vertical pressure differences for the core shroud. In evaluating the consequences of shroud failure, the MSLB has the greatest potential for vertical displacement. The current analysis basis for the MSLB calculation for the Quad Cities plant (for 108% Core Flow Analysis) is the LAMB Model. This model is documented and approved by the Nuclear Regulatory Commission as part of the 10CFR50 Appendix K Loss of Coolant Accident analysis methods contained in Reference 2-1. The LAMB model contains many simplifications and calculates very conservative shroud pressure differences. A more detailed model for this analysis is the TRACG Code (Reference 2-2). Because of its extensive capabilities and qualification (Reference 2-3), this model has been extensively used to benchmark other less detailed models, such as SAFER and ODYN. Other important applications of the TRACG Code have been in BWR conditions which are beyond the normal design basis, such as Stability and Degraded Core conditions. It is on this basis that TRACG is being applied to the evaluations in support of postulated shroud failure for the Quad Cities and Dresden plants. The results of the TRACG MSLB event will provide a more realistic basis for assessing the consequences of postulated 360 degree shroud crack at a particular weld location. However, the event assumptions, such as instantaneous break and limiting operating conditions (e.g. 100% core power and 108% core flow), have been incorporated and thus maintain some conservatism in the analysis.

The results of the TRACG MSLB analysis are contained in section two of this report. The calculation was performed using plant data applicable to the Quad Cities 1 Cycle 14 characteristics. However, the analysis is also applicable to the Quad Cities 2 and the Dresden 2 and 3 plants, because of its similarity and because the actual core characteristics have only a secondary effect on this calculation. The Dresden plants are geometrically very similar to the Quad Cities plants, but their operating conditions (e.g. power and steam flow) are slightly different. However, since the analysis is performed at the 108% core flow condition, the results will bound the Dresden 2 and 3 plants which only operate up to 100% core flow.

The critical parameter in evaluating the impact of shroud failure during a MSLB is the vertical displacement of the upper shroud portion (e.g. lift of the top guide). The consequences are very minor when the shroud separation is limited such that the core geometry is maintained. The core geometry is maintained as long as the top fuel guide lift is less than the height of the fuel channels. The depth of the top guide for the Quad Cities and Dresden plants is 13 inches, and the fuel channels extend beyond the top guide by 2 inches. For the TRACG MSLB analysis at 100% core power and 108% core flow, the maximum calculated lift of the top guide is 9.3 inches. Therefore it is concluded that core geometry will not be impacted for a postulated shroud failure during a MSLB event.

2. ANALYSIS RESULTS

2.1 TRACG MSLB Model Development

For this evaluation, the MSLB was calculated for the Quad Cities plant using the TRACG model. This model is a best-estimate computer program for the analysis of Boiling Water Reactors (BWRs). TRACG is based on a multi-dimensional two-fluid model for the reactor thermal hydraulics and a three-dimensional neutron kinetics model. The two-fluid model used for the thermal hydraulic analysis solves the conservation equations for mass, momentum and energy for both the gas and liquid phases. The thermal- hydraulic model is a multi-dimensional formulation for the vessel component and a one-dimensional formulation for all other components. The conservation equations are closed through an extensive set of basic models consisting of constitutive correlations for shear and heat transfer at the gas/liquid interface, as well as at the flow surface boundary. The TRACG structure is based on a modular approach. The thermal-hydraulic model contains a set of basic components, such as pipes, valves, tees, fuel channels, and the vessel.

Additionally, TRACG contains a control system model capable of simulating the major BWR control systems such as the pressure and water level controllers. Reactor simulations are performed by constructing a model using the basic components as building blocks. Any number of these components may be combined. The number of components, their interaction, as well as the detail in each component, are specified through code input. For the MSLB analysis, 17 components were used to model the vessel internals (such as jet pumps, fuel channels, and steam separators), and 37 components were used to model the vessel externals (such as recirculation pumps and lines, steamlines, isolation valves, and turbine).

The TRACG model prepared for the Quad Cities and Dresden plants consists of a reactor vessel, which is divided into sixteen axial levels and four radial rings. Shown in Figure 2-1 is the standard BWR nodalization used on the TRACG code qualification (Reference 2-3), which forms the basis for the model used here. For the MSLB simulation, some initial conditions were based on specific plant data, such as steamline and core pressure drop, in order to best represent and accurately simulate the actual performance of the Quad Cities plant to a MSLB event. The initial conditions used for the MSLB calculation correspond to the most limiting core power (100%) and flow (108%) operating condition. The key Quad Cities TRACG MSLB inputs are given in Table 2-1 for both ICF and rated core flow conditions. The MSLB calculation is only performed at the bounding ICF condition. The peak shroud head pressure difference for the rated core flow condition is estimated to be 14% lower (e.g. just as the initial DP is 14% lower) than that at the ICF condition. Some event characteristics, such as including the unbroken steam lines in the model, which are normally conservatively ignored or simplified, were factored into this calculation. The inclusion of the steamline lowers the calculated loads on the shroud by delaying the break flow through the unbroken steam lines. Most of the detailed characteristics are facilitated by the TRACG code capabilities.

2.2 MSLB Shroud Lift Analysis

The distance that the shroud is predicted to lift is calculated using the TRACG MSLB analysis output data. The lift calculation employs a dynamic expression for the shroud motion, considering the time history of the TRACG MSLB upward force, core flow leaving the core, and the inertia of the shroud and fluid. The calculation accounts for the fluid escaping to the outside shroud region through the gap that develops as the shroud lifts.

For purposes of shroud lift evaluations, the weight of the shroud material that will experience lift needs to be considered. The Table 2-2 lists the weight of the various components being affected. These masses are used to determine the dynamic response of the shroud, under the vertically upward load of the MSLB, when assumed to separate at the various horizontal weld locations. These weld locations, and the component weight which is above them is shown in Table 2-3.

Table 2-1 Quad Cities TRACG MSLB Inputs

Key Initial Conditions	ICF Basis	Rated Basis
Core Power	2511 MWTh	2511 MWTh
Core Flow	105.84 Mlbs/hr	98.0 Mlbs/hr
Vessel Steam Flow	9.76 Mlbs/hr	9.76 Mlbs/hr
Dome Pressure	1020 psia	1020 psia
Turbine Pressure	975 psia	975 psia
Feedwater Temperature	340 Deg F	340 Deg F
Shroud Head DP	5.7 psi	4.9 psi
Shroud Support DP	26.8 psi	23.3 psi
Normal Water Level	533" above vessel zero	533" above vessel zero
Pump Flow	36 Mlbs/hr	33 Mlbs/hr
Pump Speed (MG)	1120 rpm	1040 rpm
Key MSLB Characteristics:		
Steam Line Diameter	20 in	20 in
Recirculation Line Diameter	28 in	28 in
Vessel Steam Line Safe End	1.833 sq ft	1.833 sq ft
Steam Line Flow Limiter Area	0.611 sq ft	0.611 sq ft
MSIV Closure, time to full closure	5.5 sec	5.5 sec

Table 2-2: Key Shroud Weights

Component	Dry Weight (kips)	Submerged Weight (kips)
Shroud Head and Separators	126.9	114.2*
Shroud Studs and Guide Rods	15.0	13.5
Core Spray	2.5	2.3
Top Guide	15.2	13.7
Shroud	114.2	102.7
Core Plate	31.6	28.4

* The separators are conservatively assumed to be submerged.

Table 2-3: Horizontal Weld Identification

Weld ID	Elevation from Vessel Zero (in)	Component Weight (kips)
H1	391.4	146.02
H2	357.9	165.02
H3	355.4	184.34
H4	266.4	217.61
H5	191.1	245.73
H6	187.1	283.90
H7	131.5	304.07

2.3 TRACG MSLB Shroud Pressures

The MSLB is assumed to occur instantaneously. The important parameters for this evaluation are the pressure difference across the shroud head, and across the shroud support. The pressure difference across the shroud head determines the upward force for shroud cracking locations above the core support plate (e.g. H1 through H5). The pressure difference across the shroud support (this pressure difference captures both the upward force on the shroud head and the upward force on the core support plate) determines the upward force for shroud cracking locations below the core support plate (e.g. H6 and H7). The pressure difference across the shroud head during the event as a function of time is shown in Figure 2-2 and indicates a maximum pressure difference of 11.0 psi. This calculation shows the lifting load to last less than three seconds. The maximum pressure difference for the shroud support is 30.9 psi. Listed in Table 2-4 are the maximum pressure differences along with the calculated separations for each weld.

Table 2-4: Maximum Shroud Separation Under MSLB Conditions

Weld Location	Maximum DP, (psi)	Maximum Separation, (inches)
H1	11.0	15.8[1]
H2	11.0	13.1[1]
H3	11.0	9.3[2]
H4	11.0	6.6[2]
H5	11.0	4.9[2]
H6	30.9	0.5[3]
H7	30.9	0.5[3]

[1] Separation at H1 or H2 does not affect core geometry.
[2] Core alignment is assured if the separation of welds H3 to H5 is less than 15 inches.
[3] This separation is limited by the clearance between the core support plate and the top edge of the control rod guide tubes.

The separation at locations H1 and H2 does not impact the core geometry, as they are located above the top guide ring. The separation at locations H6 and H7 is limited by the control rod guide tubes to one half inch. For weld locations H3 through H5, the maximum lift is for the H3 location (as this location has less weight on it). The separation for H1 is not obstructed vertically, for up to 25 inches, by any vessel component. The separation for H2 through H5 is obstructed by the core spray piping, however, the resistance is conservatively ignored for the calculation of postulated lifts. The separation for H6 and H7 is obstructed by the edge of the control rod guide tubes edge, and therefore any displacement is limited to one half inch.

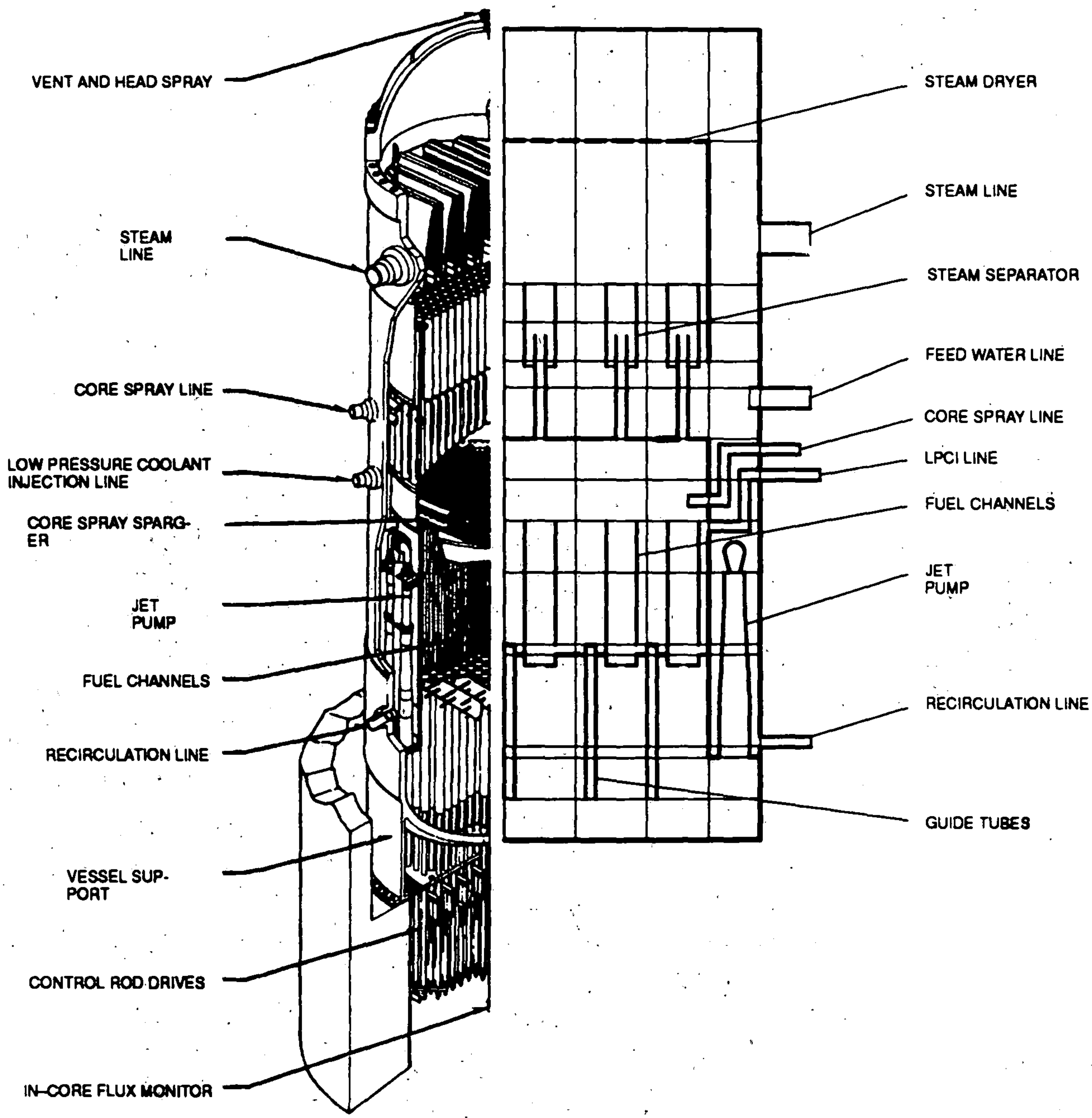

Figure 2-1: Standard BWR TRACG Model

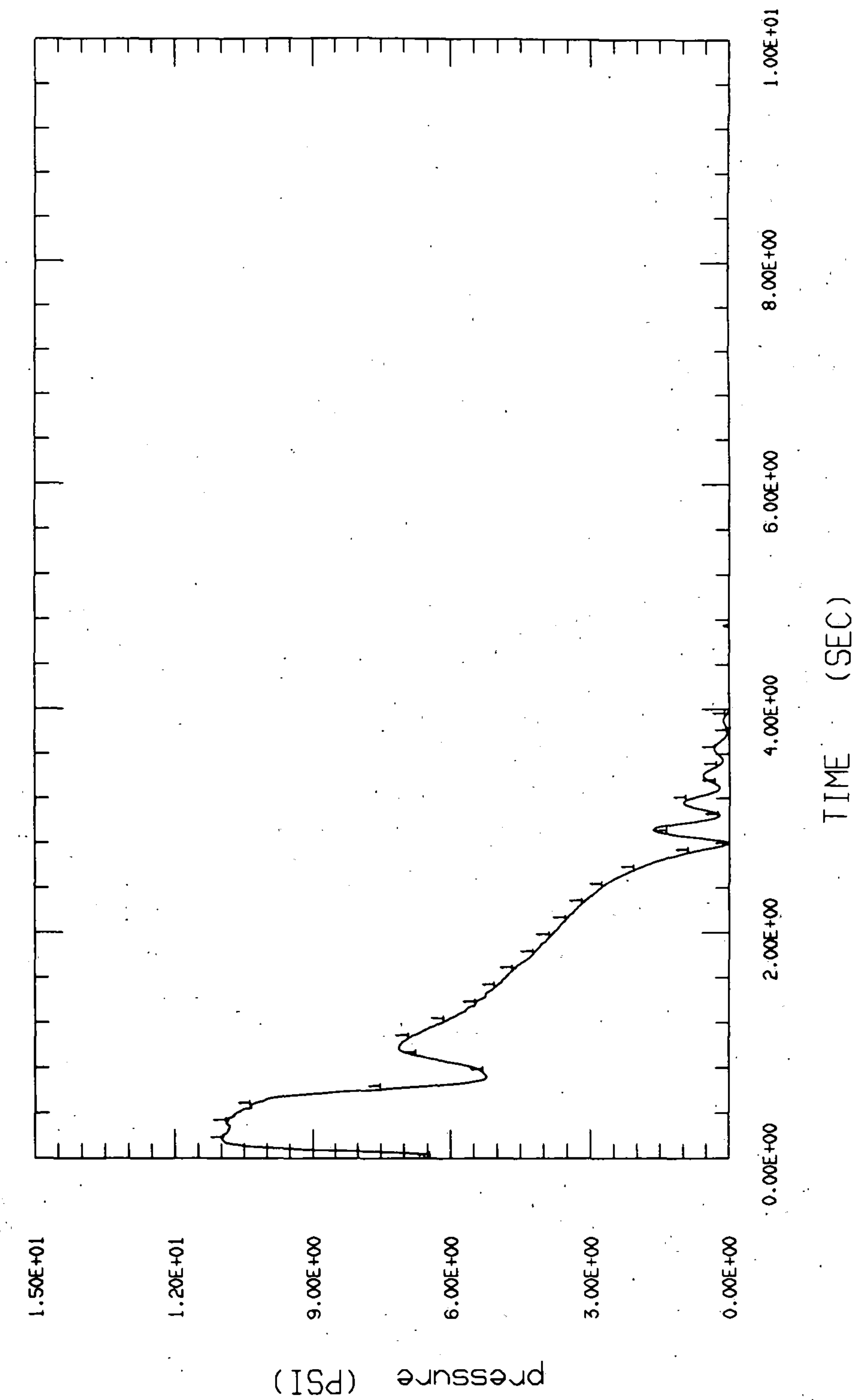

Figure 2-2: Shroud Head DP for MSLB

REFERENCES:

2-1 "Analytical Model for Loss-of-Coolant Accident Analysis in Accordance with 10CFR50 Appendix k", NEDE-20566P, January 1976. (GE PROPRIETARY).

2-2 "TRACG Model Description - Licensing Topical Report", NEDE-32176P, February 1993. (GE PROPRIETARY).

2-3 "TRACG Qualification - Licensing Topical Report", NEDE-32177P, Revision 1, June 1993. (GE PROPRIETARY)