Justification for SPC 1986 LBLOCA Evaluation Model With Interim Adjustment for Non-Physical Behavior

Table of Contents

List of Tables

List of Figures

List of Figures (continued)

Justification for SPC 1986 LBLOCA Evaluation Model With Interim Adjustment for Non-Physical Behavior

Reference: 1) Letter from R. C. Jones (NRC) to H. D. Curet (SPC), Telecons Concerning Siemens Power Corporation Large Break Loss of Coolant Accident Analysis Methodology, dated October 11, 1996.

2) *FLECHT SEASET Program Final Report*. NUREG/CR-4167, November 1985.

1.0 INTRODUCTION

In the Reference 1 letter, the NRC informed SPC of an unacceptable error in the approved 1986 LBLOCA evaluation model. The error is in the FCTF reflood heat transfer correlations over the range of reflood velocities between approximately 1.00 inches/second to 1.77 inches/second. In this range the correlation exhibits the non-physical trend of decreasing heat transfer coefficient with increasing reflood rate. SPC is responding to the NRC staff's position and is continuing to assess the impacts of possible solutions. [

] This restriction is always conservative with respect to both measured data and the 1986 evaluation model and eliminates the non-physical behavior in the FCTF reflood heat transfer correlations being questioned by the NRC. The following discussions describe the 1986 evaluation model and the non-physical trend. Also included are relevant data points to demonstrate the conservatism of the model compared to the actual FCTF data and the trend of FCTF calculations with FLECHT SEASET test data (Reference 2). This information is provided as requested by the NRC staff in the October 16,1996 meeting with affected licensees and SPC.

2.0 DESCRIPTION OF MODEL AND INTERIM ADJUSTMENT

The heat transfer coefficients calculated by the FCTF heat transfer correlations in the SPC 1986 LBLOCA ECCS evaluation model vary with time during the reflood portion of the LOCA transient. The expected behavior, as stated by the NRC, is that heat transfer coefficients will increase with increasing reflooding rate over the expected range of reflooding rates. PWR FLECHT data show this trend, and FCTF data trends are similar to FLECHT. SPC has found that early in the reflood time period, the predicted heat transfer coefficients using the FCTF correlations are calculated to decrease as the reflood rate increases. [

]

[

]

The range of conditions calculated to occur from the beginning of reflood to the time of calculated peak cladding temperature is important in assessing the conservatism of the model application. For current PWR analyses using the 1986 evaluation model, the ranges of calculated parameters are given in Table 2.1. Conditions which strongly affect PCT are those occurring prior to the calculated time of PCT. [

]

Figure 2-1 illustrates FCTF calculated results for conditions typical of a PWR near the time of calculated peak cladding temperature (PCT). The results were calculated at three different times from beginning of reflood for the conditions shown. Heat transfer coefficients versus

flooding rate are shown at 20, 40, and 60 seconds from the beginning of reflood using both the FCTF correlations and the interim model.

Table 2.1

Ranges of Calculated Parameters at PCT for PWR Application

Parameter	Maximum	Minimum
Pressure (psia)		
Inlet Subcooling (°F)		
Maximum Rod Power (kW/ft)		
Minimum Reflood Rate (in/sec)		
Time of PCT from Beginning of Reflood (sec)		

Figure 2.1

Heat Transfer Versus Reflood Rate for PWR Application

3.0 CONSERVATISM EVALUATION OF 1986 MODEL AND INTERIM ADJUSTMENT

The FCTF correlations were justified by comparison of predicted results to experimental data. The comparisons showed that the carryover rate fractions (CRF), quench times and heat transfer coefficient predictions are conservative or best estimate.

3.1 Description of Application Method

The FCTF heat transfer coefficient correlation was designed to predict the total energy (stored energy plus decay heat) which must be removed to quench the rod. As such, it is necessary to know the quench time in order to predict heat transfer coefficients. The FCTF correlations were evaluated against test data using the FCTF quench time correlation and shown to be conservative as presented in the topical report.

3.2 Selection of Tests for Comparison

It is appropriate to demonstrate the overall conservatism of the 1986 LBLOCA evaluation model and the interim model. Five high pressure FCTF test results are presented using SPC's LBLOCA methodology. These five tests are the most representative of conditions observed in current SPC's licensing analyses. Table 3-1 shows the test conditions for the five tests.

3.3 Evaluation Against High Flooding Rate Tests (1.74-1.77 in/sec)

Heat transfer coefficients are computed at the 6 foot and higher elevations. [

]

[

]

The conservatism of the calculations compared to data for both the correlation and the interim model can also be shown by computing heat transfer coefficients versus reflood rate at specific times for the FCTF tests. [

]

3.4 Evaluation Against Low Flooding Rate Tests (1.15-1.17 in/sec)

The evaluation for the two low flooding rate tests was done in the same manner as for the high flooding rate tests. [

3.5 FLECHT/FCTF Comparisons

The non-physical trend in reflood heat transfer coefficients predicted by the FCTF reflood correlations can be characterized as decreasing heat transfer coefficients with increasing reflood rate or, conversely, increasing heat transfer coefficients with decreasing reflood rate. The physical trend for heat transfer versus reflood rate is expected to be a monotonic trend as observed in the FLECHT SEASET data shown in Figure 3-15.

In Figure 3-16, FLECHT SEASET data from three experiments conducted at similar conditions to FCTF Test 3440 (See Table 3-2) are compared with FCTF correlations calculated results to show data trends. [ ] However, using the trend of the FLECHT data with reflood rate as a reference indicates that the [ ] In Figure 3-17, the FLECHT data are compared with the interim adjustment model heat transfer coefficients [ ] The comparison of the FLECHT data in Figure 3-17 and the interim heat transfer coefficients indicates the FCTF correlations with the interim adjustment are more conservative [ ] [ ]

Table 3.1

FCTF Test Conditions

Test Number	Reflood Rate (in/sec)	Pressure (psia)	Initial Subcooling (°F)	Peak Initial Temperature (°F)	Peak Initial LHGR (kW/ft)
0205					
2230					
2932					
3440					
3941					

Table 3.2

FLECHT SEASET/FCTF Test Conditions

Test	Pressure (psia)	T_{init} (°F)	Power (kW/ft)	Reflood Rate (in/sec)	Subcooling (°F)
FCTF 3440					
FLECHT SEASET 31504					
FLECHT SEASET 31203					
FLECHT SEASET 31302					

Figure 3.1

Comparison of Predicted Heat Transfer Coefficients
to Data for FCTF Test 2932 at 6.0 Feet

Figure 3.2

Comparison of Predicted Heat Transfer Coefficients
for Data for FCTF Test 2932 at 8.7 Feet

Figure 3.3

Comparison of Predicted Heat Transfer Coefficients
to Data for FCTF Test 3440 at 6.0 Feet

Figure 3.4

Comparison of Predicted Heat Transfer Coefficients
to Data for FCTF Test 3440 at 8.7 Feet

Figure 3.5

Comparison of Predicted Heat Transfer Coefficients
to Data for FCTF Test 3941 at 6.0 Feet

Figure 3.6

Comparison of Predicted Heat Transfer Coefficients
to Data for FCTF Test 3941 at 8.7 Feet

Figure 3.7

Test 3440 Heat Transfer Coefficients versus Reflood Rate at 6.0 Feet

Figure 3.8

Test 3440 Heat Transfer Coefficients versus Reflood Rate at 8.7 Feet

Figure 3.9

Comparison of Predicted Heat Transfer Coefficients
to Data for FCTF Test 0205 at 6.0 Feet

Figure 3.10

Comparison of Predicted Heat Transfer Coefficients
to Data for FCTF Test 0205 at 8.7 Feet

Figure 3.11

Comparison of Predicted Heat Transfer Coefficients to Data for FCTF Test 2230 at 6.0 Feet

Figure 3.12

Comparison of Predicted Heat Transfer Coefficients
to Data for FCTF Test 2230 at 8.7 Feet

Figure 3.13

Tests 0205 and 2230 Heat Transfer Coefficients versus Reflood Rate at 6.0 Feet

Figure 3.14

Tests 0205 and 2230 Heat Transfer Coefficients versus Reflood Rate at 8.7 Feet

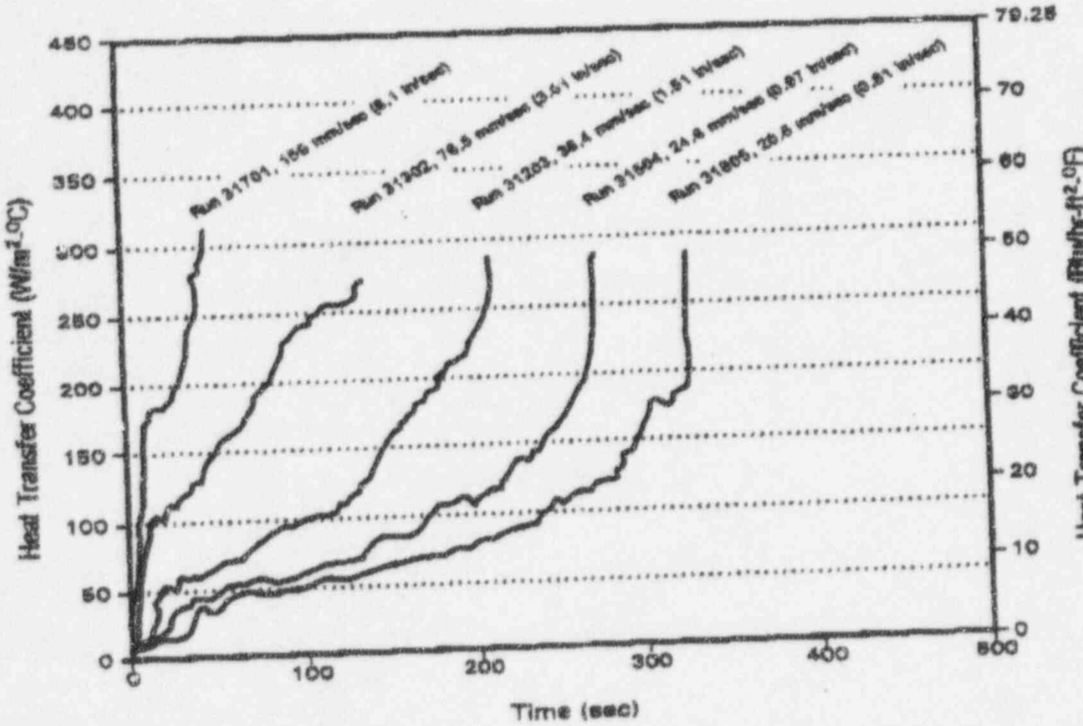

Figure 3.15

Flooding Rate Effect of FLECHT Heat Transfer

Figure 3.16

Comparison of FLECHT and FCTF Heat Transfer Coefficients at 6.0 Feet

Figure 3.17

Comparison of FLECHT and FCTF (Interim Fix) Heat Transfer Coefficients at 6.0 Feet

4.0 SUMMARY OF CONSERVATISMS

The conservatisms in the FCTF heat transfer correlation and the licensing applications are summarized below:

1. The FCTF correlations are generally conservative compared to the data. The SER states that the FCTF heat transfer correlation is conservative, or best estimate, for 93 of 112 data points. This statement is based on comparisons calculated with the FCTF quench time correlation.

2. [ ]

3. [ ]

4. [ ]

5.0 CONCLUSIONS

The information presented above leads to the following conclusions:

1. SPC's 1986 EXEM/PWR LBLOCA ECCS evaluation model as applied in licensing analyses is conservative with respect to the available data.

2. The trend of decreasing heat transfer coefficients with increasing reflood rates exists in the methodology but can be eliminated by using SPC's interim adjustment. The interim model is conservative with respect to the correlation.

3. [ ]

4. [ ]