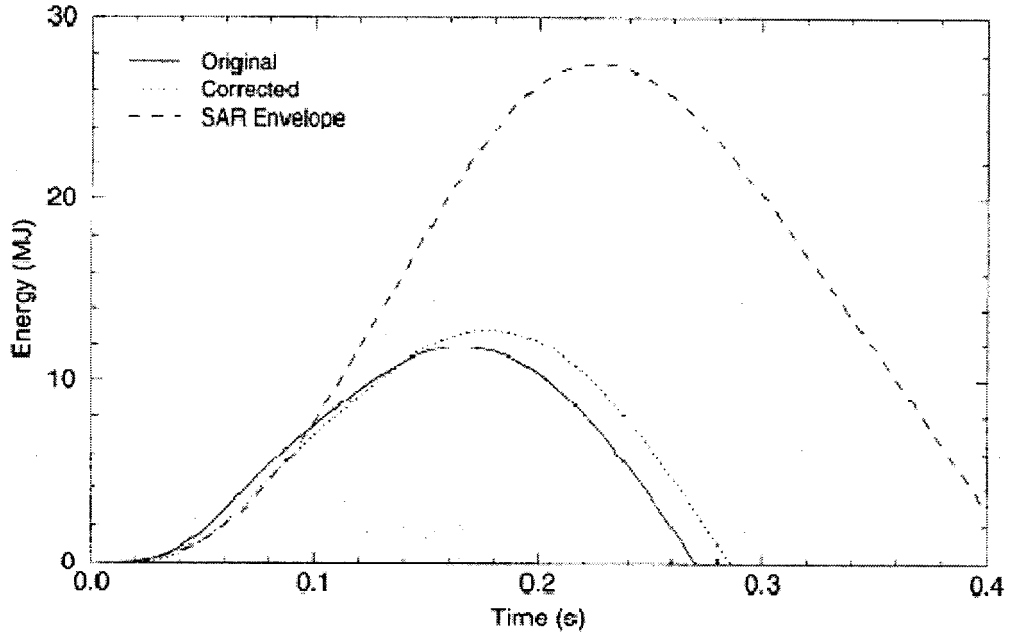

Figure 28. Core energy deposition vs. time (SIPT small break).

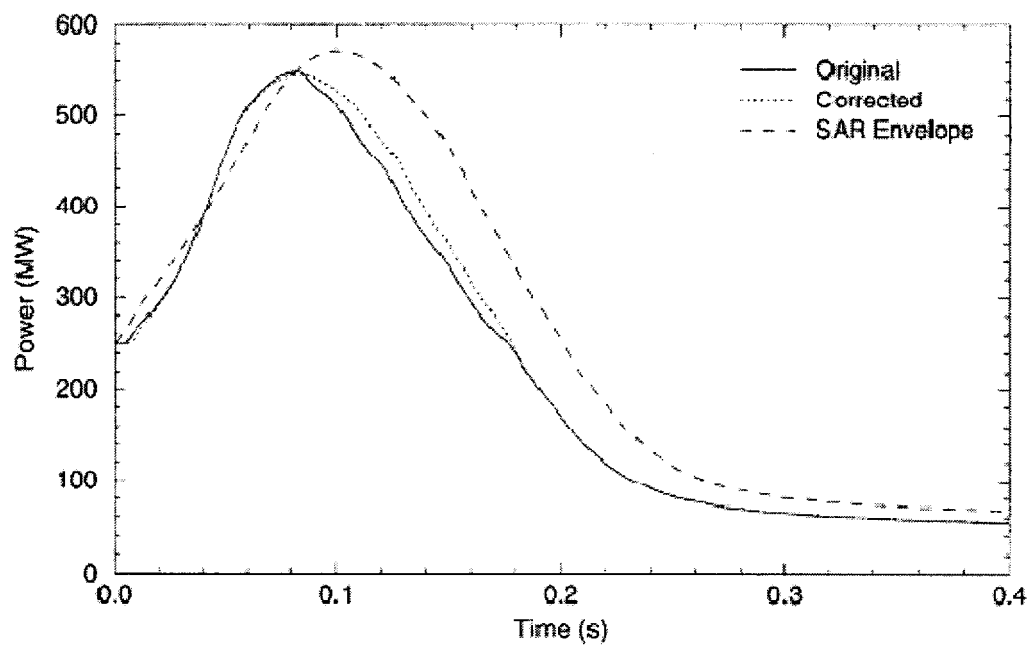

Figure 29. Core power vs. time (SIPT large break).

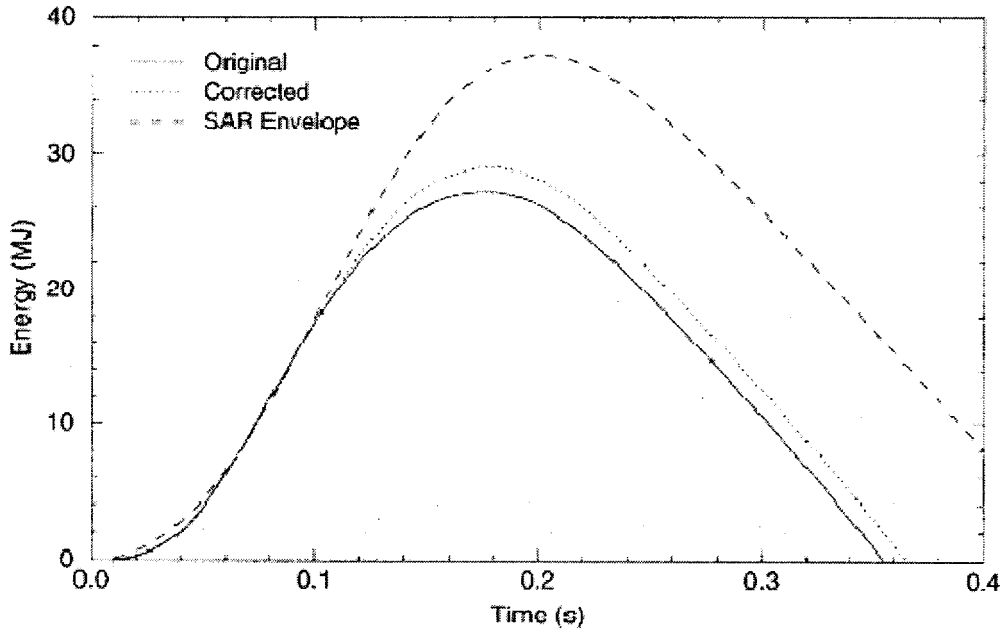

Figure 30. Core energy deposition vs. time (SIPT large break).

5.2.6.2 LIPT Small- and Large-Break RIAs

The calculations in Reference 21 were rerun with and without the error correction to calculate core energy deposition and maximum core energy deposition. The time step size in both the original and corrected calculations was 0.0001 s. The maximum core power and core energy deposition results from ECAR-402 are as follows:

Table 15. ECAR-402 results for LIPT experiment loop small and large pipe breaks.

Parameter	Small Break		Large Break	
	Original	Corrected	Original	Corrected
Scram Time (s)	0.1062	0.1128	0.0444	0.0449
Maximum Core Power (MW)	324.93	329.05	581.41	577.93
Maximum Energy Deposition (MJ)	9.0329	9.9038	29.476	31.723

The maximum core powers in the original and revised calculations were comparable. The maximum core energy depositions were higher in the revised calculations than in the original calculations (9.6% higher for the small-break and 7.6% higher for the large-break). The revised results as shown in Table 15 are bounded by the SAR Envelope curves as shown in Figures 31 through 34. Therefore, the PPC for Condition 2 and 4 faults are met.

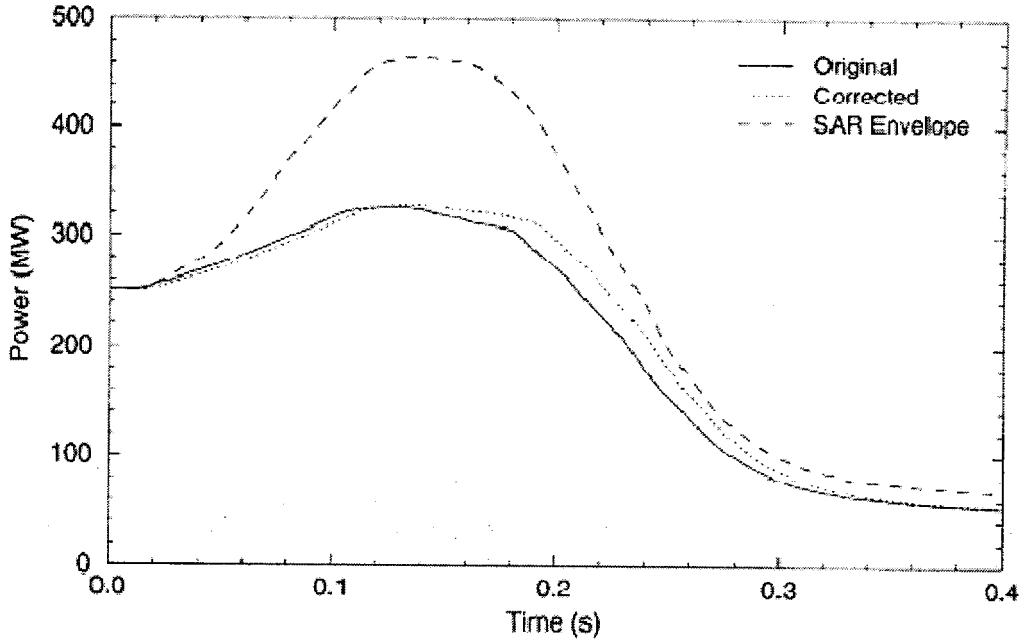

Figure 31. Core power vs. time (LIPT small break).

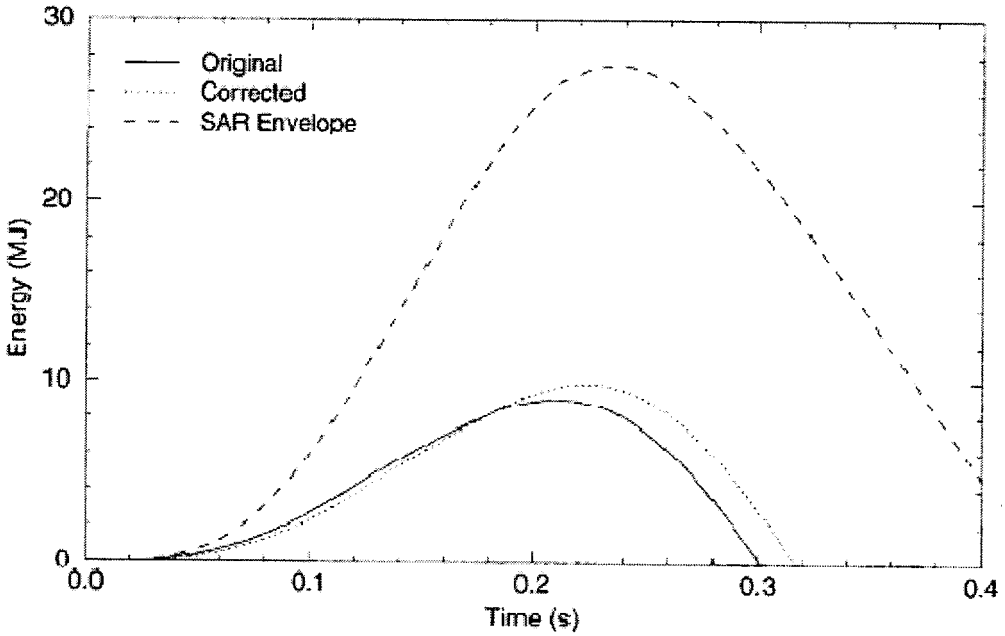

Figure 32. Core energy deposition vs. time (LIPT small break).

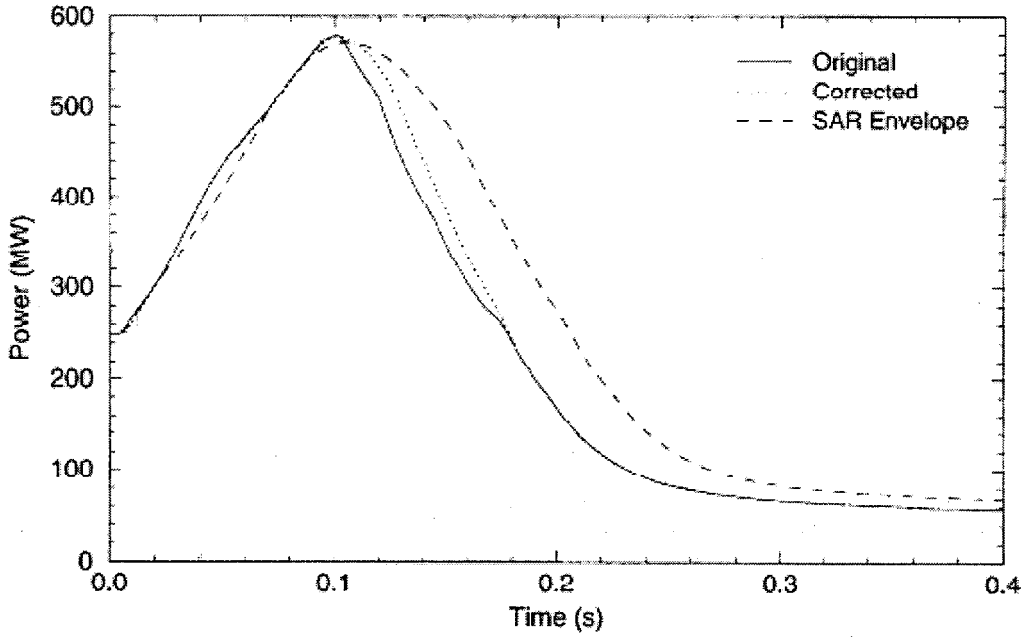

Figure 33. Core power vs. time (LIPT large break).

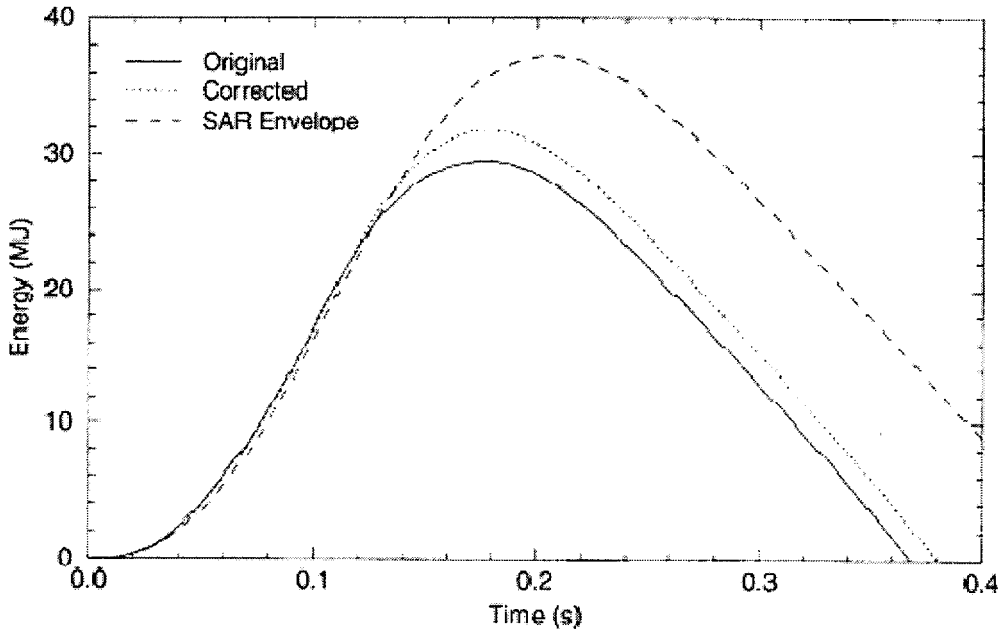

Figure 34. Core energy deposition vs. time (LIPT large break).

5.2.6.3 Standard MUCH Small- and Large-Break RIAs

The calculations in Reference 22 were updated in ECAR-402 with and without the error correction to calculate core energy deposition and maximum core energy deposition. The original time step of 0.001 s was revised to 0.0001 s.

As in Reference 22 the small-break calculation included a 0.10$ step due to test train failure. The maximum core power and core energy deposition results from ECAR-402 are as follows:

Table 16. ECAR-402 results for Standard MUCH experiment loop small and large pipe breaks.

Parameter	Small Break		Large Break	
	Original	Corrected	Original	Corrected
Scram Time (s)	0.0920	0.0939	0.0900	0.0918
Maximum Core Power (MW)	417.45	421.98	510.94	511.13
Maximum Energy Deposition (MJ)	20.776	21.293	30.094	30.254

The original and revised results as shown in Table 16 are comparable and they are bounded by the SAR Envelope curves as shown in Figures 35 through 38. Therefore, the PPC for Condition 2 and 4 faults are met.

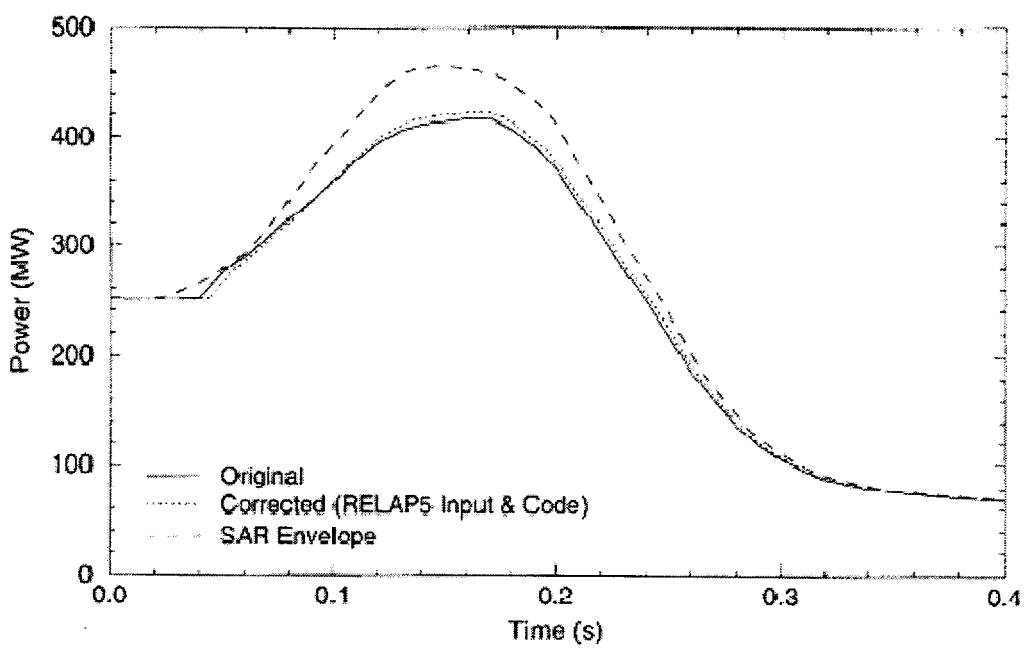

Figure 35. Core power vs. time (Standard MUCH small break).

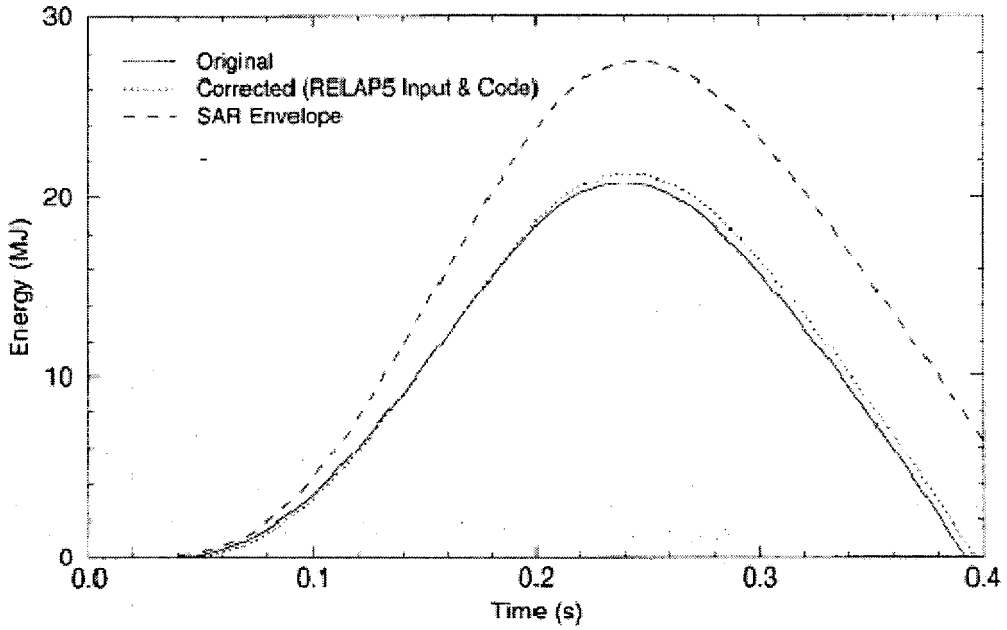

Figure 36. Core energy deposition vs. time (Standard MUCH small break).

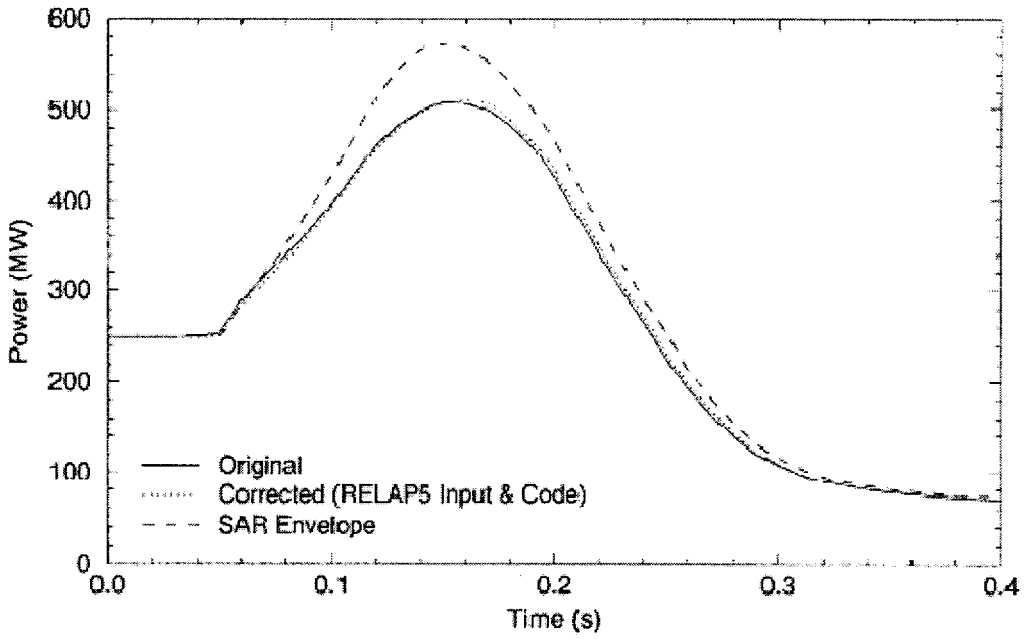

Figure 37. Core power vs. time (Standard MUCH large break).

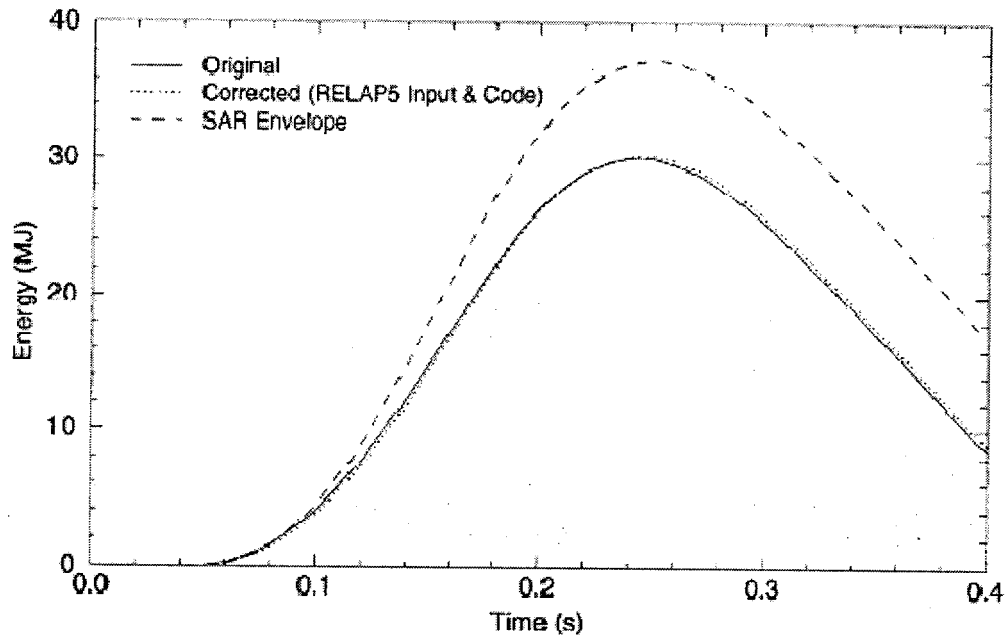

Figure 38. Core energy deposition vs. time (Standard MUCH large break).

5.2.6.4 AHTL MUCH Small- and Large-Break RIAs

The calculations in Reference 22 were updated in ECAR-402 with and without the error correction to calculate core energy deposition and maximum core energy deposition. The original time step of 0.001 s was revised to 0.0001 s. The small-break calculation included a 0.10$ step due to test train failure. The maximum core power and core energy deposition results from ECAR-402 are as follows:

Table 17. ECAR-402 results for AHTL MUCH experiment loop small and large pipe breaks.

Parameter	Small Break		Large Break	
	Original	Corrected	Original	Corrected
Scram Time (s)	0.1030	0.0993	0.1010	0.0986
Maximum Core Power (MW)	421.53	418.93	514.91	510.31
Maximum Energy Deposition (MJ)	20.808	20.874	30.256	30.331

The original and revised results as shown in Table 17 are comparable and they are bounded by the SAR Envelope curves as shown in Figures 39 through 42. Therefore, the PPC for Condition 2 and 4 faults are met.

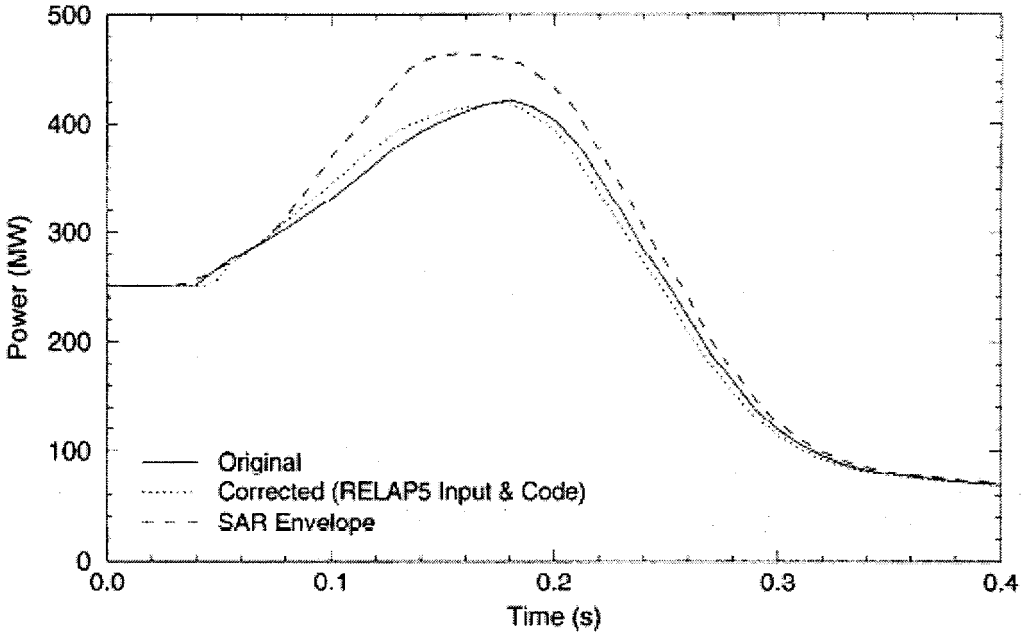

Figure 39. Core power vs. time (AHTL MUCH small break).

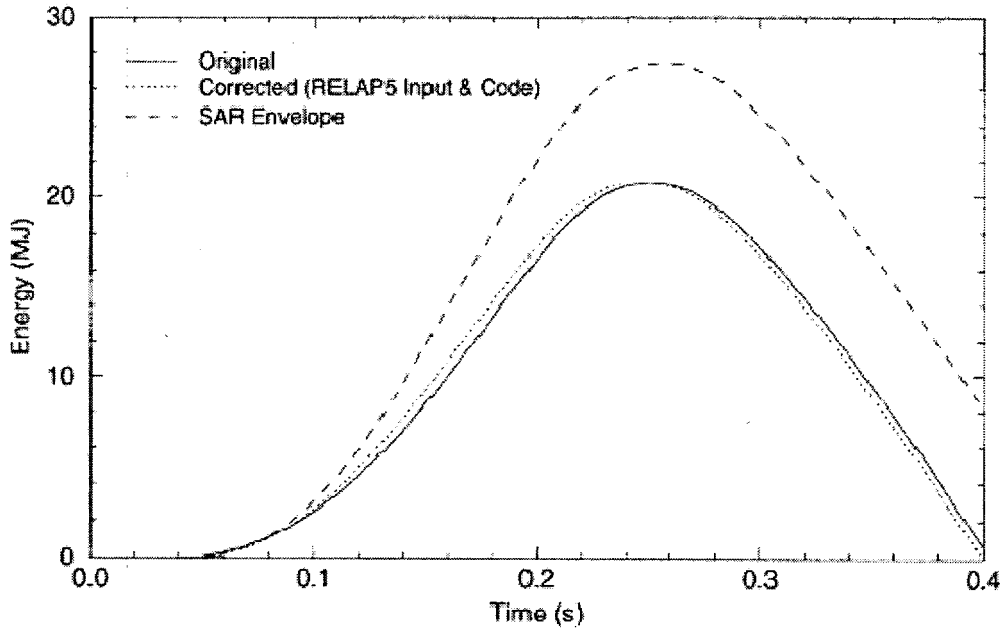

Figure 40. Core energy deposition vs. time (AHTL MUCH small break).

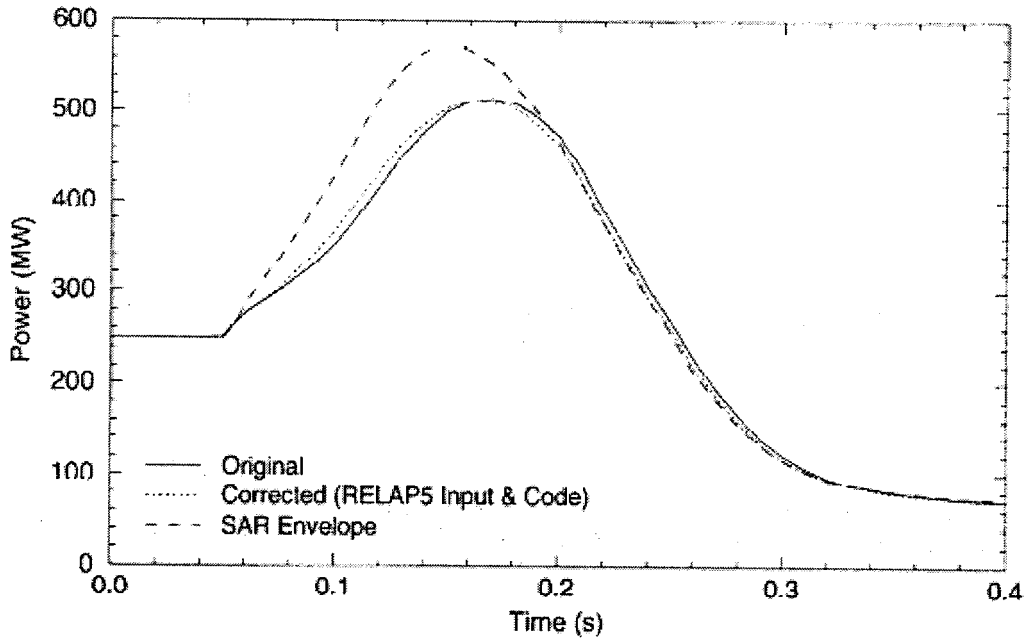

Figure 41. Core power vs. time (AHTL MUCH large break).

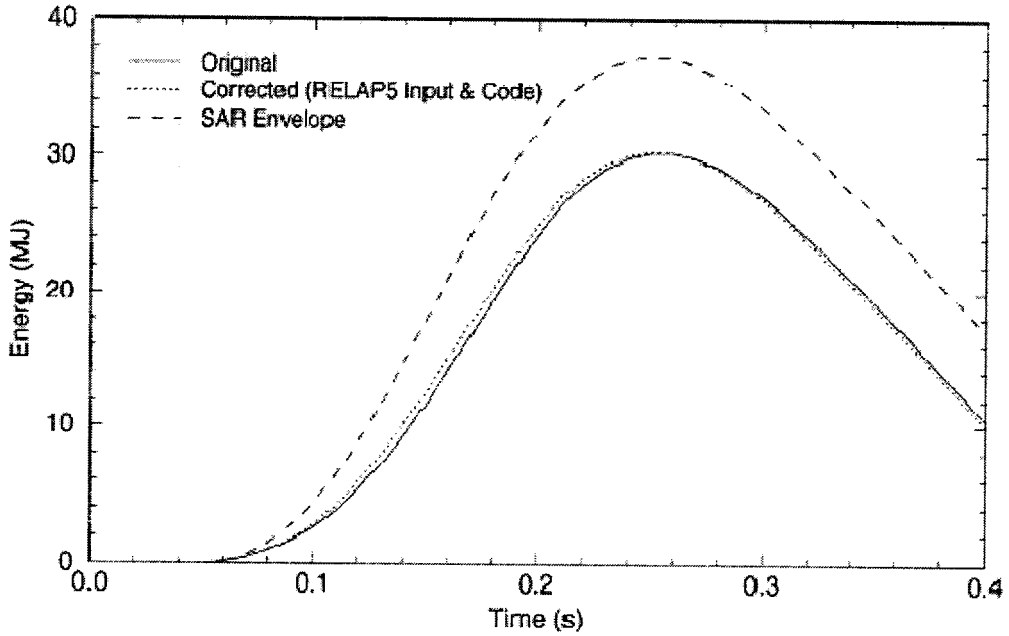

Figure 42. Core energy deposition vs. time (AHTL MUCH large break).

5.2.7 Accident Analyses (SAR-192, Section 8.4)

A core energy deposition limit (15 MJ) is used to demonstrate that no fuel melting occurs in postulated ATRC reactivity accidents. The following Condition 4 faults are the only RIAs discussed in the ATRC SAR that result in significant core energy deposition (> 1 MJ). The scram setpoint for these calculations was 6 kW, with a response time of 0.035 s.

5.2.7.1 Air Voiding of an LIPT (SAR-192, Section 8.4.8.1)

Air voiding of an LIPT results in a core reactivity insertion that results in an increase in the reactor power and a decrease in the reactor period. A scram is initiated by the neutron level subsystem or the Log-N/period subsystem of the Reactor Shutdown System (RSS), depending on the initial power level. The reactor power continues to increase until the negative reactivity addition due to safety rod insertion overcomes the positive reactivity resulting from the LIPT voiding. The voiding event was simulated by modeling a total reactivity of 1.54$ inserted into the core at a constant rate of 0.26$/s.

The calculations in Reference 23 were updated in ECAR-402 with and without the error correction to calculate core energy deposition and maximum core energy deposition. The time step size in both the original and corrected calculations was 0.001 s; a revised calculation was performed with the time step size reduced to 0.0001 s. The maximum core power and core energy deposition results from ECAR-402 are as follows:

Table 18. ECAR-402 results for air voiding of ATRC LIPT.

Parameter	Calculation		
	Original	Corrected	Revised Time Step
Scram Time (s)	4.5040	4.5050	4.5045
Maximum Core Power (MW)	30.869	31.492	30.825
Maximum Energy Deposition (MJ)	3.5460	3.6156	3.5400

As shown in Table 18 and Figures 43 and 44, the original and corrected calculations were not appreciably different. The calculations in ECAR-402 show that the maximum core power and core energy deposition decrease slightly for a revised time step size of 0.0001 s, and the maximum energy deposition is less than the 15 MJ criterion. Therefore, the original calculations are bounding.

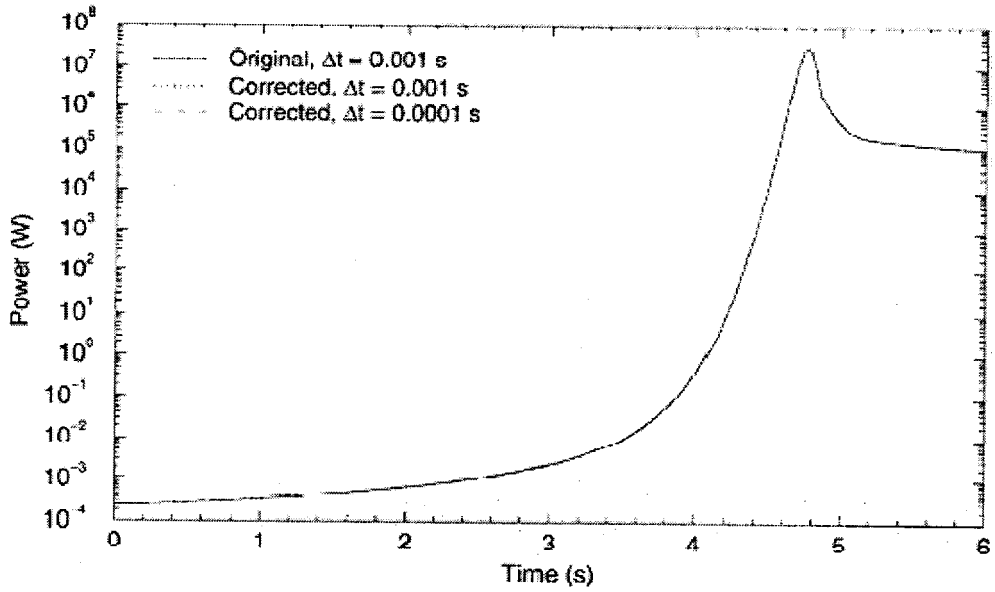

Figure 43. Core power vs. time (ATRC LIPT air voiding accident).

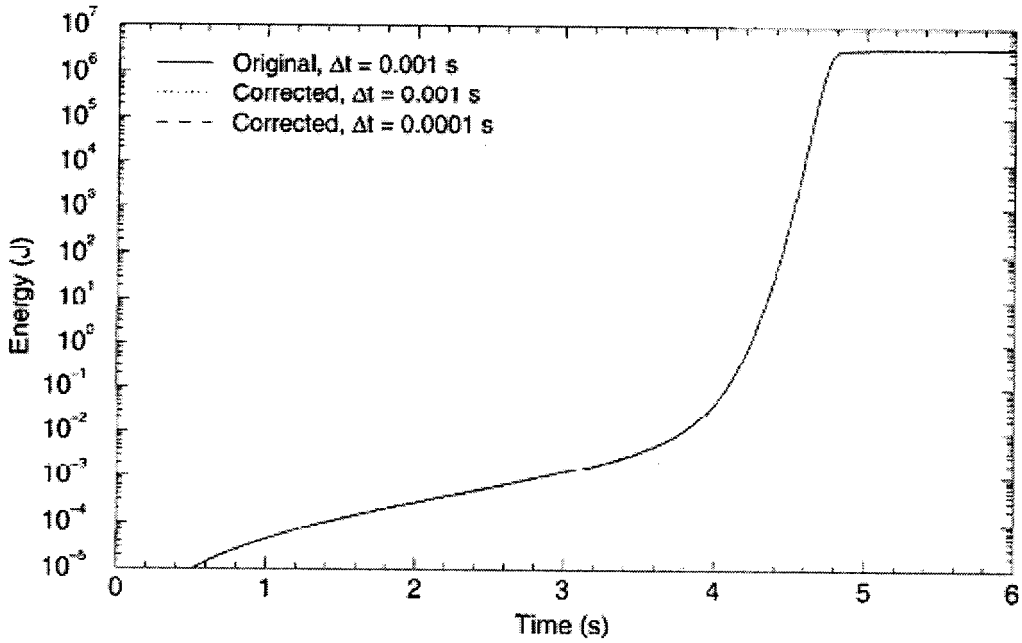

Figure 44. Core energy deposition vs. time (ATRC LIPT air voiding accident).

5.2.7.2 Aluminum Filler Piece Drop into an LIPT (SAR-192, Section 8.4.8.2)

Dropping an aluminum filler piece into a LIPT results in a rapid core reactivity insertion that results in an increase in the reactor power and a decrease in the reactor period. A scram is generated by the neutron level subsystem or the Log-N/period subsystem of the RSS, depending on the initial power level. The period subsystem generates the first scram signal at low initial powers, while the level subsystem generates the first signal at high initial powers. The reactor power continues to increase until the negative reactivity addition due to safety rod insertion overcomes the positive reactivity resulting from the drop. The filler drop event was simulated by modeling a rapid total reactivity insertion of 1.2$.

The calculations in Reference 23 were updated in ECAR-402 with and without the error correction to calculate core energy deposition and maximum core energy deposition. The time step size in both the original and corrected calculations was 0.001 s; a revised calculation was performed with the time step size reduced to 0.0001 s. The maximum core power and core energy deposition results from ECAR-402 are as follows:

Table 19. ECAR-402 results for filler piece drop into ATRC LIPT.

Parameter	Calculation		
	Original	Corrected	Revised Time Step
Scram Time (s)	0.3110	0.3110	0.3102
Maximum Core Power (MW)	73.764	73.751	71.493
Maximum Energy Deposition (MJ)	8.3888	8.3876	8.1309

As shown in Table 19 and Figures 45 and 46, the original and corrected calculations were not appreciably different. The calculations in ECAR-402 show that the maximum core power and core energy deposition decrease slightly for a revised time step size of 0.0001 s, and the maximum energy deposition is less than the 15 MJ criterion. Therefore, the original ATR-SINDA and SINDA-SAMPLE calculations are bounding.

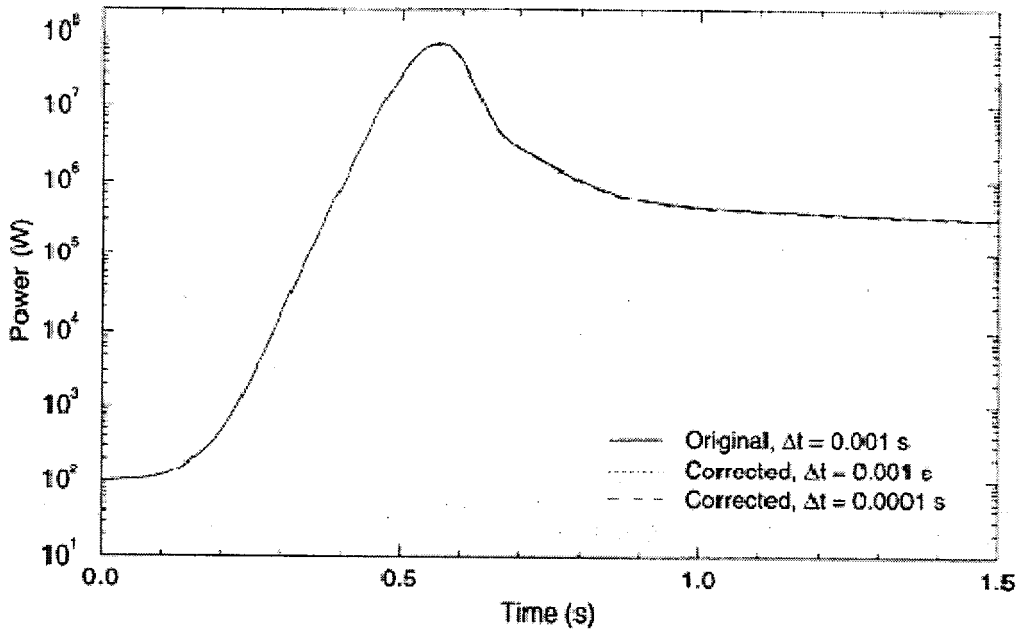

Figure 45. Core power vs. time (ATRC filler piece drop accident).

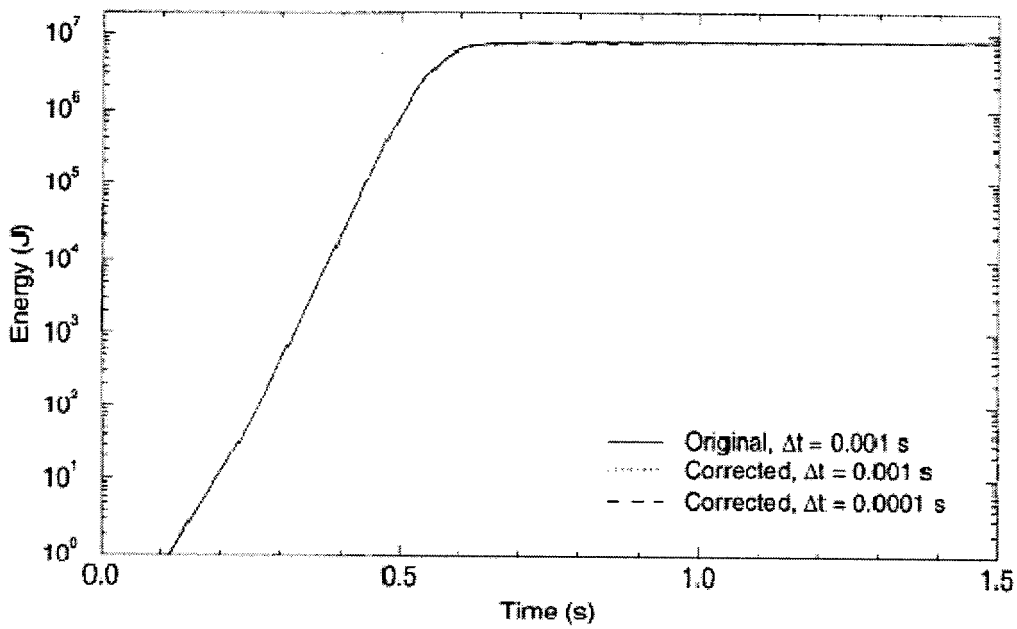

Figure 46. Core energy deposition vs. time (ATRC filler piece drop accident).

5.2.8 EDF-6937 (Analysis of AHTL Flow Coastdown with New Pumps)

The RELAP5 calculations in Reference 12 show that RIAs initiated by coast down of the AHTL pumps and by simultaneous coast down of all the experiment loop pumps are bounded by the limiting Condition 2 and 4 reactivity faults discussed in SAR-153, Section 15.4. This was confirmed by rerunning the two worst RIA calculations in Reference 12. The scram setpoint for these calculations was 20% overpower (300 MW), with a response time of 0.025 s.

5.2.8.1 Coast Down of AHTL Pumps (Condition 2 Fault)

The calculations in Reference 12 were updated in ECAR-402 with and without the error correction to calculate core energy deposition and maximum core energy deposition. The time step size in both the original and corrected calculations was 0.0002 to 0.002 s. The maximum core power and core energy deposition results from ECAR-402 are as follows:

Table 20. ECAR-402 results for RIA initiated by coast down of AHTL pumps.

Parameter	Calculation	
	Original	Corrected
Scram Time (s)	0.3598	0.3656
Maximum Core Power (MW)	308.01	308.64
Maximum Energy Deposition (MJ)	8.7988	9.2436

As shown in Table 20 and Figures 47 and 48, the maximum core powers in the original and corrected calculations were comparable. The maximum core energy deposition was 5.1% higher in the corrected calculation than in the original calculation. The corrected results are bounded by the SAR Envelope curves. Therefore, the PPC for Condition 2 faults are met.

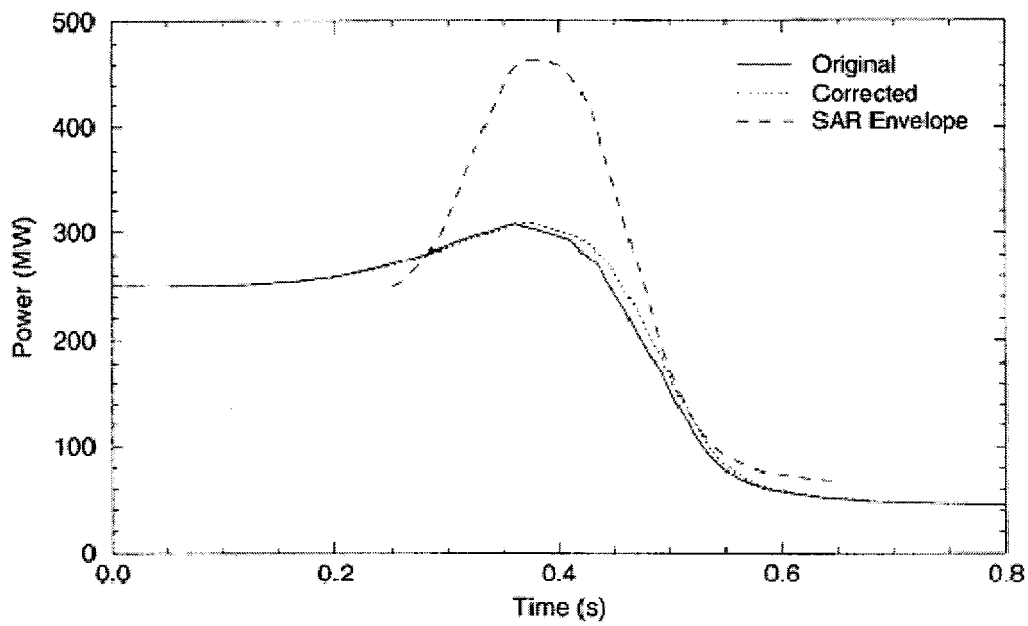

Figure 47. Core power vs. time (coast down of AHTL pumps).

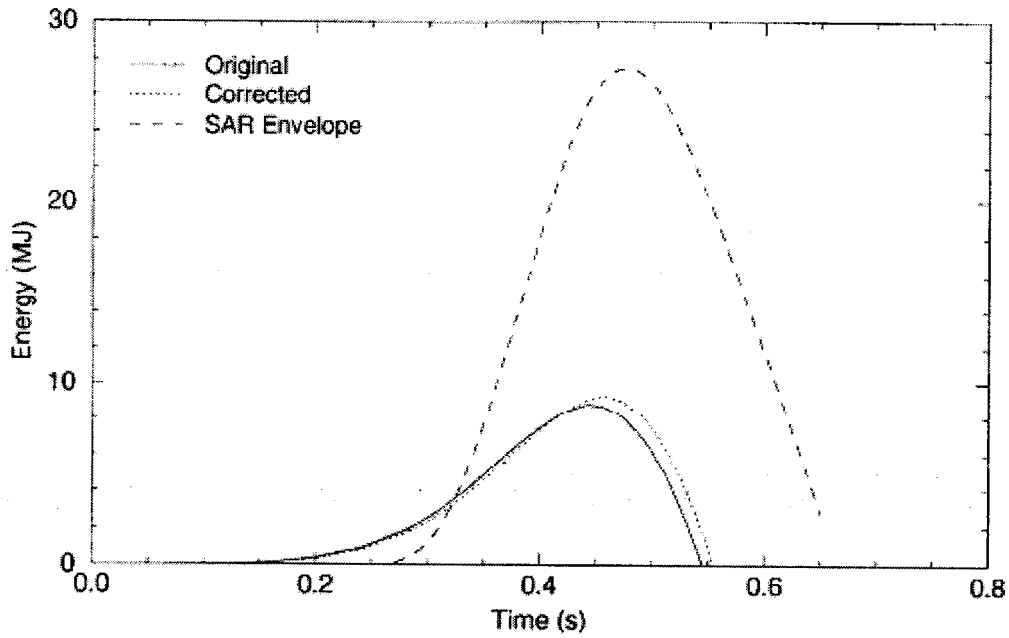

Figure 48. Core energy deposition vs. time (coast down of AHTL pumps).

5.2.8.2 Coast Down of All Experiment Loop Pumps (Condition 4 Fault)

The calculations in Reference 12 were updated in ECAR-402 with and without the error correction to calculate core energy deposition and maximum core energy deposition. The time step size in both the original and corrected calculations was 0.0002 to 0.002 s. The maximum core power and core energy deposition results from ECAR-402 are as follows:

Table 21. ECAR-402 results for RIA initiated by coast down of all experiment loop pumps.

Parameter	Calculation	
	Original	Corrected
Scram Time (s)	0.2196	0.2256
Maximum Core Power (MW)	501.53	521.36
Maximum Energy Deposition (MJ)	27.199	29.385

As shown in Table 21 and Figures 49 and 50, the maximum core power was 4.0% higher in the corrected calculation than in the original calculation; the maximum core energy deposition was 8.0% higher. The corrected results are bounded by the SAR Envelope curves. Therefore, the PPC for Condition 4 faults are met.

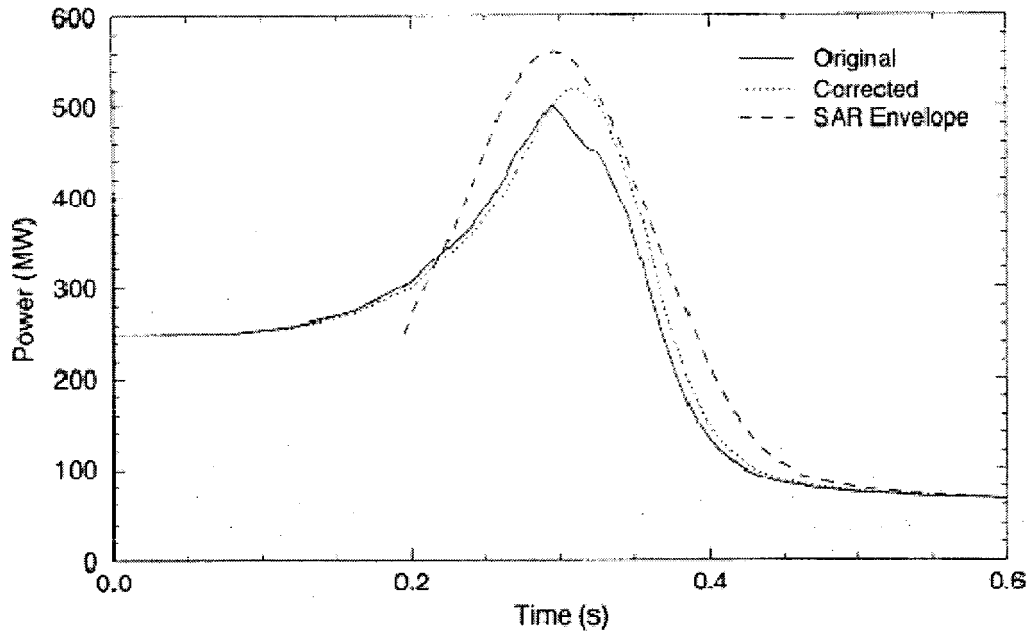

Figure 49. Core power vs. time (coast down of all experiment loop pumps).

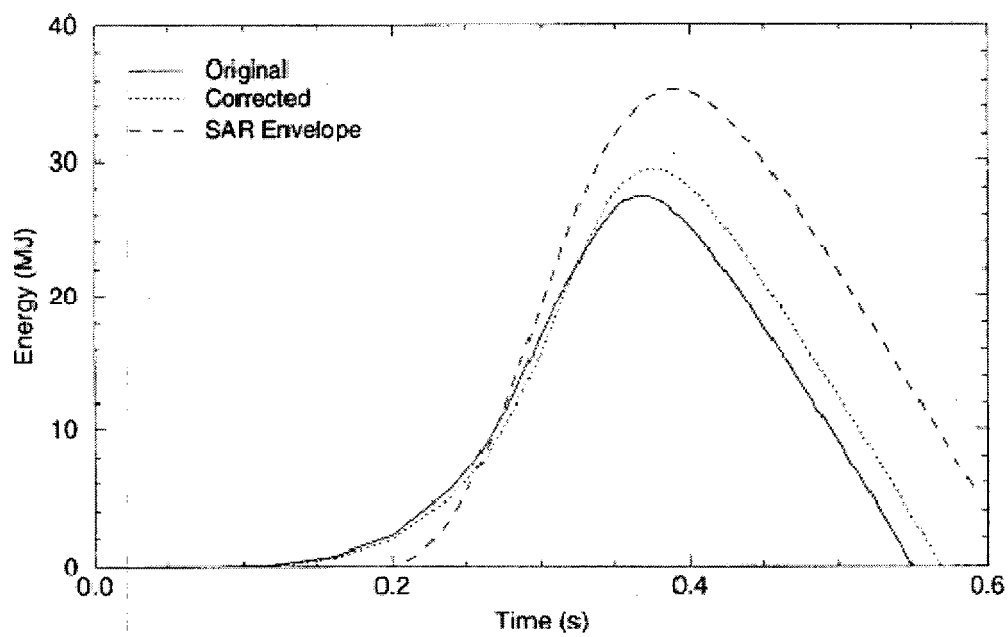

Figure 50. Core energy deposition vs. time (coast down of all experiment loop pumps).

5.2.9 Loss of Commercial Power (SAR-153, Section 15.3.1)

One of the loss-of-commercial power calculations discussed in Reference 24 was rerun to investigate the effect of the RELAP5 error on a non-RIA.

5.2.9.1 Loss of Commercial Power

This calculation was originally performed with 3-PCPs operating initially and the surge tank initially contained 40 ft^3 of air. The reactor scrammed on low vessel inlet pressure, with a response time of 0.1 s. The original plot file is no longer available; therefore, the calculation was rerun with and without the error correction. As indicated in Figure 51, the error had negligible effect on this calculation. At 30 s in the original calculation, the core power was 11.1887 MW, and at 30 s in the corrected calculation, it was 11.1888 MW. Therefore, the original ATR-SINDA and SINDA-SAMPLE calculations are conservative.

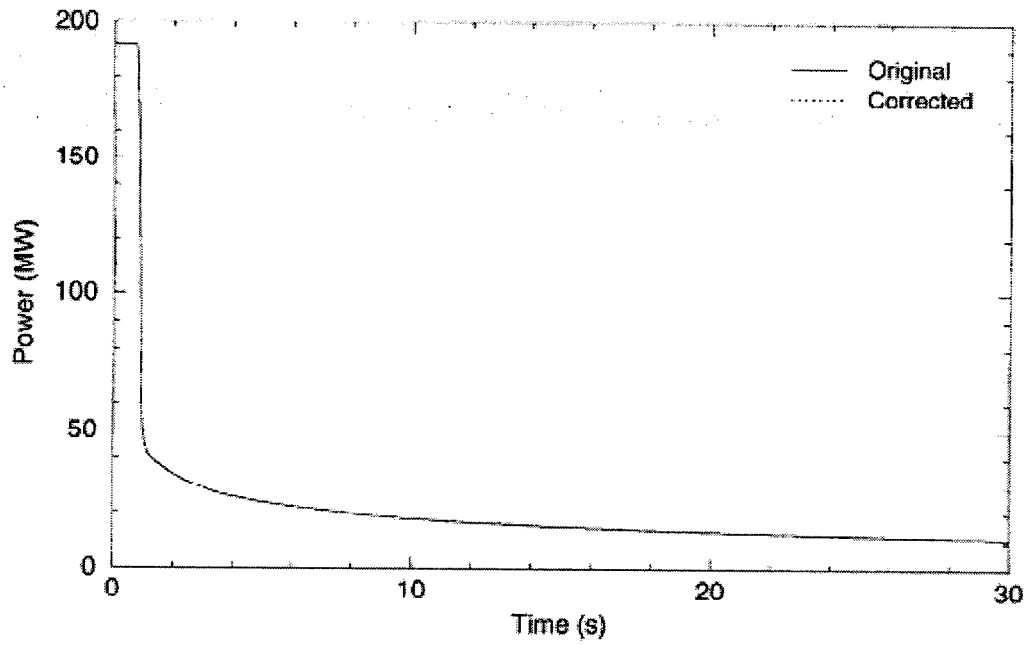

Figure 51. Core power vs. time (loss of commercial power).

5.2.10 Conclusions

In a few cases analyzed in ECAR-402, the maximum calculated core power and/or core energy deposition were higher than calculated previously (the effect of the RELAP5 error on the non-RIA calculation was negligible). However, in all cases, the ATR and ATRC PPC were met. The error in the RELAP5 reactor kinetics model does not change the conclusions in the SAR-153, SAR-192, or EDF-6937. That is, the ATR and ATRC PPC are met for all of the accidents discussed in these reports.

5.3 Resolution of RTC-USQ-2008-553

The following discusses the RTC-USQ-2008-553 USQ Determination (USQD) questions originally marked "Yes," and provides the basis for their resolution.

5.3.1 USQD Question 2: Consequences of an Accident Previously Evaluated in the Safety Basis

SAR-153, Table ES-5, Summary Table of Worst Case Events Resulting In a Radioactive Consequence, provides a summary of SAR-153, Chapter 15, events that resulted in substantial fission product release from the fuel.

As discussed above in Section 5.2, in a few analyzed cases in ECAR-402 (Reference 4), the maximum calculated core power and/or core energy deposition were higher than calculated previously (the effect of the RELAP5 error on the non-RIA calculation was negligible). However, in all cases, the ATR PPC were shown to be met.

SAR-192 events affected include 1) Air Voiding of an LIPT, and 2) Aluminum Filler Piece Drop into an LIPT. As discussed in the accident analyses there will be no radiological consequences for these events, because fuel melt will not occur. The calculations in ECAR-402 show that the maximum core power and core energy deposition decrease slightly for a revised time step size of 0.0001 s for both of these events, and the maximum energy deposition is less than the 15 MJ criterion. Therefore, the original SAR-192 conclusions are bounding.

Therefore, there are no changes to fission product barrier performance that could lead to an increased radiological dose consequence from an analyzed SAR-153 or SAR-192 accident. The radiological consequences of the bounding accidents analyzed as summarized in SAR-153 and SAR-192, are not affected by the RELAP error, and are shown to remain bounding. In the cases where the maximum calculated core power and/or core energy deposition were higher than calculated previously, it was shown in ECAR-402 that the maximum core energy deposition in each case was less than the safety analysis limit. This is discussed further in Section 5.3.3, Margin of Safety.

Therefore, although this USQD question was initially answered "Yes" in RTC-USQ-2008-553, based on the analysis provided in ECAR-402 and as discussed above, this question can be answered "No" thereby resolving the consequences of an accident previously evaluated in the safety basis.

5.3.2 USQD Question 4: Consequences of a Malfunction of Equipment Important to Safety Previously Evaluated in the Safety Basis

As identified in RTC-USQ-2008-553, the ATR and ATRC equipment important to safety that could be affected are: a) fuel element cladding (primary barrier preventing the release of fission products) and structure (heat removal), b) the Reactor Shutdown System (RSS) (mitigation of reactivity insertion), c) outer shim control cylinders, neck shim rods and regulating rods (reactivity control), d) ATR primary coolant system pumps and ATRC canal water level (heat removal), e) ATR primary coolant system pressure boundary (barrier preventing fission product release and heat removal path), and f) ATR heat exchangers and secondary (heat removal).

As discussed above, there are no changes to fission product barrier performance that could lead to an increase in the radiological dose consequence from an analyzed SAR-153 or SAR-192 accident. The radiological consequences of the bounding accidents analyzed as summarized in SAR-153 or SAR-192, are not affected by the RELAP error, and are shown to remain bounding. Therefore, there are no increases in consequences as a result of the important to safety cladding, ATR primary coolant system pumps,

ATRC canal water level, ATR primary coolant system pressure boundary, or ATR heat exchangers and secondary.

As identified in RTC-USQ-2008-553, the RELAP5 error could affect the calculated core power for the RIA. The error could result in under predicting the consequence of the malfunction of the reactivity control systems and the RSS as currently described in the accident analyses. The accident analyses are used to verify the effectiveness of RSS setpoints, the error could result in RSS setpoints that are too high to be as effective as currently demonstrated by the safety analyses. However, as analyzed in ECAR-402, with a corrected code and the analytical assumption of a neutron level subsystem initiating a reactor trip at 1.2 N_F with a response time of 0.025 s, the ATR and ATRC PPC are met for all of the accidents analyzed. However, as discussed in SAR-153, Section 15.4.4.2.3, as is evident from the time scale involved, the dominant effect in terminating the event is inherent feedback. The scram does contribute to the termination of the event and ensures the reactor remains subcritical.

Therefore, although this USQD question was initially answered "Yes" in RTC-USQ-2008-553, based on the analysis provided in ECAR-402 and as discussed above, this question can be answered "No" thereby resolving the consequences of a malfunction of equipment important to safety previously evaluated in the safety basis.

5.3.3 USQD Question 7: Potential for Reduction in a Margin of Safety

In a few cases analyzed in ECAR-402, the maximum calculated core power and/or core energy deposition were higher than calculated previously (the effect of the RELAP5 error on the non-RIA calculation was negligible). Therefore, this USQD question initially answered "Yes" in RTC-USQ-2008-553, remains answered "Yes."

However, in all analyzed cases, the ATR and ATRC PPC were met. The error in the RELAP5 reactor kinetics model does not change the conclusions in the SAR-153, SAR-192, or EDF-6937. That is, the ATR and ATRC PPC are met for all of the accidents discussed in these reports, thereby resolving the potential for reduction in a margin of safety.

5.3.4 Basis for Resolution of RTC-USQ-2008-553 Without New or Revised Operational Restrictions

Since USQD Question 7 in RTC-USQ-2008-553 is confirmed "Yes," the PISA remains a USQ. However, this ESS in conjunction with DOE approval and implementation of the resultant SAR-153 and SAR-192 changes will resolve USQD Question 7 and, therefore, RTC-USQ-2008-553 will be resolved. No new or revised operational restrictions are identified or required in this ESS. A JCO under the interim control identified in RTC-USQ-2008-553 is also not required.

6. CONCLUSION

This document provides the basis for DOE approval of proposed SAR-153 and SAR-192 changes which resolve RTC-USQ-2008-553. ECAR-402 documents that several RIA calculations discussed in SAR-153, SAR-192, and EDF-6937 were rerun with the corrected RELAP5 codes. A non-RIA calculation (ATR loss of commercial power) was also rerun. In a few cases, the maximum calculated core power and/or core energy deposition were higher than calculated previously (the effect of the RELAP5 error on the non-RIA calculation was negligible). However, in all cases, the ATR and ATRC PPC were met. The RELAP5 error does not change the conclusions of the SAR-153, SAR-192, or EDF-6937.

Therefore, no new or revised interim controls are identified in this ESS.

Appendix B provides a markup of SAR-153 and Appendix C provides a markup of SAR-192 to reflect the analyses and conclusions in ECAR-402. No changes to TSR-186 or TSR-192 are required.

7. REFERENCES

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