A Comparison of the RELAP5/MOD3 and PARET/ANL Codes with the Experimental Transient Data from the SPERT-IV D-12/25 Series

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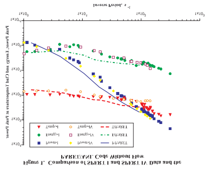
ABSTRACT

The results from the RELAP5/MOD3 and PARET/ANL codes are compared with the SPERT-IV series of experimental reactivity insertion transients. The PARET/ANL code provides conservative estimates of SPERT-IV experimental data for the midrange transients and for the more severe transients. The PARET results are similar to the results obtained earlier for the SPERT-I D-12/25 series of experiments. The RELAP5/MOD3 code (including the developmental version 3.2.1.2) gives results comparable to PARET for some midrange transients, but seriously diverges from the experimental data when significant boiling is present. Based on the results of this study, the use of the RELAP5 code for research reactor applications should be limited to transients that do not generate substantial boiling and voids. We hope to be able to resolve these differences in further work with the NRC staff and its contractors. The RELAP5 code would be a more useful tool for the analyses research reactor transients with the addition of suitable correlations for low pressures and plate type geometry.

INTRODUCTION

The results for the IAEA benchmark transients with the RELAP5/MOD3 and PARET/ANL codes were compared in an earlier report.[1] While the agreement for this series of transients was quite good, the agreement with some of the self-limiting transients was not quite as favorable. It was also noted that to our knowledge, no RELAP5 comparisons have been made with experiments such as those provided by the SPERT reactivity insertion transients and that such a comparison was in progress. This report is a follow on to that previous work where comparisons to the SPERT transients are now provided along with comparisons for the PARET/ANL code. In this report we have been able to test not only the currently released version RELAP5/MOD3.2 but the version currently under development with the designation MOD3.2.1.2 as well. As noted in the earlier report, these versions of RELAP5 include a collection of options that could be applicable to research reactors. Since the RELAP code system was developed for the analyses of pressurized power reactors with pin type fuel, one might expect that some further changes in the code would be needed to accurately model research reactor transients similar to the SPERT series.



SPERT EXPERIMENTAL DATA

The earlier comparisons with the PARET/ANL code[2,3] were limited to the SPERT-I and SPERT-II series of tests with a 2 foot head of water over each core and no forced flow. These studies included the B-24/32 and D-12/25 SPERT-I cores, where the first number in the label is the number of fuel plates in the assembly and the second number is the number of fuel assemblies in the core. While the 24 plate assembly is more prototypical, the D-12/25 core is of interest because this series included destructive tests. The PARET results for the D-12/25 core do not agree as well as the results for the B-24/32 core. The SPERT-IV[4] series of transients use a core that is identical to the D-12/25 core in SPERT-I with the same designation, but this study includes cases with forced flow and with an 18 foot head of water over the core. This series does not include destructive tests. A comparison of the SPERT-I and SPERT-IV results with no forced flow can provide a bridge to the earlier PARET evaluation. Figure 1 shows a comparison of the SPERT-I, SPERT-IV and PARET/ANL results with no forced flow. The SPERT-IV results are very similar to the earlier results, and again the PARET code overestimates the power, energy and temperature over the midrange of the transient data.

CODE MODELING

The PARET/ANL code model is the same model used in the earlier SPERT-I study. Both codes have similar physical models for the sake of comparison with a single hot channel modeled and the remainder of the core represented as a second channel. The same hot channel factors and kinetics parameters are applied in each code. The axial node structure used in RELAP5 was 21 nodes, the maximum allowed in PARET, but further tests using RELAP5 with a larger number of nodes have shown no substantial change in the results. The RELAP5/MOD3 code tests include three different versions of the code: The latest released version of the code, 3.2, with no modifications; The 3.2 version of the code with a modified heat transfer coefficient derived from PARET and imposed for low flow; A yet to be released version of the code designated as version 3.2.1.2 which also includes a selection of optional choices. The modified 3.2 code includes a fixed heat transfer coefficient extracted from the PARET code, where the Rosenthal and Miller (R&M) correlation is invoked with no forced flow and set in the RELAP5 single-phase routine as an additional selection. This insertion of the R&M value is the only modification to the RELAP5 code.

RESULTS

The results for RELAP5/MOD3.2 and PARET/ANL with no forced flow are compared with the SPERT-IV data in Figure 2. The figure shows the peak power (2a), energy to the time of peak power (2b) and the peak temperature of the clad at the time of peak power (2c) as functions of the step reactivity insertion in dollars. The RELAP5 results are shown both with and without the R&M modification. The increase in heat transfer provided by the larger R&M heat transfer coefficient brings the PARET and RELAP5 results into almost complete agreement for the lower insertion transients. However, both codes are still overestimating the experimental results. The $1.20 insertion is the approximate threshold for nucleate boiling in the SPERT-IV tests, and it is at this point and beyond that the RELAP5 results diverge from the SPERT-IV data.

Similar results are observed in comparisons for the forced flow (5000 gpm) tests as shown in Figure 3. The RELAP5 results diverge from the experimental data for insertions greater than $1.20, and again this is the point at which significant nucleate boiling begins. With forced flow the R&M correlation does not come into play, as the heat transfer coefficient for turbulent flow now has a larger value.

Comparisons were also made with the 3.2.1.2 version of the code both with and without the R&M modification. Figure 4 shows the course of the $1.20 transient without forced flow for the 3.2 and the 3.2.1.2 versions both with and without the R&M correction. In figure (4a) for the power, the 3.2 and 3.2.1.2 results are indistinguishable. The only difference observed is between the cases with and without the R&M included, where the R&M case with improved heat transfer to the coolant and more feedback gives a lower peak power at a slightly later time.

With forced flow the $1.20 case gives identical results for the 3.2 and 3.2.1.2 versions for power and temperature (see Figure 5), while the $1.20 case for version 3.2.1.2 where all of the relevant options are invoked shows some slight differences (see Figure 6). In each of these forced flow cases, the peak clad temperature curves, Figures (5b) and (6b), exhibit some structure that has no physical explanation.

Figure 2. Comparisons with SPERT-IV Data for No Forced Flow

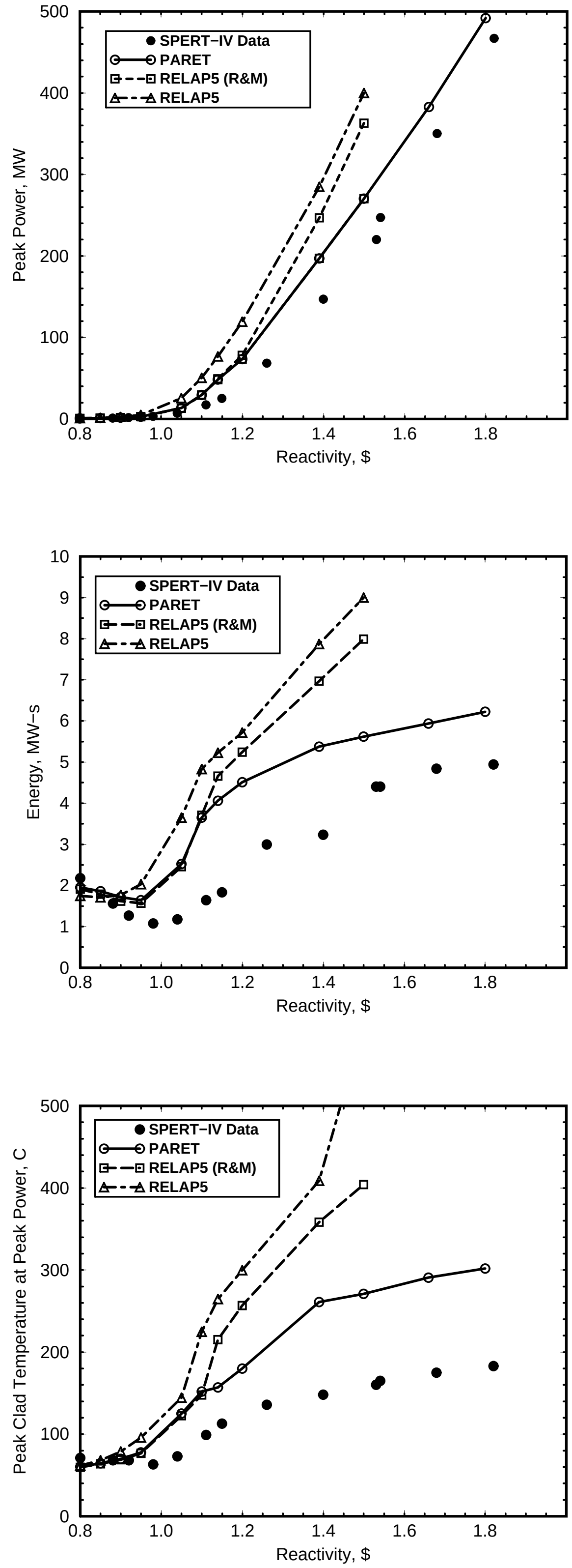
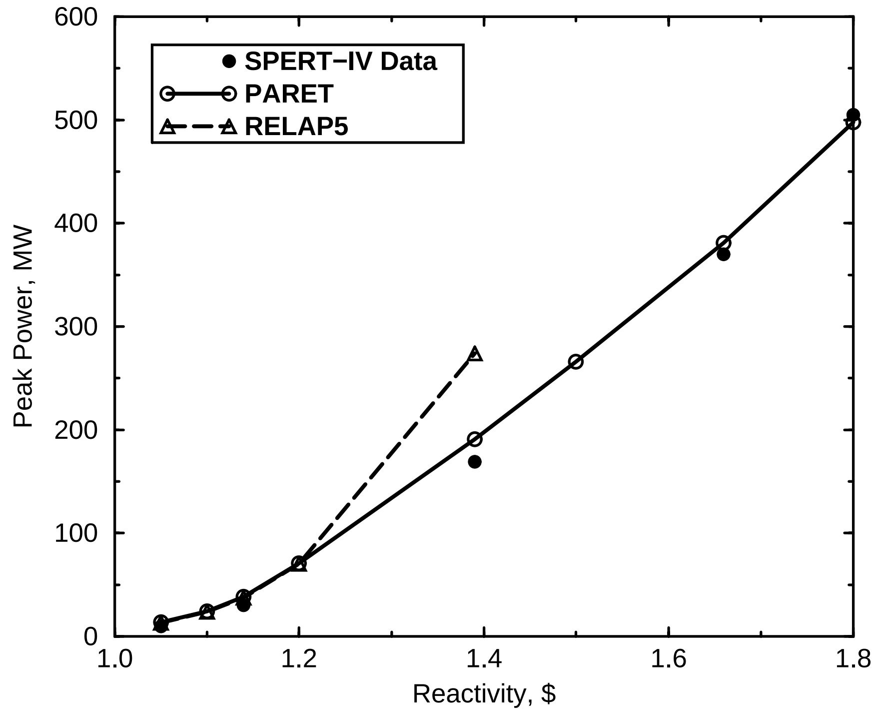


Figure 3. Comparisons with SPERT-IV Data for Forced Flow (5000 gpm)



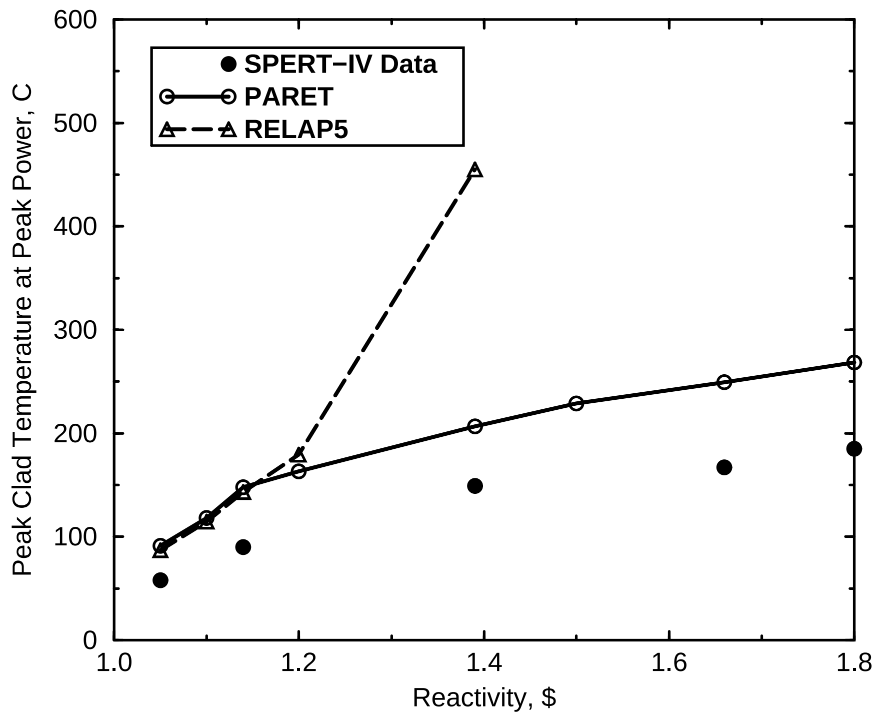


Figure 4. Comparison of MODs 3.2 and 3.2.1.2 for $1.20 with No Flow

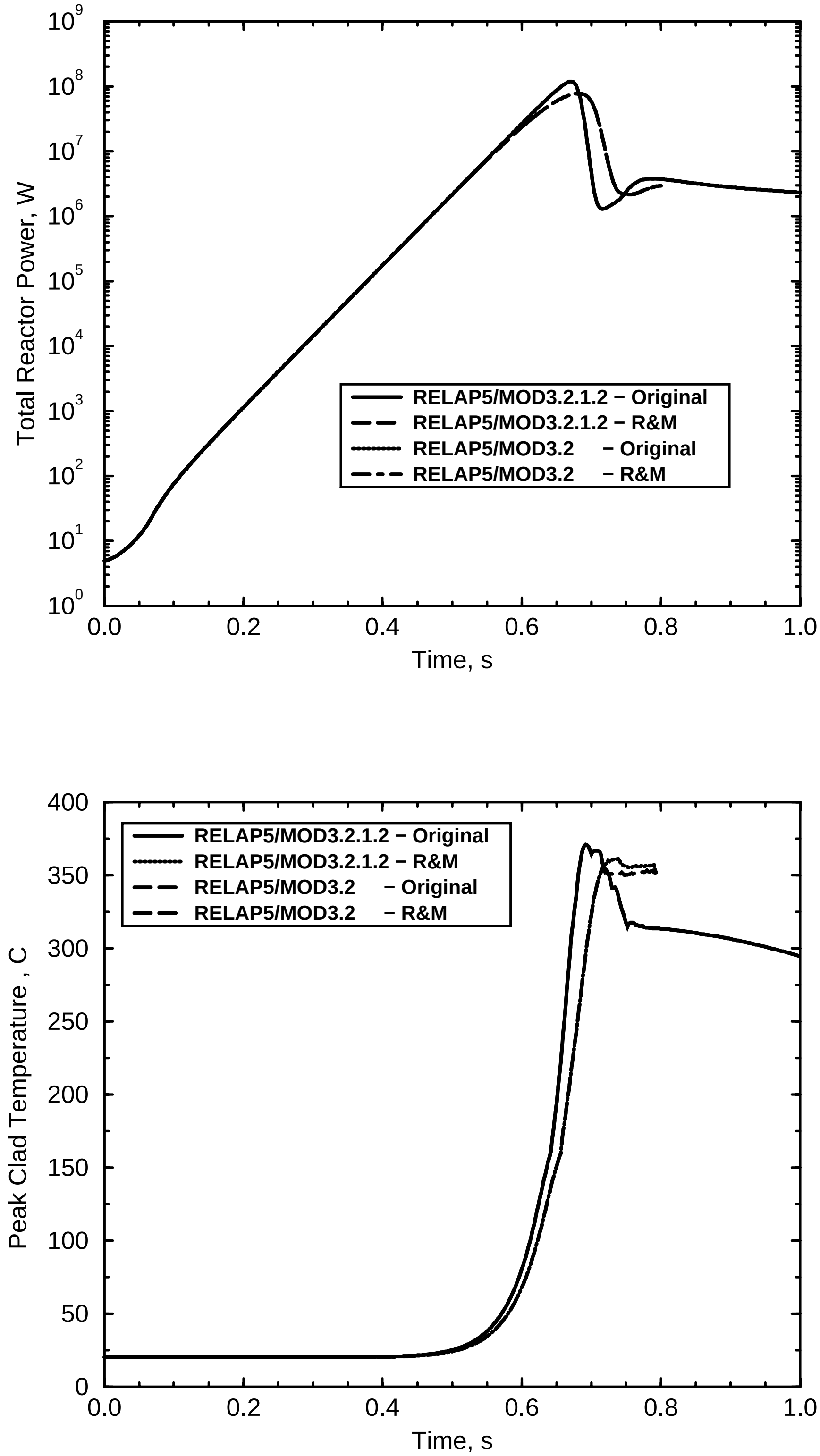
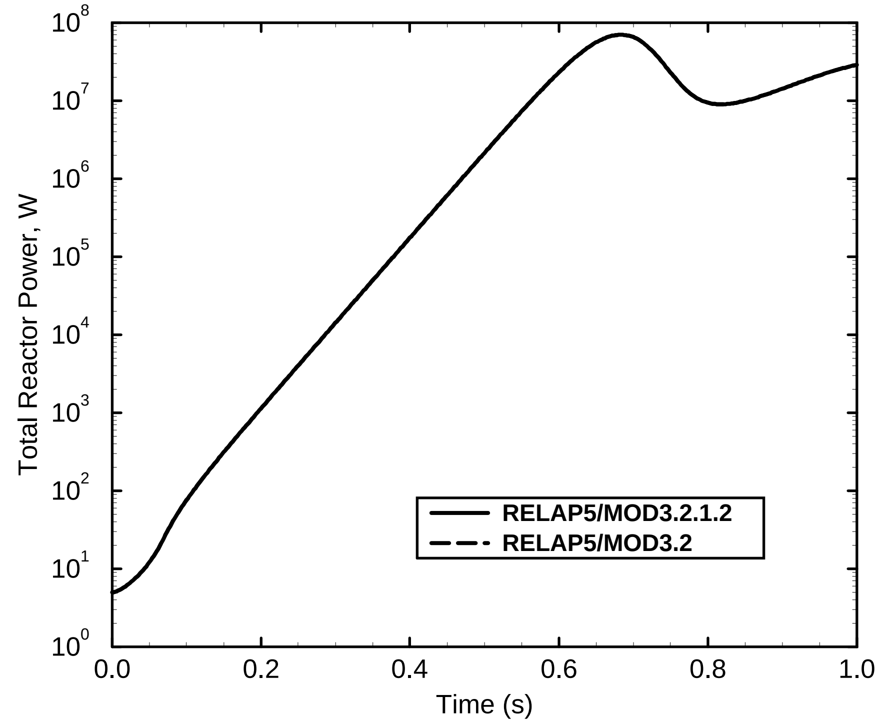


Figure 5. Comparison of MODs 3.2 and 3.2.1.2 for $1.20 with Forced Flow



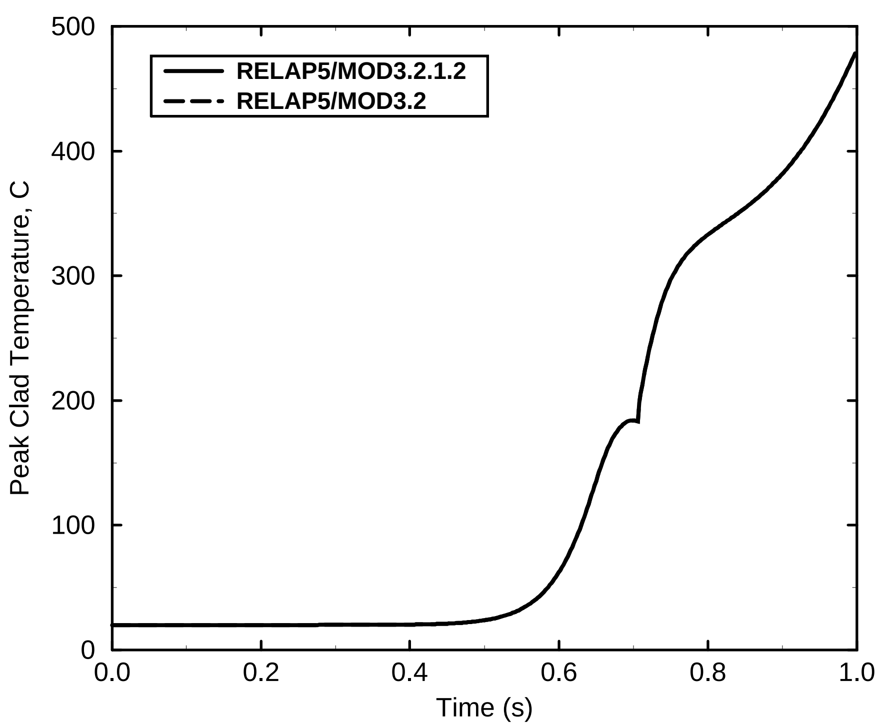
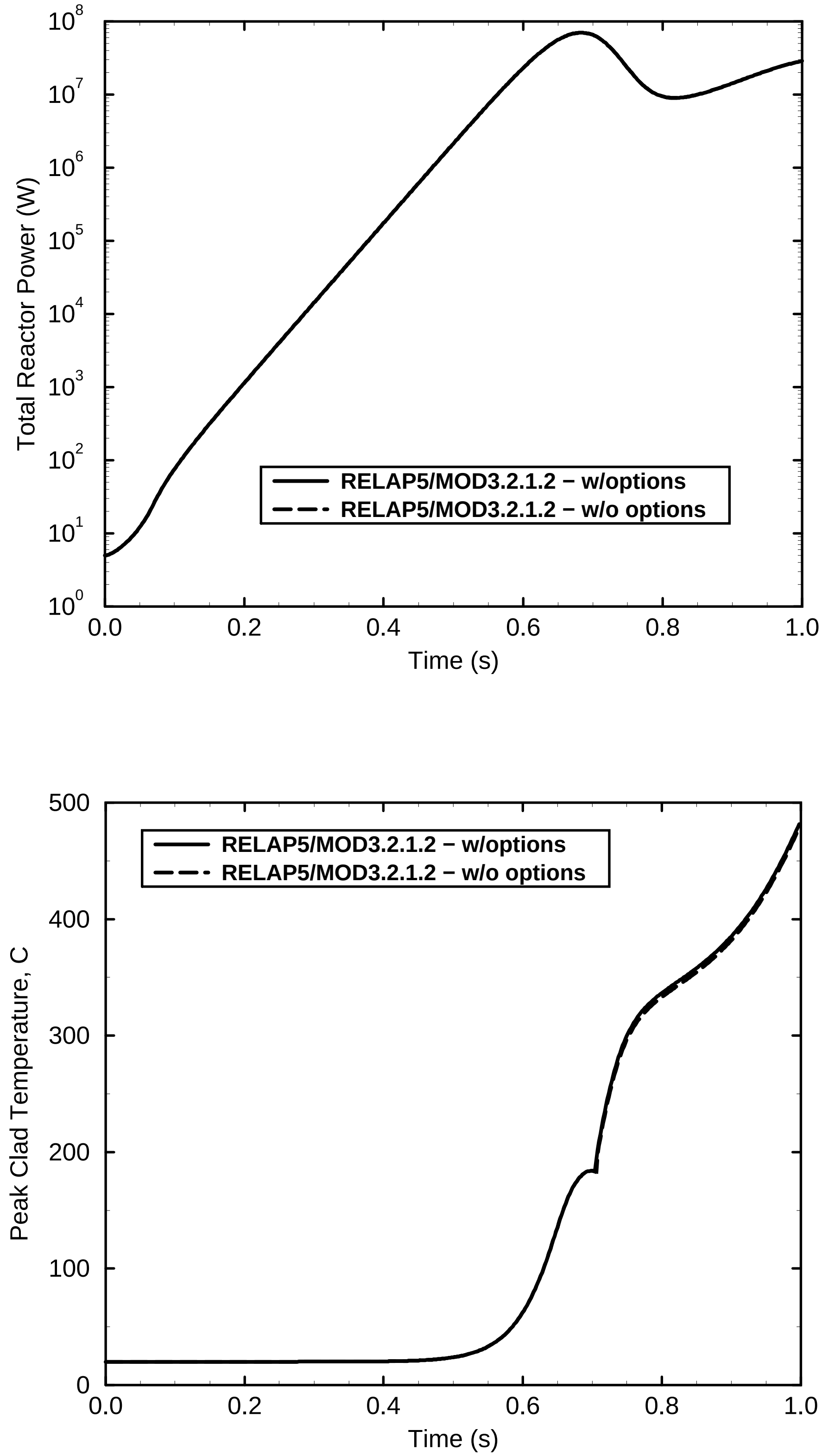


Figure 6. Comparison of MOD 3.2.1.2 for $1.20 With and Without Options



In later work with pressurized experiments, it was found that most of the changes that are observed in the transient results with pressure occur in the first 50 psi of pressurization.[5] The SPERT-IV transients were also attempted at a pressure of about 50 psig, and the RELAP5 results still show the same divergence with increased boiling and voiding. This seems to indicate that the problem is not the result of the low pressure but rather in the boiling and voiding models selected by the code.

An oral presentation of these currents results along with the earlier work will be made at the 1997 ANS Winter Meeting and a summary will be included in the transactions.[6]

CONCLUSIONS

In the earlier work[1] the agreement between the PARET and RELAP5 codes for this series of benchmark transients was excellent. In the benchmark transients reactor scram is always included. The amount of nucleate boiling present (if any) is very limited and the feedback from voiding is not a significant factor in the shutdown of the reactor. The SPERT-IV transients used in this follow on study are all self-limiting, and some have significant amounts of boiling and the subsequent voiding feedback plays a large role. Both the RELAP5 and PARET codes overestimate the transient data and give comparable results for the more modest transients. The addition of a better correlation for single-phase heat transfer with no forced flow, such as Rosenthal & Miller as used in PARET, gives a much needed improvement in the RELAP5 results. The RELAP5 results become progressively worse as the SPERT transients become more severe with more and more boiling. The as yet unreleased 3.2.1.2 version of RELAP5 and the various new options available gave no resolution of the problem. Since we are not that familiar with the structure of the source code, we have made no attempt to make changes in the code. We hope to be able to resolve these differences in further work with the NRC staff and its contractors. In the mean time, based on the results of this study, users of the RELAP5/MOD3 code for the analysis of research reactor transients should limit its use to transients that do not result in a significant amount of boiling and voiding.

REFERENCES

1. Woodruff, W. L., Hanan, N. A., Smith, R. S. and Matos, J. E. “A Comparison of the PARET/ANL and RELAP5/MOD3 Codes for the Analysis of IAEA Benchmark Transients,” Proc. Of 1996 Int. Mtg. On Reduced Enrichment for Research and Test Reactors, Seoul, Korea, pp. 260-269, October 7-10, 1996.
   This document is also available at the World Wide Web address:
   http://www.td.anl.gov/RERTR/RERTR.html

2. Woodruff, W. L., “A Kinetics and Thermal-Hydraulics Capability for the Analysis of Research Reactors,” *Nucl. Technol.*, **64**, 196 (Feb. 1984).

3. Woodruff, W. L., ”Additional Capabilities and Benchmarking with the SPERT Transients for Heavy Water Applications of the PARET Code,” Proc. of 1989 Int. Mtg. on Reduced Enrichment for Research and Test Reactors, Berlin, Germany, pp. 357-365, September 10-14, 1989.

4. Crocker, J. G. and Stephan, L. A., “Reactor Power Excursion Tests in the SPERT IV Facility,” IDO-17000 (August 1964).

5. Schroeder, F. (ed.), “Quarterly Technical Report Spert Project, Fourth Quarter 1960,” IDO-16687 (June 1961).

6. Woodruff, W. L., Hanan, N. A., Smith, R. S. and Matos, J. E., “Comparison of the PARET/ANL and RELAP5/MOD3 Codes for the Analysis of IAEA Benchmark Transients and the SPERT Experiments,” Trans. Am. Nucl. Soc., 1997 ANS Winter Meeting, November 16-20, 1997 (to be published).