UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

DEC 20 1978

MEMORANDUM FOR: Harold R. Denton, Director
Office of Nuclear Reactor Regulation

FROM: Saul Levine, Director
Office of Nuclear Regulatory Research

SUBJECT: RESEARCH INFORMATION LETTER NO.42 : CRITICAL EXPERIMENT PROGRAM FOR NEUTRONICS CODE VERIFICATION

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This research information letter transmits significant experimental results from a program of critical experiments which were performed for the NRC in the ZPR-9 facility at Argonne National Laboratory. The final report on this program will not be completed until September 1979, but the results from the comparison of experimental data to calculation using diffusion theory, transport theory and Monte Carlo methods completed thus far are significant and deserve early attention.

Introduction

This program of distorted geometry critical experiments was planned and carried out to provide benchmarks for the validation of the neutronics part of codes used in safety analysis such as SIMMER. A second objective is to validate the VIM Monte Carlo code for use as a secondary standard for validation of other neutronics methods.

Meltdown configurations in LMFBRs can be expected to have regions with high fuel concentrations giving extreme spectral changes and large regions of void giving rise to large streaming paths. Neutronics methods other than Monte Carlo have difficulty in calculating these configurations accurately. A series of experiments was needed to determine the importance of these difficulties and to provide a basis for improving the accuracy and reliability of accident analysis methods. As will be discussed later, this program has demonstrated that diffusion theory neutronics calculations would underpredict ramp rates which might occur in a meltdown and could be non-conservative.

Background

This program was initiated at ANL in FY 1975 to evaluate the ability of neutronics codes to calculate the reactivity of meltdown configurations in LMFBRs. At that time, there were no acceptable critical experiments by which to test and calibrate the codes and data used to analyze meltdown accidents. The only experimental data available were from measurements made in ZPR-III Assemblies 27 and 28, ZEBRA assemblies 8G and 12, and in the CRBR-EMC program in ZPPR. The former measurements were performed 16 years ago in uranium fueled critical assemblies with significant compositional mismatches relative to present LMFBR designs. VIM Monte Carlo calculations of these experiments have been made; however, the design of the experiments precludes a systematic validation effort (e.g., no unperturbed reference assembly was constructed, and only the eigenvalue measurements were made). In addition, the loading records of these very complicated assemblies proved hard to decipher and were sometimes inconsistent.

The more recent CRBR-EMC measurements provided some prototypical results, but the small magnitude of the reactivity changes involved (< $2) made calculations using a Monte Carlo code extremely difficult. Thus, there was a clear need for critical experiments designed explicitly to provide data for the validation of accident analysis methods including Monte Carlo methods, and a program to design such series of experiments was undertaken at ANL.

A preliminary set of experiments was designed and presented to the Fast Reactor Critical Experiment Review Group Meeting on September 21, 1976. The Review Group made several worthwhile suggestions for changes and concluded that the revised program should proceed.

Arrangements were made with the Department of Energy (then ERDA) to use the ZPR-9 facility at ANL from July 1, 1977, to December 31, 1977. On June 7, 1977, the program described in the enclosed document ZPR-TM-279 was presented to the RSR staff and approved.

The experimental portion of the program was completed on schedule in December 1977. Analysis of the data has continued through FY 1978 and will extend into FY 1979. The enclosed report ZPR-TM-327 contains the major experimental results and a comparison of these results with analysis. The final report on the program will be completed at the end of FY 1979.

Results

A summary of the results from the program is given in the enclosed memorandum ZPR-TM-327. The eight critical configurations studies are shown in Figure 1 of this report. The analytical comparison with the experimental eigenvalues are shown in Figure 2. The results of VIM Monte Carlo calculations on the critical experiments are given in Attachment A of this letter.

Examination of Figure 2 and Attachment A lead to the conclusion that diffusion theory calculations lead to non-conservative estimation of reactivity going from the reference to the slumped configurations. The significance of the ramp rate at prompt critical in an HCDA calculations has been pointed out by the NRR staff in NUREG-0122(1). The parametric study on ramp rate shown in table 5.6 of that report shows that increasing ramp rate from $50/sec. to $100/sec. can increase the work energy from the HCDA by a factor of 3. The reactivity change during the excursions reported in table 5.6 is of the order of $0.30 while the error in calculating the reactivity change between the reference and slump-in critical configuration calculated by diffusion theory is over $2.0. It is apparent there is a potential for underestimating ramp rate at prompt critical and hence work energy in an HCDA calculation.

The tendency of the Sn transport and VIM Monte Carlo methods to overpredict reactivities and the difficulty in predicting material reactivity worth make one suspect that there are serious errors in the ENDF/B-IV cross section sets. It should be noted that the VIM calculations used a plate-by-plate geometry description.

As data on the detailed measurements are reduced, they will be reported in ZPR-TM memorandums.

Users who wish to perform a detailed neutronics calculation on these experiments, will need to have detailed drawings of the ZPR-9 reactor, fuel plates and loading patterns. This material as well as homogenized number densities can be obtained from the Applied Physics Division of ANL through Dr. Dave Wade. Provisions have been made to supply this information to ORNL and LASL safety analysis groups for code verification.

(1)
Meyer, J. F. L. Lois, J. F. Carter, and T. P. Speis
"An Analysis and Evaluation of the Clinch River
Breeder Reactor Core
Disruptive Accident Energetics"
NUREG-0122, March 1977

Recommendations and Future Plans

Data reduction and preparation of the final report will be completed in FY 1979. A VIM Monte Carlo Calculation on Configuration 2 - Sodium Voided Test Zone will be made and the S_n cases not shown on Figure 2 of ZPR-TM-327 will be completed.

Analysis to resolve cross section difficulties that cause differences between experiment and VIM Monte Carlo eigenvalues is needed. The Applied Physics Division of ANL is the logical place for the work to be done. The work should be supported by DOE rather than NRC since it is not really confirmatory research. Discussions with DOE on this problem are underway.

When and if the cross section difficulties are resolved, it would be desirable to prepare secondary benchmark VIM Monte Carlo calculations using a homogenized model of the experimental configuration. This will eliminate the need for plate-by-plate description of the geometry to verify a code. Planning for these calculations will be carried out in FY 1979. Any further work in this area is dependent upon Advanced Reactors Safety Research funding levels and the relative priority assigned to this problem.

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Office of Nuclear Regulatory Research

Enclosures:

1. S. K. Bhattacharyya, et. al., "Program Description and Pre-analysis of the LMFBR Safety Related Critical Experiments on ZPR-9" ZPR-TM-279, June 7, 1977.

2. S. K. Bhattacharyya, et. al., "A Critical Experimental Study of Integral Physics Parameters in Simulated LMFBR Meltdown Cores," ZPR-TM-327, September 29, 1978.

ATTACHMENT A

RSR Core Meltdown Criticals Program
Configuration Eigenvalues and C/E Values (in parentheses)

		k_{expt}	Isotropic D's	Benoist D's	Gelbard D's	S_4/P_0 (DIF3D)	S_4/P_0 TWOTRAN	Monte Carlo 200 K hist	Ih/%Δk[a]
	Reference	1.00093	0.99270 (0.9918)	0.98976 (0.9888)	0.99093 (0.9900)	1.00232 (1.0014)	1.00328 (1.0023)	0.9939 ± 0.0015 (0.9930)	975.61
Radius = 44.2	Na Void Zone	0.99696	0.99094 (0.9940)	0.98379 (0.9868)	0.98577 (0.9888)	1.00154 (1.0046)			971.86
Radius = 44.2	Symm. Slump Out	0.98890	0.97620 (0.9872)	0.97105 (0.9819)	0.97388 (0.9848)	1.00271 (1.0140)		0.9964 ± 0.0015 (1.0076)	969.57
Radius = 44.2	Asymm. Slump Out	0.9916			0.97875 (0.9870)				971.17
Radius = 44.2	Symm. Slump In	--[b]	0.99959	0.99462	0.99824				968.18
Radius = 42.4	Symm. Slump In	1.00115			0.98308 (0.9820)		1.00823 (1.0071)	1.0041 ± 0.0015 (1.0029)	965.18
Radius = 42.4	Asymm. Slump In	0.9862			0.97231 (0.9859)				969.77
Radius = 42.4	Asymm. Slump In with Blanket Collapse	0.9920			0.98060 (0.9885)				971.17

[a] From Gelbard D Diffusion Calc.

[b] This configuration was not physically constructed for operational safety reasons.

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