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Preface

Fast Critical Facilities—Present Status and Future Potential

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In the course of the development of fast breeder reactor technology, zero-power experiments in critical facilities have been performed in various countries of the world for a considerable period of time. A large amount of neutron physics information has thus been accumulated while, on the other hand, the introduction of fast reactors proceeded at a relatively slow pace. The need for new data therefore has become less pressing, and a number of the critical facilities have recently ceased operation or have been marked for closing within the next few years. At other facilities, however, notably Argonne National Laboratory's zero-power plutonium reactor (ZPPR) in the United States and MASURCA in France, plans exist for extended programs to determine physics parameters for large fast power reactors.

Under these circumstances, it appeared useful to provide a survey of the work recently done on fast critical assemblies of the results achieved and of the aims considered most important for future activities.

Papers were solicited for this issue of *Nuclear Science and Engineering* on fast critical assembly work from experimental groups in the United States, Japan, England, France, and the Federal Republic of Germany. They were asked to report on the problems they consider most interesting, describe the results achieved so far, and indicate the most important difficulties in the experimental and calculational techniques.

In response to this request, reports were received about work performed in all the laboratories that had been approached. The topics selected by the authors were:

1. compilations of results from investigations about different types of heterogeneous cores (three papers)
2. a control rod study also involving the specific characteristics of heterogeneous cores
3. investigations of the effects of accident-caused core distortions (two papers)
4. experiments aimed at resolving the long-standing central reactivity worth discrepancy in U.S. evaluations
5. a study of some methods to extrapolate results found in relatively small critical assemblies to large power reactors.

Heterogeneous cores, with the promise of lower sodium void reactivities, higher breeding gains, and a lower irradiation load on the fuel, have been considered as a genuine alternative to conventional core design since they were put up for discussion by Mougniot et al. at the European Nuclear Conference at Paris in 1975. In order to test the reliability of neutron physics calculations for this type of reactor, critical assembly programs were performed at several locations: at ZPPR in the United States, at FCA in Japan, and as international projects with the participation of the German-Belgian-Dutch groups at ZEBRA in England (BIZET program) and at MASURCA in France (RACINE program).

As shown in the papers in this issue, the global parameters (k_{eff}, breeding ratio) are predicted in heterogeneous assemblies with an accuracy similar to that in homogeneous ones. However, due to the increased frequency of zone boundaries and due to the high sensitivity of flux distributions, problems often arise in calculating local effects, such as reaction rates and the position dependence of control rod worths. More often than for homogeneous cores the application of transport theory is required to get acceptable agreement between theory and experiment.

The sodium void effect in the fuel zones of heterogeneous cores is also calculated with an accuracy comparable to that reached for homogeneous cores. The shift of the effect toward less positive values in heterogeneous cores was confirmed by the measurements. Calculations of the sodium void effect in internal fertile zones were reported by the French and Japanese groups only. While the Japanese found about equal quality of prediction of the effect in the core and blanket zones, the French calculations, which yield mostly excellent agreement in the core zones, show fairly large discrepancies in the internal blanket zones. This is an indication that calculational methods and data that have been adapted to the treatment of homogeneous assemblies may prove less successful in the presence of internal blankets.

The paper on control rod experiments in BIZET and SNEAK 10C shows that the effect of natural boron rods in homogeneous and heterogeneous plutonium cores is described quite satisfactorily by *XY* diffusion calculations using both English and German methods and data. But the consistency of the results is worse for alternative absorbers (including ^{10}B-enriched B_4C) and for experiments performed in the SNEAK 10C compact uranium core.

Measurements in distorted cores have captured increasing interest ever since the first measurements at ZEBRA and ZPPR on this subject, particularly because of the sometimes very large discrepancies reported. In this issue, a series of experiments on this subject is presented by a Japanese and a German group. The papers include experiments and calculations on various aspects of an accident sequence, such as cavity formation, sodium removal, and the movement of core constituents; the most important results concern the reactivity effects of fuel movement and compaction. The common conclusion is that the effect of major fuel relocations can be described reasonably well by S_4 transport eigenvalue (or exact perturbation) calculations, while first-order perturbation or diffusion approaches often lead to large deviations, usually on the nonconservative side. This should always be taken into account in the accident analysis of fast power reactors.

The American work on the central reactivity discrepancy essentially eliminates this problem by a series of experiments that was planned, performed, and evaluated with particular attention to all details of the experimental situation. The central reactivity discrepancy has always tended to throw some doubt on the reactivity results (e.g., control rod worth, sodium void effect, etc.) of ZPPR experiments. Its resolution therefore adds greatly to the value of all these experimental data.

The results reported in this issue are being complemented by a number of experimental programs that are now under way. At the ZPPR, heterogeneous assemblies of increasing size are being investigated; at MASURCA, the RACINE program on heterogeneous cores is being continued, and at SNEAK, the experiments on distorted cores are extended to rod geometry using nearly prototypical fuel.

Another topic of great current interest is burnup effects and therefore the reaction rates and reactivity worths of the most important actinide isotopes. A program aiming in this direction has already been performed in Japan and is planned in France following the RACINE investigations.

Beyond this, what can be the task of fast critical assemblies in the future?

Physics parameters of most compositions or individual isotopes of interest have already been measured in typical fast breeder environments. There are still data, however, for which an improved knowledge may be worth the expenditure of further experiments. As an example, uncertainties in integral cross sections of ^{238}U still significantly affect the prediction of the breeding ratio, the sodium void effect, the burnup reactivity, and even control rod worths and interaction. Also, the integral data of other reactor materials like steel and various absorbers might merit further investigation. Before embarking on new experiments, however, one should make sure that all information available to date, notably from the U.S. diagnostic core program and from the clean physics experiments of other groups, has been fully evaluated.

Pin/plate effects, often important for the extrapolation from a fast critical assembly to a power reactor, have been investigated on various occasions, most extensively in the British CADENZA program, which became an international benchmark. As of now, there appears to be no immediate need for further experiments in this field.

From time to time, mockup-type experiments will be needed to investigate complicated neutron physics effects of technical innovations. Examples of this are the French proposals for experiments about the effects of blanket design changes and in-tank fuel element storage. Recent Japanese and German experiments on new core loadings for Joyo and KNK II belong mainly in this category.

The aim currently considered to be most important for future activities is to extend as far as possible the reliability of neutronic analysis, which has now been achieved in applications to large reactor systems with their very high sensitivity of the spatial distributions of fluxes, reaction rates, and reactivity worths.

Therefore at ZPPR, where fuel and matrix space are relatively abundant, experiments are being planned in assemblies of increasing size. Another approach is the development of improved methods to extrapolate the results of experiments in smaller assemblies to large reactors. In their contribution to this issue, Salvatores and Palmiotti propose to achieve this goal by characterizing each assembly using a single parameter that indicates the sensitivity of the space dependence of its neutron physical properties. Although these techniques will certainly help to alleviate the extrapolation problem, it will still remain important to build as large assemblies as possible to minimize extrapolation requirements. For this purpose, international pooling of fuel resources has proved to be very valuable in the past and will probably continue to be significant in the future.

In summary, given the continued development of fast reactor technology, there will still be a need for information that can best be gained by experiments in fast critical facilities. International cooperation, including the common use of fuel and the open exchange of information, will help to obtain the experimental data in the most efficient way possible.