PREFACE

MECHANICS APPLICATIONS TO FAST BREEDER REACTOR SAFETY

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The 18 articles of this issue are drawn from work of the Engineering Mechanics Program of the Reactor Analysis and Safety Division at Argonne National Laboratory (ANL). This compilation is an effort to consolidate and document recent gains made in this sector of technology and present them as an organized body of knowledge.

The theme of the issue is Mechanics Applications to Fast Breeder Reactor Safety. The technology development is in response to safety requirements posed by the fast breeder reactor plant. There are, however, significant areas of mechanics and nuclear technology that are covered by these articles, which can prove useful to safety and design questions of more conventional nuclear plants, such as the light water reactor.

The papers of this issue are complementary, reflecting an integrated approach in dealing with the mechanics problems of fast reactor safety. Like the underlying Engineering Mechanics Program, integration of subject matter in this issue proceeds along two lines. The first line pertains to development of methodology for application to fast breeder reactors. The work reflects mathematical formulation, code development, experiments, comparison of code predictions with experiments, verification or modification of codes, and project application. The second line reflects the physical unfolding of the breeder plant. It starts with the structural mechanics of the reactor core; continues with the components within the primary system cavity, the primary system boundary or primary containment, the piping and the in-line components; and terminates with the secondary containment.

The first paper provides an overview of the entire issue and ties the subject matter to the risk assessment methodology for the breeder, known as the line-of-assurance approach.

The next three papers pertain to the mechanics of the reactor core. J. M. Kennedy et al. provides unique methodology and thorough treatment with the STRAW code of fluid/structure interaction involving subassemblies and sodium coolant. The third paper, by H. J. Petroski and J. L. Glazik, covers the dynamic response of shells containing cracks and derives simple predictive techniques. These can also be used for components beyond the core. The fourth paper, by J. L. Glazik and H. J. Petroski, utilizes finite element techniques to characterize the dynamic response of hexagonal subassembly ducts containing long axial cracks.

The next four papers deal with the components and systems that are exterior to the core but located inside the primary reactor cavity. C. Y. Wang develops the hydrodynamics of the above-core regions subjected to a hypothetical core disruptive accident (HCDA). The paper by J. M. Kennedy that follows augments Wang's work on hydrodynamics with a finite element three-dimensional solid mechanics treatment of the above-core structures employing the recently developed SAFE/RAS code. The intent of these two companion papers is to reduce the conservatism in HCDA calculations by providing dissipative mechanisms. In his paper, H. Y. Chu presents a two-dimensional arbitrary Lagrangian-Eulerian treatment of the primary system components subjected to an HCDA. It combines the best attributes of the Lagrangian and Eulerian approaches in evaluating sequential damage of concentric components. Finally, the last paper in this section, by R. F. Kulak, presents the first three-dimensional treatment (NEPTUNE code) for fluid/structure interaction of eccentric components in a large, pool-type liquid-metal fast breeder reactor (LMFBR).

The next six papers treat the boundary of the primary system cavity, also referred to as the primary containment. Y. W. Chang and J. Gvildys provide in their paper validation of primary containment codes with emphasis on ANL-developed containment codes, REXCO, ICECO, ALICE, and REXALE, by the use of experiments. C. Y. Wang compares ICECO predictions with the COVA overstrong tank experiment. For the first time, analysis of high-energy excursion involving shock wave propagation and fluid cavitation is successfully performed with a Eulerian hydrodynamic code. In paper 11, R. F. Kulak provides three-dimensional elastic-plastic treatment of the upper primary system boundary, the reactor cover, with the SADCAT code developed in this program. In the next paper, W. R. Zeuch and C. Y. Wang utilize the deformed state of the reactor cover, provided by the earlier paper, to derive methodology on sodium spillage from the primary vessel into the primary cavity and into the secondary containment. Finally, the last two papers of this section deal with an alternate primary containment system that can increase the margin of safety for an HCDA by at least one order of magnitude with a concurrent potential reduction of cost. In the first, A. H. Marchertas and T. B. Belytschko describe an improved method of analysis of prestressed concrete reactor vessel (PCRV) under dynamic HCDA loading, which has been coded as DYNAPCON. The PCRV acts as an energy absorption basket. A comparison of DYNAPCON code predictions with British experiments is also made. In their paper, R. W. Seidensticker, A. H. Marchertas, and Z. P. Bažant calculate margins of increased safety against HCDA for this alternate primary containment system, employing an energy absorption basket in the form of a prestressed biological shield.

The next two papers deal with the primary piping and in-line components of loop-type reactors which are located beyond the primary cavity. In his first paper, M. T. A-Moneim summarizes recent significant improvements in the two-dimensional hydrodynamic-elastic-plastic piping code ICEPEL developed earlier in this program, and in his second, he describes the new code SHAPS—under development in this program—providing an advanced three-dimensional finite element formulation for nonlinear analysis of complex piping systems.

The last two papers of the issue pertain to the secondary containment of the LMFBR. W. R. Zeuch provides an integrated treatment of phenomena, starting from reactivity insertion in the core, through slug impact, sodium spillage, and sodium fires leading to the pressurization of secondary containment. Finally, the last paper, by R. W. Seidensticker and H. L. Schreyer, formulates the response of a new passive secondary containment concept to phenomena such as sodium fires and hydrogen deflagration.

Several papers provide comparisons between codes developed in this program and experiments. The sources of experiments are diverse. Some experiments were designed in this program and subcontracted to the SRI International. Others were performed by SRI International for the Clinch River Breeder Reactor Project. Still others were performed in Europe by the U.K. Atomic Energy Authority or on the continent by the EURATOM Joint Research Centre of Ispra. We wish to thank all these organizations for providing us with experimental results.

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