PREFACE:

SYMPOSIUM ON THEORETICAL MODELS FOR PREDICTING IN-REACTOR PERFORMANCE OF FUEL AND CLADDING MATERIAL

A. L. LOTTS *Metals and Ceramic Division, Oak Ridge National Laboratory,**
Oak Ridge, Tennessee 37830

Symposium Chairman

A cherished hope of the fuel element designer and the reactor engineer is that eventually a handbook enabling the systematic, accurate consideration of fuel-element-design alternatives will be available. The fuel development engineer or scientist has always hoped that he would be able to provide this goal and has nourished the idea that fuel-element-behavior data can be classified and combined with a mathematical description of the fundamental mechanisms in such a way that the behavior of any fuel element is accurately predictable. Real and important benefits will result from the attainment of this objective. It would enable not only accurate and quick fuel-element design but also enable the optimization of the design. In other words, there would be less conservatism employed to compensate for unknown phenomena. The economic possibilities of this are obvious. Realization of the objective would allow the prediction of fuel performance for existing or proposed fuel-element designs for steady-state, transient, and off-normal conditions and could allow the accurate simulation of fuel behavior under actual reactor operating conditions, which will include periodic and sometimes random variation in operating conditions.

Although the desire for an accurate handbook or design system has been shared by many for a long time, the problem has been so difficult and complex as to discourage a comprehensive attack upon the problem. The advent of the large, fast digital computer and the evolution of a large volume of data on fuel behavior have stimulated in the past few years a much increased level of effort that is directed toward the development of computer programs which will describe fuel element performance. This activity, which is known as fuel performance modeling, has led to the proliferation, in a relatively short time, of a number of first-generation fuel performance models. The current models are distinguished as a group by the variety of approaches that are used, by disagreement between models on interpretation of basic mechanisms, by some disagreement on the interpretation and applicability of data, and, paradoxically, by agreement on certain of the results.

Although the emphasis in the foregoing would indicate that the field is occupied only by those who are doing generalized modeling of a complete fuel element, the modeling activity also has its specialists whose contributions are essential to development of any comprehensive fuel-element performance model. Considering the fuel alone, there are investigators who have primary interests individually in thermodynamics, models of fission-gas behavior, and fuel swelling, among others. Fuel cladding specialists have individual interests in such topics as behavior of voids in metals, mechanical behavior of cladding materials, and in corrosion of the cladding. There are interrelated areas such as ratchetting, clad or fuel extension during irradiation, which is probably caused by mechanical interactions, fuel-cladding chemical interaction, and establishment of failure criteria. Obviously, all of these activities and others must be integrated to arrive at a valid fuel-element performance model.

Even though no one working in the field would claim that he has a fully developed model that is sufficiently accurate for a designer to use, certain interim benefits from the models are being

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realized at this stage of the development. The models are serving to define gaps in existing knowledge and technology; thus, they serve to guide additional theoretical and experimental fuel development. They are being used for correlation of theoretical observations and engineering data on fuel element behavior. They are also being applied in their preliminary form to the prediction of fuel element performance and to problems in design optimization.

It is within this context that the Special Symposium on Theoretical Models for Predicting In-Reactor Performance of Fuel and Cladding Materials was held at the American Nuclear Society Winter Meeting in San Francisco, November 30 through December 4, 1969. This symposium consisted of three special sessions which were organized according to the following topical interests: (1) cladding performance models; (2) fuel performance models; and (3) integrated fuel-element-performance models. The 21 papers presented at the Winter Meeting are being published in this and two succeeding issues of *Nuclear Applications and Technology* and will appear in the same order as that listed above for the symposium. In organizing the symposium, it was recognized that there is a wide variety of reactor applications and fuel materials that have received fuel modeling emphasis. For example, pyrolytically carbon-coated fuels for high temperature gas-cooled reactors have been the subject of a substantial modeling effort. Also metal fuels have received considerable attention. However, it was felt that it was necessary to limit the scope of the symposium to a more concentrated and intensive interest; and, accordingly, we chose to select the general geometry and fuels that hold the interest of the nuclear community. Therefore, the authors were requested to limit their discussion to fuel elements or applications in fuel elements having cylindrical fuel pins and to consider applications for water reactors and advanced reactors such as the liquid-metal fast breeder reactor.