PREFACE

A REVIEW OF PLUTONIUM UTILIZATION IN THERMAL REACTORS

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Increasing quantities of plutonium will rapidly become available in the U.S. during the next decade or two as uranium fuel from light water reactors is reprocessed. The importance of plutonium fuel as an energy resource for thermal reactors has been recognized by several groups who have included plutonium utilization in their power generation planning. Although estimates may vary, the cumulative dollar value of the plutonium is expected to reach about $1.7 billion by 1985. In addition to the economic incentive, the available plutonium can constitute a significant fraction of the light water reactor fuel required to meet the future energy needs. If the plutonium is not utilized in thermal reactors, then other costly alternatives such as storage must be considered.

As a result, the basic technology of plutonium utilization in thermal reactors has been studied in many national research centers of the world as well as in several privately owned laboratories. In the U.S., one of the major government programs has been the USAEC-sponsored Plutonium Utilization Program. The program began in 1956 and was completed in 1972 when the primary responsibility for implementing plutonium utilization was left to industry. The August 1972 issue of *Nuclear Technology* contained the results of some of the more significant studies which were completed in the later stages of the program. In this issue, the basic technology developed under the program is reviewed along with appropriate public information developed under other programs. In the review, five major areas are covered: the value of plutonium recycle, the neutronics of plutonium recycle, plutonium fuel technology, mixed-oxide fuel irradiation performance, and decontamination of reactor systems.

The value of plutonium is usually defined as the savings which occur when the plutonium fuel cycle is substituted for the uranium fuel cycle. Several ways of determining the value are discussed. These include an indifference method in which the costs of operating complete fuel cycles are compared and an intrinsic value approach based on initial fuel enrichments which give the same fuel burnups. Because the value is dependent on various assumptions, such as enrichment, rod separation, and fuel fabrication costs, equations are presented which permit the reader to determine appropriate values based on information available to him.

As a result of experimental and calculational neutronics studies, good progress has been made in assessing expected design method uncertainties. However, available studies need to be expanded in order to direct more attention to power distributions, control worths, and burnable poison effects. Some of the more basic studies need to be extended to permit meaningful assessments of uncertainties to be made for reactor configurations such as the plutonium-island concept for the BWR and the all mixed-oxide concept for the PWR. Control margins in current reactors will need special attention when appreciable amounts of plutonium are used. Some uranium systems have been engineered so well that an expected reduction in control worth when plutonium is used may limit plutonium utilization in some currently designed reactors.

Current neutronic studies suggest that standardized cross sections and design methods evaluated using experimental data be employed for plutonium calculations. This approach seems preferable to the common approach of normalizing methods. Such normalizations generally yield excellent results for some selected parameters, but unreliable results for other parameters. By using standardized cross sections and evaluated methods, the uncertainty and bias in calculated parameters is known and corresponding adjustments can be made in engineering estimates. In addition, estimates of bias and uncertainties can be revised as more data become available.

The technology of plutonium fuels for water-cooled commercial reactors is focused on UO_2-PuO_2 fuels. Important areas of consideration which are included as separate articles in this technology review are fuel fabrication, radiation exposure considerations associated with recycled plutonium, and nuclear criticality safety while fabricating, handling, storing, and shipping mixed-oxide fuel assemblies. Much of the technology of mixed-oxide fuels is similar to that of enriched UO_2 fuels. Therefore, where possible and applicable, emphasis is placed on changes in limitations on items such as equipment, materials, design considerations, and processing and handling procedures which are the result of substituting recycled high exposure plutonium for ^{235}U in the reactor fuel. Results obtained so far indicate that plutonium-enriched fuels can be fabricated, stored, and transported without excessive personnel exposure and with a minimum addition of special protection procedures.

Because of the irradiation of a significant amount of fuel as part of several experimental and demonstration programs, UO_2-PuO_2 can be considered a demonstrated fuel for plutonium recycle in thermal reactors. In these programs, comparisons of irradiation performance have been made between different fuel types at heat ratings greater than those utilized in present commercial reactors. Transient and defect behavior and irradiation alteration of the fuel have been reviewed along with fuel performance effects because of factors such as fission gas release, plutonium redistribution, and fission product migration. Pellet-type fuel is presently accepted as a standard by the industry. However, it is proposed that vibrationally compacted fuel should be considered as a promising alternate fuel form which may possess performance advantages.

Economic utilization of fuels in general requires that reactors operate with some defected fuel rods. Thus, information on decontamination of plutonia-contaminated thermal reactor systems is expected to be useful to facilitate maintenance and continued operation. Therefore, available information on decontamination and fuel dissolution has been reviewed and summarized. Although the number of decontaminations performed is relatively small, safe and effective procedures to remove ceramic fuel material chemically from contaminated reactor systems are available.

Although sufficient information is already available to assist in making decisions concerning the use of plutonium in commercial reactors, plutonium utilization in commercial reactors on a reload scale will add significant information to the current technology. In addition to economic advantages or perhaps economic necessity, the use of plutonium could help meet the energy needs of the future and assist in solving fuel enrichment needs. Thus, the announcement, as this journal goes to press, of approval to reload Big Rock Reactor with plutonium-containing fuel is another milestone in the history of nuclear power. It will be the first nuclear plant in the U.S. to use plutonium commercially on a reload scale.

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