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Book Reviews

ADVANCES IN NUCLEAR SCIENCE AND TECHNOLOGY

Edited by

Ernest J. Henley and Jeffrey Lewins

Academic Press, Inc., New York, San Francisco, London, 1975, 349 pages, 6x9 in., diagrams, illustrations. Price approx. $33.50.

This is the eighth volume of this serial publication, covering reviews of areas of current interest in the nuclear science and technology field. The editors point out that publication occurs at an interesting moment in the history of development of nuclear power throughout the world: conflicting and opposing views on the role of nuclear energy for future energy supplies in the USA and Japan, engineering difficulties in German plants, France pursuing a Light Water Reactor (LWR) policy and the United Kingdom opting for the Heavy Water Reactor concept.

Perhaps this characterization merits some updating. Although present forecasts indicate that by the turn of the century more than half the global production of electrical energy will be derived from nuclear fuel, the slowdown in electrical power demand, soaring capital costs, the shortage of financing for utilities, and slippage in schedule due to licensing problems have resulted in a considerable slowing in the pace of development of nuclear power in the USA: to the extent of suspension of work on nearly all of the large-scale High Temperature Reactors (HTR) units ordered by utilities. Effectively, a moratorium on nuclear power expansion is in force: construction of some 125 reactors has been postponed, and many have been cancelled. It is doubtful that nuclear energy will eventually supply 50% of the USA electricity need (as compared to its 8% present supply) as once hoped by the administration. Also in the picture are: expected future worldwide shortages in uranium supplies; delays in the USA breeder program as opposed to fast-moving European and USSR programs; a looking towards supplemental and alternative solar, coal, and fusion energy sources; industry involvement in the USA in the fuel reprocessing and enrichment processes; and an energy-hungry developing world (with or without limited oil resources) looking toward nuclear energy as a hope for development. The latter factor necessitates international efforts for the creation of regional Nuclear Fuel Cycle Centres, the ratification of the Non-Proliferation Treaty, and the creation of Nuclear-Weapons Free Zones. The approximately 70 GWe of nuclear electric generating capacity installed around the world in 1975 is projected to increase to around 500 GWe by 1985 and over 2000 GWe by the year 2000[1].

The book contains six sections by seven authors: followed by extensive bibliographies updated to 1972 or 1973, and a subject index.

J. P. Oliver's, of the OECD Nuclear Energy Agency, France, technical and philosophical discussion: "The management of fission products and long-lived alpha wastes" is of major concern for the public and the scientific community: "...the long term containment and management of high-level radioactive wastes from the reprocessing of irradiated nuclear fuels is likely to become one of the most formidable tasks that Man has ever had to face in his search for ever increasing quantities of safe energy". The author discusses the types and amounts of high-level wastes (HLW) expected from LWR and Liquid Metal Fast Breeder Reactors (LMFBR) by the year 2000, the immediate and short-term management of these wastes in liquid form and by solidification and their storage in "engineered storage structures", the long-term management by storage in deep geological formations, isolation in the ocean bed, under ice caps, transmutation of the long-lived radionuclides into shorter-lived ones in fusion-driven reactors, and the fancy transportation to outer space. The current experience and practice in high-level wastes treatment in the USA and Europe is shortly reviewed. The solidification techniques: Fluidized bed calcination, pot calcination, spray calcination, vitrification, and the characteristics of the solidified products are discussed. Then interim storage with its major problem of heat dissipation and the final disposal in salt mines, as well as the transportation of wastes, are treated. The cost of high-level wastes management is estimated to represent 0.5 - 1.0% of the cost of nuclear electricity. He concludes that: "It is recognized undoubtedly that more research work is needed on the long-term aspects of HLW management....... it is certain that satisfactory solutions will be established which will enable present and future populations to profit from the full benefits of nuclear energy".

S. Pearstein, of Brookhaven National Laboratory, treats the "Evaluated Nuclear Data Files". Fundamental data in the form of nuclear-data files are an important input to neutronics and photonics calculations to predict reactor performance before building detailed prototypes. The evaluation comprises: "...the comparison and critical assessment of the compiled experimental data and the selection by some appropriate averaging procedure of a complete and self-consistent set of preferred values"; it also comprises filling the gaps and removing inconsistencies in existing data. The author reviews the history of Evaluated Neutron data files from the General Electric Chart of the Nuclides to the present: United Kingdom Nuclear data library (UKNDL), the Karlsruhe evaluated nuclear-data file (KEDAK), the USA Brookhaven evaluated data file (ENDF), the Lawrence-Livermore library (ENDL), and the USSR evaluated Nuclear data library. Evaluated Nuclear-data files are described as to their contents: resonance parameters, angular distributions, cross sections tables, fission parameters, radioactive decay data, data uncertainties, photon production data, etc.... Procedures for data evaluation are surveyed with respect to sources of information and analysis, and a sample evaluation of the manganese cross sections in the energy range up to 50 kev is presented for illustration. An appendix discusses the formats for evaluated nuclear-data libraries, and another discusses their format and physics consistency checks. The interest in the engineering, economic, and safety aspects of reactor and shield design still creates a demand for detailed computerized cross section data files supplemented by estimates of data uncertainties to be added to these files in the near future.

E. Kiefhaber, of Karlsruhe Institut für Neutronenphysik und Reaktortechnik, considers the: "Evaluation of Integral Physics Experiments in fast zero power facilities". Integral data are reactor parameters measured in test assemblies. That kind of information is rapidly increasing in scope: to be comparable to that obtained from differential data (microscopic cross sections measurements and evaluations); both are complementary and the former: "...provides the necessary prerequisite to an extensive check of the nuclear data and calculational methods used in reactor calculations". The present status of accuracy of nuclear data used for reactor calculations are reviewed and their cost uncertainty discussed: the combined effect of nuclear-data uncertainties should not exceed an uncertainty range of $\pm$ 0.03 mill/kW(e)·H, for a 1000 MW(e) reactor, with respect to the fuel cost. The future target accuracies in data required by reactor physics are also reviewed, with the conclusion that: "...the required accuracies in nuclear data are so stringent that information on nuclear parameters needed for reactor design at present, and in the near future cannot rely solely on measurements and evaluations of differential nuclear data". The implications of nuclear data uncertainties for core design predictions for the LMFBR and for shielding calculations and the role of integral experiments in improving the nuclear data bases, by both intuitive modifications (to come to a better agreement between calculated and measured integral quantities) and analytical data adjustment procedures (sensitivity coefficients by first-order or generalized perturbation methods), are discussed. The status of evaluation efforts in both mock-up experiments specific to planned power plants (e.g., ZPR-III-47), and the so-called "clean" criticals (e.g., GODIVA, JEZEBEL, etc...), is discussed. Then the author treats the effect of the nonhomogeneous arrangement of different materials, the reactivity effects caused by addition or removal of material (material worths), the Doppler Effect which is the only mechanism that yields an immediate negative reactivity feedback in a ceramic-fueled fast reactor, the reaction rate ratios and traverses, the control rod experiments, and the effect of the fission neutron spectrum on calculated nuclear characteristics; an effect which cannot be neglected: "...it may be necessary to modify the diffusion and transport codes so that they are able to handle an isotope-dependent fission matrix which is necessary for correct representation of the dependence of the fission spectrum on the energy of the fission-inducing neutron". "...the criticality changes caused by taking account of the fission spectra of different isotopes are generally on the same order of magnitude as the criticality changes resulting from various corrections usually applied, e.g., the transport (S_N) correction, the heterogeneity correction, etc.". The author concludes with a summary and some speculations on the future trend of integral experiment; interest will turn to experiments suited to study specific aspects in fair detail: e.g., sodium void characteristics for poisoned cores; instead of global-type experiments (criticality, reaction rates, or power traverses in clean cores).

K. Hansen of MIT and C. Kang of Combustion Engineering join to review the current state of the art for: "Finite element methods in reactor physics analysis", and its application to problems of neutron diffusion with complex properties and geometries. The Monte Carlo method is still the leading method for that class of problems in neutron transport, in addition to its treatment of time-dependence and detailed cross-sections representation, when needed. The authors assert that: "...the more fine-grained and detailed information the designer attempts to calculate, the more difficult (actually, more expensive) it becomes to use the Monte Carlo method". A simple one-dimensional, one-graph, diffusion theory problem in a homogeneous region is used to illustrate application of the method: and solution is compared to that by finite-difference formulations. A general framework of the process one follows to formulate a finite-element approximation to a given problem, and the motives behind each step, is outlined. The integro-differential form of the neutron diffusion equation and its boundary conditions, and variational formulations of diffusion theory problems, are introduced. These include neutron slowing-down in infinite homogeneous media and static and time-dependent diffusion problems. An excellent review of this particular chapter has been given previously by S. Moorthy.[2]

N. Corngold, of the California Institute of Technology, treats the "Quasi-exponential decay of neutron fields". The decay constants which characterize pulsed neutron experiments and diffusion length experiments, in time and space respectively, are "natural" data for describing the considered systems. The author discusses the quasi-exponential phenomenon for two mathematical models of thermal scattering systems, and multiplying systems. The pulsed neutron experiment, the neutron wave (or pulse propagation) experiment for simple thermal systems, experiments for complex (involving lattices, voids or reflecting shells) thermal systems, and for fast systems are surveyed.

The author then utilizes the theory suggested to treat the experimental data by suitable models; and points out relevant papers which have appeared on the subject since the completion of his article. Most of the challenge in that area, "...lies in the reconciliation of experiment and theory", "Discrepancies abound. That is, there is good physics left".

N. Piccinini, of the Instituto de Chimica Industriale, Italy, treats the "Coated Nuclear

Fuel Particles". The potential utility of the helium-cooled, graphite-moderated high-temperature reactor (HTR) for both electric power generation and as a source of high-temperature heat for industrial processes or production of synthetic fuels, has provided motivation for extensive development programs dating back to the 1950's. The main effort today is on the design and development of two types of steam-cycle HTR power systems: one based on the prismatic fuel block design and the other on the pebble bed design. The gas turbine HTR and Very High Temperature Reactor (VHTR) advanced concepts development is strongly linked to progress made in introducing the steam cycle HTR. In the USA coal liquefaction studies have been made, showing the VHTR to be economically competitive with fossil-fired units (with coal prices up to around $56/ton and oil at about $17/barrel[3]). The author discusses the HTR concept and its advantages and describes some HTR reactors and experiments: Dragon, AVR, THTR, Peach Bottom I, Fort St. Vrain, and UHTREX. Different types of fuels are briefly described, and the coated fuel particle concept, based on the feasibility of retaining the fission products as close to the source as possible, is introduced. The combustible kernel, the protective coatings, binder matrix, and the structural graphite moderator and reflector are described. The retention of fission products in coated particles, their performance under irradiation (typical failure, solid fission product diffusion, fast neutron damage) and the particle design are treated. The pyrolitic carbon coatings method of deposition, structural, physical and mechanical properties, and irradiation behavior are discussed. Yet further, silicon-carbide coatings are treated. Mathematical models for the mechanical performance of BISO type particles and for the release of fission products are outlined. The production equipment for coated particles (the furnace, spouted bed and auxiliary equipment) is described. The author concludes with sections on the analysis and control of the finished particles, and irradiation tests.

The authors have made an excellent presentation of their respective subjects. The book is a "must" for engineering and physical-science library acquisition and is recommended strongly for the personal reference-book shelves of researchers and practicing engineers desiring overviews of the treated-subject areas.

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Magdi M. H. Ragheb,
Dept. of Nuclear Engineering

and

Thomas J. Higgins
Dept. of Electrical & Computer Engineering
The University of Wisconsin
Madison, WI, USA 53706