

Reactor Dosimetry

Harry Farrar IV,
E. Parvin Lippincott,
John G. Williams,
and
David W. Vehar,
editors



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Foreword

The Eighth ASTM-Euratom Symposium on Reactor Dosimetry was held in Vail, Colorado from 29 August to 3 September 1993. ASTM Committee E-10 on Nuclear Technology and Applications and The Commission of the European Communities served as sponsors. Co-sponsors were the U.S. Department of Energy, the U.S. Nuclear Regulatory Commission, the U.S. National Institute of Standards and Technology, the Institute of Electrical and Electronic Engineers, and the Electric Power Research Institute. The symposium was held in cooperation with the International Atomic Energy Agency and the American Society of Mechanical Engineers.

Appendix I lists the members of the ASTM Symposium Committee and the Euratom Programme Committee. Appendix II is a list of the symposium attendees and their addresses.

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Overview

Important advances have been made over the past three decades in neutron and gamma-ray physics and dosimetry, advances that have generated new analysis and measurement techniques, lessened uncertainties, and produced standards for international use. Most of this has been done in support of reactor development programs and the enhanced understanding of radiation damage to reactor fuels, materials, and components. An important contribution to these activities has been a series of successful symposia that have brought together leading experts from around the world, resulting in, among other things, a number of highly productive joint research projects.

This ASTM special technical publication (STP) is a compilation of peer-reviewed papers presented at the most recent of these symposia, held in Vail, Colorado from 29 August to 3 September 1993. Many of the authors were specifically invited to provide coverage of the range of topics identified by the ASTM and Euratom program committees. Therefore, this volume provides a particularly comprehensive state-of-the-art review of the subject by leading worldwide experts in the field.

The first ASTM-Euratom Symposium on Reactor Dosimetry, which took place in 1975 at the Joint Research Centre, Petten, The Netherlands, generally defined the status of reactor neutron metrology and damage-analysis programs and identified the needs of the nuclear power industry. The second symposium, hosted in 1977 by the Electric Power Research Institute, Palo Alto, California, emphasized data and techniques used to characterize neutron and gamma-ray environments, including the use of well-characterized benchmark fields. The third meeting, in 1979 at the Joint Research Centre, Ispra, Italy, focused on the interactions between materials experts and dosimetry metrologists. The thrust of the next two symposia, at the National Bureau of Standards, Washington, D.C. in 1982 and at the GKSS Research Centre, Geesthacht, Germany in 1984, was radiation metrology techniques, data bases, damage correlation analyses, and standardization. However, a growing number of papers were concerned with reactor pressure vessel surveillance techniques and correlation of the resulting data, reflecting a progression from test reactor research to applications in a maturing power reactor industry.

The sixth and seventh symposia, held in 1987 at Jackson Hole, Wyoming, and in 1990 in Strasbourg, France, again covered reactor dosimetry and dosimetry standardization. There was major input on light water reactor pressure surveillance work and on dosimetry in support of plant life extension. Progress was reported on multinational joint research projects designed to improve the accuracy of pressure vessel dosimetry and the accuracy of materials property trend curves by performing interrelated experiments in a number of well-characterized neutron fields. The technical community concerned with dosimetry for radiation effects in electronics was also strongly represented.

The eighth symposium, the proceedings of which are presented herein, provided an update of the field of reactor dosimetry. Experts were specifically invited to discuss their latest results under the broad theme of dosimetry for the correlation of radiation effects. The symposium format included oral and poster sessions and nine organized but informal round-table workshop meetings. The symposium started with a keynote session in which three papers reviewed the current status and future prospects of nuclear power, as well as historical perspectives on reactor dosimetry.

The papers in this volume have been organized by subject into nine separate sections, preceded by a summary of the three keynote presentations, and followed by summaries of the nine workshops. The first section contains 17 papers on the subject of pressure vessel surveillance dosimetry, including review papers on the current status of surveillance standards, several papers on the status of surveillance programs in central and eastern European countries, and a number of papers on handling uncertainties in surveillance data. This is followed by two sections containing papers on passive and active neutron dosimetry techniques, which describe some of the newest techniques in neutron metrology. The fourth section on benchmarks includes papers describing the analysis of benchmark neutron environments for verification and validation of measurement and calculational results. The following section on gamma-ray dosimetry techniques contains five papers describing some of the latest techniques for determining gamma-ray fluences in reactor environments.

The sixth section on radiation damage evaluation and measurements contains papers correlating various aspects of radiation damage with fluence. Eight papers in the following section on radiation field characterization describe analyses in a wide variety of neutron environments, ranging from neutron fields in light-water moderated research reactors to photoneutron fields produced by an electron accelerator. The eighth section on nuclear data contains papers on evaluations of specific cross sections important for dosimetry applications, as well as evaluation and testing of updated dosimetry cross-section libraries. In addition, this section includes two papers on the evaluation and testing of the most recent multigroup cross-section libraries used for neutron and gamma-ray transport calculations. The last section of the presented papers in this book contains five papers on high-energy neutron dosimetry used to support research in fusion energy.

The enthusiastic participation by a record number of attendees (127) for this symposium series, 48 of whom were from 16 overseas countries, is an indication of the worldwide importance that continues to be placed on the improvement and standardization of dosimetry techniques for reactor operations and for materials testing in reactors. Increased participation in the symposium by experts from central and eastern Europe was very much welcomed, and this has resulted in a decision to hold the ninth symposium in Prague, The Czech Republic, in September 1996.

The four editors of this volume would like to take this opportunity to thank the authors and the program committees of ASTM Subcommittee E10.05 and Euratom, all of whom made the symposium a success. We would also like to acknowledge the help of the ASTM staff for interacting with the authors and reviewers during the long paper-review process and for making this publication possible.

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A Note on ASTM and Committee E-10

The international standards movement is playing an increasingly critical role in the advancement of technology and in the progress towards a higher standard of living. To assist in global prosperity in the coming years, the American Society for Testing and Materials (ASTM) recognizes that it must be fully involved in this dynamic movement.

Organized in 1898, ASTM has grown today into one of the largest voluntary standards development systems in the world. ASTM is a not-for-profit organization that provides a forum for producers, users, ultimate consumers, and those having a general interest (representatives of government and academia) to meet on common ground and write standards for materials, products, systems, and services. From the work of 134 standards-writing committees, ASTM publishes standard test methods, specifications, practices, guides, classifications, and terminology. ASTM's standards development activities encompass metals, paints, plastics, textiles, petroleum, construction, energy, the environment, consumer products, medical services and devices, computerized systems, electronics, and many other areas. ASTM Headquarters has no technical research or testing facilities; such work is done voluntarily by the 33 000 technically qualified ASTM members located throughout the world. Because the society's activities are open to the entire international community, additional experts also contribute to the standards-writing process, resulting in an effective total participation of 100 000 individuals. More than 8 500 ASTM standards are published each year in the 68 volumes of the *Annual Book of ASTM Standards*. These standards and related information are distributed throughout the world.

ASTM also provides continuing education and training in the use and application of ASTM standards through standards technology training courses. ASTM members propose ideas for the courses, work with staff to establish course outlines, and serve as instructors. Attendees learn the practical application of standards and benefit from the instructors' technical expertise and knowledge of standards development.

ASTM Committee E-10 on Radioisotopes and Radiation Effects was founded in 1951 to provide an ASTM liaison function for the rapidly growing interests in the peaceful uses of atomic energy. Now named Committee E-10 on Nuclear Technology and Applications, its goal is to promote the advancement of nuclear science and technology and the safe application of nuclear energy in all its forms. Committee E-10 has published 100 standards covering a diverse range of nuclear procedures. Publication of standards follows a strict ASTM protocol that requires that the standard have the unanimous consensus of all concerned parties. Successive ballots are taken at the subcommittee, committee, and society levels, and any negative votes or comments must be satisfactorily resolved.

Committee E-10 sponsors scientific and technical symposia and generates publications in its fields of specialization. For the past 30 years, E-10 symposia have been held about once a year. Two symposia series that have attained international prominence are the ASTM-Euratom Symposia on Reactor Dosimetry and the ASTM Symposia on the Effects of Radiation on Materials. At these symposia, speakers present formal papers that are often published as ASTM special technical publications (STPs). All published papers are subject to a stringent peer-review process.

Standards and technological publications are serving as agents for change, with technology as a prime driver of the change. This is resulting in increased cooperation among nations, rapidly rising volume of world trade with emergent large new geographic markets,

increasing cooperation among organizations and nations, quality certifications and awards, such as ISO 9000, environmental and other regulatory issue resolutions, global product standards and communications, and rapidly changing geo-political and economic environments.

The greatest challenge to organizations and nations is to manage the changes taking place around them. Today's new reality for even the most challenging technical areas is that the market place is already demanding standards and technology baselines, regardless of how technically advanced the area seems to be. The point is that standards are at the heart of the changes taking place external to organizations and nations, and will certainly be drivers of the changes that must take place internally to them as well.

The ultimate goal of the series of ASTM-Euratom symposia on Reactor Dosimetry is to obtain international standardization of nuclear radiation physics and dosimetry methods with improved accuracy and well-quantified uncertainty limits. Physics and dosimetry in connection with the characterization of the effects of ionizing radiation continues to be a focus of interest to Committee E-10. Committee E-10 strongly encourages technical contributions in this area and invites all who are interested to become involved in the standards development process.

On behalf of ASTM Committee E-10, I wish all participants in this vital area of work continued success and a productive future.

Paul S. Olson, Chairman

ASTM Committee E-10 on Nuclear

Technology and Applications, Rockwell International