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the determination of thermal energy deposition rates in nuclear reactors

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American National Standard for the Determination of Thermal Energy Deposition Rates in Nuclear Reactors

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American Nuclear Society

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American National Standard

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Foreword

(This foreword is not a part of American National Standard for the Determination of Thermal Energy Deposition Rates in Nuclear Reactors N676-1976/ANS-19.3.4.)

It is the intent of this American National Standard to provide guidance for performing and validating the sequence of calculations leading to prediction of thermal energy deposition rates in nuclear reactors, and to provide guidelines by which the adequacy of design calculations may be demonstrated. This Standard recognizes the diversity of the calculational procedures employed in reactor design. Consequently, the major thrust of this Standard is in the areas of verification and documentation. The standard is intended to cover thermal energy deposition calculations for the entire nuclear industry; from fast to thermal reactors, research to power reactors. Since many different kinds of calculations are performed, each having its own requirement for accuracy and verification, it is necessary that this Standard be of a general nature.

Compliance with the intent of this Standard can be demonstrated for an intended area of applicability of the calculational system used by meeting the following requirements:

1. **Source Distribution.** Neutron reaction rate distributions and photon and beta particle emitter distributions to be obtained from calculations made in accordance with American National Standard Neutron Reaction Rate Distributions and Reactivity of Nuclear Reactors, N412-1975 (ANS-19.3), or similar applicable standard. Data to be found in accordance with American National Standard Nuclear Data Sets for Reactor Design Calculations, N411-1975 (ANS-19.1), or equivalent standard.

2. **Selection of Models and Methods.** Consideration of all phenomena listed in Table 1 and their treatment justified. Use of any approximation and application not explicitly permitted in Table 2 to be justified. Acceptable justification may be degree of rigor, conservatism or increased margin incorporated in design.

3. **Verification.** The method of analysis to be verified against experiments or more rigorous and well-established analytical methods.

4. **Evaluation of Accuracy.** Evaluation of accuracy and range of applicability of data and methods by establishment of biases and uncertainties, with degree of confidence, for the calculations including allowance for uncertainties in the comparison data.

5. **Documentation.** Documentation of details of the above procedures.

It is the intent of this Standard to require the individual to: (1) give careful consideration to those physical and numerical effects that may contribute to the validity of his results, (2) document the reasons for his choice of calculational path, and (3) verify the calculational system used over the intended range of applicability by testing it against appropriate experiments or more rigorous calculations.

The requirement for documentation is a crucial part of this Standard and will provide an auditable path. In those instances where the foregoing documentation is proprietary in nature, documentation edited by excluding the proprietary information shall be prepared and be publicly available or available on request. Areas omitted due to proprietary consideration shall be noted where possible. The standard would not require all documentation to be made public, and thus by implication acknowledges the existence of proprietary documentation.

This is a first attempt to produce a standard for thermal energy deposition calculations in nuclear reactors and it should therefore undergo review and revision within two years. Suggestions for the improvement of this Standard will be welcome. They should be sent to the American Nuclear Society, 244 East Ogden Avenue, Hinsdale, Illinois 60521.

This Standard was developed by Working Group ANS-19.3.4 of the American Nuclear Society which had the participation of the following members during the period it prepared and approved the Standard:

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The American National Standards Committee N17, Research Reactors, Reactor Physics, and Radiation Shielding, had the following membership at the time it reviewed and approved this Standard:

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The Determination of Thermal Energy Deposition Rates in Nuclear Reactors

1. Introduction

Establishment of the thermal energy source distribution is essential to the determination of the temperature field within a nuclear reactor, and thus to the calculation of heat transfer and transport, thermal stress and the many physical and chemical properties of materials which depend upon temperature. The energy of interest is ultimately deposited by charged particles resulting from nuclear or atomic interactions with ambient neutrons and photons. The charged particles are primarily fission products, recoiling nuclei and electrons. In the general case, nearly all of the many phenomena of atomic and low-energy nuclear physics are involved in the conversion of the energy released by fission into the molecular motion known as thermal energy. Because of this inherent complexity and the importance of the results to the achievement of a safe and reliable reactor design, adherence to good practice in these calculations is important.

2. Scope

It is the purpose of this Standard to provide criteria for:

(1) determination of the energy allocation among the principal particles and photons produced in fission, both prompt and delayed

(2) Adoption of appropriate treatment of heavy charged particle and electron slowing-down in matter

(3) Determination of the spatial energy deposition rates resulting from the interactions of neutrons

(4) Calculation of the spatial energy deposition rates resulting from the various interactions of photons with matter

(5) Presentation of the results of such computations, including verification of accuracy and specification of uncertainty

This Standard addresses the energy generation and deposition rates for all types of nuclear reactors where the neutron reaction rate distribution and photon and beta emitter distributions are known. Its scope is limited to the reactor core, including blanket zones, control elements and core internals, pressure vessel, and the thermal and biological shielding.

3. Definitions

3.1 Limitations. The definitions given below are of a restricted nature for the purpose of this Standard. Other specialized terms are defined in American National Standard Glossary of Terms in Nuclear Science and Technology, N 1.1-1976 (ANS-9) [1][1], or in the definition sections of standards specified in Section 4 of this Standard.

3.2 Glossary of Terms.

shall, should, and may. The word "shall" is used to denote a requirement, the word "should" to denote a recommendation, and the word "may" to denote permission, neither a requirement nor a recommendation.

experimental data. The expression "experimental data" is used to denote any experimentally measured quantity or quantities. As such it is applied herein to both energy generation and deposition measurements relevant to this Standard.

energy generation rate density. The amount of original energy source per unit volume per unit time (watts/cm^3).

energy deposition rate density. The amount of energy deposited per unit volume per unit time (watts/cm^3).

4. Relation to Other Standards

American National Standard for the Determination of Neutron Reaction Rate Distributions and Reactivity of Nuclear Reactors, N412-1975 (ANS-19.3) [2], in general, provides guidance for performing and validating the sequence of calculations leading to prediction of neutron reaction rate spatial distributions and reactivity of nuclear reactors. This Standard (N676-1976) provides criteria for the establishment of the thermal energy deposition rate distribution within a nuclear

[1]Numbers in brackets refer to corresponding numbers in Section 9, References.