A REVIEW OF ANS STANDARD 19.3.4, THE DETERMINATION OF THERMAL ENERGY DEPOSITION RATES IN NUCLEAR REACTORS: THE PAST, PRESENT, AND FUTURE

R. T. Perry, Chair ANS 19.3.4
Los Alamos National Laboratory
ESH-12   MS K483
Los Alamos, NM 87545
rtperry@lanl.gov

ABSTRACT

The Standard ANS 19.3.4 provides guidance for performing calculations to predict the thermal energy deposition rates in nuclear reactors. It also provides guidance for demonstrating the adequacy of the design calculations. In this paper, a review of the original guidelines contained in the Standard are discussed. The changes made in the 1999 revision, which now make the Standard applicable to CANDU reactors, are presented. The changes affected the acceptable approximations used in making energy deposition calculations. In addition, in view of the current programmatic activities of accelerator driven devices, the need and necessary considerations for expanding the Standard to encompass higher particle energies than found in reactors is discussed. The paper concludes that it would be prudent to expand the Standard to cover such devices.

1. INTRODUCTION

The American National Standard (ANSI/ANS 19.3.4),[1] *The Determination of Thermal Energy Deposition Rates in Nuclear Reactors*, provides guidance for performing and validating the sequence of calculations leading to prediction of thermal energy in nuclear reactors. In 1976, ANS 19.3.4 was first approved. It was reaffirmed in 1983 and again in 1989. A revision, intended to make the Standard applicable to CANDUs, was approved in 1999. Following the revision, ANS-19 gave the ANS 19.3.4 Committee approval to explore the possibility of expanding the scope of the Standard to include energy deposition in accelerator driven devices.

In this paper, a review partitioned into three sections will be presented. The first section will discuss the standard and its purpose. Next, a summary of the revisions completed in 1999 will be presented. The third section will discuss the proposed revisions and the impact the revisions will have on the Standard.

2. THE STANDARD

The intent of the American National Standard is to provide guidance for performing and validating the sequence of calculations leading to prediction of thermal energy in nuclear reactors. Its scope is limited to the reactor core, including blanket zones, control elements and core internals, pressure vessel, and the thermal and biological shielding.

It is also intended to cover energy deposition calculations for the entire nuclear industry; from fast to thermal reactors, research to power reactors. The diversity of the calculational procedures leading to the prediction of thermal energy was recognized, and as a result, the Standard is of a general nature.

This Standard requires 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 and more rigorous calculations.

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.

The initial step in the calculation of the local energy deposition is, therefore, the determination of the magnitude and energy, and spatial distribution of the production rates of the photons and charged particles. The Standard requires that the calculations to obtain the distributions would be made in accordance with other Standards, for example, American National Standard N412-1975 (ANSI/ANS 19.3-1995)[2].

In various sections of the Standard, guidelines are given for the calculation of the energy deposition rate, categorized by the type of particle involved. The phenomena to be considered is given in Table 1. The Standard also lists acceptable approximations to the calculation of the energy deposition rates.

The calculations of energy deposition rates are subject to several sources of uncertainty. Thus, the Standard requires that the calculational results be verified by comparisons with experiment or by comparison with a more rigorous calculation. Next, an evaluation of accuracy is required. A written report of the verification of the calculational system completes the requirements of the Standard.

In summary, the Standard requires that: 1) the source distributions be made in accordance with a ANSI/ANS Standard or similar applicable standard, 2) consideration be given to all phenomena listed in Table 1 and the treatment justified, 3) the method of analysis verified, 4) an estimation is made of the accuracy, and 5) the procedures are documented.

Table 1.
Phenomena to be considered

(1) Fission
  (a) Fission Products/Kinetic Energy
  (b) Prompt and Decay Beta Particle Energy

(2) Neutron Capture
  (a) Kinetic Energy of Charged Particle Products
  (b) Decay Beta Particle Energy
  (c) Nuclear Recoil

(3) Neutron Scattering
  (a) Nuclear Recoil Following Elastic Scattering Interactions
  (b) Nuclear Recoil Following Inelastic Scattering and Subsequent Nuclear De-excitation

(4) Photon Sources
  (a) Prompt Fission
  (b) Fission Product Decay
  (c) Neutron Capture
  (d) Inelastic Scatter De-excitation
  (e) Transmutation Product Decay
  (f) Positron Annihilation
  (g) Bremsstrahlung
  (h) Atomic De-excitation

(5) Photon Transport

(6) Photon Interactions
  (a) Photoelectric Absorption
  (b) Compton Scattering
  (c) Pair Production
  (d) Photonuclear Reactions

3. THE 1999 STANDARD REVISIONS

The revisions to the Standard which were approved in 1999, were necessitated by the Standard not being completely applicable to CANDU reactors. This was in contrast to the statement in the Standard that it applies to "all types of nuclear reactors." Details of the revisions were discussed in an earlier paper.[3] Here, a summary of the revisions will be presented.

As noted earlier, the Standard enumerates acceptable approximations to the calculation of the energy deposition rates. The acceptable approximations along with the areas where the approximation is acceptable are listed in the Standard. The areas listed are: Steady

State Thermal Limits, Burnup, Core Component Design, Transient Thermal Limits, and Loss of Coolant Accident. It was found that some of the approximations were not applicable to CANDU reactors, and it is here that the significant changes to the Standard were made.

The following approximations noted in the Standard, which are valid for other reactors, is not acceptable for a CANDU: 1) The particle (neutron or photon) energy is deposited at the point of fission; 2) For burnup calculations, the average energy of particle rather than spectrum may be used; 3) For burnup calculations, the average energy is independent of the incident neutron energy; and 4) The core may be treated as homogeneous for the purpose of establishing a photon source distribution. The Standard now reflects these approximations are not valid for the CANDU and gives the reasons that the approximations are not valid.

4. FUTURE OF THE STANDARD

Following the revision, ANS-19 gave the ANS 19.3.4 Committee approval to explore the possibility of expanding the scope of the Standard to include energy deposition to cover nuclear systems, such as accelerator driven devices, with higher particle energies than found in reactors. The ANS 19.3.4 Committee has begun this task of which there are three major considerations that must be answered prior to actual expansion of the Standard.

The first major consideration in expanding the Standard is to determine if accelerators may be properly considered under the auspices of ANS-19, Reactor Physics. It is planned that the ANS 19.3.4 committee, after an appropriate study will present its recommendations to ANS-19 in a White Paper for its consideration.

Secondly, the current Standard's scope is limited to a nuclear reactor's core, including blanket zones, control elements and core internals, pressure vessel, and the thermal and biological shielding. Assuming that accelerators may be considered under the auspices of ANS-19, considerable attention will have to be made to determine what functional parts of an accelerator will be added to the scope. Should it be the entire accelerator or just those components at the beam target? Should devices other than accelerators be considered? Recommendations to these questions will be made by the committee following due deliberation and study and will be contained in the White Paper to ANS-19.

The third major activity would be to determine if the calculational technologies, i.e., computer codes and cross sections, are sufficiently mature that reliable recommendations can be made for determining energy deposition at energies from 20 to 300 MeV or more. Again, recommendations will be presented to ANS-19 in the White Paper.

Currently, with the increased activity in the accelerator technology, it appears prudent to pursue these activities as there is little guidance in the literature for calculations in this energy range.

5. CONCLUSION

For 25 years, the Standard ANS 19.3.4 has given guidance for energy deposition calculations in most reactors. With the latest revision, it now provides guidance for energy deposition calculations in CANDUs. It has been proposed to expand the Standard to cover much higher particle energies that will encompass accelerator driven devices. In view of current programmatic activities concerning high energy particles, that expansion would be the judicious path to follow.

6. REFERENCES

1. *American National Standard for the Determination of Thermal Energy Deposition Rates in Nuclear Reactors*, N676-1976 (ANSI/ANS - 19.3.4 - 1999) American Nuclear Society, LaGrange Park, IL.

2. *American National Standard for the Determination of Neutron Reaction Rate Distributions and Reactivity of Nuclear Reactors*, N412-1975 (ANSI/ANS - 19.3 -1995) American Nuclear Society, LaGrange Park, IL.

3. C.R. Boss and R.T. Perry, "Revision of ANS 19.3.4, The Determination of Thermal Energy Deposition Rates in Nuclear Reactors," Proceedings of the American Nuclear Society International Conference on the Physics of Nuclear Science and Technology (October 5-8, 1998, Long Island, New York) pp 1079-1086.