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AN OVERVIEW OF REACTOR PHYSICS STANDARDS - PAST, PRESENT AND FUTURE*

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Department of Nuclear Energy
Brookhaven National Laboratory

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T.M. Cokinos

Standards for determining key static reactor physics parameters have been developed by groups of experts (working groups) under the aegis of ANS-19, the ANS Reactor Physics Standards Committee. Following a series of sequential reviews, augmented by feedback from potential users, a proposed standard is brought into final form by the working group before it is adopted as a formal standard by the American National Standards Institute (ANSI). Reactor Physics standards are intended to provide guidance in the performance and qualification of complex sequences of reactor calculations and/or measurements and are regularly reviewed for possible updates and/or revisions. Table 1 lists the reactor physics standards developed to date (References 1-7) and Table 2 shows those standards now being developed by the respective working groups (References 8-11). The standards listed in Table-1 cover a wide range of physics calculations and measurements and are widely applied in the nuclear industry. They are an important part of the ANSI/ANS standards program which also includes standards in many other areas of nuclear technology.

Standard ANSI/ANS-19.1 describes the criteria and specifications for generating and documenting nuclear data sets for reactor design calculations (References 1, 12 and 13). The scope of this standard is to identify and describe specifications for developing, preparing, and documenting nuclear data sets for use in reactor design calculations. Three major classes of data sets are established: (a) evaluated nuclear data sets, derived from basic experimental and theoretical data, specified over broad energy ranges; (b) processed continuous data sets, derived from evaluated data sets and used in calculations where continuous energy representations are required; and (c) averaged data sets, also derived from evaluated or processed continuous data sets by appropriate averaging. These data sets are tested by application to benchmark experiments. The Evaluated Nuclear Data File (ENDF) system Versions V, ENDF/B-V, and the recently released Version VI, ENDF/B-VI, are identified as standard data sets. This standard is discussed in more detail in Reference 14.

Guidance for performing and qualifying the sequence of reactor physics calculations aimed at determining reaction rate spatial distributions, reactivity and changes in isotopic compositions with burnup in light water reactors, fast breeder reactors and research reactors are provided in Standard ANSI/ANS-19.3. This standard also provides guidance in the selection of computational methods, criteria for the verification of calculational methods and for the evaluation of accuracy and range of applicability of the data and methods. Because of the nature and wide range of topics covered by this standard, compliance with the intent of this standard directly, or indirectly, involves the use of all standards listed in Table 1 and those proposed in Table 2. The revised version of this standard includes pressurized heavy water reactors (PHWR's) and high temperature gas cooled reactors (HTGR's).

Standard ANSI/ANS-19.3.4 provides guidance for performing and validating the sequence of calculations designed to evaluate thermal energy deposition rates in nuclear reactors and provides criteria for demonstrating the adequacy of the design calculations. This standard is general in nature and covers thermal energy deposition calculations for all classes of reactors from fast to thermal reactors and from research to power reactors. The distributions of neutron reaction rates and photon and beta emitters are

determined in accordance with the ANSI/ANS-19.3 standard (Reference 2).

Standard ANSI/ANS-19.4 specifies criteria for performing and documenting measurements on light water power reactors which are to be used as reference measurements in the validation and verification of reactor physics calculational methods (References 4 and 18). It identifies the types of parameters of interest, test conditions and experimental data needed for such reference measurements. When performance characteristics, carefully measured in an LWR, are successfully calculated, considerable confidence is gained in the nuclear analysis methods. Well documented reactor core operating performance such as the well known Quad Cities 1 Cycle-1 and Cycle-2 and Zion Cycles 1 and 2 measurements (References 15 and 16) including gamma scan data, have served to verify LWR computer codes and benchmark physics methodologies and have led to better predictions of reactor behavior. Criteria for the qualification of reference reactor physics measurements obtained from subcritical, critical or other relevant experiments for the purpose of verifying nuclear design and analysis methods are specified in standard ANSI/ANS-19.5 (Reference 5). In general, measurements carried out in an operating power reactor consist of integral data and it is not possible, on the basis of such measurements, to extract specific parameter values without resorting to various assumptions and/or approximations which result in increased uncertainties of the target parameters. However, the integral data obtained in the measurements can be valuable since they can be used to compare against the end result of the calculational stream. Examples of such comparisons include the measured vs. calculated radial assembly-wise distributions and control rod worths. Verification of the adequacy of parameters evaluated at intermediate steps of the calculational process (e.g., local reactivities, reaction rates, isotopic concentrations) with measured data requires elaborate measurement procedures in which special measurement methods are used. When core-wide or local parameters are measured in accordance with standard ANSI/ANS-19.4, the results of these measurements will serve as quality reference data for validating nuclear analysis methods.

There is currently an effort to document some of the important experimental data obtained from various critical experiments. These data are expected to provide additional opportunities for verification and benchmarking of nuclear analysis methods. While standards ANSI/ANS-19.4 and ANSI/ANS-19.5 are designed to ensure that the selected calculational method can adequately predict reactor behavior, standard ANS-19.6.1, "Reload Startup Physics Tests for PWR's" (Reference 6), may be said to fulfill a complementary, or reverse function, i.e., it prescribes the test procedures which must be followed in order to ensure that the operating characteristics of the core are consistent with design predictions.

The decay heat standard in light water reactors, ANSI/ANS-5.1 (References 7 and 17), for which ANS-19 provides technical support, is widely used throughout the nuclear industry. It sets forth values for the decay heat power from fission products and U^{239} and Np^{239} following shutdown of light water reactors containing U^{235}, U^{238} and plutonium. The data are presented in tables and in analytical form. This standard represents a significant contribution to the overall ANS standards program. Recent integral experimental results with summation calculations using the ENDF/B-VI files are being incorporated in the standard. The format and approach used by ANSI/ANS-5.1 have been recently adopted by the European and Japanese standards groups.

Kinetic parameter standards, currently in various phases of development are intended to complement the existing reactor physics standards in the area of reactor transients (References

8, 9, and 19). Proposed standard ANS-19.8, "Fission Product Chain Yields," (Reference 8) is nearing completion. It includes 107 mass chain yields and uncertainties for $U^{233,235,238}$, $Pu^{239,240,241}$, Th^{232} and Cf^{252}. The proposed standard for "Delayed Neutron Data," ANS-19.9 (Reference 8) will provide ν_d (E) data for reactor design and control including spectra for β_{eff} calculations. An international working group has recently been formed to define appropriate benchmarks.

Proposed standard ANS-19.7 "Calculation of Doppler Reactivity for Use in Thermal LWR Safety Analysis," (Reference 9) is intended to provide guidance in the calculation of the reactivity effects associated with changes in fuel temperature for use in thermal light water reactor transient analysis. This proposed standard documents acceptable calculational approaches, provides guidance for the use of these approaches and establishes criteria for the evaluation of the accuracy of the calculated parameters. The recently proposed standards ANS-19.10 and ANS-19.11 (References 10 and 11), provide guidance and criteria for evaluating the fast neutron fluences at the PWR pressure vessels and moderator temperature coefficients in LWR's, respectively.

Plans are being developed to expand existing and proposed Reactor Physics Standards to incorporate standard benchmark problems covering a wide spectrum of reactor calculations. Efforts are already underway to combine the rigors of the mathematics and computation benchmark criteria with the more complex and physically descriptive conditions encountered in the real world of reactor physics.

The ANS Reactor Physics Standards program is well situated to play an important role in the adoption of international standards in Reactor Physics. As stated earlier, existing RP standards have been in use by foreign analysts. Foreign participation in the RP Standards maintenance and development program has been steadily expanding in an effort to ensure a universal applicability of the ANSI/ANS RP Standards.

References

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3. "American National Standard for the Determination of Thermal Energy Deposition Rates in Nuclear Reactors," ANS-19.3.4/ANSI N676-1976, P. Greebler, Chair Published by the American Nuclear Society, 1976.

4. "American National Standard: A Guide for Acquisition and Documentation of Reference Power Reactor Physics Measurements for Nuclear Analysis Verification" ANS-19.4/ANSI N652-1976.

5. "American National Standard for Requirements for Reference Reactor Physics Measurements ANSI/ANS-19.5-1983, Published by the American Nuclear Society, 1983.

6. "American National Standard, Reload Startup Physics Tests for Pressurized Water Reactors," ANSI/ANS-19.6.1, 1984, Published by the American Nuclear Society, 1984.

7. "American National Standard, Decay Heat Power in Light Water Reactors" ANSI/ANS-5.1, 1979, Published by the American Nuclear Society, 1979.

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9. Proposed Standard ANS-19.7, "Calculation of Doppler Reactivity for Use in Thermal LWR Safety Analysis," Draft Report June 1990.

10. Proposed Standard ANS-19.10, "Fast Neutron Fluence Evaluation at the Pressure Vessel of PWR's," May 1992.

11. Proposed Standard ANS-19.11, "Calculation of the Moderator Temperature Coefficient in LWR's," May 1992.

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TABLE 1

ANSI REACTOR PHYSICS STANDARDS

Standard Designation	Subject of American National Standard	References
ANS-19.1	Nuclear Data Sets for Reactor Design Calculations	1
ANS-19.3	Determination of Neutron Reaction Rate Distributions and Reactivity of of Nuclear Reactors	2
ANS-19.3.4	Determination of Thermal Energy Deposition Rates in Nuclear Reactors	3
ANS-19.4	A Guide for Acquisition and Documentation of Reference Power Reactor Physics Measurements for Nuclear Analysis Verification	4
ANS-19.5	Requirements for Reference Reactor Physics Measurements	5
ANS-19.6.1	Reload Startup Physics Tests for Pressurized Water Reactors	6
ANS-5.1	Decay Heat Power in Light Water Reactors	7

TABLE 2

ANS-19 REACTOR PHYSICS STANDARDS IN PROGRESS

Proposed Standard Designation	Subject	References
ANS-19.7	Calculation of Doppler Reactivity for Use in Thermal LWR Safety Analysis	9
ANS-19.8	Fission Product Chain Yields	8
ANS-19.9	Delayed Neutron Parameters	8
ANS-19.10	Fast Neutron Fluence Evaluation at the Pressure Vessel of PWR's	10
ANS-19.11	Calculation of the Moderator Temperature Coefficient in LWR's	11

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