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Decay Heat Power in Light Water Reactors

REAFFIRMED

February 5, 2019

ANSI/ANS-5.1-2014 (R2019)

An American National Standard

This standard has been reviewed and reaffirmed with the recognition that it may reference other standards and documents that may have been superseded or withdrawn. The requirements of this document will be met by using the version of the standards and documents referenced herein. It is the responsibility of the user to review each of the references and to determine whether the use of the original references or more recent versions is appropriate for the facility. Variations from the standards and documents referenced in this standard should be evaluated and documented. This standard does not necessarily reflect recent industry initiatives for risk informed decision-making or a graded approach to quality assurance. Users should consider the use of these industry initiatives in the application of this standard.

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ERRATUM

ANSI/ANS-5.1-2014

Decay Heat Power in Light Water Reactors

A typographical error was identified on page 30, formula (28). Time should be 10^4 s not 10^{-4} s." The corrected formula is provided below:

6 Total decay heat power

The total decay heat power from the fission products and actinides is calculated as

$$P_T(t, T) = P'_d(t, T) + P_{dc}(t, T) + P_{dHE}(t, T) + P_{dA}(t, T), \quad (27)$$

where

$$P_{dc}(t, T) = \begin{cases} P'_d(t, T) \cdot G(t), & t \leq 10^4 \text{ s} \\ P_{dcs}(t, T) + P_{dE}(t, T), & t > 10^4 \text{ s} \end{cases}. \quad (28)$$

The total uncertainty is determined from the uncertainty in the fission product decay heat power without neutron capture in fission products, $\Delta P'_d(t, T)$, as described in Eq. (6), and the uncertainty in the operating power, ΔP , as described in Eq. (7). The other terms in Eq. (27) are defined to provide conservative overestimates of their contributions to the decay heat power, and the uncertainties in these terms are therefore not included in the total uncertainty.

ANSI/ANS-5.1-2014

**American National Standard
Decay Heat Power
in Light Water Reactors**

Secretariat
American Nuclear Society

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American National Standard

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American National Standard ANSI/ANS-5.1-2014

Foreword (This Foreword is not a part of American National Standard “Decay Heat Power in Light Water Reactors,” ANSI/ANS-5.1-2014.)

This American National Standard provides values for the decay heat power from fission products and actinides following the shutdown of light water reactors operated with nuclear fuel consisting of uranium. The energy released in the fission process is divided into (1) prompt energy from the kinetic energy of fission fragments, neutrons, and gamma rays from prompt de-excitation of fission products and (2) delayed energy from beta particles and gamma rays emitted from the decay of fission products.

The development of this standard was initiated due to the importance of energy release after reactor shutdown and the need for accurate data to evaluate fuel rod heating during a loss-of-coolant accident. The ANS Standards Subcommittee first proposed the adoption of a new standard on decay heat power in October, 1971. Following minor revisions in 1973, it was submitted to the American National Standards Institute but remained as a draft standard. After significant technical developments based on data from new experimental programs, the draft standard was revised and approved and released as the 1979 standard. Since then, it was reaffirmed in 1985, revised in 1994, and revised again in 2005. The revisions since 1979 have been guided largely by recommendations made by Dickens, England, and Schenter on future improvements to the standard.¹⁾ A detailed technical summary of the development of the standard and revisions is provided as an Appendix to this standard.

The standard prescribes methods that enable the calculation of fission product decay heat power and uncertainty with accuracies comparable to those of summation codes but without the need for complex calculations. Fission product decay heat values are provided for thermal neutron-induced fission of ²³⁵U, ²³⁹Pu, and ²⁴¹Pu and fast fission of ²³⁸U.

As revised, this standard provides better guidance on methods and implementation, an improved representation of uncertainties in the fission product decay heat values, and an improved method for the neutron capture correction. Also included, for the first time, is a complete estimate of all actinide contributions to decay heat power. The changes in this revision do not alter the tabular data for standard fission product decay heat power and uncertainty values from the 1994 and 2005 standards, but they do include several recommendations for near-term improvements to the standard identified by Dickens, England, and Schenter.

Relationship to Other Standards

ANSI/ANS-19.3.4-2002 (R2008), “Determination of Thermal Energy Deposition Rates in Nuclear Reactors”

Proposed American National Standard ANS-19.8, “Fission-Product Yields for ²³⁵U, ²³⁸U, and ²³⁹Pu” (in draft form)

ANSI/ANS 19.1-2002 (R2011), “Nuclear Data Sets for Reactor Design Calculations”

This standard might reference documents and other standards that may have been superseded or withdrawn at the time this standard is applied.

¹⁾J. K. Dickens, T. R. England, and R. E. Schenter, “Current Status and Proposed Improvements to the ANSI/ANS-5.1 American National Standard for Decay Heat Power in Light Water Reactors,” *Nucl. Safety*, **32**, 209 (1991).

This standard does not incorporate the concepts of generating risk-informed insights, performance-based requirements, or a graded approach to quality assurance. The user is advised that one or more of these techniques could enhance the application of this standard.

The working group acknowledges the substantial efforts of earlier working groups in establishing and maintaining this standard. The working group specifically acknowledges the significant contributions made to the standard by the late J. Kirk Dickens and Robert Schenter, who passed away before this standard was issued. Both of these working group members played key roles in the development and advancement of the standard and provided a roadmap for future improvements of the standard that was used to guide this revision.

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American National Standard ANSI/ANS-5.1-2014

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Decay Heat Power in Light Water Reactors

1 Scope and purpose

1.1 Scope

This standard sets forth values for the decay heat power from fission products and actinides following shutdown of light water reactors (LWRs) using nuclear fuel initially containing ^{235}U and ^{238}U . The decay heat power from fission products is presented in tables and equivalent analytical representations. Contributions from the decay of ^{239}U and ^{239}Np and the contributions from all other actinides are represented separately. Methods are described that account for the reactor operating history, for the effect of neutron capture in fission products, and for assessing the uncertainty in the resultant decay heat power.

The standard applies to decay times of up to 10^{10} s after shutdown.

1.2 Purpose and application

This standard provides bases for determining the decay heat power and its uncertainty following shutdown of LWRs. The information in this standard can be used in the design, performance evaluation, and assessment of the safety of LWRs.

The methods prescribed in this standard enable the calculation of fission product decay heat power with accuracies comparable to those of summation codes but without the need for complex calculations. The fission product decay heat power values in this standard have the advantage of being developed directly from experimental measurements for time periods $<10^5$ s after fission. Therefore, this standard can be used as the basis for comparison with results of alternate methods for determining fission product decay heat power.¹⁾

2 Range of application

2.1 Limitations

The standard methods for evaluating decay heat described herein are applicable to LWRs containing ^{235}U as the initial major fissile material and ^{238}U as the fertile material. The contributions from the fission of ^{235}U , ^{238}U , ^{239}Pu , and ^{241}Pu are treated explicitly; other fissionable nuclides are accounted for by treating them as ^{235}U . The application of this standard to mixed oxide or other recycled nuclear fuels is not supported.

Decay heat power from activation products in structural materials and fission power from delayed neutron-induced fission are not included in this standard and shall be evaluated by the user and appropriately included in any analysis of decay heat power.

2.2 Standard decay heat power representation

Standard fission product decay heat power values are provided in tabular form and as analytical representations of the thermal reactor neutron spectrum fission of ^{235}U , ^{239}Pu , and ^{241}Pu and for fast fission of ^{238}U at various times after fission. Uncertainties are provided for each shutdown time for each of the tabulations.

¹⁾Examples of the use of the standard methods are presented in Appendix B.