

# American Nuclear Society

**methods for determining  
neutron fluence in BWR and PWR  
pressure vessel and reactor internals**

**an American National Standard**

**REAFFIRMED**

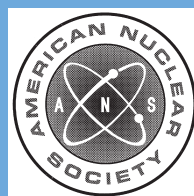
**October 7, 2021**

**October 11, 2016**

**ANSI/ANS-19.10-2009; R2021**

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reviewed and reaffirmed with the recognition that it may reference other standards and documents that may have been superseded or withdrawn.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.



**published by the  
American Nuclear Society  
555 North Kensington Avenue  
La Grange Park, Illinois 60526 USA**

**American National Standard  
Methods for Determining  
Neutron Fluence in BWR and PWR  
Pressure Vessel and Reactor Internals**

Secretariat  
**American Nuclear Society**

Prepared by the  
**American Nuclear Society  
Standards Committee  
Working Group ANS-19.10**

Published by the  
**American Nuclear Society  
555 North Kensington Avenue  
La Grange Park, Illinois 60526 USA**

Approved February 24, 2009  
by the  
**American National Standards Institute, Inc.**

## **American National Standard**

Designation of this document as an American National Standard attests that the principles of openness and due process have been followed in the approval procedure and that a consensus of those directly and materially affected by the standard has been achieved.

This standard was developed under procedures of the Standards Committee of the American Nuclear Society; these procedures are accredited by the American National Standards Institute, Inc., as meeting the criteria for American National Standards. The consensus committee that approved the standard was balanced to ensure that competent, concerned, and varied interests have had an opportunity to participate.

An American National Standard is intended to aid industry, consumers, governmental agencies, and general interest groups. Its use is entirely voluntary. The existence of an American National Standard, in and of itself, does not preclude anyone from manufacturing, marketing, purchasing, or using products, processes, or procedures not conforming to the standard.

By publication of this standard, the American Nuclear Society does not insure anyone utilizing the standard against liability allegedly arising from or after its use. The content of this standard reflects acceptable practice at the time of its approval and publication. Changes, if any, occurring through developments in the state of the art, may be considered at the time that the standard is subjected to periodic review. It may be reaffirmed, revised, or withdrawn at any time in accordance with established procedures. Users of this standard are cautioned to determine the validity of copies in their possession and to establish that they are of the latest issue.

The American Nuclear Society accepts no responsibility for interpretations of this standard made by any individual or by any ad hoc group of individuals. Requests for interpretation should be sent to the Standards Department at Society Headquarters. Action will be taken to provide appropriate response in accordance with established procedures that ensure consensus on the interpretation.

Comments on this standard are encouraged and should be sent to Society Headquarters.

Published by

**American Nuclear Society  
555 North Kensington Avenue  
La Grange Park, Illinois 60526 USA**

Copyright © 2009 by American Nuclear Society. All rights reserved.

Any part of this standard may be quoted. Credit lines should read "Extracted from American National Standard ANSI/ANS-19.10-2009 with permission of the publisher, the American Nuclear Society." Reproduction prohibited under copyright convention unless written permission is granted by the American Nuclear Society.

Printed in the United States of America

## Foreword

(This Foreword is not part of American National Standard “Methods for Determining Neutron Fluence in BWR and PWR Pressure Vessel and Reactor Internals,” ANSI/ANS-19.10-2009.)

It is the intent of this American National Standard to provide guidance for the evaluation of pressurized water reactor (PWR) and boiling water reactor (BWR) pressure vessel and reactor internals fast ( $E > 1.0$  MeV) neutron fluence. This standard outlines the attributes of the method(s), the necessary types of data, the required benchmarking of the method, and the necessary steps in performing the calculations. The method(s) described herein require both experimentally measured vessel dosimetry data and corresponding fast neutron fluence calculations to perform the benchmark. This also allows the user to determine the existence of a bias in the calculated values and to quantify its magnitude. Likewise, the information needed for the benchmark allows the quantification of uncertainties. The method or methods described in this standard calculates a best-estimate value that is suitable (and acceptable) for use in applications related to *Code of Federal Regulations*, Title 10, “Energy,” Part 50, “Domestic Licensing of Production and Utilization Facilities,” Section 61, “Fracture Toughness Requirements for Protection Against Pressurized Thermal Shock Events,” Appendix G, “Fracture Toughness Requirements,” and Appendix H, “Reactor Vessel Material Surveillance Program Requirements.” The intended applications are for American-made PWRs and BWRs.

Compliance with the intent of this standard can be demonstrated by meeting the following two requirements:

- (1) The calculation must be validated as described in Sec. 5 of this standard;
- (2) the validation must be based on a qualified data set from dosimetry measurements performed as described in Sec. 4 of this standard.

This standard might reference documents and other standards that have been superseded or withdrawn at the time the standard is applied. A statement has been included in the reference section that provides guidance on the use of references.

This standard was developed by Working Group ANS-19.10 of the American Nuclear Society. At the time of the standard’s completion, the following members participated in the current version:

L. Lois (Chair), *U.S. Nuclear Regulatory Commission*  
J. F. Carew (Secretary), *Brookhaven National Laboratory*

J. M. Adams, *National Institute of Standards and Technology*  
S. Anderson, *Westinghouse Electric Company, LLC*  
R. J. Cacciapouti, *Individual*  
A. Haghghat, *University of Florida*  
W. C. Hopkins, *Individual*  
J. R. Worsham, *AREVA*  
M. Mahgerfteh, *Exelon Corporation*  
S. P. Baker, *Transware Enterprises*  
J. C. Wagner, *Oak Ridge National Laboratory*  
Y. Orechwa, *U.S. Nuclear Regulatory Commission*  
R. C. Little, *Los Alamos National Laboratory*

The membership of Subcommittee ANS-19, Reactor Physics Standards, at the time of its review and approval of this standard was as follows:

D. M. Cokinos (Chair), *Brookhaven National Laboratory*  
C. T. Rombough (Secretary), *CTR Technical Services, Inc.*

W. H. Bell, *American Institute of Chemical Engineers*  
M. Brady-Raap, *Pacific Northwest National Laboratory*  
D. J. Diamond, *Brookhaven National Laboratory*  
J. Katakura, *Japan Atomic Energy Research Institute*  
E. R. Knuckles, *Florida Power and Light*  
R. C. Little, *Los Alamos National Laboratory*  
L. Lois, *U.S. Nuclear Regulatory Commission*  
R. D. Mosteller, *Los Alamos National Laboratory*  
B. Rouben, *12 & 1 Consulting*  
A. Weitzberg, *Individual*

Consensus Committee N17, Research Reactors, Reactor Physics, Radiation Shielding and Computational Methods, had the following membership at the time it reviewed and approved the standard:

T. M. Raby (Chair), *National Institute of Standards and Technology*  
A. Weitzberg (Vice Chair), *Individual*

S. Anderson, *Westinghouse Electric Company, LLC*  
W. H. Bell, *American Institute of Chemical Engineers*  
(Alt. R. D. Zimmerman, *American Institute of Chemical Engineers*)  
R. E. Carter, *Individual*  
D. M. Cokinos, *Brookhaven National Laboratory*  
M. L. Corradini, *National Council on Radiation Protection & Measurement*  
B. Dodd, *Health Physics Society*  
E. Ehrlich, *General Electric Company*  
B. K. Grimes, *Individual*  
N. E. Hertel, *Georgia Institute of Technology*  
C. J. Heysel, *McMasters University*  
W. A. Holt, *Individual*  
W. C. Hopkins, *Individual*  
M. A. Hutmaker, *U.S. Department of Energy*  
A. C. Kadak, *Massachusetts Institute of Technology*  
L. I. Kopp, *Individual*  
P. M. Madden, *U.S. Nuclear Regulatory Commission*  
(Alt. A. Adams, *U.S. Nuclear Regulatory Commission*)  
J. F. Miller, *Institute of Electrical and Electronics Engineers*  
J. E. Olhoeft, *Individual*  
R. E. Pevey, *University of Tennessee, Knoxville*  
W. J. Richards, *National Institute of Standards and Technology*  
C. T. Rombough, *CTR Technical Services, Inc.*  
T. R. Schmidt, *Sandia National Laboratories*  
S. H. Shepherd, *Individual*  
A. O. Smetana, *Savannah River National Laboratory*  
R. R. Tsukimura, *Aerotest Operations*  
A. R. Veca, *General Atomics*  
S. H. Weiss, *National Institute of Standards and Technology*  
(Alt. T. J. Myers, *National Institute of Standards and Technology*)

<b>Contents</b>	<b>Section</b>	<b>Page</b>
<b>1</b>	Introduction and scope .....	1
1.1	Introduction .....	1
1.2	Scope, purpose, and application .....	1
<b>2</b>	Definitions .....	1
<b>3</b>	Transport theory calculational methods .....	2
3.1	General .....	2
3.2	Transport calculation .....	2
3.2.1	Input data .....	2
3.2.2	Discrete ordinates ( $S_N$ ) method .....	2
3.2.3	Monte Carlo transport method .....	2
3.2.4	Adjoint fluence calculations .....	3
3.3	Validation of neutron fluence calculational values .....	3
3.4	Determination of calculational uncertainties .....	3
<b>4</b>	Reactor pressure vessel neutron dosimetry measurements .....	3
4.1	General requirements for reactor pressure vessel neutron metrology .....	3
4.2	Stable-product neutron monitors .....	4
4.3	Dosimeter response parameters .....	4
4.4	Uncertainty estimates and measurement validation in standard neutron fields .....	4
<b>5</b>	Comparison of calculations with measurements .....	5
5.1	Direct comparison of calculated activities with measured sensor activities .....	5
5.2	Comparison of calculated rates with measured average full-power reaction rates .....	5
5.3	Comparison of the calculations against measurements using least-squares methods .....	5
<b>6</b>	Determination of the best-estimate fluence .....	6
<b>7</b>	References .....	6