American Nuclear Society

burnup credit for LWR fuel

an American National Standard

ANSI/ANS-8.27-2008

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

American National Standard
Burnup Credit for LWR Fuel

Secretariat
American Nuclear Society

Prepared by the
American Nuclear Society
Standards Committee
Working Group ANS-8.27

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

Approved August 14, 2008
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 It may be reaffirmed, revised, or withdrawn at any time in accordance with established procedures.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

Printed in the United States of America

Foreword

(This Foreword is not a part of American National Standard "Burnup Credit for LWR Fuel," ANSI/ANS-8.27-2008.)

Burnup credit is a term commonly used in accounting for an overall negative reactivity effect resulting from irradiation. In order to apply burnup credit, there need to be both supporting analyses and implementation steps (such as procedures, burnup assignments, and verification techniques).

Including burnup credit in the design and operation enables much improved flexibility (e.g., wider range of acceptable fuel) and efficiency (e.g., higher loading capacities), as compared to spent fuel system designs based on unirradiated fuel without credit for fixed burnable absorbers. These advantages have encouraged burnup credit to be applied in the criticality safety analysis of storage, transportation, and disposal systems containing irradiated fuel. The scope of this standard is restricted to burnup credit for commercial light water reactor fuel applications.

Burnup credit requires evaluation of the effect of irradiation on the fuel composition, which increases the *computation* complexity. However, the negative reactivity determined through burnup credit may be used to reduce the *overall* complexity of maintaining criticality safety. Several American National Standards Institute/American Nuclear Society (ANSI/ANS) standards provide guidance that is relevant to burnup credit. This standard supplements the guidance given in those standards and provides requirements and recommendations for handling the unique issues associated with the implementation of burnup credit.

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.

Working Group ANS-8.27 of ANS Subcommittee 8, Fissionable Materials Outside Reactors, drafted this standard. The following members participated in the preparation:

D. B. Lancaster (Chair), *NuclearConsultants.com*
C. T. Rombough (Secretary), *CTR Technical Services, Inc.*

S. Anton, *Holtec International*
A. C. Attard, *U.S. Nuclear Regulatory Commission*
S. P. Baker, *TransWare Enterprises, Inc.*
R. Beall, *Constellation Energy*
M. C. Brady Raap, *Pacific Northwest National Laboratory*
J. P. Coletta, *Duke Energy*
R. A. Hommerson, *Individual*
L. I. Kopp, *Individual*
Z. Martin, *Tennessee Valley Authority*
J. R. Massari, *Constellation Energy*
R. D. McKnight, *Argonne National Laboratory*
D. Mennerdahl, *Individual-Sweden*
P. Narayanan, *TransNuclear, Inc.*
C. V. Parks, *Oak Ridge National Laboratory*
H. Pfeifer, *Nuclear Analysis Company International*
M. Rahimi, *U.S. Nuclear Regulatory Commission*
D. A. Thomas, *AREVA NP, Inc.*
S. E. Turner, *Individual*
G. R. Walden, *Duke Energy*
A. H. Wells, *Electric Power Research Institute*
C. J. Withee, *U.S. Nuclear Regulatory Commission*
A. Zimmer, *General Atomics*
J. F. Zino, *GE Nuclear Energy*

The following is a list of people who supported the working group but were not able to actively participate throughout the entire process:

J. Boshoven, D. Cacciapouti, M. DeHart, M. DeVoe, D. Galvin, J. Gulliford, L. Hassler, D. Hutson, R. Jones, R. Kunita, A. J. Machiels, L. Markova, M. Mason, S. Mitake, D. Mueller, G. O'Connor, P. O'Donnell, H. Toffer, J. C. Wagner, C. Walker, B. Wilson.

This standard was prepared under the guidance of ANS Subcommittee 8, which had the following membership at the time of its approval:

T. P. McLaughlin (Chair), *Individual*
B. O. Kidd (Vice Chair), *Babcock & Wilcox*
J. A. Schlesser (Secretary), *Washington Safety Management Solutions*

F. M. Alcorn, *Individual*
H. D. Felsher, *U.S. Nuclear Regulatory Commission*
A. S. Garcia, *U.S. Department of Energy*
N. Harris, *British Nuclear Fuels, PLC*
R. A. Libby, *Pacific Northwest National Laboratory*
D. A. Reed, *Oak Ridge National Laboratory*
T. A. Reilly, *Individual*
H. Toffer, *Fluor Federal Services*
G. E. Whitesides, *Individual*

The American National Standards Committee N16, Nuclear Criticality Safety, which reviewed and approved this standard in 2008, had the following membership:

C. M. Hopper (Chair), *Oak Ridge National Laboratory*
R. Knief (Vice Chair), *Institute of Nuclear Materials Management*

G. H. Bidinger, *Individual*
R. D. Busch, *University of New Mexico*
R. S. Eby, *American Institute of Chemical Engineers*
D. Jackson, *U.S. Nuclear Regulatory Commission*
C. D. Manning, *AREVA NP*
S. P. Murray, *Health Physics Society*
R. E. Pevey, *University of Tennessee*
R. L. Reed, *Westinghouse*
B. Rothleder, *U.S. Department of Energy*
W. R. Shackelford, *Nuclear Fuel Services, Inc.*
R. G. Taylor, *INM Nuclear Safety Services*
R. M. Westfall, *Oak Ridge National Laboratory*
L. L. Wetzel, *Babcock & Wilcox*
R. E. Wilson, *U.S. Department of Energy*

Contents

Burnup Credit for LWR Fuel

1 Introduction

The purpose of this standard[1)] is to provide guidance for criticality safety control (by analysis and implementation) that accounts for reactivity effects of fuel burnup in a UO_2-fueled light water reactor (LWR). The American National Standard "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors," American National Standards Institute/American Nuclear Society (ANSI/ANS)-8.1-1998 (R2007) [1],[2)] provides broad guidance for administrative and technical practices for the prevention of criticality accidents in the handling, storing, processing, and transporting of fissionable material outside reactors. Generalized basic criteria are presented, and some single unit limits are specified. This standard is intended to provide specific guidance relative to burnup credit and not to replace the criteria of ANSI/ANS-8.1-1998 (R2007) [1].

It has often been a practice to base the criticality safety control of systems with irradiated fuel on fresh fuel conditions. Accounting for a reduction in k_{eff} due to irradiation is called "burnup credit."

Systems with fuel containing fixed burnable absorbers can increase in reactivity with irradiation. Therefore, credit for the presence of a burnable absorber must account for the change in reactivity with irradiation. This standard considers such credit for irradiated burnable absorbers a subset of burnup credit. This subset of burnup credit is often called "burnable absorber credit" (e.g., gadolinium credit). Other aspects of accounting for fixed neutron absorbers are addressed in American National Standard "Use of Fixed Neutron Absorbers in Nuclear Facilities Outside Reactors," ANSI/ANS-8.21-1995 (R2001) [2].

Two additional American National Standards provide guidance relevant to validating burnup credit methods. The American National Standard "Validation of Neutron Transport Methods for Nuclear Criticality Safety Calculations," ANSI/ANS-8.24-2007 [3], provides criteria for establishing the validation applicability, estimating the biases and uncertainties, and selecting appropriate subcritical margins, both within and beyond the established benchmark applicability. This standard provides additional requirements for establishing benchmarks for burnup credit applications. The American National Standard "A Guide for Acquisition and Documentation of Reference Power Reactor Physics Measurements for Nuclear Analysis Verification," ANSI/ANS-19.4-1976 (R2000) [4], provides guidance by which reactor physics measurements from power reactors can be evaluated to determine the appropriateness of their use as reference measurements. This standard provides additional requirements for using the data from power reactors for verification and validation of burnup credit parameters and methods.

2 Scope

This standard provides criteria for accounting for reactivity effects of fuel irradiation and radioactive decay in criticality safety control of storage, transportation, and disposal of commercial LWR UO_2 fuel assemblies.

This standard assumes the fuel and any fixed burnable absorbers are contained in an intact assembly. Additional considerations could be necessary for fuel assemblies that have been disassembled, consolidated, damaged, or reconfigured in any manner.

3 Definitions

3.1 Limitations

The definitions given below are of a restricted nature for the purpose of this standard. Other

---

[1)] The current standard, ANSI/ANS-8.27-2008, is herein referred to as "this standard."

[2)] Numbers in brackets refer to corresponding numbers in Sec. 8, "References."