American Nuclear Society

nuclear criticality safety in operations with fissionable materials outside reactors

an American National Standard

REAFFIRMED

November 29, 2018

ANSI/ANS-8.1-2014 (R2018)

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reviewed and reaffirmed with the recognition that it may reference other standards and documents that may have been superseded or withdrawn.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

ANSI/ANS-8.1-2014

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

ANSI/ANS-8.1-2014

American National Standard Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors

Secretariat
American Nuclear Society

Prepared by the
American Nuclear Society
Standards Committee
Working Group ANS-8.1

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

Approved April 15, 2014
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 the 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. Responses to inquiries about requirements, recommendations, and/or permissive statements (i.e., “shall,” “should,” and “may,” respectively) 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.

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.

Inquiry Requests

The American Nuclear Society (ANS) Standards Committee will provide responses to inquiries about requirements, recommendations, and/or permissive statements (i.e., "shall," "should," and "may," respectively) in American National Standards that are developed and approved by ANS. Responses to inquiries will be provided according to the Policy Manual for the ANS Standards Committee. Nonrelevant inquiries or those concerning unrelated subjects will be returned with appropriate explanation. ANS does not develop case interpretations of requirements in a standard that are applicable to a specific design, operation, facility, or other unique situation only, and therefore is not intended for generic application.

Responses to inquiries on standards are published in the Society's magazine, *Nuclear News*, and are available publicly on the ANS Web site or by contacting the ANS standards administrator.

Inquiry Format

Inquiry requests must include the following:

(1) the name, company name if applicable, mailing address, and telephone number of the inquirer;

(2) reference to the applicable standard edition, section, paragraph, figure, and/or table;

(3) the purposes of the inquiry;

(4) the inquiry stated in a clear, concise manner;

(5) a proposed reply, if the inquirer is in a position to offer one.

Inquiries should be addressed to:

American Nuclear Society
ATTN: Standards Administrator
555 N. Kensington Avenue
La Grange Park, IL 60526

or standards@ans.org

Foreword

(This Foreword is not a part of American National Standard "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors," ANSI/ANS-8.1-2014.)

This standard provides guidance for the prevention of criticality accidents in the handling, storing, processing, and transportation of fissionable material. It was first approved as American Standard N6.1-1964. A substantial revision that included the specification of subcritical limits applicable to process variables was approved as American National Standard N16.1-1969 and was affirmed, with minor revisions, as American National Standard N16.1-1975/ANS-8.1. It was subsequently supplemented by American National Standard for Validation of Calculational Methods for Nuclear Criticality Safety, ANSI N16.9-1975/ANS-8.11. The two standards were consolidated in 1983.

The subcritical limits given in the standard make no allowance for operating contingencies (e.g., double batching) or for inaccurate knowledge of process variables (e.g., concentrations, masses, and dimensions) and are "maximum subcritical limits" for the stated conditions. That is, under the stated conditions, the limits are close enough to critical to provide little incentive for attempting to justify slightly larger values, but concomitantly, they are confidently expected actually to be subcritical. The stated conditions (infinitely long cylinders, absence of neutron-absorbing vessel wall, plutonium solutions without free nitric acid, etc.) are unlikely to be approached in practice; hence, if a limit is reached, there will ordinarily be a larger margin of subcriticality than the minimal value used in its derivation. However, no account was taken of this unlikelihood in setting the limits. It is legitimate for the users of the standard, if they so choose, to make conservative adjustments in the limits to take advantage of the extent to which process conditions may deviate from stated conditions, e.g., to increase a cylinder diameter limit to take advantage of a finite height and of neutron absorption in steel walls.

The present revision of the standard is primarily intended to clarify the use and interpretation of the process analysis requirement, the double-contingency-principle recommendation, and their relationship in a new Appendix. In addition, the definitions for "parameter" and "process conditions" were added to assist with the understanding of the double-contingency recommendation. These and other minor changes were made that do not change the intent of the words in the previous revision. They represent clarification and amplification that should aid in uniform application of the 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 references section that provides guidance on the use of references.

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 would like to gratefully acknowledge the contributions by Terry L. Hofer, who died prior to the publication of this revision.

This revision of American National Standard ANSI/ANS-8.1-2014 was prepared by Working Group ANS-8.1 of Subcommittee 8 of the Standards Committee of the American Nuclear Society. Working Group ANS-8.1 had the following membership at the time of the revision:

D. G. Bowen (Cochair), *Oak Ridge National Laboratory*
N. W. Brown (Cochair), *Nuclear Fuel Services, Inc.*

R. Beck, *USEC Incorporated*
A. Garcia, *U.S. Department of Energy*

S. Goluoglu, *University of Florida*
C. Gross, *Paschal Solutions Incorporated*
C. Haught, *B&W Y-12*
J. Hicks, *U.S. Department of Energy*
T. Hofer, *USEC Incorporated*
M. LeTellier, *C. S. Engineering, Inc.*
T. Marenchin, *U.S. Nuclear Regulatory Commission*
J. Miller, *Sigma Science, Inc.*
L. Montierth, *Idaho National Laboratory*
J. Morman, *Argonne National Laboratory*
L. Paschal, *Paschal Solutions Incorporated*
L. Paulson, *GE Hitachi, Nuclear Energy*
K. Reynolds, *B&W Y-12*
E. Saylor, *Oak Ridge National Laboratory*
F. Winstanley, *Sellafield Ltd.*
K. Woods, *Paschal Solutions Incorporated*

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*
M. Crouse (Secretary), *Washington Safety Management Solutions*

F. M. Alcorn, *Individual*
J. Baker, *Los Alamos National Laboratory*
E. Elliott, *Defense Nuclear Facilities Safety Board*
D. Erickson, *Savannah River Nuclear Solutions*
A. S. Garcia, *U.S. Department of Energy*
D. A. Reed, *Individual*
T. A. Reilly, *Individual*
H. Toffer, *Individual*
C. Tripp, *U.S. Nuclear Regulatory Commission*
F. Winstanley, *Sellafield Ltd.*

The American Nuclear Society Nuclear Criticality Safety Consensus Committee had the following membership at the time of its approval:

R. D. Busch (Chair), *University of New Mexico*
L. L. Wetzel (Vice Chair), *Babcock & Wilcox Nuclear Operations Group*

L. Berg, *U.S. Department of Energy*
G. H. Bidinger, *Individual*
R. S. Eby, *American Institute of Chemical Engineers (Employed by USEC, Inc.)*
C. M. Hopper, *Individual*
R. Knief, *Institute of Nuclear Materials Management (Employed by Sandia National Laboratories)*
W. Doane, *AREVA*
T. Marenchin, *U.S. Nuclear Regulatory Commission*
T. P. McLaughlin, *Individual*
S. P. Murray, *Health Physics Society (Employed by General Electric)*
R. E. Pevey, *University of Tennessee*
R. L. Reed, *URS Professional Solutions LLC*
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 Nuclear Operations Group*
R. E. Wilson, *U.S. Department of Energy*

Contents

Tables

Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors

1 Introduction

Operations with some fissionable materials introduce risks of a criticality accident resulting in a release of radiation that can be lethal to nearby personnel. However, experience has shown that extensive operations can be performed safely and economically when proper precautions are exercised. The few criticality accidents that have occurred show frequency and severity rates far below those typical of nonnuclear accidents. This favorable record can be maintained only by continued adherence to good operating practices such as are embodied in this standard; however, the standard, by itself, cannot establish safe processes in an absolute sense. Good safety practices should recognize economic considerations, but the protection of operating personnel and the public is the dominant consideration. Guidance for establishing an alarm system for protection of personnel is contained in ANSI/ANS-8.3-1997 (R2012) [1].[1)]

2 Scope

This standard is applicable to operations with fissionable materials outside nuclear reactors, except for the assembly of these materials under controlled conditions, such as in critical experiments. Generalized basic criteria are presented, and limits are specified for some single fissionable units of simple shape containing ^{233}U, ^{235}U, or ^{239}Pu, but not for multiunit arrays. Subcritical limits for certain multiunit arrays are contained in ANSI/ANS-8.7-1998 (R2012) [2]. Requirements are stated for validation of any calculational method used in assessing nuclear criticality safety. This standard does not include the details of administrative controls, the design of processes or equipment, the description of instrumentation for process control, nor detailed criteria to be met in transporting fissionable materials. Guidance for transporting light water reactor (LWR) fuel is contained in ANSI/ANS-8.17-2004 (R2009) [3].

3 Definitions

3.1 Limitations

The definitions given below are of a restricted nature for the purposes of this standard. Other specialized terms are defined in *Glossary of Nuclear Criticality Terms* [4].

3.2 Shall, should, and may

The word "shall" is used to denote a requirement; the word "should" is used to denote a recommendation; and the word "may" is used to denote permission, neither a requirement nor a recommendation.

3.3 Glossary of terms

areal density: The total mass of fissionable material per unit area projected perpendicularly onto a plane. (For an infinite, uniform slab, it is the product of the slab thickness and the density of fissionable material within the slab.)

calculational method: The mathematical procedures, equations, approximations, assumptions, and associated numerical parameters (e.g., cross sections) that yield the calculated results.

controlled parameter: A parameter that is kept within specified limits.

criticality accident: The release of energy as a result of accidental production of a self-sustaining or divergent neutron chain reaction.

effective multiplication factor (k_{eff}): *Physically,* the ratio of the total number of neutrons produced during a time interval (excluding neutrons produced by sources whose strengths are not a function of fission rate) to the

[1)] Numbers in brackets refer to corresponding numbers in Sec. 7, "References."