American Nuclear Society

nuclear criticality safety control
of selected actinide nuclides

an American National Standard

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American Nuclear Society
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American National Standard Nuclear Criticality Safety Control of Selected Actinide Nuclides

Secretariat
American Nuclear Society

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American National Standard

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Foreword

(This Foreword is not a part of American National Standard "Nuclear Criticality Safety Control of Selected Actinide Nuclides," ANSI/ANS-8.15-2014.)

This standard provides guidance for the prevention of criticality accidents in the handling, storing, processing, and transportation of nineteen selected actinide nuclides. The revision revises most of the subcritical limits for the original fourteen nuclides in the 1981 standard and adds five additional nuclides, bringing the total number of nuclides to nineteen. The nuclides were selected on the basis that they have half-lives greater than 45 days and it is judged there is sufficient knowledge of their physical properties to support evaluation of subcritical mass limits. The working group has elected to change the title of the standard by referring to "selected actinide nuclides" rather than "special actinide elements." This is the first revision of ANS-8.15 since its publication in 1981. ANS-8.15 is intended to be complementary to ANSI/ANS-8.1-2014 by providing technical nuclear criticality safety guidance for nuclides other than ^{233}U, ^{235}U, and ^{239}Pu.

In Footnote 5, the 1981 standard speculates that ^{232}U and ^{236}Pu may be "exceptions" to the correlation of critical mass with the even-number and odd-number neutron of the nuclide. Both nuclides are included in the scope of this revision with ^{236}Pu appearing in Table 2, clearly breaking the correlation.

No significant advancement in understanding the criticality of californium isotopes has occurred since 1981. Consequently, the water-reflected subcritical limits for the californium isotopes ^{249}Cf and ^{251}Cf are brought forward to this revision unmodified from the original standard. In addition, isotopic mixtures of plutonium, americium, and curium are not addressed in this revision. Instead, this topic has been moved from Section 6.1 of the 1981 version to an Appendix (called Appendix A). The revised standard urges users to calculate subcritical limits for mixtures using modern methods rather than use the 1981 tables.

Currently, the usage of the words fissionable and fissile within the community is not consistent (see "The Heritage and Usage of the Words Fissionable and Fissile in Criticality," Norman L. Pruvost, J. Eric Lynn and Charles D. Harmon, II, LA-UR-04-6514, Los Alamos National Laboratory, September 2004). Since ANS standards can be viewed as models of proper usage, the working group has chosen to omit these words from the revision. "Modern Fission Theory for Criticality," J. Eric Lynn, LA-14098, Los Alamos National Laboratory, February 2004, examines the understanding gained during the forty-five years since the formulation of the structure underlying the original 1981 Appendix A (primarily from "Considerations on the Probability of Nuclear Fission," R. Vandenbosch and G. T. Seaborg, *The Physical Review*, 110 (2), 507-513, April 1958) and concludes that its basis is empirical, unexplained, and "totally outmoded" (LA-14098) thus, the original 1981 Appendix A has been removed. Appendix B of the original standard was mostly composed of technical reference material and is reproduced from the original standard with no attempt to update any of the information.

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 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.

This standard was prepared by the ANS-8.15 Working Group of the American Nuclear Society. The following members contributed to the development of this standard:

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The membership of the ANS-8 Subcommittee at the time of its approval of this standard was as follows:

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Nuclear Criticality Safety Control of Selected Actinide Nuclides

1 Introduction

ANSI/ANS-8.1-2014, "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors," [1][1)] provides single parameter limits for operations with ^{233}U, ^{235}U, and ^{239}Pu. The principal interest in criticality safety is in these three isotopes of uranium and plutonium since they are the most abundant; however, there are also other isotopes of uranium, plutonium, and other elements within the actinide group that are capable of supporting a chain reaction and that may be encountered in sufficient quantities to cause concern. In many practical conditions, these nuclides may be dispersed with an effective concentration smaller than that required to achieve criticality for a homogeneous metal-water mixture of infinite dimensions. This revision provides guidance for such conditions in Table 3 by tabulating *subcritical* concentration limits (and the associated minimum hydrogen to fissile atom ratios), which are about one-half the estimated critical concentration limit.

The experimental data for nuclides other than ^{233}U, ^{235}U, and ^{239}Pu are dramatically fewer. Consequently, calculation results based on evaluated neutron cross sections play a major role in providing the basis for guidance in this standard. The subcritical limits in the standard are in some cases substantially less than the estimated minimum critical values. No experimental systems containing the nuclides in the scope of this standard have achieved criticality based solely on the neutronic properties of the nuclide. Some experimental data are available for estimating the critical mass of ^{237}Np and ^{242}Pu where critical experiments have been performed with substantial fractions of these two nuclides.

For the purpose of this standard, the nuclides selected are actinides having half-lives greater than 45 days.

2 Scope

This standard is applicable to operations with the following nuclides:

^{232}U, ^{234}U, ^{237}Np, ^{236}Pu, ^{238}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{241}Am, ^{242m}Am, ^{243}Am, ^{242}Cm , ^{243}Cm, ^{244}Cm, ^{245}Cm, ^{246}Cm, ^{247}Cm, ^{249}Cf, and ^{251}Cf.

Subcritical mass limits are presented for isolated units. These limits are not applicable to interacting units.

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* [2].

3.2 Shall, should, may

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

3.3 Glossary of terms

nuclear criticality safety: Protection against the consequences of a criticality accident, preferably by prevention of the accident.

subcritical limit: The limiting value assigned to a controlled parameter that results in a subcritical system under specified conditions. The parameter limit allows for uncertainties in the calculation and experimental data used in its derivation, but not for contingencies, e.g., double batching or failure of analytical techniques to yield accurate values.

1) Numbers in brackets refer to corresponding numbers in Sec. 6, "References."