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American National Standard for Nuclear Criticality Control of Special Actinide Elements

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Foreword

(This Foreword is not a part of American National Standard for Nuclear Criticality Control of Special Actinide Elements, ANSI/ANS-8.15-1981.)

This standard provides guidance for the prevention of criticality accidents in the handling, storing, processing and transporting of special actinide elements. Subcritical mass limits are provided for fourteen nuclides beginning with ^{237}Np and ending with ^{251}Cf. The standard constitutes an extension of American National Standard for Nuclear Criticality Safety in Operations With Fissionable Materials Outside Reactors, N16.1-1975 (ANS-8.1). The subcritical limits in the standard are in some cases substantially less than the estimated minimum critical values. This is to account for uncertainties in calculations. In view of the limited availability of most of the nuclides in the near term, there was no reason to push the limits to higher values. The limits are considered adequate for current needs.

In addition, the heat generation from alpha particle decay may in some cases actually be the more limiting factor that controls the quantity of nuclear material assembled.

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This standard was prepared under the direction of Subcommittee 8, Fissionable Materials Outside Reactors, of the Standards Committee of the American Nuclear Society (ANS). The membership of this Subcommittee at the time of preparation was:

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The American National Standards Committee N16, Nuclear Criticality Safety, which reviewed and approved this standard in 1981, had the following membership:

Dixon Callihan, Chairman
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Nuclear Criticality Control of Special Actinide Elements

1. Introduction

The American National Standard for Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors, N16.1-1975 (ANS-8.1)[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 isotopes of uranium and plutonium since they are the most abundant, but there are also other isotopes of these nuclides 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. It has been speculated that potential requirements for certain of the synthetic actinide elements could lead to their production in large, possibly ton, quantities.[2, 3]

Pertaining to criticality safety, a key factor is whether the nuclide contains an odd or even number of neutrons. Those with odd numbers of neutrons, such as $^{241}_{94}Pu$, $^{242m}_{95}Am$, $^{243}_{96}Cm$, $^{245}_{96}Cm$, $^{247}_{96}Cm$, $^{249}_{98}Cf$, and $^{251}_{98}Cf$, can be expected to have critical masses in aqueous solutions that are less than 1 kg, and in certain cases, very much less.

Those with even numbers of neutrons, for example, $^{237}_{93}Np$, $^{238}_{94}Pu$, $^{240}_{94}Pu$, $^{242}_{94}Pu$, $^{241}_{95}Am$, $^{243}_{95}Am$ and $^{244}_{96}Cm$, can in many cases be made critical, but the mass required may be kilograms. The effect of moderation on these nuclides, such as in an aqueous solution, is to prevent — rather than enhance — criticality. These nuclides characteristically exhibit rather sharp thresholds in their fission cross sections, with little or no probability for subthreshold fission. As a consequence, the value of k_∞ will be reduced if even a small quantity of hydrogen is mixed uniformly with the element.

1 Numbers in brackets refer to corresponding numbers in Section 7, References.

2 See Reference A1 in the Bibliography.

3 The physical characteristics of the principal actinide elements of interest are given in Appendix B.

2. Scope

This standard is applicable to operations with the following:

$^{237}_{93}Np$, $^{238}_{94}Pu$, $^{240}_{94}Pu$, $^{241}_{94}Pu$, $^{242}_{94}Pu$, $^{241}_{95}Am$, $^{242m}_{95}Am$, $^{243}_{95}Am$, $^{243}_{96}Cm$, $^{244}_{96}Cm$, $^{245}_{96}Cm$, $^{247}_{96}Cm$, $^{249}_{98}Cf$ and $^{251}_{98}Cf$.

Subcritical mass limits are presented for isolated fissionable units.[4] The limits are not applicable to interacting units.

3. Definitions

3.1 Limitations. The definitions given below are of a restricted nature for the purpose of this standard. Other specialized terms are defined in American National Standard Glossary of Terms in Nuclear Science and Technology, N1.1-1976 (ANS-9). [2]

3.2 Glossary of Terms

fissile nuclide. A nuclide capable of undergoing fission by interaction with slow neutrons provided the effective thermal neutron production cross section, $\overline{\nu\sigma}_f$, exceeds the effective thermal neutron absorption cross section, $\overline{\sigma}_a$. [2][5]

shall, should, and may. The word "shall" is used to denote a requirement, the word "should" to denote a recommendation, and the word "may"

4 To give further guidance as to where criticality problems may exist with special actinide elements on which subcritical limits are not provided herein, a discussion, together with a table, is presented in Appendix A.

5 Most actinide nuclides containing an even number of neutrons are non-fissile, but there may be exceptions, such as ^{232}U and ^{236}Pu, which have even numbers of neutrons and approximately equal thermal capture and fission cross sections, which perhaps can be made critical with slow neutrons. Conversely, whereas most nuclides with an odd number of neutrons are fissile, ^{237}U, which is an odd-N nuclide with a very small thermal fission cross section, cannot be made critical with thermal neutrons.