

LA-UR-96-2292

Title: American National Standard ANSI/ANS-8.12-1987:  
Criticality Control of Plutonium-Uranium Mixtures

CONF-961103--22

RECEIVED

JUL 19 1996

OSTI

Author(s): E. D. Clayton (PNNL) and Thomas P. McLaughlin (ESH-6)

Submitted to: American Nuclear Society 1996 Winter Meeting

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

MASTER

**Los Alamos**  
NATIONAL LABORATORY

Los Alamos National Laboratory, an affirmative action/equal opportunity employer, is operated by the University of California for the U.S. Department of Energy under contract W-7405-ENG-36. By acceptance of this article, the publisher recognizes that the U.S. Government retains a nonexclusive, royalty-free license to publish or reproduce the published form of this contribution, or to allow others to do so, for U.S. Government purposes. The Los Alamos National Laboratory requests that the publisher identify this article as work performed under the auspices of the U.S. Department of Energy.

Form No. 836 R5  
ST 2629 10/91

**DISCLAIMER**

**Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.**

## **DISCLAIMER**

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

**AMERICAN NATIONAL STANDARD ANSI/ANS-8.12-1987:  
CRITICALITY CONTROL OF PLUTONIUM-URANIUM MIXTURES**

E. D. Clayton (PNNL) and T. P. McLaughlin (LANL)

American National Standard ANSI/ANS-8.12-1987 (Ref. 1) was approved for use on September 11, 1987. The history of the development of the standard is discussed in Ref. 2. The first version of this standard, which only included subcritical limits on homogeneous plutonium-uranium fuel mixtures, was approved July 17, 1978. The current version was revised to include limits on heterogeneous systems as well (Ref. 3). This paper provides additional information on the limits presented in the standard.

As stated in its forward, the standard ". . . provides guidance for the prevention of criticality accidents in the handling, storing, processing, and transporting of plutonium-uranium fuel mixtures outside reactors and is applicable to all operations involving mixtures of plutonium and natural uranium. It constitutes an extension of the American National Standard for Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors, ANSI/ANS-8.1-1983 (Ref. 4).

The standard includes subcritical limits<sup>1</sup> for both homogeneous mixtures and heterogeneous lattices of plutonium and uranium. The uranium is assumed to be natural or depleted. Limits

---

<sup>1</sup>The limiting value assigned to a controlled parameter that results in a system known to be subcritical, provided the limiting value of no other controlled parameter of the system is violated. The subcritical limit allows for uncertainties in the calculations used in its derivation, but not for contingencies, e.g., double batching or failure of analytical techniques to yield accurate values of process variables.

are provided for a variety of mixtures, including aqueous solutions, dry  $[H/(Pu + U) = 0]$  mixed oxides at theoretical density, and damp  $[H/(Pu + U) \leq 0.45]$  mixed oxides at both theoretical and one-half theoretical density. The limits for homogeneous mixtures shown in Table I cover four different plutonium contents (3, 8, 15, and 30 wt%  $PuO_2$  in  $PuO_2 + UO_2$ ) and three different isotopic compositions ( $^{240}Pu > ^{241}Pu$ ;  $^{240}Pu \geq 15$  wt% and  $^{241}Pu \leq 6$  wt%; and  $^{240}Pu \geq 25$  wt% and  $^{241}Pu \leq 15$  wt%).

Heterogeneous lattice limits for mass, spherical volume, cylinder diameter, and slab thickness are also presented in the standard. Figure 1 shows one such set of limits: the limiting volume curves for heterogeneous systems. Anomalous behavior was noted for the heterogeneous cases with 30 wt% plutonium in  $PuO_2 + UO_2$  with 25 wt%  $^{240}Pu$  and 15 wt%  $^{241}Pu$ . For these cases, the minima calculated for the lattices were greater than the minima for dry theoretical oxide. The lattice minima occurred with very small rod diameters, and it is believed that the resonance absorption treatment employed could not adequately handle the unusual geometry (Ref 5). Thus, the standard does not extrapolate beyond 15 wt% plutonium in the mixed oxide for the isotopic mixture of 25 wt%  $^{240}Pu$  and 15 wt%  $^{241}Pu$ .

The current version of the standard has now been available for 13 years. The last reaffirmation was on February 17, 1993. The standard provides useful subcritical limits for mixed-oxide systems in the range of 3 to 30 wt%  $PuO_2$  in  $PuO_2 + UO_2$ . To cover interest in metal fuels (such as the uranium, plutonium, and zirconium fuel used in the integral fast reactor concept [Ref. 6]), a work group is likely to be formed to establish limits applicable to these fuel types.

1. "Nuclear Criticality Control and Safety of Plutonium-Uranium Fuel Mixtures Outside Reactors," ANSI/ANS-8.12-1987, American Nuclear Society (1987).
2. R. A. LIBBY, E. D. CLAYTON, "American National Standard ANSI/ANS-8.12-1987 -- History and Limits," *Trans. Am. Nucl. Soc.*, **62**, 335 (1990).
3. E. D. CLAYTON, H. K. CLARK, G. WALKER, "Basis for Extending Limits in ANSI Standard for Mixed Oxides to Heterogeneous Systems," *Nuc. Tech.*, **75**, (November 1986).
4. "Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors," ANSI/ANS-8.1-1983 (reaffirmed 1988), American Nuclear Society (1988).
5. E. D. CLAYTON, "Safety Implications of Anomalous Effects of Neutron Absorbers on Criticality," *Proc. Int. Seminar Nuclear Criticality Safety*, Tokyo, Japan, October 19-23, 1987, p. 194.
6. D. R. PEDERSEN, B. R. SEIDEL, "A Status Report on the Integral Fast Reactor Fuels and Safety Program," *Trans. Am. Nucl. Soc.*, **61**, 300 (1990).

**TABLE I**  
**Subcritical Limits for Uniform Aqueous Mixtures of the Oxides of Plutonium and Natural Uranium\***

	PuO <sub>2</sub> in (PuO <sub>2</sub> + UO <sub>2</sub> ) (wt%)											
	3			8			15			30 <sup>a</sup>		
	Plutonium Isotopic Composition <sup>b</sup>											
	I	II	III	I	II	III	I	II	III	I	II	III
Mass of plutonium in oxide mixture (kg)	0.73	1.35	2.00	0.61	1.06	1.53	0.54	0.94	1.28	0.50	0.87	1.16
Mass of (PuO <sub>2</sub> + UO <sub>2</sub> ) (kg)	27.5	51.3	75.9	8.6	15.1	21.7	4.1	7.1	9.7	1.9	3.3	4.4
Diameter of infinite cylinder (cm)	24.3	30.8	34.8	19.8	24.9	27.5	17.8	22.5	24.8	16.2	21.0	23.4
Thickness of infinite slab (cm)	11.0	14.9	17.4	8.2	11.2	12.9	6.9	9.6	11.0	5.9	8.7	9.9
Volume of oxide mixture (ℓ)	23.5	44.8	63.4	14.0	25.9	34.4	11.0	20.4	26.6	8.5	16.8	21.6
Concentration of plutonium (g Pu/ℓ)	6.8 <sup>c</sup>	8.1	9.3	6.9	8.2	9.4	7.0	8.2	9.4	7.0	8.1	9.3
Concentration of oxides [g(PuO <sub>2</sub> + UO <sub>2</sub> )/ℓ]	257 <sup>c</sup>	305	351	97.3	116	134	52.9	61.7	71.0	26.5	30.7	35.2
H:Pu atomic ratio	3780	3203	2780	3780	3210	2790	3780	3237	2818	3780	3253	2848
Areal density of plutonium (g Pu/cm <sup>2</sup> )	0.27	0.38	0.47	0.25	0.34	0.42	0.25	0.33	0.41	0.24	0.32	0.37
Areal density of oxides [g(PuO <sub>2</sub> + UO <sub>2</sub> )/cm <sup>2</sup> ]	10.2	14.4	17.7	3.5	4.8	5.9	1.9	2.5	3.1	0.9	1.2	1.4

\*All values are upper limits except atomic ratios, which are lower limits.

<sup>a</sup>Dimensional and volume limits do not apply for isotopic compositions II and III unless, for II, the concentration of oxides is < 5700 g/l and, for III, < 4500 g/l.

<sup>b</sup>Plutonium isotopic composition: I -- <sup>240</sup>Pu > <sup>241</sup>Pu, II -- <sup>240</sup>Pu ≥ 15 wt% and <sup>241</sup>Pu ≤ 6 wt%, and III -- <sup>240</sup>Pu ≥ 25 wt% and <sup>241</sup>Pu ≤ 15 wt%.

<sup>c</sup>This concentration limit is not applicable to oxide mixtures in which the PuO<sub>2</sub>/(PuO<sub>2</sub> + UO<sub>2</sub>) ratio is < 3 wt% because of the increased relative importance of <sup>235</sup>U in high-uranium-bearing materials.

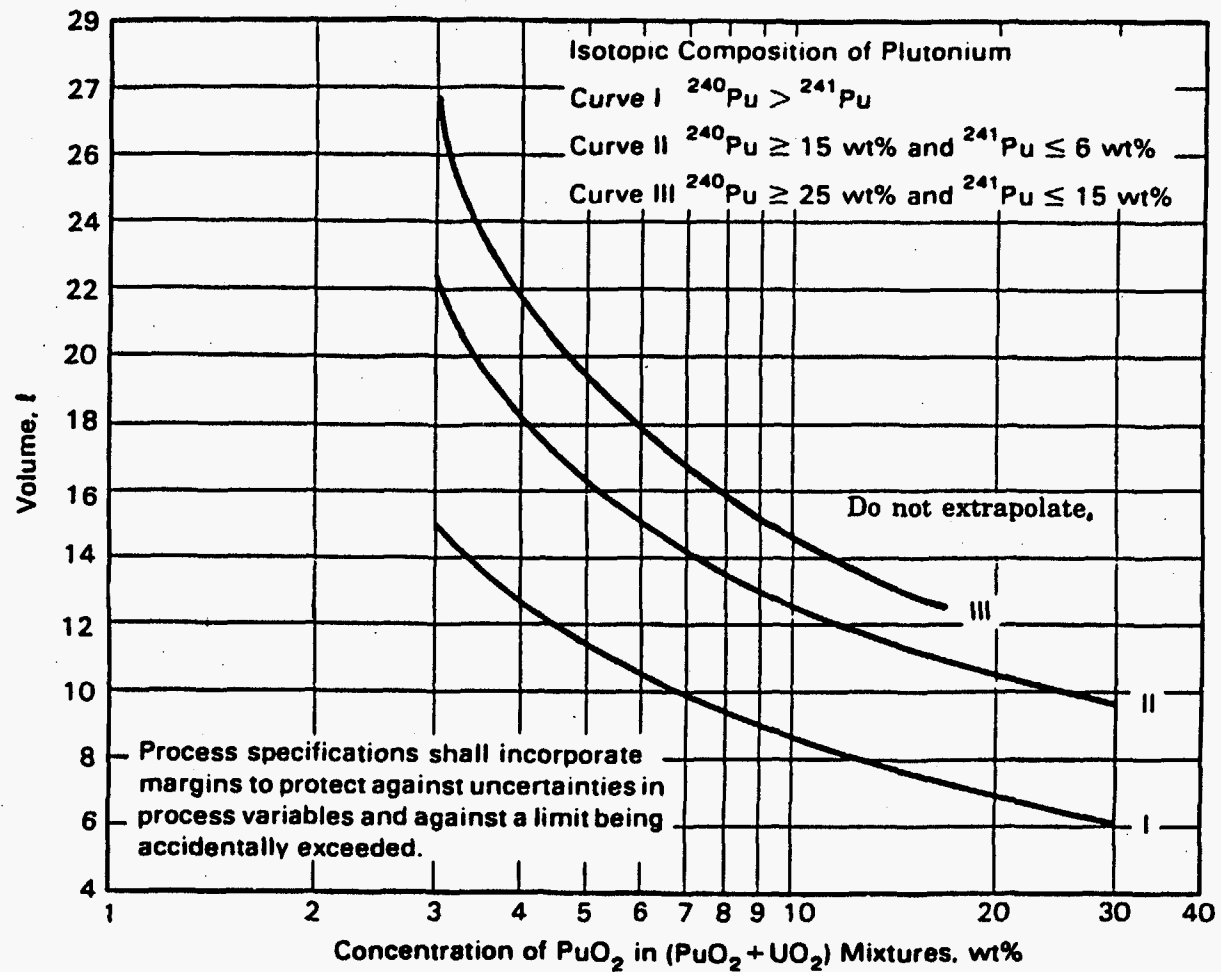


Fig. 1. Limiting volume of heterogeneous mixtures of the oxides of plutonium and natural uranium in water as a function of the plutonium oxide content.