DATE OF ISSUE: March 21, 1997

DOCUMENT NUMBER: KY/G-632
Rev. 1

JUSTIFICATION THAT OPERATIONS WITH LESS THAN 15 GRAMS ^{235}U DO NOT REQUIRE A NUCLEAR CRITICALITY SAFETY APPROVAL (NCSA) OR A CRITICALITY ACCIDENT ALARM SYSTEM (CAAS)

T.J. Cahill

Lockheed Martin Utility Services, Incorporated

T Cahill — Originator — 3/21/97 — Date

Vinie Rosier — Nuclear Criticality Safety Review — 3-21-97 — Date

J Dean — NCS Manager — 3/21/97 — Date

TABLE OF CONTENTS

1.0 Introduction 1

2.0 Process Description 1

3.0 Technical Justification 1

4.0 Nuclear Criticality Parameter Discussion 4

5.0 Conclusions and Recommendations 4

5.1 Evaluation Summary 5

5.2 Conditions of Approval 6

5.3 Limits of Applicability 6

5.4 Criticality Safety Related Items 6

6.0 References 7

1.0 INTRODUCTION

The purpose of this document is to demonstrate that neither a Nuclear Criticality Safety Approval (NCSA) nor Criticality Accident Alarm System (CAAS) coverage is necessary for all operations involving small masses of fissionable materials at the Paducah Gaseous Diffusion Plant (PGDP). Specific isotopes of U, Np, Pu, Am, Cm, Cf, Th, Pa, and Es are addressed in this report.

2.0 PROCESS DEFINITION

A process boundary considered for the CAAS at PGDP is defined as the boundary between two unrelated areas. An unrelated area is defined as an area in which there can be no interchange of material across boundaries.[1] At PGDP, unrelated areas include processes performed in different rooms, or within the same room with immovable physical barriers for which there is no need to transfer fissionable material into or out of the area.

Each process or operation within the scope of this justification must be capable of measuring or conservatively estimating the isotopic mass present. Controls must be in place to assure that the mass limits on the fissionable isotopes which could be transferred into the process are not violated. Such controls include equipment decontamination requirements or operational limitations restricting the accumulation of fissile/potentially fissile materials.

3.0 TECHNICAL JUSTIFICATION

Figure III.B.6(100)-2 of ARH-600[2] specifies the minimum critical mass for ^{235}U at 100 wt.% to be approximately 830 grams. However, a more conservative mass of 15 grams ^{235}U is considered in this report to be consistent with the Department of Transportation (DOT) fissile exempt quantities for packaging and transporting radioactive material.[3] It would require a substantial violation of the 15 gram ^{235}U mass limit in order to approach the minimum critical mass of 830 grams (an increase in mass by approximately a factor of 55). In addition, a potential criticality would require the optimization of all other parameters associated with this minimum critical mass (e.g., geometry, moderation, reflection, etc.) and such a condition is not credible. Based on USEC-01,[4] a 15 gram mass of ^{235}U does not require CAAS coverage and does not require specific handling or storage requirements to be established in an NCSA.

Specific mass limits for other isotopes are not directly available and therefore must be established. However, the cross section libraries are not available for several actinides considered in this report and the computer code validation does not bound uranium enrichments greater than 5.5 wt% ^{235}U. Therefore, conservative estimates for the mass limits of these isotopes have been established such that neither specific NCSA restrictions nor CAAS coverage is required.

The method for determining acceptable mass limits for the other fissionable isotopes discussed in this report uses the ratio of the mass limit for ^{235}U to its minimum critical mass. For ^{235}U, this ratio is 15/840 or 1.8%. This ratio can also be used to estimate a similar mass limit for each of the other fissionable isotopes addressed in this report as discussed in ANSI/ANS 8.15.[5] The minimum critical mass for each isotope is also provided in ANSI/ANS 8.15. The mass limit of isotopes aggregated together can also be estimated using this ratio. This combined mass limit is based on the total mass of the mixture together with the mass limit of the most reactive isotope (i.e., the isotope with the lowest mass limit); however, the sum of the ratios of the mass of each isotope to its mass limit must not exceed unity.

A separate analysis completed at PGDP used a similar methodology to determine the safe handling and storage requirements for the same isotopes considered in this report[6] in the form of sources and standards. This analysis established a value of the ratio for the mass limit to the minimum critical mass of 1.6% assuming worst-case accident conditions (e.g., double batching, spacing violations, etc.). This value is more conservative than the value of 1.8% discussed above and therefore is used in establishing the mass limits in this report.

The values for the minimum critical mass and the mass limit for each isotope are presented in the following table of CAAS/NCS Mass Limits. The minimum critical mass values were obtained from ANSI/ANS standards[5],[7] as identified in the table. Each of these values was then multiplied by 1.6% to obtain the mass limit for each isotope which will not require a NCSA or CAAS coverage for handling or storage.

CAAS/NCS Mass Limits

Nuclide (Mixture of Nuclides)	Subcritical Mass (g)	Mass Limit (g)
U-233	540[a]	8.64[f]
U-235 with enrichments greater than or equal to 1.0 wt.%	760[a]	15[ef]
Combination of U-233 and U-235	540[c]	8.64[f]
Pu-238	3000[c]	48
Pu-239	450[b]	7.2
Pu-240	3000[c]	48
Pu-241	200[b]	3.2
Pu-242	3000[c]	48
Am-241	3000[c]	48
Am-242m	13[b]	0.208
Am-243	3000[c]	48
Cm-243	90[b]	1.44
Cm-244	3000[c]	48
Cm-245	30[b]	0.48
Cm-247	900[b]	14.4
Np-237	3000[c]	48
Cf-249	10[b]	0.16
Cf-251	5[b]	0.08
Cf-252	5[d]	0.08
Cf-250	5[d]	0.08
Th-228	5[d]	0.08
Pa-231	3000[c]	48
Cm-246	5[d]	0.08
Es-254	0	0
Combination of any two or more	*	*

[a]ANSI/ANS-8.1-1983 (uranium isotopes are bound by ^{235}U and ^{233}U)

[b]ANSI/ANS-8.15-1981 Table 2

[c]ANSI/ANS-8.15-1981 Table 1 (requires the lowest value in Table 1 for mixtures)

[d]A 5 gram limit was used for Cf-252 based on the Cf-251 limit since a computed value is not available. This is a conservative value to use since these nuclides are not fissile while Cf-251 is fissile and based upon several comparisons between thermal and fast systems, fast fission systems are less reactive than thermal systems.

[e]This limit is based on 10 CFR 71 requirements.

[f]This mass limit bounds uranium and its daughter products. This is a conservative value to use since the daughter products are not fissile while U-235 and U-233 are fissile and based upon several comparisons between thermal and fast systems, fast fission systems are less reactive than thermal systems.

*** The mass limit for combinations of nuclides shall be based on the nuclide with the lowest mass limit. This does not apply to the combination of uranium with its daughter products.**

4.0 NUCLEAR CRITICALITY PARAMETER DISCUSSION

This section provides a discussion of the parameters that can affect criticality safety during the handling and use of the sources and standards.

Mass: The masses for each isotope in any mixture are controlled with mass limits that have been shown to be equivalent to 15 grams of ^{235}U.

Enrichment: Not controlled

Volume: Not controlled.

Geometry: Not controlled.

Concentration: Not controlled.

Density: Not controlled.

Moderation: Not controlled.

Interaction: Not controlled

Reflection: Not controlled.

Neutron Absorption: Not controlled.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Evaluation Summary

There are adequate safeguards to ensure that the mass of any isotope identified in Section 3.0 will not exceed their respective mass limits which ensure safe operations without relying on the CAAS or specific NCSA requirements. This analysis assumed an enrichment of 100 wt.% for ^{235}U and therefore can be implemented for plant operation at any assay.

5.2 Conditions of Approval

In order for a process to be exempted from requiring an NCSA or CAAS coverage, it is necessary for measurements to be taken or conservative estimates to be made to assure the mass limits presented in Section 3.0 are not exceeded. In addition, each process must be separated by a process boundary to prevent the transference of materials which could result in the mass limits being exceeded.

5.3 Limits of Applicability

The conclusions of this evaluation are applicable to processes which satisfy the isotopic mass limits in Section 3.0 assuming that the isotopic mass values can be accurately measured or conservatively estimated. Such processes will be designated as not requiring an NCSA or CAAS coverage.

5.4 Criticality Safety Related Items

There are no items related to criticality safety which need to be implemented.

6.0 REFERENCES

1. ANSI/ANS-8.3-1986, *Criticality Accident Alarm System.*

2. ARP-600, Vol. II, *Criticality Handbook,* Atlantic Richfield Hanford Co., 5/23/69.

3. 10 CFR 71.53, *Packaging and Transportation of Radioactive Material - Fissile Material Exemptions*, Nuclear Regulatory Commission, 4/30/92.

4. USEC-01, *Application for United States Nuclear Regulatory Commission Certification, Paducah Gaseous Diffusion Plant,* updated through 3/7/97.

5. ANSI/ANS-8.15-1981, *American National Standard for Nuclear Criticality Control of Special Actinide Elements.*

6. NCSE GEN-24, Request 1744, *Nuclear Criticality Safety Evaluation for the Storage and Use of Standards and Sources at the Paducah Gaseous Diffusion Plant.*

7. ANSI/ANS 8.1-1983, *American National Standard for Nuclear Criticality Safety in Operations with Fissionable Materials Outside Reactors.*

ENCLOSURE 1

Technical Justification for the Exemption of C-746-A, C-733, C-754, C-754-A, C-333 and C-757 Waste Storage Facilities from Criticality Alarm Requirements, KY/S-267, Revision 1, dated March 10, 1997