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To: R.S. Osteen, 704-30L

From: D.W. Vinson, 773-41A

Subject: Transmittal of Report, *Classification of the Special Mk-50A Target Test Specimens as DOE Low-Level Waste for Disposal (WSRC-TR-2005-00274)*

Attached is the subject white paper report that describes the classification of the special Mk-50A target test specimens. After evaluating these materials against DOE Order 435.1 "Radioactive Waste Management" requirements and guidance as well as referenced statutes and requirements, the paper confirms that the special Mk-50A target test specimens are low-level waste. The special Mk-50A target test specimens are currently being stored in the SRS L-Basin.

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Classification of the Special Mk-50A Target Test Specimens As DOE Low-Level Waste for Disposal

Savannah River National Laboratory
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TITLE: **Classification of the Special Mk-50A Target Test Specimens As DOE Low-Level Waste for Disposal**

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Table of Contents

List of Tables

1.0 PURPOSE

Mk-50A target test specimens being stored in the SRS L-Basin are destined for permanent disposal. The Mk-50A target test specimens consist of two irradiated instrumented Mk-50A target assemblies and a single irradiated Mk-50A slug. This document demonstrates that the irradiated Mk-50A target test specimens are generated from a DOE activity and are subject to requirements for classification and disposal as radioactive waste in accordance with DOE Order 435.1. This document further demonstrates that, based on a technical interpretation of the order, the irradiated Mk-50A target test specimens are properly categorized as low-level waste (LLW) and will be safely managed consistent with DOE Order 435.1 requirements and guidance that are protective of the worker, public and environment.

2.0 DESCRIPTION OF WASTE

2.1 SRS Production of U^{233} Using Mk-50A Targets

Mk-50A targets that have a thorium oxide core and aluminum cladding were used for the production of ^{233}U in the Mixed Lattice Core in 1967-8 in K-Reactor. After irradiation, the targets were processed and the ^{233}U was recovered. The Mk-50A target pieces that are the subject of the current report are test specimens that were not processed to recover the ^{233}U generated during their service.

2.2 Mk-50A Target Test Specimens

The two specially instrumented test targets, each consisting of 8 target slugs and two dummy slugs, evaluated in the current analysis were irradiated in K-Reactor at the end of the Curium II charges (K-27-29) in 1967. One of these assemblies was positioned adjacent to the reactor core (identified as the core target) while the other instrumented assembly was positioned in the reflector or blanket region of the Curium II core (blanket target). The single Mk-50A target slug was irradiated in K-Reactor in the K-5.2 (Mixed Lattice) charge in 1968. This slug was set aside for a special evaluation upon removal from the reactor core. This slug is bounded in exposure and irradiation product content by a single slug of the blanket target assembly. Tables 1 & 2 provide the detailed contents of the subject Mk-50A target test specimens.

2.3 Waste Materials

The waste will consist of two general purpose (GP) bundles, each containing a single instrumented Mk-50A target test specimen, and a single target slug all packaged together in a Mk-50A carrier. The total volume of the waste is estimated by using the dimensions of an aluminum GP-Bundle as 12.7-cm diameter by 433.07-cm length and those of the carrier as a rectangle with the dimensions 40.64 × 53.34 × 14.605-cm. The volume of the two GP-Bundles plus one carrier is approximately 0.14-m^3.

Table 1 Calculated Mass (g) for Isotopes in Mk-50A Target Test Specimens

Contributing Isotope	Core Target (8 slugs)	Blanket Target (8 slugs)	Single Slug	Total
^{16}O	3.695E+03	3.698E+03	4.622E+02	**7.854E+03**
^{27}Al	5.295E+02	5.303E+02	6.628E+01	**1.126E+03**
^{85}Kr	1.024E-04	6.147E-04	7.683E-05	**7.938E-04**
^{90}Sr	6.713E-03	4.060E-02	5.075E-03	**5.238E-02**
^{90}Y		1.055E-05	1.319E-06	**1.186E-05**
^{99}Tc	1.335E-02	8.116E-02	1.014E-02	**1.046E-01**
^{129}I	5.779E-03	3.524E-02	4.405E-03	**4.542E-02**
^{137}Cs	1.075E-02	6.506E-02	8.133E-03	**8.394E-02**
^{232}Th	2.676E+04	2.670E+04	3.345E+03	**5.680E+04**
^{231}Pa	1.780E-03	2.578E-03	3.222E-04	**4.679E-03**
^{232}U		3.075E-05	3.844E-06	**3.459E-05**
^{233}U	7.163E+01	1.225E+02	7.310E+00	**2.014E+02**
^{234}U	6.203E-01	1.824E+00	2.280E-01	**2.672E+00**
^{235}U	2.069E-03	1.350E-02	1.688E-03	**1.725E-02**
^{236}U		6.613E-05	8.266E-06	**7.439E-05**
Total Mass (g)	**3.106E+04**	**3.105E+04**	**3.882E+03**	**6.599E+04**

Table 2 Calculated Activity (Ci) for Isotopes in Mk-50A Target Test Specimens

Contributing Isotope	Core Target (8 slugs)	Blanket Target (8 slugs)	Single Slug	Total
^{3}H	1.366E-03	8.221E-03	1.028E-03	**1.061E-02**
^{85}Kr	4.017E-02	2.413E-01	3.016E-02	**3.115E-01**
^{90}Sr	9.476E-01	5.731E+00	7.164E-01	**7.395E+00**
^{90}Y	9.479E-01	5.733E+00	7.166E-01	**7.397E+00**
^{99}Tc	2.285E-04	1.389E-03	1.736E-04	**1.791E-03**
^{137}Cs	9.351E-01	5.662E+00	7.077E-01	**7.304E+00**
^{137m}Ba	8.830E-01	5.346E+00	6.683E-01	**6.897E+00**
^{231}Pa	8.411E-05	1.218E-04	1.523E-05	**2.211E-04**
^{232}U	1.611E-04	6.791E-04	8.489E-05	**9.251E-04**
^{233}U	6.911E-01	1.182E+00	7.053E-02	**1.943E+00**
^{234}U	3.858E-03	1.135E-02	1.419E-03	**1.662E-02**
Total Activity (Ci)	**4.518E+00**	**2.407E+01**	**3.008E+00**	**3.159E+01**

3.0 DOE WASTE CLASSIFICATION

3.1 Definitions of DOE Waste Materials

DOE Manual 435.1-1 provides the definition of LLW as follows:

> Low-level radioactive waste is radioactive waste that is not high-level radioactive waste, spent nuclear fuel, transuranic waste, byproduct material (as defined in section 11e.(2) of the Atomic Energy Act of 1954, as amended), or naturally occurring radioactive material. [Adapted from: Nuclear Waste Policy Act of 1982, as amended].

The following definitions from DOE Manual 435.1-1 must be considered in order to determine the classification for the special Mk-50A targets.

> "High-level waste is the highly radioactive waste material resulting from the reprocessing of spent nuclear fuel, including liquid waste produced directly in reprocessing and any solid material derived from such liquid waste that contains fission products in sufficient concentrations; and other highly radioactive material that is determined, consistent with existing law, to require permanent isolation. [Adapted from: Nuclear Waste Policy Act of 1982, as amended]."

> Spent Nuclear Fuel is "fuel that has been withdrawn from a nuclear reactor following irradiation, the constituent elements of which have not been separated by reprocessing. Test specimens of fissionable material irradiated for research and development only, and not production of power or plutonium, may be classified as waste, and managed in accordance with the requirements of this Order when it is technically infeasible, cost prohibitive, or would increase worker exposure to separate the remaining test specimens from other contaminated material. [Adapted from: DOE 5820.2A]."

> "Transuranic waste is radioactive waste containing more than 100 nanocuries (3700 becquerels) of alpha-emitting transuranic isotopes per gram of waste, with half-lives greater than 20 years, except for: (1) high-level radioactive waste; (2) waste that the Secretary of Energy has determined, with the concurrence of the Administrator of the Environmental Protection Agency, does not need the degree of isolation required by the 40 CFR Part 191 disposal regulations; or (3) waste that the Nuclear Regulatory Commission has approved for disposal on a case-by-case basis in accordance with 10 CFR Part 61. [Source: WIPP Land Withdrawal Act of 1992, as amended]."

> Byproduct Material is "(1) Any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material, and (2) the tailings or wastes produced by the extraction or concentration of uranium or

thorium from any ore processed primarily for its source material content. [Source: Atomic Energy Act of 1954, as amended, section 11(e)]."

Source Material is "(1) Uranium or thorium, or any combination thereof, in any physical or chemical form or (2) ores which contain by weight one-twentieth of one percent (0.05%) or more of (i) uranium, (ii) thorium or (iii) any combination thereof. Source material does not include special nuclear material. [Source: 10 CFR Part 40]."

Special Nuclear Material is "(1) Plutonium, uranium enriched in the isotope 233 or in the isotope 235, and any other material which is determined, pursuant to the provisions of section 51 [of the *Atomic Energy Act of 1954*, as amended], to be special nuclear material, but does not include source material; or (2) any material artificially enriched by any of the foregoing, but does not include source material. [Source: *Atomic Energy Act of 1954*, as amended]."

3.2 Determination of Mk-50A Target Test Specimen Waste Category

Evaluating the special Mk-50A target test specimens against each of these definitions, the following logic is contained in the DOE 435.1-1 Manual and Guidance.

The target test specimens are not high-level waste based on the following arguments.

The subject waste is not high-level waste since it is not the results of any reprocessing activity. In fact, reactor irradiated targets or fuel, the constituent elements of which have not been separated by reprocessing, are considered spent nuclear fuel (not high-level waste) if they contain transuranium elements.

The subject waste is not spent nuclear fuel based upon the following arguments.

1) The target test specimens were manufactured with no fissile isotopes, and could thus not drive the nuclear chain reaction. They could therefore not technically be labeled as "fuel" in the first place.
2) The two instrumented target assemblies were very specifically fabricated as test specimens to evaluate the materials behavior and reaction while in reactor service prior to the actual Mixed Lattice core operation. They were instrumented to monitor and evaluate temperature and pressure in the assemblies during irradiation and therefore they were for research and development only. The single slug would be considered a test specimen when it was set aside for evaluation after irradiation.
3) The target test specimens were not used in the production of power or plutonium.
4) As seen in the definition of Spent Nuclear Fuel above, test specimens may be classified as waste, and managed in accordance with the requirements of DOE Order 435.1. In this case the test specimens are expected to meet the waste acceptance criteria for low-level waste (LLW) disposal in accordance with the Order.

5) Also, from DOE Guide 435.1Ch2, "excluded from spent nuclear fuel are target elements, that after irradiation contain no transuranium elements." The subject target test specimens contain no transuranium elements after irradiation, therefore, they are excluded from spent nuclear fuel. Historically, such spent targets have been managed as LLW and DOE Order 435.1 supports the continuation of this practice.

The subject waste is not transuranic waste based on the following arguments.

The subject waste is not transuranic waste as it contains no transuranic elements as defined by the 1S Manual WAC 2.02, Attachment 6 and presented in Tables 3 & 4.

Table 3 TRU† and Fissile Isotopes Common to SRS

Nuclide	Fissile	TRU
^{233}U	Yes	No
^{235}U	Yes	No
^{237}Np	No	Yes
^{238}Pu	No	Yes
^{239}Pu	Yes	Yes
^{240}Pu	No	Yes
^{241}Pu	Yes	No
^{242}Pu	No	Yes
^{241}Am	No	Yes

†DOE definition of TRU isotopes that contribute to TRUW is:
· Transuranic (atomic number > 92)
· Alpha emitter
· Half-life > 20 years

Table 4 Other TRU and Fissile Isotopes

Nuclide	Fissile	TRU
^{242m}Am	Yes	Yes
^{243}Am	No	Yes
^{244}Pu	No	Yes
^{243}Am	No	Yes
^{243}Cm	Yes	Yes
^{245}Cm	Yes	Yes
^{246}Cm	No	Yes
^{247}Cm	Yes	Yes
^{248}Cm	No	Yes
^{247}Bk	No	Yes
^{249}Cf	Yes	Yes
^{251}Cf	Yes	Yes

The subject waste is not byproduct material based upon the following arguments.

1) The targets are not tailings or wastes produced by the extraction or concentration of uranium or thorium from any ore.
2) The instrumented target assemblies were not irradiated to produce or utilize special nuclear material (SNM).
3) The definition of special nuclear material stipulates that the SNM does not include source material. The definition of source material states that source material does not include SNM. An unirradiated Mk-50A target would be considered source material based upon the definition. The irradiation process yields a product that contains ^{233}U and thorium. Taken separately, these would be considered SNM and source material, respectively. However, the combination of the two materials would be considered neither source material nor SNM based upon their respective definitions, as provided previously. The subsequent processing of the target assembly to recover the ^{233}U (SNM) from the target assembly would yield some quantity of other material that would meet part (1) of the definition of byproduct material. The subject Mk-50A target assemblies have clearly not been generated incident to the process of producing or utilizing SNM, as this process (extraction of SNM) has not been performed on these assemblies. We therefore conclude that the target pieces are not byproduct material.

The subject target test specimens are low-level wastes based upon the definition provided in Section 3.1.

Having evaluated the subject targets against all other possibilities, it is concluded based upon the definition of LLW that these targets are indeed LLW and would be managed by DOE Order 435.1 and its Manual and Guidance. DOE Order 435.1 provides requirements for the management of LLW, TRU and HLW and the requirements are performance based. In the case of LLW disposal, the Order sets out performance objectives that must be demonstrated. Chapter IV.P says that LLW disposal facilities shall be sited, designed, operated, maintained, and closed so that a reasonable expectation exists that the following performance objectives will be met for waste disposed of after September 26, 1988:

- Dose to representative members of the public shall not exceed 25 mrem in a year total effective dose equivalent from all exposure pathways, excluding the dose from radon and its progeny in air.

- Dose to representative members of the public via the air pathway shall not exceed 10 mrem in a year total effective dose equivalent, excluding the dose from radon and its progeny.

- Release of radon shall be less than an average flux of 20 $pCi/m^2/s$ at the surface of the facility.

3.3 NRC Waste Classification

A performance assessment (PA) and composite analysis (CA) is conducted on a DOE disposal facility to provide a reasonable expectation that the performance objectives will be met by establishing parameters, limits, and controls on the siting, design, operations, maintenance, and closure of the facility in order for there to continue to be an expectation that the criteria delineated in the objectives are met. Disposal of DOE LLW is authorized by DOE-HQ based on the PA and CA demonstration of performance of the waste form in the disposal facility including the properties and radionuclide content.

The DOE Order 435.1 requirements and system for LLW disposal does not use the waste classification system provided by the Nuclear Regulatory Commission (NRC) for waste generated, treated stored or disposed by NRC licensed commercial activities. The NRC waste classification system for waste generated by commercial activities uses waste concentration limits that designate a waste as Class A, B, C, or greater-than-Class C (GTCC) in accordance with 10 CFR 61.55. The target test specimen waste as discussed above is not a waste proposed for disposal in an NRC licensed commercial LLW disposal facility nor was it generated from a commercial activity, therefore the waste is not subject to the NRC waste classification system. However, for additional information the calculations were completed to determine the equivalent NRC waste classification. Table 5 provides the summary of the calculations used for the classification of the subjected target test specimens based upon the NRC waste classification system. Results of this calculations shows that the amount of ^{99}Tc in the subject waste is less than the limit provided by Table 1 of 10CFR61.55 for Class C waste. The sum-of-fractions rule is used for ^{3}H, ^{90}Sr, and ^{137}Cs isotopes listed in Table 2 of 10CFR61.55. Since the activity density, or concentration, of ^{137}Cs the Class B limit, the isotopes are evaluated against the Class C limits shown in the fifth column of Table 5. The results show that the waste is clearly not GTCC waste as the calculated sum-of-fractions, 0.0187, is not greater than 1.

Table 5 Evaluation of the NRC Waste Classification of the Mk-50A Target Test Specimens

Nuclide	Activity (Ci)	Activity Density (Ci/m^3)	Class B Limit (Ci/m^3)	Class C Limit (Ci/m^3)	Fraction Class C
Table 1 10CFR61.55					
^{99}Tc	1.791E-03	1.267E-02		3.000E+00	N/A
Table 2 10CFR61.55					
^{3}H	1.061E-02	7.505E-02	No Limit	No Limit	
^{90}Sr	7.395E+00	5.231E+01	1.500E+02	7.000E+03	7.472E-03
^{137}Cs	7.304E+00	5.166E+01	4.400E+01	4.600E+03	1.123E-02
				Sum of Fractions	**1.870E-02**

4.0 CONCLUSION

Irradiated Mk-50A target test specimens that are currently being stored in L-Area Disassembly area have been demonstrated to be LLW as defined by DOE Order 435.1 and its Manual and Guidance. Further, it has been determined that the subject material is not GTCC waste in accordance with the NRC waste classification system. This material can be disposed of pursuant to DOE Order 435.1.