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DOE Packaging Certification Program

Safety Evaluation Report for Content Amendment for Low Melting Point Target Capsule Design and Contents in the Model SAFESHIELD 2999A Package

Docket No. 16-40-9519

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This Safety Evaluation Report (SER) documents the U.S. Department of Energy (DOE) Packaging Certification Program (PCP) independent technical review of the application submitted by the Los Alamos Field Office (LAFO) to amend DOE Certificate of Compliance (CoC) Number 9519 to authorize a new design of the Low Melting Point (LMP) Target Capsule for transport of irradiated LMP targets in the Model SAFESHIELD 2999A packaging.

Summary

By memorandum [1] dated December 14, 2016, LAFO requested DOE to authorize a content amendment to DOE CoC Number 9519, Revision 4, to include a new design of the LMP Target Capsule for transport of irradiated LMP targets in the Model SAFESHIELD 2999A package. The CoC amendment was required due to a new design for a rubidium target required by LANL for Sr-82 production.

The applicant submitted Revisions 6 and 7 page changes [2, 3] to the SAFESHIELD Safety Analysis Report for Packaging (SARP) [4] in support of this request. The addition of this content does not affect the packaging design or operational features.

On the basis of the statements and representations in the SARP, Revision 5 (i.e., Revision 4 and Revision 5 page changes), as supplemented by page change Revisions 6 and 7, and PCP staff's confirmatory evaluation as summarized in this SER, staff finds this amendment to the Model SAFESHIELD 2999A package acceptable, and will provide reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

This SER will hereafter refer to page change Revisions 6 and 7 as the "application", the LMP Target Capsule as the "Target Capsule" and the Model SAFESHIELD 2999A as the "package", unless otherwise specified.

Evaluation

SARP Revision 5 (i.e., Revision 4 and Revision 5 page changes) was supplemented by this application to incorporate a change to the LMP Target Capsule design. The change was required due to a new design for a rubidium target required by LANL for Sr-82 production. The new target is larger than those previously used and therefore could not fit into the existing Target Capsule design, so the new LMP Target Capsule design has a larger cavity size. In addition, the construction material of the Target Capsule has been changed from stainless steel to titanium to reduce the capsule weight and for compatibility with liquid gallium and rubidium.

PCP staff reviewed the SARP Revision 6 page changes and generated four (4) Q1 questions for the applicant. The applicant responded to staff's questions and submitted SARP Revision 7 page changes to incorporate the responses accepted by staff. Staff also conducted independent confirmatory structural, thermal, containment, and shielding evaluations of the page changes to the SARP in support of this amendment to the CoC.

1.0 General Information

1.1 Packaging Description

There are no changes to the existing packaging design or operational features authorized in the CoC and described in the SARP. This packaging is used as a general purpose container for the shipment of radioactive material (RAM) in special form capsules, welded capsules not qualified as special form, capsules having a removable top (e.g. screw or bayonet fastening), or accelerator targets containing solid, liquid (metal) or gaseous radioactive material. The RAM is loaded in various product containers described in the SARP and authorized in the CoC.

The Target Capsule is an important-to-safety packaging component (Category A) and product container that is required for liquid gallium and rubidium targets to provide additional confinement under Hypothetical Accident Conditions (HAC). The overall dimensions of the capsule are approximatley180 millimeters (7.09 inches) in diameter by 140 millimeters (5.5 inches) in height, with a usable cavity of approximately 105 millimeters (4.1 inches) in diameter by 96 millimeters (3.8 inches) in height. The capsule consists of a flanged-body and lid constructed of ASTM B348 Grade 5 titanium alloy; the lid is secured to the body by twelve modified 3/-8 inch ASTM A193 Grade B8M Class 1 stainless steel screws. O-ring grooves are milled into the flanged-body for leak testing the closure. The O-ring material for the inner seal is Inconel® for compatibility with the contents and ethylene propylene for the outer seal for testing the closure. The Target Capsule design is defined on *Target Capsule Design No. 4082*, Drawing No. 1C-7060, Issue C, dated 9/16/2015. Up to three Target Capsules may be loaded per package.

1.2 Contents

Table 1.1-VI, *Contents Type VI* of the SARP was revised by SARP Revision 6 page changes for irradiated LMP metal accelerator targets to clarify and correct the physical form of the

radioactive material; number of contents items; product containers; radionuclides, and the addition of trace quantities of radionuclides. Specifically,

- The physical form of the radioactive material was revised to clarify metal gallium and rubidium (which may be liquid), and with no water present.

- The number of content items was revised to authorize up to four targets (each in its Target Cell) per Target Capsule. Irradiated Target Cells per Table 3 of the CoC may also be loaded in the containment vessel together with Target Capsules. Up to three Target Capsules may be loaded in the package containment vessel.

- The product container information was revised to; authorize the use of Inconel®, in addition to stainless steel, for Target Cell material for rubidium metal contents; reference the new Target Capsule drawing (1C-7060), define its function (confinement under HAC), and leakage test requirements (annual leak test, pass criterion of 10^{-3} reference cubic centimeters); clarify the function of the Target Cell (further confinement of the RAM); and define the use of the Target Carrier (convenience handling of Target Capsules or Target Cells, and shoring between the contents and the CV to prevent no more than 15 millimeters of movement of the contents).

- The radionuclides were revised to define the limits for metallic gallium and rubidium and all other radionuclides; and Irradiated Target Cells per Table 3 of the CoC that may be included with Target Capsules in the containment vessel. A formula for calculating the sum of the activity fractions to their respective activity limits (i.e., sum less than or equal to 1) was added to Table 1.1. This formula was described in the SARP Table 1.1.

- Trace quantities of radionuclides were added to authorize up to 1% of total activity of the contents.

The applicant also revised SARP Table 1.2, *Radionuclide Limits*, in the SARP Revision 6 page changes to update the activity, A_2 values, or mass values for the following radionuclides: Kr (74-77, 79, 81, and 85m), Rb-82m, Xe (121-125, 127, 129m, 313m, 133m, and 133), and Bi (205-207). Table Note 2 was revised to add Rb-82m and its reference.

1.3 Radiation Level and Transport Index

The actual TI of the package will be determined by measurement prior to shipment.

1.4 Conclusion

Based on a review and evaluation of the statements and representations in the SARP, page change Revisions 6 and 7, and PCP staff's confirmatory evaluation, staff concludes that the package has been described in sufficient detail to provide an adequate basis for its evaluation under 10 CFR Part 71.

2.0 Structural Evaluation

PCP staff reviewed and evaluated the structural design and performance of the package as described in Chapter 2 of the application for the new Target Capsule design. The review and evaluation focused on: (a) weight of the Target Capsules with RAM contents, (b) design, performance and test results of the Target Capsule, and c) material compatibility between the Target Capsule, RAM contents, and other packaging components.

The LMP Target Cells contain radioactive metal gallium and rubidium, which may be in liquid form under Normal Conditions of Transport (NCT) and HAC temperatures. Up to 4 targets (each in its Target Cell) may be loaded in a Target Capsule and up to three Target Capsules per package. The maximum content weight for LMP metal targets is 100 kg (220 lb.), which is same as the authorized maximum content weight for the package.

The Target Capsule is constructed of ASTM B348 Grade 5 titanium alloy, and is subjected to a sub-set of the §71.75 special form tests to demonstrate its performance and capability to provide confinement of the LMP gallium and rubidium, should they leak from the Target Cells under HAC. Test results were summarized in *Test Report for Target Capsule Design No. 4082 – Special Form Tests*, TR 2016/08/01, Issue A, dated September 19, 2016. A 9-meter drop test and 1-meter percussion tests were performed in accordance with the test requirements detailed in the test plan *Target Capsule Design No 4082 Test Plan and Procedure for Special Form Mechanical Tests*, CP 501 Issue B, dated July 25, 2016. Following the 9-meter drop test and the 1-meter percussion test, the Target Capsules was removed from the test container and visually examined showing no significant damage; furthermore, the Target Capsule also passed the leakage test. The maximum temperature of the package under HAC is less than the design bounding temperature of 200-degrees C, which is lower than the Inconel® metal O-ring continuous working temperature. In summary, the titanium Target Capsule has been demonstrated to be capable of providing confinement of the LMP metals in liquid form should they leak from the Target Cells under HAC.

The material for the Target Cells is niobium for gallium metal contents, and Inconel® or stainless steel for rubidium metal contents. The Target Capsule is constructed of titanium alloy whose O-ring material is Inconel®. The containment vessel portion of Flask 2993 is made from stainless steel, so there are no material compatibility issues between the new Target Capsule, Target Cells, and other packaging components.

2.1 Evaluation Findings

Based on review of the statements and representations in the SARP, page change Revisions 6 and 7, and the PCP staff's confirmatory evaluation, staff finds the structural design and performance presented in Chapter 2 of the application acceptable and will provide reasonable assurance that the regulatory requirements in 10 CFR 71 have been met.

3.0 Thermal Evaluation

PCP staff reviewed and evaluated the thermal design and performance of the package described in Chapter 3 of the application for the new Target Capsule design and LMP metal targets. The review and evaluation focused on: (a) the decay heat of the LMP metal targets, and (b) the maximum temperatures of packaging components with new capsule material and new configuration.

LMP metal targets have maximum decay heat up to 200W per package, as shown in Table 1.1-VI *Contents Type VI* of the application, which is lower than authorized maximum decay heat of 250W for the package. For the 250W heat load, the calculated temperature of the accessible surface in shade is below 50-degrees C under NCT, and the peak temperatures of the O-ring and other packaging components are all below the allowable temperature limits of the material under both NCT and HAC. The larger new Target Capsule and change of the construction material from stainless steel to titanium does not alter the thermal performance of the packaging because the thermal conductivity of titanium is slightly higher than that of stainless steel. Therefore, the package with Contents Type VI should satisfy the regulatory requirements as specified under both NCT (§§71.43(g) and 71.71) and HAC (§71.73).

3.1 Evaluation Findings

Based on the statements and representations in the SARP, page change Revisions 6 and 7, and PCP staff's confirmatory evaluation, staff finds the thermal design and performance presented in Chapter 3 of the application acceptable and will provide reasonable assurance that the regulatory requirements in 10 CFR 71 have been met.

4.0 Containment

PCP staff reviewed and evaluated the containment design and performance of the package described in Chapter 4 of the application for the new Target Capsule design containing the new LMP targets. The review focused on the confinement capability of the Target Capsule should the LMP metals leak out of the Target Cells under HAC, in which case the containment function of the packaging may be compromised.

The containment system of packaging is provided by the sealing system of the Flask 2993, to which is fitted a stainless steel containment vessel. The containment vessel employs double EPM O-rings. The packaging was subjected to NCT and HAC tests and the containment vessel was shown to be leaktight following these tests.

The Target Capsule design passed a sub-set of the §71.75 special form tests, as discussed in Section 2 of this SER. The Inconel® metal O-ring used as the inner O-ring for the Target Capsule has a working temperature of greater than 200-degrees C for continuous operation, which is higher than the calculated O-ring temperature under HAC. Section 2 of this SER also discussed material compatibility between titanium, Inconel®, and the LMP metals and concluded that the Target Capsule design is capable of providing confinement of the LMP metal contents, should they leak out of the Target Cells under HAC. Therefore, the EPM O-ring of the

containment vessel should be intact and remain effective for the containment performance of the package.

4.1 Evaluation Findings

Based on the statements and representations in the SARP, page change Revisions 6 and 7, and PCP staff's confirmatory evaluation, staff finds the containment design and performance of the package presented in Chapter 4 of the application acceptable and will provide reasonable assurance that the regulatory requirements in 10 CFR 71 have been met.

5.0 Shielding Evaluation

PCP staff reviewed the shielding design and performance of the package as described in Chapter 5 of the application for the new Target Capsule design containing the new LMP metal targets. The content limit for Rb-82m was determined by calculation of the dose rate on the package surface and at 1-meter from the package surface for 1-Curie of Rb-82m. The applicant used Microshield® code versions 9.05 for their shielding evaluation in the application and version 6.02 in the SARP; staff used Monte Carlo N-Particle Transport Code 5 (MCNP 5) version 5.1.6 for the confirmatory shielding evaluation.

5.1 Shielding Design

The package consists of a shielding flask (Flask 2993) inside a double-skinned insulated casket (Casket 2999).

The Casket 2999 consists of a double-skinned, low carbon steel base assembly and a double-skinned low carbon steel cover assembly. The cover assembly is fastened to the base assembly with stainless steel studs and nuts. The cavity between the double skin of the base assembly and cover assembly is filled with a Thermal Insulating and Shock Absorbing Foam (TISAF).

Flask 2993 is fabricated as a stainless steel shell to which is fitted a stainless steel containment vessel, with the space between the containment vessel and Flask 2993 body shell filled with 4% Sb-lead shielding. The radial thickness of the 4% Sb-lead shielding on the flask side is nominally 213 millimeters (8.38 inches). The shielding in the base and top plug is slightly greater than the radial thickness.

Restricting the amount of source material in the package is the primary means for keeping the radiation dose rates below the regulatory limits.

5.2 Source Specification

The photon spectrum and source strength (photons/s) for a point source of 1-Curie of Rb-82m was used in the shielding calculations. The photon spectrum was described with 12 energy groups in the Microshield® version 6.02 calculations in the SARP, whereas PCP staff used 56 energy groups in the MCNP5 calculations in the confirmatory analyses.

5.3 Shielding Model

The shield regions, materials, dimension and densities for the NCT and HAC configurations used in the applicant's shielding model are shown in Tables 5.2, 5.3 and 5.4 of the SARP. Staff confirmed that the limiting configuration is the exposure at the side of the package. The Rb-82m source was modeled as a point source located at the center of the flask cavity at the centerline. The dose rates for the NCT and HAC configurations were calculated at the surface and at 1-meter from the surface of the package.

In the HAC model the honeycomb is assumed to be reduced in thickness to represent the deformation after impact, all TISAF is replaced by air, the surface of the Casket 2999 is assumed to be deformed inwards radially by 2.5 cm, and the air gaps are closed up such that the source to external surface distance is reduced. The shield regions, materials, dimensions, and densities for the NCT and HAC configurations used in the applicant's shielding calculations are shown in Tables 5.2 through 5.4 of the SARP.

5.4 Shielding Analysis

Microshield® code version 9.05 was used for the shielding calculations in the application and PCP staff used MCNP5, version 5.1.6 (ENDF/B-VII cross sections) for the confirmatory evaluation. The ANSI/ANS-6.1.1-1977 *Neutron and Gamma-Ray Fluence-to-Dose Factors* were used to calculate personnel doses. Table 5.1 below compares the applicant's calculated NCT and HAC dose rates for 1-Curie (1.53×10^{11} photon/s) of Rb-82m verses staff's results.

Table 5.1 - Maximum Dose Rates Calculated for the Package under NCT and HAC

Package Location	Dose Rate (mSv/hr.)			
	NCT/Application	NCT/Staff	HAC/Application	HAC/Staff
Surface	2.43×10^{-4}	2.39×10^{-4}	3.55×10^{-4}	2.60×10^{-4}
1-meter from Surface	1.91×10^{-5}	1.36×10^{-5}	2.15×10^{-5}	1.50×10^{-5}

Based on the calculated dose rates for 1-Ci of Rb-82m, the content limit was determined for the NCT configuration to meet the §71.47(a) limits. Table 5.2 below compares the applicant's calculated maximum allowable activity verses PCP staff's results.

Table 5.2 - Maximum Allowable Activity Based on the §71.47(a) Dose Rate Limits under NCT

Package Location	§71.47(a) Limit (mSv/h)	Max. Activity/Application (Ci)	Max. Activity/Staff (Ci)
Surface	2.0	8,200	8,300
1-meter from Surface	0.1	5,236	7,300

The activity limit for Rb-82m in Table 1.2 of the application is 1,000 Curies, which is much lower than the applicant's calculated maximum allowable activity of 5,236 Curies (rounded to 5.2 kilocuries) under NCT in Table 5.2.

Under HAC, the applicant's calculated dose rate at 1-meter from the surface of the package containing 5.2 kilocuries would be 0.11 mSv/hr., compared with PCP staff's result of 0.08 mSv/hr. The calculated dose rates are below the 10 mSv/hr. limit specified in §71.51(a)(2) under HAC.

5.5 Evaluation Findings

Based on the statements and representations in the SARP, page change Revisions 6 and 7, and PCP staff's confirmatory evaluation, staff finds the shielding design and performed presented in Chapter 5 of the application acceptable and will provide reasonable assurance that the regulatory requirements in 10 CFR 71 have been met.

6.0 Criticality Evaluation

PCP staff reviewed and evaluated the criticality safety design and performance of the package as described in Chapter 6 of the application for the new Target Capsule design containing the new LMP metal targets. The LMP metal targets do not contain any fissile material.

6.1 Evaluation Findings

Based on the statements and representations in the SARP, page change Revisions 6 and 7, and PCP staff's confirmatory evaluation, staff finds that the criticality safety design and performance presented in Chapter 6 of the application acceptable, and will provide reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met.

7.0 Package Operations

PCP staff reviewed and evaluated the package operations as described in Chapter 7 of the application for the new Target Capsule design containing the new LMP metal targets. The LMP targets do not affect package operations.

7.1 Evaluation Findings

Based on the statements and representations in the SARP, page change Revisions 6 and 7, and PCP staff's confirmatory evaluation, staff finds the package operations presented in Chapter 7 of the application acceptable, and will provide reasonable assurance that the regulatory requirements in 10 CFR 71 have been met.

8.0 Acceptance Tests and Maintenance Program

PCP staff reviewed and evaluated the acceptance tests and maintenance program of the packaging as described in the application for the new Target Capsule design containing the new LMP metal targets. The LMP targets do not affect the acceptance tests and maintenance program.

8.1 Evaluation Findings

Based on the statements and representations in the SARP, page change Revisions 6 and 7, and PCP staff's confirmatory evaluation, staff finds the acceptance tests and maintenance program presented in Chapter 8 of the application acceptable, and will provide reasonable assurance that the regulatory requirements in 10 CFR 71 have been met.

9.0 Quality Assurance

PCP staff reviewed and evaluated the quality assurance program packaging as described in the application for the new Target Capsule design containing the new LMP metal targets. The LMP targets do not affect the quality assurance program.

The quality level assigned to the Target Capsule is addressed in Table 9.1, *Q-List for SAFESHIELD 2999A (Graded Approach Assessment Results)*, of the application. PCP staff concurs with the applicant's quality category assignment (Quality Category A) and rational for that assignment for the Target Capsule.

9.1 Evaluation Findings

Based on the statements and representations in the SARP, page change Revisions 6 and 7, and PCP staff's confirmatory evaluation, staff finds the quality assurance program presented in Chapter 9 of the application acceptable, and will provide reasonable assurance that the regulatory requirements in 10 CFR 71 have been met.

Conditions of Approval

The following changes to the CoC are required to implement the conditions in this SER.

- Packaging 5.(a)(3), replace "DL-2C-5449, Sheet 1/1, Issue A Drawing List for Target Capsule Design No. 3963" with "DL-1C-7060, Sheet 1/1,Issue B, Drawing List for Target Capsule Design No 4082".
- Contents 5.(b)(1) added "(vi) Irradiated LMP metal accelerator targets as specified in Table 6."
- Contents 5.(b)(1), added Table 6, from Table 1.1-VI *Contents Type VI* of the application.
- Contents 5(b)(2), revised <u>from</u> "...specified in Tables 1 through 5. For the contents described in 5(b)(1)(i) through 5(b)(1)(v)" <u>to</u> "...specified in Tables 1 through 6. For the contents described in 5(b)(1)(i) through 5(b)(1)(vi)"
- Conditions 5.(c)(9), revised <u>from</u> "...requirements of Chapter 9 of the SARP." <u>to</u> "...requirements of Chapter 9 of the SARP, as supplemented by 5.(d)(2) and 5.(d)(3) of this certificate."
- Condition 5.(c)(10), replaced with "Revision 4 of this certificate may be used until August 30, 2018."
- Supplements 5.(d)(2) added "*Safety Analysis Report for Packaging SAFESHIELD 2999A,* Rev. 6 page changes, dated September 26, 2016"

- Supplements 5.(d)(3) added "*Safety Analysis Report for Packaging SAFESHIELD 2999A,* Rev. 7 page changes, dated March 21, 2017."

Conclusion

Based on the statements and representations in the SARP Revision 5, as supplemented by page change Revisions 6 and 7, and PCP staff's confirmatory evaluation as summarized in this SER, staff finds this amendment to the Model SAFESHIELD 2999A package acceptable, and will provide reasonable assurance that the regulatory requirements of 10 CFR Part 71 have been met, subject to the Conditions in the CoC and listed above.

References

[1] *SAFESHIELD 2999A Safety Analysis Report for Packaging Revision - Docket 16-40-9519*, from Kimberly Davis Lebak to James M. Shuler, December 14, 2016.

[2] *Safety Analysis Report for Packaging SAFESHIELD 2999A,* Rev. 6 page changes, September 26, 2016.

[3] *Safety Analysis Report for Packaging SAFESHIELD 2999A,* Rev. 7 page changes, March 21, 2017.

[4] *Safety Analysis Report for Packaging SAFESHIELD 2999A,* Rev. 5, October 17, 2011.