SANDIA REPORT

SAND2010-6113
Unlimited Release
Printed September 2010

PAT-1 Safety Analysis Report Addendum Author Responses to Request for Additional Information

Docket No. 71-0361

Reference: Letter Eric Brenner, U.S. NRC to Maximo Barela, U.S. DOE-NNSA, dated March 1, 2010

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Abstract

The Plutonium Air Transportable Package, Model PAT-1, is certified under Title 10, Code of Federal Regulations Part 71 by the U.S. Nuclear Regulatory Commission (NRC) per Certificate of Compliance (CoC) USA/0361B(U)F-96 (currently Revision 9). The National Nuclear Security Administration (NNSA) submitted SAND Report SAND2009-5822 to NRC that documented the incorporation of plutonium (Pu) metal as a new payload for the PAT-1 package. NRC responded with a Request for Additional Information (RAI), identifying information needed in connection with its review of the application. The purpose of this SAND report is to provide the authors' responses to each RAI. SAND Report SAND2010-6106 containing the proposed changes to the Addendum is provided separately.

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INTRODUCTION

In 2009, the National Nuclear Security Administration (NNSA) submitted SAND2009-5822, PAT-1 Safety Analysis Report Addendum to the U.S. Nuclear Regulatory Commission (NRC) for revision of the Certificate of Compliance (CoC) No. 0361 for the Model No. PAT-1 transportation package. The Safety Analysis Report (SAR) Addendum proposed to add plutonium metal to the list of authorized contents.

The NRC responded to the application for revision with a Request for Additional Information (RAI). This document addresses each of the NRC's RAI questions. A companion document, SAND2010-6109 provides the proposed changes to SAR Addendum.

Format of RAIs and Responses

In the next segment of this document, "Requests for Additional Information and Responses," each Request for Additional Information and its response is listed by section number, e.g., Section 1: General Information. The section number refers to the text in the original SAND document, SAND2009-5822. Eight sections are listed in the current document because RAI queries were submitted for 8 of the 9 sections in SAND2009-5822.

REQUESTS FOR ADDITIONAL INFORMATION AND RESPONSES

Section 1: General Information

Request for Additional Information: 1-1

(a) Clarify whether the elastomeric O-ring or the copper gasket (within the TB-1 vessel) serve as parts of the PAT-1 containment boundary.

The applicant stated in the PAT-1 SAR Addendum 1.0 that the TB-1 vessel is the containment boundary of the PAT-1 package. However, based on the thermal tests performed in the PAT-1 SAR Addendum 3.0, the TB-1 maintains containment, when the elastomeric O-ring decomposes, but the copper gasket still maintains its seal during post-fire plutonium air transport accident conditions. The applicant should clarify whether the elastomeric O-ring or the copper gasket at TB-1 is a part of the PAT-1 containment boundary.

(b) Clarify how pre-shipment leak testing will verify that the copper gasket is able to maintain containment, independently of the elastomer seals.

The elastomer seals do not contribute to containment during the 60-min. fire test, thus pre-shipment leak testing of only the copper gasket may be necessary to meet the regulatory requirements.

This information is required by the staff to determine compliance with 10 CFR 71.33, 71.43, 71.74, and 71.88.

Applicant Response:

(a) The copper gasket within the TB-1 containment vessel is the containment boundary seal and is supplemented by the elastomer O-ring for the plutonium oxide contents except in the case of the accident conditions for air transport of plutonium one-hour fire where the elastomer seal decomposed. For the plutonium metal contents covered by this Addendum, the copper seal is the containment boundary seal and the elastomer O-ring is not used. The following arguments demonstrate that the copper gasket is the containment boundary seal for Normal Conditions of Transport (NCT), Hypothetical Accident Conditions (HAC), and accident conditions for air transport of plutonium:

A comparison is made for the copper gasket and elastomeric seal leakage rates. The copper gasket provided the low leakage rates observed in the NCT and HAC (Appendix A and B, respectively, of 10 CFR 71 for the 1978 period) as cited in Table 4-1 of the PAT-1 SAR, which shows the post test results of helium leak rate of less than 1×10^{-10} atm-cc/sec for NCT and 1×10^{-10} atm-cc/sec for HAC. Note that 10^{-7} atm-cc/sec is the leak test criterion for the TB-1 for the acceptance, periodic, and maintenance tests. The 1×10^{-10} atm-cc/sec leakage rate demonstrated that the copper gasket with knife-edge sealing surfaces was the containment boundary seal because this very low leak rate can be achieved only with a copper gasket and not an elastomer seal due to permeation. As described in the SAR, the TB-1 was filled with helium prior to testing. During the period after filling, the elastomer seal would have been saturated with helium and would have produced a permeation leak rate of about 10^{-6} std cc/sec. From page 691 of the "Nondestructive Testing Handbook[a]", Table 2. Air permeabilities of elastomers (reproduced below), the permeability for Viton® A is (0.88 x 10^{-7} std cm^3/s)/(cm^2/cm). The air permeability multiplied by the length of the O-ring (πD or π x 4.22) x 0.88 x 10^{-7} = 1.17 x 10^{-6} std cm^3/s for the permeation leak rate.

TABLE 2. Air permeabilities of elastomers

	Permeability $[\mu Pa \cdot m^3/s]/[m^2/m]$ $\times 10^{-6}$	$[std\ cm^3/s]/[cm^2/cm]$ $\times 10^{-7}$
Butyl	0.32	0.32
Thiokol	0.37	0.37
Nitrile [high acrilo nitrile]	0.41	0.41
Hypalon S-2	0.7	0.7
Kel-F	0.80	0.80
Nitrile [low acrilo nitrile]	0.8	0.8
Viton A	0.88	0.88
Polyurethane	0.97	0.97
Chloroprene	0.98	0.98
Acrylon EA-5	1.5	1.5
Hycar 4021	1.8	1.8
GR-S	2.9	2.9
Natural	4.4	4.4
Fluoro-rubber 1F4	9.6	9.6
Fluoro-silicone	12.8	12.8
Silicone	45.0	45.0

Note: Permeability is expressed in $(Pa \cdot m^3/s)/(m^2/m)$ at 22 °C, which would permeate through one square meter of elastomer 1m thick at a differential pressure of 1 atm (100 kPa) at a temperature of 80 °C (176 °F). Table provided by Parker Seal Co. Data obtained from WADC Technical Report 56-331, Development of High Temperature Resistant Rubber Compounds, B. A. Hayes, F. M. Smith, W. A. Smith, and L. J. Kitchen, Feb 1958. Values were converted to SI units. The permeabilities given are for typical reinforced compounds; special compounding techniques can substantially change these rates.

[a] *Nondestructive Testing Handbook, Second Edition, Volume One Leak Testing", ASNT and ASM, 1982, Table 2.*

Since the measured leak rate was less than 1x10^{-10} atm-cc/sec for the TB-1 for both NCT and HAC, clearly it was the copper seal that provided the very low leak rate. Otherwise, the O-ring would have been saturated after more than a day of being exposed to the helium fill tracer gas within the TB-1 in preparation for and during testing. The helium mass spectrometer leak test measurement device used to test the TB-1 would have produced a higher leak rate measurement if the copper seal had not functioned properly.

For accident conditions of air transport of plutonium (10 CFR 71.74), the copper gasket clearly provided the containment boundary seal since the elastomer decomposed under the 582°C (1080°F) environment experienced by the TB-1 in the post test fire environment.

No leakage or seal area (or any other visible) deformation occurred during the original PAT-1 certification tests and, based upon the structural analysis performed in Section 2 of the Addendum, none would occur with the new metal contents except for minimal localized denting of the TB-1. Thus for NCT, HAC, and accident conditions for air transport of plutonium, the area around the copper seal remained elastic. Because the strength of the elastomer is negligible relative to the strength of the PH13-8Mo stainless steel of the TB-1, the structural performance of the TB-1 containment vessel without the elastomeric O-ring will not be affected.

(b) As stated in (a), the package configuration for plutonium metal shipments will not include the TB-1 elastomeric O-ring. Because of the need to meet the requirements for overseas transports, the preshipment leakage rate criterion is 10^{-7} atm cc/s. For the pre-shipment leakage rate test, the copper gasket is directly tested against the internal pressure (atmospheric when the vessel was closed) within the TB-1 containment vessel and the pressure outside of the TB-1 provided by the leak test vessel; thus a pressure differential of one atmosphere is provided to test the copper gasket. Since the copper seal is directly tested with each use for the plutonium metal shipments, we recommend performing an annual maintenance leakage rate test rather than testing after every third shipment as specified in the SAR for plutonium oxide. See Sections 8.2.2 and 8.3.2 of SAND2010-6109 for leakage tests.

Change Pages for SAR Addendum:

Section 1
Page 1-1, added note about removing use of the TB-1 O-ring in paragraphs 1 and 2.
Page 1-2, Section 1.2.1, first and second paragraph, added note on TB-1 O-ring.
Page 1-4, Figure 1-2 was revised to show empty O-ring groove.
Page 1-14, Section 1.2.4, second paragraph, deleted "a fluorocarbon O-ring."
Page 1-15, Updated revision issue for Drawing 2A0263, deleted TB-1 O-ring.
New Section 1.3.4. Justification for exclusion of TB-1 O-ring.

Section 7
Page 7-3, deleted bullet.
Page 7-6, Table 7-1, second row, deleted row that starts with "O-ring, Viton, for TB-1".
Page 7-14a, deleted Step 2 in 7.1.2.3 and Note for Step 2 on Page 7-15.
Page 7-15, Section 7.1.2.3, Step 3, deleted "O-ring" and insert "knife edge sealing surfaces".
Page 7-25, Step 4 in 7.3.1, deleted "and "O-ring".
Page 7-26, 7.3.2, Step 1, deleted "and O-ring".

Section 4
Page 4-9, deleted mention of TB-1 O-ring in 4.3.1, second paragraph.

Section 8
No changes regarding TB-1 O-ring. See Section 8.2.2 and 8.3.2 for leakage tests of the TB-1.

Request for Additional Information: 1-2

Explain the need to require a minimum content weight for the Pu hollow cylinder within the T-ampoule.

The applicant does not require the minimum content weight limits for the T-ampoule with the sample containers (SC-1 or SC-2), but requires a minimum content weight of 731 grams (electro-refined or alloyed) for the Pu hollow cylinder within the T-ampoule in SAR Addendum Table 1-1. Compared to the zero content weight allowed in the T-ampoule with sample container SC-1 or SC-2, the applicant should explain this non-zero minimum weight requirement (731 grams) from both containment and transportation safety views and should document it as guidelines in SAR Addendum for package users for preparing the air-transport of the Pu hollow cylinder within the T-ampoule.

This information is required by the staff to determine compliance with 10 CFR 71.33, 71.64, and 71.88.

Applicant Response:

The minimum content weight for the Pu hollow cylinder was specified because a complete weight range for the hollow cylinder was not evaluated. The range of 831 and 731 grams was selected because of user considerations for fabrication of the hollow plutonium metal cylinders for transport. We did not specify a lower weight than evaluated because of a concern that a lighter, shorter cylinder may impart higher stresses due to impact loading to the TB-1 because of its potential to travel a longer distance within the container before hitting the opposite end. This would require additional analyses to determine that the loads are acceptable.

Change Pages for SAR Addendum:

Section 1
Page 1-13, Table 1-1, added note d which appears on Page 1-14.

Request for Additional Information: 1-3

(a) Specify the limit of surface oxides allowed in plutonium metals such that the surface oxides will not cause a chemical-reaction issue for the PAT-1 package and;
(b) Explain how the limit of surface oxides is determined with respect to 71.64 requirements.

The applicant addressed in SAR Addendum 1.2.2 that the plutonium metal must be in solid form (pure, alloyed or composite) with small amounts of surface oxides. The staff needs to know: (a) what will be the maximum amount of surface oxides allowed in Pu metal such that the existence of surface oxides will not be significant to safety, and (b) how the limit of the surface oxides is determined, in compliance with Part 71.

This information is required by the staff to determine compliance with 10 CFR 71.31, 71.43(d), 71.64, and 71.88.

Applicant Response:

(a) The amount of surface oxides allowed on the plutonium metal such that the surface oxides will not cause a chemical-reaction issue in the PAT-1 package are not limited by the amount of plutonium metal (831 grams as determined by the structural analysis) shipped in the package because the maximum allowable releases to comply with the regulations were calculated based upon the metal content mass as plutonium oxide powder, which is in a much more dispersive form (see (b)). The plutonium in oxide form met the containment release requirements for NCT, HAC, and accident conditions for air transport of plutonium. Thus there is no limit to the surface oxide on the amount of plutonium metal proposed for the authorized contents.

Plutonium oxide is a high-melting-point (2400°C (4352°F), yellow-brown, crystalline solid at STP. The plutonium metal will oxidize any oxygen to form PuO_2 and H_2 gas. Since the plutonium metal is contained within the TB-1, any oxygen present will be converted to plutonium oxide until all of the oxygen is depleted. The oxygen supply is limited by the containment provided by the TB-1 and, once the oxygen is depleted, the reaction from metal to oxide will stop. Note that the T-Ampoule and sample containers, when used, are filled in a glove box atmosphere that has a very small amount of oxygen and moisture (< 100 ppm oxygen and moisture), and the TB-1 containment vessel was not ruptured in its post tested condition and met the containment requirement that restricted the accumulated loss of plutonium contents to not more than an A_2 quantity in a week per 10 CFR 71.64(a)(1). Plutonium oxide does not react with other material within the TB-1 that includes the PH13-8Mo stainless steel, Ti-6Al-4V, and tantalum foil.

(b) The 10 CFR 71.64(a)(1)(i) regulation specifies the requirements for containment for shipment of plutonium by air subject to §71.88(a)(4), in addition to satisfying the requirements of §§71.41 through 71.63, as applicable, such that the containment vessel would not be ruptured in its post-tested condition, and the package must provide a sufficient degree of containment to restrict accumulated loss of plutonium contents to not more than an A_2 quantity in a period of one week when subjected to §71.74.

Based upon the added Sections 4.5.5 and 4.5.6, which addressed the containment criteria under 10 CFR 71.71(a)(1) for NCT, 71.51(a)(2) for HAC and 71.64(a)(i) for Special requirements for plutonium air shipments, the A_2 value of the plutonium content was determined to establish the content containment criteria and to determine the maximum release quantity that is allowed by the regulations. The maximum activity, minimum A_2 value, and minimum leakage requirements were determined for the proposed contents. The PAT-1 leak-testing requirements of the containment boundary were based on the smallest maximum allowable leakage rate generated from the maximum plutonium content defined in Table 4.5.5.1. ANSI N14.5-1997 defines the maximum allowable leakage rate based on the maximum allowable release rate. The worst case maximum allowable leakage rates are used to calculate an equivalent leakage hole diameter following ANSI N-14.5-1997, Appendix B, for each condition of transport. The leakage hole diameter was used to calculate a reference air and helium leakage rate for leak testing. The maximum allowable release rate was calculated based upon a conservative bounding plutonium mass limit of 1300 grams. [Note that this limit is higher than the 831 g specified as a maximum as defined by the structural analysis for the plutonium metal shipment.] The resulting calculations indicate that the allowable release was within the HAC and accident conditions of plutonium air transport conditions of 1 A_2 per week. The maximum allowable leakage rates were calculated using this maximum content mass of 1300 grams in a much more dispersive form (oxide powder) at the highest calculated pressures and temperatures. This is more than the maximum 831 grams of proposed plutonium metal content analyzed in the structural analysis.

There is a practical limit of plutonium oxide formed on the metal surface from the amount of oxygen and moisture (< 100 ppm combined) that would be present in the glove box atmosphere when the metal is loaded in the TB-1. If 100 ppm oxygen concentration is assumed, the amount of oxide formed is1.65 milligrams. If air is assumed to fill the TB-1, the maximum amount of oxide based on 21% oxygen is 3.4 grams.

<u>Change Pages for SAR Addendum:</u>

<u>Section 1</u>

Page 1-10, added note to indicate that a small amount of surface oxides is permitted while still maintaining product quality. The amount of surface oxides does not affect safety as demonstrated in Section 4.5.5 and 4.5.6. These sections were added to determine the maximum allowable leakage rate where 100% oxide was assumed in the leakage and release calculations for NCT, HAC, and Accident conditions for air transport of plutonium.

Request for Additional Information: 1-4

Clarify and document the factors that may differentiate the level of volatilization between the fluorocarbon O-rings located within the TB-1 container and the Viton Parker O-rings located within the following containers: T-ampoule, SC-1, and SC-2.

SAR Addendum 1.2.2 indicates that the O-rings within the TB-1, T-ampoule, and sample containers (SC-1 or SC-2) are subject to the volatilization, and pressure increase due to O-Ring decomposition during post-fire plutonium air transport accident (SAR Addendum 4.5.4)..

The applicant should clarify the factors (such as temperature, pressure, and reaction with oxygen) that may differentiate the level of volatilization between the fluorocarbon O-rings in the TB-1 and the elastomeric Viton Parker O-rings located in the following containers: T-ampoule, SC-1 and SC-2. The applicant should document these factors in the SAR Addendum to instruct the package users how to use of the O-rings.

This information is required by the staff to determine compliance with 10 CFR 71.33, 71.43(d), 71.64, 71.74, and 71.88.

Applicant Response:

The Viton® elastomer O-ring in the TB-1 is no longer used for plutonium metal shipments (See RAI 1-1). Based on a reevaluation of O-ring material, requirements, and data availability, we are using only one elastomer material (DuPont Viton® A) for the T-Ampoule and sample containers SC-1 and SC-2. Since the O-ring materials are all the same, there is no difference in the level of volatilization and pressure increase due to O-ring decomposition from that analyzed in Sections 2.12.8 and 4.5.4.

The specification for Viton® A O-rings for the T-Ampoule and SC-1 and SC-2 sample containers was developed using SAE standards, AS568C for dimensions, and AMS 7276G specifying Viton® A for physical properties.

Change Pages for SAR Addendum:

Section 1
Page 1-1 Introduction, second paragraph, the TB-1 O-ring is not used for plutonium metal shipments.
Page 1-2, Section 1.2.1, first and second paragraph, the TB-1 O-ring is not used for plutonium metal shipments.
Page 1-14, Section 1.2.4, second paragraph, fluorocarbon O-ring was deleted.
Page 6 of the Specification, Section 3.2.1, defined the O-rings used in the T-Ampoule and SC-1 and SC-2 sample containers.

Request for Additional Information: 1-5

Specify the criteria or conditions in which the bare or tantalum-foil-wrapped plutonium metal contents should be packed with Cu foam pieces in the sample containers.

The applicant described in SAR Addendum 1.2.1 that, as a packing option, the bare or tantalum-foil-wrapped plutonium metal contents may be packed in the sample containers using Cu foam pieces. It's not clear what kind of criteria or conditions are used to justify that the bare or tantalum-foil-wrapped plutonium metal contents be packed with Cu foam. The applicant should clarify and document these standards and conditions in the SAR Addendum for appropriate packing operations.

This information is required by the staff to determine compliance with 10 CFR 71.33, 71.43(d), 71.64, and 71.88.

Applicant Response:

The copper foam material has been eliminated as a packing option. Only tantalum foil is used for packing of the plutonium metal contents. The use of the tantalum foil is user defined.

Change Pages for SAR Addendum:

Section 1
Page 1-5, Section 1.2.1.2, second paragraph, third bullet and fourth paragraph, deleted reference to use of copper foam.
Page 1-12, heading Subsection b, bullets 3, 4, and 5. Section 1.2.2.1, second paragraph, fourth bullet, deleted reference to use of copper foam.
Page 1-13, footnote a, b, and c in Table 1-1, deleted reference to use of copper foam.

(See RAI 4-5 of this document for additional deletions of references to use of copper foam.)

Request for Additional Information: 1-6

(a) Clarify how the limits of oxygen content (< 0.5%) and moisture content (< 20 ppm) are determined when assembling the PAT-1 package in a glove box,

(b) Provide the required procedures to maintain a standard glove box line atmosphere with oxygen and water contents below allowable limits during package assembly, and

(c) Evaluate the performance of inert gases being used to prevent the oxidation and specify the criteria used for prevention of oxidation during package assembly.

The applicant addressed in SAR Addendum 1.2.2 that the T-ampoule, sample containers and radioactive materials will be assembled in a typical glove box and/or laboratory with a standard line atmosphere consisting of nitrogen, argon, or helium inert gas, with an oxygen content not exceeding 0.5% and water content not exceeding 20 ppm (parts per million). The applicant should:

(a) Provide information or calculation package to clarify how these limits are determined and demonstrate these limits are acceptable to safety,

(b) Provide the procedures to maintain a standard glove box line atmosphere with both oxygen and water contents below their allowable limits during the assembly of the T-ampoule, sample containers, and radioactive materials, and

(c) Evaluate performance of nitrogen, argon, and helium being used as inert gases to prevent oxidation during package assembly and specify the criteria per which nitrogen, argon, or helium is selected as an oxidation barrier.

This information is required by the staff to determine compliance with 10 CFR **71.33**, 71.35, 71.43(d), 71.64, and 71.88.

Applicant Response:

(a) The limits of oxygen and moisture content are not important to safety but are limited to maintain product quality by minimizing oxidation on the surface of the plutonium metal contents. The specification limits of < 0.5% oxygen content and moisture content < 20 ppm have been revised to < 100 ppm combined oxygen and moisture as specified in an operating procedure for sample cutting of plutonium materials. The purpose of the < 100 ppm oxygen and moisture limits and inert gas in the glove box atmospheric specification is to maintain product quality of the plutonium content. These limits and specification are not important to safety since the oxide does not react with any of the materials within the TB-1. This atmospheric specification is typically used in the glove boxes of user facilities for machining operations. This limit of combined oxygen and moisture content is not applicable to the PAT-1 safety envelope as the Addendum conservatively assumes 100% oxide in the leakage rate and the containment calculations in Section 4.5.5 and 4.5.6.

In the glove boxes, the oxygen content may be typically monitored with a Delta F DF-300ε Series and Coulometric ε-Sensor, and the moisture content can be typically measured with a KAHN Cermet II Hygrometer. Two brochures are attached for information. The flow of argon is monitored by standard industrial flow meters. The information on the glove boxes is provided to demonstrate that the plutonium metal content is packaged in a controlled manner to maintain product quality.

(b) Laboratories that will utilize the PAT-1 have conduct of operation procedures for glove box operations. The procedures address the control and monitoring of oxygen and moisture content within the glove boxes. As an example, LANL glove boxes that will be used for metal sample preparation use a continuous flush of argon though the glove boxes. Oxygen and moisture concentrations are continuously monitored during operations. The procedures to maintain a standard glove-box line atmosphere of < 100 ppm oxygen and moisture and inert atmosphere are site-specific. They are intended to maintain product quality of the plutonium material and are not important to the safety of the PAT-1 package. The procedures in Section 7 were modified to include the glove box oxygen and moisture specification of < 100 ppm.

(c) All of the inert gasses function equally well in the prevention of oxidation to the plutonium metal samples. The selection is typically argon, but helium is used on occasions where leak testing of the sample container may be needed. Nitrogen is rarely used. The gases used are inert and, in combination with the < 100 ppm oxygen and moisture specification, are intended to maintain product quality and are not important to safety for the PAT-1 shipments.

Attachments:

DF-300E Series and E-Sensor, Delta F	Page 86
Cermet II Hygrometer, Kahn Hygrometers	Page 90

Change Pages for SAR Addendum:

Section 1
Page 1-11, next to last bullet. Corrected moisture and oxygen concentration and added statement on maintenance of product quality.

Section 2
Page 2-12, first paragraph, last line. Corrected moisture and oxygen concentration.

Section 4
Page 4-3, last paragraph and page 4-4, first paragraph. Corrected concentration.
Page 4-5, Section 4.1.2, deletions made in first, second, and third bullets.
Page 4-17b and page 4-18, revisions made.

Section 7
Page 7-5, first bullet, revised moisture/oxygen specification and added glove box picture. Added discussion of facility procedures for maintenance of glove box atmosphere criteria.

Section 8
None regarding oxygen content.

Section 2: Package Description

Request for Additional Information: 2-1

Place restrictions on the operating time of the package to prevent radiation damage to the elastomer seals in the package, and/or change the elastomeric seal materials. Clarify the radiation dose received by the elastomer seal on the TB-1.

The analysis in Section 2.2.3 of the SAR states that the calculated gamma dose to the seal on the T-ampoule is 3.38 x 10^6 rads / yr. In general, however, 10^6 rads is considered the threshold dose for radiation damage in non-fluorine bearing elastomeric materials. The threshold radiation dose for fluorine bearing elastomers (including Viton®) is significantly lower, approximately 10^4 rads. Degradation of fluorine bearing elastomers could result in the release of corrosive fluorine compounds during Normal Conditions of Transport.

The basis for the staff's limits on the threshold dose for radiation damage are taken from the References 1 and 2 cited below.

This information is needed to determine compliance with 10 CFR 71.43(d).

References:

1. The Parker O-ring Handbook, ORD-5700, Sections 3.9.13 and 3.9.14, pp 3-4. Parker Hannifin Corporation, Cleveland, OH, 2007.
2. Radiation Damage in Materials, 4th ed, Figure 1-1, pp 1-3. F. Bouquet. Systems Co., Inc., 1994.

Applicant Response:

The contact dose analysis for the elastomer seal was revisited and a more realistic evaluation was performed using the bounding source model in the Addendum, and the conservation in the over prediction (Table 5-12, Addendum) was considered in the calculation. Based on the initial RAI evaluation, the TB-1 elastomer seal will not be used for the plutonium metal shipments (See RAI 1-1). Data from DuPont Performance Elastomers (Ref. 2), as well as the information contained in a 1985 article by F. Bouquet (Ref. 3) entitled "Radiation Thresholds for Synthetic Elastomers," was used to provide radiation damage information for the Viton® A seal material in the *T-Ampoule* and sample containers SC-1 and SC-2. The information demonstrates that there is no need to place restrictions on the operating time of the package since the calculated doses are an order of magnitude below the threshold at which DuPont and Bouquet state that there is no damage to the Viton® elastomer seal material.

Radiation Dose Evaluation

A calculation of contact dose was performed by ORNL for the elastomer seal using surface dose rates based on a bounding source mass model (a cylinder with a hemisphere on the bottom as described in Section 5 of the Addendum). The mass was distributed to minimize self-shielding due to the source material. ORNL notes that previous sensitivity analyses have shown that the dose rates were insensitive to the source geometry. Based on this model and using the source terms in Table 5.3 and 5.4 of the SAR Addendum, a conservative estimate of the contact gamma dose with the elastomer is 8.3×10^5 rad/year, and contact neutron dose is 1.7×10^5 rem/year. . Further review of the ORNL shielding analysis for the PAT-1 SAR Addendum is indicated in Table 5-12. Estimation of Degree of Over Prediction in Bounding Pu Source Used in This Study indicated that the gamma source could be over predicted by 36.3 times and the neutron source by 6.0 times based on 1300 grams of plutonium, with an isotopic distribution corresponding to source scenario "N_Reactor 2 GWd/t". The ORNL shielding analyst recommended the following as realistic doses for the elastomer dose calculation (taking partial credit for using reduction factors of 30 for gamma and 5 for neutron):

Realistic surface gamma dose = $8.3 \times 10^5/30 = 2.8 \times 10^4$ rad/year
Realistic neutron dose = $1.7 \times 10^5/5 = 3.4 \times 10^4$ rem/year

The results for neutrons are expressed in rem rather than rad because the neutron results have been multiplied by a quality factor to account for the greater damage caused by neutrons than gamma rays. The quality factor makes the doses from different radiation sources approximately additive.

Effect of Dose on Physical Properties and Operating Time

The elastomer compound for the T-Ampoule and sample container SC-1 and SC-1 O-rings is Viton® A, which is a fluorocarbon elastomer trademarked by DuPont. The "Viton fluoroelastomer from DuPont Performance Elastomers" for the Radiation Resistance of Viton Technical Bulletin states that "Vulcanizates of Viton® fluoroelastomer, irrespective of the type or filler, can withstand $10^5 - 10^6$ rad ($10^3 - 10^4$ J/kg) with little or no effect on physical properties and 10^6 - 10^7 rad ($10^4 - 10^5$ J/kg) with moderate effect (50% loss of elongation at break, 50% increase in modulus); and 10^8 rad (10^6 J/kg) produces a severe effect (final elongation at break <50%). The technical brochure further states "Concerning elastomer serviceability, a gamma radiation dose less than 5×10^6 rad (5×10^4 J/kg) is considered low. Up to 10^8 rad (10^6 J/kg) is considered intermediate and 10^8-10^9 rad (10^6-10^7 J/kg) is high."

The ORNL predicted doses for gamma (2.8×10^4 rad/year) and neutron (3.4×10^4 rem/year) radiation based on a realistic source are less that the 10^5 rad cited for no effect in the DuPont technical bulletin and are only marginally above 10^4 rad (cited in Bouquet, 3rd edition, 1990, (Ref. 1), treating neutrons and gammas equally and exposing for a full year. Note that the 3rd edition Bouquet reference only cites "fluorocarbons" and does not provide further details regarding manufacturers' data. In a 1985 article by Bouquet (Ref. 3), he shows in *Figure 4 Summary of Radiation Data for Elastomers. Property: Tensile Strength. Above Average Response Level* that the lowest threshold damage for Viton A® starts at about 6×10^6 rads and the 25% change dose is at about 6×10^7 rads. In *Figure 6 Summary of Radiation Data for Elastomers. Property: Elongation.*

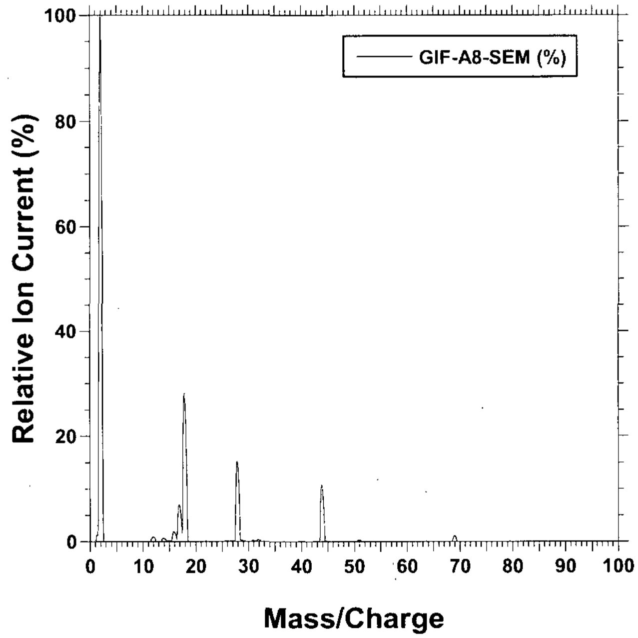
Average Response Level for Viton A, the lowest threshold dose starts at about 10^7 rads and the 25% change dose is slightly above 10^7 rads. Thus this conservative dose estimate of about 5 x 10^4 rads from the ORNL analysis places the seals under the "little or no effect" dose range for Viton® seals with a full year of contact according to DuPont (also conservative since most shipments should be completed within a month) and at least an order of magnitude below the threshold damage level data for tensile strength and elongation from the Bouquet 1985 article. Furthermore, the amount of time the seals would be typically in close proximity to the contents would make these estimates even closer to a 1 x 10^4 rad cumulative dose for one year.

In conclusion, there is no need to place restrictions for the one year operating time of the package to prevent radiation damage to the elastomer seals because the Viton® A elastomer seals would experience no loss or minor loss in mechanical properties from radiation from the plutonium metal during NCT. Furthermore, the Viton® A elastomer seals in the T-Ampoule and SC-1 and SC-2 sample containers are not containment boundary components and do not provide a safety function but serve to maintain product quality.

HF Evaluation and Materials Compatibility

The NRC commenter stated that the "Degradation of fluorine bearing elastomers could result in the release of corrosive fluorine compounds during Normal Conditions of Transport." It is very unlikely that any fluorinated compounds (assuming the outgassing of fluorine species to be HF) would be formed based on the information in the DuPont reference since the physical properties of the Viton® material are little changed at that dose level (10^6 rads). Unpublished experimental data show that HF gas is not evolved under vacuum for doses up to 10^6 rads, thus there are no material compatibility issues.

No data was found in a literature survey regarding the onset of outgassing of HF from Viton® A due to gamma radiation. The likelihood of HF outgassing is very low considering the data in the DuPont literature because mechanical properties are minimally affected by radiation doses of 10^6 rad. Unpublished information from a LANL experimenter (Andrea Labouriau) using the Gamma Irradiation Facility (GIF) at Sandia National Laboratories report no HF gas generation when Viton® A material was exposed to 10^6 rads of gamma radiation in a vacuum for 24 hours. The head space gas of the sample was analyzed with a Pfeiffer QMG422 quadrupole mass spectrometer. She reports, "The mass scan was taken with a secondary electron multiplier (SEM) detector while flowing the gas in the 33 cc volume through a Granville-Phillip leak valve (at a setting of 30) into the mass spectrometer (shown in the figure below). Hydrogen (mass/charge: 2) is the predominant gas and some amounts of carbon dioxide (CO_2; mass/charge peaks: 44, 28, 16, 12) and carbon monoxide (CO; mass/charge: 28, 12, 16, 29). The molecular species with mass/charge 69 was not identified. No HF was detected."



From Andrea Labouriau, LANL, email dated July 1, 2010.[4]

To address possible compatibility issues, an evaluation of O-ring materials such as Viton®, Kel-F®, FKM, Fluorel™ and Kalrez® was performed to examine the compatibility of fluorocarbon O-ring decomposition products with the containment and packing materials in the TB-1. The structural materials considered are Ti-6Al-4V in the *T-Ampoule* and *SC-1* and *SC-2* sample containers, the PH13-8Mo material in the TB-1, and the tantalum foil as packing material. The concern is that degradation of fluorine bearing elastomers, by decomposition and out gassing, could result in the release of corrosive fluorine compounds during normal conditions of transport. It is assumed that "corrosive fluorine compounds" refers to the formation of hydrogen fluorine (HF). In the presence of water, HF (gas) reacts to form aqueous HF, or hydrofluoric acid, which is a corrosive, according to the reaction below:

$$HF + H_20 \rightarrow H_30^+ + F^-$$

Considering the availability of water within the T-Ampoule which is closely surrounded by the TB-1, the atmosphere within the T-Ampoule, which is sealed by an O-ring, is filled with a standard glove box atmosphere consisting of a gaseous mixture of N/Ar/He with an oxygen and moisture content not exceeding 100 ppm. In this case, the water content is not a concern, as the dew point corresponding to 100 ppm (by volume), assuming all water, is -40°C (-40°F). In addition to the negligible moisture content, the sample container is at a temperature of 103°C (218°F) at NCT. Therefore, at NCT, there is insufficient water content within the TB-1 to react with any available outgassed HF species. Even in an air environment, which is considered the worst case scenario, any available water would likely be evaporated due to heating (103°C (218°F)) from the plutonium content.

For the corrosion resistance of the materials within the TB-1, the Ti-6Al-4V T-Ampoule is susceptible to corrosive attack when exposed to 1wt% hydrofluoric acid solutions. As noted above, free water is not available in the glove box atmosphere that fills the T-Ampoule (< 100 ppm oxygen or moisture concentration) and certainly unavailable at NCT temperature and pressure (103.3°C (218°F), 132.4 kPa (19.2 psig)).

Per a literature search, no information was found on the resistance of PH13-8Mo stainless steel to corrosive attack by fluorine compounds. The corrosion resistance of this material (which nominally contains 13wt% Cr) is considered to be similar to that of type 302 stainless steel, and is susceptible to pitting attack in the presence of halide species (Cl^-, F^-, etc.). During NCT, the scenario in which this material would come into contact with an aqueous halide species is not considered likely.

For the tantalum packing foil, tantalum is nonresistant to both aqueous and anhydrous hydrofluoric acid. Tantalum is a packing material and does not provide any structural strength. Based on the Viton® A irradiation experiments at the GIF, no HF gas was detected at an exposure level of 10^6 rads. This is below the radiation exposure level the tantalum foil is expected to see at NCT for a year, thus no damage is expected to the tantalum foil packing material.

<u>Summary</u>

Based on calculated doses, unpublished experimental data and radiation damage data for Viton® A O-ring material used in the T-Ampoule and sample containers, there is little possibility that degradation of the material would cause any loss of mechanical properties of the elastomer or cause release of HF to form corrosive fluorine compounds under NCT for a period of one year.

References:

1. Bouquet, F., "Radiation Damage in Materials," 3rd Edition, Systems Company, 1990.
2. DuPont Performance Elastomers, "Radiation Resistance of Viton," Technical Information, Wilmington, DE, December 1998.
3. Bouquet, F., "Radiation Thresholds for Synthetic Elastomers," Jet Propulsion Laboratory, California Institute of Technology, IEEE Transactions on Nuclear Science, Vol. NS-32, No. 6, December 1985.
4. Andrea Labouriau, LANL, email personal communication to R. H. Yoshimura, July 1, 2010.

<u>Change Pages for SAR Addendum:</u>

<u>Section 2</u>

Page 2-12, rewrote Section 2.2.3, inserted new text.
Add DuPont Performance Elastomers reference as Section 2.2.3.4.

Revised Drawing 2A0263, delete Item 1, drawing modification.
Revised Drawing 2A0261, changed O-ring specification for Item 3.
Revised Drawing 2A0265, changed O-ring specification for Item 3.
Revised Drawing 2A0268, changed O-ring specification for Item 3.
Revised Section 1 in Specification following Page 1-43a: Page 6, Section 3.2.1.

Request for Additional Information: 2-2

Correct or justify the thermal conductivity of Ti-6Al-4V alloy in Table 3-4. If necessary perform a new thermal analysis of the package.

The thermal conductivity of Ti-6Al-4V alloy listed in Table 3-4 appears to be incorrect. Correct or justify the thermal conductivity of Ti-6Al-4V alloy.

This information is needed to determine compliance with 10 CFR 71.73(c)(4).

Applicant Response:

Thermal conductivity values were verified and were found to be correct. While the thermal conductivity of pure titanium decreases as temperature increases from 100 Kelvin to about 600 Kelvin and increases with temperatures above 600 Kelvin, the thermal conductivity of Ti-6Al-4V alloy increases with temperature as shown in Table 3-4 of the Addendum. A new reference that supports this statement was added to the Addendum.

Change Pages for SAR Addendum:

Section 3

The following sentence was added to the first paragraph on page 3-6: Reference 8 supports the temperature-dependent trend of the data presented in Table 3-4.
A new reference was added to Section 3.5.1.

Request for Additional Information: 2-3

Restrict the shipping temperature of the package, or use alternate elastomer seal materials, if the elastomer seals are necessary for containment.

Elastomeric seals of Viton® are not acceptable for maintaining leak tight seals at -40°C.[1,2] Without direct leak test measurements of the containment vessel at -40°C, the staff considers the temperature of retraction (TR-10) the minimum permissible operating temperature of the seal.

References:
[1] "Performance Testing of Elastomeric Seal Materials Under Low- and High-Temperature." D. Bronowksi. Sandia National Labs Report SAND94-2207, June 2000.

[2] "Investigation into Replacement of Viton 'O'-Rings." G. Holden and G. Hall. RAMTRANS, Volume 13, No. 3-4, pp. 233 – 242, 2002.

This information is needed to determine compliance with 10 CFR 71.71(c)(2).

Applicant Response:

The Viton elastomer seals used in the T-Ampoule and SC-1 and SC-2 sample containers are not containment boundary components and do not serve a safety function. The seals are used to retain the glove box atmosphere to maintain product quality for the plutonium metal contents.

The TB-1 elastomeric O-ring is not used for plutonium metal shipments. See RAI 1-1.

Change Pages for SAR Addendum:

Section 1
Specification following Page 1-43a: Page 6, Section 3.2.1: Deleted mention of TB-1 O-ring.

Request for Additional Information: 2-4

Provide Pronto 3D post processor as requested during the June 11, 2009 meeting.

Staff requested a Pronto 3D post-processor from Sandia staff and an action item was recorded which indicated Sandia National Lab staff would provide the necessary software as requested. Staff requests this software so that output may be verified.

This information is needed to determine compliance with 10 CFR 71.73 (c) (2) and 71.74.

Applicant Response:

During the NRC videoconference on 4/23/10, various results files were opened and viewed in BLOT using basic commands, determining 10 CFR 71.73 and 71.74 compliance. Since compliance was already demonstrated during that public video conference, the NRC no longer needs specific output files or the BLOT post-processing software to view them.

If the NRC still wants to use BLOT to view additional files (remember that the commercially available ParaView or Ensight can also be used to view the Exodus II-format results files from PRONTO3D), there is an open-source blot available at http://sourceforge.net/projects/seacas. This has the same functionality as the internal Sandia version and can be obtained with no licensing or fee. This also includes other Exodus II-related codes which may be helpful.

A compressed tar file of all of the source code is on the order of 30 MB. The following .readme file is part of the tar file and lists the steps necessary to download/install the code (note that SEACAS stands for Sandia Engineering Analysis Code Access System):

(First cut at build for external SEACAS distribution. Assumes you know what the codes are and how to use them.)

1. Create the directory which will serve as the root of the SEACAS installation. This will be your AccessRoot.

\---

IF YOU DOWNLOADED THE TAR FILE

2. Untar the SEACAS source code in this area:
        tar zxvf /path/to/file/ACCESS.tar.gz
  -- Will create a directory 'ACCESS' in the current directory
go to step 5.

\---

IF YOU CHECKOUT FROM CVS

2. Checkout the SEACAS source code:
  cvs -d:pserver:anonymous@seacas.cvs.sourceforge.net:/cvsroot/seacas login
  (hit return for password)
  cvs -z3 -d:pserver:anonymous@seacas.cvs.sourceforge.net:/cvsroot/seacas co -P ACCESS

3. Merge in the exodusII and nemesis libraries:
  cd ACCESS/libraries
  cvs -d:pserver:anonymous@exodusii.cvs.sourceforge.net:/cvsroot/exodusii login
  (hit return for password)
  cvs -z3 -d:pserver:anonymous@exodusii.cvs.sourceforge.net:/cvsroot/exodusii co -P exodusii nemesis

4. Download netcdf. At this time, netcdf-4.0 is recommended.
  * cd ../netcdf
  * Download netcdf-4.0.1.tar.gz from
    http://www.unidata.ucar.edu/downloads/netcdf/ftp/netcdf-4.0.1.tar.gz
  * tar zxvf netcdf-4.0.1.tar.gz
  * If the untar does not create a netcdf-4.0.1 directory, modify the Imakefile in the current directory such that V_NUM specifies the correct name
  * Modify the following defines in libsrc/netcdf.h and libsrc4/netcdf.h:

```
#define NC_MAX_DIMS     65536   /* max dimensions per file */
#define NC_MAX_VARS     524288  /* max variables per file */
#define NC_MAX_VAR_DIMS 8       /* max per variable dimensions */
```

----

5. cd back to your AccessRoot location (see step 1)

6. Edit ACCESS/itools/config/cf/site.def
  * Update the Owner and Group defines with your username and whatever group you want the codes available as.

  * Update the AccessRoot to point to the AccessRoot in step 1.

7. Edit the ACCESS/itools/config/cf/linux.cf (or corresponding file if not on linux)

  * If not building on a 64-bit system, change the Build64BitAccess define to NO

  * Pick your compiler. Typically, gcc-3.X would be the GCCG77 define and gcc-4.X would be the GCC4GFORTRAN define. If using a gcc-3.X or gcc-4.0 compiler, you cannot build a 64-bit version due to some strangeness in the way we originally set up the fortran builds; gcc-4.1 and later work fine.

* If the compiler is not in your path, locate the CcCmd, CplusplusCmd, and FortranCmd definitions in the proper area and update the path to point to the correct compiler location.

8. Build the software.
   * cd to AccessRoot as specified in step 1.
   * sh ACCESS/scripts/buildSEACAS
   * Enter option 1 -- Build all of SEACAS (including the Imake tools)
   * The SEACAS root directory default should be correct; otherwise you are in the wrong directory when you execute the script.
   * Return for the group or enter a new group.
   * Typically, choose '10' if building on Linux for the BOOTSTRAPCFLAGS
   * Follow prompts and hope no errors occur...

To use this installation of SEACAS:

CSH:
* setenv ACCESS /path/specified/as/AccessRoot
* set path=($ACCESS/etc $ACCESS/bin $path)

SH:
* export ACCESS=/path/specified/as/AccessRoot
* export PATH=$ACCESS/etc:$ACCESS/bin:$PATH

<u>Change Pages for SAR Addendum:</u>

No pages were changed in the SAR Addendum as per this RAI.

Request for Additional Information: 2-5

Staff requests output files for a representative sample of the PAT-1 accident scenarios for plutonium transport as well as for dynamic crush.

This information is needed to determine compliance with 10 CFR 71.73 (c) (2) and 71.74.

Applicant Response:

After the NRC videoconference on 4/23/10 and seeing various results files directly and verifying 10 CFR 71.73 and 71.74 compliance, NRC no longer needs specific output files.

NRC originally requested ~4 "representative" and worst-case Tearing Parameter (TP) results cases. If the NRC still requires these results files, these can be sent via and external 1 TB hard drive (USB interface compatible).

Change Pages for SAR Addendum:

No pages were changed in the SAR Addendum as per this RAI.

Request for Additional Information: 2-6

Given that the PAT-1 as tested was not instrumented with accelerometers or strain gauges, provide reasonable assurance that the results derived from analytical calculations are representative of those that would be found in a testing scenario.

While exhaustive, the analysis presented by the applicant is insufficient for the staff to make a safety finding due to the following factors:

a) Use of gross deformation results to "tune" a constitutive model is not aligned with best practices for modeling impact limiting material, specifically one such as wood or other material with properties that are environmentally sensitive. [a]

b) Limitations of constituent model behavior subsequently obscure any potential spurious effects due to the fact that tuning of material properties have been incorporated in the model development. This approach makes it nearly impossible to discern whether a material is behaving as expected in a test scenario. [b]

c) While employing component testing to remove uncertainty from the use of only gross package deformation is ideal, the component testing must be sufficient for the range of behaviors that could reasonably be expected under testing conditions. Because the velocity limitations of the component testing, it is unreasonable to assume that structural and material behavior under component test conditions sufficiently envelope structural and material behavior under regulatory test conditions. [c]

[a] *Section 2.8.1, pp 2-23 states: "this deformation data from the original certification tests was used to tune the redwood constitutive properties and finally validate the high-speed impact model."*

[b] *Section 2.12.2.2, pp 2-38 states: "However, the orthotropic crush model in PRONTO-3D is oriented relative to the three orthogonal global axes of the model; a local coordinate system is not available in this model. Therefore, modeling many small segments around the circumference is not possible. Instead, the model material blocks were constructed in 90° segments rotated 45° to the model's global axes; this is shown in Figure 2-10. This is an attempt to maximize the strength of the material in the radial direction during side impacts within the constraints imposed by the constitutive model."*

[c] *Section 2.12.3.1, pp 2-49: "Although the actuator assembly has a limited velocity of 200 ft/sec, which is less than the 422 ft/sec specified for the aircraft accident (10 CFR 71.74), this is not a problem, since the impact between the TB-1 wall and the contents will not be at the maximum velocity. The impact between the contents and the TB-1 occurs while the TB-1 is decelerating but is still moving. Therefore, the relative velocity between the TB-1 and the contents is only a fraction of the initial package velocity."*

This information is necessary to determine compliance with 10 CFR 71.73 and 10 CFR 71.74.

Applicant Response to a):

(a) Sandia did not "tune" the redwood constitutive model (as incorrectly stated by a previous author) to match the tested gross deformations of the PAT-1. Sandia used a previously developed constitutive model that was validated through previous testing. The redwood material model (as well as simulating the grain orientation with sections of stronger and weaker redwood) was previously validated against regulatory aircraft impact test data associated with the slightly smaller PAT-2 package (Reference: Attaway, S.W., "A Local Isotropic Global Orthotropic Finite Element Technique for Modeling the Crush of Wood," SAND88-1449, 1988, SNL). The previously developed constitutive model originated from a DYNA model which was tuned in the late 1980's to match referenced Hill and Johnson compression testing of redwood parallel to the grain, producing a relatively constant stress up to about 60% nominal strain, where lockup begins. This orthotropic redwood constitutive model was compared with a more detailed LIGO model (above reference) and validated against PAT-2 package regulatory impact test data, comparing very well.

It is true that no acceleration or elastic strain history data was taken during the regulatory tests performed in the 1970's, but overall gross deformations of the redwood overpack were recorded, including radiography. With a relatively short crush distance, there is not much room for variation in load path, thus variations in acceleration due to different load paths would be small and TB-1 (and contents) loading due to acceleration and contact with the redwood overpack should be very similar to the loads observed during testing. Although the FEA model of the PAT-1 uses only 4 circumferential redwood blocks (instead of the actual 8), the half-symmetric model is oriented with the grain aligned along the symmetry plane; thus for side and CGOC impacts the "strong" axis of the redwood (parallel to the grain) is properly aligned, just as it would be in virtually any circumferential orientation with the actual package, since it possesses 8 circumferential blocks and could be "misaligned" by at most only 22.5 degrees. Using this 4 circumferential redwood sections in the FEA model and the previously validated redwood constitutive model, the overall FEA model redwood overpack deformation results at the tested 445 ft/sec impact match the 1970's certification test results and produced no visible deformation of the TB-1 containment boundary, even in the 11-percent-of-kinetic-energy over test beyond the regulatory 422 ft/sec impact (same in test and analysis).

Change Pages for SAR Addendum in Response to a):

Section 2

The text in the 3rd paragraph of Section 2.8.1, the 5th paragraph of Section 2.12.2.2 (p. 2-38), and references in Sections 2.12.2.9 and 2.12.4.2 were changed in response to this RAI.

Applicant Response to b):

b) Again, Sandia did not "tune" the redwood constitutive model to match the PAT-1 certification test data. The force/deflection shape of redwood is generally matched or validated by previous analyses of redwood crush environments using the same redwood constitutive model (references include the previous SAND88-1449; Cramer, Steven M., Hermanson, John C., and McMurtry, Wayne M., "Characterizing Large Strain Crush Response of Redwood," SAND96-2966, 1996, Sandia National Laboratories; as well as two proprietary reports: SAND89-0474, and SAND92-0278; these last two are Proprietary and cannot be released to the public).

Change Pages for SAR Addendum in Response to b):

Section 2
The text in the 3rd paragraph of Section 2.8.1, Section 2.12.2.2, and references in Sections 2.12.2.9 and 2.12.4.2 were changed in the SAR Addendum in response to this RAI.

Applicant Response to c):

c) Component tests were intended to generate similar strain rates, strains and stress triaxialities to those expected in regulatory high speed impact tests. The strain rates in the T-Ampoule during regulatory impacts were in fact bounded by the component tests, and strains and stress triaxialities were nearly bounded. For the relatively few cases where plastic strain vs. stress triaxialities were not bounded, the Tearing Parameter failure criterion was used to demonstrate that not even the initiation of a ductile tear occurred in the T-Ampoule, and thus structural integrity was maintained.
See also question 2-9 response.

Change Pages for SAR Addendum in Response to c):

Section 2
The text in Section 2.12.3.7 and the last two references in Section 2.12.3.9 were changed in the SAR Addendum in response to this RAI and RAI 2-9.

Request for Additional Information: 2-7

Demonstrate that Equation 2-7 is applicable to the titanium alloy (Ti-6Al-4V) used to construct the T-Ampoule.

The applicant states that this equation is generally true for most ductile metals, but the work presented by Bao only appears to consider thin plates comprised of aluminum. Previous work (Johnson and Cook) upon which this equation was based, focused on copper, iron, and 4350 steel, although it was unclear if the samples used in that work were also thin plates. Staff is unclear as to whether the titanium alloy (Ti-6Al-4V) is similar enough to aluminum, steel, copper, and iron such that this equation can be universally used, whether there is a significance in the types of specimens tested (thin plate punching versus thicker plate or shell behavior), and whether this equation, which considers three dimensional behavior can be used as part of an acceptance criteria method wherein the Critical Tearing Parameter only considers a static uniaxial tension test (see RAIs ST4 and ST5).

This information is necessary to determine compliance with 10 CFR 71.74.

Applicant Response:

Clarification – Equation 2-7 (shown below) is the definition of average stress triaxiality and is not specific to any particular material.

$$\left(\frac{\sigma_m}{\bar{\sigma}}\right)_{av} = \frac{1}{\varepsilon_f}\int_0^{\bar{\varepsilon}_f}\frac{\sigma_m(\bar{\varepsilon})}{\bar{\sigma}(\bar{\varepsilon})}d\varepsilon$$

Ti-6Al-4V is the most commonly used alloy in aircraft applications, used for fan, rotor, and compressor blades which often withstand high-energy bird strike impacts during high rotational rates. This alloy is a combined hexagonal close packed and body centered cubic structure which has a fracture toughness between aluminum alloys and steel. It was chosen for the T-Ampoule application because it has excellent corrosion resistance, low weight, high strength, and good ductility. The exact shape of the failure boundary curve generated by Bao for an aluminum alloy was specific to that material, but the general finding that failure does not occur in ductile metals below a stress triaxiality of -1/3 and does occur at relatively low strains when stress triaxiality is high is true for all ductile metals. We merely used Bao's test methodology to sample the stress-triaxiality vs. EQPS space for our ductile material (Ti-6Al-4V), but instead of defining a failure boundary (by testing to failure), we generated a locus of points at or below which on the stress-triaxiality vs. EQPS space we DO NOT get failure. Since this locus turned out not to be completely all-encompassing of all stress-triaxiality vs. plastic strain states during aircraft impacts, we used a true failure criterion (Tearing Parameter) to show that those points outside the tested "no fail" locus (our test apparatus could not quite generate high enough velocities to extend to these regions) would not fail, or even initiate the smallest of ductile tears, and would thus maintain integrity for its eutectic barrier function (remember, this is not a "containment boundary" in the regulatory sense).

3-D stress states are encompassed by not only the average stress triaxiality definition (and the stress-triaxiality/EQPS space), but also by the Tearing Parameter. Sandia's improvement to Brozzo's original failure criterion (adding the Heaviside function and the exponent of 4) was to better fit 3-D notched tensile specimens to failure (reference: Dawson, D. B., Antoun, B. R., and Mosher, D. A., "Fracture of Weapons Materials," Memo report to distribution, page 18, October 5, 1998, Sandia National Laboratories). The relatively simple (appears 1-D) standard tensile specimen test to failure (which becomes a 2-D axisymmetric stress state at failure in ductile materials due to localization or necking after peak load) is merely used to calibrate the Critical Tearing Parameter for a specific material, which, in the case of our Ti-6Al-4V alloy, was 1.012. Determination of the Critical Tearing Parameter requires performing a tensile test to failure, then modeling it using a constitutive model to match the test data, and iteratively arriving at a Critical Tearing Parameter value that matches the initiation of failure in the tested tensile specimen.

Change Pages for SAR Addendum:

Section 2

The text in the last paragraph of Section 2.12.3.2, Section 2.12.3.6, and Figures 2-54 and 2-55 were changed in the SAR Addendum in response to this RAI.

Request for Additional Information: 2-8

Describe in detail how the critical tearing parameter is determined and its relationship to the locus in equivalent plastic strain – stress triaxiality space.

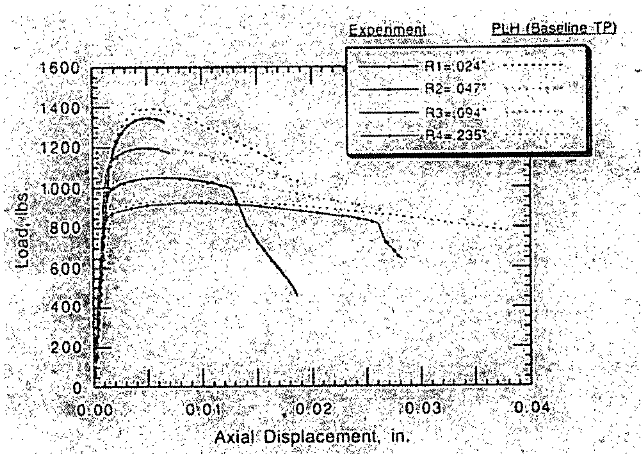
The applicant derived the critical tearing parameter based on a finite element simulation of a uniaxial tension test. Given the multiple references to stress triaxiality, staff is unclear whether the formulation and use of a 1D acceptance criterion in conjunction with a 3D stress strain state locus is a consistent and relevant methodology.

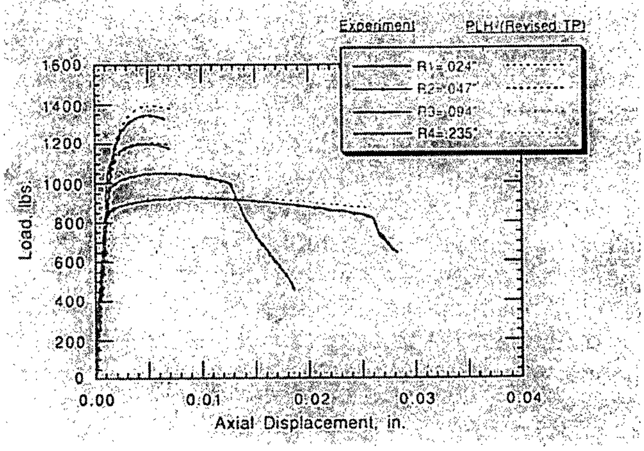
This information is necessary to determine compliance with 10 CFR 71.74.

Applicant Response:

Again, please keep in mind that the Ti-6-Al-4V T-Ampoule is not a containment boundary in the regulatory sense. It is a thin but strong and ductile eutectic barrier whose purpose is to merely maintain integrity (denting and plasticity is acceptable) throughout regulatory accident sequences to ensure no possible Pu-Fe eutectic formation could occur if the 1103 degrees Fahrenheit minimum eutectic formation temperature were somehow reached after a long fire. We are only trying to demonstrate through a combination of direct stress-triaxiality vs. EQPS locus testing and a uniaxial tension test-to-failure calibrated Critical Tearing Parameter failure criterion that not even the *initiation* of a small ductile tear occurs (and thus eutectic barrier integrity is maintained).

First, this isn't a 1D acceptance criterion at all; it has been proven to work exceedingly well for many 3D stress states (in fact the addition of the 4th power over Brozzo's similar original failure criterion in 1975 was to better match highly notched, highly 3D specimens. See the figure below, where the upper graph compares notched tensile tests with FEA using the Brozzo failure criterion, and the lower graph shows a much better match using the updated Tearing Parameter (TP) [reference: Dawson, D. B., Antoun, B. R., and Mosher, D. A., "Fracture of Weapons Materials," Memo report to distribution, page 18, October 5, 1998, Sandia National Laboratories]). Even the uniaxial tension test used to determine the critical TP value is actually a 3D stress state (or at least 2D axisymmetric) due to the necking that occurs up to failure.





The TP equation needs to be slightly modified in SAR; (see below). The TP almost appears to have stress triaxiality within its definition because it (the integral) only accumulates value when the ratio inside the Heaviside brackets (tends to mimic stress triaxiality) is positive, but it also accumulates value (damage) much more quickly when the Heaviside ratio (mimicking stress triaxiality) is highly positive, as in near-perfect hydrostatic tension. But stress triaxiality is the mean stress (average of 3 principal stresses) divided by the von Mises stress, whereas TP has the difference of the maximum principal stress and the mean stress in the denominator.

$$\left(\frac{\sigma_m}{\overline{\sigma}}\right)_{av} = \frac{1}{\varepsilon_f}\int_0^{\overline{\varepsilon}_f}\frac{\sigma_m(\overline{\varepsilon})}{\overline{\sigma}(\overline{\varepsilon})}d\varepsilon$$

$$TP = \int_0^{\overline{\varepsilon}_{pf}}\left\langle\frac{2\sigma_1}{3(\sigma_1 - \sigma_m)}\right\rangle^4 d\overline{\varepsilon}_p$$

In the 3D case:

$$\sigma_m = \frac{\sigma_1 + \sigma_2 + \sigma_3}{3}$$

$$\bar{\sigma} = \sqrt{\frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}{2}}$$

Bao showed how specifically for aluminum (but it is also true for all ductile metals), that 1) ductility decreases with increasing stress triaxiality (can be thought of simply as the degree of which the three principal stresses are equal and positive), and 2) that as stress triaxiality becomes very negative (can be thought of as all three principal stresses are negative and equal value, as in hydrostatic compression), ductile metals do not fail at all. SNL performed component tests to generate a locus of "non-failure" points in the stress-triaxiality vs. equivalent plastic strain space originally intending to fully encompass all the stress-tri/EQPS states for the T-Ampoule under regulatory impact conditions (strain rates generated in the test specimens encompassed those found under regulatory impact conditions). Since our test apparatus was velocity limited and we didn't quite fully encompass the range of stress-tri/EQPS to guarantee "non-failure" (thus maintaining structural integrity) in all modeled regulatory high-speed impact cases, we had to also use an empirically-based failure criterion instead of relying only on our previous "non-failure" tested locus.

The Tearing Parameter does not map directly to stress triaxiality (because they are defined differently), but TP does accumulate value and thus get closer to a "critical" (failure) value as the difference between the maximum principal stress and the mean stress (the denominator, which is very similar to a high stress triaxiality) gets small. TP does not accumulate value if the numerator or denominator in the TP integral definition is negative (which is very similar to negative stress triaxiality).

A fairly recent (2007) journal article reviewed numerous ductile fracture prediction models (reference: Zheng, C., Cesar de Sa, J. M. A., Andrade Pires, F. M., "A Comparison of Models for Ductile Fracture Prediction in Forging Processes," Computer Methods in Computer Science, Vol. 7, 2007, No. 4). This review stated that it is generally accepted that ductile damage criteria should take into account the following:

- The deformation path, because the current stress/strain state is not enough to characterize the damage state.
- The hydrostatic or mean stress, σ_m, because ductility grows rapidly as σ_m decreases.
- An adequate ratio of stresses, namely the triaxiality stress ratio, σ_m / σ_{eq}, in which

σ_{eq} is the equivalent for Mises stress, so that the general state of plasticity and fracture may be better described.

The review article stated that Brozzo's original TP model works well in compression (which transitions to shear near failure), and Sandia has improved the model to work very well in tension and notched tension as well, with the 4^{th} power and Heaviside function, but this fact has not been widely published due to its primary application in weapons modeling. Of the two most common failure criteria for ductile materials (Johnson-Cook, and Tearing Parameter), TP was chosen because of Sandia's previous success using it to match test-to-failure data in varying 3-D stress states.

Change Pages for SAR Addendum:

Section 2

Changed the text in Section 2.12.3.2 and Section 2.12.3.6. In Section 2.12.3.3, moved Figure 2-52 from Section 2.12.3.6 to 2.12.3.5. Section 2.12.3.8, and the third-to-last reference in Section 2.12.3.9 were changed in the SAR Addendum in response to this RAI and RAI 2-6.

Request for Additional Information: 2-9

Demonstrate that the locus in equivalent plastic strain – stress triaxiality space is not strain rate dependent.

Given that this locus was developed at speeds of 200 ft/s rather than 422 ft/s, the applicant should provide a velocity range for which the locus is applicable. Alternatively, the applicant should provide a thorough explanation as to why the locus developed at lower velocity is acceptable to use outside of the regulatory framework requiring a velocity of 422 ft/s.

This information is necessary to determine compliance with 10 CFR 71.74.

Applicant Response:

Some materials have high strain rate dependencies, but Ti-6Al-4V was chosen for the T-Ampoule eutectic barrier material due not only to its high strength, light weight, good ductility, and excellent corrosion resistance, but also because of its low strain rate sensitivity. For example, the material is commonly used in the aerospace industry for jet engine fan blades, in part because of its resistance to failure during bird strikes. At lower strain rates (0 to 1 inverse seconds), the yield and ultimate stresses harden slightly, but ductility is unaffected (reference graph from: "Department of Defense Aerospace Structural Metals Handbook", code 3707, page 12, March 1965), as shown below.

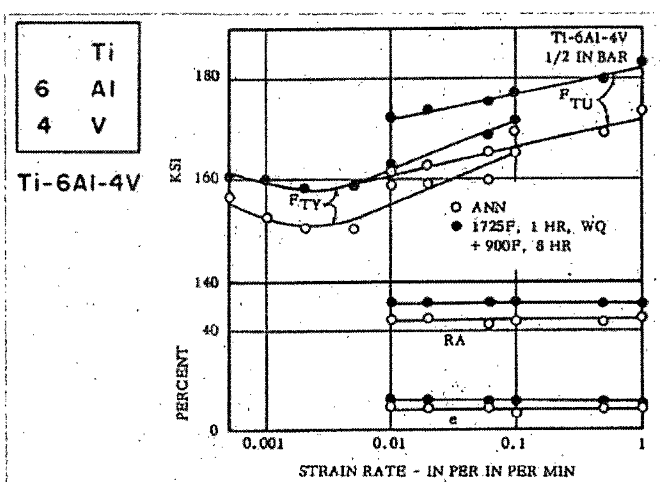
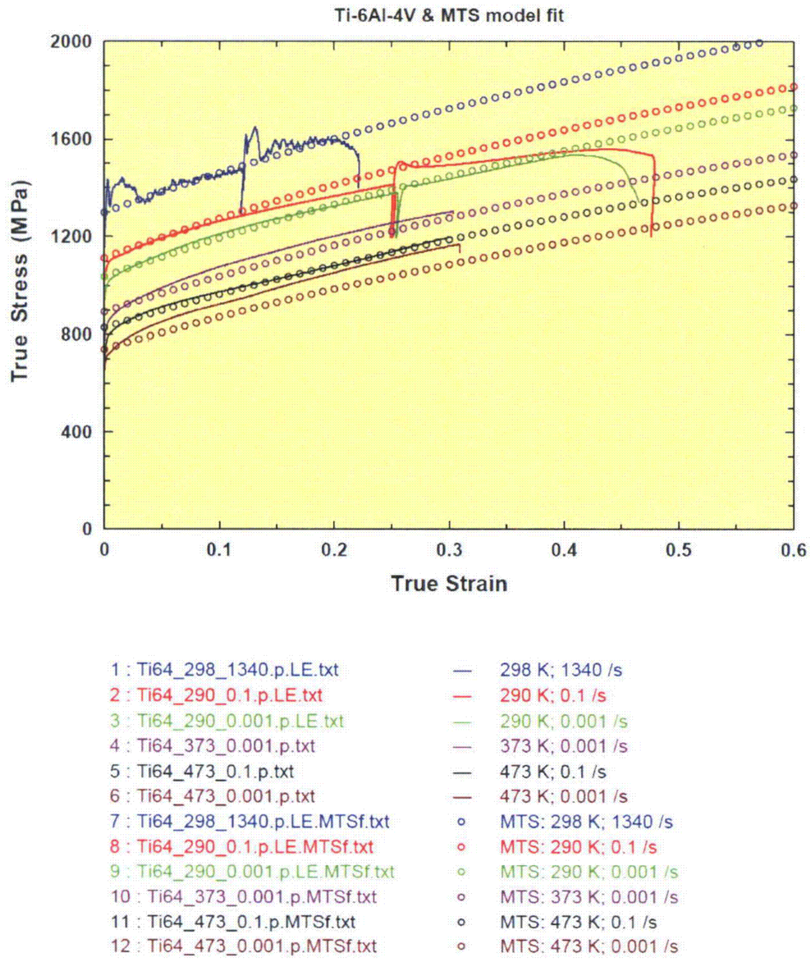


FIG. 3.0219 EFFECT OF STRAIN RATE ON TENSILE PROPERTIES OF ANNEALED AND AGED BAR (13, p. 9)

Los Alamos National Laboratories compiled historical data on higher strain rate testing of Ti-6Al-4V (Reference: Strain Rate Sensitivity Data Used in LANL's Ti-6Al-4V MTS Strength Model, e-mail from George T. Gray (Los Alamos National Labs) to David C. Harding (Sandia National Laboratories), February 19, 2010) and it shows only relatively modest increases in strength and decreases in ductility (especially relative to other ductile metals, which are typically much more strain rate sensitive) up to 1340 /sec strain rates (see graph below, the solid curves).



Although Sandia did test lower strain rate deformations of the T-Ampoule material (using softer impactor materials such as brass), SNL believed it was more important to use strain rates similar to the regulatory high speed impact tests. The net impact velocity between solid contents and the T-Ampoule (and indirectly TB-1 wall) during regulatory high speed impacts was less than the regulatory impact velocity since the wall is still slowing down when contents/T-Ampoule contact occurs. Analyses of the 200 ft/sec horizontal actuator tests of a Ti-6Al-4V slug impacting a hemispherical T-Ampoule and TB-1 combination show peak strain rates at individual elements of -1.18E5 to +1.19E5 1/sec in the T-Ampoule and -4.11E4 to +5.40E4 1/sec in the Ti slug (as shown in the table below, which also lists the peak strain rate in any element within individual "high speed" or "HSRun" analyses). These relatively high strain rates were due to the high yield strength Ti-6Al-4V (141 ksi) plug impacting the thin Ti-6Al-4V T-Ampoule, backed by 140 ksi PH13-8Mo SS TB-1, which was held rigidly. It is important to note that these horizontal actuator tests were used to generate a locus of stress triaxiality vs. equivalent plastic strain that did NOT induce any ductile tearing (no failure).

Run	Max Strain Rate	Min Strain Rate
Impact Test (dish)	1.19E+05	-1.18E+05
Impact Test (plug)	5.40E+04	-4.11E+04
Drop Table	1.78E+03	-2.73E+03
HSRun2	7.42E+04	-6.30E+04
HSRun3	1.71E+04	-2.99E+04
HSRun4	4.72E+04	-9.04E+04
HSRun5	1.21E+04	-1.70E+04
HSRun7	5.92E+04	-8.07E+04
HSRun8	2.20E+04	-2.47E+04
HSRun9	4.26E+04	-9.18E+04
HSRun10	4.14E+04	-5.15E+04
HSRun12	3.66E+04	-2.05E+04
HSRun13	4.98E+04	-4.06E+04
HSRun17	3.92E+04	-3.63E+04
HSRun18	8.94E+04	-1.08E+05
HSRun22	3.15E+04	-2.75E+04
HSRun23	1.84E+04	-2.14E+04
HSRun26	9.75E+04	-7.59E+04
HSRun27	4.06E+04	-5.30E+04

Although the 422 ft/sec impact analyses with various contents (ER cylinders, SC-1's and SC-2's) had a higher overall initial velocity, the relative velocities between the Pu contents and the T-Ampoule were in the 186-405 ft/sec range due to overpack crush still occurring upon contents impact with the T-Ampoule. Higher relative impact velocities are typically associated with smaller contents located initially farther away from the T-Ampoule wall. More importantly than these relative impact velocities, though, is the peak strain rates in the T-Ampoule, which were ALWAYS lower than the peaks during the horizontal actuator tests, and ranged from -9.18E4 to +9.75E4 1/sec. These slightly lower strain rates (despite higher relative impact velocities) are due largely to the lower yield strengths of the Pu (36 ksi for alpha and 9.2 ksi for delta) impacting the T-Ampoule in the regulatory high speed impact analyses vs. the "harder" Ti-on-Ti for the actuator tests.

Thus, any relatively small strain rate sensitivity of the Ti-6Al-4V T-Ampoule (remember, this is NOT a containment boundary; only a eutectic barrier) material would have been observed in the horizontal actuator tests. No failure occurred in these component tests *at even higher strain rates* (and virtually identical stress-tri/EQPS states), *thus none* would be anticipated due to small rate sensitivities during regulatory high speed impacts.

Change Pages for SAR Addendum:

Section 2
A new section, 2.12.3.7, Strain Rate Dependencies, was added to the SAR Addendum in response to this RAI.

Request for Additional Information: 2-10

Define the terms “Function” and “Function Calc” with respect to comparison graphs of deceleration time history.

Figures 2-13, 2-16, and 2-19 show the analytical deceleration time history and another curve labeled “Function” or “Function Calc”

This information is necessary to determine compliance with 10 CFR 71.73 and 71.74.

Applicant Response:

We mistakenly left old hand calculation data in those acceleration history graphs from long ago before we performed detailed finite element analyses (FEAs). These graphs have been rectified.

Change Pages for SAR Addendum:

Section 2
Figures 2-13, 2-16, and 2-19 were corrected in the SAR Addendum in response to this RAI.

Section 3: Thermal Evaluation

Request for Additional Information: 3-1

Justify that the thermal performance of the PAT-1 package as described in the original 1978 SAR satisfies the current 10 CFR 71.71, 71.73, and 71.74 regulations.

Page 3-1 of the addendum states that "The thermal performance of the PAT-1 package is adequate and will safely contain its contents as described in the SAR under the test conditions specified in 10 CFR 71.71, 71.73, and 71.74." This should be clarified since the original SAR does not reference these regulations explicitly. For example, the 1978 SAR refers to Appendix A and Appendix B of 10 CFR 71.

This information is needed to determine compliance with 10 CFR 71.71, 71.73, and 71.74.

Applicant Response:

Package performance to meet 10 CFR 71.71 and 71.73 was demonstrated in the Addendum by analysis. The thermal tests performed and discussed in the SAR meet the test specified in NUREG-0360 which is the same test specified in 10 CFR 71.74. The internal heat limit of the package as described in the addendum is the same as the limit specified in the current COC (and the SAR). Therefore, the maximum temperatures of the package as discussed in the SAR also apply to this addendum.

Change Pages for SAR Addendum:

The sentence in page 3-1 was changed to read: "The thermal performance of the PAT-1 package is adequate and will safely contain its contents as described in this Addendum under the test conditions specified in 10 CFR 71.71, 71.73, and 71.74."

Request for Additional Information: 3-2

Show that the safety performance of the PAT-1 package will not be adversely affected if the maximum TB-1 vessel temperature is 1100°F.

It is stated twice on page 3-24 of the original SAR that the maximum TB-1 vessel temperature is approximately 1100°F. The basis of many current addendum calculations is 1080°F. The effects of a higher vessel temperature should be evaluated, especially relating to the eutectic state and TB-1 pressures described in Section 3.4.5 of the addendum.

This information is needed to determine compliance with 10 CFR 71.73 and 71.74.

Applicant Response:

The maximum pressure calculation in Chapter 3 of the SAR was based on the estimated maximum TB-1 temperature of 1080°F and not 1100°F. In Section 3.6.6 of the SAR, the authors used the expression "approximately 1100°F" when referring to the maximum TB-1 temperature instead of stating the estimated maximum temperature used for the maximum pressure calculation. It is correct to use 1080°F as the maximum TB-1 temperature for the calculations presented in this addendum. Therefore, no changes were made to the Addendum.

Change Pages for SAR Addendum:

None

Request for Additional Information: 3-3

Resolve the correct TB-1 O-ring/seal operating temperature range between the top of page 3-15 and Table 3-5 of the addendum.

The service temperature range of the TB-1 O-ring is listed as -40°C to 204°C in Table 3-5. Page 3-15 of the addendum states a TB-1 elastomeric seal operating temperature range of -40°C to 248°C. This discrepancy should be resolved.

This information is needed to determine compliance with 10 CFR 71.71, 71.73, and 71.74.

Applicant Response:

This was a typographical error. The value in the text is incorrect and the value in Table 3-5 is correct. The correct value is 204°C. However, now that the elastomeric seal was removed from the TB-1, there is no need to mention the operating range of the elastomeric seal in the paragraph identified in this comment.

Change Pages for SAR Addendum:

Section 3
The following sentence was added to the first paragraph on page 3-15:
"As discussed in Section 3.4.6 of the SAR, the copper seal used in the TB-1 is unaffected at this low temperature."

The following sentence was removed from first paragraph on page 3-15:
"The specifications given by the manufacturer of the elastomeric seal of the TB-1 indicate an operating temperature range of -40°C to 204°C (-40°F to 400°F)."

Request for Additional Information: 3-4

Provide a derivation of the maximum pressure calculations listed on pages 3-15 and 3-27 of the addendum.

The basis of the 1.801 atm pressure presented on page 3-15 and 3-27 of the addendum should be justified.

This information is needed to determine compliance with 10 CFR 71.71 and 71.73.

Applicant Response:

There was a correction to the helium pressure generation number presented in Section 4.5.3 of the Addendum. The pressure in atmospheres for helium generation from the largest amount of content (1300 g Pu) is 0.005 atm when added to 1 atm would result in a total of 1.005 atm. This number is used below.

The 1.005 atm value is the sum of the initial internal pressure (1 atm) and the internal pressure increase due to alpha decay obtained from Section 4 of the addendum (0.005 atm). That is,

$$P_{initial} + P_{alpha\_decay} = 1\ atm + 0.005\ atm = 1.005\ atm$$

Equations on pages 3-15 and 3-27 of Section 3 were expanded to reflect the explanation above and make this clearer.

Change Pages for SAR Addendum:

Section 3

The last sentence of the last paragraph on page 3-15 was changed

from:

"The MNOP was then estimated as P_{gauge} = [1.801 atm * (678°R / 530°R) -1 atm] = 1.304 atm or ~ 132.4 kPa (19.2 psig), assuming initial fill of the TB-1 is done with gas at a room temperature of 21°C (70°F) and in an environment with an atmospheric pressure of one."

to:

"The MNOP was then estimated as $P_{gauge} = (P_{initial} + P_{alpha\_decay})*(T_2/T_1)$ - 1atm = [(1 atm + 0.005 atm) * (678°R / 530°R) -1 atm] = 0.286 atm or ~ 29 kPa (4.2 psig), assuming initial fill of the TB-1 is done with gas at a room temperature of 21°C (70°F) and in an environment with an atmospheric pressure of one."

Equation 3-10 on page 3-27 was changed

from:

$$P_{TB\text{-}1@276°F\text{-}gauge} = (P_{initial} + P_{alpha\_decay})*(T_2/T_1) - 1atm = [1.801\ atm*(736°R/530°R) - 1atm]$$

$$= 1.5\ atm\ \underline{or} \sim 152\ kPa\ (22.1psig)$$

to:

$$P_{TB\text{-}1@276°F\text{-}gauge} = (P_{initial} + P_{alpha\_decay})*(T_2/T_1) - 1atm$$

$$= (1\ atm + 0.005\ atm) * (736°R/530°R) - 1atm$$

$$= 0.4\ atm\ \underline{or} \sim 40\ kPa\ (5.8\ psig)$$

Request for Additional Information: 3-5

Confirm that the horizontal position of the package is the bounding orientation when performing the HAC analysis.

The HAC analysis starting on page 3-16 of the addendum is based on horizontal cylinder heat transfer correlations during the fire and cool down process after the fire. It should be confirmed that horizontal cylinder correlations provide conservative heat transfer coefficients.

This information is needed to determine compliance with 10 CFR 71.73.

Applicant Response:

The analysis discussed in page 3-16 relates to the verification model of the fire test that is presented in the SAR, in which the packages was positioned horizontally. For the HAC analysis in Section 3.4.2 (page 3-21), convection heat transfer coefficients were estimated assuming that the package was positioned inside the fire in both the horizontal and the vertical orientation. As demonstrated in Section 3.5.4 (a new section in the Addendum), the horizontal orientation is bounding when performing the HAC analysis. The natural convection heat transfer coefficient for the cool-down process was also justified in that new section of the Addendum.

Change Pages for SAR Addendum:

To reflect this clarification, the following text was added in Section 3.4.2 (page 3-21): "For the simulation of the HAC, the effect of a vertical and a horizontal package orientation in the fire were considered to determine the most damaging configuration. The calculations presented in Section 3.5.4 show that the package would receive more heat during HAC if it is positioned horizontally in the fire. Thus that conservative configuration was assumed for the fire analysis summarized in this section of the Addendum. Section 3.5.4 also shows that the value used for the cool-down is bounding."

Section 3.5.4 was added to show the calculations that support the horizontal orientation as the most damaging configuration.

Request for Additional Information: 3-6

Clarify how the PAT-1 package finite element analysis model was modified to consider the effect of wood burn/decomposition on the package thermal response during and after the regulatory fire.

Page 3-25 of the SAR addendum states that the redwood regions to the outer skin of the package are expected to degrade as wood chars at temperatures above 288°C. The PAT-1 thermal model developed by the applicant does not appear to address these phenomena.

This information is needed to determine compliance with 10 CFR 71.71 and 71.73.

Applicant Response:

The PAT-1 thermal model does include the degradation of the wood as a function of temperature. The second paragraph in Section 3.2.1 of the Addendum explains how wood was treated in the computer model. A table of the material properties used in the model is also presented in that section of the Addendum. The second sentence of the second paragraph in Section 3.4.3 (page 3-25) was simplified and modified to make reference to Section 3.2.1 of the Addendum for clarification.

Change Pages for SAR Addendum:

Section 3

The second sentence of the second paragraph on page 3-25 now reads: "Only the redwood regions closer to the outer skin of the package are expected to degrade (see Section 3.2.1 of the Addendum)."

Request for Additional Information: 3-7

Provide a copy of Reference 12, Nakos, J.T., "Uncertainty Analysis of Steady-State Incident Heat Flux Measurements in Hydrocarbon Fuel Fires," SAND2005-7144, Sandia National Laboratories, Albuquerque, NM, December 2004.

Reference 12 (page 3-30 of the Addendum) was used to calculate proposed heat transfer coefficients associated with HAC fire conditions. A review of this document will aid in evaluating the addendum's HAC calculations.

This information is needed to determine compliance with 10 CFR 71.73.

Applicant Response:

A copy of the report has been provided to the NRC.

Change Pages for SAR Addendum:

None

Section 4: Containment

Request for Additional Information: 4-1

Revise the markings of the Viton Parker O-rings in SAR Addendum Table 4-1 or drawings of 2A0263, 2A0265, and 2A0268.
(a) The applicant marked Viton Parker O-ring, at TB-1, as Parker 1-147 in SAR Addendum drawing of 2A0263, but listed it as Parker 2-242 in SAR Addendum 4.5.4 Table 1.

(b) The applicant marked Viton Parker O-rings, at SC-1/SC-2, as Parker 1-147 in SAR Addendum drawings of 2A0265 and 2A0268, but listed them as Parker 2-147 in SAR Addendum 4.5.4 Table 1.

The applicant should revise all inconsistency per NUREG/CR-5502 because these Viton Parker O-rings are different in size.

This information is required by the staff to determine compliance with 10 CFR 71.33 and 71.43.

Applicant Response:

The drawings have been changed. The Parker specification is no longer used for the *T-Ampoule* and *SC-1* and *SC-2* O-rings.

A specification for Viton A O-rings for the *T-Ampoule* and *SC-1* and *SC-2* sample containers was developed using SAE standards, AS568C for dimensions and AMS 7276G specifying Viton A for physical properties.

Change Pages for SAR Addendum:

Section 1
Drawing 2A0263 The O-ring specification was provided as ITEM 3.
Drawing 2A0265 The O-ring specification was provided as ITEM 3.
Drawing 2A0268 The O-ring specification was provided as ITEM 3.

Section 4
Addendum Section 4.5.4 Table 1 was corrected.

Request for Additional Information: 4-2

(a) Clarify the bases and performance criteria for selection of the part materials used to make the O-rings for both TB-1 and T-ampoule,

(b) Determine how the part material is qualified as an approved equivalent for an elastomeric Viton O-ring, and

(c) Clarify why the service temperature range for the O-rings within T-ampoule and TB-1 (SAR Addendum Table 3-5) are the same.

The applicant identified in SAR Addendum 4.3.1 that the O-rings at TB-1 and T-ampoule are elastomeric O-rings, but specified in Table 7-1 that the O-rings at TB-1 are made of part materials of Viton®, and the O-rings at T-ampoule are made of part materials of AMS-R-832488/1, Viton®, Parker Compound V0747-75 or approved equivalent. The applicant also stated in Table 3-5 that both O-rings at T-ampoule and TB-1, which are made of different part materials, have the identical service temperature range. The applicant should:

(a) Clarify the bases and performance criteria in SAR Addendum that the part materials used for O-ring at TB-1 are different from the part materials used for O-rings at T-ampoule,

(b) Justify the qualification of an approved equivalent based on the critical characteristics of a part material in low temperature performance, high temperature performance under NCT, high temperature performance under HAC, dimensional tolerance, hardness, permeability, radiation resistance, and environmental (corrosion) resistance, and

(c) Address why the service temperature ranges are the same when both elastomeric Viton O-ring (at T-ampoule) and fluorocarbon O-ring (at TB-1) are made of different part materials.

This information is required by the staff to determine compliance with 10 CFR 71.33, 71.43, 71.64, and 71.88.

Applicant Response:

(a) The TB-1 O-ring is not used for shipment of plutonium metal as described in this Addendum (See RAI 1-1). The performance criteria for the part materials used to make the O-rings for the T-Ampoule and SC-1 and SC-2 sample containers are that they retain the glovebox atmosphere, are readily available, and have information regarding characterization of decomposition products at high temperatures. The O-ring specification was based upon SAE AS568 and AMS 7276 standards that provided dimensional and physical properties.

(b) The requirement for an "approved equivalent" for an O-ring is no longer used in favor of a material specification that has good low and high temperature properties, retention of glovebox atmosphere (low permeability), long use history, and identified decomposition characteristics for high temperature evaluation.

(c) The TB-1 O-ring is not used for shipment of plutonium metal as described in this Addendum (See RAI 1-1). The TR-10 from the DuPont Performance Elastomers website (http://www.dupontelastomers.com/Products/Viton/techInfo.asp) is -17°C (1.4°F); the upper temperature range is 204°C (400°F). This is discussed in an RAI in the thermal section.

Change Pages for SAR Addendum:

Check sections and remove language for "approved equivalent" for the following:
Section 1, none.
Section 2, none.
Section 4, none.

Section 1
Drawing 2A0263 The O-ring specification was provided as ITEM 3.
Drawing 2A0265 The O-ring specification was provided as ITEM 3.
Drawing 2A0268 The O-ring specification was provided as ITEM 3.

Section 3
Page 3-6, correct Table 3-5 for temperature range of *T-Ampoule* Viton® O-ring.

Section 4
Clarify why the service temperature range for the O-rings within T-ampoule and TB-1 (SAR Addendum Table 3-5) are the same.
Replace Addendum Section 4.5.4, including correction to Table 1.

Section 7
Page 7-6, Table 7-1, "approved equivalent" removed. Also, Parker Compound V0717 replaced with Viton® A.
Section 8, Page 8-1, Table 8-1, "approved equivalent" removed. Also, Parker Compound V0717 replaced with Viton® A

Request for Additional Information: 4-3

Provide the calculations of allowable helium leak rate and maximum mass of powder release from TB-1 vessel during the post-fire plutonium air transport accident.

The original SAR and SAR Addendum state that based on the thermal tests performed for plutonium air transport accident, the TB-1 vessel maintained containment after experiencing temperature as high as 582°C during post-fire plutonium air transport accident, because (a) the copper gasket at TB-1 maintains seal even though the elastomeric O-ring seal at TB-1 fails at 582°C which is above its service temperature range (-40 to 204°C), (b) the maximum internal pressure of 964.2 psia is below the maximum allowable pressure of 1,100 psia within TB-1, and (c) both helium leak-rate and maximum mass of powder release from TB-1 are below the allowable limits of 4.5×10^{-5} atm-cc/sec and 0.17 mg/week, respectively.

NUREG-0361 (PAT-1 SAR issued in 1978) and PAT-1 Addendum do not have any calculations demonstrating both allowable leak-rate (from ANSI N14.5) and maximum mass powder release from TB-1 are below the allowable limits. The applicant should provide the calculations of both allowable helium leak rate and maximum mass of powder release from TB-1, for validation, in accordance with ANSI N14.5, for plutonium air transport HAC.

This information is required by the staff to determine compliance with 10 CFR 71.35, 71.51, and 71.88.

Applicant Response:

New Addendum Sections 4.5.5 and 4.5.6 were prepared to provide a determination of A_2 for the PAT-1 package with plutonium contents and calculations of the PAT-1 containment vessel's regulatory reference air and other leakage rates. These sections address the question of allowable helium leak rate and maximum mass of powder release from the TB-1 containment vessel during the post fire plutonium air transport accident.

The containment criteria for radioactive, fissile material packages are given in 10 CFR 71.51(a)(1) for NCT ($\leq 10^{-6}$ A_2/h), in 71.51(a)(2) for HAC ($\leq A_2$ in a week), and 71.64(a)(1)(i) for Accident conditions for air transport of plutonium($\leq A_2$ in a week). In Section 4.5.5, the A_2 value for the mixture of isotopes was determined to establish the content containment criteria and to determine the maximum release quantity that is allowed by the regulations. The A_2 values of the plutonium content to be shipped were evaluated based on the mass and weight percents of materials shown in Section 1.2.2. The analysis in Section 4.5.5 was conducted to establish an upper limit for the total activity and the maximum number of A_2s proposed for transport in the PAT-1 package. The values were determined using a maximum of 1300 g of plutonium as a bounding condition.

The PAT-1 leak-testing requirements of the containment boundary are based on the smallest maximum allowable leakage rate generated from the maximum plutonium content defined in Table 4.5.5.1 given the allowable leak rates defined in ANSI N14.5-1997 which defines the maximum allowable leakage rate based on the maximum allowable release rate. L_N, L_A, and L_{PA} are the maximum allowable seal leakage rates for NCT, HAC, and air transport of plutonium. The worst case maximum allowable leakage rates are used to calculate an equivalent leakage hole diameter following ANSI N14.5-1997, Appendix B, for each condition of transport. This leakage hole diameter is used to calculate a reference air and helium leakage rate for leak testing. The bounding mass for the plutonium content of 1300 g was used in this calculation; note that an 831 g weight limit for the plutonium hollow cylinder was used in the structural analysis and is the maximum plutonium metal content for certification. The use of 1300 g was conservative; the maximum allowable leak rates are calculated using this maximum content mass in a much more dispersive form (oxide powder) for additional conservatism at the highest calculated pressures and temperatures as analyzed in LA-UR-08-05154.

Change Pages for SAR Addendum:

Section 4
Added new Sections 4.5.5 and 4.5.6.

Added table in Section 4.1 summarizing release and leakage rates and maximum mass of powder released from Sections 4.5.5 and 4.5.6.

Request for Additional Information: 4-4

Provide the equations and the related parameters/values used to derive the helium generation per gram of plutonium isotopic mixture.

The applicant calculated the helium generation based on the mass loss of the Pu isotopic mixture up to 52 weeks and displayed the helium generation per gram of Pu isotopic mixture in Table 2 of SAR Addendum 4.5.3. The applicant should provide the equations and the related parameters/values used in the equations for validation.

This information is required by the staff to determine compliance with 10 CFR 71.35 71.43(d), 71.64, and 71.88.

Applicant Response:

The equations for helium generation were added to Section 4.5.3. Corrections to the helium pressure from alpha decay were made in Sections 2, 3, and 4.

Change Pages for SAR Addendum:

Section 4
Page 4-19, added equations for helium generation and revised tables in section.

Request for Additional Information: 4-5

Evaluate the potential risks and reactions due to damage of copper foam under post-fire plutonium air transport test.

The applicant stated in SAR Addendum 1.2.1.2 that as a package option, the bare or tantalum-foil-wrapped plutonium metal may be packed with copper (Cu) before they are loaded in sample containers and indicated that the Cu foam material is high-purity Cu foam shapes with a minimum of 1.24 Mpa (180 psi) compressive strength and nominal 9.5% relative density.

With the maximum pressure within TB-1 up to 964.2 psia (SAR Addendum 4.3.1) which is much above the compression limit of 180 psi of Cu foam, the applicant is required to evaluate the potential risks or the unexpected reactions caused by damage of the copper foam under the post-fire plutonium air transport test.

This information is required by the staff to determine compliance with 10 CFR 71.35, 71.43(d), 71.74, and 71.88.

Applicant Response:

The copper foam is no longer included as a packing material for the plutonium metal contents of the T-Ampoule.

For information, the copper foam originally considered is an open cell foam; thus it would be unaffected by the pressure within the TB-1 even though it has a crush strength of 1.24 Mpa (180 psi) after the post-fire accident conditions of air transport of plutonium fire test.

Change Pages for SAR Addendum:

Delete and modify the following sections of the Addendum that included reference to the copper foam as packing material:

Section 1
Page 1-5, 1-12, 1-13, and 1-14.

Section 2
Page 2-2, 2-3, 2-12, 2-19, and 2-355.

Section 4
Page 4-4.

Section 7
Pages 7-8, 7-9, 7-10, and 7-11.

Section 8
None.

Request for Additional Information: 4-6

Correct the typo errors of R value of the Viton O-ring (Parker 2-241) contained within the TB-1 containment boundary.

The applicant listed the dimensions and volumes of Viton A O-rings in SAR Addendum 4.5.4 Table 1. The applicant should correct the typo errors of the R value (a distance from the center of the torus to the center of the cross-sectional area) for the Viton O-ring Parker 2-241 located at T-ampoule. The volumes of the Viton O-rings are important to evaluate the pressure rise in TB-1 during post-fire accidents.

This information is required by the staff to determine compliance with 10 CFR 71.33 and 71.43.

Applicant Response:

The typo errors of R value for the Viton® O-ring were corrected.

Change Pages for SAR Addendum:

A revised Section 4.5.4 was provided.

Request for Additional Information: 4-7

Provide the referenced literature to validate the reaction products which are produced by pyrolysis of Viton A O-rings in air.

The applicant stated in SAR Addendum 4.5.4 that based on the literature review (no literatures are listed in Reference), the reaction products produced by pyrolysis of Viton A in air is similar to that of pyrolysis of PTFE in air, namely, CO, CO_2, HF, CF_4, C_2F_4, C_3F_6, C_4F_8. The applicant should provide the literature to staff to ensure that the pyrolysis reaction and its products by pyrolysis, described in literatures, can be applied to the thermal decomposition of Viton O-rings during post-fire plutonium air transport test in this application.

This information is required by the staff to determine compliance with 10 CFR 71.35, 71.43(d), 71.74, and 71.88.

Applicant Response:

A thorough literature search did not result in any published information on the complete volatilization of either PTFE or Viton® O-rings. Such a complete volatilization has, to our knowledge, never been ***intentionally*** performed, as this type of experiment would have little or no benefit in terms of the intended end-use of a PTFE or Viton® O-ring, which is to act as a robust seal in a fluid environment.

However, several studies, referenced in the submitted paper LA-UR-09-05112 "Thermal Decomposition of Viton® O-rings for the PAT-1 Packaging Accident Scenario," and updated in the more recent submission (LA-UR-10-05846), give results for ***incomplete*** volatilization of PTFE and Viton® in oxidative and non-oxidative environments. These studies show the formation of HF and lower molecular weight saturated fluorocarbons, as we suggest, as well as higher molecular weight, oxygenated compounds.

It was not our intent to suggest that the reaction scheme presented in LA-UR-09-05112 represents the true thermochemically-derived gas-phase equilibrium reaction product mixture, but rather it is postulated in order to put forward a most conservative estimate.

The basis of the submitted calculation assumes the sequential formation of

(1) HF, to completely account for the hydrogen present in the original O-ring material, then
(2) saturated fluorocarbon (CF_4), to account for the excess amount of fluorine over that taken up by HF formation, followed lastly by
(3) either CO or CO_2, to account for the excess amount of carbon remaining after accounting for the hydrogen and fluorine present in the original O-ring(s).

As stated in the submitted paper (LA-UR-09-05112) this scheme results in the maximum number of moles of gaseous reaction products, thereby generating the highest amount of internal pressure in the TB-1 unoccupied volume. This is the most conservative case.

If the formation of higher molecular weight, oxygenated compounds were to be presumed, the result would be a lower number of moles of gaseous reaction products, thereby generating a lower, and less conservative, internal pressure in the TB-1 unoccupied volume.

Change Pages for SAR Addendum:

A revised Section 4.5.4 is provided.

Request for Additional Information: 4-8

Provide References III and IV in SAR Addendum 4.5.4 to validate the excess of carbon will not form CO(g) or CO_2(g) under post-fire plutonium air transport accident.

The applicant assumed in SAR Addendum 4.5.4 that instead of further reacting with oxygen to form CO(g) or CO_2(g), the theoretical excess of carbon after decomposition reaction will remain as solid, unreactive char based on (a) any oxygen present at the time of initial packaging is scavenged completely by the formation of plutonium oxide and (b) the TB-1 remains intact at the theoretical accident conditions. The applicant is required to provide References III and IV in SAR Addendum 4.5.4 to ensure that the phenomena and criteria in References III and IV can be suitably applied to this application.

This information is required by the staff to determine compliance with 10 CFR 71.35, 71.43(d), 71.74, and 71.88.

Applicant Response:

The submitted calculation of O-ring degradation (LA-UR-09-05112) ***does***, in fact, assume that the excess carbon forms either CO(g) or CO_2(g). While the references contained within LA-UR-09-05112 show incomplete volatilization to occur in high-temperature, oxidative environments, we made the assumption, for the purposes of a most conservative estimate, that the maximum number of moles of gaseous reaction products would form, which requires that all of the carbon initially present in the O-ring(s) is volatilized, thereby generating the highest amount of internal pressure in the TB-1 unoccupied volume.

Change Pages for SAR Addendum:

A revised Section 4.5.4 is provided.

Request for Additional Information: 4-9

(a) Demonstrate that the amount of carbon char represents 32% of the original elastomer mass and 93% of the carbon contained in the original elastomer for PAT-1 package,

(b) Clarify how the statement above provides evidence that the volatilization of the polymer is incomplete under thermal degradation of the O-rings in a non-oxidizing environment.

The applicant cited the references and delineated in SAR Addendum 4.5.4 that (a) an incomplete volatilization of the polymer is evidenced by a low yield of fluorine due to thermal degradation of the Viton® O-rings in non-oxidizing environments, and (b) the calculated amount of char represents 32% of the original elastomer mass and 93% of the carbon contained in the original elastomer.

The applicant should provide the calculations to demonstrate that the amount of char represents 32% of the original elastomer mass and 93% of the carbon contained in the original elastomer; and explain how these data of 32% and 93% can be used to identify the volatilization of polymer is incomplete under thermal degradation of O-rings in a non-oxidizing environment.

This information is required by the staff to determine compliance with 10 CFR 71.33, 71.35, 71.43(d), 71.74, and 71.88.

Applicant Response:

As mentioned above, in our Response to RAI 4-8, the submitted calculation assumes complete, total volatilization of the O-ring material. In the original submission (LA-UR-09-05112), an estimate was made for the fraction of original O-ring material which would be left as un-volatilized carbon "char", based on the sequential reaction scheme described in RAI 4-7. This was presented as informational only. The calculation went on to assume that additional oxygen from an unknown source was made available to volatilize this un-volatilized "char". The estimated fraction of un-volatilized "char" is therefore irrelevant for the purposes of determining the final, calculated, internal TB-1 pressure. The updated submission has deleted the section related to the un-volatilized "char".

Change Pages for SAR Addendum:

A revised Section 4.5.4 is provided.

Request for Additional Information: 4-10

Explain why the exhaust filtration system is needed during loading and unloading of T-ampoule assembly in the PAT-1 package.

The applicant stated in SAR Addendum 4.5.4 that the excess of carbon will not react with oxygen to form CO and CO_2 in the thermal decomposition of Viton O-ring. Then, the applicant should explain (a) why the exhaust filtration system is needed (SAR Addendum 7.1.2.1 and 7.2.2.2) when there is no CO or CO_2 generated during loading/unloading of T-ampoule and (b) what kinds of gases are filtrated from the package during loading and unloading of T-ampoule assembly.

This information is required by the staff to determine compliance with 10 CFR 71.43(d), 71.87 and 71.88.

Applicant Response:

The HEPA exhaust filtration systems used in the glove boxes are for particulate control only, not for gasses.

The analysis in Addendum Section 4.5.4 deals with the decomposition of the O-rings contained within the TB-1 during the post-fire period after the accident conditions of air transport of plutonium fire test where CO or CO_2 gases would be generated from decomposition due to the high temperature of the thermal environment.

Change Pages for SAR Addendum:

No Addendum change pages are necessary.

Request for Additional Information: 4-11

Reconcile the Table 4-4 and Table 4-5 designations on page 4-7 of the addendum and their descriptions in the text on page 4-6.

The applicant should correct the inconsistent designation of "No Pu-241 Decay" in Table 4-2 and "100% Pu-241 Decay" in Table 4-3 to make both tables consistent with the text in SAR Addendum 4.1.2.2 (page 4-6).

This information is required by the staff to determine compliance with 10 CFR 71.31 and 71.33.

Applicant Response:

The tables (4-2 through 4-6) were revised for consistency.

Change Pages for SAR Addendum:

Sections 1 and 4
Tables 4-2 through 4-6 on Pages 4-6 through 4-8, as well as tables on Pages 1-9 and 1-10 in Section 1, were revised for to make the tables consistent with the text in referencing Pu-241.

Request for Additional Information: 4-12

Correct the activity A^2 to A_2 in Tables 4-2, 4-3, 4-4, 4-5, and 4-6.

The applicant should correct the typo errors and revise the activity A^2 to A_2 in SAR Addendum Tables 4-2, 4-3, 4-4, 4-5, and 4-6.

This information is required by the staff to determine compliance with 10 CFR 71.31 and 71.33.

Applicant Response:

Tables 4-2, 4-3, 4-4, 4-5, and 4-6 were corrected.

Change Pages for SAR Addendum:

Section 4
The tables on Pages 4-6 through 4-7 were corrected.

Section 7: Package Operations

Request for Additional Information: 7-1

Explain the basis that the O-ring for the containment vessel (TB-1) is replaced after every third use.

The applicant addressed in SAR Addendum 7.1.1 (step f) that the O-ring for the TB-1 is replaced after every third use for radioactive material shipment or annually, whichever occurs first. The applicant should provide the basis, based on O-ring material characteristics and performance, to support that the O-ring can be replaced after every third use of shipment.

This information is required by the staff to determine compliance with 10 CFR 71.33 and 71.87.

Applicant Response:

The O-ring for the TB-1 containment vessel is not used for plutonium metal shipments. See RAI 1-1 for discussion and Addendum change pages.

The following changes were made to delete reference of the use of the TB-1 O-ring. The deletions are similar to RAI 7-5, which mentions lubrication of the TB-1 O-ring.

Page 7-3, Step f on the reference to the TB-1 O-ring has been deleted.

Page 7-6, the reference to the TB-1 O-ring in the second row of Table 7-1, has been deleted.

Page 7-13a, Table 7-3, deleted reference to TB-1 O-ring in fifth row.

Page 7-14a, Step 2 in Section 7.1.2.3, along with the note on Page 7-15 has been deleted.

Page 7-15, Step 3 in Section 7.1.2.3 has been revised to delete mention of the TB-1 O-ring.

Page 7-25, Step 4 in Section 7.3.1, deleted "and O-ring" in Step 4.

Page 7-26, Step 1 in Section 7.3.2, deleted mention of TB-1 O-ring.

Change Pages for SAR Addendum:

See above changes. They are similar to RAI 7-5.

Request for Additional Information: 7-2

Describe the criteria for selecting the inert glove box/bag for loading and unloading plutonium metal and include the photos or schematic drawings of the glove box/bag in the SAR Addendum.

The applicant stated in SAR Addendum 7.1.1 that the glove box/bag can be used to load and unload the plutonium metal contents into the SC-1, SC-2 or T-ampoule. The applicant should describe any criteria of selecting the inert glove box/bag for usage and provide the photos or schematic drawings in the SAR Addendum for documentation.

This information is required by the staff to determine compliance with 10 CFR 71.33 and 71.87.

Applicant Response:

The selection of glove box or glove bag is based on organizational preference. Both are operationally acceptable provided the inert atmosphere is adequate for sample integrity. The atmosphere in the glove box/bag for loading and unloading the plutonium metal contents is to be inert with an oxygen and moisture concentration < 100 ppm to maintain product quality and not for safety purposes. There are a number of glove box/bag manufacturers that can meet the inert atmosphere requirements and instrument manufacturers that have hardware that can measure the oxygen and moisture concentration to < 100 ppm within the enclosures.

Change Pages for SAR Addendum:

Section 7
An example glove box was provided on Page 7-5, courtesy of Innovative Technology.

The above text and example glove box was added to Page 7-5.

Request for Additional Information: 7-3

Provide the criteria required to characterize a part material as an approved equivalent used to make the O-ring.

The applicant identified Viton O-rings for both the T-ampoule and sample containers made of part material AMS-R-83248/1, Viton, Parker Compound V0747-75 or approved equivalent in SAR Addendum Table 7-1. The applicant should provide the criteria to characterize a part material as an approved equivalent for the O-ring, based on the critical characteristics of a seal in low temperature performance, high temperature performance under NCT, high temperature performance under HAC and 60-minute post-fire accident, dimensional tolerance, hardness, permeability, radiation resistance, and environmental (corrosion) resistance.

This information is required by the staff to determine compliance with 10 CFR 71.33 and 71.87.

Applicant Response:

The "approved equivalent" requirement for O-rings was deleted and a specific named manufacturer's material (Viton® A) was selected because the chemical formulations for various manufacturer's source material for O-ring fabrication are proprietary and not publicly available. This change was made since complete knowledge of the manufacturers' chemical formulations for the base material was not available for the decomposition calculations in Section 4.5.4.

Change Pages for SAR Addendum:

Section 7
Pages 7-6, replaced "AMS R 83248/1, Viton®, Parker Compound V0717 75 *or approved equivalent* O-ring" with"100% virgin Viton® A per SAE AMS 7276G, 75 Durometer Shore A" in Rows 5 and 8 of Table 7-1.

Section 8
Pages 8-1 and 8-1a, replaced "AMS R 83248/1, Viton®, Parker Compound V0717 75 *or approved equivalent*" with "O-ring, 100% virgin Viton® A per SAE AMS 7276G, 75 Durometer Shore A" in Rows 3 and 6 of Table 8-1.

Request for Additional Information: 7-4

Specify the free release limits and describe the procedures/methods to determine the free release limits for decontamination of the T-ampoule assembly exterior.

The applicant described in SAR Addendum 7.1.2.1 that the appropriate processing, handling, and contamination control in loading the T-ampoule assembly is implemented to maintain an uncontaminated (≤ free release limits) T-ampoule assembly exterior. The applicant should specify the free release limits and describe the procedures or the methods to determine the free release limits (for SC-1, SC-2, and Pu hollow cylinder) to instruct the cask user for appropriate decontamination of the T-ampoule assembly.

This information is required by the staff to determine compliance with 10 CFR 71.33, 71.37, and 71.87.

Applicant Response:

The surface contamination values for "free release" as measured on the exterior of the T-Ampoule and SC-1 or SC-2 sample containers are provided in a table in Appendix D of 10 CFR Part 835. This information is used to identify the need for posting of contamination and high contamination areas in accordance with §835.603(e) and (f) and identifying the need for surface contamination monitoring and control in accordance with §§835.1101 and 835.1102. DOE Order 5400.5 provides the surface contamination guidelines in Chapter IV, Figure IV-1 for DOE sites. The purpose for decontaminating the outside surface of the T-Ampoule is to permit loading of the T-Ampoule with its contents into the TB-1 outside of the contaminated area. This would make closure of the TB-1 lid and body easier, and leak testing would be easier to perform.

The exterior surface of the SC-1 and SC-2 sample containers are decontaminated since they are loaded with plutonium metal content and sealed inside of the glove box or glove bag which provides an inert atmosphere and controlled oxygen and moisture content for product quality. The sample containers may be loaded into the T-Ampoule in a glove box or glove bag or in an open front hood and downdraft room. There is no requirement for decontamination of the Pu hollow cylinder (content) since it would be loaded into the T-Ampoule inside of the glove box or glove bag.

The exterior surface of the T-Ampoule and sample containers will be decontaminated using industry accepted decontamination procedures and surface measurements performed using standard Health Physics survey measurement equipment.

Change Pages for SAR Addendum:

Section 7

Page 7-7, third bullet. Added a note to the bullet that includes 10 CFR 835 Appendix D citation, DOE Order 5400.5, and general decontamination procedures.

Request for Additional Information: 7-5

Clarify the need to lubricate the O-ring installed in the TB-1 container to ensure containment integrity.

The applicant stated in SAR Addendum 7.1.2.1 that the O-ring installed at the body of the T-ampoule and the O-ring installed in the SC-1 or SC-2 are visually inspected and lubricated to ensure proper installation. The applicant should clarify whether the lubrication is also required for the O-ring installed in the TB-1 containment vessel (containment boundary) or not and what is the basis for the decision with respect to containment safety.

This information is required by the staff to determine compliance with 10 CFR 71.33, 71.51, and 71.87.

Applicant Response:

The TB-1 O-ring is no longer a part of the TB-1 assembly for shipment of plutonium metals as described in RAI 1-1. Thus the requirement for lubrication is no longer needed. The copper gasket (Drawing No. 1019) provides the containment boundary seal. The changes to the text in Section 7 follow:

In Section 7.1.1 on Page 7-3, deleted (f) regarding TB-1 O-ring.

Row 2 describing the O-ring for the TB-1 in Table 7-1 was deleted.

In Section 7.1.2.3, Step 2 in Page 7-14 describing the lubrication and installation of the TB-1 elastomer and accompanying note was deleted since the TB-1 O-ring is not used for plutonium metal shipments.

In Step 3 on Page 7-15, revised sentence to read:

> "3. Insert the *Lid, TB* into the *Body, TB*, taking care not to damage the knife edge seal surfaces."

Lubrication is used to ease closure of the T-Ampoule and Sample Containers. The grease reduces friction between the elastomer and the titanium during the lid installation step. It also provides limited sealing assistance. It is an operational aid and does not contribute to the PAT-1 containment safety.

In Section 7.1.2.4 on Page 7-15c, corrected reference to *TB-1 / T-Ampoule Shipping Vessel* (2 places) and revised second bullet to read:

- Major imperfections of the T-Ampoule and SC-1 and SC-2 O-rings are an indication of marring or chafing (i.e., scuff marks), or the O-ring does not have a round cross section.

In Section 7.3.1 on Page 7-25, Step 4, deleted “and O-ring” from sentence.

In Section 7.3.2 on Page 7-26, Step 1, deleted “and O-ring” from sentence.

Change Pages for SAR Addendum:

Section 7

Page 7-3, Section 7.1.1, deleted (f) regarding TB-1 O-ring.

Page 7-6, Table 7-1, deleted Row 2 describing the TB-1 O-ring.

Page 7-14a and 7-15, deleted Step 2 describing the lubrication and installation of the TB-1 O-ring.

Page 7-15, Section 7.1.2.3, Step 3, revised sentence to read as above, under Applicant Response.

Page 7-25, Section 7.3.1, Step 4, deleted “and O-ring”.

Page 7-26, Section 7.3.2, Step 1, deleted “and O-ring”.

Request for Additional Information: 7-6

Explain why the step 8 in SAR Addendum 7.1.2.1.2 is repeated for the SC-1, but not repeated for the SC-2, when loading these sample containers into the T-ampoule.

The applicant described in step 12 of SAR Addendum 7.1.2.1.2 (Loading the Sample Containers) that the user should repeat the steps 3 through 8 to ensure the sample container-1 (SC-1) are in place (only to step 7 for sample container-2, SC-2).

The applicant should explain why there is no need to repeat step 8: “the lid of sample container should be engaged and tightened by hand until the lid and body flange are fully seated and the hand tightening until seated is only required for proper closure,” for the SC-2, when both SC-1 and SC-2 are similar in configuration.

This information is required by the staff to determine compliance with 10 CFR 71.87 and 71.88.

Applicant Response:

There was an error in the procedure for loading the SC-1 or SC-2 sample containers in the T-Ampoule. Section 7.1.2.1.2, Step 12, was revised to read:

12. Repeat Steps 3 through 11 until the sample containers are in place in the Inner Cradle.

To address the comment about repeating Step 8, it is correct that the lid of each sample container must be engaged and tightened by hand prior to loading into the T-Ampoule. The revision of Step 12 addresses that comment.

Change Pages for SAR Addendum:

Section 7
Page 7-12, corrected Step 12 and revised the Note under Step 12.

Section 8: Acceptance Tests and Maintenance Program

Request for Additional Information: 8-1

Provide the criteria or the guidance used to: (a) define the leak rates on the T-ampoule, SC-1 and SC-2, and (b) to ensure the retention of the glove box atmosphere in acceptance tests.

The applicant noted in SAR Addendum Table 8.2 that both the T-ampoule and sample containers (SC-1 and SC-2) are not containment boundaries, and the leakage rate tests on the T-ampoule and sample containers are mainly used to demonstrate retention of the glove box atmosphere that is required as part of laboratory support operations to minimize metal contents degradation. Therefore, these leakage rate acceptance requirements are user-defined.

The applicant should provide the criteria or the guidelines in the SAR Addendum to instruct the cask users how to define the leakage rates for the T-ampoule, SC-1, and SC-2, and provide the required guidance and procedures for package users to ensure the retention of glove box atmosphere in package acceptance test.

This information is required by the staff to determine compliance with 10 CFR 71.35, 71.87, and 71.88.

Applicant Response:

The leak rate for the T-Ampoule and SC-1 and SC-2 sample containers is 10^{-3} cc/s and is for retention of glove box atmosphere for product quality and not for PAT-1 containment safety. The T-Ampoule and sample containers are carried within the TB-1, which has a metal seal demonstrated during pre-shipment, maintenance, periodic, and acceptance leak tests to 10^{-7} atm cc/s.

A leak test will be conducted to demonstrate leakage rate of 10^{-3} atm cc/s. The requirements are based on ANSI N-14.5 97 and are specified in Section 8.2.2.1 of this Addendum.

The leakage rate acceptance test criteria for the T-Ampoule is the same as for the PC-1 product can for the oxide shipments.

Change Pages for SAR Addendum:

Added Section 8.2.2.1 to include text originally under Section 8.2.2 with revisions and additions.
Added Section 8.2.2.2.

Request for Additional Information: 8-2

Describe the test or procedure necessary to ensure that any adverse effects of accumulated moisture absorption by the redwood do not affect package integrity and operation.

The applicant should provide a test or procedure to ensure that any adverse effects of accumulated moisture absorption by the redwood in the PAT-1 package do not affect the package integrity and operation.

This information is required by the staff to determine compliance with 10 CFR 71.85 and 71.87.

Applicant Response:

In PAT-1029, "Material Specification, Redwood for PAT Package," Section 3 of the SAR provides the requirements for the redwood used in the AQ overpack. The moisture content shall not exceed 12% and the material shall be protected, as necessary, to assure this condition. The redwood blocks for the impact absorber are kiln dried to a moisture content to not exceed 12 %. The blocks are glued together and machined to final dimensions. The exterior of the machined block assembly is sealed and then glued to the stainless steel drum per 9.2.3.3 b. in the SAR. About 50% of the exposed surface of the wood is covered by the stainless steel. Section 4 of PAT-1029, Quality Assurance Provisions, states that the redwood shall be inspected after final machining and just before application of sealant to assure that the moisture content in 3.1.c in PAT-1029 is not exceeded using a moisture meter per manufacturer's specifications. The sealant is intended to prevent excessive moisture retention or loss from the wood.

The PAT-1 packages have been stored in a low humidity location (Albuquerque) since the late 1970s. It is not expected that these packages would have absorbed excess moisture since they were sealed on the exposed surfaces of the glued wood structure and covered and sealed by the surrounding stainless steel drum and kept in a dry location.

From "Wood Handbook, Wood as an Engineering Material," [Ref. 1], Page 12-15 in the Finish and Factory Lumber section, Table 12-4 describes the increase in temperature storage temperature above outside temperature to maintain equilibrium moisture content in the wood. For the less than 12% moisture content redwood that we have in the PAT-1, Table 12-4 (shown below) from the Wood Handbook indicates that for heating methods to maintain equilibrium, moisture content for an outside relative humidity of 60% or less, that no increase in temperature differential would be required to maintain the equilibrium moisture content.

Table 12–4. Amount by which temperature of storage area must be increased above outside temperature to maintain equilibrium moisture content

Outside relative humidity (%)	Temperature differential (°C (°F)) for desired equilibrium moisture content						
	6%	7%	8%	9%	10%	11%	12%
90	18.3 (33)	16.1 (29)	12.8 (23)	10.0 (18)	8.3 (15)	6.1 (11)	5.0 (9)
80	16.7 (30)	13.9 (25)	10.5 (19)	7.8 (14)	6.1 (11)	4.4 (8)	3.3 (6)
70	13.9 (25)	11.1 (20)	8.3 (15)	5.6 (10)	3.9 (7)	2.2 (4)	1.7 (3)
60	11.1 (20)	8.3 (15)	5.0 (9)	3.3 (6)	1.7 (3)	—	—
50	8.3 (15)	5.6 (10)	2.8 (5)	0.6 (1)	—	—	—

Table 12-4 from Ref. 1:

For Albuquerque, New Mexico [Ref. 2], the highest average temperature in July is 33°C (91°F) and average relative humidity is 23%. In January, the lowest average temperature is -5°C (23°F) and the average relative humidity is 49%.

At the sending and receiving facilities where the PAT-1 will be used for plutonium metals shipments, the following temperature and humidity data are provided.

At the facility located in New Mexico [Ref. 3], the temperatures in July, range from 12.7°C (55°F) to 27.2°C (81°F) and relative humidity is 40%. In January, the temperatures range from -8.3°C (17°F) to 4.4°C (40°F) and average relative humidity is 55%.

The second facility is located near an area next to the ocean and the site provided the data for the handling facility [Ref. 4]. The temperature for summer conditions is 27°C (80.6°F) and the temperature for winter conditions is -5°C (23°F). Inside of the facility, the temperature is 22°C (71.6°F) and 50% relative humidity maximum.

The relative humidity information for the PAT-1 using sites indicate that the 12% moisture content of the redwood would be in equilibrium when compared to the heating and storage information in Table 12-4 of the Wood Handbook. Thus no major change in moisture is expected. No accumulated moisture absorption by the redwood in the PAT-1 package is predicted by Table 12-4, and thus the package integrity and operation would not be affected.

An administrative procedure will be implemented that requires the PAT-1 packagings be stored within the user facilities when not in use. No external storage of the packagings is permitted.

References:

1. "Wood Handbook, Wood as an Engineering Material," United States Department of Agriculture, Forest Service, Forest Products Laboratory, FPL-GTR-113, March 1999.
2. "What is the Climate, Average Temperature/Weather in Albuquerque, New Mexico?, http://www.climatetemp.info/usa/albuquerque-new-mexico.html .
3. Los Alamos National Laboratory, http://public.lanl.gov/radiant/losalamos.html , 2001.

4. Personal communication, Fred Gill, UK, June 18. 2010.

Change Pages for SAR Addendum:

Section 7
Page 7-27, Added new section, 7.3.3 Storage of an Empty PAT-1 Package with or without the TB-1 and Internal Hardware, with the following text:

"The PAT-1 packaging when not in use shall be stored assembled (with lids in place) inside of a temperature and humidity controlled building. The temperature shall be between 10°C (50°F) and 27°C (80°F), and the relative humidity shall not exceed 60% within the building."

Request for Additional Information: 8-3

Explain why the original SAR lists a leak test specification for the PC-1 product can, while the current addendum does not provide a detailed leakage test specification for the T-Ampoule.

The applicant should explain why the original SAR lists a leak test specification for PC-1, while the current addendum does not provide a leak test specification for the T-Ampoule.

This information is required by the staff to determine compliance with 10 CFR 71.87 and 71.88.

Applicant Response:

The original SAR lists a leak test specification for the PC-1 product can because the PAT-1 was designed to meet the then existing containment acceptance standards (1978) specified in 10 CFR 71 and in the NRC Qualification Criteria set forth in NUREG-0360. The leak test requirement for the PC-1 is stated in Section 8.2.2 of the SAR; the leakage test shall indicate a leakage of less than 10^{-3} atm cm^3/s. The PC-1 product can provides the separate inner container required by 10 CFR §71.42 (1978).

For the T-Ampoule, the same leak test requirement as for the PC-1, 10^{-3} atm cm^3/s, is maintained. This requirement may be met with a pressure change test. The T-Ampoule is an inner vessel similar to the PC-1 Pu oxide container inside of the TB-1, but holds metal contents.

Change Pages for SAR Addendum:

Section 7
Page 7-13, 7.1.2.2, added leakage rate test of 10^{-3} atm cc/s for T-Ampoule.

Section 8
Page 8-3, second and fourth rows of Table 8-2, third column, add "Perform leakage rate test – acceptance is less than 10^{-3} atm cc/s.

Page 8-4, first row in continuation of Table 8-2, third column, add "Perform leakage rate test – acceptance is less than 10^{-3} atm cc/s.

Page 8-5, Section 8.1.4, delete "user will define" and "s" in requirements and add "is 10^{-3} atm cc/s and is" after "*...SC-2 Assembly*" and "to maintain product quality" after "...support operations."

Page 8-7, added leak tests in 8.2.2.1 for *T-Ampoule*, *SC-1*, and *SC-2*.

APPENDIX: CORRESPONDENCE

March 1, 2010

Mr. Maximo A. Barela
Radioactive Material Packaging Manager
DOE-NNSA
P.O. Box 5400
Albuquerque, NM 87185

SUBJECT: REQUEST FOR ADDITIONAL INFORMATION FOR REVIEW OF THE MODEL NO. PAT-1 PACKAGING

Dear Mr. Barela:

By letter dated September 21, 2009, you submitted an application for revision to Certificate of Compliance (CoC) No. 0361 for the Model No. PAT-1. The application proposes to add plutonium metals to the list of authorized contents for the PAT-1 transportation package. Our established schedule provides a CoC issuance date of May 31, 2010.

In connection with the staff=s review, we need the information identified in the enclosure to this letter. We request that you provide this information by April 5, 2010, or earlier if possible. Inform us at your earliest convenience, but no later than March 22, 2010, if you are not able to provide the information by that date. To assist us in re-scheduling your review, you should include a new proposed submittal date and the reasons for the delay.

Please reference Docket No. 71-0361 in future correspondence related to this request. The staff is available to meet to discuss your proposed responses. If you have any questions regarding this matter, I may be contacted at (301) 492-3394 or you may contact Chris Staab of my staff at (301) 492-3321.

Sincerely,

/RA/

Eric Benner, Chief
Licensing Branch
Division of Spent Fuel Storage and Transportation
Office of Nuclear Material Safety
and Safeguards

Docket No. 71-0361
TAC No. L24377

Enclosure: Request for Additional Information

cc: E. Redmond, Nuclear Energy Institute

March 1, 2010

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Radioactive Material Packaging Manager
DOE-NNSA
P.O. Box 5400
Albuquerque, NM 87185

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Office of Nuclear Material Safety
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Docket No. 71-0361
TAC No. L24377
Enclosure: Request for Additional Information
cc: E. Redmond, Nuclear Energy Institute

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OFC:	SFST	E	SFST		SFST		SFST		SFST		SFST	
NAME:	CStaab		DForsyth		JSmith		JChang		JSolis		MGordan	
DATE:	2/23/2010		2/23/2010		2/26/2010		2/23/2010		3/1/2010		2/26/2010	
OFC:	SFST		SFST		SFST		SFST		SFST		SFST	
NAME:	JPiotter		MWaters		CRegan		LCampbell		MDeBose		EBenner	
DATE:	2/26/2010		3/1/2010		2/26/2010		2/23/2010		2/26/2010		3/1/2010	

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DOE-NNSA

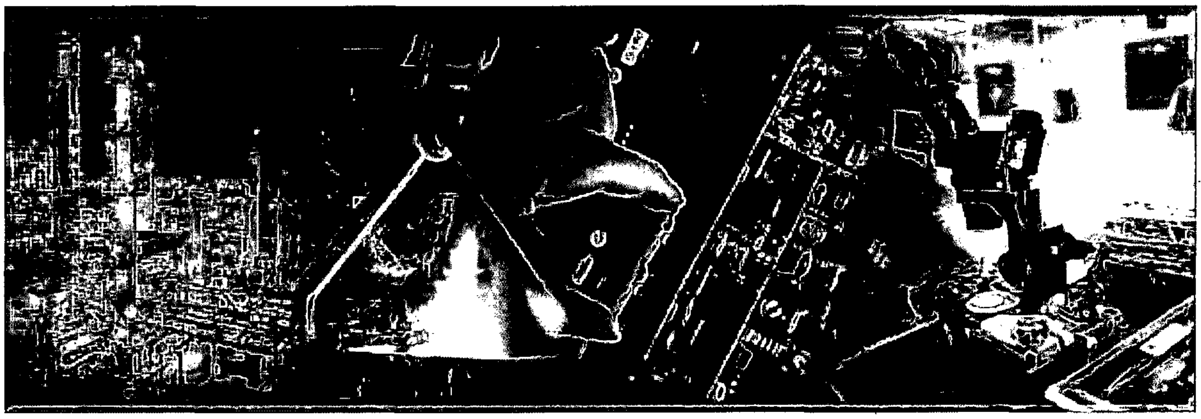
Docket No. 71-0361

Request for Additional Information

Model No. PAT-1

By letter dated September 21, 2009, you submitted an application for revision to Certificate of Compliance (CoC) No. 0361 for the Model No. PAT-1 packaging. This Request for Additional Information (RAI) identifies information needed by the U.S. Nuclear Regulatory Commission (NRC) staff in connection with its review of the application. Each individual RAI describes information needed by the staff for it to complete its review of the application to determine whether the applicant has demonstrated compliance with the regulatory requirements.

ATTACHMENTS: GLOVE BOX BROCHURES



A Breakthrough In
Enhanced Oxygen Sensing
Performance

The New DF-300$\mathcal{E}$ Series and $\mathcal{E}$-Sensor

Delta F Delivers a Breakthrough
in Enhanced Oxygen Sensing Performance

For years, you have depended on Delta F for advances in oxygen analysis. We have consistently introduced technological advancements starting with our unique non-depleting coulometric sensor and built upon the expertise and experience we have accumulated in over 30 years of pushing the boundaries of oxygen analysis. Now we have reinvented our sensor technology from the ground up to develop a performance breakthrough in oxygen analysis with the DF-300$\mathcal{E}$ Series and our unique new enhanced performance $\mathcal{E}$-Sensor.

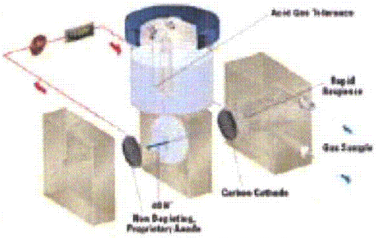
The $\mathcal{E}$-Sensor - Enhanced Oxygen Analysis Performance

At heart the $\mathcal{E}$-Sensor is the next evolutionary stage in Delta F's unique electrochemical sensor technology. Intensive research to identify and resolve performance-limiting elements in the sensor led to a new proprietary carbon-based cathode system, new proprietary anode system, new electrode fabrication processes, new sensor assembly and conditioning processes, and a new high purity electrolyte formulation. These enhancements are all embodied in the $\mathcal{E}$-Sensor to deliver unsurpassed analytical performance, dependability and reliability.

The $\mathcal{E}$-Sensor's new design and use of enhanced sensor materials significantly improves performance to deliver a price/performance breakthrough with:

- Faster purge down on initial start-up
- Faster recovery from upset
- Improved speed of response
- More stable baseline with improved temperature stability
- No need for customer "zeroing"
- Reduced fluid loss and accompanying maintenance
- Improved hardiness and acid gas tolerance

For more detailed information on our $\mathcal{E}$-Sensor and its performance, download our $\mathcal{E}$-Sensor technical bulletin from www.delta-f.com.

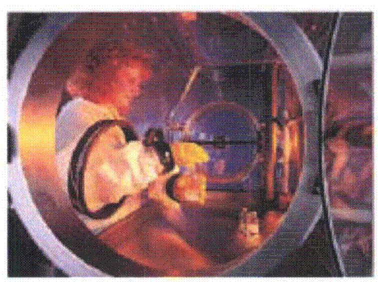


$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$ (cathode)

$4OH^- \rightarrow O_2 + 2H_2O + 4e^-$ (anode)

How Enhanced Oxygen Analysis Can Improve Your Process and Yield

There are many industrial processes where even the slightest presence of oxygen can have a negative effect on process yield or quality. The expanded DF-300$\mathcal{E}$ series of oxygen analyzers with $\mathcal{E}$-Sensor technology has the flexibility to apply its price/performance advantages across a wide range of applications.

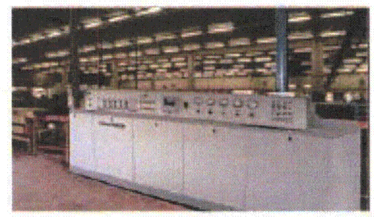


Glovebox applications – where materials processing and experiments must be carefully controlled and performed under low oxygen conditions - for example in bio-research or nuclear applications.

Metals/Heat Treating – metals processing, steel production, bright annealing, sintering, specialty welding – all require close analysis and control of oxygen levels.

Bulk Industrial and Specialty Gases - production of high purity gases, transportation of bulk industrial gases, gas cylinder certification, air separation unit control – requiring low level detection and control of oxygen.

Chemical/Petrochemical - control of undesirable oxidation during steam cracking of hydrocarbon feedstocks, quality assurance of polyolefin production, quality control and process performance enhancement of plastics such as polyethylene, polypropylene, polyesters and other polymers – oxygen analysis improves both quality and processing performance.



Electronics and Semiconductors – production furnaces, chip fabrication, heat treating for silicon wafers, leadless soldering, ceramic production – oxygen control is key for greater yield and better quality yield with fewer defects and less scrap.

$\mathcal{E}$-Sensor Benefit	Electronics	Indust. & Spec Gas	OEM	Petro/ Processing	Glovebox	Heat Treating
Faster purge down on startup	MAJOR!	Secondary	MAJOR!	Secondary	Secondary	MAJOR!
Faster recovery from upsets	MAJOR!	MAJOR!	MAJOR!	MAJOR!	MAJOR!	MAJOR!
Faster speed of response	MAJOR!	MAJOR!	MAJOR!	MAJOR!	MAJOR!	MAJOR!
Lower baseline/no customer zero	MAJOR!	MAJOR!	MAJOR!	MAJOR!	MAJOR!	MAJOR!
Reduced water consumption	Secondary	Secondary	MAJOR!	Secondary	MAJOR!	Secondary
Improved acid gas tolerance	MAJOR!	Secondary	MAJOR!	MAJOR!	Secondary	MAJOR!

The DF-300ℰ Product Family

The DF-300ℰ Series of Analyzers – The Right Analyzer for Your Application
In addition to providing enhanced performance, the DF-300ℰ Series offers a wide range of analyzers to meet your specific application requirements. Each member of the DF-300ℰ family delivers:

- Lowest available detection levels
- Elimination of false low readings and periodic sensor replacement
- Unmatched reliability and stability
- Fast response so you can react to problems immediately
- Compact and modular design to fit into your plant and process easily
- Affordable choices that easily justify implementation – including the availability of our ℰ-Sensor and models with our solid state coulometric sensor

The DF-310ℰ – Flexible, Adaptable Oxygen Analyzer
The DF-310ℰ with the ℰ-Sensor is a flexible and adaptable O_2 analyzer ready to handle almost any application. The DF-310ℰ packs analysis power into a compact package and is available in 24 VDC and 110VAC and 220 VAC versions.

The DF-310ℰ delivers:

- Accuracy: the greater of ±3 reading or ±0.02% Range
- Ranges from 0-0.5 ppm to 25%
- Instantaneous response to oxygen change
- Fast response: typically less than 10 seconds to read 90% of a step change
- Background gas compatibility including N_2, H_2, CO, freons, hydrocarbons, etc.
- Stab-EL™ option removes acids and ionic impurities from the electrolyte that could affect sensor performance
- Optional battery back-up for extended use and process protection

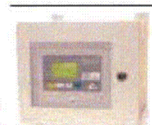
DF-320ℰ – O_2 Analyzer for Hazardous Areas
The DF-320ℰ is specifically designed for the rigors of harsh and hazardous environments. It can handle Class I, Div 2, Groups A,B,C,D, and ATEX Zone 2 certification, where potential explosions are a possibility – for example in natural gas lines or LNG storage, etc.

- Designed to handle Class I Div. 2
- Best analyzer for harsh or hazardous environments.

DF-330ℰ- Solid State Coulometric Sensor
The DF-330ℰ provide an ideal oxygen analyzer for many industrial applications where very fast response is essential. The DF-330ℰ uses a unique solid state coulometric sensor with a solid electrolyte to deliver fast response across a wide measurement range.

The DF-330ℰ features:

- Exceptionally fast response – ppm levels from air in 5 minutes
- The ability to be mounted in-situ or in flow-through applications
- Quick recovery down to low levels after exposure to air
- Good low-end sensitivity plus a wide measurement range
- Consistent accuracy from sub-atmospheric pressure too 100 psig



DF-340ℰ and the new DF-370ℰ Designed for the Dirty Work
The DF-340ℰ provides a tough, durable NEMA 4x version of the standard DF-310ℰ that is protected by a dustproof, waterproof enclosure with the sensor in a Nema 7 enclosure

The DF-370ℰ provides the same hard working, industrial strength analyzer, in a NEMA 7 enclosure with the option to also place a remote sensor in a NEMA 7 enclosure.

The DF-340ℰ and DF-370ℰ provide the ultimate in O_2 sensing for harsh and hazardous environments where enclosure is required.

www.delta-f.com

Performance

Accuracy: (at constant conditions)

Standard Models: the greater of ±3% Reading or 0.5% of Range

High Resolution Models: the greater of ±3% Reading or 0.02% of Range (except for 310-H00100: ±3% Reading or 50 ppb)

Oxygen Sensitivity

Lowest detectable change	3 ppb (310E-H0050M model)
Low detection limit	3 ppb (310E-H0050M model)

Response Time

Responds instantaneously to O_2 change. Typically less than 10 seconds to read 90% of a step change. (Equilibration time depends on specific conditions.)

Range Ranges are available from 0-0.5 ppm to 100%

Ambient Operating Temperature

DF-310E, 320E, 340E, 370E:	32° to 113° F (0° to 45° C)
DF-330E:	32° to 176° F (0° to 80° C)

Background Gas Compatibility

Basic Sensor:

All inert and passive gases including N_2, H_2, CO, freons, hydrocarbons, etc.

Sensor with Stab-EL™ Option:

Neutralizes trace contaminants including acids such as CO_2, H_2S, Cl_2, NO_X, SO_X, etc. (Consult Delta F for concentration limits)

Solid State Sensor:

Not compatible with gases containing hydrocarbons, combustibles, H_2, CO, NO_2, S or Pb

Gas Sample Conditions

Sample Pressure

Operating limits for DF-310E, 320E, 340E, 370E:

- 0.2 to 1.0 psig (1.03 to 1.08 Bar) – Standard
- 15-25 psig with welded sample inlet (orifice restricted)
- 2.0 psi vacuum to 0.2 psig (.88 to 1.03 Bar) use pump
- 1.0 to 10 psig (1.08 to 1.7 Bar) use valve (standard) or regulator (optional)
- Above 10 psig (1.7 Bar) use regulator

Sensor overpressure damage limit: 10 psig (1.7 Bar)

Operating limits for DF-330E:

300 Torr to 100 psig (17 Bar)

Return Pressure:	Atmospheric Vent (optimal)
Limits	+5 psig (1.36 Bar) to –5 psig (0.67 Bar) (no limits for DF-330E)
Flow Rate:	1.0 to 3.0 SCFH (0.5 to 1.5 slpm) (ambient to 3.0 SCFH for DF-330E)
Temperature (Gas Sample)	0° to 150° F (-17.8° to 66°C) (except 32° to 176° F (0° to 80° C) for DF-330E)
Moisture:	No limits (avoid condensation)
Oil/Solvent Mist:	< 0.5 mg/ft3 (standard) > 0.5 mg/ft3 – use filter
Solid Particles:	< 2 mg/ft3 (standard) > 2 mg/ft3 use filter

Gas Flow System

Construction Materials:	300 Series stainless steel
Gas Connections:	1/8" compression tube fittings VCR compatible (optional for DF-310E and DF-320E except standard for 310E-H0050M and 320E-H0050M)

Construction

Enclosures:	NEMA 1, NEMA 4, NEMA 7 Remote NEMA 4, NEMA 7 or sensor bracket (optional for DF-310E and DF-340E)
Weight:	10 lbs. (4.52 kg.) (NEMA 1)
Dimensions:	8.32" W x 7.75" H x 7.91" D (21.1 cm W x 19.7 cm H x 20.1 cm D)

Electrical

Power Input	110 VAC, 220 VAC and 22-26 VDC (optional), 1 Amp (max)
Output Signals	Isolated 0 - 5, 10 VDC AND Isolated 4-20, 2-20 mADC (optional)

User adjustable to 10% of Full Scale to Full Scale (Std Res)

User adjustable to 1% of Full Scale to Full Scale (High Res)

User selectable Output Freeze during Calibration

Alarms, audible/visual	4 Oxygen (optional) (adjustable set-point) Electrolyte Condition (standard) Temperature (optional) Low Flow (optional)
Alarm Relays	4 independently assignable relays to Alarms, In-Calibration, Sensor Off and Expanded Range Scale (optional)
Alarm Relay Rating	0.3 Amps at 30 VDC Failsafe Action
Display:	Supertwist LCD graphics
Certifications:	ATEX Class 1, Division II (DF-320E)

Configuration and Installation

Delta F provides comprehensive assistance for a broad variety of application problems including measurements of semiconductor specialty gases. Depending on the model, Delta F analyzers can be configured to provide a wide choice of outputs for data collection and process control systems. Most Delta F analyzers can be configured for remote operation and all can be ordered with classified area enclosures. Contact your Delta F representative for an Applications Data Sheet and pricing information.

THE DIFFERENCE
DELTA F

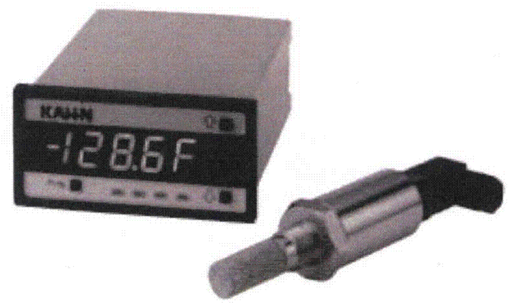
Delta F Corporation 4 Constitution Way Woburn, MA 01801-1087 Tel: 781.935.4600 Fax: 781.938.0531 Email: marketing@delta-f.com

www.delta-f.com

KAHN Hygrometers

Cermet II Hygrometer

A panel-mounted hygrometer designed for moisture measurement from -100° to +20°C dewpoint. Applications include dewpoint monitoring of non-flammable process gases such as air, nitrogen, sulfur hexafluoride, carbon dioxide, helium or argon in industries ranging from heat treating to pharmaceutical to utilities to semiconductor manufacturing.



- Digital Display
- High Accuracy and Repeatability
- Digital Signal Processing
- PPMV Pressure Compensated Readout
- Multiple Engineering Unit Display
- Optional Second Process Variable Input
- Dual Alarm Relays & Scalable 4-20 mA Output
- NIST Traceability
- Interchangeable Sensors
- NEMA 4 Sensor Housing

General Description

The Kahn Cermet II Hygrometer consists of a digital display with integral signal conditioning board, ceramic dewpoint sensor and an interconnecting cable. The sensor can be installed directly in the gas line or in a separate sampling gas stream by utilizing the optional sensor block. The display can be easily mounted in a control panel or other appropriate location.

Two independent, adjustable set-point relays are provided which can be used to provide an operator alarm should the dewpoint exceed user programmable limits. For systems that use PLCs or other controllers, a 4-20 mA scalable, linear output is provided as standard. Open sensor and sensor failure indication is standard and relay contacts are also offered as an option.

The digital display mounts in a 1/8 DIN cutout. It features a large, easily readable indicator with programmable brightness. Engineering units offered include PPMV (pressure compensated), °F, °C, #/MMSCF (pressure compensated), and g/m³ (pressure compensated).

The optional second input accepts a 4-20 mA signal from any 2-wire transmitter. It can be configured as a separate display for pressure, temperature, flow or other process variable. When displaying in PPMV, #/MMSCF or g/m³ line pressure can be entered manually, or a pressure transmitter can be connected to the optional second input to provide automatic pressure compensation.

Sensor

The Kahn ceramic sensor is made from state-of-the-art metalized ceramic and replaces traditional materials such as aluminum, silicon and hygroscopic salts. This sensor is made from a ceramic tile that is plated and vapor deposited to form a surface that is very sensitive to small changes in water vapor pressure.

Our proprietary coating processes make the Kahn ceramic sensor inherently faster to respond than other impedance sensors currently available. It also features greater resistance to corrosive gases and other contaminants. All of Kahn's ceramic sensors are fully interchangeable without display recalibration.

The sensor features the latest digital technology with calibration data stored directly in the sensor's memory. It can be located up to 4000 feet from the digital display without affecting calibration and will operate at pressures from near vacuum to 5000 PSIG and temperatures from -40°C to +60°C. The sensor is equipped with a built-in thermistor for automatic temperature compensation.

When used in conjunction with an appropriate intrinsically safe barrier unit, the special configuration of the Cermet II may be used in environments containing flammable gases.

What is Dewpoint?

Dewpoint is defined as the temperature at which the water vapor pressure of a gas equals the saturated water vapor pressure. It is therefore the temperature at which condensation "just begins" to occur if a gas is cooled.

Dewpoint is a fundamental unit and directly equivalent to water vapor pressure or parts per million. It is a very convenient measure of actual water content of a gas because it is not a function of temperature in the same way relative humidity is.

Calibration

The Kahn Cermet II Hygrometer is factory calibrated to insure consistent, accurate readings. The calibration of all Kahn ceramic, aluminum oxide and chilled mirror hygrometers is traceable to the National Institute of Standards and Technology through master Kahn optical hygrometers which have been directly calibrated at the NIST and are periodically recalibrated. A certificate of traceability is available with any of these instruments. <u>All sensors are fully interchangeable without the need for display recalibration. In addition all calibrations are guaranteed for one year.</u>

Installation

The meter can be installed in a control panel or used as a stand alone device. The sensor can be installed directly in the main gas line or in a sample stream.

SPECIFICATIONS

Measurement Range
-100° to +20°C
-148° to +68°F
0.001 to 9999 PPMV
(pressure compensated)
0-1000 #/MMSCF of natural gas
(pressure compensated)

Accuracy
±1°C from -59° to +20°C
±2°C from -100° to -60°C

Resolution
0.1°C from -79° to +20°C
1.0°C from -100° to -80°C

Outputs
4-20 mA
0-10 VDC (optional)
RS232 (optional)
RS485 (optional)
Relay, Dual, Adjustable
(10A/240VAC)

Display
°C, °F, PPMV, #/MMSCF, g/m³

Sensor
Ceramic moisture sensor with 80μ sintered metal guard, NEMA 4 housing.

Dimensions
Display:
1.9" x 3.8" x 5.6"
Panel cutout:
1.77" x 3.62" (1/8 DIN)
Sensor: 5.4"L x 1.23"W

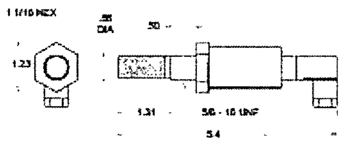
Operating Conditions
Pressure:
Vacuum to 5000 PSIG
Temperature
Sensor Operating:
-40° to +60°C
Sensor Compensated:
-20°C to +40°C
Display Operating:
0° to +50°C

Flow
Recommended rate:
1-5 L/min (2-10 SCFH)
Velocity:
20 meters/second maximum

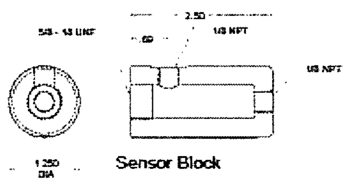
Power Requirements
115 or 220 VAC (standard)
9-60 VDC (optional)

Sensor Cable
6 feet (standard)
Operational to 4000 ft.

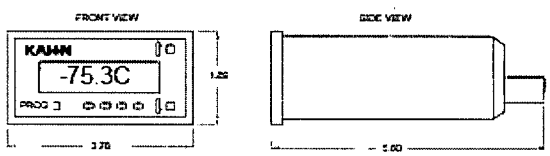
Options, Accessories
Sensor Block
Second Process Variable Input
10μ Sintered Metal Guard
Sample System
Coalescing/Particulate Filter
NEMA 4 Enclosure (Display)
Isolated Analog Output
Intrinsically Safe Barrier Unit with I.S. Sensor
Open Sensor Alarm Relay



Ceramic Sensor



Sensor Block



Digital Display Meter

NOTE:

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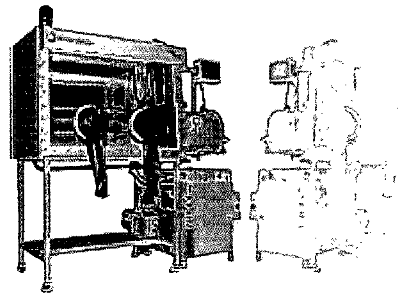

HIGHLIGHTS

- » **US Manufactured / European CE**
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- » **Variety of Configurations and Sized Systems**
- » **Maintainable Inert Atmosphere at <1ppm O2 and H2O**
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Contact Us

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