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Memorandum

Nuclear Engineering and Nonproliferation
International Threat Reduction

Subject: Monsanto Research Corp Model 2493 Series Special Form Re-Evaluation

The purpose of this memo is to characterize Monsanto Research Corp. (MRC) model 2493 series radioactive sealed sources as US Department of Transportation (DOT) Special Form Radioactive material, with the goal of achieving shipment, consolidation, interim storage, and final disposition.

Documentation

In February 1977, MRC applied to the DOT for a special form status for the model 2493- (or Ohmart Model B 18248-9/4) sealed source series. The Certificate of Competent Authority (COCA) was granted by DOT and assigned number USA/128/S. Revision 3 of this COCA was re-issued in August of 2004 with an expiration date of February 28, 2005 (see attachment A). There were two special conditions applied to Revision 3; Paragraph 5.a. says the COCA is valid only for use in the US to facilitate final disposal, and Paragraph 5.b. says the COCA is valid only for highway or surface transport, unless packaged in a Type B package.

The model 2493 is a neutron and gamma combination source potentially containing Cs-137 or Co-60 and Pu-238 or Am-241 isotopes for use in Ohmart model NMG-1 fixed moisture density nuclear gauges. In this memo we will re-evaluate the special form character of the model 2493 sealed source by reviewing the original special form evaluation and the salient underlying assumptions.

Combination sources were being used by Ohmart Inc. in model NMG-1 nuclear gauges as evidenced by Sealed Source Device Registry (SSDR) NR-522-D-867-S (see attachment B). In this SSDR, the Nuclear Regulatory Commission (NRC) approved MRC sealed source designation 2493 Series based on specifications for these sources to be used by Ohmart. Combination sources such as Pu8Li/Cs-137 sources are less common in having two types of isotopic sources incorporated in their matrix.

Physical Features of the Model 2493 - COCA

According to COCA USA/128/S, the model 2493 sealed source has cylindrical double encapsulation made of welded stainless steel. Approximate outer dimensions are 16.1 mm (0.635 in) in diameter and 203 mm (8 in) to 280 mm (11 in) in length. Construction is in accordance with MRC drawing numbers B2493-AA00 and MRC B2491-AA00, or Ohmart drawing numbers B-18138 and B-18248-A/C.

Radioactive contents were limited to a max. of 444 GBq (12 Ci) of Pu-238 and/or Am-241, and 222 GBq (6 Ci) of Cs-137 or 370 GBq (10 Ci) of Co-60. The Pu-238 or Am-241 are in the form of oxide mixed with beryllium or lithium powder (lithium hydrides, oxides or hydroxides were used). The Cs-137 is in the form of ceramic microspheres. The Co-60 is in metallic form.

OHMART Model NMG-1 Moisture Density Gauge Specification

NRC SSDR number NR-522-D-867-S (attachment B) serves as a primary description of the source and device. This document also serves as acceptable knowledge (AK) in the EPA mandated disposition process for OSRP TRU sealed sources, per the Peer Review Report, in lieu of other manufacturing information or source markings.

The model NMG-1 was manufactured for moisture/density gauge measurements of bulk material on conveyor belts. In this function the gauge emits gamma and neutron radiations to allow measurement of density and moisture content. The NMG-1 was described as using MRC model 2493 capsules having a maximum activity content 32 Ci Pu-238 or 4 Ci of Am-241 and 100 mCi of Cs-137 or 30 mCi of Co-60.

Typical model 2493 source activities are reflected in the shipping papers generated by MRC to Ohmart (see attachment C). These activities are about 12 Ci for Pu-238 oxide mixed with lithium oxide, lithium hydride, or lithium hydroxide powder; and 40 mCi of Cs-137 (2 sources per rod) or 7 mCi of Co-60. All of these sources were DOT special form at the time of distribution.

Special Form Analysis

The special form analysis for MRC model 2493 series sources is documented in MRC manufacturing order 803.1930 from February of 1977 (see attachment D). The special form evaluation relied upon previous testing of the MRC model 24148 source which corresponded to the 203 mm long version of the 2493 source. To accommodate the longer version of model 2493, with 280 mm of length, additional drop tests and a bending test were conducted.

After evaluating the minimum possible theoretical dimensions of the source components and the corresponding minimum source internal volume, a gas volume (He-4) for total decay from the alpha emitting isotope was calculated. The pressure generated by the emitted gas in the calculated internal volume at a maximum test temperature (800°C) was then calculated. Mechanical stress in the walls, head, and welds of the source cladding were calculated using the ASME Pressure Vessel code with a safety factor of 4. The model 2493 source was found to be able to maintain the safety factor of 4 for 20 years of source lifetime.

At least four possibilities of potential sources of excess conservatism exist in these engineering calculations of special form character for the model 2493 series. The excess conservatism is found in the quantity of gas generated by decaying Pu-238, the clad weld thickness, MRC extra 20%, and the ASME pressure vessel code safety factor of 4. These conservatisms exist because of the philosophy of MRC methods used to demonstrate DOT special form character. If the real case is re-examined and the degree of conservatism is re-evaluated, then special form character may be established for these 40+ year old sources.

The number of Pu-238 alpha decays was assumed to be a constant rate equal to the initial emission rate of 3.7×10^{10} decays/sec per Ci. Since the quantity of source material is decreasing constantly for Pu-238 (half-life 87.4 yr), this assumption assumes more alpha decays and hence more gas emission than in reality exists. The actual gas emission is 17.4 % less by decay calculation, or the pressure is lower by 17.4 % than that used in the MRC calculation.

The next source of conservatism is the minimum weld thickness for the outer capsule. The outer clad tube OD is a nominal 0.625 in, and the ID is a nominal 0.569 in. The nominal wall thickness is then 0.028 in. A value of 0.023 in was used for the welded joint thickness calculation as this was the absolute extreme minimum. The construction of the capsule cap creates a geometry that is difficult to over or under weld. If the nominal wall thickness is used 18% greater pressure can be accommodated in the source cladding interior volume.

The ASME Pressure Vessel code safety factor is applied to the overall calculation. The safety factor is a factor of 4.0. The ASME Pressure Vessel code is designed to prevent injury, loss of life, and significant facility damage if a large pressure vessel fails. The ASME code was specifically developed to prevent steam boiler explosions common prior to the turn of the 20th Century in locomotive and facility boilers. It can be argued that this code is unnecessarily conservative in that the failure of a small, sealed source will not cause the type of damage (energetic shrapnel) that can accompany a boiler explosion.

MRC created an extra 20 percent safety factor, as documented in Dr. Janzow's calculation. This increase of the safety factor to be conservative is unnecessary. The mechanical engineering of the capsule is well understood, and the QA program of MRC sources has withstood the test of time.

If the safety factor required was 2.7 along with the reduced gas production rate (17 % less), and the increased integrity of the nominal weld thickness (18% greater), and the extra conservatism factor (20%) is removed, then it can logically be argued that the original 20-year recommended working life calculated by MRC engineers is in fact a 50-year recommended working life simply by removing some of the excess conservatisms in the original calculation.

Summary

The MRC model 2493 series sealed sources are very similar to other combination type sources intended for use in fixed moisture density gauges (MRC 24148). Examining the basis of the original Recommended Working Life (RWL) calculation clarifies the inherent conservancy of the original engineers and emphasizes the safety of these combination source 50 years after manufacture.

Conclusion

The MRC model 2493 radioactive sealed source as documented in SSDR NR-522-D-867-S can be shown to meet DOT special form radioactive material requirements, within the limits and scope of this memo, and a RWL of up to 50 years. After this 50yr RWL, MRC model 2493 series radioactive sealed sources need to be re-evaluated or re-encapsulated in OSRP Special Form capsules.

Attachment(s):

A. COCA for USA/0128/S, Rev 3
B. NRC SSDR NR-522-D-867-S
C. MRC Shipping Papers to Ohmart with typical activity values
D. Special form engineering analysis for MRC model 2493 by Dr. Ed Janzow, MRC

Cc: Justin Griffin, LANL OSRP
NEN-3 File