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Title: SHIELDING ANALYSIS OF NEUTRON EMITTING SEALED SOURCES IN S100 PIPE COMPONENT OVERPACK/TRUPACT-II GEOMETRIES USING MCNP TRANSPORT CODE AND EMPIRICAL MEASUREMENTS

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Shielding Analysis of Neutron Emitting Sealed Sources in S100 Pipe Component Overpack/TRUPACT-II Geometries Using MCNP Transport Code and Empirical Measurements

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SUMMARY

The purpose of this work was to estimate an upper bound for the dose at the mid-plane on the surface of a S100 Overpack[1], i.e., a specially designed drum for transuranium (TRU) waste containing shielding and sealed neutron sources. In addition, the dose at the surface and at a distance for a TRUPACT-II Container[1] with 14 S100 Overpack drums was also estimated for the Normal Conditions of Transport (NCT), for Normal Condition of Transport with crushed Overpacks and for accident conditions. The source modeled was a Plutonium-Beryllium source with the Plutonium infinitely dilute in the Beryllium. In the calculations, a source of one curie per drum was modeled. The resulting dose from the calculations may be scaled to reflect multi-curie level sources. When these results are scaled to 28 curies per drum, the limiting payload, the dose rates obtained meet the requirements of the TRUPACT-II Safety Analysis Report[1].

INTRODUCTION

It is estimated that some 18,000 sealed radioactive sources are currently unwanted or will become excess over the next five to ten years nationwide. The Off-Site Source Recovery Project at Los Alamos[2] has the responsibility for addressing the problem of collecting for ultimate disposal these unwanted and excess radioactive sources.

The vast majority of these sources are either Am-Be or Pu-Be neutron-producing sources. They will be shipped to the Los Alamos National Laboratory for interim storage before ultimate disposal. The sources are often contained in a S100 Pipe Overpack, a specially designed TRU waste-containing drum. The S100 Overpacks will be transported to WIPP in a TRUPACT-II Container.

The purpose of work was to estimate an upper bound on the dose at the mid-plane on the surface and at one-meter from a S100 Overpack containing alpha-n neutron sources. In addition, the dose at the surface and at various distances for a TRUPACT-II Container with 14 S100 Overpack drums was also determined for the NCT, NCT with crushed Overpacks, and for hypothetical accident conditions. The calculations were made using the transport code Monte Carlo N-Particle[3] (MCNP). In the calculations, a source strength of one-curie per drum was modeled. Fluence is converted to dose using an American National Standard.[4] The resulting dose from the calculations is linear and may be scaled to higher source strengths. The results of the calculations, dose at various distances from the source, may be used for planning purposes to determine transportation requirements and radiation protection requirements of various storage configurations. A more detailed description of this work may be found in Reference 5.

THE NEUTRON SOURCE MODEL

The absolute neutron source strength and spectra produced from (alpha,n) reactions and spontaneous fission was determined for an infinite dilute mixture of one-curie of ^{238}Pu in Beryllium using the SOURCES-4A[6] computer code. The actinide ^{238}Pu was chosen for the source material because it is the conservative choice, producing more neutrons per curie than ^{239}Pu. This is a result of having a higher average energy for the alpha particles produced, 5.49 MeV, compared to 5.15 MeV for ^{239}Pu. It also has a slightly higher average energy than ^{241}Am with its average energy of 5.48 MeV. It is also conservative to use an infinite dilute mixture of ^{238}Pu in Beryllium as more neutrons are produced than with the normal Be/^{239}Pu atomic ratio of 13:1.

The source strength was estimated to be 2.937E+06 neutrons/sec for the one-curie ^{238}Pu-Be source. Calculations using this source strength and its associated spectra were distributed uniformly in a cylindrical volume with a diameter of 3/4 inches and a length of six-inches in the center of the pipe component within the S100 Overpack drum. The source volume was based on the fact that Am-Be and Pu-Be sources are typically packaged in a nominal 3/4" diameter x 2" long cylinder, thus three of these sources, under the current assumptions of a maximum 28 curies per drum, could be packaged in the drum. In these calculations, there was no material placed in the volume inside a polyethylene sleeve within the pipe component that normally contains the sources. Although, in practice, sources will be confined in an interior package made of clear polycarbonate plastic that is centrally positioned within the pipe component.

S100 OVERPACK

The S100 Overpack is a modified 55-gallon drum. The calculational model, noted in Figure 1, is a slightly simplified version; for example, the flange (but not the lid) is missing from the pipe component containing the source.

The drum is steel, and the pipe component is also steel. The shielding material, Boronated Water Extended Polyester-Polyethylene Composite[7] (WEP) surrounds the source container on the sides, and polyethylene plugs are located on the top and bottom of the source container. The top and bottom of the drum contains dunnage (Celotex). The reader is referred to Figure 1 for visual perception of the geometry.

S100 OVERPACK DOSE CALCULATIONS

The dose calculations are made using the transport code MCNP. A one-curie neutron source of ^{238}Pu-Be as described previously was placed in the center of the steel pipe component. The dose was calculated at the midplane on the surface of the drum.

Earlier calculations, using drum geometry equivalent to that used in an experiment[8] (the experimental geometry did not have a sleeve) indicated that the calculational results are conservative. The experiment resulted in a dose of 2.91 mrem/hr while the calculational result was 7.6 mrem/hr for one-curie. Other calculations indicate that the dose at the midplane of the cylindrical surface is greater than that at the top or bottom of the S100 Overpack. The gamma dose does not include any delayed gammas, that is, gammas arising from the decay of activation products because this is expected to be very small.

TRUPACT-II DOSE CALCULATIONS - NORMAL CONDITIONS OF TRANSPORT

The S100 Overpacks will be shipped in a TRUPACT-II Container. Up to 14 Overpacks may be placed in a single container. In this set of calculations, the dose on the surfaces, at two meters from the surfaces, and at five meters from the surfaces of a TRUPACT-II Container with 14 Overpacks was estimated. This set of calculations is for NCT operations.

The dose calculations are made using the transport code MCNP. The TRUPACT-II calculational model was a set of concentric steel shells with flat ends. Polyurethane at a density of 0.13 g/cc was placed in the TRUPACT-II walls. Two stacks of seven S100 Overpacks were placed within the center steel cylinder. A cross-sectional view is shown in Figure 2. The Overpack model was described in a previous section. A one-curie neutron source of ^{238}Pu-Be as described previously was placed in each Overpack. The dose was calculated at the midplane on the surface and at two meters from the surface at three locations on the side of the TRUPACT-II Container. The first was at the midplane of the first stack of Overpacks, the midplane of the second stack of Overpacks, and at the midplane of the TRUPACT–II Container which also separated the two Overpack stacks. In addition the dose was calculated at the center on the surface and at 2 meter on the top and bottom to insure that the maximum dose is found on the side. In all cases, the side dose is the greatest

TRUPACT-II DOSE CALCULATIONS WITH CRUSHED S100 OVERPACKS – NCT

In these calculations, the dose on the surface and at 2 meters from the surface of a TRUPACT-II Container with 14 Overpacks

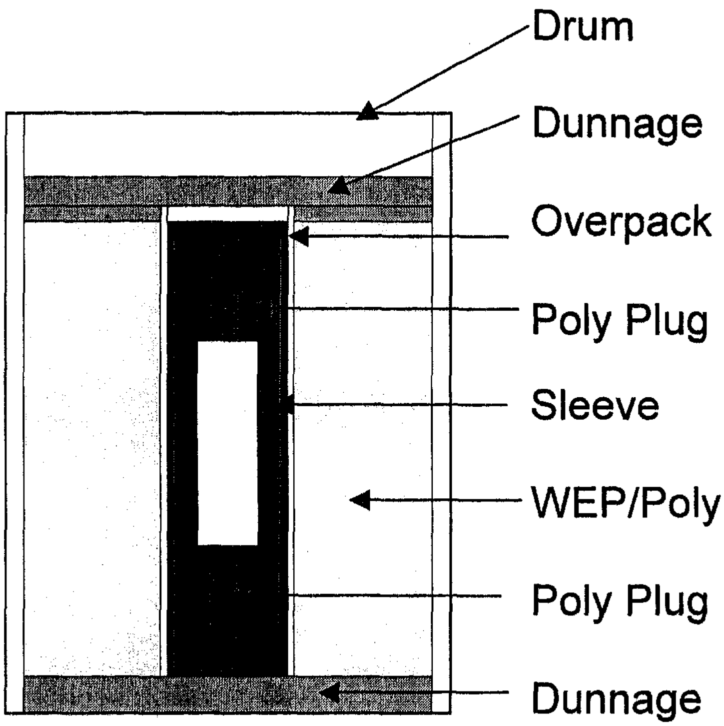

Figure 1. *Cross Sectional View of S100 Overpack*

was estimated in a condition with crushed S100 Overpacks. This condition includes damage to the Overpacks as a result of the NCT free drop, and includes an offset of the array of drums toward the impact side. The amount of crush of the WEP shielding material is 3 inches, and the offset distance is calculated as follows. First, the free radial gap between the payload outer diameter and the TRUPACT-II Inner Containment Vessel inner diameter is ½ (72.64 - 3 × 24) = 0.32 inches. Next, since the outer diameter of each drum is 24 inches and the outer diameter of the WEP shielding is 22 inches, the drum has a "free crush" distance of one inch radially. The sum of all of the lateral motion of the payload drum array is equal to a) 0.32 inches of free movement, b) one inch of crush of the drum before contact with the WEP is made, and c) 3 inches of crush of the WEP, for a total value of 4.32 inches. This arrangement is shown in Figure 3, where the center of the seven payload drums has moved laterally 4.32 inches off of the TRUPACT-II centerline. As shown in Figure 3, the most crush occurs for the drum on the bottom, nearest the impact. The drums on each side also experience a smaller amount of crush, equal to 1.84 inches (one inch of drum "free crush" and 0.84 inches of WEP crush). The other, undamaged drums rest on top of the lower, damaged drums. The same damage is assumed to occur to both the upper and lower tiers of seven drums.

The dose calculations are made using the transport code MCNP. The TRUPACT-II calculational model remained as in the first NCT case, an undisturbed set of concentric steel shells with polyurethane placed in the two outer shells. Two stacks of seven S100 Overpacks were placed within the cylinder, however as opposed to the previous case,

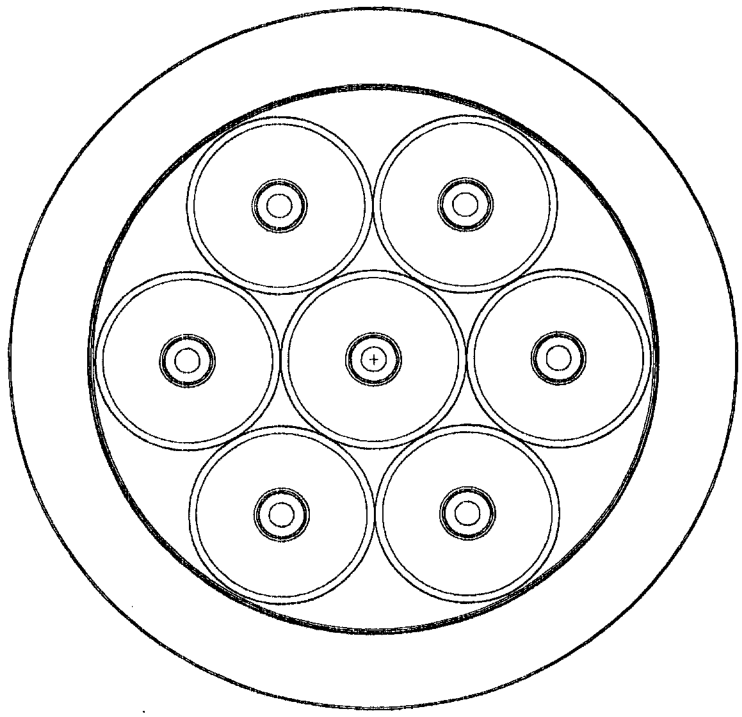

Figure 2. Cross-sectional view of TRUPACT-II Container with S100 Overpacks in place under Normal Conditions of Transport.

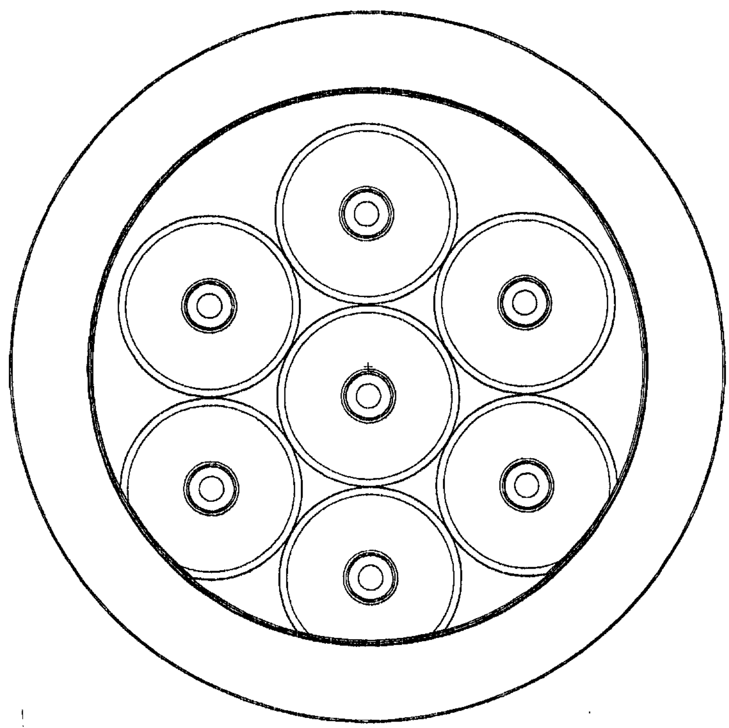

Figure 3. Cross-sectional view of TRUPACT-II Container with Crushed S100 Overpacks under Normal Conditions of Transport.

six of the Overpacks, as noted, lie on the the crushed material has been removed from the calculational model. The Overpack model was described in a previous section. A one-curie neutron source of ^{238}Pu-Be as described previously was placed in each Overpack.

The dose was calculated at the midplane on the surface and at two meters from the surface at three locations on the TRUPACT-II. The first was at the midplane of the first stack of Overpacks, directly in front of the crushed Overpack where the shielding is thinnest. The second is located at the midplane of the second stack of Overpacks, directly in front of the crushed Overpack where the shielding is thinnest. The third is at the midplane of the TRUPACT-II, which also separated the two Overpack stacks.

HYPOTHETICAL ACCIDENT CONDITIONS (HAC)

This evaluation provides activity limits for neutron sources transported in a TRUPACT II with 14 Pipe Component Over-Packs subjected to Hypothetical Accident Conditions (HAC). The dose rate at any point one meter from the outside surface of the TRUPACT must not exceed one rem/hr for HAC.

To avoid performing HAC thermal and mechanical tests, the state of the TRUPACT-II and the over-packs and contents are assumed to be in states for which dose rates are expected to be greater than any possible state resulting from the HAC tests. Essentially, the sources are located as close as possible to the dose point. The closest possible point is then one meter plus the thickness of a crushed TRUPACT-II Container. This distance is 116.51 cm and assumes the source lies against the wall.

The calculational model assumes all sources are combined into one point source for a total of 392 curies (28 curies/source x 14 sources). The dose is calculated on a sphere of 116.51 cm from the source. No material is used in the calculation.

RESULTS

Using one curie per Overpack, the maximum dose for the S100 Overpacks was 5.63 mrem/hr at the surface. The gamma contribution to the dose was 0.30 mrem/hr. The maximum dose for the TRUPACT-II Container at the surface was 2.15 mrem/hr, 0.253 mrem/hr at two meters and 0.0652 mrem/hr at five meters for the NCT case. The gamma contribution to the three cases were 0.11, 0.014, 0.004 mrem/hr respectively. The TRUPACT-II results for the NCT with crushed Overpacks, the results were 4.48 mrem/hr at the surface and 0.350 mrem/hr at two meters. The gamma contribution to this dose was 0.15 and 0.016 mrem/hr respectively.

The bounding payload is 28 curies per S100 Overpack. Scaling the results at the surface of the S100 Overpack to 28 curies, the maximum dose would be 158 mrem/hr at the surface. The maximum dose permitted by the SAR is 200 mrem/hr.

For the TRUPACT-II, under NCT, if each drum contained 28 curies (392 curies total) the maximum doses would be 60.2 mrem/hr at the surface and 7.08 mrem/hr at two meters and 1.83 mrem/hr at five meters. The SAR limits at these distances are 200 mrem/hr, 10 mrem/hr and 2 mrem/hr respectively.

For the TRUPACT-II, under NCT with crushed Overpacks, if each drum contained 28 curies (392 curies total) the maximum dose at the surface would be 125 mrem/hr and 9.80 mrem/hr at two meters. The SAR limit is 200 mrem/hr and 10 mrem/hr respectively.

For the TRUPACT II with 14 Pipe Component Over-Packs subjected to Hypothetical Accident Conditions (HAC), the dose rate at any point one-meter from the outside surface of the TRUPACT must not exceed 1 rem/hr. The calculations indicated that the maximum possible dose at one-meter from the surface of the TRUPACT-II would be 0.96 rem/hr.

CONCLUSION

Dose calculations using S100 Overpack Storage drums have been calculated. In addition, dose calculations under NCT and NCT with crushed Overpack conditions have also been made for TRUPACT-II containers with 14 S100 Overpacks, each containing a one curie ^{238}Pu-Be source. The dose rates were calculated under conservative conditions. When these results are scaled to 28 curies per drum, the limiting payload, the dose rates obtained meet the requirements of the TRUPACT Safety Analysis Report.

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