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EVALUATION OF URANIUM SHIELDING IN THE TRANSPORTATION OF RADIOISOTOPES

J. Stuart Lichliter

August 1960
EVALUATION OF URANIUM SHIELDING IN THE TRANSPORTATION OF RADIOISOTOPES*

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Advantages of uranium as a general shielding material for shipment of radioisotopes are set forth (density, 18.7; density of lead, 11.34). Uranium is more readily machinable than tungsten, and less expensive for large containers than the tungsten-nickel-copper alloys. Each inch of uranium gives about 65% more shielding than an inch of lead for 1-Mev gamma rays (1.65 lead-equivalent, and is lighter. The U metal is easily contained to prevent contamination. In weekly air shipments of Na\textsuperscript{24} from Oak Ridge to LRL, uranium shielding material has saved an estimated $5,000 per year in shipping costs. Various combinations of nesting uranium containers have been designed and fabricated here for safe shipment of irradiated slugs from reactors. Special problems of design to meet complex requirements of air transportation are considered.

INTRODUCTION

Radioisotopes present many complex problems, particularly in respect to the adequacy of shielding, proper packaging, and handling techniques. Characteristics of the different isotopes must be considered fully when arrangements are being made for their transportation, whether for thousands of miles or from one laboratory room to another only twenty feet away.

*Work performed under the auspices of the U.S. Atomic Energy Commission.
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Users of radioisotopes—such as industrial firms, universities, hospitals, research laboratories and AEC contractors—are usually located at a considerable distance from the source of production of these isotopes, thus creating a problem of shielding and packaging for common carrier transportation.

Either the shipper or the user of each radioisotope is confronted with four major considerations:

1. use of a properly designed container for containment of the active material;
2. compliance with the appropriate regulations (State-Federal-international);
3. cost of shipment;
4. time in transit (especially for short-half-life materials).

It might appear easy to fabricate a container that would cover all shipments, but let's consider a few of the isotopes in common use and their characteristics.

EXAMPLES OF SPECIAL SHIELDING REQUIREMENTS

Example (1). Co$^{60}$, Cs$^{137}$, etc., are all primarily gamma emitters and require heavy material for shielding, particularly if in multicurie quantities. The half life is relatively long, so that we are not concerned about shipment transit time.

Example (2). Na$^{24}$ is also a gamma emitter that requires heavy shielding, but has a relatively short half life, so that in transit time is of great importance.

Example (3). In general, alpha- and beta-emitting radioisotopes with a weak gamma radiation do not require the heavy shielding mentioned in the first two examples. Containment now becomes the most important criterion in design work, so that contamination can be avoided.

Example (4). Ra$^{226}$ combines the heavy-shielding requirement with the extra precaution for containment. In addition the ICC requires special packaging when radium is being transported by common carrier.

Example (5). RaBe sources used by many research laboratories require, in addition to heavy shielding for gamma and proper containment for alpha radiation, proper shielding material for neutrons.

Example (6). Isotopes undergoing spontaneous fission generally present all of the problems in the five examples above, plus the fact that the thermal...
heat produced during shipment must be considered when designing the shipping container.

The Health Chemistry department of the Lawrence Radiation laboratory has, over the past twelve years, investigated various materials for shielding, keeping in mind the problems stated in the examples above on one hand, and the economics of shipping, plus cost of design, materials, and fabrication on the other.

MATERIALS CONSIDERED FOR SHIELDING CONTAINERS

It is recognized that each material considered has certain advantages and disadvantages, as related to the design criteria for any single shipping container. We must weigh these very carefully when designing for general use. The comments about the individual materials will indicate in part the reasons for our selection of material for shielding containers.

Lead as a shielding material is somewhat conventional; it has a density of 11.34, is relatively cheap, easy to cast, and readily machinable. As increased quantities of radioactive materials are transported the lead containers required get larger and their weight increases rapidly. This creates problems in handling, increases the cost of shipments, and in some cases restricts the use of air transport because of weight limitations.

The use of tungsten (density 19.1) as a shielding material for shipping containers is somewhat limited because of difficulty in machining. We do have one container that has tungsten plates held together in a square design, but this type of construction generally does not give as much shielding for the weight involved, as a cylindrical design of material with about the same density.

Other shielding materials, such as Hevimet and Mallory 1000, with densities about 16.8 to 17.2, are used occasionally as parts of our shipping containers. These metals, according to the manufacturers, are usually about 90 to 95% tungsten and about 5 to 10% nickel and copper. This alloyed combination is such that the metal can be machined or soldered. Our brief experience with these metals as shielding material for large shipping containers indicates that their initial cost is uneconomical for our particular application.

Uranium (density 18.7) can be used as a shielding material under certain conditions. It is largely controlled by the AEC but usually can be made available to AEC contractors in small quantities, particularly if the use of the material is justifiable. Under controlled conditions, uranium is relatively easy to machine. It is also radioactive, but can be encased in a metal can to prevent contamination problems. Each inch of uranium gives about 65% more shielding than 1 inch of lead for 1-Mev gamma rays.
USE OF URANIUM-SHIELDED CONTAINERS AT LRL

One of the first problems that led to our consideration of uranium as a shielding material concerned weekly shipments of Na\(^{24}\) from Oak Ridge. As this is a short-half-life material, it was necessary that shipments from Oak Ridge be sent by air. The weight of the lead shielding caused problems in handling and sometimes the airlines were hesitant about loading this weight on the plane.

To overcome these problems, two uranium-shielded containers were designed and fabricated. * One container arrives each week from Oak Ridge with the Na\(^{24}\) by air express, while the second container is being shipped empty to Oak Ridge by rail express. The saving in shipping costs by the use of uranium as the shielding material is estimated at about $5,000 per year.

Following the successful use of the two uranium containers for shipments of Na\(^{24}\), additional data were accumulated on the advantages of uranium as shielding material. It was apparent that a chief advantage was the saving in shipping costs, based on a rate per 100 lb. For shielding purposes, we calculate 1 in. of uranium to be equivalent to 1.65 in. of lead for 1-Mev gamma radiation.

The saving in shipping costs is illustrated in the tabulations below, which show the difference in weight between lead shielding and uranium shielding. The comparison of four different sizes of shipping containers shows the lead thickness and the equivalent thickness of uranium, and the weight for each. (The weight of the metal can around the shielding material is not included.) Each container has an inner cavity 2 in. diam x 4 in. long.

In view of the continuing accumulation of information about the use of uranium as shielding material, we decided to design and fabricate six additional containers especially to provide more flexibility for our ever-increasing shipping-container requirements. These containers were to be used for irradiated slugs coming to us from the different reactors. Depending on the material being irradiated and length of bombardment, a selected container could be made up for either air shipment or railway express shipment.

Actually we designed these as two sets of nested containers; each set can be used as one container, or as three separate containers of different size and weight. Figure 1 shows the large-sized container into which the other nesting cylinder of uranium can be inserted. Figure 2 shows the three units used individually and with various sizes of cavities.

All uranium pieces were completely covered with stainless steel, so that there was no problem of contamination. Various plugs were designed to fit any combination of container use. When shipping a small irradiated
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slug we can use a Hevimet liner in the cavity of the smallest uranium cylinder, which increases the total shielding about 0.6 in. lead equivalent.

Figure 3 illustrates these nesting uranium containers. The accompanying table shows various combinations that can be used, gives information as to lead-equivalent shielding for 1-Mev gamma rays, weights, cavity sizes, and outside dimensions.

The uranium containers described have been in constant use over the past few years. However, as the number and quantities of radioisotopes increase in our research programs the need for additional shipping containers increases.

One of the areas where this increased need shows up is in the transportation of short-half-life materials from reactor sites. Problems of design for maximum shielding for air transportation can be very complex due to floor-loading restrictions and weight limitations by the different airlines.

Although most airlines carry radioactive shipping containers weighing up to nearly 300 lbs, for some the weight limitation may be less than that. One reason for this difference is that at some of the smaller air stations the airlines do not have the manpower or equipment to handle a compact 300-lb container.

To meet situations like this we recently designed another uranium shielded shipping container. It has an inner cavity 1-1/2 in. diam by 3-3/4 in. long, and the side shielding walls are 2-1/4 in. thick, giving 3.7 in. lead-equivalent for 1-Mev gamma radiation. The container is so designed that we can add a small Hevimet liner to obtain 4.1 in. lead equivalent. The total weight for this container is 170 lbs.

In order to assure more positive closing and a tighter fit of the plug, we departed slightly from typical design. We retained the offset shoulder on the plug, but by machining the plug and the opening to a radius originating at one side of the top, we provided for a hinged attachment and easy handling without sacrificing a tight fit. See Figure 4.

CONCLUSION

For our particular application in the transporting of radioisotopes for our research programs we find that the use of uranium-shielded containers gives economy in shipping costs and flexibility for different modes of shipment.

When shielding required for transportation of radioisotopes exceeds 5 in. of uranium, lead (which costs less and is easier to fabricate) may be
preferable. A uranium shipping container of this size weighs about 1050 lb, which is about the upper limit that can be handled with ease on a standard 1/2-ton pickup truck. Therefore, we may as well use lead as the shielding material, rather than uranium, because heavy lifting and hauling equipment will be required. Our radioisotope transporting program seldom requires such heavy shielding, however.

The chart below gives a better indication of weight comparisons between a lead container and a uranium container. The cavity-size may be smaller for some irradiated slugs; therefore, the o.d. of the container would be smaller and the weight considerably less than the figures shown on the chart. (The thickness of lead shielding is shown in inches, and we have not considered in these calculations any application of the inverse square law for gamma radiation.)
FIGURES

Figure 1 Larger-sized container into which the other nesting cylinder of uranium can be inserted. (URANIUM SHIELDING, Lichliter)

Figure 2 The three units used individually and with various sizes of cavities. (URANIUM SHIELDING, Lichliter)

Figure 3 Combinations, weights, Pb-equivalent shielding for 1-Mev gamma rays, etc. (URANIUM SHIELDING, Lichliter)

Figure 4 Lightweight uranium-shielded shipping container (170 lbs) of new design. (URANIUM SHIELDING, Lichliter)

Figure 5 Weight comparisons: lead shielding - uranium shielding (URANIUM SHIELDING, Lichliter)
<table>
<thead>
<tr>
<th>CONTAINER</th>
<th>Pb EQUIV.</th>
<th>WT. lbs.</th>
<th>O. DIA.</th>
<th>HEIGHT</th>
<th>CAVITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.65</td>
<td>35</td>
<td>4</td>
<td>6</td>
<td>$1\frac{1}{2} \times 3$</td>
</tr>
<tr>
<td>2</td>
<td>3.3</td>
<td>295</td>
<td>$8\frac{1}{2}$</td>
<td>$10\frac{1}{2}$</td>
<td>$3\frac{3}{4} \times 5\frac{1}{4}$</td>
</tr>
<tr>
<td>3</td>
<td>1.65</td>
<td>345</td>
<td>$10\frac{1}{2}$</td>
<td>13</td>
<td>$8 \times 9\frac{3}{4}$</td>
</tr>
<tr>
<td>1 &amp; 2</td>
<td>5</td>
<td>325</td>
<td>$8\frac{1}{2}$</td>
<td>$10\frac{1}{2}$</td>
<td>$1\frac{1}{2} \times 3$</td>
</tr>
<tr>
<td>2 &amp; 3</td>
<td>5</td>
<td>580</td>
<td>$10\frac{1}{2}$</td>
<td>13</td>
<td>$3\frac{3}{4} \times 5\frac{1}{4}$</td>
</tr>
<tr>
<td>1,2 &amp; 3</td>
<td>6.6</td>
<td>610</td>
<td>$10\frac{1}{2}$</td>
<td>13</td>
<td>$1\frac{1}{2} \times 3$</td>
</tr>
<tr>
<td>A</td>
<td>.6</td>
<td>$2\frac{1}{2}$</td>
<td>$\frac{7}{16}$</td>
<td>$2\frac{15}{16}$</td>
<td>$\frac{3}{4} \times 2\frac{1}{8}$</td>
</tr>
<tr>
<td>1,2 &amp; A</td>
<td>5.6</td>
<td>328</td>
<td>$8\frac{1}{2}$</td>
<td>$10\frac{1}{2}$</td>
<td>$\frac{3}{4} \times 2\frac{1}{8}$</td>
</tr>
<tr>
<td>1,2,3 &amp; A</td>
<td>7.2</td>
<td>613</td>
<td>$10\frac{1}{2}$</td>
<td>13</td>
<td>$\frac{3}{4} \times 2\frac{1}{8}$</td>
</tr>
</tbody>
</table>
CALCULATIONS FOR THIS GRAPH ARE BASED ON THE FOLLOWING INFORMATION:

1. EACH CONTAINER HAS A CAVITY 2" DIAMETER AND 4" LONG.

2. SHIELDING FIGURES ARE FOR 1 MEV GAMMA.

3. 1" OF URANIUM EQUIVALENT TO 1.65" LEAD.

4. NO DEDUCTION FOR WEIGHT OF CAVITY MATERIAL.

5. WEIGHTS DO NOT INCLUDE S.S. CASINGS.