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# Testing a Hazmatpac Can with Locking Ring as a Secondary Shipping Container for Radium-224/Lead-212 Generators



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Radioisotope Science and Technology Division  
Isotope Processing and Manufacturing Division

**TESTING A HAZMATPAC CAN WITH LOCKING RING AS A SECONDARY  
SHIPPING CONTAINER FOR RADIUM-224/LEAD-212 GENERATORS**

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## ABBREVIATIONS

BLD	Below Limit of Detection
dpm	disintegrations per minute
ORNL	Oak Ridge National Laboratory
RCT	Radiological Control Technician

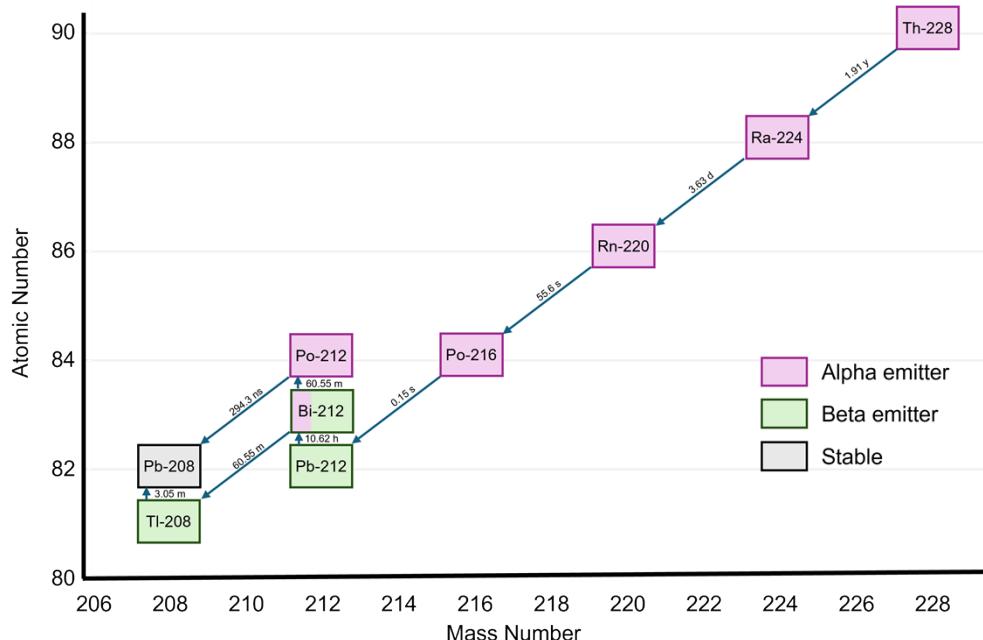
## ABSTRACT

A Hazmatpac can—paint-can-style shipping container with locking ring—was tested for use as an alternative shipping configuration for shipping  $^{224}\text{Ra}/^{212}\text{Pb}$  generators. The  $^{224}\text{Ra}$  ( $t_{1/2} = 3.63$  days) decays by alpha emission to  $^{220}\text{Rn}$  ( $t_{1/2} = 55.6$  s). The potential for the radioactive Rn gas to escape the generator column and the shipping container is of particular concern for safely delivering  $^{224}\text{Ra}/^{212}\text{Pb}$  generators to customers. The purpose of this study was to evaluate whether the Hazmatpac can is a suitable shipping configuration capable of containing the Rn gas that may escape the generator column during transit. A 17.3 mCi  $^{224}\text{Ra}/^{212}\text{Pb}$  generator was built and packaged into a Hazmatpac can. A radiological control technician (RCT) smeared the can every day for 7 days to analyze for radioactive contamination on the outside of the can. Over the course of the study, no radioactive contamination was found on the outside of the can. Therefore, the Hazmatpac can was approved as an alternative shipping configuration for shipping  $^{224}\text{Ra}/^{212}\text{Pb}$  generators.

## 1. BACKGROUND

The Building 4501 Operations Group at Oak Ridge National Laboratory (ORNL) maintains a stock solution of  $^{228}\text{Th}$  that is used as a source of  $^{224}\text{Ra}$  and  $^{212}\text{Pb}$ . The  $^{212}\text{Pb}$  and its daughter  $^{212}\text{Bi}$  are of interest to customers across the world for use in targeted alpha therapy. Due to its short half-life of only 10.6 h, the most effective way for ORNL to deliver  $^{212}\text{Pb}$  to customers is through  $^{224}\text{Ra}/^{212}\text{Pb}$  generators. The Building 4501 Operations Group currently builds and sells  $^{224}\text{Ra}/^{212}\text{Pb}$  generators approximately every 3 weeks.

The biggest concern with shipping  $^{224}\text{Ra}/^{212}\text{Pb}$  generators is the emission of the gaseous daughter,  $^{220}\text{Rn}$ , produced through alpha decay of  $^{224}\text{Ra}$  (Figure 1). The  $^{220}\text{Rn}$  daughter ( $t_{1/2} = 55.6$  s) is continuously produced by  $^{224}\text{Ra}$  decay and has the potential to escape from the generator column, creating a contamination risk for postal workers and customers.



**Figure 1. Decay scheme for  $^{228}\text{Th}$ .** The  $^{224}\text{Ra}$  is isolated from  $^{228}\text{Th}$  and loaded onto a generator to be used as a source of  $^{212}\text{Pb}$ . The  $^{220}\text{Rn}$  daughter is of particular concern in shipping generators due to its gaseous state.

The current shipping configuration for a  $^{224}\text{Ra}/^{212}\text{Pb}$  generator involves placing the loaded generator inside a 1.25 in. Pb pig (with openings for the generator inlet and outlet leads) and then placing the pig inside of a sealed isotope can (Figure 2). This configuration has been tested for Rn leaks and was proven to contain any released  $^{220}\text{Rn}$ .



**Figure 2. The current standard shipping container for  $^{224}\text{Ra}/^{212}\text{Pb}$  generators.** (left) Drawing of the 1.25 in. lead pig used for generator shipments. (right) Example of a can with crimp-style lid that is the standard for  $^{224}\text{Ra}/^{212}\text{Pb}$  shipments. The original isotope cans have a pull tab at the bottom to open the can. The can shown here requires a can opener.

On January 28, 2025 (campaign ID RaGen083), the Building 4501 Operations Group was informed that the shipping department did not have any isotope cans available for shipping generators. This lack of available shipping material resulted in a 24 h delay in shipping generators to customers, which equated to an approximately 17% loss of the product ordered by the customer because of decay.

To avoid this problem with future orders, the Building 4501 Operations Group performed Rn leak testing on an alternative shipping configuration that could be used when isotope cans are not available. This configuration uses a paint-can-style Hazmatpac can with a locking ring (Figure 3).



**Figure 3. Picture of the paint-can-style Hazmatpac can shipping container with locking ring.** This can was tested as a secondary shipping configuration for  $^{224}\text{Ra}/^{212}\text{Pb}$  generators.

## 2. PURPOSE

The purpose of this study was to perform Rn leak testing on a Hazmatpac can with a locking ring to certify the can as an alternative shipping configuration for shipping  $^{224}\text{Ra}/^{212}\text{Pb}$  generators.

## 3. METHOD

1. A 17.3 mCi  $^{224}\text{Ra}/^{212}\text{Pb}$  generator (campaign ID RaGen084-B) was built following procedure IPMD-4501-OP-18, *Radium-224 Lead-212 Generator Production or Dispensing from Thorium-228 Cow* (WA 7008038).
2. Per the procedure, the generator was loaded into a 1.25 in. Pb pig with built-in holes for the generator inlet and outlet leads, and the pig was taped closed.
3. The pig containing the generator was transferred to a Hazmatpac can.
4. The Hazmatpac can was sealed with a hammer, and the locking ring was attached.
5. The sealed Hazmatpac can was placed inside of a yellow radioactive materials bag, and the bag was closed with a gooseneck and tape (Figure 4).
6. After approximately 24 h, the outside of the bag was smeared by an RCT. Then, the bag was carefully opened, and a smear was taken of the outside of the Hazmatpac can.
7. The bag was resealed with a gooseneck and tape.
8. The smear was analyzed, and results were recorded (Table 1).
9. Steps 5–8 were repeated every day for 1 week (except for the weekend).



**Figure 4. Sealed Hazmatpac can with locking ring containing the 1.25 in. Pb pig with the 17.3 mCi  $^{224}\text{Ra}/^{212}\text{Pb}$  generator.** Each day, the outside of the radioactive materials bag and the outside of the Hazmatpac can were smeared and analyzed for contamination.

#### 4. RESULTS

The Building 4501 Operations Group maintains a  $^{228}\text{Th}$  supply that allows for recovering  $\geq 20$  mCi of  $^{224}\text{Ra}$  every 3 weeks. The excess  $^{224}\text{Ra}$  recovered from campaign RaGen084, after building a generator for a customer, was used to build a 17.3 mCi generator for testing the Hazmatpac can. This generator represents roughly the maximum-activity generator that can be built for customers (i.e., 20 mCi).

The generators shipped by ORNL are expected to be delivered to the customer within 6 days of the generator build time. The Hazmatpac can was monitored for Rn leaks across 7 days, giving a slight buffer from the expected maximum 6-day transit time.

Smears taken of the outside of the radioactive materials bag and the Hazmatpac can itself were analyzed for gross removable alpha and beta contamination. The smears were taken and analyzed by an RCT. Smears were not taken over the weekend (February 22 and 23).

The smears analyzed over the course of this study showed no evidence of Rn leaks from the Hazmatpac can across the 7 days of testing (see Figure 5, Table 1, and Appendix A). All smears taken of the outside of the can showed removable alpha and beta contamination that were below the limit of detection for the instrument. A few alpha and beta counts were observed on the smears taken of the outside of the radioactive materials bag; however, these counts were well below the threshold for the bag to be considered contaminated.

Date	Time smear was taken	Smear clean? YES or NO	Comments	Initials
02/19/25	0855	YES	Survey # 4501-658196	<i>CJ</i>
02/20/25	1500	YES	Survey # 4501-658332	<i>CJ</i>
02/21/25	0915	YES	Survey # 4501-658383	<i>CJ</i>
02/24/25	0845	YES	Survey # 4501-658519	<i>CJ</i>
02/25/25	1000	YES	Survey # 4501-658659	<i>CJ</i>

**Figure 5. Observation log updated daily by an RCT from Rn leak testing of the Hazmatpac can.**

**Table 1. Results from the smears taken during Rn leak testing of Hazmatpac can (data taken from smear reports in Appendix A)**

Date	Survey #	Removable alpha contamination (dpm per 100 cm <sup>2</sup> )		Removable beta contamination (dpm per 100 cm <sup>2</sup> )	
		Outside of bag	Outside of can	Outside of bag	Outside of can
02/19/25	4501-658196	3	BLD	15	BLD
02/20/25	4501-658332	2	BLD	BLD	BLD
02/21/25	4501-658383	5	BLD	BLD	BLD
02/24/25	4501-658519	BLD	BLD	BLD	BLD
02/25/25	4501-658659	BLD	BLD	73	BLD

BLD = below limit of detection (corrected for background); dpm = disintegrations per minute; detection limit = 1.7 dpm alpha, 44.7 dpm beta

## 5. CONCLUSIONS

The Hazmatpac can passed the Rn leak test in a single experiment with a high-activity <sup>224</sup>Ra/<sup>212</sup>Pb generator. If isotope cans are not available for shipping generators, the Hazmatpac can with a locking ring can be used as a secondary option.

Additional testing of the Hazmatpac can with <sup>224</sup>Ra/<sup>212</sup>Pb generators can be performed when excess <sup>224</sup>Ra is available from generator campaigns. Additional tests may consider performing Rn leak testing with the Hazmatpac can in the full shipping configuration (generator, Pb pig, Hazmatpac can, bag, shipping box) and smearing each level all the way to the inside of the Hazmatpac can to evaluate the extent of Rn release inside of the can, monitoring for Rn leaks over a longer period of time, and performing the Rn leak test in triplicate.

## 6. REFERENCES

Isotope Processing and Manufacturing Division. *Radium-224 Lead-212 Generator Production or Dispensing from Thorium-228 Cow*. IPMD-4501-OP-18 (WA 7008038). Oak Ridge National Laboratory.

## APPENDIX A. SMEAR REPORTS

3/26/25, 10:11 AM

Surveys: View 4501-658196

### ORNL Radiological Survey (4501-658196)

Survey Number:	4501-658196	Survey Date:	02/19/2025 8:55 AM
Field Office:	4501	Submitted Date:	02/19/2025
Surveyor:	Corey Jones (00968229)	Approved Date:	03/03/2025
Surveyor (Other):	NA	Survey Type:	Job Coverage - RWP Required
Division / Group:	Isotope Processing and Manufacturing Div	RWP Number:	4501-24967-6
Building:	4501	Tickler Number:	NA
Room:	127	Survey Plan:	
Person-Hours:	0.5		

Specific Location:  
4501 Lab 127

**COPY**

#### Description:

- Perform survey on Hazmatpac can containing 18 mCi Ra224/Pb212 generator pig
- Can is bagged on shelf under Glovebox #6
- Testing as shipping container

#### Radiological Conditions:

Lab 127: Radiation Area / Radiological Buffer Area

- Dose rates:
  - Shipping Can containing Generator pig:
    - 630 mrem/hr on contact γ
    - 26 mrem/hr @ 30cm γ

- Removable contamination survey performed on o/s of bag and o/s of can.

See Smears for removable contamination results / locations

#### Instruments (3)

Instrument	Next Cal	α / β Eff	α / β-γ / γ Lc	Comments
M308178 3002	04/08/2025	0.155 / ---	1.80 / 34.24 / --- cpm	
0107928 5 XLB	07/31/2025	0.297 / 0.302	2.73 / 8.44 / --- dpm	
M147115 RadEye B20ER	06/10/2025		--- / 13.98 / --- cpm	

#### Smears (2) (dpm/100cm<sup>2</sup> unless noted)

Number	Alpha	Beta	Location
1	3	15	O/s bag
2	<Lc	<Lc	Shipping can

#### Attachments (0)

Reviewed By: Suzanne Eubanks

Date: 03/03/2025

## ORNL Radiological Survey (4501-658332)

<b>Survey Number:</b>	4501-658332	<b>Survey Date:</b>	02/20/2025 3:00 PM
<b>Field Office:</b>	4501	<b>Submitted Date:</b>	02/21/2025
<b>Surveyor:</b>	Corey Jones (00968229)	<b>Approved Date:</b>	03/04/2025
<b>Surveyor (Other):</b>	NA	<b>Survey Type:</b>	Job Coverage - RWP Required
<b>Division / Group:</b>	Isotope Processing and Manufacturing Div	<b>RWP Number:</b>	4501-24967-6
<b>Building:</b>	4501	<b>Tickler Number:</b>	NA
<b>Room:</b>	127	<b>Survey Plan:</b>	
<b>Person-Hours:</b>	0.5		

**COPY**

### SURVEY COPIED FROM 4501-658196

**Specific Location:**  
4501 Lab 127

**Description:**

- Perform survey on Hazmatpac can containing 18 mCi Ra224/Pb212 generator pig
- Can is bagged on shelf under Glovebox #6
- Testing as shipping container

**Radiological Conditions:**

Lab 127: Radiation Area / Radiological Buffer Area

▪ Dose rates:

- Shipping Can containing Generator pig:
  - 692 mrem/hr on contact  $\gamma$
  - 30 mrem/hr @ 30cm  $\gamma$

- Removable contamination survey performed on o/s of bag and o/s of can.

See **Smears** for removable contamination results / locations

**Instruments (3)**

Instrument	Next Cal	$\alpha / \beta$ Eff	$\alpha / \beta - \gamma / \gamma$ Lc	Comments
M308178 3002	04/08/2025	0.155 / ---	4.04 / 41.22 / --- cpm	
M133830 3030	12/31/2025	0.338 / 0.286	1.69 / 44.72 / --- dpm	
M147115 RadEye B20ER	06/10/2025		--- / 17.40 / --- cpm	

**Smears (2) (dpm/100cm<sup>2</sup> unless noted)**

Number	Alpha	Beta	Location
1	2	<Lc	O/s bag
2	<Lc	<Lc	Shipping can

**Attachments (0)**

Reviewed By: Suzanne Eubanks

Date: 03/04/2025

## ORNL Radiological Survey (4501-658383)

<b>Survey Number:</b>	4501-658383	<b>Survey Date:</b>	02/21/2025 9:15 AM
<b>Field Office:</b>	4501	<b>Submitted Date:</b>	02/21/2025
<b>Surveyor:</b>	Corey Jones (00968229)	<b>Approved Date:</b>	03/05/2025
<b>Surveyor (Other):</b>	NA	<b>Survey Type:</b>	Job Coverage - RWP Required
<b>Division / Group:</b>	Isotope Processing and Manufacturing	<b>RWP Number:</b>	4501-24967-6
<b>Building:</b>	Div	<b>Tickler Number:</b>	NA
<b>Room:</b>	127	<b>Survey Plan:</b>	
<b>Person-Hours:</b>	0.5	<b>COPY</b>	

**SURVEY COPIED FROM 4501-658332**

**Specific Location:**  
4501 Lab 127

**Description:**

- Perform survey on Hazmatpac can containing 18 mCi Ra224/Pb212 generator pig
- Can is bagged on shelf under Glovebox #6
- Testing as shipping container

**Radiological Conditions:**  
Lab 127: Radiation Area / Radiological Buffer Area

- Dose rates:
  - Shipping Can containing Generator pig:
    - 622 mrem/hr on contact  $\gamma$
    - 25 mrem/hr @ 30cm  $\gamma$
  - Removable contamination survey performed on o/s of bag and o/s of can.

See **Smears** for removable contamination results / locations

**Instruments (3)**

Instrument	Next Cal	$\alpha / \beta$ Eff	$\alpha / \beta - \gamma / \gamma$ Lc	Comments
M308178 3002	04/08/2025	0.155 / ---	1.80 / 39.13 / --- cpm	
M133830 3030	12/31/2025	0.338 / 0.286	4.14 / 40.84 / --- dpm	
M147115 RadEye B20ER	06/10/2025		--- / 15.42 / --- cpm	

**Smears (2) (dpm/100cm<sup>2</sup> unless noted)**

Number	Alpha	Beta	Location
1	5	<Lc	O/s bag
2	<Lc	<Lc	Shipping can

**Attachments (0)**

Reviewed By: Suzanne Eubanks

Date: 03/05/2025

## ORNL Radiological Survey (4501-658519)

Survey Number:	4501-658519	Survey Date:	02/24/2025 8:45 AM
Field Office:	4501	Submitted Date:	02/24/2025
Surveyor:	Corey Jones (00968229)	Approved Date:	03/06/2025
Surveyor (Other):	NA	Survey Type:	Job Coverage - RWP Required
Division / Group:	Isotope Processing and Manufacturing Div	RWP Number:	4501-24967-6
Building:	4501	Tickler Number:	NA
Room:	127	Survey Plan:	
Person-Hours:	0.5		

COPY

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**Specific Location:**  
4501 Lab 127

**Description:**

- Perform survey on Hazmatpac can containing 18 mCi Ra224/Pb212 generator pig
- Can is bagged on shelf under Glovebox #6
- Testing as shipping container

**Radiological Conditions:**

Lab 127: Radiation Area / Radiological Buffer Area

- Dose rates:
  - Shipping Can containing Generator pig:
    - 365 mrem/hr on contact
    - 15 mrem/hr @ 30cm  $\gamma$

- Removable contamination survey performed on o/s of bag and o/s of can.

See **Smears** for removable contamination results / locations

**Instruments (3)**

Instrument	Next Cal	$\alpha$ / $\beta$ Eff	$\alpha$ / $\beta$ - $\gamma$ / $\gamma$ Lc	Comments
M308178 3002	04/08/2025	0.155 / ---	1.80 / 38.07 / --- cpm	
M133830 3030	12/31/2025	0.338 / 0.286	4.76 / 40.24 / --- dpm	
M147115 RadEye B20ER	06/10/2025		--- / 14.55 / --- cpm	

**Smears (2) (dpm/100cm<sup>2</sup> unless noted)**

Number	Alpha	Beta	Location
1	<Lc	<Lc	O/s bag
2	<Lc	<Lc	Shipping can

**Attachments (0)**

Reviewed By: Suzanne Eubanks

Date: 03/06/2025

## ORNL Radiological Survey (4501-658659)

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Survey Number:	4501-658659	Survey Date:	02/25/2025 10:00 AM
Field Office:	4501	Submitted Date:	02/25/2025
Surveyor:	Corey Jones (00968229)	Approved Date:	03/10/2025
Surveyor (Other):	NA	Survey Type:	Job Coverage - RWP Required
Division / Group:	Isotope Processing and Manufacturing Div	RWP Number:	4501-24930-5
Building:	4501	Tickler Number:	NA
Room:	127	Survey Plan:	
Person-Hours:	0.5		

COPY

**SURVEY COPIED FROM 4501-658519**

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**Specific Location:**  
4501 Lab 127

**Description:**

- Perform survey on Hazmatpac can containing 18 mCi Ra224/Pb212 generator pig
- Can is bagged on shelf under Glovebox #6
- Testing as shipping container

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**Radiological Conditions:**  
Lab 127: *Radiation Area / Radiological Buffer Area*

- Dose rates:
  - Shipping Can containing Generator pig:
    - 305 mrem/hr on contact  $\gamma$
    - 10 mrem/hr @ 30cm  $\gamma$

▪ Removable contamination survey performed on o/s of bag and o/s of can.  
See **Smears** for removable contamination results / locations

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**Instruments (3)**

Instrument	Next Cal	$\alpha$ / $\beta$ Eff	$\alpha$ / $\beta$ - $\gamma$ / $\gamma$ Lc	Comments
M308178 3002	04/08/2025	0.155 / ---	1.80 / 39.40 / --- cpm	
M133830 3030	12/31/2025	0.338 / 0.286	4.76 / 38.22 / --- dpm	
M147115 RadEye B20ER	06/10/2025		--- / 15.63 / --- cpm	

---

**Smears (2) (dpm/100cm<sup>2</sup> unless noted)**

Number	Alpha	Beta	Location
1	<Lc	73	O/s bag
2	<Lc	<Lc	Shipping can

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**Attachments (0)**

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Reviewed By: Suzanne Eubanks

Date: 03/10/2025

