



Idaho National Laboratory

Consideration of In-Growth of Radionuclides for Facility Hazard Categorization

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May 23, 2007

Issues Associated with In-growth

- **Artificial Concentration of Nuclides in Decay Chains**
- **Inconsistent Methodologies for Exposure Pathways**
- **Significant Differences in Radiotoxicity Between Parent and Daughter Products**
- **Threshold Quantity Values (TQVs) Derived Based on a 24 hour Accident Scenario – No In-growth Consideration in the EPA Methodology**

Radioactive Decay

Three types of Equilibrium

- **Secular**
- **Transient**
- **No Equilibrium**

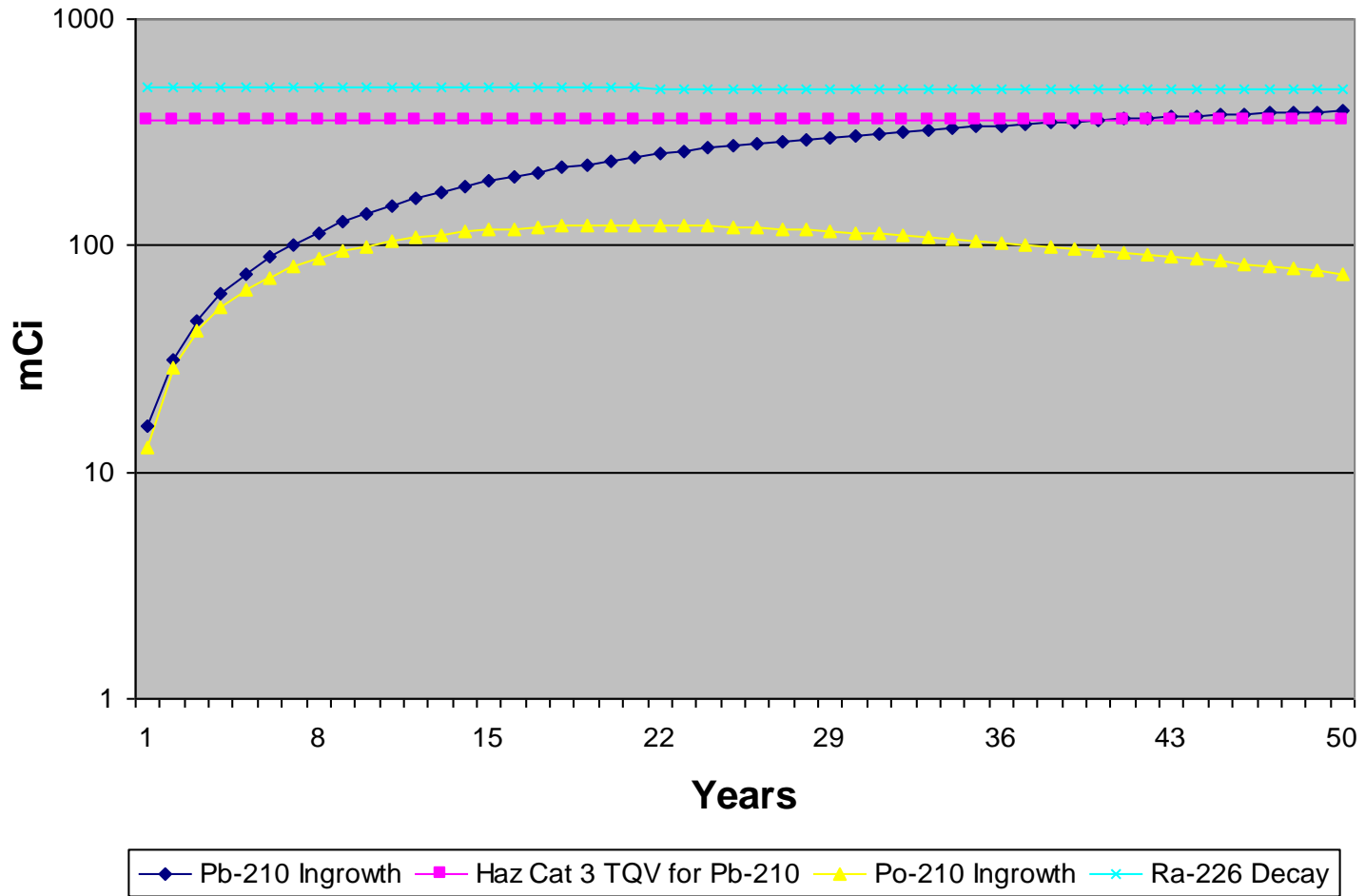
Radioactive Decay

- **Secular** – When the half-life of the parent nuclide is infinitely longer than that of the daughter

For $\lambda_1 \ll \lambda_2$

$$A_2 = A_1^0 \left(e^{-\lambda_1 t} - e^{-\lambda_2 t} \right)$$

In-growth of Pb-210 from Ra-226



Radioactive Decay

- **Transient** – When the half-life of the parent nuclide is larger than that of the daughter, but not infinitely

For $\lambda_1 < \lambda_2$

$$A_2 = \frac{\lambda_2}{\lambda_2 - \lambda_1} A_1^0 e^{-\lambda_1 t}$$

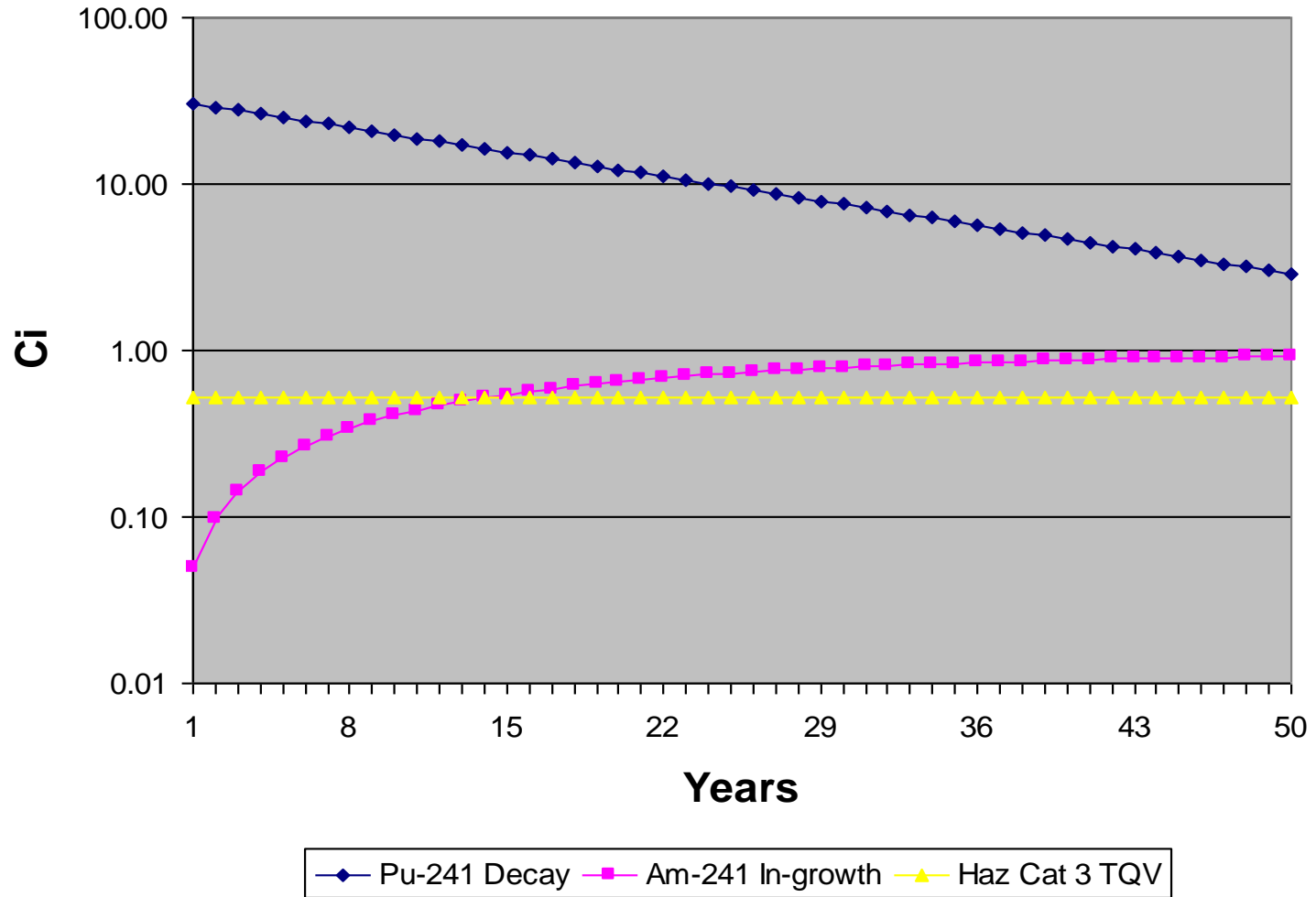
Radioactive Decay

- **No Equilibrium – When the half-life of the daughter nuclide is larger than that of the parent**

For $\lambda_1 > \lambda_2$

$$A_2 = \frac{\lambda_2}{\lambda_2 - \lambda_1} A_1^0 e^{-\lambda_2 t}$$

In-growth of Am-241 from Pu-241



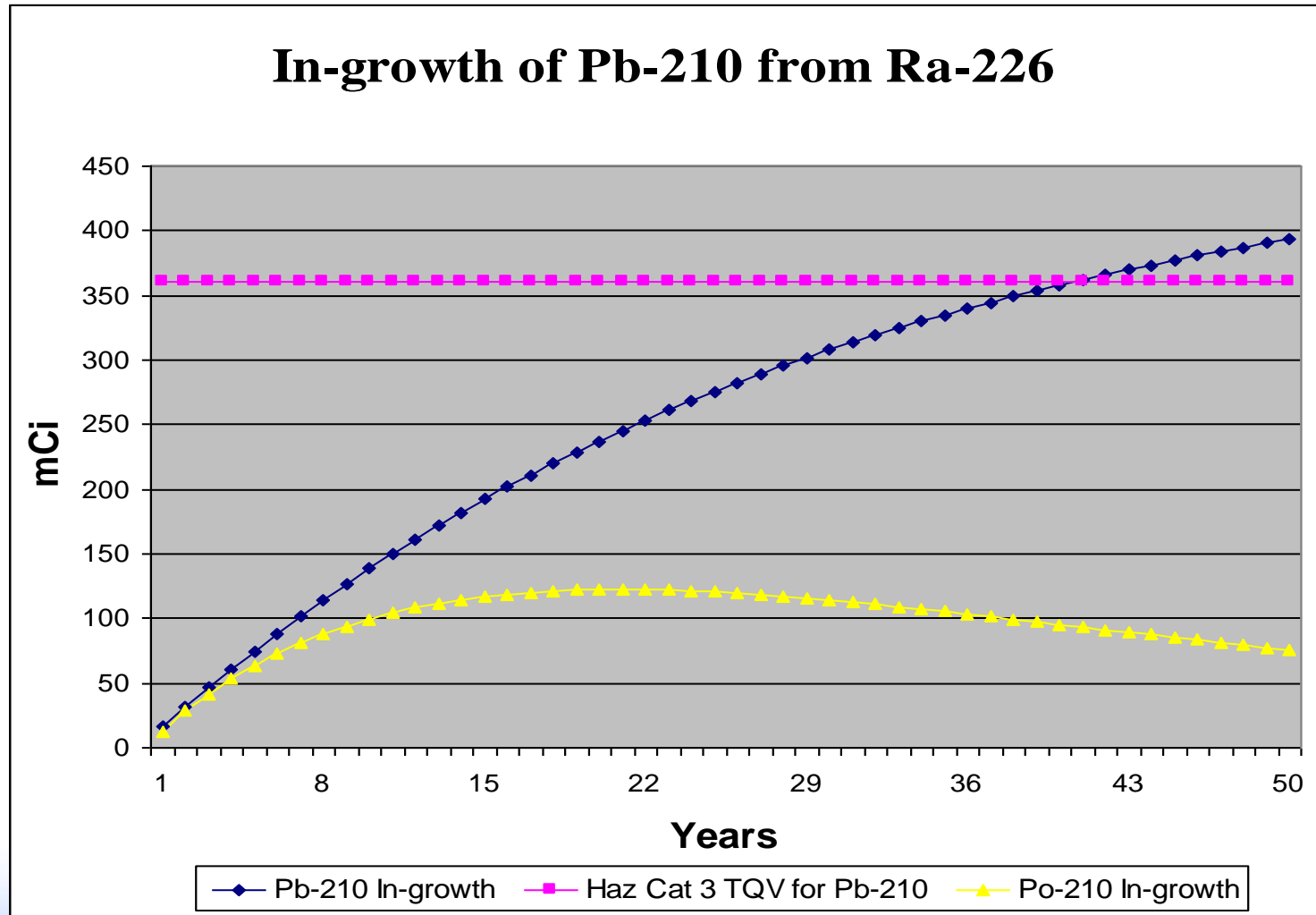
Daughter Concentration Outside of Natural Decay Chains

- **The Four Natural Decay Chains**
 - **Thorium ($4N + 0$)** **Parent nuclide Th-232**
 - **Neptunium ($4N + 1$)** **Parent nuclide Pu-241**
 - **Uranium ($4N + 2$)** **Parent nuclide U-238**
 - **Actinium ($4N + 3$)** **Parent nuclide U-235**

Daughter Concentration Outside of Natural Decay Chains

- **More than 100K years to in-grow Pb-210 to HC3 TQV**
- **Tons of natural Uranium are required to produce HC3 TQV of Pb-210**
- **Only 500 mCi of Ra-226 in 41.5 yrs to reach HC3 TQV for Pb-210**

Time to Haz Cat 3 TQV limit – 41.5 yrs



Daughter Concentration Outside of Natural Decay Chains

- **Not all in-growth issues deal with altering the natural decay chains**
- **Fission Product Decay (No Equilibrium)
Mo-99 to Tc-99 or Xe-135 to Cs-135**
- **Low irradiation experiments with test fuels or materials**

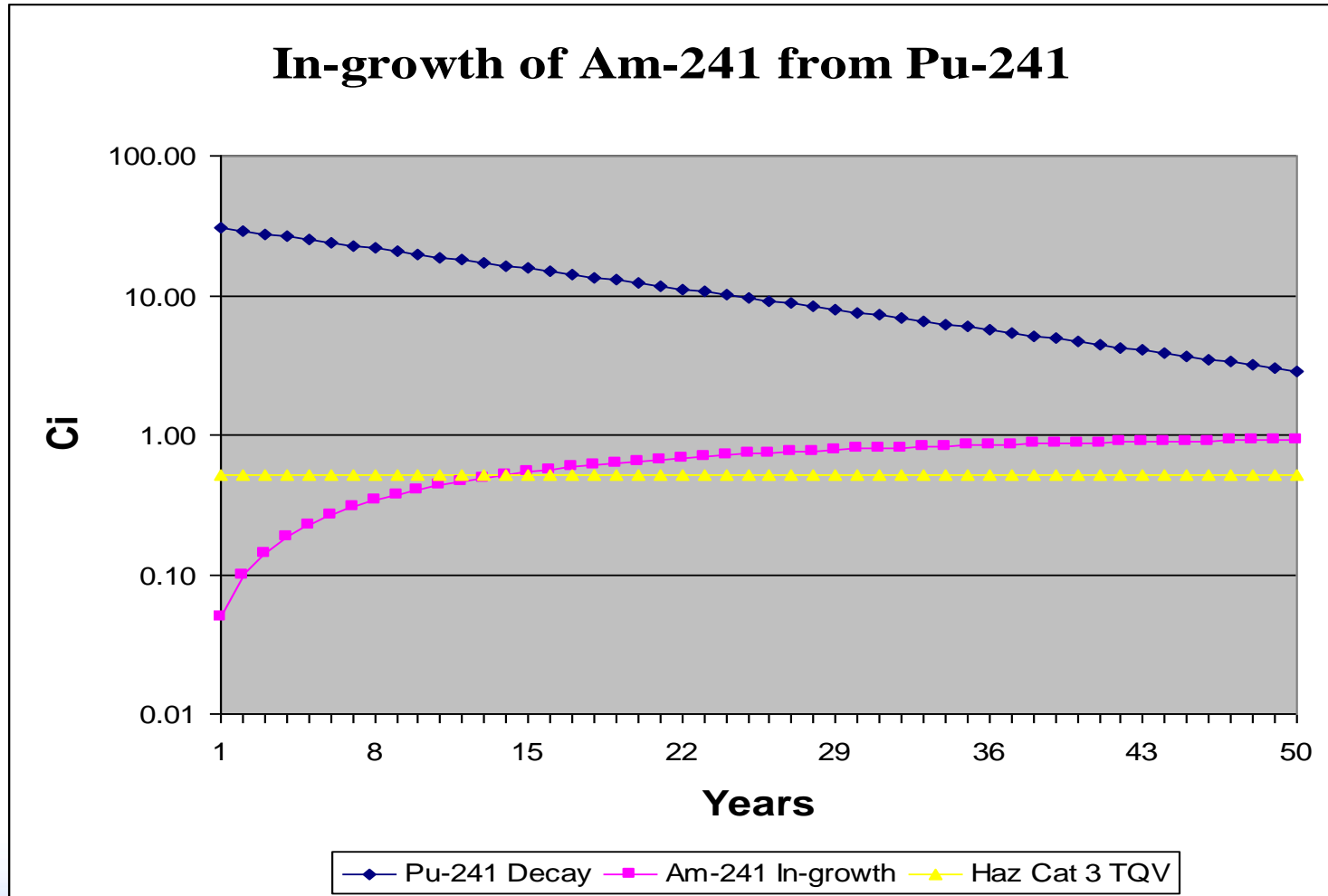
Different Exposure Pathways

- Parent nuclide is evaluated using inhalation pathway while the daughter product is evaluated for ingestion pathway
- U-238 inhalation and daughter Pb-210 ingestion
- Intakes and systemic pathways are not tied to TQVs
- EPA study used lowest TQV irrespective of pathway or biokinetics

Same Exposure Pathway - Different Radiotoxicity

- EPA methodology and DOE-STD-1027-92 utilize the ICRP 30 DCFs
- Pu-241 & Am-241 same pathway – Inhalation
- Am-241 is approximately 52 times more radiotoxic than Pu-241 (ICRP 30)
- Am-241 has the same HC3 TQV as Pu-239 (STD-1027-92)
- Approximately 300 mg of Pu-241 in 14.5 yrs to reach HC3 TQV for Am-241

Time to Haz Cat 3 TQV limit – 14.5 yrs



Methodology Used in EPA Study

- EPA used a 24 hour exposure scenario – no consideration was given to in-growth of daughters
- Four pathways were evaluated
 - Water (w)
 - Food (f)
 - Direct Exposure (d)
 - Inhalation (i)
- Current DOE-STD-3009 does not require the ingestion pathway (Appendix A Section A.3)

Methodology Used in EPA Study

- **EPA study clearly stated decay not accounted for due to short release & exposure time to dose receptors**
- **This methodology is sufficient for accident and emergency scenarios (up to four days)**
- **Not sufficient for long term operations and storage involving legacy materials**

Methodology Used in EPA Study

- **New staff and personnel could be unaware of legacy sources and material**
- **There is no formal mechanism to deal with the in-growth issue under the current guidance system (STD-1027-92 Section 4.1.1.a)**
- **No decayed inventory is required and even then it would only be a “Snap Shot” in time**

Conclusions

- **The current methodology is incomplete at best**
- **Need mechanism that provides “real time” inventories to ensure materials are properly categorized against TQVs**
- **Radioactive material tracking & inventory software is commercially available with built-in auto decay functions**

Conclusion

- **Since the ingestion pathway has been omitted from the required accident scenario methodology, a reevaluation of the TQVs for nuclides needs to be performed**
- **Address the issue of converting from ICRP 26/30 to ICRP 68/72**
- **A complete methodology reevaluation is needed or a stop gap measure of instituting “real time” inventories should be established**

Examples of Commercial Software

Radioactive Material Receiving

Package Receiving Workflow - Maintains accurate records on radiological material receiving including:

- a. Overall License-offers on overall license limit along with individual Permit Limits
- b. Auto inserts order information for the order requisition
- c. Assigns and tracks individual items by an inventory number
- d. Assigns shipment to user inventory at time of receipt
- e. Offers an overall license limit check along with individual Permit limit check by shipment limit, annual limit and possession limit
- f. Allows for PI Compliance Category Audit, i.e., permit restrictions, expired permit, training not up-to-date, sealed source leak test, PI information requests, survey meter calibrations overdue etc
- g. Allows for checking of permit conditions and restrictions
- h. Documents survey meter readings, wipe test results, DOT designation transport index and package comments
- i. Documents order status i.e. order complete or partial receipt
- j. Documents material location within the institution
- k. Automatically perform decay corrections for radioactive materials for each inventory item
- l. Automatically archives requisition upon receipt
- l. Customized reports

Editing Permit

PI: JRUSS | Dr. James Russell

Permit #: JRUSS | Current Amendment #: 0

Protocol Type: RAM | Inspector: MD

Permit Status: Non-Restricted

Site Visit: / /

Internal Permit #: _____

Permit Title: _____

Inspection Frequency

Jan May Sep
 Feb Jun Oct
 Mar Jul Nov
 Apr Aug Dec

Save Cancel

Isotopes |
 Workers |
 Labs |
 Amendments |
 Conditions |
 Permit History |
 Protocols

Add |
 Edit |
 Archive |
 Transfer

Isotope	Compound	Sealed?	Possession Limit	Unit	Lic. Line #
Am-241	SEALED SOU	<input checked="" type="checkbox"/>	5.00000	mCi	BFF
P-32		<input type="checkbox"/>	10.00000	mCi	BG
S-35		<input type="checkbox"/>	10.00000	mCi	BG

Editing RAM Requisition Record

PI Requisition #

Isotope License Line # Permit #

PO #

Account #

Lab

Vendor Code

Vendor Catalog

Compound

Blanket Requisition?

Comments

Contact Information

Contact Lab Phone

E-Mail

Requisition Date	# of Units	Activity per Unit	Order Amount	Units
<input type="text" value="03/29/2004"/>	<input type="text" value="1"/>	<input type="text" value="2.00000"/>	<input type="text" value="2.00000"/>	<input type="text" value="mCi"/>

Adding RAM Inventory Record

PI: JRUSS Dr. James Russell

Isotope: S-35 License Line #: BG Permit #: JRUSS

Requisition #: 04032906

Inventory #: 060225000 Transaction Code: SHP Shipment

Physical Form: Solid

PO #: 251604A635 Lot #:

Compound: Volatile?

Lab: HBLDG:101A Heritage Building: 101A

Vendor Code: PER Perkin Elmer Catalog #: NEG772

Comments:

Contact: Smith, Archibald Lab Phone: (314)963-0440

Contact EMail: asmith@techu.edu

Assay Detail

Assay Date: / /

Receipt Date: / /

Assay Activity per Unit: 2.00000 mCi

× # of Units: 1

Total Activity: 2.00000 mCi

Receipt Activity: 0.00000 mCi

Volume: 0.00000 mL

Check Permit Limits

PI Compliance Status

Permit Conditions

Package Inspection

Order Status

Partial Order Order is Complete

Save Cancel

Requisition Information

Requisition Date	# of Units	Activity per Unit	Total Activity Req
03/29/2004	1	2.00000	2.00000 mCi

Compound: Blanket Requisition?

Comments: Received 03/30/2004

Check RAM Permit Limits

PI	PI Name	Permit #	Isotope	License Line #
JRUSS	Russel, James	JRUSS	P-32	BG

Possession Limit

Possession Limit	10.00000	mCi
- Balance	0.00000	mCi
- On Order	5.50000	mCi
= Remaining	4.50000	mCi

OK

Organizational License Limit

License Limit	5000.00000	mCi
- Balance	0.00023	mCi
= Remaining	4999.99977	mCi

OK

Return

RAM Package Check-In

Ship Code Isotope

Converter

Counts Per Minute(CPM) Background Efficiency Disintegrations Per Minute

(-) ÷ =

Package Wipe Counter Survey Instrument

Package Wipe Exterior dpm Exposure: Surface mR/hr

Package Wipe Interior dpm Exposure: 1 Meter mR/hr

DOT Designation Transport Index

Package Comments

Package Processed by:



Compliance Category	#		View
Permit Restrictions	0		
Expired Permit	0		
Sealed Source Leaktests	0		
P.I. Information Requests	0		
Past Due Training	3		
Survey Meter Calibration	2		
X-Ray Compliance	1		
Laser Compliance or Alignment	0		
General Licensed Material	0		

Return