

INSTRUMENTATION



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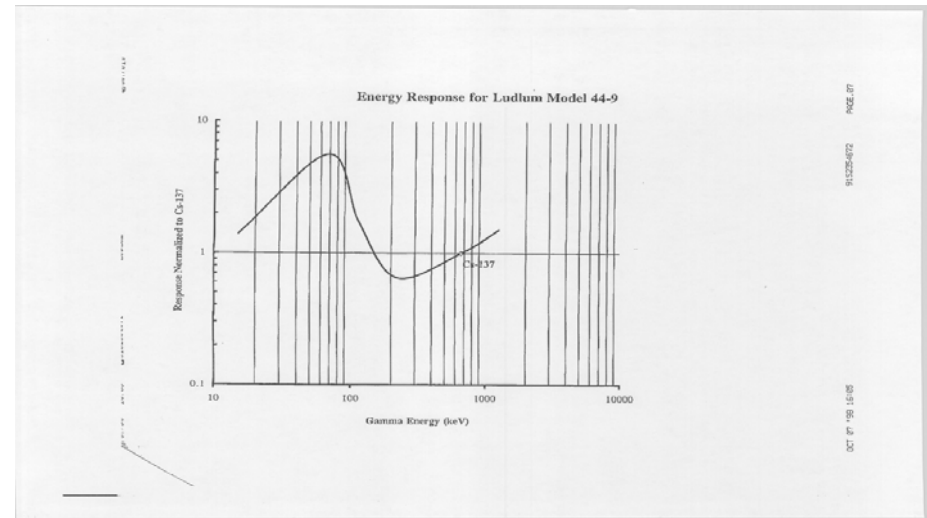


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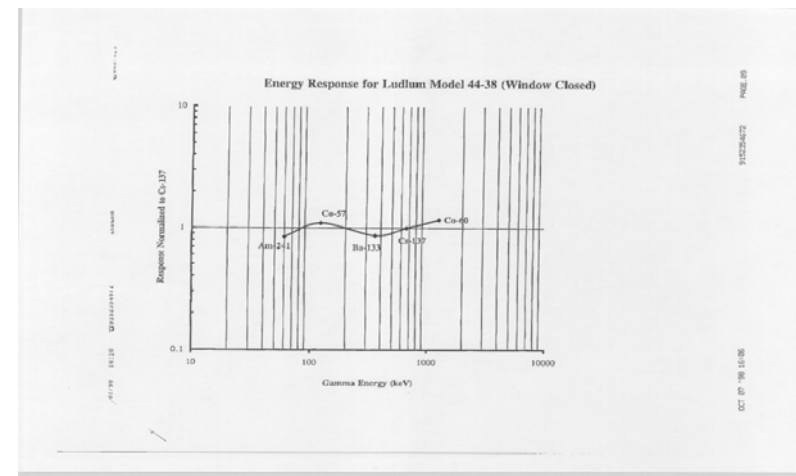
G-M Detectors

- Ludlum 44-9 Pancake
- Not for use in DOT Surveys
- Over-responds to low-energy photons
- Excellent for contamination surveys of positron and beta emitters (CPM)
- Low efficiency for high energy photons



G-M Detectors

- Energy Compensated G-M
- Ludlum 44-38
- Use for DOT Surveys and area radiation level surveys (mR/hr)
- Not for use in personal contamination surveys



Personnel Contamination Surveys

Constant
reinforcement of
need for personal
contamination
surveys



Meter: Ludlum Model 177

Hand Probe: Ludlum Model 44-9 (Pancake)

Foot Probe: Ludlum Model 44-26 (3 or 2 Pancakes)

Which one is correct?



Single Channel Analyzer

- Workhorse used for multiple functions
- Usually a quarterly calibration for efficiency
- Define energy windows if needed

Single Channel Analyzers (SCA)



Photo of Back



Single Channel Analyzers (SCA)

- Operational Parameters
 - High voltage
 - Properly set per manufacturer recommendations or via procedure to identify the peak count rate point
 - Energy windows
 - Usually necessary to reduce background and achieve MDA with reasonable count times
 - For SPECT, need multiple windows
 - For PET, just one window



Single Channel Analyzers (SCA)

- Operational Parameters
 - Efficiency Calibration
 - Sodium Iodide (NaI) scintillation detectors have a fairly flat energy response over the region of interest for nuclear medicine
 - For SPECT, use multiple standards
 - ^{137}Cs (661 keV, 30.17y $T_{1/2}$) for ^{131}I
 - ^{57}Co (122 keV, 271d $T_{1/2}$) for $^{99\text{m}}\text{Tc}$, ^{111}In , ^{123}I , ^{201}Tl
 - For PET
 - ^{137}Cs (661 keV, 30.17y $T_{1/2}$) for any PET radionuclides

[illegible]

A line graph titled "Counts Vs. High Voltage" showing the relationship between high voltage (kV) and counts (cpm). The x-axis is labeled "High Voltage" and ranges from 244 to 252 kV. The y-axis is labeled "Counts (cpm)" and ranges from 0 to 12000. The graph shows a sharp peak in counts at 248 kV, reaching approximately 11000 cpm. The counts drop significantly at 249 kV and remain low for higher voltages.

High Voltage (kV)	Counts (cpm)
244	0
245	3000
246	8500
247	11000
248	9000
249	4000
250	500
251	200
252	0
253	0
254	0
255	0
256	0
257	0
258	0
259	0
260	0
261	0
262	0
263	0
264	0
265	0
266	0
267	0
268	0
269	0
270	0

Efficiency Calibration Worksheet					
					Date of test: 5/16/2005
SCA Make:	Ludlum	Model:	2200	S/N:	165687
Source used:	Cs-137 rod	Half Life:	11012.05	days	
Original Activity:	0.108 uCi	on	3/9/2000		
Current Activity:	0.096 uCi	S/N:	693-91-20		
High Voltage Setting:		248	channel		
Source Counts		Count Time:	1	Minutes	
1)	20674				
2)	20634				
3)	20655				
Gross Average =	20654.33333	cpm	Background Count	33.0	cpm
Net Average =	20621	cpm			
Single Channel Analyzer Quarterly Efficiency Calculation					
Eff =	$\frac{\text{Net cpm (rod source)}}{2.22 \times 10^6 \text{ dpm/uCi} \times \text{uCi of rod source}}$				
Eff =	20654.33	-	33.00	=	0.10
	2.22x10+6 dpm/uCi	x	0.095864889 uCi		
		Eff =	9.69	%	
MDA Calculation					
MDA (cpm) =	4.67 x	$\sqrt{\text{Background (cpm) / Count Time (min)}}$			
MDA (dpm) =	4.67 x	$\frac{\sqrt{\text{Background (cpm) / Count Time (min)}}}{\text{Eff}}$			
MDA for 220 dpm			MDA for 2200 dpm		
If Bkg (cpm)	Required	MDA	If Bkg (cpm)	Required	MDA
< than	Time (min)	(dpm)	< than	Time (min)	(dpm)
21	1	219	208	0.1	2199
41	2	219	416	0.2	2199
62	3	219	625	0.3	2199
83	4	219	833	0.4	2199
103	5	219	1041	0.5	2199
Performed By:					
RSO Review:					

This form must be completed, cut out and posted at the instrument.

Efficiency factor using Cs-137

Efficiency Factor (using Cs-137)

= 0.10

Date Calculated: 5/16/2005

Wipe Test Conversion:

Count time = 120 sec

Multiply net counts by 5.16 to obtain DPM.



Single Channel Analyzers (SCA)

- **Daily Constancy**
 - **Day of use**
 - **Usually ^{137}Cs source**
 - **Compare to action levels determined at most recent calibration**
 - **Notify site RSO if results are outside action levels**

Single Channel Analyzers (SCA)

Attachment 1

Single-Channel Analyzer Daily Constancy

	Month/Year	April-10		
Calibration Source:	Cs-137		Instrument Information	
Manufacturer, Model, & S/N:	IPL, XX-xx	Manufacturer:	Ludlum	
Original Activity:	100 uCi	Model:	2200	
Calibration Date:	3/20/1994	S/N:	123456	
Most Recent Efficiency Calibration				
Calibration Date:	3/1/2010	High Voltage:	925	
Cs-137 Net Counts:	10000			

Day	Gross Counts (cpm)	Background Counts (cpm)	Net Counts (cpm)	% Difference	Performed By
1	12000	2000	10000	0.00	
2	15000	1000	14000	-40.00	
3	11000	1500	9500	5.00	
4	Sat		#VALUE!	#VALUE!	
5	Sun		#VALUE!	#VALUE!	



SCA Count Time

- If the MDA is greater than 220 dpm, then a count time longer than one minute will be required.
- For $MDA < 220$ dpm
 - Reduce Background
 - Increase Shielding
 - Relocate to lower background areaOtherwise: Longer count time?

Dose Calibrators

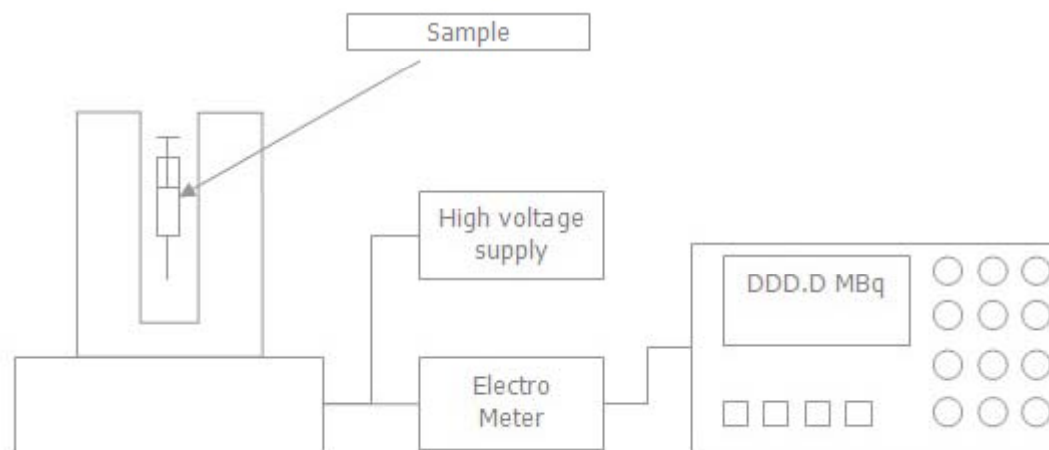
- **Sec. 32.72 Manufacture, preparation, or transfer for commercial distribution of radioactive drugs containing byproduct material for medical use under part 35**
(c)
- **A licensee shall possess and use instrumentation to measure the radioactivity of radioactive drugs. The licensee shall have procedures for use of the instrumentation. The licensee shall measure, by direct measurement or by combination of measurements and calculations, the amount of radioactivity in dosages of alpha-, beta-, or photon-emitting radioactive drugs prior to transfer for commercial distribution. In addition, the licensee shall:**
 - **(1) Perform tests before initial use, periodically, and following repair, on each instrument for accuracy, linearity, and geometry dependence, as appropriate for the use of the instrument; and make adjustments when necessary; and**
 - **(2) Check each instrument for constancy and proper operation at the beginning of each day of use.**



Dose Calibrators

- Dose calibrators are a sealed ionization chamber in a well configuration
- Because of the low efficiency for photons, the gas is typically pressurized with argon to increase efficiency (2.5 atmospheres for Capintec CRC-15BT)
 - This requires an exemption for air shipments

Dose Calibrators



Dose Calibrators

- **Dose Calibrator Operational Tests**
 - **Daily Constancy**
 - **Quarterly Linearity**
 - **Annual Accuracy**
 - **Geometry before first use and after repairs for all geometries in use**

Dose Calibrators

- Daily Constancy
- Shows continued performance of dose calibrator
 - Zero dose calibrator
 - Background Correction
 - Constancy check with NIST traceable ^{137}Cs source
 - Compare to action levels in SOP usually within $\pm 10\%$

Dose Calibrators

Dose Calibrator Constancy Log

Month:
 Year: January-07

Page 1 of 3

Dose Calibrator: 1

Reference Source

Make & Model:

Isotope: Cs-137

Calibration

Date: 2/1/2006

SN:

Activity : 200 µCi

Half Life: 11012 days

Day	Cs-137 µCi	- 10%	DC µCi	+ 10%	Mo-99 µCi	- 10%	DC µCi	+ 10%	Tc-99m µCi	- 10%	DC µCi	+ 10%	Tl-201 µCi	- 10%	DC µCi	+ 10%
1-Jan-07	195.84	176.26		215.42		0.00		0.00		0.00		0.00		0.00		0.00
2-Jan-07	195.83	176.24		215.41	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
3-Jan-07	195.82	176.23		215.40	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
4-Jan-07	195.80	176.22		215.38	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
5-Jan-07	195.79	176.21		215.37	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
6-Jan-07	195.78	176.20		215.36	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
7-Jan-07	195.77	176.19		215.34	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
8-Jan-07	195.75	176.18		215.33	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
9-Jan-07	195.74	176.17		215.32	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
10-Jan-07	195.73	176.16		215.30	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
11-Jan-07	195.72	176.15		215.29	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
12-Jan-07	195.70	176.13		215.28	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
13-Jan-07	195.69	176.12		215.26	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
14-Jan-07	195.68	176.11		215.25	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
15-Jan-07	195.67	176.10		215.23	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
16-Jan-07	195.66	176.09		215.22	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
17-Jan-07	195.64	176.08		215.21	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
18-Jan-07	195.63	176.07		215.19	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
19-Jan-07	195.62	176.06		215.18	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
20-Jan-07	195.61	176.05		215.17	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
21-Jan-07	195.59	176.03		215.15	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
22-Jan-07	195.58	176.02		215.14	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
23-Jan-07	195.57	176.01		215.13	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
24-Jan-07	195.56	176.00		215.11	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
25-Jan-07	195.54	175.99		215.10	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
26-Jan-07	195.53	175.98		215.09	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
27-Jan-07	195.52	175.97		215.07	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
28-Jan-07	195.51	175.96		215.06	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
29-Jan-07	195.50	175.95		215.04	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
30-Jan-07	195.48	175.93		215.03	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00
31-Jan-07	195.47	175.92		215.02	0.00	0.00		0.00	0.00	0.00		0.00	0.00	0.00		0.00

RSO Review: _____



Dose Calibrators

- Quarterly Linearity
- Demonstrates response of the dose calibrator is linear across the range of activities to be measured
 - This test can be performed by either of two methods, the decay or shield test
 - Linearity must be tested from the highest administered activity down less than 1 mCi or below
 - Dose calibrators can usually pass this test easily

Dose Calibrator Linearity Test

Dose Calibrator 1

Make/Model: CRC-127 RH

Performed by:

S/N: 770763

Date: 7/11-12/02

Chamber #: 7

Assay Time	Decay Time, t (min)	Decay Factor, $e^{-\lambda t}$	Measured Activity, A_m (mCi)	Calculated Activity (mCi), A_c $A_c = A_0 e^{-\lambda t}$	Linearity Error $(A_m - A_c)/A_c$	% Error Error X 100
7/11/02 11:05	0	1	1013			
7/11/02 12:25	80	0.60	633	611.23	0.036	3.6
7/11/02 13:03	118	0.47	465	480.83	0.033	3.3
7/11/02 14:17	192	0.30	303	301.33	0.006	0.6
7/11/02 15:54	289	0.16	165	163.31	0.010	1.0
7/12/02 9:32	1347	0.00	0.212	0.20	0.035	3.5
7/12/02 11:19	1454	0.00	0.103	0.10	0.012	1.2
7/12/02 11:53	1488	0.00	0.082	0.08	0.025	2.5
7/12/02 12:43	1538	0.00	0.061	0.06	0.005	0.5

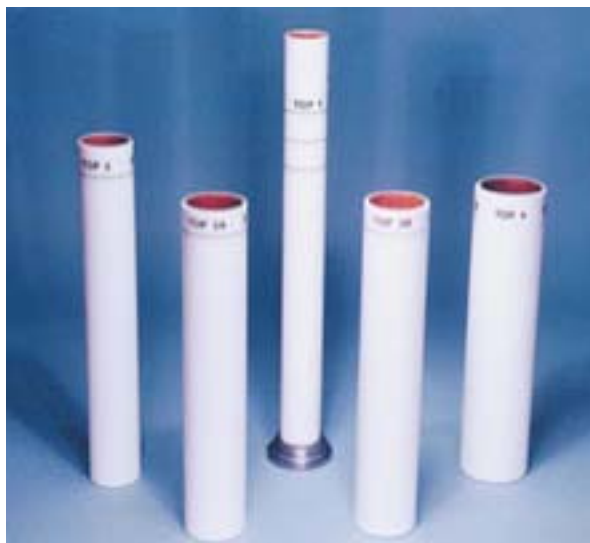
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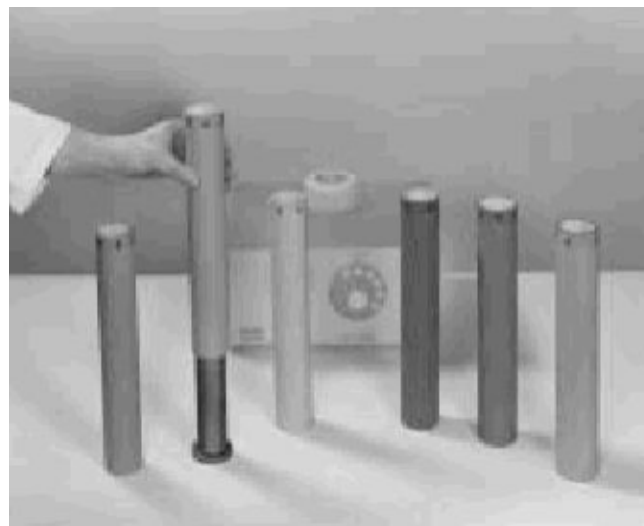
Dose Calibrators

- Quarterly Linearity
 - Shield Method
 - CaliCheck or Lineator devices must be calibrated before first use.
 - Do not recalibrate after initial calibration
 - Must be approved on license before use
 - Store tubes carefully
 - Entire test must be completed as quickly as possible
 - Follow manufacturer's instructions

Dose Calibrators



Lineator



Calichek



Dose Calibrators

- **Annual Accuracy**
 - Measuring the certified activity of a traceable standard determines dose calibrator accuracy
 - Use average of ten consecutive readings
 - Agreement within $\pm 5\%$ to source
 - Repeat for standards of various energies (e.g. Co-57, Cs-137, Ba-133)
 - The degree of overall accuracy depends on the combined accuracy of the detector, the electrometer, the (digital) readout, and the traceable standard

Dose Calibrators

- **Geometry**
- **Dose Calibrator response to differences in sample geometry can vary due to holder, differences in wall thickness, position within well, and sample size**
 - **For instance, the response for a vial source will differ from a syringe**
- **Lower energy radionuclides are more susceptible and usually require a correction factor to compensate for the differences**



Dose Calibrators

- **Mo-99 breakthrough**
 - **Mo-99 is assayed directly in the special lead pig supplied by manufacturer of your dose calibrator**
 - **Tc-99m is then assayed directly in the plastic sleeve**
 - **Activity (uCi) of Mo-99 is divided by activity (mCi) of Tc-99m to obtain a ratio**
 - **Ratio must be <0.15 uCi Mo-99 per mCi of Tc-99m at time of administration**

Dose Calibrators

- Mo-99 breakthrough shield



Dose Calibrators

- Assay of pure beta emitters (^{153}Sm , ^{90}Y , ^{89}Sr , ^{32}P)
 - Beta particles cannot penetrate into the ion chamber directly but produce a secondary signal through the production of Bremsstrahlung (x-ray) radiation
 - Geometry, dipper, and vial material variations greatly affect results
 - Follow the radiopharmaceutical supplier's recommendations
- NRC INFORMATION NOTICE 2002-19:
 - MEDICAL MISADMINISTRATIONS CAUSED BY FAILURE TO PROPERLY PERFORM TESTS ON DOSE CALIBRATORS FOR BETA- AND LOW ENERGY PHOTON-EMITTING RADIONUCLIDES

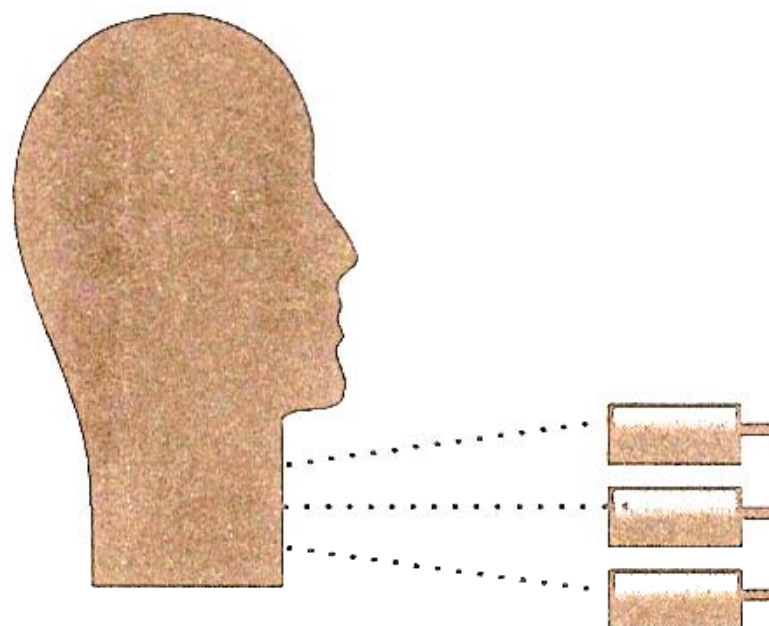
Thyroid Bioassay

- **Scaler, NaI scintillation detector, ^{133}Ba source (NIST traceable), thyroid phantom**
- **Frequency**
 - **weekly for those routinely involved with producing capsules or oral solutions, or within 6 to 72 hours of completing work for those not routinely compounding Iodine products**
 - **If suspected contamination from operation**
 - **Survey skin to eliminate potential for a false result**



Thyroid Bioassay

Take three readings at slightly different positions on neck



PRCP No. D0008402 Rev. A
Attachment 2
$$Q = \text{Thyroid Burden} = \frac{cpm_{neck} - cpm_{bkg}}{CF}$$

Date and Time	Employee Name	Count in 2 minutes	CPM _{each}	BKG (cpm)	Net CPM	MDA (uCi)	I-131 Deposited Q (uCi)	Exceed Action Level
11/13/06 1:30pm	Juan Del Pueblo	500	250	60.0	190	2.5E-03	0.012	NO
		600	300	60.0	240	2.5E-03	0.015	NO
		475	237.5	60.0	178	2.5E-03	0.011	NO
		450	225	60.0	165	2.5E-03	0.010	NO
		100	50	60.0	-10	2.5E-03	-0.001	NO
		125	112.5	60.0	53	2.5E-03	0.003	NO
		100	50	60.0	-10	2.5E-03	-0.001	NO
		200	100	60.0	40	2.5E-03	0.002	NO
		123	61.5	60.0	2	2.5E-03	0.000	NO
		100	50	60.0	-10	2.5E-03	-0.001	NO
		100	50	60.0	-10	2.5E-03	-0.001	NO
		100	50	60.0	-10	2.5E-03	-0.001	NO
		100	50	60.0	-10	2.5E-03	-0.001	NO
		100	50	60.0	-10	2.5E-03	-0.001	NO
		100	50	60.0	-10	2.5E-03	-0.001	NO
		100	50	60.0	-10	2.5E-03	-0.001	NO
		100	50	60.0	-10	2.5E-03	-0.001	NO
		0	0	60.0	-60	2.5E-03	-0.004	NO
		0	0	0	0	2.5E-03	0.000	NO
		0	0	0	0	2.5E-03	0.000	NO
		0	0	0	0	2.5E-03	0.000	NO
		0	0	0	0	2.5E-03	0.000	NO


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Air Samplers

- For sites preparing Iodine capsules, it is necessary to monitor for airborne radioactivity in the room air and in the ventilation
- Flow measurements must be accurate, requiring annual calibration
- Discussed calculations earlier

Effluent Monitoring

- PET effluent monitoring covered later



Instrumentation Recap

- **Handheld instrumentation**
 - usually includes dose rate measurements and contamination measurements
 - Calibration and daily checks (condition & constancy)
- **Dose calibrators**
 - Daily constancy, quarterly linearity, annual accuracy, geometry
- **Air flow measurements**
 - Annual calibration

DOSIMETRY



External Dosimetry

- SPECT Pharmacy Source Term
 - Radiation fields encountered are composed of beta and photon radiations of varying energies
 - ^{131}I at 364 keV, is the highest photon energy typically encountered for open sources, ^{137}Cs at 661 keV for sealed sources
 - Beta energies exceed 2 MeV for therapy products

External Dosimetry

- **PET Pharmacy Source Term**

- Radiation fields are primarily composed of 511 keV photons and to a lesser extent positrons
 - Positron energies can be upwards of 2 MeV, but due to shielding required for photon radiation fields, positrons are normally not a potential for exposure
- Cyclotron servicing personnel have a potential for exposure to neutrons, however over eight years of monitoring experience shows less than ten results with neutron exposure, and all were below 50 mrem
- Neutron spectral surveys show the neutrons are mostly thermal with some extending up to 1 MeV outside of shields and bunkers, but for shielding calculations a higher energy is typically used (5 MeV for Siemens)

External Dosimetry

- Standard β/γ TLD or OSL whole body dosimeters from a NVLAP accredited vendor will accurately assess deep-dose equivalent
- Standard TLD ring extremity dosimeters will generally provide accurate results for shallow-dose equivalent for extremities, but caution should be exercised in situations where the ring is not the closest body part to the source of radiation
- Monitoring period usually monthly for body badge, and often weekly for rings – emphasize timely return of badges at end of monitoring period

External Dosimetry

- If neutron monitoring is needed, then the CR39 track etch detector can be added to a standard OSL badge or use a combination of TLD 600 and TLD 700 chips and the appropriate algorithm for TLD badges – consult with dosimetry vendor



External Dosimetry

- Skin Contamination
 - Many of the SPECT and PET radionuclides can deliver a significant shallow dose in a short amount of time
 - Therapy radionuclides such as ^{131}I , ^{153}Sm , ^{90}Y are of particular concern
 - ^{18}F can also result in a significant skin dose



Skin Contamination

- 1 μCi of ^{131}I gives an initial SDE of 500 mrem/h averaged over 10 cm^2 area
- Assuming a 25% efficiency = ~500k cpm with a pancake

The screenshot shows the 'Varskin 3 Results' window. It displays the radionuclide 'I-131' with an activity of '1.00E+00 μCi '. Below this, there are two tables of dose rates and doses. The first table is for 'I-131' and the second is for 'All Radionuclides'. Both tables show 'Initial Dose Rate', 'Dose (No Decay)', and 'Decay-Corrected Dose' for Beta and Photon emissions, as well as a 'Total'. The values are consistent between the two tables. At the bottom, there are input fields for 'Date' (6/17/2010), 'Calculation Summary' (2-D Disk Source), 'Time' (10:16:00 AM), 'Source Diameter' (3.57E+00 cm), 'Cover Thickness' (0 mm), 'Air Gap Thickness' (0 mm), 'Skin Density Thickness' (7 mg/cm²), 'Irradiation Time' (60 min), and 'Irradiation Area' (10 cm²). There are also buttons for 'Print Results', 'Return to Geometry Screen', and 'Exit Program'.

	Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose
Beta	5.15E-01 rad/h	5.15E-01 rad	5.14E-01 rad
Photon	6.95E-03 rad/h	6.95E-03 rad	6.94E-03 rad
Total	5.22E-01 rad/h	5.22E-01 rad	5.21E-01 rad

	Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose
Beta	5.15E-01 rad/h	5.15E-01 rad	5.14E-01 rad
Photon	6.95E-03 rad/h	6.95E-03 rad	6.94E-03 rad
Total	5.22E-01 rad/h	5.22E-01 rad	5.21E-01 rad

Date: 6/17/2010 Calculation Summary: 2-D Disk Source Time: 10:16:00 AM
Source Diameter: 3.57E+00 cm
Cover Thickness: 0 mm
Air Gap Thickness: 0 mm Irradiation Time: 60 min
Skin Density Thickness: 7 mg/cm² Irradiation Area: 10 cm²
Print Results Return to Geometry Screen Exit Program

Skin Contamination

- 1 μCi of ^{153}Sm gives an initial SDE of 560 mrem/h averaged over 10 cm^2 area
- Assuming a 25% efficiency = ~500k cpm with a pancake

Varskin 3 Results

Help

Radionuclide: Activity
Sm-153: 1.00E+00 μCi

	Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose
Beta	5.58E-01 rad/h	5.58E-01 rad	5.54E-01 rad
Photon	7.81E-03 rad/h	7.81E-03 rad	7.75E-03 rad
Total	5.66E-01 rad/h	5.66E-01 rad	5.62E-01 rad

All Radionuclides

SI Units

	Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose
Beta	5.58E-01 rad/h	5.58E-01 rad	5.54E-01 rad
Photon	7.81E-03 rad/h	7.81E-03 rad	7.75E-03 rad
Total	5.66E-01 rad/h	5.66E-01 rad	5.62E-01 rad

Date: 6/17/2010 Calculation Summary: 2-D Disk Source Time: 10:17:33 AM

Source Diameter 3.57E+00 cm

Cover Thickness 0 mm

Air Gap Thickness 0 mm Irradiation Time 60 min

Skin Density Thickness 7 mg/cm^2 Irradiation Area 10 cm^2

Print Results Return to Geometry Screen Exit Program

Skin Contamination

- 1 μCi of $^{99\text{m}}\text{Tc}$ gives an initial SDE of 2 mrem/h averaged over 10 cm^2 area
- Assuming a 25% efficiency = ~500k cpm with a pancake

The screenshot shows the 'Varskin 3 Results' window. It displays the radionuclide 'Tc-99m' with an activity of 1.00E+00 μCi . The interface is divided into two main sections: 'Radionuclide: Activity' and 'All Radionuclides'. Both sections show dose rate calculations for Beta, Photon, and Total radiation types. The 'Initial Dose Rate' is 0.00E+00 rad/h for Beta and 2.49E-03 rad/h for Photon. The 'Dose (No Decay)' is 0.00E+00 rad for Beta and 2.49E-03 rad for Photon. The 'Decay-Corrected Dose' is 0.00E+00 rad for Beta and 2.35E-03 rad for Photon. The 'Total' dose rate is 2.49E-03 rad/h for Photon. The 'Date' is 6/17/2010, 'Calculation Summary' is 2-D Disk Source, and 'Time' is 10:18:32 AM. Other parameters include 'Source Diameter' (3.57E+00 cm), 'Cover Thickness' (0 mm), 'Air Gap Thickness' (0 mm), 'Skin Density Thickness' (7 mg/cm²), 'Irradiation Time' (60 min), and 'Irradiation Area' (10 cm²). Buttons for 'Print Results', 'Return to Geometry Screen', and 'Exit Program' are visible at the bottom.

Radionuclide: Activity			
	Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose
Beta	0.00E+00 rad/h	0.00E+00 rad	0.00E+00 rad
Photon	2.49E-03 rad/h	2.49E-03 rad	2.35E-03 rad
Total	2.49E-03 rad/h	2.49E-03 rad	2.35E-03 rad

All Radionuclides			
	Initial Dose Rate	Dose (No Decay)	Decay-Corrected Dose
Beta	0.00E+00 rad/h	0.00E+00 rad	0.00E+00 rad
Photon	2.49E-03 rad/h	2.49E-03 rad	2.35E-03 rad
Total	2.49E-03 rad/h	2.49E-03 rad	2.35E-03 rad

Date: 6/17/2010 Calculation Summary: 2-D Disk Source Time: 10:18:32 AM

Source Diameter: 3.57E+00 cm

Cover Thickness: 0 mm

Air Gap Thickness: 0 mm Irradiation Time: 60 min

Skin Density Thickness: 7 mg/cm² Irradiation Area: 10 cm²

Print Results Return to Geometry Screen Exit Program

- **Actual ^{18}F skin contamination**
- **Used Ludlum 44-9 pancake with 10% efficiency**


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 O R I S E
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Contact Exposure

- Extremely high exposures with unshielded ^{18}F
- Rule of Thumb
 - Contact exposure for ^{18}F = 23 Rad/Ci/Sec @ Contact
 - Exposure @ 1 cm for ^{18}F = 1.15 Rad/Ci/Sec
 - RDS-111/112 Targets (3.5Ci) = 115 Rad/Sec @ Contact
 - RDS-111 Eclipse (7Ci) = 161 Rad/Sec @ Contact
- Finger Tip Exposure vs. Ring Badge Results
- Do not touch unshielded source with bare hands (Avoid contact exposure)
- Use tongs or remote device to handle unshielded sources



Contact Exposure

- **Extremity Exposure**
 - On four occasions, a nuclear pharmacist reconnected lines leading to the MP1 trap while they contained high activity.
 - Left Ring – 72,810 mrem; Right Ring – 54,820 mrem (rings dated 8/26 – 9/01)
 - Left Ring – 11,390 mrem; Right Ring – 6870 mrem (rings dated 9/02 – 9/08)
 - Whole Body result for August badge: 2687 mrem.

Contact Exposure

- ^{18}F activity on the trap ranged from 2.9 to 7.8 Curies.
- Trap was held between thumb and index finger of left hand while thumb and index finger of right hand held the line.
- Biological Effects begin several days after the incident – pain in fingertips.
- Blisters appear 1 ½ weeks after incident.

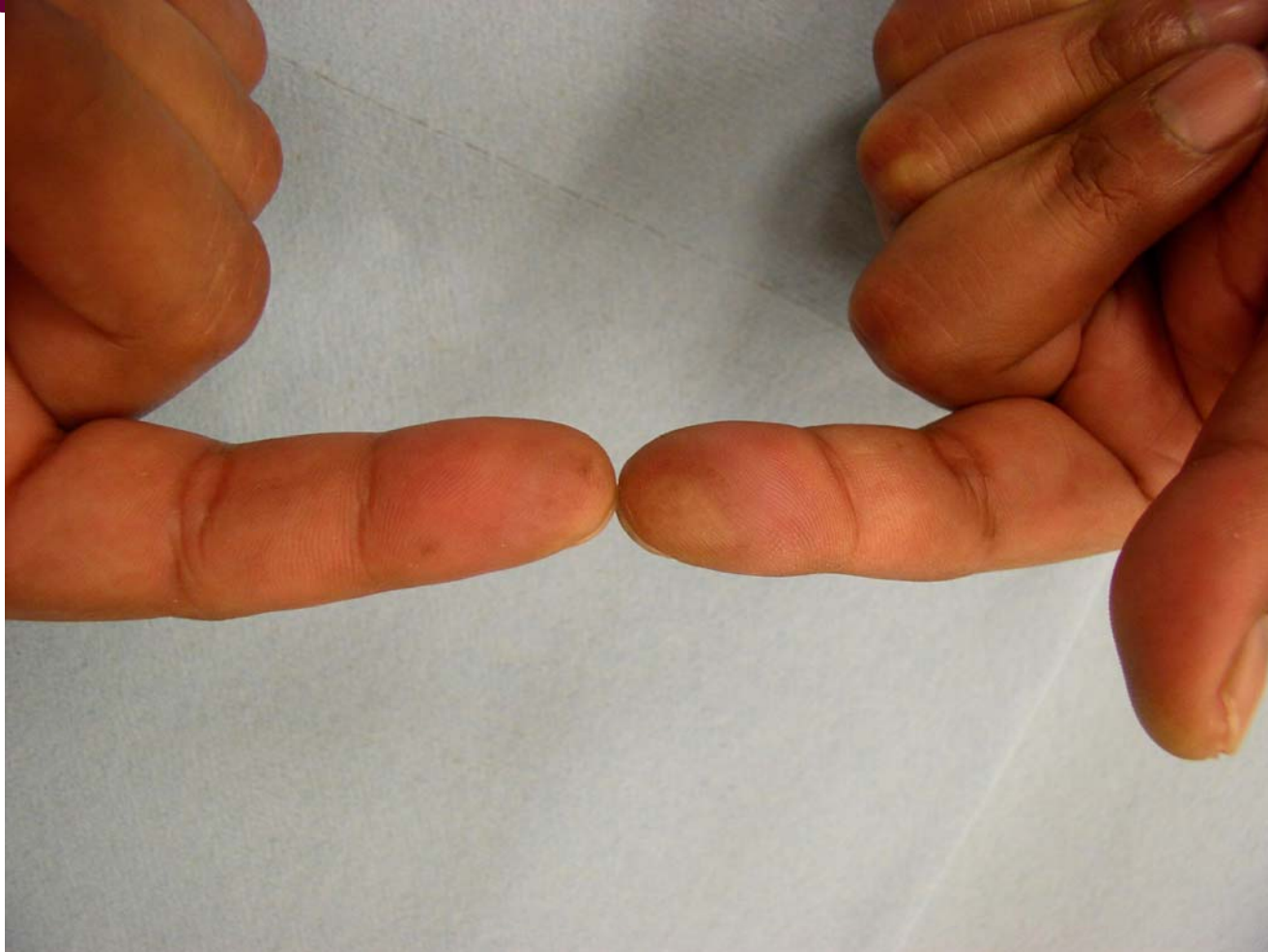
Contact Exposure

- Initial Dose Calculations for the fingertips range from 900 to 22,000 rads.
- Biological Effects (earlier incidence indicates higher dose)
- Dry desquamation begins at 1000 rads.
- Moist desquamation begins above 2000 rads.
- Necrosis begins above 3500 rads.
- Medical assistance was received from REACT/TS in Oak Ridge and from a physician in Houston. No long term effects are anticipated.

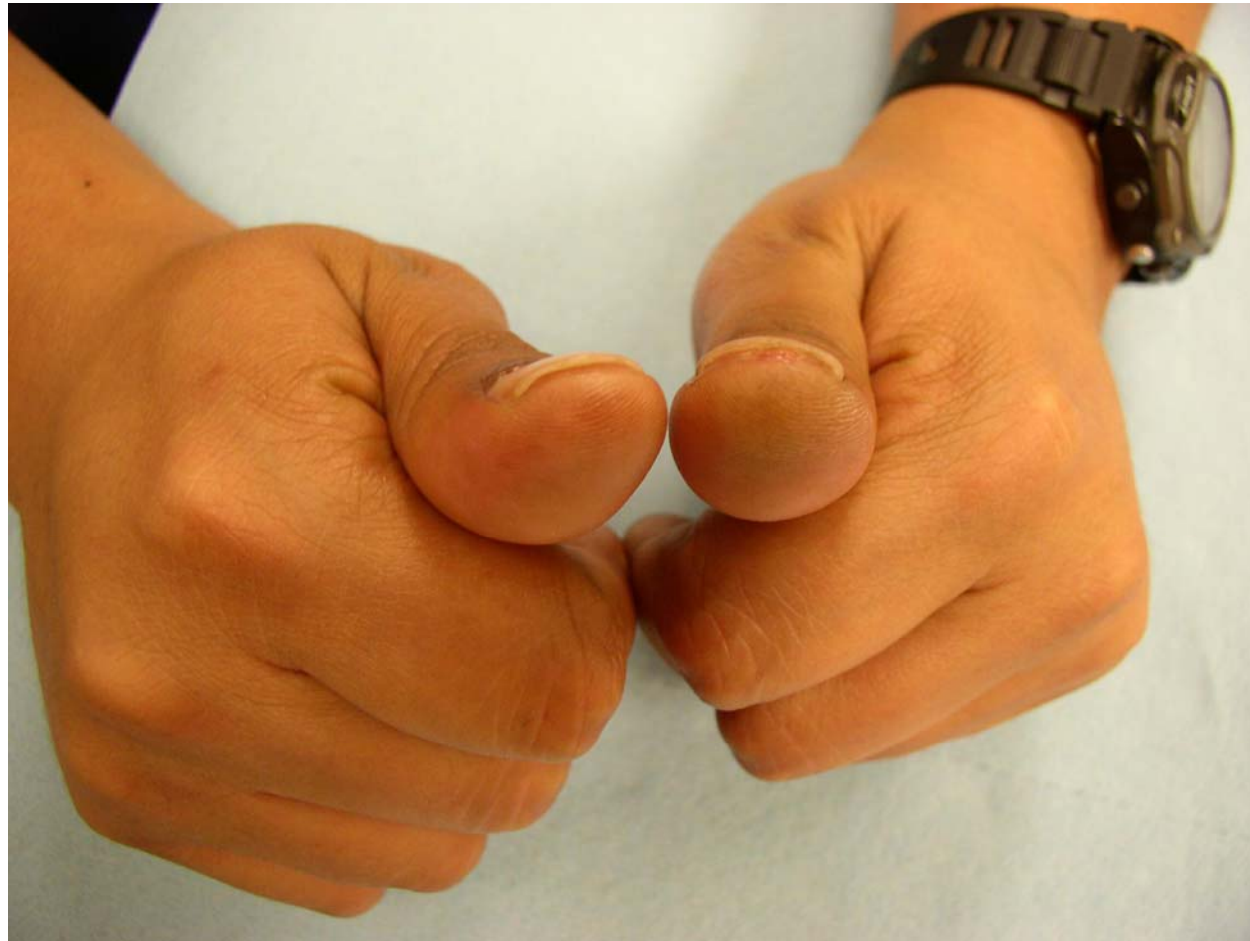
Contact Exposure

- Contacted REAC/TS
- Second estimate using ion chamber in contact with a similar geometry yielded 460 rads
- Third estimate 16,300 rads using a contact rule-of-thumb
- Irradiated area very small
- Blisters appeared first on left thumb and index finger, and then on right thumb and index finger
- Blisters on left hand larger than on right and consistent with individual holding source using left hand and manipulating connections with right

Pictures 15 days post exposure



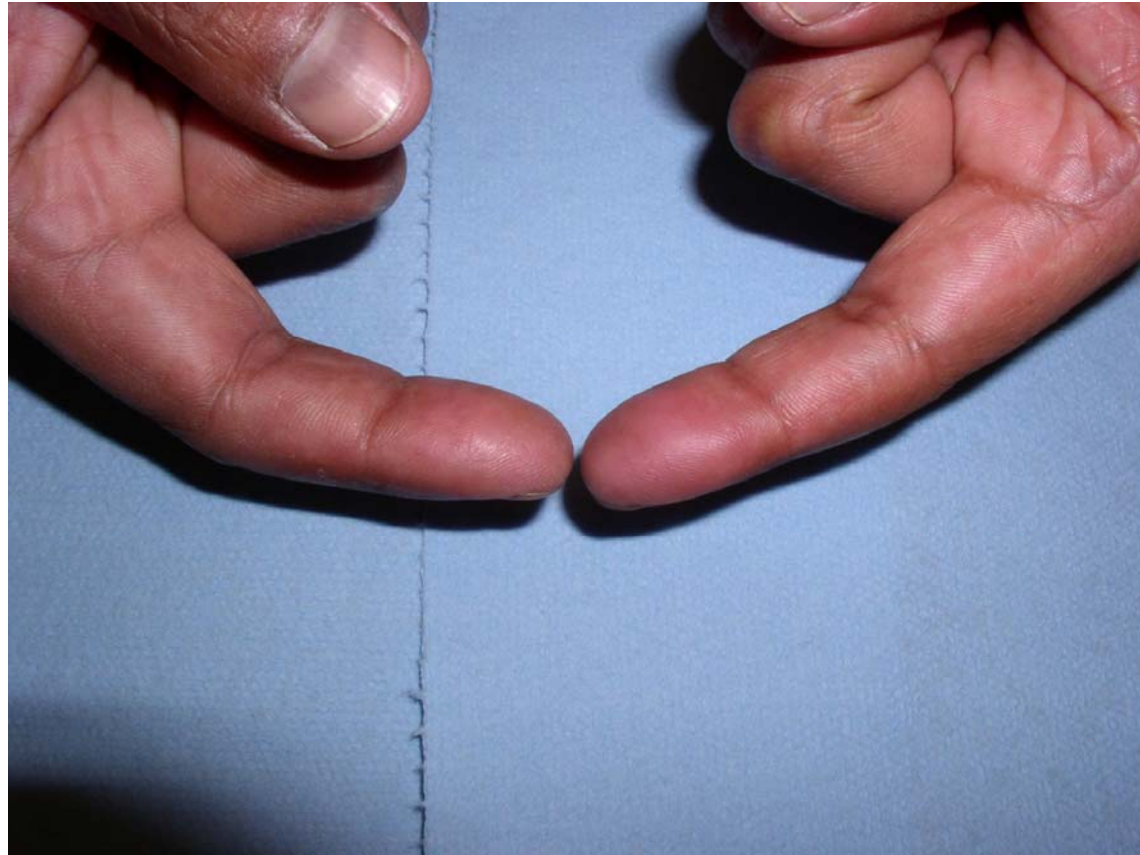
Pictures 15 days post exposure



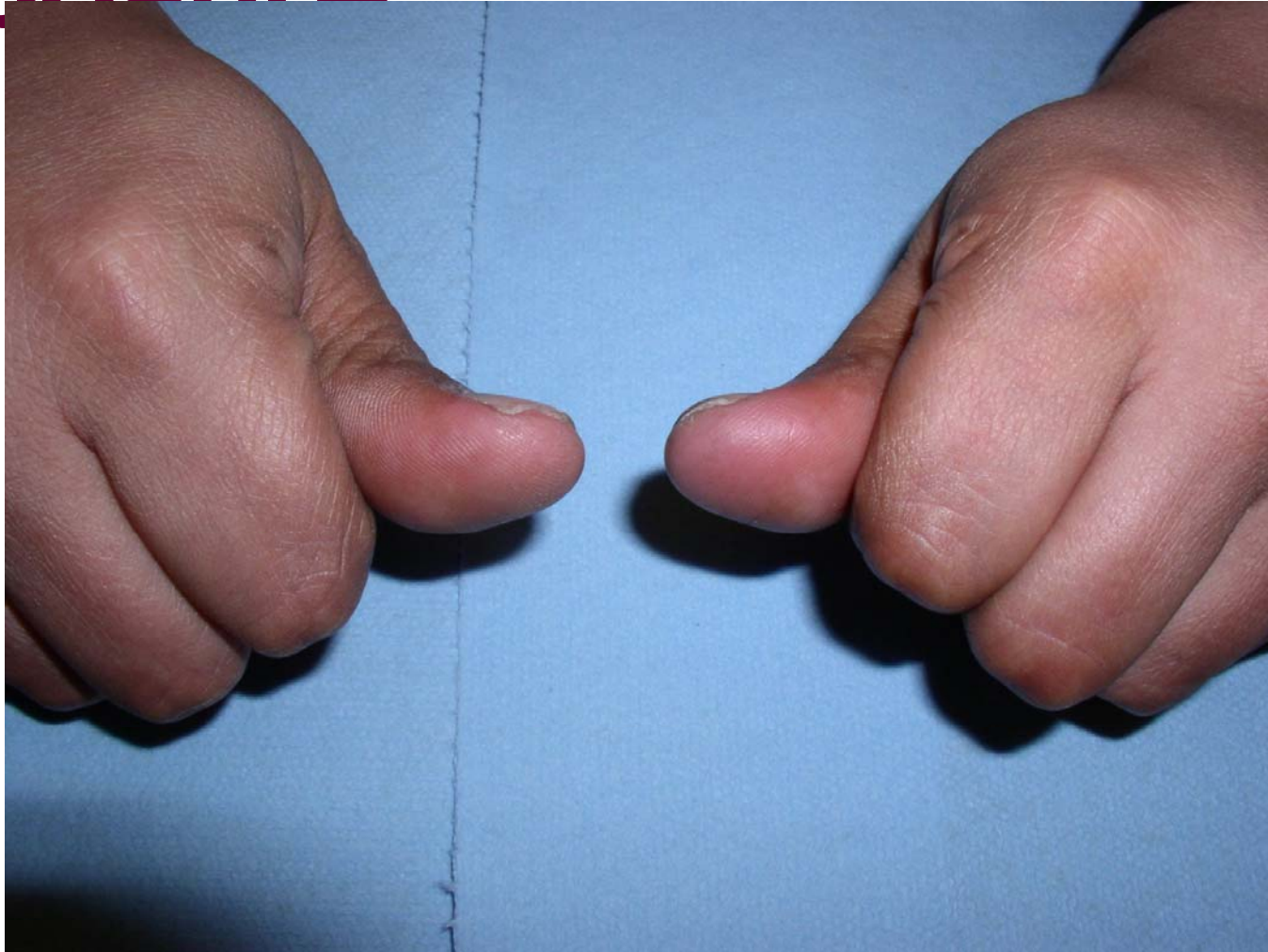
Pictures 20 days post exposure



Pictures 45 days post exposure



Pictures 45 days post exposure



Dose Calculations

- TLD Irradiation Experiment
- Rings attached to finger phantom on both sides
- Ratio of near-side to far-side 25:1 but wide variation.
- Average of 4.3 rad/s/Ci
- Total 3170 rads

Dose Calculations

Date	Contact time (s)	Source activity (Ci)	Dose rate (rad/s)	Dose (rad)
9/13/2002	30	2.92	12.56	377
9/16/2002 a	45	7.01	30.14	1356
9/16/2002 b	30	7.84	33.71	1011
9/17/2002	15	6.58	28.29	424



Internal Dosimetry

- ^{131}I bioassays are required for staff that compound custom capsules and oral therapy solutions
- Other radionuclides or situations on a case by case basis



¹³¹I Bioassay action levels

- **Action Level I—a quantity of Iodine I-131 which is > 2% of the Annual Limit on Intake (ALI) i.e., 1 microcurie inhaled, or 0.133 microcuries deposited in the thyroid gland**
- **Additional data, such as airborne measurements or additional bioassays should be performed to obtain the best estimate of actual intake**

¹³¹I Bioassay action levels

- **Action Level II—a quantity of Iodine I-131 which is > 10% of the ALI, i.e., 5 microcuries inhaled, or 0.665 microcurie deposited in the thyroid gland**
- **If the total of all thyroid uptake measurements for an individual during any one year exceeds 0.665 microcurie, the CDE (committed dose equivalent) for the thyroid and the CEDE (committed effective dose equivalent) must be calculated and added to the individual's NRC-Form 5**



TRANSPORTATION



Transportation

- **Many nuclear pharmacies use their own employees and others use contracted couriers**
 - **CAH delivers over 10 million doses per year**
 - **The fleet of vehicles logged over 45 million miles in 2003**
 - **Training**
 - **Commercial Drivers License requirements**
 - **Accidents**
- **Pharmacy Management software can include modules for printing shipping papers, be sure correct options are chosen**



Transportation

- Type A containers are provided by several vendors, or else developed internally to meet specific needs
- Test certificates must be kept on-hand for each package configuration in use
- Differences in package requirements for air transport or containing liquids



Transportation

- **Package Markings & Labeling**
 - Proper shipping name
 - Identification number
 - Package Type-"Type A" or "Type B"
 - Mass of package if > 110 lbs
 - Arrows if liquid



Transportation

• <u>Proper Shipping Name</u>	<u>ID No.</u>
• Radioactive Material, Type A package	UN2915
• Radioactive Material, excepted package empty packaging	UN2908
• Radioactive Material, excepted package low specific activity LSA	UN2912
• Radioactive Material, excepted package limited quantity of material	UN2910
• Instruments and Articles	UN2911



DOT LABELS - Type A

- White I ≤ 0.5 mR/hr @ Surface
0 @ 1 meter
- Yellow II ≤ 50 mR/hr @ Surface
 ≤ 1.0 @ 1 meter
- Yellow III ≤ 200 mR/hr @ Surface
 ≤ 10 @ 1 meter



DOT LABELS - Type A

- Must use two labels on opposite sides of package
- Do not overlap labels or bend around corners
- Radioactive Yellows must include Transport Index
 - T.I. = dose rate at 1 meter, rounded to 1st decimal place, e.g. 0.3



DOT Labels

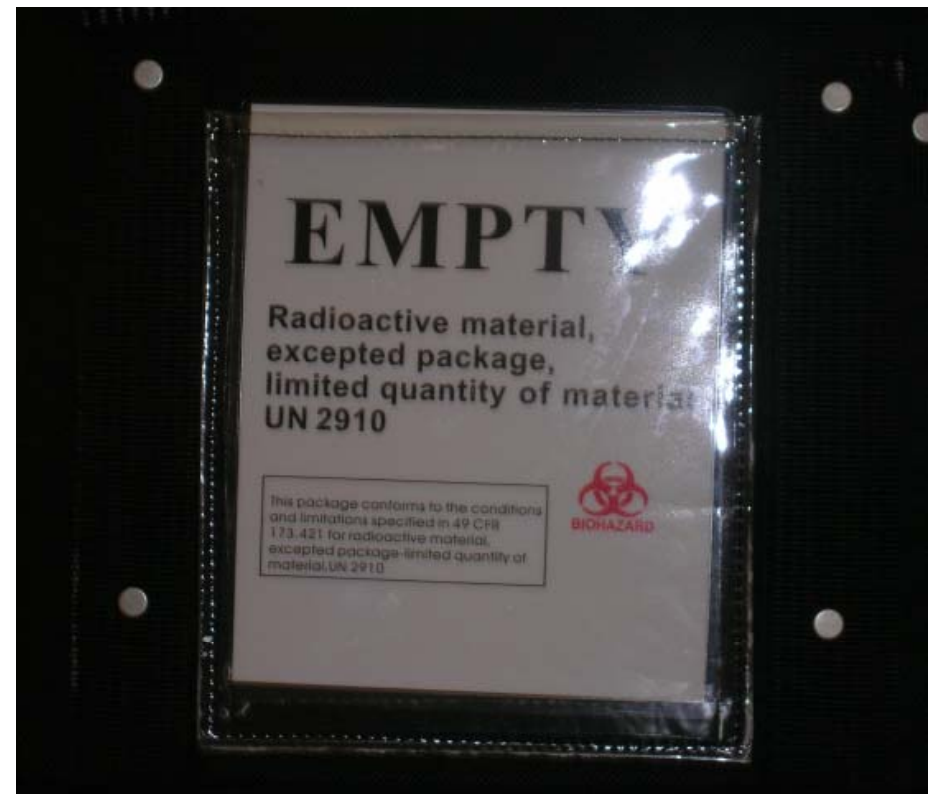
Front

For Packages delivered to customers



Back

For Limited Quantity Packages returned by customers



SHIPPING PAPERS

Ground Mode: Bill of Lading (BOL)

Air Mode: Declaration of Dangerous Goods



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SHIPPING PAPERS

(Ground Mode)

- Proper shipping name
- Hazard class
- Identification number
- Quantity (i.e., Activity amount)
- Radionuclide(s)- element and mass number
- Form - Physical and chemical forms
- Activity in Bq, MBq, GBq or TBq
- Warning label used (none, white I, yellow II or III)
- Transport Index if applicable
- Package Identification- Type A or Type B
- 24 hour emergency phone number



SHIPPER'S CERTIFICATION

Shipping papers must include signed certification:

“This is to certify that the above-named materials are properly classified, described, packaged, marked, and labeled, and are in proper condition for transportation according to the applicable regulations of the Department of Transportation.”



SHIPPING PAPERS

(Ground Mode)

My Pharmacy - Hospital
Nuclear Medicine
Somewhere, New Jersey
Shipper's Report

Printed: 07-06-2006 16:14

(Case: 1)

Run:1

Shipping Date/Time: 06-28-2006 05:00

Shipper: My Pharmacy - Hospital
Nuclear Medicine
1234 Main Street
Somewhere, New Jersey 00000
EMERGENCY CONTACT #: 1-888-88899999
TEST SHIPPER COMMENT

Ship To: My Hospital
Nuclear Medicine Department
100 Main Street
Somewhere

BILL OF LADING

Radioactive Material, Type A package, 7, UN 2915
USA DOT 7A TYPE A

RX. #	HM	Radio Nuclide	Chemical Form	Phys. Form	Cal. Date Time	Cal. Activity	Volume or Quantity	Activity at Time of shipment
128885		Tc99m MDP	Medronate	Liq.	06-28-06 12:00	25.000 mCi	0.396 ml	55.973 mCi

Total Rxs: 1

Total Activity:

2.071 GBq (55.973 mCi)

Label Required: ☐ Radioactive (White I) ☐ Radioactive (Yellow II) ☐ Radioactive (Yellow III)



Trans. Index at 1 Meter

Survey Meter ID

mR/hr 1 Meter Reading

Background

IM Survey Meter Id

SIGNATURE

CARRIER: _____ DATE: _____ TIME: _____

CONSIGNEE: _____ DATE: _____ TIME: _____

_____ DPM WIPE

_____ LIMIT

_____ INITIAL



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SHIPPING BY AIR

- May not transport on passenger plane if T.I. exceeds 3.0
- May transport on passenger plane only if material is to be used for research or medical procedures
- A label of “CARGO AIRCRAFT ONLY” must be on package if only authorized on cargo aircraft



SHIPPING BY AIR



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SHIPPER'S CERTIFICATION - Air

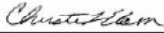
Shipping papers must include signed certification:

"I hereby certify that the contents of this consignment are fully and accurately described above by proper shipping name, and are classified, packed, marked, and labeled, and in proper condition for carriage by air according to applicable national government regulations. I declare that all the applicable air transport requirements have been met"

"This shipment is within the limitations for passenger carrying / cargo aircraft only." (delete non-applicable)



SHIPPER'S DECLARATION FOR DANGEROUS GOODS

Shipper PETNET Solutions, Inc. 810 Innovation Drive Knoxville, TN 37932 865-218-2235		Air Waybill No. AF330-071105 Page 1 of 1 Pages Shipper's Reference Number				
Consignee PETNET Solutions, Inc. Albany 14 Walker Way Albany, NY 12205 518-452-5403						
Two completed and signed copies of this Declaration must be handed to the operator		WARNING Failure to comply in all respects with the applicable Dangerous Goods Regulations may be in breach of the applicable law, subject to legal penalties.				
TRANSPORT DETAILS This shipment is within the limitations prescribed for: (delete non applicable) <table border="1"><tr><td>PASSENGER AND CARGO AIRCRAFT</td><td>☒</td></tr></table>		PASSENGER AND CARGO AIRCRAFT	☒	Airport of Departure TYS Airport of Destination: ALB		
PASSENGER AND CARGO AIRCRAFT	☒					
Shipment type: (delete non-applicable) ☒ RADIOACTIVE						
NATURE AND QUANTITY OF DANGEROUS GOODS						
Dangerous Goods Identification						
UN or ID No.	Proper Shipping Name	Class or Division (Subsidiary Risk)	Packing Group	Quantity and type of packaging	Packing Inst.	Authorization
UN2915	Radioactive Material, TYPE A Package	7		F-18 Liquid Fluorodeoxyglucose One Type A Package x 0.8 GBq	II-Yellow II=0.7 DEM 34x25x19cm	
Additional Handling Information						
Emergency Telephone Number 865-218-2235						
I hereby declare that the contents of this consignment are fully and accurately described above by the proper shipping name, and are classified, packaged, marked and labelled/placarded, and are in all respects in proper condition for transport according to applicable International and National Governmental Regulations. I declare that all of the applicable air transport requirements have been met.				Name/Title of Signatory Christi Elam / Health Physicist Place and Date Knoxville, TN 11/07/2006 Signature (see warning above) 		
FOR RADIOACTIVE MATERIAL SHIPMENT ACCEPTABLE FOR PASSENGER AIRCRAFT, THE SHIPMENT CONTAINS RADIOACTIVE MATERIAL INTENDED FOR USE IN OR INCIDENT TO RESEARCH, MEDICAL DIAGNOSIS, OR TREATMENT.						

Nov 2006 Rev 00



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Loading and Unloading of Packages

- **Vehicles**
 - **Blocking & Bracing: Racks with bungee cords**
 - **Passenger seat: Clip board**
 - **Emergency response sheet**
 - **Bill of Lading (shipping paper)**
 - **MSDS for each product**
 - **Spill kit**
 - **Vehicle lock**
- **BOL: Receipt/ Acknowledgement**
- **Return Packages**
- **Security reminders by DOT**



Blocking & Bracing



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Blocking & Bracing



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Vehicle Locking



Lock vehicle when unattended and
during transportation



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Shipping Papers: Clipboard



Clipboard- Front passenger seat-for HAZMAT Responders

Top: (underclip)

-Emergency Response- Single sheet (Tape it)

-BOL(s): removable

Placards/Registration

- Placards: Transportation vehicle only
- For RAM transportation Vehicle PLACARDING only if carrying Yellow III Package(s)
- DOT registration: Shippers and carriers Yellow III transportation only
- Additional requirements for drivers



Return packages – EMPTY Labeling

- **Previously contained Class 7 RAM and now empty**
- **Do not need shipping papers or certifications**
- **Provided**
 - **Industrial Packaging Type I - no leakage**
 - **Surface dose rate less than or equal 0.5 mR/hr**
 - **Surface contamination < Limits**
 - **Internal contamination limited to 100 x outer limits**
 - **Previous labels removed, obliterated, or covered with “Empty” label**
 - **UN number marked on package - UN2910**



DOT- Security Rules

- **Shippers and carriers of certain highly hazardous materials must develop and implement security plans. In addition, all shippers and carriers of hazardous materials must assure that their employee training includes a security component.**
 - **Personnel Security: Report Problems, communications, inspections**
 - **Facility Security: Access, locks, unauthorized visitors**
 - **Transportation Security: Driver identity, unauthorized or altered routes, change of vehicles**



DOT Reporting Requirements

- 49 CFR 171.15 contains immediate reporting requirements to the National Response Center for incidents involving Hazardous Materials Shipments, as well the content of the report
 - Fatality
 - Injury requiring hospitalization
 - Evacuation > 1h
 - Major transportation artery closed > 1h
 - Operational flight patterns or routine aircraft movement altered



DOT Reporting Requirements

- Fire, breakage, spillage or suspected radioactive contamination occurs (also 176.48)
- Any other situation involving hazardous materials shipments that creates a continuing danger to life and the person possessing the hazmat determines a report should be made
- EPA reporting requirement is a release is greater than the Reportable Quantity (RQ – will be noted on shipping papers if present)
- A written report is also required per 171.16



Transportation Recap

- **Type A Package certifications available for each type of package in use**
- **Marking & Labeling correct on package**
- **Shipping papers filled out correctly for mode of transportation**
- **Packages blocked & braced, spill procedures and placement of shipping papers in vehicle**
- **Security in transport**
- **Reporting Requirements for incidents**

