Calibration of the Accuscan II IN Vivo System for High Energy Lung Counting

O. R. Perry

July 2011

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July 2011

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<http://www.inl.gov>

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Health Physics Dosimetry Laboratory

Calibration of the Accuscan II IN Vivo System for High
Energy Lung Counting

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Approved by:

Orval R. Perry

Date

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Date

ABSTRACT

This report describes the April 2011 calibration of the Accuscan II HpGe In Vivo system for high energy lung counting. The source used for the calibration was a NIST traceable lung set manufactured at the University of Cincinnati #UCLL43AMEU & UCLL43AMEU containing Am-241 and Eu-152 with energies from 26 keV to 1408 keV. The lung set was used in conjunction with a Realistic Torso phantom. The phantom was placed on the RMC II counting table (with pins removed) between the v-ridges on the backwall of the Accuscan II counter. The top of the detector housing was positioned perpendicular to the junction of the phantom clavicle with the sternum. This position places the approximate center line of the detector housing with the center of the lungs. The energy and efficiency calibrations were performed using a Realistic Torso phantom (Appendix I) and the University of Cincinnati lung set. This report includes an overview introduction and records for the energy/FWHM and efficiency calibration including performance verification and validation counting. The Accuscan II system was successfully calibrated for high energy lung counting and verified in accordance with ANSI/HPS N13.30-1996 criteria.

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ACRONYMS

<i>ANSI.</i>	American National Standard Institute
<i>ASF.</i>	Analysis Sequence File
<i>BE.</i>	Broad Energy
<i>CFA</i>	Central Facility Area
<i>CPS.</i>	Counts per second
<i>FWHM.</i>	Full Width at Half Maximum
<i>HPGe.</i>	High Purity Germanium –also HPGe
<i>HPL.</i>	Health Physics Laboratory
<i>HPS.</i>	Health Physics Society
<i>INL.</i>	Idaho National Laboratory
<i>MDA.</i>	Minimum Detectable Activity
<i>NIST.</i>	National Institute of Standards and Testing
<i>PC.</i>	Personal Computer
<i>PMC.</i>	Radiation Management Corporation
<i>WBC</i>	Whole Body Counting

Calibration of the Accuscan II IN Vivo System for High Energy Lung Counting

1. INTRODUCTION

This document describes the April 2011 calibration of the Accuscan II in vivo system for high energy lung counting. The new calibration files were stored on the system disk and made available for high energy (HE) lung counting after all verification counts were completed. This is the initial calibration of the Accuscan II for personnel HE lung counting.

The energy/FWHM-Low Tail calibration was performed on April 5, 2011 and is documented in Appendix C. A University of Cincinnati manufactured (NIST traceable) lung set containing Am-241 and Eu-152 was used together with a Realistic Torso phantom to perform the calibration. This source (UCLL43AMEU and UCL43AMEU) is NIST traceable and is documented in Appendix A. The source has a reference date of June 24, 1996 with the current activity documented in Appendix B. The Realistic Torso phantom was used for both the energy and efficiency calibrations. The lung set was positioned in the Realistic Torso phantom and counted for 7228 seconds for the energy calibration and 7226 seconds for the efficiency calibration with the top of the detector housing position perpendicular to the junction of the phantom clavicle with the sternum.

An efficiency calibration was performed subsequent to the energy/FWHM calibration on April 5, 2011 and is documented in Appendix D. To calibrate this counting geometry, a mathematical function relating efficiency versus photopeak energy was created. The mathematical efficiency function generated on April 5, 2011 is expressed as a Dual fit using a 5th order polynomial with no cross over. The efficiency is determined empirically by measuring known standards and using least squares fitting techniques. The efficiency function is stored as a calibration file, which is used to analyze spectra, collected under the same counting conditions.

Replicate performance (verification) counts (using the new calibration files) were performed to confirm that the accuracy and precision of the calibration satisfied ANSI/HPS N13.30-1996 (see Reference 1) performance criteria and are documented in Appendix E.

In addition to the performance tests, a set of 5 validation counts were performed using a DOE manufactured NIST traceable Lung Set # MFP-1-001. The validation counts Relative Bias and Relative Precision were tested to ANSI/HPS N13.30-1996 criteria. The results are documented in Appendix H.

2. COUNTING SYSTEM DESCRIPTION

The Accuscan II system contains two broad energy BE type HpGe detectors used for both low and high energy photon counting. This would include Whole Body, High Energy Lung, Thyroid, and Low Energy Lung (although at this time the system is not calibrated for energies <26 keV). The Canberra Apex-InVivo software system, supported by Genie 2000 Spectroscopy software, operates on a Dell Optiplex 780 PC. The counter system is located in a 9'4" high $\times$ 8'71/2" wide $\times$ 11'5" deep counting vault constructed of concrete and masonry blocks. The counting system is standup with the detectors scanning from head to foot for whole body counting. For Lung and Thyroid counting the detectors are stationary at fixed counting positions. Personnel are positioned in a counting shield (tub) constructed of 4" of low background steel and face the detectors which are "shadow shielded" with both lead and copper. The counting vault is located on the INL site at HPL-1618. The detectors are cooled to -185°C by an electrically refrigerated cryostat system.

3. CALIBRATION SOURCES AND PHANTOMS

A NIST traceable lung set manufactured by the University of Cincinnati # UCLL43AMEU & UCL43AMEU was used for both the energy and efficiency calibrations. The lung set contains uniformly distributed Am-241 and Eu-152 and is described in Appendix A. The source activity was decayed to the efficiency calibration date of April 5, 2011 by the Apex-InVivo software. The Apex-InVivo software also decayed the source for verification testing and displayed the results in gammas per second.

A Realistic Torso Phantom was used with the University of Cincinnati lung set to perform both the energy and efficiency calibrations. The phantom is described in Appendix I.

Validation counting of the calibration was performed using a NIST traceable DOE manufactured lung set # MFP-1-001 containing Co-57, Co-60, CS-134 and Cs-137. This source certificate is documented in Appendix A. The source was decayed to the validation count date and is documented in Appendix B.

4. DETECTOR AND LYNX DIGITAL AMPLIFIER TESTING

A Pole Zero was performed in accordance with MCP-3336 for both detectors during the I-131 calibration of March 1, 2011. No pole zero was performed for this calibration.

5. ENERGY/FWHM CALIBRATION

On April 4, 2011 the CWI Realistic Torso Phantom was used together with the lung set #UCLL43AMEU and UCLL43AMEU to obtain a calibration count to be used for the High Energy Lung (energy) calibration. The RMC-II counting stand and table were mounted in the Accuscan II counter with the pins removed. The Realistic phantom was placed on the table with the shoulder of the phantom between the v-ridges on the counter rearwall. The phantom chest plate was removed for the energy calibration. The Accuscan II detector housing was positioned such that the top of the detector housing was perpendicular to the junction of the phantom clavicle and sternum. This placed the center of the housing at the approximate midpoint of the phantom lungs. The calibration count was collected for 7228 seconds real time (2 hours).

The energy calibration was performed on April 5, 2011 for both the left, right and summed detectors. The energy calibration is documented in Appendix C.

6. EFFICIENCY CALIBRATION

Subsequent to the High Energy Lung (energy) calibration, a calibration count was collected for the efficiency calibration. The CWI Realistic Torso Phantom was used together with the lung set #UCLL43AMEU and UCSL43AMEU to obtain the calibration count. The RMC-II counting stand and table were mounted in the Accuscan II counter with the pins removed. The Realistic phantom was placed on the table with the shoulder of the phantom between the v-ridges on the counter rearwall. The phantom chest plate was reinstalled and the detector housing aligned such that the top of the housing was positioned perpendicular to the junction of the phantom clavicle and sternum. This placed the center of the housing at the approximate midpoint of the phantom lungs. The calibration count was collected for 7226.91 seconds real time (2 hours).

The efficiency calibration was performed on April 5, 2011 at 4:05 PM for the summed detector. The efficiency calibration is documented in Appendix D.

7. CALIBRATION COUNT REANALYSIS

The calibration count collected 4/5/2011 at 2:02 PM was reanalyzed using the new energy and efficiency calibration dated 4/5/2011 8:18 AM and 4/5/2011 4:05 PM respectively. The results of the reanalysis indicated a Relative bias within 0.06 to -0.03 with an average bias of 0.012. This result is well within the bias criteria of ANSI/HPS N13.30-1996. The results also indicated an excellent calibration. The summary result and supporting documentation is attached as Appendix E.

8. PERFORMANCE (VERIFICATION) TESTING

Verification testing was conducted subsequent to the High Energy Lung efficiency calibration and was performed using the CWI Realistic Torso Phantom together with the lung set #UCLL43AMEU and UCL43AMEU to obtain a set (5) of verification counts. The RMC-II counting stand and Table were mounted in the Accuscan II counter with the pins removed. The Realistic phantom was placed on the table with the shoulder of the phantom between the v-ridges on the counter rearwall. The phantom chest plate was installed. The Accuscan II detector housing was positioned such that the top of the detector housing was perpendicular to the junction of the phantom clavicle and sternum. This placed the center of the housing at the approximate midpoint of the phantom lungs. The verification counts were collected for 600 seconds real time (10 minutes). The Apex software verification provision was used to collect the 5 counts on 4/6/2011. The Lung Set contained the radionuclides Am-241 and Eu-152. The result of the verification testing is summarized in Appendix F and indicates a Relative Bias between +5.14% and -14.80% (1086 keV peak of Eu-152). The average Relative Bias was 4.23%. The Relative Precision indicated 1.03% to 24.56% (444 keV peak of Eu-152) with an average Relative Precision of 9.45%.

9. MDA CALCULATIONS

MDA testing was conducted on April 6, 2011. The Realistic Torso phantom was counted three times with a blank (no activity) set of lungs installed. The counts were performed using the ROUNPPGE.ASF file which contained the Detection Limit – Curie MDA equation $(4.65 * S_b + 3) / KT$. The INLPLANTLIB.NLB library was installed which contains the radionuclides of interest at the INL. The MDA summary and supporting documentation are attached as Appendix G.

10. VALIDATION TESTING

High Energy Lung validation testing was conducted on 4/5/2011 and 4/6/2011 using the DOE Lung set # MFP-1-001 and CWI Realistic Torso phantom. The RMC-II counting stand and Table were mounted in the Accuscan II counter with the pins removed. The Realistic phantom was placed on the table with the shoulder of the phantom between the v-ridges on the counter rearwall. The phantom chest plate was installed and the detector housing aligned such that the top of the housing was positioned perpendicular to the junction of the phantom clavicle and sternum. This placed the center of the housing at the approximate midpoint of the phantom lungs. The validation counts were collected for the normal chest counting time of 10 minutes. The MFP-1-001 phantom contained the radionuclides Co-57, Co-60, Cs-134 and Cs-137. The lung set also contained Mn-54; however, the activity was well below minimum testing detection levels. The results of the validation testing is summarized in Appendix H with a Relative Bias of 0.3% to -3.6% and a Relative Precision of 1.1% to 18%. Testing results are within the acceptance criteria of ANSI/HPS N13.30-1996.

11. SUMMARY AND CONCLUSION

Final review of all calibration and verification count results confirmed that the high energy lung calibration created on April 5, 2011 for the Accuscan II counter is satisfactory for counting high energy photons when the detectors are positioned in-accordance-with Reference 2 (top of the detector housing is perpendicular to the junction of the individual's clavicle and sternum) – TEV-1273 - Basis for Positioning of the In Vivo Accuscan II Detectors. A summary of current calibration files for this counter geometry is shown in Table 1.

The INLPLANTLIB.NLB nuclide library file is the default for high energy lung counting. Non-systematic and systematic errors for the in vivo system are described and quantified in Reference 3 - TEV-1275 (INL In Vivo System Counting Uncertainty).

The overall percent (%) counting uncertainty using the Accuscan II for high energy lung counting is:

$$\text{Total \% Uncertainty (Accuscan II) for High Energy Lung} = \sqrt{(\% \text{counting uncertainty})^2 + (6.7)^2 + (18.0)^2}$$

Table 1. Calibration summary table.

Facility:	Idaho National Laboratory, Building HPDL CFA-1618	
Counting System:	Accuscan II High Energy Lung Stationary Position	
Counter Arrangement:	Accuscan II for High Energy Lung	
Detector	Energy Calibration Date	Time
Accuscan II BE Detectors	04/05/2011	8:18 AM
Efficiency Calibration:		
Detector	Energy Calibration Date	Time
Accuscan II BE Detectors	04/05/2011	4:05 PM

12. REFERENCES

1. American National Standard, American National Standards Institute/Health Physics Society ANSI/HPS N13.30-1996, "Performance Criteria for Radiobioassay," 1996.
2. Idaho National Laboratory, Basis Document TEV-1273, "Basis for Positioning of the In Vivo Accuscan II Detectors," 2011.
3. Idaho National Laboratory, Basis Document TEV-1275, "INL In Vivo System Counting Uncertainty," 2011.

Appendix A

Source Certificate

Appendix A Source Certificate

UCLL43AMEU & UCSL43AMEU

University of Cincinnati

3 June, 1996

Mr. Patrick Rielly
U. S. Department of Energy
Lockheed Idaho Technologies Co.
Idaho National Engineering Lab
CF-690
Scoville, Idaho 83415

Dear Mr. Rielly,

Department of Mechanical, Industrial
and Nuclear Engineering

Center for Radiological Assessment
and Measurement
University of Cincinnati
PO Box 210072
Cincinnati OH 45221-0072

Phone (513) 556-2003
Lab (513) 556-2052
Fax (513) 556-3390
Email hspitz@uceng.uc.edu

Calibration Certificates for Calibration Phantom Lungs PO# C96-540439

Enclosed please find the calibration certificates for the phantom lungs UCLL43AMEU and UCSL43AMEU containing ^{241}Am and ^{152}Eu . There are four sets of certificates: Each lung phantom has one certificate for ^{241}Am and one for ^{152}Eu . The final certified value of activity content is given on the third page of each certificate in the blocks labeled *corrected activity of lung* and *error in corrected activity of lung*. The correction is associated with the change in mass during foaming as a result of the loss of CO_2 . The parameters adopted for lung density, volume, and attenuation coefficient are the same as those used for the original Livermore National Laboratory lung phantoms and cited in ICRU publication #44.

The sum of activity contained in the large and small lung phantoms combined is $1,247.53 \text{ nCi} \pm 10.91 \text{ nCi}$ ^{241}Am and $543.05 \text{ nCi} \pm 1.45 \text{ nCi}$ ^{152}Eu . The total propagated uncertainty reported for the lung phantom represents 1 standard deviation and amounts to approximately 1% to 2% of the total activity. Factors for radioactive decay were obtained from *Table of Isotopes* by Browne, Firestone, Shirley (1986). Copies of the certificates for the original radioactive materials used in construction of the phantom have also been included to demonstrate traceability of these solutions to the National Institute for Standards and Technology.

The materials used to fabricate these lung phantoms exactly duplicate the original materials used in the construction of the Livermore National Laboratory phantom lungs, including the epoxy coating used on the surface of the lung phantoms. This epoxy resin coating requires a long time to become fully cured and hard. Curing is enhanced by removing the lung phantoms from the plastic bags used in shipping and allowing the phantoms to be open to the air. It is possible that this coating will become damaged with use and can easily be reapplied at any time in the future.

If you have any questions regarding the calibration phantom lungs or the calibration documentation, please do not hesitate to contact me.

Very truly yours,

Henry B. Spitz, Ph. D.
Associate Professor of Nuclear Engineering
Health Physics Program Director

encl: Certificates

National Bureau of Standards

Certificate

THIS IS A PHOTOCOPY OF THE CERTIFICATE
WHICH IS BEING MAILED TO YOU UNDER
SEPARATE COVER.

Standard Reference Material 4370C

Received
5/11/95

Radioactivity Solution Standard

Radionuclide	Europium-152
Source identification	4370C
Source description	Liquid in 5-ml. flame-sealed glass ampoule (1) ^a
Source mass	5.0338 ± 0.0019 grams (2)
Solution composition	277 µg Eu per gram of 1 M HCl
Radioactivity concentration	9.390 × 10 ⁴ Bq g ⁻¹
Reference time	1200 EST February 2, 1987
Overall uncertainty	1.1 percent (3)
Photon-emitting impurities (activity ratio at reference time)	¹⁵⁴ Eu/ ¹⁵² Eu: (2.9±0.3)×10 ⁻³ (4)
Half life	13.55 ± 0.06 years (5)
Measuring instrument	4π pressurized ionization-chamber "A" previously standardized by 4π counting with the NBS 8"x8" NaI(Tl) crystals

This Standard Reference Material was prepared in the Center for Radiation Research, Ionizing Radiation Division, Radioactivity Group, Dale D. Hoppes, Group Leader.

Gaithersburg, MD 20899
March, 1987

Stanley D. Raspberry, Chief
Office of Standard Reference Materials

^aNotes on back

NOTES

- (1) Approximately five milliliters of solution. Ampoule specifications:

body diameter	16.5 ± 0.5 mm
wall thickness	0.60 ± 0.04 mm
barium content	less than 2.5 percent
lead oxide content	less than 0.02 percent
other heavy elements	trace quantities

- (2) The standard deviation is 0.0019 grams based on mass measurements of 15 ampoules.

- (3) The overall uncertainty was formed by taking three times the quadratic combination of standard deviations of the mean, or approximations thereof, for the following:

a) 1987 ionization-chamber measurements on 17 sources	0.02 percent
b) original ionization-chamber calibration using 7 sources	0.08 percent
c) ratio of radium reference sources	0.05 percent
d) solution attenuation of γ -rays	0.10 percent
e) gravimetric measurements	0.15 percent
f) impurities	0.10 percent
g) decay correction	0.02 percent
h) NaI(Tl) measurements on 6 sources	0.02 percent
i) NaI(Tl) detector efficiency	0.27 percent
j) fluorescence yield	0.10 percent
Combined	0.37 percent
	<u>x 3</u>
Overall	1.1 percent

- (4) The limit of detection, expressed as a percentage of the gamma-ray-emission rate of the 1408-keV gamma rays emitted in the decay of europium-152, is

0.1 percent between 90 and 1900 keV.

provided that the impurity photons are separated in energy by 5 keV or more from photons emitted in the decay of europium-152 and europium-154.

- (5) NBS-measured half-life value. NCRP Report No. 58, 2nd edition, 1985, p. 464 lists a value of 13.4 ± 0.1 years.

For further information please contact Ms. J.M. Calhoun at (301) 975-5538 or Dr. Bert N. Coursey at (301) 975-5539.

4370C

CERTIFICATE OF CALIBRATION ALPHA STANDARD SOLUTION

Radionuclide	Am-241	Customer:	UNIVERSITY OF CINCINNATI
Half Life:	432.32 ± 0.66 years	P.O.No.:	PC96M-04887
Catalog No.:	7241-100U	Reference Date:	15 April 1996 12:00 PST.
Source No.:	519-87-1	Contained Radioactivity:	95.11 µCi
		Contained Radioactivity:	3519 kBq

Description of Solution

a. Mass of solution:	25.38287 g in 50 ml flame sealed ampoule
b. Chemical form:	AmCl ₃ in 1M HCl
c. Carrier content:	None added
d. Density:	1.0171 g/ml @ 20°C.

Radioimpurities

None detected

Radioactive Daughters

None

Radionuclide Concentration

3.747 µCi/g

Method of Calibration

The source was prepared from a weighed aliquot of solution whose concentration in µCi/g was determined by gamma spectrometry integrating under the 59.5 keV peak and using a branching ratio of 0.360 gamma rays per decay.

Uncertainty of Measurement

a. Systematic uncertainty in instrument calibration:	± 3.0%
b. Random uncertainty in assay:	± 2.2%
c. Random uncertainty in weighing(s):	± 0.0%
d. Total uncertainty at the 99% confidence level:	± 3.7%

NIST Traceability

This calibration is traceable to the National Institute of Standards and Technology.

Notes

1. IPL participates in an NIST measurement assurance program to establish and maintain implicit traceability for a number of nuclides, based on the blind assay (and later NIST certification) of Standard Reference Materials (As in NRC Regulatory Guide 4.15).

Peter D. Becker
QUALITY CONTROL
10 Apr 96
Date Signed

ISOTOPE PRODUCTS LABORATORIES

1800 N. KEYSTONE STREET
BURBANK, CALIFORNIA 91504

818-843-7000 FAX 818-843-6168

The University of Cincinnati
Center for Radiological Assessment And Measurement
Small Lung Phosphate Production Form Version 1.0

Small Lung Number: <u>UCSL43AMJ013</u>		
Isotope: <u>Am-241</u>	Concentration of Stock Solution:	<u>3749.2667</u> rCi/g
Activity of Lung to be prepared: _____		<u>459.600</u> rCi
Density of Large Lung to Prepare: _____	Wt of Small Lung to Prepare: _____	<u>439.14</u> g
Expected Amount of Material to be Lost in Bucket and in Flask: _____		<u>122.00</u> g
Expected Amount of ¹⁹⁴ DXA to be Lost in Beaker: _____		<u>8.76</u> g
Total Weight of Material to Prepare in Beaker: _____		<u>599.14</u> g

I. Prepare Mold

- Wash mold with 50/50 mixture of acetone and toluene
- Place mold in oven at 35-38 degrees overnight
- Spray mold with release agent

II. Prepare Components ¹⁹⁴DXD and Additives

1. Prepare _____ g of concentrate

- Add 91.93 g of CaCO₃ to Beaker

Wt of Beaker+CaCO ₃	<u>150.77</u> g
Wt of Beaker	<u>48.77</u> g
Wt of CaCO ₃ added to beaker	<u>91.93</u> g
- Add 193.89 g of ¹⁹⁴DXD to Beaker

Wt of Beaker+CaCO ₃ + ¹⁹⁴ DXD	<u>340.83</u> g
Wt of Beaker+CaCO ₃	<u>150.77</u> g
Wt of ¹⁹⁴ DXD added to beaker	<u>190.06</u> g
- Stir concentrate until homogeneous (approximately 2 minutes)
- Place concentrate in duplicate mold ready to use

2. Add 251.51 g of ¹⁹⁴DXB to bucket

Wt of Bucket+ ¹⁹⁴ DXB	<u>383.24</u> g
Wt of Bucket	<u>88.11</u> g
Wt of ¹⁹⁴ DXB added	<u>295.13</u> g

3. Add 25 drops of T-9 Catalyst to Bucket and Weigh Bucket

4. Add 803.46 g Concentrate to Bucket

Wt of Bucket+ ¹⁹⁴ DXB+Catalyst+Concentrate	<u>481.60</u> g
Wt of Bucket+ ¹⁹⁴ DXB+Catalyst	<u>384.44</u> g
Wt of Concentrate Added	<u>97.16</u> g

5. Add 0.1130 g of Am-241 Stock Solution to Bucket

Wt of Solution+Concentrate Initial	<u>1.8258</u> g
Wt of Solution+Concentrate Final	<u>1.6848</u> g
Wt of Solution Added	<u>0.1410</u> g

6. Add 1.34 mL of H₂O to Bucket and Weigh Bucket (**including radiowater additions**)

Wt of Bucket+ ¹⁹⁴ DXB+Catalyst+Concentrate+NaClO ₂ +Water	<u>496.58</u> g
Wt of Bucket+ ¹⁹⁴ DXB+Catalyst+Concentrate+NaClO ₂	<u>485.02</u> g
Wt of Bucket+ ¹⁹⁴ DXB+Catalyst+Concentrate	<u>488.60</u> g
TOTAL Wt of Water added (includes radiowater additions)	<u>1.00</u> g

7. Mix Bucket and Contents for 2 minutes with 1/4" drill (2400 rpm)

III. Prepare and Add Component ¹⁹⁴DXA

1. Add 164.15 g of ¹⁹⁴DXA to Clean Beaker

Wt of Beaker+ ¹⁹⁴ DXA	<u>206.83</u> g
Wt of Beaker	<u>42.65</u> g
Wt of ¹⁹⁴ DXA in Beaker	<u>164.17</u> g

2. Quickly Add ¹⁹⁴DXA to Bucket and Stir for 10 seconds

3. Add Bucket Contents to Molded Side of Lung Mold, close, clamp bottom loosely, and turn on edge 1

4. Weigh ¹⁹⁴DXA Beaker and Residual

Wt of Beaker+ ¹⁹⁴ DXA (before addition to bucket)	<u>206.83</u> g
Wt of Beaker+ ¹⁹⁴ DXA (after addition to bucket)	<u>48.68</u> g
Wt of ¹⁹⁴ DXA Added to Beaker	<u>158.14</u> g

5. Weigh Bucket and Residual Material Before Reaction

6. Weight of Bucket and Residual Material After Reaction

	<u>183.87</u> g
	<u>183.60</u> g

7. Allow lung to set 1 hour, remove lung, wire, and weigh lung

Wt of Treated Lung	<u>451.41</u> g
Uncorrected Activity of Prepared Lung	<u>587.6928</u> rCi

Comments: Spills/Reversions/Zuckerman Heavy salt droplet. Large bag adjusted accordingly
Unrevised @ 461.75 g

Reviewed By: NEWAY SP, D Date: 6/24/96

UCSL43AMJ013
11/95
8/3/00

The University of Cincinnati
Center for Radiological Assessment And Measurement
Small Lung Phantom Production Form Version 1.0

Lung Activity Analysis Sheet

Identification of Lung	UCSL43AMBU
Isotope	Au-241
Half Life	4.327672 year
Half Life Error	3.560E-3 year
Decay Constant	1.902E-02 per year
Decay Constant Error	1.851E-06 per year
Date of Certification of Activity	4/15/96
Activity of Solution at Certification	1.318E+2 Bq/g
Error in Original Solution Activity	1793.98E0 Bq/g
Date of Lung Production	5/24/96
Time since date of certification	0.11 years
Activity of Solution	1.218E+2 Bq/g = 3345.30E3 pCi/g
Error in activity of Solution	1793.98E0 Bq/g = 48.70E3 pCi/g
Weight of radionuclide added to beaker	0.1920 g
Net weight of material in beaker before reaction	500.83 g
Concentration of radionuclide in beaker before reaction	1.301E-03 pCi/g material
Weight of trimmed lung	451.41 g
Uncorrected Activity of Prepared Lung	517.67E2 pCi
Error in Uncorrected Activity of Prepared Lung	7.26E5 pCi
Weight of Residual Materials in Beaker Before Reaction	95.56 g
Weight of Residual Materials in Beaker after Reaction	95.52 g
Concentration Correction Factor	1.00
Error in Concentration Correction Factor	0.00
Corrected Activity of Lung	518.39E2 pCi
Error in Corrected Activity of Lung	7.27E5 pCi

The University of Cincinnati
Center for Radiological Assessment And Measurement
Small Lung Phantom Production Form Version 1.0

Quality Assurance Worksheet

	WT Added to Beaker (g)	% Total Weight added to Beaker	Expected % Total Weight	Accepted (Y/N)
1940D (A+B) (Uncorrected)	523.87	91.40	92.34	Y
Corrected Weight of Polystyrene	524.77			
CaCl ₂	34.71	6.37	6.37	Y
H ₂ O (including any radioactivity)	1.69	0.285	0.24	Y
Catalyst	6.70	0.125	0.12	Y
Uncorrected Material Weight	560.83			
Corrected Material Weight	560.19			

	Found	Expected	Accepted
Density	0.97	0.95	Y
Concentration Correction Factor	1.00	1.01	Y
Wt % H	7.92	7.92	Y
Wt % C	60.29	60.22	Y
Wt % N	4.16	4.13	Y
Wt % O	25.03	25.04	Y
Wt % Ca	5.68	5.78	Y
Wt % Mg	0.03	0.19	Y
Wt % Si	0.83	0.03	Y
Corrected Activity of Lung (uCi)	588.2572	458.0066	Y
Error in Corrected Activity of Lung (uCi)	7.2723		
Standard Solution ID	515-43-1 (PL)		

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Small Lung Number <u>UCSL43ANSEU</u>		
Concave: <u>Am-241</u>	Concentration of Stock Solution	<u>2745.2673</u> µCi/g
Activity of Lung to be prepared*		<u>451.000</u> µCi
Density of Large Lung to Prepare*	<u>0.23</u> g/cm ³	Wt of Small Lung to Prepare*
Expected Amount of Material to Be Lost in Bucket and in Flask*		<u>479.34</u> g
Expected Amount of 1940DA to Be Lost in Bucket*		<u>170.89</u> g
Total Weight of Material to Prepare in Bucket*		<u>8.50</u> g
		<u>379.14</u> g

I. Prepare Mold

1. Wash mold with 50/50 mixture of acetone and toluene
2. Place mold in oven at 35-38 degrees centigrade
3. Spray mold with release agent

II. Prepare Component 1940DA and Add Givers

1. Prepare 240.00 g of component 1940DA
 - a. Add 10.00 g of CaCO₃ to Bucket

Wt of Bucket+CaCO ₃	<u>116.77</u> g
Wt of Bucket	<u>16.77</u> g
Wt of CaCO ₃ added to bucket	<u>10.00</u> g
 - b. Add 100.00 g of 1940DA to Bucket

Wt of Bucket+CaCO ₃ +1940DA	<u>210.43</u> g
Wt of Bucket+CaCO ₃	<u>116.77</u> g
Wt of 1940DA added to bucket	<u>93.66</u> g
 - c. Stir Contents until homogeneous (approx. 15-20 minutes)
 - d. Place contents in desiccator until ready to use
2. Add 195.31 g of 1940DA to Bucket

Wt of Bucket+1940DA	<u>203.74</u> g
Wt of Bucket	<u>16.77</u> g
Wt of 1940DA added	<u>186.97</u> g
3. Add 15 drops of T-9 Catalyst to Bucket and Weigh Bucket
4. Add 100.44 g Component to Bucket

Wt of Bucket+1940DA+Catalyst+Component	<u>488.50</u> g
Wt of Bucket+1940DA+Catalyst	<u>384.44</u> g
Wt of Component Added	<u>104.06</u> g
5. Add 0.1938 g of Am-241 Stock Solution to Bucket

Wt of Solution+Container Initially	<u>1.8798</u> g
Wt of Solution+Container Final	<u>1.6860</u> g
Wt of Solution Added	<u>0.1938</u> g
6. Add 1.34 mL of H₂O to Bucket and Weigh Bucket (**including radiolabeled solutions**)

Wt of Bucket+1940DA+Catalyst+Component+NaCl+Water	<u>490.20</u> g
Wt of Bucket+1940DA+Catalyst+Component+NaCl	<u>489.02</u> g
Wt of Bucket+1940DA+Catalyst+Component	<u>488.50</u> g
TOTAL Wt of Water added (includes radiolabeled solutions)	<u>1.50</u> g
7. Mix Bucket and Contents for 2 minutes with 1/4" drill (2100 rpm)

III. Prepare and Add Component 1941DA

1. Add 155.13 g of 1941DA to Clean Bucket

Wt of Bucket+1941DA	<u>208.82</u> g
Wt of Bucket	<u>48.68</u> g
Wt of 1941DA to Bucket	<u>160.14</u> g
2. Quickly Add 1940DA to Bucket and Stir for 30 seconds
3. Add Bucket Contents to Molded Side of Lung Mold, close, clamp bottom loosely, and turn on edge 1
4. Weigh 1941DA Bucket and Record

Wt of Bucket+1940DA (before addition to bucket)	<u>208.82</u> g
Wt of Bucket+1940DA (after addition to bucket)	<u>48.68</u> g
Wt of 1941DA Added to Bucket	<u>158.74</u> g
5. Weigh Bucket and Residual Material Before Reaction
6. Weigh of Bucket and Residual Material After Reaction
7. Allow lung to set 1 hour, remove lung, clean, and weigh lung

Wt of Trained Lung*	<u>451.41</u> g
Unreacted Activity of Trained Lung*	<u>387.6928</u> µCi

Comments: Split/Tu/Je/We/Th/Fr/Sa/Su Heavy soln drops: Large lung of listed accordingly
Unreacted @ 461.75 g

Reviewed By: Henry Sp. B Date: 6/24/76

UCSL43AM.XLS
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Long Activity Analysis Sheet

Identification of Lung	UCS-LASAN01
Isotope	Am-241
Half Life	4.327×10^2 year
Half Life Error	5.000×10^{-1} year
Decay Constant	1.672×10^{-3} per year
Decay Constant Error	1.831×10^{-5} per year
Date of Certification of Activity	4/15/94
Activity of Solution at Certification	1.586×10^5 Bq/g
Error in Original Solution Activity	1.00×10^6 Bq/g
Date of Lung Production	5/24/94
Time since date of certification	8.11 years
Activity of Solution	1.369×10^5 Bq/g = 2745.3251 nCi/g
Error in activity of Solution	1.00×10^6 Bq/g = 46.5054 nCi/g
Weight of a solid added to bucket	0.1910 g
Net weight of material in bucket before reaction	560.81 g
Concentration of material in bucket before reaction	1.3919×10^3 nCi/g material
Weight of trimmed lung	43.141 g
Uncorrected Activity of Prepared Lung	597.8929 nCi
Error in Uncorrected Activity of Prepared Lung	2.3629 nCi
Weight of Residual Materials in Bucket before Reaction	95.61 g
Weight of Residual Materials in Bucket after Reaction	95.58 g
Concentration Correction Factor	1.00
Error in Concentration Correction Factor	0.00
Corrected Activity of Lung	588.5092 nCi
Error in Corrected Activity of Lung	2.3723 nCi

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Quality Assurance Worksheet				
	Wt Added to Bucket (g)	% Total Weight added to Bucket	Expected % Total Weight	Accepted (Y/N)
1940D (A+B) (Uncorrected)	323.82	93.40	93.34	Y
Corrected Weight of Polyacrylamide	324.79			
CaCO ₃	34.71	9.79	9.17	Y
H ₂ O (including any moisture)	0.60	0.265	0.34	N
Catalyst	0.70	0.125	0.12	Y
Uncorrected Material Weight	360.83			
Corrected Material Weight	360.19			

	Result	Expected	Accepted
Density	0.27	0.26	Y
Concentration Correction Factor	1.00	1.01	Y
Wt % H	7.93	7.92	Y
Wt % C	93.29	93.37	Y
Wt % N	4.16	4.15	Y
Wt % O	25.03	25.04	Y
Wt % Ca	2.48	2.93	N
Wt % Mg	0.10	0.10	Y
Wt % Zn	0.03	0.03	Y
Corrected Activity of Lung (nCi)	118.2092	118.0000	Y
Error in Corrected Activity of Lung (nCi)	7.2723		
Standard Solution ID	309-87-1 (PL)		

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Small Lung Number <u>UCSL438EU</u>		
Isotope <u>65-152</u>	Concentration of Stock Solution	<u>1525.8565</u> $\mu\text{Ci/g}$
Activity of Lung to be prepared		<u>250.000</u> μCi
Density of Lung to be prepared		<u>0.9914</u> g/cm^3
Expected Amount of Material to be Lost in Beaker and to Flask	Wt of Small Lung to be prepared	<u>250.00</u> g
Expected Amount of ^{194}DGA to be Lost in Beaker		<u>8.79</u> g
Total Weight of Material to be prepared in Beaker		<u>559.14</u> g

I. Prepare Mold

- Wash mold with 50:50 solution of acetone and toluene
- Place mold in oven at 75-80 degrees and grade
- Spray mold with release agent

II. Prepare Components ^{194}DGA and Additives

- Prepare 248.00 g of concentrate
 - Add 80.00 g of CaCO_3 to Beaker

Wt of Beaker+ CaCO_3	<u>128.77</u> g
Wt of Beaker	<u>48.77</u> g
Wt of CaCO_3 added to beaker	<u>80.00</u> g
 - Add 166.00 g of ^{194}DGA to Beaker

Wt of Beaker+ CaCO_3 + ^{194}DGA	<u>294.77</u> g
Wt of Beaker+ CaCO_3	<u>128.77</u> g
Wt of ^{194}DGA added to beaker	<u>166.00</u> g
 - Stir Concentrate until homogeneous (approximately 2 minutes)
 - Place concentrate in desiccator until ready to use
- Add 295.11 g of ^{194}DGA to Beaker

Wt of Beaker+ ^{194}DGA	<u>343.74</u> g
Wt of Beaker	<u>48.11</u> g
Wt of ^{194}DGA added	<u>295.63</u> g
- Add 23 drops of T-9 Catalyst to Beaker and Weigh Beaker

Wt of Beaker+ ^{194}DGA +Catalyst+Concentrate	<u>488.63</u> g
Wt of Beaker+ ^{194}DGA +Catalyst	<u>284.44</u> g
Wt of Concentrate Added	<u>154.19</u> g
- Add 0.2010 g of Tru-152 Stock Solution to Beaker

Wt of Solution+Container Initially	<u>2.0978</u> g
Wt of Solution+Container Final	<u>1.8962</u> g
Wt of Solution Added	<u>0.2016</u> g
- Add 1.34 ml of H_2O to Beaker and Weigh Beaker (**including radioactive solution**)

Wt of Beaker+ ^{194}DGA +Catalyst+Concentrate+Nucleide+Water	<u>492.25</u> g
Wt of Beaker+ ^{194}DGA +Catalyst+Concentrate+Nucleide	<u>488.63</u> g
Wt of Beaker+ ^{194}DGA +Catalyst+Concentrate	<u>488.64</u> g
TOTAL Wt of Water added (not including radioactive solution)	<u>1.60</u> g
- Mix Beaker and Contents for 2 minutes with 1/4" drill (1000 rpm)

III. Prepare and Add Components ^{194}DGA

- Add 166.17 g of ^{194}DGA to Clean Beaker

Wt of Beaker+ ^{194}DGA	<u>206.82</u> g
Wt of Beaker	<u>40.65</u> g
Wt of ^{194}DGA to Beaker	<u>166.17</u> g
- Quickly Add ^{194}DGA to Beaker and Stir for 10 seconds
- Add Beaker Contents to Molded Side of Lung Mold, close, clamp bottom loosely, and turn on edge 1
- Weigh ^{194}DGA Beaker and Record

Wt of Beaker+ ^{194}DGA (before addition to beaker)	<u>206.82</u> g
Wt of Beaker+ ^{194}DGA (after addition to beaker)	<u>48.08</u> g
Wt of ^{194}DGA Added to Beaker	<u>158.74</u> g
- Weigh Beaker and Residual Material Before Reaction
- Weigh of Beaker and Residual Material After Reaction

Wt of Beaker+Residual	<u>181.81</u> g
Wt of Residual	<u>782.92</u> g
- Allow lung to set 1 hour, remove lung, trim, and weigh lung

Wt of Trimmed Lung	<u>451.41</u> g
Uncorrected Activity of Prepared Lung	<u>250.00</u> μCi

Comments: Spills/Damage/Errors:

Reviewed By: AC/LL/SJB Date: 6/2/96

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Lung Activity Analysis Sheet

Identification of Lung	UCLA1A.M001
Isotope	Eu-152
Half Life	1.335E+1 year
Half Life Error	8.000E-2 year
Decay Constant	5.113E-02 per year
Decay Constant Error	2.765E-04 per year
Date of Certification of Activity	2/3/87
Activity of Solution at Certification	9.723E-4 Bq/g
Error in Original Solution Activity	3.072E-05 Bq/g
Date of Lung Production	2/24/86
Time since date of certification	9.37 years
Activity of Solution	5.833E-4 Bq/g = 1338.2906 nCi/g
Error in activity of Solution	2.058E-6 Bq/g = 5.8379 nCi/g
Weight of oxide added to bucket	0.2858 g
Net weight of material in bucket before reaction	200.83 g
Concentration of oxide in bucket before reaction	0.001438 g/g material
Weight of irradiated lung	451.41 g
Uncorrected Activity of Prepared Lung	258.6723 nCi
Error in Uncorrected Activity of Prepared Lung	0.2727 nCi
Weight of residual materials in bucket before reaction	95.59 g
Weight of residual materials in bucket after reaction	95.56 g
Concentration Correction Factor	1.00
Error in Concentration Correction Factor	0.00
Corrected Activity of Lung	258.2716 nCi
Error in Corrected Activity of Lung	0.9164 nCi

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	Quality Assurance Worksheet			Accepted (Y/N)
	Wt Added to Bucket (g)	% Total Weight Added to Bucket	Expected % Total Weight	
15480 (A+B) (Uncorrected)	523.82	55.46	91.34	PS
Corrected Weight of Polyurethane	524.72			
CaCO ₃	20.78	0.22	0.07	PS
IDO (including any radioactivity)	1.92	0.20	0.24	PS
Catalyst	0.70	0.12	0.02	PS
Uncorrected Material Weight	593.83			
Corrected Material Weight	593.72			
	Results		Expected	Accepted
Density	0.22		0.38	PS
Concentration Conversion Factor	1.00		1.00	PS
Wt % E	7.22		7.52	PS
Wt % C	60.56		60.27	PS
Wt % N	4.16		4.33	PS
Wt % O	24.03		23.91	PS
Wt % Ca	2.48		2.58	PS
Wt % Mg	0.00		0.00	PS
Wt % Si	0.03		0.02	PS
Corrected Activity of Lung (uCi)	258.9709		259.0099	PS
Error in Corrected Activity of Lung (uCi)	0.0384			
Standard Solution ID	MIST A47JAC20			

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Large Lung Phantom Production Form Version 1.0

Large Lung Number: <u>UCL43AM01</u>		
Isotope: <u>Am-241</u>	Concentration of Stock Solution: <u>3745.3657</u> $\mu\text{Ci/g}$	
Activity of lung to be prepared: <u> </u>		<u>639.390</u> μCi
Density of Lung to Prepare: <u>0.50</u> g/cm ³	Wt of Large Lung to Prepare: <u> </u>	<u>565.80</u> g
Expected Amount of Material to Be Lost in Bucket and to Flare: <u> </u>		<u>120.00</u> g
Expected Amount of 1940DA to Be Lost in Bucket: <u> </u>		<u>8.70</u> g
Total Weight of Material to Prepare in Bucket: <u> </u>		<u>685.80</u> g

I. Prepare Mold

1. Wash mold with 50:50 mixture of acetone and isopropanol
2. Place mold in oven at 35-50 degrees celsius
3. Spray mold with release agent

II. Prepare Component 1940D/B and Additives

1. Prepare 240.00 g of concentrate
 - a. Add 80.00 g of CaCO₃ to Bucket

Wt of Bucket+CaCO ₃	<u>128.77</u> g
Wt of Bucket	<u>48.77</u> g
Wt of CaCO ₃ added to bucket	<u>80.00</u> g
 - b. Add 160.00 g of 1940D/B to Bucket

Wt of Bucket+CaCO ₃ +1940D/B	<u>288.87</u> g
Wt of Bucket+CaCO ₃	<u>128.77</u> g
Wt of 1940D/B added to bucket	<u>160.00</u> g
 - c. Stir Concentrate until homogeneous (approximately 2 minutes)
 - d. Place concentrate in desiccator until ready to use
2. Add 322.87 g of 1940D/B to Bucket

Wt of Bucket+1940D/B	<u>459.67</u> g
Wt of Bucket	<u>87.64</u> g
Wt of 1940D/B added	<u>362.94</u> g
3. Add 51 drops of T-9 Catalyst to Bucket and Weigh Bucket
4. Add 127.05 g Concentrate to Bucket

Wt of Bucket+1940D/B+Catalyst+Concentrate	<u>578.61</u> g
Wt of Bucket+1940D/B+Catalyst	<u>431.25</u> g
Wt of Concentrate Added	<u>127.36</u> g
5. Add 0.0046 g of Am-241 Stock Solution to Bucket

Wt of Solution+Container Initially	<u>2.0947</u> g
Wt of Solution+Container Final	<u>1.8768</u> g
Wt of Solution Added	<u>0.2179</u> g
6. Add 1.85 mL of H₂O to Bucket and Weigh Bucket (**including enclosed lids on buckets**)

Wt of Bucket+1940D/B+Catalyst+Concentrate+NaCl+H ₂ O	<u>580.41</u> g
Wt of Bucket+1940D/B+Catalyst+Concentrate+NaCl	<u>578.61</u> g
Wt of Bucket+1940D/B+Catalyst+Concentrate	<u>578.61</u> g
TOTAL Wt of Water added (includes enclosed lids on buckets)	<u>1.80</u> g
7. Mix Bucket and Contents for 2 minutes with 1/2" drill (2000 rpm)

III. Prepare and Add Component 1940DA

1. Add 262.10 g of 1940DA to Clean Bucket

Wt of Bucket+1940DA	<u>264.77</u> g
Wt of Bucket	<u>48.64</u> g
Wt of 1940DA in Bucket	<u>264.13</u> g
2. Quickly Add 1940DA to Bucket and Stir for 10 seconds
3. Add Bucket Contents to Molded Side of Lung Mold, close, stamp bottom loosely, and turn on edge 3
4. Weigh 1940DA Bucket and Record

Wt of Bucket+1940DA (before addition to bucket)	<u>264.77</u> g
Wt of Bucket+1940DA (after addition to bucket)	<u>49.64</u> g
Wt of 1940DA Added to Bucket	<u>195.13</u> g
5. Weigh Bucket and Residual Material Before Reaction
6. Weigh of Bucket and Residual Material After Reaction

Wt of Bucket+Residual	<u>199.81</u> g
Wt of Residual	<u>199.84</u> g
7. Allow lung to set 1 hour, remove lung, slice, and weigh lung

Wt of Trimmed Lung	<u>559.37</u> g
Unreacted Activity of Prepared Lung	<u>654.3699</u> μCi

Concentration: unreacted = 368.0 g: Spill/Kalman/Zachary

Reviewed By: [Signature] Date: 5/3/96

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6/3/96

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Lung Activity Analysis Sheet

Identification of Lung		UCLL/AMBU	
Isotope		Am-241	
Half Life		4.32(10) ² year	
Half Life Error		5.99(0) ⁻¹ year	
Decay Constant		1.62(1) ⁻⁴ per year	
Decay Constant Error		1.83(1) ⁻⁴ per year	
Date of Certification of Activity		4/15/98	
Activity of Solution at Certification		1.388(0) ³ Bq/g	
Error in Original Solution Activity		1.786(0)(0) Bq/g	
Date of Lung Production		5/20/98	
Time since date of certification		0.1684 year	
Activity of Solution		1.394(0) ³ Bq/g	7745.3(13) nCi/g
Error in activity of Solution		1.759(0)(0) Bq/g	46.2(19) nCi/g
Weight of residue added to bucket		0.2159 g	
Net weight of material in bucket before reaction		687.52 g	
Concentration of residue in bucket before reaction		1.1702 nCi/g material	
Weight of removed lung		398.19 g	
Uncorrected Activity of Implanted Lung		654.7(6) nCi	
Error in Uncorrected Activity of Implanted Lung		8.0(4) nCi	
Weight of Residual Material in Bucket Before Reaction		112.21 g	
Weight of Residual Material in Bucket after Reaction		121.46 g	
Concentration Correction Factor		1.0073	
Error in Concentration Correction Factor		0.0005	
Corrected Activity of Lung		659.15(1) nCi	
Error in Corrected Activity of Lung		8.3(4) nCi	

UCLL/AMBU/LS
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Quality Assurance Worksheet

	Wt Added to Beaker (g)	% Total Weight added to Beaker	Expected % Total Weight	Accepted (Y/N)
194ED (A+B) (Uncorrected)	642.81	93.45	93.34	
Corrected Weight of Polystyrene	629.69			
CaCO ₃	42.33	6.16	6.17	
HCO (including any radioactivity)	1.81	0.252	0.24	
Catalyst	0.89	0.129	0.12	
Uncorrected Material Weight	687.50			
Corrected Material Weight	682.97			

	Results	Expected	Accepted
Density	0.35	0.35	
Compressibility Correction Factor	1.91	1.91	
Wt % H	7.92	7.92	
Wt % C	66.25	66.27	
Wt % N	4.16	4.15	
Wt % O	17.0	15.04	
Wt % Ca	2.48	2.18	
Wt % Mg	0.12	0.18	
Wt % Se	0.03	0.03	
Corrected Activity of Lung (uCi)	632.1581	631.8888	
Error in Corrected Activity of Lung (uCi)	8.1444		
Standard Solution ID	#19-87-1 (PL)		

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Large Lung Phantom Production Form Version 1.0

Large Lung Number: <u>UCRL43EJ</u> Recipe: <u>8a-152</u> Activity of Lung to be prepared: _____ Density of Large Lung to Prepare: <u>0.25</u> g/cm ³ Expected Amount of Material to Be Lost in Bucket and to Flask: _____ Expected Amount of ¹⁹⁴ Os to Be Lost in Bucket: _____ Total Weight of Material to Prepare in Bucket: _____	Concentration of Stock Solution: <u>1575.2750</u> g/g Wt of Large Lung to Prepare: _____ _____ _____ _____ _____	1575.2750 g/g 275.000 g 566.80 g 120.72 g 8.70 g 665.60 g
I. Prepare Mold 1. Wash mold with 50% solution of acetone and solvent 2. Place mold in oven at 25-30 degrees centigrade 3. Spray mold with release agent II. Prepare Component 194Os and Additives 1. Prepare: <u>240.00</u> g of concentrate a. Add <u>80.00</u> g of CaCO ₃ to Bucket Wt of Bucket+CaCO ₃ : <u>120.72</u> g Wt of Bucket: <u>40.72</u> g Wt of CaCO ₃ added to bucket: <u>80.00</u> g b. Add <u>100.00</u> g of 194Os to Bucket Wt of Bucket+CaCO ₃ +194Os: <u>280.43</u> g Wt of Bucket+CaCO ₃ : <u>120.72</u> g Wt of 194Os added to bucket: <u>160.00</u> g c. Stir concentrate until homogeneous (approximately 2 minutes) d. Place concentrate in desiccator until ready to use 2. Add <u>342.57</u> g of 194Os to Bucket Wt of Bucket+194Os: <u>439.43</u> g Wt of Bucket: <u>87.64</u> g Wt of 194Os added: <u>351.79</u> g 3. Add <u>31</u> drops of T-3 Catalyst to Bucket and Weigh Bucket 4. Add <u>127.65</u> g Concentrate to Bucket Wt of Bucket+194Os+Catalyst+Concentrate: <u>578.61</u> g Wt of Bucket+194Os+Catalyst: <u>451.52</u> g Wt of Concentrate Added: <u>127.09</u> g 5. Add <u>0.2114</u> g of <u>8a-152</u> Stock Solution to Bucket Wt of Solution+Concentrate Initially: <u>2.2730</u> g Wt of Solution+Concentrate Final: <u>2.0520</u> g Wt of Solution Added: <u>0.2210</u> g 6. Add <u>1.83</u> ml of H ₂ O to Bucket and Weigh Bucket (**including radioactive solutions**) Wt of Bucket+194Os+Catalyst+Concentrate+NaCl+H ₂ O: <u>580.41</u> g Wt of Bucket+194Os+Catalyst+Concentrate+NaCl: <u>379.11</u> g Wt of Bucket+194Os+Catalyst+Concentrate: <u>378.61</u> g TOTAL Wt of Water added (including radioactive solutions): <u>1.80</u> g 7. Mix Bucket and Contents for 2 minutes with 1/4" drill (#400 rpm)		
III. Prepare and Add Component 194OsA 1. Add <u>200.00</u> g of 194OsA to Clean Bucket Wt of Bucket+194OsA: <u>244.72</u> g Wt of Bucket: <u>40.64</u> g Wt of 194OsA to Bucket: <u>204.08</u> g 2. Quickly Add 194OsA to Bucket and Stir for 10 seconds 3. Add Bucket Contents to Molded Side of Lung Mold, close, clamp bottom loosely, and turn on edge 1 4. Weigh 194OsA Bucket and Record Wt of Bucket+194OsA (before addition to bucket): <u>244.72</u> g Wt of Bucket+194OsA (after addition to bucket): <u>49.94</u> g Wt of 194OsA Added to Bucket: <u>194.78</u> g 5. Weigh Bucket and Residual Material Before Reaction 6. Weigh of Bucket and Residual Material After Reaction Wt of Residual Lung: <u>352.13</u> g Uncorrected Activity of Prepared Lung: <u>282.0330</u> gCi		

Concentrate corrected = 388.56g; 342.57g/0.8957246666666666

Reviewed By: Heidi S. Smith Date: 6/3/96

UCRL43EJ.XLS
11:49
6/3/96

The University of Cincinnati
Center for Radiological Assessment And Measurement
Large Lung Phantom Production Form Version 1.0

Lung Activity Analysis Sheet

Identification of Lung	UCLLQAMBU		
Isotope	Eu-152		
Half Life	1.2520E+1	year	
Half Life Error	6.000E-2	year	
Decay Constant	5.1151E-02	per	year
Decay Constant Error	3.769E-04	per	year
Date of Certification of Activity	3/3/97		
Activity of Solution at Certification	3.3902E+4	Bq/g	
Error in Original Solution Activity	247.4000	Bq/g	
Date of Lung Production	5/24/98		
Time since date of certification	0.3060	years	
Activity of Solution	1.8332E+4	Bq/g =	1.576.5995 uCi/g
Error in activity of Solution	119.8174	Bq/g =	5.8329 uCi/g
Weight of scandium added to bucket	0.3304	g	
Net weight of material in bucket before reaction	287.59	g	
Concentration of scandium in bucket before reaction	0.5044	uCi/g material	
Weight of prepared lung	339.17	g	
Uncorrected Activity of Prepared Lung	282.8370	uCi	
Error in Uncorrected Activity of Prepared Lung	1.8901	uCi	
Weight of Residual Materials in Bucket Before Reaction	112.21	g	
Weight of Residual Materials in Bucket after Reaction	111.48	g	
Concentration Correction Factor	1.9773		
Error in Concentration Correction Factor	0.0002		
Corrected Activity of Lung	284.5837	uCi	
Error in Corrected Activity of Lung	1.9086	uCi	

UCLLQAMBU.XLS
11/92
6/3/98

The University of Cincinnati
Center for Radiological Assessment And Measurement
Large Lung Phantom Production Form Version 1.0

	Quality Assurance Worksheet			Accepted (YES)
	Wt Added to Bucket (g)	% Total Weight added to Bucket	Expected % Total Weight	
IS-40P (A+B) (Uncorrected)	642.85	63.65	91.34	☒
Corrected Weight of Polyurethane	676.07			
CuCO ₃	42.35	4.36	6.07	☒
H ₂ O (including any reactivity)	1.93	0.19	0.34	☒
Catalyst	0.89	0.12	0.02	☒
Uncorrected Material Weight	687.93			
Corrected Material Weight	682.93			
Density	0.26		0.26	☒
Concentration Correction Factor	1.01		1.01	☒
Wt % H	7.92		7.92	☒
Wt % C	60.29		60.27	☒
Wt % N	4.16		4.15	☒
Wt % O	25.03		25.04	☒
Wt % Ca	2.48		2.50	☒
Wt % Mg	0.10		0.08	☒
Wt % Si	0.83		0.83	☒
Corrected Activity of Lung (nC)	284.8877		275.0099	☒
Error in Corrected Activity of Lung (nC)	1.0645			
Standard Deviation ID	NIST 430C123			

UCR-ARL-01-01
11/01
G/2006

Certified Reference Material

Certificate of Traceability

U.S. Department of Energy Radiological and Environmental Sciences Laboratory

Standard Identification: MFP-1-001

Radionuclide	Activity
Mn-54	5.44+/-0.04 E2 nCi
Co-57	4.39+/-0.04 E3 nCi
Co-60	3.53+/-0.03 E2 nCi
Cs-134	3.92+/-0.03 E2 nCi
Cs-137	4.56+/-0.04 E2 nCi

This Certified Reference Material (CRM) contains a known quantity of radionuclides in a stable and homogeneous matrix. This material is intended for the calibration of instruments and for the verification of the accuracy and precision of analytical radiochemistry measurements. The activities listed for each radionuclide are traceable to NIST through an unbroken chain of comparisons, all having stated uncertainties ($k=1$) calculated according to ISO and NIST Guidelines.

This material was prepared by the Radiological and Environmental Sciences Laboratory (RESL). RESL maintains direct traceability to NIST through successful participation in the NIST/RESL Radiological Traceability Program and is accredited to ISO 17043 as a Performance Testing Provider and ISO 17025 as a Chemical Testing Laboratory by The American Association for Laboratory Accreditation.

David S. Sill
Senior Technical Manager - Chemistry

April 22, 2005
Reference Date

Supplemental Information

	Left Lung	Right Lung	Total
Density(g/cm3)	0.269+/-0.002	0.259+/-0.001	0.263+/-0.001
Activity(nCi)			
Mn-54	2.50+/-0.04 E2	2.94+/-0.01 E2	5.44+/-0.04 E2
Co-57	2.02+/-0.03 E3	2.370+/-0.011 E3	4.39+/-0.04 E3
Co-60	1.62+/-0.03 E2	1.91+/-0.01E2	3.53+/-0.03 E2
Cs-137	1.80+/-0.03E2	2.12+/-0.01E2	3.92+/-0.03 E2
Cs-137	2.09+/-0.03E2	2.47+/-0.01 E2	4.56+/-0.04 E2

Reference Date April 22, 2005

DOE Source Certificate I-125 BEA Thyroid 002

Certified Reference Material

Certificate of Traceability

U.S. Department of Energy Radiological and Environmental Sciences Laboratory

Standard Identification: I-125 BEA Thyroid 002

Radionuclide	Activity
I-125	(1.33± 0.02) E2 nCi

This Certified Reference Material (CRM) contains a known quantity of radionuclides in a stable and homogeneous matrix. This material is intended for the calibration of instruments and for the verification of the accuracy and precision of analytical radiochemistry measurements. The activities listed for each radionuclide are traceable to NIST through an unbroken chain of comparisons, all having stated uncertainties ($k=1$) calculated according to ISO and NIST Guidelines.

This material was prepared by the Radiological and Environmental Sciences Laboratory (RESL). RESL maintains direct traceability to NIST through successful participation in the NIST/RESL Radiological Traceability Program and is accredited to ISO 17043 as a Performance Testing Provider and ISO 17025 as a Chemical Testing Laboratory by The American Association for Laboratory Accreditation.

David S. Sill
Senior Technical Manager - Chemistry

February 28, 2011
Reference Date

Supplemental Information

I-125 BEA Thyroid 002

Final weight of vial with sticker and tape: 38.885 grams

Weight of solution in vial: 29.955 +/- 0.002 grams

Solution Used: I-125-80943-370

Solution in vial: Solidified with 0.432 grams of WaterWorks Crystal SP400.

Half life: 59.40 days

Certificate and dilution information attached.

Prepared by Guy Backström, 2/28/2011

Appendix B

Source Decay

Appendix B

Source Decay

UCLL43AMEU & UCL43AMEU Lung Set

Eu-152, Am-241 Source Decay
Source ID - UCLL43AMEU, UCL43AMEU
Accuscan II Calibration for High Energy Lung Geometry

Reference Date	Calibration date	Decay Time in Days
5/24/1996 0:00	4/5/2011 0:00	5429.00

Radionuclide	Half Life (days)	Initial Activity (uCi)	New Activity (uCi)
Eu-152	4946	0.5431	0.2538
Am-241	157760.3	1.2475	1.2181

DOE Manufactured Lung Set # MFP-1-001 Decay

DOE Manufactured Source MFP-1-001

Reference
Date 4/4/2011
Current Date 4/5/2011
Elapsed Time 1

Identity	Energy (keV)	Reference Activity (nCi)	Yield %	T1/2 Days	G/nCi	Reference GPS	Current Activity (nCi)
Co-60	1173.2	161	99.9	1925	37	5.95E+03	1.61E+02
	1332.5	161	100	1925	37	5.96E+03	1.61E+02
Cs-137	661.7	398	85.1	10980.00	37	1.25E+04	3.98E+02
Cs-134	123	53.2	2.47	752.6	37	4.86E+01	5.32E+01
	475	53.2	1.46	752.6	37	2.87E+01	5.32E+01
	563	53.2	8.38	752.6	37	1.65E+02	5.32E+01
	604	53.2	97.6	752.6	37	1.92E+03	5.32E+01
	795.8	53.2	85.4	752.6	37	1.68E+03	5.32E+01
	801.9	53.2	8.73	752.6	37	1.72E+02	5.32E+01
Co-57	122.06	16.9	85.6	270.9	37	5.35E+02	1.69E+01
Mn-54	834.8	4.4	100	312.5	37	1.63E+02	4.40E+00

Appendix C

Energy/FWH and Low Tail Calibration Documentation

Appendix C

Energy/FWH and Low Tail Calibration Documentation

Energy Calibration

Calibration Information

Calibration Title	Energy Calibration (HE Lung) 4/5/2011 8:17 AM
Calibration Date	4/5/2011 8:17:58 AM
Performed By	David Georgeson
Count Used	Calibration Count 4/4/2011 4:49 PM
Is Default	Yes

Counter Information

Counter Name	Accuscan II
Counter Location	Battelle

Detector Group Information

Detector Group Name	Left
Calibration Source	Am241/Eu152 CWI Lung Set
Analysis Sequence File	QCPEAKBE.ASF
Nuclide Library	
Peak Search Library	

Energy Calibration Coefficients

$$\text{Energy} = -0.236715 + 0.461979 * \text{ch} + 1.14186\text{e-}08 * \text{ch}^2$$

$$\text{FWHM} = 1.22288 + 0.0195807 * E^{1/2}$$

$$\text{LOW TAIL} = 0.864533 + 0.000833452 * E$$

Energy Calibration Results Table

<u>Centroid Channel</u>	<u>Centroid Error</u>	<u>Energy (keV)</u>
57.49	0.19	26.34
129.53	0.02	59.54
264.11	0.01	121.78
530.10	0.03	244.70
745.63	0.02	344.28
890.15	0.04	411.10
961.30	0.07	443.97
1686.35	0.06	778.00
1877.80	0.08	867.40
2086.97	0.05	964.10
2350.42	0.11	1086.00
2407.45	0.05	1112.00
2625.97	0.20	1213.00
2812.33	0.23	1299.00
3047.92	0.05	1408.00

Approved by: _____

Date: _____

User: David Georgeson

Energy Calibration

Energy Calibration Results Table

<u>Energy (keV)</u>	<u>FWHM Channels</u>	<u>FWHM Error</u>
26.34	2.61	0.47
59.54	3.07	0.04
121.78	3.14	0.02
244.70	3.21	0.07
344.28	3.38	0.04
411.10	3.09	0.06
443.97	3.80	0.14
778.00	3.75	0.12
867.40	4.07	0.17
964.10	4.11	0.10
1086.00	3.65	0.23
1112.00	4.28	0.12
1213.00	3.22	0.31
1299.00	4.00	0.49
1408.00	4.59	0.09

User: David Georgeson

Energy Calibration

User: David Georgeson

Energy Calibration

Calibration Information

Calibration Title Energy Calibration (HE Lung) 4/5/2011 8:13 AM
Calibration Date 4/5/2011 8:13:56 AM
Performed By David Georgeson
Count Used Calibration Count 4/4/2011 4:49 PM
Is Default Yes

Counter Information

Counter Name Accuscan II
Counter Location Battelle

Detector Group Information

Detector Group Name Right
Calibration Source Am241/Eu152 CWI Lung Set
Analysis Sequence File QCPEAKBE.ASF
Nuclide Library
Peak Search Library

Energy Calibration Coefficients

$$\begin{aligned}\text{Energy} &= -0.244432 + 0.461855 * \text{ch} + 3.89635\text{e-}08 * \text{ch}^2 \\ \text{FWHM} &= 0.577324 + 0.0294204 * E^{1/2} \\ \text{LOW TAIL} &= 0.726181 - 0.000167099 * E\end{aligned}$$

Energy Calibration Results Table

<u>Centroid Channel</u>	<u>Centroid Error</u>	<u>Energy (keV)</u>
57.61	0.09	26.34
129.57	0.02	59.54
264.23	0.01	121.78
530.24	0.02	244.70
745.81	0.01	344.28
890.50	0.03	411.10
961.61	0.03	443.97
1686.55	0.04	778.00
1878.09	0.04	867.40
2087.36	0.03	964.10
2350.75	0.16	1086.00
2407.67	0.03	1112.00
2626.15	0.23	1213.00
2813.14	0.30	1299.00
3048.21	0.04	1408.00

Approved by: _____

Date: _____

Energy Calibration Results Table

<u>Energy (keV)</u>	<u>FWHM Channels</u>	<u>FWHM Error</u>	<u>TAIL Channels</u>	<u>TAIL Error</u>
26.34	1.61	0.27	0.72	0.37
59.54	1.82	0.03	1.16	0.12
121.78	1.97	0.02	1.67	0.18
244.70	2.21	0.04	1.60	0.19
344.28	2.39	0.02	2.09	0.18
411.10	2.63	0.07	6.42	1.00
443.97	2.46	0.06	1.49	0.20
778.00	2.99	0.08	2.28	0.48
867.40	2.85	0.08	2.04	0.48
964.10	3.31	0.06	18.97	1.00
1086.00	3.06	0.36	1.78	0.86
1112.00	3.47	0.06	2.69	0.38
1213.00	2.84	0.53	0.88	0.46
1299.00	2.68	0.31	0.56	0.11
1408.00	3.90	0.07	3.12	0.39

Energy Calibration

Calibration Information

Calibration Title Energy Calibration (HE Lung) 4/5/2011 8:13 AM
Calibration Date 4/5/2011 8:13:56 AM
Performed By David Georgeson
Count Used Calibration Count 4/4/2011 4:49 PM
Is Default Yes

Counter Information

Counter Name Accuscan II
Counter Location Battelle

Detector Group Information

Detector Group Name Right
Calibration Source Am241/Eu152 CWI Lung Set
Analysis Sequence File QCPEAKBE.ASF
Nuclide Library
Peak Search Library

Energy Calibration Coefficients

$$\begin{aligned}\text{Energy} &= -0.244432 + 0.461855 * \text{ch} + 3.89635\text{e-}08 * \text{ch}^2 \\ \text{FWHM} &= 0.577324 + 0.0294204 * E^{1/2} \\ \text{LOW TAIL} &= 0.726181 - 0.000167099 * E\end{aligned}$$

Energy Calibration Results Table

<u>Centroid Channel</u>	<u>Centroid Error</u>	<u>Energy (keV)</u>
57.61	0.09	26.34
129.57	0.02	59.54
264.23	0.01	121.78
530.24	0.02	244.70
745.81	0.01	344.28
890.50	0.03	411.10
961.61	0.03	443.97
1686.55	0.04	778.00
1878.09	0.04	867.40
2087.36	0.03	964.10
2350.75	0.16	1086.00
2407.67	0.03	1112.00
2626.15	0.23	1213.00
2813.14	0.30	1299.00
3048.21	0.04	1408.00

Approved by: _____

Date: _____

Energy Calibration Results Table

<u>Energy (keV)</u>	<u>FWHM Channels</u>	<u>FWHM Error</u>	<u>TAIL Channels</u>	<u>TAIL Error</u>
26.34	1.61	0.27	0.72	0.37
59.54	1.82	0.03	1.16	0.12
121.78	1.97	0.02	1.67	0.18
244.70	2.21	0.04	1.60	0.19
344.28	2.39	0.02	2.09	0.18
411.10	2.63	0.07	6.42	1.00
443.97	2.46	0.06	1.49	0.20
778.00	2.99	0.08	2.28	0.48
867.40	2.85	0.08	2.04	0.48
964.10	3.31	0.06	18.97	1.00
1086.00	3.06	0.36	1.78	0.86
1112.00	3.47	0.06	2.69	0.38
1213.00	2.84	0.53	0.88	0.46
1299.00	2.68	0.31	0.56	0.11
1408.00	3.90	0.07	3.12	0.39

Shape

Energy Calibration

Calibration Information

Calibration Title Energy Calibration (HE Lung) 4/5/2011 8:18 AM
Calibration Date 4/5/2011 8:19:05 AM
Performed By David Georgeson
Count Used Calibration Count 4/4/2011 4:49 PM
Is Default Yes

Counter Information

Counter Name Accuscan II
Counter Location Battelle

Detector Group Information

Detector Group Name Summed
Calibration Source Am241/Eu152 CWI Lung Set
Analysis Sequence File
Nuclide Library Am241/Eu152 CWI Lung Set
Peak Search Library Am241/Eu152 CWI Lung Set

Energy Calibration Coefficients

$$\begin{aligned}\text{Energy} &= -0.0852164 + 0.461564 * \text{ch} + 1.38308\text{e-}07 * \text{ch}^2 \\ \text{FWHM} &= 0.790531 + 0.0308963 * E^{1/2} \\ \text{LOW TAIL} &= 0.590587 + 0.000758722 * E\end{aligned}$$

Energy Calibration Results Table

<u>Centroid Channel</u>	<u>Centroid Error</u>	<u>Energy (keV)</u>
57.59	0.09	26.34
129.53	0.03	59.54
264.16	0.02	121.78
530.11	0.02	244.70
745.63	0.02	344.28
890.24	0.03	411.10
961.37	0.03	443.97
1686.31	0.02	778.00
1877.81	0.05	867.40
2087.02	0.03	964.10
2350.40	0.12	1086.00
2407.40	0.04	1112.00
2625.58	0.14	1213.00
2812.33	0.11	1299.00
3047.92	0.02	1408.00

Approved by: _____

Date: _____

User: David Georgeson

Database: InVivo Server: 127.0.0.1

Energy Calibration Results Table

<u>Energy (keV)</u>	<u>FWHM Channels</u>	<u>FWHM Error</u>	<u>TAIL Channels</u>	<u>TAIL Error</u>
26.34	1.96	0.23	0.70	0.23
59.54	2.37	0.06	1.42	0.18
121.78	2.46	0.05	1.52	0.16
244.70	2.75	0.04	1.84	0.19
344.28	2.91	0.05	2.17	0.24
411.10	2.99	0.06	6.12	1.00
443.97	3.17	0.06	1.96	0.22
778.00	3.47	0.05	2.58	0.26
867.40	3.55	0.11	2.45	0.55
964.10	3.77	0.05	5.69	1.00
1086.00	3.46	0.27	2.74	1.62
1112.00	3.93	0.08	2.55	0.25
1213.00	4.34	0.32	3.36	2.44
1299.00	3.89	0.24	3.81	6.09
1408.00	4.33	0.04	3.83	0.32

Appendix D

Efficiency Calibration Documentation

Appendix D

Efficiency Calibration Documentation

Page 1 of 5
Created 4/26/2011 4:56:05 PM
Idaho Falls Id.
Battelle Energy Alliance LLC

Efficiency Calibration

Calibration Information

Calibration Title	Eff. Calibration (HE Lung Realistic)4/5/2011 4:05 PM
Calibration Date	4/5/2011 4:03:37 PM
Performed By	David Georgeson
Count Used	Calibration Count 4/5/2011 2:02 PM
Approved	4/7/2011 9:16:28 AM by David Georgeson
Is Default	Yes
Is Multi Curve	No

Counter Information

Counter Name	Accuscan II
Counter Location	Battelle
Counter Configuration	Lung - High Energy

Detector Group Information

Detector Group Name	Summed
Calibration Source	Am241/Eu152 CWI Lung Set
Analysis Sequence File	ROUNPPGE.ASF
Nuclide Library	Am241/Eu152 CWI Lung Set
Peak Search Library	Am241/Eu152 CWI Lung Set

Approved by: _____

Date: _____

User: David Georgeson

Database: InVivo Server: 127.0.0.1

Efficiency Triplets

<u>Energy</u>	<u>Efficiency</u>	<u>Error</u>	<u>Dual</u>	<u>Difference</u>	<u>Empirical</u>	<u>Difference</u>	<u>Linear</u>	<u>Difference</u>
2.634E+001	1.047E-003	1.464E-005	1.047E-003	0.03 %	1.047E-003	0.04 %	1.047E-003	0.00 %
5.954E+001	1.275E-003	4.390E-006	1.275E-003	-0.02 %	1.275E-003	-0.02 %	1.275E-003	0.00 %
1.218E+002	1.595E-003	1.499E-005	1.589E-003	0.38 %	1.588E-003	0.39 %	1.593E-003	0.09 %
2.447E+002	1.105E-003	2.485E-005	1.151E-003	-4.18 %	1.151E-003	-4.17 %	1.143E-003	-3.41 %
3.443E+002	8.668E-004	8.175E-006	8.654E-004	0.17 %	8.653E-004	0.17 %	8.626E-004	0.49 %
4.111E+002	8.097E-004	5.015E-005	7.390E-004	8.74 %	7.390E-004	8.74 %	7.424E-004	8.32 %
4.440E+002	7.315E-004	3.472E-005	6.903E-004	5.63 %	6.903E-004	5.63 %	6.961E-004	4.85 %
7.780E+002	4.318E-004	8.934E-006	4.382E-004	-1.48 %	4.382E-004	-1.47 %	4.446E-004	-2.95 %
8.674E+002	4.180E-004	2.106E-005	4.053E-004	3.04 %	4.052E-004	3.04 %	4.091E-004	2.12 %
9.641E+002	3.794E-004	7.380E-006	3.762E-004	0.84 %	3.762E-004	0.84 %	3.775E-004	0.50 %
1.086E+003	3.435E-004	7.133E-006	3.457E-004	-0.64 %	3.457E-004	-0.64 %	3.447E-004	-0.34 %
1.112E+003	3.373E-004	7.344E-006	3.399E-004	-0.76 %	3.399E-004	-0.76 %	3.385E-004	-0.36 %
1.408E+003	2.830E-004	4.676E-006	2.821E-004	0.30 %	2.821E-004	0.30 %	2.815E-004	0.52 %

Dual

$\ln(\text{eff}) = 125.58 - 132.962 * \ln(E) + 51.6697 * (\ln(E))^2 - 9.71828 * (\ln(E))^3 + 0.887749 * (\ln(E))^4 - 0.0316986 * (\ln(E))^5$

where E = Energy in keV

User: David Georgeson

Database: InVivo Server: 127.0.0.1

Interpolated

Linear

$$\log(\text{eff}) = -0.000149837 * E - 3.48852 + 226.571 / E - 24386.4 / E^2 + 999396 / E^3 - 1.32987e+07 / E^4$$

Empirical

$$\ln(\text{eff}) = -7.6726 + 0.751366 * x + 0.143931 * x^2 + 0.0741517 * x^3 - 0.154391 * x^4 + 0.0316986 * x^5$$

where $x = \ln(717.17 / E)$

Appendix E

High Energy Lung Calibration Count Reanalysis

Appendix E

High Energy Lung Calibration Count Reanalysis

Summary

Reanalysis of the Calibration Count

Arrangement/Geometry: High Energy Lung

Analysis Library: Am241/Eu152 CWI Lung Set.NLB

Energy Calibration Time: 4/5/2011 8:18 AM

Efficiency Calibration Time: 4/5/2011 4:05 PM

Count Type/Live Time: 7226.91 seconds

Count Start Times: 4/5/2011 2:02 PM

Nuclide	Energy	Expected	Count Results	Relative
Energy	Energy	Activity		Bias
(keV)	keV	(nCi)	(nCi)	
Am-241	26.44	1218.1	1242	0.02
	59.69	1218.1	1256.6	0.03
Eu-152	121.84	253.78	256.6	0.01
	244.61	253.78	245.9	-0.03
	344.18	253.78	257.1	0.01
	410.97	253.78	265.9	0.05
	443.78	253.78	267.9	0.06
	778.69	253.78	250.9	-0.01
	867.1	253.78	263.4	0.04
	963.82	253.78	254.9	0
	1085.67	253.78	251.5	-0.01
	1111.89	253.78	248.7	-0.02
	1408.06	253.78	254.4	0
			Average	0.011538

Analysis Report - Calibration Count 4/5/2011 2:02 PM

COUNTER INFORMATION

Counter Name Accuscan II
Counter Location Battelle
Configuration Name Lung - High Energy

COUNT INFORMATION

Count Operation Calibration Count
Comment
Intake Date
Acquisition Started 4/5/2011 2:02:02 PM
Acquisition Time 7226.91
Operator Name David Georgeson
Count Status Not Reviewed
Primary Review No
Secondary Review No

DETECTOR COUNT RATE REPORT

Detector Name	Count Rate	Count Rate	Live Time	Analyzed	Analyzed Date	File Name
Left	80.44	1 - 4096	7200.0	Yes	4/5/2011 2:01:56 PM	b35455fe1401.cnf
Right	83.42	1 - 4096	7200.0	Yes	4/5/2011 2:01:56 PM	44abf7001401.cnf
Summed	0.00	1 - 4096	7200.0	Yes	4/27/2011 9:25:00 AM	0514db5c1401.cnf

Primary Review by: _____

Secondary Review by: _____

Date: _____

Date: _____

DETECTOR GROUP INFORMATION

Detector Group Name Left
Detector Group Configuration Lung Screening
Analysis Date 4/5/2011 2:01:56 PM
Energy Calibration
Efficiency Calibration
Multi Curve
Source Distribution Lung
Analysis Sequence File QCPEAKBE.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library
Tentative NID Library
Peak Search Library
Analysis Limits (channels) 100 - 4095
Energy Tolerance (FWHM) 0.40
Comment

PEAK SEARCH RESULTS FOR Accuscan II <Left>

Peak Analysis						Nuclide Information			
	No	Peak Centroid	Energy (keV)	Net Peak Area	Continuum Counts	Nuclide Name	Activity (nCi)	Error (1SD)	Yield (%)
F	1	108.12	49.71	2.08E+003	2.56E+004	Unknown			100.00
F	2	129.50	59.59	7.31E+004	2.32E+004	Unknown			100.00
F	3	264.14	121.79	1.52E+004	8.98E+003	Unknown			100.00
F	4	530.00	244.62	2.80E+003	2.70E+003	Unknown			100.00
F	5	745.65	344.24	7.70E+003	1.14E+003	Unknown			100.00
F	6	796.44	367.71	2.24E+002	7.03E+002	Unknown			100.00
F	7	890.29	411.07	5.64E+002	8.11E+002	Unknown			100.00
F	8	961.43	443.93	7.56E+002	6.63E+002	Unknown			100.00
F	9	1686.45	778.90	1.91E+003	4.52E+002	Unknown			100.00
F	10	1877.88	867.34	5.96E+002	3.68E+002	Unknown			100.00
F	11	2087.03	963.98	1.85E+003	2.47E+002	Unknown			100.00
F	12	2350.58	1085.75	1.06E+003	3.40E+002	Unknown			100.00
F	13	2407.37	1111.98	1.53E+003	2.86E+002	Unknown			100.00
F	14	2625.26	1212.66	1.38E+002	1.40E+002	Unknown			100.00
F	15	2812.42	1299.13	1.88E+002	6.15E+001	Unknown			100.00
F	16	3047.97	1407.97	1.94E+003	6.77E+001	Unknown			100.00
F	17	3162.47	1460.87	2.69E+002	7.77E+001	Unknown			100.00

For unknown peaks we assume yield to be 100% and no decay correction is performed.

M = First peak in a multiplet region

m = Other peak in a multiplet region

F = Fitted singlet

DETECTOR GROUP INFORMATION

Detector Group Name Right
Detector Group Configuration Lung Screening
Analysis Date 4/5/2011 2:01:56 PM
Energy Calibration
Efficiency Calibration
Multi Curve
Source Distribution Lung
Analysis Sequence File QCPEAKBE.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library
Tentative NID Library
Peak Search Library
Analysis Limits (channels) 100 - 4095
Energy Tolerance (FWHM) 0.40
Comment

PEAK SEARCH RESULTS FOR Accuscan II <Right>

Peak Analysis						Nuclide Information			
	No	Peak Centroid	Energy (keV)	Net Peak Area	Continuum Counts	Nuclide Name	Activity (nCi)	Error (1SD)	Yield (%)
F	1	129.55	59.59	7.46E+004	1.46E+004	Unknown			100.00
F	2	264.22	121.79	1.54E+004	5.59E+003	Unknown			100.00
F	3	530.27	244.67	2.91E+003	1.67E+003	Unknown			100.00
F	4	745.83	344.24	7.80E+003	8.75E+002	Unknown			100.00

F	5	796.65	367.72	2.41E+002	5.92E+002	Unknown			100.00
F	6	890.47	411.06	5.37E+002	6.35E+002	Unknown			100.00
F	7	961.68	443.95	7.01E+002	5.89E+002	Unknown			100.00
F	8	1686.74	778.90	1.86E+003	3.38E+002	Unknown			100.00
F	9	1878.07	867.29	5.88E+002	4.16E+002	Unknown			100.00
F	10	2087.42	964.01	1.83E+003	2.25E+002	Unknown			100.00

User: David Georgeson

Database: InVivo Server: 127.0.0.1

PEAK SEARCH RESULTS FOR Accuscan II <Right>

Peak Analysis						Nuclide Information			
	No	Peak Centroid	Energy (keV)	Net Peak Area	Continuum Counts	Nuclide Name	Activity (nCi)	Error (1SD)	Yield (%)
M	11	2351.06	1085.82	1.14E+003	1.49E+002	Unknown			100.00
m	12	2359.42	1089.68	2.06E+002	1.89E+002	Unknown			100.00
F	13	2407.79	1112.03	1.50E+003	2.24E+002	Unknown			100.00
F	14	2626.12	1212.91	1.76E+002	1.12E+002	Unknown			100.00
F	15	2812.93	1299.23	1.79E+002	6.25E+001	Unknown			100.00
F	16	3048.57	1408.12	1.94E+003	8.45E+001	Unknown			100.00
F	17	3162.79	1460.90	2.88E+002	7.21E+001	Unknown			100.00

For unknown peaks we assume yield to be 100% and no decay correction is performed.

M = First peak in a multiplet region

m = Other peak in a multiplet region

F = Fitted singlet

DETECTOR GROUP INFORMATION

Detector Group Name	Summed
Detector Group Configuration	Lung Screening
Analysis Date	4/27/2011 9:25:00 AM
Energy Calibration	Energy Calibration (HE Lung) 4/5/2011 8:18 AM
Efficiency Calibration	Eff. Calibration (HE Lung Realistic) 4/5/2011 4:05 PM (Dual)
Multi Curve	No
Source Distribution	Lung
Analysis Sequence File	ROUNPPGE.ASF
Bkg Acq used for area correction	Not Performed

Nuclide Identification

Nuclide Identification Library	Am241/Eu152 CWI Lung Set
Tentative NID Library	Am241/Eu152 CWI Lung Set
Peak Search Library	Am241/Eu152 CWI Lung Set
Analysis Limits (channels)	40 - 4095
Energy Tolerance (FWHM)	1.20
Comment	

User: David Georgeson

Database: InVivo Server: 127.0.0.1

PEAK SEARCH RESULTS FOR Accuscan II <Summed>

Peak Analysis						Nuclide Information			
	No	Peak Centroid	Energy (keV)	Net Peak Area	Continuum Counts	Nuclide Name	Activity (nCi)	Error (1SD)	Yield (%)
	1	45.85	21.08	5.71E+002	6.96E+003	Unknown	1.527294E+ 000		100.00
M	2	57.47	26.44	8.29E+003	7.74E+003	Am-241	1.241986E+ 000	1.99 %	2.40
m	3	65.33	30.07	1.75E+003	1.13E+004	Unknown	6.689168E+ 000		100.00
M	4	79.65	36.68	4.52E+003	2.68E+004	Unknown	1.713211E+ 000		100.00
m	5	86.83	39.99	3.75E+004	4.27E+004	Unknown	1.378703E+ 000		100.00
M	6	98.91	45.57	7.63E+003	3.92E+004	Unknown	2.631127E+ 000		100.00
m	7	107.47	49.52	3.31E+003	6.13E+004	Unknown	1.089826E+ 000		100.00
	8	129.51	59.69	1.48E+005	3.44E+004	Am-241	1.215659E+ 000	0.52 %	35.70
	9	264.14	121.84	3.08E+004	1.37E+004	EU-152	2.565976E+ 000	1.45 %	28.40
	10	530.07	244.61	5.65E+003	3.79E+003	EU-152	2.458505E+ 000	3.11 %	7.49
	11	745.70	344.18	1.58E+004	1.74E+003	EU-152	2.570705E+ 000	1.38 %	26.60
	12	796.56	367.67	3.74E+002	1.42E+003	Unknown	1.718182E+ 000		100.00
	13	890.33	410.97	1.15E+003	1.44E+003	EU-152	2.648766E+ 000	7.47 %	2.21
	14	961.39	443.78	1.53E+003	1.20E+003	EU-152	2.678836E+ 000	5.39 %	3.11
	15	1221.52	563.93	3.18E+002	1.11E+003	Unknown	2.123933E+ 000		100.00
	16	1469.08	678.29	2.18E+002	6.50E+002	Unknown	1.685309E+ 000		100.00
	17	1491.10	688.46	3.17E+002	9.26E+002	Unknown	2.477440E+ 000		100.00
	18	1557.36	719.07	1.08E+002	6.56E+002	Unknown	8.741767E- 000		100.00
	19	1686.41	778.69	3.81E+003	8.08E+002	EU-152	2.509298E+ 000	2.56 %	13.00
	20	1822.56	841.60	1.20E+002	5.68E+002	Unknown	1.091253E+ 000		100.00
	21	1877.75	867.10	1.18E+003	8.03E+002	EU-152	2.633928E+ 000	6.08 %	4.16
	22	1990.44	919.18	9.74E+001	3.74E+002	Unknown	9.402959E- 000		100.00
	23	2087.04	963.82	3.70E+003	5.12E+002	EU-152	2.548510E+ 000	2.40 %	14.50
	24	2176.36	1005.10	1.92E+002	4.42E+002	Unknown	1.978180E+ 000		100.00
M	25	2350.69	1085.67	2.36E+003	3.19E+002	EU-152	2.515171E+ 000	2.31 %	10.20
m	26	2358.89	1089.46	4.06E+002	3.42E+002	Unknown	4.418480E+ 000		100.00
	27	2407.42	1111.89	3.05E+003	5.11E+002	EU-152	2.486969E+ 000	2.64 %	13.55
	28	2625.59	1212.75	3.02E+002	2.96E+002	Unknown	3.553563E+ 000		100.00
	29	2812.20	1299.02	3.49E+002	1.77E+002	Unknown	4.340987E+ 000		100.00
	30	3048.02	1408.06	3.99E+003	1.17E+002	EU-152	2.542381E+ 000	2.33 %	20.90
	31	3162.42	1460.95	6.27E+002	1.41E+002	Unknown	8.631526E+ 000		100.00
	32	3308.00	1528.28	3.68E+001	4.92E+001	Unknown	5.281573E- 000		100.00
	33	3820.02	1765.11	7.85E+001	4.85E+001	Unknown	1.319411E+ 000		100.00

For unknown peaks we assume yield to be 100% and no decay correction is performed.

M = First peak in a multiplet region

m = Other peak in a multiplet region

F = Fitted singlet

NUCLIDE RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Id Confidence	Wt Mean Activity (nCi)	Error (1SD)	Action Level 1	Action Level 2	MDA (nCi)
	EU-152	0.999	2.545804E+00	0.70 %	Not Performed	Not Performed	3.770E+000
	Am-241	0.999	1.217271E+00	0.50 %			8.264E+000

User: David Georgeson

Database: InVivo Server: 127.0.0.1

? = Nuclide is part of an undetermined solution

X = Nuclide rejected by the interference analysis

@ = Nuclide contains energy lines not used in Weighted Mean Activity

! = Nuclide was corrected for parent/daughter

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Energy (keV)	Yield (%)	Line MDA (nCi)	Nuclide MDA (nCi)	Activity (nCi)
+	EU-152	121.78 *	28.40	5.7831E+000	3.7696E+000	2.5660E+002
+		244.70 *	7.49	1.5430E+001		2.4585E+002
+		344.28 *	26.60	4.3428E+000		2.5707E+002
+		411.10 *	2.21	4.1981E+001		2.6488E+002
+		443.97 *	3.11	2.9096E+001		2.6788E+002
+		778.90 *	13.00	9.5153E+000		2.5093E+002
+		867.40 *	4.16	3.2034E+001		2.6339E+002
+		964.13 *	14.50	8.1094E+000		2.5485E+002
+		1086.00 *	10.20	6.2626E+000		2.5152E+002
+		1112.12 *	13.55	9.6235E+000		2.4870E+002
+		1408.01 *	20.90	3.7696E+000		2.5424E+002
+	Am-241	26.30 *	2.40	4.3428E+001	8.2644E+000	1.2420E+003
+		59.54 *	35.70	8.2644E+000		1.2157E+003

+ = Nuclide Identified during the nuclide identification

* = Energy Line found in the spectrum

Appendix F

Accuscan II High Energy Lung Calibration Verification

Appendix F

Accuscan-II High Energy Lung Calibration Verification

Page 1 of 2
Created 4/26/2011 4:35:40 PM
Idaho Falls Id.
Battelle Energy Alliance LLC

Efficiency Verification

Calibration Information

Calibration Title Eff. Calibration (HE Lung Realistic)4/5/2011 4:05 PM
Calibration Date 4/5/2011 4:03:37 PM
Operator Name David Georgeson
Detector Group Summed
Detector Group Lung Screening
Source Distribution Lung

Counter Information

Counter Name Accuscan II
Counter Location Battelle
Counter Lung - High Energy

Count List

<u>Num</u>	<u>Date</u>	<u>Name</u>
1	4/6/2011	Verification Count 4/6/2011 11:57 AM (1/5)
2	4/6/2011	Verification Count 4/6/2011 11:57 AM (2/5)
3	4/6/2011	Verification Count 4/6/2011 11:57 AM (3/5)
4	4/6/2011	Verification Count 4/6/2011 11:57 AM (4/5)
5	4/6/2011	Verification Count 4/6/2011 11:57 AM (5/5)

User: David Georgeson

Database: InVivo Server: 127.0.0.1

Source Certificate Am241/Eu152 CWI Lung Set

Nuclide	Energy	Certificate Activity (g/s)	Half Life	Count 1	Count 2	Count 3	Count 4	Count 5	Relative Bias (%)	Relative Precision (%)
Am-241	26.34	1110.00	432.19 y	1016.09 1083.84	1145.33 1083.84	1307.94 1083.84	1073.65 1083.84	1154.98 1083.84	5.14 %	9.06 %
Am-241	59.54	16500.00	432.19 y	16413.18 16111.21	16023.05 16111.21	16366.68 16111.21	16520.87 16111.20	16322.24 16111.20	1.35 %	1.03 %
EU-152	121.83	5710.00	4946.22 d	2641.94 2667.67	2646.89 2667.67	2518.99 2667.66	2837.34 2667.66	2652.13 2667.65	-0.31 %	3.82 %
EU-152	244.70	1510.00	4946.22 d	836.12 705.46	744.21 705.46	679.54 705.46	695.02 705.46	608.73 705.46	1.03 %	10.69 %
EU-152	344.28	5350.00	4946.22 d	2460.29 2499.48	2579.14 2499.48	2169.32 2499.48	2454.12 2499.47	2378.46 2499.47	-3.65 %	5.43 %
EU-152	411.10	444.00	4946.22 d	151.16 207.43	268.12 207.43	265.65 207.43	168.20 207.43	172.47 207.43	-1.12 %	24.56 %
EU-152	443.97	625.00	4946.22 d	232.98 292.00	339.83 292.00	283.14 291.99	364.50 291.99	305.83 291.99	4.54 %	15.63 %
EU-152	778.00	2610.00	4946.22 d	1389.23 1219.37	998.63 1219.37	1182.95 1219.37	1345.13 1219.37	1284.97 1219.37	1.71 %	11.41 %
EU-152	867.40	836.00	4946.22 d	371.09 390.57	253.38 390.57	412.66 390.57	428.77 390.57	296.17 390.57	-9.77 %	17.28 %
EU-152	964.10	2910.00	4946.22 d	1516.45 1359.53	1431.85 1359.53	1376.08 1359.53	1396.82 1359.52	1305.95 1359.52	3.38 %	5.08 %
EU-152	1086.00	2050.00	4946.22 d	808.41 957.75	907.99 957.74	698.91 957.74	772.01 957.74	892.63 957.74	-14.80 %	8.09 %
EU-152	1112.00	2720.00	4946.22 d	1177.78 1270.77	1206.34 1270.76	1325.15 1270.76	1123.22 1270.76	1067.97 1270.76	-7.14 %	6.82 %
EU-152	1408.00	4200.00	4946.22 d	1976.29 1962.21	2032.22 1962.21	2067.48 1962.21	2005.11 1962.20	1839.92 1962.20	1.12 %	3.98 %
xbar =									4.23 %	9.45 %

For each count, the number on the top is the observed activity and the number on the bottom is the expected activity.

References:

Draft American National Standard, Performance Criteria for Radiobioassay, ANSI N13.30
Certificate of Calibration, Standard Radionuclide Source, Analytics

Appendix G

MDA Determination

Appendix G

MDA Determination

MDA Calculations for High Energy Lung

Arrangement Geometry: High Energy Lung

Analysis Library: INLPLANTLIB.NLB

Energy Calibration Time: 4/5/2011 8:18 AM

Efficiency Calibration Time: 4/5/2011 4:05 PM

Count Live Time: 600 Seconds

Count Start Times:

1. 4/6/11 4:13 PM
2. 4/6/11 4:25 PM
3. 4/6/11 4:36 PM

$$\text{MDA} = (4.65\text{Sb} + 3)/\text{KT}$$

Where:

Sb = Standard deviation of the blank phantom counts = SQRT
(gross rate (CPS) x routine counting time)

K = Efficiency X Abundance X 37 Bq/nCi

T = Routine counting time in seconds = 600 seconds

MDA Calculated From Phantom Data

Nuclide	Count #1 nCi	Count #2 nCi	Count #3 nCi	Average MDA nCi
K-40	42.501	50.186	4.641	32.4
Cr-51	16.81	15.347	14.957	15.7
Mn-54	2.207	2.207	2.0673	2.2
Co-57	3.2975	3.1373	3.0256	3.2
Co-58	2.6436	2.4218	2.3016	2.5
Fe-59	4.4446	3.757	3.2915	3.8
Co-60	1.9839	1.8735	1.6957	1.9
Zn-65	3.77664	6.2281	5.9488	5.3
Nb-95	2.199	1.8024	2.0767	2.0
Zr-95	3.9342	3.4803	3.4803	3.6
Ru-106	23.623	24.415	24.415	24.2
Ag-110m	1.8338	2.6492	2.5633	2.3
I-131	2.4636	2.4197	2.5067	2.5
I-133	1.9027	2.4317	2.2709	2.2
Cs-134	1.8758	1.761	2.6834	2.1
Cs-137	2.8555	3.304	2.6524	2.9
Ba-140	6.9931	9.5074	8.2184	8.2
La-140	1.8059	2.3195	1.8059	2.0
Ce-141	5.0959	5.4244	5.2862	5.3
Ce-144	23.401	25.41	25.596	24.8
Eu-152	8.01	6.6483	6.2201	7.0

Analysis Report - Lung Test [999-99-9996]

SOURCE INFORMATION

Primary ID 999-99-9996
Last Name Test
First Name Lung
Height (in)
Weight (lb)
Chest Wall Thickness (cm)

COUNTER INFORMATION

Counter Name Accuscan II
Counter Location Battelle
Configuration Name Lung - High Energy

COUNT INFORMATION

Count Operation Individual 10 minutes
Count Reason Routine operation
Frequency
Comment Lung MDA Count #1
Intake Date
Acquisition Started 4/6/2011 4:13:10 PM
Acquisition Time 601.47
Operator Name David Georgeson
Count Status Not Reviewed
Primary Review No
Secondary Review No

DETECTOR COUNT RATE REPORT

Detector Name	Count Rate	Count Rate	Live Time	Analyzed	Analyzed Date	File Name
Left	16.12	1 - 4096	600.0	No		ef0a51021613.cnf
Right	17.30	1 - 4096	600.0	No		aac71c231613.cnf
Summed	33.37	1 - 4096	600.0	Yes	4/6/2011 4:13:01 PM	5b8312b31613.cnf

Primary Review by: _____

Secondary Review by: _____

Date: _____

Date: _____

DETECTOR GROUP INFORMATION

Detector Group Name Summed
Detector Group Configuration Lung Screening
Analysis Date 4/6/2011 4:13:01 PM
Energy Calibration Energy Calibration (HE Lung) 4/5/2011 8:18 AM
Efficiency Calibration Eff. Calibration (HE Lung Realistic) 4/5/2011 4:05 PM (Dual)
Multi Curve No
Source Distribution Lung
Analysis Sequence File ROUNPPGE.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library INLPLANTLIB.NLB
Tentative NID Library INLPLANTLIB.NLB
Peak Search Library INLPLANTLIB.NLB
Analysis Limits (channels) 40 - 4095
Energy Tolerance (FWHM) 1.20

Comment**PEAK SEARCH RESULTS FOR Accuscan II <Summed>**

Peak Analysis						Nuclide Information			
No	Peak Centroid	Energy (keV)	Net Peak Area	Continuum Counts		Nuclide Name	Activity (nCi)	Error (1SD)	Yield (%)
1	3162.11	1460.82	5.25E+001	6.50E+000		K-40	8.121071E+001	17.19 %	10.67

For unknown peaks we assume yield to be 100% and no decay correction is performed.

M = First peak in a multiplet region

m = Other peak in a multiplet region

F = Fitted singlet

NUCLIDE RESULTS FOR Accuscan II <Summed>

Nuclide Name	Id Confidence	Wt Mean Activity (nCi)	Error (1SD)	Action Level 1	Action Level 2	MDA (nCi)
K-40	1.000	8.121071E+001	17.19 %	Not Performed	Not Performed	4.250E+001

? = Nuclide is part of an undetermined solution

X = Nuclide rejected by the interference analysis

@ = Nuclide contains energy lines not used in Weighted Mean Activity

! = Nuclide was corrected for parent/daughter

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Energy (keV)	Yield (%)	Line MDA (nCi)	Nuclide MDA (nCi)	Activity (nCi)
+	K-40	1460.81 *	10.67	4.2501E+001	4.2501E+001	8.1211E+001
	CR-51	320.08	9.83	1.6810E+001	1.6810E+001	-3.3864E+000
	MN-54	834.83	99.97	2.2070E+000	2.2070E+000	-8.9644E-001
	CO-57	122.06	85.51	3.2975E+000	3.2975E+000	-1.9838E-001
		136.48	10.60	2.3105E+001		-1.1639E+001
	CO-58	810.76	99.40	2.6436E+000	2.6436E+000	2.0342E-001
	FE-59	142.65	1.03	2.3890E+002	4.4446E+000	2.8436E+001
		192.34	3.11	6.8361E+001		-2.1492E+001
		1099.22	56.50	4.4446E+000		-4.6520E-001

		1291.56	43.20	6.5678E+000		5.1558E-001
	CO-60	1173.22	100.00	1.9839E+000	1.9839E+000	-6.8933E-002
		1332.49	100.00	2.4602E+000		-4.1886E-001
	ZN-65	1115.52	50.75	3.7664E+000	3.7664E+000	-1.5704E+000
	NB-95	765.79	99.81	2.1990E+000	2.1990E+000	-6.0447E-001
	ZR-95	724.18	43.70	5.5354E+000	3.9342E+000	-3.8537E-001
		756.72	55.30	3.9342E+000		-2.7321E-001

User: David Georgeson

Database: InVivo Server: 127.0.0.1

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Energy (keV)	Yield (%)	Line MDA (nCi)	Nuclide MDA (nCi)	Activity (nCi)
	RU-106	621.84	9.80	2.3623E+001	2.3623E+001	7.4155E+000
		1050.47	1.73	1.1878E+002		2.5737E+001
	AG-110M	446.80	3.64	6.2256E+001	1.8338E+000	-1.6419E+001
		620.35	2.77	8.3417E+001		7.8075E+000
		657.75	94.40	1.8338E+000		-5.0383E-001
		677.61	10.68	2.5434E+001		2.4953E+000
		686.99	6.47	2.9537E+001		-7.4467E+000
		706.67	16.68	1.5326E+001		1.1917E+000
		744.26	4.64	3.0857E+001		-6.4329E+000
		763.93	22.28	1.0348E+001		9.1058E-001
		818.02	7.30	3.1539E+001		1.3689E+000
		884.67	72.60	3.3538E+000		-2.9113E-002
		937.48	34.20	6.5604E+000		-5.1500E-001
		1384.27	24.26	9.3312E+000		-5.4037E-001
		1475.76	3.97	4.0190E+001		-1.4689E+001
		1505.00	13.06	1.2444E+001		0.0000E+000
		1562.27	1.18	1.4288E+002		-5.2223E+001
	I-131	80.18	2.62	1.2173E+002	2.4636E+000	-6.9453E+000
		284.30	6.05	2.9737E+001		1.0409E+001
		364.48	81.20	2.4636E+000		1.3747E-001
		636.97	7.26	2.4824E+001		-3.8246E+000
		722.89	1.80	1.3421E+002		1.6965E+001
	I-133	529.87	86.30	1.9027E+000	1.9027E+000	-3.0830E-001
		875.33	4.47	5.6887E+001		9.8727E+000
	CS-134	475.35	1.46	1.4287E+002	1.8758E+000	-2.2047E+001
		563.23	8.38	2.8747E+001		4.7450E+000
		569.32	15.43	1.5751E+001		4.3228E+000
		604.70	97.60	1.8758E+000		-6.5132E-002
		795.84	85.40	2.1666E+000		3.6713E-001
		801.93	8.73	3.2147E+001		6.9899E+000
		1038.57	1.00	2.5744E+002		-1.2620E+001
		1167.94	1.80	1.7348E+002		1.7810E+001
		1365.15	3.04	6.2894E+001		-5.3690E+001
	CS-137	661.65	85.12	2.8555E+000	2.8555E+000	2.6726E-001
	BA-140	162.64	6.70	3.7456E+001	6.9931E+000	4.7712E+000
		304.84	4.50	4.1816E+001		1.3718E+001
		423.70	3.20	5.2260E+001		3.3110E+000
		437.55	2.00	8.8916E+001		-3.2670E+001

		537.32	25.00	6.9931E+000		-1.6923E+000
	LA-140	328.77	20.50	8.5857E+000	1.8059E+000	2.7428E-001
		432.53	2.94	5.9868E+001		1.0921E+001
		487.03	45.50	5.1518E+000		1.3401E+000
		751.79	4.40	3.2785E+001		-6.4552E+000
		815.85	23.50	9.7791E+000		-1.9807E-001
		867.82	5.63	3.1898E+001		-5.9245E+000
		919.63	2.88	7.1209E+001		-1.4077E+001

User: David Georgeson

Database: InVivo Server: 127.0.0.1

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Energy (keV)	Yield (%)	Line MDA (nCi)	Nuclide MDA (nCi)	Activity (nCi)
	LA-140	925.24	7.09	2.9048E+001	1.8059E+000	-3.2815E+000
		1596.49	95.49	1.8059E+000		1.8858E-001
	CE-141	145.44	48.40	5.0959E+000	5.0959E+000	7.1776E-002
	CE-144	80.11	1.60	1.9941E+002	2.3401E+001	-1.1377E+001
		133.54	10.80	2.3401E+001		1.2105E-001
	EU-152	121.78	28.40	1.0016E+001	8.0100E+000	4.8692E+000
		244.69	7.49	2.5366E+001		-1.5236E+000
		344.27	26.50	8.0100E+000		-3.5716E-001
		411.11	2.21	9.5256E+001		1.7387E+001
		443.98	3.11	6.6431E+001		-1.0159E+001
		778.89	12.74	1.6473E+001		1.6151E+000
		867.32	4.16	4.3153E+001		-1.0019E+001
		964.01	14.40	1.5889E+001		3.2568E+000
		1085.78	10.00	2.4894E+001		3.2569E+000
		1112.02	13.30	2.1522E+001		4.3592E+000
		1407.95	20.70	9.4862E+000		-1.9281E+000

+ = Nuclide Identified during the nuclide identification

* = Energy Line found in the spectrum

Analysis Report - Lung Test [999-99-9996]

SOURCE INFORMATION

Primary ID 999-99-9996
Last Name Test
First Name Lung
Height (in)
Weight (lb)
Chest Wall Thickness (cm)

COUNTER INFORMATION

Counter Name Accuscan II
Counter Location Battelle
Configuration Name Lung - High Energy

COUNT INFORMATION

Count Operation Individual 10 minutes
Count Reason Routine operation
Frequency
Comment Lung MDA Count #2
Intake Date
Acquisition Started 4/6/2011 4:25:09 PM
Acquisition Time 601.35
Operator Name David Georgeson
Count Status Not Reviewed
Primary Review No
Secondary Review No

DETECTOR COUNT RATE REPORT

Detector Name	Count Rate	Count Rate Range	Live Time	Analyzed	Analyzed Date	File Name
Right	17.65	1 - 4096	600.0	No		7bf99bdf1625.cnf
Left	15.93	1 - 4096	600.0	No		d129dcf51625.cnf
Summed	33.57	1 - 4096	600.0	Yes	4/6/2011 4:25:01	7ba6552a1625.cnf

Primary Review by: _____

Secondary Review by: _____

Date: _____

Date: _____

User: David Georgeson

Database: InVivo Server: 127.0.0.1

DETECTOR GROUP INFORMATION

Detector Group Name Summed
Detector Group Configuration Lung Screening
Analysis Date 4/6/2011 4:25:01 PM
Energy Calibration Energy Calibration (HE Lung) 4/5/2011 8:18 AM
Efficiency Calibration Eff. Calibration (HE Lung Realistic) 4/5/2011 4:05 PM (Dual)
Multi Curve No
Source Distribution Lung
Analysis Sequence File ROUNPPGE.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library INLPLANTLIB.NLB
Tentative NID Library INLPLANTLIB.NLB
Peak Search Library INLPLANTLIB.NLB
Analysis Limits (channels) 40 - 4095
Energy Tolerance (FWHM) 1.20

Comment**PEAK SEARCH RESULTS FOR Accuscan II <Summed>**

Peak Analysis						Nuclide Information			
No	Peak Centroid	Energy (keV)	Net Peak Area	Continuum Counts	Nuclide Name	Activity (nCi)	Error (1SD)	Yield (%)	
1	3161.97	1460.75	3.85E+001	9.51E+000	K-40	5.953245E+001	23.13 %	10.67	

For unknown peaks we assume yield to be 100% and no decay correction is performed.

M = First peak in a multiplet region

m = Other peak in a multiplet region

F = Fitted singlet

NUCLIDE RESULTS FOR Accuscan II <Summed>

Nuclide Name	Id Confidence	Wt Mean Activity (nCi)	Error (1SD)	Action Level 1	Action Level 2	MDA (nCi)
K-40	1.000	5.953245E+001	23.13 %	Not Performed	Not Performed	5.019E+001

? = Nuclide is part of an undetermined solution

X = Nuclide rejected by the interference analysis

@ = Nuclide contains energy lines not used in Weighted Mean Activity

! = Nuclide was corrected for parent/daughter

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Energy (keV)	Yield (%)	Line MDA (nCi)	Nuclide MDA (nCi)	Activity (nCi)
+	K-40	1460.81 *	10.67	5.0186E+001	5.0186E+001	5.9532E+001
	CR-51	320.08	9.83	1.5347E+001	1.5347E+001	-1.9591E+000
	MN-54	834.83	99.97	2.2070E+000	2.2070E+000	-3.7867E-001
	CO-57	122.06	85.51	3.1373E+000	3.1373E+000	5.0330E-001
		136.48	10.60	2.4432E+001		-2.2843E+000
	CO-58	810.76	99.40	2.4218E+000	2.4218E+000	2.1311E-001
	FE-59	142.65	1.03	2.4776E+002	3.7570E+000	2.4033E+001
		192.34	3.11	6.7599E+001		2.1597E+001
		1099.22	56.50	3.7570E+000		1.1630E-001

		1291.56	43.20	4.9461E+000		-1.1457E+000
	CO-60	1173.22	100.00	2.8123E+000	1.8735E+000	7.3857E-001
		1332.49	100.00	1.8735E+000		-3.8079E-001
	ZN-65	1115.52	50.75	6.2281E+000	6.2281E+000	2.8791E-001
	NB-95	765.79	99.81	1.8024E+000	1.8024E+000	-1.2217E+000
	ZR-95	724.18	43.70	5.7518E+000	3.4803E+000	2.2311E+000
		756.72	55.30	3.4803E+000		-1.8214E-001

User: David Georgeson

Database: InVivo Server: 127.0.0.1

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Energy (keV)	Yield (%)	Line MDA (nCi)	Nuclide MDA (nCi)	Activity (nCi)
	RU-106	621.84	9.80	2.4415E+001	2.4415E+001	4.4221E-001
		1050.47	1.73	1.5000E+002		3.3091E+001
	AG-110M	446.80	3.64	5.1317E+001	2.6492E+000	1.3159E+001
		620.35	2.77	8.3417E+001		-1.4414E+000
		657.75	94.40	2.6492E+000		5.0383E-001
		677.61	10.68	1.7705E+001		-2.1079E+000
		686.99	6.47	3.2910E+001		-4.7462E+000
		706.67	16.68	1.4236E+001		1.7475E+000
		744.26	4.64	4.6317E+001		-1.0185E+001
		763.93	22.28	9.8342E+000		9.1058E-001
		818.02	7.30	2.5852E+001		-1.4164E+001
		884.67	72.60	2.9669E+000		8.1516E-001
		937.48	34.20	7.0036E+000		1.1771E+000
		1384.27	24.26	1.0474E+001		-8.1056E-002
		1475.76	3.97	5.1622E+001		5.2461E+000
		1505.00	13.06	1.8700E+001		-7.7972E+000
		1562.27	1.18	2.1471E+002		1.4921E+001
	I-131	80.18	2.62	1.2795E+002	2.4197E+000	9.8526E+000
		284.30	6.05	2.9317E+001		9.1842E+000
		364.48	81.20	2.4197E+000		3.0751E-001
		636.97	7.26	3.5661E+001		-3.7268E+000
		722.89	1.80	1.1684E+002		-2.0285E+000
	I-133	529.87	86.30	2.4317E+000	2.4317E+000	-1.2521E+000
		875.33	4.47	5.6887E+001		1.4739E+001
	CS-134	475.35	1.46	1.2231E+002	1.7610E+000	7.1166E+000
		563.23	8.38	2.7177E+001		-5.1231E+000
		569.32	15.43	1.4890E+001		1.1507E+000
		604.70	97.60	2.1546E+000		3.4737E-001
		795.84	85.40	1.7610E+000		-1.2034E+000
		801.93	8.73	3.1028E+001		4.8142E+000
		1038.57	1.00	1.5523E+002		-4.1016E+001
		1167.94	1.80	1.2329E+002		1.3358E+001
		1365.15	3.04	9.7705E+001		3.0680E+001
	CS-137	661.65	85.12	3.3034E+000	3.3034E+000	4.2762E-001
	BA-140	162.64	6.70	3.5275E+001	9.5074E+000	3.1119E+000
		304.84	4.50	3.6632E+001		7.3680E+000
		423.70	3.20	5.7335E+001		3.9131E+000
		437.55	2.00	8.6033E+001		9.6628E+000

		537.32	25.00	9.5074E+000		7.9485E-001
	LA-140	328.77	20.50	8.9064E+000	2.3195E+000	8.0642E-001
		432.53	2.94	7.3399E+001		-2.2673E+000
		487.03	45.50	4.5561E+000		-8.5998E-001
		751.79	4.40	5.4213E+001		1.1392E+000
		815.85	23.50	1.0773E+001		5.8856E-001
		867.82	5.63	3.7735E+001		6.5828E+000
		919.63	2.88	7.1209E+001		-5.6309E+000

User: David Georgeson

Database: InVivo Server: 127.0.0.1

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Energy (keV)	Yield (%)	Line MDA (nCi)	Nuclide MDA (nCi)	Activity (nCi)
	LA-140	925.24	7.09	3.7291E+001	2.3195E+000	1.2944E+001
		1596.49	95.49	2.3195E+000		-4.7145E-001
	CE-141	145.44	48.40	5.4244E+000	5.4244E+000	1.3594E-001
	CE-144	80.11	1.60	2.0959E+002	2.5410E+001	1.6140E+001
		133.54	10.80	2.5410E+001		7.4528E+000
	EU-152	121.78	28.40	9.3976E+000	6.6483E+000	-2.9954E-001
		244.69	7.49	2.4353E+001		-1.0519E+001
		344.27	26.50	6.6483E+000		6.4288E-001
		411.11	2.21	9.1388E+001		-1.3790E+001
		443.98	3.11	6.3178E+001		9.3174E+000
		778.89	12.74	1.5431E+001		1.0767E+000
		867.32	4.16	5.7708E+001		2.1373E+001
		964.01	14.40	2.2955E+001		8.1964E+000
		1085.78	10.00	2.6575E+001		-8.8403E+000
		1112.02	13.30	1.6094E+001		-1.6191E+000
		1407.95	20.70	1.3654E+001		2.0052E+000

+ = Nuclide Identified during the nuclide identification

* = Energy Line found in the spectrum

Analysis Report - Lung Test [999-99-9996]

SOURCE INFORMATION

Primary ID 999-99-9996
Last Name Test
First Name Lung
Height (in)
Weight (lb)
Chest Wall Thickness (cm)

COUNTER INFORMATION

Counter Name Accuscan II
Counter Location Battelle
Configuration Name Lung - High Energy

COUNT INFORMATION

Count Operation Individual 10 minutes
Count Reason Routine operation
Frequency
Comment Lung MDA Count #3
Intake Date
Acquisition Started 4/6/2011 4:36:01 PM
Acquisition Time 601.49
Operator Name David Georgeson
Count Status Not Reviewed
Primary Review No
Secondary Review No

DETECTOR COUNT RATE REPORT

Detector Name	Count Rate	Count Rate Range	Live Time	Analyzed	Analyzed Date	File Name
Left	16.01	1 - 4096	600.0	No		7bb7cef01635.cnf
Right	17.54	1 - 4096	600.0	No		cbaa1b691635.cnf
Summed	33.52	1 - 4096	600.0	Yes	4/6/2011 4:35:53 PM	6c28bddd1635.cnf

Primary Review by: _____ Secondary Review by: _____

Date: _____ Date: _____

User: David Georgeson

Database: InVivo Server: 127.0.0.1

DETECTOR GROUP INFORMATION

Detector Group Name Summed
Detector Group Configuration Lung Screening
Analysis Date 4/6/2011 4:35:53 PM
Energy Calibration Energy Calibration (HE Lung) 4/5/2011 8:18 AM
Efficiency Calibration Eff. Calibration (HE Lung Realistic) 4/5/2011 4:05 PM (Dual)
Multi Curve No
Source Distribution Lung
Analysis Sequence File ROUNPPGE.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library INLPLANTLIB.NLB
Tentative NID Library INLPLANTLIB.NLB
Peak Search Library INLPLANTLIB.NLB
Analysis Limits (channels) 40 - 4095
Energy Tolerance (FWHM) 1.20

Comment**PEAK SEARCH RESULTS FOR Accuscan II <Summed>**

Peak Analysis						Nuclide Information			
No	Peak Centroid	Energy (keV)	Net Peak Area	Continuum Counts		Nuclide Name	Activity (nCi)	Error (1SD)	Yield (%)
1	3162.20	1460.85	6.10E+001	0.00E+000		K-40	9.436748E+001	12.98 %	10.67

For unknown peaks we assume yield to be 100% and no decay correction is performed.

M = First peak in a multiplet region

m = Other peak in a multiplet region

F = Fitted singlet

NUCLIDE RESULTS FOR Accuscan II <Summed>

Nuclide Name	Id Confidence	Wt Mean Activity (nCi)	Error (1SD)	Action Level 1	Action Level 2	MDA (nCi)
K-40	1.000	9.436748E+00	12.98 %	Not Performed	Not Performed	4.641E+000

? = Nuclide is part of an undetermined solution

X = Nuclide rejected by the interference analysis

@ = Nuclide contains energy lines not used in Weighted Mean Activity

! = Nuclide was corrected for parent/daughter

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Energy (keV)	Yield (%)	Line MDA (nCi)	Nuclide MDA (nCi)	Activity (nCi)
+	K-40	1460.81 *	10.67	4.6410E+000	4.6410E+000	9.4367E+001
	CR-51	320.08	9.83	1.4957E+001	1.4957E+001	-4.3824E-001
	MN-54	834.83	99.97	2.0673E+000	2.0673E+000	-4.8686E-001
	CO-57	122.06	85.51	3.0256E+000	3.0256E+000	-1.2972E+000
		136.48	10.60	2.5101E+001		-2.8910E+000
	CO-58	810.76	99.40	2.3016E+000	2.3016E+000	-7.3255E-001
	FE-59	142.65	1.03	2.7126E+002	3.2915E+000	1.1047E+002
		192.34	3.11	7.6221E+001		2.4573E+001
		1099.22	56.50	4.7448E+000		4.8182E-001

		1291.56	43.20	3.2915E+000		-8.5929E-001
	CO-60	1173.22	100.00	1.6957E+000	1.6957E+000	-8.9613E-001
		1332.49	100.00	2.9104E+000		9.1389E-001
	ZN-65	1115.52	50.75	5.9488E+000	5.9488E+000	4.2168E-001
	NB-95	765.79	99.81	2.0767E+000	2.0767E+000	-4.7267E-001
	ZR-95	724.18	43.70	5.0708E+000	3.4803E+000	8.1806E-001
		756.72	55.30	3.4803E+000		-8.1962E-001

User: David Georgeson

Database: InVivo Server: 127.0.0.1

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Energy (keV)	Yield (%)	Line MDA (nCi)	Nuclide MDA (nCi)	Activity (nCi)
	RU-106	621.84	9.80	2.4415E+001	2.4415E+001	7.7386E+000
		1050.47	1.73	1.0582E+002		-1.2256E+001
	AG-110M	446.80	3.64	5.8419E+001	2.5633E+000	1.1717E+001
		620.35	2.77	7.7483E+001		-3.1230E+001
		657.75	94.40	2.5633E+000		1.3288E-001
		677.61	10.68	1.9727E+001		-3.6164E+000
		686.99	6.47	3.1276E+001		-2.8960E+000
		706.67	16.68	1.0964E+001		-2.1039E+000
		744.26	4.64	5.3201E+001		2.3392E+000
		763.93	22.28	1.0348E+001		2.5041E+000
		818.02	7.30	2.5852E+001		-1.5770E+001
		884.67	72.60	2.7490E+000		-3.5712E-001
		937.48	34.20	7.0036E+000		0.0000E+000
		1384.27	24.26	1.2391E+001		9.7267E-001
		1475.76	3.97	8.5611E+001		1.9486E+001
		1505.00	13.06	3.8986E+000		0.0000E+000
		1562.27	1.18	1.8353E+002		1.1191E+001
	I-131	80.18	2.62	1.2392E+002	2.5067E+000	2.8936E+001
		284.30	6.05	2.5682E+001		7.1104E+000
		364.48	81.20	2.5067E+000		1.3263E+000
		636.97	7.26	2.3253E+001		-5.4762E+000
		722.89	1.80	1.1684E+002		-6.0854E+000
	I-133	529.87	86.30	2.2709E+000	2.2709E+000	4.4043E-002
		875.33	4.47	4.0428E+001		1.0012E+001
	CS-134	475.35	1.46	1.4660E+002	2.6834E+000	5.2715E-001
		563.23	8.38	2.7177E+001		-2.5456E+000
		569.32	15.43	1.2446E+001		-8.3686E-001
		604.70	97.60	2.6834E+000		7.0439E-001
		795.84	85.40	3.0362E+000		6.6194E-001
		801.93	8.73	2.5997E+001		1.5044E+000
		1038.57	1.00	2.8684E+002		3.0149E+001
		1167.94	1.80	1.2329E+002		-7.6329E+001
		1365.15	3.04	8.2591E+001		-1.9175E+001
	CS-137	661.65	85.12	2.6524E+000	2.6524E+000	1.8465E-001
	BA-140	162.64	6.70	3.2369E+001	8.2184E+000	-9.1150E+000
		304.84	4.50	2.8715E+001		-6.2411E+000
		423.70	3.20	5.8919E+001		-4.7762E+000
		437.55	2.00	1.2759E+002		4.6496E+001

		537.32	25.00	8.2184E+000		1.0651E-001
	LA-140	328.77	20.50	7.1444E+000	1.8059E+000	-8.2283E-001
		432.53	2.94	7.1861E+001		2.7367E+000
		487.03	45.50	4.5561E+000		2.7208E-001
		751.79	4.40	4.9212E+001		1.3385E+001
		815.85	23.50	9.2352E+000		8.0846E-001
		867.82	5.63	3.4964E+001		2.3698E+000
		919.63	2.88	6.4966E+001		-4.0221E+000

User: David Georgeson

Database: InVivo Server: 127.0.0.1

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Energy (keV)	Yield (%)	Line MDA (nCi)	Nuclide MDA (nCi)	Activity (nCi)
	LA-140	925.24	7.09	3.9042E+001	1.8059E+000	4.9222E+000
		1596.49	95.49	1.8059E+000		1.8858E-001
	CE-141	145.44	48.40	5.2862E+000	5.2862E+000	2.4244E-001
	CE-144	80.11	1.60	2.0299E+002	2.5596E+001	4.7400E+001
		133.54	10.80	2.5596E+001		9.9842E+000
	EU-152	121.78	28.40	9.3976E+000	6.2201E+000	2.8961E+000
		244.69	7.49	2.6575E+001		4.1789E+000
		344.27	26.50	6.2201E+000		-3.1430E+000
		411.11	2.21	8.3055E+001		-1.2330E+001
		443.98	3.11	5.6038E+001		-2.3400E+000
		778.89	12.74	2.1570E+001		2.2984E+000
		867.32	4.16	4.3153E+001		-8.0149E+000
		964.01	14.40	2.1437E+001		4.4348E+000
		1085.78	10.00	2.9610E+001		5.2835E+000
		1112.02	13.30	1.6094E+001		1.9928E+000
		1407.95	20.70	1.2457E+001		-3.8562E-001

+ = Nuclide Identified during the nuclide identification

* = Energy Line found in the spectrum

Appendix H

Calibration Validation Using a DOE Manufactured BOMAB #MFP-1-001

Appendix H

Calibration Validation Using a DOE Manufactured BOMAB #MFP-1-001

SUMMARY

Calibration Validation Counts
Accuscan II High Energy Calibration for Lung Geometry

Arrangement/Geometry: Fixed Detectors
Analysis Library: Am-241/Eu-152 CWI Lung Set
Energy Calibration Date: 4/5/2011 8:18
Efficiency Calibration Date: 4/5/2011 4:05
Live Time: 600 seconds

Count Start Times:

Count # 1 - 4/5/2011 4:18 PM
Count # 2 - 4/6/2011 8:24
Count # 3 - 4/6/2011 8:47
Count # 4 - 4/6/2011 9:13
Count # 5 - 4/6/2011 9:35

Nuclide/ Energy (keV)	Expected Activity (nCi)	Observed Activity (nCi)					Relative Bias	Relative Precision
		#1	#2	#3	#4	#5		
Co-60	161.0000	162.53	162.91	162.86	160.15	159.3	0.003	0.011
Cs-137	398.0000	407.9	392.6	397.97	382.6	391.51	-0.009	0.023
Cs-134	53.2000	51.33	52.73	53.83	48.64	50.44	-0.034	0.038
Co-57	16.9000	11.690	19.140	16.530	15.220	18.880	-0.036	0.180
Mn-54	4.4000							
Average							-0.036	0.180

COUNT 1

Analysis Report - Lung Test [999-99-9996]

SOURCE INFORMATION

Primary ID 999-99-9996
Last Name Test
First Name Lung
Height (in)
Weight (lb)
Chest Wall Thickness (cm)

COUNTER INFORMATION

Counter Name Accuscan II
Counter Location Battelle
Configuration Name Lung - High Energy

COUNT INFORMATION

Count Operation Individual 5 minutes
Count Reason Routine operation
Frequency
Comment
Intake Date
Acquisition Started 4/5/2011 11:00:51 AM
Acquisition Time 301.21
Operator Name David Georgeson
Count Status Not Reviewed
Primary Review No
Secondary Review No

DETECTOR COUNT RATE REPORT

Detector Name	Count Rate	Count Rate Range	Live Time	Analyzed
Right	84.73	1 - 4096	300.0	No
Left	81.53	1 - 4096	300.0	No
Summed	166.31	1 - 4096	300.0	Yes

Primary Review by: _____

Date: _____

User: David Georgeson

DETECTOR GROUP INFORMATION

Detector Group Name Summed
Detector Group Configuration Lung Screening
Analysis Date 4/5/2011 11:00:42 AM
Energy Calibration Energy Calibration (HE Lung) 4/5/2011 8:18 AM
Efficiency Calibration HE Lung Realistic Summed Eff Cal 4/5/2011 10:43 AM (Dual)
Multi Curve No
Source Distribution Lung
Analysis Sequence File ROUNPPGE.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library INLPLANTLIB.NLB
Tentative NID Library INLPLANTLIB.NLB
Peak Search Library INLPLANTLIB.NLB
Analysis Limits (channels) 40 - 4095
Energy Tolerance (FWHM) 1.20

Comment

PEAK SEARCH RESULTS FOR Accuscan II <Summed>

Peak Analysis					
No	Peak Centroid	Energy (keV)	Net Peak Area	Continuum Counts	
1	69.76	32.12	1.56E+002	3.30E+002	
2	264.85	122.17	2.77E+002	6.90E+002	
3	1309.67	604.65	3.04E+002	8.62E+001	
4	1432.89	661.57	1.87E+003	6.63E+001	
5	1723.32	795.75	2.04E+002	4.92E+001	
6	2540.05	1173.20	5.28E+002	6.69E+001	
7	2884.51	1332.45	5.49E+002	4.27E+000	
8	3162.18	1460.85	2.55E+001	2.48E+000	

For unknown peaks we assume yield to be 100% and no decay correction is performed.

M = First peak in a multiplet region

m = Other peak in a multiplet region

F = Fitted singlet

NUCLIDE RESULTS FOR Accuscan II <Summed>

Nuclide Name	Id Confidence	Wt Mean Activity (nCi)	Error (1SD)
K-40	1.000	1.619072E+002	23.13 %
CO-57	1.000	3.872478E+001	23.24 %
CO-60	1.000	3.387544E+002	3.55 %
CS-134	0.880	1.063828E+002	6.67 %
CS-137	1.000	8.208113E+002	2.72 %

? = Nuclide is part of an undetermined solution

X = Nuclide rejected by the interference analysis

@ = Nuclide contains energy lines not used in Weighted Mean Activity

! = Nuclide was corrected for parent/daughter

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Energy (keV)	Yield (%)	Line MDA (nCi)
+	K-40	1460.81 *	10.67	1.0766E+002
	CR-51	320.08	9.83	1.5974E+002
	MN-54	834.83	99.97	1.7832E+001
+	CO-57	122.06 *	85.51	4.0816E+001
+		136.48	10.60	1.5067E+002

User: David Georgeson

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Energy (keV)	Yield (%)	Line MDA (nCi)
	CO-58	810.76	99.40	1.5478E+001
	FE-59	142.65	1.03	1.4739E+003
		192.34	3.11	5.6446E+002
		1099.22	56.50	2.7983E+001
		1291.56	43.20	1.4145E+001
+				
	CO-60	1173.22 *	100.00	5.3892E+001
+		1332.49 *	100.00	1.6286E+001
	ZN-65	1115.52	50.75	3.7810E+001
	NB-95	765.79	99.81	1.5238E+001
	ZR-95	724.18	43.70	3.2542E+001
		756.72	55.30	2.0945E+001
	RU-106	621.84	9.80	1.5947E+002
		1050.47	1.73	7.9329E+002
	AG-110M	446.80	3.64	5.1419E+002
		620.35	2.77	5.5632E+002
		657.75	94.40	1.8557E+001
		677.61	10.68	1.1309E+002
		686.99	6.47	2.2170E+002
		706.67	16.68	9.1072E+001
		744.26	4.64	3.1978E+002
		763.93	22.28	6.0116E+001
		818.02	7.30	2.0812E+002
		884.67	72.60	2.0945E+001
		937.48	34.20	5.3882E+001
		1384.27	24.26	3.3547E+001
		1475.76	3.97	2.1055E+002
		1505.00	13.06	1.5712E+001
		1562.27	1.18	8.4290E+002
	I-131	80.18	2.62	4.4673E+002
		284.30	6.05	2.4532E+002
		364.48	81.20	2.1755E+001
		636.97	7.26	2.2738E+002
		722.89	1.80	7.0932E+002
	I-133	529.87	86.30	1.7857E+001
		875.33	4.47	2.8436E+002
+	CS-134	475.35	1.46	1.4419E+003
+		563.23	8.38	2.2787E+002
+		569.32	15.43	1.4267E+002

+		604.70 *	97.60	3.4462E+001
+		795.84 *	85.40	3.6731E+001
+		801.93	8.73	2.3311E+002
+		1038.57	1.00	1.8555E+003
+		1167.94	1.80	1.2143E+003
+		1365.15	3.04	5.5737E+002
+	CS-137	661.65 *	85.12	3.6557E+001
	BA-140	162.64	6.70	2.4230E+002

User: David Georgeson

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide	Energy (keV)	Yield (%)	Line MDA
	BA-140	304.84	4.50	3.2793E+002
		423.70	3.20	6.1478E+002
		437.55	2.00	8.9001E+002
		537.32	25.00	6.8449E+001
	LA-140	328.77	20.50	7.2270E+001
		432.53	2.94	6.4535E+002
		487.03	45.50	3.6939E+001
		751.79	4.40	3.6418E+002
		815.85	23.50	5.7389E+001
		867.82	5.63	3.4215E+002
		919.63	2.88	7.4100E+002
		925.24	7.09	3.0255E+002
		1596.49	95.49	8.9436E+000
	CE-141	145.44	48.40	3.4561E+001
	CE-144	80.11	1.60	7.3105E+002
		133.54	10.80	1.4124E+002
	EU-152	121.78	28.40	7.2607E+001
		244.69	7.49	2.2678E+002
		344.27	26.50	6.0718E+001
		411.11	2.21	8.8878E+002
		443.98	3.11	6.1895E+002
		778.89	12.74	1.0943E+002
		867.32	4.16	4.8187E+002
		964.01	14.40	1.2863E+002
		1085.78	10.00	1.5157E+002
		1112.02	13.30	1.1601E+002
		1407.95	20.70	4.6360E+001

+ = Nuclide Identified during the nuclide identification

* = Energy Line found in the spectrum

COUNT 2

Analysis Report - Lung Test [999-99-9996]

SOURCE INFORMATION

Primary ID 999-99-9996
Last Name Test
First Name Lung
Height (in)
Weight (lb)
Chest Wall Thickness (cm)

COUNTER INFORMATION

Counter Name Accuscan II
Counter Location Battelle
Configuration Name Lung - High Energy

COUNT INFORMATION

Count Operation Individual 10 minutes
Count Reason Routine operation
Frequency
Comment MFP-1-001 Validation Count 2
Intake Date
Acquisition Started 4/6/2011 8:24:09 AM
Acquisition Time 602.21
Operator Name David Georgeson
Count Status Not Reviewed
Primary Review No
Secondary Review No

DETECTOR COUNT RATE REPORT

Detector Name	Count Rate	Count Rate Range	Live Time	Analyzed
Left	82.01	1 - 4096	600.0	No
Right	83.62	1 - 4096	600.0	No
Summed	165.08	1 - 4096	600.0	Yes

Primary Review by: _____

Date: _____

User: David Georgeson

DETECTOR GROUP INFORMATION

Detector Group Name Summed
Detector Group Configuration Lung Screening
Analysis Date 4/6/2011 8:23:58 AM
Energy Calibration Energy Calibration (HE Lung) 4/5/2011 8:18 AM
Efficiency Calibration Eff. Calibration (HE Lung Realistic) 4/5/2011 4:05 PM (Dual)
Multi Curve No
Source Distribution Lung
Analysis Sequence File ROUNPPGE.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library INLPLANTLIB.NLB
Tentative NID Library INLPLANTLIB.NLB
Peak Search Library INLPLANTLIB.NLB
Analysis Limits (channels) 40 - 4095
Energy Tolerance (FWHM) 1.20

Comment**PEAK SEARCH RESULTS FOR Accuscan II <Summed>**

Peak Analysis					
	No	Peak Centroid	Energy (keV)	Net Peak Area	Continuum Counts
	1	69.84	32.15	1.64E+002	8.35E+002
	2	264.74	122.12	5.77E+002	1.52E+003
M	3	1220.16	563.30	6.12E+001	1.34E+002
m	4	1232.70	569.09	1.14E+002	1.90E+002
	5	1309.73	604.67	6.15E+002	1.65E+002
	6	1432.94	661.59	3.67E+003	1.12E+002
M	7	1723.48	795.82	4.25E+002	8.97E+001
m	8	1736.87	802.01	2.77E+001	1.10E+002
	9	2540.08	1173.22	1.16E+003	5.40E+001
	10	2884.62	1332.50	1.09E+003	1.27E+001
	11	3161.97	1460.75	6.55E+001	2.52E+000

For unknown peaks we assume yield to be 100% and no decay correction is performed.

M = First peak in a multiplet region

m = Other peak in a multiplet region

F = Fitted singlet

NUCLIDE RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Id Confidence	Wt Mean Activity (nCi)	Error (1SD)
	K-40	1.000	1.012900E+00	13.36 %
	CO-57	1.000	1.914159E+00	17.75 %
	CO-60	1.000	1.629071E+00	2.39 %
	CS-134	1.000	5.272515E+00	3.66 %
	CS-137	1.000	3.925997E+00	2.07 %

? = Nuclide is part of an undetermined solution

X = Nuclide rejected by the interference analysis

@ = Nuclide contains energy lines not used in Weighted Mean Activity

! = Nuclide was corrected for parent/daughter

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Energy (keV)	Yield (%)	Line MDA (nCi)
+>	K-40	1460.81 *	10.67	0.0000E+000
>	CR-51	320.08	9.83	0.0000E+000

User: David Georgeson

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Energy (keV)	Yield (%)	Line MDA (nCi)
>	MN-54	834.83	99.97	0.0000E+000
+>	CO-57	122.06 *	85.51	0.0000E+000
+>		136.48	10.60	0.0000E+000
>	CO-58	810.76	99.40	0.0000E+000
>	FE-59	142.65	1.03	0.0000E+000
>		192.34	3.11	0.0000E+000
>		1099.22	56.50	0.0000E+000
>		1291.56	43.20	0.0000E+000
+>	CO-60	1173.22 *	100.00	0.0000E+000
+>		1332.49 *	100.00	0.0000E+000
>	ZN-65	1115.52	50.75	0.0000E+000
>	NB-95	765.79	99.81	0.0000E+000
>	ZR-95	724.18	43.70	0.0000E+000
>		756.72	55.30	0.0000E+000
>	RU-106	621.84	9.80	0.0000E+000
>		1050.47	1.73	0.0000E+000
>	AG-110M	446.80	3.64	0.0000E+000
>		620.35	2.77	0.0000E+000
>		657.75	94.40	0.0000E+000
>		677.61	10.68	0.0000E+000
>		686.99	6.47	0.0000E+000
>		706.67	16.68	0.0000E+000
>		744.26	4.64	0.0000E+000
>		763.93	22.28	0.0000E+000
>		818.02	7.30	0.0000E+000
>		884.67	72.60	0.0000E+000
>		937.48	34.20	0.0000E+000
>		1384.27	24.26	0.0000E+000
>		1475.76	3.97	0.0000E+000
>		1505.00	13.06	0.0000E+000
>		1562.27	1.18	0.0000E+000
>	I-131	80.18	2.62	0.0000E+000
>		284.30	6.05	0.0000E+000
>		364.48	81.20	0.0000E+000
>		636.97	7.26	0.0000E+000
>		722.89	1.80	0.0000E+000
>	I-133	529.87	86.30	0.0000E+000
>		875.33	4.47	0.0000E+000

+>	CS-134	475.35	1.46	0.0000E+000
+>		563.23 *	8.38	0.0000E+000
+>		569.32 *	15.43	0.0000E+000
+>		604.70 *	97.60	0.0000E+000
+>		795.84 *	85.40	0.0000E+000
+>		801.93 *	8.73	0.0000E+000
+>		1038.57	1.00	0.0000E+000
+>		1167.94	1.80	0.0000E+000

User: David Georgeson

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Energy (keV)	Yield (%)	Line MDA (nCi)
+>	CS-134	1365.15	3.04	0.0000E+000
+>	CS-137	661.65 *	85.12	0.0000E+000
>	BA-140	162.64	6.70	0.0000E+000
>		304.84	4.50	0.0000E+000
>		423.70	3.20	0.0000E+000
>		437.55	2.00	0.0000E+000
>		537.32	25.00	0.0000E+000
>	LA-140	328.77	20.50	0.0000E+000
>		432.53	2.94	0.0000E+000
>		487.03	45.50	0.0000E+000
>		751.79	4.40	0.0000E+000
>		815.85	23.50	0.0000E+000
>		867.82	5.63	0.0000E+000
>		919.63	2.88	0.0000E+000
>		925.24	7.09	0.0000E+000
>		1596.49	95.49	0.0000E+000
>	CE-141	145.44	48.40	0.0000E+000
>	CE-144	80.11	1.60	0.0000E+000
>		133.54	10.80	0.0000E+000
>	EU-152	121.78	28.40	0.0000E+000
>		244.69	7.49	0.0000E+000
>		344.27	26.50	0.0000E+000
>		411.11	2.21	0.0000E+000
>		443.98	3.11	0.0000E+000
>		778.89	12.74	0.0000E+000
>		867.32	4.16	0.0000E+000
>		964.01	14.40	0.0000E+000
>		1085.78	10.00	0.0000E+000
>		1112.02	13.30	0.0000E+000
>		1407.95	20.70	0.0000E+000

+ = Nuclide Identified during the nuclide identification

* = Energy Line found in the spectrum

> = MDA Value not calculated

COUNT 3

Analysis Report - Lung Test [999-99-9996]

SOURCE INFORMATION

Primary ID 999-99-9996
Last Name Test
First Name Lung
Height (in)
Weight (lb)
Chest Wall Thickness (cm)

COUNTER INFORMATION

Counter Name Accuscan II
Counter Location Battelle
Configuration Name Lung - High Energy

COUNT INFORMATION

Count Operation Individual 10 minutes
Count Reason Routine operation
Frequency
Comment MFP-1-001 validation count 3
Intake Date
Acquisition Started 4/6/2011 8:47:28 AM
Acquisition Time 602.21
Operator Name David Georgeson
Count Status Not Reviewed
Primary Review No
Secondary Review No

DETECTOR COUNT RATE REPORT

Detector Name	Count Rate	Count Rate	Live Time	Analyzed
Left	80.44	1 - 4096	600.0	No
Right	83.32	1 - 4096	600.0	No
Summed	163.23	1 - 4096	600.0	Yes

Primary Review by: _____

Date: _____

User: David Georgeson

DETECTOR GROUP INFORMATION

Detector Group Name Summed
Detector Group Configuration Lung Screening
Analysis Date 4/6/2011 8:47:08 AM
Energy Calibration Energy Calibration (HE Lung) 4/5/2011 8:18 AM
Efficiency Calibration Eff. Calibration (HE Lung Realistic) 4/5/2011 4:05 PM (Dual)
Multi Curve No
Source Distribution Lung
Analysis Sequence File ROUNPPGE.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library INLPLANTLIB.NLB
Tentative NID Library INLPLANTLIB.NLB
Peak Search Library INLPLANTLIB.NLB
Analysis Limits (channels) 40 - 4095
Energy Tolerance (FWHM) 1.20
Comment

PEAK SEARCH RESULTS FOR Accuscan II <Summed>

Peak Analysis					
	No	Peak Centroid	Energy (keV)	Net Peak Area	Continuum Counts
	1	69.80	32.13	2.91E+002	7.27E+002
	2	264.54	122.03	5.11E+002	1.36E+003
M	3	1219.99	563.22	7.70E+001	9.96E+001
m	4	1233.07	569.27	1.15E+002	1.58E+002
	5	1309.78	604.70	5.94E+002	1.47E+002
	6	1433.00	661.62	3.72E+003	1.19E+002
	7	1723.39	795.78	4.36E+002	8.77E+001
	8	1807.73	834.75	3.23E+001	8.07E+001
	9	2539.98	1173.17	1.18E+003	3.58E+001
	10	2884.51	1332.45	1.08E+003	8.50E+000

For unknown peaks we assume yield to be 100% and no decay correction is performed.

M = First peak in a multiplet region

m = Other peak in a multiplet region

F = Fitted singlet

NUCLIDE RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Id Confidence	Wt Mean Activity (nCi)	Error (1SD)
	MN-54	1.000	3.497251E+000	57.13 %
	CO-57	1.000	1.695289E+001	18.27 %
	CO-60	1.000	1.628637E+002	2.34 %
	CS-134	0.941	5.382743E+001	4.03 %
	CS-137	1.000	3.979652E+002	2.07 %

? = Nuclide is part of an undetermined solution

X = Nuclide rejected by the interference analysis

@ = Nuclide contains energy lines not used in Weighted Mean Activity

! = Nuclide was corrected for parent/daughter

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Energy (keV)	Yield (%)	Line MDA (nCi)
>	K-40	1460.81	10.67	0.0000E+000
>	CR-51	320.08	9.83	0.0000E+000
+>	MN-54	834.83 *	99.97	0.0000E+000

User: David Georgeson

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Energy (keV)	Yield (%)	Line MDA (nCi)
+>	CO-57	122.06 *	85.51	0.0000E+000
+>		136.48	10.60	0.0000E+000
>	CO-58	810.76	99.40	0.0000E+000
>	FE-59	142.65	1.03	0.0000E+000
>		192.34	3.11	0.0000E+000
>		1099.22	56.50	0.0000E+000
>		1291.56	43.20	0.0000E+000
+>	CO-60	1173.22 *	100.00	0.0000E+000
+>		1332.49 *	100.00	0.0000E+000
>	ZN-65	1115.52	50.75	0.0000E+000
>	NB-95	765.79	99.81	0.0000E+000
>	ZR-95	724.18	43.70	0.0000E+000
>		756.72	55.30	0.0000E+000
>	RU-106	621.84	9.80	0.0000E+000
>		1050.47	1.73	0.0000E+000
>	AG-110M	446.80	3.64	0.0000E+000
>		620.35	2.77	0.0000E+000
>		657.75	94.40	0.0000E+000
>		677.61	10.68	0.0000E+000
>		686.99	6.47	0.0000E+000
>		706.67	16.68	0.0000E+000
>		744.26	4.64	0.0000E+000
>		763.93	22.28	0.0000E+000
>		818.02	7.30	0.0000E+000
>		884.67	72.60	0.0000E+000
>		937.48	34.20	0.0000E+000
>		1384.27	24.26	0.0000E+000
>		1475.76	3.97	0.0000E+000
>		1505.00	13.06	0.0000E+000
>		1562.27	1.18	0.0000E+000
>	I-131	80.18	2.62	0.0000E+000
>		284.30	6.05	0.0000E+000
>		364.48	81.20	0.0000E+000
>		636.97	7.26	0.0000E+000
>		722.89	1.80	0.0000E+000
>	I-133	529.87	86.30	0.0000E+000
>		875.33	4.47	0.0000E+000
+>	CS-134	475.35	1.46	0.0000E+000

+>		563.23 *	8.38	0.0000E+000
+>		569.32 *	15.43	0.0000E+000
+>		604.70 *	97.60	0.0000E+000
+>		795.84 *	85.40	0.0000E+000
+>		801.93	8.73	0.0000E+000
+>		1038.57	1.00	0.0000E+000
+>		1167.94	1.80	0.0000E+000
+>		1365.15	3.04	0.0000E+000

User: David Georgeson

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Energy (keV)	Yield (%)	Line MDA (nCi)
+>	CS-137	661.65 *	85.12	0.0000E+000
>	BA-140	162.64	6.70	0.0000E+000
>		304.84	4.50	0.0000E+000
>		423.70	3.20	0.0000E+000
>		437.55	2.00	0.0000E+000
>		537.32	25.00	0.0000E+000
>	LA-140	328.77	20.50	0.0000E+000
>		432.53	2.94	0.0000E+000
>		487.03	45.50	0.0000E+000
>		751.79	4.40	0.0000E+000
>		815.85	23.50	0.0000E+000
>		867.82	5.63	0.0000E+000
>		919.63	2.88	0.0000E+000
>		925.24	7.09	0.0000E+000
>		1596.49	95.49	0.0000E+000
>	CE-141	145.44	48.40	0.0000E+000
>	CE-144	80.11	1.60	0.0000E+000
>		133.54	10.80	0.0000E+000
>	EU-152	121.78	28.40	0.0000E+000
>		244.69	7.49	0.0000E+000
>		344.27	26.50	0.0000E+000
>		411.11	2.21	0.0000E+000
>		443.98	3.11	0.0000E+000
>		778.89	12.74	0.0000E+000
>		867.32	4.16	0.0000E+000
>		964.01	14.40	0.0000E+000
>		1085.78	10.00	0.0000E+000
>		1112.02	13.30	0.0000E+000
>		1407.95	20.70	0.0000E+000

+ = Nuclide Identified during the nuclide identification

* = Energy Line found in the spectrum

> = MDA Value not calculated

COUNT 4

Analysis Report - Lung Test [999-99-9996]

SOURCE INFORMATION

Primary ID 999-99-9996
Last Name Test
First Name Lung
Height (in)
Weight (lb)
Chest Wall Thickness (cm)

COUNTER INFORMATION

Counter Name Accuscan II
Counter Location Battelle
Configuration Name Lung - High Energy

COUNT INFORMATION

Count Operation Individual 10 minutes
Count Reason Routine operation
Frequency
Comment MFP-1-001 Validation count #4
Intake Date
Acquisition Started 4/6/2011 9:13:21 AM
Acquisition Time 602.28
Operator Name David Georgeson
Count Status Not Reviewed
Primary Review No
Secondary Review No

DETECTOR COUNT RATE REPORT

Detector Name	Count Rate	Count Rate Range	Live Time	Analyzed
Right	83.80	1 - 4096	600.0	No
Left	80.31	1 - 4096	600.0	No
Summed	164.16	1 - 4096	600.0	Yes

Primary Review by: _____

Date: _____

User: David Georgeson

DETECTOR GROUP INFORMATION

Detector Group Name Summed
Detector Group Configuration Lung Screening
Analysis Date 4/6/2011 9:13:11 AM
Energy Calibration Energy Calibration (HE Lung) 4/5/2011 8:18 AM
Efficiency Calibration Eff. Calibration (HE Lung Realistic) 4/5/2011 4:05 PM (Dual)
Multi Curve No
Source Distribution Lung
Analysis Sequence File ROUNPPGE.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library INLPLANTLIB.NLB
Tentative NID Library INLPLANTLIB.NLB
Peak Search Library INLPLANTLIB.NLB
Analysis Limits (channels) 40 - 4095
Energy Tolerance (FWHM) 1.20

Comment

PEAK SEARCH RESULTS FOR Accuscan II <Summed>

Peak Analysis					
No	Peak Centroid	Energy (keV)	Net Peak Area	Continuum Counts	
1	70.15	32.29	3.04E+002	6.40E+002	
2	264.64	122.07	4.59E+002	1.32E+003	
3	1232.74	569.11	1.11E+002	1.45E+002	
4	1309.64	604.63	5.69E+002	1.68E+002	
5	1432.96	661.60	3.58E+003	1.81E+002	
6	1723.50	795.83	3.83E+002	1.09E+002	
7	2539.95	1173.16	1.16E+003	5.88E+001	
8	2884.31	1332.36	1.06E+003	2.12E+001	
9	3161.83	1460.68	5.65E+001	1.15E+001	

For unknown peaks we assume yield to be 100% and no decay correction is performed.

M = First peak in a multiplet region

m = Other peak in a multiplet region

F = Fitted singlet

NUCLIDE RESULTS FOR Accuscan II <Summed>

Nuclide Name	Id Confidence	Wt Mean Activity (nCi)	Error (1SD)
K-40	0.999	8.732788E+00	18.93 %
CO-57	1.000	1.522031E+00	19.29 %
CO-60	1.000	1.601501E+00	2.43 %
CS-134	0.935	4.864050E+00	4.88 %
CS-137	1.000	3.825975E+00	2.15 %

? = Nuclide is part of an undetermined solution

X = Nuclide rejected by the interference analysis

@ = Nuclide contains energy lines not used in Weighted Mean Activity

! = Nuclide was corrected for parent/daughter

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide	Energy (keV)	Yield (%)	Line MDA
+>	K-40	1460.81 *	10.67	0.0000E+000
>	CR-51	320.08	9.83	0.0000E+000
>	MN-54	834.83	99.97	0.0000E+000
+>	CO-57	122.06 *	85.51	0.0000E+000

User: David Georgeson

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Energy (keV)	Yield (%)	Line MDA (nCi)
+>	CO-57	136.48	10.60	0.0000E+000
>	CO-58	810.76	99.40	0.0000E+000
>	FE-59	142.65	1.03	0.0000E+000
>		192.34	3.11	0.0000E+000
>		1099.22	56.50	0.0000E+000
>		1291.56	43.20	0.0000E+000
+>	CO-60	1173.22 *	100.00	0.0000E+000
+>		1332.49 *	100.00	0.0000E+000
>	ZN-65	1115.52	50.75	0.0000E+000
>	NB-95	765.79	99.81	0.0000E+000
>	ZR-95	724.18	43.70	0.0000E+000
>		756.72	55.30	0.0000E+000
>	RU-106	621.84	9.80	0.0000E+000
>		1050.47	1.73	0.0000E+000
>	AG-110M	446.80	3.64	0.0000E+000
>		620.35	2.77	0.0000E+000
>		657.75	94.40	0.0000E+000
>		677.61	10.68	0.0000E+000
>		686.99	6.47	0.0000E+000
>		706.67	16.68	0.0000E+000
>		744.26	4.64	0.0000E+000
>		763.93	22.28	0.0000E+000
>		818.02	7.30	0.0000E+000
>		884.67	72.60	0.0000E+000
>		937.48	34.20	0.0000E+000
>		1384.27	24.26	0.0000E+000
>		1475.76	3.97	0.0000E+000
>		1505.00	13.06	0.0000E+000
>		1562.27	1.18	0.0000E+000
>	I-131	80.18	2.62	0.0000E+000
>		284.30	6.05	0.0000E+000
>		364.48	81.20	0.0000E+000
>		636.97	7.26	0.0000E+000
>		722.89	1.80	0.0000E+000
>	I-133	529.87	86.30	0.0000E+000
>		875.33	4.47	0.0000E+000
+>	CS-134	475.35	1.46	0.0000E+000
+>		563.23	8.38	0.0000E+000

+>		569.32 *	15.43	0.0000E+000
+>		604.70 *	97.60	0.0000E+000
+>		795.84 *	85.40	0.0000E+000
+>		801.93	8.73	0.0000E+000
+>		1038.57	1.00	0.0000E+000
+>		1167.94	1.80	0.0000E+000
+>		1365.15	3.04	0.0000E+000
+>	CS-137	661.65 *	85.12	0.0000E+000

User: David Georgeson

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide	Energy (keV)	Yield (%)	Line MDA
>	BA-140	162.64	6.70	0.0000E+000
>		304.84	4.50	0.0000E+000
>		423.70	3.20	0.0000E+000
>		437.55	2.00	0.0000E+000
>		537.32	25.00	0.0000E+000
>	LA-140	328.77	20.50	0.0000E+000
>		432.53	2.94	0.0000E+000
>		487.03	45.50	0.0000E+000
>		751.79	4.40	0.0000E+000
>		815.85	23.50	0.0000E+000
>		867.82	5.63	0.0000E+000
>		919.63	2.88	0.0000E+000
>		925.24	7.09	0.0000E+000
>		1596.49	95.49	0.0000E+000
>	CE-141	145.44	48.40	0.0000E+000
>	CE-144	80.11	1.60	0.0000E+000
>		133.54	10.80	0.0000E+000
>	EU-152	121.78	28.40	0.0000E+000
>		244.69	7.49	0.0000E+000
>		344.27	26.50	0.0000E+000
>		411.11	2.21	0.0000E+000
>		443.98	3.11	0.0000E+000
>		778.89	12.74	0.0000E+000
>		867.32	4.16	0.0000E+000
>		964.01	14.40	0.0000E+000
>		1085.78	10.00	0.0000E+000
>		1112.02	13.30	0.0000E+000
>		1407.95	20.70	0.0000E+000

+ = Nuclide Identified during the nuclide identification

* = Energy Line found in the spectrum

> = MDA Value not calculated

User: David Georgeson

User: David Georgeson

COUNT 5

Analysis Report - Lung Test [999-99-9996]

SOURCE INFORMATION

Primary ID 999-99-9996
Last Name Test
First Name Lung
Height (in)
Weight (lb)
Chest Wall Thickness (cm)

COUNTER INFORMATION

Counter Name Accuscan II
Counter Location Battelle
Configuration Name Lung - High Energy

COUNT INFORMATION

Count Operation Individual 10 minutes
Count Reason Routine operation
Frequency
Comment MFP-1-001 validation count #5
Intake Date
Acquisition Started 4/6/2011 9:35:00 AM
Acquisition Time 602.3099999
Operator Name David Georgeson
Count Status Not Reviewed
Primary Review No
Secondary Review No

DETECTOR COUNT RATE REPORT

Detector Name	Count Rate	Count Rate	Live Time	Analyzed
Left	81.57	1 - 4096	600.0	No
Right	82.33	1 - 4096	600.0	No
Summed	163.63	1 - 4096	600.0	Yes

Primary Review by: _____

Date: _____

User: David Georgeson

DETECTOR GROUP INFORMATION

Detector Group Name Summed
Detector Group Configuration Lung Screening
Analysis Date 4/6/2011 9:34:50 AM
Energy Calibration Energy Calibration (HE Lung) 4/5/2011 8:18 AM
Efficiency Calibration Eff. Calibration (HE Lung Realistic) 4/5/2011 4:05 PM (Dual)
Multi Curve No
Source Distribution Lung
Analysis Sequence File ROUNPPGE.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library INLPLANTLIB.NLB
Tentative NID Library INLPLANTLIB.NLB
Peak Search Library INLPLANTLIB.NLB
Analysis Limits (channels) 40 - 4095
Energy Tolerance (FWHM) 1.20

Comment

PEAK SEARCH RESULTS FOR Accuscan II <Summed>

Peak Analysis					
No	Peak Centroid	Energy (keV)	Net Peak Area	Continuum Counts	
1	264.76	122.13	5.69E+002	1.18E+003	
2	1233.05	569.25	8.47E+001	1.45E+002	
3	1309.72	604.67	5.93E+002	1.74E+002	
4	1433.03	661.64	3.66E+003	1.09E+002	
5	1723.48	795.82	4.06E+002	8.82E+001	
6	2539.80	1173.09	1.18E+003	3.64E+001	
7	2884.44	1332.42	1.02E+003	1.27E+001	
8	3161.76	1460.65	5.30E+001	7.00E+000	

For unknown peaks we assume yield to be 100% and no decay correction is performed.

M = First peak in a multiplet region

m = Other peak in a multiplet region

F = Fitted singlet

NUCLIDE RESULTS FOR Accuscan II <Summed>

Nuclide Name	Id Confidence	Wt Mean Activity (nCi)	Error (1SD)
K-40	0.999	8.196945E+00	17.52 %
CO-57	1.000	1.888056E+00	14.85 %
CO-60	1.000	1.592995E+00	2.37 %
CS-134	1.000	5.044263E+00	4.65 %
CS-137	1.000	3.915122E+00	2.07 %

? = Nuclide is part of an undetermined solution

X = Nuclide rejected by the interference analysis

@ = Nuclide contains energy lines not used in Weighted Mean Activity

! = Nuclide was corrected for parent/daughter

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Energy (keV)	Yield (%)	Line MDA (nCi)
+>	K-40	1460.81 *	10.67	0.0000E+000
>	CR-51	320.08	9.83	0.0000E+000
>	MN-54	834.83	99.97	0.0000E+000
+>	CO-57	122.06 *	85.51	0.0000E+000
+>		136.48	10.60	0.0000E+000

User: David Georgeson

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Energy (keV)	Yield (%)	Line MDA (nCi)
>	CO-58	810.76	99.40	0.0000E+000
>	FE-59	142.65	1.03	0.0000E+000
>		192.34	3.11	0.0000E+000
>		1099.22	56.50	0.0000E+000
>		1291.56	43.20	0.0000E+000
+>	CO-60	1173.22 *	100.00	0.0000E+000
+>		1332.49 *	100.00	0.0000E+000
>	ZN-65	1115.52	50.75	0.0000E+000
>	NB-95	765.79	99.81	0.0000E+000
>	ZR-95	724.18	43.70	0.0000E+000
>		756.72	55.30	0.0000E+000
>	RU-106	621.84	9.80	0.0000E+000
>		1050.47	1.73	0.0000E+000
>	AG-110M	446.80	3.64	0.0000E+000
>		620.35	2.77	0.0000E+000
>		657.75	94.40	0.0000E+000
>		677.61	10.68	0.0000E+000
>		686.99	6.47	0.0000E+000
>		706.67	16.68	0.0000E+000
>		744.26	4.64	0.0000E+000
>		763.93	22.28	0.0000E+000
>		818.02	7.30	0.0000E+000
>		884.67	72.60	0.0000E+000
>		937.48	34.20	0.0000E+000
>		1384.27	24.26	0.0000E+000
>		1475.76	3.97	0.0000E+000
>		1505.00	13.06	0.0000E+000
>		1562.27	1.18	0.0000E+000
>	I-131	80.18	2.62	0.0000E+000
>		284.30	6.05	0.0000E+000
>		364.48	81.20	0.0000E+000
>		636.97	7.26	0.0000E+000
>		722.89	1.80	0.0000E+000
>	I-133	529.87	86.30	0.0000E+000
>		875.33	4.47	0.0000E+000
+>	CS-134	475.35	1.46	0.0000E+000
+>		563.23	8.38	0.0000E+000
+>		569.32 *	15.43	0.0000E+000

+>		604.70 *	97.60	0.0000E+000
+>		795.84 *	85.40	0.0000E+000
+>		801.93	8.73	0.0000E+000
+>		1038.57	1.00	0.0000E+000
+>		1167.94	1.80	0.0000E+000
+>		1365.15	3.04	0.0000E+000
+>	CS-137	661.65 *	85.12	0.0000E+000
>	BA-140	162.64	6.70	0.0000E+000

User: David Georgeson

NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Energy (keV)	Yield (%)	Line MDA (nCi)
>	BA-140	304.84	4.50	0.0000E+000
>		423.70	3.20	0.0000E+000
>		437.55	2.00	0.0000E+000
>		537.32	25.00	0.0000E+000
>	LA-140	328.77	20.50	0.0000E+000
>		432.53	2.94	0.0000E+000
>		487.03	45.50	0.0000E+000
>		751.79	4.40	0.0000E+000
>		815.85	23.50	0.0000E+000
>		867.82	5.63	0.0000E+000
>		919.63	2.88	0.0000E+000
>		925.24	7.09	0.0000E+000
>		1596.49	95.49	0.0000E+000
>	CE-141	145.44	48.40	0.0000E+000
>	CE-144	80.11	1.60	0.0000E+000
>		133.54	10.80	0.0000E+000
>	EU-152	121.78	28.40	0.0000E+000
>		244.69	7.49	0.0000E+000
>		344.27	26.50	0.0000E+000
>		411.11	2.21	0.0000E+000
>		443.98	3.11	0.0000E+000
>		778.89	12.74	0.0000E+000
>		867.32	4.16	0.0000E+000
>		964.01	14.40	0.0000E+000
>		1085.78	10.00	0.0000E+000
>		1112.02	13.30	0.0000E+000
>		1407.95	20.70	0.0000E+000

+ = Nuclide Identified during the nuclide identification

* = Energy Line found in the spectrum

> = MDA Value not calculated

Appendix I

CWI Realistic Torso Phantom

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CWI Realistic Torso Phantom

IAEA-SM-229/56

A TISSUE-EQUIVALENT TORSO PHANTOM*

For intercalibration of in-vivo,
transuranic-nuclide counting facilities

R.V. GRIFFITH, P.N. DEAN,
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Lawrence Livermore Laboratory,
University of California,
Livermore, California,
United States of America

Abstract

A TISSUE-EQUIVALENT TORSO PHANTOM FOR INTERCALIBRATION OF IN-VIVO, TRANSURANIC-NUCLIDE COUNTING FACILITIES.

A tissue-equivalent human-torso phantom has been constructed for calibration of the counting systems used for in-vivo measurement of transuranic nuclides. The phantom contains a human male rib cage, removable model organs, and includes tissue-equivalent chest plates that can be placed over the torso to simulate people with a wide range of statures. The organs included are lungs, heart, liver, kidneys, spleen, and tracheo-bronchial lymph nodes. Polyurethane with different concentrations of calcium carbonate was used to simulate the linear photon-attenuation properties of various human tissues — lean muscle, adipose-tissue/muscle mixtures and cartilage. Foamed polyurethane with calcium carbonate simulates lung tissue. Transuranic isotopes can be incorporated uniformly in the phantom's lungs and other polyurethane-based organs by dissolution of the nitrate form in acetone with lanthanum nitrate carrier. Organs have now been labelled with highly pure ^{238}Pu , ^{239}Pu and ^{241}Am for calibration measurements. This phantom is the first of three that will be used in a United States Department of Energy programme of intercomparisons involving more than ten laboratories. The results of the intercomparison will allow participating laboratories to prepare sets of transmission curves that can be used to predict the performance of their counting systems for a wide range of subject builds and organ depositions. The intercomparison will also provide valuable information on the relative performances of a variety of detector systems and counting techniques.

1. INTRODUCTION

One of the most difficult health-physics problems is the accurate and sensitive in-vivo measurement of ^{239}Pu and other transuranic nuclides in the human body. Low photon-emission rates, absorption of the low-energy photons

* Work performed under the auspices of the United States Department of Energy by the Lawrence Livermore Laboratory under contract number W-7403-Eng-48.

FIG. 1. Relative X-ray transmission through tissue-equivalent materials: (a) 16.6 keV X-rays from ^{235}Nb , (b) 17 keV X-rays from ^{239}Pu .

by bone and soft tissue, uncertainties in estimate of internal deposition patterns, and low permissible organ burdens (for example, 16 nCi (592 Bq) ^{239}Pu in lung) make detection and quantification of transuranic elements at health-protection levels difficult).

A key aspect of the *in vivo* assay problem is the need for a realistic phantom that (a) reproducibly simulates the counting geometry of internally deposited radionuclides, (b) is made of materials that simulate the photon-attenuation properties of human tissues (muscle, bone, adipose tissue, cartilage and lung) at energies below 20 keV, and (c) is rugged enough to be used in comparing the performance of counting systems at a number of widely separated laboratories.

The first of these phantoms has now been completed at the Lawrence Livermore Laboratory (LLI). Phantom-construction criteria are based on requirements established by the United States Department of Energy Intercomparison Committee for Low-Energy Photon Measurements [1]. This committee is composed of whole-body-counting specialists from Argonne National Laboratory,

FIG.2. Comparison of real and tissue-equivalent organs: (a) liver, (b) heart, (c) kidneys and (d) lung with mould used for casting.

Battelle Pacific Northwest Laboratories, Lawrence Livermore Laboratory, Los Alamos Scientific Laboratory, Mound Laboratory (Monsanto), Rocky Flats Plant (Rockwell International), and Savannah River Plant (Du Pont).

The phantom simulates a human male torso without head or arms and is terminated just above the pelvis. The stature is that of a man 1.77 m tall, weighing 76 kg. The phantom consists of a tissue-equivalent (TE) polyurethane torso shell with a human male rib cage embedded therein. Tissue-equivalent lungs, heart, liver, kidneys and spleen, with additional TE material simulating intestines and body fluids, fill the phantom abdominal cavity. We have made chest plates of TE material that can be overlaid on the phantom to simulate the geometry and chest-wall attenuation of the range of statures seen in male radiation workers. Two sets of chest plates have been made in order to simulate tissue attenuation provided by lean muscle or by a combination of adipose tissue and muscle (50% of each by weight).

FIG. 2. Final torso form with adhesive mould used for casting.

FIG. 4. Plaster torso organ cavity cast with rib cage in place: (a) front view, (b) rear view. assembly in place in torso mould

FIG.3. Completed phantom: (a) with 11 mm thick chest plate in place, (b) with chest plate removed, and (c) with torso cover removed showing organs.

Uniform deposition of transuranic isotopes in an individual organ can be simulated by labelling the TE organ with the appropriate materials. We have now made sets of lungs and lymph nodes that are each labelled with highly pure ^{138}Pu , ^{239}Pu or ^{241}Am (Table I). By placing the labelled organs in the phantom, we can make measurements with and without chest plates and acquire data that can be used to develop counter-calibration curves for each of the isotopes of interest. The phantom includes a 1 cm dia. channel behind the tracheo-bronchial plane so that calibrations can be made with oesophageal detectors.

2. TISSUE-EQUIVALENT MATERIAL

Radiologists and whole-body-counting specialists have used various materials to simulate tissue. The selection includes readily available materials such as

TABLE I. RELATIVE X-RAY CONTRIBUTIONS OF TRANSURANIC NUCLIDES
(USED TO MAKE LAMBLERH OCEANS ONE OF 5 AUGUST 1977)

Contributing nuclide	Relative contribution primary labelling nuclide		
	^{239}Pu	^{240}Pu	^{241}Am
^{239}Pu	0.999	0.003	≤ 1.0001
^{240}Pu	≤ 1.0001	0.994	≤ 1.0001
^{241}Pu	≤ 1.0001	0.995	≤ 1.0001
^{241}Am	≤ 1.0001	0.007	0.999
Others	≤ 1.001	≤ 1.001	≤ 1.001
	1.000	1.000	1.000

^aby alpha peak-height analysis.^bby mass spectrometry.

TABLE II. COMPARATIVE ORGAN VOLUMES

Organ	Volume (cm^3)	
	Reference Man ^a	Phantom
Lungs		
Left	1752	1489
Right	2151	2181
Total	3903	3670
Heart	742	741
Liver	1700	2050
Kidney		
Left	149 ^b	170
Right		150
Spleen	171	155

^aBased on data from Ref. [6].^bDistinction between left and right kidneys not made.TABLE III. DENSITIES OF TISSUE AND TISSUE-EQUIVALENT PLASTIC
MEASURED WITH A COMPUTERIZED AXIAL TOMOGRAPHIC SCANNER

Tissue	Density (g/cm^3)	
	Tissue	TE polycarbonate
Muscle	1.06	1.09
87% adipose, 13% muscle	—	1.01
Adipose tissue	0.93	—
Water	1.00	0.98

Lucite, Perspex, Presdwood, polyethylene, and even water.¹ However, when low-energy X-rays are involved, the radiation-attenuation properties of human tissue must be simulated more carefully. Even differences in attenuation between soft tissues such as muscle, adipose tissue and cartilage become important. To simulate these attenuations precisely, other researchers have developed some specific TE material formulations. These include: Mix-D, a mixture of paraffin, polyethylene, titanium oxide, and magnesium oxide [2]; Tenax, a depolymerized rubber [3]; and Rando muscle-equivalent material, a rigid filled epoxy resin.²

None of these materials were satisfactory for construction of the intercalibration phantom because we required that (a) the tissue simulation be accurate at energies as low as 15 keV for tissue thicknesses greater than 4 cm, (b) the TE material be easy to form into irregular shapes and (c) the TE material be durable and not deform significantly over many years. In addition, we must be able to vary the composition of the material to simulate the different soft tissues — muscle, adipose tissue and cartilage. We also need a lung-tissue simulant that has a density of 0.25 to 0.30 g/cm³. Finally, it is necessary to label the TE materials uniformly with plutonium, americium, uranium and other heavy elements.

Polyurethane proved to be an appropriate basis for our family of TE materials. With a composition of 9.2% hydrogen, 58.9% carbon, 3.7% nitrogen, and 18.2% oxygen (by weight) and a density of 1.06 g/cm³, polyurethane has linear-attenuation properties that approximate those of tissue with 8% adipose tissue and 13 wt% muscle. By adding small quantities of materials of higher atomic number, such as calcium, we can simulate more dense tissues such as muscle and cartilage. Because there are commercial polyurethane formulations that involve mixing two fluid components, this TE material can easily be cast in quite irregular shapes. There are also commercial formulations that can be used to produce foamed polyurethane with densities in the range needed to simulate lung tissue.

Although we have selected one commercial polyurethane (Scotchcast by the Minnesota Mixing and Manufacturing Company), there are other products that would be suitable as solid TE material. We begin making the TE plastic by using a small, laboratory rolling mill to incorporate CaCO₃ powder into component A of the polyurethane. Our present TE material formulations call for 2.1 wt% CaCO₃ to simulate chest tissue having equal weights of adipose tissue and muscle, 4.3 wt% CaCO₃ for muscle simulation and 5.8 wt% for cartilage simulation.

¹ Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the United States Department of Energy to the exclusion of others that may be suitable.

² Manufactured by Adanson Research Laboratories, USA.

Our formulation of the lung-equivalent material also involves a two-component polyurethane, 1940D (black), available from the CPR division of Upjohn Corporation. A small quantity of water is added to generate foaming. The specific formulation is 30.0% 1940D component A, 68.4% component B, 0.15% H_2O , and 0.15% acetone (by weight), with transuranic tracer. We add 6.3% $CaCO_3$ to component A to achieve the proper X-ray transmission. Under proper conditions, the foam expands uniformly and we can control lung density by the amount of polyurethane poured into the mould. We used lanthanum nitrate carrier for the transuranic nuclides to achieve uniform distribution of the radioactive material in the model lungs. X-ray fluorescence measurements of the lanthanum concentration showed that the carrier distribution in sample lungs was uniform to within $\pm 4\%$ of the average value.

We have measured the photon transmissions of various tissues and TE materials using 16.6 keV X-rays from $^{90}Nb^{13}$, L-series X-rays from ^{238}Pu , and the 60 keV gamma ray from ^{241}Am . Transmission curves for $^{90}Nb^{13}$ and ^{238}Pu are shown in Fig. 1. The ^{241}Am transmission through soft tissue, excluding lung, has a very narrow spread, through 4.0 mm of sample, 63.0% for muscle and muscle-equivalent polyurethane to 66.7% for adipose tissue and unloaded polyurethane. The ^{238}Pu transmission data show curvature because the three L-series X-rays (13.6, 17.2 and 20.2 keV) have different attenuation coefficients.

3. FABRICATION TECHNIQUES

The torso and organ moulds are all based on solid plaster casts made from a male cadaver provided by the Anatomy Department at the University of California, San Francisco. The cadaver was 1.77 m tall, weighed 75 kg, and had a chest circumference of 1.01 m. In comparison, a random sample of 500 male LLL and Los Alamos Scientific Laboratory employees on the average were 1.77 m tall, weighed 75 kg, and had a chest circumference of 1 m. The organs and TE replicas are shown in Fig. 2. Organ-replica volumes are presented in Table II, together with values for Reference Man [4].

An important part of the phantom construction was modification of the torso casts so that the phantom chest wall overlying the lungs would be as thin as possible while still accommodating the rib cage. (This allows us to measure attenuation for the widest range of chest-wall thicknesses.) We made a thin plastic reproduction of the chest exterior by vacuum forming a plastic sheet on the plaster torso cast. We marked this chest plate with a grid, drilled holes at the grid points, and placed the plate over a cast of the organ cavity. From ultrasonic-scan data taken on the chests and abdomens of a large group of radiation workers and from published anatomical data [5], we tabulated the thinnest realistic profiles of chest-wall and abdominal-wall thicknesses for the

FIG. 6. Phantom construction from computerized axial tomographic (CAT) scanner: (a) display of section through the chest, (b) drawing of section contours with chest-plate profiles.

phantom. With the plastic chest plate in place on the organ-cavity cast, we mapped the actual chest and abdominal-wall spacings. The differences between the mapping and the desired profiles were then removed from the plaster torso cast. A silicon-rubber mould for the phantom was made from this cast. The final torso model is shown in Fig. 3 together with its mould.

After removal from the cadaver, the rib cage was cleaned to remove soft tissue. We then used a colony of Dermestid beetles maintained in the Museum of Vertebrate Zoology, University of California, Berkeley Campus, to remove traces of remaining soft tissue. The beetles were particularly useful for this purpose because they have access to small voids in the skeleton (particularly in the vertebrae) but do not attack cartilage. The cartilage was thus saved for future use. Finally, we used ammonia and a vapour solvent to degrease the bones. We used a vacuum filling technique to replace lost marrow in the bone trabeculae with Mix-D tissue simulant. We completed the rib-cage assembly by connecting vertebrae with nylon pins and the ribs with nylon string. Special sections of polyurethane cartilage-simulant connect the ribs to the sternum. The rib cage is shown in place on the organ-cavity model in Fig. 4(a). Figure 4(b) shows the rib cage and the organ-cavity model placed in the torso mould before casting.

The final major task in phantom construction was fabrication of T.E. chest plates, which will be used to simulate the chest-wall attenuation of a wide variety of male statures. Based on requirements established by the Department of Energy Inter calibration Committee [1], we made moulds for four chest-plate thicknesses: 6, 11, 16, and 24 mm. This allows us to make five measurements covering the range of chest-wall thickness - from 19 mm without chest plates to

FIG. 7. Stability of two 100 cm² photodiode detectors to 120Pa uniformly deposited in phantom lungs.

43 mm with the thickest plates. This range includes more than 95% of the male radiation workers monitored in the USA. Two sets of plates have now been cast: one with muscle-equivalent material and one with polyurethane to simulate tissue composed of 50% muscle and 50% adipose tissue. Figure 5(a) shows the phantom assembled with the 11 mm thick chest plate in place. Figure 5(b) shows the phantom and chest plate apart, and Fig. 5(c) shows the phantom with both the chest plate and torso cover removed.

4. PHANTOM EVALUATIONS

The success of the phantom in an intercalibration programme depends on how faithfully it simulates human morphology and radiation transmission of human tissue. We used a computerized axial tomographic (CAT) scanner at a local hospital to help evaluate these qualities. The CAT scanner yields excellent morphological data through cross-sectional scans. It also provides data on the density of tissue in each section. Figure 6(a) shows a typical scan of the phantom through the lung region. The schematic in Fig. 6(b) shows contours of a typical section of the phantom chest and the relative profiles of the four chest plates. Comparative tissue densities measured with the CAT scanner for typical human

and phantom tissues are shown in Table III. The CAT scanner data depends on the radiation transmission of the tissue, so the agreement in Table III indicates that the phantom will provide an accurate measurement of internal attenuation.

We have made preliminary body-attenuation measurements with the phantom using two 127 mm dia. phoswich scintillation detectors placed over the lungs. Data for attenuation of L X-rays from ^{238}Pu are presented in Fig. 7. For comparison, we give data from both muscle-equivalent chest plates and chest plates simulating a combination of muscle and adipose tissue.

ACKNOWLEDGEMENTS

The authors wish to thank Harry P. Conrad, Norman W. Boyer, Robert S. Taylor, Steve W. Winchester, and all the personnel in the LLL plastic shop for their valuable technical contributions. We want to thank Sexton Sutherland, C.W. Asling, and Jerry Ritchie, all of the U.C. San Francisco Medical Center, for their help with the anatomical work: Robert Jones in the U.C. Berkeley Zoology Department for his help in preparing the skeleton; and Patrick Anderson and the staff of Valley Memorial Hospital for their work with the CAT scanner. We also want to thank Patrick E. Barry, Charles A. Harder, and Robert D. Taylor of the Special Projects Division, Hazards Control Department, LLL, for their continuing support.

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DISCUSSION

M. OBERHOFER: I have two questions regarding your tissue-equivalent material for the phantom and its dimensions. Is there any special reason why you did not use Shonka material? And, secondly, why did you not choose the dimensions of the "standard man"?

R.V. GRIFFITH: In answer to your first question, we needed a material from which it would be easy to make irregular shapes such as those of the torso shell and organs. Also, we wanted a material whose composition could easily be changed to simulate the radiation attenuation properties of tissues other than muscle. Finally, the method of incorporation of the radionuclides in the organs had to be fairly simple. The Shonka plastic does not meet these requirements.

We did not use "standard man" dimensions because the typical worker was found from our studies at Los Alamos and the Lawrence Livermore Laboratory to be somewhat large. A "standard man" phantom would then have been smaller than the average person we wanted to simulate.

D.J. COULSTON: What is the cost and potential availability of the phantom described?

R.V. GRIFFITH: A very rough estimate of cost based on the labour involved is \$125 000. The material costs are incidental. The cost of future phantoms would, of course, be much less, as we now have all the moulds necessary for the casting.

We do not intend to mass-produce these phantoms and have not yet decided what to do with the moulds when the last one is finished. However, anyone using the moulds would have to face the practical problem of obtaining the rib cage. The phantoms will be used in an intercomparison programme sponsored by the United States Department of Energy. The protocol for the first round of the programme has now been established. However, after that part of the work has been completed, it is quite possible that intercomparison studies could be extended to other qualified laboratories.

P. KOTRAPPA: I should like to put a general question. We have heard several papers today on the measurement of ^{239}Pu in lungs. If one has to choose between different detection systems, which system do you think would give the best performance for the investment? Also, what is the minimum ^{239}Pu that can be detected in the lungs of a standard man at the present time?

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REALISTIC PHANTOM

Sample Serial No. A 138 (01 CaCO₃)
 Mean Diameter 4.031
 Mean Thickness .7734
 Volume 161.7366

LLNL Sample Volume: 156.39 cc
 LLNL Sample thickness: .758 in
 Volume (weight) adjustment factor .9669

(Note: This is to adjust sample volume to LLNL sample volume. Since variations are dimensional, this will have no effect on counting.)

Humanoid Weight 174g Adjusted Weight 168.24g

LLNL Sample Weight: 169.55 gms. Error -.7673

LLNL & Humanoid Sample Counting Time: 480 secs (3 x 160 sec)

LLNL (counts at center) Background 48

Count 9725 9549 9397

Less Background 48 48 48

Net Count 9675 9501 9349

Standard Deviation from Mean: 1.25 1.67

HUMANOID (3 positions in line)

Thickness:	Pos. #1	Pos. #2	Pos. #3
Pos. #1	.7717	.7739	.7746
Count	9145	9206	8996
Less Back.	48	48	48
Net Count	9097	9158	8948
Adj. for thickness	9274	9318	9332
Result	9371	9476	9280

Mean 9375.6 Deviation from Mean 1.07 1.02

Error -1.394 (Means: H.S. to LLNL)

*Based on plot of number of counts vs thickness: 20/.001 in.
 deviation from LLNL sample

Signed [Signature]
 Technician
 Date 12-20-84

USAGE

Chest Plate Serial No. A 138 -1
 Chest Plate Serial No. A 138 -2
 Chest Plate Serial No. A 138 -3
 Chest Plate Serial No. A 138 -4

IAEA

June 78 IAEA-SM-207

Griess/Andersson 56.

Count date 12-15-84
 By [Signature]

Count date 12-15-84
 By [Signature]

Handwritten notes:
 19 mm Chest Pl.
 6 mm
 11 "
 16 "
 24 "

R.V. GRIFFITH: In answer to your first question, we needed a material from which it would be easy to make irregular shapes such as those of the torso shell and organs. Also, we wanted a material whose composition could easily be changed to simulate the radiation attenuation properties of tissues other than muscle. Finally, the method of incorporation of the radionuclides in the organs had to be fairly simple. The Shonka plastic does not meet these requirements.

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Sample Serial No. C-1 134 (4.3% CaCO₃)

PART

SERIAL NO.

Mean Diameter 4.033

Torso

C-1-134

Mean Thickness .7873

Volume 164.806

LLNL Sample Volume: 162.27 cc

LLNL Sample Thickness: .790 in

Volume (weight) adjustment factor .9846

(Note: This is to adjust sample volume to LLNL sample volume. Since variations are diametrical, this will have no effect on counting.)

Humanoid Weight 181.7 Adjusted Weight 178.4

LLNL Sample Weight: 180.92 gms Error -1.11

LLNL & Humanoid Sample Counting Time: 1200 sec 3 x 400 sec

LLNL (counts at center) Background = 120 sec

Count Date 12-15-84

Count: #1 9823 #2 9865 #3 10032

By [Signature]

Less Background #1 -12 #2 -12 #3 -12

Net Count #1 9863 #2 9845 #3 9912

Mean: 9873.3 Deviation from Mean: .3916 +1 2869 -1

HUMANOID (3 positions in line)

Count Date 12-17-84

Thickness: Pos #1 .7873 Center Pos #2 .7873 Pos #3 .7871

By [Signature]

Count: Pos #1 9772 Pos #2 9772 Pos #3 9649

Less Back.: Pos #1 -12 Pos #2 -12 Pos #3 -12

Net count: Pos #1 9660 Pos #2 9660 Pos #3 9529

Adj. for thickness* Result #1 9523.5 #2 9523.5 #3 9427.5

Mean 9496.16 Deviation from Mean +4259.5 -723%

% Error -3.8% (Mean: H.S. to LLNL)

*Based on plot of number of counts vs thickness: 35/.001 in deviation from LLNL sample.

Signed [Signature]
Technician

Date 12-20-84

Sample Serial No. F-180 (6.2% CaCO₃)

Mean Diameter 3.734"

Mean Thickness 1.51683"

Volume 272.184 cc

LLNL Sample Volume: 226.47 cc

LLNL Sample Thickness: 1.390 in

Volume (Weight) adjustment factor .832

(Note: This is to adjust sample volume to LLNL sample volume. Since variations are diametrical, this will have no effect on counting.)

Humandol Weight: 65.58 Adjusted Weight 54.56g

LLNL Sample Weight: 55.30 gms Error -7.98

LLNL & Humandol Sample Counting Time: 360 sec

LLNL (counts at center)

Count date 12-13-84

By MA

Count 10233 10146 10185

Less Background 10 36 36

Net Count 10223 10110 10149

Mean: 10218.6 Deviation from Mean: .297 -1.062

HUMANDOL (3 positions in line)

Count date 12-13-84

By MA

Center

Thickness: Pos. #1 1.5175 Pos. #2 1.516 Pos. #3 1.517

Count Pos. #1 9084 Pos. #2 9637 Pos. #3 10099

Less Back. Pos. #1 36 Pos. #2 36 Pos. #3 36

Net Count Pos. #1 9048 Pos. #2 9601 Pos. #3 10063

Adj. for Pos. #1 11475 Pos. #2 1134 Pos. #3 1143

thickness* Result 10195 10735 11206

Mean 10712 Deviation from Mean 4.61 4.827

Error +4.828% (Mean: H.S. to LLNL)

*Based on plot of number of counts vs thickness: 9/.001 in.

deviation from LLNL sample

Sample may represent up to 5 pairs of lung kits molded at IPL.

IPL SECTION

Used on Lung No. F180-1

F180-2

Isotope X Amount X

Signed J. Golden

Technician

Date 12-20-84

Figure 1
Grid marks and Detector Position
on Realistic Phantom

Table 1
CI-134, Right Side

	col. 5	col. 6	Col. 7	col. 8	Col. 9	col. 10	Col. 11
row 4	XXXXXXX	XXXXXXX	16.24 mm	16.63 mm	15.58 mm	XXXXXXX	XXXXXXX
row 5	XXXXXXX	16.65 mm	15.17 mm	14.59 mm	14.71 mm	14.54 mm	XXXXXXX
row 6	16.12 mm	14.55 mm	14.46 mm	13.28 mm	13.54 mm	13.41 mm	12.70 mm
row 7	15.24 mm	13.23 mm	12.17 mm	12.90 mm	12.95 mm	12.88 mm	12.72 mm
row 8	XXXXXXX	11.71 mm	12.65 mm	12.12 mm	12.62 mm	12.75 mm	XXXXXXX
row 9	XXXXXXX	XXXXXXX	13.23 mm	12.73 mm	12.05 mm	XXXXXXX	XXXXXXX

Table 2
CI-134, Right Side

	col. 4	col. 5	Col. 6	col. 7	col. 8	col. 9
row 10	XXXXXXXX	XXXXXXXX	13.71 mm	13.03 mm	XXXXXXXX	XXXXXXXX
row 11	XXXXXXXX	13.20 mm	12.54 mm	12.14 mm	13.21 mm	XXXXXXXX
row 12	14.50 mm	13.71 mm	12.77 mm	13.33 mm	13.33 mm	13.94 mm
row 13	13.76 mm	13.34 mm	13.53 mm	13.90 mm	14.35 mm	15.57 mm
row 14	13.35 mm	13.38 mm	13.60 mm	14.21 mm	16.02 mm	15.94 mm
row 15	XXXXXXXX	13.59 mm	12.97 mm	15.33 mm	16.22 mm	XXXXXXXX
row 16	XXXXXXXX	XXXXXXXX	13.91 mm	14.07 mm	XXXXXXXX	XXXXXXXX

Table 3
CI-134, Left Side

	col. 19	col. 20	Col. 21	Col. 22	col. 23	Col. 24
row 4	XXXXXXXX	XXXXXXXX	14.39 mm	14.63 mm	XXXXXXXX	XXXXXXXX
row 5	XXXXXXXX	11.76 mm	12.39 mm	12.23 mm	12.31 mm	XXXXXXXX
row 6	14.21 mm	11.49 mm	11.55 mm	11.76 mm	12.68 mm	14.14 mm
row 7	14.09 mm	12.72 mm	12.09 mm	12.15 mm	13.56 mm	15.17 mm
row 8	XXXXXXXX	12.97 mm	12.55 mm	12.00 mm	12.47 mm	XXXXXXXX
row 9	XXXXXXXX	XXXXXXXX	12.40 mm	11.70 mm	XXXXXXXX	XXXXXXXX

Average Thickness for CI-134 = 13.55 mm

Table 7
A-138-1, Left Side

	col. 19	col. 20	Col. 21	col. 22	col. 23	Col. 24
row 4	XXXXXXXX	XXXXXXXX	6.06 mm	6.06 mm	XXXXXXXX	XXXXXXXX
row 5	XXXXXXXX	6.03 mm	6.03 mm	6.01 mm	6.01 mm	XXXXXXXX
row 6	5.29 mm	5.29 mm	5.29 mm	5.29 mm	5.29 mm	5.29 mm
row 7	5.08 mm	5.08 mm	5.08 mm	5.05 mm	5.05 mm	5.05 mm
row 8	XXXXXXXX	5.46 mm	5.46 mm	5.87 mm	5.87 mm	XXXXXXXX
row 9	XXXXXXXX	XXXXXXXX	5.25 mm	5.25 mm	XXXXXXXX	XXXXXXXX

Average Thickness for A-138-i = 6.10 mm

Table 9
A-138-2, Right Side

	col. 5	col. 6	col. 7	col. 8	col. 9	col. 10	Col. 11
row 4	XXXXXX	XXXXXX	11.05 mm	11.05 mm	11.05 mm	XXXXXX	XXXXXX
row 5	XXXXXX	11.12 mm	11.12 mm	11.12 mm	10.47 mm	10.47 mm	XXXXXX
row 6	10.89 mm	10.89 mm	10.89 mm	11.06 mm	11.06 mm	10.81 mm	10.81 mm
row 7	11.00 mm	11.00 mm	11.00 mm	11.30 mm	11.30 mm	11.20 mm	11.20 mm
row 8	XXXXXX	11.04 mm	11.04 mm	11.04 mm	10.95 mm	10.95 mm	XXXXXX
row 9	XXXXXX	XXXXXX	11.29 mm	11.29 mm	11.29 mm	XXXXXX	XXXXXX

Table 10
A-138-2, Right Side

	col. 4	col. 5	Col. 6	col. 7	col. 8	Col. 9
row 10	XXXXXXXX	XXXXXXXX	11.06 mm	11.06 mm	XXXXXXXX	XXXXXXXX
row 11	XXXXXXXX	11.00 mm	11.00 mm	11.15 mm	11.15 mm	XXXXXXXX
row 12	11.16 mm	11.16 mm	11.16 mm	11.49 mm	11.49 mm	11.49 mm
row 13	11.49 mm	11.49 mm	11.49 mm	11.38 mm	11.38 mm	11.38 mm
row 14	11.39 mm	11.39 mm	11.39 mm	11.33 mm	11.33 mm	11.33 mm
row 15	XXXXXXXX	11.38 mm	11.38 mm	11.34 mm	11.34 mm	XXXXXXXX
row 16	XXXXXXXX	XXXXXXXX	11.32 mm	11.32 mm	XXXXXXXX	XXXXXXXX

Table 13
A-138-3, Right Side

	col. 5	col. 6	col. 7	col. 8	col. 9	col. 10	Col. 11
row 4	XXXXXX	XXXXXX	16.38 mm	16.38 mm	16.38 mm	XXXXXX	XXXXXX
row 5	XXXXXX	17.12 mm	17.12 mm	17.12 mm	16.34 mm	16.34 mm	XXXXXX
row 6	17.04 mm	17.04 mm	16.75 mm	16.75 mm	16.38 mm	16.38 mm	16.38 mm
row 7	17.01 mm	17.02 mm	17.02 mm	16.99 mm	16.99 mm	17.04 mm	17.04 mm
row 8	XXXXXX	17.25 mm	17.25 mm	17.25 mm	17.25 mm	17.25 mm	XXXXXX
row 9	XXXXXX	XXXXXX	17.18 mm	17.18 mm	17.18 mm	XXXXXX	XXXXXX

Table 14
A-138-3, Right Side

	col. 4	col. 5	Col. 6	col. 7	col. 8	Col. 9
row 10	XXXXXXXX	XXXXXXXX	17.15 mm	17.15 mm	XXXXXXXX	XXXXXXXX
row 11	XXXXXXXX	17.12 mm	17.12 mm	17.02 mm	17.02 mm	XXXXXXXX
row 12	17.19 mm	17.19 mm	17.19 mm	17.19 mm	17.19 mm	17.19 mm
row 13	17.81 mm	17.81 mm	17.81 mm	17.81 mm	17.81 mm	17.81 mm
row 14	18.15 mm	18.15 mm	18.15 mm	18.15 mm	18.15 mm	18.15 mm
row 15	XXXXXXXX	18.27 mm	18.27 mm	18.27 mm	18.27 mm	XXXXXXXX
row 16	XXXXXXXX	XXXXXXXX	18.06 mm	18.06 mm	XXXXXXXX	XXXXXXXX

Table 15
A-138-3, Left Side

	col. 19	col. 20	Col. 21	col. 22	col. 23	Col. 24
row 4	XXXXXXXX	XXXXXXXX	16.49 mm	16.49 mm	XXXXXXXX	XXXXXXXX
row 5	XXXXXXXX	16.29 mm	16.29 mm	16.57 mm	16.57 mm	XXXXXXXX
row 6	16.11 mm	16.11 mm	16.11 mm	16.25 mm	16.25 mm	16.25 mm
row 7	16.15 mm	16.15 mm	16.15 mm	16.33 mm	16.33 mm	16.33 mm
row 8	XXXXXXXX	16.63 mm	16.63 mm	16.63 mm	16.54 mm	XXXXXXXX
row 9	XXXXXXXX	XXXXXXXX	16.14 mm	16.14 mm	XXXXXXXX	XXXXXXXX

Average Thickness for A-138-3 = 17.02 mm

Table 17
A-138-4, Right Side

	col. 5	col. 6	col. 7	col. 8	col. 9	col. 10	Col. 11
row 4	XXXXXX	XXXXXX	21.6 mm	21.6 mm	21.6 mm	XXXXXX	XXXXXX
row 5	XXXXXX	21.82 mm	21.82 mm	21.26 mm	21.26 mm	21.84 mm	XXXXXX
row 6	21.88 mm	21.88 mm	21.95 mm	21.95 mm	21.88 mm	21.88 mm	21.88 mm
row 7	21.87 mm	21.87 mm	21.87 mm	21.87 mm	21.87 mm	22.96 mm	22.96 mm
row 8	XXXXXX	22.28 mm	22.28 mm	22.74 mm	22.74 mm	22.74 mm	XXXXXX
row 9	XXXXXX	XXXXXX	21.96 mm	21.96 mm	21.96 mm	XXXXXX	XXXXXX

Table 18
A-138-4, Right Side

	col. 4	col. 5	Col. 6	col. 7	col. 8	col. 9
row 10	XXXXXXXX	XXXXXXXX	21.88 mm	21.88 mm	XXXXXXXX	XXXXXXXX
row 11	XXXXXXXX	22.15 mm	22.15 mm	21.56 mm	21.56 mm	XXXXXXXX
row 12	22.24 mm	22.24 mm	22.24 mm	22.36 mm	22.36 mm	22.36 mm
row 13	22.84 mm	22.84 mm	22.84 mm	22.58 mm	22.58 mm	22.58 mm
row 14	22.73 mm	22.73 mm	22.73 mm	23.00 mm	23.00 mm	23.00 mm
row 15	XXXXXXXX	22.78 mm	22.78 mm	22.92 mm	22.92 mm	XXXXXXXX
row 16	XXXXXXXX	XXXXXXXX	22.92 mm	22.92 mm	XXXXXXXX	XXXXXXXX

Table 19
A-138-4, Left Side

	col. 19	col. 20	Col. 21	col. 22	col. 23	col. 24
row 4	XXXXXXX	XXXXXXX	21.85 mm	21.85 mm	XXXXXXX	XXXXXXX
row 5	XXXXXXX	22.26 mm	22.26 mm	22.27 mm	22.27 mm	XXXXXXX
row 6	21.48 mm	21.48 mm	21.48 mm	21.47 mm	21.47 mm	21.47 mm
row 7	21.61 mm	21.61 mm	21.61 mm	21.20 mm	21.20 mm	21.20 mm
row 8	XXXXXXX	21.54 mm	21.54 mm	21.27 mm	21.27 mm	XXXXXXX
row 9	XXXXXXX	XXXXXXX	21.36 mm	21.36 mm	XXXXXXX	XXXXXXX

Average Thickness for A-138-4 = 22.07 mm