Calibration of the Accuscan II In Vivo System for Whole Body Counting

O. R. Perry

August 2011

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August 2011

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<http://www.inl.gov>

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Health Physics Dosimetry Laboratory

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Whole Body Counting

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ABSTRACT

This report describes the April 2011 calibration of the Accuscan II HpGe In Vivo system for whole body counting. The source used for the calibration was a NIST traceable BOMAB manufactured by DOE as INL2006 BOMAB containing Eu-154, Eu-155, Eu-152, Sb-125 and Y-88 with energies from 27 keV to 1836 keV with a reference date of 11/29/2006. The actual usable energy range was 86.5 keV to 1597 keV on 4/21/2011. The BOMAB was constructed inside the Accuscan II counting “tub” in the order of legs, thighs, abdomen, thorax/arms, neck, and head. Each piece was taped to the backwall of the counter. The arms were taped to the thorax. The phantom was constructed between the v-ridges on the backwall of the Accuscan II counter. The energy and efficiency calibrations were performed using the INL2006 BOMAB. The calibrations were performed with the detectors in the scanning mode. 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 whole body counting and verified in accordance with ANSI/HPS N13.30-1996 criteria.

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ACRONYMS

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

Calibration of the Accuscan II In Vivo System for Whole Body Counting

1. INTRODUCTION

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

The energy/FWHM-Low Tail calibration was performed on April 21, 2011 and is documented in Appendix C. A Doe manufactured Bottle Manikin Absorption Phantom (BOMAB) designated INL2006 BOMAB was used for the energy/FWHM – Low Tail calibration. The INL2006 BOMAB is NIST traceable and is documented in Appendix A. The source has a reference date of November 29, 2006 with the current activity documented in Appendix B. The INL2006 BOMAB phantom was used for both the energy and efficiency calibrations. The INL2006 BOMAB was positioned in the Accuscan II counter and counted for 10,833 seconds for both the energy and efficiency calibrations with the detectors in a scanning mode (counting from head to foot).

An efficiency calibration was performed subsequent to the energy/FWHM calibration on April 21, 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 21, 2011 is expressed as a dual fit using a 4th 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 N13.30-1996¹ 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 BOMAB DL#BM09A4GA. 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 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 is supported by a Genie 2000 spectroscopy system operating on a Dell Optiplex 780 PC. The counter system is located in a 9'4" high $\times$ 8'7 1/2" 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 constructed of 4" of low background 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 BOMAB # INL2006 BOMAB manufactured by DOE was used for both the energy and efficiency calibrations. The BOMAB contains uniformly distributed Eu-154, Eu-155, Eu-152, Sb-125 and Y-88 and the source certificate is described in Appendix A. The reference date for the BOMAB is 11/29/2006 and at the calibration date of 4/21/2011 the Y-88 is well below minimum testing levels as described in ANSI/HPS N13.30-1996. Eu-152 is also part of the source manufacture with very small activity levels and does not present interference. The source activity was decayed to the efficiency calibration date of April 21, 2011 and is documented in Appendix B.

The BOMAB phantom is described in Appendix I.

Validation counting of the calibration was performed using a NIST traceable DOE manufactured BOMAB DL#BM09A4GA containing Mn-54, Co-60, CS-134 and Cs-137. This source certificate is documented in Appendix A and source decay in Appendix B.

4. DETECTOR AND LYNX DIGITAL AMPLIFIER TESTING

A Pole Zero was performed in accordance with MCP-3336² for both detectors. The Left detector pole zero remained unchanged at 2421 units and the Right detector changed from 2677 to 2676. This adjustment indicates that the pole zero values are stable and have remained stable since the I-131 calibration in March 2011.

The Co-60/Cs-137 check source was positioned on the Canberra Calibration Table top 5½” from the counter rearwall and 14¾” from the counter left wall. The center line of the detectors was raised 38¾” from the concrete vault floor. This places the center line of the detectors in line with the check source. To perform a pole zero on the amplifiers the count rate must be within 200 to 2000 cps.

5. ENERGY/FWHM CALIBRATION

On April 20, 2011 the CWI INL 2006 BOMAB Phantom was counted 10,833 seconds and was used for the Energy Calibration as well as the Efficiency calibration. The phantom was built in counter in accordance with ANSI HPS N13.35-1999 (Appendix I³) and MCP-3336 (legs, thighs, abdomen, thorax/arms, neck, and head). The phantom was built against the counter rearwall in the same position as personnel counting (between the v-ridges). The Accuscan II detectors were in the scanning mode (head to foot scanning).

The energy calibration was performed on April 21, 2011 for both the left, right and summed detectors. The energy calibration is documented in Appendix C.

6. EFFICIENCY CALIBRATION

Subsequent to the Whole Body (energy) calibration, the April 20, 2011 calibration count was used to perform an efficiency calibration. The calibration used a dual fit with a 4th order polynomial with no crossover.

The efficiency calibration was performed on April 21, 2011 at 9:11 AM for the summed detector. The efficiency calibration is documented in Appendix D.

7. CALIBRATION COUNT REANALYSIS

The calibration count collected 4/20/2011 at 4:28 PM was reanalyzed using the new energy and efficiency calibration dated 4/21/2011 9:06 AM and 4/21/2011 9:11 AM respectively. The results of the reanalysis indicated a Relative bias within -0.029 to 0.524 with an average bias of 0.051. One result lying outside the ANSI/HPS N13.30 criteria was the 1596 keV energy line of Eu-154. This energy line has a yield of only 1.8% and resulted in the large relative bias. This is not considered a substantial problem in that the only INL plant radionuclide to be analyzed at this energy is La-140 (1596 keV) with a yield of 95.49%. The yield of La-140 should return a bias well within the bias criteria of ANSI/HPS N13.30-1996. The Relative Bias results (excluding the 1596 keV energy line of Eu-154) was within -0.029 to 0.078. The results indicate 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 Whole Body efficiency calibration and was performed on 4/21/2011 using the INL 2006 BOMAB phantom to obtain a set (5) of verification counts. The verification counts were collected for 600 seconds real time (10 minutes). Five individual counts were performed and the summary analysis performed in EXCEL. The BOMAB contained the radionuclides Sb-125, Eu-154, Eu-155 and low to undetectable amounts of Y-88 and Eu-152. The result of the verification testing is summarized in Appendix F and indicates a Relative Bias spread between -5% and +9.70%. The average Relative Bias was 2.3%. The Relative Precision has a spread of 2.2% to 23.3% with an average Relative Precision of 9.7%. The upper value for the Relative Precision was associated with the 1596 keV peak of Eu-154. It should be noted that the yield for this peak is only 1.8% which results in a larger variance of test values. The results are within the acceptance criteria of ANSI/HPS N13.30-1996.

9. MDA CALCULATIONS

MDA testing was conducted on April 26, 2011. Three individuals with no internal radionuclide deposits were counted for 10 minutes each. Individuals were used because no clean BOMAB phantom exists at the INL facility. 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

Whole Body Counting validation testing was conducted on 4/21/2011 using the DOE BOMAB DL#BM09A4GA. The validation counts were collected for the normal chest counting time of 10 minutes. The DL#BM09A4GA BOMAB contained the radionuclides Mn-54, Co-60, Cs-134 and Cs-137. The results of the validation testing are summarized in Appendix H with a Relative bias of -6.4% to 8.7% and a Relative precision of 1.1% to 13.9%. 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 whole body calibrations created on April 21, 2011 for the Accuscan II counter is satisfactory for counting personnel when the detectors are in the scanning mode. A summary of current calibration files for this counter is shown in Table 1.

The INLPLANTLIB.NLB nuclide library file is the default for whole body counting. Non-systematic and systematic errors for the in vivo system are described and quantified in Reference 4 - TEV-1275 (INL In Vivo System Counting Uncertainty).

The overall percent (%) counting uncertainty using the Accuscan II for whole body counting is:

$$\text{Total \% Uncertainty (Accuscan II) for wholebody} = \sqrt{(\% \text{counting uncertainty})^2 + (7.66)^2 + (18.0)^2}$$

Table 1. Calibration summary.

Facility:	Idaho National Laboratory, Building HPDL CFA-1618	
Counting System:	Accuscan II Scanning Whole Body	
Counter Arrangement:	Accuscan II for Whole Body	
Detector	Energy Calibration Date	Time
Accuscan II BE Detectors	04/21/2011	9:06 AM
Efficiency Calibration:		
Detector	Energy Calibration Date	Time
Accuscan II BE Detectors	04/21/2011	9:11 AM

12. REFERENCES

1. American National Standard, American National Standards Institute/Health Physics Society ANSI/HPS N13.30-1996, "Performance Criteria for Radiobioassay," 1996
2. MCP-3336, "Accuscan II Calibration, Performance Testing and Reporting, 2011
3. ANSI/HPS N13.35-1999, "Specifications for the Bottle Manikin Absorption Phantom," September 1999
4. Idaho National Laboratory, Basis Document TEV-1275, "INL In Vivo System Counting Uncertainty," 2011

Appendix A

Source Certificate

Appendix A

Source Certificate

INL2006 BOMAB

CERTIFICATE OF CALIBRATION

TOTAL ACTIVITY
(uCi)

Eu-154	<u>0.466 +/- 0.009</u>
Eu-155	<u>0.433 +/- 0.009</u>
Eu-152	<u>0.029 +/- 0.001</u>
Sb-125	<u>0.974 +/- 0.019</u>
Y-88	<u>0.887 +/- 0.018</u>

Stated activities are calibrated as of 29 November 2006 12:00 PST

Total Uncertainty is reported as the calculated sum of squares and is reported as 1 sigma.

Method of Calibration:

This source was prepared from weighed aliquots of solutions from Isotope Product Laboratories, whose activities in uCi/g was determined using gamma ray spectrometry or a pressurized well type ionization chamber, that were subsequently mixed, diluted and solidified. Both IPL and RESL participate in NIST measurement assurance programs to establish and maintain implicit traceability of Standard Reference Materials. The attached documents show the unbroken chain of traceability for the INL2006 BOMAB.

RESL is an accredited ISO 17025:2005 Chemical Testing and ISO 43 Performance Test Material Provider.

11/29/2006

L. Guy Backstrom
Radiochemist
United States Department of Energy
Radiation and Environmental Sciences Laboratory

Page 2

Notes:

The INL 2006 BOMAB was made using SP400 waterworks crystal as a solidifier (3% by weight). The Attenuation properties are not affected at γ energies greater than 60 KeV.

This BOMAB was prepared in accordance with RESL Technical Procedure RB-TP-DR.01 Rev 3 Authorized 9/6/06.

11/22/2006

INL2006 BOMAB

BOMAB "SPIKE SOLUTION" WORKSHEET

page 3 of 18

By *[Signature]*
11/29/06

DOELAP SESSION

NA

BOMAB NUMBER

INL2006

DATE

11/29/2006

SPIKE SOLUTION BOTTLE

	Amount Needed	Amount Added	
KOH	25.0 g	24.99 +/- 0.02	
DTPA	36.0 g	36.02 +/- 0.02	
Mn(NO3)2 51% soln.	4.4 g	4.40 +/- 0.02	
Co Hold Back soln.	113.0 g	113.00 +/- 0.02	
Eu Hold Back soln. 10 mg/mL	5.0 mL	5.0 +/- 0.1	
Y Hold Back soln. 10 mg/mL	5.0 mL	5.0 +/- 0.1	
Sb Hold Back soln. 10 mg/mL	5.0 mL	5.0 +/- 0.1	
501.1g Added 1.302g Eu-155 ACTIVITY ADDED (pCi)	(pCi)	18 for +/- TOTAL Activity	DATE
1.301g Eu-154 ACTIVITY ADDED (pCi)	+/-	AS OF	
1.356g Sb-125 ACTIVITY ADDED (pCi)	+/-	AS OF	
3.758g Y-88 ACTIVITY ADDED (pCi)	+/-	AS OF	

Mettler PB303 ID# 1112201120 calibrated 9-23-06 Due 3-07

Check Balance with TROEMNER CLASS 1 weight set s/n 15685

calibrated 3/10/06

Known	Exp'l
2.000g	2.000g
5.000g	5.000g
7.000g	7.000g
10.000g	10.000g
20.000g	20.000g
50.000g	49.999g

BALANCE OK LRB 11/29/06

Solutions used

Eu-155-1

Eu-154-1

Y-88-1

Sb-125-1

see BACKSTRAHL STANDARDIS & TRACER LAB NOTEBOOK
FOR HOW SOLUTIONS WERE PREPARED

BALANCE VERIFICATION FORM
page 4 of 18

METTLER DJ300J

DATE CHECKED

11/29/06

CALIBRATION DUE

3/07

LAST CALIBRATION

9/21/06

PERFORMED BY

Jim Faltner

Weights Used	SERIAL NO.	CALIBRATION DUE	Expected Mass (kg)	Expl' Mass (kg)
TROEMNER	#1 20kg	See Note	20.000g	20.0kg
TROEMNER	#2 20kg	See Note	20.000g	20.0kg
TROEMNER	#3 20kg	See Note	20.000g	20.0kg
#1 + #2 + #3		See Note	60.0kg	60.0kg
TROEMNER			50kg	50.0kg

Expected Regression Value: PASS FAIL VERIFICATION

Expl' Regression Line $y = 1x$ $y = 1.00x + 0.05$

R-squared value 1.00 1.00

PASS/FAIL criteria: Expl' Regression Slope and R-squared Values must be the same as Expected Regression Values. The Expl' Intercept value must be between 0.04-0.06.

Pb#1 - Pb#6 Bricks are located in room 122.

Note: self calibrated by Jim Faltner 11/29/06

using the TROEMNER masses that were verified on different balance.

BALANCE VERIFICATION FORM

page 5 of 18

PM 34-K Delta Range

DATE CHECKED

11/29/06

CALIBRATION DUE

3/07

LAST CALIBRATION

9/21/06

PERFORMED BY

[Signature]

Weights Used	SERIAL NO.	CALIBRATION DUE	Expected Mass (g)	Expl' Mass (g)
TROEMNER #1	211	See Note	20000g	20002g
TROEMNER #2	212	See Note	20000g	20002g
500 1706g	1kg	9/22/07	1000.01g	1000.00g
500 268g	2kg	9/28/07	2000.01g	2000.5g
500 1180g	500g	9/29/07	500.01g	500.2g

Expl' Regression Line	$y = 1x$	Expected Regression Value	PASS/FAIL VERIFICATION
R-squared value	0.9999	$y = 1.00x + 0.05$	1.00

PASS/FAIL criteria: Expl' Regression Slope and R-squared Values must be the same as Expected Regression Values. The Expl' Intercept value must be between 0.04-0.06.

Verified weights on SF 32001 Delta Range ID# 2115137444
 Cal. bracket 19/6/06 due 3/07
 TROEMNER #1 20000g Expected 20001g
 TROEMNER #2 20000g 20001g

BOMAB "GUT SOLUTION" ACTIVITY CONCENTRATION WORKSHEET
page 6 of 18

page 1 of 2

DOELAP SESSION NA

BOMAB NUMBER INL2006

STANDARDS LABORATORY NOTEBOOK USED
Backstrom#1 STANDARDS AND TRACERS

PAGE NUMBER 34,35,36,37

LOCATION CFA690 RM 122

PERFORMED BY Guy Backstrom

INITIAL SPIKE DILUTION

LINE

MASS (grams)

A MASS 50 L CARBOY EMPTY
(with cap, stirring bar and hose attachment)

4407 +/- 2

TARE BALANCE

(yes/no)

TARED 50 L CARBOY TARGET DILUTION
(BOMAB SPIKE + enough H2O rinses to make 6000 g)

6000 grams

B TARED CARBOY EXPL' DILUTION
(ACTUAL BOMAB SPIKE + H2O rinses)

6021 +/- 1

REMOVE CARBOY AND TARE BALANCE

(yes/no)

C MASS 50 L CARBOY WITH SPIKE
(with cap, stirring bar and hose attachment)

10419 +/- 1

10419
- 4407
6012

In Agreement

BOMAB "GUT SOLUTION" ACTIVITY CONCENTRATION WORKSHEET

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page 2 of 2

DOELAP SESSION NA

BOMAB NUMBER INL2006

FIRST "GUT SOLUTION" ADDITION

MASS (grams)

D MASS 20 L CARBOY EMPTY
(with spiket and hose)

1941.1 ± 0.2 g

E MASS 20 L CARBOY with "GUT SOLUTION"
(add about 14000 g "GUT SOLUTION")

15941 ± 1 g

F MASS 20 L CARBOY after emptying into
50 L CARBOY

2006.7 ± 0.2 g

FIRST H2O ADDITION

G MASS 20 L CARBOY with H2O
(add about 14000 g H2O)

16053 ± 2 g

H MASS 20 L CARBOY after emptying into
50 L CARBOY

1948.3 ± 0.2 g

SECOND H2O ADDITION

I MASS 20 L CARBOY with H2O
(add about 14000 g H2O)

15968 ± 1 g

J MASS 20 L CARBOY after emptying into
50 L CARBOY

2062.2 ± 0.2 g

TOTAL MASS OF BOMAB "SPIKED GUT SOLUTION" = $B + (E - F) + (G - H) + (I - J)$

K

47947.5 ± 11 g

L MASS 50 L CARBOY FULL (weigh of Mettler DT300J
(with cap, stirring bar and hose attachment)

52.4 ± 0.1 kg

inc A + K $\Rightarrow 52354.5$ g - 52.4 kg

COMPARE (K+A) to L

L must be within ± 100 grams of (K+A)

within limits (yes/no)

use 47948 ± 11 g as the spike dilution

5906.7
1941.1
59.6

Spilled a little
of the gut
soln.

so use
weight from
50 L carboy

24345 ± 1 g

mass with
lid + stirring
bar

24345
- 10419

13926 g added

24345

- 4407

19938 g total

(6011) + (13926) + (14104.7) + (13905.8)

19938

627

1941.1

14062

16003

+ 50

BOMAB HEAD WORKSHEET

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DOELAP SESSION NA

BOMAB NUMBER INL2006

PART NUMBER INL2006-1

BALANCE USED PM 34-K Delta Range

CALIBRATION DUE January 00 → 3/07

FILL DATE November 28, 2006

PERFORMED BY Guy Backstrom

MASS (grams)

MASS EMPTY (no cap) 889.0 +/- 0.5

MASS EMPTY (with cap) 919.8 +/- 0.5

TARGET MASS FILL 2610 grams

EXPL' MASS FILL 2531.9 +/- 0.5g

MASS FULL (with cap) 3482.2 +/- 0.5g

MASS FULL (with cap/^{SP 400}silicone) 3529.8 +/- 0.5g

The first number on Target mass fill represents 97% of the printed Target mass fill. The second number represents 3% of Target mass fill.

Amount of spilled g of solution to add.

Amount of SP 400 water works crystals to add.

[Signature]

EXTERIOR DIMENSIONS (cm) LEAK CHECK DATE MASS (grams)

D1 10/4/06 3543.3g

D2 11/27/06 3543.3g

H

BOMAB NECK WORKSHEET

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DOELAP SESSION	<u>NA</u>
BOMAB NUMBER	<u>INL2006</u>
PART NUMBER	<u>INL2006-2</u>
BALANCE USED	<u>PM 34-K Delta Range</u>
CALIBRATION DUE	<u>January 00 3/07</u>
FILL DATE	<u>November 29, 2006</u>
PERFORMED BY	<u>Guy Backstrom</u>

MASS (grams)

MASS EMPTY (no cap)	<u>410.0 +/- 0.5g</u>	<u>409.60</u>
MASS EMPTY (with cap)	<u>416.8 +/- 0.5g</u>	<u>416.63</u>
TARGET MASS FILL	560 grams	<u>543/17</u>
EXPL' MASS FILL	<u>543.00 +/- 0.05g</u>	
MASS FULL (with cap)	<u>550.01 +/- 0.05g</u>	
MASS FULL (with cap/ ^{sp. 400} silicone)	<u>976.40 +/- 0.05g</u>	

EXTERIOR DIMENSIONS	LEAK CHECK DATE	MASS (grams)
(cm)		
D1	<u>10/4/06</u>	<u>974.0 g</u>
D2	<u>11/27/06</u>	<u>974.0 g</u>
H		

BOMAB ARM-1 WORKSHEET

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DOELAP SESSION	<u>NA</u>
BOMAB NUMBER	<u>INL2006</u>
PART NUMBER	<u>INL2006-4</u>
BALANCE USED	<u>PM 34-K Delta Range</u>
CALIBRATION DUE	<u>January 00 3/07</u>
FILL DATE	<u>November 28, 2006</u>
PERFORMED BY	<u>Guy Backstrom</u>

MASS (grams)

MASS EMPTY (no cap)	<u>1091.5 +/- 0.5g</u>
MASS EMPTY (with cap)	<u>1078.6 +/- 0.5g</u>
TARGET MASS FILL	3080 grams 2988/92
EXPL' MASS FILL	<u>2988.0 +/- 0.5g</u>
MASS FULL (with cap)	<u>4087 +/- 1g</u>
MASS FULL (with cap/ ^{51,400} silicone)	<u>4178 +/- 1g</u>

EXTERIOR DIMENSIONS	LEAK CHECK DATE	MASS (grams)
(cm)		
D1	<u>10/4/06</u>	<u>4235g</u>
D2	<u>11/27/06</u>	<u>4235g</u>
H		

BOMAB ARM-2 WORKSHEET

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DOELAP SESSION NA

BOMAB NUMBER INT.2006

PART NUMBER INT.2006.5

BALANCE USED PM 34-K Delta Range

CALIBRATION DUE ~~January-00~~ 3/07

FILL DATE November 28, 2006

PERFORMED BY Guy Backstrom

MASS (grams)

MASS EMPTY (no cap) 1089.3 +/- 0.5 g

MASS EMPTY (with cap) 1096.4 +/- 0.5 g

TARGET MASS FILL 3080 grams 2988/92

EXPL' MASS FILL 2988.0 +/- 0.5 g

MASS FULL (with cap) 4084 +/- 1g

MASS FULL (with cap ⁸⁴⁴⁰silicone) 4176 +/- 1g

EXTERIOR DIMENSIONS	LEAK CHECK DATE	MASS (grams)
(cm)		
D1 _____	<u>10/4/06</u>	<u>4228.7</u>
D2 _____	<u>11/27/06</u>	<u>4228.7</u>
H _____		

BOMAB UPPER TORSO WORKSHEET

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DOELAP SESSION	<u>NA</u>
BOMAB NUMBER	<u>INL2006</u>
PART NUMBER	<u>INL2006-3</u>
BALANCE USED	<u>PM 34-K Delta Range</u>
CALIBRATION DUE	<u>January-00 3/07</u>
FILL DATE	<u>November 28, 2006</u>
PERFORMED BY	<u>Guy Backstrom</u>

MASS (grams)

MASS EMPTY (no cap)

2455.8 +/- 0.5 g

MASS EMPTY (with cap)

2486.9 +/- 0.5 g

TARGET MASS FILL

13371 grams

12970 / 401

EXPL' MASS FILL

12970 +/- 1 g

MASS FULL (with cap)

15457 +/- 1 gMASS FULL (with cap ⁵⁰⁴⁰⁰silicone)15851 +/- 1 g**EXTERIOR DIMENSIONS**
(cm)**LEAK CHECK DATE** **MASS (grams)**

D1 _____

10/4/06 15801 g

D2 _____

11/27/06 15801 g

H _____

BOMAB LOWER TORSO WORKSHEET

page 13 of 18

DOELAP SESSION	<u>NA</u>
BOMAB NUMBER	<u>INL2006</u>
PART NUMBER	<u>INL2006-6</u>
BALANCE USED	<u>PM 34-K Delta Range</u>
CALIBRATION DUE	<u>January-00 3/07</u>
FILL DATE	<u>November 28, 2006</u>
PERFORMED BY	<u>Guy Backstrom</u>

MASS (grams)

MASS EMPTY (no cap) 1464.8 +/- 0.5

MASS EMPTY (with cap) 1495.8 +/- 0.5

TARGET MASS FILL 7375 grams 7154/221

EXPL' MASS FILL 7154 +/- 1 g

MASS FULL (with cap) 8649 +/- 1 g

MASS FULL (with cap/silicone) ^{58.100} 8870 +/- 1 g

EXTERIOR DIMENSIONS LEAK CHECK DATE MASS (grams)

(cm)		
D1	<u>8903 g</u>	<u>10/4/06</u>
D2	<u>1122/06</u>	<u>8903 g</u>
H		

BOMAB THIGH-1 WORKSHEET

page 14 of 18

DOELAP SESSION	<u>NA</u>
BOMAB NUMBER	<u>INL2006</u>
PART NUMBER	<u>INL2006-7</u>
BALANCE USED	<u>PM 34-K Delta Range</u>
CALIBRATION DUE	<u>January-00 3/07</u>
FILL DATE	<u>November 28, 2006</u>
PERFORMED BY	<u>Guy Backstrom</u>

	MASS (grams)
MASS EMPTY (no cap)	<u>1247.5 +/- 0.5</u>
MASS EMPTY (with cap)	<u>1278.3 +/- 0.5</u>
TARGET MASS FILL	4775 grams

EXPL' MASS FILL	<u>4632 +/- 1g</u>
MASS FULL (with cap)	<u>4663 +/- 1g</u>
MASS FULL (with cap/ ^{Sp. 400} silicone)	<u>6052 +/- 1g</u>

EXTERIOR DIMENSIONS	(cm)
D1	<u> </u>
D2	<u> </u>
H	<u> </u>

LEAK CHECK DATE	MASS (grams)
<u>10/4/06</u>	<u>6066g</u>
<u>10/27/06</u>	<u>6066g</u>

4632/143

← I didn't Re-Tare cap
so
Empty no cap 1247.5
+ Expl mass fill 4663
+ cap
5910.5
+ 143
6053.5g
IS in agree-
with 6052g

BOMAB THIGH-2 WORKSHEET

page 15 of 18

DOELAP SESSION	<u>NA</u>
BOMAB NUMBER	<u>INL2006</u>
PART NUMBER	<u>INL2006-8</u>
BALANCE USED	<u>PM 34-K Delta Range</u>
CALIBRATION DUE	<u>January-00 3/07</u>
FILL DATE	<u>November 29, 2006</u>
PERFORMED BY	<u>Guy Backstrom</u>

	MASS (grams)
MASS EMPTY (no cap)	<u>1248.5 +/- 0.5</u>
MASS EMPTY (with cap)	<u>1279.3 +/- 0.5</u>
TARGET MASS FILL	4775 grams <u>4632/143</u>
EXPL' MASS FILL	<u>4632 +/- 1g</u>
MASS FULL (with cap)	<u>5911 +/- 1g</u>
MASS FULL (with cap ^{8.400} silicone)	<u>6054 +/- 1g</u>

EXTERIOR DIMENSIONS	LEAK CHECK DATE	MASS (grams)
(cm)		
D1	<u>10/4/06</u>	<u>6071g</u>
D2	<u>11/27/06</u>	<u>6021g</u>
H		

BOMAB LEG-1 WORKSHEET

page 16 of 18

DOELAP SESSION	<u>NA</u>
BOMAB NUMBER	<u>INL2006</u>
PART NUMBER	<u>INL2006-9</u>
BALANCE USED	<u>PM 34-K Delta Range</u>
CALIBRATION DUE	<u>January 00 3/07</u>
FILL DATE	<u>November 28, 2006</u>
PERFORMED BY	<u>Guy Backstrom</u>

MASS (grams)

MASS EMPTY (no cap) 1037.4 +/- 0.1

MASS EMPTY (with cap) 1069.4 +/- 0.1

TARGET MASS FILL 3140 grams 3046/94

EXPL' MASS FILL 3046.2 +/- 0.5 g

MASS FULL (with cap) 4116 +/- 1 g

MASS FULL (with cap/silicone) ³¹⁴⁰⁰ 4209 +/- 1 g

EXTERIOR DIMENSIONS **LEAK CHECK DATE** **MASS (grams)**

(cm)			
D1	<u> </u>	<u>10/4/06</u>	<u>4236g</u>
D2	<u> </u>	<u>11/27/06</u>	<u>4236g</u>
H	<u> </u>		

BOMAB LEG-2 WORKSHEET

page 17 of 18

DOELAP SESSION	<u>NA</u>
BOMAB NUMBER	<u>INL2006</u>
PART NUMBER	<u>INL2006-10</u>
BALANCE USED	<u>PM 34-K Delta Range</u>
CALIBRATION DUE	<u>January 00 3/07</u>
FILL DATE	<u>November 29, 2006</u>
PERFORMED BY	<u>Gry Backstrom</u>

MASS (grams)

MASS EMPTY (no cap) 1036.6 +/- 0.1

MASS EMPTY (with cap) 1066.8 +/- 0.1

TARGET MASS FILL 3140 grams

3046/94

EXPL MASS FILL 3046.0 +/- 0.5

MASS FULL (with cap) ~~3076.3 +/- 0.5~~

4112 +/- 1g

MASS FULL (with cap/silicone) ^{SPR}
₊₅₇₉₀₀ 4206 +/- 1g

EXTERIOR DIMENSIONS (cm)

LEAK CHECK DATE

MASS (grams)

D1

D2

H

10/4/06 4220g

10/27/06 4220g

BOMAB TOTAL ACTIVITY WORKSHEET
page 18 of 18

BOMAB NUMBER INL2006

EXPL MASS FILL
(grams)

HEAD 2531.6 +/- 0.5
NECK 543.00 +/- 0.05
ARM-1 2988.0 +/- 0.5
ARM-2 2988.0 +/- 0.5
UPPER TORSO 12920 +/- 1
LOWER TORSO 7154 +/- 1
THIGH-1 4632 +/- 1
THIGH-2 4632 +/- 1
LEG-1 3046.2 +/- 0.5
LEG-2 3046.0 +/- 0.5
TOTAL MASS 44531 +/- 23

TOTAL ACTIVITY

	(uCi)	DATE
Eu-154 TOTAL ACTIVITY (uCi)	<u>0.466 +/- 0.009</u>	AS OF <u>November 29, 2006 12:00 PST</u>
Eu-155 TOTAL ACTIVITY (uCi)	<u>0.433 +/- 0.009 0.461 +/- 0.009</u>	AS OF <u>November 29, 2006 12:00 PST</u>
Eu-152 TOTAL ACTIVITY (uCi)	<u>0.029 +/- 0.001</u>	AS OF <u>November 29, 2006 12:00 PST</u>
Sb-125 TOTAL ACTIVITY (uCi)	<u>0.974 +/- 0.019</u>	AS OF <u>November 29, 2006 12:00 PST</u>
Y-88 TOTAL ACTIVITY (uCi)	<u>0.887 +/- 0.018</u>	AS OF <u>November 29, 2006 12:00 PST</u>

(Note: Total Uncertainty is calculated as the sum of squares and is reported as 1 sigma.)

RESL TECHNICAL PROCEDURE

Attachment 1
Page 1 of 1

Standards Preparation Form

Solution ID: Eu-154-1 Date Prepared: 11/15/2006 Matrix: 5% HNO₃
Final Activity: 7.72 ± 0.097E4 pCi/g as of 15-Jul-06
Final Activity: 9.96 ± 0.099E4 pCi/mL as of 15-Jul-06

Sol. ID Used In Prep: _____ Certificate Number: 1199-6-2
Act. of Sol. Used in Prep: 1.995 ± 1% d.c./g as of 15-Jul-06
Weight of Aliquot Taken: _____ g or Vol. of Aliquot Taken: _____ mL

Diluted to: 100 mL Ref: _____

Weight of Pycnometer Full: 6.519 g

Weight of Pycnometer Empty: 1.526 g

Net Weight of Solution: 4.993 g

169.165g

Weight of Vol. Flask Full: 168.065 g

Weight of Vol. Flask Empty: 66.731 g

Net Weight of Solution: 102.434 g

Prepared by: [Signature] Density: _____ g/mL

Comments: 10 mg Eu hold back carrier added.
Radio impurities: Eu-152 = 6.20%, Eu-155 = 17.4% as
of 15-Jul-06

This form is controlled as part of CHEM-TP-CA.1 (Rev 1) and cannot be informally altered.

**Isotope Products
Laboratories**

An Eckert & Ziegler Company

24937 Avenue Tibbitts
Valencia, California 91355

Tel 661•309•1010

Fax 661•257•8303

CERTIFICATE OF CALIBRATION GAMMA STANDARD SOLUTION

Radionuclide:	Eu-154	Customer:	IDAHO NATIONAL LABS
Half-life:	3136.8 ± 2.9 days	P.O. No.:	00053800
Catalog No.:	7154	Reference Date:	15-Jul-06 12:00 PST
Source No.:	1199-6-2	Contained Radioactivity:	10.05 μ Cl 371.9 kBq

Physical Description:

A. Mass of solution:	5.03872 g in 5 mL flame-sealed ampoule
B. Chemical form:	EuCl ₃ in 0.5M HCl
C. Carrier content:	10 μ g Eu/mL of solution
D. Density:	1.0077 g/mL @ 20°C

Radioimpurities:

Eu-152 = 6.20%; Eu-155 = 17.4% on 15-Jul-06

Radionuclide Concentration: 1.995 μ Cl/g, 73.82 kBq/g

Method of Calibration:

This source was prepared from a weighed aliquot of solution whose activity in μ Cl/g was determined using gamma ray spectrometry.

Peak energy used for integration:	723.3, 1274 keV
Branching ratio used:	0.202, 0.350 gammas per decay

Uncertainty of Measurement:

A. Type A (random) uncertainty:	± 0.3 %
B. Type B (systematic) uncertainty:	± 3.0 %
C. Uncertainty in aliquot weighing:	± 0.0 %
D. Total uncertainty at the 99% confidence level:	± 3.0 %

Notes:

- See reverse side for leak test(s) performed on this source.
- IPL participates in a 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).
- Nuclear data was taken from IAEA-TECDOC-619, 1991.
- This solution has a working life of 5 years

Quality Control

10-Jul-06
Date

IPL Ref. No.: 1199-6

ISO 9001 CERTIFIED

Medical Imaging Laboratory
24937 Avenue Tibbitts Valencia, California 91355

Industrial Gauging Laboratory
1800 North Keystone Street Burbank, California 91504

DL#BM09A4GA

Certified Reference Material

Certificate of Traceability

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

Standard Identification: BOMAB DL#BM09A4GA

Radionuclide	Activity
Cs-137	(3.86± 0.04) E2 nCi
Cs-134	(5.50± 0.06) E2 nCi
Co-60	(7.59± 0.08) E1 nCi
Mn-54	(3.89± 0.04) E1 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.

for David S. Sill

David S. Sill

Senior Technical Manager - Chemistry

April 19, 2011

Reference Date

Appendix B

Source Decay

Appendix B

Source Decay

INL2006 BOMAB DECAY

Decay Correction Worksheet for INL-2006 BOMAB Phantom

Date/Time: 4/21/11 12:00 AM
Source ID: INL2006 BOMAB PHANTOM
Source Description: BOMAB Phantom
Reference date: 11/29/06 12:00 PM
Elapsed Time: 1602.5

Nuclide	Energy (keV)	Abundanc (%)	T 1/2 Days	REF gammas/ sec	Present Activity (nCi)
Sb-125	27.47	38.7	1011.05	13946.7	324.66
Eu-155	86.5	30.9	1810.40	4950.489	234.44
Eu-155	105.3	20.6	1810.40	3300.326	234.44
Eu-154	123.1	40.5	3212.00	6983.010	329.76
Sb-125	176.3	6.7	1011.05	2414.546	324.66
Eu-154	247.9	6.6	3212.00	1137.972	329.76
Sb-125	427.9	29.5	1011.05	10631.210	324.66
Sb-125	463.4	10.3	1011.05	3711.914	324.66
Eu-154	591.8	4.8	3212.00	832.789	329.76
Sb-125	600.0	17.6	1011.05	6342.688	324.66
Sb-125	636.0	11.3	1011.05	4072.294	324.66
Eu-154	723.3	19.7	3212.00	3396.674	329.76
Eu-154	873.2	11.5	3212.00	1982.830	329.76
Y-88	898.0	93.4	106.64	30652.946	0.027
Eu-154	996.3	10.3	3212.00	1775.926	329.76
Eu-154	1005.0	17.9	3212.00	3086.318	329.76
Eu-154	1274.0	35.5	3212.00	6120.910	329.76
Eu-154	1597.0	1.8	3212.00	315.529	329.76
Y-88	1836.0	99.3	106.64	32589.267	0.027

DOE MANUFACTURED BOMAB SOURCE DL#BM09A4GA DECAY

Decay Correction for DOE BOMAB DL#BM09A4GA

Reference Date 4/19/2011
Current Date 4/27/2011
Elapsed Time 8

Identity	Energy (keV)	Reference Activity (nCi)	Yield %	T1/2 Days	G/nCi	Reference GPS	Current Activity (nCi)
Co-60	1173.2	75.9	99.9	1925	37	2.81E+03	7.59E+01
	1332.5	75.9	100	1925	37	2.81E+03	7.59E+01
Cs-137	661.7	386	85.1	10980.00	37	1.22E+04	3.86E+02
Cs-134	123	550	2.47	752.6	37	5.03E+02	5.50E+02
	475	550	1.46	752.6	37	2.97E+02	5.50E+02
	563	550	8.38	752.6	37	1.71E+03	5.50E+02
	604	550	97.6	752.6	37	1.99E+04	5.50E+02
	795.8	550	85.4	752.6	37	1.74E+04	5.50E+02
	801.9	550	8.73	752.6	37	1.78E+03	5.50E+02
Co-57	122.06	16.9	85.6	270.9	37	5.35E+02	1.69E+01
Mn-54	834.8	38.9	100	312.5	37	1.44E+03	3.89E+01

Appendix C

**Energy/FWHM and Low Tail Calibration
Documentation**

Appendix C

Energy/FWHM and Low Tail Calibration Documentation

Energy Calibration

Calibration Information

Calibration Title	WB-Left Energy Calibration 4/21/2011 8:58 AM
Calibration Date	4/21/2011 8:59:16 AM
Performed By	David Georgeson
Count Used	WB Calibration Count 4/20/2011 4:28 PM
Is Default	Yes

Counter Information

Counter Name	Accuscan II
Counter Location	Battelle

Detector Group Information

Detector Group Name	Left
Calibration Source	INL 2006 BOMAB
Analysis Sequence File	
Nuclide Library	INL 2006 BOMAB (Sb-125, Eu-154, Eu-155, Y-88)
Peak Search Library	INL 2006 BOMAB (Sb-125, Eu-154, Eu-155, Y-88)

Energy Calibration Coefficients

$$\text{Energy} = -0.224546 + 0.462114 * \text{ch} - 5.08754\text{e-}08 * \text{ch}^2$$

$$\text{FWHM} = 1.22855 + 0.0189769 * E^{1/2}$$

$$\text{LOW TAIL} = 0.45235 + 0.00181992 * E$$

Energy Calibration Results Table

<u>Centroid Channel</u>	<u>Centroid Error</u>	<u>Energy (keV)</u>
58.82	0.16	27.47
187.92	0.07	86.50
228.48	0.04	105.30
266.82	0.02	123.10
381.99	0.07	176.30
537.11	0.06	247.90
926.54	0.03	427.90
1003.29	0.05	463.40
1281.47	0.09	591.80
1300.29	0.10	600.00
1376.90	0.06	636.00
1566.06	0.05	723.30
1890.37	0.04	873.20

2156.78	0.09	996.30
2175.11	0.06	1005.00
2758.85	0.06	1274.00
3456.52	0.19	1597.00

Approved by: _____

Date: _____

User: David Georgeson

Energy Calibration Results Table

<u>Energy (keV)</u>	<u>FWHM Channels</u>	<u>FWHM Error</u>
27.47	4.60	0.39
86.50	3.00	0.17
105.30	2.85	0.11
123.10	3.20	0.05
176.30	3.18	0.17
247.90	3.19	0.14
427.90	3.43	0.05
463.40	3.59	0.12
591.80	3.16	0.23
600.00	3.44	0.20
636.00	3.72	0.13
723.30	3.90	0.11
873.20	3.70	0.09
996.30	3.64	0.21
1005.00	4.19	0.11
1274.00	4.38	0.11
1597.00	4.10	0.37

Energy Calibration

Calibration Information

Calibration Title WB-Right Energy Calibration 4/21/2011 9:03 AM
Calibration Date 4/21/2011 9:03:59 AM
Performed By David Georgeson
Count Used WB Calibration Count 4/20/2011 4:28 PM
Is Default Yes

Counter Information

Counter Name Accuscan II
Counter Location Battelle

Detector Group Information

Detector Group Name Right
Calibration Source INL 2006 Bomab
Analysis Sequence File
Nuclide Library INL 2006 BOMAB (Sb-125, Eu-154, Eu-155, Y-88)
Peak Search Library INL 2006 BOMAB (Sb-125, Eu-154, Eu-155, Y-88)

Energy Calibration Coefficients

$$\text{Energy} = -0.292078 + 0.462004 * \text{ch} - 1.86818\text{e-}08 * \text{ch}^2$$

$$\text{FWHM} = 0.50794 + 0.0326202 * E^{1/2}$$

$$\text{LOW TAIL} = -0.68983 + 0.0109714 * E$$

Energy Calibration Results Table

<u>Centroid Channel</u>	<u>Centroid Error</u>	<u>Energy (keV)</u>
59.76	0.23	27.47
187.95	0.04	86.50
228.55	0.02	105.30
267.01	0.02	123.10
382.15	0.05	176.30
537.21	0.05	247.90
926.74	0.02	427.90
1003.57	0.04	463.40
1281.64	0.09	591.80
1300.66	0.03	600.00
1377.05	0.03	636.00
1566.28	0.03	723.30
1890.67	0.05	873.20
2157.10	0.03	996.30
2175.38	0.03	1005.00

2759.09	0.04	1274.00
3456.50	0.26	1597.00

Approved by: _____

Date: _____

User: David Georgeson

Energy Calibration Results Table

<u>Energy (keV)</u>	<u>FWHM Channels</u>	<u>FWHM Error</u>
27.47	2.08	0.44
86.50	1.91	0.09
105.30	1.84	0.04
123.10	1.93	0.05
176.30	2.11	0.11
247.90	2.07	0.12
427.90	2.46	0.05
463.40	2.53	0.09
591.80	2.64	0.21
600.00	2.70	0.07
636.00	2.75	0.07
723.30	2.95	0.06
873.20	3.27	0.10
996.30	3.35	0.04
1005.00	3.53	0.07
1274.00	3.69	0.07
1597.00	3.56	0.53

Energy Calibration

Calibration Information

Calibration Title WB-Summed Energy Calibration 4/21/2011 9:06 AM
Calibration Date 4/21/2011 9:06:13 AM
Performed By David Georgeson
Count Used WB Calibration Count 4/20/2011 4:28 PM
Is Default Yes

Counter Information

Counter Name Accuscan II
Counter Location Battelle

Detector Group Information

Detector Group Name Summed
Calibration Source INL 2006 Bomab
Analysis Sequence File
Nuclide Library INL 2006 BOMAB (Sb-125, Eu-154, Eu-155, Y-88)
Peak Search Library INL 2006 BOMAB (Sb-125, Eu-154, Eu-155, Y-88)

Energy Calibration Coefficients

$$\text{Energy} = -0.261309 + 0.462146 * \text{ch} - 6.52091\text{e-}08 * \text{ch}^2$$

$$\text{FWHM} = 0.769313 + 0.0315245 * E^{1/2}$$

$$\text{LOW TAIL} = 0.308208 + 0.00142436 * E$$

Energy Calibration Results Table

<u>Centroid Channel</u>	<u>Centroid Error</u>	<u>Energy (keV)</u>
59.48	0.28	27.47
187.84	0.05	86.50
228.42	0.02	105.30
266.85	0.02	123.10
381.98	0.05	176.30
537.05	0.04	247.90
926.48	0.01	427.90
1003.28	0.03	463.40
1281.39	0.03	591.80
1300.33	0.02	600.00
1376.81	0.03	636.00
1565.99	0.03	723.30
1890.35	0.02	873.20
2156.77	0.07	996.30
2175.08	0.02	1005.00
2758.82	0.02	1274.00
3456.40	0.12	1597.00

Approved by: _____

Date: _____

User: David Georgeson

Energy Calibration Results Table

<u>Energy (keV)</u>	<u>FWHM Channels</u>	<u>FWHM Error</u>
27.47	2.32	0.61
86.50	2.44	0.12
105.30	2.38	0.05
123.10	2.54	0.06
176.30	2.64	0.12
247.90	2.68	0.10
427.90	3.06	0.02
463.40	3.16	0.06
591.80	3.05	0.08
600.00	3.28	0.05
636.00	3.35	0.06
723.30	3.56	0.06
873.20	3.59	0.05
996.30	3.66	0.15
1005.00	3.94	0.04
1274.00	4.16	0.04
1597.00	4.02	0.26

Appendix D

Efficiency Calibration Documentation

Appendix D

Efficiency Calibration Documentation

Efficiency Calibration

Calibration Information

Calibration Title	WB-Summed Efficiency Calibration 4/21/2011 9:11 AM
Calibration Date	4/21/2011 9:07:11 AM
Performed By	David Georgeson
Count Used	WB Calibration Count 4/20/2011 4:28 PM
Approved	4/22/2011 1:01:04 PM by David Georgeson
Is Default	Yes
Is Multi Curve	No

Counter Information

Counter Name	Accuscan II
Counter Location	Battelle
Counter Configuration	Total Body Scan

Detector Group Information

Detector Group Name	Summed
Calibration Source	INL 2006 Bomab
Analysis Sequence File	CALWBCGE.ASF
Nuclide Library	INL 2006 BOMAB (Sb-125, Eu-154, Eu-155, Y-88)
Peak Search Library	INL 2006 BOMAB (Sb-125, Eu-154, Eu-155, Y-88)

Approved by: _____

Date: _____

User: David Georgeson

Efficiency Triplets

Energy (keV)	Efficiency	Error	Dual	Difference
8.650E+001	3.777E-004	2.166E-005	3.718E-004	1.56 %
1.053E+002	4.220E-004	2.613E-005	4.279E-004	-1.40 %
1.231E+002	4.326E-004	2.227E-005	4.429E-004	-2.38 %
1.763E+002	4.238E-004	3.124E-005	4.013E-004	5.30 %
2.479E+002	3.224E-004	2.213E-005	3.219E-004	0.17 %
4.279E+002	2.100E-004	1.098E-005	2.144E-004	-2.10 %
4.634E+002	2.140E-004	1.285E-005	2.028E-004	5.22 %
5.918E+002	1.618E-004	1.431E-005	1.725E-004	-6.67 %
6.000E+002	1.676E-004	8.848E-006	1.710E-004	-2.03 %
6.360E+002	1.603E-004	9.701E-006	1.649E-004	-2.89 %
7.233E+002	1.522E-004	8.226E-006	1.522E-004	-0.03 %
8.732E+002	1.446E-004	8.356E-006	1.352E-004	6.53 %
9.963E+002	1.201E-004	6.838E-006	1.236E-004	-2.93 %
1.005E+003	1.252E-004	6.715E-006	1.229E-004	1.88 %
1.274E+003	1.003E-004	5.263E-006	1.016E-004	-1.34 %
1.597E+003	8.015E-005	1.004E-005	7.976E-005	0.48 %

Dual

$\ln(\text{eff}) = -160.954 + 102.97 * \ln(E) - 25.589 * (\ln(E))^2 + 2.79382 * (\ln(E))^3 - 0.113839 * (\ln(E))^4$
 where E = Energy in keV

Interpolated

Linear

$$\log(\text{eff}) = -0.000274415 * E - 3.6544 - 10.9338 / E + 33646 / E^2 - 4.97711e+06 / E^3 + 2.00236e+08 / E^4$$

where E = Energy in keV

Empirical

$$\ln(\text{eff}) = -8.88463 + 0.59522 * x - 0.107843 * x^2 + 0.438841 * x^3 - 0.27104 * x^4 + 0.0376868 * x^5$$

where $x = \ln(841.75 / E)$
 where E = Energy in keV

Appendix E

Whole Body Calibration Count Reanalysis

Appendix E

Whole Body Calibration Count Reanalysis

Summary of the Reanalysis of the Efficiency Calibration Count
For the Whole Body Efficiency Calibration

Arrangement/Geometry: Accuscan II
Analysis Library: INL 2006 BOMAB (Sb-125, Eu-154, Eu-155, Y-88). NLB
Energy Calibration Time: 4/21/2011 9:06 AM
Efficiency Calibration Time: 4/21/2011 9:11 AM
Count Live Time: 10833 Seconds
Count Start Time: 4/20/2011 4:28 PM

Nuclide	Energy keV	Expected Activity (μ Ci)	Observed Activity (μ Ci)	Relative Bias
Eu-155	86.52	234.44	235.5	0.005
Eu-154	123.06	329.76	320.3	-0.029
Sb-125	176.25	324.66	350.1	0.078
Eu-154	247.9	329.76	338.1	0.025
Sb-125	427.86	324.66	317.200	-0.023
Sb-125	463.33	324.66	345.100	0.063
Sb-125	600.58	324.66	318.000	-0.021
Sb-125	635.88	324.66	317.300	-0.023
Eu-154	723.29	329.76	332.600	0.009
Eu-154	873.13	329.76	363.500	0.102
Eu-154	996.17	329.76	327.500	-0.007
Eu-154	1004.63	329.76	340.900	0.034
Eu-154	1274.24	329.76	323.8	-0.018
Eu-154	1596.26*	329.76	502.5	0.524
			Average	0.051

* The Extremely low yield of 1.8% resulted in the high bias.

Analysis Report - WB Calibration Count 4/20/2011 4:28 PM

COUNTER INFORMATION

Counter Name Accuscan II
Counter Location Battelle
Configuration Name Total Body Scan

COUNT INFORMATION

Count Operation Calibration Count
Comment
Intake Date
Acquisition Started 4/20/2011 4:28:46 PM
Acquisition Time 10833.64
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	48.71	1 - 4096	10800.0	No		b4d0bf1d1627.cnf
Right	50.03	1 - 4096	10800.0	No		9b080a981627.cnf
Summed	0.00	1 - 4096	10800.0	Yes	4/27/2011 10:35:34 AM	c33677ed1627.cnf
MCS Full Range		-	0.0	No		5c47588b1627.cnf

Primary Review by: _____ Secondary Review by: _____

Date: _____ Date: _____

DETECTOR GROUP INFORMATION

Detector Group Name Summed
Detector Group Configuration Total Body Scan
Analysis Date 4/27/2011 10:35:34 AM
Energy Calibration WB-Summed Energy Calibration 4/21/2011 9:06 AM
Efficiency Calibration WB-Summed Efficiency Calibration 4/21/2011 9:11 AM (Dual)
Multi Curve No
Source Distribution Whole Body
Analysis Sequence File ROUNPPGE.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library INL 2006 BOMAB (Sb-125, Eu-154, Eu-155, Y-88)
Tentative NID Library INL 2006 BOMAB (Sb-125, Eu-154, Eu-155, Y-88)
Peak Search Library INL 2006 BOMAB (Sb-125, Eu-154, Eu-155, Y-88)
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 (%)
M	1	59.27	27.13	1.00E+004	1.05E+004	Unknown	1.014909E+004		100.00
m	2	67.06	30.73	2.16E+003	1.86E+004	Unknown	7.717803E+002		100.00
M	3	78.60	36.07	1.78E+003	1.25E+004	Unknown	2.094159E+002		100.00
m	4	86.20	39.57	3.11E+003	2.19E+004	Unknown	2.122394E+002		100.00
m	5	93.11	42.77	1.24E+004	2.61E+004	Unknown	5.687669E+002		100.00
m	6	106.02	48.74	2.82E+003	2.79E+004	Unknown	7.267015E+001		100.00
	7	187.79	86.52	1.08E+004	2.38E+004	Eu-155	2.355117E+002	6.43 %	30.90
	8	228.46	105.32	7.98E+003	2.15E+004	Unknown	4.667159E+001		100.00
	9	266.84	123.06	2.30E+004	1.64E+004	Eu-154	3.203062E+002	3.95 %	40.50
	10	381.96	176.25	3.76E+003	1.19E+004	Sb-125	3.501264E+002	8.92 %	6.70
M	11	529.82	244.57	1.94E+002	3.93E+003	Unknown	1.490240E+000		100.00
m	12	537.03	247.90	2.87E+003	5.46E+003	Eu-154	3.381541E+002	4.87 %	6.60
	13	745.56	344.26	7.80E+002	2.75E+003	Unknown	7.766666E+000		100.00
	14	823.84	380.43	5.03E+002	2.69E+003	Unknown	5.397528E+000		100.00
	15	926.49	427.86	8.02E+003	2.27E+003	Sb-125	3.171632E+002	3.48 %	29.50
	16	961.64	444.10	2.92E+002	1.75E+003	Unknown	3.498629E+000		100.00
	17	1003.26	463.33	2.88E+003	1.83E+003	Sb-125	3.451349E+002	4.72 %	10.30
	18	1106.52	511.03	8.98E+002	1.76E+003	Unknown	1.184042E+001		100.00
	19	1260.31	582.08	2.29E+002	9.61E+002	Unknown	3.281639E+000		100.00
	20	1281.38	591.82	1.06E+003	1.28E+003	Unknown	1.542068E+001		100.00
M	21	1300.35	600.58	3.82E+003	1.07E+003	Sb-125	3.180126E+002	2.88 %	17.60
m	22	1313.54	606.67	1.07E+003	1.05E+003	Unknown	1.580822E+001		100.00
	23	1376.76	635.88	2.36E+003	1.15E+003	Sb-125	3.172547E+002	4.44 %	11.30
	24	1454.12	671.62	3.80E+002	9.98E+002	Unknown	5.964312E+000		100.00

	25	1499.18	692.43	4.02E+002	7.98E+002	Unknown	6.432090E+000		100.00
	26	1565.99	723.29	3.99E+003	7.95E+002	Eu-154	3.325709E+002	3.18 %	19.70
	27	1638.44	756.76	9.48E+002	8.36E+002	Unknown	1.602859E+001		100.00
	28	1686.44	778.93	2.35E+002	7.12E+002	Unknown	4.048318E+000		100.00
	29	1830.88	845.65	1.27E+002	7.16E+002	Unknown	2.304791E+000		100.00
	30	1890.35	873.13	2.26E+003	5.72E+002	Eu-154	3.634678E+002	4.11 %	11.50
	31	1957.08	903.95	1.44E+002	4.18E+002	Unknown	2.736106E+000		100.00

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 (%)
	32	2087.17	964.03	1.34E+002	5.80E+002	Unknown	2.648152E+000		100.00
M	33	2156.75	996.17	1.67E+003	4.79E+002	Eu-154	3.275306E+002	3.88 %	10.30
m	34	2175.07	1004.63	3.00E+003	4.41E+002	Eu-154	3.409470E+002	3.30 %	17.90
	35	2350.92	1085.85	9.34E+001	3.61E+002	Unknown	2.014486E+000		100.00
	36	2407.43	1111.95	1.38E+002	3.07E+002	Unknown	3.038952E+000		100.00
	37	2443.98	1128.83	5.97E+001	1.69E+002	Unknown	1.326887E+000		100.00
	38	2697.28	1245.80	1.14E+002	2.51E+002	Unknown	2.760760E+000		100.00
	39	2758.86	1274.24	4.67E+003	3.25E+002	Eu-154	3.238415E+002	4.12 %	35.50
	40	3047.87	1407.70	2.09E+002	1.24E+002	Unknown	5.683761E+000		100.00
	41	3162.28	1460.52	1.57E+003	1.22E+002	Unknown	4.439757E+001		100.00
	42	3234.22	1493.74	1.07E+002	1.93E+002	Unknown	3.089417E+000		100.00
	43	3456.27	1596.26	2.88E+002	1.88E+002	Eu-154	5.025343E+002	18.30 %	1.80
	44	3820.03	1764.20	1.72E+002	4.93E+001	Unknown	6.162593E+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)
	Sb-125	0.997	3.221576E+002	1.79 %	Not Performed	Not Performed	8.982E+000
	Eu-154	0.999	3.346237E+002	1.44 %			6.691E+000
	Eu-155	1.000	2.355117E+002	6.43 %			1.923E+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)
+	Sb-125	176.30 *	6.70	6.2709E+001	8.9824E+000	3.5013E+002
+		427.90 *	29.50	9.0515E+000		3.1716E+002
+		463.40 *	10.30	2.5328E+001		3.4513E+002
+		600.00 *	17.60	8.9824E+000		3.1801E+002
+		636.00 *	11.30	2.3106E+001		3.1725E+002
+	Eu-154	123.10 *	40.50	1.0178E+001	6.6913E+000	3.2031E+002
+		247.90 *	6.60	2.8697E+001		3.3815E+002

+		723.30 *	19.70	1.1305E+001		3.3257E+002
+		873.20 *	11.50	1.9548E+001		3.6347E+002
+		996.30 *	10.30	1.4174E+001		3.2753E+002
+		1005.00 *	17.90	7.8724E+000		3.4095E+002
+		1274.00 *	35.50	6.6913E+000		3.2384E+002
+		1596.49 *	1.80	1.7332E+002		5.0253E+002
+	Eu-155	86.50 *	30.90	1.9234E+001	1.9234E+001	2.3551E+002

+ = Nuclide Identified during the nuclide identification

* = Energy Line found in the spectrum

User: David Georgeson

Database: InVivo Server: 127.0.0.1

MCS GROUPS

MCS Full Range

Appendix F

Accuscan II Whole Body Calibration Verification

Appendix F

Accuscan II Whole Body Calibration Verification

EFFICIENCY CALIBRATION VERIFICATION COUNTS

Arrangement/Geometry: Whole Body

Analysis Library: Verification for INL 2006

Energy Calibration Time: 4/21/2011 9:06

Efficiency Calibration Time: 4/21/2011 9:11

Count Type/Live Time: 10 Minutes

Count Start Times: 1 4/21/2011 1:39 4 4/21/2011 2:21

2 4/21/2011 1:54 5 4/21/2011 2:35

3 4/21/2011 2:07

Nuclide	Expected	Observed Activity (nCi)					Relative	Relative
Energy	Activity						Bias	Precision
(keV)	(nCi)	#1	#2	#3	#4	#5		
Eu-155								
86.5	234.44	240	235	276	218	297	0.08	0.138
Eu-155								
105.3	48.29464			Eu-105 keV Energy Line not used				
Eu-154								
123.1	329.76	345	324	349	349	285	0.002	0.083
Sb-125*								
176.3	324.66			Low Yield Prevents Verification				
Eu-154								
247.9	329.76			Low Yield Prevents Verification				
Sb-125*								
427.9	324.66	331	326	313	318	319	-0.01	0.022
Sb-125*								
463.4	324.66	357	376	355	310	318	0.057	0.087
Eu-154								
591.8	15.82848			Eu-154 591 keV energy line not used				
Sb-125*								
600	324.66	357	325	310	328	377	0.045	0.084
Sb-125*								
636	324.66	339	297	316	255	335	-0.05	0.106
Eu-154								
723.3	329.76	379	360	334	337	303	0.039	0.086
Eu-154								
873.2	329.76	315	385	338	287	348	0.014	0.111
Eu-154								
996.3	329.76	359	352	362	332	403	0.097	0.079
Eu-154								
1005	329.76	331	348	356	348	391	0.076	0.067
Eu-154								
1274	329.76	329	323	293	322	355	-0.016	0.067
Eu-154								
1597	329.76	259	377	267	235	406	-0.064	0.233
Average =							0.023	0.097

Analysis Report - Verification Count 4/21/2011 1:39 PM (1/5)

COUNTER INFORMATION

Counter Name Accuscan II
Counter Location Battelle
Configuration Name Total Body Scan

COUNT INFORMATION

Count Operation Verification Count
Comment
Intake Date
Acquisition Started 4/21/2011 1:39:43 PM
Acquisition Time 601.85
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	49.45	1 - 4096	600.0	No		7bfdb08b1338.cnf
Right	50.73	1 - 4096	600.0	No		8373bd031338.cnf
Summed	99.97	1 - 4096	600.0	Yes	4/25/2011 11:36:49 AM	e2063a7b1136.cnf
MCS Full Range		-	0.0	No		ae1111181338.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 Total Body Scan
Analysis Date 4/25/2011 11:36:49 AM
Energy Calibration WB-Summed Energy Calibration 4/21/2011 9:06 AM
Efficiency Calibration WB-Summed Efficiency Calibration 4/21/2011 9:11 AM (Dual)
Multi Curve No
Source Distribution Whole Body
Analysis Sequence File ROUNPPGE.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library Verification for INL 2006 BOMAB
Tentative NID Library Verification for INL 2006 BOMAB
Peak Search Library Verification for INL 2006 BOMAB
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	59.13	27.07	5.28E+002	6.37E+002	Unknown	9.810091E+003		100.00
	2	93.54	42.97	3.82E+002	9.45E+002	Unknown	3.078363E+002		100.00
	3	187.98	86.61	6.13E+002	1.38E+003	Eu-155	2.400551E+002	16.31 %	30.90
	4	228.44	105.31	4.88E+002	9.91E+002	Unknown	5.138176E+001		100.00
	5	266.92	123.09	1.37E+003	8.74E+002	Eu-154	3.448230E+002	6.96 %	40.50
	6	381.89	176.22	1.61E+002	4.94E+002	Unknown	1.810653E+001		100.00
	7	537.05	247.92	1.27E+002	3.41E+002	Unknown	1.771559E+001		100.00
	8	745.69	344.32	7.70E+001	1.20E+002	Unknown	1.380274E+001		100.00
	9	926.55	427.88	4.65E+002	1.07E+002	Sb-125	3.311993E+002	7.20 %	29.50
	10	1003.27	463.33	1.66E+002	9.13E+001	Sb-125	3.572788E+002	14.54 %	10.30
	11	1280.99	591.64	7.55E+001	5.55E+001	Unknown	1.970539E+001		100.00
M	12	1300.31	600.56	2.38E+002	4.35E+001	Sb-125	3.567469E+002	6.89 %	17.60
m	13	1313.55	606.68	7.89E+001	4.02E+001	Unknown	2.093020E+001		100.00
	14	1376.72	635.86	1.40E+002	4.16E+001	Sb-125	3.393729E+002	12.90 %	11.30
	15	1565.90	723.25	2.52E+002	4.89E+001	Eu-154	3.787416E+002	9.04 %	19.70
	16	1890.48	873.18	1.09E+002	3.13E+001	Eu-154	3.148867E+002	14.78 %	11.50
M	17	2156.66	996.13	1.02E+002	1.30E+001	Eu-154	3.591730E+002	10.60 %	10.30
m	18	2175.23	1004.71	1.62E+002	1.40E+001	Eu-154	3.311321E+002	8.42 %	17.90
	19	2758.96	1274.29	2.64E+002	2.04E+001	Eu-154	3.292761E+002	8.08 %	35.50
	20	3162.57	1460.66	6.75E+001	6.50E+000	Unknown	3.433020E+001		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)
	Sb-125	0.997	3.442540E+002	4.43 %	Not Performed	Not Performed	3.254E+001
	Eu-154	0.999	3.425577E+002	3.64 %			2.524E+001
	Eu-155	1.000	2.400551E+002	16.31 %			8.330E+001

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	Energy (keV)	Yield (%)	Line MDA (nCi)	Nuclide MDA	Activity (nCi)
+	Sb-125	427.90 *	29.50	3.5367E+001	3.2536E+001	3.3120E+002
+		463.40 *	10.30	9.9221E+001		3.5728E+002
+		600.00 *	17.60	3.2536E+001		3.5675E+002
+		636.00 *	11.30	7.4824E+001		3.3937E+002
+	Eu-154	123.10 *	40.50	4.2330E+001	2.5244E+001	3.4482E+002
+		723.30 *	19.70	5.3381E+001		3.7874E+002
+		873.20 *	11.50	8.0116E+001		3.1489E+002
+		996.30 *	10.30	4.2019E+001		3.5917E+002
+		1005.00 *	17.90	2.5244E+001		3.3113E+002
+		1274.00 *	35.50	2.7950E+001		3.2928E+002
+		1596.49	1.80	3.5840E+002		2.5903E+002
+	Eu-155	86.50 *	30.90	8.3303E+001	8.3303E+001	2.4006E+002

+ = Nuclide Identified during the nuclide identification

* = Energy Line found in the spectrum

MCS GROUPS

MCS Full Range

MCS GROUPS

Analysis Report - Verification Count 4/21/2011 1:39 PM (2/5)

COUNTER INFORMATION

Counter Name Accuscan II
Counter Location Battelle
Configuration Name Total Body Scan

COUNT INFORMATION

Count Operation Verification Count
Comment
Intake Date
Acquisition Started 4/21/2011 1:54:07 PM
Acquisition Time 601.83
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	50.73	1 - 4096	600.0	No		664fad571338.cnf
Left	49.49	1 - 4096	600.0	No		b3d22b671338.cnf
Summed	100.19	1 - 4096	600.0	Yes	4/25/2011 11:41:23 AM	a462f1171141.cnf
MCS Full Range		-	0.0	No		b32d504e1338.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 Total Body Scan
Analysis Date 4/25/2011 11:41:23 AM
Energy Calibration WB-Summed Energy Calibration 4/21/2011 9:06 AM
Efficiency Calibration WB-Summed Efficiency Calibration 4/21/2011 9:11 AM (Dual)
Multi Curve No
Source Distribution Whole Body
Analysis Sequence File ROUNPPGE.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library Verification for INL 2006 BOMAB
Tentative NID Library Verification for INL 2006 BOMAB
Peak Search Library Verification for INL 2006 BOMAB
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	58.76	26.89	7.38E+002	5.05E+002	Unknown	1.454201E+004		100.00
	2	93.06	42.74	4.79E+002	9.59E+002	Unknown	3.960367E+002		100.00
	3	188.02	86.63	6.01E+002	1.37E+003	Eu-155	2.353557E+002	16.51 %	30.90
	4	228.49	105.33	4.25E+002	1.26E+003	Unknown	4.474400E+001		100.00
	5	266.90	123.08	1.29E+003	9.57E+002	Eu-154	3.240558E+002	7.46 %	40.50
	6	382.16	176.34	3.27E+002	4.42E+002	Unknown	3.669313E+001		100.00
	7	536.97	247.88	1.47E+002	3.74E+002	Unknown	2.051968E+001		100.00
	8	926.52	427.87	4.58E+002	1.28E+002	Sb-125	3.259799E+002	7.40 %	29.50
	9	1003.35	463.37	1.74E+002	7.88E+001	Sb-125	3.757251E+002	12.78 %	10.30
	10	1281.71	591.97	6.10E+001	5.10E+001	Unknown	1.594279E+001		100.00
	11	1300.30	600.56	2.17E+002	4.28E+001	Sb-125	3.251464E+002	9.34 %	17.60
	12	1376.85	635.92	1.23E+002	8.49E+001	Sb-125	2.974833E+002	18.57 %	11.30
	13	1566.10	723.35	2.40E+002	5.65E+001	Eu-154	3.597953E+002	9.71 %	19.70
	14	1638.57	756.82	6.12E+001	3.48E+001	Unknown	1.861550E+001		100.00
	15	1890.46	873.17	1.33E+002	2.43E+001	Eu-154	3.846570E+002	11.81 %	11.50
M	16	2156.80	996.19	9.94E+001	2.47E+001	Eu-154	3.515370E+002	11.23 %	10.30
m	17	2174.88	1004.54	1.70E+002	2.48E+001	Eu-154	3.483780E+002	8.36 %	17.90
	18	2758.65	1274.14	2.58E+002	1.16E+001	Eu-154	3.226928E+002	7.83 %	35.50
	19	3162.39	1460.57	7.91E+001	1.09E+001	Unknown	4.021181E+001		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)
	Sb-125	0.997	3.291584E+002	5.09 %	Not Performed	Not Performed	3.694E+001
	Eu-154	0.999	3.401227E+002	3.67 %			2.205E+001
	Eu-155	0.999	2.353557E+002	16.51 %			8.284E+001

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)
+	Sb-125	427.90 *	29.50	3.6937E+001	3.6937E+001	3.2598E+002
+		463.40 *	10.30	8.6269E+001		3.7573E+002
+		600.00 *	17.60	4.5303E+001		3.2515E+002
+		636.00 *	11.30	1.1130E+002		2.9748E+002
+	Eu-154	123.10 *	40.50	4.4401E+001	2.2047E+001	3.2406E+002
+		723.30 *	19.70	5.7504E+001		3.5980E+002
+		873.20 *	11.50	6.7703E+001		3.8466E+002
+		996.30 *	10.30	5.7935E+001		3.5154E+002
+		1005.00 *	17.90	3.3619E+001		3.4838E+002
+		1274.00 *	35.50	2.2047E+001		3.2269E+002
+		1596.49	1.80	3.5840E+002		3.7678E+002
+						
+	Eu-155	86.50 *	30.90	8.2841E+001	8.2841E+001	2.3536E+002

+ = Nuclide Identified during the nuclide identification

* = Energy Line found in the spectrum

MCS GROUPS

MCS Full Range

MCS GROUPS

Analysis Report - Verification Count 4/21/2011 1:39 PM (3/5)

COUNTER INFORMATION

Counter Name Accuscan II
Counter Location Battelle
Configuration Name Total Body Scan

COUNT INFORMATION

Count Operation Verification Count
Comment
Intake Date
Acquisition Started 4/21/2011 2:07:59 PM
Acquisition Time 601.8099999
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	50.75	1 - 4096	600.0	No		6ed9e2fd1338.cnf
Left	49.51	1 - 4096	600.0	No		cc0f85751338.cnf
Summed	100.24	1 - 4096	600.0	Yes	4/25/2011 11:43:01 AM	9dd0f2711143.cnf
MCS Full Range		-	0.0	No		7f2048dd1338.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 Total Body Scan
Analysis Date 4/25/2011 11:43:01 AM
Energy Calibration WB-Summed Energy Calibration 4/21/2011 9:06 AM
Efficiency Calibration WB-Summed Efficiency Calibration 4/21/2011 9:11 AM (Dual)
Multi Curve No
Source Distribution Whole Body
Analysis Sequence File ROUNPPGE.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library Verification for INL 2006 BOMAB
Tentative NID Library Verification for INL 2006 BOMAB
Peak Search Library Verification for INL 2006 BOMAB
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	58.96	26.98	5.58E+002	5.99E+002	Unknown	1.066606E+004		100.00
	2	93.30	42.86	5.65E+002	8.80E+002	Unknown	4.603387E+002		100.00
	3	187.93	86.59	7.04E+002	1.28E+003	Eu-155	2.757864E+002	14.05 %	30.90
	4	228.47	105.32	4.61E+002	9.39E+002	Unknown	4.849031E+001		100.00
	5	266.91	123.08	1.39E+003	9.03E+002	Eu-154	3.491713E+002	6.97 %	40.50
	6	537.00	247.89	1.45E+002	2.70E+002	Unknown	2.029520E+001		100.00
	7	926.56	427.89	4.40E+002	1.62E+002	Sb-125	3.133623E+002	8.10 %	29.50
	8	1003.13	463.27	1.65E+002	1.06E+002	Sb-125	3.552292E+002	15.13 %	10.30
	9	1281.42	591.84	6.27E+001	6.83E+001	Unknown	1.638201E+001		100.00
	10	1300.15	600.49	2.07E+002	6.00E+001	Sb-125	3.098957E+002	10.51 %	17.60
	11	1377.08	636.03	1.31E+002	6.14E+001	Sb-125	3.157386E+002	15.36 %	11.30
	12	1566.14	723.36	2.22E+002	5.28E+001	Eu-154	3.338473E+002	9.96 %	19.70
	13	1890.44	873.17	1.17E+002	3.44E+001	Eu-154	3.378093E+002	14.13 %	11.50
M	14	2156.74	996.16	1.02E+002	1.00E+001	Eu-154	3.624316E+002	10.47 %	10.30
m	15	2175.21	1004.70	1.74E+002	2.14E+001	Eu-154	3.559046E+002	8.27 %	17.90
	16	2758.69	1274.16	2.35E+002	1.33E+001	Eu-154	2.931199E+002	8.37 %	35.50
	17	3162.34	1460.55	8.60E+001	0.00E+000	Unknown	4.373596E+001		100.00
	18	3456.67	1596.45	8.50E+000	4.50E+000	Eu-154	2.668692E+002	57.49 %	1.80

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)
	Sb-125	0.998	3.171096E+002	5.52 %	Not Performed	Not Performed	4.230E+001
	Eu-154	0.999	3.342025E+002	3.69 %			2.492E+001
	Eu-155	1.000	2.757864E+002	14.05 %			8.003E+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

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)
+	Sb-125	427.90 *	29.50	4.2297E+001	4.2297E+001	3.1336E+002
+		463.40 *	10.30	1.0444E+002		3.5523E+002
+		600.00 *	17.60	5.4363E+001		3.0990E+002
+		636.00 *	11.30	9.1215E+001		3.1574E+002
+	Eu-154	123.10 *	40.50	4.3086E+001	2.4917E+001	3.4917E+002
+		723.30 *	19.70	5.4333E+001		3.3385E+002
+		873.20 *	11.50	8.1320E+001		3.3781E+002
+		996.30 *	10.30	3.6866E+001		3.6243E+002
+		1005.00 *	17.90	3.1201E+001		3.5590E+002
+		1274.00 *	35.50	2.4917E+001		2.9312E+002
+		1596.49 *	1.80	2.8135E+002		2.6687E+002
+	Eu-155	86.50 *	30.90	8.0035E+001	8.0035E+001	2.7579E+002

+ = Nuclide Identified during the nuclide identification

* = Energy Line found in the spectrum

MCS GROUPS**MCS Full Range**

User: David Georgeson

Database: InVivo Server: 127.0.0.1

MCS GROUPS

Analysis Report - Verification Count 4/21/2011 1:39 PM (4/5)

COUNTER INFORMATION

Counter Name Accuscan II
Counter Location Battelle
Configuration Name Total Body Scan

COUNT INFORMATION

Count Operation Verification Count
Comment
Intake Date
Acquisition Started 4/21/2011 2:21:43 PM
Acquisition Time 601.97
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	51.40	1 - 4096	600.0	No		5e26aa6c1338.cnf
Left	49.55	1 - 4096	600.0	No		4453012b1338.cnf
Summed	100.75	1 - 4096	600.0	Yes	4/25/2011 11:44:15 AM	123b5ee11144.cnf
MCS Full Range		-	0.0	No		ec21aea11338.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 Total Body Scan
Analysis Date 4/25/2011 11:44:15 AM
Energy Calibration WB-Summed Energy Calibration 4/21/2011 9:06 AM
Efficiency Calibration WB-Summed Efficiency Calibration 4/21/2011 9:11 AM (Dual)
Multi Curve No
Source Distribution Whole Body
Analysis Sequence File ROUNPPGE.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library Verification for INL 2006 BOMAB
Tentative NID Library Verification for INL 2006 BOMAB
Peak Search Library Verification for INL 2006 BOMAB
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	59.18	27.09	6.42E+002	5.69E+002	Unknown	1.184934E+004		100.00
	2	93.12	42.77	3.49E+002	1.15E+003	Unknown	2.872453E+002		100.00
	3	187.99	86.61	5.56E+002	1.38E+003	Eu-155	2.177659E+002	17.76 %	30.90
	4	228.45	105.31	4.69E+002	9.55E+002	Unknown	4.941208E+001		100.00
	5	266.83	123.05	1.39E+003	9.97E+002	Eu-154	3.491131E+002	7.35 %	40.50
	6	381.66	176.11	2.49E+002	5.73E+002	Unknown	2.798618E+001		100.00
	7	536.93	247.86	1.26E+002	3.09E+002	Unknown	1.767931E+001		100.00
	8	926.49	427.86	4.47E+002	8.72E+001	Sb-125	3.181691E+002	7.02 %	29.50
	9	1003.28	463.34	1.44E+002	1.13E+002	Sb-125	3.096611E+002	17.48 %	10.30
	10	1281.31	591.78	4.34E+001	5.76E+001	Unknown	1.132495E+001		100.00
	11	1300.53	600.67	2.19E+002	6.33E+001	Sb-125	3.274993E+002	10.53 %	17.60
	12	1376.94	635.96	1.05E+002	6.95E+001	Sb-125	2.549760E+002	18.79 %	11.30
	13	1565.88	723.25	2.25E+002	3.74E+001	Eu-154	3.373668E+002	9.23 %	19.70
	14	1638.59	756.83	7.19E+001	3.31E+001	Unknown	2.189103E+001		100.00
	15	1890.46	873.17	9.89E+001	4.31E+001	Eu-154	2.866433E+002	17.16 %	11.50
	16	2085.35	963.19	1.68E+001	1.42E+001	Unknown	5.974810E+000		100.00
M	17	2156.85	996.21	9.40E+001	1.95E+001	Eu-154	3.323655E+002	11.31 %	10.30
m	18	2175.18	1004.68	1.70E+002	2.25E+001	Eu-154	3.476130E+002	8.31 %	17.90
	19	2758.82	1274.22	2.58E+002	1.60E+001	Eu-154	3.222811E+002	8.06 %	35.50
	20	3162.85	1460.79	8.45E+001	6.50E+000	Unknown	4.298182E+001		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)
	Sb-125	0.996	3.119298E+002	5.33 %	Not Performed	Not Performed	3.110E+001
	Eu-154	0.999	3.347338E+002	3.75 %			2.624E+001
	Eu-155	1.000	2.177659E+002	17.76 %			8.329E+001

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)
+	Sb-125	427.90 *	29.50	3.1102E+001	3.1102E+001	3.1817E+002
+		463.40 *	10.30	1.0871E+002		3.0966E+002
+		600.00 *	17.60	5.9030E+001		3.2750E+002
+		636.00 *	11.30	9.4432E+001		2.5498E+002
+	Eu-154	123.10 *	40.50	4.7086E+001	2.6237E+001	3.4911E+002
+		723.30 *	19.70	4.6619E+001		3.3737E+002
+		873.20 *	11.50	9.1142E+001		2.8664E+002
+		996.30 *	10.30	5.1463E+001		3.3237E+002
+		1005.00 *	17.90	3.2001E+001		3.4761E+002
+		1274.00 *	35.50	2.6237E+001		3.2228E+002
+		1596.49	1.80	3.5840E+002		2.3549E+002
+	Eu-155	86.50 *	30.90	8.3292E+001	8.3292E+001	2.1777E+002

+ = Nuclide Identified during the nuclide identification

* = Energy Line found in the spectrum

MCS GROUPS

MCS Full Range

MCS GROUPS

Analysis Report - Verification Count 4/21/2011 1:39 PM (5/5)

COUNTER INFORMATION

Counter Name Accuscan II
Counter Location Battelle
Configuration Name Total Body Scan

COUNT INFORMATION

Count Operation Verification Count
Comment
Intake Date
Acquisition Started 4/21/2011 2:35:14 PM
Acquisition Time 601.89
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	49.04	1 - 4096	600.0	No		d211fa331338.cnf
Right	50.86	1 - 4096	600.0	No		8ae857c51338.cnf
Summed	99.74	1 - 4096	600.0	Yes	4/25/2011 11:45:15 AM	049624ca1145.cnf
MCS Full Range		-	0.0	No		358b567d1338.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 Total Body Scan
Analysis Date 4/25/2011 11:45:15 AM
Energy Calibration WB-Summed Energy Calibration 4/21/2011 9:06 AM
Efficiency Calibration WB-Summed Efficiency Calibration 4/21/2011 9:11 AM (Dual)
Multi Curve No
Source Distribution Whole Body
Analysis Sequence File ROUNPPGE.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library Verification for INL 2006 BOMAB
Tentative NID Library Verification for INL 2006 BOMAB
Peak Search Library Verification for INL 2006 BOMAB
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	59.24	27.12	6.73E+002	4.90E+002	Unknown	1.229839E+004		100.00
	2	93.35	42.88	4.12E+002	9.41E+002	Unknown	3.351563E+002		100.00
	3	187.77	86.51	7.58E+002	1.22E+003	Eu-155	2.970634E+002	13.00 %	30.90
	4	228.52	105.34	4.35E+002	1.23E+003	Unknown	4.577839E+001		100.00
	5	266.92	123.09	1.14E+003	1.05E+003	Eu-154	2.854828E+002	8.43 %	40.50
	6	381.74	176.15	1.03E+002	5.85E+002	Unknown	1.161173E+001		100.00
	7	537.00	247.89	1.28E+002	3.18E+002	Unknown	1.795216E+001		100.00
	8	926.57	427.90	4.48E+002	1.24E+002	Sb-125	3.190382E+002	7.53 %	29.50
	9	1003.19	463.29	1.48E+002	8.55E+001	Sb-125	3.181134E+002	14.96 %	10.30
	10	1281.38	591.82	6.71E+001	6.09E+001	Unknown	1.751043E+001		100.00
M	11	1300.52	600.66	2.52E+002	4.98E+001	Sb-125	3.771889E+002	6.76 %	17.60
m	12	1313.70	606.75	7.79E+001	6.16E+001	Unknown	2.065407E+001		100.00
	13	1376.95	635.97	1.39E+002	3.83E+001	Sb-125	3.353516E+002	12.93 %	11.30
	14	1453.84	671.49	2.56E+001	3.84E+001	Unknown	7.222451E+000		100.00
	15	1500.13	692.87	2.06E+001	4.44E+001	Unknown	5.929979E+000		100.00
	16	1565.91	723.26	2.02E+002	6.70E+001	Eu-154	3.034099E+002	11.08 %	19.70
	17	1890.61	873.24	1.20E+002	3.50E+001	Eu-154	3.477398E+002	14.14 %	11.50
M	18	2156.53	996.07	1.14E+002	2.21E+001	Eu-154	4.032364E+002	10.32 %	10.30
m	19	2175.21	1004.70	1.91E+002	3.07E+001	Eu-154	3.905816E+002	8.04 %	17.90
	20	2758.94	1274.28	2.84E+002	1.95E+001	Eu-154	3.553744E+002	7.82 %	35.50
	21	3162.45	1460.60	8.36E+001	8.40E+000	Unknown	4.251619E+001		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)
	Sb-125	0.996	3.420652E+002	4.49 %	Not Performed	Not Performed	3.483E+001
	Eu-154	0.999	3.373684E+002	3.86 %			2.864E+001
	Eu-155	1.000	2.970634E+002	13.00 %			7.819E+001

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)
+	Sb-125	427.90 *	29.50	3.7156E+001	3.4833E+001	3.1904E+002
+		463.40 *	10.30	8.9857E+001		3.1811E+002
+		600.00 *	17.60	3.4833E+001		3.7719E+002
+		636.00 *	11.30	7.3903E+001		3.3535E+002
+	Eu-154	123.10 *	40.50	4.6520E+001	2.8641E+001	2.8548E+002
+		723.30 *	19.70	5.8225E+001		3.0341E+002
+		873.20 *	11.50	8.4790E+001		3.4774E+002
+		996.30 *	10.30	5.4742E+001		4.0324E+002
+		1005.00 *	17.90	3.7408E+001		3.9058E+002
+		1274.00 *	35.50	2.8641E+001		3.5537E+002
+		1596.49	1.80	3.8711E+002		4.0593E+002
+						
+	Eu-155	86.50 *	30.90	7.8192E+001	7.8192E+001	2.9706E+002

+ = Nuclide Identified during the nuclide identification

* = Energy Line found in the spectrum

MCS GROUPS

MCS Full Range

MCS GROUPS

Appendix G

MDA Determination

Appendix G

MDA Determination

MDA COUNT DATA

MDA SUMMARY CALCULATIONS FROM COUNT DATA

Energy Calibration Time: 4/21/2011 9:06 AM

Efficiency Calibration Time: 4/21/2011 9:11 AM

Count Type/Live Time: 600 Seconds

Count Start Times:

1. 4/26/11 8:05 AM
2. 4/26/11 8:21 AM
3. 4/26/11 8:50 AM

$$MDA = (4.65Sb + 3)/KT$$

Where:

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

K = Efficiency X Abundance X 37 Bq/nCi

T = Routine counting time in seconds = 600 seconds

Nuclide	Energy keV	Count (MD (nCi)	Count (MD (nCi)	Count (MD (nCi)	Average (nCi)
Cr-51	320.08	2.48E+01	3.06E+01	2.61E+01	2.72E+01
Mn-54	834.83	3.70E+00	2.13E+00	3.70E+00	3.18E+00
Co-57	122.06	5.36E+00	5.63E+00	6.21E+00	5.73E+00
Co-58	1099.22	2.11E+00	3.31E+00	2.98E+00	2.80E+00
Fe-59	1099.22	6.85E+00	5.11E+00	5.93E+00	5.96E+00
Co-60	1173.22	2.36E+00	3.33E+00	2.64E+00	2.78E+00
Zn-65	1115.52	5.75E+00	6.30E+00	5.15E+00	5.73E+00
Nb-95	765.79	2.86E+00	3.36E+00	2.67E+00	2.96E+00
Zr-95	724.18	6.70E+00	5.13E+00	4.44E+00	5.42E+00
Ru-106	621.84	2.72E+01	2.86E+01	3.62E+01	3.07E+01
Ag-110	657.75	3.64E+00	2.92E+00	2.58E+00	3.05E+00
I-133	529.87	3.47E+00	3.83E+00	3.94E+00	3.75E+00
I-131	364.48	3.60E+00	3.71E+00	3.56E+00	3.62E+00
Cs-134	795.84	2.71E+00	2.42E+00	2.68E+00	2.60E+00
Cs-137	661.65	3.43E+00	3.60E+00	4.36E+00	3.80E+00
Ba-140	537.32	1.12E+01	1.45E+01	1.37E+01	1.31E+01
La-140	1596.49	2.76E+00	2.76E+00	3.90E+00	3.14E+00
Ce-141	145.44	8.77E+00	8.74E+00	9.41E+00	8.97E+00
Ce-144	80.11	4.43E+01	4.23E+01	4.27E+01	4.31E+01
Eu-152	344.27	1.07E+01	1.05E+01	9.97E+00	1.04E+01

Analysis Report - test Person [0000-0000]

SOURCE INFORMATION

Primary ID 0000-0000
Last Name Person
First Name test
Height (in)
Weight (lb)
Chest Wall Thickness (cm)

COUNTER INFORMATION

Counter Name Accuscan II
Counter Location Battelle
Configuration Name Total Body Scan

COUNT INFORMATION

Count Operation Individual 10 minutes
Count Reason Routine operation
Frequency
Comment MDA Person count #1 for 4/21/2011 calibration
Intake Date
Acquisition Started 4/26/2011 8:05:29 AM
Acquisition Time 601.01
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	16.33	1 - 4096	600.0	Yes	4/26/2011 8:04:25 AM	e9ff260c0804.cnf
Right	17.08	1 - 4096	600.0	Yes	4/26/2011 8:04:25 AM	4cc1a5a80804.cnf
Summed	33.30	1 - 4096	600.0	Yes	4/26/2011 8:04:25 AM	e83762c50804.cnf
MCS Full Range		-	0.0	No		75f1f0670804.cnf

Primary Review by: _____

Secondary Review by: _____

Date: _____

Date: _____

DETECTOR GROUP INFORMATION

Detector Group Name Left
Detector Group Configuration Total Body Scan
Analysis Date 4/26/2011 8:04:25 AM
Energy Calibration WB-Left Energy Calibration 4/21/2011 8:58 AM
Efficiency Calibration
Multi Curve
Source Distribution Whole Body
Analysis Sequence File NO_ANALY.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library
Tentative NID Library
Peak Search Library
Analysis Limits (channels) 1 - 4096
Energy Tolerance (keV) 1.00
Comment

DETECTOR GROUP INFORMATION

Detector Group Name Right
Detector Group Configuration Total Body Scan
Analysis Date 4/26/2011 8:04:25 AM
Energy Calibration WB-Right Energy Calibration 4/21/2011 9:03 AM
Efficiency Calibration
Multi Curve
Source Distribution Whole Body
Analysis Sequence File NO_ANALY.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library

Tentative NID Library
Peak Search Library
Analysis Limits (channels) 1 - 4096
Energy Tolerance (keV) 1.00
Comment

User: David Georgeson

Database: InVivo Server: 127.0.0.1

DETECTOR GROUP INFORMATION

Detector Group Name Summed
Detector Group Configuration Total Body Scan
Analysis Date 4/26/2011 8:04:25 AM
Energy Calibration WB-Summed Energy Calibration 4/21/2011 9:06 AM
Efficiency Calibration WB-Summed Efficiency Calibration 4/21/2011 9:11 AM (Dual)
Multi Curve No
Source Distribution Whole Body
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	3163.17	1460.94	7.42E+001	3.77E+000		K-40	3.538676E+002	14.44 %	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	0.999	3.538676E+002	14.44 %	Not Performed	Not Performed	4.736E+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	4.7363E+001	4.7363E+001	3.5387E+002
	CR-51	320.08	9.83	2.4785E+001	2.4785E+001	-1.5258E+001
	MN-54	834.83	99.97	3.6963E+000	3.6963E+000	9.4448E-001
	CO-57	122.06	85.51	5.3618E+000	5.3618E+000	-2.0598E+000
		136.48	10.60	4.2354E+001		1.5775E+000
	CO-58	810.76	99.40	2.1069E+000	2.1069E+000	-2.0780E+000
	FE-59	142.65	1.03	3.9805E+002	6.8538E+000	-1.7297E+002
		192.34	3.11	1.1715E+002		-2.6529E+001
		1099.22	56.50	6.8538E+000		2.6193E+000
		1291.56	43.20	7.6583E+000		1.2473E+000
	CO-60	1173.22	100.00	2.3553E+000	2.3553E+000	6.8781E-001
		1332.49	100.00	3.0480E+000		-1.5609E+000
	ZN-65	1115.52	50.75	5.7529E+000	5.7529E+000	1.2492E+000
	NB-95	765.79	99.81	2.8631E+000	2.8631E+000	1.7856E+000
	ZR-95	724.18	43.70	6.6990E+000	6.6990E+000	-2.5224E+000
		756.72	55.30	6.7853E+000		4.0490E+000
	RU-106	621.84	9.80	2.7170E+001	2.7170E+001	3.2066E+000
		1050.47	1.73	1.4419E+002		1.0940E+001
	AG-110M	446.80	3.64	8.9847E+001	3.6437E+000	3.6409E+001
		620.35	2.77	9.0490E+001		9.7092E+000
		657.75	94.40	3.6437E+000		2.4909E+000
		677.61	10.68	3.5072E+001		1.2473E+001
		686.99	6.47	4.6162E+001		4.6516E+000
		706.67	16.68	1.8222E+001		-5.2462E-001
		744.26	4.64	6.0502E+001		-3.1646E+001
		763.93	22.28	1.1091E+001		-3.7787E+000
		818.02	7.30	4.3275E+001		-1.1674E+001
		884.67	72.60	4.5763E+000		1.3888E+000
		937.48	34.20	1.1163E+001		2.7393E+000
		1384.27	24.26	1.3050E+001		-4.9506E+000
		1475.76	3.97	6.0381E+001		-3.2393E+001
		1505.00	13.06	2.2984E+001		1.2082E+001
		1562.27	1.18	2.6584E+002		1.3974E+002

	I-131	80.18	2.62	2.6244E+002	3.5595E+000	6.8725E+001
		284.30	6.05	3.8697E+001		-3.8197E+001
		364.48	81.20	3.5595E+000		-1.3818E+000
		636.97	7.26	3.7234E+001		-6.6962E+000
		722.89	1.80	1.7124E+002		-8.2168E+000
	I-133	529.87	86.30	3.4728E+000	3.4728E+000	-7.4441E-001
		875.33	4.47	5.5019E+001		-1.1201E+001
	CS-134	475.35	1.46	1.6920E+002	2.7098E+000	-4.7854E+001
		563.23	8.38	2.9838E+001		-7.7136E+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)
	CS-134	569.32	15.43	2.3075E+001	2.7098E+000	1.1279E+001
		604.70	97.60	3.0952E+000		1.8981E+000
		795.84	85.40	2.7098E+000		-7.3555E-001
		801.93	8.73	4.6135E+001		3.1812E+001
		1038.57	1.00	2.4737E+002		-2.0644E+002
		1167.94	1.80	1.9913E+002		1.0768E+002
		1365.15	3.04	7.2611E+001		-8.5700E+001
	CS-137	661.65	85.12	3.4277E+000	3.4277E+000	-5.7567E-001
	BA-140	162.64	6.70	5.7466E+001	1.1201E+001	-2.7450E+001
		304.84	4.50	6.2200E+001		-1.5069E+001
		423.70	3.20	8.0386E+001		-1.0339E+002
		437.55	2.00	1.6114E+002		5.4882E+001
		537.32	25.00	1.1201E+001		1.4719E+000
	LA-140	328.77	20.50	1.2751E+001	2.7550E+000	-6.7955E+000
		432.53	2.94	9.1896E+001		-1.8002E+001
		487.03	45.50	6.6567E+000		-5.0504E-001
		751.79	4.40	6.0055E+001		-3.4443E+000
		815.85	23.50	1.6739E+001		4.7518E+000
		867.82	5.63	5.4944E+001		-1.9528E+001
		919.63	2.88	8.8220E+001		-2.3947E+000
		925.24	7.09	4.2576E+001		-1.7093E+001
		1596.49	95.49	2.7550E+000		-8.8680E-001
	CE-141	145.44	48.40	8.7733E+000	8.7733E+000	1.7833E-001
	CE-144	80.11	1.60	4.3029E+002	4.4268E+001	1.1268E+002
		133.54	10.80	4.4268E+001		1.0398E+001
	EU-152	121.78	28.40	1.6103E+001	1.0687E+001	-2.7742E-001
		244.69	7.49	4.8021E+001		2.4001E+001
		344.27	26.50	1.0687E+001		-1.3526E+000
		411.11	2.21	1.2917E+002		-2.2072E+001
		443.98	3.11	7.9142E+001		-7.4534E+001
		778.89	12.74	2.7763E+001		2.0268E+000
		867.32	4.16	8.7163E+001		3.7340E+001
		964.01	14.40	1.9956E+001		6.1811E+000
		1085.78	10.00	2.5573E+001		-2.1342E+001
		1112.02	13.30	2.5909E+001		5.5193E+000
		1407.95	20.70	1.1006E+001		-1.1809E+000

+ = Nuclide Identified during the nuclide identification

* = Energy Line found in the spectrum

MCS GROUPS
MCS Full Range

Analysis Report - test Person [0000-0000]

SOURCE INFORMATION

Primary ID 0000-0000
Last Name Person
First Name test
Height (in)
Weight (lb)
Chest Wall Thickness (cm)

COUNTER INFORMATION

Counter Name Accuscan II
Counter Location Battelle
Configuration Name Total Body Scan

COUNT INFORMATION

Count Operation Individual 10 minutes
Count Reason Routine operation
Frequency
Comment MDA Person count #2 for 4/21/2011 calibration
Intake Date
Acquisition Started 4/26/2011 8:21:51 AM
Acquisition Time 601.1
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	16.32	1 - 4096	600.0	Yes	4/26/2011 8:20:44 AM	5bd92fba0820.cnf
Right	17.63	1 - 4096	600.0	Yes	4/26/2011 8:20:44 AM	fc73f6470820.cnf
Summed	33.78	1 - 4096	600.0	Yes	4/26/2011 8:20:44 AM	4406579c0820.cnf
MCS Full Range		-	0.0	No		a850f6530820.cnf

Primary Review by:

Secondary Review by:

Date:

Date:

DETECTOR GROUP INFORMATION

Detector Group Name Left
Detector Group Configuration Total Body Scan
Analysis Date 4/26/2011 8:20:44 AM
Energy Calibration WB-Left Energy Calibration 4/21/2011 8:58 AM
Efficiency Calibration
Multi Curve
Source Distribution Whole Body
Analysis Sequence File NO_ANALY.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library
Tentative NID Library
Peak Search Library
Analysis Limits (channels) 1 - 4096
Energy Tolerance (keV) 1.00
Comment

DETECTOR GROUP INFORMATION

Detector Group Name Right
Detector Group Configuration Total Body Scan
Analysis Date 4/26/2011 8:20:44 AM
Energy Calibration WB-Right Energy Calibration 4/21/2011 9:03 AM
Efficiency Calibration
Multi Curve
Source Distribution Whole Body
Analysis Sequence File NO_ANALY.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library
Tentative NID Library

Peak Search Library**Analysis Limits (channels)** 1 - 4096**Energy Tolerance (keV)** 1.00**Comment**

User: David Georgeson

Database: InVivo Server: 127.0.0.1

DETECTOR GROUP INFORMATION

Detector Group Name	Summed
Detector Group Configuration	Total Body Scan
Analysis Date	4/26/2011 8:20:44 AM
Energy Calibration	WB-Summed Energy Calibration 4/21/2011 9:06 AM
Efficiency Calibration	WB-Summed Efficiency Calibration 4/21/2011 9:11 AM (Dual)
Multi Curve	No
Source Distribution	Whole Body
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	3162.18	1460.48	5.72E+001	1.08E+001		K-40	2.727902E+002	19.17 %	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	0.996	2.727902E+002	19.17 %	Not Performed	Not Performed	7.831E+001

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)
+	K-40	1460.81 *	10.67	7.8312E+001	7.8312E+001	2.7279E+002
	CR-51	320.08	9.83	3.0621E+001	3.0621E+001	1.2258E+001
	MN-54	834.83	99.97	2.1341E+000	2.1341E+000	-3.2787E+000
	CO-57	122.06	85.51	5.6277E+000	5.6277E+000	4.8695E-001
		136.48	10.60	4.3882E+001		-4.5763E-001
	CO-58	810.76	99.40	3.3313E+000	3.3313E+000	1.6464E+000
	FE-59	142.65	1.03	4.2973E+002	5.1086E+000	-1.5161E+002
		192.34	3.11	1.0887E+002		-1.5159E+001
		1099.22	56.50	5.1086E+000		-2.2880E+000
		1291.56	43.20	6.8498E+000		-7.2757E+000
	CO-60	1173.22	100.00	3.3309E+000	3.3309E+000	7.2220E-001
		1332.49	100.00	4.0321E+000		4.6250E-001
	ZN-65	1115.52	50.75	6.3019E+000	6.3019E+000	1.8218E+000
	NB-95	765.79	99.81	3.3573E+000	3.3573E+000	-8.3781E-002
	ZR-95	724.18	43.70	8.3551E+000	5.1292E+000	2.3718E+000
		756.72	55.30	5.1292E+000		-2.6485E+000
	RU-106	621.84	9.80	2.8640E+001	2.8640E+001	-1.8415E+001
		1050.47	1.73	2.2799E+002		2.0348E+002
	AG-110M	446.80	3.64	8.0838E+001	2.9214E+000	7.4901E+001
		620.35	2.77	1.2391E+002		6.4728E+001
		657.75	94.40	2.9214E+000		6.4032E-001
		677.61	10.68	3.0373E+001		1.3304E+001
		686.99	6.47	6.1933E+001		4.3932E+001
		706.67	16.68	2.0776E+001		1.3452E+001
		744.26	4.64	7.0944E+001		-1.9475E+001
		763.93	22.28	1.4318E+001		-3.4352E+000
		818.02	7.30	4.0800E+001		2.8729E+001
		884.67	72.60	4.8238E+000		1.3888E+000
		937.48	34.20	5.8295E+000		-2.7238E+000
		1384.27	24.26	9.2279E+000		-2.4753E+000
		1475.76	3.97	8.5391E+001		5.1829E+001
		1505.00	13.06	2.2984E+001		-1.6109E+001
		1562.27	1.18	1.5348E+002		2.3290E+001
	I-131	80.18	2.62	2.5329E+002	3.7178E+000	-1.2138E+002
		284.30	6.05	4.6252E+001		-1.2814E+001

		364.48	81.20	3.7178E+000		2.3031E+000
		636.97	7.26	2.7753E+001		-5.7252E+001
		722.89	1.80	1.7960E+002		-1.2101E+002
	I-133	529.87	86.30	3.8268E+000	3.8268E+000	8.2844E-002
		875.33	4.47	6.5099E+001		-6.4004E+001
	CS-134	475.35	1.46	2.2237E+002	2.4237E+000	-7.8226E+001
		563.23	8.38	3.7214E+001		7.9772E+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)
	CS-134	569.32	15.43	2.2425E+001	2.4237E+000	1.4030E+001
		604.70	97.60	3.5740E+000		2.4404E+000
		795.84	85.40	2.4237E+000		-1.1033E+000
		801.93	8.73	3.3692E+001		-2.1690E+001
		1038.57	1.00	2.7656E+002		-3.4157E+002
		1167.94	1.80	1.0644E+002		-1.2563E+002
		1365.15	3.04	8.8930E+001		1.0388E+001
	CS-137	661.65	85.12	3.5950E+000	3.5950E+000	1.8691E+000
	BA-140	162.64	6.70	6.3752E+001	1.4460E+001	6.1928E+001
		304.84	4.50	6.4463E+001		4.2591E+000
		423.70	3.20	9.1149E+001		-6.7735E+001
		437.55	2.00	1.3619E+002		1.2272E+002
		537.32	25.00	1.4460E+001		7.4576E+000
	LA-140	328.77	20.50	1.0776E+001	2.7550E+000	-4.2220E+000
		432.53	2.94	7.5033E+001		6.4807E+000
		487.03	45.50	7.9811E+000		-2.1409E+000
		751.79	4.40	6.4202E+001		-5.0803E+001
		815.85	23.50	8.9473E+000		-1.0182E+001
		867.82	5.63	5.8277E+001		-4.7163E+001
		919.63	2.88	9.6640E+001		5.3880E+001
		925.24	7.09	3.5983E+001		-9.7672E+000
		1596.49	95.49	2.7550E+000		-3.1038E+000
	CE-141	145.44	48.40	8.7448E+000	8.7448E+000	-5.9317E-001
	CE-144	80.11	1.60	4.1528E+002	4.2250E+001	-1.9901E+002
		133.54	10.80	4.2250E+001		1.0357E+001
	EU-152	121.78	28.40	1.6531E+001	1.0452E+001	-2.7424E+000
		244.69	7.49	4.4816E+001		-8.1230E+000
		344.27	26.50	1.0452E+001		9.1300E+000
		411.11	2.21	1.3952E+002		6.4677E+001
		443.98	3.11	7.9142E+001		-3.9867E+001
		778.89	12.74	2.6581E+001		-1.2051E+001
		867.32	4.16	7.8842E+001		-3.1459E+001
		964.01	14.40	2.4441E+001		4.9449E+000
		1085.78	10.00	4.2408E+001		1.6051E+001
		1112.02	13.30	2.1897E+001		-1.0699E+001
		1407.95	20.70	1.7402E+001		7.0855E+000

+ = Nuclide Identified during the nuclide identification

* = Energy Line found in the spectrum

MCS GROUPS
MCS Full Range

Analysis Report - test Person [0000-0000]

SOURCE INFORMATION

Primary ID 0000-0000
Last Name Person
First Name test
Height (in)
Weight (lb)
Chest Wall Thickness (cm)

COUNTER INFORMATION

Counter Name Accuscan II
Counter Location Battelle
Configuration Name Total Body Scan

COUNT INFORMATION

Count Operation Individual 10 minutes
Count Reason Routine operation
Frequency
Comment MDA Person count #3 for 4/21/2011 calibration
Intake Date
Acquisition Started 4/26/2011 8:50:17 AM
Acquisition Time 601.05
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	17.53	1 - 4096	600.0	Yes	4/26/2011 8:49:13 AM	8708f3370849.cnf
Left	16.64	1 - 4096	600.0	Yes	4/26/2011 8:49:13 AM	491e79210849.cnf
Summed	34.09	1 - 4096	600.0	Yes	4/26/2011 8:49:13 AM	008d5a8d0849.cnf
MCS Full Range		-	0.0	No		44d3bcf60849.cnf

Primary Review by:

Secondary Review by:

Date:

Date:

DETECTOR GROUP INFORMATION

Detector Group Name Left
Detector Group Configuration Total Body Scan
Analysis Date 4/26/2011 8:49:13 AM
Energy Calibration WB-Left Energy Calibration 4/21/2011 8:58 AM
Efficiency Calibration
Multi Curve
Source Distribution Whole Body
Analysis Sequence File NO_ANALY.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library
Tentative NID Library
Peak Search Library
Analysis Limits (channels) 1 - 4096
Energy Tolerance (keV) 1.00
Comment

DETECTOR GROUP INFORMATION

Detector Group Name Right
Detector Group Configuration Total Body Scan
Analysis Date 4/26/2011 8:49:13 AM
Energy Calibration WB-Right Energy Calibration 4/21/2011 9:03 AM
Efficiency Calibration
Multi Curve
Source Distribution Whole Body
Analysis Sequence File NO_ANALY.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library
Tentative NID Library

Peak Search Library**Analysis Limits (channels)** 1 - 4096**Energy Tolerance (keV)** 1.00**Comment**

User: David Georgeson

Database: InVivo Server: 127.0.0.1

DETECTOR GROUP INFORMATION

Detector Group Name Summed
Detector Group Configuration Total Body Scan
Analysis Date 4/26/2011 8:49:13 AM
Energy Calibration WB-Summed Energy Calibration 4/21/2011 9:06 AM
Efficiency Calibration WB-Summed Efficiency Calibration 4/21/2011 9:11 AM (Dual)
Multi Curve No
Source Distribution Whole Body
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	57.98	26.54	6.68E+001	1.05E+002	Unknown	1.488297E+003		100.00	
2	3162.87	1460.80	7.00E+001	1.40E+001	K-40	3.334973E+002	17.73 %	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	3.334973E+002	17.73 %	Not Performed	Not Performed	8.881E+001

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)
+	K-40	1460.81 *	10.67	8.8814E+001	8.8814E+001	3.3350E+002
	CR-51	320.08	9.83	2.6057E+001	2.6057E+001	1.4134E+001
	MN-54	834.83	99.97	3.6963E+000	3.6963E+000	-2.1588E+000
	CO-57	122.06	85.51	6.2120E+000	6.2120E+000	2.3533E+000
		136.48	10.60	4.3766E+001		3.5614E+001
	CO-58	810.76	99.40	2.9796E+000	2.9796E+000	2.5576E+000
	FE-59	142.65	1.03	4.2204E+002	5.9321E+000	4.6264E+002
		192.34	3.11	1.2425E+002		4.5939E-001
		1099.22	56.50	6.4619E+000		-5.6333E-001
		1291.56	43.20	5.9321E+000		2.0788E+000
	CO-60	1173.22	100.00	3.3309E+000	2.6396E+000	-2.6481E+000
		1332.49	100.00	2.6396E+000		1.3875E+000
	ZN-65	1115.52	50.75	5.1455E+000	5.1455E+000	2.2447E+000
	NB-95	765.79	99.81	2.6782E+000	2.6782E+000	-1.5799E+000
	ZR-95	724.18	43.70	7.7353E+000	4.4420E+000	4.1225E+000
		756.72	55.30	4.4420E+000		-4.8614E+000
	RU-106	621.84	9.80	3.6227E+001	3.6227E+001	-4.1228E+000
		1050.47	1.73	1.4419E+002		-6.0169E+001
	AG-110M	446.80	3.64	8.5461E+001	2.5765E+000	-2.2078E+001
		620.35	2.77	1.3573E+002		3.3982E+001
		657.75	94.40	2.5765E+000		-1.0977E+000
		677.61	10.68	3.3958E+001		1.5965E+000
		686.99	6.47	4.6162E+001		8.4173E+000
		706.67	16.68	1.9961E+001		-2.3316E+000
		744.26	4.64	7.0944E+001		-2.9802E+001
		763.93	22.28	1.4318E+001		8.7942E+000
		818.02	7.30	5.5868E+001		-1.1382E+001
		884.67	72.60	3.7365E+000		-1.2345E+000
		937.48	34.20	8.2442E+000		-1.7024E+000
		1384.27	24.26	1.1302E+001		5.9407E+000
		1475.76	3.97	7.3951E+001		3.8872E+001
		1505.00	13.06	1.8767E+001		-2.8190E+001
		1562.27	1.18	2.1706E+002		1.1645E+001
	I-131	80.18	2.62	2.5329E+002	3.5595E+000	6.9360E+001
		284.30	6.05	4.6252E+001		-9.2258E+000

		364.48	81.20	3.5595E+000		-8.7935E-001
		636.97	7.26	4.2994E+001		-1.8519E+001
		722.89	1.80	1.8758E+002		-1.0956E+001
	I-133	529.87	86.30	3.9377E+000	3.9377E+000	2.4411E+000
		875.33	4.47	4.2617E+001		-3.9825E+001
	CS-134	475.35	1.46	1.9088E+002	2.6805E+000	-8.5706E+001
		563.23	8.38	3.7214E+001		1.1642E+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)
	CS-134	569.32	15.43	1.8840E+001	2.6805E+000	-6.8773E+000
		604.70	97.60	2.6805E+000		-2.1090E-001
		795.84	85.40	2.7098E+000		2.2066E-001
		801.93	8.73	4.1264E+001		4.8201E+000
		1038.57	1.00	3.4983E+002		-1.5483E+002
		1167.94	1.80	1.5053E+002		-1.3134E+002
		1365.15	3.04	1.4522E+002		1.0713E+001
	CS-137	661.65	85.12	4.3358E+000	4.3358E+000	6.5791E-001
	BA-140	162.64	6.70	5.9635E+001	1.3718E+001	-2.1881E+001
		304.84	4.50	5.7408E+001		-5.8756E+001
		423.70	3.20	9.8452E+001		-1.3971E+001
		437.55	2.00	1.5726E+002		7.0432E+001
		537.32	25.00	1.3718E+001		-1.6900E+000
	LA-140	328.77	20.50	1.2751E+001	3.8961E+000	4.2220E+000
		432.53	2.94	1.1129E+002		5.9734E+001
		487.03	45.50	5.2626E+000		-3.9141E+000
		751.79	4.40	6.0055E+001		-1.1317E+001
		815.85	23.50	1.0003E+001		-1.6971E+001
		867.82	5.63	4.7583E+001		1.4738E+001
		919.63	2.88	1.0438E+002		-7.4405E+001
		925.24	7.09	3.5983E+001		-1.9046E+001
		1596.49	95.49	3.8961E+000		2.3648E+000
	CE-141	145.44	48.40	9.4057E+000	9.4057E+000	6.1141E+000
	CE-144	80.11	1.60	4.1528E+002	4.2707E+001	1.1372E+002
		133.54	10.80	4.2707E+001		2.5793E+001
	EU-152	121.78	28.40	1.8595E+001	9.9660E+000	6.1264E-001
		244.69	7.49	4.0454E+001		1.5143E+001
		344.27	26.50	9.9660E+000		0.0000E+000
		411.11	2.21	1.2553E+002		-3.1251E+001
		443.98	3.11	1.0217E+002		-1.5947E+001
		778.89	12.74	1.7921E+001		-1.3620E+001
		867.32	4.16	6.4374E+001		-1.9939E+001
		964.01	14.40	1.8217E+001		-6.6755E+000
		1085.78	10.00	2.8591E+001		-3.8804E+000
		1112.02	13.30	1.6962E+001		-1.9317E+001
		1407.95	20.70	1.5565E+001		-8.5616E+000

+ = Nuclide Identified during the nuclide identification

* = Energy Line found in the spectrum

MCS GROUPS

MCS Full Range

Appendix H

Whole Body Calibration Validation

Appendix H

Whole Body Calibration Validation

Summary

Validation Test Summary
With DOE DL#BM09A4GA BOMAB

Counting System Accuscan II
Counting Geometry Whole Body
Energy Calibration 4/21/11 9:06 AM
Efficiency Calibration 4/21/11 9:11 AM
Count Times
#1- 4/21/2011 9:59:00 AM
#2 - 4/21/2011 10:15 AM
#3 - 4/21/2011 10:45 AM
#4 - 4/21/2011 11:06 AM
#5 - 4/21/2011 11:21 AM

Nuclide Energy (keV)	Expected Activity (nCi)	Observed Activity (nCi)					Relative Bias	Relative Precision
		#1	#2	#3	#4	#5		
Cs-137	386	363.77	373.17	372.43	364.48	368.83	-0.045	0.011
Cs-134	549	534.20	527.60	520.60	510.94	529.22	-0.045	0.139
Co-60	75.8	67.60	72.44	64.40	70.46	79.96	-0.064	0.077
Mn-54	38.7	39.40	41.12	44.37	39.16	46.21	0.087	0.081
Average =							-0.017	0.077

CALIBRATION VALIDATION – COUNT 1

Page 1 of 7
Created 4/25/2011 11:59:56 AM
Idaho Falls Id.

Battelle Energy Alliance LLC

Analysis Report - Whole Body [Bomab]

SOURCE INFORMATION

Primary ID Bomab
Last Name Body
First Name Whole
Height (in)
Weight (lb)
Chest Wall Thickness (cm)

COUNTER INFORMATION

Counter Name Accuscan II
Counter Location Battelle
Configuration Name Total Body Scan

COUNT INFORMATION

Count Operation Individual 10 minutes
Count Reason Routine operation
Frequency
Comment Test Count One
Intake Date
Acquisition Started 4/21/2011 9:59:24 AM
Acquisition Time 601.97
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	72.41	1 - 4096	600.0	Yes	4/21/2011 9:58:16 AM	e628f7110958.cnf
Right	73.69	1 - 4096	600.0	Yes	4/21/2011 9:58:16 AM	936ab1ba0958.cnf
Summed	146.12	1 - 4096	600.0	Yes	4/21/2011 9:58:16 AM	5d0b93b50958.cnf
MCS Full Range		-	0.0	No		b4371f850958.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 Left
Detector Group Configuration Total Body Scan
Analysis Date 4/21/2011 9:58:16 AM
Energy Calibration WB-Left Energy Calibration 4/21/2011 8:58 AM
Efficiency Calibration
Multi Curve
Source Distribution Whole Body
Analysis Sequence File NO_ANALY.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library
Tentative NID Library
Peak Search Library
Analysis Limits (channels) 1 - 4096
Energy Tolerance (keV) 1.00
Comment

DETECTOR GROUP INFORMATION

Detector Group Name Right
Detector Group Configuration Total Body Scan
Analysis Date 4/21/2011 9:58:16 AM
Energy Calibration WB-Right Energy Calibration 4/21/2011 9:03 AM
Efficiency Calibration
Multi Curve
Source Distribution Whole Body
Analysis Sequence File NO_ANALY.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library
Tentative NID Library
Peak Search Library
Analysis Limits (channels) 1 - 4096
Energy Tolerance (keV) 1.00
Comment

DETECTOR GROUP INFORMATION

Detector Group Name	Summed
Detector Group Configuration	Total Body Scan
Analysis Date	4/21/2011 9:58:16 AM
Energy Calibration	WB-Summed Energy Calibration 4/21/2011 9:06 AM
Efficiency Calibration	WB-Summed Efficiency Calibration 4/21/2011 9:11 AM (Dual)
Multi Curve	No
Source Distribution	Whole Body
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 (%)
M	1	1219.50	563.23	1.74E+002	1.66E+002	CS-134	5.266097E+002	9.53 %	8.38
m	2	1232.82	569.38	2.97E+002	1.98E+002	CS-134	4.895051E+002	7.07 %	15.43
	3	1309.32	604.73	2.00E+003	2.35E+002	CS-134	5.421229E+002	3.58 %	97.60
	4	1432.59	661.67	1.11E+003	1.01E+002	CS-137	3.637704E+002	4.24 %	85.12
M	5	1722.97	795.81	1.46E+003	3.74E+001	CS-134	5.364683E+002	3.59 %	85.40
m	6	1736.39	802.01	1.61E+002	2.51E+001	CS-134	5.829001E+002	8.46 %	8.73
	7	1807.37	834.80	1.22E+002	4.52E+001	MN-54	3.944515E+001	15.01 %	99.97
	8	2539.54	1172.96	1.40E+002	2.43E+001	CO-60	5.766163E+001	11.44 %	100.00

	9	2884.60	1332.30	1.72E+002	3.66E+000	CO-60	7.970092E+001	9.11 %	100.00
	10	2956.26	1365.39	2.74E+001	8.57E+000	CS-134	4.275103E+002	28.89 %	3.04

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 (%)
11	3161.99	1460.39	9.04E+001	3.56E+000	K-40	4.309707E+002	13.09 %	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	0.994	4.309707E+002	13.09 %	Not Performed	Not Performed	4.497E+001
MN-54	1.000	3.944515E+001	15.01 %			1.077E+001
CO-60	0.998	6.762841E+001	7.22 %			4.460E+000
CS-134	1.000	5.341852E+002	2.23 %			7.414E+000
CS-137	1.000	3.637704E+002	4.24 %			1.680E+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	4.4974E+001	4.4974E+001	4.3097E+002
	CR-51	320.08	9.83	7.2149E+001	7.2149E+001	-5.8114E+001
+	MN-54	834.83 *	99.97	1.0766E+001	1.0766E+001	3.9445E+001
	CO-57	122.06	85.51	1.0142E+001	1.0142E+001	-1.2693E+001
		136.48	10.60	8.1226E+001		2.7985E+001
	CO-58	810.76	99.40	4.0800E+000	4.0800E+000	-7.9925E-001
	FE-59	142.65	1.03	8.3823E+002	7.9141E+000	-4.7367E+001
		192.34	3.11	2.7331E+002		1.0585E+002
		1099.22	56.50	7.9141E+000		-6.9333E+000
		1291.56	43.20	1.0275E+001		7.9686E+000
+	CO-60	1173.22 *	100.00	9.5244E+000	4.4603E+000	5.7662E+001
+		1332.49 *	100.00	4.4603E+000		7.9701E+001
	ZN-65	1115.52	50.75	8.9123E+000	8.9123E+000	-4.2943E+000
	NB-95	765.79	99.81	5.0613E+000	5.0613E+000	-2.5252E+000
	ZR-95	724.18	43.70	1.0233E+001	9.9327E+000	-6.9380E-001
		756.72	55.30	9.9327E+000		4.2193E+000
	RU-106	621.84	9.80	7.4684E+001	7.4684E+001	2.9507E+001

		1050.47	1.73	2.8838E+002		5.4699E+000
	AG-110M	446.80	3.64	2.5563E+002	7.1549E+000	-7.4691E+001
		620.35	2.77	2.5394E+002		-1.2576E+002
		657.75	94.40	7.2873E+000		-5.5940E-001
		677.61	10.68	5.0368E+001		-7.1360E+000
		686.99	6.47	8.7587E+001		-1.3044E+001
		706.67	16.68	2.3759E+001		-2.7363E+001
		744.26	4.64	1.1115E+002		4.5681E+000
		763.93	22.28	2.0749E+001		-1.3937E+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)
	AG-110M	818.02	7.30	5.5868E+001	7.1549E+000	-3.3125E+001
		884.67	72.60	7.1549E+000		9.5744E-001
		937.48	34.20	1.3877E+001		1.1746E+001
		1384.27	24.26	2.0634E+001		8.9111E+000
		1475.76	3.97	6.0381E+001		2.5914E+001
		1505.00	13.06	2.9673E+001		-1.6109E+001
		1562.27	1.18	3.0697E+002		1.8632E+002
	I-131	80.18	2.62	4.2878E+002	1.1127E+001	-3.3895E+002
		284.30	6.05	1.3000E+002		1.0524E+002
		364.48	81.20	1.1127E+001		-8.2235E+000
		636.97	7.26	8.9500E+001		-3.0604E+001
		722.89	1.80	2.5970E+002		9.0385E+001
	I-133	529.87	86.30	9.2348E+000	9.2348E+000	-3.0984E+000
		875.33	4.47	9.8421E+001		-1.1201E+001
+	CS-134	475.35	1.46	7.0506E+002	7.4138E+000	7.5211E+002
+		563.23 *	8.38	1.2816E+002		5.2661E+002
+		569.32 *	15.43	7.6561E+001		4.8951E+002
+		604.70 *	97.60	2.0641E+001		5.4212E+002
+		795.84 *	85.40	7.4138E+000		5.3647E+002
+		801.93 *	8.73	5.9686E+001		5.8290E+002
+		1038.57	1.00	7.1051E+002		4.6749E+002
+		1167.94	1.80	4.1906E+002		5.6182E+002
+		1365.15 *	3.04	2.1057E+002		4.2751E+002
+	CS-137	661.65 *	85.12	1.6803E+001	1.6803E+001	3.6377E+002
	BA-140	162.64	6.70	1.2323E+002	3.4674E+001	4.0214E+001
		304.84	4.50	1.6716E+002		1.0600E+001
		423.70	3.20	3.1793E+002		1.0755E+002
		437.55	2.00	4.2343E+002		-2.1343E+001
		537.32	25.00	3.4674E+001		1.2351E+001
	LA-140	328.77	20.50	3.5957E+001	3.3742E+000	1.1357E+001
		432.53	2.94	3.1388E+002		3.2764E+002
		487.03	45.50	1.6971E+001		-7.8233E+000
		751.79	4.40	1.0886E+002		-5.8553E+001
		815.85	23.50	1.8445E+001		4.0730E+000
		867.82	5.63	7.5236E+001		2.6529E+001
		919.63	2.88	1.5280E+002		1.1973E+001
		925.24	7.09	6.6349E+001		-2.4418E+000
		1596.49	95.49	3.3742E+000		1.7736E+000
	CE-141	145.44	48.40	1.7475E+001	1.7475E+001	-1.6390E+001
	CE-144	80.11	1.60	7.0302E+002	8.2348E+001	-5.5574E+002

		133.54	10.80	8.2348E+001		4.5250E+001
	EU-152	121.78	28.40	3.0173E+001	1.7402E+001	-3.5170E+000
		244.69	7.49	1.0598E+002		-3.3940E+001
		344.27	26.50	2.8884E+001		2.5361E-001
		411.11	2.21	4.3909E+002		2.3299E+001
		443.98	3.11	2.9347E+002		3.6978E+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)
	EU-152	778.89	12.74	4.3159E+001	1.7402E+001	3.3003E+001
		867.32	4.16	1.0178E+002		3.5890E+001
		964.01	14.40	3.1553E+001		-1.0137E+001
		1085.78	10.00	5.2720E+001		1.8717E+001
		1112.02	13.30	2.9378E+001		-2.0308E+001
		1407.95	20.70	1.7402E+001		1.1809E+000

+ = Nuclide Identified during the nuclide identification

* = Energy Line found in the spectrum

MCS GROUPS**MCS Full Range**

MCS GROUPS

CALIBRATION VALIDATION – COUNT 2

Page 1 of 7
Created 4/25/2011 12:01:27 PM
Idaho Falls Id.

Battelle Energy Alliance LLC

Analysis Report - Whole Body [Bomab]

SOURCE INFORMATION

Primary ID Bomab
Last Name Body
First Name Whole
Height (in)
Weight (lb)
Chest Wall Thickness (cm)

COUNTER INFORMATION

Counter Name Accuscan II
Counter Location Battelle
Configuration Name Total Body Scan

COUNT INFORMATION

Count Operation Individual 10 minutes
Count Reason Routine operation
Frequency
Comment DOE Bomab Test count #2
Intake Date
Acquisition Started 4/21/2011 10:15:16 AM
Acquisition Time 602.19
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	71.63	1 - 4096	600.0	Yes	4/21/2011 10:14:07 AM	cc86d7651014.cnf
Right	73.72	1 - 4096	600.0	Yes	4/21/2011 10:14:07 AM	c6549ea51014.cnf
Summed	144.95	1 - 4096	600.0	Yes	4/21/2011 10:14:07 AM	0c7521391014.cnf
MCS Full Range		-	0.0	No		6e022b311014.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	Left
Detector Group Configuration	Total Body Scan
Analysis Date	4/21/2011 10:14:07 AM
Energy Calibration	WB-Left Energy Calibration 4/21/2011 8:58 AM
Efficiency Calibration	
Multi Curve	
Source Distribution	Whole Body
Analysis Sequence File	NO_ANALY.ASF
Bkg Acq used for area correction	Not Performed
Nuclide Identification	
Nuclide Identification Library	
Tentative NID Library	
Peak Search Library	
Analysis Limits (channels)	1 - 4096
Energy Tolerance (keV)	1.00
Comment

DETECTOR GROUP INFORMATION

Detector Group Name	Right
Detector Group Configuration	Total Body Scan
Analysis Date	4/21/2011 10:14:07 AM
Energy Calibration	WB-Right Energy Calibration 4/21/2011 9:03 AM
Efficiency Calibration	
Multi Curve	
Source Distribution	Whole Body
Analysis Sequence File	NO_ANALY.ASF
Bkg Acq used for area correction	Not Performed
Nuclide Identification	
Nuclide Identification Library	
Tentative NID Library	
Peak Search Library	
Analysis Limits (channels)	1 - 4096
Energy Tolerance (keV)	1.00
Comment

DETECTOR GROUP INFORMATION

Detector Group Name	Summed
Detector Group Configuration	Total Body Scan
Analysis Date	4/21/2011 10:14:07 AM
Energy Calibration	WB-Summed Energy Calibration 4/21/2011 9:06 AM
Efficiency Calibration	WB-Summed Efficiency Calibration 4/21/2011 9:11 AM (Dual)
Multi Curve	No
Source Distribution	Whole Body
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 (%)
M	1	1219.80	563.37	1.84E+002	1.35E+002	CS-134	5.554602E+002	8.76 %	8.38
m	2	1232.72	569.34	3.51E+002	1.63E+002	CS-134	5.792126E+002	6.28 %	15.43
	3	1309.31	604.72	1.94E+003	1.66E+002	CS-134	5.272120E+002	3.50 %	97.60
	4	1432.50	661.63	1.13E+003	6.76E+001	CS-137	3.731728E+002	4.04 %	85.12
M	5	1723.02	795.83	1.40E+003	6.07E+001	CS-134	5.160626E+002	3.63 %	85.40
m	6	1736.22	801.93	1.41E+002	4.71E+001	CS-134	5.109091E+002	9.48 %	8.73

	7	1807.29	834.76	1.27E+002	2.80E+001	MN-54	4.112497E+001	12.79 %	99.97
	8	2248.50	1038.54	2.19E+001	2.51E+001	CS-134	8.201829E+002	50.86 %	1.00
	9	2539.81	1173.08	1.53E+002	1.96E+001	CO-60	6.328508E+001	10.54 %	100.00
	10	2884.58	1332.30	1.85E+002	1.03E+001	CO-60	8.542877E+001	9.31 %	100.00

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 (%)
	11	2956.02	1365.28	2.37E+001	8.31E+000	CS-134	3.691322E+002	31.77 %	3.04
	12	3162.43	1460.59	5.56E+001	1.94E+001	K-40	2.649791E+002	22.36 %	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	0.998	2.649791E+002	22.36 %	Not Performed	Not Performed	1.032E+002
MN-54	1.000	4.112497E+001	12.79 %			8.499E+000
CO-60	0.999	7.243290E+001	7.06 %			7.275E+000
CS-134	1.000	5.275928E+002	2.20 %			9.439E+000
CS-137	1.000	3.731728E+002	4.04 %			1.376E+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	1.0317E+002	1.0317E+002	2.6498E+002
	CR-51	320.08	9.83	7.6920E+001	7.6920E+001	2.2065E+001
+	MN-54	834.83 *	99.97	8.4994E+000	8.4994E+000	4.1125E+001
	CO-57	122.06	85.51	1.0307E+001	1.0307E+001	4.7888E+000
		136.48	10.60	7.9842E+001		4.9699E+001
	CO-58	810.76	99.40	3.9416E+000	3.9416E+000	-4.1218E+000
	FE-59	142.65	1.03	8.3888E+002	7.6583E+000	3.1218E+002
		192.34	3.11	2.8422E+002		5.0139E+001
		1099.22	56.50	8.8483E+000		4.5529E+000
		1291.56	43.20	7.6583E+000		-7.2757E-001
+	CO-60	1173.22 *	100.00	8.9578E+000	7.2754E+000	6.3285E+001
+		1332.49 *	100.00	7.2754E+000		8.5429E+001
	ZN-65	1115.52	50.75	8.1358E+000	8.1358E+000	-1.9910E+000
	NB-95	765.79	99.81	4.9590E+000	4.9590E+000	-4.0448E+000
	ZR-95	724.18	43.70	1.0939E+001	9.9327E+000	-4.0378E+000
		756.72	55.30	9.9327E+000		5.0265E+000

	RU-106	621.84	9.80	6.8377E+001	6.8377E+001	6.9196E+000
		1050.47	1.73	2.8838E+002		1.8598E+002
	AG-110M	446.80	3.64	2.4013E+002	6.2895E+000	-9.2107E+001
		620.35	2.77	2.4154E+002		8.6616E+001
		657.75	94.40	6.8167E+000		3.2837E-001
		677.61	10.68	5.3333E+001		-7.6231E+000
		686.99	6.47	8.8795E+001		3.7656E+001
		706.67	16.68	3.0491E+001		1.8362E+001
		744.26	4.64	1.2473E+002		6.5870E+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)
	AG-110M	763.93	22.28	2.4383E+001	6.2895E+000	1.0993E+001
		818.02	7.30	6.2878E+001		3.5713E+001
		884.67	72.60	6.2895E+000		-3.1316E-001
		937.48	34.20	1.6488E+001		1.3789E+001
		1384.27	24.26	1.5983E+001		7.5909E+000
		1475.76	3.97	7.3951E+001		3.8872E+001
		1505.00	13.06	1.8767E+001		-2.2150E+001
		1562.27	1.18	2.6584E+002		2.3290E+001
	I-131	80.18	2.62	4.4186E+002	1.0866E+001	-1.3024E+002
		284.30	6.05	1.2695E+002		5.4883E+001
		364.48	81.20	1.0866E+001		1.0044E+000
		636.97	7.26	9.6936E+001		9.0182E+001
		722.89	1.80	2.9161E+002		6.5168E+001
	I-133	529.87	86.30	1.0293E+001	1.0293E+001	3.7888E+000
		875.33	4.47	9.8421E+001		2.4502E+001
+	CS-134	475.35	1.46	6.6124E+002	9.4392E+000	5.2391E+002
+		563.23 *	8.38	1.1536E+002		5.5546E+002
+		569.32 *	15.43	6.9522E+001		5.7921E+002
+		604.70 *	97.60	1.7325E+001		5.2721E+002
+		795.84 *	85.40	9.4392E+000		5.1606E+002
+		801.93 *	8.73	8.1726E+001		5.1091E+002
+		1038.57 *	1.00	8.8032E+002		8.2018E+002
+		1167.94	1.80	4.6396E+002		6.0079E+002
+		1365.15 *	3.04	2.0426E+002		3.6913E+002
+	CS-137	661.65 *	85.12	1.3758E+001	1.3758E+001	3.7317E+002
	BA-140	162.64	6.70	1.1939E+002	3.5272E+001	1.5813E+001
		304.84	4.50	1.6844E+002		-6.6894E+001
		423.70	3.20	3.0154E+002		1.2552E+002
		437.55	2.00	4.5983E+002		-6.1688E+001
		537.32	25.00	3.5272E+001		1.1136E+001
	LA-140	328.77	20.50	3.6913E+001	2.7550E+000	-4.2326E+001
		432.53	2.94	3.0754E+002		6.4657E+001
		487.03	45.50	1.8230E+001		7.6809E-001
		751.79	4.40	1.1349E+002		4.1056E+001
		815.85	23.50	1.8445E+001		9.1841E-001
		867.82	5.63	8.6875E+001		-1.8570E+001
		919.63	2.88	1.4225E+002		-3.4078E+001
		925.24	7.09	6.6349E+001		1.1347E+001
		1596.49	95.49	2.7550E+000		0.0000E+000

	CE-141	145.44	48.40	1.7129E+001	1.7129E+001	-1.9057E+000
	CE-144	80.11	1.60	7.2446E+002	7.7868E+001	-2.1353E+002
		133.54	10.80	7.7868E+001		6.8977E+001
	EU-152	121.78	28.40	3.1038E+001	2.1897E+001	-3.5210E-001
		244.69	7.49	1.0598E+002		-7.5785E+001
		344.27	26.50	2.5988E+001		-3.5506E+000
		411.11	2.21	4.3056E+002		-2.1473E+002

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)
	EU-152	443.98	3.11	2.7032E+002	2.1897E+001	-2.1355E+002
		778.89	12.74	3.8436E+001		-2.1626E+001
		867.32	4.16	1.2875E+002		4.6358E+001
		964.01	14.40	4.0735E+001		2.9817E+001
		1085.78	10.00	4.4293E+001		-7.7608E+000
		1112.02	13.30	2.1897E+001		-3.4474E+001
		1407.95	20.70	2.2012E+001		-6.6426E+000

+ = Nuclide Identified during the nuclide identification

* = Energy Line found in the spectrum

MCS GROUPS**MCS Full Range**

MCS GROUPS

CALIBRATION VALIDATION – COUNT 3

Page 1 of 7
Created 4/25/2011 12:02:49 PM
Idaho Falls Id.

Battelle Energy Alliance LLC

Analysis Report - Whole Body [Bomab]

SOURCE INFORMATION

Primary ID Bomab
Last Name Body
First Name Whole
Height (in)
Weight (lb)
Chest Wall Thickness (cm)

COUNTER INFORMATION

Counter Name Accuscan II
Counter Location Battelle
Configuration Name Total Body Scan

COUNT INFORMATION

Count Operation Individual 10 minutes
Count Reason Routine operation
Frequency
Comment DOE Bomab count 3
Intake Date
Acquisition Started 4/21/2011 10:45:43 AM
Acquisition Time 602.1
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	73.81	1 - 4096	600.0	Yes	4/21/2011 10:44:34 AM	e9ec0a301044.cnf
Left	72.46	1 - 4096	600.0	Yes	4/21/2011 10:44:34 AM	c07920571044.cnf
Summed	146.07	1 - 4096	600.0	Yes	4/21/2011 10:44:34 AM	820b9fc91044.cnf
MCS Full Range		-	0.0	No		8866405b1044.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 Left
Detector Group Configuration Total Body Scan
Analysis Date 4/21/2011 10:44:34 AM
Energy Calibration WB-Left Energy Calibration 4/21/2011 8:58 AM
Efficiency Calibration
Multi Curve
Source Distribution Whole Body
Analysis Sequence File NO_ANALY.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library
Tentative NID Library
Peak Search Library
Analysis Limits (channels) 1 - 4096
Energy Tolerance (keV) 1.00
Comment

DETECTOR GROUP INFORMATION

Detector Group Name Right
Detector Group Configuration Total Body Scan
Analysis Date 4/21/2011 10:44:34 AM
Energy Calibration WB-Right Energy Calibration 4/21/2011 9:03 AM
Efficiency Calibration
Multi Curve
Source Distribution Whole Body
Analysis Sequence File NO_ANALY.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library
Tentative NID Library
Peak Search Library
Analysis Limits (channels) 1 - 4096
Energy Tolerance (keV) 1.00
Comment

DETECTOR GROUP INFORMATION

Detector Group Name Summed
Detector Group Configuration Total Body Scan
Analysis Date 4/21/2011 10:44:34 AM
Energy Calibration WB-Summed Energy Calibration 4/21/2011 9:06 AM
Efficiency Calibration WB-Summed Efficiency Calibration 4/21/2011 9:11 AM (Dual)
Multi Curve No
Source Distribution Whole Body
Analysis Sequence File ROUNPPGE.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library INPLANTLIB.NLB
Tentative NID Library INPLANTLIB.NLB
Peak Search Library INPLANTLIB.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 (%)
M	1	1219.57	563.26	1.89E+002	1.68E+002	CS-134	5.698646E+002	9.06 %	8.38
m	2	1232.76	569.36	3.13E+002	1.63E+002	CS-134	5.164887E+002	6.68 %	15.43
	3	1309.35	604.74	1.90E+003	2.09E+002	CS-134	5.147963E+002	3.63 %	97.60
	4	1432.46	661.61	1.13E+003	1.13E+002	CS-137	3.724339E+002	4.25 %	85.12
M	5	1723.05	795.85	1.43E+003	4.93E+001	CS-134	5.241390E+002	3.61 %	85.40
m	6	1736.09	801.87	1.41E+002	4.59E+001	CS-134	5.097424E+002	9.42 %	8.73
	7	1807.49	834.85	1.37E+002	3.00E+001	MN-54	4.436663E+001	12.45 %	99.97
	8	2539.84	1173.10		2.61E+001	CO-60	5.647704E+001	11.80 %	100.00

	9	2884.56	1332.29	1.60E+002	9.94E+000	CO-60	7.402396E+001	9.93 %	100.00
	10	2955.85	1365.20	3.03E+001	5.75E+000	CS-134	4.713822E+002	24.72 %	3.04

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 (%)	
11	3162.22	1460.50	8.14E+001	7.56E+000	K-40	3.880872E+002	14.81 %	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	0.996	3.880872E+002	14.81 %	Not Performed	Not Performed	6.743E+001
MN-54	1.000	4.436663E+001	12.45 %			9.007E+000
CO-60	0.999	6.439221E+001	7.67 %			7.107E+000
CS-134	1.000	5.205908E+002	2.24 %			8.510E+000
CS-137	1.000	3.724339E+002	4.25 %			1.777E+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	6.7430E+001	6.7430E+001	3.8809E+002
	CR-51	320.08	9.83	7.5220E+001	7.5220E+001	-3.1022E+001
+	MN-54	834.83 *	99.97	9.0075E+000	9.0075E+000	4.4367E+001
	CO-57	122.06	85.51	1.0004E+001	1.0004E+001	1.3906E+000
		136.48	10.60	8.0095E+001		2.0345E+001
	CO-58	810.76	99.40	4.0800E+000	4.0800E+000	-1.5346E+000
	FE-59	142.65	1.03	8.2177E+002	9.0614E+000	-3.2102E+002
		192.34	3.11	2.7188E+002		-2.5497E+001
		1099.22	56.50	9.4197E+000		1.7741E+000
		1291.56	43.20	9.0614E+000		3.6378E+000
+	CO-60	1173.22 *	100.00	9.9455E+000	7.1074E+000	5.6477E+001
+		1332.49 *	100.00	7.1074E+000		7.4024E+001
	ZN-65	1115.52	50.75	1.0608E+001	1.0608E+001	6.4988E+000
	NB-95	765.79	99.81	5.4512E+000	5.4512E+000	-1.7902E+000
	ZR-95	724.18	43.70	1.2433E+001	9.4230E+000	3.1588E+000
		756.72	55.30	9.4230E+000		6.5226E+000
	RU-106	621.84	9.80	6.8377E+001	6.8377E+001	2.4665E+001

		1050.47	1.73	3.3038E+002		1.7973E+002
	AG-110M	446.80	3.64	2.4331E+002	6.8167E+000	-6.7228E+000
		620.35	2.77	2.3291E+002		-1.5315E+002
		657.75	94.40	6.8167E+000		1.1821E-001
		677.61	10.68	5.1125E+001		-4.1048E+001
		686.99	6.47	8.9987E+001		1.9761E+001
		706.67	16.68	2.8811E+001		-1.1437E+001
		744.26	4.64	1.1519E+002		-6.0887E+001
		763.93	22.28	2.5210E+001		1.5957E+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)
	AG-110M	818.02	7.30	5.5868E+001	6.8167E+000	1.0944E+001
		884.67	72.60	7.7782E+000		4.7718E+000
		937.48	34.20	1.1659E+001		-7.3201E+000
		1384.27	24.26	1.4591E+001		6.3368E+000
		1475.76	3.97	1.0458E+002		1.9436E+001
		1505.00	13.06	1.8767E+001		-5.0340E+000
		1562.27	1.18	2.1706E+002		-2.4454E+002
	I-131	80.18	2.62	4.4092E+002	1.0997E+001	-1.7759E+002
		284.30	6.05	1.3137E+002		1.2685E+002
		364.48	81.20	1.0997E+001		-1.3423E+000
		636.97	7.26	8.7762E+001		-6.5011E+001
		722.89	1.80	2.7612E+002		-1.1788E+002
	I-133	529.87	86.30	9.9097E+000	9.9097E+000	6.4784E+000
		875.33	4.47	1.0439E+002		2.7380E+001
+	CS-134	475.35	1.46	6.6517E+002	8.5104E+000	6.2703E+002
+		563.23 *	8.38	1.2883E+002		5.6986E+002
+		569.32 *	15.43	6.9500E+001		5.1649E+002
+		604.70 *	97.60	1.9861E+001		5.1480E+002
+		795.84 *	85.40	8.5104E+000		5.2414E+002
+		801.93 *	8.73	8.0679E+001		5.0974E+002
+		1038.57	1.00	6.6606E+002		4.9055E+002
+		1167.94	1.80	3.8378E+002		5.6664E+001
+		1365.15 *	3.04	1.7616E+002		4.7138E+002
+	CS-137	661.65 *	85.12	1.7771E+001	1.7771E+001	3.7243E+002
	BA-140	162.64	6.70	1.2762E+002	3.2815E+001	1.4918E+002
		304.84	4.50	1.6369E+002		-3.5959E+001
		423.70	3.20	2.8339E+002		-5.3996E+001
		437.55	2.00	4.3637E+002		2.6627E+002
		537.32	25.00	3.2815E+001		-8.3836E-001
	LA-140	328.77	20.50	3.4864E+001	0.0000E+000	-2.0169E+001
		432.53	2.94	2.8768E+002		2.2616E+002
		487.03	45.50	1.7924E+001		1.5674E-001
		751.79	4.40	1.2011E+002		2.4110E+001
		815.85	23.50	1.7326E+001		-3.2584E+000
		867.82	5.63	8.4675E+001		4.2974E+001
		919.63	2.88	1.4225E+002		-1.0131E+002
		925.24	7.09	6.8273E+001		7.0812E+001
>		1596.49	95.49	0.0000E+000		0.0000E+000
	CE-141	145.44	48.40	1.7688E+001	1.7688E+001	-4.4867E+000
	CE-144	80.11	1.60	7.2292E+002	7.8550E+001	-2.9117E+002

		133.54	10.80	7.8550E+001		-9.1315E+000
	EU-152	121.78	28.40	3.0632E+001	1.7402E+001	2.3879E+001
		244.69	7.49	1.0598E+002		-1.8588E+001
		344.27	26.50	2.8188E+001		-9.6795E-001
		411.11	2.21	4.1410E+002		-1.2840E+002
		443.98	3.11	2.7794E+002		2.8249E+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)
	EU-152	778.89	12.74	3.9263E+001	1.7402E+001	-1.0540E+001
		867.32	4.16	1.1455E+002		6.7793E+001
		964.01	14.40	3.6434E+001		1.2177E+001
		1085.78	10.00	4.6102E+001		-2.6417E+001
		1112.02	13.30	2.7698E+001		-7.4298E+000
		1407.95	20.70	1.7402E+001		1.1809E+001

+ = Nuclide Identified during the nuclide identification

* = Energy Line found in the spectrum

> = MDA Value not calculated

MCS GROUPS**MCS Full Range**

MCS GROUPS

CALIBRATION VALIDATION – COUNT 4

Page 1 of 7
Created 4/25/2011 12:04:03 PM
Idaho Falls Id.

Battelle Energy Alliance LLC

Analysis Report - Whole Body [Bomab]

SOURCE INFORMATION

Primary ID Bomab
Last Name Body
First Name Whole
Height (in)
Weight (lb)
Chest Wall Thickness (cm)

COUNTER INFORMATION

Counter Name Accuscan II
Counter Location Battelle
Configuration Name Total Body Scan

COUNT INFORMATION

Count Operation Individual 10 minutes
Count Reason Routine operation
Frequency
Comment DOE
Intake Date
Acquisition Started 4/21/2011 11:06:49 AM
Acquisition Time 602.09
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	73.16	1 - 4096	600.0	Yes	4/21/2011 11:05:40 AM	4c528a6f1105.cnf
Left	71.85	1 - 4096	600.0	Yes	4/21/2011 11:05:40 AM	b4f3324f1105.cnf
Summed	145.02	1 - 4096	600.0	Yes	4/21/2011 11:05:40 AM	2e4edb491105.cnf
MCS Full Range		-	0.0	No		f4a3e7ca1105.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 Left
Detector Group Configuration Total Body Scan
Analysis Date 4/21/2011 11:05:40 AM
Energy Calibration WB-Left Energy Calibration 4/21/2011 8:58 AM
Efficiency Calibration
Multi Curve
Source Distribution Whole Body
Analysis Sequence File NO_ANALY.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library
Tentative NID Library
Peak Search Library
Analysis Limits (channels) 1 - 4096
Energy Tolerance (keV) 1.00

Comment **DETECTOR GROUP INFORMATION**

Detector Group Name Right
Detector Group Configuration Total Body Scan
Analysis Date 4/21/2011 11:05:40 AM
Energy Calibration WB-Right Energy Calibration 4/21/2011 9:03 AM
Efficiency Calibration
Multi Curve
Source Distribution Whole Body
Analysis Sequence File NO_ANALY.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
Nuclide Identification Library

Tentative NID Library
Peak Search Library

Analysis Limits (channels) 1 - 4096
Energy Tolerance (keV) 1.00

Comment

User: David Georgeson

Database: InVivo Server: 127.0.0.1

DETECTOR GROUP INFORMATION

Detector Group Name Summed
Detector Group Configuration Total Body Scan
Analysis Date 4/21/2011 11:05:40 AM
Energy Calibration WB-Summed Energy Calibration 4/21/2011 9:06 AM
Efficiency Calibration WB-Summed Efficiency Calibration 4/21/2011 9:11 AM (Dual)
Multi Curve No
Source Distribution Whole Body
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	1029.60	475.49	4.83E+001	2.03E+002	CS-134	7.485933E+002	58.94 %	1.46	

M	2	1219.56	563.26	1.83E+002	1.25E+002	CS-134	5.524372E+002	8.82 %	8.38
m	3	1232.72	569.33	3.35E+002	1.48E+002	CS-134	5.527722E+002	6.48 %	15.43
	4	1309.35	604.74	1.93E+003	1.70E+002	CS-134	5.223497E+002	3.52 %	97.60
	5	1432.62	661.69	1.11E+003	9.80E+001	CS-137	3.644825E+002	4.20 %	85.12
M	6	1723.07	795.85	1.40E+003	5.74E+001	CS-134	5.133862E+002	3.65 %	85.40
m	7	1736.08	801.87	9.53E+001	6.43E+001	CS-134	3.443078E+002	12.36 %	8.73
	8	1807.43	834.82	1.21E+002	2.81E+001	MN-54	3.915533E+001	13.12 %	99.97
	9	2540.08	1173.21	1.87E+002	1.66E+001	CO-60	7.732575E+001	9.15 %	100.00
	10	2884.58	1332.30	1.41E+002	0.00E+000	CO-60	6.520431E+001	9.49 %	100.00

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 (%)	
11	3162.75	1460.74	8.11E+001	1.09E+001	K-40	3.863528E+002	15.57 %	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	3.863528E+002	15.57 %	Not Performed	Not Performed	7.954E+001
MN-54	1.000	3.915533E+001	13.12 %			8.330E+000
CO-60	0.999	7.046165E+001	6.61 %			0.000E+000
CS-134	0.972	5.109425E+002	2.25 %			9.182E+000
CS-137	1.000	3.644825E+002	4.20 %			1.613E+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	7.9536E+001	7.9536E+001	3.8635E+002
	CR-51	320.08	9.83	7.1699E+001	7.1699E+001	-3.0312E+001
+	MN-54	834.83 *	99.97	8.3301E+000	8.3301E+000	3.9155E+001
	CO-57	122.06	85.51	1.0381E+001	1.0381E+001	-7.5317E-001
		136.48	10.60	8.5304E+001		1.0560E+002
	CO-58	810.76	99.40	4.8275E+000	4.8275E+000	1.7812E+000
	FE-59	142.65	1.03	8.3365E+002	7.9141E+000	3.1951E+002
		192.34	3.11	2.7331E+002		-3.4235E+001
		1099.22	56.50	7.9141E+000		2.3111E-001
		1291.56	43.20	9.0614E+000		-2.3015E+000
+	CO-60	1173.22 *	100.00	8.2985E+000	0.0000E+000	7.7326E+001
+	CO-60	1332.49 *	100.00	0.0000E+000		6.5204E+001
	ZN-65	1115.52	50.75	9.6264E+000	9.6264E+000	-7.8078E-001
	NB-95	765.79	99.81	5.9886E+000	5.9886E+000	-1.1410E+000
	ZR-95	724.18	43.70	1.2231E+001	1.0574E+001	7.3414E-001
		756.72	55.30	1.0574E+001		3.5772E+000
	RU-106	621.84	9.80	6.5935E+001	6.5935E+001	-2.6682E+001

		1050.47	1.73	2.4975E+002		9.4811E+001
	AG-110M	446.80	3.64	2.3446E+002	6.2895E+000	-1.1582E+002
		620.35	2.77	2.4154E+002		5.1782E+001
		657.75	94.40	6.8859E+000		1.6305E+000
		677.61	10.68	5.1872E+001		5.9680E+000
		686.99	6.47	8.8795E+001		1.8559E+001
		706.67	16.68	3.3600E+001		2.2014E+001
		744.26	4.64	1.0695E+002		-5.9593E+001
		763.93	22.28	3.0034E+001		2.0611E+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)
	AG-110M	818.02	7.30	5.9476E+001	6.2895E+000	2.1889E+000
		884.67	72.60	6.2895E+000		5.0378E-001
		937.48	34.20	1.5052E+001		-2.0428E+000
		1384.27	24.26	9.2279E+000		-9.9012E-001
		1475.76	3.97	6.0381E+001		-6.4786E+000
		1505.00	13.06	3.5109E+001		-7.1914E+000
		1562.27	1.18	1.5348E+002		2.3290E+001
	I-131	80.18	2.62	4.4343E+002	1.1153E+001	5.0075E+000
		284.30	6.05	1.2120E+002		-1.4928E+001
		364.48	81.20	1.1153E+001		4.2862E-001
		636.97	7.26	8.9500E+001		4.1722E+001
		722.89	1.80	2.8654E+002		-5.3996E+001
	I-133	529.87	86.30	9.0938E+000	9.0938E+000	-5.6745E+000
		875.33	4.47	1.0439E+002		-4.6048E+001
+	CS-134	475.35 *	1.46	9.9574E+002	9.1819E+000	7.4859E+002
+		563.23 *	8.38	1.1134E+002		5.5244E+002
+		569.32 *	15.43	6.6188E+001		5.5277E+002
+		604.70 *	97.60	1.7464E+001		5.2235E+002
+		795.84 *	85.40	9.1819E+000		5.1339E+002
+		801.93 *	8.73	9.5506E+001		3.4431E+002
+		1038.57	1.00	5.5313E+002		1.9894E+002
+		1167.94	1.80	4.5782E+002		6.2351E+002
+		1365.15	3.04	2.7169E+002		3.6617E+002
+	CS-137	661.65 *	85.12	1.6134E+001	1.6134E+001	3.6448E+002
	BA-140	162.64	6.70	1.2208E+002	3.4066E+001	-6.3777E+001
		304.84	4.50	1.6971E+002		-5.4058E+001
		423.70	3.20	3.0307E+002		1.0566E+001
		437.55	2.00	4.1755E+002		4.8022E+001
		537.32	25.00	3.4066E+001		1.3260E+000
	LA-140	328.77	20.50	3.5414E+001	3.3742E+000	4.5087E+000
		432.53	2.94	3.1745E+002		2.4746E+002
		487.03	45.50	1.9120E+001		-1.5840E+000
		751.79	4.40	1.0886E+002		1.3777E+001
		815.85	23.50	2.1455E+001		1.0655E+001
		867.82	5.63	8.9020E+001		4.5057E+001
		919.63	2.88	1.6739E+002		1.1308E+001
		925.24	7.09	7.0144E+001		-3.8940E+001
		1596.49	95.49	3.3742E+000		-2.0692E+000
	CE-141	145.44	48.40	1.7490E+001	1.7490E+001	1.0841E+001
	CE-144	80.11	1.60	7.2703E+002	7.8612E+001	8.2102E+000

		133.54	10.80	7.8612E+001		-2.1843E+000
	EU-152	121.78	28.40	3.1374E+001	1.9063E+001	-6.8008E+000
		244.69	7.49	1.1011E+002		-4.6441E+000
		344.27	26.50	2.7565E+001		-2.8404E+001
		411.11	2.21	4.2840E+002		-2.7299E+001
		443.98	3.11	2.8808E+002		-2.8148E+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)
	EU-152	778.89	12.74	5.2554E+001	1.9063E+001	2.1551E+001
		867.32	4.16	1.2327E+002		9.1720E+001
		964.01	14.40	3.1553E+001		-3.7086E+000
		1085.78	10.00	4.2408E+001		-5.8206E+000
		1112.02	13.30	2.1897E+001		-3.2988E+001
		1407.95	20.70	1.9063E+001		9.4473E+000

+ = Nuclide Identified during the nuclide identification

* = Energy Line found in the spectrum

> = MDA Value not calculated

MCS GROUPS**MCS Full Range**

MCS GROUPS

CALIBRATION VALIDATION – COUNT 5

Page 1 of 7
Created 6/14/2011 12:08:31 PM
Idaho Falls Id.

Battelle Energy Alliance LLC

Analysis Report - Whole Body [Bomab]

SOURCE INFORMATION

Primary ID Bomab
Last Name Body
First Name Whole
Height (in)
Weight (lb)
Chest Wall Thickness (cm)

COUNTER INFORMATION

Counter Name Accuscan II
Counter Location Battelle
Configuration Name Total Body Scan

COUNT INFORMATION

Count Operation Individual 10 minutes
Count Reason Routine operation
Frequency
Comment DOE Bomab test count #5
Intake Date
Acquisition Started 4/21/2011 11:20:57 AM
Acquisition Time 602.1
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	73.24	1 - 4096	600.0	Yes	4/21/2011 11:19:49 AM	ab8ce2f31119.cnf
Left	72.06	1 - 4096	600.0	Yes	4/21/2011 11:19:49 AM	eaabdbfb1119.cnf
Summed	145.09	1 - 4096	600.0	Yes	6/14/2011 9:56:34 AM	b08e5ab30956.cnf
MCS Full Range		-	0.0	No		7bfde3bd1119.cnf

Primary Review by:

Date:

**Secondary Review
by:**

Date:

User: David Georgeson

Database: InVivo Server: 127.0.0.1

DETECTOR GROUP INFORMATION

Detector Group Name	Left
Detector Group Configuration	Total Body Scan
Analysis Date	4/21/2011 11:19:49 AM
Energy Calibration	WB-Left Energy Calibration 4/21/2011 8:58 AM
Efficiency Calibration	Multi Curve
Source Distribution	Whole Body
Analysis Sequence File	NO_ANALY.ASF
Bkg Acq used for area correction	Not Performed
Nuclide Identification	
Nuclide Identification Library	
Tentative NID Library	
Peak Search Library	
Analysis Limits (channels)	1 - 4096
Energy Tolerance (keV)	1.00
Comment

DETECTOR GROUP INFORMATION

Detector Group Name	Right
Detector Group Configuration	Total Body Scan
Analysis Date	4/21/2011 11:19:49 AM
Energy Calibration	WB-Right Energy Calibration 4/21/2011 9:03 AM
Efficiency Calibration	

Multi Curve
Source Distribution Whole Body
Analysis Sequence File NO_ANALY.ASF
Bkg Acq used for area correction Not Performed
Nuclide Identification
 Nuclide Identification Library
 Tentative NID Library
 Peak Search Library
 Analysis Limits (channels) 1 - 4096
 Energy Tolerance (keV) 1.00
Comment

User: David Georgeson

Database: InVivo Server: 127.0.0.1

DETECTOR GROUP INFORMATION

Detector Group Name Summed
Detector Group Configuration Total Body Scan
Analysis Date 6/14/2011 9:56:34 AM
Energy Calibration WB-Summed Energy Calibration 4/21/2011 9:06 AM
Efficiency Calibration WB-Summed Efficiency Calibration 4/21/2011 9:11 AM (Dual)
Multi Curve No
Source Distribution Whole Body
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 (%)
M	1	1219.53	563.24	1.61E+002	1.60E+002	CS-134	4.856400E+002	9.96 %	8.38
m	2	1232.94	569.44	3.37E+002	1.46E+002	CS-134	5.558671E+002	6.50 %	15.43
	3	1309.42	604.77	1.94E+003	1.94E+002	CS-134	5.268890E+002	3.57 %	97.60
	4	1432.55	661.65	1.12E+003	8.68E+001	CS-137	3.688250E+002	4.13 %	85.12
M	5	1723.00	795.82	1.44E+003	3.48E+001	CS-134	5.304701E+002	3.59 %	85.40

m	6	1736.10	801.87	1.50E+002	2.11E+001	CS-134	5.426861E+002	8.71 %	8.73
	7	1807.16	834.70	1.43E+002	2.13E+001	MN-54	4.620806E+001	10.93 %	99.97
	8	2539.72	1173.04	1.98E+002	1.75E+001	CO-60	8.190206E+001	8.93 %	100.00
	9	2884.70	1332.35	1.69E+002	7.45E+000	CO-60	7.794761E+001	9.54 %	100.00
	10	2954.61	1364.63	2.91E+001	8.89E+000	CS-134	4.533280E+002	28.05 %	3.04

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 (%)
11	3162.72	1460.73	8.97E+001	3.34E+000	K-40	4.273609E+002	13.06 %	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	4.273609E+002	13.06 %	Not Performed	Not Performed	4.251E+001
MN-54	0.999	4.620806E+001	10.93 %			7.089E+000
CO-60	0.999	7.995753E+001	6.52 %			6.429E+000
CS-134	1.000	5.292165E+002	2.21 %			7.146E+000
CS-137	1.000	3.688250E+002	4.13 %			1.513E+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	4.2507E+001	4.2507E+001	4.2736E+002
	CR-51	320.08	9.83	7.4789E+001	7.4789E+001	4.6372E+001
+	MN-54	834.83 *	99.97	7.0893E+000	7.0893E+000	4.6208E+001
	CO-57	122.06	85.51	1.0337E+001	1.0337E+001	1.0709E+000
		136.48	10.60	7.9905E+001		8.3268E-001
	CO-58	810.76	99.40	3.6492E+000	3.6492E+000	-2.2112E+000
	FE-59	142.65	1.03	8.5309E+002	6.8498E+000	8.2615E+002
		192.34	3.11	2.7188E+002		-7.6916E+001
		1099.22	56.50	8.5482E+000		4.5067E+000
		1291.56	43.20	6.8498E+000		5.1969E-001
+	CO-60	1173.22 *	100.00	8.6079E+000	6.4291E+000	8.1902E+001
+		1332.49 *	100.00	6.4291E+000		7.7948E+001
	ZN-65	1115.52	50.75	8.9123E+000	8.9123E+000	2.6351E+000
	NB-95	765.79	99.81	5.6360E+000	5.6360E+000	6.9367E-001
	ZR-95	724.18	43.70	1.2025E+001	9.4230E+000	6.8117E+000
		756.72	55.30	9.4230E+000		6.7264E-001
	RU-106	621.84	9.80	7.3578E+001	7.3578E+001	-1.3743E+000

		1050.47	1.73	2.4975E+002		-8.2048E+000
	AG-110M	446.80	3.64	2.4409E+002	6.4719E+000	-3.0902E+001
		620.35	2.77	2.6382E+002		1.1508E+002
		657.75	94.40	7.0222E+000		1.0159E+000
		677.61	10.68	5.6823E+001		3.7252E+001
		686.99	6.47	9.2325E+001		4.6627E+001
		706.67	16.68	2.9382E+001		-9.6181E+000
		744.26	4.64	1.0259E+002		3.5704E+001
		763.93	22.28	2.3959E+001		4.6621E+000

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NUCLIDE MDA RESULTS FOR Accuscan II <Summed>

	Nuclide Name	Energy (keV)	Yield (%)	Line MDA (nCi)	Nuclide MDA (nCi)	Activity (nCi)
	AG-110M	818.02	7.30	6.2878E+001	6.4719E+000	2.2465E+001
		884.67	72.60	6.4719E+000		-1.9932E+000
		937.48	34.20	1.2135E+001		-6.2071E+000
		1384.27	24.26	1.8456E+001		1.6089E+000
		1475.76	3.97	6.0381E+001		2.5914E+001
		1505.00	13.06	3.2505E+001		6.0408E+000
		1562.27	1.18	1.5348E+002		-1.6303E+002
	I-131	80.18	2.62	4.2846E+002	1.1307E+001	-2.0056E+002
		284.30	6.05	1.2324E+002		-2.5519E+001
		364.48	81.20	1.1307E+001		3.1496E+000
		636.97	7.26	8.1387E+001		-6.6178E+001
		722.89	1.80	2.6528E+002		-6.5734E+001
	I-133	529.87	86.30	9.2813E+000	9.2813E+000	6.8446E-001
		875.33	4.47	1.0725E+002		5.7772E+001
+	CS-134	475.35	1.46	6.6321E+002	7.1456E+000	2.5848E+002
+		563.23 *	8.38	1.2573E+002		4.8564E+002
+		569.32 *	15.43	6.5786E+001		5.5587E+002
+		604.70 *	97.60	1.9161E+001		5.2689E+002
+		795.84 *	85.40	7.1456E+000		5.3047E+002
+		801.93 *	8.73	5.4745E+001		5.4269E+002
+		1038.57	1.00	6.3066E+002		6.6337E+002
+		1167.94	1.80	4.4527E+002		3.4947E+002
+		1365.15 *	3.04	2.1650E+002		4.5333E+002
+	CS-137	661.65 *	85.12	1.5130E+001	1.5130E+001	3.6882E+002
	BA-140	162.64	6.70	1.1856E+002	3.2974E+001	-7.7040E+001
		304.84	4.50	1.8115E+002		1.7801E+002
		423.70	3.20	2.9379E+002		1.7728E+002
		437.55	2.00	4.8342E+002		3.1450E+001
		537.32	25.00	3.2974E+001		-1.6040E+001
	LA-140	328.77	20.50	3.4864E+001	3.3742E+000	-3.2114E+001
		432.53	2.94	3.0293E+002		2.1602E+002
		487.03	45.50	1.8606E+001		7.6949E+000
		751.79	4.40	1.0151E+002		-1.5155E+001
		815.85	23.50	1.4837E+001		-7.0968E+000
		867.82	5.63	8.4675E+001		-4.8093E+000
		919.63	2.88	2.0117E+002		3.1545E+001
		925.24	7.09	6.6349E+001		3.6627E+001
		1596.49	95.49	3.3742E+000		-1.3795E+000
	CE-141	145.44	48.40	1.7490E+001	1.7490E+001	2.9943E+000
	CE-144	80.11	1.60	7.0249E+002	7.9165E+001	-3.2883E+002

		133.54	10.80	7.9165E+001		-4.5712E+000
	EU-152	121.78	28.40	3.0700E+001	1.9063E+001	-2.1174E+001
		244.69	7.49	1.0528E+002		4.3941E+001
		344.27	26.50	2.8451E+001		2.0662E+001
		411.11	2.21	4.1745E+002		5.7231E+001
		443.98	3.11	2.9258E+002		-7.1533E+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)
	EU-152	778.89	12.74	4.0072E+001	1.9063E+001	1.2161E+000
		867.32	4.16	1.2327E+002		2.9546E+001
		964.01	14.40	3.0483E+001		2.5960E+001
		1085.78	10.00	5.2720E+001		1.1413E+000
		1112.02	13.30	3.2479E+001		9.4561E-001
		1407.95	20.70	1.9063E+001		4.7236E+000

+ = Nuclide Identified during the nuclide identification

* = Energy Line found in the spectrum

MCS GROUPS**MCS Full Range**

MCS GROUPS

Appendix I

ANSI/HPS N13.35-1999

Specifications for the Bottle Manikin Absorption Phantom

Appendix I

ANSI/HPS N13.35-1999

ANSI/HPS N13.35-1999

American National Standard –
Specifications for the Bottle Manikin
Absorption Phantom

Approved September 21, 1999
American National Standards Institute, Inc.

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ANSIHP3 N13.35-1999

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The Health Physics Society Standards Working Group responsible for this standard had the following members:

Timothy Lynch, Working Group Chair

Peter Olsen

Debbie Kruchten

Casper Sun

This standard was developed under the direction of the Health Physics Society Standards Committee and approved on 23 June 1997. At that time, the Standards Committee had the following membership:

Chairperson:	Harley Pittingsrud
Members:	John Buchanan Nancy Daugherty Jack Fix William Inkret Harold Peterson Kathryn Pryor Ronald Stafford Toshihide Ushino
Internal Dosimetry Section Manager:	Gary Kramer

This standard was consensus balloted and approved by the ANSI-Accredited HPS N13 Committee on 12 January 1999. At the time of balloting, the HPS N13 Committee had the following membership:

Chairperson	Jerre Forbes
Vice Chairperson	Joseph Ring
American Chemical Society	Al Zirkes
American College of Occupational and Environmental Medicine	Bryce Breitenstein
American Industrial Hygiene Association	Bruce Zaczynski
American Iron and Steel Institute	Anthony LaMlastra
	Peter Hernandez (alt.)
American Mining Congress	Scott Munson
American Nuclear Insurers	Jerre Forbes
American Nuclear Society	Joyce Davis
	Nolan Hertel (alt.)
Conference of Radiation Control Program Directors	Roland Fletcher
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Individual	Al Tschaeche
Individual	McDonald Wrenn

1 Scope and Purpose

1.1 Introduction

The calibration of in vivo counting equipment is commonly performed using anthropometric phantoms containing a known distribution and known activity of radioactive material. Physical characteristics of the phantoms, such as height, mass, density, volume, shape, and effective atomic number are designed to adequately represent a reference structure. The bottle manikin absorption phantom (BOMAB) is comprised of 10 plastic containers and is used to calibrate in vivo counting systems that are designed to measure the radionuclides that emit high energy photons ($200 \text{ keV} < E < 3 \text{ MeV}$).

because many different types of phantoms are used to calibrate in vivo counting systems, the importance of establishing standard specifications for phantoms was emphasized at the 1990 meeting of in vivo counting professionals held at the National Institute of Standards and Technology (NIST) (Kramer et al. 1991). The consensus of the NIST meeting attendees was that standard specifications were needed for the bottle manikin absorption (BOMAB) phantom. The standard specifications for the BOMAB phantom provide the basis for a consistent phantom design for calibrating in vivo measurement systems. Such systems are designed to measure radionuclides that emit high-energy photons and that are assumed to be homogeneously distributed in the body.

1.2 Scope

This standard provides the specifications for the design, fabrication, and quality (accuracy and precision) of the BOMAB phantom. It addresses material composition, physical specifications, quality assurance and quality control, and incorporation of the radioactive material in the phantom. The standard does not specify particular fabrication techniques or component testing techniques, but instead addresses specifications for the

finished phantom. Annex A contains information about typical materials used in the construction of BOMAB phantoms. Annex B contains information on the applications for BOMAB phantoms. Annex C contains a brief summary of historical BOMAB phantom designs and a photograph of a BOMAB phantom.

1.3 Purpose

The purpose of this standard is to establish the specifications for the design and fabrication of BOMAB phantoms used to calibrate monitoring systems for in vivo measurement of high energy photons emitted from the radionuclides that are homogeneously distributed in the body. The specifications provide the basis for a consistent design of the BOMAB phantom.

2 References

2.1 Normative references

ANSI N13.30 — 1996 Performance Criteria for Radiobioassay.

ANSI N42.22 — 1995 Traceability of Radioactive Sources to the National Institute of Standards and Technology and Associated Instrument Quality Control.

Berger, M.J., Hubbell, J.H., XCOM: Photon Cross Sections on a Personal Computer, NBSIR 87-3597, U.S. Department of Commerce, National Bureau of Standards, Gaithersburg, Maryland; 1987.

Bush, F., "The integral dose received from a uniformly distributed radioactive isotope," British Journal of Radiology, 22, 96, 1949.

Bush, F., "Energy Absorption in Radium Therapy," British Journal of Radiology, 19, 14, 1946.

DeLafield, H.J., "The neutron capture probability for sodium activation in man phantoms," AERE-RT128, UKAEA, Harwell; 1974.

International Commission on Radiological Protection, ICRP 66, The Human Respiratory Tract Model, Pergamon Press, New York, NY; 1994.

International Commission on Radiation Units and Measurements, ICRU 44, Tissue Substitutes in Radiation Dosimetry and Measurement; 1989.

International Commission on Radiation Units and Measurements, ICRU 46, Photon, Electron, Proton and Neutron Interaction Data for Body Tissues; 1992.

International Commission on Radiation Units and Measurements, ICRU 48, Phantoms and Computational Models in Therapy, Diagnosis and Protection; 1992.
Sanders, F.W., Auxier, J.A., "Neutron activation of sodium in anthropomorphic phantoms," Health Physics, August 1962; 8(4):371-379.

2.2 Informative reference

Kramer, G.H., Burns, L., Noel, L., The BRMD BOMAB Phantom Family, Health Physics 61 (5), pp. 895-902; 1991.

3 Definitions

average soft tissue: Soft tissues are defined in ICRU 46 (p. 8) as the body tissues in a human subject other than osseous tissue, teeth, hair, and nails. The composition of average soft tissue for adults is defined in Table B1 of ICRU Report 46 (pp. 30-32).

becquerel (Bq): The SI unit of activity given as one disintegration per second, 1 Bq = 1 s⁻¹.

bioassay: Techniques used to determine the amount or concentration of radioactive material in the body relative to a standard using in vivo and in vitro measurement methods. Synonymous with radiobioassay.

BOMAB: Abbreviation for bottle manikin absorption.

bottle manikin absorption phantom: A representation of the human body consisting

of containers formed into various sizes of ellipsoids and cylinders to simulate the head, neck, arms, torso, pelvis, thighs, and legs. The radioactive material is homogeneously distributed in the filler material.

effective atomic number (Z_{eff}): The effective atomic number is calculated using the following equation from ICRU 44, Appendix C:

$$Z_{\text{eff}} = \left\{ \sum_i w_i Z_i \right\}^{1/x}$$

where w_i is the mass fraction of the i^{th} element with atomic number, Z_i . The value of x varies with the photon interaction process considered. For photon energies between 200 keV and 3 MeV, the Compton effect predominates. For Compton processes, the value of x is unity. An element of this atomic number would interact with photons in the same way as the compound or mixture.

electron density: Number of electrons (e⁻) per unit volume typically expressed in m⁻³.

high-energy photon: For purposes of this standard, a high-energy photon has an energy that is greater than 200 keV and less than 3 MeV.

In vivo: From the Latin meaning "within a living organism." Thus, in vivo counting of radioactive material is the measurement of radioactive material in living organisms.

mass attenuation coefficient (μ/ρ): The quotient, in units of cm²g⁻¹, of dN/N divided by ρ dl, where dN/N is the fraction of uncharged ionizing particles that experience interactions in traversing a distance dl in a material of density ρ.

MDA: Abbreviation for minimum detectable activity.

minimum detectable activity: The smallest amount of activity of an analyte in a sample that will be detected with a certain probability of non-detection (Type II error) – yet accepting a probability of erroneously deciding that a positive (nonzero) quantity of analyte is present in an appropriate blank sample (Type I error).

NIST: Abbreviation for National Institute of Standards and Technology.

phantom: A complete or partial anthropometric representation of the human body used for the calibration of *in vivo* measurement systems. A phantom is constructed to allow placement of radionuclides in a geometry approximating internal depositions.

QA: Abbreviation for quality assurance.

Reference Man: A compilation of characteristics, contained in ICRP Publication 23, that describe a typical occupational worker and that are pertinent to the metabolism, distribution, retention, and excretion of radionuclides in the body.

specific gravity: The ratio of the mass of a body to the mass of an equal volume of water at 4° Celsius or other specified temperature.

SRM: Abbreviation for standard reference material.

tissue substitute: Any material that simulates a body tissue in its interaction with ionizing radiation.

4 Material composition

Each section of a BOMAB phantom shall be composed of a shell and a tissue-substitute material used to fill the container volume. The composition of the phantom materials shall simulate the soft tissues of the body with respect to their radiation interaction properties for high-energy photons. However, precise simulation of the structure and composition of the tissues and organs of the body is not required at energies between 200 keV and 3 MeV. Annex A contains additional information describing materials used for the fabrication of BOMAB phantoms.

4.1 BOMAB phantom shell

The shell of the BOMAB phantom containers shall be constructed from a material with known radiation interaction properties for

high energy photons and suitable physical characteristics for the particular application (for example, physical integrity to prevent leakage from a phantom containing liquid). The material should have a density of $950 \text{ kgm}^{-3} \pm 5\%$. High-density polyethylene with a density between 0.940 kgm^{-3} and 0.965 kgm^{-3} meets the requirements of this standard. The tolerance for the mass attenuation coefficient of the shell material should be within 10% of the soft tissue values shown in Table 1 over the range from 200 keV to 3 MeV.

4.2 BOMAB phantom filler material

The filler material comprises most of the mass of the BOMAB phantom. The filler material shall simulate the radiation interaction properties of the average soft tissues of the human body over the energy range from 200 keV to 3 MeV. The density of the filler material shall be $1005 \text{ kgm}^{-3} \pm 5\%$.

The mass attenuation coefficients for tissue substitutes over the photon energy range of 200 keV to 3 MeV shall be within 5% of the values for the mass attenuation coefficients shown in Table 1 for average soft tissue. Table 1 lists the values for the mass attenuation coefficients for average soft tissue, polyethylene, polyurethane mixtures, and water over the energy range from 200 keV to 3 MeV. The data were generated using the XCOM code (Berger 1987). The mass attenuation coefficients for average soft tissue given in Table 1 are for an adult male as defined in ICRU 46 and are based on a specific gravity of 1.04, an electron density of $3.42 \times 10^{29} \text{ m}^{-3}$, and an effective atomic number of 6.8.

The proper quantity of the trace amounts of specific compounds shall be added to the filler material to achieve the correct high-energy photon interaction properties.

4.3 Potassium-40 content

The amounts of potassium-40 shown in Table 2 shall be used for such applications as estimating MDA or person background count rate that require a phantom to contain

a representative amount of potassium. The tolerance for the potassium-40 activity shall be $\pm 10\%$. The potassium shall be homogeneously distributed in the filler material. The amount of potassium added to the phantom shall be factored into the determination of the radiation interaction coefficients for the phantom.

Annex A contains further discussion about the different types of materials currently used to construct BOMAB phantoms.

Table 2 – Potassium content for different size BOMAB phantoms

Phantom type	Potassium (g)
4 yr. Old	30 ± 3
10 yr. Old	60 ± 6
Ref. Female	100 ± 10
Ref. Male	140 ± 14
95% Male	190 ± 19

Table 1 – Mass attenuation coefficients for average soft tissue and several tissue substitutes

Photon Energy	Tissue ^a	Polyethylene	Polyurethane ^b CaCO ₃	Polyurethane ^b Bi ₂ O ₃	Water
MeV	m ² kg ⁻¹	m ² kg ⁻¹	m ² kg ⁻¹	m ² kg ⁻¹	m ² kg ⁻¹
0.2	1.36E-02	1.40E-02	1.34E-02	1.41E-02	1.37E-02
0.5	9.62E-03	9.98E-03	9.50E-03	9.46E-03	9.69E-03
1.0	7.02E-03	7.26E-03	6.93E-03	6.87E-03	7.07E-03
1.5	5.72E-03	5.91E-03	5.64E-03	5.58E-03	5.76E-03
2.0	4.91E-03	5.06E-03	4.84E-03	4.84E-03	4.94E-03
2.5	4.34E-03	4.48E-03	4.30E-03	4.20E-03	4.40E-03
3.0	3.94E-03	4.04E-03	3.88E-03	3.84E-03	3.97E-03

a Average soft tissue defined in ICRU 46.

b Tissue substitute polyurethane incorporating listed compounds; the weight percent for the CaCO₃ and Bi₂O₃ compounds listed in Table 1 are 4.3% and 7.5% respectively.

5 Physical specifications for the BOMAB phantom

Table 3 contains the reference height and mass values that were used as the basis to determine the physical characteristics of the different size BOMAB phantoms.

The BOMAB phantom shall meet the specifications in Tables 4 through 8 for the reference 4-year-old, a reference 10-year-old, a reference adult female (equivalent to a fifth percentile male), a reference male, and a reference

ninety-fifth percentile male. The a and b values in Tables 4 through 8 are outside dimensions and refer to Fig. C2 in Annex C. The shapes of the different containers should be right circular cylinders for the arms, thighs, legs, and neck. The containers for the head, thorax, and abdomen should be ellipsoid. The thickness of the shell walls should be 0.5-cm $\pm$ 5%. The tolerance for the total volume of the phantom and for the volume of each phantom section shall be $\pm$ 10%. The tolerance for the phantom heights shall be $\pm$ 5%; the tolerance for the phantom mass shall be $\pm$ 10%.

Table 3 – Reference heights and weights for different ages^a

Height	1 Year	5 Years	10 Years ^b	Reference Female ^c	Reference Male ^c	95% Male
cm	76 $\pm$ 0.7	109 $\pm$ 0.9	136 $\pm$ 2.3	163 $\pm$ 4.0	175 $\pm$ 4.3	185 $\pm$ 4.6
Weight						
kg	10 $\pm$ 0.3	18 $\pm$ 0.6	31 $\pm$ 1.9	59 $\pm$ 1.1	70 $\pm$ 3.6	77 $\pm$ 3.9

a Data ($\pm$ 1 std. Dev.) based on Table A.2.5. from ICRU 48 and Table 7 from ICRP 66.

b Also applicable to 5th percentile female.

c Also applicable to 5th percentile male.

d Also applicable to 95th percentile female.

Table 4 - Dimensions for the reference 4-year-old BOMAB phantom

Section	Dimension a (cm)	Dimension b (cm)	Height (cm)	Fill Vol. (cc)
Head	9.4	12.2	12.2	840
Neck	8.4	8.4	6.8	250
Thorax	13.2	19.1	25.6	4300
Abdomen	12.5	23.1	12.5	2300
Thighs	9.8	9.8	24.5	1490
Legs	8.0	8.0	24.6	920
Arms	6.1	6.1	35.8	730

Table 5 – Dimensions for the reference 10-year-old BOMAB phantom

Section	Dimension a (cm)	Dimension b (cm)	Height (cm)	Fill Vol. (cc)
Head	11.4	14.8	16.3	1740
Neck	10.5	10.5	8.90	560
Thorax	16	23.3	34	8730
Abdomen	15.2	28.2	16.5	4760
Thighs	12	12	33.5	3100
Legs	9.4	9.4	32.8	1780
Arms	7.6	7.6	46.0	1620

Table 6 – Dimensions for the reference female BOMAB phantom

Section	Dimension a (cm)	Dimension b (cm)	Height (cm)	Fill Vol. (cc)
Head	13	17.5	18	1670
Neck	12	12	9	780
Thorax	18	28	39	13850
Abdomen	16	30	19	6230
Thighs	13.5	13.5	38	4570
Legs	10	10	38	2380
Arms	8.5	8.5	52	2280

Table 7 – Dimensions for the reference male BOMAB phantom

Section	Dimension a (cm)	Dimension b (cm)	Height (cm)	Fill Vol. (cc)
Head	14	19	20	3500
Neck	13	13	10	1050
Thorax	20	30	40	17000
Abdomen	20	36	20	9990
Thighs	15	15	40	6060
Legs	12	12	40	3740
Arms	10	10	60	3790

Table 8 – Dimensions for the reference 95th percentile male BOMAB phantom

Section	Dimension a (cm)	Dimension b (cm)	Height (cm)	Fill Vol. (cc)
Head	15	21	22	4500
Neck	14	14	11	1400
Thorax	22	32	43	21000
Abdomen	22	39	22	13000
Thighs	16	16	43	7300
Legs	13	13	43	4800
Arms	11	11	65	5200

6 Quality assurance and quality control for phantom fabrication

6.1 Scope

This section covers the pertinent quality assurance and quality control provisions to control work activities associated with the design, construction, and verification of a BOMAB phantom.

6.2 Quality assurance program

Each manufacturer should maintain a continuing quality assurance (QA) and quality control program that encompasses standard reference material preparation and certification, training of personnel, procedures, product quality control, and record management. The QA program should meet the specifications prescribed by appropriate standards. The ANSI N13.30 standard and the ANSI N42.22 standard are applicable to the provisions of this section.

6.3 Product quality control

6.3.1 Phantom shells

Phantom shells shall be constructed of the material specified in section 4 of this standard and have the volumes and dimension specified in section 5 of this standard.

After construction, the phantom shell dimensions and composition shall be verified to meet the specifications in sections 4 and 5. As a minimum, the following shall be verified:

- outer dimensions of each section;
- volume of each section by volume or weight measurements;
- integrity of each section by leak testing, if applicable;
- uniformity of the shell wall thickness.

6.3.2 Filled phantom

The material used to fill the phantom shall meet the criteria specified in section 4 of this

standard. The uncertainty in the density of the filler material should be 5% or less as measured by a quantitative process (such as weighing the phantom). Visual inspection shall not be used in place of quantitative testing, but shall be used only to check for gross defects.

Aqueous solutions shall maintain all chemical species in solution and inhibit plate-out of material on the walls of the phantom shell. The solution chemistry shall prevent precipitation of the radioactive material and other additives. The shells shall be leak tested and found to have no measurable leakage.

If a phantom is stored for a prolonged period of time, measures shall be taken to minimize biological growths in the phantom to preclude changes in chemical species and the activity distribution.

6.3.3 Control of radioactive material standard preparation

Procedures for the preparation of radioactive material standards shall be documented. Calibration certificates for Standard Reference Material (SRM), the calculations used to determine the dilution of the standards, and the final results shall be kept as project records. The calculations used to determine the dilutions shall be reviewed and approved by a qualified person other than the person preparing the standard. The review should be performed prior to the preparation of the final standard solutions that are incorporated into the phantom.

6.3.4 Radioactive material content

The radioactive material standard that is incorporated in the phantom shall be traceable to NIST. The quantity of radioactive material incorporated and the associated uncertainties shall be known and documented for each section of the phantom and for the total phantom. The total uncertainty should include the uncertainties in the SRM, dilution procedures, gravimetric analysis, counting errors, and other errors, as appropriate.

The radioactive material contained in each section shall be homogeneously distributed

throughout the section. The tolerance for the variability of the activity distribution should be less than 10%. At least one time, the variability of the activity distribution in the material used to fill the phantom should be determined by quantitative methods to evaluate the adequacy of the mixing method.

6.3.5 Records

The phantom documentation shall include the following:

- material composition and density of the shell and filler matrix materials;
- shell wall thickness, uniformity, and tolerances;
- height, mass, and dimensions, including tolerances of each section and the total phantom;
- total volume with tolerances of the individual containers and the total phantom;
- high energy photon interaction properties of the phantom shell and fill materials (needs to be done only once, if the density is measured and remains constant);
- total quantity and type of radioactive material in each container, including uncertainty;
- variability in the distribution of radioactive material;
- NIST calibration certificate, or equivalent, for the GRM materials used in the phantom; and
- results of leakage tests.

Annex A Informative

Materials for phantom construction

A.1 Shell material

The shells for BOMAB phantoms typically are made from high-density polyethylene. The specific gravity of high-density polyethylene ranges from 0.941 to 0.965.

A.2 Filler materials for the BOMAB phantom

A.2.1 Aqueous

The BOMAB phantom commonly is filled with radioactive material dissolved in an acidified deionized water solution. The correct volume of an aqueous radioactive solution can be prepared with a minimum residual volume. The reference amount of potassium for each phantom size (for example, 140 g for Reference Man) can be added by dissolving the proper amount of the particular potassium compound. It is possible to refill the phantom shell with aqueous solutions after emptying and rinsing it to remove residual activity that may persist. An acidic solution can be used to help remove residual activity. However, measurements should be made after emptying the solution and rinsing the containers to determine whether residual activity is still present in the phantom shell.

Altering the distribution of radioactive material or the distribution of nonradioactive components in the phantom must be avoided. The uniformity of the activity distribution in aqueous solutions should be checked after periods of storage. Precautions must be taken to prevent biological growth when an aqueous solution is used in a BOMAB phantom for an extended period of time.

A leak test of the phantom should be performed prior to filling the phantom with a solution containing radioactive material. As with most liquid containers, the possibility exists for leakage from a phantom containing liquids.

A.2.2 Gel

Formulations using gelatin have been used as the filler material for a BOMAB phantom. The components must be properly mixed to ensure a homogeneous distribution of both radioactive and nonradioactive components in the matrix. Exposure of gel-filled phantoms to temperature extremes should be avoided, as experience has shown this can cause degradation of the gelatin matrix. Agents such as benzalkonium chloride have been added to prevent biological growth. Sodium metabisulfate has been added to retard the oxidation of the gelatin.

An organic polymer material – Safe-T-Set[®] – has been used as a tissue-substitute material. It is non-biological in origin and therefore does not promote growth of biological organisms. A 12:1 ratio of water to powder is used to form the solid matrix. Limited experience with the material has shown the solid can separate into liquid and solid phases; apparently due to exposure of the phantoms to high temperatures. The effects of the phase separation on the distribution of the activity in the phantom have not been characterized. The tissue-substitute properties of Safe-T-Set, in terms of attenuation coefficients, are not well characterized; however, with a density of 0.88 gm/ml, it will have adequate tissue-substitute properties at a concentration of 8 to 9% by weight for high energy applications (from 200 keV to 3 MeV).

A.2.3 Plastic

Tissue-substitute polyurethane compounds are used as filler materials for BOMAB and other calibration phantoms. Polyurethanes, when mixed properly with filler chemicals, can simulate the radiation attenuation and interaction properties of various tissues within 3 to 5% over a range of energies from 200 keV to above 3 MeV. Experience has shown that by tailoring a polyurethane tissue substitute to the range of energies of interest, even closer tolerances can be obtained. Potassium compounds, such as potassium chloride or potassium bitartrate, can be used to add the proper amount of potassium-40 activity to the phantom. The relative amounts of filler materials may have to be adjusted, when potassium is added, to ensure proper tissue-substitute properties with respect to radiation interactions. ICRU 44 contains more detailed information related to tissue-substitute material for phantoms.

BOMAB phantoms filled with cured polyurethane-based material are insensitive to most of the environmental and chemical factors encountered during normal use. They also have a low coefficient of expansion. The physical resiliency of solid polyurethane-based phantoms makes them especially durable when exposed to extreme environmental conditions and rough handling. In addition, leakage of the filler material is not an issue.

Annex B Informative

Applications for the BOMAB phantom

B.1 In vivo applications

BOMAB phantoms have been used for a variety of in vivo counting applications in:

- determining a counting system background;
- determining the minimum detectable activity (MDA);
- determining counting efficiency as a function of energy for calibration;
- determining the activity distribution dependence of a counting system;
- determining sodium-24 content of the body from neutron activation.

A phantom that does not contain radioactive material is used to characterize the count rate contributions from the background sources (terrestrial or cosmic) of radiation for a particular counting system. The phantom is used to simulate the radiation absorption and scattering properties of the human body.

This type of phantom should not be used to determine the MDA of the system. A phantom containing only the appropriate amount of potassium for the particular size phantom should be used (such as 140 g of potassium for Reference Man) to determine the MDA for a counting system.

Phantoms filled with radioactive materials that emit photons with energies in the energy range of 200 keV to 3 MeV can be used to establish the counting efficiency of the system in the desired counting geometry. The activity content of these phantoms must be known accurately and traceable to NIST. If they have water-based filler, phantoms prepared for this function should contain an acid solution to prevent hydrolysis. Such phantoms also need a sufficiently stable element carrier to prevent a migration of the radioactive material to the interior walls of the phantom shell and subsequent plate-out.

Although the activity is homogeneously distributed in each section, the effects of different activity distributions on a detection system response can be evaluated using a combination of an active phantom and a blank phantom. By intermixing the sections, a heterogeneous distribution can be simulated. Different-sized phantoms can be used to establish the response of the counting system to a range of body sizes.

BOMAB phantoms have been used for decades to calibrate measurement systems to quantify sodium-24 activity that could result from neutron exposures sustained in a critically. The phantom is typically filled with a solution of sodium salt and exposed to an appropriate neutron source. Aliquots of the solution are obtained and analyzed to determine the sodium-24 activity.

B.2 Other applications

BOMAB phantoms are also used in applications other than in vivo measurements, such as medical research at Brookhaven National Laboratory in neutron activation measurements related to neutron therapy. This type of BOMAB phantom incorporates a simulated skeleton made from epoxy resin with calcium carbonate and calcium phosphate, so the calcium mass is 900 g and the phosphorous mass is 535 g. A solution of calcium chloride has been successfully used in these phantoms to simulate the scattering characteristics of human subjects for neutron therapy.

Annex C Informative

BOMAB phantom photograph and cross sectional diagram

Fig. C1 is a photograph of a Reference Man-size BOMAB phantom. Right circular cylinders are used for the neck, arms, and legs; ellipsoid-shaped containers are used for the head, thorax, and abdomen.

Fig. C2 illustrates the dimensions of the BOMAB containers that are referenced in section 5, Tables 4 to 8.

Tables C1 through C4 contain historical information on the BOMAB dimensions. These data were used to help derive the tolerances for the BOMAB dimensions and volumes used in this standard. Table C1 contains information on the dimensions of the BOMAB phantom used by Delafeld in a 1974 report that describes neutron capture probability related to sodium activation in the body. The wall thickness for this phantom design was 0.48 cm.

Table C.2 contains volume data for the BOMAB phantom described in a 1962 article by Sanders et al. showing the relationship between neutron dose and sodium-24 production in anthropomorphic phantoms. The upper and lower torso sections for this style of phantom correspond to the abdomen and thorax sections, respectively, that are described in the other BOMAB phantom references.

The data in Table C3 is for a BOMAB phantom from a 1949 article by Bush that describes a methodology for calculating auto-integral doses from homogeneously distributed radioactive material in the body. A density of 1 gm ml⁻¹ was assumed to determine the 68,300-cc volume.

The data in Table C4 is for a BOMAB phantom described in a 1946 article by Bush that pertains to estimating energy absorption in the body from radium therapy.

The data in Table C5 is taken from ICRU 48. The lengths of the phantom arm sections are not specified. The height of the reference adult male phantom is given as 180 cm. This measurement is 10 cm taller than the previously defined phantoms and is due to the head section height (30 cm) being 10 cm greater than the height of the head sections for other BOMAB designs. The height of the reference adult female is given as 160 cm, the reference 4-year-old as 105 cm, and the reference 10-year-old as 140 cm.

Fig. C1 – BOMAB phantom

Fig. C2 – BOMAB phantom container cross-section

Table C1 – BOMAB dimensions from Delafield — 1974

Section	Dimension a (cm)	Dimension b (cm)	Height (cm)	Fill Vol. (cc)
Head	14	19	20	3500
Neck	13	13	10	1050
Thorax	20	30	40	17000
Abdomen	20	36	20	9990
Thighs	15	15	40	6060
Legs	12	12	40	3740
Arms	10	10	60	3790

Table C2 – BOMAB fill volumes from Sanders et al. 1962

Section	Volume (ml)
Head	3450
Neck	972
Upper Torso	9715
Lower torso	17015
Left upper leg	5940
Left lower leg	3670
Right upper leg	5940
Right lower leg	3670
Left arm	3720
Right arm	3720

Table C3 – BOMAB section diameters and ellipse dimensions from Bush – 1949

Part of Body	Cross Section	Vertical length
head	Ellipse 19 x 14 cm.	20 cm.
Neck	Circle 13 cm.	10 cm.
Body, Upper	Ellipse 30 x 20 cm.	40 cm.
Body, Lower	Ellipse 36 x 20 cm.	20 cm.
Thigh	Circle 15 cm.	40 cm.
Leg	Circle 12 cm.	40 cm.
Arm	Circle 10 cm.	40 cm.
Total height of phantom = 170 cm.		
Total weight of phantom = 68,300 gm.		

Table C4 – Model patient phantom dimensions from Bush – 1946

Phantom Section	Cross Section	Vertical Length
Head	Ellipse 19 x 14 cm.	20 cm.
Neck	Circle 13 cm. Diameter	10 cm.
Body, Upper	Ellipse 30 x 20 cm.	40 cm.
Body, Lower	Ellipse 36 x 20 cm.	20 cm.
Thigh	Circle 15 cm. diameter	40 cm.
Leg	Circle 12 cm. diameter	40 cm.
Arm and forearm	Circle 10 cm. diameter	60 cm.

Table C5 – ICRU Report 48 BOMAB phantom – 1992

Phantom Section	Vertical Length (cm)
Head	30
Neck	10
Torso	40
Abdomen	20
Thighs	40
Legs	40