Similarity Analysis: Comparison of a Standard 60mL With a 50mL Container for MicroCT

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Work performed on the
Science & Technology Directorate of the
Department of Homeland Security
Statement of Work
HSHQPM-10-X-00005 P00007

July 22, 2014
LLNL-TR-663740

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This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

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Executive Summary

A 50mL container with a one inch outer diameter has been proposed for holding specimen materials scanned at LLNL and Tyndall Air Force Research Laboratory (TAFRL). In order to determine whether or not this new container would significantly affect MicroCT results, a similarity analysis procedure developed at LLNL was used[1]. This procedure compares multiple first and second order statistics obtained from CT reconstructed images generated by the MicroCT analysis process, and prescribes similarity constraints as guidance. For this study, water was scanned on the MicroCT system at LLNL, twice in the standard 60mL container and twice in the proposed 50mL container. Data were analyzed following the Standard Operating Procedure (SOP) for MicroCT analysis[2]. Comparison of analytical results shows that the new container does not satisfy all similarity analysis criteria (certain second order statistics are outside of similarity analysis constraints).

[1] Harry E. Martz, Jr. and Carl Crawford, *Validation of Explosive Simulants Requirement Specification, Draft Version 12,* LLNL-TR-416983, Lawrence Livermore National Laboratory, Livermore, CA 94551, October 26, 2009.

[2] Isaac Seetho, *MicroCT: Analysis of CT Reconstructed Data of Home Made Explosive Materials Using the Matlab MicroCT Analysis GUI*, Lawrence Livermore National Laboratory, IDD-MCT-SOP-007, January 13, 2011.

Similarity Analysis Summary

Date: **July 22, 2014**

Author: **Isaac Seetho (LLNL)** _____

Typed or Printed Name *Signature*

Container 1 ID(s): **Water (Standard container – 60mL HDPE Nalgene bottle)**

Container 2 ID(s): **Water (50mL 1" outer diameter Polypropylene (PP) vial)**

Similarity Analysis Request Form:

Did not receive Similarity Analysis Request Form

Result: **Meets all criteria / Does not meet all criteria**
Underline One

Summary Explanation: **Water was scanned twice in both the standard 60mL Nalgene container, and also in a new 50mL 1" outer diameter container. The containers were scanned at 160kV and 100kV (with water BHC). Water-calibrated Livermore Modified Hounsfield Units ($LMHU_w$) were measured. All first-order statistics satisfied constraints. Certain second-order statistics did not meet constraints.**

Type of Validation Test *Check or Underline One*	Source of Features for Standard Container *Check or Underline One*
☐ **Standard Container, Proposed Container**	☐ **Measured**
☐ **One object to multiple objects**	☐ **Modeled**
☐ **Multiple objects to multiple objects**	

First Order Summary Analysis:
Standard container, Proposed 50mL container

H2O_143 (50 mL Container) vs H2O_145 (60mL Standard Container)

Data Set	Test	Standard (60mL) ($LMHU_w$)	Proposed (50mL) ($LMHU_w$)	Relative difference(%) $\left\lvert\frac{Proposed - Standard}{Standard}\right\rvert$	Similar Criterion (%)	Meets Criterion
LAC–100 Al	Mean Value	1507	1514	0.4%	≤ 1	Yes
	Std. Dev.	48	54	12.1%	≤ 20	Yes
	Entropy	5.3	5.4	2.4%	≤ 8	Yes
	KDE Similarity	92.2			≥ 88	Yes
LAC–160 AlCu	Mean Value	1013	1014	0.1%	≤1	Yes
	Std. Dev.	55	58	5.9%	≤ 20	Yes
	Entropy	5.4	5.5	1.1%	≤ 8	Yes
	KDE Similarity	96.9			≥ 88	Yes
Observations	Texture in LAC-160 slice	Qualitatively Similar: (Underline one) Yes / No				
	Viscosity	Qualitatively Similar: (Underline one) Yes / No				
	Moldability	Qualitatively Similar: (Underline one) Yes / No or NA				

H2O_144 (50 mL Container) vs H2O_145 (60mL Standard Container)

Data Set	Test	Standard (60mL) ($LMHU_w$)	Proposed (50mL) ($LMHU_w$)	Relative difference(%) $\left\lvert\frac{Proposed - Standard}{Standard}\right\rvert$	Similar Criterion (%)	Meets Criterion
LAC–100 Al	Mean Value	1506	1514	0.5%	≤ 1	Yes
	Std. Dev.	48	54	11.8%	≤ 20	Yes
	Entropy	5.3	5.4	2.3%	≤ 8	Yes
	KDE Similarity	92.4			≥ 88	Yes
LAC–160 AlCu	Mean Value	1012	1014	0.1%	≤1	Yes
	Std. Dev.	55	58	5.9%	≤ 20	Yes
	Entropy	5.4	5.5	1.1%	≤ 8	Yes
	KDE Similarity	96.9			≥ 88	Yes
Observations	Texture in LAC-160 slice	Qualitatively Similar: (Underline one) Yes / No				
	Viscosity	Qualitatively Similar: (Underline one) Yes / No				
	Moldability	Qualitatively Similar: (Underline one) Yes / No or NA				

H2O_143 (50 mL Container) vs H2O_146 (60mL Standard Container)

Data Set	Test	Standard (60mL) ($LMHU_w$)	Proposed (50mL) ($LMHU_w$)	Relative difference(%) $\left\lvert\frac{Proposed - Standard}{Standard}\right\rvert$	Similar Criterion (%)	Meets Criterion
LAC–100 Al	Mean Value	1507	1508	0.4%	≤ 1	Yes
	Std. Dev.	48	54	12.1%	≤ 20	Yes
	Entropy	5.3	5.4	2.4%	≤ 8	Yes
	KDE Similarity	94.3			≥ 88	Yes
LAC–160 AlCu	Mean Value	1013	1015	0.1%	≤1	Yes
	Std. Dev.	55	58	5.9%	≤ 20	Yes
	Entropy	5.4	5.5	1.1%	≤ 8	Yes
	KDE Similarity	96.9			≥ 88	Yes
Observations	Texture in LAC-160 slice	Qualitatively Similar: (Underline one) Yes / No				
	Viscosity	Qualitatively Similar: (Underline one) Yes / No				
	Moldability	Qualitatively Similar: (Underline one) Yes / No or NA				

H2O_144 (50 mL Container) vs H2O_146 (60mL Standard Container)

Data Set	Test	Standard (60mL) ($LMHU_w$)	Proposed (50mL) ($LMHU_w$)	Relative difference(%) $\left\lvert\frac{Proposed - Standard}{Standard}\right\rvert$	Similar Criterion (%)	Meets Criterion
LAC–100 Al	Mean Value	1506	1508	0.1%	≤ 1	Yes
	Std. Dev.	48	54	10.3%	≤ 20	Yes
	Entropy	5.3	5.4	2.0%	≤ 8	Yes
	KDE Similarity	94.8			≥ 88	Yes
LAC–160 AlCu	Mean Value	1012	1015	0.3%	≤1	Yes
	Std. Dev.	55	58	5.4%	≤ 20	Yes
	Entropy	5.4	5.5	1.0%	≤ 8	Yes
	KDE Similarity	96.8			≥ 88	Yes
Observations	Texture in LAC-160 slice	Qualitatively Similar: (Underline one) Yes / No				
	Viscosity	Qualitatively Similar: (Underline one) Yes / No				
	Moldability	Qualitatively Similar: (Underline one) Yes / No or NA				

Second Order Summary Analysis:
Standard container, Proposed 50mL container

H2O_143 (50 mL Container) vs H2O_145 (60mL Standard Container)

Difference image (DX) Data Set	Test	Standard (60mL) ($LMHU_w$)	Proposed (50mL) ($LMHU_w$)	Relative difference(%) $\left\lvert\frac{Proposed - Standard}{Standard}\right\rvert$	Similar Criterion (%)	Meets Criterion
LAC–100 Al	Mean Value	45	51	11.1%	≤ 5	No
	Std. Dev.	34	39	11.2%	≤ 5	No
	Entropy	4.8	4.9	2.3%	≤ 5	Yes
	KDE Similarity	94.4			≥ 88	Yes
LAC–160 AlCu	Mean Value	51	54	5.3%	≤5	Yes
	Std. Dev.	39	41	4.9%	≤ 5	Yes
	Entropy	4.9	5.0	1.0%	≤ 5	Yes
	KDE Similarity	97.3			≥ 88	Yes
Observations	Texture in LAC-160 slice	Qualitatively Similar: (Underline one) Yes / No				

H2O_144 (50 mL Container) vs H2O_145 (60mL Standard Container)

Difference image (DX) Data Set	Test	Standard (60mL) ($LMHU_w$)	Proposed (50mL) ($LMHU_w$)	Relative difference(%) $\left\lvert\frac{Proposed - Standard}{Standard}\right\rvert$	Similar Criterion (%)	Meets Criterion
LAC–100 Al	Mean Value	45	51	10.5%	≤ 5	No
	Std. Dev.	34	39	10.8%	≤ 5	No
	Entropy	4.8	4.9	2.2%	≤ 5	Yes
	KDE Similarity	94.7			≥ 88	Yes
LAC–160 AlCu	Mean Value	52	54	4.3%	≤5	Yes
	Std. Dev.	39	41	4.2%	≤ 5	Yes
	Entropy	4.9	5.0	0.8%	≤ 5	Yes
	KDE Similarity	97.8			≥ 88	Yes
Observations	Texture in LAC-160 slice	Qualitatively Similar: (Underline one) Yes / No				

H2O_143 (50 mL Container) vs H2O_146 (60mL Standard Container)

Difference image (DX) Data Set	Test	Standard (60mL) ($LMHU_w$)	Proposed (50mL) ($LMHU_w$)	Relative difference(%) $\left\lvert\frac{Proposed - Standard}{Standard}\right\rvert$	Similar Criterion (%)	Meets Criterion
LAC–100 Al	Mean Value	45	50	11.1%	≤ 5	No
	Std. Dev.	34	38	11.2%	≤ 5	No
	Entropy	4.8	5.0	2.3%	≤ 5	Yes
	KDE Similarity	95.0			≥ 88	Yes
LAC–160 AlCu	Mean Value	51	54	5.3%	≤5	No
	Std. Dev.	39	41	4.9%	≤ 5	Yes
	Entropy	4.9	5.0	1.0%	≤ 5	Yes
	KDE Similarity	97.8			≥ 88	Yes
Observations	Texture in LAC-160 slice	Qualitatively Similar: (Underline one) Yes / No				

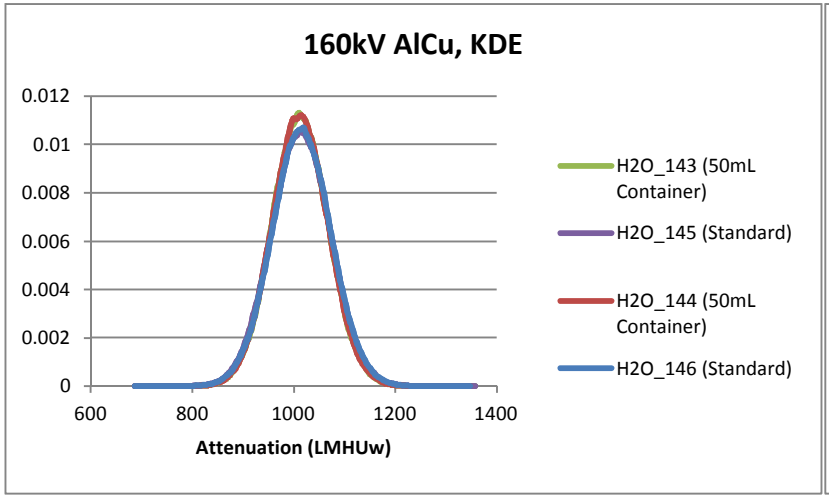
H2O_144 (50 mL Container) vs H2O_146 (60mL Standard Container)

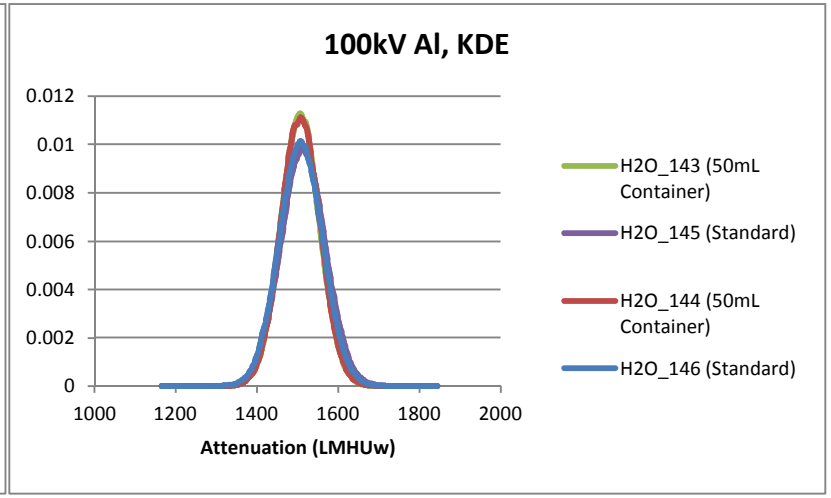
Difference image (DX) Data Set	Test	Standard (60mL) ($LMHU_w$)	Proposed (50mL) ($LMHU_w$)	Relative difference(%) $\left\lvert\frac{Proposed - Standard}{Standard}\right\rvert$	Similar Criterion (%)	Meets Criterion
LAC–100 Al	Mean Value	45	50	9.3%	≤ 5	No
	Std. Dev.	34	38	9.7%	≤ 5	No
	Entropy	4.8	5.0	1.9%	≤ 5	Yes
	KDE Similarity	95.3			≥ 88	Yes
LAC–160 AlCu	Mean Value	52	54	3.7%	≤5	Yes
	Std. Dev.	39	41	3.8%	≤ 5	Yes
	Entropy	4.9	5.0	0.7%	≤ 5	Yes
	KDE Similarity	98.2			≥ 88	Yes
Observations	Texture in LAC-160 slice	Qualitatively Similar: (Underline one) Yes / No				

Supplemental Analysis — Standard container, 50mL 1” outer diameter container

Other Supporting Data:

1. **Graphs of Kernel Density Estimation (KDE) functions**
   a. **First order statistics**

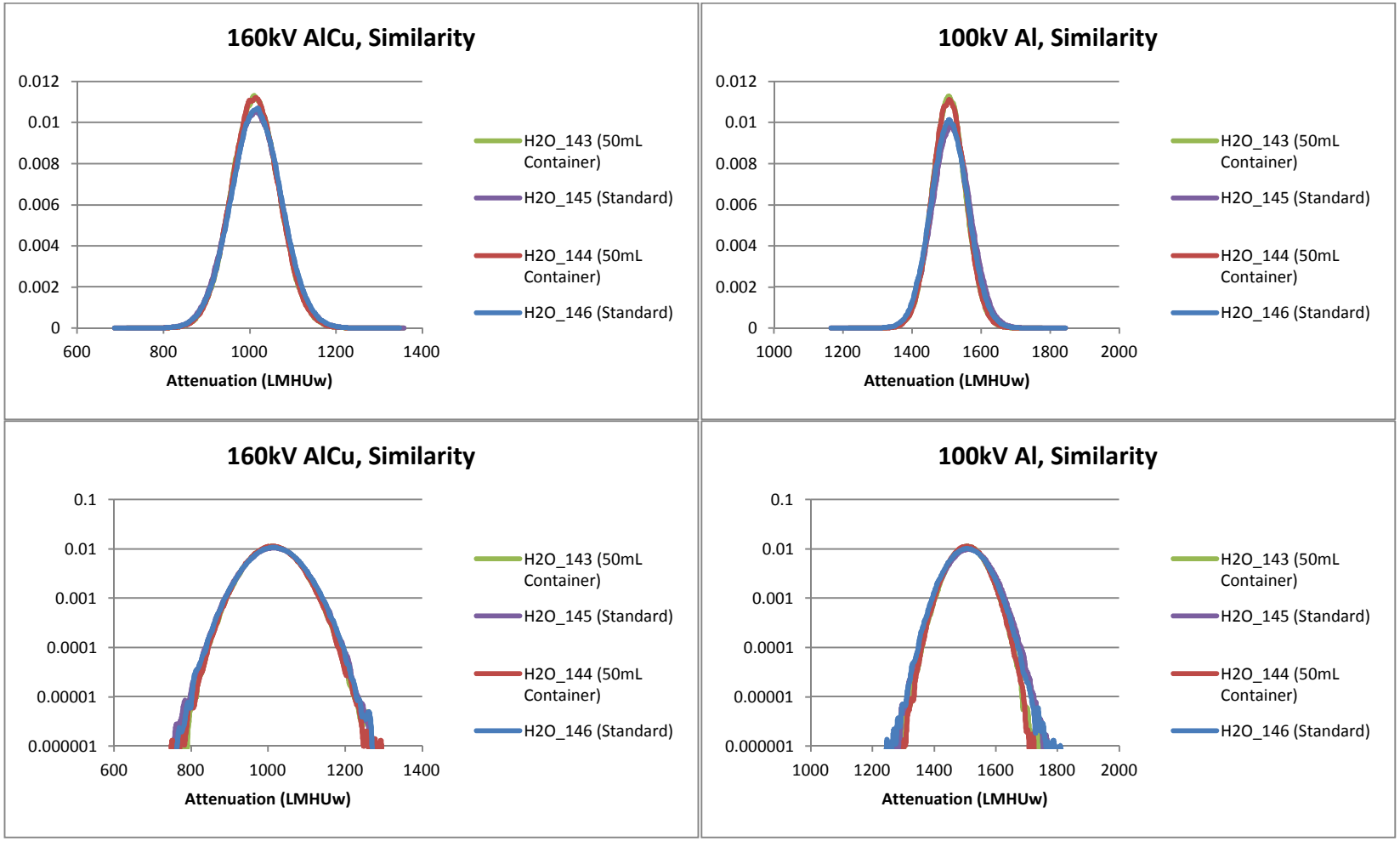




All values meet criteria.

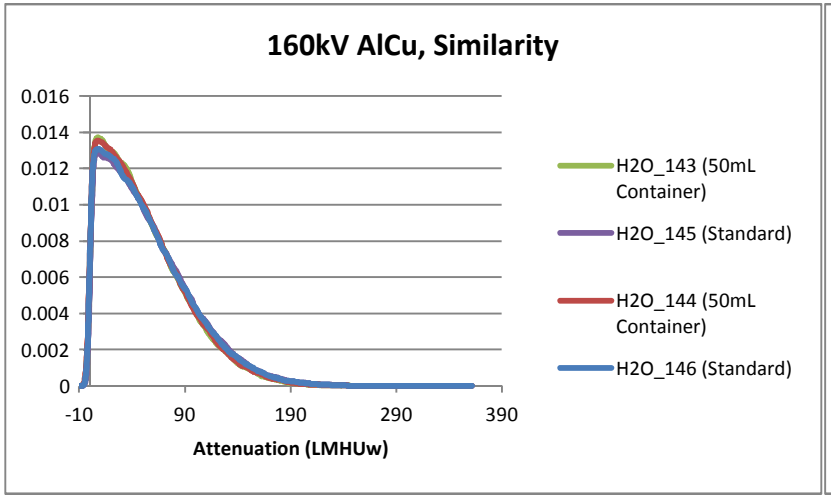
160kV	Standard		50mL Container		Diff%			
ID	H2O_145	H2O_146	H2O_143	H2O_144	143 vs 145	144 vs 145	143 vs 146	144 vs 146
Mean:	1013.79	1015.15	1012.67	1012.47	0.1%	0.1%	0.1%	0.3%
Std Dev	58.31	58.05	54.85	54.90	5.9%	5.9%	5.9%	5.4%
Entropy	5.49	5.48	5.43	5.43	1.1%	1.1%	1.1%	1.0%
100kV	**Standard**		**50mL Container**		**Diff%**			
ID	H2O_145	H2O_146	H2O_143	H2O_144	143 vs 145	144 vs 145	143 vs 146	144 vs 146
Mean:	1513.58	1508.19	1506.87	1506.37	0.4%	0.5%	0.4%	0.1%
Std Dev	54.53	53.63	47.91	48.08	12.1%	11.8%	12.1%	10.3%
Entropy	5.42	5.40	5.29	5.30	2.4%	2.3%	2.4%	2.0%

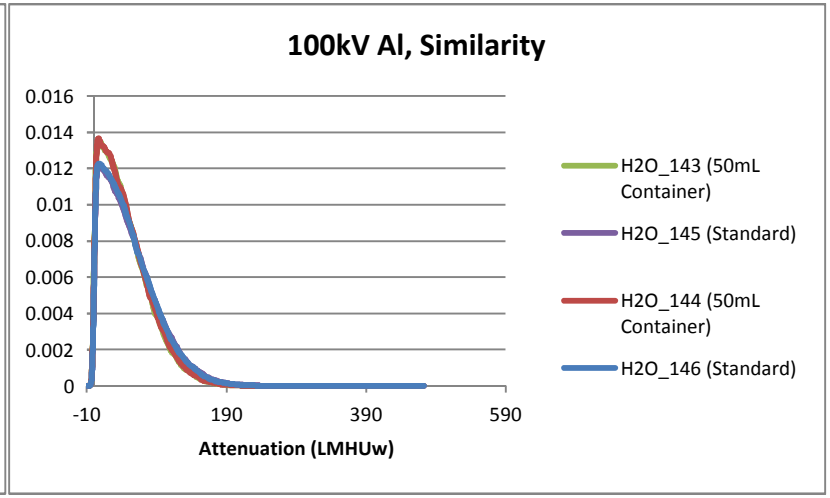
b. First order linear (top) and semi-log (bottom) density functions



The log plot emphasizes the similarity between the 50mL container and standard bottle's distributions.

c. **Second order statistics**





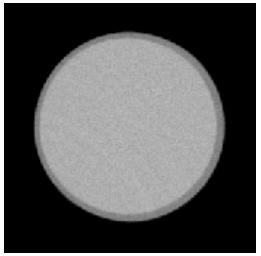
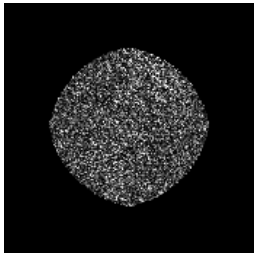
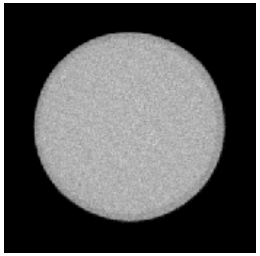
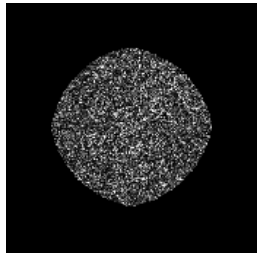
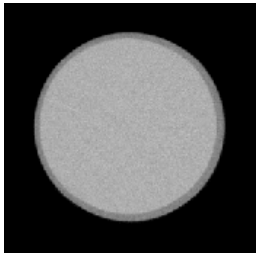
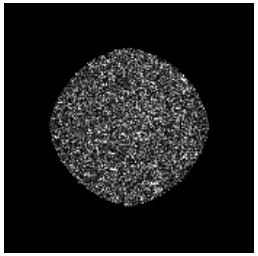
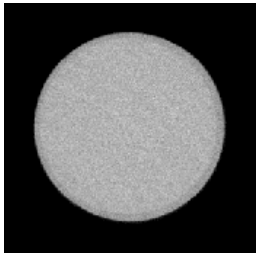
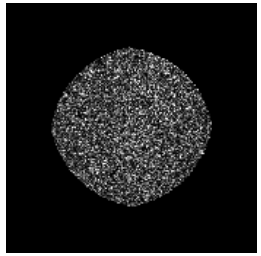
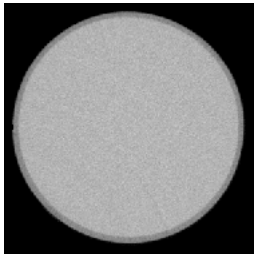
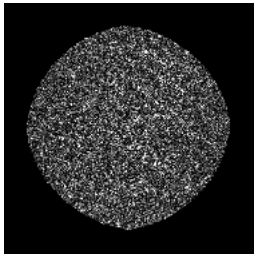
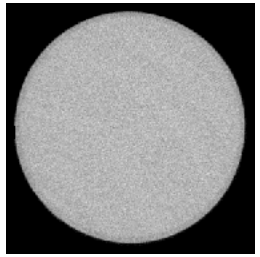
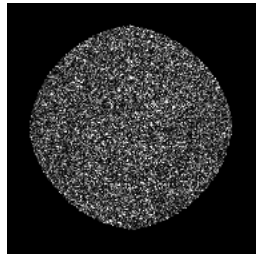
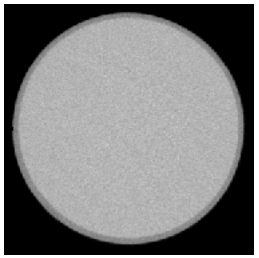
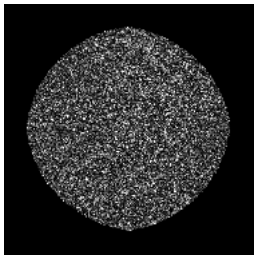
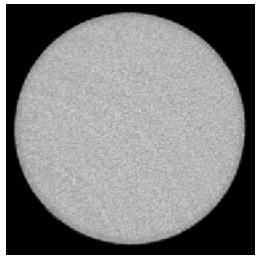
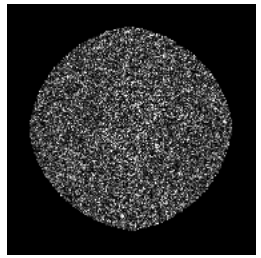
Certain second order statistics do not meet criteria (mean and standard deviation).

160kV	Standard		50mL Container		Diff%			
ID	H2O_145	H2O_146	H2O_143	H2O_144	143 vs 145	144 vs 145	143 vs 146	144 vs 146
Mean:	54.19	53.81	51.32	51.84	5.3%	4.3%	5.3%	3.7%
Std Dev	41.09	40.92	39.09	39.35	4.9%	4.2%	4.9%	3.8%
Entropy	4.98	4.97	4.93	4.94	1.0%	0.8%	1.0%	0.7%
100kV	**Standard**		**50mL Container**		**Diff%**			
ID	H2O_145	H2O_146	H2O_143	H2O_144	143 vs 145	144 vs 145	143 vs 146	144 vs 146
Mean:	50.81	50.17	45.19	45.49	11.1%	10.5%	11.1%	9.3%
Std Dev	38.66	38.20	34.32	34.49	11.2%	10.8%	11.2%	9.7%
Entropy	4.92	4.90	4.80	4.81	2.3%	2.2%	2.3%	1.9%

2. Photos

a. **New 50mL container: None available**
b. **Material(s): None available**

3. **Screen shots of x-ray images Water in standard container and 50mL 1” diameter PP container**

	100kV Al	100kV Al DX*	160kV AlCu	160kV AlCu DX
50mL Container (H2O_143)				
50mL Container (H2O_144)				
Standard (H2O_145)				
Standard (H2O_146)				

***DX images show gradient taken after segmentation and erosion.**

Summary of Data Used for Analysis

Container 1 (Standard 60mL HDPE Nalgene bottle)

ID	Provided by	Date Obtained	Date x-rayed	X-rayed at	X-rayed by	Data sent to LLNL to	On LEDP server
Water	LLNL	4-17-14	4-17-14	LLNL	Strout	N/A	4-17-2014
Water	LLNL	4-18-14	4-18-14	LLNL	Strout	N/A	4-18-2014

Container 2 (50mL 1" outer diameter Polypropylene vial)

Water	LLNL	4-15-14	4-15-14	LLNL	Strout	N/A	4-15-2014
Water	LLNL	4-16-14	4-16-14	LLNL	Strout	N/A	4-16-2014
ID	**Provided by**	**Date Obtained**	**Date x-rayed**	**X-rayed at**	**X-rayed by**	**Data sent to LLNL to**	**On LEDP server**

Experimental Measurements

Material Sample ID	Date	Radiologist	Slits	kVp	mA	Al Filter (mm)*	Cu Filter (mm)*	Directory
H2O_143_140415	4-15-14	Strout	2	100	1.1	1.943	N/A	X:\HEAF_MicroCT_System_Tests\H2O\H2O_143_140415\Test_Data\H2O_143_140415_100Al
	4-15-14	Strout	2	160	4.35	1.943	1.905	X:\HEAF_MicroCT_System_Tests\H2O\H2O_143_140415\Test_Data\H2O_143_140415_160AlCu
H2O_144_140416	4-16-14	Strout	2	100	1.1	1.943	N/A	X:\HEAF_MicroCT_System_Tests\H2O\H2O_144_140416\Test_Data\H2O_144_140416_100Al
	4-16-14	Strout	2	160	4.35	1.943	1.905	X:\HEAF_MicroCT_System_Tests\H2O\H2O_144_140416\Test_Data\H2O_144_140416_160AlCu
H2O_145_140417	4-17-14	Strout	2	100	1.1	1.943	N/A	X:\HEAF_MicroCT_System_Tests\H2O\H2O_145_140417\Test_Data\H2O_145_140417_100Al
	4-17-14	Strout	2	160	4.35	1.943	1.905	X:\HEAF_MicroCT_System_Tests\H2O\H2O_145_140417\Test_Data\H2O_145_140417_160AlCu
H2O_146_140418	4-18-14	Strout	2	100	1.1	1.943	N/A	X:\HEAF_MicroCT_System_Tests\H2O\H2O_146_140418\Test_Data\H2O_146_140418_100Al
	4-18-14	Strout	2	160	4.35	1.943	1.905	X:\HEAF_MicroCT_System_Tests\H2O\H2O_146_140418\Test_Data\H2O_146_140418_160AlCu

*** Not in sct file, values confirmed in data acquisition test plan.**

1. **50mL container preparation**

Person responsible:	LLNL Personnel
Date/time put into container:	Unknown
Location:	LLNL
Identifier:	Water (H2O_143/H2O_144)
Digital picture:	N/A
Preparation procedure:	N/A
Containment:	50mL PP vial w/ Screw Cap
Observations:	Transparent colorless liquid

2. **Standard container preparation**

Person responsible:	LLNL Personnel
Date/time put into container:	Unknown
Location:	LLNL
Identifier:	Water (H2O_145/H2O_146)
Digital picture:	N/A
Preparation procedure:	N/A
Containment:	60 mL LDPE Nalgene Bottle
Observations:	Transparent colorless liquid

3. **50mL container scanning**

Person responsible:	Stephen A. Strout
Date/time acquired:	4-15-2014 / 4-16-2014
Location:	LLNL
Scan description:	Water (50mL PP Vial)
Observations:	
Date and time sent to LLNL:	N/A

4. **Standard container scanning**

Person responsible:	Stephen A. Strout
Date/time acquired:	4-17-2014 / 4-18-2014
Location:	LLNL
Scan description:	Water (60mL LDPE Bottle)
Observations:	
Date and time sent to LLNL:	N/A

5. Reconstruction: Standard Container

Reconstructed by: Isaac Seetho (H2O_145) / Stephen A. Strout (H2O_146)
Date: 4-29-14 / 4-18-14
Location: LLNL B327 R1280 (H2O_145) / R1285 (H2O_146)
Computer: HP Z210 Workstation / Dell Precision 690
Reconstruction Software:
Software: Imgrec
Version: 2.8.1.1c11
Script Files:
Directory:
X:\HEAF_MicroCT_System_Tests\H2O\H2O_145_140417\Reconstruction\Special_Recon\Scripts
X:\HEAF_MicroCT_System_Tests\H2O\H2O_146_140418\Reconstruction\Special_Recon\Scripts
Files:
LLNL_script_H2O_145_100Al.txt LLNL_script_H2O_145_160AlCu.txt
LLNL_script_H2O_146_100Al.txt LLNL_script_H2O_146_160AlCu.txt
Raw Data Files: H2O_145_160AlCu_*nn*.sdt H2O_145_100Al_*nn*.sdt
H2O_146_160AlCu_*nn*.sdt H2O_146_100Al_*nn*.sdt
Reconstructed Files: recobj_46 to 56

6. Reconstruction: 50mL Container

Reconstructed by: Isaac Seetho
Date: 4-29-14
Location: LLNL B327 R1280
Computer: HP Z210 Workstation
Reconstruction Software:
Software: Imgrec
Version: 2.8.1.1c11
Script Files:
Directory:
X:\HEAF_MicroCT_System_Tests\H2O\H2O_143_140415\Reconstruction\Special_Recon\Scripts
X:\HEAF_MicroCT_System_Tests\H2O\H2O_144_140416\Reconstruction\Special_Recon\Scripts
Files:
LLNL_script_H2O_143_100Al.txt LLNL_script_H2O_143_160AlCu.txt
LLNL_script_H2O_144_100Al.txt LLNL_script_H2O_144_160AlCu.txt
Raw Data Files: H2O_143_160AlCu_*nn*.sdt H2O_143_100Al_*nn*.sdt
H2O_144_160AlCu_*nn*.sdt H2O_144_100Al_*nn*.sdt
Reconstructed Files: recobj_46 to 56

7. Analysis

Person responsible: Isaac Seetho
Date: 4-29-2014 (H2O_143, 144, 145)
4-18-2014 (H2O_146)
Location: LLNL B327 R1280
Segmentation/ROI: Used automated snakes and erosion
Filename(s): Automated MicroCT Analysis v1.3
Observation(s): N/A