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# Final Report for DHS FY10 Uranium Methodology Project

Analyses of PTRM10 1.1, 1.2, 3.1, and 3.2

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November 2010



**Pacific Northwest**  
NATIONAL LABORATORY

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Analyses of PTRM10 1.1, 1.2, 3.1, and 3.2

KL Noyes, SL Petersen, SJ Garofoli, KB Wagnon, MM Huff, SM Schulte, and JI Friese

11/30/2010

This report contains a description of activities performed in support of the FY10 Uranium Methodologies Project at PNNL, as well as the final data from the analyses.

## ***Measurement Scheme***

The samples were received in lab 329/131, then transferred to lab 329/121 for aliquotting and distribution for analyses. Alpha aliquots were chemically separated and electrodeposited in lab 329/121, with alpha counting taking place in 329/16A. Thermal ionization mass spectrometry (TIMS) aliquots were transferred to lab 320/113 for TIMS source preparation under radiological control; no chemical separations were performed on TIMS aliquots. In both labs, each set of replicate samples were accompanied by one chemical (laboratory) process blank for quality assurance purposes.

All  $^{232}\text{U}/^{234}\text{U}$  ratios are measured via alpha energy analysis (AEA). The following ratios were measured by TIMS:  $^{233}\text{U}/^{235}\text{U}$ ,  $^{234}\text{U}/^{235}\text{U}$ ,  $^{236}\text{U}/^{235}\text{U}$ , and  $^{238}\text{U}/^{235}\text{U}$ , where  $^{235}\text{U}$  was the dominant isotope; analogous measurements were made in cases where  $^{238}\text{U}$  was the dominant isotope. All  $^{232}\text{U}/^{235}\text{U}$  and  $^{232}\text{U}/^{238}\text{U}$  ratios are calculated using a combination of the AEA and TIMS data.

## ***Methods Used***

The methods used in these analyses are the same methods that are normally used on samples and are described in the SOPs in the following section. Not all of the methods in the SOPs section were used; this report does not cover PTRM10-2. Chemical separations were not necessary for the TIMS samples, but were required for the AEA samples.

## ***SOPs Used***

1. 320-A-13: U Determinations by TIMS for NTNFC Samples
2. 320-113-3: Sample Dissolution, Preliminary Analysis, Splitting, Spiking, and Equilibration for U and Pu Determinations
3. 320-113-2: Anion Exchange Separation and Purification of U and Pu for Samples Containing ppm Levels of Iron
4. 320-A-11: TIMS Source Preparation for Purified U and Pu Fractions of Samples
5. Alpha Calibrations [not yet a formalized procedure]
6. 329-AEA-1: Alpha Spectroscopy Sample Analysis
7. 329-ED-USTUR-1: 329-Electrodeposition of Radiological Samples via USTUR Method
8. 329-ED-EICM-1: 329-Electrodeposition of Radiological Samples via EICROM Method
9. 329-AEAPREP-01: Alpha Spectroscopy Sample Preparation
10. RC-UTEVA-TRU: Chemical Separations for Analysis of Actinides
11. 329-NC-1: Operations Protocol for Radiochemical Analytical Work Performed in 329 Building, Labs 121, 122, 126 and 127

### ***Additional Planning/Processes***

None.

### ***Calculation of Uncertainties***

Uncertainties for individual measurements are propagated errors based on counting statistics, detector dark noise, and background noise (at mass 243 for TIMS). TIMS data is also corrected for mass bias based on the analysis of many natural uranium standards (CRM-129a) analyzed in a manner as similar as possible to the samples. Reported uncertainties are GUM compliant.

For the TIMS data, the single measurand values were calculated as an average of all replicates (10-11 measurements, depending on the sample). The GUM uncertainties were generated using the following general equation:

$$\text{combined}_{\text{avgMP}} = ((X_{\text{MPDay1}} * \delta_{\text{MPBCFDay1}} + X_{\text{MPDay2}} * \delta_{\text{MPBCFDay2}})/2) * \delta_{\text{Reproducibility}} * \delta_{\text{Repeatability}}$$

Where  $\text{combined}_{\text{avgMP}}$  is the combined average over both days for a ratio-ed minor mass (M) to a primary mass (P),  $X_{\text{MPDay1}}$  is the average ratio for the sample for the M/P ratio on day 1,  $X_{\text{MPDay2}}$  is the average ratio for the M/P ratio of the sample on day2,  $\delta_{\text{MPBCFDay1}}$  is the delta factor for the M/P ratio bias correction on day 1,  $\delta_{\text{MPBCFDay2}}$  is the delta factor for the M/P ratio bias correction on day 2,  $\delta_{\text{Reproducibility}}$  is the delta factor for day-to-day reproducibility of the  $^{235}\text{U}/^{238}\text{U}$  ratio of a certified isotopic standard, and  $\delta_{\text{Repeatability}}$  is the delta factor characterizing the intra-day repeatability of the  $^{235}\text{U}/^{238}\text{U}$  ratio of a certified isotopic standard.

The delta factors are entered as  $1 \pm$  uncertainty at the 1-sigma level. The bias correction delta factor uncertainties are calculated as  $(P-M)/3 * (\text{RSD}_{\text{BCF58}})$ , where P is the primary mass, M is the minor mass, and  $\text{RSD}_{\text{BCF58}}$  is the relative standard deviation of the bias correction factor for the  $^{235}\text{U}/^{238}\text{U}$  ratio based on the 5-6 certified isotopic standards run at the same time as the PTRM10 sample they are associated with. The repeatability uncertainty is the relative standard deviation of  $^{235}\text{U}/^{238}\text{U}$  ratio of the six certified isotopic standards run at the same time as the sample they are associated with. The reproducibility uncertainty is the relative standard deviation of the  $^{235}\text{U}/^{238}\text{U}$  ratio of the 48 certified isotopic standards run throughout the PTRM10 analytical process.

### ***Number of Analysts Performing Tasks for this Project***

1. Sample Aliquoting: 2 analysts
2. Chemical Separations for AEA: 1 analyst
3. Electrodepositions for AEA: 1 analyst
4. Alpha Counting for AEA: 2 analysts
5. TIMS Source Loading for TIMS Samples: 1 analyst

6. TIMS Source Loading for TIMS QA/QC Samples: 2 analysts
7. TIMS Source Processing: 2 analysts
8. TIMS Instrument Operation: 1 analyst
9. Alpha Data Analysis: 2 analysts
10. TIMS Data Analysis: 2 analysts

### ***Calibrations, Reference Materials, and Quality Control Samples***

The settings used for each mass on the TIMS instrument are calibrated quarterly with DAC check standards. Certified reference materials are run with each set of samples analyzed on the TIMS instrument as well (CRM-129a for uranium samples). Each set is co-processed with a chemical process blank as the quality control sample.

### ***Review Process for Analytical Data***

All data, both TIMS and alpha, undergoes a two-person review before it is ready for reporting. This review process entails checking for typos, ensuring that the correct subset of raw data has been used (for alpha, that the peak is appropriately defined; for TIMS, that invalid data points are excluded), and that calibrations/mass biases are appropriately incorporated.

### ***Deviations from, Additions to, or Exclusions from Analysis Methods***

None.

# Appendix A: Measurement Data

## U Methodology Isotopic Data Reporting

Facility Name:	PNNL	Division:	NSD
Report Author:	KLN	Date:	11/29/2010
Analysis Method 1:	TIMS	Analyst 1:	
Analysis Method 2:	AEA	Analyst 2:	
Analysis Method 3:		Analyst 3:	

Sample ID	Replicate Number	Isotopic Ratio 232U/235U	Isotopic Ratio 233U/235U	Isotopic Ratio 234U/235U	Isotopic Ratio 236U/235U	Isotopic Ratio 238U/235U	Analysis Date
PTRM10-1.1	86471A	7.83881E-10	2.19408E-06	0.009730798	0.015163155	0.55054734	8/21/2010
	86471B	8.00E-10	2.00018E-06	0.009761917	0.015175165	0.551461606	
	86471C	8.05E-10	2.34994E-06	0.009772958	0.015176105	0.551208952	
	86471D	7.98E-10	2.19279E-06	0.009764111	0.015148191	0.551211033	
	86471E		2.00503E-06	0.009766408	0.015171618	0.551091784	
	Average	7.96585E-10	2.1484E-06	0.009759238	0.015166847	0.551104143	
	Std Uncert	4.45189E-12	6.60298E-08	7.34653E-06	5.19299E-06	0.000151719	8/30/2010
	86475A	8.02363E-10	2.42268E-06	0.009722974	0.015109038	0.550243287	
	86475B	8.05548E-10	2.40439E-06	0.009706158	0.015141825	0.549914578	
	86475C	8.00298E-10	2.1744E-06	0.009732986	0.015133193	0.550278577	
	86475D	8.10573E-10	2.43275E-06	0.009705294	0.015152122	0.551545784	
	86475E		2.78279E-06	0.009709785	0.015120466	0.549911968	
	86475F		2.06784E-06	0.009720329	0.015129225	0.549732549	
	Average	8.04696E-10	2.38081E-06	0.009716254	0.015130978	0.550271124	
	Std Uncert	2.23695E-12	1.01184E-07	4.49301E-06	6.2305E-06	0.000269058	
Combined Average		8.01E-10	2.27E-06	0.009738	0.015149	0.5507	
Expanded Uncertainty (U=k•u <sub>c</sub> )			6.00E-08	4.70E-05	7.30E-05	2.90E-03	

Sample ID	Replicate Number	Isotopic Ratio 232U/238U	Isotopic Ratio 233U/238U	Isotopic Ratio 234U/238U	Isotopic Ratio 235U/238U	Isotopic Ratio 236U/238U	Analysis Date
PTRM10-1.2	86472A	9.55518E-12	---	0.000411302	0.047457123	0.000290002	8/6/2010
	86472B	9.20876E-12	---	0.000408035	0.047397343	0.000290326	
	86472C	8.93176E-12	---	0.000408923	0.04735173	0.000289918	
	86472D		---	0.000411729	0.047529634	0.000291453	
	86472E		---	0.000401937	0.047133707	0.000289821	
	Average	9.2319E-12	#DIV/0!	0.000408385	0.047373907	0.000290304	
	Std Uncert	1.80336E-13	#DIV/0!	1.75614E-06	6.70495E-05	2.99436E-07	8/13/2010
	86476A		---	0.000403867	0.047363245	0.000287692	
	86476B		---	0.000406773	0.047461333	0.000289585	
	86476C		---	0.000409239	0.047385994	0.000289216	
	86476D		---	0.000407413	0.047402334	0.000290479	
	86476E		---	0.000405985	0.047264853	0.00028843	
	Average	#DIV/0!	#DIV/0!	0.000406655	0.047375552	0.000289081	
	Std Uncert	#DIV/0!	#DIV/0!	8.79888E-07	3.20862E-05	4.78468E-07	
Combined Average			---	4.08E-04	0.04737	2.90E-04	
Expanded Uncertainty (U=k•u <sub>c</sub> )			---	2.40E-06	2.40E-04	1.40E-06	

# U Methodology Isotopic Data Reporting

Facility Name:	PNNL	Division:	NSD
Report Author:	KLN	Date:	11/29/2010
Analysis Method 1:	TIMS	Analyst 1:	
Analysis Method 2:	AEA	Analyst 2:	
Analysis Method 3:		Analyst 3:	

Sample ID	Replicate Number	Isotopic Ratio	Isotopic Ratio	Isotopic Ratio	Isotopic Ratio	Isotopic Ratio	Analysis Date
		232U/238U	233U/238U	234U/238U	235U/238U	236U/238U	
PTRM10-3.1	86473A	1.98334E-11	---	0.000494615	0.05282504	0.000158349	8/23/2010
	86473B	1.98E-11	---	0.000491909	0.05260334	0.00015898	
	86473C	1.91E-11	---	0.000488544	0.052736766	0.000159703	
	86473D	1.92E-11	---	0.000494491	0.052799979	0.00015796	
	86473E		---	0.000490652	0.052759713	0.000159031	
	Average	1.94812E-11	#DIV/0!	0.000492042	0.052744967	0.000158805	
	Std Uncert	1.98254E-13	#DIV/0!	1.15753E-06	3.85882E-05	3.00738E-07	8/31/2010
	86477A		---	0.000493173	0.05300798	0.000159901	
	86477B		---	0.000498534	0.052921012	0.000158215	
	86477C		---	0.000494448	0.052977792	0.000159461	
	86477D		---	0.000490501	0.052873863	0.000158569	
	86477E		---	0.00049569	0.053020497	0.000161082	
	86477F		---	0.000495331	0.053022601	0.000160177	
	Average	#DIV/0!	#DIV/0!	0.000494613	0.052970624	0.000159568	
	Std Uncert	#DIV/0!	#DIV/0!	1.09629E-06	2.48057E-05	4.32663E-07	
Combined Average			---	4.93E-04	0.05286	1.59E-04	
Expanded Uncertainty (U=k•u <sub>c</sub> )			---	2.60E-06	2.60E-04	8.20E-07	

Sample ID	Replicate Number	Isotopic Ratio	Isotopic Ratio	Isotopic Ratio	Isotopic Ratio	Isotopic Ratio	Analysis Date
		232U/238U	233U/238U	234U/238U	235U/238U	236U/238U	
PTRM10-3.2	86474A	2.35245E-11	---	0.000502686	0.05303912	0.000168261	8/9/2010
	86474B	2.25466E-11	---	0.000498089	0.052965388	0.000168949	
	86474C	2.2929E-11	---	0.000502844	0.052944809	0.000168515	
	86474D	2.27449E-11	---	0.00049931	0.05285607	0.000168925	
	86474E		---	0.000503356	0.052681033	0.000168201	
	Average	2.29363E-11	#DIV/0!	0.000501257	0.052897284	0.00016857	
	Std Uncert	2.11043E-13	#DIV/0!	1.06761E-06	6.14318E-05	1.58703E-07	8/16/2010
	86478A		---	0.000499813	0.053077291	0.000165994	
	86478B		---	0.00050244	0.053174329	0.000166197	
	86478C		---	0.000496826	0.053036653	0.000169246	
	86478D		---	0.000503313	0.05301602	0.000167283	
	86478E		---	0.000503971	0.053055935	0.000168242	
	86478F		---	0.000507268	0.053152491	0.000168306	
	Average	#DIV/0!	#DIV/0!	0.000502272	0.053085453	0.000167545	
	Std Uncert	#DIV/0!	#DIV/0!	1.46813E-06	2.61619E-05	5.24426E-07	
Combined Average			---	5.02E-04	0.05299	1.68E-04	
Expanded Uncertainty (U=k•u <sub>c</sub> )			---	3.00E-06	2.80E-04	8.90E-07	



## Appendix B: Uncertainty Budgets

### Exhibit B.1: Uncertainty Budgets from PTRM10-1.1.

GUM for PTRM-10-1.1																																																																							
<p><b>GUM for PTRM-10-1.1</b>            Author: d3m597</p> <p>Modified to simplify. RSD (or delta) values come from spreadsheet containing all CRM-129A data and calculated individual BCF delta factors.</p> <p><b>Model Equation:</b></p> $\text{combined}_{\text{avg35}} = ((X_{35\text{Day1}} * \delta_{35\text{BCFDay1}} + X_{35\text{Day2}} * \delta_{35\text{BCFDay2}}) / 2) * \delta_{\text{Repeatability}} * \delta_{\text{Reproducibility}}$ $\text{combined}_{\text{avg45}} = ((X_{45\text{Day1}} * \delta_{45\text{BCFDay1}} + X_{45\text{Day2}} * \delta_{45\text{BCFDay2}}) / 2) * \delta_{\text{Repeatability}} * \delta_{\text{Reproducibility}}$ $\text{combined}_{\text{avg65}} = ((X_{65\text{Day1}} * \delta_{65\text{BCFDay1}} + X_{65\text{Day2}} * \delta_{65\text{BCFDay2}}) / 2) * \delta_{\text{Repeatability}} * \delta_{\text{Reproducibility}}$ $\text{combined}_{\text{avg85}} = ((X_{85\text{Day1}} * \delta_{85\text{BCFDay1}} + X_{85\text{Day2}} * \delta_{85\text{BCFDay2}}) / 2) * \delta_{\text{Repeatability}} * \delta_{\text{Reproducibility}}$ <p><b>List of Quantities:</b></p> <table> <tr> <th>Quantity</th><th>Unit</th><th>Definition</th></tr> <tr> <td>combined<sub>avg35</sub></td><td>atom/atom</td><td>combined average 23/25 sample ratio</td></tr> <tr> <td>X<sub>35Day1</sub></td><td>atom/atom</td><td>average sample 23/25 ratio from day 1</td></tr> <tr> <td>δ<sub>35BCFDay1</sub></td><td>atom/atom</td><td>delta factor for bias correction of 23/25 ratio on day 1</td></tr> <tr> <td>X<sub>35Day2</sub></td><td>atom/atom</td><td>average sample 23/25 ratio from day 2</td></tr> <tr> <td>δ<sub>35BCFDay2</sub></td><td>atom/atom</td><td>delta factor for bias correction of 23/25 ratio on day 2</td></tr> <tr> <td>δ<sub>Repeatability</sub></td><td>atom/atom</td><td>delta factor for relative uncertainty characterizing intra-day repeatability of 25/28 for control standard</td></tr> <tr> <td>δ<sub>Reproducibility</sub></td><td>atom/atom</td><td>delta factor for relative uncertainty characterizing day-to-day reproducibility of 25/28 for control standard</td></tr> <tr> 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from day 2	δ <sub>35BCFDay2</sub>	atom/atom	delta factor for bias correction of 23/25 ratio on day 2	δ <sub>Repeatability</sub>	atom/atom	delta factor for relative uncertainty characterizing intra-day repeatability of 25/28 for control standard	δ <sub>Reproducibility</sub>	atom/atom	delta factor for relative uncertainty characterizing day-to-day reproducibility of 25/28 for control standard	combined <sub>avg45</sub>	atom/atom	combined average 24/25 sample ratio	X <sub>45Day1</sub>	atom/atom	average sample 24/25 ratio from day 1	δ <sub>45BCFDay1</sub>	atom/atom	delta factor for bias correction of 24/25 ratio on day 1	X <sub>45Day2</sub>	atom/atom	average sample 24/25 ratio from day 2	δ <sub>45BCFDay2</sub>	atom/atom	delta factor for bias correction of 24/25 ratio on day 2	combined <sub>avg65</sub>	atom/atom	combined average 26/25 sample ratio	X <sub>65Day1</sub>	atom/atom	average sample 26/25 ratio from day 1	δ <sub>65BCFDay1</sub>	atom/atom	delta factor for bias correction of 26/25 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X <sub>65Day2</sub>	atom/atom	average sample 26/25 ratio from day 2																																																																					
δ <sub>65BCFDay2</sub>	atom/atom	delta factor for bias correction of 26/25 ratio on day 2																																																																					
combined <sub>avg85</sub>	atom/atom	combined average 28/25 sample ratio																																																																					
X <sub>85Day1</sub>	atom/atom	average sample 28/25 ratio from day 1																																																																					
δ <sub>85BCFDay1</sub>	atom/atom	delta factor for bias correction of 28/25 ratio on day 1																																																																					
X <sub>85Day2</sub>	atom/atom	average sample 28/25 ratio from day 2																																																																					
δ <sub>85BCFDay2</sub>	atom/atom	delta factor for bias correction of 28/25 ration on day 2																																																																					
Date: 12/01/2010	File: PTRM10-1.1 11-29-10KLN.smu	Page 1 of 8																																																																					

	GUM for PTRM-10-1.1															
$X_{35\text{Day1}}$ :	<div>Type A Method of observation: Direct Number of observations: 5</div> <table><tr><td>No.</td><td>Observation</td></tr><tr><td>1</td><td><math>2.1941 \cdot 10^{-6}</math> atom/atom</td></tr><tr><td>2</td><td>0.00000200018 atom/atom</td></tr><tr><td>3</td><td>0.00000234994 atom/atom</td></tr><tr><td>4</td><td>0.00000219279 atom/atom</td></tr><tr><td>5</td><td>0.000002005029 atom/atom</td></tr></table> <div>Arithmetic Mean: <math>2.1484 \cdot 10^{-6}</math> atom/atom Pooled Standard Deviation: 0.000000066030 atom/atom Pooled Degrees of Freedom: 49 Standard Uncertainty: <math>33.7 \cdot 10^{-9}</math> atom/atom</div>	No.	Observation	1	$2.1941 \cdot 10^{-6}$ atom/atom	2	0.00000200018 atom/atom	3	0.00000234994 atom/atom	4	0.00000219279 atom/atom	5	0.000002005029 atom/atom			
No.	Observation															
1	$2.1941 \cdot 10^{-6}$ atom/atom															
2	0.00000200018 atom/atom															
3	0.00000234994 atom/atom															
4	0.00000219279 atom/atom															
5	0.000002005029 atom/atom															
$\delta_{35\text{BCFDay1}}$ :	<div>Type B normal distribution Value: 1 atom/atom Expanded Uncertainty: 0.0014305 atom/atom Coverage Factor: 1</div>															
$X_{35\text{Day2}}$ :	<div>Type A Method of observation: Direct Number of observations: 6</div> <table><tr><td>No.</td><td>Observation</td></tr><tr><td>1</td><td>0.00000242268 atom/atom</td></tr><tr><td>2</td><td>0.00000240439 atom/atom</td></tr><tr><td>3</td><td>0.00000217440 atom/atom</td></tr><tr><td>4</td><td>0.00000243275 atom/atom</td></tr><tr><td>5</td><td>0.00000278279 atom/atom</td></tr><tr><td>6</td><td>0.00000206784 atom/atom</td></tr></table> <div>Arithmetic Mean: <math>2.3808 \cdot 10^{-6}</math> atom/atom Pooled Standard Deviation: 0.000000097368 atom/atom Pooled Degrees of Freedom: 49 Standard Uncertainty: <math>48.8 \cdot 10^{-9}</math> atom/atom</div>	No.	Observation	1	0.00000242268 atom/atom	2	0.00000240439 atom/atom	3	0.00000217440 atom/atom	4	0.00000243275 atom/atom	5	0.00000278279 atom/atom	6	0.00000206784 atom/atom	
No.	Observation															
1	0.00000242268 atom/atom															
2	0.00000240439 atom/atom															
3	0.00000217440 atom/atom															
4	0.00000243275 atom/atom															
5	0.00000278279 atom/atom															
6	0.00000206784 atom/atom															
$\delta_{35\text{BCFDay2}}$ :	<div>Type B normal distribution Value: 1 atom/atom Expanded Uncertainty: 0.00049908 atom/atom Coverage Factor: 1</div>															
Date: 12/01/2010	File: PTRM10-1.1 11-29-10KLN.smu	Page 2 of 8														

	GUM for PTRM-10-1.1															
$\delta_{\text{Repeatability}}$ :	Type B normal distribution Value: 1 atom/atom Expanded Uncertainty: 0.0011178 atom/atom Coverage Factor: 1															
$\delta_{\text{Reproducibility}}$ :	Type B normal distribution Value: 1 atom/atom Expanded Uncertainty: 0.0021029 atom/atom Coverage Factor: 1															
$X_{45\text{Day}1}$ :	Type A Method of observation: Direct Number of observations: 5															
	<table><tr><th>No.</th><th>Observation</th></tr><tr><td>1</td><td>0.009731 atom/atom</td></tr><tr><td>2</td><td>0.009762 atom/atom</td></tr><tr><td>3</td><td>0.009773 atom/atom</td></tr><tr><td>4</td><td>0.009764 atom/atom</td></tr><tr><td>5</td><td>0.009766 atom/atom</td></tr></table>		No.	Observation	1	0.009731 atom/atom	2	0.009762 atom/atom	3	0.009773 atom/atom	4	0.009764 atom/atom	5	0.009766 atom/atom		
No.	Observation															
1	0.009731 atom/atom															
2	0.009762 atom/atom															
3	0.009773 atom/atom															
4	0.009764 atom/atom															
5	0.009766 atom/atom															
	Arithmetic Mean: $9.75920 \cdot 10^{-3}$ atom/atom Pooled Standard Deviation: 0.000073465 atom/atom Pooled Degrees of Freedom: 49 Standard Uncertainty: $3.74 \cdot 10^{-6}$ atom/atom															
$\delta_{45\text{BCFDay}1}$ :	Type B normal distribution Value: 1 atom/atom Expanded Uncertainty: 0.00071524 atom/atom Coverage Factor: 1															
$X_{45\text{Day}2}$ :	Type A Method of observation: Direct Number of observations: 6															
	<table><tr><th>No.</th><th>Observation</th></tr><tr><td>1</td><td>0.009723 atom/atom</td></tr><tr><td>2</td><td>0.009706 atom/atom</td></tr><tr><td>3</td><td>0.009733 atom/atom</td></tr><tr><td>4</td><td>0.009705 atom/atom</td></tr><tr><td>5</td><td>0.009710 atom/atom</td></tr><tr><td>6</td><td>0.009720 atom/atom</td></tr></table>		No.	Observation	1	0.009723 atom/atom	2	0.009706 atom/atom	3	0.009733 atom/atom	4	0.009705 atom/atom	5	0.009710 atom/atom	6	0.009720 atom/atom
No.	Observation															
1	0.009723 atom/atom															
2	0.009706 atom/atom															
3	0.009733 atom/atom															
4	0.009705 atom/atom															
5	0.009710 atom/atom															
6	0.009720 atom/atom															
	Arithmetic Mean: $9.71617 \cdot 10^{-3}$ atom/atom Pooled Standard Deviation: 0.0000054115 atom/atom Pooled Degrees of Freedom: 49 Standard Uncertainty: $2.51 \cdot 10^{-6}$ atom/atom															
$\delta_{45\text{BCFDay}2}$ :	Type B normal distribution Value: 1 atom/atom Expanded Uncertainty: 0.00024954 atom/atom Coverage Factor: 1															
Date: 12/01/2010	File: PTRM10-1.1 11-29-10KLN.smu	Page 3 of 8														

	GUM for PTRM-10-1.1																														
<div><div><div><div>X<sub>65Day1</sub>:</div><div>Type A</div><div>Method of observation: Direct</div><div>Number of observations: 5</div><div><table><tr><th>No.</th><th>Observation</th></tr><tr><td>1</td><td>0.015163 atom/atom</td></tr><tr><td>2</td><td>0.015175 atom/atom</td></tr><tr><td>3</td><td>0.015176 atom/atom</td></tr><tr><td>4</td><td>0.015148 atom/atom</td></tr><tr><td>5</td><td>0.015172 atom/atom</td></tr></table></div><div>Arithmetic Mean: 0.01516680 atom/atom</div><div>Pooled Standard Deviation: 0.0000051930 atom/atom</div><div>Pooled Degrees of Freedom: 49</div><div>Standard Uncertainty: 2.66·10<sup>-6</sup> atom/atom</div></div><div><div><div>δ<sub>65BCFDay1</sub>:</div><div>Type B normal distribution</div><div>Value: 1 atom/atom</div><div>Expanded Uncertainty: 0.00071524 atom/atom</div><div>Coverage Factor: 1</div></div><div><div><div>X<sub>65Day2</sub>:</div><div>Type A</div><div>Method of observation: Direct</div><div>Number of observations: 6</div><div><table><tr><th>No.</th><th>Observation</th></tr><tr><td>1</td><td>0.015109 atom/atom</td></tr><tr><td>2</td><td>0.015142 atom/atom</td></tr><tr><td>3</td><td>0.015133 atom/atom</td></tr><tr><td>4</td><td>0.015152 atom/atom</td></tr><tr><td>5</td><td>0.015120 atom/atom</td></tr><tr><td>6</td><td>0.015129 atom/atom</td></tr></table></div><div>Arithmetic Mean: 0.01513083 atom/atom</div><div>Pooled Standard Deviation: 0.0000076187 atom/atom</div><div>Pooled Degrees of Freedom: 49</div><div>Standard Uncertainty: 3.52·10<sup>-6</sup> atom/atom</div></div><div><div><div>δ<sub>65BCFDay2</sub>:</div><div>Type B normal distribution</div><div>Value: 1 atom/atom</div><div>Expanded Uncertainty: 0.00024954 atom/atom</div><div>Coverage Factor: 1</div></div></div></div></div></div><tr><td>Date: 12/01/2010</td><td>File: PTRM10-1.1 11-29-10KLN.smu</td><td>Page 4 of 8</td></tr></div>			No.	Observation	1	0.015163 atom/atom	2	0.015175 atom/atom	3	0.015176 atom/atom	4	0.015148 atom/atom	5	0.015172 atom/atom	No.	Observation	1	0.015109 atom/atom	2	0.015142 atom/atom	3	0.015133 atom/atom	4	0.015152 atom/atom	5	0.015120 atom/atom	6	0.015129 atom/atom	Date: 12/01/2010	File: PTRM10-1.1 11-29-10KLN.smu	Page 4 of 8
No.	Observation																														
1	0.015163 atom/atom																														
2	0.015175 atom/atom																														
3	0.015176 atom/atom																														
4	0.015148 atom/atom																														
5	0.015172 atom/atom																														
No.	Observation																														
1	0.015109 atom/atom																														
2	0.015142 atom/atom																														
3	0.015133 atom/atom																														
4	0.015152 atom/atom																														
5	0.015120 atom/atom																														
6	0.015129 atom/atom																														
Date: 12/01/2010	File: PTRM10-1.1 11-29-10KLN.smu	Page 4 of 8																													

	GUM for PTRM-10-1.1															
$\bar{X}_{85\text{Day1}}$ :	Type A Method of observation: Direct Number of observations: 5 <table><tr><td>No.</td><td>Observation</td></tr><tr><td>1</td><td>0.5505 atom/atom</td></tr><tr><td>2</td><td>0.5515 atom/atom</td></tr><tr><td>3</td><td>0.5512 atom/atom</td></tr><tr><td>4</td><td>0.5512 atom/atom</td></tr><tr><td>5</td><td>0.5511 atom/atom</td></tr></table> Arithmetic Mean: 0.5511000 atom/atom Pooled Standard Deviation: 0.00015172 atom/atom Pooled Degrees of Freedom: 49 Standard Uncertainty: $79.3 \cdot 10^{-6}$ atom/atom		No.	Observation	1	0.5505 atom/atom	2	0.5515 atom/atom	3	0.5512 atom/atom	4	0.5512 atom/atom	5	0.5511 atom/atom		
No.	Observation															
1	0.5505 atom/atom															
2	0.5515 atom/atom															
3	0.5512 atom/atom															
4	0.5512 atom/atom															
5	0.5511 atom/atom															
$\delta_{85\text{BCFDay1}}$ :	Type B normal distribution Value: 1 atom/atom Expanded Uncertainty: 0.0021457 atom/atom Coverage Factor: 1															
$\bar{X}_{85\text{Day2}}$ :	Type A Method of observation: Direct Number of observations: 6 <table><tr><td>No.</td><td>Observation</td></tr><tr><td>1</td><td>0.55024 atom/atom</td></tr><tr><td>2</td><td>0.54991 atom/atom</td></tr><tr><td>3</td><td>0.55028 atom/atom</td></tr><tr><td>4</td><td>0.55155 atom/atom</td></tr><tr><td>5</td><td>0.54991 atom/atom</td></tr><tr><td>6</td><td>0.54973 atom/atom</td></tr></table> Arithmetic Mean: 0.550270 atom/atom Pooled Standard Deviation: 0.00030197 atom/atom Pooled Degrees of Freedom: 49 Standard Uncertainty: $143 \cdot 10^{-6}$ atom/atom		No.	Observation	1	0.55024 atom/atom	2	0.54991 atom/atom	3	0.55028 atom/atom	4	0.55155 atom/atom	5	0.54991 atom/atom	6	0.54973 atom/atom
No.	Observation															
1	0.55024 atom/atom															
2	0.54991 atom/atom															
3	0.55028 atom/atom															
4	0.55155 atom/atom															
5	0.54991 atom/atom															
6	0.54973 atom/atom															
$\delta_{85\text{BCFDay2}}$ :	Type B normal distribution Value: 1 atom/atom Expanded Uncertainty: 0.00074862 atom/atom Coverage Factor: 1															
Date: 12/01/2010	File: PTRM10-1.1 11-29-10KLN.smu	Page 5 of 8														

GUM for PTRM-10-1.1						
<b>Uncertainty Budgets:</b> <b>combined<sub>avg35</sub>: combined average 23/25 sample ratio</b>						
Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$X_{35\text{Day1}}$	$2.1484 \cdot 10^{-6}$ atom/atom	1.6 % (rel)	normal	0.50	$17 \cdot 10^{-9}$ atom/atom	31.2 %
$\delta_{35\text{BCFDay1}}$	1.00000 atom/atom	0.14 % (rel)	normal	$1.1 \cdot 10^{-6}$	$1.5 \cdot 10^{-9}$ atom/atom	0.3 %
$X_{35\text{Day2}}$	$2.3808 \cdot 10^{-6}$ atom/atom	2.0 % (rel)	normal	0.50	$24 \cdot 10^{-9}$ atom/atom	65.4 %
$\delta_{35\text{BCFDay2}}$	1.000000 atom/atom	0.050 % (rel)	normal	$1.2 \cdot 10^{-6}$	$590 \cdot 10^{-12}$ atom/atom	0.0 %
$\delta_{\text{Repeatability}}$	1.00000 atom/atom	0.11 % (rel)	normal	$2.3 \cdot 10^{-6}$	$2.5 \cdot 10^{-9}$ atom/atom	0.7 %
$\delta_{\text{Reproducibility}}$	1.00000 atom/atom	0.21 % (rel)	normal	$2.3 \cdot 10^{-6}$	$4.8 \cdot 10^{-9}$ atom/atom	2.5 %
combined <sub>a</sub> vg35	$2.2646 \cdot 10^{-6}$ atom/atom	$30.2 \cdot 10^{-9}$ atom/atom				
<b>combined<sub>avg45</sub>: combined average 24/25 sample ratio</b>						
Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$\delta_{\text{Repeatability}}$	1.00000 atom/atom	0.11 % (rel)	normal	$9.7 \cdot 10^{-3}$	$11 \cdot 10^{-6}$ atom/atom	21.3 %
$\delta_{\text{Reproducibility}}$	1.00000 atom/atom	0.21 % (rel)	normal	$9.7 \cdot 10^{-3}$	$20 \cdot 10^{-6}$ atom/atom	75.3 %
$X_{45\text{Day1}}$	$9.75920 \cdot 10^{-3}$ atom/atom	0.038 % (rel)	normal	0.50	$1.9 \cdot 10^{-6}$ atom/atom	0.6 %
$\delta_{45\text{BCFDay1}}$	1.000000 atom/atom	0.072 % (rel)	normal	$4.9 \cdot 10^{-3}$	$3.5 \cdot 10^{-6}$ atom/atom	2.2 %
$X_{45\text{Day2}}$	$9.71617 \cdot 10^{-3}$ atom/atom	0.026 % (rel)	normal	0.50	$1.3 \cdot 10^{-6}$ atom/atom	0.3 %
$\delta_{45\text{BCFDay2}}$	1.000000 atom/atom	0.025 % (rel)	normal	$4.9 \cdot 10^{-3}$	$1.2 \cdot 10^{-6}$ atom/atom	0.3 %
combined <sub>a</sub> vg45	$9.7377 \cdot 10^{-3}$ atom/atom	$23.6 \cdot 10^{-6}$ atom/atom				
Date: 12/01/2010	File: PTRM10-1.1 11-29-10KLN.smu				Page 6 of 8	

GUM for PTRM-10-1.1						
<b>combined<sub>avg65</sub>: combined average 26/25 sample ratio</b>						
Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$\delta_{\text{Repeatability}}$	1.00000 atom/atom	0.11 % (rel)	normal	0.015	$17 \cdot 10^{-6}$ atom/atom	21.4 %
$\delta_{\text{Reproducibility}}$	1.00000 atom/atom	0.21 % (rel)	normal	0.015	$32 \cdot 10^{-6}$ atom/atom	75.8 %
$X_{65\text{Day1}}$	0.01516680 atom/atom	0.018 % (rel)	normal	0.50	$1.3 \cdot 10^{-6}$ atom/atom	0.1 %
$\delta_{65\text{BCFDay1}}$	1.000000 atom/atom	0.072 % (rel)	normal	$7.6 \cdot 10^{-3}$	$5.4 \cdot 10^{-6}$ atom/atom	2.2 %
$X_{65\text{Day2}}$	0.01513083 atom/atom	0.023 % (rel)	normal	0.50	$1.8 \cdot 10^{-6}$ atom/atom	0.2 %
$\delta_{65\text{BCFDay2}}$	1.000000 atom/atom	0.025 % (rel)	normal	$7.6 \cdot 10^{-3}$	$1.9 \cdot 10^{-6}$ atom/atom	0.3 %
combined <sub>a</sub> vg65	0.0151488 atom/atom	$36.6 \cdot 10^{-6}$ atom/atom				
<b>combined<sub>avg85</sub>: combined average 28/25 sample ratio</b>						
Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
$\delta_{\text{Repeatability}}$	1.00000 atom/atom	0.11 % (rel)	normal	0.55	$620 \cdot 10^{-6}$ atom/atom	17.9 %
$\delta_{\text{Reproducibility}}$	1.00000 atom/atom	0.21 % (rel)	normal	0.55	$1.2 \cdot 10^{-3}$ atom/atom	63.3 %
$X_{85\text{Day1}}$	0.5511000 atom/atom	0.014 % (rel)	normal	0.50	$40 \cdot 10^{-6}$ atom/atom	0.0 %
$\delta_{85\text{BCFDay1}}$	1.00000 atom/atom	0.21 % (rel)	normal	0.28	$590 \cdot 10^{-6}$ atom/atom	16.5 %
$X_{85\text{Day2}}$	0.550270 atom/atom	0.026 % (rel)	normal	0.50	$72 \cdot 10^{-6}$ atom/atom	0.2 %
$\delta_{85\text{BCFDay2}}$	1.000000 atom/atom	0.075 % (rel)	normal	0.28	$210 \cdot 10^{-6}$ atom/atom	2.0 %
combined <sub>a</sub> vg85	0.55068 atom/atom	$1.46 \cdot 10^{-3}$ atom/atom				
Date: 12/01/2010	File: PTRM10-1.1 11-29-10KLN.smu				Page 7 of 8	

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## Exhibit B.2: Uncertainty Budgets from PTRM10-1.2.

	GUM for PTRM-10-1.2		
<b>GUM for PTRM-10-1.2</b>			
Author: d3m597			
Modified to simplify. RSD (or delta) values come from spreadsheet containing all CRM-129A data and calculated individual BCF delta factors.			
<b>Model Equation:</b>			
$\text{combined}_{\text{avg48}} = ((X_{48\text{Day1}} * \delta_{48\text{BCFDay1}} + X_{48\text{Day2}} * \delta_{48\text{BCFDay2}}) / 2) * \delta_{\text{Repeatability}} * \delta_{\text{Reproducibility}}$			
$\text{combined}_{\text{avg58}} = ((X_{58\text{Day1}} * \delta_{58\text{BCFDay1}} + X_{58\text{Day2}} * \delta_{58\text{BCFDay2}}) / 2) * \delta_{\text{Repeatability}} * \delta_{\text{Reproducibility}}$			
$\text{combined}_{\text{avg68}} = ((X_{68\text{Day1}} * \delta_{68\text{BCFDay1}} + X_{68\text{Day2}} * \delta_{68\text{BCFDay2}}) / 2) * \delta_{\text{Repeatability}} * \delta_{\text{Reproducibility}}$			
<b>List of Quantities:</b>			
<b>Quantity</b>	<b>Unit</b>	<b>Definition</b>	
combined <sub>avg48</sub>	atom/atom	combined average of 24/28 of sample	
X <sub>48Day1</sub>	atom/atom	average value of 24/28 of sample for day 1	
δ <sub>48BCFDay1</sub>	atom/atom	delta factor for relative uncertainty for bias correction factor for 24/28 ratio for Day 1	
X <sub>48Day2</sub>	atom/atom	average value of 24/28 of sample for day 2	
δ <sub>48BCFDay2</sub>	atom/atom	delta factor for relative uncertainty for bias correction factor for 24/28 ratio for Day 2	
δ <sub>Repeatability</sub>	atom/atom	delta factor for relative uncertainty characterizing intra-day repeatability of 25/28 for control standard	
δ <sub>Reproducibility</sub>	atom/atom	delta factor for relative uncertainty characterizing day-to-day reproducibility of 25/28 for control standard	
combined <sub>avg58</sub>	atom/atom	combined average of the 25/28 of the sample	
X <sub>58Day1</sub>	atom/atom	average value of the 25/28 of sample for day 1	
δ <sub>58BCFDay1</sub>	atom/atom	delta factor for relative uncertainty for bias correction factor for 25/28 ratio for Day 1	
X <sub>58Day2</sub>	atom/atom	average value of the 25/28 of sample for day 2	
δ <sub>58BCFDay2</sub>	atom/atom	delta factor for relative uncertainty for bias correction factor for 25/28 ratio for Day 2	
combined <sub>avg68</sub>	atom/atom	combined average of the 26/28 of the sample	
X <sub>68Day1</sub>	atom/atom	average value of the 26/28 of sample for day 1	
δ <sub>68BCFDay1</sub>	atom/atom	delta factor for relative uncertainty for bias correction factor for 26/28 ratio for Day 1	
X <sub>68Day2</sub>	atom/atom	average value of the 26/28 of sample for day 2	
δ <sub>68BCFDay2</sub>	atom/atom	delta factor for relative uncertainty for bias correction factor for 26/28 ratio for Day 2	

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GUM for PTRM-10-1.2													
$X_{48\text{Day1}}$	<p>Type A  Method of observation: Direct  Number of observations: 5</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>No.</th> <th>Observation</th> </tr> </thead> <tbody> <tr><td>1</td><td>0.0004113 atom/atom</td></tr> <tr><td>2</td><td>0.0004080 atom/atom</td></tr> <tr><td>3</td><td>0.0004089 atom/atom</td></tr> <tr><td>4</td><td>0.0004117 atom/atom</td></tr> <tr><td>5</td><td>0.0004019 atom/atom</td></tr> </tbody> </table> <p>Arithmetic Mean: <math>408.360 \cdot 10^{-6}</math> atom/atom  Pooled Standard Deviation: 0.0000017561 atom/atom  Pooled Degrees of Freedom: 49  Standard Uncertainty: <math>897 \cdot 10^{-9}</math> atom/atom</p> <p>24/28 for day 1</p>	No.	Observation	1	0.0004113 atom/atom	2	0.0004080 atom/atom	3	0.0004089 atom/atom	4	0.0004117 atom/atom	5	0.0004019 atom/atom
No.	Observation												
1	0.0004113 atom/atom												
2	0.0004080 atom/atom												
3	0.0004089 atom/atom												
4	0.0004117 atom/atom												
5	0.0004019 atom/atom												
$\delta_{48\text{BCFDay1}}$	<p>Type B normal distribution  Value: 1 atom/atom  Expanded Uncertainty: 0.0019145 atom/atom  Coverage Factor: 1</p>												
$X_{48\text{Day2}}$	<p>Type A  Method of observation: Direct  Number of observations: 5</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>No.</th> <th>Observation</th> </tr> </thead> <tbody> <tr><td>1</td><td>0.0004039 atom/atom</td></tr> <tr><td>2</td><td>0.0004068 atom/atom</td></tr> <tr><td>3</td><td>0.0004092 atom/atom</td></tr> <tr><td>4</td><td>0.0004074 atom/atom</td></tr> <tr><td>5</td><td>0.0004060 atom/atom</td></tr> </tbody> </table> <p>Arithmetic Mean: <math>406.660 \cdot 10^{-6}</math> atom/atom  Pooled Standard Deviation: 0.00000087989 atom/atom  Pooled Degrees of Freedom: 49  Standard Uncertainty: <math>447 \cdot 10^{-9}</math> atom/atom</p> <p>24/28 day 2</p>	No.	Observation	1	0.0004039 atom/atom	2	0.0004068 atom/atom	3	0.0004092 atom/atom	4	0.0004074 atom/atom	5	0.0004060 atom/atom
No.	Observation												
1	0.0004039 atom/atom												
2	0.0004068 atom/atom												
3	0.0004092 atom/atom												
4	0.0004074 atom/atom												
5	0.0004060 atom/atom												
$\delta_{48\text{BCFDay2}}$	<p>Type B normal distribution  Value: 1 atom/atom  Expanded Uncertainty: 0.0010210 atom/atom  Coverage Factor: 1</p>												
$\delta_{\text{Repeatability}}$	<p>Type B normal distribution  Value: 1 atom/atom  Expanded Uncertainty: 0.0011178 atom/atom  Coverage Factor: 1</p>												
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	GUM for PTRM-10-1.2													
$\delta_{\text{Reproducibility}}$ :	Type B normal distribution Value: 1 atom/atom Expanded Uncertainty: 0.0021029 atom/atom Coverage Factor: 1													
$x_{58\text{Day1}}$ :	Type A Method of observation: Direct Number of observations: 5 <table><tr><td>No.</td><td>Observation</td></tr><tr><td>1</td><td>0.047457 atom/atom</td></tr><tr><td>2</td><td>0.047397 atom/atom</td></tr><tr><td>3</td><td>0.04735 atom/atom</td></tr><tr><td>4</td><td>0.047530 atom/atom</td></tr><tr><td>5</td><td>0.047134 atom/atom</td></tr></table> Arithmetic Mean: 0.0473736 atom/atom Pooled Standard Deviation: 0.000067050 atom/atom Pooled Degrees of Freedom: 49 Standard Uncertainty: $34.2 \cdot 10^{-6}$ atom/atom		No.	Observation	1	0.047457 atom/atom	2	0.047397 atom/atom	3	0.04735 atom/atom	4	0.047530 atom/atom	5	0.047134 atom/atom
No.	Observation													
1	0.047457 atom/atom													
2	0.047397 atom/atom													
3	0.04735 atom/atom													
4	0.047530 atom/atom													
5	0.047134 atom/atom													
$\delta_{58\text{BCFDay1}}$ :	Type B normal distribution Value: 1 atom/atom Expanded Uncertainty: 0.0014358 atom/atom Coverage Factor: 1													
$x_{58\text{Day2}}$ :	Type A Method of observation: Direct Number of observations: 5 <table><tr><td>No.</td><td>Observation</td></tr><tr><td>1</td><td>0.047363 atom/atom</td></tr><tr><td>2</td><td>0.047461 atom/atom</td></tr><tr><td>3</td><td>0.047386 atom/atom</td></tr><tr><td>4</td><td>0.047402 atom/atom</td></tr><tr><td>5</td><td>0.047265 atom/atom</td></tr></table> Arithmetic Mean: 0.0473754 atom/atom Pooled Standard Deviation: 0.000032086 atom/atom Pooled Degrees of Freedom: 49 Standard Uncertainty: $16.4 \cdot 10^{-6}$ atom/atom		No.	Observation	1	0.047363 atom/atom	2	0.047461 atom/atom	3	0.047386 atom/atom	4	0.047402 atom/atom	5	0.047265 atom/atom
No.	Observation													
1	0.047363 atom/atom													
2	0.047461 atom/atom													
3	0.047386 atom/atom													
4	0.047402 atom/atom													
5	0.047265 atom/atom													
$\delta_{58\text{BCFDay2}}$ :	Type B normal distribution Value: 1 atom/atom Expanded Uncertainty: 0.00076574 atom/atom Coverage Factor: 1													
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	GUM for PTRM-10-1.2													
$\bar{X}_{68\text{Day1}}:$	<p>Type A</p> <p>Method of observation: Direct</p> <p>Number of observations: 5</p> <table><tr><td>No.</td><td>Observation</td></tr><tr><td>1</td><td>0.0002900 atom/atom</td></tr><tr><td>2</td><td>0.0002903 atom/atom</td></tr><tr><td>3</td><td>0.0002899 atom/atom</td></tr><tr><td>4</td><td>0.0002915 atom/atom</td></tr><tr><td>5</td><td>0.0002898 atom/atom</td></tr></table> <p>Arithmetic Mean: <math>290.300 \cdot 10^{-6}</math> atom/atom</p> <p>Pooled Standard Deviation: <math>0.00000029944</math> atom/atom</p> <p>Pooled Degrees of Freedom: 49</p> <p>Standard Uncertainty: <math>155 \cdot 10^{-9}</math> atom/atom</p>		No.	Observation	1	0.0002900 atom/atom	2	0.0002903 atom/atom	3	0.0002899 atom/atom	4	0.0002915 atom/atom	5	0.0002898 atom/atom
No.	Observation													
1	0.0002900 atom/atom													
2	0.0002903 atom/atom													
3	0.0002899 atom/atom													
4	0.0002915 atom/atom													
5	0.0002898 atom/atom													
$\delta_{68\text{BCFDay1}}:$	<p>Type B normal distribution</p> <p>Value: 1 atom/atom</p> <p>Expanded Uncertainty: <math>0.00095723</math> atom/atom</p> <p>Coverage Factor: 1</p>													
$\bar{X}_{68\text{Day2}}:$	<p>Type A</p> <p>Method of observation: Direct</p> <p>Number of observations: 5</p> <table><tr><td>No.</td><td>Observation</td></tr><tr><td>1</td><td>0.0002877 atom/atom</td></tr><tr><td>2</td><td>0.0002896 atom/atom</td></tr><tr><td>3</td><td>0.0002892 atom/atom</td></tr><tr><td>4</td><td>0.0002905 atom/atom</td></tr><tr><td>5</td><td>0.0002884 atom/atom</td></tr></table> <p>Arithmetic Mean: <math>289.080 \cdot 10^{-6}</math> atom/atom</p> <p>Pooled Standard Deviation: <math>0.00000047847</math> atom/atom</p> <p>Pooled Degrees of Freedom: 49</p> <p>Standard Uncertainty: <math>245 \cdot 10^{-9}</math> atom/atom</p>		No.	Observation	1	0.0002877 atom/atom	2	0.0002896 atom/atom	3	0.0002892 atom/atom	4	0.0002905 atom/atom	5	0.0002884 atom/atom
No.	Observation													
1	0.0002877 atom/atom													
2	0.0002896 atom/atom													
3	0.0002892 atom/atom													
4	0.0002905 atom/atom													
5	0.0002884 atom/atom													
$\delta_{68\text{BCFDay2}}:$	<p>Type B normal distribution</p> <p>Value: 1 atom/atom</p> <p>Expanded Uncertainty: <math>0.00051050</math> atom/atom</p> <p>Coverage Factor: 1</p>													
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GUM for PTRM-10-1.2						
<b>Uncertainty Budgets:</b> <b>combined<sub>avg48</sub>: combined average of 24/28 of sample</b>						
Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
X <sub>48Day1</sub>	408.360·10 <sup>-6</sup> atom/atom	0.22 % (rel)	normal	0.50	450·10 <sup>-9</sup> atom/atom	14.5 %
δ <sub>48BCFDay1</sub>	1.00000 atom/atom	0.19 % (rel)	normal	200·10 <sup>-6</sup>	390·10 <sup>-9</sup> atom/atom	11.0 %
X <sub>48Day2</sub>	406.660·10 <sup>-6</sup> atom/atom	0.11 % (rel)	normal	0.50	220·10 <sup>-9</sup> atom/atom	3.6 %
δ <sub>48BCFDay2</sub>	1.00000 atom/atom	0.10 % (rel)	normal	200·10 <sup>-6</sup>	210·10 <sup>-9</sup> atom/atom	3.1 %
δ <sub>Repeatability</sub>	1.00000 atom/atom	0.11 % (rel)	normal	410·10 <sup>-6</sup>	460·10 <sup>-9</sup> atom/atom	14.9 %
δ <sub>Reproducibility</sub>	1.00000 atom/atom	0.21 % (rel)	normal	410·10 <sup>-6</sup>	860·10 <sup>-9</sup> atom/atom	52.9 %
combined <sub>a</sub> vg48	407.51·10 <sup>-6</sup> atom/atom	1.18·10 <sup>-6</sup> atom/atom				
<b>combined<sub>avg58</sub>: combined average of the 25/28 of the sample</b>						
Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
δ <sub>Repeatability</sub>	1.00000 atom/atom	0.11 % (rel)	normal	0.047	53·10 <sup>-6</sup> atom/atom	19.2 %
δ <sub>Reproducibility</sub>	1.00000 atom/atom	0.21 % (rel)	normal	0.047	100·10 <sup>-6</sup> atom/atom	68.1 %
X <sub>58Day1</sub>	0.0473736 atom/atom	0.072 % (rel)	normal	0.50	17·10 <sup>-6</sup> atom/atom	2.0 %
δ <sub>58BCFDay1</sub>	1.00000 atom/atom	0.14 % (rel)	normal	0.024	34·10 <sup>-6</sup> atom/atom	7.9 %
X <sub>58Day2</sub>	0.0473754 atom/atom	0.035 % (rel)	normal	0.50	8.2·10 <sup>-6</sup> atom/atom	0.5 %
δ <sub>58BCFDay2</sub>	1.000000 atom/atom	0.077 % (rel)	normal	0.024	18·10 <sup>-6</sup> atom/atom	2.3 %
combined <sub>a</sub> vg58	0.047374 atom/atom	121·10 <sup>-6</sup> atom/atom				
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		GUM for PTRM-10-1.2				
<b>combined<sub>avg68</sub>:    combined average of the 26/28 of the sample</b>						
Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
δ <sub>Repeatability</sub>	1.00000 atom/atom	0.11 % (rel)	normal	290·10 <sup>-6</sup>	320·10 <sup>-9</sup> atom/atom	20.1 %
δ <sub>Reproducibility</sub>	1.00000 atom/atom	0.21 % (rel)	normal	290·10 <sup>-6</sup>	610·10 <sup>-9</sup> atom/atom	71.1 %
X <sub>68Day1</sub>	290.300·10 <sup>-6</sup> atom/atom	0.053 % (rel)	normal	0.50	77·10 <sup>-9</sup> atom/atom	1.1 %
δ <sub>68BCFDay1</sub>	1.000000 atom/atom	0.096 % (rel)	normal	150·10 <sup>-6</sup>	140·10 <sup>-9</sup> atom/atom	3.7 %
X <sub>68Day2</sub>	289.080·10 <sup>-6</sup> atom/atom	0.085 % (rel)	normal	0.50	120·10 <sup>-9</sup> atom/atom	2.9 %
δ <sub>68BCFDay2</sub>	1.000000 atom/atom	0.051 % (rel)	normal	140·10 <sup>-6</sup>	74·10 <sup>-9</sup> atom/atom	1.0 %
combined <sub>a</sub> vg68	289.690·10 <sup>-6</sup> atom/atom	722·10 <sup>-9</sup> atom/atom				

Results:

Quantity	Value	Expanded Uncertainty	Coverage factor	Coverage
combined <sub>avg48</sub>	407.5·10 <sup>-6</sup> atom/atom	2.4·10 <sup>-6</sup> atom/atom	2.00	95% (t-table 95.45%)
combined <sub>avg58</sub>	0.04737 atom/atom	240·10 <sup>-6</sup> atom/atom	2.00	95% (t-table 95.45%)
combined <sub>avg68</sub>	289.7·10 <sup>-6</sup> atom/atom	1.4·10 <sup>-6</sup> atom/atom	2.00	95% (t-table 95.45%)

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### Exhibit B.3: Uncertainty Budgets from PTRM10-3.1.

	GUM for PTRM-10-3.1		
<b>GUM for PTRM-10-3.1</b>			
Author: d3m597			
Modified to simplify. RSD (or delta) values come from spreadsheet containing all CRM-129A data and calculated individual BCF delta factors.			
<b>Model Equation:</b>			
$\text{combined}_{\text{avg48}} = ((X_{48\text{Day1}} * \delta_{48\text{BCFDay1}} + X_{48\text{Day2}} * \delta_{48\text{BCFDay2}}) / 2) * \delta_{\text{Repeatability}} * \delta_{\text{Reproducibility}};$			
$\text{combined}_{\text{avg58}} = ((X_{58\text{Day1}} * \delta_{58\text{BCFDay1}} + X_{58\text{Day2}} * \delta_{58\text{BCFDay2}}) / 2) * \delta_{\text{Repeatability}} * \delta_{\text{Reproducibility}};$			
$\text{combined}_{\text{avg68}} = ((X_{68\text{Day1}} * \delta_{68\text{BCFDay1}} + X_{68\text{Day2}} * \delta_{68\text{BCFDay2}}) / 2) * \delta_{\text{Repeatability}} * \delta_{\text{Reproducibility}};$			
<b>List of Quantities:</b>			
<b>Quantity</b>	<b>Unit</b>	<b>Definition</b>	
combined <sub>avg48</sub>	atom/atom	combined average of 24/28 of sample	
X <sub>48Day1</sub>	atom/atom	average value of 24/28 of sample for day 1	
δ <sub>48BCFDay1</sub>	atom/atom	delta factor for relative uncertainty for bias correction factor for 24/28 ratio for Day 1	
X <sub>48Day2</sub>	atom/atom	average value of 24/28 of sample for day 2	
δ <sub>48BCFDay2</sub>	atom/atom	delta factor for relative uncertainty for bias correction factor for 24/28 ratio for Day 1	
δ <sub>Repeatability</sub>	atom/atom	delta factor for relative uncertainty characterizing intra-day repeatability of 25/28 for control standard	
δ <sub>Reproducibility</sub>	atom/atom	delta factor for relative uncertainty characterizing day-to-day reproducibility of 25/28 for control standard	
combined <sub>avg58</sub>	atom/atom	combined average of the 25/28 of the sample	
X <sub>58Day1</sub>	atom/atom	average value of the 25/28 of sample for day 1	
δ <sub>58BCFDay1</sub>	atom/atom	delta factor for relative uncertainty for bias correction factor for 25/28 ratio for Day 1	
X <sub>58Day2</sub>	atom/atom	average value of the 25/28 of sample for day 2	
δ <sub>58BCFDay2</sub>	atom/atom	delta factor for relative uncertainty for bias correction factor for 25/28 ratio for Day 2	
combined <sub>avg68</sub>	atom/atom	combined average of the 26/28 of the sample	
X <sub>68Day1</sub>	atom/atom	average value of the 26/28 of sample for day 1	
δ <sub>68BCFDay1</sub>	atom/atom	delta factor for relative uncertainty for bias correction factor for 26/28 ratio for Day 1	
X <sub>68Day2</sub>	atom/atom	average value of the 26/28 of sample for day 2	
δ <sub>68BCFDay2</sub>	atom/atom	delta factor for relative uncertainty for bias correction factor for 26/28 ratio for Day 2	
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	GUM for PTRM-10-3.1																											
$X_{48\text{Day1}}^{\circ}$	<div>Type A</div> <div>Method of observation: Direct</div> <div>Number of observations: 5</div> <table><tr><th>No.</th><th>Observation</th></tr><tr><td>1</td><td>0.0004946 atom/atom</td></tr><tr><td>2</td><td>0.0004919 atom/atom</td></tr><tr><td>3</td><td>0.0004885 atom/atom</td></tr><tr><td>4</td><td>0.0004945 atom/atom</td></tr><tr><td>5</td><td>0.0004907 atom/atom</td></tr></table> <div>Arithmetic Mean: <math>492.040 \cdot 10^{-6}</math> atom/atom</div> <div>Pooled Standard Deviation: 0.0000011575 atom/atom</div> <div>Pooled Degrees of Freedom: 49</div> <div>Standard Uncertainty: <math>591 \cdot 10^{-9}</math> atom/atom</div> <div>24/28 for day 1</div> <div><math>\delta_{48\text{BCFDay1}}^{\circ}</math></div> <div>Type B normal distribution</div> <div>Value: 1 atom/atom</div> <div>Expanded Uncertainty: 0.0011962 atom/atom</div> <div>Coverage Factor: 1</div> <div><math>X_{48\text{Day2}}^{\circ}</math></div> <div>Type A</div> <div>Method of observation: Direct</div> <div>Number of observations: 6</div> <table><tr><th>No.</th><th>Observation</th></tr><tr><td>1</td><td>0.0004932 atom/atom</td></tr><tr><td>2</td><td>0.0004985 atom/atom</td></tr><tr><td>3</td><td>0.0004944 atom/atom</td></tr><tr><td>4</td><td>0.0004905 atom/atom</td></tr><tr><td>5</td><td>0.0004957 atom/atom</td></tr><tr><td>6</td><td>0.0004953 atom/atom</td></tr></table> <div>Arithmetic Mean: <math>494.600 \cdot 10^{-6}</math> atom/atom</div> <div>Pooled Standard Deviation: 0.0000012009 atom/atom</div> <div>Pooled Degrees of Freedom: 49</div> <div>Standard Uncertainty: <math>573 \cdot 10^{-9}</math> atom/atom</div> <div>24/28 day 2</div> <div><math>\delta_{48\text{BCFDay2}}^{\circ}</math></div> <div>Type B normal distribution</div> <div>Value: 1 atom/atom</div> <div>Expanded Uncertainty: 0.0012480 atom/atom</div> <div>Coverage Factor: 1</div> <div><math>\delta_{\text{Repeatability}}^{\circ}</math></div> <div>Type B normal distribution</div> <div>Value: 1 atom/atom</div> <div>Expanded Uncertainty: 0.0011178 atom/atom</div> <div>Coverage Factor: 1</div>		No.	Observation	1	0.0004946 atom/atom	2	0.0004919 atom/atom	3	0.0004885 atom/atom	4	0.0004945 atom/atom	5	0.0004907 atom/atom	No.	Observation	1	0.0004932 atom/atom	2	0.0004985 atom/atom	3	0.0004944 atom/atom	4	0.0004905 atom/atom	5	0.0004957 atom/atom	6	0.0004953 atom/atom
No.	Observation																											
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5	0.0004907 atom/atom																											
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5	0.0004957 atom/atom																											
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Date: 12/01/2010	File: PTRM10-3.1 11-29-10KLN.smu	Page 2 of 6																										



	GUM for PTRM-10-3.1															
$\delta_{\text{Reproducibility}}$ :	Type B normal distribution Value: 1 atom/atom Expanded Uncertainty: 0.0021029 atom/atom Coverage Factor: 1															
$x_{58\text{Day1}}$ :	Type A Method of observation: Direct Number of observations: 5 <table><tr><td>No.</td><td>Observation</td></tr><tr><td>1</td><td>0.052825 atom/atom</td></tr><tr><td>2</td><td>0.05260 atom/atom</td></tr><tr><td>3</td><td>0.052737 atom/atom</td></tr><tr><td>4</td><td>0.052800 atom/atom</td></tr><tr><td>5</td><td>0.052760 atom/atom</td></tr></table> Arithmetic Mean: 0.0527444 atom/atom Pooled Standard Deviation: 0.000038588 atom/atom Pooled Degrees of Freedom: 49 Standard Uncertainty: $19.8 \cdot 10^{-6}$ atom/atom		No.	Observation	1	0.052825 atom/atom	2	0.05260 atom/atom	3	0.052737 atom/atom	4	0.052800 atom/atom	5	0.052760 atom/atom		
No.	Observation															
1	0.052825 atom/atom															
2	0.05260 atom/atom															
3	0.052737 atom/atom															
4	0.052800 atom/atom															
5	0.052760 atom/atom															
$\delta_{58\text{BCFDay1}}$ :	Type B normal distribution Value: 1 atom/atom Expanded Uncertainty: 0.00089717 atom/atom Coverage Factor: 1															
$x_{58\text{Day2}}$ :	Type A Method of observation: Direct Number of observations: 6 <table><tr><td>No.</td><td>Observation</td></tr><tr><td>1</td><td>0.05301 atom/atom</td></tr><tr><td>2</td><td>0.052921 atom/atom</td></tr><tr><td>3</td><td>0.052978 atom/atom</td></tr><tr><td>4</td><td>0.052874 atom/atom</td></tr><tr><td>5</td><td>0.053020 atom/atom</td></tr><tr><td>6</td><td>0.05302 atom/atom</td></tr></table> Arithmetic Mean: 0.0529705 atom/atom Pooled Standard Deviation: 0.000027173 atom/atom Pooled Degrees of Freedom: 49 Standard Uncertainty: $13.0 \cdot 10^{-6}$ atom/atom		No.	Observation	1	0.05301 atom/atom	2	0.052921 atom/atom	3	0.052978 atom/atom	4	0.052874 atom/atom	5	0.053020 atom/atom	6	0.05302 atom/atom
No.	Observation															
1	0.05301 atom/atom															
2	0.052921 atom/atom															
3	0.052978 atom/atom															
4	0.052874 atom/atom															
5	0.053020 atom/atom															
6	0.05302 atom/atom															
$\delta_{58\text{BCFDay2}}$ :	Type B normal distribution Value: 1 atom/atom Expanded Uncertainty: 0.00093599 atom/atom Coverage Factor: 1															
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	GUM for PTRM-10-3.1																											
<div><div><div>X<sub>68Day1</sub>:</div><div>Type A Method of observation: Direct Number of observations: 5</div><table><tr><th>No.</th><th>Observation</th></tr><tr><td>1</td><td>0.0001583 atom/atom</td></tr><tr><td>2</td><td>0.0001590 atom/atom</td></tr><tr><td>3</td><td>0.0001597 atom/atom</td></tr><tr><td>4</td><td>0.0001580 atom/atom</td></tr><tr><td>5</td><td>0.0001590 atom/atom</td></tr></table><div>Arithmetic Mean: 158.800·10<sup>-6</sup> atom/atom Pooled Standard Deviation: 0.00000030074 atom/atom Pooled Degrees of Freedom: 49 Standard Uncertainty: 153·10<sup>-9</sup> atom/atom</div></div><div><div>δ<sub>68BCFDay1</sub>:</div><div>Type B normal distribution Value: 1 atom/atom Expanded Uncertainty: 0.00059812 atom/atom Coverage Factor: 1</div></div><div><div>X<sub>68Day2</sub>:</div><div>Type A Method of observation: Direct Number of observations: 6</div><table><tr><th>No.</th><th>Observation</th></tr><tr><td>1</td><td>0.0001599 atom/atom</td></tr><tr><td>2</td><td>0.0001582 atom/atom</td></tr><tr><td>3</td><td>0.0001595 atom/atom</td></tr><tr><td>4</td><td>0.0001586 atom/atom</td></tr><tr><td>5</td><td>0.0001611 atom/atom</td></tr><tr><td>6</td><td>0.0001602 atom/atom</td></tr></table><div>Arithmetic Mean: 159.583·10<sup>-6</sup> atom/atom Pooled Standard Deviation: 0.00000047396 atom/atom Pooled Degrees of Freedom: 49 Standard Uncertainty: 227·10<sup>-9</sup> atom/atom</div></div><div><div>δ<sub>68BCFDay2</sub>:</div><div>Type B normal distribution Value: 1 atom/atom Expanded Uncertainty: 0.00062399 atom/atom Coverage Factor: 1</div></div></div>			No.	Observation	1	0.0001583 atom/atom	2	0.0001590 atom/atom	3	0.0001597 atom/atom	4	0.0001580 atom/atom	5	0.0001590 atom/atom	No.	Observation	1	0.0001599 atom/atom	2	0.0001582 atom/atom	3	0.0001595 atom/atom	4	0.0001586 atom/atom	5	0.0001611 atom/atom	6	0.0001602 atom/atom
No.	Observation																											
1	0.0001583 atom/atom																											
2	0.0001590 atom/atom																											
3	0.0001597 atom/atom																											
4	0.0001580 atom/atom																											
5	0.0001590 atom/atom																											
No.	Observation																											
1	0.0001599 atom/atom																											
2	0.0001582 atom/atom																											
3	0.0001595 atom/atom																											
4	0.0001586 atom/atom																											
5	0.0001611 atom/atom																											
6	0.0001602 atom/atom																											
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GUM for PTRM-10-3.1						
<b>Uncertainty Budgets:</b> <b>combined<sub>avg48</sub>: combined average of 24/28 of sample</b>						
Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
X <sub>48Day1</sub>	492.040·10 <sup>-6</sup> atom/atom	0.12 % (rel)	normal	0.50	300·10 <sup>-9</sup> atom/atom	5.0 %
δ <sub>48BCFDay1</sub>	1.00000 atom/atom	0.12 % (rel)	normal	250·10 <sup>-6</sup>	290·10 <sup>-9</sup> atom/atom	5.0 %
X <sub>48Day2</sub>	494.600·10 <sup>-6</sup> atom/atom	0.12 % (rel)	normal	0.50	290·10 <sup>-9</sup> atom/atom	4.7 %
δ <sub>48BCFDay2</sub>	1.00000 atom/atom	0.12 % (rel)	normal	250·10 <sup>-6</sup>	310·10 <sup>-9</sup> atom/atom	5.5 %
δ <sub>Repeatability</sub>	1.00000 atom/atom	0.11 % (rel)	normal	490·10 <sup>-6</sup>	550·10 <sup>-9</sup> atom/atom	17.6 %
δ <sub>Reproducibility</sub>	1.00000 atom/atom	0.21 % (rel)	normal	490·10 <sup>-6</sup>	1.0·10 <sup>-6</sup> atom/atom	62.2 %
combined <sub>a</sub> vg48	493.32·10 <sup>-6</sup> atom/atom	1.32·10 <sup>-6</sup> atom/atom				
<b>combined<sub>avg58</sub>: combined average of the 25/28 of the sample</b>						
Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
δ <sub>Repeatability</sub>	1.00000 atom/atom	0.11 % (rel)	normal	0.053	59·10 <sup>-6</sup> atom/atom	20.3 %
δ <sub>Reproducibility</sub>	1.00000 atom/atom	0.21 % (rel)	normal	0.053	110·10 <sup>-6</sup> atom/atom	72.0 %
X <sub>58Day1</sub>	0.0527444 atom/atom	0.038 % (rel)	normal	0.50	9.9·10 <sup>-6</sup> atom/atom	0.6 %
δ <sub>58BCFDay1</sub>	1.000000 atom/atom	0.090 % (rel)	normal	0.026	24·10 <sup>-6</sup> atom/atom	3.3 %
X <sub>58Day2</sub>	0.0529705 atom/atom	0.024 % (rel)	normal	0.50	6.5·10 <sup>-6</sup> atom/atom	0.2 %
δ <sub>58BCFDay2</sub>	1.000000 atom/atom	0.094 % (rel)	normal	0.026	25·10 <sup>-6</sup> atom/atom	3.6 %
combined <sub>a</sub> vg58	0.052857 atom/atom	131·10 <sup>-6</sup> atom/atom				
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		GUM for PTRM-10-3.1				
<b>combined<sub>avg68</sub>:    combined average of the 26/28 of the sample</b>						
Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
δ <sub>Repeatability</sub>	1.00000 atom/atom	0.11 % (rel)	normal	160·10 <sup>-6</sup>	180·10 <sup>-9</sup> atom/atom	18.9 %
δ <sub>Reproducibility</sub>	1.00000 atom/atom	0.21 % (rel)	normal	160·10 <sup>-6</sup>	330·10 <sup>-9</sup> atom/atom	67.0 %
X <sub>68Day1</sub>	158.800·10 <sup>-6</sup> atom/atom	0.096 % (rel)	normal	0.50	77·10 <sup>-9</sup> atom/atom	3.5 %
δ <sub>68BCFDay1</sub>	1.000000 atom/atom	0.060 % (rel)	normal	79·10 <sup>-6</sup>	47·10 <sup>-9</sup> atom/atom	1.3 %
X <sub>68Day2</sub>	159.583·10 <sup>-6</sup> atom/atom	0.14 % (rel)	normal	0.50	110·10 <sup>-9</sup> atom/atom	7.7 %
δ <sub>68BCFDay2</sub>	1.000000 atom/atom	0.062 % (rel)	normal	80·10 <sup>-6</sup>	50·10 <sup>-9</sup> atom/atom	1.5 %
combined <sub>a</sub> vg68	159.192·10 <sup>-6</sup> atom/atom	409·10 <sup>-9</sup> atom/atom				

Results:

Quantity	Value	Expanded Uncertainty	Coverage factor	Coverage
combined <sub>avg48</sub>	493.3·10 <sup>-6</sup> atom/atom	2.6·10 <sup>-6</sup> atom/atom	2.00	95% (t-table 95.45%)
combined <sub>avg58</sub>	0.05286 atom/atom	260·10 <sup>-6</sup> atom/atom	2.00	95% (t-table 95.45%)
combined <sub>avg68</sub>	159.19·10 <sup>-6</sup> atom/atom	820·10 <sup>-9</sup> atom/atom	2.00	95% (t-table 95.45%)

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## Exhibit B.4: Uncertainty Budgets from PTRM10-3.2.

GUM for PTRM-10-3.2		
<b>GUM for PTRM-10-3.2</b> Author: d3m597  Modified to simplify. RSD (or delta) values come from spreadsheet containing all CRM-129A data and calculated individual BCF delta factors.  <b>Model Equation:</b> $\text{combined}_{\text{avg48}} = ((X_{48\text{Day1}} * \delta_{48\text{BCFDay1}} + X_{48\text{Day2}} * \delta_{48\text{BCFDay2}}) / 2) * \delta_{\text{Repeatability}} * \delta_{\text{Reproducibility}}$ $\text{combined}_{\text{avg58}} = ((X_{58\text{Day1}} * \delta_{58\text{BCFDay1}} + X_{58\text{Day2}} * \delta_{58\text{BCFDay2}}) / 2) * \delta_{\text{Repeatability}} * \delta_{\text{Reproducibility}}$ $\text{combined}_{\text{avg68}} = ((X_{68\text{Day1}} * \delta_{68\text{BCFDay1}} + X_{68\text{Day2}} * \delta_{68\text{BCFDay2}}) / 2) * \delta_{\text{Repeatability}} * \delta_{\text{Reproducibility}}$ <b>List of Quantities:</b>		
Quantity	Unit	Definition
combined <sub>avg48</sub>	atom/atom	combined average of 24/28 of sample
X <sub>48Day1</sub>	atom/atom	average value of 24/28 of sample for day 1
δ <sub>48BCFDay1</sub>	atom/atom	delta factor for relative uncertainty for bias correction factor for 24/28 ratio for Day 1
X <sub>48Day2</sub>	atom/atom	average value of 24/28 of sample for day 2
δ <sub>48BCFDay2</sub>	atom/atom	delta factor for relative uncertainty for bias correction factor for 24/28 ratio for Day 2
δ <sub>Repeatability</sub>	atom/atom	delta factor for relative uncertainty characterizing intra-day repeatability of 25/28 for control standard
δ <sub>Reproducibility</sub>	atom/atom	delta factor for relative uncertainty characterizing day-to-day reproducibility of 25/28 for control standard
combined <sub>avg58</sub>	atom/atom	combined average of the 25/28 of the sample
X <sub>58Day1</sub>	atom/atom	average value of the 25/28 of sample for day 1
δ <sub>58BCFDay1</sub>	atom/atom	delta factor for relative uncertainty for bias correction factor for 25/28 ratio for Day 1
X <sub>58Day2</sub>	atom/atom	average value of the 25/28 of sample for day 2
δ <sub>58BCFDay2</sub>	atom/atom	delta factor for relative uncertainty for bias correction factor for 25/28 ratio for Day 2
combined <sub>avg68</sub>	atom/atom	combined average of the 26/28 of the sample
X <sub>68Day1</sub>	atom/atom	average value of the 26/28 of sample for day 1
δ <sub>68BCFDay1</sub>	atom/atom	delta factor for relative uncertainty for bias correction factor for 26/28 ratio for Day 1
X <sub>68Day2</sub>	atom/atom	average value of the 26/28 of sample for day 2
δ <sub>68BCFDay2</sub>	atom/atom	delta factor for relative uncertainty for bias correction factor for 26/28 ratio for Day 2
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GUM for PTRM-10-3.2															
<b>X<sub>48Day1</sub></b> :	<p>Type A  Method of observation: Direct  Number of observations: 5</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>No.</th> <th>Observation</th> </tr> </thead> <tbody> <tr><td>1</td><td>0.0005027 atom/atom</td></tr> <tr><td>2</td><td>0.0004981 atom/atom</td></tr> <tr><td>3</td><td>0.0005028 atom/atom</td></tr> <tr><td>4</td><td>0.0004993 atom/atom</td></tr> <tr><td>5</td><td>0.0005034 atom/atom</td></tr> </tbody> </table> <p>Arithmetic Mean: <math>501.260 \cdot 10^{-6}</math> atom/atom  Pooled Standard Deviation: 0.0000010676 atom/atom  Pooled Degrees of Freedom: 49  Standard Uncertainty: <math>545 \cdot 10^{-9}</math> atom/atom</p> <p>24/28 for day 1</p>	No.	Observation	1	0.0005027 atom/atom	2	0.0004981 atom/atom	3	0.0005028 atom/atom	4	0.0004993 atom/atom	5	0.0005034 atom/atom		
No.	Observation														
1	0.0005027 atom/atom														
2	0.0004981 atom/atom														
3	0.0005028 atom/atom														
4	0.0004993 atom/atom														
5	0.0005034 atom/atom														
<b>δ<sub>48BCFDay1</sub></b> :	<p>Type B normal distribution  Value: 1 atom/atom  Expanded Uncertainty: 0.0021214 atom/atom  Coverage Factor: 1</p>														
<b>X<sub>48Day2</sub></b> :	<p>Type A  Method of observation: Direct  Number of observations: 6</p> <table border="1" style="margin-left: auto; margin-right: auto;"> <thead> <tr> <th>No.</th> <th>Observation</th> </tr> </thead> <tbody> <tr><td>1</td><td>0.0004998 atom/atom</td></tr> <tr><td>2</td><td>0.0005024 atom/atom</td></tr> <tr><td>3</td><td>0.0004968 atom/atom</td></tr> <tr><td>4</td><td>0.0005033 atom/atom</td></tr> <tr><td>5</td><td>0.0005040 atom/atom</td></tr> <tr><td>6</td><td>0.0005073 atom/atom</td></tr> </tbody> </table> <p>Arithmetic Mean: <math>502.267 \cdot 10^{-6}</math> atom/atom  Pooled Standard Deviation: 0.0000016083 atom/atom  Pooled Degrees of Freedom: 49  Standard Uncertainty: <math>770 \cdot 10^{-9}</math> atom/atom</p> <p>24/28 day 2</p>	No.	Observation	1	0.0004998 atom/atom	2	0.0005024 atom/atom	3	0.0004968 atom/atom	4	0.0005033 atom/atom	5	0.0005040 atom/atom	6	0.0005073 atom/atom
No.	Observation														
1	0.0004998 atom/atom														
2	0.0005024 atom/atom														
3	0.0004968 atom/atom														
4	0.0005033 atom/atom														
5	0.0005040 atom/atom														
6	0.0005073 atom/atom														
<b>δ<sub>48BCFDay2</sub></b> :	<p>Type B normal distribution  Value: 1 atom/atom  Expanded Uncertainty: 0.0021033 atom/atom  Coverage Factor: 1</p>														
<b>δ<sub>Repeatability</sub></b> :	<p>Type B normal distribution  Value: 1 atom/atom  Expanded Uncertainty: 0.0011178 atom/atom  Coverage Factor: 1</p>														
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	GUM for PTRM-10-3.2															
$\delta_{\text{Reproducibility}}$ :	Type B normal distribution Value: 1 atom/atom Expanded Uncertainty: 0.0021029 atom/atom Coverage Factor: 1															
$x_{58\text{Day1}}$ :	Type A Method of observation: Direct Number of observations: 5 <table><tr><td>No.</td><td>Observation</td></tr><tr><td>1</td><td>0.05304 atom/atom</td></tr><tr><td>2</td><td>0.05297 atom/atom</td></tr><tr><td>3</td><td>0.05294 atom/atom</td></tr><tr><td>4</td><td>0.052856 atom/atom</td></tr><tr><td>5</td><td>0.05268 atom/atom</td></tr></table> Arithmetic Mean: 0.0528972 atom/atom Pooled Standard Deviation: 0.000061432 atom/atom Pooled Degrees of Freedom: 49 Standard Uncertainty: $31.4 \cdot 10^{-6}$ atom/atom		No.	Observation	1	0.05304 atom/atom	2	0.05297 atom/atom	3	0.05294 atom/atom	4	0.052856 atom/atom	5	0.05268 atom/atom		
No.	Observation															
1	0.05304 atom/atom															
2	0.05297 atom/atom															
3	0.05294 atom/atom															
4	0.052856 atom/atom															
5	0.05268 atom/atom															
$\delta_{58\text{BCFDay1}}$ :	Type B normal distribution Value: 1 atom/atom Expanded Uncertainty: 0.0015911 atom/atom Coverage Factor: 1															
$x_{58\text{Day2}}$ :	Type A Method of observation: Direct Number of observations: 6 <table><tr><td>No.</td><td>Observation</td></tr><tr><td>1</td><td>0.05308 atom/atom</td></tr><tr><td>2</td><td>0.05317 atom/atom</td></tr><tr><td>3</td><td>0.05304 atom/atom</td></tr><tr><td>4</td><td>0.053016 atom/atom</td></tr><tr><td>5</td><td>0.053056 atom/atom</td></tr><tr><td>6</td><td>0.05315 atom/atom</td></tr></table> Arithmetic Mean: 0.0530853 atom/atom Pooled Standard Deviation: 0.000028659 atom/atom Pooled Degrees of Freedom: 49 Standard Uncertainty: $13.5 \cdot 10^{-6}$ atom/atom		No.	Observation	1	0.05308 atom/atom	2	0.05317 atom/atom	3	0.05304 atom/atom	4	0.053016 atom/atom	5	0.053056 atom/atom	6	0.05315 atom/atom
No.	Observation															
1	0.05308 atom/atom															
2	0.05317 atom/atom															
3	0.05304 atom/atom															
4	0.053016 atom/atom															
5	0.053056 atom/atom															
6	0.05315 atom/atom															
$\delta_{58\text{BCFDay2}}$ :	Type B normal distribution Value: 1 atom/atom Expanded Uncertainty: 0.0015775 atom/atom Coverage Factor: 1															
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	GUM for PTRM-10-3.2															
$\bar{X}_{68\text{Day1}}:$	<p>Type A Method of observation: Direct Number of observations: 5</p> <table><tr><th>No.</th><th>Observation</th></tr><tr><td>1</td><td>0.0001683 atom/atom</td></tr><tr><td>2</td><td>0.0001689 atom/atom</td></tr><tr><td>3</td><td>0.0001685 atom/atom</td></tr><tr><td>4</td><td>0.0001689 atom/atom</td></tr><tr><td>5</td><td>0.0001682 atom/atom</td></tr></table> <p>Arithmetic Mean: <math>168.5600 \cdot 10^{-6}</math> atom/atom Pooled Standard Deviation: 0.00000015870 atom/atom Pooled Degrees of Freedom: 49 Standard Uncertainty: <math>79.3 \cdot 10^{-9}</math> atom/atom</p>		No.	Observation	1	0.0001683 atom/atom	2	0.0001689 atom/atom	3	0.0001685 atom/atom	4	0.0001689 atom/atom	5	0.0001682 atom/atom		
No.	Observation															
1	0.0001683 atom/atom															
2	0.0001689 atom/atom															
3	0.0001685 atom/atom															
4	0.0001689 atom/atom															
5	0.0001682 atom/atom															
$\delta_{68\text{BCFDay1}}:$	<p>Type B normal distribution Value: 1 atom/atom Expanded Uncertainty: 0.0010607 atom/atom Coverage Factor: 1</p>															
$\bar{X}_{68\text{Day2}}:$	<p>Type A Method of observation: Direct Number of observations: 6</p> <table><tr><th>No.</th><th>Observation</th></tr><tr><td>1</td><td>0.0001660 atom/atom</td></tr><tr><td>2</td><td>0.0001662 atom/atom</td></tr><tr><td>3</td><td>0.0001692 atom/atom</td></tr><tr><td>4</td><td>0.0001673 atom/atom</td></tr><tr><td>5</td><td>0.0001682 atom/atom</td></tr><tr><td>6</td><td>0.0001683 atom/atom</td></tr></table> <p>Arithmetic Mean: <math>167.533 \cdot 10^{-6}</math> atom/atom Pooled Standard Deviation: 0.00000057448 atom/atom Pooled Degrees of Freedom: 49 Standard Uncertainty: <math>273 \cdot 10^{-9}</math> atom/atom</p>		No.	Observation	1	0.0001660 atom/atom	2	0.0001662 atom/atom	3	0.0001692 atom/atom	4	0.0001673 atom/atom	5	0.0001682 atom/atom	6	0.0001683 atom/atom
No.	Observation															
1	0.0001660 atom/atom															
2	0.0001662 atom/atom															
3	0.0001692 atom/atom															
4	0.0001673 atom/atom															
5	0.0001682 atom/atom															
6	0.0001683 atom/atom															
$\delta_{68\text{BCFDay2}}:$	<p>Type B normal distribution Value: 1 atom/atom Expanded Uncertainty: 0.0010517 atom/atom Coverage Factor: 1</p>															
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GUM for PTRM-10-3.2						
<b>Uncertainty Budgets:</b> <b>combined<sub>avg48</sub>: combined average of 24/28 of sample</b>						
Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
X <sub>48Day1</sub>	501.260·10 <sup>-6</sup> atom/atom	0.11 % (rel)	normal	0.50	270·10 <sup>-9</sup> atom/atom	3.4 %
δ <sub>48BCFDay1</sub>	1.00000 atom/atom	0.21 % (rel)	normal	250·10 <sup>-6</sup>	530·10 <sup>-9</sup> atom/atom	12.8 %
X <sub>48Day2</sub>	502.267·10 <sup>-6</sup> atom/atom	0.15 % (rel)	normal	0.50	390·10 <sup>-9</sup> atom/atom	6.7 %
δ <sub>48BCFDay2</sub>	1.00000 atom/atom	0.21 % (rel)	normal	250·10 <sup>-6</sup>	530·10 <sup>-9</sup> atom/atom	12.6 %
δ <sub>Repeatability</sub>	1.00000 atom/atom	0.11 % (rel)	normal	500·10 <sup>-6</sup>	560·10 <sup>-9</sup> atom/atom	14.2 %
δ <sub>Reproducibility</sub>	1.00000 atom/atom	0.21 % (rel)	normal	500·10 <sup>-6</sup>	1.1·10 <sup>-6</sup> atom/atom	50.3 %
combined <sub>a</sub> vg48	501.76·10 <sup>-6</sup> atom/atom	1.49·10 <sup>-6</sup> atom/atom				
<b>combined<sub>avg58</sub>: combined average of the 25/28 of the sample</b>						
Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
δ <sub>Repeatability</sub>	1.00000 atom/atom	0.11 % (rel)	normal	0.053	59·10 <sup>-6</sup> atom/atom	17.8 %
δ <sub>Reproducibility</sub>	1.00000 atom/atom	0.21 % (rel)	normal	0.053	110·10 <sup>-6</sup> atom/atom	62.9 %
X <sub>58Day1</sub>	0.0528972 atom/atom	0.059 % (rel)	normal	0.50	16·10 <sup>-6</sup> atom/atom	1.2 %
δ <sub>58BCFDay1</sub>	1.00000 atom/atom	0.16 % (rel)	normal	0.026	42·10 <sup>-6</sup> atom/atom	9.0 %
X <sub>58Day2</sub>	0.0530853 atom/atom	0.025 % (rel)	normal	0.50	6.8·10 <sup>-6</sup> atom/atom	0.2 %
δ <sub>58BCFDay2</sub>	1.00000 atom/atom	0.16 % (rel)	normal	0.027	42·10 <sup>-6</sup> atom/atom	8.9 %
combined <sub>a</sub> vg58	0.052991 atom/atom	141·10 <sup>-6</sup> atom/atom				
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		GUM for PTRM-10-3.2				
combined <sub>avg68</sub> :    combined average of the 26/28 of the sample						
Quantity	Value	Standard Uncertainty	Distribution	Sensitivity Coefficient	Uncertainty Contribution	Index
δ <sub>Repeatability</sub>	1.00000 atom/atom	0.11 % (rel)	normal	170·10 <sup>-6</sup>	190·10 <sup>-9</sup> atom/atom	18.0 %
δ <sub>Reproducibility</sub>	1.00000 atom/atom	0.21 % (rel)	normal	170·10 <sup>-6</sup>	350·10 <sup>-9</sup> atom/atom	63.7 %
X <sub>68Day1</sub>	168.5600·10 <sup>-6</sup> atom/atom	0.047 % (rel)	normal	0.50	40·10 <sup>-9</sup> atom/atom	0.8 %
δ <sub>68BCFDay1</sub>	1.00000 atom/atom	0.11 % (rel)	normal	84·10 <sup>-6</sup>	89·10 <sup>-9</sup> atom/atom	4.1 %
X <sub>68Day2</sub>	167.533·10 <sup>-6</sup> atom/atom	0.16 % (rel)	normal	0.50	140·10 <sup>-9</sup> atom/atom	9.5 %
δ <sub>68BCFDay2</sub>	1.00000 atom/atom	0.11 % (rel)	normal	84·10 <sup>-6</sup>	88·10 <sup>-9</sup> atom/atom	4.0 %
combined <sub>a</sub> vg68	168.047·10 <sup>-6</sup> atom/atom	443·10 <sup>-9</sup> atom/atom				

Results:

Quantity	Value	Expanded Uncertainty	Coverage factor	Coverage
combined <sub>avg48</sub>	501.8·10 <sup>-6</sup> atom/atom	3.0·10 <sup>-6</sup> atom/atom	2.00	95% (t-table 95.45%)
combined <sub>avg58</sub>	0.05299 atom/atom	280·10 <sup>-6</sup> atom/atom	2.00	95% (t-table 95.45%)
combined <sub>avg68</sub>	168.05·10 <sup>-6</sup> atom/atom	890·10 <sup>-9</sup> atom/atom	2.00	95% (t-table 95.45%)

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