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Graphite Specimen Mass Measurements for NESHAP Calculations

April 2018

W. Dave Swank

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ENGINEERING CALCULATIONS AND ANALYSIS

Title: Graphite Specimen Mass Measurements for NESHAP Calculations

ECAR No.: 3611 Rev. No.: 1 Project No.: 23747 Date: 02/15/2018

SIGNATURES

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1. Confirmation of completeness, mathematical accuracy, and correctness of data and appropriateness of assumptions.
2. Concurrence of method or approach. See definition, LWP-10106.
3. Concurrence of procedure compliance. Concurrence with method/approach and conclusion.
4. Concurrence with the document's assumptions and input information. See definition of Acceptance, LWP-10200.
5. Does the document contain CUI material please check either yes or no.

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REVISION LOG

Rev.	Date	Affected Pages	Revision Description
0	02/14/17	All	New ECAR.
1	02/15/2018	all	Addition of modified emission factors for calculating heated graphite source term.

Title: Graphite Specimen Mass Measurements for NESHAP Calculations

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1. Quality Level (QL) No.	NA	**Professional Engineer's Stamp** N/A See LWP-10010 for requirements.
2. QL Determination No.	NA	
3. Engineering Job (EJ) No.	Not Applicable	
4. SSC ID	AGC Experiment	
5. Building	IF-603	
6. Site Area	REC	

7. Objective/Purpose:

The Advanced Graphite Creep (AGC) experiments were designed to irradiate various types of graphite specimens to gain an understanding of how the physical and thermal properties of the graphite change. The graphite specimens are machined from nuclear grade graphite that is very pure relative to other graphite types. However, it still contains parts per million (PPM) levels of metal contaminants that are dispersed throughout it. During irradiation in the Advanced Test Reactor (ATR) these metal contaminants become activated resulting in the graphite specimens being classified as a radioactive material.

Following their irradiation, a variety of measurements and experiments are performed on these specimens that require them to be heated above 100°C.Whenever a radioactive material is heated to above 100°C the National Emission Standards for Hazardous Air Pollutants (NESHAP) calculations require the activity content, in Curies, of the isotopes that could potentially be released to the environment. The purpose of this ECAR is to document the method by which the mass loss of each sample is determined and how the isotopic content of this mass loss is determined.

8. If revision, please state the reason and list sections and/or pages being affected:

As of November 1, 2017, modified emission factors can be applied to the calculation of the irradiated graphite source term per EPA guidance. Revisions to this ECAR describe how these emission factors are applied to NESHAP calculations for graphite specimens being tested in the INL Carbon Characterization Laboratory (IRC Lab C-18).

- Section 9 pg. 2 and 3
- Design, Discussion and Analysis pg. 7 and 8
- Computer Code and Validation pg. 9
- References pg. 10
- Addition of Appendix F.

9. Conclusions/Recommendations:

Attached in Appendix A is an Excel spread sheet with the mass measurements of all irradiated graphite specimens heated above 100°C in IRC C18 during calendar year 2016. The spread sheet contains the mass of individual specimens pre and post heating and the table of gamma spec measurements made on 12 different samples that represent 6 different graphite types and irradiation histories. This spread sheet uses the described method to calculate the total activity of the lost material to be 0.45 µCi.

As of November 1, 2017, modified emission factors can be applied to the calculation of the irradiated graphite source term per EPA guidance, Appendix C, D and E. These modified emission factors are determined based on the temperature to which the specimen is heated relative to the materials melting and boiling point. Although specimens are normally heated to <1000°C a conservative temperature of 1200°C was used to determine the modified emission factors. This method of estimating the potential exposure was performed for two different cases. In the first case, emission factors were applied to the specimens of Appendix A and an estimated activity of the material that could potentially vaporize is 893 µCi. In the second case the estimated potential activity that could be emitted for 20 specimens that are oxidized to 10% mass loss is calculated using both the emission factors and the mass loss technique (Appendix F). In this case the emission factor method results in predicting 24.5 µCi while the mass loss technique predicts 64.2 µCi.

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Title: Graphite Specimen Mass Measurements for NESHAP Calculations

ECAR No.: 3611 Rev. No.: 1 Project No.: 23747 Date: 02/15/2018

PROJECT ROLES AND RESPONSIBILITIES

Project Role	Name (Typed)	Organization	Pages covered (if applicable)
Performer	W. Dave Swank	B120	
Checker[a]	David Rohrbaugh	D520	
Manager[d]	Michael Davenport	C020	
Requestor[e]	William E. Windes	B120	
Document Owner[e]	W. David Swank	B120	

Responsibilities:

a. Confirmation of completeness, mathematical accuracy, and correctness of data and appropriateness of assumptions.

b. Concurrence of method or approach. See definition, LWP-10106.

c. Concurrence with the document's markings in accordance with LWP-11202.

d. Concurrence of procedure compliance. Concurrence with method/approach and conclusion.

e. Concurrence with the document's assumptions and input information. See definition of Acceptance, LWP-10200.

SCOPE AND BRIEF DESCRIPTION

The Advanced Graphite Creep (AGC) experiments were designed to irradiate various types of graphite specimens to gain an understanding of how the physical and thermal properties of the graphite change. These specimens are either a “creep” specimen, 0.5” dia. X 1.0” lg., or a “piggyback” specimen, 0.5” dia. X 0.25” lg. They are machined from nuclear grade graphite that is very pure relative to other graphite types. However, nuclear grade graphite still contains parts per million (PPM) levels of metal contaminants that are dispersed throughout it. During irradiation in the Advanced Test Reactor (ATR) these metal contaminants become activated resulting in the graphite specimens being classified as a radioactive material.

Following their irradiation, a variety of measurements and experiments are performed on these specimens that require them to be heated above 100°C. Details of how these measurements are carried out can be found in the AGC post irradiation characterization plan PLN-4888 and Laboratory Instruction LI-709.

Whenever a radioactive material is heated above 100°C the National Emission Standards for Hazardous Air Pollutants (NESHAP) calculations require the total radioactivity, in Curies, of the isotopes that could potentially be released as a gas to the environment. The purpose of this ECAR is to document the method by which the mass loss of each sample is determined and how the isotopic content of this mass loss is determined.

DESIGN, DISCUSSION AND ANALYSIS

For normal testing operations, mass measurements of all specimens is collected before and after heating the specimen above 100°C using the analytical balance listed in Table 1. These before and after mass measurements provide an accurate measurement of the mass loss for each specimen. It should be noted that these mass measurements are carried out under the quality program plan of the Advanced Reactor Technology (ART) Materials Program which is ASME NQA-1 compliant. This measured mass loss fraction is applied to the total radionuclide inventory available within a sample to calculate the potential environmental release for each specimen. Radionuclide content is derived from gamma spectroscopy data that is documented in INL/EXT-14-31843 Rev 0. The specimens measured in this report cover the range of the various graphite types and irradiation conditions (temperature and dose).

Described in words the calculation is carried out as follows:

- The mass loss of an individual specimen is normalized to the initial mass of that specimen
- This fraction is multiplied by the activity per specimen of each isotope found in that graphite grade and summed for all isotopes present.
- This calculation is performed for each specimen of each different graphite grade and summed to arrive at the total activity that was potentially released to the environment.

Mathematically the calculation of total activity of the specimen mass loss is represented by,

$$A = \sum_{i=1}^{g} \left\{ \sum_{j=1}^{n} \left[\sum_{k=1}^{r} \left(\frac{m_{j,initial} - m_{j,final}}{m_{j,initial}} \right) a_k \right]_j \right\}_i \qquad \text{EQ. 1}$$

Where,

A = Total activity of all graphite specimens heated above 100°C

g = different graphite types/grades

r = different radionuclides or isotopes contained in the graphite type/grade

n = number of specimens in each type/grade of graphite

$m_{initial}$ = mass of specimen prior to heating above 100°C

m_{final} = mass of specimen after heating above 100°C

a = activity of the specific radionuclide found in the specific graphite grade/type in µCi/specimen.

Table 1: Analytical balance used for performing mass measurements

Balance used:	
Sartorius ME235P	
Accuracy:	0.00019 g
INL Cal ID:	412642
Cal Due Date:	5/25/2017

As of November 1, 2017, the following modified emission factors can be applied to the calculation of the irradiated graphite source term per EPA guidance, Appendix C, D and E. These modified emission factors are determined based on the temperature to which the specimen is heated relative to the materials melting and boiling point.

1. An emission factor of 1 will be applied to radioactive solid materials heated to temperatures greater than or equal to 90 percent of the boiling or subliming point.

2. An emission factor of 10E-3 will be applied to radioactive solid materials heated to temperatures greater than or equal to their melting point but less than 90 percent of their boiling or subliming point.

3. An emission factor of 10E-6 will be applied to radioactive solid materials heated to temperatures above ambient temperature but less than their melting point.

These modified emission factors are determined based on the temperature to which the specimen is heated relative to the materials melting and boiling point. Although the AGC graphite specimens are

normally heated to <1000°C a conservative temperature of 1200°C was used to determine the modified emission factors, Table 2.

These modified emission factors are applied to the calculation of the irradiated graphite source term as shown in the equation 2.

$$A = \sum_{i=1}^{g}\left\{\sum_{j=1}^{n}\left[\sum_{k=1}^{r}(a_k f_k)\right]_j\right\}_i \qquad \text{EQ. 2}$$

Where,

A = Total activity of all graphite specimens heated above 100°C

g = different graphite types/grades

r = different radionuclides or isotopes contained in the graphite type/grade

n = number of specimens in each type/grade of graphite

f = modified emission factor of the specific radionuclide determined for a specimen heating temperature of 1200°C, Table 2.

Table 2: Modified Emission Factors base on a specimen heating temperature of 1200°C.

Element	M.P. (°C)[4]	B.P. (°C)[4]	Emission Factor
SC	1541	2836	1x10E-6
Mn	1246	2061	1x10E-6
Co	1495	2927	1x10E-6
Zn	420	907	1
Zr	1851	4406	1x10E-6
Mb	1016	3074	1x10E-3
Ag	962	2162	1x10E-3
Cs	28.5	671	1
Ce	799	3443	1x10E-3
Eu	822	1529	1x10E-3

ASSUMPTIONS

- This calculation conservatively assumes activated metal contaminants in the graphite are vaporized and escape to the atmosphere in the same ratio as the overall mass loss of the graphite itself. For example if 1% of the graphite is lost this calculation assumes 1% of the radionuclides are lost to the atmosphere. The emission factor technique attempts to consider the various vapor pressures of the isotopes, however, it should be noted that any activated species contained within the graphite that could potentially vaporize during heating will condense almost immediately as it leaves the heated

portion of the furnace. It should also be noted that all off-gases are exhausted through a dispersed oil particulate (DOP) qualified high-efficiency particulate air filter system and that the measurement apparatus and off-gas tubing is routinely monitored by Radiological Control technicians for unexpected contamination that would come from the heated graphite specimens.

- Thirteen of the specimens showed an increase in mass, but in all of these cases the increase was less than the accuracy (+/- 190 µg) of the balance, therefore they were not included in the calculation(appendix A).

- Metal containments of graphite types 2114 and PCIB are similar to IG-110, therefore the gamma spectroscopy data for IG-110 was used.

- Because the gamma spectroscopy measurements were made on 0.5" dia. × 1.0" lg. "creep" specimens the 0.5" dia. × 0.25" lg. "piggy back" specimens are assumed to have ¼ of the activity of a "creep" specimen.

- Gamma spectroscopy was performed on high dose specimens located in the center of the AGC experiment and low dose specimens located at the periphery of the experiment. It is assumed that an averaged activity of these two extremes represent an average for all specimens irradiated.

- There was approximately a 1 year duration between the time that the gamma spectroscopy measurements were made and the specimens were heated. No isotope decay credit was taken on these values. This is assumed to represent a worst case value for the isotopic activity.

COMPUTER CODE AND VALIDATION

Attached in Appendix A is an Excel spread sheet with the mass measurements of all irradiated graphite specimens heated above 100°C in IRC C18 during calendar year 2016. The spread sheet contains the mass of individual specimens pre and post heating and the table of gamma spectroscopy measurements made on 12 different samples that represent 6 different graphite types and irradiation histories (INL/EXT-14-31843 Rev 0). This spread sheet uses the above described method to calculate a total activity of the lost material. It has been reviewed internally by the graphite program (David Swank and David Rohrbaugh) and independently by Todd Echeverria, Radiological Engineering, William Bauer, Chemical and Radiation Measurements, Robert Montgomery, Regulatory Compliance – Environmental, and Mark Verdoorn, Regulatory and Monitoring Services. John Espinosa, Regulatory Compliance – Environmental has reviewed calculations using the emission factor method in Appendix F. Independent concurrence with the method and accuracy of the spreadsheet calculations is contained in Appendix B.

REFERENCES

1. “AGC-3 Graphite Specimen Post Irradiation Characterization Plan”, W. David Swank, PLN-4888 Rev0, May 2015.

2. “Graphite Gamma Scan Results”, Mark Dirgert, INL/EXT-14-31843 Rev 0, April 2014.

3. “Irradiated Graphite Characterization Laboratory Instruction”, W. David Swank and Patrick Laney, LI-709 Rev 1, January 2017.

4. CRC Handbook of Chemistry and Physics 98th Edition Editor-in-Chief: John R. Rumble

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Appendix A

Mass Measurements and Isotope Activity Calculation Excel Spread Sheet

Id	Grade Code	Type	All in grams PreMass	PostMass	Diff	% Mass Loss	Isotopes (μCi) ^{46}Sc	^{54}Mn	^{60}Co	^{65}Zn	^{95}Zr	^{95}Nb	^{110m}Ag	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	Total (μCi)
AL3101	A	CR	5.58625	5.58598	0.000270	0.0048	0.0001	0.0001	0.0039	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0043
AL3103	A	CR	5.58844	5.58819	0.000250	0.0045	0.0001	0.0001	0.0036	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0039
AL3202	A	CR	5.56708	5.56682	0.000260	0.0047	0.0001	0.0001	0.0037	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0041
AL3203	A	CR	5.57369	5.57348	0.000210	0.0038	0.0001	0.0001	0.0030	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0033
AL3204	A	CR	5.57269	5.57250	0.000190	0.0034	0.0001	0.0001	0.0027	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0030
AL3301	A	CR	5.55606	5.55582	0.000240	0.0043	0.0001	0.0001	0.0034	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0038
AP3001	A	CR	5.51792	5.51767	0.000250	0.0045	0.0001	0.0001	0.0036	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0040
AP3002	A	CR	5.53620	5.53600	0.000200	0.0036	0.0001	0.0001	0.0029	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0032
AP3003	A	CR	5.54377	5.54372	0.000050	0.0009	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0008
AP3004	A	CR	5.56575	5.56532	0.000430	0.0077	0.0002	0.0002	0.0062	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0068
AP3101	A	CR	5.52654	5.52639	0.000150	0.0027	0.0001	0.0001	0.0022	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0024
AP3102	A	CR	5.53928	5.53902	0.000260	0.0047	0.0001	0.0001	0.0037	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0041
AP3103	A	CR	5.55950	5.55950	0.000000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AP3202	A	CR	5.53489	5.53460	0.000290	0.0052	0.0001	0.0001	0.0042	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0046
AP3203	A	CR	5.56080	5.56071	0.000090	0.0016	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014
AP3204	A	CR	5.57538	5.57521	0.000170	0.0030	0.0001	0.0001	0.0024	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0027
AP3301	A	CR	5.52182	5.52155	0.000270	0.0049	0.0001	0.0001	0.0039	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0043
AP3302	A	CR	5.53906	5.53886	0.000200	0.0036	0.0001	0.0001	0.0029	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0032
AP3303	A	CR	5.56097	5.56079	0.000180	0.0032	0.0001	0.0001	0.0026	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0028
AP3304	A	CR	5.57664	5.57644	0.000200	0.0036	0.0001	0.0001	0.0029	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0032
AP3401	A	CR	5.52511	5.52497	0.000140	0.0025	0.0001	0.0001	0.0020	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0022
AP3402	A	CR	5.53551	5.53532	0.000190	0.0034	0.0001	0.0001	0.0027	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0030
AP3403	A	CR	5.54985	5.54959	0.000260	0.0047	0.0001	0.0001	0.0037	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0041
AP3404	A	CR	5.57474	5.57465	0.000090	0.0016	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014
AW3001	A	CR	5.53883	5.53881	0.000020	0.0004	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003
AW3002	A	CR	5.54124	5.54104	0.000200	0.0036	0.0001	0.0001	0.0029	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0032
AW3003	A	CR	5.53768	5.53760	0.000080	0.0014	0.0000	0.0000	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013
AW3004	A	CR	5.54639	5.54617	0.000220	0.0040	0.0001	0.0001	0.0032	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0035
AW3101	A	CR	5.53455	5.53424	0.000310	0.0056	0.0002	0.0001	0.0045	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0049
AW3102	A	CR	5.53542	5.53527	0.000150	0.0027	0.0001	0.0001	0.0022	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0024
AW3103	A	CR	5.54055	5.54027	0.000280	0.0051	0.0001	0.0001	0.0040	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0044
AW3104	A	CR	5.53931	5.53908	0.000230	0.0042	0.0001	0.0001	0.0033	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0037
AW3201	A	CR	5.53879	5.53865	0.000140	0.0025	0.0001	0.0001	0.0020	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0022
AW3202	A	CR	5.54088	5.54088	0.000000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
AW3203	A	CR	5.54549	5.54532	0.000170	0.0031	0.0001	0.0001	0.0024	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0027
AW3204	A	CR	5.55408	5.55391	0.000170	0.0031	0.0001	0.0001	0.0024	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0027
BL3001	B	CR	5.67965	5.67949	0.000160	0.0028	0.0002	0.0001	0.0031	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0036
BL3002	B	CR	5.66259	5.66255	0.000040	0.0007	0.0001	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007
BL3003	B	CR	5.67534	5.67527	0.000070	0.0012	0.0001	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0016
BL3004	B	CR	5.66524	5.66518	0.000060	0.0011	0.0001	0.0000	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014
BL3101	B	CR	5.67965	5.67960	0.000050	0.0009	0.0001	0.0000	0.0010	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0011
BL3102	B	CR	5.66024	5.66014	0.000100	0.0018	0.0001	0.0001	0.0020	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0023
BL3104	B	CR	5.64654	5.64651	0.000030	0.0005	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007
BL3201	B	CR	5.64862	5.64833	0.000290	0.0051	0.0004	0.0002	0.0057	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0066
BL3202	B	CR	5.65946	5.65936	0.000100	0.0018	0.0001	0.0001	0.0020	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0023
BL3203	B	CR	5.66242	5.66221	0.000210	0.0037	0.0003	0.0001	0.0041	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0048
BL3204	B	CR	5.67834	5.67829	0.000050	0.0009	0.0001	0.0000	0.0010	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0011
BP3002	B	CR	5.69294	5.69296	0.000000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
BP3003	B	CR	5.68031	5.68022	0.000090	0.0016	0.0001	0.0001	0.0017	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0020
BP3004	B	CR	5.68223	5.68213	0.000100	0.0018	0.0001	0.0001	0.0019	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0023
BP3005	B	CR	5.64422	5.64414	0.000080	0.0014	0.0001	0.0001	0.0016	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0018
BP3101	B	CR	5.66777	5.66774	0.000030	0.0005	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007
BP3102	B	CR	5.69403	5.69398	0.000050	0.0009	0.0001	0.0000	0.0010	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0011
BP3103	B	CR	5.68799	5.68792	0.000070	0.0012	0.0001	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0016
BP3104	B	CR	5.66728	5.66723	0.000050	0.0009	0.0001	0.0000	0.0010	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0011
BP3201	B	CR	5.65427	5.65410	0.000170	0.0030	0.0002	0.0001	0.0033	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0039
BP3202	B	CR	5.66764	5.66745	0.000190	0.0034	0.0002	0.0001	0.0037	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0043
BP3205	B	CR	5.68096	5.68078	0.000180	0.0032	0.0002	0.0001	0.0035	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0041
BP3301	B	CR	5.66554	5.66545	0.000090	0.0016	0.0001	0.0001	0.0018	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0020
BP3303	B	CR	5.69182	5.69172	0.000100	0.0018	0.0001	0.0001	0.0019	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0023
BP3304	B	CR	5.70487	5.70485	0.000020	0.0004	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004

Title: Graphite Specimen Mass Measurements for NESHAP Calculations

ECAR No.: 3611 Rev. No.: 1 Project No.: 23747 Date: 02/15/2018

			All in grams			Isotopes (µCi)																
Id	Grade Code	Type	PreMass	PostMass	Diff	% Mass Loss	^{46}Sc	^{54}Mn	^{60}Co	^{65}Zn	^{95}Zr	^{95}Nb	^{110m}Ag	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	Total (µCi)
BP3601	B	CR	5.65059	5.65058	0.000010	0.0002	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
BP3602	B	CR	5.66726	5.66723	0.000030	0.0005	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007
BP3603	B	CR	5.70168	5.70163	0.000050	0.0009	0.0001	0.0000	0.0010	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0011
BP3604	B	CR	5.69995	5.69983	0.000120	0.0021	0.0002	0.0001	0.0023	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0027
BP3605	B	CR	5.67865	5.67865	0.000000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
BP3702	B	CR	5.66648	5.66637	0.000110	0.0019	0.0001	0.0001	0.0021	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0025
BP3703	B	CR	5.68453	5.68440	0.000130	0.0023	0.0002	0.0001	0.0025	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0029
BP3801	B	CR	5.64887	5.64889	0.000000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
BW3001	B	CR	5.64294	5.64281	0.000130	0.0023	0.0002	0.0001	0.0025	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0030
BW3002	B	CR	5.65130	5.65126	0.000040	0.0007	0.0001	0.0000	0.0008	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0009
BW3101	B	CR	5.66376	5.66372	0.000040	0.0007	0.0001	0.0000	0.0008	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0009
BW3103	B	CR	5.63958	5.63945	0.000130	0.0023	0.0002	0.0001	0.0025	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0030
BW3202	B	CR	5.63612	5.63601	0.000110	0.0020	0.0001	0.0001	0.0022	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0025
BW3301	B	CR	5.63941	5.63932	0.000090	0.0016	0.0001	0.0001	0.0018	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0020
BW3303	B	CR	5.61775	5.61745	0.000300	0.0053	0.0004	0.0002	0.0059	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0069
BW3401	B	CR	5.64790	5.64784	0.000060	0.0011	0.0001	0.0000	0.0012	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0014
BW3402	B	CR	5.64212	5.64201	0.000110	0.0019	0.0001	0.0001	0.0022	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0025
BW3501	B	CR	5.63778	5.63767	0.000110	0.0020	0.0001	0.0001	0.0022	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0025
BW3502	B	CR	5.63621	5.63614	0.000070	0.0012	0.0001	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0016
BW3503	B	CR	5.66327	5.66311	0.000160	0.0028	0.0002	0.0001	0.0031	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0036
DA3001	D	CR	5.44905	5.44882	0.000230	0.0042	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004
DA3003	D	CR	5.42399	5.42363	0.000360	0.0066	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006
DA3004	D	CR	5.42055	5.42040	0.000150	0.0028	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
DA3104	D	CR	5.40787	5.40777	0.000100	0.0018	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
DA3203	D	CR	5.43040	5.43020	0.000200	0.0037	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003
DA3204	D	CR	5.41359	5.41345	0.000140	0.0026	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
DA3301	D	CR	5.45898	5.45878	0.000200	0.0037	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003
DA3302	D	CR	5.43919	5.43905	0.000140	0.0026	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
DA3303	D	CR	5.41651	5.41618	0.000330	0.0061	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005
DA3401	D	CR	5.49521	5.49495	0.000260	0.0047	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004
DA3403	D	CR	5.44576	5.44549	0.000270	0.0050	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004
DA3404	D	CR	5.43818	5.43788	0.000300	0.0055	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0005
DW3001	D	CR	5.38924	5.38877	0.000470	0.0087	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007
DW3002	D	CR	5.39546	5.39532	0.000140	0.0026	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
DW3003	D	CR	5.41858	5.41839	0.000190	0.0035	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003
DW3004	D	CR	5.39305	5.39286	0.000190	0.0035	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003
DW3101	D	CR	5.37206	5.37204	0.000020	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DW3102	D	CR	5.40985	5.40962	0.000230	0.0043	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004
DW3103	D	CR	5.41472	5.41458	0.000140	0.0026	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
DW3201	D	CR	5.42086	5.42086	0.000000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DW3202	D	CR	5.41487	5.41463	0.000240	0.0044	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004
DW3203	D	CR	5.42244	5.42239	0.000050	0.0009	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
DW3204	D	CR	5.43264	5.43247	0.000170	0.0031	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003
DW3301	D	CR	5.39299	5.39283	0.000160	0.0030	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
DW3302	D	CR	5.42761	5.42714	0.000470	0.0087	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0007
DW3303	D	CR	5.41107	5.41071	0.000360	0.0067	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0006
DW3304	D	CR	5.40836	5.40826	0.000100	0.0018	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
DW3401	D	CR	5.41258	5.41241	0.000170	0.0031	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003
DW3402	D	CR	5.42778	5.42768	0.000100	0.0018	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
DW3403	D	CR	5.41879	5.41856	0.000230	0.0042	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004
DW3404	D	CR	5.42442	5.42415	0.000270	0.0050	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004
DW3501	D	CR	5.42626	5.42609	0.000170	0.0031	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003
DW3502	D	CR	5.41341	5.41321	0.000200	0.0037	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003
DW3504	D	CR	5.42882	5.42867	0.000150	0.0028	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
DW3601	D	CR	5.40532	5.40506	0.000260	0.0048	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004
DW3602	D	CR	5.41651	5.41635	0.000160	0.0030	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
DW3603	D	CR	5.42059	5.42046	0.000130	0.0024	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
DW3604	D	CR	5.41134	5.41127	0.000070	0.0013	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
DW3701	D	CR	5.40052	5.40031	0.000210	0.0039	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003
DW3702	D	CR	5.41794	5.41795	0.000000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DW3703	D	CR	5.40170	5.40154	0.000160	0.0030	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
DW3704	D	CR	5.39836	5.39827	0.000090	0.0017	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001

Title: Graphite Specimen Mass Measurements for NESHAP Calculations

ECAR No.: 3611 Rev. No.: 1 Project No.: 23747 Date: 02/15/2018

Id	Grade Code	Type	All in grams				Isotopes (µCi)												Total (µCi)
			PreMass	PostMass	Diff	% Mass Loss	^{46}Sc	^{54}Mn	^{60}Co	^{65}Zn	^{95}Zr	^{95}Nb	^{108m}Ag	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	
DW3801	D	CR	5.39698	5.39676	0.000220	0.0041	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0003
DW3803	D	CR	5.40641	5.40629	0.000120	0.0022	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0002
DW3804	D	CR	5.38906	5.38892	0.000140	0.0026	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0002
DW3901	D	CR	5.41337	5.41308	0.000290	0.0054	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0004
DW3902	D	CR	5.42503	5.42489	0.000140	0.0026	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0002
DW3903	D	CR	5.41475	5.41462	0.000130	0.0024	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0002
EA3001	E	CR	5.35930	5.35904	0.000260	0.0049	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0007
EA3002	E	CR	5.34544	5.34502	0.000420	0.0079	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0002		0.0011
EA3003	E	CR	5.37270	5.37246	0.000240	0.0045	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0006
EA3004	E	CR	5.37000	5.36979	0.000210	0.0039	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0005
EA3101	E	CR	5.35555	5.35516	0.000390	0.0073	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0001		0.0010
EA3103	E	CR	5.39275	5.39248	0.000270	0.0050	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0007
EA3104	E	CR	5.40086	5.40055	0.000310	0.0057	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0001		0.0008
EA3201	E	CR	5.27610	5.27585	0.000250	0.0047	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0007
EA3202	E	CR	5.31345	5.31320	0.000250	0.0047	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0006
EA3203	E	CR	5.36916	5.36892	0.000240	0.0045	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0006
EA3204	E	CR	5.38814	5.38789	0.000250	0.0046	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0006
EA3301	E	CR	5.33502	5.33473	0.000290	0.0054	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0007
EW3001	E	CR	5.40735	5.40718	0.000170	0.0031	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001		0.0004
EW3003	E	CR	5.42687	5.42658	0.000290	0.0053	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0007
EW3004	E	CR	5.41207	5.41189	0.000180	0.0033	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001		0.0005
EW3101	E	CR	5.38158	5.38147	0.000110	0.0020	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0003
EW3103	E	CR	5.37847	5.37814	0.000330	0.0061	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0001		0.0008
EW3104	E	CR	5.37806	5.37774	0.000320	0.0060	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0001		0.0008
EW3201	E	CR	5.40317	5.40295	0.000220	0.0041	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0006
EW3202	E	CR	5.40004	5.39991	0.000130	0.0024	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0003
EW3203	E	CR	5.40166	5.40138	0.000280	0.0052	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0007
EW3204	E	CR	5.40349	5.40330	0.000190	0.0035	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0005
EW3301	E	CR	5.37135	5.37116	0.000190	0.0035	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0005
EW3302	E	CR	5.39075	5.39049	0.000260	0.0048	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0007
EW3303	E	CR	5.38973	5.38959	0.000140	0.0026	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001		0.0004
EW3304	E	CR	5.38191	5.38178	0.000130	0.0024	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0003
EW3401	E	CR	5.39920	5.39893	0.000270	0.0050	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0007
EW3402	E	CR	5.41925	5.41909	0.000160	0.0030	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001		0.0004
EW3403	E	CR	5.43841	5.43801	0.000400	0.0074	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0001		0.0010
EW3501	E	CR	5.37740	5.37749	0.000000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0000
EW3502	E	CR	5.39672	5.39640	0.000320	0.0059	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0001		0.0008
EW3503	E	CR	5.43585	5.43544	0.000410	0.0075	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0001		0.0010
EW3504	E	CR	5.43871	5.43839	0.000320	0.0059	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0001		0.0008
EW3601	E	CR	5.41226	5.41192	0.000340	0.0063	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0001		0.0009
EW3602	E	CR	5.42117	5.42071	0.000460	0.0085	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0002		0.0012
EW3603	E	CR	5.41106	5.41083	0.000230	0.0043	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0006
EW3604	E	CR	5.42155	5.42132	0.000230	0.0042	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0006
EW3701	E	CR	5.40285	5.40234	0.000510	0.0094	0.0000	0.0000	0.0006	0.0001	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0002		0.0013
EW3702	E	CR	5.40511	5.40486	0.000250	0.0046	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0006
EW3704	E	CR	5.39886	5.39855	0.000310	0.0057	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0001		0.0008
EW3801	E	CR	5.40452	5.40417	0.000350	0.0065	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0001		0.0009
EW3802	E	CR	5.41952	5.41920	0.000320	0.0059	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0001		0.0008
TW3001	T	CR	5.51957	5.51929	0.000280	0.0051	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0007
TW3002	T	CR	5.55435	5.55407	0.000280	0.0050	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0007
TW3003	T	CR	5.54027	5.54015	0.000120	0.0022	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0003
TW3004	T	CR	5.54305	5.54297	0.000080	0.0014	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0002
TW3005	T	CR	5.53627	5.53616	0.000110	0.0020	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0003
TW3006	T	CR	5.54052	5.54042	0.000100	0.0018	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0002
TW3008	T	CR	5.53106	5.53087	0.000190	0.0034	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0005
TW3009	T	CR	5.53943	5.53924	0.000190	0.0034	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0005
TW3010	T	CR	5.54427	5.54405	0.000220	0.0040	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0005
TW3101	T	CR	5.53104	5.53081	0.000230	0.0042	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0006
TW3102	T	CR	5.54157	5.54138	0.000190	0.0034	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0005
TW3103	T	CR	5.53463	5.53451	0.000120	0.0022	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0003
TW3105	T	CR	5.53210	5.53193	0.000170	0.0031	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001		0.0004
TW3106	T	CR	5.52387	5.52376	0.000110	0.0020	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0003

Title: Graphite Specimen Mass Measurements for NESHAP Calculations

ECAR No.: 3611 Rev. No.: 1 Project No.: 23747 Date: 02/15/2018

			All in grams			Isotopes (µCi)														
Id	Grade Code	Type	PreMass	PostMass	Diff	% Mass Loss	^{46}Sc	^{54}Mn	^{60}Co	^{65}Zn	^{95}Zr	^{95}Nb	^{110m}Ag	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	Total (µCi)
TW3107	T	CR	5.53214	5.53198	0.000160	0.0029	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0004
TW3108	T	CR	5.52758	5.52733	0.000250	0.0045	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001	0.0006
TW3109	T	CR	5.53280	5.53249	0.000310	0.0056	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0001	0.0008
TW3201	T	CR	5.49983	5.49958	0.000250	0.0045	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001	0.0006
TW3202	T	CR	5.53756	5.53732	0.000240	0.0043	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001	0.0006
TW3402	T	CR	5.54733	5.54706	0.000270	0.0049	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001	0.0007
TW3403	T	CR	5.54205	5.54180	0.000250	0.0045	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001	0.0006
TW3404	T	CR	5.53374	5.53364	0.000100	0.0018	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0002
TW3406	T	CR	5.53116	5.53083	0.000330	0.0060	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0001	0.0008
TW3407	T	CR	5.52914	5.52900	0.000140	0.0025	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0003
TW3408	T	CR	5.52411	5.52379	0.000320	0.0058	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0001	0.0008
TW3409	T	CR	5.52732	5.52710	0.000220	0.0040	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001	0.0005
TW3410	T	CR	5.54588	5.54573	0.000150	0.0027	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0004
TW3501	T	CR	5.54622	5.54589	0.000330	0.0059	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0001	0.0008
TW3502	T	CR	5.54972	5.54955	0.000170	0.0031	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0004
TW3503	T	CR	5.54270	5.54238	0.000320	0.0058	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0001	0.0008
TW3504	T	CR	5.53757	5.53749	0.000080	0.0014	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0002
TW3505	T	CR	5.53587	5.53571	0.000160	0.0029	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0004
TW3506	T	CR	5.52973	5.52969	0.000040	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
TW3507	T	CR	5.52943	5.52912	0.000310	0.0056	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0001	0.0008
TW3508	T	CR	5.53053	5.53006	0.000470	0.0085	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0004	0.0000	0.0000	0.0002	0.0012
TW3509	T	CR	5.53168	5.53154	0.000140	0.0025	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0003
TW3602	T	CR	5.52640	5.52609	0.000310	0.0056	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0001	0.0008
TW3605	T	CR	5.51341	5.51322	0.000190	0.0034	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001	0.0005
TW3606	T	CR	5.51341	5.51327	0.000140	0.0025	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0003
TW3607	T	CR	5.52274	5.52255	0.000190	0.0034	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001	0.0005
TW3608	T	CR	5.52269	5.52247	0.000220	0.0040	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001	0.0005
TW3609	T	CR	5.53072	5.53055	0.000170	0.0031	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0004
TW3610	T	CR	5.53339	5.53314	0.000250	0.0045	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001	0.0006
TW3702	T	CR	5.53991	5.53951	0.000400	0.0072	0.0000	0.0000	0.0005	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0001	0.0010
TW3703	T	CR	5.53691	5.53669	0.000220	0.0040	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001	0.0005
TW3704	T	CR	5.54067	5.54030	0.000370	0.0067	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0003	0.0000	0.0000	0.0001	0.0009
TW3705	T	CR	5.54375	5.54366	0.000090	0.0016	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0002
BL3603	B	PB	1.43677	1.43669	0.000080	0.0056	0.0001	0.0001	0.0015	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0018
BP3404	B	PB	1.43327	1.43329	0.000000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
BW4004	B	PB	1.43357	1.43350	0.000070	0.0049	0.0001	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0016
BW4005	B	PB	1.43065	1.43057	0.000080	0.0056	0.0001	0.0001	0.0015	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0018
BW4102	B	PB	1.43431	1.43423	0.000080	0.0056	0.0001	0.0001	0.0015	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0018
BP3409	B	PB	1.43926	1.43918	0.000080	0.0056	0.0001	0.0001	0.0015	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0018
BP3408	B	PB	1.43494	1.43486	0.000080	0.0056	0.0001	0.0001	0.0015	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0018
BW4101	B	PB	1.43373	1.43365	0.000080	0.0056	0.0001	0.0001	0.0015	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0018
BL3602	B	PB	1.43233	1.43213	0.000200	0.0140	0.0003	0.0001	0.0039	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0045
BW4006	B	PB	1.43013	1.42995	0.000180	0.0126	0.0002	0.0001	0.0025	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0040
BW4007	B	PB	1.43069	1.43055	0.000140	0.0098	0.0002	0.0001	0.0027	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0031
BP3406	B	PB	1.42177	1.42161	0.000160	0.0113	0.0002	0.0001	0.0031	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0036
BP3502	B	PB	1.42673	1.42664	0.000090	0.0063	0.0001	0.0001	0.0017	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0020
BW4003	B	PB	1.43305	1.43295	0.000100	0.0070	0.0001	0.0001	0.0019	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0022
BP3405	B	PB	1.42709	1.42702	0.000070	0.0049	0.0001	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0016
BP3407	B	PB	1.43211	1.43202	0.000090	0.0063	0.0001	0.0001	0.0017	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0020
P3-09	P	PB	1.40826	1.40816	0.000100	0.0071	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0002
P3-07	P	PB	1.41596	1.41579	0.000170	0.0120	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0004
DA3608	D	PB	1.37259	1.37243	0.000160	0.0117	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
DA3606	D	PB	1.37433	1.37438	0.000000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DW4601	D	PB	1.37370	1.37374	0.000000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DA3607	D	PB	1.36265	1.36254	0.000110	0.0081	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
DA3512	D	PB	1.38177	1.38176	0.000010	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
DA3504	D	PB	1.39072	1.39057	0.000150	0.0108	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
DW4504	D	PB	1.36570	1.36557	0.000130	0.0095	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
DW4505	D	PB	1.37951	1.37941	0.000100	0.0072	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002
DA3509	D	PB	1.37291	1.37272	0.000190	0.0138	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0003
DA3508	D	PB	1.37287	1.37264	0.000230	0.0168	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0004
DA3507	D	PB	1.38513	1.38497	0.000160	0.0116	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0002

Title: Graphite Specimen Mass Measurements for NESHAP Calculations

ECAR No.: 3611 Rev. No.: 1 Project No.: 23747 Date: 02/15/2018

Id	Grade Code	Type	All in grams			Isotopes (µCi)													Total (µCi)
			PreMass	PostMass	Diff	% Mass Loss	^{46}Sc	^{54}Mn	^{60}Co	^{65}Zn	^{95}Zr	^{95}Nb	^{110m}Ag	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	
DW4508	D	PB	1.37109	1.37093	0.000160	0.0117	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0002
DA3605	D	PB	1.37652	1.37639	0.000130	0.0094	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0002
DA3511	D	PB	1.37645	1.37623	0.000220	0.0160	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0003
DW4506	D	PB	1.36211	1.36191	0.000200	0.0147	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0003
DA3506	D	PB	1.38090	1.38076	0.000140	0.0101	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0002
DW4507	D	PB	1.37534	1.37506	0.000280	0.0204	0.0000	0.0000	0.0004	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0004
DW4512	D	PB	1.37950	1.37928	0.000220	0.0159	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0003
DW4502	D	PB	1.38078	1.38071	0.000070	0.0051	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0001
DA3503	D	PB	1.40437	1.40418	0.000190	0.0135	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0003
DA3501	D	PB	1.41076	1.41064	0.000120	0.0085	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0002
DW4503	D	PB	1.37596	1.37578	0.000180	0.0131	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0003
AW3812	A	PB	1.40990	1.40976	0.000140	0.0099	0.0001	0.0001	0.0020	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0022
AL3805	A	PB	1.41346	1.41342	0.000040	0.0028	0.0000	0.0000	0.0006	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0006
AL3804	A	PB	1.41173	1.41160	0.000130	0.0092	0.0001	0.0001	0.0018	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0020
AW3903	A	PB	1.40753	1.40756	0.000000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0000
AL3803	A	PB	1.41063	1.41047	0.000160	0.0113	0.0001	0.0001	0.0023	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0025
AP3504	A	PB	1.39752	1.39733	0.000190	0.0136	0.0001	0.0001	0.0027	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0030
AW3804	A	PB	1.40339	1.40310	0.000290	0.0207	0.0001	0.0001	0.0041	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0045
AL3807	A	PB	1.41024	1.41026	0.000080	0.0057	0.0000	0.0000	0.0011	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0012
AW3803	A	PB	1.40304	1.40294	0.000100	0.0071	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0016
AP3509	A	PB	1.40886	1.40875	0.000110	0.0078	0.0001	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0017
AW3809	A	PB	1.40776	1.40768	0.000080	0.0057	0.0000	0.0000	0.0011	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0012
AP3508	A	PB	1.40716	1.40703	0.000130	0.0092	0.0001	0.0001	0.0018	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0020
AL3806	A	PB	1.40857	1.40842	0.000150	0.0106	0.0001	0.0001	0.0021	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0023
AP3507	A	PB	1.40657	1.40648	0.000090	0.0064	0.0000	0.0000	0.0013	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0014
AL3802	A	PB	1.41123	1.41108	0.000150	0.0106	0.0001	0.0001	0.0021	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0023
AW3805	A	PB	1.40317	1.40295	0.000220	0.0157	0.0001	0.0001	0.0031	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0034
AP3506	A	PB	1.40456	1.40439	0.000170	0.0121	0.0001	0.0001	0.0024	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0027
AW3806	A	PB	1.40589	1.40562	0.000270	0.0192	0.0001	0.0001	0.0038	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0042
AW3808	A	PB	1.40309	1.40296	0.000130	0.0093	0.0001	0.0001	0.0018	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0020
AW3810	A	PB	1.40952	1.40939	0.000130	0.0092	0.0001	0.0001	0.0018	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0020
AW3801	A	PB	1.40116	1.40105	0.000110	0.0079	0.0001	0.0000	0.0016	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0017
AP3503	A	PB	1.39836	1.39824	0.000120	0.0086	0.0001	0.0000	0.0017	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0019
AP3502	A	PB	1.40832	1.40810	0.000220	0.0156	0.0001	0.0001	0.0031	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0034
AW3902	A	PB	1.41038	1.41028	0.000100	0.0071	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0016
EW4601	E	PB	1.35132	1.35119	0.000130	0.0096	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0003
EW4603	E	PB	1.35458	1.35453	0.000050	0.0037	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0001
EA3609	E	PB	1.35489	1.35497	0.000000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0000
EW4511	E	PB	1.35198	1.35198	0.000000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0000
EW4503	E	PB	1.35590	1.35576	0.000140	0.0103	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0004
EA3507	E	PB	1.33715	1.33697	0.000180	0.0135	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0005
EW4504	E	PB	1.35414	1.35403	0.000110	0.0081	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0003
EW4609	E	PB	1.35982	1.35967	0.000150	0.0110	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001		0.0004
EW4608	E	PB	1.35753	1.35727	0.000260	0.0192	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0007
EA3511	E	PB	1.35021	1.35008	0.000130	0.0096	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0003
EW4508	E	PB	1.35383	1.35361	0.000220	0.0163	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0006
EW4505	E	PB	1.35538	1.35521	0.000170	0.0125	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001		0.0004
EA3610	E	PB	1.35793	1.35779	0.000140	0.0103	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0004
EW4506	E	PB	1.35644	1.35637	0.000070	0.0052	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0002
EA3510	E	PB	1.35249	1.35233	0.000160	0.0118	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001		0.0004
EA3509	E	PB	1.35170	1.35145	0.000250	0.0185	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0006
EW4507	E	PB	1.35554	1.35530	0.000240	0.0177	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0006
EW4510	E	PB	1.35495	1.35478	0.000170	0.0125	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001		0.0004
EA3508	E	PB	1.34384	1.34368	0.000160	0.0119	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001		0.0004
EW4502	E	PB	1.35349	1.35334	0.000150	0.0111	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001		0.0004
EA3505	E	PB	1.33655	1.33642	0.000130	0.0097	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0003
EA3506	E	PB	1.34187	1.34166	0.000210	0.0156	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0005
TW3823	T	PB	1.40614	1.40634	0.000200	0.0142	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001		0.0005
TW3829	T	PB	1.40704	1.40691	0.000130	0.0092	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0003
TW3808	T	PB	1.40678	1.40669	0.000090	0.0064	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000		0.0002
TW3806	T	PB	1.40706	1.40706	0.000000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0000
TW3807	T	PB	1.40757	1.40752	0.000050	0.0036	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000		0.0001

Title: Graphite Specimen Mass Measurements for NESHAP Calculations

ECAR No.: 3611 Rev. No.: 1 Project No.: 23747 Date: 02/15/2018

Id	Grade Code	Type	All in grams PreMass	PostMass	Diff	% Mass Loss	Isotopes (µCi) ^{46}Sc	^{54}Mn	^{60}Co	^{65}Zn	^{95}Zr	^{95}Nb	^{108m}Ag	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	Total (µCi)
TW3904	T	PB	1.41309	1.41298	0.000110	0.0078	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0003
TW3815	T	PB	1.40660	1.40672	0.000000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
TW3816	T	PB	1.40601	1.40592	0.000090	0.0064	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0002
TW3811	T	PB	1.40568	1.40561	0.000070	0.0050	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0002
TW3813	T	PB	1.40491	1.40481	0.000100	0.0071	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0002
TW3814	T	PB	1.40739	1.40730	0.000090	0.0064	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0002
TW3805	T	PB	1.40904	1.40885	0.000190	0.0135	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001	0.0005
TW3821	T	PB	1.40832	1.40818	0.000140	0.0099	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0003
TW3809	T	PB	1.40713	1.40695	0.000180	0.0128	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0004
TW3802	T	PB	1.41130	1.41120	0.000100	0.0071	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0002
200-12	P	PB	1.38264	1.38265	0.000000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
325-12	P	PB	1.39009	1.39002	0.000070	0.0050	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0002
325-11	P	PB	1.40710	1.40696	0.000140	0.0099	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0003
200-10	P	PB	1.42424	1.42419	0.000050	0.0035	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
325-4	P	PB	1.38708	1.38693	0.000150	0.0108	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0004
324-3	P	PB	1.42590	1.42572	0.000180	0.0126	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0004
325-3	P	PB	1.38245	1.38223	0.000220	0.0159	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001	0.0005
328-4	P	PB	1.33074	1.33056	0.000180	0.0135	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001	0.0005
324-4	P	PB	1.42461	1.42464	0.000000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
200-3	P	PB	1.36361	1.36360	0.000010	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
200-4	P	PB	1.38409	1.38414	0.000000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
328-3	P	PB	1.32943	1.32932	0.000110	0.0083	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0003
325-14	P	PB	1.38241	1.38229	0.000120	0.0087	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0003
324-8	P	PB	1.42853	1.42848	0.000050	0.0035	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
200-14	P	PB	1.37582	1.37570	0.000120	0.0087	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0003
325-8	P	PB	1.38340	1.38323	0.000170	0.0123	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0004
328-9	P	PB	1.33302	1.33289	0.000130	0.0098	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0003
328-8	P	PB	1.32754	1.32736	0.000180	0.0136	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0005
200-8	P	PB	1.37341	1.37329	0.000120	0.0087	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0003
200-13	P	PB	1.37561	1.37544	0.000170	0.0124	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0004
324-9	P	PB	1.42509	1.42493	0.000160	0.0112	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0004
200-7	P	PB	1.37924	1.37903	0.000210	0.0152	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001	0.0005
325-7	P	PB	1.45541	1.45539	0.000020	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
200-6	P	PB	1.38049	1.38032	0.000170	0.0123	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0001	0.0004
325-5	P	PB	1.39594	1.39580	0.000140	0.0100	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0003
325-6	P	PB	1.38239	1.38238	0.000010	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
328-6	P	PB	1.33073	1.33050	0.000230	0.0173	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001	0.0006
200-5	P	PB	1.42692	1.42670	0.000220	0.0154	0.0000	0.0000	0.0003	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001	0.0005
324-7	P	PB	1.42960	1.42948	0.000120	0.0084	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0003
325-2	P	PB	1.39261	1.39252	0.000090	0.0065	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0002
200-2	P	PB	1.38694	1.38683	0.000110	0.0079	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0003
328-1	P	PB	1.33371	1.33360	0.000110	0.0082	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0003
200-1	P	PB	1.38555	1.38549	0.000060	0.0043	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0001
325-10	P	PB	1.40655	1.40646	0.000090	0.0064	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0002
328-2	P	PB	1.32939	1.32931	0.000080	0.0060	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0002
328-7	P	PB	1.33510	1.33501	0.000090	0.0067	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0002
324-6	P	PB	1.42518	1.42514	0.000040	0.0028	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
328-5	P	PB	1.32432	1.32413	0.000190	0.0143	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001	0.0005
324-5	P	PB	1.42658	1.42644	0.000140	0.0098	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0003
325-9	P	PB	1.40388	1.40368	0.000200	0.0142	0.0000	0.0000	0.0002	0.0000	0.0000	0.0000	0.0000	0.0002	0.0000	0.0000	0.0001	0.0005
S3	A	PB	1.40836	1.40816	0.000200	0.0142	0.0001	0.0001	0.0028	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0031
S4	A	PB	1.40755	1.40742	0.000130	0.0092	0.0001	0.0001	0.0018	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0020
S8	A	PB	1.40821	1.40811	0.000100	0.0071	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0016
S7	A	PB	1.39870	1.39862	0.000080	0.0057	0.0000	0.0000	0.0011	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0013
S5	A	PB	1.40511	1.40492	0.000190	0.0135	0.0001	0.0001	0.0027	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0030
S6	A	PB	1.41308	1.41298	0.000100	0.0071	0.0000	0.0000	0.0014	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0016
D	A	PB	1.45879	1.45847	0.000320	0.0219	0.0001	0.0001	0.0044	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0048
C	A	PB	1.46090	1.45953	0.001370	0.0938	0.0006	0.0005	0.0187	0.0001	0.0000	0.0000	0.0000	0.0004	0.0000	0.0001	0.0001	0.0206
H	A	PB	1.46478	1.46473	0.000050	0.0034	0.0000	0.0000	0.0007	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0008
E	A	PB	1.44403	1.44283	0.001200	0.0831	0.0006	0.0005	0.0166	0.0001	0.0000	0.0000	0.0000	0.0004	0.0000	0.0001	0.0001	0.0183
F	A	PB	1.45490	1.45462	0.000280	0.0192	0.0001	0.0001	0.0038	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0042
G	A	PB	1.46187	1.46179	0.000080	0.0055	0.0000	0.0000	0.0011	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0012

	Id	Grade Code	Type	All in grams PreMass	PostMass	Diff	% Mass Loss	Isotopes (µCi) ^{46}Sc	^{54}Mn	^{60}Co	^{65}Zn	^{95}Zr	^{95}Nb	^{110m}Ag	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	Total (µCi)
B		A	PB	1.47642	1.47618	0.000240	0.0163	0.0001	0.0001	0.0032	0.0000	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0036
	Total (µCi)							0.0147	0.0097	0.3718	0.0049	0.0005	0.0005	0.0007	0.0346	0.0006	0.0017	0.0130	0.4527

Table from : INL/EXT-14-31843 Rev 0, Graphite Gamma Scan Results

all µCi

		^{46}Sc	^{54}Mn	^{60}Co	^{65}Zn	^{95}Zr	^{95}Nb	^{110m}Ag	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu
A	NBG-17	1.72	1.47	55.20	0.31	0.12	0.06	0.12	1.37	0.07	0.02	0.76
		3.70	2.91	104.33	0.23	-	0.14	0.09	2.21	0.12	0.55	0.28
	Avg	2.71	2.19	79.77	0.27	0.12	0.10	0.11	1.79	0.10	0.29	0.52
B	NBG-18	5	2.52	77.9	0.28	0.14	0.15	0.08	3.77	0.13	0.5	0.98
		9.87	4.76	142.89	0.17	0.16	0.31	-	5.21	0.25	1.15	0.41
	Avg	7.44	3.64	110.40	0.23	0.15	0.23	0.08	4.49	0.19	0.83	0.70
C	H-451	0.12	1.22	13.84	0.70	-	-	0.67	0.20	-	-	0.02
		0.06	0.56	6.68	1.11	-	-	0.27	0.13	-	0.01	0.03
	Avg	0.09	0.89	10.26	0.91	-	-	0.47	0.17	-	0.01	0.03
D	PCEA	0.02	0.04	11.87	0.38	-	-	0.02	0.01	0.01	0.02	0.03
		0.05	0.03	3.67	0.35	0.01	0.02	0.02	0.03	0.02	0.10	
	Avg	0.04	0.04	7.77	0.37	0.01	0.02	0.02	0.02	0.02	0.06	0.03
E	IG-110	0.01	0.06	4.62	0.57	-	-	0.05	-	0.02	-	0.45
		0.03	0.05	8.60	0.55	-	-	0.06	4.50	-	-	3.40
	Avg	0.02	0.06	6.61	0.56	-	-	0.06	4.50	0.02	-	1.93
F	IG-430	0.02	0.01	0.92	0.18	-	-	0.01	-	0.02	-	-
		0.01	0.04	1.17	0.17	-	-	0.01	-	0.02	-	0.02
	Avg	0.02	0.03	1.05	0.18	-	-	0.01	-	0.02	-	0.02
T	2114	0.01	0.06	4.62	0.57	-	-	0.05	-	0.02	-	0.45
		0.03	0.05	8.60	0.55	-	-	0.06	4.50	-	-	3.40
	Avg	0.02	0.06	6.61	0.56	-	-	0.06	4.50	0.02	-	1.93
P	PCIB	0.01	0.06	4.62	0.57	-	-	0.05	-	0.02	-	0.45
		0.03	0.05	8.60	0.55	-	-	0.06	4.50	-	-	3.40
	Avg	0.02	0.06	6.61	0.56	-	-	0.06	4.50	0.02	-	1.93

Title: Graphite Specimen Mass Measurements for NESHAP Calculations

ECAR No.: 3611 Rev. No.: 1 Project No.: 23747 Date: 02/15/2018

Spread Sheet Notes:

Balance used
Sartorius ME235P
Accuracy: 0.00019 g
Cal ID: 412642
Cal Due Date: 5/25/2017

13 of the specimens showed an increase in mass, but in all of these cases the increase was less than the accuracy (+/- 190 µg) of the balance, therefor they were not included in the calculation.

Metal contaniments of graphite types 2114 and PCIB are similar to IG-110, therefore the gamma spec. data for IG-110 was used.

Graphite Grade Designations:

Graphite	designation	QA No:
2114	TW	AGC-10-002
NBG-18	BP, BW, BL	150280
NBG-17	AP, AW, AL	AGC-11-004
IG-110	EA, EW	AGC-11-001
PCEA	DA, DW	153718
PCIB	P3	AGC-09-013
HOPG	CAN101-117	150197
MLRF	CAN121-129	AGC-12-002
SGL-NBG-17 SiC	letter A-Z	AGC-12-003
SGL-NBG-17	S-1 thru S20	AGC-12-003
PCIB-200	200	AGC-12-001
PCIB-325	325	AGC-12-001
TS5324	324	AGC-12-001
TS5328	328	AGC-12-001

Appendix B

Concurrence with Methods and Calculations

2/8/2017 Idaho National Laboratory Mail - Re: Review of Graphite Mass Loss Activity

Idaho National Laboratory

Swank, W David <w.swank@inl.gov>

Re: Review of Graphite Mass Loss Activity

1 message

Echeverria, Todd C <todd.echeverria@inl.gov> Wed, Nov 16, 2016 at 8:09 AM
To: "Swank, W David" <w.swank@inl.gov>

Dave,

I concur with this spreedsheet. To me it proves what we thought, very little activity is lost.

Todd

On Mon, Nov 14, 2016 at 5:03 PM, Swank, W David <w.swank@inl.gov> wrote:

> Gentlemen,
>
> We have completed our mass measurements of all graphite specimens heated above 100°C in CY-16. Attached is the Excel spreadsheet that contains both the pre and post heating mass measurements and the calculation of the µCi contained in this mass loss from the isotopes measured, ref: INL/EXT-14-31843.
>
> I'm asking that you please review this spreadsheet for accuracy prior to me releasing it to the environmental folks for their calculation of the NESHAP value. I would be happy to discuss the spreadsheet logic to make your review efficient as possible.
>
> During the "Fact Finding" meeting of 11-9-16 I committed to have this task completed by 11-16-16 COB. I did this without considering that we would want a review of these calculations and correspondingly, the availability of your time. Please let me know if you don't have time to perform this review and I will find an alternate.
>
> Thanks!
>
> swank
>
> --
> W. David Swank
> W.Swank@INL.GOV
> 208-526-1698

--
Todd C Echeverria
CFA Radiological Engineer
CFA-615
Work: 208-526-0608
Cell: 208-569-6375

https://mail.google.com/mail/u/0/?ui=2&ik=c2ffb564eb&view=pt&q=neshap%20review%20spread%20sheet&qs=true&search=query&th=1586daf4a158... 1/1

Idaho National Laboratory

Swank, W David <w.swank@inl.gov>

Fwd: Review of Graphite Mass Loss Activity

1 message

Swank, W David <w.swank@inl.gov> Wed, Nov 16, 2016 at 5:41 PM
To: David B Lively <david.lively@inl.gov>
Cc: "Montgomery, Robert A" <robert.montgomery@inl.gov>, Todd C Echeverria <todd.echeverria@inl.gov>, Bill Bauer <William.Bauer@inl.gov>

Attached is Bill Bauer's review of our activity calculation spread sheet.

Addressing his question in comment #2: These specimens, identified as "Type PB" in the spreadsheet, are 1/4 the size of the specimens that gamma spectroscopy was performed on therefore 1/4 of the activity was used.

Dave S.

---------- Forwarded message ----------
From: **Bauer, William F** <william.bauer@inl.gov>
Date: Wed, Nov 16, 2016 at 5:11 PM
Subject: Re: Review of Graphite Mass Loss Activity
To: "Swank, W David" <w.swank@inl.gov>
Cc: Todd C Echeverria <todd.echeverria@inl.gov>

I have reviewed the spreadsheet and all looks reasonable to me. Below are some comments that need to be considered.

1. Use of the average concentration for the mid (low?) and high level samples is most realistic.
2. I am a little confused that activities on the bottom portion of the sheet are divided by 4. Why? Was the actual coupon on which the activity was measured 4x larger?
3. Since I have been unable to get in contact with Bob, I don't have a the right table by which to to compare the activities and the sum of ratios to the actual table. But as a first estimation, I think the worst case scenario is that if we were 40x (i.e. sum of ratios =40) over the NESHAP limit originally when assuming that all of the activity (using the worst case concentrations for everything) went up the stack, then if we reasonably tie radionuclide loss to weight loss (0.0063%), the new contribution to the sum of ratios would be 0.0025 or <0.0085 at the 95% confidence interval. Since the spreadsheet actually uses an average suspected activity for each graphite type with no decay correction, then we can assume the actual contribution to the emission sum of ratios will be considerably less still because the actual activities for some of the graphite types are significantly less than the worst case activity.
4. Supplemental information that needs to be noted to support the new estimates is that
    - after heating, the samples actually still contain significant activity as measured by the pancake probe
    - after heating no activity has been noted downstream of the purged tube furnace.
    - the isotope in question would not likely volatilize at the temperatures in question (we can verify with CRC data) and if they did they would immediately condense on the walls of the downstream tubing and or be captured as nanoparticulates in the HEPA filter. No activity has be measured in these areas
    - The primary radionculide in these samples is Co-60 which should be readily found because each decay produces 2 relatively high energy gammas.
5.

William F, Bauer, Ph.D.
Chemical and Radiation Measurements
Idaho National Laboratory
1765 N. Yellowstone Hwy
Idaho Falls, ID 83415-3531
ph: 208-526-1180
cell: 208-360-9824
email: william.bauer@inl.gov

On Mon, Nov 14, 2016 at 5:03 PM, Swank, W David <w.swank@inl.gov> wrote:

> Gentlemen,
>
> We have completed our mass measurements of all graphite specimens heated above 100°C in CY-16. Attached is the Excel spreadsheet that contains both the pre and post heating mass measurements and the calculation of the µCi contained in this mass loss from the isotopes measured, ref: INL/EXT-14-31843.
>
> I'm asking that you please review this spreadsheet for accuracy prior to me releasing it to the environmental folks for their calculation of the NESHAP value. I would be happy to discuss the spreadsheet logic to make your review efficient as possible.
>
> During the "Fact Finding" meeting of 11-9-16 I committed to have this task completed by 11-16-16 COB. I did this without considering that we would want a review of these calculations and correspondingly, the availability of your time. Please let me know if you don't have time to perform this review and I will find an alternate.
>
> Thanks!
>
> swank
>
> --
> W. David Swank
> W.Swank@INL.GOV
> 208-526-1698

--
W. David Swank
W.Swank@INL.GOV
208-526-1698

Idaho National Laboratory

Swank, W David <w.swank@inl.gov>

Re: Graphite mass measurements and calculation of isotope activity

1 message

Montgomery, Robert A <robert.montgomery@inl.gov> Thu, Nov 17, 2016 at 8:35 AM
To: "Swank, W David" <w.swank@inl.gov>
Cc: David B Lively <david.lively@inl.gov>, Heather G Silverman <heather.silverman@inl.gov>, Gabriel O Ilevbare <gabriel.ilevbare@inl.gov>, Scott L Lyman <scott.lyman@inl.gov>, Garold L Gresham <garold.gresham@inl.gov>, Les Scott <les.scott@inl.gov>, Will Windes <William.Windes@inl.gov>, "Hendricks, Terry Neal" <terry.hendricks@inl.gov>, Todd C Echeverria <todd.echeverria@inl.gov>, Patrick T Laney <Patrick.Laney@inl.gov>, James A Durrant <james.durrant@inl.gov>, dave rohrbaugh <David.Rohrbaugh@inl.gov>, Bill Bauer <William.Bauer@inl.gov>, "Sandvig, Michael D" <michael.sandvig@inl.gov>, Mark A Verdoorn <mark.verdoorn@inl.gov>, Kent L Miller <kent.miller@inl.gov>, Timothy A Miller <timothy.miller@inl.gov>, John M Espinosa <john.espinosa@inl.gov>, Donald T Maiers <Donald.Maiers@inl.gov>

Dave,

Mark Verdoorn and I have reviewed both the weights/calculation spreadsheet and Heather's Rad Neshap estimate spreadsheet. We agree that weight/calculation spreadsheet establishes a reasonable estimate of uncontrolled emissions based upon initial gamma-spec analysis and sample weight loss during heating. We agree that Heather's Rad Neshap spreadsheet accurately reflects the estimated material loss and estimates a resulting potential off-site dose of 5.92E-5 mr.

Our concerns regarding the Potential to Emit associated with this workscope have been fully addressed. Thank-You, Dave, and all those who participated in this special effort, for your prompt and professional response to resolve the issue.

Because of the importance of these estimates and their potential future use, I urge that we formalize and retain the data and calculations in a document such as an ECAR.

Mike Sandvig, Les Scott, and Don Maiers,

I suggest we work with Scott Lyman and Dave Lively to effect a schedule to resume work with unsealed rad material at the IRC campus in accordance with the list of Corrective Actions.

Thank-You Again
Bob

On Wed, Nov 16, 2016 at 4:29 PM, Swank, W David <w.swank@inl.gov> wrote:

> Please find attached an Excel spread sheet with the mass measurements of all irradiated graphite specimens heated above 100°C in IRC C-18 during CY-16 (note that no further heating of irradiated graphite specimens is planned for CY-16).
>
> The spread sheet contains the mass of individual specimens pre and post heating. The ratio of the difference in mass to the original mass is used to calculate the potential isotope loss using a table of gamma spec measurements made on 12 different samples that represent 6 different graphite types and irradiation histories.
>
> The value for the isotope activity that potentially could exit from the building is **0.45 µCi**. As expected this value, calculated empirically, is significantly lower than the first "worst case" value of ~36K µCi. calculated earlier.
>
> This Excel spread sheet has been reviewed internally by the graphite program (myself and David Rohbaugh) and independently by Todd Echeverria, Radiological Engineering. I have also requested a review from Bill Bauer but have not yet heard back from Bill. Once I receive a response from him I will forward it on to the group.
>
> Please do not hesitate to call if their are questions or you need more information,

2/8/2017 Idaho National Laboratory Mail - Re: Graphite mass measurements and calculation of isotope activity

Dave Swank

--
W. David Swank
W.Swank@INL.GOV
208-526-1698

Idaho National Laboratory

Swank, W David <w.swank@inl.gov>

Re: Graphite Oxidation Experiments
1 message

Espinosa, John M <john.espinosa@inl.gov> Wed, Jan 3, 2018 at 10:54 AM
To: "Swank, W David" <w.swank@inl.gov>

Dave,
I have reviewed both spreadsheets. I concur with the calculations in both spreadsheets for the 20 samples identified. The use of the new emission factors appears to result in a lower potential dose to the public than using the difference in the weights. In either case this is a significant portion of the allotted dose and Heather Silverman should be consulted so that she can use it in her projected estimates for the facility.

Let me know if you have any other questions.
Thank you for your patience.
John

John M. Espinosa
R&D Program Environmental Lead
(208) 526-4919
(208) 520-1384 (cell)

On Wed, Jan 3, 2018 at 8:27 AM, Swank, W David <w.swank@inl.gov> wrote:

> John,
>
> I know this is a busy time of year with the curtailment and all but I'm wondering if you have had a chance to look at this. Is there more information you need or questions?
>
> Dave S.
>
> ---------- Forwarded message ----------
> From: **Swank, W David** <w.swank@inl.gov>
> Date: Mon, Dec 4, 2017 at 10:07 AM
> Subject: Re: Graphite Oxidation Experiments
> To: "Espinosa, John M" <john.espinosa@inl.gov>
>
> John, Thanks for your help on this. Yes, you are right, it looks like we need to continue with our mass loss measurements and source term calcs as we have been doing.
>
> We have an oxidation experiment planned in which we need to purposely oxidize ~20 specimens to 10% mass loss. I used the spread sheet to estimate the potential exposure for such an experiment. Using the "mass loss" method I calculate 0.057 mRem. Using the "emission factor" method results in 0.013 mRem.
> (spread sheets attached)
>
> Note that the specimens used in the oxidation experiment are 1/4 the size of the specimens that the activity measurements were made on. Therefore I divided the activities by 4 for each isotope.
>
> Is it permissible for us to use the "mass loss" method for our standard testing (as has been done) but use the "emission factor" method for this oxidation experiment?
>
> What is the the permissible estimated exposure for our facility?
>
> Thanks again for your help,
> Dave S.
>
> On Mon, Nov 27, 2017 at 1:20 PM, Espinosa, John M <john.espinosa@inl.gov> wrote:
>
>> Dave,
>> I apologize for the delay in reviewing your revised ECAR. We probably didn't communicate the application of the emission factors using the approach approved by EPA. You can either apply the difference method as you had done in the previous version of the ECAR or using the new approach but you can't do both. So in order to use the new method you have to apply the calculations to the entire sample mass NOT just the difference. I recalculated the dose using the total activity of all of the samples, converted to curies and multiplied the Unit Dose Factor to come up with a total

dose to the Maximally Exposed Individual (MEI) at 100 meters. I calculated a total dose of 0.63 mrem/yr for all of your samples. Cs-134 is the largest contributor at 0.58 mrem/yr. I added the calculations in the "comparison" tab in Rows 377 and 378.

So it appears that you would be better staying with the mass loss calculation method of determining your emissions.
Let me know if you have any questions.
Thanks.
John

John M. Espinosa
R&D Program Environmental Lead
(208) 526-4919
(208) 520-1384 (cell)

On Tue, Nov 14, 2017 at 12:14 PM, Espinosa, John M <john.espinosa@inl.gov> wrote:

Dave,
I have not had time to look at it yet. There are many competing priorities.

I'll try to get to it soon.
John

John M. Espinosa
R&D Program Environmental Lead
(208) 526-4919
(208) 520-1384 (cell)

On Tue, Nov 14, 2017 at 12:10 PM, Swank, W David <w.swank@inl.gov> wrote:

John,
Just wondering if you have had a chance to look at the changes to ECAR-3611. Let me know if you have any questions.

Dave S.

On Tue, Nov 7, 2017 at 10:42 AM, Swank, W David <w.swank@inl.gov> wrote:

John,

As we discussed on the phone I have modified ECAR-3611 to include the approved "modified emission factors". Please review the modifications (in RED) and let me know what you think. I have also attached the spread sheet used for the source term estimation. The only thing that was changed in the spread sheet is the addition of the emission factors. As noted on the spread sheet (first tab) and in the ECAR, this was done for a specimen heating limit of 1200°C. Each emission factor was added into the calculation for each isotope (rows H thru R on the "comparison" tab). The accuracy of the spread sheet was reviewed by David Rohrbaugh.

Please let me know your comments as soon as possible. We have work planned for this year that needs this documentation completed.

Thanks for your help,
Dave S.

On Tue, Oct 31, 2017 at 2:59 PM, Espinosa, John M <john.espinosa@inl.gov> wrote:

Dave,
Attached is the letter that we sent with additional references and the approval letter.

Let me know if you need anything else.
Thanks.
John

John M. Espinosa
R&D Program Environmental Lead
(208) 526-4919

(208) 520-1384 (cell)

On Tue, Oct 31, 2017 at 2:41 PM, Swank, W David <w.swank@inl.gov> wrote:

John,

I have a couple of questions, the answers to which could significantly impact our research in the ART Graphite program... in a good way.

We have some research planned that is going to help answer the question that deals with graphite oxidation in a gas cooled reactor. One of the things we need to do is understand how oxidation of irradiated graphite is different from virgin graphite. Long story short, we need to oxidize approximately 25 irradiated specimens until we have 10% mass loss. From this data we can get rates of oxidation and property change information.

1. If I use our method of accounting for the potential loss of rad material and the activity that would go along with it by associating it with the mass loss of the carbon (as we currently do for the NESHAP estimate), I estimate 80 µCi (this assumes worst case activities as measure by gamma spec). Can you tell me what that is in mRem exposure and what percent of the allowable it is?

2. What is the status of the DOE letter that would allow a 1E-6 factor applied to isotope activities heated up to their melting point? If I can apply the guidance in the letter you sent earlier, question #1 would go away.

Please call me and we can discuss this in more detail, or better yet we can arrange a time for you to come see how and what we need to do.

Thanks,
Dave

--
W. David Swank
W.Swank@INL.GOV
208-526-1698

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W.Swank@INL.GOV
208-526-1698

Appendix C
DOE-ID Letter Requesting EPA Approval to Use Physical State Factors in Calculating Source Term OS-ESD-17-056

Department of Energy
Idaho Operations Office
1955 Fremont Avenue
Idaho Falls, ID 83415

May 22, 2017

Mr. Don Dossett, Unit Manager Stationary Source Unit
U.S. Environmental Protection Agency, Region 10
Office of Air and Waste
1200 6th Avenue, Suite 900, M/S OAW-150
Seattle, WA 98101

SUBJECT: Request for Alternative Method Approval of 40 Code of Federal Regulations Part 61 Appendix D Physical State Emission Factors to Heated Radioactive Solid Materials with High Melting and Boiling Points (OS-ESD-17-056)

REFERENCE: Letter; Johnny O. Moore, Manger ORNL Site Office to Gregg Worley, Chief Air Analysis and Support Branch Air, Pesticides and Toxics Management Division United States Environmental Protection Agency Region 4, Dated February 3, 2016

Dear Mr. Dossett:

The U.S. Department of Energy, Idaho Operations Office (DOE-ID) is submitting a request for approval from the Environmental Protection Agency (EPA) Region 10 to allow the Idaho National Laboratory (INL) Site to use modified emission factors for radioactive solid materials that have melting and boiling points above 100 degrees Celsius for the determination of the source term. The source term is then used for the calculation of the effective dose equivalent as required in 40 Code of Federal Regulations Part 61, Subpart H - National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities (Subpart H), Section 61.96 – Applications to Construct or Modify.

The INL Site is a designated facility as defined in Subpart H and is therefore required to estimate the effective dose equivalent, for the purpose of determining the requirement to submit an application for approval to construct, using the source term derived from the procedures in Appendix D to Part 61 - Methods for Estimating Radionuclide Emissions (Appendix D). Subpart H, §61.96 (b) allows EPA to approve other procedures for estimating the source term as long as the facility is in compliance with Subpart H based on its last annual report. The INL Site was in compliance with Subpart H on its last annual report for calendar year 2015, and therefore meets the criteria to request an approval to use an alternative method for calculating source term.

DOE-ID requests, pursuant to Subpart H, §61.96 (b), approval for an alternative method for calculating the source term using physical state factors for radioactive solid materials with high melting and boiling points. Approval is requested to use the following alternative method:

1. An emission factor of 1 will be applied to radioactive solid materials heated to temperatures greater than or equal to 90 percent of the boiling or subliming point.
2. An emission factor of 10^{-3} will be applied to radioactive solid materials heated to temperatures greater than or equal to their melting point but less than 90 percent of their boiling or subliming point.
3. An emission factor of 10^{-6} will be applied to radioactive solid materials heated to temperatures above ambient temperature but less than their melting point.

Melting, subliming and boiling points will be obtained from reference standards such as CRC Handbook of Chemistry and Physics, Lange's Handbook of Chemistry or other widely accepted authoritative resources. Adjustments for control devices listed in Table 1 of Appendix D will be applied as required by the procedure. The emission factors described above will also apply to finely divided radioactive solid materials, except that the emission factor shall not be less than 10^{-3} if the material is considered a particulate.

The U.S. Department of Energy's Oak Ridge National Laboratory (ORNL) has received EPA approval for an alternative method for calculating source term emissions similar to that being requested by INL Site. Included for your information is a copy of the EPA Region 4 approval for ORNL to use modified emission factors.

If you have any question regarding this request please contact me at (208) 526-5670 or saffortj@id.doe.gov.

Sincerely,

Tim Safford
Environment & Sustainability Division

Enclosure

cc: Jim McAuley, EPA
Ron Brown, NRF
Walker Howell, Fluor
Chris Kent, NRF
Scott Lee, BEA
Timothy Miller, BEA
Jason Redman, NRF
Scott Reno, Fluor
Mark Verdoorn, BEA

Department of Energy
ORNL Site Office
P.O. Box 2008
Oak Ridge, Tennessee 37831-6269

February 3, 2016

Mr. Gregg Worley, Chief
Air Analysis and Support Branch
Air, Pesticides and Toxics Management Division
United States Environmental Protection Agency
Region 4
61 Forsythe Street South West
Atlanta, Georgia 30303-3104

Dear Mr. Worley:

REQUEST FOR APPROVAL FOR A MODIFICATION IN APPLYING APPENDIX D OF 40 CODE OF FEDERAL REGULATIONS (CFR) PART 61 TO HEATED RADIOACTIVE SOLID MATERIALS WITH HIGH MELTING AND BOILING POINTS

Reference:
1. Letter from Winston A. Smith to Ronald R. Nelson, subject, *Request to Modify 40 CFR Part 61, Appendix D, Emission Factors For Uranium at the Department of Energy (DOE) Oak Ridge Reservation (ORR) and Paducah Gaseous Diffusion Plant (PGDP)*, dated December 2, 1991

2. Letter from Beverly H. Banister to Johnny O. Moore, no subject, responding to: Letter from Johnny O. Moore to Gregg Worley, subject *Request for Approval for a Modification in Applying Appendix D of 40 Code of Federal Regulations (CFR) Part 61 to Heated Radioactive Tungsten Metal and Approval for Surrogate for Niobium (NB)-91M*, dated June 25, 2015

Appendix D of 40 CFR Part 61 is a procedure that allows facility owners and operators to estimate radionuclide emissions to the atmosphere for dose calculations instead of measuring emissions for minor sources under the Radionuclide National Emission Standards for Hazardous Air Pollutants Regulation (40 CFR Part 61, Subpart H). The procedure assumes that any radioactive material heated above 100 °C is completely vaporized and emitted to the atmosphere (i.e., emission factor of 1.0). On August 1, 1991, the Department of Energy (DOE) Oak Ridge Reservation requested approval to use different emission factors for uranium since the melting and boiling points are 1,132 °C and 3,818 °C, respectively. United States Environmental Protection Agency (EPA) Region 4 granted approval on December 2, 1991, to use modified emission factors for elemental uranium provided that no reaction takes place to alter its chemical form. This approval letter is included as Enclosure 1. On June 3, 2015, DOE requested approval to use different emission factors for tungsten, again due to its high (significantly above 100 °C) melting and boiling points. EPA Region 4 granted approval on June 25, 2015, to use modified emission factors for heated radioactive tungsten metal. This approval letter is included as Enclosure 2.

REQUEST FOR APPROVAL FOR A MODIFICATION IN APPLYING APPENDIX D OF 40 CODE OF FEDERAL REGULATIONS (CFR) PART 61 TO HEATED RADIOACTIVE SOLID MATERIALS WITH HIGH MELTING AND BOILING POINTS

In line with these two precedents, DOE and Oak Ridge National Laboratory (ORNL) request approval to use modified emission factors in a similar fashion for other radioactive solid metals and compounds whose melting and boiling points are significantly above 100 °C (i.e., > 500 °C) in accordance with the following:

1) An emission factor of 1 will be applied to radioactive solid metals and compounds heated to temperatures greater than or equal to the boiling point of the solid.
2) An emission factor of 10^{-3} will be applied to radioactive solid metals and compounds heated to temperatures greater than or equal to 90 percent of the melting point[1] and less than the boiling point.
3) An emission factor of 10^{-6} will be applied to radioactive solid metals and compounds heated to temperatures above ambient temperature, but below 90 percent of the melting point[1].
4) Additional adjustments to emission factors for effluent controls will be allowed as presented in Table 1 of Appendix D.

Table 1 in Enclosure 3 is a listing of potential radioactive solid metals and compounds that ORNL may heat above 100 °C in future research experiments. Most of these compounds are materials associated with nuclear fuel rods, spent fuel, depleted uranium, and uranium enrichment processing.

Ms. Linda L. Smith of the environmental staff at ORNL spoke with Mr. Lloyd Generette of EPA Region 4 on October 7, 2015, requesting approval to use modified emission factors for other radioactive solid metals and compounds with high melting and boiling points similar to uranium and tungsten metal. He indicated that he foresaw no issues with the request, but asked that a formal written request for approval be submitted. On November 10, 2015, Ms. Smith emailed Mr. Generette with a draft listing of potential radioactive solid metals and compounds that ORNL may heat above 100 °C in future research experiments to clarify if EPA Region 4 would grant approval to use modified emission factors for radioactive solid compounds, as well as radioactive solid elemental metals with high melting and boiling points. On November 18, 2015, Mr. Generette responded by phone that approval would be granted for the heating of radioactive solid compounds with high melting and boiling points as well.

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[1] Most pure solids typically melt at a sharply defined, single temperature value. However, impurities can cause the melting point to spread out over a range of several degrees and even lower the melting point of the substance. Therefore a conservative factor of 90% of the melting point is chosen to mitigate this effect. (Loudon, G. Marc (1988). *Organic Chemistry Third Edition* (p.70). Redwood City, CA: The Benjamin/Cummings Publishing Company, Inc.)

Mr. Gregg Worley -3- February 3, 2016

REQUEST FOR APPROVAL FOR A MODIFICATION IN APPLYING APPENDIX D OF 40 CODE OF FEDERAL REGULATIONS (CFR) PART 61 TO HEATED RADIOACTIVE SOLID MATERIALS WITH HIGH MELTING AND BOILING POINTS

DOE and ORNL appreciate your assistance. If there are any questions or additional information is required, please contact Eric Moore at (865) 576-7321, or either Linda L. Smith at (865) 241-3711 or Jim M. Eaton at (865) 576-8115, both of whom are with ORNL's Environmental Protection Air Quality group.

Sincerely,

Johnny O. Moore, Manager
ORNL Site Office

Enclosures

cc w/enclosures:
Lloyd Generette, EPA
Richard W. Martin, SC-OR
Mary R. Dunsmore, ORNL
Jim M. Eaton, ORNL
Brian Egle, ORNL
Mike B. Farrar, ORNL
Angel K. Kennedy, ORNL
R. Steve Owens, ORNL
Cecil V. Parks, ORNL
Michael J. Pierce, ORNL
John E. Powell, ORNL
Patricia A. Scofield, ORNL
David D. Skipper, ORNL
Linda L. Smith, ORNL
Raymond J. Vedder, ORNL
Michelle W. Owenby, TDEC
Hernan R. Flores, Jr., TDEC

ENCLOSURE 1

Letter from Winston A. Smith to Ronald R. Nelson, subject, *Request to Modify 40 CFR Part 61, Appendix D, Emission Factors For Uranium at the Department of Energy (DOE) Oak Ridge Reservation (ORR) and Paducah Gaseous Diffusion Plant (PGDP)*, dated December 2, 1991

WDD

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IV
345 COURTLAND STREET, N.E.
ATLANTA, GEORGIA 30365

4APT-AEB

DEC - 2 1991

CRITICAL FILE COPY

ENVIRONMENTAL PROTECTION DIVISION
Log No. F 5061
Date Received DEC 05 1991
File Code 9255.9

Mr. R.R. Nelson, Assistant Manager of
Environment, Safety and Quality
Department of Energy
Oak Ridge Operations
P.O. Box 2001
Oak Ridge, Tennessee 37831-8739

RE: REQUEST TO MODIFY 40 CFR PART 61, APPENDIX D, EMISSION FACTORS FOR URANIUM AT THE DEPARTMENT OF ENERGY (DOE) OAK RIDGE RESERVATION (ORR) AND PADUCAH GASEOUS DIFFUSION PLANT (PGDP)

Dear Mr. Nelson:

References: 1. 8/1/91 letter, R.R. Nelson to W.A. Smith, subj: ORR Compliance Plan alternative monitoring methods.

2. 7/31/91 letter, D.C. Booher to W.A. Smith, subj: PGDP Compliance Plan alternative monitoring methods.

We have reviewed your Agency's request to use uranium emission factors different from those listed in 40 CFR Part 61, Appendix D, and have made the following determination:

1. An emission factor of 1 shall be applied to elemental uranium heated to temperatures greater than 3000°C.

2. Emission factors less than 1 may be considered for elemental uranium heated at temperatures less than 3000°C, provided no reaction takes place to alter its chemical form.

3. An emission factor of 10^{-3} may be applied to elemental uranium heated at temperatures greater than 1100°C but less than 3000°C.

4. An emission factor of 10^{-4} may be applied to elemental uranium heated at temperatures below 1100°C, provided the uranium is in solid form.

5. The exclusion for sealed radionuclides cannot be extended to radionuclides in solid form. Appendix D of 40 CFR Part 61, explicitly requires an emission factor of 10^{-4} for radionuclides in solid form. Depending on the degree of friability, dusting of radionuclides in solids will form airborne emissions.

If you should have any questions, please contact Mr. Brian L. Beals of my staff at FTS 257-5014.

Sincerely yours,

Winston A. Smith, Director
Air, Pesticides and Toxics
Management Division

cc: Mr. Harold Hodges, P.E., Director
Division of Air Pollution Control
Tennessee Department of Health and Environment
Customs House, 4th Floor
701 Broadway
Nashville, Tennessee 37219-5403

Mr. Michael Mobley, Director
Division of Radiological Health
Tennessee Department of Health and Environment
150 9th Avenue, North
Nashville, Tennessee 37219-5404

Mr. Weldon Dillow
U.S. Department of Energy
P.O. Box 2001
Oak Ridge, Tennessee 37831-8739

ENCLOSURE 2

Letter from Beverly H. Banister to Johnny O. Moore, no subject, dated June 25, 2015; responding to: Letter from Johnny O. Moore to Gregg Worley, *Request for Approval for a Modification in Applying Appendix D of 40 Code of Federal Regulations (CFR) Part 61 to Heated Radioactive Tungsten Metal and Approval for Surrogate for Niobium (NB)-91M*

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
ATLANTA FEDERAL CENTER
61 FORSYTH STREET
ATLANTA, GEORGIA 30303-8960

JUN 25 2015

Mr. Johnny Moore
Manager
Oak Ridge National Laboratory Site Office
P.O. Box 2008
Oak Ridge, Tennessee 37831-6269

Dear Mr. Moore:

This is in response to your letter dated June 3, 2015, requesting approval for a modification in applying appendix D of 40CFR part 61 to heated radioactive tungsten metal. A letter from Winston Smith to Ronald R. Nelson was enclosed where approval was granted for the use of modified emission factors based on the high melting point of uranium and given that the physical state of the element would not be altered. Additionally, you requested that Niobium 95 be used as a surrogate for Niobium 91m in the CAP88PC v3 code, which is used to demonstrate compliance with the air dose to the maximally exposed member of the public. A second enclosure provided the technical justification for using Niobium 95 instead of Niobium 91m in RadNESHAPs dose calculations.

The U.S. Environmental Protection Agency approves your request to modify emissions factors in Appendix D of 40CFR part 61. Also the EPA approves your request to use Niobium 95 instead of Niobium 91m in RadNESHAPs calculations. If you have any questions, please feel free to contact Lloyd Generette of my staff at (404) 562-9138 or generette.lloyd@epa.gov.

Sincerely,

Carol L. Kemker for

Beverly H. Banister
Director
Air, Pesticides and Toxics Management Division

ENCLOSURE 3

Listing of Potential Radioactive Solid Metals and Compounds that ORNL may Heat Above 100° in Future Research Experiments

Table 1. Listing of potential radioactive solid materials that ORNL may heat above 100 °C in future research experiments

Radioactive Compound	Melting Point (°C)	Boiling Point (°C)	Reference
TUNGSTEN METAL[1]	3,410	5,660	CRC Handbook of Chemistry and Physics
URANIUM METAL[1]	1,132	3,818	CRC Handbook of Chemistry and Physics
COMPOUNDS OF ACTINIUM			
Actinium Metal	1,050	3,200	CRC Handbook of Chemistry and Physics
Actinium Bromide	800 (sublimes)	NA	CRC Handbook of Chemistry and Physics
Actinium Iodide	700-800 (sublimes)	NA	CRC Handbook of Chemistry and Physics
Actinium Trichloride	960 (sublimes)	NA	CRC Handbook of Chemistry and Physics
COMPOUNDS OF BARIUM			
Barium Metal	725.0	1,640	CRC Handbook of Chemistry and Physics
Barium *ortho*Arsenate	1,605	Not Known	CRC Handbook of Chemistry and Physics
Barium Bromide	847	Not Known	CRC Handbook of Chemistry and Physics
Barium Bromide Dihydrate	880	Not Known	CRC Handbook of Chemistry and Physics
Barium Carbonate (α)	1,740	Decomppses	CRC Handbook of Chemistry and Physics
Barium Carbonate (β)	982 (transition point to α)	NA	CRC Handbook of Chemistry and Physics
Barium Carbonate (γ)	811 (transition point to β)	NA	CRC Handbook of Chemistry and Physics
Barium perchlorate	505	Not Known	CRC Handbook of Chemistry and Physics
Barium Chloride	963	1,560	CRC Handbook of Chemistry and Physics
Barium Fluoride	1,355	2,137	CRC Handbook of Chemistry and Physics
Barium Hydride	675 (decomposes)	1400(?)	CRC Handbook of Chemistry and Physics
Barium Hexaboride	2,270	Not Known	CRC Handbook of Chemistry and Physics
Barium Iodide	711	2027	Lange's Handbook of Chemistry
Barium Iodide Hydrate	539; 740 (decomposes)	NA	CRC Handbook of Chemistry and Physics
Barium Molybdate	1,480	Not Known	CRC Handbook of Chemistry and Physics
Barium Niobate	1,455	Not Known	Lange's Handbook of Chemistry
Barium Nitrate	592	Decomposes	CRC Handbook of Chemistry and Physics
Barium Nitride	Not Known	1,000 (decomposes)	CRC Handbook of Chemistry and Physics
Barium Oxide	1,973	3088	Lange's Handbook of Chemistry
Barium Selenide	1,780	Not Known	Lange's Handbook of Chemistry
Barium *meta*silicate	1,604	Not Known	CRC Handbook of Chemistry and Physics
Barium Sulphate	1,580	1,149 (transition point)	CRC Handbook of Chemistry and Physics
Barium Monosulphide	1,200	Not Known	CRC Handbook of Chemistry and Physics
Barium Trisulphide	554	Not Known	CRC Handbook of Chemistry and Physics
Barium Titanate	1,625	Not Known	Lange's Handbook of Chemistry
Barium *pyro*vanadate	863	Not Known	CRC Handbook of Chemistry and Physics
Barium Zirconate	2,500	Not Known	Lange's Handbook of Chemistry
COMPOUNDS OF NEPTUNIUM			
Neptunium Metal	644	>3,900	Lange's Handbook of Chemistry

[1] Already Approved

Neptunium Tribromide	800 (sublimes)	NA	CRC Handbook of Chemistry and Physics
Neptunium Tetrachloride	538	Not Known	CRC Handbook of Chemistry and Physics
Neptunium Trichloride	800 (sublimes)	NA	CRC Handbook of Chemistry and Physics
Neptunium Oxide	2,547	Not Known	Lange's Handbook of Chemistry
Neptunium Octatrioxide	500 (decomposes)	NA	CRC Handbook of Chemistry and Physics
COMPOUNDS OF PLUTONIUM			
Plutonium Metal	641	3,232	CRC Handbook of Chemistry and Physics
Diplutonium Trioxide	2,085 (in Helium)	Not Known	Lange's Handbook of Chemistry
Plutonium Dihyride	~727	Not Known	Lange's Handbook of Chemistry
Plutonium Dioxide	2,390	2,800 (decomposes)	Lange's Handbook of Chemistry
Plutonium Oxide	1,900	Not Known	Lange's Handbook of Chemistry
Plutonium Sulphide	1,927	Not Known	Lange's Handbook of Chemistry
Plutonium Tetrafluoride	1,037 (decomposes)	NA	Lange's Handbook of Chemistry
Plutonium Tribromide	681	>1,300 (decomposes)	Lange's Handbook of Chemistry
Plutonium Trichloride	760	1,767	Lange's Handbook of Chemistry
Plutonium Trifluoride	1,425	2,000 (decomposes)	Lange's Handbook of Chemistry
Plutonium Triiodide	777	Not Known	CRC Handbook of Chemistry and Physics
COMPOUNDS OF RADIUM			
Radium Metal	700.1	1737.0	Lange's Handbook of Chemistry
Radium Bromide	728	900 (sublimes)	Lange's Handbook of Chemistry
Radium Carbonate	>1,100	Not Known	CRC Handbook of Chemistry and Physics
Radium Chloride	1,000	Not Known	Lange's Handbook of Chemistry
COMPOUNDS OF THORIUM			
Thorium Metal	1,750	4,788	Lange's Handbook of Chemistry
Thorium Hexaboride	2,195	Not Known	CRC Handbook of Chemistry and Physics
Thorium Bromide	610 (sublimes)	NA	CRC Handbook of Chemistry and Physics
Thorium Carbide	2,655	5,000	CRC Handbook of Chemistry and Physics
Thorium Chloride	770	928 (decomposes)	CRC Handbook of Chemistry and Physics
Thorium Fluoride	1,110	1,680	Lange's Handbook of Chemistry
Thorium Iodide	570	837	Lange's Handbook of Chemistry
Thorium Nitrate	500 (decomposes)	NA	CRC Handbook of Chemistry and Physics
Thorium Oxide	3,220	4,400	CRC Handbook of Chemistry and Physics
Thorium Sulphide	1,925	Not Known	CRC Handbook of Chemistry and Physics
COMPOUNDS OF TUNGSTEN			
Ditungsten Carbide	2,860	6,000	CRC Handbook of Chemistry and Physics
Tungsten Carbide	2,870	6,000	CRC Handbook of Chemistry and Physics
Tungsten Diboride	2,900	Not Known	CRC Handbook of Chemistry and Physics
Tungsten Dioxide	1,550	1,724 (decomposes)	Lange's Handbook of Chemistry
Tungsten Pentoxide	800 (sublimes)	1,530 (decomposes)	CRC Handbook of Chemistry and Physics
Tungsten Trioxide	1,472	1,837	Lange's Handbook of Chemistry

Tungsten Silicide	>900	Not Known	CRC Handbook of Chemistry and Physics
Tungsten Sulfide	1,250 (decomposes)	NA	Lange's Handbook of Chemistry
COMPOUNDS OF URANIUM			
Uranium Diboride	2,365	Not Known	CRC Handbook of Chemistry and Physics
Uranium Dicarbide	2,350	4,370	CRC Handbook of Chemistry and Physics
Uranium Dioxide	2,827	Not Known	Lange's Handbook of Chemistry
Uranium Disulfide	>1,100	Not Known	CRC Handbook of Chemistry and Physics
Uranium Mononitride	2,630	Decomposes	CRC Handbook of Chemistry and Physics
Uranium Monosulphide	>2,000	Not Known	CRC Handbook of Chemistry and Physics
Uranium Tetrabromide	519	777	Lange's Handbook of Chemistry
Uranium Tetrachloride	590	790	Lange's Handbook of Chemistry
Uranium Tetrafluoride	1,036	1,414	Lange's Handbook of Chemistry
Uranium Tetraiodide	506	757	Lange's Handbook of Chemistry
Uranium Tribromide	730	Not Known	CRC Handbook of Chemistry and Physics
Uranium Trichloride	837	1,657	Lange's Handbook of Chemistry
Uranium Trifluoride	>1,000 (decomposes)	NA	CRC Handbook of Chemistry and Physics
Uranium Trioxide	1,300 (decomposes)	NA	Lange's Handbook of Chemistry
Uranyl Acetate Chloride	577	Not Known	Lange's Handbook of Chemistry
Triuranium Octoxide	1300 (decomposes to UO_2)	NA	Lange's Handbook of Chemistry
COMPOUNDS OF ZIRCONIUM			
Zirconium Metal	1,852	3,577	Lange's Handbook of Chemistry
Zirconium Carbide	3,532	5,100	Lange's Handbook of Chemistry
Zirconium Chloride	727	1,292	Lange's Handbook of Chemistry
Zirconium Diboride	3,245	4,193 (decomposes)	Lange's Handbook of Chemistry
Zirconium Fluoride	932	912 (sublimes)	Lange's Handbook of Chemistry
Zirconium Nitride	2,980	Not Known	CRC Handbook of Chemistry and Physics
Zirconium Oxide	2,678	4,300	Lange's Handbook of Chemistry
Zirconium Silicate	1,540 (decomposes)	NA	Lange's Handbook of Chemistry
Zirconium Sulphide	~1,550	Not Known	CRC Handbook of Chemistry and Physics

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 4
ATLANTA FEDERAL CENTER
61 FORSYTH STREET
ATLANTA, GEORGIA 30303-8960

FEB 23 2016

Mr. Johnny Moore
Manager
Oak Ridge National Laboratory Site Office
P.O. Box 2008
Oak Ridge, Tennessee 37831-6269

Dear Mr. Moore:

This is in response to your letter dated February 3, 2016, requesting approval for a modification in applying appendix D of 40 CFR Part 61 to heated radioactive solid materials with high melting and boiling points. A letter requesting approval for a modification in applying appendix D of 40 CFR Part 61 to heated radioactive tungsten metal and approval for surrogate for niobium dated June 25, 2015, was included as an enclosure. Your letter requested approval to use modified emission factors in a similar fashion for other radioactive solid metals and compounds whose melting and boiling points are significantly above 100 degrees Centigrade.

The U.S. Environmental Protection Agency has reviewed your enclosed Table 1 listing potential radioactive solid materials that Oak Ridge National Laboratory may heat above 100 degrees Centigrade in future research experiments and the list of references. The EPA approves your request to use modified emissions factors for the solids materials listed in Table 1. If you have any questions, please feel free to contact Lloyd Generette of my staff at (404) 562-9138 or generette.lloyd@epa.gov.

Sincerely,

Beverly H. Banister
Director
Air, Pesticides and Toxics Management Division

Appendix D

DOE-ID Letter Providing Additional Information (Acceptable References for Melting, Subliming and Boiling Points) to the Original Request for EPA Approval to Use Physical State Factors in Calculating Source Term OS-ESD-17-100

lDepartment of Energy
Idaho Operations Office
1955 Fremont Avenue
Idaho Falls, ID 83415

August 30, 2017

Mr. Don Dossett, Unit Manager Stationary Source Unit
U.S. Environmental Protection Agency, Region 10
Office of Air and Waste
1200 6th Avenue, Suite 900, M/S OAW-150
Seattle, WA 98101

CCN241065

SUBJECT: Request for Alternative Method Approval of 40 Code of Federal Regulations Part 61 Appendix D Physical State Emission Factors to Heated Radioactive Solid Materials with High Melting and Boiling Points (OS-ESD-17-100)

REFERENCE: Letter: U.S. Department of Energy, Idaho Operation Office, Tim Safford – Environment and Sustainability Division to Don Dossett, Unit Manager Stationary Source Unit, U.S. Environmental Protection Agency, Region 10, Dated May 22, 2017 (OS-ESD-17-056)

Dear Mr. Dossett:

The U.S. Department of Energy, Idaho Operations Office (DOE-ID) requested (referenced letter) U.S. Environmental Protection Agency, Region 10 approval to allow the Idaho National Laboratory (INL) Site to use modified emission factors for radioactive solid materials that have melting and boiling points above 100 degrees Celsius for the determination of the source term. Based on discussions with Mr. Jim McAuley of your staff and an email (7/18/2017) requesting clarification of the statement "best available data from the laboratory," DOE-ID has provided additional information to better define how the INL will implement the alternative method for calculating source term. The information, provided below, is primarily in the form of listed reference standards and other sources of published data. As a result of this additional information DOE-ID is submitting this second request for approval for the INL to use modified emission factors for the determination of source term.

Additional Information:

Melting, subliming and boiling points will be obtained from the following list of reference standards and other sources of published data:

1. American Society of Metals references
2. Center for Information and Numerical Data Analysis (CINDAS) databases and handbooks

Don Dossett 2 OS-ESD-17-100

3. CRC Handbook of Chemistry & Physics, Kirk-Othmer Encyclopedia of Chemical Technology, Lange's Handbook of Chemistry and Perry's Chemical Engineers' Handbook
4. Journal of Physical and Chemical Reference Data
5. Critical reviews of physical/chemical data published by Office of Scientific and Technical Information (OSTI), U.S. national laboratories, Naval Nuclear Laboratory, or the International Atomic Energy Agency
6. Department of Energy, Department of Defense and Nuclear Regulatory Commission technical and reference standards
7. International Critical Tables of Numerical Data, Physics, Chemistry and Technology
8. National Technical Reports Library.

For referenced materials that give a range for melting, subliming and boiling points the lowest temperature in the published range will be used to ensure the maximum conservative emission estimate.

DOE-ID appreciates EPA's consideration of this request and the assistance provided by Jim McAuley. If you have any questions regarding the suggested changes please contact me at (208) 526-5670 or saffortj@id.doe.gov.

Sincerely,

Tim Safford
Environment & Sustainability Division

cc: Jim McAuley, EPA
Ron Brown, NRF
Walker Howell, Fluor
Chris Kent, NRF
Scott Lee, BEA
Timothy Miller, BEA
Jason Redman, NRF
Scott Reno, Fluor
Mark Verdoorn, BEA

Appendix E
EPA Approval to Use Modified Emission Factors – Donald Dossett rcvd 10-19-2017

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 Sixth Avenue, Suite 900
Seattle, WA 98101-3140

OFFICE OF
AIR AND WASTE

OCT 19 2017

Mr. Tim J. Safford
Department of Energy
Idaho Operations Office
1955 Fremont Avenue
Idaho Falls, Idaho 83402

Dear Mr. Safford:

This letter is in response to the request from the Department of Energy, Idaho Operations Office (DOE-ID) to the United States Environmental Protection Agency, Region 10, as defined in 40 CFR Subpart H, §61.96 (b), to allow the Idaho National Laboratory (INL) Site to use modified emission factors for radioactive solid materials that have boiling points above 100 degrees Celsius for determining the source term, see Reference 1.

Background:

As described by DOE-ID, INL will use the following alternative method to determine physical state factors used for radioactive solid materials with high melting and boiling points:

1. An emission factor of 1 will be applied to radioactive solid materials heated to temperatures greater than or equal to 90 percent of the boiling or subliming point.
2. An emission factor of 10^{-3} will be applied to radioactive solid materials heated to temperatures greater than or equal to their melting point but less than 90 percent of their boiling or subliming point.
3. An emission factor of 10^{-6} will be applied to radioactive solid materials heated to temperatures above ambient temperature but less than their melting point.

DOE-ID added that melting, subliming and boiling points will be obtained from reference standards such as CRC Handbook of Chemistry and Physics, Lange's Handbook of Chemistry or other widely accepted authoritative resources. Adjustments for control devices listed in Table 1 of Appendix D will be applied as required by the procedure. The emission factors described above will also apply to finely divided radioactive solid materials, except that the emission factor shall not be less than 10^{-3} if the material is considered a particulate.

Reference 1: Submitted for approval letter (Safford to Dossett, 05/23/2017): Request for Alternative Method Approval of 40 Code of Federal Regulations Part 61 Appendix D Physical State Emission Factors to Heated Radioactive Solid Materials with High Melting and Boiling Points (OS-ESD-17-056)

Determination:

DOE-ID provided a reference of a similar approval by EPA for an alternative method for calculating source term emissions given to the U.S. Department of Energy's Oak Ridge National Laboratory (ORNL), see Reference 2.

In a discussion with DOE-ID on July 18, 2017, the EPA, Region 10 requested clarification on which "widely accepted authoritative resources" for melting, subliming and boiling points will be used from reference standards. On August 30, 2017 this clarification was provided, see Reference 3.

After the provided reference and the clarification on accepted authoritative resources were reviewed by the EPA, Region 10, it has been determined that DOE ID's alternative method for calculating the source term using physical state factors for radioactive solid materials with high melting and boiling points is adequate and therefore approved.

If you have any further questions regarding this matter, please contact Mr. Jim McAuley of my staff at 206-553-1987, or email at McAuley.Jim@epa.gov.

Sincerely,

Donald Dossett

Donald Dossett, P.E.,
Manager, Stationary Source Unit

Reference 2: Submitted for approval letter (Moore to Worley, 02/03/2016): Request for Approval for a Modification in Applying Appendix D of 40 Code of Federal Regulations (CFR) part 61 to Heated Radioactive Solid Materials with IDGH Melting and Boiling Points. (3) Attachments.

Reference 3: Submitted clarification letter (Safford to Dossett, 08/30/2017): Request for Alternative Method Approval of 40 Code of Federal Regulations Part 61 Appendix D Physical State Emission Factors to Heated Radioactive Solid Materials with High Melting and Boiling Points. (OS-ESD-17-100).

Title: Graphite Specimen Mass Measurements for NESHAP Calculations

ECAR No.: 3611 Rev. No.: 1 Project No.: 23747 Date: 02/15/2018

Appendix F
Comparison of Isotope Activity Calculation

			All in grams				Isotopes (µCi)											
Id	Grade Code	Type	PreMass	PostMass	Diff	% Mass Loss	^{46}Sc	^{54}Mn	^{60}Co	^{65}Zn	^{95}Zr	^{95}Nb	^{110m}Ag	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	Total (µCi)
Bxxx	B	PB	1.43677	0.00000	1.436770	100.0	0.0000	0.0000	0.0000	0.0563	0.0000	0.0001	0.0000	1.1225	0.0475	0.0002	0.0002	1.2267
Bxxx	B	PB	1.43677	0.00000	1.436770	100.0	0.0000	0.0000	0.0000	0.0563	0.0000	0.0001	0.0000	1.1225	0.0475	0.0002	0.0002	1.2267
Bxxx	B	PB	1.43677	0.00000	1.436770	100.0	0.0000	0.0000	0.0000	0.0563	0.0000	0.0001	0.0000	1.1225	0.0475	0.0002	0.0002	1.2267
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Total (µCi)							0.0000	0.0000	0.0006	1.1250	0.0000	0.0012	0.0004	22.4500	0.9500	0.0041	0.0035	24.5348
Unit Dose Factor (mrem/yr/Ci) at 100m							**45**	**64**	**1000**	**100**	**26**	**7.6**	**170**	**520**	**1300**	**33**	**780**	
Dose (mrem)							**1.67288E-09**	**1.165E-09**	**5.52E-07**	**0.0001125**	**1.95E-11**	**8.74E-09**	**6.8E-08**	**0.011674**	**0.001235**	**1.36125E-07**	**2.711E-06**	0.0130

ESTIMATE OF POTENTIAL EXPOSSURE USING EMISSION FACTORS FOR OXIDATION EXPERIMENT

Note that PB specimens will be used in the oxidation experiment. These specimens are 1/4 the size of those used in the gamma spec measurements. Therefore all activities are divided by 4.

			All in grams				Isotopes (µCi)											
Id	Grade Code	Type	PreMass	PostMass	Diff	% Mass Loss	^{46}Sc	^{54}Mn	^{60}Co	^{65}Zn	^{95}Zr	^{95}Nb	^{110m}Ag	^{134}Cs	^{137}Cs	^{144}Ce	^{154}Eu	Total (µCi)
Bxxx	B	PB	1.43677	0.00000	1.436770	10.0	0.1859	0.0910	2.7599	0.0056	0.0038	0.0058	0.0020	0.1123	0.0048	0.0206	0.0174	3.2089
Bxxx	B	PB	1.43677	0.00000	1.436770	10.0	0.1859	0.0910	2.7599	0.0056	0.0038	0.0058	0.0020	0.1123	0.0048	0.0206	0.0174	3.2089
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Total (µCi)							3.7175	1.8200	55.1975	0.1125	0.0750	0.1150	0.0400	2.2450	0.0950	0.4125	0.3475	64.1775
Unit Dose Factor (mrem/yr/Ci) at 100m							**45**	**64**	**1000**	**100**	**26**	**7.6**	**170**	**520**	**1300**	**33**	**780**	
Dose (mrem)							**0.000167288**	**0.0001165**	**0.0551975**	**1.125E-05**	**0.00000195**	**8.74E-07**	**0.0000068**	**0.0011674**	**0.0001235**	**1.36125E-05**	**0.0002711**	0.0571

ESTIMATE OF POTENTIAL EXPOSSURE USING 10 PERCENT MASS LOSS FOR OXIDATION EXPERIMENT

Note that PB specimens will be used in the oxidation experiment. These specimens are 1/4 the size of those used in the gamma spec measurements. Therefore all activities are divided by 4.