

Vitrification of Hanford Tank 241-AW-106 Waste and Equivalent Simulant

September 2026

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Pacific Northwest National Laboratory
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0	September 2026	Initial issue.

Summary

Hanford Site nuclear waste is to be vitrified at the Waste Treatment and Immobilization Plant (WTP), which is a part of the safe and efficient retrieval, treatment, and disposal mission of the U.S. Department of Energy - Hanford Field Office. A portion of Hanford tank 241-AW-106 (referred to herein as AW-106) waste supernatant was retrieved by Hanford Tank Waste Operations and Closure (H2C) and transferred to Pacific Northwest National Laboratory (PNNL) at the Radiochemical Processing Laboratory (RPL). Compared to previously received and vitrified wastes (AP-107, AP-101, AN-107, AW-105, and AP-105), there were no extreme analyte concentrations in the AW-106 waste, but rather all major analytes were in the middle of the expected concentration ranges for direct-feed low-activity wastes.

The AW-106 waste went through dilution in the RPL by blending with Columbia River water to reach an actual sodium (Na) concentration of 5.5 M, solids filtration, and cesium removal by ion exchange. To demonstrate the effectiveness of waste disposal, gather insight about AW-106 specific melting behavior, and thus reduce the risk of anomalous performance during WTP operations, the AW-106 was then set for dynamic vitrification. A target glass composition, glass forming chemical (GFC) additions, and waste loading were calculated from the Kim et al. glass models¹ to satisfy the WTP baseline requirements based on analysis of the AW-106 sample received by PNNL (prior to dilution) and the target dilution to 5.5 M Na. A simulant version of this melter feed was calculated and batched based on the understood best-basis inventory of tank AW-106 since analysis of the actual samples was not yet available.

To gain insight into AW-106 waste melter feed processing, the simulant version was subject to property testing for rheology, expansion/bubbling, and evolved gas. No concerns arose during the property testing so the AW-106 simulant melter feed was then processed in a non-radioactive, continuous laboratory-scale melter (CLSM) system to understand production expectations. The AW-106 simulant melter feed was charged into the CLSM for 6.13 h, which produced 6.66 kg of glass, for an average glass production rate of 2305 kg m⁻² d⁻¹ without any issues pumping the slurry or visual anomalous behavior during vitrification. During CLSM processing, evolved-gas equipment was connected to the CLSM offgas treatment system to monitor the partial pressure of gases when glass was poured.

Since there were no processing issues with the AW-106 simulant melter feed, the actual AW-106 waste melter feed was then processed in a CLSM system built into a contamination area in a radioactive environment as a part of the Radioactive Waste Test Platform. The melting behavior characteristics were similar for both the simulant and waste melter feeds. The AW-106 waste melter feed was charged into the CLSM for 5.80 h of processing, with a ~3 h idling period for offgas management, which produced 6.13 kg of glass, for an average glass production rate of 2245 kg m² d⁻¹. A 3-hour idling time period in the middle of the operation afforded the opportunity to measure the change in content of semi-volatile components (⁹⁹Tc, Cl, F, and S) in the melt glass pool based on glass poured at the beginning and end of this period. The volatilization of these components from the glass after idling ranged from 7% (SO₃) to 30% (Cl). The processing rates for both the AW-106 simulant and waste were at the top of the ranges measured for melter feeds processed previously in the CLSM².

Samples of the AW-106 simulant and waste melter feeds as well as selected glass and offgas liquid samples were analyzed to determine the concentration of certain chemical constituents. Based on this

¹ Kim DS, JD Vienna, and AA Kruger. 2012. *Preliminary ILAW Formulation Algorithm Description*, 24590 LAW RPT-RT-04-0003, Rev. 1. ORP-56321, Revision 0. U. S. Department of Energy Office of River Protection, Richland, Washington.

² Dixon DR, JB Lang, MA Hall, RK Brown, JC Rigby, WC Eaton, and RA Peterson. 2025. *Vitrification of Hanford Tank 241-AW-105 Waste and Equivalent Simulant*. PNNL-38189, Rev. 0 (RPT-DFTP-047, Rev. 0). Pacific Northwest National Laboratory, Richland, Washington.

analysis, most of the primary components in the glass produced from the conversion of the AW-106 melter feeds were within 10% of their target values, as has routinely been the case with glasses produced through vitrification in both the radioactive and non-radioactive CLSM systems².

A constituent of interest present in low quantities in the AW-106 waste is ⁹⁹Tc or its non-radioactive surrogate, Re, added to the AW-106 simulant. Analysis for the quantities of ⁹⁹Tc and Re in the AW-106 glass product, captured while the melter feed processing was at a steady state, resulted in an average single-pass retention from the melter feed during relative chemical steady state of $46 \pm 2\%$ for ⁹⁹Tc and $49 \pm 1\%$ for Re. Compared to the processing of other melter feeds in the CLSM, the retention of ⁹⁹Tc in the AW-106 glass was in the middle of the range, while the retention of Re in the AW-106 was also in the middle of the retention range previously measured.

A spike of iodine was added into the AW-106 simulant melter feed that could be detected above the analysis detection limits and was measured in all glass pours after melter feed charging had begun. The total retention of iodine from the simulant melter feed into the glass product was measured to be 21%. Iodine was also recovered in the CLSM offgas system primarily in the liquid samples, with low quantities (<2 %) partitioning to the filters, signaling that iodine may be recycled from offgas streams to the melter feed in high quantities. The concentration of iodine in the AW-106 waste was below its analytical quantification level, thus no iodine retention value could be determined for the waste.

The condensate and demister solutions from the AW-106 simulant and waste runs were analyzed for acetonitrile and their concentrations were in the same range, 100 – 450 mg L⁻¹, as previous melter feeds processed in the CLSM. Scaling the acetonitrile production during the AW-106 simulant and waste runs by the total amount of organic carbon in their respective melter feeds yielded a range of production slightly greater than previous runs, thus expanding the range to 5 – 15 g-acetonitrile per kg-total organic carbon. The acetonitrile production was not strongly dependent on the CLSM plenum temperature, as previously anticipated.

The ammonia concentration of the liquids collected from the CLSM offgas treatment system were measured for the first time after the AW-106 simulant and waste runs. The ammonia concentration in the condensate and demister was ~5 times that of acetonitrile. The ratio of ammonia to nitrate (another source of nitrogen in the liquids) decreased in the liquids of each successive unit in the CLSM offgas treatment system indicating that the condensed nitrogen product preferred the nitrate reaction over ammonia as the offgas cooled.

Ultimately, it was demonstrated that AW-106 waste, a waste without extreme analyte concentrations, could be vitrified at the upper end of expected production ranges while retained ⁹⁹Tc in the glass was in the middle of its expected range. These runs, added to the growing database of wastes and simulants vitrified in the CLSM at PNNL, expand process knowledge to further compositional ranges thus preparing for a variety of feed vectors that may be vitrified at the WTP.

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The authors thank Jackie Ranger and the team at the Southwest Research Institute for performing the chemical analysis of all radioactive and non-radioactive products from the continuous laboratory-scale melter system. We thank Renee Russell and Jess Rigby for reviewing all the data, calculations, and figures associated with this technical report. The authors gratefully acknowledge funding of this work by Hanford Tank Waste Operations and Closure and the project direction provided by Matt Landon.

Acronyms and Abbreviations

ARL	analytical reporting limit
BBI	best-basis inventory
CA	contamination area
CLSM	continuous laboratory-scale melter
DF	decontamination factor
DFLAW	direct-feed low-activity waste
DM10	DuraMelter10
DOE-HFO	U.S. Department of Energy - Hanford Field Office
EGA	evolved gas analysis (test)
EMF	Effluent Management Facility
ETF	Effluent Treatment Facility
FET	feed volume expansion test
GFC(s)	glass-forming chemical(s)
H2C	Hanford Tank Waste Operations and Closure
HCA	high contamination area
HEPA	high-efficiency particulate air (filters)
HLW	high-level waste
IC	ion chromatography
ICP-AES	inductively coupled plasma atomic emission spectroscopy
ICP-MS	inductively coupled plasma mass spectrometry
LAW	low-activity waste
LERF	Liquid Effluent Retention Facility
LSL2	Life Sciences Laboratory 2
MCR	Modular Compact Rheometer
PNNL	Pacific Northwest National Laboratory
QA	quality assurance
<i>R</i>	retention
R&D	research and development
Rec	recovery
RPL	Radiochemical Processing Laboratory
RWTP	Radioactive Waste Test Platform
SBS	submerged-bed scrubber
scm	standard cubic centimeters per minute
SwRI	Southwest Research Institute
TC	thermocouple
TIC	total inorganic carbon
TOC	total organic carbon
TSCR	Tank Side Cesium Removal
WTP	Waste Treatment and Immobilization Plant

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1.0 Introduction

It is the responsibility of the U.S. Department of Energy-Hanford Field Office (DOE-HFO) to safely and efficiently retrieve, treat, and dispose of many million gallons of legacy nuclear waste stored in underground tanks on the Hanford Site in Washington State. The Hanford Site waste tanks are currently operated and managed by Hanford Tank Waste Operations and Closure (H2C). As part of tank farm operations, H2C supports DOE-HFO's waste retrieval mission. An important element of the DOE-HFO mission is the construction and operation of the Waste Treatment and Immobilization Plant (WTP), which will process and stabilize tank waste through vitrification into glass. The WTP will generate immobilized high-level waste (HLW) glass to be disposed of at a yet-to-be-determined federal geologic repository and immobilized low-activity waste (LAW) glass to be disposed of onsite. The vitrification of the LAW began in 2025. This process involves directly processing only the liquid supernatant portion of the waste by vitrification in electric melters in the WTP LAW facility with the deployment of a Tank Side Cesium Removal (TSCR) system located at the AP Farm as a part of the TSCR Demonstration Project, which began operations in January 2022 (Schubick et al. 2023).

The TSCR system allows the supernatant to meet the acceptance criteria at the WTP LAW facility by removing suspended solids through filtration and cesium ($\text{Cs}/^{137}\text{Cs}$) by ion exchange (Schubick et al. 2023). After these processes, the waste will be combined with glass-forming chemicals (GFCs) to form a mixed slurry, called melter feed, that can be charged into the melters. During vitrification, stable glass will be produced for disposal while water, volatile waste components, and a portion of semi-volatiles from the waste-to-glass conversion process will escape to the offgas treatment system, where they will be captured, primarily as condensate. This offgas condensate will then be concentrated by evaporation in the Effluent Management Facility (EMF) and recycled back to the LAW facility to be incorporated into the melter feed. Recycled radionuclides, technetium-99 (^{99}Tc) and iodine-129 (^{129}I), are expected to accumulate in the offgas treatment waste stream. Under normal operations, the evaporator bottoms will be returned to the LAW melter facility but could also be returned to the tank farm without evaporation when the EMF evaporator is unavailable. The evaporator overhead condensate will be sent to one of the Liquid Effluent Retention Facility (LERF) basins from which campaigns will be processed through the Effluent Treatment Facility (ETF).

A test program was established at Pacific Northwest National Laboratory (PNNL) to conduct scaled unit operation process steps with actual Hanford tank waste (Peterson et al. 2017). To facilitate this program, the Radioactive Waste Test Platform (RWTP) was established to allow for baseline and alternative flowsheets and unit operations, like filtration and ion exchange processes that mimic TSCR, to be tested in comparable tests where both the direct effect of changes and the downstream effects of changes could be evaluated. As a part of this platform, a continuous laboratory-scale melter (CLSM) system was designed and constructed in the Radiochemical Processing Laboratory (RPL) at PNNL for vitrifying treated tank waste samples. An identical, duplicate CLSM system (to process and study non-radioactive waste simulants) was also constructed at PNNL, and a study was performed to evaluate the system performance (Dixon et al. 2020a).

Since its commissioning in 2018, the radioactive CLSM system located in the RPL (hereafter referred to as the rad-CLSM) has processed many samples of Hanford tank waste while simulant versions of these wastes have also been processed in the simulant CLSM system located in the Life Sciences Laboratory 2 (LSL2) (hereafter referred to as the sim-CLSM). A summary of each waste vitrification campaign is given in Table 1.1 along with the reports that describe each aspect of the campaign.

Table 1.1. Summary of Hanford Waste CLSM Vitrification Campaigns

Glass Name	Waste	Condensate Recycle	Filtration Report	Cs Removal Report	Vitrification Report	Notes
AP-105	241-AP-105	n/a	Geeting et al. 2018a	Fiskum et al. 2018	Dixon et al. 2018	Condensate post-processing ^(a)
AP-107	241-AP-107	n/a	Geeting et al. 2018b	Westesen et al. 2021a	Dixon et al. 2019	Simulant run separately ^(b)
AP-107-1R	241-AP-107	From AP-107	Geeting et al. 2019	Fiskum et al. 2019	Dixon et al. 2020b	No simulant run
AP-107-2R & AP-105	241-AP-107 & 241-AN-105	From AP-107-1R	Allred et al. 2021 & Allred et al. 2020	Westesen et al. 2021b & Fiskum et al. 2021	Dixon et al. 2022a	No simulant run
AP-101	241-AP-101	n/a	Allred et al. 2022	Westesen et al. 2022	Dixon et al. 2022b	n/a
7 M Na AP-105	241-AP-105	n/a	Allred et al. 2023	Westesen et al. 2023	Dixon et al. 2023	n/a
AN-107	241-AN-107	n/a	Allred et al. 2024	Westesen et al. 2024	Dixon et al. 2024	n/a
AW-105	241-AW-105	n/a	Allred et al. 2025	Westesen et al. 2025	Dixon et al. 2025	n/a

^(a) Cantrell et al. 2018
^(b) Dixon et al. 2022c

The purpose of the work described in this report was to reduce the risk to WTP operations by demonstrating the efficacy of AW-106 waste vitrification and providing details about how the AW-106 processing compares to other vitrified wastes. To accomplish this purpose, the post-ion exchange AW-106 waste samples were combined with GFCs and processed in the rad-CLSM until the test objectives were completed by producing at least 4 kg of glass and collecting at least 1 offgas sample. Times of steady cold-cap coverage and glass melt compositional steady state were achieved from these objectives during this test, which allowed for data and observations collected to be sufficient for comparing the AW-106 processing characteristics with other wastes that had been vitrified in the rad-CLSM.

Since a fixed amount of AW-106 waste was present for vitrification, to reduce the risk of failing to achieve the objectives of the rad-CLSM test by previewing the AW-106 processing expectations, a simulant of the AW-106 melter feed was designed and processed in the sim-CLSM. Previous rad-CLSM runs without simulant previews (Dixon et al. 2020b and 2022a) encountered processing difficulties, demonstrating the usefulness of sim-CLSM tests as a screening tool, the results from which enhance the growing database of cold-cap behavior under different melter feed compositions and the distribution of semi-volatile components between glass and offgas products. The database will be updated at the end of this report. The goal of the database of rad-CLSM and sim-CLSM process knowledge is to enhance the readiness of PNNL to respond to emerging feed vectors and production conditions at the WTP.

2.0 Quality Assurance

This work was performed in accordance with the PNNL Nuclear Quality Assurance Program (NQAP). The NQAP works in conjunction with PNNL's laboratory-level Quality Management Program, which is based upon the requirements as defined in the DOE Order 414.1D, *Quality Assurance*, and 10 CFR 830, Subpart A, *Quality Assurance Requirements*. The NQAP uses NQA-1-2012, *Quality Assurance Requirements for Nuclear Facility Applications*, as its consensus standard and NQA-1-2012, Subpart 4.2.1, as the basis for its graded approach to quality (ASME 2012). The work described in this report was assigned the technology readiness level (TRL) 4. All staff members contributing to the work received proper technical and quality assurance training prior to performing quality-effecting work.

3.0 Experimental

This section describes the experimental process used to prepare the AW-106 simulant melter feed and the AW-106 waste melter feed from the actual Hanford tank 241-AW-106 waste. The sim-CLSM and rad-CLSM, which were used to vitrify the melter feeds, and the analyses of the resultant samples are also explained.

3.1 Melter Feed Preparation

The simulant version of the AW-106 waste was designed based on the best-basis inventory (BBI) of the liquid present in Hanford Tank 241-AW-106 (Menjivar and Anderson 2018). The sodium molarity of AW-106 based on the BBI was 9.72 M, which was reduced to a target dilution of 5.5 M Na. The resulting, estimated AW-106 simulant composition used for input into the Kim et al. (2012) glass models is shown in Table 3.1 and the chemical recipe for the AW-106 waste simulant created from this composition is shown in Table 3.2. The amount of GFCs to be added per liter of AW-106 waste simulant, as determined by the Kim et al. (2012) glass models to calculate a glass composition to satisfy the WTP baseline requirements, are shown in Table 3.2. These GFCs were estimated to increase the volume of the resultant AW-106 simulant melter feed by 0.39 L per liter of waste simulant. Ultimately, 10.0 L of AW-106 simulant melter feed was batched, which weighed 15.88 kg for a measured melter feed bulk density of 1.59 kg L⁻¹ and water percentage of 43%, while the calculated glass yield was 711 g of glass L⁻¹ of melter feed. This melter feed was spiked with Re₂O₇, to a desired target of 8.1 ppm Re in the final glass if 100 % retained, and KI was spiked to a desired target of 150 ppm I in the final glass if 100% retained, during batching.

Table 3.1. AW-106 Simulant and Waste Compositions

Analyte	AW-106 Simulant Composition (mg L ⁻¹)	AW-106 Waste Composition (mg L ⁻¹)	% Difference Sim to Was (%)
Al	6925	7716	-10
Cl	2119	1649	29
Cr	400	537	-26
F	1007	324	211
K	3661	4125	-11
Na	126445	126059	0
P	918	348 ^(a)	--
S	1750	767	128
N as NO ₂	44243	34329	29
N as NO ₃	126880	92664	37
TOC	1766	4776	-63
TIC	36337	301675	-88
	M	M	
Na	5.5	5.5	--

^(a) Value was less than the analytical reporting limit (ARL), but greater than the detection limit, and thus the reporting limit is listed

Table 3.2. AW-106 Simulant Chemical Recipe and Melter Feed GFCs Additions

Chemicals	Amount (g L ⁻¹)	Assay
Re Solution (769 ppm-Re)	7.49	1
KI	0.14	0.99
Al(NO ₃) ₃ · 9H ₂ O	70.68	0.98
NaOH	48.35	0.97
KOH	3.74	0.999
NaF	1.61	0.993
Na ₂ CrO ₄	0.91	0.98
Na ₃ PO ₄ · 12H ₂ O	8.10	1
NaCl	2.54	0.99
Na ₂ SO ₄	5.63	0.99
NaC ₂ H ₃ O ₂ (sodium acetate)	1.46	0.99
NaHCO ₂ (sodium formate)	2.45	0.98
Na ₂ C ₂ O ₄ (sodium oxalate)	1.03	0.999
C ₂ H ₄ O ₃ (glycolic acid)	1.37	0.98
NaNO ₂	48.70	0.98
NaNO ₃	78.43	0.995
Na ₂ CO ₃	46.40	0.995
GFCs		
C ₁₂ H ₂₂ O ₁₁ (Sucrose)	43.27	1
H ₃ BO ₃ (Boric Acid)	126.56	1.002
TiO ₂ (Rutile)	9.57	0.954
Li ₂ CO ₃ (Lithium Carbonate)	15.70	0.996
Mg ₂ SiO ₄ (Olivine)	20.84	0.9053
ZnO (Zinc Oxide)	25.02	0.999
ZrSiO ₄ (Zircon)	32.17	0.99
Fe ₂ O ₃ (Iron Oxide)	37.27	0.994
Al ₂ SiO ₅ (Kyanite)	56.42	0.9806
CaSiO ₃ (Wollastonite)	61.19	0.9778
SiO ₂ (Silica)	252.82	0.995
Waste Loading (%)	19.9	
Target Glass Yield (g L-feed ⁻¹)	711	

Actual supernatant from Hanford tank 241-AW-106 was collected by H2C and received by PNNL. Upon receipt, PNNL diluted the AW-106 waste with Columbia River water to a target of 5.5 M and passed the liquid through a back-pulse dead-end filter system for solids removal (Allred et al. 2026). The analyzed sodium molarity of the diluted AW-106 waste was 5.73 M. The approximately 12.5 L of resulting liquid were processed through an ion exchange column system at 16 °C, which collected ~100 % of the ¹³⁷Cs activity from the AW-106 waste, while >95% of all desired analytes (see Table 3.1) remained in the waste (Bachman et al. 2026).

The composition of the AW-106 waste was measured after ion exchange (Bachman et al. 2026) and the primary analyte values are shown in Table 3.1. The difference between the AW-106 composition used to batch the simulant compared to the actual AW-106 waste is also given in Table 3.1. The AW-106 waste vs simulant compositions show the variance possible between a full tank inventory and individual grab samples. Two batches of AW-106 waste melter feed were prepared, batch 1 used 5.619 kg of AW-106 waste and batch 2 used 3.417 kg of AW-106 waste. Given a composite density for the AW-106 waste of 1.24 g mL⁻¹, the volume of waste in batch 1 was 4.52 L and batch 2 was 2.75 L. The final AW-106 waste

melter feed in batch 1 weighed 10.046 kg with an estimated volume of 6.287 L and batch 2 weighed 6.109 kg with an estimated volume of 3.823 L. Both batches of AW-106 waste melter feed had an estimated resultant density of 1.60 kg L⁻¹.

The target glass composition expected from the vitrification of the AW-106 melter feed (referred to as AW-106), as calculated by the Kim et al. (2012) glass models, is shown in Table 3.3. Target glass compositions of other melter feeds processed in the rad-CLSM and sim-CLSM are also displayed in Table A.1 of Appendix A.

Table 3.3. Target Glass Composition for the AW-106 Glass

Component	AW-106 (wt%)
Al ₂ O ₃	6.12
B ₂ O ₃	9.94
CaO	3.95
Cl	0.12
Cr ₂ O ₃	0.06
F	0.07
Fe ₂ O ₃	5.52
K ₂ O	0.45
Li ₂ O	0.89
MgO	1.49
Na ₂ O	17.12
NiO	0.01
P ₂ O ₅	0.21
SO ₃	0.37
SiO ₂	45.75
TiO ₂	1.40
ZnO	3.51
ZrO ₂	3.01
Total	100.0

3.2 Melter Feed Property Measurement

The AW-106 simulant melter feed was subjected to several property measurements to determine if any indicators of potential processing difficulty may arise.

Rheological behavior was analyzed using an Anton Paar Modular Compact Rheometer (MCR) 102e Rheometer. A 110 mL volume of slurry was transferred to a cup holder for the measurement. The equipment then applied shear rates from 0.01 to 1000 s⁻¹ and back from 1000 to 0.01 s⁻¹ with a helical spindle (Giancontieri et al. 2024). Measurements were performed at 20 °C, 25 °C, 40 °C, and 50 °C. Down-ramp Bingham consistency, yield stress, and apparent viscosities were derived from the down-ramp (1000 s⁻¹ to 0.01 s⁻¹) flow curve at 25 °C. Viscosities of standard fluids were measured concurrently for comparison against standard values to ensure reliability of the measurement geometry to provide accurate viscosities. Measurements of pH were taken both before and after rheological measurements. Potential warning indicators from this measurement would include the shear stress or apparent viscosity of the melter feed slurry being outside the WTP desired operational range at a given shear rate (Poloski et al. 2004).

A portion of the AW-106 simulant melter feed was dried and powdered for testing. Approximately 0.9 g of powdered feed was pressed into a pellet of 13-mm diameter by applying 7 MPa pressure in 3 cycles for 30 s each followed by release. The pellet was then placed in a furnace at room temperature and heated at

10 K min⁻¹ to 1150 °C while the side-profile of the pellet was photographed every 10 s. The images from this feed volume expansion test (FET) were then measured in the manner described by Marcial et al. (2022) and Rigby et al. (2024) to determine the volume of pellet at each temperature increment with respect to volume of glass at 1150 °C. Two FET runs were performed for the AW-106 simulant melter feed. Potential warning indicators from this measurement would include the pellet's initial expansion starting at temperatures greater than 900 °C, the pellet having multiple expansion peaks, or the maximum normalized volume being much higher or lower than similar types of melter feeds (Rigby et al. 2024 and Dixon et al. 2025).

An additional 1.5 g portion of the powdered feed was added into a quartz ampule that was sealed with an outlet tubing stopper which was connected to a Hiden Analytical HPR R&D20 evolved gas analyzer to monitor the signals of the mass-to-charge (m/z) values. The quartz ampule was then placed in a furnace at room temperature and heated at 10 K min⁻¹ to 1150 °C while an argon carrier gas at a flow rate of 50 mL min⁻¹ directed the gases into the analyzer. The methods described in Rigby et al. (2024 and 2025) were used to normalize the signal intensities and calculate concentrations in parts per million (ppm) for particular gases over the experimental temperature range for this evolved gas analysis (EGA) test. Background measurements were recorded for ~5 min before starting the furnace to subtract background gases from the final data. Two EGA runs were performed for the AW-106 simulant melter feed, both scanning for the gases CO₂, NO, N₂, O₂, NO₂, SO₂, acetonitrile, Ar, CO, and H₂O, while the second run also scanned for Cl₂, F₂, I₂, and acrylonitrile. Potential warning indicators from this measurement would include the presence of SO₂ gas at temperatures greater than 900 °C or the primary detected gases (CO₂, NO, N₂, and O₂) evolving at significantly different temperatures than similar types of melter feeds (Rigby et al. 2024 and Dixon et al. 2025).

3.3 CLSM System

This section describes the sim-CLSM, assembled under a fume canopy in the LSL2, and the rad-CLSM assembled in a high contamination area (HCA) fume hood in the RPL with supporting equipment located in an adjacent contamination area (CA) fume hood and the surrounding areas. The general operating conditions for the performance of both CLSM systems are also detailed.

3.3.1 System Design and Configuration

The CLSM system was designed to collect samples of glass, offgas particulate, and offgas condensate without upsetting continuous operation. The CLSM was not designed to be fully prototypic of the WTP LAW melter, but to reproduce the feed-to-glass conversion process performed in the melter. A simplified flow diagram of both the radioactive and simulant CLSM systems is shown in Figure 3.1.

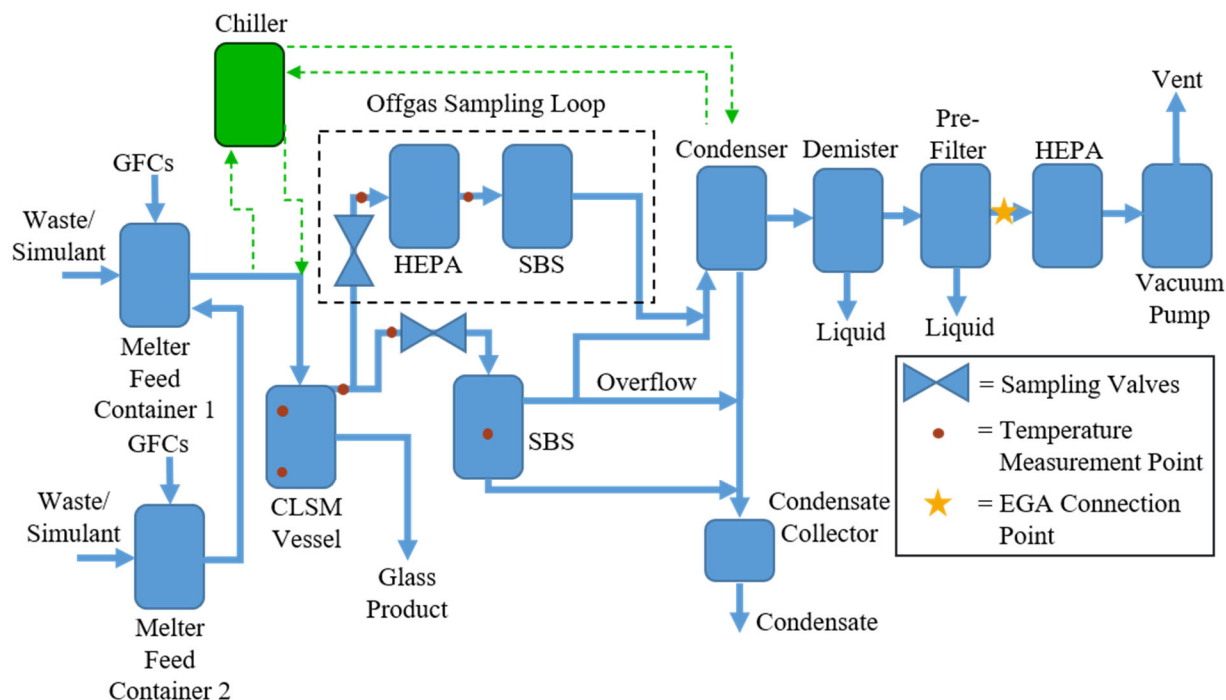


Figure 3.1. Simplified flow diagram of the CLSM systems.

The AW-106 simulant CLSM run used one container of melter feed, placed in the ‘Melter Feed Container 1’ position, while the AW-106 waste CLSM run used two containers of melter feed so that both the ‘Melter Feed Container 1’ and ‘Melter Feed Container 2’ positions were occupied. Each container was agitated by an overhead mixer and spindle for at least 12 h prior to processing in the CLSM system and remained continuously agitated during testing. In the rad-CLSM, a peristaltic pump was used to move the melter feed from Container 2, in the CA fume hood, into Container 1, in the HCA hood, when desired. The melter feed was pumped from Container 1 to the CLSM vessel by a progressive cavity pump through quarter-inch, stainless-steel tubing, which could produce a continuous drip of melter feed at a steady rate. The stainless-steel feed tubing that entered the CLSM vessel was water-cooled to prevent evaporation of the melter feed in the tubing that could result in feed line blockage.

The CLSM vessel was fabricated as an octagonal cross-sectional design using Inconel 690 plate and sized to an equivalent cylindrical diameter of approximately 12.0 cm (4.7 in.), resulting in a cross-section and glass surface area of 0.0113 m² with a plenum volume of 0.0018 m³. A see-through, acrylic version of the CLSM vessel and the actual Inconel version are shown in Figure 3.2. The glass inventory in the CLSM vessel was approximately 2.0 kg, resulting in a glass melt pool depth of ~6.4 cm (2.5 in.).

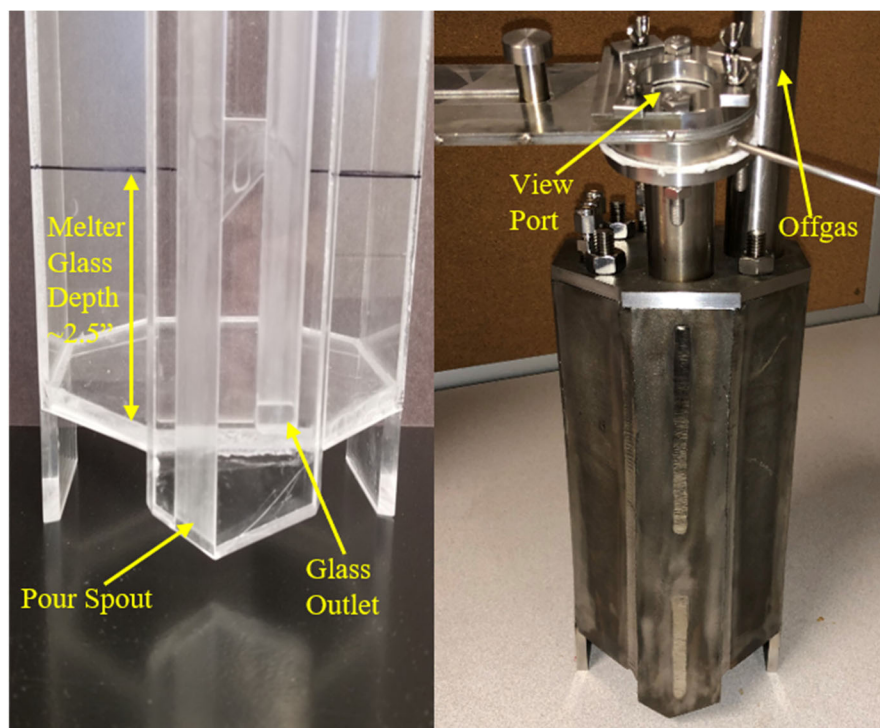


Figure 3.2. Acrylic CLSM vessel model (left) and actual CLSM vessel (right).

As seen in Figure 3.3, the lid of the CLSM vessel contained eight access ports: three for thermocouples (“TC” in the figure), one for an air bubbler, one for the feed tubing, one for a sight glass into the vessel (“Viewport” in the figure), one for the connection to the offgas system, and one for pressure relief (“Back-Up Offgas” in the figure). Heat was supplied externally to the CLSM vessel by a surrounding furnace. The hot zone of the furnace was located below and around the glass melt pool while the offgas head space, called the plenum, of the CLSM vessel was surrounded by insulation. The CLSM achieved continuous operation by periodically pouring glass out of the melt pool to a glass discharge box located below the CLSM vessel. Pouring was achieved by lowering the vacuum maintained on the CLSM vessel by the offgas system, which allowed glass to pour by rising through a discharge riser and passing over an overflow weir.

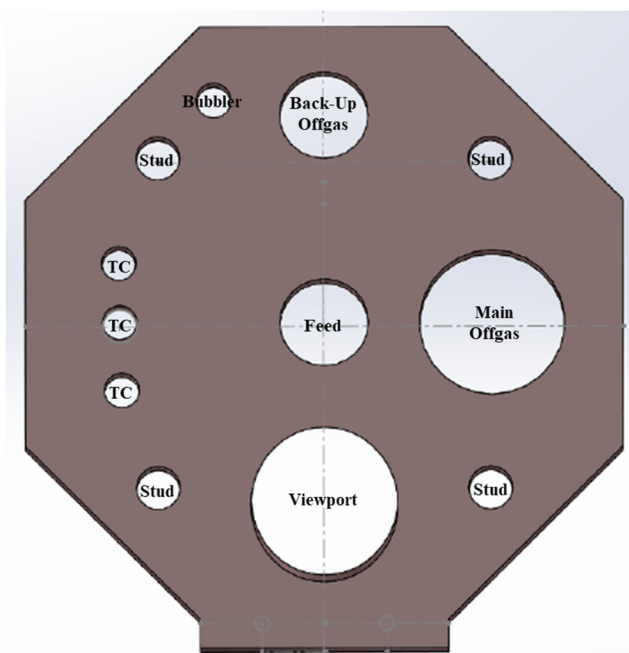


Figure 3.3. CLSM vessel lid and identified ports. The designation 'TC' stands for a thermocouple port.

The offgas produced by the conversion of melter feed to molten glass was drawn off from a port in the CLSM vessel lid into the offgas system with a vacuum pump. The offgas system was constructed of stainless-steel piping and the units described subsequently. Except when the offgas stream was sampled, the offgas would flow through the primary pathway in the offgas system, which consisted of a submerged-bed scrubber (SBS; referred to as the primary SBS), a condenser, a demister, a polypropylene pre-filter, and a high-efficiency particulate air (HEPA) filter (referred to as the primary HEPA filter). The primary SBS and the condenser worked together to both cool the offgas, causing condensation of steam, and perform scrubbing to remove other soluble gases and aerosols as much as possible. The cool liquid from the condenser along with the liquid overflow from the primary SBS drained into a collector where this condensate liquid could be drained periodically. Offgas from the condenser passed through a demister, that allowed any remaining liquid to accumulate before the pre-filter and primary HEPA filter captured any remaining difficult-to-remove particulates. A line to the Hiden Analytical HPR R&D20 EGA equipment was connected to the offgas treatment system between the pre-filter and primary HEPA filter only in the sim-CLSM (at the spot shown in Figure 3.1). The EGA vacuum pump could pull gases to the analyzer only when glass was being poured from the CLSM vessel and the analyzer was scanning for CO₂, NO, N₂, O₂, NO₂, SO₂, acetonitrile, Ar, CO, and H₂O, Cl₂, F₂, I₂, and acrylonitrile gases. After HEPA filtration, the offgas flowed through the vacuum pump and was released into the HCA fume hood ventilation system for the rad-CLSM or the top of the fume canopy for the sim-CLSM. If needed, the pre-filter and primary HEPA filter could be bypassed and the offgas could flow directly from the demister to the vacuum pump.

The total offgas stream could be sampled by closing the sampling valve in the primary offgas pathway to divert the full offgas flow through a sampling loop containing heated HEPA filters (referred to as the sampling HEPA filters) followed by an SBS (referred to as the sampling SBS). This sampling train consisted of three parallel housings, each with a sampling HEPA filter. Each housing was available for a discrete sampling evolution. The sampled offgas stream was then released back into the primary offgas pathway before the condenser unit. Sampling of the total offgas stream avoided the inherent issues with offgas piping geometry and design that are encountered with slip-stream sampling and ensured that the

sample was representative. Offgas sampling durations were typically 10-30 min or until the sampling HEPA filters became impassable.

The CLSM system consisted of commercially available as well as custom-built parts. In addition to the CLSM system described above (shown in Figure 3.1), supporting equipment included a controller for the furnace; a water chiller pumping system to cool all of the necessary locations in the CLSM system, such as the condenser and the primary SBS, with a separate liquid pump plumbed into the chiller line to transport cooling water to the feed nozzle at a controlled rate; a water flush pump for washing out the melter feed pumping system; a controller for the heat trace around the sampling and primary HEPA filters; and a computer for controlling the CLSM system while continuously recording process data. An image of the sim-CLSM layout under the fume canopy in LSL2 is shown in Figure 3.4 and an image of the rad-CLSM layout in the fume hoods in RPL is shown in Figure 3.5.

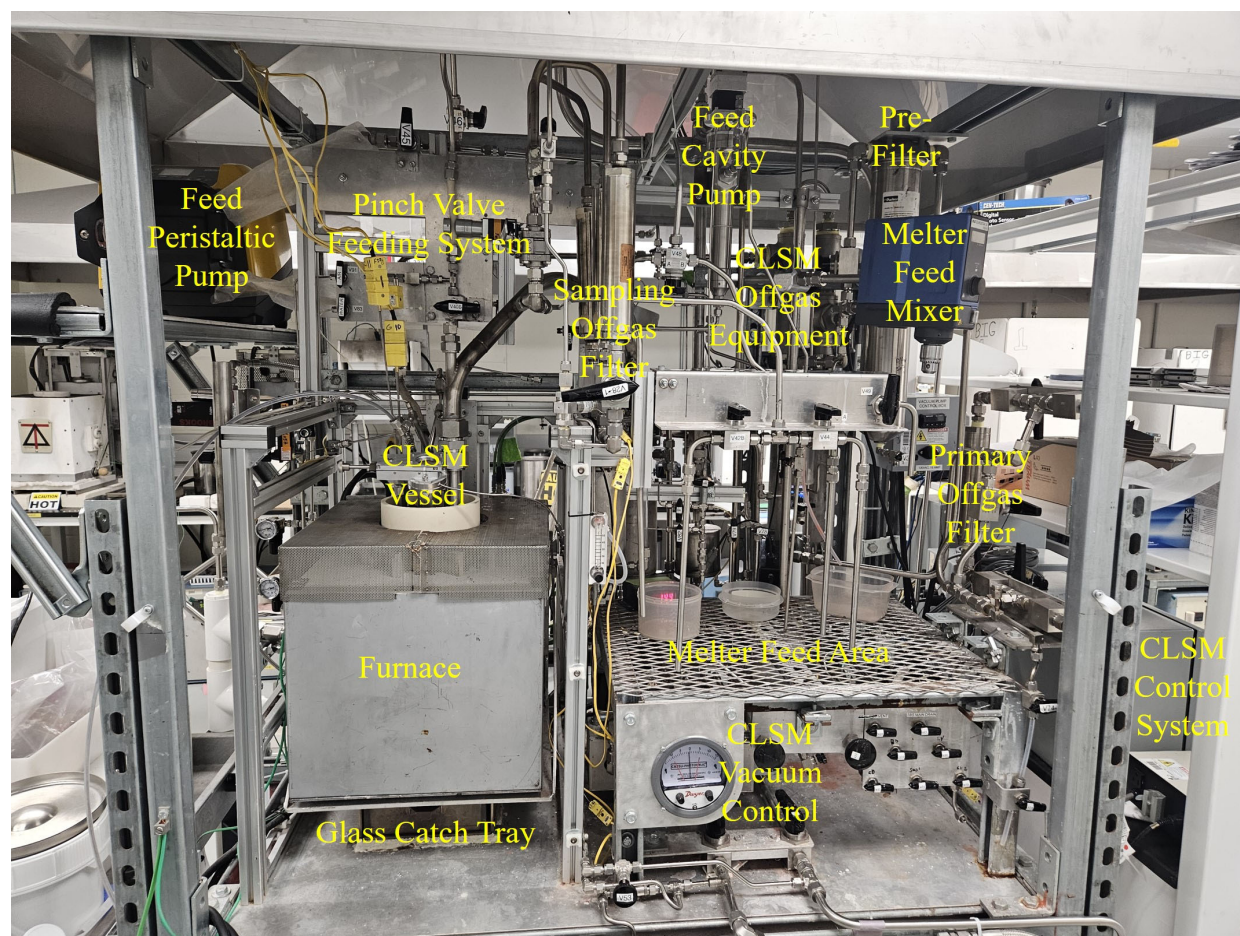


Figure 3.4. The sim-CLSM layout under the fume canopy in the LSL2.

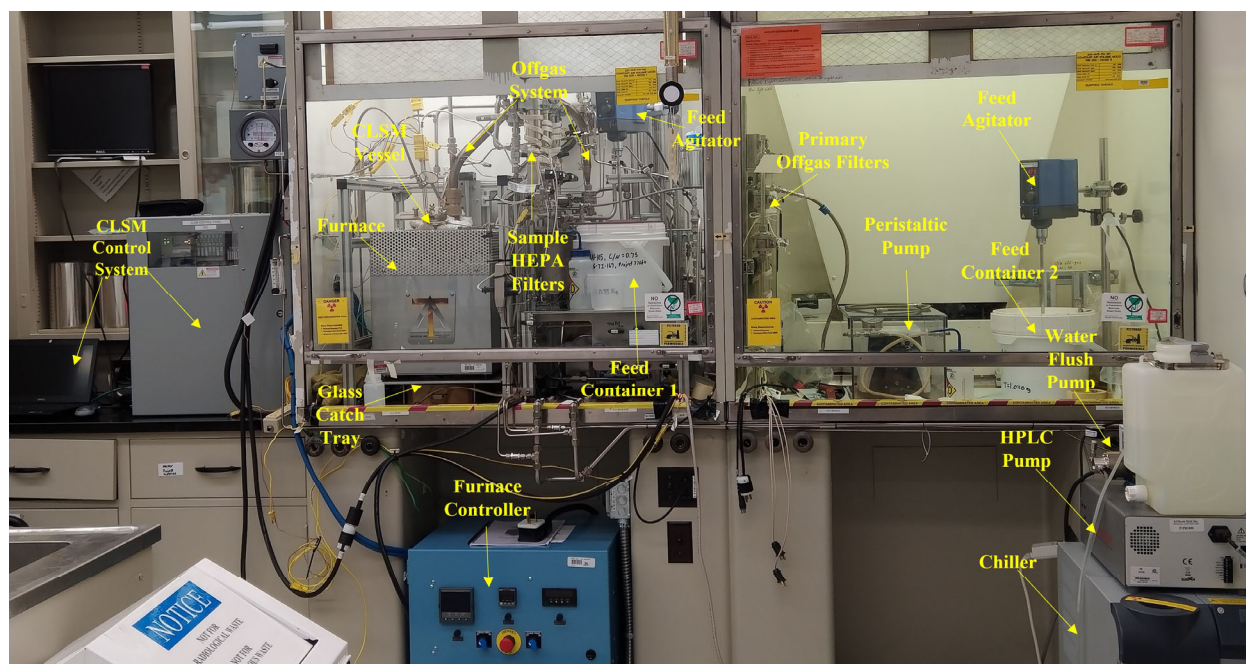


Figure 3.5. The rad-CLSM layout in the RPL HCA (left) and CA (right) fume hoods.

3.3.2 Test Conditions

The CLSM system was operated to maintain a glass melt pool temperature of $1150\text{ }^{\circ}\text{C}$ ($\pm 30\text{ }^{\circ}\text{C}$) by manually adjusting the control temperature of the surrounding furnace as necessary. During feeding operations, the melter feed was charged onto the glass melt surface in the CLSM vessel, forming a batch blanket, called a cold cap, where the feed was heated and converted to glass. The feeding rate (governed by the progressive cavity pump with an operational range from 0 to 100 revolutions per minute [rpm]) and air bubbling rate (governed by a mass flow controller that could deliver air at 50 to 3000 standard cubic centimeters per minute [sccm] through an Inconel-690 tube that was submerged in the glass melt pool) were varied to maintain a target cold-cap coverage over the glass melt surface of 75-95%. The cold-cap coverage was determined to be in the appropriate range when the temperature in the plenum fell into the $500\text{--}700\text{ }^{\circ}\text{C}$ range and this could be confirmed through visual observation (by visually estimating the cold-cap coverage) through the viewport of the CLSM vessel lid. The CLSM briefly produced glass melt pool and plenum temperatures above and below the target ranges during testing.

Typical of slurry-fed melters, the plenum temperature and cold-cap coverage are influenced by many factors, including feed composition and component concentrations, which may vary between different melter feeds (Matlack et al. 2011). The target production rate range for both the AW-106 simulant and waste melter feeds processed in the CLSM were derived from the previous processing of LAW melter feeds in the CLSM (Dixon et al. 2020a, 2020b, 2022a, 2022b, 2023, 2024, and 2025) and are listed in Table 3.4. The general production range values aligned with the designed operation rates at the WTP of 15 metric tons of glass per day [MTG d^{-1}] of immobilized LAW (Schubick et al. 2023).

Table 3.4. Target CLSM Operating Conditions

Parameter	CLSM Target Range
Target glass production rate, kg m ⁻² d ⁻¹	1500 – 2000
Melt surface area, m ²	0.0113
Target feeding rate, kg-feed h ⁻¹	1.59 – 2.12
Target feeding rate, L-feed h ⁻¹	1.01 – 1.35
Bubbling rate, sccm	50 – 2000
Target glass melt temperature, °C	1150 ± 30
Plenum temperature range, °C	500 – 700
Plenum vacuum normal operation, in-H ₂ O	2 – 4
Offgas piping temperature range, °C	< 500
Primary SBS temperature, °C	15 – 35

The condenser in the offgas system was operated with chilled water and the condensate drained periodically from a collector vessel. The liquid level in the primary SBS was maintained by overflow so that the pressure-drop across the primary SBS remained relatively constant. The temperature was maintained by circulating chilled water through cooling coils in the primary SBS to achieve a temperature range of 30 – 40 °C during operation. In the offgas sampling loop, the sampling HEPA filters were wrapped with heat trace and covered with insulation to maintain an elevated temperature (>100 °C) and prevent/reduce condensation prior to the sampling SBS. The offgas system vacuum pump was operated such that it pulled a vacuum on the CLSM vessel during feeding operation. The nominal operating vacuum was 2–4 in-H₂O. As described in Section 3.3.1, the CLSM vessel vacuum was reduced periodically to pour glass. At the end of the run, the bubbler air and viewport purge air were adjusted to increase the pressure in the melter, pouring controlled volumes of glass from the CLSM vessel until the remainder of the glass inventory had exited the vessel.

3.4 Sample Analysis Methods

The mass of the container with the AW-106 simulant melter feed was measured upon completion of batching, then before and after processing to determine the initial and final mass of melter feed. For the AW-106 waste melter feed, the masses of the AW-106 waste and each individual GFCs added to the two batches of AW-106 waste melter feed were measured and totaled to calculate the initial mass in each container before processing. The containers with the two batches of AW-106 waste melter feed could not be removed from the HCA/CA fume hoods to have their masses measured directly, so the leftover melter feeds after processing had ended were transferred into separate containers (one for batch 1 and another for batch 2) that were measured to determine the final mass of melter feed processed through the rad-CLSM. This transfer process resulted in a necessary, but minimum amount of melter feed as a heel that was unprocessed and not accounted for in the measured mass of unprocessed feed.

The masses of all product streams were weighed after the run; these included the glass from each pour, the total condensate, the final sump contents from both the sampling SBS and primary SBS (the SBS sumps contained only the liquid from the final capacity of each SBS since, during operation, the SBS liquid would overflow into the condensate collector), the liquid in the demister, the liquid that had accumulated in the pre-filter housing, the pre-filter, the primary HEPA filters, and the sampling HEPA filters. Approximately 10-mL or 10-g samples (for liquid or solid streams, respectively) were taken of the melter feed and from selected product streams. Appropriate product streams were selected by the operational team to gain insight of the operational behavior of each CLSM run. These selected samples, and whole primary/sampling HEPA filters, were sent to the Southwest Research Institute (SwRI) for

cation and anion chemical analysis. The analysis methods employed by SwRI and each component measured using each method are given in Table 3.5.

Table 3.5. Sample Chemical Analysis Methods and Components Scanned

Methods	Component
ICP-AES (inductively coupled plasma-atomic emission spectroscopy)	Ag, Al, As, B, Ba, Be, Bi, Ca, Cd, Co, Cr, Cu, Fe, K, La, Li, Mg, Mn, Mo, Na, Ni, P, Pb, Pd, S, Sb, Se, Si, Sn, Sr, Th, Ti, Tl, U, V, W, Y, Zn, and Zr
ICP-MS (inductively coupled plasma mass spectrometry)	Total Cs, Total I, Re, and ⁹⁹ Tc
IC (ion chromatography) or Ion-Specific Electrode	Bromide/Bromine, Chloride/Chlorine, Fluoride/Fluorine, Nitrate, Nitrite, Phosphate, and Sulfate
Alpha Spectroscopy	²⁴¹ Am, ²⁴² Cm, ^{243/244} Cm, ²⁴³ Am ²³⁷ Np, ²³⁸ Pu, ^{239/240} Pu, and ²⁴⁴ Pu
SW-846 Method 9060M	Total Organic Carbon (TOC)
SW-846 Method 9060M	Total Inorganic Carbon (TIC), Carbonate
SW-846 Method 8260D	Acetonitrile (CH ₃ CN)
EPA 350	Ammonia as N

4.0 CLSM Run Results

This section describes the operation of the CLSM for the AW-106 simulant run in the LSL2 on February 2, 2026, and the AW-106 waste run in the RPL on March 3, 2026. The feed properties, production, and chemical analysis results are also detailed.

4.1 Melter Feed Properties

Figure 4.1 displays the results for shear stress and dynamic viscosity of the AW-106 simulant melter feed measured during the shear rate down ramp at 25 °C. These results were within the expected upper and lower bounding limits for WTP melter feed rheology (Poloski et al. 2004), displayed with red lines in Figure 4.1, which indicates that there should be no expected difficulties pumping the AW-106 simulant melter feed slurry into the CLSM system.

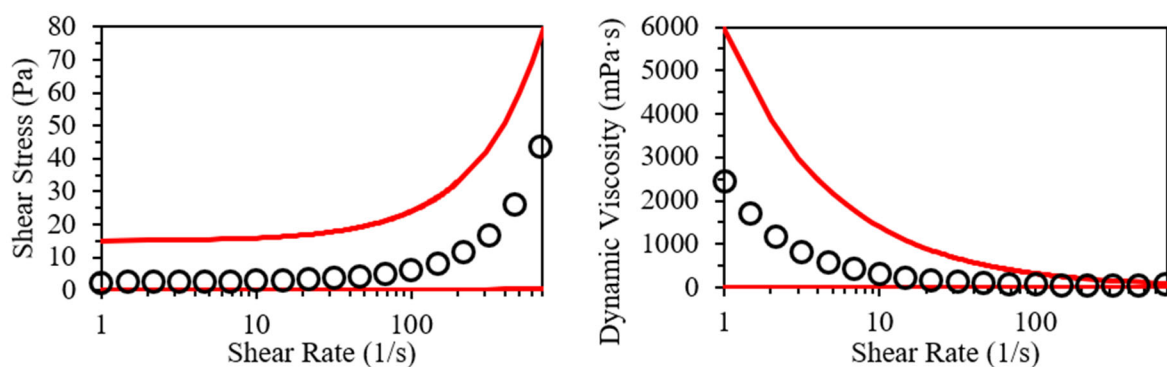


Figure 4.1. Shear stress and dynamic viscosity vs shear rate results for AW-106 simulant melter feed slurry. The red lines indicate the upper and lower limits for the WTP (Poloski et al. 2004).

The FET results for the AW-106 simulant melter feed are shown in Figure 4.2. The initial expansion for Runs 1 and 2 occurred between 635 °C and 650 °C and their peaks reached an expansion of $\sim 16 \text{ V V}_g^{-1}$. The initial expansion temperature was lower for AW-106 than for AW-105 (also displayed on Figure 4.2; Dixon et al. 2025) and AP-107 at the nominal sucrose ratio performed in Rigby et al. (2024), while the maximum expansion values were approximately the same for all 3 melter feeds. These differences in FET measurement do not raise warnings about potential processing difficulties of AW-106 melter feed in the CLSM according to the indicators mentioned in Section 3.2. The spikes in volume during the AW-106 runs observed after 900 °C were a result of the analysis program mis-interpreting reflections from the heating elements as a light source in the FET furnace and should not be considered as a secondary expansion peak for the melter feed.

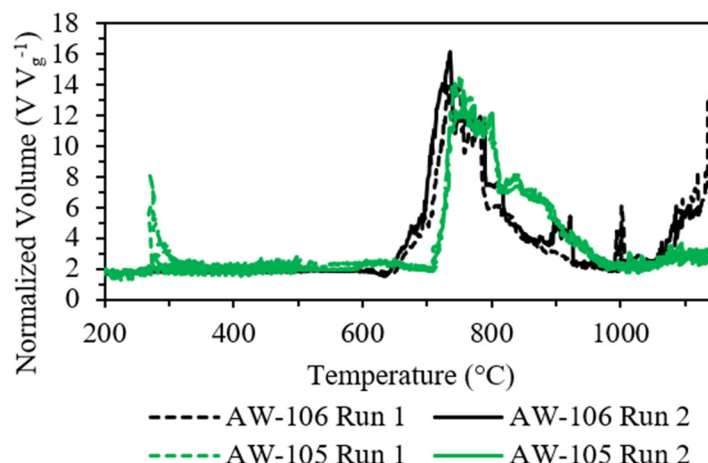


Figure 4.2. FET results for AW-106 (and AW-105 [Dixon et al. 2025]) simulant melter feed.

Figure 4.3 displays the primary gas evolutions (CO_2 , NO , N_2 , O_2 , NO_2 , acetonitrile, and SO_2) from runs 1 and 2 performed with the AW-106 simulant melter feed along with the results from the AW-105 simulant melter feed (Dixon et al. 2025). During AW-106 EGA run 2, the quartz tube which contained the powdered melter feed developed a crack at a low temperature ($<80^\circ\text{C}$), which caused the total amount of gas received by the EGA analyzer to be an order of magnitude less than during run 1 (or the AW-105 run). Under these conditions, the temperature at which the gases evolved compare well between AW-106 runs 1 and 2, but the magnitude of the gases measured differed and run 2 had more discernable noise in all the detected gas curves. In both EGA runs for the AW-106 simulant melter feed, there was no spike of SO_2 gas above 900°C , indicating that there is a low presence of secondary foam in the glass, so the AW-106 melter feed should not have difficulty melting in the CLSM. The temperatures at which the primary gases evolved were similar between the AW-106 simulant melter feed and the AW-105 simulant melter feed (Dixon et al. 2025).

Additional minor gases, NH_3 and acrylonitrile, were scanned during EGA run 1 for the AW-106 simulant melter feed, the results of their evolutions are shown in Figure 4.4. The noise in the NH_3 curve was great at the low ($<250^\circ\text{C}$) and high (800°C) temperature ranges due to its scanned mass value (17 atomic mass units) being close to that of water (18). Both gases had peaks around 300°C that aligned with the peak of acetonitrile showing that the carbon and nitrogen combustion reactions that produce these gases occur simultaneously.

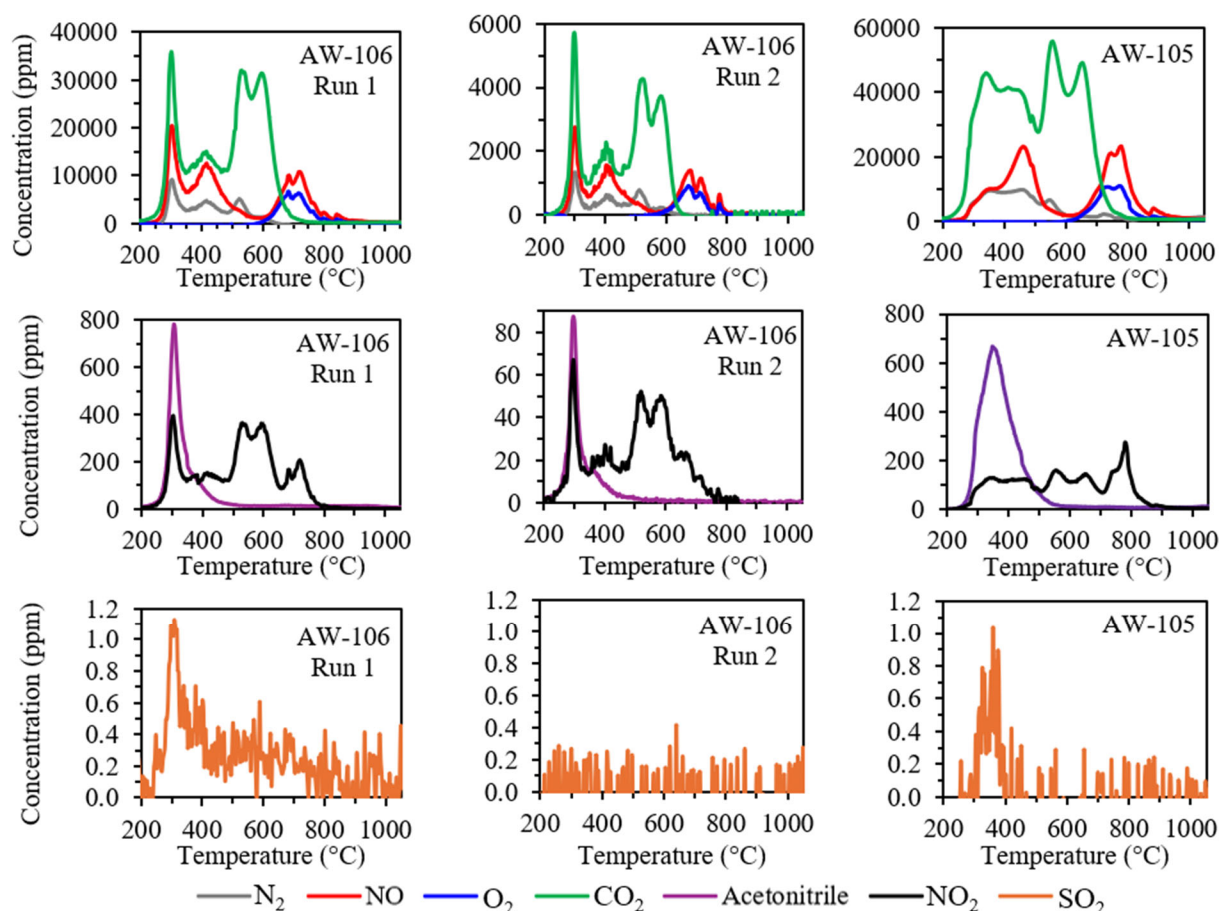


Figure 4.3. EGA results for the primary gases collection during run 1 and run 2 for the AW-106 simulant melter feed. The EGA results for AW-105 (Dixon et al. 2025) are also included for comparison.

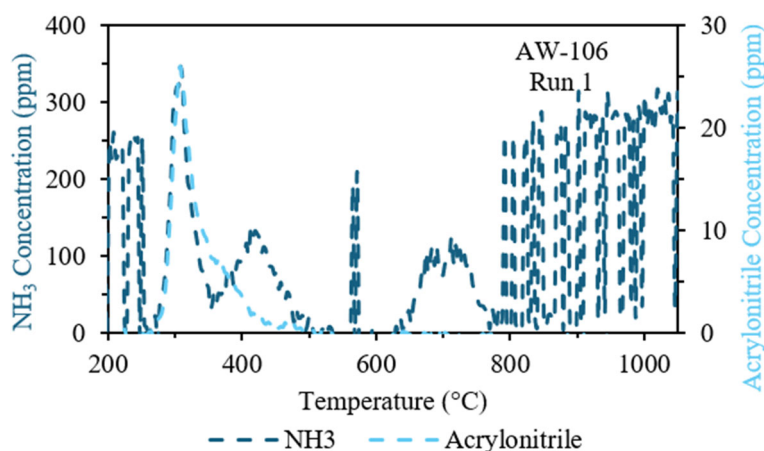


Figure 4.4. EGA results for the selected minor gases collection during run 1 for the AW-106 simulant melter feed.

4.2 Operational Description and Production Results

For the AW-106 simulant run, during set-up of the sim-CLSM, approximately 2.0 kg of AN-107 glass pieces, produced previously (Dixon et al. 2024), were loaded into the CLSM vessel as the initial glass inventory. An amount of Re had been retained in this glass mixture during the previous runs. The furnace surrounding the CLSM vessel was heated from room temperature to 1250 °C at 10 °C min⁻¹ and held at this setpoint for the duration of the run so that the temperature of the glass melt in the CLSM vessel could be ~1150 °C. The CLSM run then began by charging the AW-106 simulant melter feed into the CLSM vessel at 9:37 AM on February 2, 2026, when the glass temperature had reached its desired range, shown in Table 3.4. The runtime (using the start of feeding as 0.00 h), mass of each individual glass pour (including the mass loaded into the vessel as well as the initial and final pours before or after the runtime, respectively), and cumulative mass of glass poured during the run are given in Table 4.1. The EGA equipment collected gas pressures during the entire runtime while processing the AW-106 simulant melter feed, the results of which will be discussed in Section 4.3. Following the termination of feeding, the cold cap burned off (all remaining melter feed in the cold cap and plenum walls was converted into glass), a dip sample of glass was procured through the viewport of the CLSM vessel lid, and the glass inventory was poured out of the CLSM vessel, corresponding with the final glass pour reported for the run. Given the total mass of glass poured and the inventory of glass loaded into the CLSM vessel, the mass of glass produced during the AW-106 simulant run was 6.66 kg, corresponding to over 3 turnovers of the 2.0 kg glass inventory.

For the AW-106 waste run performed on March 3, 2026, during set-up of the CLSM system, approximately 2.0 kg of AW-106 glass pieces, from the final pour of AW-106 simulant run, were loaded into the CLSM vessel as the initial glass inventory. The furnace surrounding the CLSM vessel was heated from room temperature to 1250 °C at 10 °C min⁻¹. The CLSM run then began by charging the AW-106 waste melter feed into the CLSM vessel at 9:57 AM, when the glass temperature had reached its desired range, shown in Table 3.4. The runtime and mass of each individual glass pour of the AW-106 waste run, and the cumulative mass of total AW-106 waste glass poured, are given in Table 4.1. After 3.62 h of runtime, the condensate collector unit in the offgas treatment system became full of liquid, necessitating a pause in feeding so the unit could be drained. While this action was being performed, a blockage developed in the feeding line, which subsequently required manual reaming to clear. After these issues were resolved, feeding began again after a 2.95 h long pause.

Following the termination of feeding, the cold cap burned off and the remaining glass inventory was poured out of the CLSM vessel, corresponding with the final glass pour reported for the run. Given the total mass of glass poured and the inventory of glass loaded into the CLSM vessel, the mass of glass produced during the total waste CLSM run was 6.13 kg, corresponding to 3 turnovers of the 2.0 kg glass inventory. It was also noted during the run that the transfer of AW-106 waste melter feed from ‘Melter Feed Container 2’ into ‘Melter Feed Container 1’, see Figure 3.5 for positioning, began at 2.52 h and ended after about 0.7 h when as much feed as possible had been transferred. After 5.80 h of total feeding time, the objectives of the AW-106 waste run had been accomplished and feeding was stopped.

Table 4.1. Timing and Mass of Glass Pours During the AW-106 Simulant and Waste CLSM Runs

2-2-2026			3-3-2026		
Simulant Pour Time (h)	Simulant Glass Mass Poured (g)	Simulant Cumulative Glass Mass Poured (kg)	Waste Pour Time (h)	Waste Glass Mass Poured (g)	Waste Cumulative Glass Mass Poured (kg)
Load	1992.83	--	Load	1992.38	--
Initial	92.64	0.09	Initial	54.09	0.05
0.63	562.02	0.65	0.95	733.56	0.79
1.13	436.36	1.09	1.34	644.78	1.43
1.63	490.42	1.58	1.62	176.70	1.61
2.13	531.02	2.11	2.18	476.87	2.09
2.64	758.67	2.87	2.72	662.70	2.75
3.14	561.83	3.43	3.37	1132.63	3.88
3.63	787.78	4.22	6.82	170.28	4.05
4.52	772.86	4.99	7.50	512.61	4.56
5.05	540.03	5.53	7.94	455.52	5.02
5.55	609.32	6.14	Final	3106.52	8.13
6.01	530.52	6.67			
Dip	9.05	6.68			
Final	1966.82	8.65			
Total Produced		6.66	Total Produced		6.13

The production results from the AW-106 simulant and waste CLSM runs are given in Table 4.2. The production results include the total values of the feeding time (and low flow duration within the feeding time), operational downtime, measured mass of glass produced, calculated mass of melter feed consumed, and average values for the glass production rate, feeding rate, glass temperature, and plenum temperature. The processing values recorded during the simulant CLSM run are displayed in Figure 4.5 and those recorded during the waste CLSM run are displayed in Figure 4.6. These results include the glass and plenum temperatures, the average glass production rate, the bubbling flux rate, and the CLSM vessel vacuum measurements. Three offgas samples were collected during the simulant CLSM run and three offgas samples were also collected during the waste CLSM run. The occurrence of each offgas sample in the timeline for each of the runs is shown in relation to the processing values in Figure 4.5 and Figure 4.6.

Table 4.2. CLSM Production Results During Both AW-106 CLSM Runs

Parameter	AW-106 Simulant CLSM Run	AW-106 Waste CLSM Run
Test Date	2/2/2026	3/3/2026
Feeding Duration, h	6.13	5.80
Low Flow Duration, h	--	--
Downtime, h	--	2.95
Glass Produced, kg	6.66	6.13
Melter Feed Consumed, kg	14.95	13.31
Average Glass Production Rate, kg m ⁻² d ⁻¹	2305	2245
Average Feeding Rate, kg h ⁻¹	2.44	2.30
Average Bubbling Flux Rate, L m ⁻² min ⁻¹	49	38
Average Glass Temperature, °C	1143	1135
Average Plenum Temperature, °C	655	665

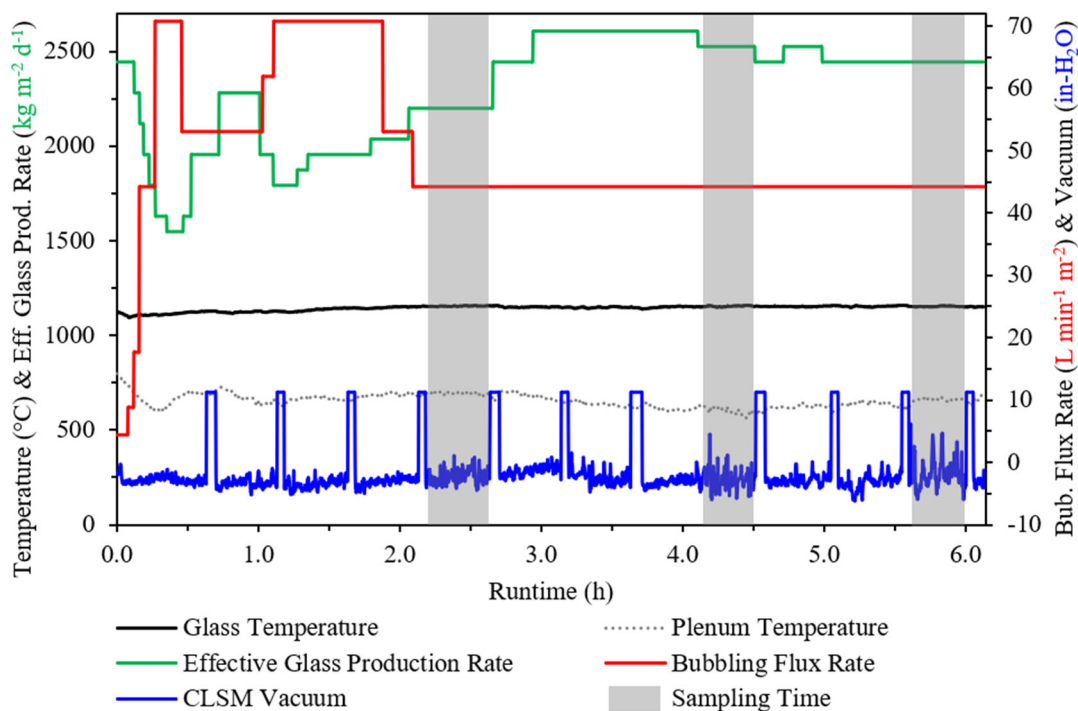


Figure 4.5. Processing values (glass and plenum temperatures, effective glass production rate, bubbling flux rate, and CLSM vacuum measurements) and offgas sample timing recorded during the AW-106 simulant CLSM run.

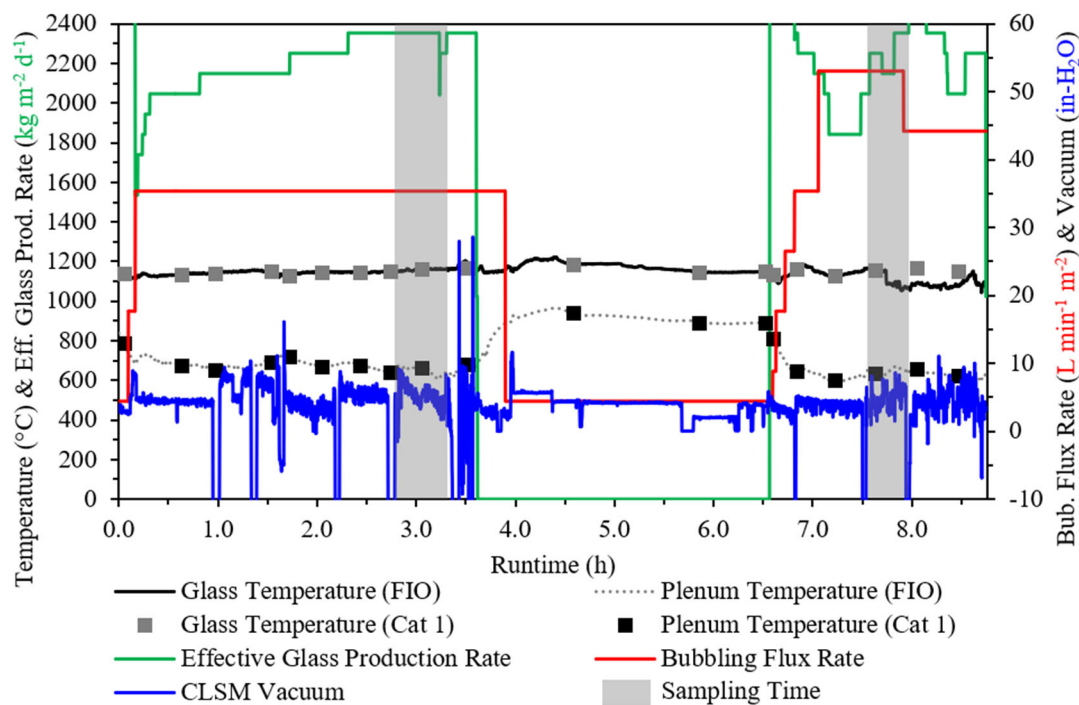


Figure 4.6. Processing values (glass and plenum temperatures, effective glass production rate, bubbling flux rate, and CLSM vacuum measurements) and offgas sample timing recorded during the AW-106 waste CLSM run.

The cold cap during both the AW-106 simulant and waste melter feed charging appeared to have appropriate coverage over the glass melt surface (90 – 100%) and its thickness remained uniform, responding quickly to production changes by increasing/decreasing the feed charging or bubbling rates. These qualities adhered closely to cold-cap behaviors while processing AP-107, AN-107, and AW-105 melter feeds in the CLSM (Dixon et al. 2019, 2020b, 2022a, 2024, 2025).

4.3 Evolved Gas Monitoring During Sim-CLSM Run

The evolutions of gases captured by the EGA equipment during the sim-CLSM run with AW-106 simulant melter feed are shown in Figure 4.7 with respect to the runtime. Nitrogen (N_2) and oxygen (O_2) gases were detected continuously during operations while all other gases were only above their baseline values during the glass pour times listed in Table 4.1. Without the presence of a carrier gas at a known flowrate, the concentration of these gases could not be directly calculated.

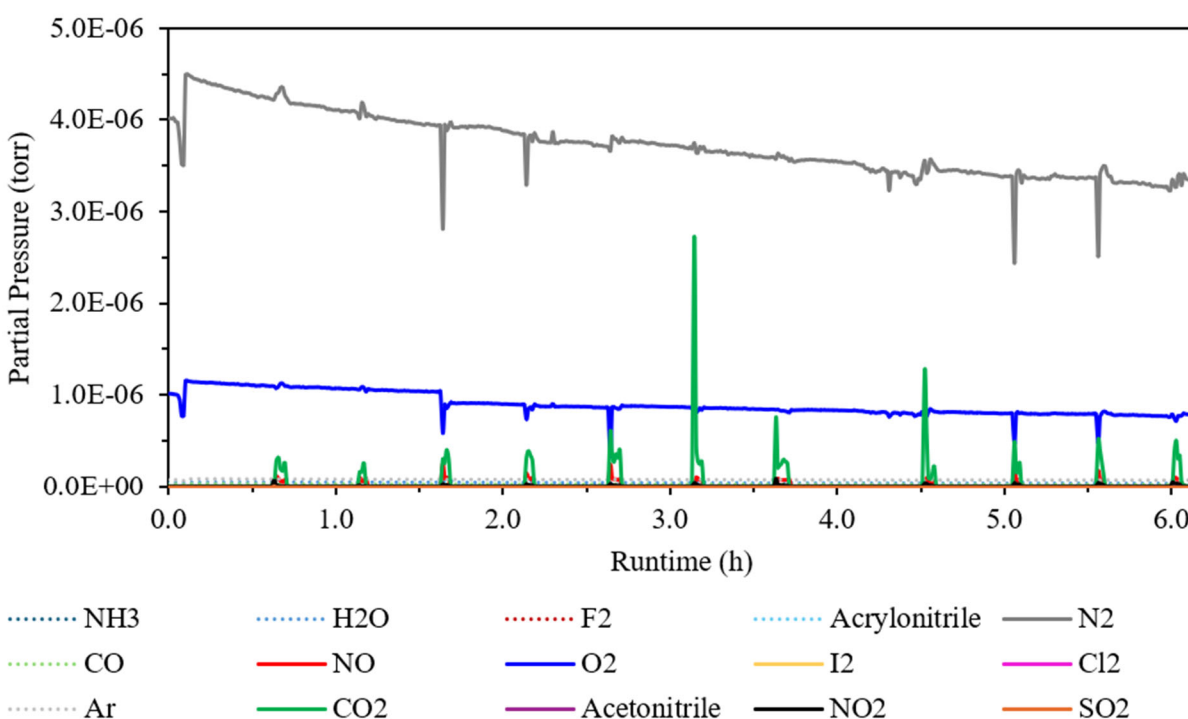


Figure 4.7. Evolved gases captured during the processing of AW-106 simulant melter feed in the CLSM.

Each gas evolution curve recorded in Figure 4.7 was normalized by the partial pressure of air (the summation of the N_2 and O_2 curves). The background measurements for each gas, recorded for ~5 min prior to the start of feeding into the CLSM, was then subtracted from its curve to baseline the curves. The values for each gas to air pressure ratio (torr torr^{-1}) were averaged for each glass pour time, the results of which are displayed in Figure 4.8.

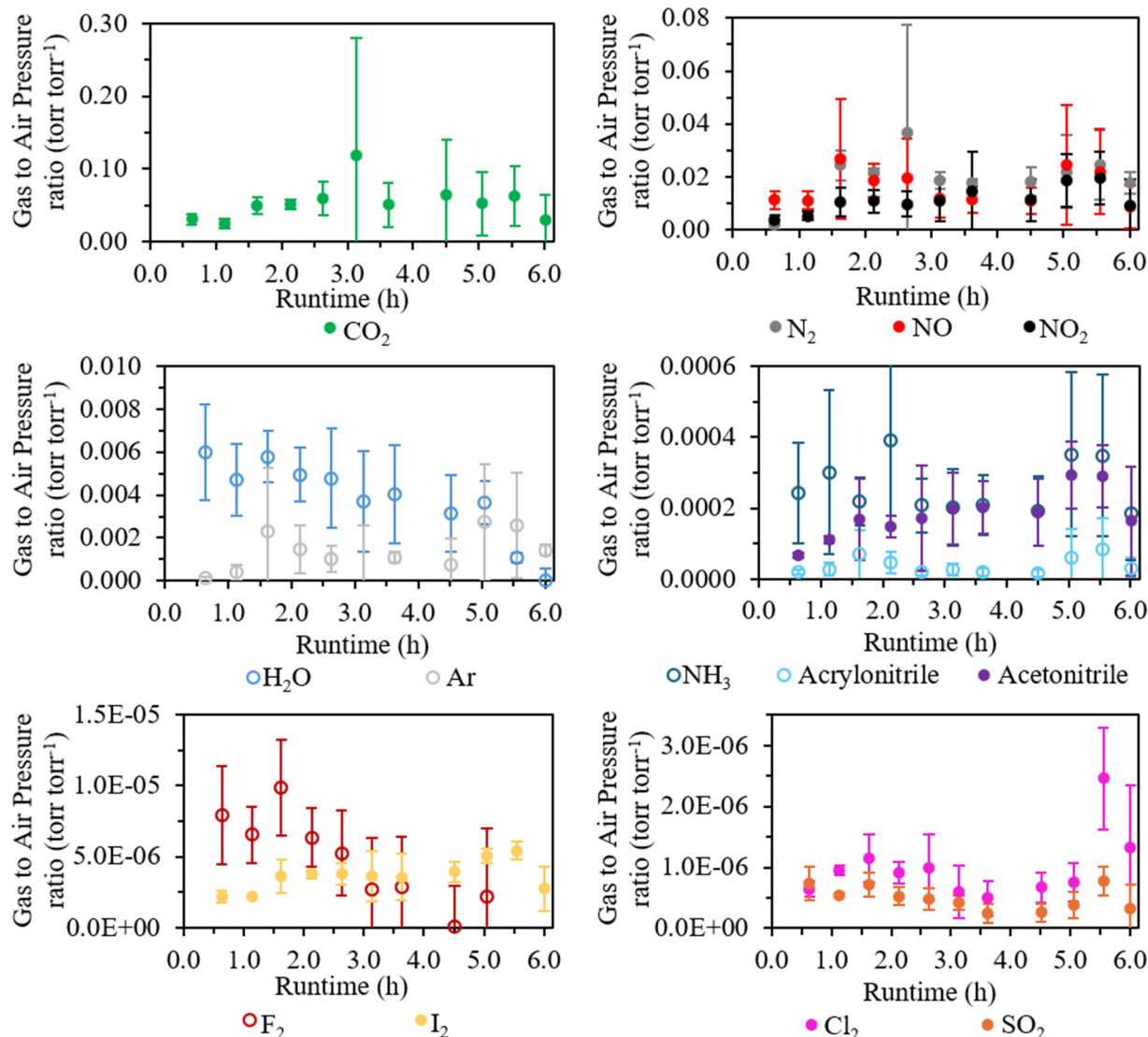


Figure 4.8. Measured gas to air pressure ratio for each gas captured during the glass pour times while processing AW-106 simulant melter feed in the CLSM.

The trends of these gases measured during glass pour times may reveal changes in processing of melter feed that aren't evident from visual observation of the cold cap or analysis of samples post-run. While comparable data is not available for associating the AW-106 simulant melter feed processing to other melter feed formulations, changes to individual gas trends within the run are evident. The acetonitrile gas trends to higher values over the course of the run, which may indicate that more acetonitrile is produced as the cold cap covers more of the glass melt surface and the plenum temperature cools. The F₂ gas trends to lower values over the course of the run, which aligns with the composition trend of F₂ in the glass that shows more F₂ being retained in the glass (with less expected F₂ to volatilize into gas) as the run progressed (see Figure B.5 in Appendix B). Additional revelations about processing characteristics may become evident as more gas data is captured during the processing of melter feeds in the CLSM under this operational arrangement.

4.4 Sample Chemical Analysis

The samples selected for chemical analysis from the AW-106 simulant CLSM run are listed in Table A.2 in Appendix A along with the total mass of each sample stream and the concentration of each analyzed component listed in Table 3.5. Similarly, the samples selected for chemical analysis from the AW-106 waste CLSM run are listed in Table A.3 in Appendix A along with the total mass of each sample stream and the concentration of each analyzed component.

The melter feed samples sent for analysis were pumped from their respective containers into sample vials. Two samples of the AW-106 waste melter feed were sent for analysis because one became diluted with flushing water during the pumping process and is marked as '(dilute)' in Table A.3 in Appendix A. A sample of the powdered AW-106 simulant melter feed was also sent for complete analysis and is marked as '(Dry)' in Table A.2 in Appendix A. Glass pours were selected for analysis over the range of each CLSM run. The occurrence of each glass pour in the timeline for each of the runs is listed in the sample name. For the collection of each offgas sample, the complete sampling HEPA filters were digested and analyzed independently while the same process was performed for the used primary HEPA filter. Due to their size, the pre-filters had to be split into three portions for shipment, but all three portions were digested and combined for analysis.

The samples of condensate collected throughout the simulant run and waste run were each combined into two separate containers and subsampled. Similarly, the liquids that accumulated in the demister during the simulant run and the waste run were each combined into two separate containers and subsampled. Liquid accumulated in the pre-filter housing during each run was drained from the housing and collected. The sump from the primary SBS that remained at the end of each run was drained and collected. For the AW-106 simulant run, the offgas piping was washed with water into two volumes: 1) from the CLSM vessel lid to the offgas switch (denoted in Table A.2 as Primary Offgas Wash); and 2) the sampling loop piping (denoted in Table A.2 as Sampling Offgas Wash). Due to radioactive contamination restrictions, the offgas piping was not able to be disassembled and washed after the AW-106 waste run. Aliquots of all the liquid portions described were sent for chemical analysis.

5.0 Discussion

This section discusses the insights gained from the CLSM runs with both the AW-106 simulant and AW-106 waste melter feeds and compares data to previous CLSM runs (Dixon et al. 2018, 2019, 2020a, 2020b, 2022a, 2022b, 2023, 2024, and 2025).

5.1 Glass Composition

Table 5.1 compares the average composition of the glass produced during the CLSM runs with the AW-106 target glass composition, given in Table 3.3. The average glass composition produced during each run was calculated by converting the analyzed component concentrations in each glass sample, listed in Table A.2 and Table A.3 of Appendix A, to their associated oxides and averaging based on the mass of each glass poured with each composition. For each primary glass component (present in >1.00 wt% amounts), the percent differences between the measured composition and the target composition are reported in Table 5.1.

Table 5.1. Comparison of AW-106 Simulant and Waste CLSM Run Glass Products with Target Compositions

Component	Target	Measured	% Diff.	Measured	% Diff.
	AW-106	Average	Target to	Average	Target to
	wt%	Simulant	Simulant	Waste	Waste
		AW-106	AW-106	AW-106	AW-106
	wt%	wt%	%	wt%	%
Al ₂ O ₃	6.12	5.80	-5.3	6.11	-0.2
B ₂ O ₃	9.94	10.34	4.0	9.08	-8.7
CaO	3.95	3.78	-4.3	3.98	0.9
Cl	0.12	0.20	--	0.20	--
Cr ₂ O ₃	0.06	0.10	--	0.07	--
F	0.07	0.09	--	0.05	--
Fe ₂ O ₃	5.52	5.22	-5.3	5.50	-0.3
K ₂ O	0.45	0.44	--	0.51	--
Li ₂ O	0.89	0.90	--	0.93	--
MgO	1.49	1.55	4.0	1.67	12.0
Na ₂ O	17.12	16.64	-2.8	17.68	3.3
NiO	0.01	0.06	--	0.02	--
P ₂ O ₅	0.21	0.23	--	0.12	--
SO ₃	0.37	0.50	--	0.38	--
SiO ₂	45.75	46.37	1.4	45.73	0.0
TiO ₂	1.40	1.40	-0.1	1.49	6.4
ZnO	3.51	3.58	2.1	3.74	6.6
ZrO ₂	3.01	2.80	-7.0	2.75	-8.8
Total	100.0	100.0		100.0	

Compositional trends for each composition component measured in the glass product from the CLSM runs with respect to the amount of glass discharged are displayed in Figure B.1 through Figure B.5 of Appendix B with the AW-106 simulant in column A and the AW-106 waste in column B. Most of the primary components measured in the AW-106 glass compositions produced from the AW-106 simulant and waste CLSM runs were within $\pm 10\%$ of their target values as has previously been shown for a variety of glass compositions produced in the CLSM (Dixon et al. 2020a and 2020b).

Since no AW-106 glass had been produced prior to the sim-CLSM run, the CLSM vessel was loaded with 2 kg of glass with a different target composition to start the run. As a result, several components were present in the initial load of glass at quantities that differed from their AW-106 target. The components CaO and Li₂O were above the AW-106 target and K₂O, Cl, F, and P₂O₅ were below the target. As a result, in Figure B.2, Figure B.3, Figure B.4, and Figure B.5 the amount of those components in the glasses poured during the initial stages of the AW-106 simulant CLSM run differ from their targets by >10 % until ~4 kg had been discharged from the CLSM vessel. This amount corresponds to 2 turnovers of the glass quantity in the CLSM vessel, after which all the component contents aligned with the incoming melter feed and target AW-106 glass.

Both P₂O₅ and F in the analyzed AW-106 waste melter feed and glasses poured from the CLSM were 50 % less than their desired glass target values since the AW-106 waste samples received had lower concentrations of P and F than expected based on the AW-106 tank BBI. Since the BBI values were used with the Kim et al. (2012) models to calculate the glass target, this difference was expected once all the analysis had been received after processing.

The glass dip sample taken during the AW-106 sim-CLSM run (the 6th measured glass sample, which occurs at 6.68 h) was deficient in both P₂O₅ and SO₃ compared to the glass poured before and after the dip (shown in Figure B.4 and Figure B.5 of Appendix B). Additional CLSM runs with glass dip samples are needed to verify if this trend is representative of all glasses processed in the CLSM or unique to the AW-106 composition.

The trends for Cr₂O₃ and NiO in Figure B.4 revealed a spike in their content above the glass target and melter feed levels at the start of each run, followed by a decrease with each subsequent glass pour. These trends indicated that when the glass inventory was idling in the CLSM vessel, during heat-up of the system or idling periods as previously observed (Dixon et al. 2020a and 2020b), Cr and Ni from the walls of the CLSM vessel were incorporated into the glass melt due to corrosion of the vessel. The CLSM vessel is constructed from Inconel-690, an alloy with relatively high Ni (minimum of 58.0 %) and Cr (a range from 27.0 to 31.0 %), with the balance provided by several additional components (Fe range from 7.0 to 11.0 %, Si at 0.50 % maximum, Mn at 0.50 % maximum, S at 0.015 % maximum, and Cu at 0.50 % maximum). A similar phenomenon has been observed in the DuraMelt10 (DM10) melter, which is lined with refractory with high Cr levels and heated by Inconel-690 electrodes, after idling periods (Matlack et al. 2010, 2011, and 2018).

In the Kim et al. (2012) glass models used to determine the expected AW-106 glass composition, three primary glass components, Cl, F, and SO₃, were calculated with retention factors less than 95%. Figure B.5 in Appendix B displays the composition trends during the AW-106 simulant and waste CLSM runs for these components where the trends show SO₃ and Cl were present in the glass at greater levels than the target anticipated. The F content was also at greater levels than the target anticipated in the AW-106 simulant glass, but below the level expected in the AW-106 waste glass since the AW-106 had one third of the F concentration expected based on the tank BBI. Such behavior has been measured with SO₃ and Cl in previous CLSM runs (Dixon et al. 2022a, 2022b, 2023, 2024, and 2025). For F, only one previous CLSM run was performed with a waste (or simulant) at F levels above the analysis detection limit: the AW-105 run (Dixon et al. 2025). In the AW-105 simulant and waste runs, the F in the melter feed was ~50% greater than that in the AW-106 melter feed and the subsequent retention of F in the AW-105 glass aligned with its expected glass target value (0.13 wt%). In the AW-106 simulant run, the F level in the glass was greater than the expected glass target value (0.07 wt%). These results indicate that the retention factors applied for SO₃, Cl, and F in the Kim et al. (2012) glass models may be more conservative than actual results derived while processing melter feed in the CLSM. The behavior of SO₃, Cl, and F (along with other semi-volatile components) in the CLSM offgas treatment system will be discussed further in Section 5.3.

Several components were present as minor (250 ppm or less) impurities in the melter feeds and glass product during the AW-106 simulant and waste CLSM runs. The compositional trends for each minor impurity are shown in Figure B.6 through Figure B.8 of Appendix B with respect to the amount of glass discharged. The content of the impurity components in the AW-106 glass product followed two general trends. The first trend was a spike (or deficiency) of the component in the initial glass that decreased (or increased) with each subsequent pour until the component reached its expected value based on the content in the AW-106 melter feeds. This trend applied to Ba, Cu, La, Mn, Mo, Sn, Sr, and Pb in the AW-106 CLSM runs. Following this trend, all components had reached their expected values by 2 turnovers of the CLSM vessel contents (4 kg of glass discharged) as previously observed for similar impurity spikes in the CLSM vessel (Dixon et al. 2020a and 2020b).

The impurity of Y, at ~40 ppm, and V, ~75 ppm, remained relatively constant in all glass pours, but at a level greater than expected based on the AW-106 melter feeds. The Y and V trend has been previously analyzed in CLSM glass products (Dixon et al. 2020a, 2020b, and 2025). The source of Y and V at these levels in the glass products is likely leaching as an impurity from the material of the CLSM vessel, as described regarding the Cr₂O₃ and NiO content in the glass product.

The measured activity of each analyzed radionuclide in the glass products from the AW-106 waste CLSM run, with respect to the mass of glass discharged, are shown in Figure B.9 of Appendix B. There were no radionuclides present in the AW-106 simulant feed, so only the AW-106 waste CLSM run is shown. The activity of all the radionuclides for AW-106 displayed in Figure B.9 were in the ranges previously measured for the AW-105, 7 M Na AP-105, AP-101, AP-107 2x recycle/AP-105 changeover, and AP-107 1x recycle (Dixon et al. 2025, 2023, 2022b, 2022a, and 2020b) and 2 to 3 orders of magnitude less than the AN-107 (Dixon et al. 2024). The trend for most of the radionuclides in the glass product began around 0 in the initial glass and increased until they reached the expected values of ~80-100% retention of the analyzed melter feed by two turnovers of the CLSM glass contents. However, the behavior of ²⁴¹Am in the AW-106 glass was similar to the AW-105 glass (Dixon et al. 2025) in that its retention was about 50% of the analyzed melter feed, although given the low quantity of such radionuclides in the glass, the analytical uncertainty in these measurements is about 15% of the total activity.

5.2 DF, R, and Rec Calculations

The decontamination factor (DF) of any component through any unit in a melter system is described as the mass flow rate of the component into the unit divided by the mass flow rate of the component out of the unit in the secondary product stream. In the CLSM system, there is one incoming mass flow stream, the melter feed, and there are two output mass flow streams, the glass (primary product stream) produced from the CLSM and the offgas (secondary product stream) exiting the CLSM. The CLSM offgas is comprised of gaseous mass exiting the system, vapor which is condensed by the offgas system as condensate, and solids that settle or are filtered. Thus, the DF of any component through the CLSM vessel is defined as the mass flow rate of that component in the melter feed divided by the mass flow rate of that component in the offgas stream. Given a state of no component accumulation in the CLSM vessel, the DF for a component in the CLSM vessel can be given by Eq. (5.1):

$$DF_i = \frac{\dot{m}_{i,feed}}{\dot{m}_{i,offgas}} \quad (5.1)$$

where $\dot{m}_{i,feed}$ is the mass flow rate [mg min⁻¹] of a component (*i*) in the melter feed and $\dot{m}_{i,offgas}$ is the mass flow rate [mg min⁻¹] of the same component in the offgas as recovered by the units in the CLSM offgas system in the glass product.

The retention (R) of any component in the glass produced from the CLSM vessel is then defined as the mass flow rate of that component in the glass product divided by the mass flow rate of the same component in the melter feed and this value can be determined by Eq. (5.2):

$$R_i = \frac{\dot{m}_{i,glass}}{\dot{m}_{i,feed}} \quad (5.2)$$

where $\dot{m}_{i,glass}$ is the mass flow rate [mg min^{-1}] of a component (i) in the glass product. The R_i value can be reported as a fraction or percentage (if Eq. (5.2) is multiplied by 100).

Finally, the recovery (Rec) of any component in the CLSM system is defined as the mass flow rate of the component out of the system in the summation of the glass and offgas divided by the mass flow rate of the same component into the system via the melter feed. The Rec_i value can be reported as a fraction or percentage (if multiplied by 100) and is defined in Eq. (5.3):

$$Rec_i = \frac{\dot{m}_{i,glass} + \dot{m}_{i,offgas}}{\dot{m}_{i,feed}} \quad (5.3)$$

For Eq. (5.1), Eq. (5.2), and Eq. (5.3), if the values are calculated for a fixed amount of time (e.g., the offgas sampling times or the total runtime) mass flow rates become total mass values (m_i ; [mg]).

The components of primary interest in the CLSM glass product are ^{99}Tc (or Re in the simulant), Cs, I, and the measured radionuclides. Given the demonstrated volatility behavior of meta-stable technetium, ^{99m}Tc , from an idling glass melt (Matlack et al. 2010; Pegg 2015) and the potential unsteady incorporation of components into the glass melt while the cold cap varies from its target coverage and thickness, the $R_{^{99}\text{Tc}}$, R_{Re} , and R_{I} values were calculated during the total runtime, each individual glass pour, and during the offgas sampling timeframes (for ^{99}Tc and Re only) when the cold-cap characteristics were believed to be steady.

The values for DF, R , and Rec were calculated separately for the CLSM runs processing the AW-106 simulant melter feed and AW-106 waste melter feed. For each component of the AW-106 glass compositions captured in the CLSM glass product (Table 5.1), and the additional desired nuclides ^{99}Tc , Re, Cs, and I where applicable, the following mass flow rates were calculated:

- Input into the CLSM vessel from the melter feed; $\dot{m}_{i,feed}$. Calculated during each run by dividing the total mass of each component (given the melter feed component concentrations listed in Table A.2 and Table A.3 and the total mass of each melter feed composition calculated to have been consumed during the run, shown in Table 4.2) by the total runtime of 6.13 h for the AW-106 simulant run and 5.80 h for the AW-106 waste run.
- Output from the CLSM vessel in the glass product; $\dot{m}_{i,glass}$. Calculated from the glass component concentrations and the total glass mass produced in the AW-106 simulant run of 6.66 kg and in the AW-106 waste run of 6.13 kg, with the amount of each component present in the initial glass subtracted from the total mass. The component masses were then divided by the total runtime for their respective runs.
- Output from the CLSM vessel in the captured offgas; $\dot{m}_{i,offgas}$. Calculated for each component from the summation of all the offgas units, primarily the collected condensate, demister liquid, primary SBS sump, sampling SBS sump (if applicable), piping washes (if applicable), and filters. For components collected on filters, the amount of that component present in a blank HEPA filter had to be subtracted. For the AW-106 simulant run, the mass of each offgas unit can be found in

Table A.2 of Appendix A and for the AW-106 waste run, in Table A.3 of Appendix A. The component masses were then divided by the total runtime for their respective runs.

The mass flow rate data for the entire runtime of the AW-106 simulant CLSM run are given in Table 5.2 and the mass flow rate data for the entire runtime of the AW-106 waste CLSM run are given in Table 5.3. Note that the chemical analysis results for Cs in both the AW-106 simulant and waste melter feeds, and the results for I in the AW-106 waste melter feeds and most glass pour samples, were below the analytical limit of detection, thus the values for the detection limits, given in Table A.3 of Appendix A, were used for calculations where necessary and all related results should be treated as best estimates. From these mass flow rates, the DF_i , R_i , and Rec_i values, the latter two reported as percentages, were calculated as shown in Equations (5.1), (5.2), and (5.3), respectively. The values were calculated for the entire runtime of both the AW-106 simulant and waste CLSM runs and are reported in Table 5.2 and Table 5.3, respectively.

Table 5.2. Component Mass Flow Rates, DFs, Retentions, and Recoveries During the AW-106 Simulant CLSM Run

Component	$\dot{m}_{i,feed}$	$\dot{m}_{i,glass}$	$\dot{m}_{i,offgas}$	Melter DF	R	Rec
Units	mg min ⁻¹	mg min ⁻¹	mg min ⁻¹		%	%
Re	0.11	0.05	0.06	1.8	48	103
Total Cs ^(a)	--	--	--	--	--	--
Total I	2.54	0.53	2.68	0.9	21	127
Al	504	550	0	1499	109	109
B	610	576	3	215	94	95
Ca	492	484	0	1060	98	98
Cl	51	36	8	6	70	86
Cr	10	13	0	67	126	128
F	19	16	1	15	87	94
Fe	651	655	1	850	101	101
K	71	66	1	67	93	94
Li	74	75	0	422	101	101
Mg	176	167	0	2894	95	95
Na	2308	2213	12	200	96	96
Ni	1	8	0	162	536	537
P	15	18	0	2187	117	117
S	38	36	2	25	95	99
Si	3792	3887	1	3809	103	103
Ti	149	151	0	3092	101	101
Zn	502	516	1	643	103	103
Zr	365	372	0	26923	102	102
Total	9831	9839	33	298	100	100

^(a) Component concentrations were below analytical reporting limits in the measured melter feed and glass samples, so values were not calculated.

Table 5.3. Component Mass Flow Rates, DFs, Retentions, and Recoveries During the AW-106 Waste CLSM Run

Component	$\dot{m}_{i,feed}$	$\dot{m}_{i,glass}$	$\dot{m}_{i,offgas}$	Melter		
				DF	<i>R</i>	Rec
Units	mg min ⁻¹	mg min ⁻¹	mg min ⁻¹		%	%
⁹⁹ Tc	0.08	0.04	0.03 ^(b)	2.8	51	87
Total Cs ^(a)	--	0.00	0.01 ^(b)	0.0	--	--
Total I ^(a)	--	0.02	0.05 ^(b)	0.0	--	--
Al	545	591	7	79	108	110
B	520	515	2	283	99	99
Ca	474	520	0	974	110	110
Cl	32	36	6 ^(b)	5	111	131
Cr	11	9	0	25	85	89
F	5	9	0 ^(b)	12	163	172
Fe	681	703	2	389	103	103
K	69	77	2 ^(b)	39	111	114
Li	73	79	0	985	107	107
Mg	195	184	0	2674	94	94
Na	2211	2396	9	237	108	109
Ni	2	3	0	12	162	170
P	6	9	0	95	147	148
S	24	28	1 ^(b)	22	116	121
Si	3718	3906	1	4836	105	105
Ti	147	163	0	3828	111	111
Zn	520	549	1	897	105	106
Zr	321	372	0	14259	116	116
Total	9557	10148	32	296	106	107

^(a) Component concentrations were below analytical reporting limits in the measured melter feed and glass samples, so values were not calculated.

^(b) Values include an adjusted amount of the component expected from an offgas piping wash as described in Section 5.3.

For the AW-106 simulant run, most component recoveries were within ± 10 % of complete recovery. The *Rec_i* values for Cr and Ni were outside of the 90 – 110 % range, most likely due to how the spikes of those components being present in the initial glass from CLSM vessel leaching, as demonstrated in Figure B.4 of Appendix B for Cr₂O₃ and NiO, affected the calculations. Additional component *Rec_i* values were outside the desired range for the AW-106 simulant run, I, Cl, and P, due to reasons including pickup of additional components during the washing of the offgas treatment system, the initial glass loaded into the CLSM vessel varying from the AW-106 glass target, or analytical uncertainty in the methods used for analysis.

In the AW-106 waste run, the *Rec_i* values for ⁹⁹Tc, Cl, F, K, P, S, Ti, and Zr were also outside of the 90 – 110 % range, while most other component *Rec_i* values were greater than 100 %. The primary cause for these numbers being above 100 % is that the methods available to measure the mass of unused AW-106 waste melter feed after the conclusion of the run results in an underestimate of the amount of melter feed processed during the run. Additional uncertainties include those given for the components in the AW-106 simulant melter feed run.

5.3 Offgas Analysis

The seven components detected in appreciable quantities in the samples collected from the various units in the CLSM offgas treatment system during prior runs (Dixon et al. 2020b, 2022a, 2023, 2024, and 2025) were ⁹⁹Tc (or Re), Cs, I, S, K, Cl, and F. These components were likewise present in the samples

collected from the offgas treatment system during the AW-106 simulant and waste CLSM runs. The total quantities of these components collected in the CLSM vessel output streams, the glass, and 6 collective units in the offgas treatment system (offgas piping wash, the sampling loop, primary SBS sump, accumulated condensate, demister, and end filters) are shown in Table 5.4. The “Sampling + Wash” unit includes the offgas piping wash with the filters and SBS in the sampling loop. The “SBS + Condensate + Demister” unit contains the summation of the primary SBS sump with the accumulated condensate liquid and the demister liquid from the entirety of each run. The “End Filters” unit described in Table 5.4 includes the liquids that accumulated in the pre-filter housing, as well as the pre-filter and primary HEPA filter, all totaled together.

Table 5.4. Quantities of Selected Components in CLSM Output Streams During the AW-106 Simulant and Waste CLSM Runs

AW-106 Simulant CLSM Run							
	Re (mg)	Cs (mg)	I (mg)	Cl (mg)	F (mg)	K (mg)	S (mg)
Glass	19.9	-- ^(a)	194	13183	5947	24115	13142
Sampling + Wash	5.4	-- ^(a)	2.0	692	109	132	141
SBS + Condensate + Demister	15.7	-- ^(a)	920	2308	346	220	381
End Filters	1.4	-- ^(a)	5	32	0	37	32
AW-106 Waste CLSM Run							
	⁹⁹ Tc (mg)	Cs (mg)	I (mg)	Cl (mg)	F (mg)	K (mg)	S (mg)
Glass	14.3	1.15 ^(b)	6.42 ^(b)	12574	3087	26646	9788
Sampling + Wash ^(c)	2.69 (1.10)	0.0233 (0.0233)	1.99 (1.97)	396 (177)	31.7 (7.44)	107 (66.8)	80.8 (23.3)
SBS + Condensate + Demister	5.17	1.38	13.59	1810	119	355	240
End Filters	2.33	0.705	0.140	2.94	2.94	147	60.9

^(a) The component concentrations in AW-106 samples were below analytical reporting limits.

^(b) The concentrations of Cs and I in the AW-106 waste glass were below detection limits for most samples, so this value should be considered a best estimate calculation based on detection limits.

^(c) Values outside of parentheses were calculated to consider the amount of each component expected to be present during an offgas piping wash; the values inside of parentheses were calculated only from the sampling HEPA filters.

The measured sampling loop values for the AW-106 waste CLSM run are given in parentheses in the ‘Wash + Sampling’ row of Table 5.4. From previous offgas analysis in the simulant CLSM system (Dixon et al. 2020a, 2022b, 2023, 2024, and 2025), when the offgas piping from the CLSM vessel to the sampling loop was washed upon the conclusion of each CLSM run, an amount of the inventory of each component (Re, S, K, Cl, and F) recovered in the offgas system was found in the offgas piping wash. Since the radioactive CLSM system in the RPL cannot be disassembled and washed for analysis due to safety restrictions, the same recovery principle was applied as an assumption for all the components recovered in the offgas system during the AW-106 waste CLSM run. Thus, the estimated quantities of each component, factoring into the percentage recovered in the sim-CLSM offgas piping wash, are shown without parentheses in the ‘Wash + Sampling’ row of Table 5.4 for the AW-106 waste CLSM run.

The quantities of each component in the output streams from Table 5.4 were converted to percentages of the total quantities in the output streams via Eq. (5.4):

$$Output\%_{i,s} = \frac{m_{i,s}}{\sum_s m_{i,s}} \times 100 \quad (5.4)$$

where $Output\%_{i,s}$ is the percentage (%) of the quantity of a component (i ; ^{99}Tc , Re, Cs, I, Cl, F, K, S) in each output stream (s ; Glass, Wash + Sampling, SBS + Condensate + Demister, End Filters) and $m_{i,s}$ is the mass of a component (i) in stream (s). The $Output\%_{i,s}$ for each of the streams in the offgas treatment system during the AW-106 simulant CLSM run is displayed in Figure 5.1a and during the AW-106 waste CLSM run is displayed in Figure 5.1b. The shape of these $Output\%$ values in the offgas treatment system for both AW-106 runs resembles previous runs in the sim-CLSM and rad-CLSM (Dixon et al. 2023, 2024, and 2025), indicating no unexpected volatility or capture when processing AW-106 melter feed.

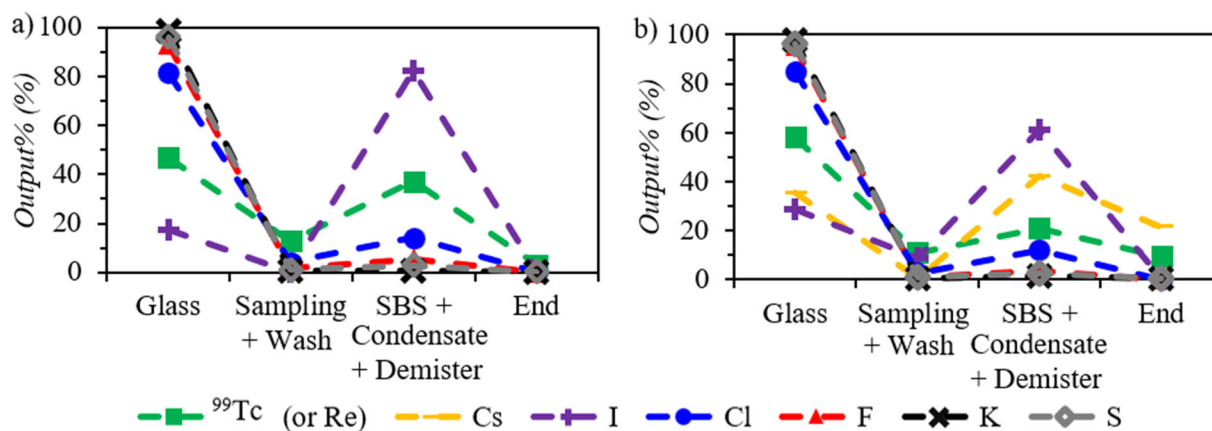


Figure 5.1. Percentage of the quantity of each component in the output stream ($Output\%$) in the CLSM offgas treatment system during a) the AW-106 simulant run and, b) the AW-106 waste run.

5.4 Re, I, ^{99}Tc , and Cs Retention and Analysis

The measured content of ^{99}Tc , Re, or I in the glass product from the AW-106 simulant and waste runs were used to calculate retention values ($R_{99\text{Tc}}$, R_{Re} , and R_{I}) based on the ^{99}Tc , Re, and I concentrations in their respective melter feeds. The ^{99}Tc or Re retention values, $R_{99\text{Tc}}$ and R_{Re} , calculated for each glass pour are also displayed as outlined (□) or filled (■) squares, respectively, in Figure 5.2 with respect to the mass of glass discharged while the I retention value, R_{I} , is displayed as purple crosses (✚) in Figure 5.2a only, since I concentration was below the analytical reporting limit in the AW-106 waste melter feed. The characteristic relationships between Re or ^{99}Tc and I are shown in Table 5.5 for the AW-106 simulant CLSM run and in Table 5.6 for the AW-106 waste CLSM run. These tables include $R_{99\text{Tc}}$ (or R_{Re}) values calculated exclusively during the sampling time periods, marked on Figure 4.5 for the AW-106 simulant CLSM run and on Figure 4.6 for the AW-106 waste CLSM run.

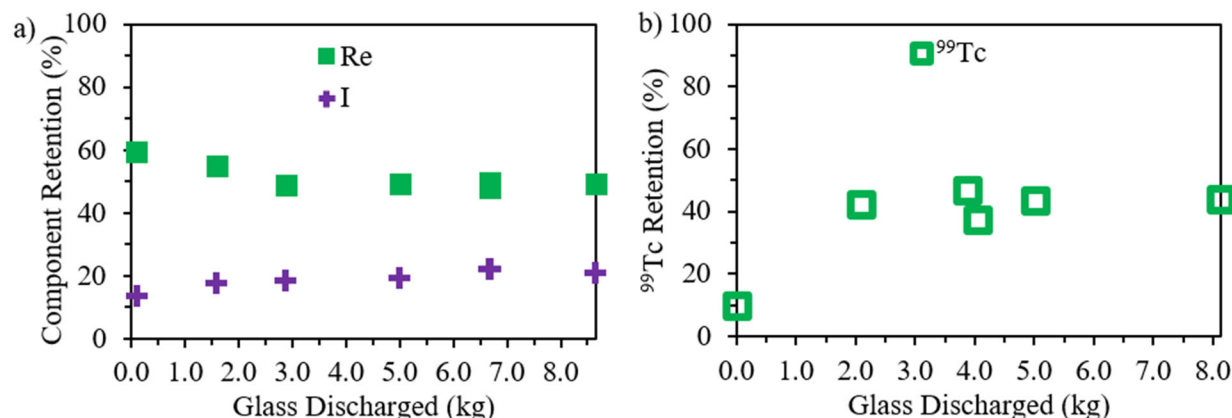


Figure 5.2. a) Re and I retention in the glass product from the AW-106 simulant CLSM run and b) ⁹⁹Tc retention in the glass product from the AW-106 waste CLSM run.

The 2.0 kg of glass pieces loaded into the CLSM vessel for the start of the AW-106 simulant run contained Re that had been retained during a previous run, which account for the high R_{Re} value during the initial glass pour. The retention of Re in the glass during the processing of the AW-106 simulant melter feed then reached a relative chemical steady state after two turnovers of the CLSM vessel glass inventory to arrive at a single pass R_{Re} value of 49 ± 1 %. Compared to the previous CLSM simulant runs, this value was slightly greater than the single pass R_{Re} value when processing AW-105 (Dixon et al. 2025) and AP-101 (Dixon et al. 2022b), but less than the CLSM runs with the highest R_{Re} values, the AN-107 and AP-107 melter feeds (Dixon et al. 2022c and 2024). Thus, the steady-state, single-pass retention of Re in the CLSM when processing the corresponding melter feed, from greatest to least was AN-107 = AP-107 > AW-106 > AP-101 = AW-105 > AP-105 = AN-105.

Table 5.5. Re and I Relationships During the AW-106 Simulant CLSM Run

Re Glass Target (ppm)	I Glass Target ^(a) (ppm)	Glass Pour Time (h)	Glass Discharged (kg)	Re Glass Actual (ppm)	I Glass Actual ^(a) (ppm)	Re Retention (%)	I Retention (%)	Re Sampling ^(a) Retention (%)	Re Sampling ^(b) Recovery (%)
6.18	140	Initial	0.09	3.65	19.2	59	14		
6.18	140	1.63	1.58	3.38	24.5	55	18		
6.18	140	2.64	2.87	3.04	26.4	49	19	49	93
6.18	140	4.52	4.99	3.06	27.5	49	20	50	90
6.18	140	6.01	6.67	2.94	30.7	48	22	48	92
6.18	140	Dip	6.68	3.07	31.4	50	22		
6.18	140	Final	8.65	3.06	29.2	49	21		
Total, R_i						48	21		
Total, Rec_i						103	127		

^(a) Sampling is a limited time when the offgas passes first through a heated HEPA filter as described in Section 3.3.1.

Table 5.6. ⁹⁹Tc and I Relationships During the AW-106 Waste CLSM Run

⁹⁹ Tc Glass Target (ppm)	I Glass Target ^(a) (ppm)	Glass Pour Time (h)	Glass Discharged (kg)	⁹⁹ Tc Glass Actual (ppm)	I Glass Actual ^(a) (ppm)	⁹⁹ Tc Retention (%)	⁹⁹ Tc Sampling ^(b) Retention (%)	⁹⁹ Tc Sampling ^(b) Recovery (%)
4.58	3.69	Initial	0.00	0.451	15.6	10		
4.58	3.69	2.18	2.09	1.97	5.47	42		
4.58	3.69	3.37	3.88	2.18	2.86	47	48	71
4.58	3.69	6.82	4.05	1.77	1.66	37		
4.58	3.69	7.94	5.02	2.06	1.75	44	45	83
4.58	3.69	Final	8.13	2.08	1.76	44		
Total, R_i						51		
Total, Rec_i						87 ^(c)		

^(a) The I glass target based on analysis of the melter feed and the I in 4 of the poured glasses (shown in red) were below the analysis limit of quantification, but above the limit of detection, thus the values for the quantification limit are displayed.

^(b) Sampling is a limited time when the offgas passes first through a heated HEPA filter as described in Section 3.3.1.

^(c) Values reported include the estimate for mass recovered in offgas piping wash, described in Section 5.3.

At the I spike level in the AW-106 simulant melter feed of 140 ppm in the glass if 100% retained, I was detected above analytical limits in all analyzed glasses in the CLSM simulant run. The 2.0 kg of glass pieces loaded into the CLSM vessel for the start of the AW-106 simulant run contained I that had been retained during a previous run, which account for the initial R_{Re} value being greater than 0 during the initial glass pour. The relative chemical steady state was then reached before two turnovers of the CLSM vessel glass inventory during the AW-106 simulant run and the total run R_i value was 21 %. The value was greater than equivalent to the processing of AW-105 simulant melter feed (R_i value = 14 %, Dixon et al. 2025) 7 M Na AP-105 simulant melter feed (R_i value = 14 %, Dixon et al. 2023), and AN-107 simulant (R_i value = 10 %, Dixon et al. 2024). All these CLSM R_i values continue to reinforce the suggestion in Dixon et al. (2023) that the retention factor used in the Kim et al. (2012) glass models for I of ~50 % appears greater than achievable for single-pass retention when processing LAW melter feeds. The AW-106 simulant glass pieces loaded into the CLSM vessel for the AW-106 waste run contained a spike of ~15 ppm of I that fell below 10 % of this initial spike value in the glass after two turnovers of the CLSM vessel glass inventory which then remained below the analytical detection limit in the glass since the I concentration was also below the analytical detection limit in the AW-106 waste melter feed.

Following the trend discussed in Dixon et al. (2024 and 2025), the behavior of I in the CLSM offgas treatment system was preferentially captured in liquid units over filter matrices. During the AW-106 simulant CLSM run, <1% of the total 927 mg I was captured on filters while in the AW-106 waste CLSM run, 1.5% of the total 71 mg I was captured on filters. Compared to other semi-volatile components, like Re (18% of the total 23 mg on filters) and Cl (12% of the total 3032 mg on filters) in the AW-106 simulant CLSM run and ⁹⁹Tc (32% of the total 10 mg on filters) and Cl (8% of the total 2210 mg on filters) in the AW-106 waste CLSM run, I capture in the CLSM indicates that even more iodine could be recycled back to the feed than other semi-volatile components that may accumulate on offgas filters. The average single-pass R_i value during the processing of AW-106 simulant melter feed in the CLSM was subsequently not calculated since I was below or at the detection limit in the sampling HEPA filters.

The glass loaded into the CLSM vessel for the start of the AW-106 waste run did not contain any ⁹⁹Tc, but small amount of ⁹⁹Tc (0.451 ppm) was found in the initial glass poured from the melter due to the heel of glass present on the walls of the CLSM vessel from the previous AW-105 rad-CLSM run (Dixon et al. 2025). The relative chemical steady state was then reached after two turnovers of the CLSM vessel glass inventory, so the average single pass R_{99Tc} value was 46 ± 2 %. Compared to the previous CLSM waste runs, this value was in the middle of the achieved ⁹⁹Tc retention range. Thus, the steady-state, single-pass

retention of ^{99}Tc in the CLSM when processing the corresponding melter feed, from greatest to least was AN-107 > AP-101 > AW-106 > AP-105 $\geq$ AP-107 > AW-105 (and thin cold-cap AP-105).

The Cs content in both the AW-106 simulant and waste melter feeds was below the analytical detection limits using ICP-MS. Subsequently, the Cs content was below or at the analytical detection limits for all glasses produced during the AW-106 simulant and waste CLSM runs, the latter of which picked up Cs from the traces of glass present in the CLSM vessel from previous runs. As such, the steady-state, single-pass retention for Cs could not be calculated.

It was hypothesized that the single-pass $R_{99\text{Tc}}$ (and R_{Re}) values in the CLSM may have dependence on their spike levels in the waste (or simulant) samples, as represented by the target concentration of ^{99}Tc (or Re) in the glass product if 100 % retained, in addition to the melter feed composition. Figure 5.3 displays this relationship for all rad-CLSM and sim-CLSM runs (Dixon et al. 2018, 2019, 2020a, 2020b, 2022a, 2022b, 2023, 2024, and 2025). While the trend, shown by the linear regression fit line in Figure 5.3, suggests an inverse correlation of $R_{99\text{Tc}}$ (and R_{Re}) values with increasing target in the glass, the dependence of the data is low, shown by the R^2 value in Figure 5.3, due to the limited number data points with many values clustered between the 5 - 9 ppm target range. Acquiring additional $R_{99\text{Tc}}$ (and R_{Re}) values outside of this cluster range would increase confidence in this trend.

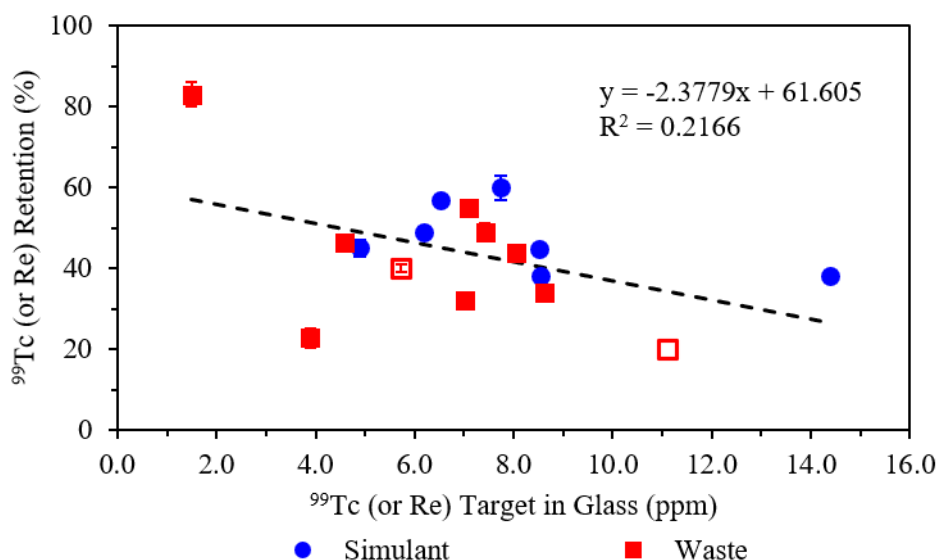


Figure 5.3. Comparison of component retention vs component target in glass if 100 % retained for all melter feeds processed in the CLSM. Waste run values with open boxes had their target values estimated based on melter feed to glass conversion instead of measured.

5.5 CLSM Idling Lessons

During the rad-CLSM run with AW-106 waste melter feed, an almost 3 h idling period occurred while offgas management and feed line blockage removal were operated. When feeding stopped, the cold cap burnt off and the average temperature in the plenum region was 903 °C while idling, which was hotter than the average plenum temperature of 665 °C during melter feed charging. The bubbling flux rate was decreased to a minimum value (7 L min⁻¹ m⁻²) while idling which slightly increased the glass temperature from a value of 1135 °C during melter feed charging to 1169 °C while idling. Directly prior to the feeding resumption after idling, glass was poured from the CLSM vessel to compare compositional characteristics before and after the idling period. The glass pour prior to idling was taken at 3.37 h of runtime,

corresponding to 3.88 kg of glass discharged shown in Figure B.1 through Figure B.9 of Appendix B. The glass pour after idling was taken at 6.82 h of runtime, corresponding to 4.05 kg of glass discharged shown in Figure B.1 through Figure B.9 of Appendix B.

Table 5.7 shows the composition of the glass poured before and after the idling period. A majority of the components in the glass after idling were within 3 % of their values before idling or, like P_2O_5 the compositional trend of which is shown in Figure B.4 of Appendix B, aligned with the changing trend of composition based on the analyzed AW-106 waste melter feed. However, the content of Cr_2O_3 and NiO in the glass increased due to leaching from the CLSM vessel during idling, as described in Section 5.1. The semi-volatile components, analyzed in the CLSM offgas treatment system in Section 5.3, except for K_2O , varied by more than 3 % of their content in the glass before to after idling. The changes in total amount (in wt% of glass) and percentage are calculated in Table 5.7. Additional idling testing for shorter and/or longer times could elucidate trends in these changes in semi-volatiles, leading to understanding if their volatilization continues unabated or plateaus at a particular value.

Table 5.7. AW-106 Waste Glass Composition Before and After Idling

Component	AW-106		Total	%
	Waste	Waste	Difference	Difference
	Glass	Glass	in Glass	in Glass
	Before	After	After vs	Before
	Idling	Idling	Before	Idling
	wt%	wt%	wt%	%
Al_2O_3	6.08	6.10	0.02	0
B_2O_3	9.20	9.06	-0.14	-2
CaO	3.94	3.89	-0.04	-1
Cl	0.22	0.15	-0.07	-32
Cr_2O_3	0.11	0.12	0.02	15
F	0.06	0.05	-0.01	-16
Fe_2O_3	5.61	5.49	-0.12	-2
K_2O	0.59	0.58	-0.02	-3
Li_2O	0.91	0.90	0.00	-1
MgO	1.69	1.64	-0.05	-3
Na_2O	18.05	17.83	-0.22	-1
NiO	0.02	0.04	0.01	56
P_2O_5	0.13	0.13	-0.01	-7
SO_3	0.41	0.38	-0.03	-7
SiO_2	44.94	45.60	0.67	1
TiO_2	1.51	1.49	-0.02	-2
ZnO	3.77	3.74	-0.03	-1
ZrO_2	2.76	2.81	0.06	2
^{99}Tc (ppm)	2.18	1.77	-0.41	-19
Total	100.0	100.0	--	--

5.6 Acetonitrile and Ammonia Analysis

The measured levels of acetonitrile in the condensate and demister liquids collected in the CLSM offgas system for the AW-106 simulant CLSM run are listed in Table A.2 of Appendix A and the AW-106 waste CLSM run are listed in Table A.3 of Appendix A. As discussed in Dixon et al. (2022b), the acetonitrile concentrations in the liquids collected in the CLSM offgas system are greater than the levels of acetonitrile in the liquids collected in other scaled melter systems (Matlack et al. 2011, 2017, and 2018). Table 5.8 displays the acetonitrile production calculated based both on the total amount of sucrose processed and total amount of organic carbon consumed from the melter feed vitrification, using the

acetonitrile concentration in the CLSM offgas treatment system liquids, the liquid density, and the total mass of liquid collected. All ‘Acetonitrile per Sucrose’ and ‘Acetonitrile per TOC’ values in Table 5.8 factored in CLSM system rule (determined in Dixon et al. 2022b) that ~90 % of the total acetonitrile collected during the run was found in the combination of the condensate and demister liquids.

Table 5.8. Acetonitrile Production During CLSM Runs

CLSM Run	Average Plenum Temp (°C)	Total Acetonitrile (mg)	Melter Feed Processed (kg)	Sucrose Added per Waste Volume (g L ⁻¹)	TOC Concentration (mg kg ⁻¹)	Acetonitrile per Sucrose (g kg ⁻¹)	Acetonitrile per TOC (g kg ⁻¹)
AW-106 Simulant	655	1891	14.95	43.3	10500	4.64	12.05
AW-106 Waste	665	1772	13.31	45.1	9270	4.76	14.37
AW-105 Simulant	648	1353	16.42	63.3	11500	2.69	7.17
AW-105 Waste	695	728	13.81	32.3	6908	3.33	7.63
AN-107 Simulant	593	1406	14.81	1.1	9060	146	10.48
7 M Na AP-105 Simulant	609	1889	14.37	74.4	24300	4.25	5.41
7 M Na AP-105 Waste	660	1788	13.99	74.4	24275	3.75	5.26
AP-101 Simulant	610	1104	13.86	71.1	12000	2.44	6.64
AP-101 Waste	695	2930	22.19	66.6	13800	4.93	9.57

The two AW-106 CLSM runs produced more acetonitrile per total organic carbon than previous CLSM runs, expanding the expected range from 5 to 15 g kg⁻¹ for 5 melter feed compositions in 9 different runs. The average plenum temperatures during both AW-106 CLSM runs were in the middle of the range of previous runs, which contributes to the observation that there is yet any discernable relationship to the average plenum temperature, as shown in Figure 5.4, given the limited number of current data points. While Dellinger et al. (1984) suggests that elevated temperatures above 800 °C destroy acetonitrile, there are many reasons that such a correlation would not be observed in the CLSM including low residence time for gases in the plenum space, rapid cooling of the gases upon exiting the CLSM vessel due to the water-cooled SBS, fluctuation of the plenum temperature over the course of each CLSM run, the limited range of operable CLSM plenum temperatures, or a need for more data before a correlation can be observed.

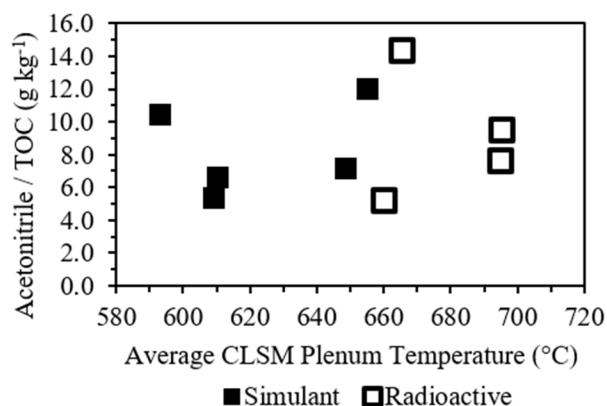


Figure 5.4. Acetonitrile production per TOC in the melter feed for all measured CLSM runs.

The liquids collected in the CLSM offgas treatment system during the AW-106 simulant and waste melter feed runs were also analyzed for ammonia concentration. This was the first CLSM run for which this measurement was performed. Table 5.9 displays the ammonia concentration (and total amount) in each of

the CLSM offgas treatment system units along with the values for nitrate, acetonitrile, and TOC for comparison to other measured nitrogen and carbon sources.

Table 5.9. Ammonia and Other Carbon/Nitrogen Sources in CLSM Offgas Treatment System Liquids While Processing AW-106 Melter Feed

Offgas Liquid	Liquid Mass (kg)	Nitrate (mg kg ⁻¹)	Ammonia (mg kg ⁻¹)	TOC (mg kg ⁻¹)	Acetonitrile (mg kg ⁻¹)	Total Nitrate (mg)	Total Ammonia (mg)	Total TOC (mg)	Total Acetonitrile (mg)	Ammonia/Nitrate Ratio
Simulant										
Sampling Offgas Wash	0.18	1341	2.47 ^(a)	20.3 ^(a)	--	238	0 ^(a)	4 ^(a)	--	--
Primary Offgas Wash	0.22	1133	3.79	26.4	--	245	1	6	--	0.003
Sampling SBS Sump	1.18	1310	880	130	--	1546	1039	153	--	0.672
Primary SBS Sump	0.88	11506	1410	170	--	10167	1246	150	--	0.123
Condensate	5.85	15312	1089	185	209	89544	6369	1082	1220	0.071
Demister	1.53	38236	1252	291	315	58637	1920	446	483	0.033
Pre-Filter Fluid	0.01	477944	163	1460	--	5506	2	17	--	0.000
Waste										
Sampling SBS Sump	1.09	1755	1301	189	--	1916	1420	206	--	0.741
Primary SBS Sump	1.12	12435	2237	294	--	13910	2502	329	--	0.180
Condensate	3.43	10400	1483	297	258	35722	5094	1020	887	0.143
Demister	2.12	20932	1641	339	334	44349	3477	718	708	0.078
Pre-filter fluid	0.02	446966	246	136	--	9771	5	3	--	0.001

^(a) The concentrations of ammonia and TOC in the 'Sampling Offgas Wash' were below the analytical reporting limit, so the values reported are the analytical report limits.

In the CLSM offgas treatment system collected condensate and demister liquids, the concentration of ammonia was ~5x greater than that of acetonitrile. However, in the offgas measured by the EGA equipment in the AW-106 sim-CLSM run, after passing through all units in the offgas treatment system, the NH₃ gas partial pressure was at the same order of magnitude as the acetonitrile, shown in Figure 4.7, indicating that the units are more efficient at condensing NH₃ compared to acetonitrile. The liquids collected in each subsequent unit in the CLSM offgas treatment system (see Figure 3.1) showed a decreasing ratio of ammonia to nitrate, indicating that the condensed nitrogen product preferentially nitrate over ammonia as the offgas cooled. In the offgas measured by the EGA equipment in the AW-106 sim-CLSM run, after passing through all units in the offgas treatment system, the NO₂ and NO gas partial pressures were ~2 orders of magnitude greater than that of the NH₃ gas, shown in Figure 4.7.

5.7 Production Comparison

Table 4.2 reported the production characteristics for both the AW-106 simulant and waste CLSM runs while Table 5.10 displays selected characteristics compared to previous, relevant CLSM runs (see Table 1.1 for references of each run). For the processing of AW-106, the simulant processed at approximately the same rate as the waste in the CLSM. Both values were greater than the rate for any other melter feed compositions in the sim-CLSM and rad-CLSM. The AW-106 waste (and simulant) composition fell generally in the middle of the ranges of expected LAW compositions, indicating that the lack of extreme component concentrations may lead to high melting rates.

Table 5.10. Production Characteristics When Processing Melter Feeds in the CLSM

Melter Feed	Type	Average Glass Production Rate (kg m ⁻² d ⁻¹)	Average Plenum Temperature (°C)	Bubbling Flux Rate (L min ⁻¹ m ⁻²)	⁹⁹ Tc Retention (%)	Re Retention (%)
AW-106	Simulant	2305	655	49	--	49±1
AW-106	Waste	2245	665	38	46±2	--
AW-105	Simulant	2023	648	59	--	45±1
AW-105	Waste	1330	695	78	23±2	--
AN-107	Simulant	1864	593	99	--	60±3
AN-107	Waste	1565	656	73	83±3	--
7 M Na AP-105	Simulant	1735	609	118	--	38±1
7 M Na AP-105	Waste	2079	660	106	49±2	--
AP-101	Simulant	2275	610	99	--	45±2
AP-101	Waste	1530 ^(a)	695	42	55±2	--
AP-107, 2x Recycle Changeover	Waste	1511 ^(a)	705	-- ^(b)	34	--
AP-105 Changeover	Waste	Same values as AP-107, 2x Recycle Changeover			44	--
AP-107, 1x Recycle	Waste	1739	700	70	32	--
AP-107	Simulant	1942	618	130	--	57
AP-107	Waste	1477	648	149	40±1	--
AP-105	Simulant	1574	579	101	--	38±1
AP-105	Waste	1330	673	125	20 ^(c)	--

^(a) These values are believed to be low due to feeding pump blockage and higher production rate is believed to be achievable.

^(b) The bubbling flux rate for this run was not recorded due to a data logging error (Dixon et al. 2022a).

^(c) This value was presumed to be lower than achievable due to the cold-cap coverage during the run (Dixon et al. 2018), so the ⁹⁹Tc retention while processing AP-105 melter feed during the changeover run is considered the best-case, single-pass retention.

As observed in Figure 5.5, the average plenum temperature when processing waste melter feeds has generally been hotter than when processing simulant melter feeds. This is likely a product of the arrangement of the two systems (see Figure 3.4 and Figure 3.5), but an upgrade to the capacity of the sim-CLSM furnace is believed to have led to the runs with the new furnace, both the AW-106 simulant run and the previous AW-105 simulant run (Dixon et al. 2025), to have hottest average plenum temperatures than previous sim-CLSM runs.

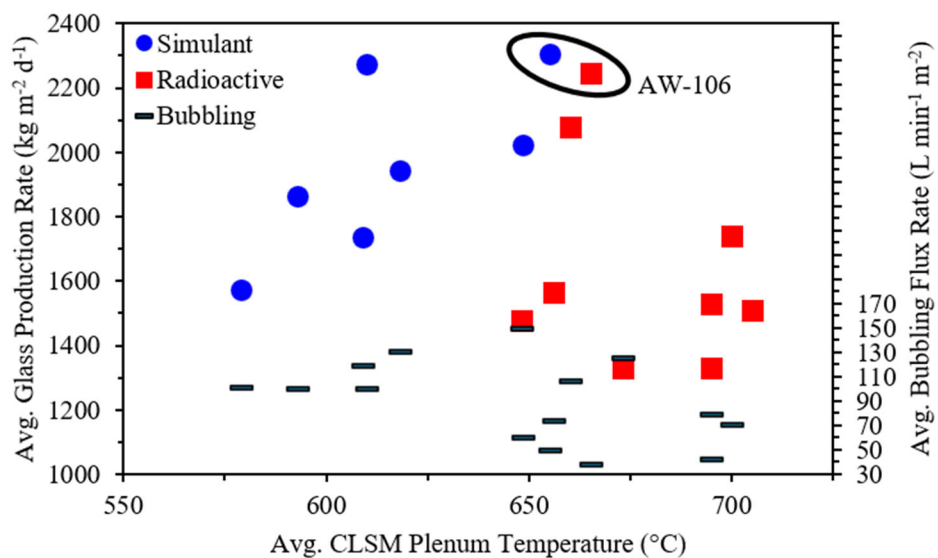


Figure 5.5. Comparison of average glass production rate vs plenum temperature for melter feeds processed in the CLSM.

6.0 Conclusions

A sample of AW-106 waste was procured by H2C and transferred to PNNL for processing through the RWTP. To demonstrate the efficacy of AW-106 waste vitrification and provide details about how the AW-106 processing compares to previously vitrified wastes, the objective was set to perform dynamic vitrification to produce at least 4 kg of glass from AW-106 waste while taking at least 1 offgas sample with a steady cold cap to determine the distribution of semi-volatile components between glass and offgas products. To reduce the risk of failing to achieve this objective, a simulant version of the AW-106 waste was designed based on the BBI of tank 241-AW-106 and an assumed target dilution of the waste to a sodium molarity of 5.5 M. A glass composition was calculated for this AW-106 simulant from the Kim et al. (2012) glass models, GFCs were added to the simulant, and the resultant melter feed was subject property testing that included rheological measurement, feed-volume expansion, and evolved gas analysis. The property testing revealed no qualities of concern for vitrification, so the AW-106 simulant melter feed was processed in the sim-CLSM over a 6.13 h processing period, producing 6.66 kg of glass for an average glass production rate of $2305 \text{ kg m}^{-2} \text{ d}^{-1}$. The simulant processing demonstrated that AW-106 melter feed could be vitrified without any aberrant behavior and defined the expected production ranges for waste processing. Two new capabilities were developed during the AW-106 sim-CLSM run:

- The EGA equipment was connected to the sim-CLSM offgas treatment system prior to the final HEPA filters and measured gas partial pressures when glass was poured. Without the presence of a carrier gas, the gas data remains as partial pressures that can be compared with other CLSM runs when performed.
- The liquids collected in the sim-CLSM offgas treatment system were analyzed for ammonia concentration. These results led to the same ammonia analysis being performed on the liquids collected in the rad-CLSM offgas treatment system.

The sample of AW-106 waste went through solids filtration and cesium removal by ion exchange, ending at an actual sodium concentration of 5.5 M. The same glass composition and GFCs additions calculations used for the AW-106 simulant were used for the formation of the AW-106 waste melter feed. Over 5.80 h of processing, 6.13 kg of glass were produced for an average glass production rate of $2245 \text{ kg m}^{-2} \text{ d}^{-1}$ for AW-106 waste melter feed in the CLSM system. The average glass production rate for both the AW-106 simulant and waste melter feeds were at the top of the range expected based on the processing of previous melter feeds. Overall, the objective of the AW-106 vitrification were accomplished and through the offgas sampling and ^{99}Tc mass balance it was demonstrated that a middle-range concentration waste can be processed without an unexpected issue, at the high end of production rate and middle range of ^{99}Tc retention. Other conclusions from the AW-106 simulant and waste CLSM runs include:

- Most of the primary components in the glass produced during the CLSM runs were within 10 % of their targets based on the AW-106 glass compositions.
- Components recovered in the CLSM offgas system (Re, ^{99}Tc , Cs, I, S, K, Cl, and F) during the AW-106 simulant and waste runs were recovered in similar proportions and totals in each unit of the offgas system compared to previous CLSM runs.
- A 3-h idling time period in the middle of the AW-106 waste melter feed run revealed a change in content of semi-volatile components (^{99}Tc , Cl, F, and S) in the melt glass pool ranging from 7 to 30 % loss after idling.

- The relative chemical steady-state, single-pass retention of Re when processing the AW-106 simulant melter feed was 49 ± 1 %, which was in the middle of the range measured for melter feeds processed in the sim-CLSM.
- The relative chemical steady-state single-pass retention of ^{99}Tc when processing the AW-106 waste melter feed was 46 ± 2 %, was in the middle of the range measured for melter feeds processed in the rad-CLSM.
- The total retention of I when processing the AW-106 simulant melter feed was 21 %, which was slightly greater than the range measured with melter feeds processed in the sim-CLSM (10 – 14 %).
- Iodine was recovered in the CLSM offgas system primarily in the liquid samples, with low quantities (<2 %) partitioning to the filters, leading to the indication that iodine has a high potential to be recycled with the liquids from the offgas system back to the melter feed.
- The activities of radionuclides (^{241}Am , ^{242}Am , $^{243/244}\text{Cm}$, ^{243}Am , ^{238}Pu , and $^{239/240}\text{Pu}$) in the AW-106 waste were in the ranges of previous wastes processed in the rad-CLSM, except for AN-107, which had much greater radionuclide levels. While the activity of most of the radionuclides in AW-106 waste reached ~80 - 100 % retention in the glass after 2 turnovers like what had been measured for previous wastes, the behavior of ^{241}Am was similar to the AW-105 rad-CLSM run in that its retention was only about 50%.
- Acetonitrile was detectable in the condensate and demister liquids collected from the CLSM offgas treatment system during the AW-106 simulant and waste runs in the same concentration ranges as previous CLSM runs. The production of acetonitrile per amount of total organic carbon processed was greater than any previous run, expanding the measured range to 5 – 15 g-acetonitrile per kg-total organic carbon.
- Ammonia was detectable in all liquids collected from the CLSM offgas treatment system during the AW-106 simulant and waste runs, but not in the washes of the offgas piping. Its concentration was ~5x that of acetonitrile in the measured liquids. The ratio of ammonia to nitrate (another source of nitrogen in the liquids) decreased in the liquids of each successive unit in the CLSM offgas treatment system indicating that the condensed nitrogen product preferred the nitrate reaction over ammonia as the offgas cooled.

7.0 References

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Appendix A – CLSM Glass Compositions and Chemical Analysis of Samples Collected from the AW-106 Simulant and Waste CLSM Runs

The first table in this section lists the glass compositions previously run in the rad-CLSM. The remaining tables display the complete chemical analytical results for all samples from the AW-106 simulant and waste CLSM run that were sent to SwRI for analysis. Values colored in red indicate the associated sample results were less than the analytical reporting limit (ARL), but greater than the detection limit, and thus the reporting limits are listed in the tables. Values marked with "--" denote that the analysis was not performed for a specific sample.

Table A.1. Target Glass Compositions for Previous Rad-CLSM Produced Glasses

Component	AW-105 ^(a) (wt%)	AN-107 ^(b) (wt%)	AP-101-S ^(c) (wt%)	AP-101-W ^(c) (wt%)	AP-107-2R ^(d) (wt%)	AP-107-1R ^(e) (wt%)	AP-107 ^(f) (wt%)	AP-105-7M ^(g) (wt%)	AP-105 ^(h) (wt%)
Al ₂ O ₃	6.13	6.12	6.13	6.12	6.13	6.13	6.12	6.13	6.13
B ₂ O ₃	9.96	9.93	9.95	9.95	9.95	9.95	9.95	9.95	9.95
CaO	2.03	4.82	4.45	3.39	4.09	4.53	3.69	2.07	2.64
Cl	0.14	0.05	0.16	0.17	0.19	0.18	0.15	0.24	0.22
Cr ₂ O ₃	0.06	0.02	0.09	0.08	0.08	0.07	0.08	0.06	0.06
F	0.13	0.00	0.01	0.00	0.03	0.03	0.00	0.00	0.00
Fe ₂ O ₃	5.53	5.51	5.52	5.52	5.52	5.52	5.52	5.52	5.52
K ₂ O	2.82	0.09	0.39	0.47	0.49	0.36	0.47	0.51	0.49
Li ₂ O	0.00	1.79	1.44	0.00	1.06	1.52	0.50	0.00	0.00
MgO	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49	1.49
Na ₂ O	19.55	16.07	16.44	17.96	16.89	16.34	17.49	20.95	19.35
NiO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
P ₂ O ₅	0.12	0.11	0.12	0.10	0.16	0.19	0.15	0.10	0.11
SO ₃	0.26	0.40	0.39	0.36	0.38	0.39	0.37	0.29	0.33
SiO ₂	43.84	45.68	45.49	46.45	45.60	45.36	46.08	44.73	45.76
TiO ₂	1.41	1.40	1.40	1.40	1.40	1.40	1.40	1.40	1.40
ZnO	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51	3.51
ZrO ₂	3.02	3.01	3.02	3.01	3.02	3.02	3.01	3.02	3.02
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

^(a) Dixon et al. (2025)

^(e) Dixon et al. (2020b)

^(b) Dixon et al. (2024)

^(f) Dixon et al. (2019)

^(c) Dixon et al. (2022b)

^(g) Dixon et al. (2023)

^(d) Dixon et al. (2022a)

^(h) Dixon et al. (2018)

Table A.2. Chemical Analysis of Samples Produced During the AW-106 Simulant CLSM Run

Sample Name	Sample Mass (kg)	Component Concentration (mg kg ⁻¹)										
		Re	Total Cs	Total I	Ag	Al	As	B	Ba	Be	Bi	Ca
AW-106 Melter Feed (Slurry)	14.95	2.75	0.195	62.4	0.972	12400	2.92	15000	6.27	0.972	9.72	12100
AW-106 Melter Feed (Dry)	--	4.82	2.76	166	0.980	20900	2.94	24650	11.6	0.980	9.80	21250
Glass Pour (Initial)	0.09	3.65	0.196	19.2	49.1	30900	2.94	31500	68.0	9.81	98.1	29000
Glass Pour (1.63 h)	1.49	3.38	0.194	24.5	48.5	30600	2.91	31300	31.7	9.70	97.0	27900
Glass Pour (2.64 h)	1.29	3.04	0.192	26.4	48.1	30800	2.88	34100	30.9	9.61	96.1	27500
Glass Pour (4.52 h)	2.12	3.06	0.197	27.5	49.2	30400	2.95	31100	26.5	9.85	98.5	26800
Glass Pour (6.01 h)	1.68	2.94	0.197	30.7	49.3	30100	2.96	31100	28.5	9.86	98.6	26500
Glass Dip	0.01	3.07	0.250	31.4	62.6	30900	3.75	31200	116	12.5	125	27000
Glass Pour (Final)	1.97	3.06	0.196	29.2	49.0	30550	2.94	30800	25.0	9.79	97.9	26750
Primary HEPA Filter	0.02	2.61	0.194	2.69	1.61	12250	2.92	12000	15600	0.971	9.71	4920
Sampling HEPA Filter 1	0.02	55.7	0.187	24.5	0.935	11000	2.81	11400	12700	0.935	9.35	4560
Sampling HEPA Filter 2	0.02	49.7	0.191	26.3	0.954	12000	2.86	12100	15400	0.954	9.54	4880
Sampling HEPA Filter 3	0.02	58.4	0.187	14.8	0.937	11600	2.81	12100	14200	0.937	9.37	4690
Pre-Filter	0.26	4.77	0.0152	5.87	0.076	1.64	0.228	74.7	0.0760	0.076	0.760	2.28
Sampling Offgas Wash	0.18	4.32	0.1005	2.68	0.503	42.4	1.51	205	0.503	0.503	5.03	59.9
Primary Offgas Wash	0.22	8.94	0.100	2.08	0.501	54.3	1.50	225	0.501	0.501	5.01	130
Sampling SBS Sump	1.18	0.100	0.100	51.5	0.502	2.51	1.51	77.0	0.502	0.502	5.02	5.02
Primary SBS Sump	0.88	3.14	0.0995	128	0.497	22.0	1.49	190	0.497	0.497	4.97	33.0
Condensate	5.85	1.62	0.0998	117	0.499	11.3	1.50	102	0.499	0.499	4.99	13.7
Demister	1.53	2.24	0.0977	80.1	0.488	12.3	1.47	126	0.488	0.488	4.88	14.8
Pre-Filter Fluid	0.01	5.94	0.0787	266	0.528	57.5	1.18	135	0.394	0.394	3.94	10.3

Table A.2. Chemical Analysis of Samples Produced During the AW-106 Simulant CLSM Run (cont.)

Sample Name	Component Concentration (mg kg ⁻¹)											
	Cd	Co	Cr	Cu	Fe	K	La	Li	Mg	Mn	Mo	Na
AW-106 Melter Feed (Slurry)	0.972	1.14	247	0.972	16000	1735	1.59	1830	4330	29.5	0.972	56750
AW-106 Melter Feed (Dry)	0.980	2.60	443	1.78	31150	3125	2.65	3070	7185	49.8	1.26	100100
Glass Pour (Initial)	0.981	1.06	1070	18.2	39100	2020	2.30	6320	8230	205	8.89	117000
Glass Pour (1.63 h)	0.970	0.970	926	11.3	37300	2840	2.64	5200	8740	135	5.24	118000
Glass Pour (2.64 h)	0.961	0.961	885	8.04	37200	3200	2.82	4770	9030	110	3.63	122000
Glass Pour (4.52 h)	0.985	0.985	694	4.93	36300	3530	2.97	4250	9120	82.7	1.89	122000
Glass Pour (6.01 h)	0.986	0.986	623	4.02	36100	3640	2.97	4080	9240	72.8	1.26	122000
Glass Dip	1.25	1.25	623	4.62	37000	3750	3.11	4100	9300	75.5	1.69	125000
Glass Pour (Final)	0.979	0.979	654	3.65	36250	3725	3.06	4115	9370	74.0	1.24	123500
Primary HEPA Filter	0.971	2.27	100	1.77	250	9420	0.971	7.44	594	7.55	40.3	24400
Sampling HEPA Filter 1	0.935	2.99	265	2.85	586	9170	0.935	145	561	11.9	33.0	31500
Sampling HEPA Filter 2	0.954	2.18	159	1.81	338	9650	0.954	70.6	599	7.28	37.8	29800
Sampling HEPA Filter 3	0.937	2.23	154	1.58	432	9730	0.937	92.9	548	9.17	20.3	31500
Pre-Filter	0.076	0.0971	15.3	0.100	8.84	65.8	0.076	6.38	0.760	0.101	0.234	687
Sampling Offgas Wash	0.503	0.503	17.3	0.503	136	70.1	0.503	23.4	4.08	0.503	0.503	1415
Primary Offgas Wash	0.501	0.501	31.9	0.501	176	136	0.501	34.7	15.9	0.501	0.568	2090
Sampling SBS Sump	0.502	0.502	0.534	0.502	2.51	10.0	0.502	1.51	2.51	0.502	0.502	10.0
Primary SBS Sump	0.497	0.497	12.2	0.497	41.4	59.6	0.497	12.5	4.13	0.497	0.497	853
Condensate	0.499	0.499	4.44	0.499	23.1	21.4	0.499	5.48	2.49	0.499	0.499	360
Demister	0.488	0.488	5.71	0.488	30.9	27.4	0.488	6.55	2.44	0.488	0.488	442
Pre-Filter Fluid	0.394	6.65	444	10.8	1820	72.1	0.394	8.12	1.97	37.7	52.2	883

Table A.2. Chemical Analysis of Samples Produced During the AW-106 Simulant CLSM Run (cont.)

Sample Name	Component Concentration (mg kg ⁻¹)											
	Ni	P	Pb	Pd	S	Sb	Se	Si	Sn	Sr	Th	Ti
AW-106 Melter Feed (Slurry)	35.8	372	1.95	29.2	926	19.5	3.89	93250	1.95	13.8	97.2	3670
AW-106 Melter Feed (Dry)	58.8	578	2.17	29.4	1690	19.6	3.92	157500	3.04	24.4	98.0	6205
Glass Pour (Initial)	1390	614	8.73	29.4	1850	19.6	3.92	212000	38.0	15.3	98.1	8180
Glass Pour (1.63 h)	1180	809	5.37	29.1	1870	19.4	3.88	213000	27.9	23.0	97.0	8340
Glass Pour (2.64 h)	841	889	4.29	28.8	1920	19.2	3.84	213000	24.7	26.1	96.1	8210
Glass Pour (4.52 h)	407	955	2.73	29.5	1990	19.7	3.94	217000	21.0	29.2	98.5	8370
Glass Pour (6.01 h)	225	962	2.65	29.6	1980	19.7	3.94	213000	19.7	30.1	98.6	8260
Glass Dip	216	133	6.94	37.5	1880	25.0	5.01	214000	20.2	32.5	125	8230
Glass Pour (Final)	221	989	2.47	29.4	2030	19.6	3.92	215500	19.7	30.3	97.9	8320
Primary HEPA Filter	17.7	16.3	6.83	29.2	278	19.4	3.89	395000	3.12	269	97.1	23.95
Sampling HEPA Filter 1	74.4	47.1	9.30	28.1	1320	18.7	3.74	355000	3.99	241	93.5	32.9
Sampling HEPA Filter 2	17.9	36.0	7.51	28.6	967	19.1	3.82	374000	3.43	263	95.4	28.4
Sampling HEPA Filter 3	11.6	45.7	7.29	28.1	1190	18.7	3.75	381000	3.06	256	93.7	28.9
Pre-Filter	1.01	4.56	0.152	0.228	110	0.152	0.304	15.8	0.152	0.076	7.60	0.0760
Sampling Offgas Wash	10.6	5.95	1.01	1.51	135	1.01	2.01	107	1.01	0.503	5.03	6.54
Primary Offgas Wash	0.941	6.86	1.00	1.50	309	1.00	2.00	225	1.00	0.501	5.01	8.22
Sampling SBS Sump	0.853	5.02	1.00	1.51	5.02	1.00	2.01	5.02	1.00	0.502	5.02	0.502
Primary SBS Sump	0.497	4.97	0.995	1.49	94.3	0.995	1.99	58.1	0.995	0.497	4.97	3.15
Condensate	0.499	4.99	0.998	1.50	38.3	0.998	2.00	32.4	0.998	0.499	4.99	1.60
Demister	0.797	4.88	0.977	1.47	47.8	0.977	1.95	37.5	0.977	0.488	4.88	1.74
Pre-Filter Fluid	273	3.94	0.787	1.18	101	0.787	1.57	3.94	0.787	0.394	59.0	1.04

Table A.2. Chemical Analysis of Samples Produced During the AW-106 Simulant CLSM Run (cont.)

Sample Name	Component Concentration (mg kg ⁻¹)											
	Tl	U	V	W	Y	Zn	Zr	Br	Cl	F	N as NO ₃	N as NO ₂
AW-106 Melter Feed (Slurry)	97.2	97.2	4.51	97.2	1.48	12350	8980	247	1265	458	12550	6100
AW-106 Melter Feed (Dry)	98.0	98.0	22.5	98.0	2.82	22400	15500	198	1880	1090	21700	10050
Glass Pour (Initial)	98.1	346	73.6	98.1	42.0	27600	20000	231	704	239	--	--
Glass Pour (1.63 h)	97.0	336	72.1	97.0	42.6	28900	20400	208	1680	588	--	--
Glass Pour (2.64 h)	96.1	373	72.8	96.1	43.5	28300	20300	205	1590	691	--	--
Glass Pour (4.52 h)	98.5	361	71.2	98.5	44.2	28500	20700	224	1820	870	--	--
Glass Pour (6.01 h)	98.6	344	70.1	98.6	43.6	27900	20400	226	1920	931	--	--
Glass Dip	125	327	71.9	125	44.2	28300	20300	242	1960	911	--	--
Glass Pour (Final)	97.9	350	71.9	97.9	44.9	28450	20600	171	2005	883	--	--
Primary HEPA Filter	97.1	97.1	0.971	97.1	2.36	12000	76.6	9.92	13.7	14.3	773	9.92
Sampling HEPA Filter 1	93.5	93.5	0.935	93.5	2.16	11200	77.9	19.8	6810	652	2970	119
Sampling HEPA Filter 2	95.4	95.4	0.954	95.4	2.32	11900	77.0	18.4	5950	550	859	150
Sampling HEPA Filter 3	93.7	93.7	1.32	93.7	2.28	11700	80.9	19.6	7720	960	586	39.3
Pre-Filter	0.760	0.760	0.076	0.760	0.0760	2.85	0.228	7.60	81.1	7.60	2095	7.60
Sampling Offgas Wash	5.03	5.03	0.503	5.03	0.503	118	3.82	10.0	585	126	303	46.5
Primary Offgas Wash	5.01	5.01	1.21	5.01	0.501	121	6.69	10.2	1160	237	256	32.1
Sampling SBS Sump	5.02	5.02	0.502	5.02	0.502	1.00	1.51	7.67	16.3	7.67	296	358
Primary SBS Sump	4.97	4.97	0.527	4.97	0.497	50.7	3.24	9.42	466	87.8	2600	9.42
Condensate	4.99	4.99	0.499	4.99	0.499	25.7	1.50	9.04	239	37.8	3460	9.04
Demister	4.88	4.88	0.488	4.88	0.488	29.4	1.47	7.94	325	31.1	8640	15.1
Pre-Filter Fluid	3.94	3.94	2.31	3.94	0.394	23.4	1.18	72.6	935	72.6	108000	72.6

Table A.2. Chemical Analysis of Samples Produced During the AW-106 Simulant CLSM Run (cont.)

Sample Name	Component Concentration (mg kg ⁻¹)						Component Concentration (µg L ⁻¹)	Ash (%)	Loss on Ignition (%)
	P as PO ₄	Total S (Solids) or SO ₄ (All Others)	TOC	TIC	Carbonate	N as Ammonia	Acetonitrile	--	--
AW-106 Melter Feed (Slurry)	146	2650	10500	7900	18400	--	--	41.92	58.09
AW-106 Melter Feed (Dry)	198	4335	17900	12000	29900	--	--	65.20	34.80
Glass Pour (Initial)	--	1670	--	--	--	--	--	95.59	4.41
Glass Pour (1.63 h)	--	1660	--	--	--	--	--	96.51	3.49
Glass Pour (2.64 h)	--	1710	--	--	--	--	--	96.34	3.66
Glass Pour (4.52 h)	--	1800	--	--	--	--	--	95.96	4.04
Glass Pour (6.01 h)	--	1740	--	--	--	--	--	95.32	4.68
Glass Dip	--	1840	--	--	--	--	--	93.46	6.54
Glass Pour (Final)	--	1790	--	--	--	--	--	96.32	3.68
Primary HEPA Filter	9.92	252	--	--	--	--	--	95.93	4.07
Sampling HEPA Filter 1	19.8	4670	--	--	--	--	--	88.62	11.38
Sampling HEPA Filter 2	18.4	2430	--	--	--	--	--	92.31	7.69
Sampling HEPA Filter 3	19.6	3455	--	--	--	--	--	94.92	5.08
Pre-Filter	7.60	664	--	--	--	--	--	--	--
Sampling Offgas Wash	10.0	425	20.3	20.2	--	2.03	--	--	--
Primary Offgas Wash	10.2	983	26.4	20.2	--	3.12	--	--	--
Sampling SBS Sump	7.67	7.86	130	20.3	--	724	--	--	--
Primary SBS Sump	9.42	501	170	20.2	--	1160	--	--	--
Condensate	9.04	319	185	20.1	--	896	210000	--	--
Demister	7.94	178	291	19.9	--	1030	320000	--	--
Pre-Filter Fluid	72.6	494	1460	15.6	--	134	--	--	--

Table A.3. Chemical Analysis of Samples Produced During the AW-106 Waste CLSM Run

Sample Name	Sample Mass (kg)	Component Concentration (mg kg ⁻¹)										
		⁹⁹ Tc	Total Cs	Total I	Ag	Al	As	B	Ba	Be	Bi	Ca
AW-106 Melter Feed (dilute)	--	1.08	0.197	1.72	9.85	11600	2.96	10000	4.36	0.985	9.85	8590
AW-106 Melter Feed	13.31	2.11	0.193	1.70	9.67	14250	2.90	13600	6.11	0.967	9.67	12400
Glass Pour (Initial)	0.05	0.451	1.28	15.6	49.3	32200	2.96	29000	13.1	9.86	98.6	25400
Glass Pour (2.18 h)	2.03	1.97	0.497	5.47	49.5	32700	2.97	29100	13.4	9.91	99.1	27900
Glass Pour (3.37 h)	1.80	2.18	0.324	2.86	49.3	32100	2.96	28500	13.5	9.86	98.6	28050
Glass Pour (6.82 h)	0.17	1.77	0.433	1.66	49.4	32700	2.97	28500	13.4	9.89	98.9	28200
Glass Pour (7.94 h)	1.14	2.06	0.224	1.75	49.2	32500	2.95	28500	13.2	9.83	98.3	28400
Glass Pour (Final)	3.11	2.08	0.197	1.76	49.3	32600	2.96	27700	13.1	9.86	98.6	28700
Primary HEPA Filter	0.02	4.77	2.04	1.71	9.95	13600	2.99	11700	20300	0.995	9.95	5880
Primary HEPA Filter (blank)	0.01	0.00238	0.195	1.65	9.74	12000	2.92	9930	18000	0.974	9.74	4890
Sampling HEPA Filter 1	0.02	23.8	0.962	1.57	9.87	11950	2.96	10900	18350	0.987	9.87	5160
Sampling HEPA Filter 2	0.02	26.5	0.288	10.0	9.85	8140	2.96	7270	12100	0.985	9.85	3330
Pre-filter	0.28	7.64	2.30	0.279	0.459	1.71	0.670	167	0.223	0.223	2.23	2.23
Sampling SBS Sump	1.09	0.0640	0.0500	1.59	0.500	2.50	1.50	27.4	0.500	0.500	5.00	5.00
Primary SBS Sump	1.12	1.15	0.154	2.48	0.497	310	1.49	128	0.497	0.497	4.97	17.2
Condensate	3.43	0.644	0.184	1.91	0.500	316	1.50	71.0	0.500	0.500	5.00	28.1
Demister	2.12	0.787	0.270	2.01	0.496	461	1.49	94.4	0.496	0.496	4.96	25.2
Pre-filter fluid	0.02	6.07	1.51	6.41	0.392	19.5	11.6	313	0.386	0.386	3.86	8.21

Table A.3. Chemical Analysis of Samples Produced During the AW-106 Waste CLSM Run (cont.)

Sample Name	Component Concentration (mg kg ⁻¹)											
	Cd	Co	Cr	Cu	Fe	K	La	Li	Mg	Mn	Mo	Na
AW-106 Melter Feed (dilute)	0.985	0.985	178	0.985	11250	1240	0.985	1305	2925	22.3	8.98	39100
AW-106 Melter Feed	0.967	1.71	283	1.20	17800	1800	1.54	1920	5110	36.3	13.2	57800
Glass Pour (Initial)	0.986	0.986	2380	3.56	39400	9020	2.95	3360	9900	105	6.56	140000
Glass Pour (2.18 h)	1.04	0.991	752	2.89	39100	5380	3.10	4110	10100	88.3	19.3	135000
Glass Pour (3.37 h)	1.39	0.986	721	3.55	39100	4910	3.13	4205	10150	86.9	23.4	133500
Glass Pour (6.82 h)	1.50	0.989	842	2.99	38900	4840	3.12	4250	10000	102	26.5	134000
Glass Pour (7.94 h)	1.69	0.983	735	2.81	38700	4550	3.18	4270	10100	90.5	27.7	132000
Glass Pour (Final)	1.78	0.986	734	2.82	38600	4520	3.10	4300	10100	90.6	30.2	132000
Primary HEPA Filter	0.995	10.3	91.4	1.18	278	10600	0.995	7.78	824	7.70	40.1	29600
Primary HEPA Filter (blank)	0.974	9.74	86.8	0.974	148	9330	0.974	3.38	573	4.40	21.3	25000
Sampling HEPA Filter 1	0.987	11.9	270	5.61	1017	10150	0.987	44.7	706	33.2	46.5	31000
Sampling HEPA Filter 2	0.985	9.85	91.8	1.28	188	6980	0.985	39.6	394	7.16	18.6	21500
Pre-filter	0.223	0.404	94.8	1.17	135	368	0.223	11.9	1.12	2.37	4.60	1580
Sampling SBS Sump	0.500	0.500	0.500	0.500	2.88	9.99	0.500	1.50	2.50	0.500	0.500	21.2
Primary SBS Sump	0.497	0.497	14.8	0.497	48.8	67.2	0.497	6.11	4.25	0.497	0.497	575
Condensate	0.500	0.500	10.7	0.500	45.3	47.8	0.500	2.59	3.99	0.500	0.500	342
Demister	0.496	0.496	16.0	0.496	103	54.7	0.496	3.22	3.26	0.794	0.587	450
Pre-filter fluid	0.386	21.1	1570	35.7	6530	428	0.386	3.92	2.63	127	195	1600

Table A.3. Chemical Analysis of Samples Produced During the AW-106 Waste CLSM Run (cont.)

Sample Name	Component Concentration (mg kg ⁻¹)											
	Ni	P	Pb	Pd	S	Sb	Se	Si	Sn	Sr	Th	Ti
AW-106 Melter Feed (dilute)	29.4	112	1.97	2.96	412	1.97	3.94	87400	4.73	9.53	98.5	3050
AW-106 Melter Feed	50.4	163	1.93	2.90	632	1.93	3.87	97200	6.52	13.8	96.7	3855
Glass Pour (Initial)	523	942	1.97	29.6	1990	19.7	3.94	203000	33.3	29.1	98.6	8860
Glass Pour (2.18 h)	227	676	1.98	29.7	1760	19.8	3.96	208000	27.4	31.7	99.1	9000
Glass Pour (3.37 h)	188	586	1.97	29.6	1655	19.7	3.94	209500	27.8	32.0	98.6	9030
Glass Pour (6.82 h)	297	555	1.98	29.7	1560	19.8	3.96	216000	28.4	32.3	98.9	9030
Glass Pour (7.94 h)	218	503	1.97	29.5	1530	19.7	3.93	217000	27.6	32.2	98.3	8970
Glass Pour (Final)	189	488	1.97	29.6	1520	19.7	3.94	219000	27.9	32.6	98.6	9000
Primary HEPA Filter	22.5	17.6	8.94	2.99	343	1.99	3.98	373000	5.43	308	9.95	29.6
Primary HEPA Filter (blank)	2.14	15.5	8.38	2.92	247	1.95	3.90	383000	3.87	278	9.74	23.0
Sampling HEPA Filter 1	175	22.0	9.02	2.96	879	1.97	3.95	348000	4.97	275	9.87	28.1
Sampling HEPA Filter 2	23.6	14.9	4.20	2.96	655	1.97	3.94	246500	1.97	187	9.85	17.6
Pre-filter	21.1	2.23	0.446	0.670	201	0.446	0.893	40.4	1.34	0.223	2.23	0.223
Sampling SBS Sump	0.500	5.00	0.999	1.50	5.00	0.999	2.00	8.43	3.00	0.500	5.00	0.500
Primary SBS Sump	2.49	4.97	0.993	1.49	59.4	0.993	1.99	36.1	2.98	0.497	4.97	1.31
Condensate	3.57	5.00	0.999	1.50	31.1	0.999	2.00	24.4	3.00	0.500	5.00	1.49
Demister	5.90	4.96	0.993	1.49	31.6	0.993	1.99	62.3	2.98	0.496	4.96	3.20
Pre-filter fluid	1020	6.61	0.772	1.16	141	0.772	1.54	3.86	2.32	0.386	38.6	1.70

Table A.3. Chemical Analysis of Samples Produced During the AW-106 Waste CLSM Run (cont.)

Sample Name	Component Concentration (mg kg ⁻¹)											
	Tl	U	V	W	Y	Zn	Zr	Br	Cl	F	N as NO ₃	N as NO ₂
AW-106 Melter Feed (dilute)	9.85	98.5	2.97	98.5	1.05	9450	6040	76.4	574	117	7600	3980
AW-106 Melter Feed	9.67	96.7	4.47	96.7	1.56	13600	8395	62.6	850	142	10900	5860
Glass Pour (Initial)	493	98.6	73.0	98.6	45.3	29600	20200	196	2130	1020	--	--
Glass Pour (2.18 h)	495	99.1	73.5	99.1	45.8	30300	20800	209	2070	674	--	--
Glass Pour (3.37 h)	493	98.6	74.7	98.6	46.2	30200	20350	186	2215	594	--	--
Glass Pour (6.82 h)	494	98.9	74.0	98.9	46.1	30400	21100	208	1530	509	--	--
Glass Pour (7.94 h)	492	98.3	72.8	98.3	45.9	30100	20300	219	2030	500	--	--
Glass Pour (Final)	493	98.6	73.1	98.6	46.0	30100	20100	221	1990	489	--	--
Primary HEPA Filter	9.95	99.5	0.995	99.5	2.52	14300	79.4	4.75	21.2	40.9	636	4.75
Primary HEPA Filter (blank)	9.74	97.4	0.974	97.4	2.29	12500	74.6	5.04	5.04	5.04	56.3	5.04
Sampling HEPA Filter 1	9.87	98.7	0.987	98.7	2.29	12700	71.5	9.77	4220	143	2840	9.77
Sampling HEPA Filter 2	9.85	98.5	0.985	98.5	1.63	8570	50.1	30.7	4460	212	1655	9.07
Pre-filter	2.23	2.23	0.223	2.23	0.223	6.78	0.670	11.2	11.2	11.2	4865	11.2
Sampling SBS Sump	5.00	5.00	0.500	5.00	0.500	1.58	1.50	50.1	50.1	50.1	397	562
Primary SBS Sump	4.97	4.97	0.497	4.97	0.497	29.3	1.49	49.3	398	49.3	2810	49.3
Condensate	5.00	5.00	0.500	5.00	0.500	24.2	1.50	49.6	229	49.6	2350	49.6
Demister	4.96	4.96	0.496	4.96	0.496	39.3	3.68	49.1	273	56.3	4730	49.1
Pre-filter fluid	3.86	3.86	6.17	6.61	0.386	27.4	1.68	76.3	119	104	101000	76.3

Table A.3. Chemical Analysis of Samples Produced During the AW-106 Waste CLSM Run (cont.)

Sample Name	Component Concentration (mg kg ⁻¹)						Component Concentration (µg L ⁻¹)	Component Concentration (pCi g ⁻¹)		
	P as PO ₄	Total S (Solids) or SO ₄ (All Others)	TOC	TIC	Carbonate	N as Ammonia	Acetonitrile	²⁴¹ Am	²⁴² Cm	^{243/244} Cm
AW-106 Melter Feed (dilute)	76.4	936	6420	4780	11200	--	--	5.71E+01	2.53E-01	2.10E+00
AW-106 Melter Feed	62.6	1380	9270	6430	15700	--	--	2.37E+01	5.31E-01	-2.18E-01
Glass Pour (Initial)	--	1750	--	--	--	--	--	2.22E+01	1.86E-01	4.03E-01
Glass Pour (2.18 h)	--	1480	--	--	--	--	--	2.37E+01	1.07E+00	1.76E+00
Glass Pour (3.37 h)	--	1410	--	--	--	--	--	2.65E+01	0.00E+00	1.21E+00
Glass Pour (6.82 h)	--	1270	--	--	--	--	--	3.07E+01	5.23E-01	1.29E+00
Glass Pour (7.94 h)	--	1160	--	--	--	--	--	2.51E+01	2.64E-01	8.68E-01
Glass Pour (Final)	--	1200	--	--	--	--	--	2.93E+01	0.00E+00	1.32E+00
Primary HEPA Filter	4.75	121	--	--	--	--	--	6.30E-01	1.03E-01	1.78E-01
Primary HEPA Filter (blank)	5.04	12.2	--	--	--	--	--	-4.47E-02	0.00E+00	0.00E+00
Sampling HEPA Filter 1	9.77	1980	--	--	--	--	--	4.54E-01	4.73E-02	1.64E-01
Sampling HEPA Filter 2	9.07	1790	--	--	--	--	--	8.34E-01	0.00E+00	9.18E-02
Pre-filter	11.2	717	--	--	--	--	--	1.31E-01	-2.94E-03	0.00E+00
Sampling SBS Sump	50.1	50.1	189	--	--	1070	--	3.13E-01	-1.30E-02	-7.64E-02
Primary SBS Sump	49.3	497	294	--	--	1840	--	5.48E+00	-2.44E-02	1.06E-01
Condensate	49.6	395	297	--	--	1220	260000	5.55E+00	5.25E-02	9.10E-02
Demister	49.1	554	339	--	--	1350	340000	1.36E+01	9.59E-02	1.45E-01
Pre-filter fluid	76.3	1730	136	--	--	202	--	1.52E+00	-3.87E-02	-1.67E-02

Table A.3. Chemical Analysis of Samples Produced During the AW-106 Waste CLSM Run (cont.)

Sample Name	Component Concentration (pCi g ⁻¹)					Ash (%)	Loss on Ignition (%)
	²⁴⁴ Cm	²³⁷ Np	²³⁸ Pu	^{239/240} Pu	²⁴⁴ Pu	--	--
AW-106 Melter Feed (dilute)	1.58E+00	2.38E+00	3.51E+01	2.90E+02	5.42E-01	30.84	69.16
AW-106 Melter Feed	4.90E-01	8.01E+00	7.79E+01	5.73E+02	5.26E-01	43.12	56.89
Glass Pour (Initial)	4.30E-02	9.18E-01	1.83E+00	1.57E+01	6.47E-01	97.36	2.64
Glass Pour (2.18 h)	4.19E-01	8.68E+00	6.26E+01	4.92E+02	6.59E-01	97.59	2.41
Glass Pour (3.37 h)	7.66E-01	1.18E+01	8.33E+01	7.02E+02	5.50E-01	97.80	2.21
Glass Pour (6.82 h)	5.61E-01	1.20E+01	9.20E+01	8.16E+02	6.88E-01	97.52	2.48
Glass Pour (7.94 h)	7.83E-01	1.70E+01	1.10E+02	9.88E+02	5.54E-01	98.20	1.80
Glass Pour (Final)	3.07E-01	1.69E+01	1.07E+02	9.28E+02	1.92E+00	97.82	2.18
Primary HEPA Filter	-4.16E-02	-4.79E-02	-4.62E-02	1.71E+00	0.00E+00	96.61	3.39
Primary HEPA Filter (blank)	4.13E-02	-9.28E-02	-8.91E-02	8.91E-01	1.78E-01	97.53	2.47
Sampling HEPA Filter 1	8.29E-02	5.06E-02	9.82E-01	4.30E+00	4.67E-02	89.57	10.43
Sampling HEPA Filter 2	2.52E-01	-5.25E-02	2.86E-01	5.29E+00	2.86E-01	63.87	36.13
Pre-filter	2.35E-03	-5.35E-03	2.19E-02	2.23E-01	5.82E-02	--	--
Sampling SBS Sump	-2.11E-02	-2.29E-02	7.08E-02	2.84E-01	2.32E-02	--	--
Primary SBS Sump	2.90E-01	4.56E-02	1.15E-01	1.15E+00	4.58E-02	--	--
Condensate	2.51E-01	-2.59E-02	2.42E-01	8.46E-01	1.93E-01	--	--
Demister	3.54E-01	4.57E-02	6.64E-01	2.49E+00	0.00E+00	--	--
Pre-filter fluid	2.10E-01	0.00E+00	1.08E-01	8.97E-01	1.61E-01	--	--

Appendix B – Compositional Trends in Glass Pours from the AW-106 Simulant and Waste CLSM Runs

The figures in this section display compositional trends for selected glass components, impurities, and radionuclides measured in the glass product from the CLSM runs with respect to the amount of glass discharged. In figures with labeled columns, the label ‘Simulant’ displays results from the AW-106 simulant CLSM run, and the label ‘Waste’ displays results from the AW-106 waste CLSM run. Each graph shows the measured component content in the glass as black squares (■), the anticipated component content in the glass based on the target glass composition as a black, solid line (—), the expected component content in the glass based on the analyzed melter feed slurry samples as a red, solid line (—), and the expected component content in the glass based on the analyzed melter feed powder samples as a blue, solid line (—; simulant run only). Red lines that are dashed instead of solid and dots that are red instead of black indicate that the measured values were below the analysis limit of detection, thus the value for the detection limit was used for the calculation.

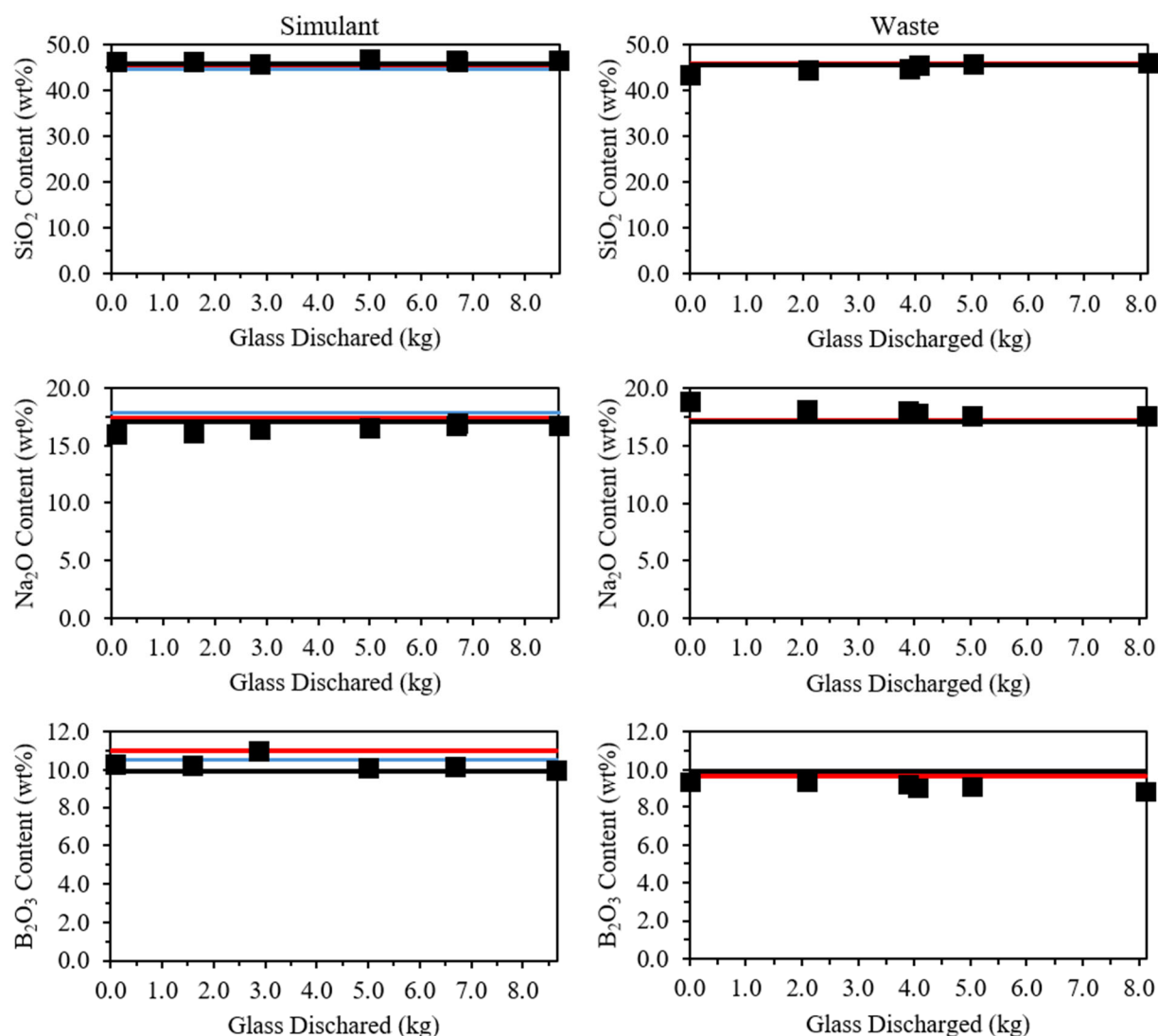


Figure B.1. Content of a set of components (SiO₂, Na₂O, and B₂O₃) in the glass produced during CLSM runs with AW-106 simulant and AW-106 waste melter feeds.

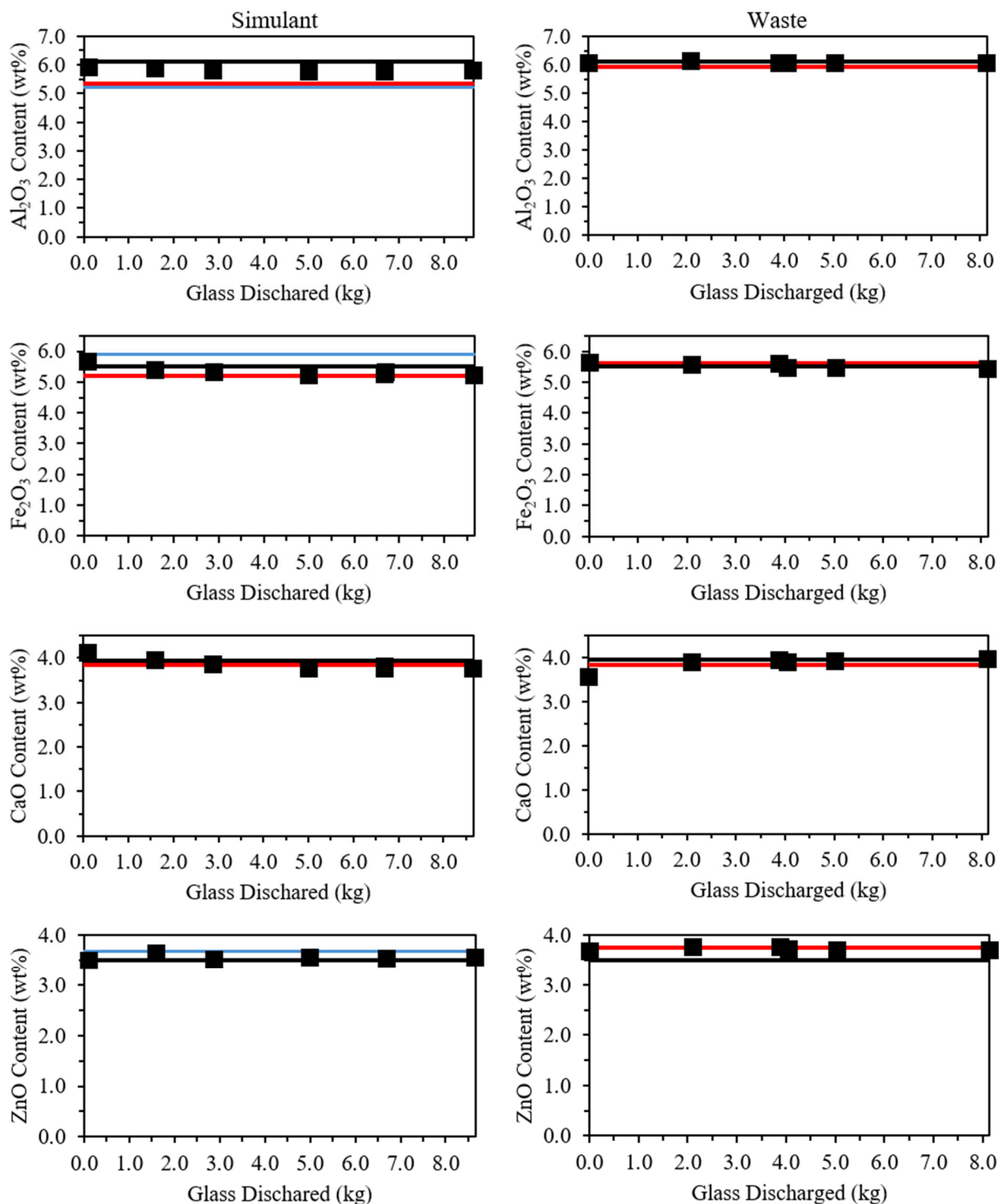


Figure B.2. Content of a set of components (Al_2O_3 , Fe_2O_3 , CaO , and ZnO) in the glass produced during CLSM runs with AW-106 simulant and AW-106 waste melter feeds.

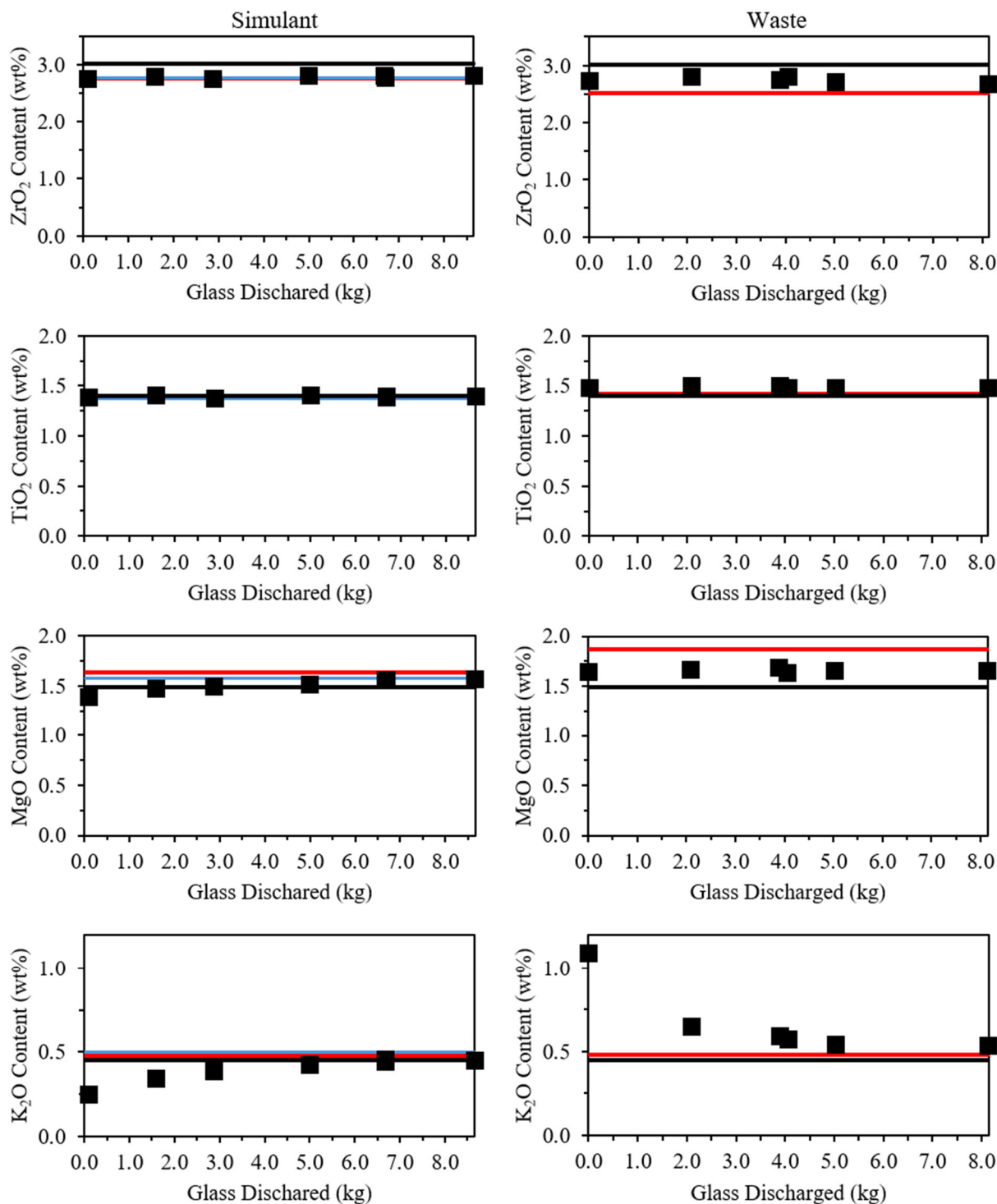


Figure B.3. Content of a set of components (ZrO_2 , TiO_2 , MgO , and K_2O) in the glass produced during CLSM runs with AW-106 simulant and AW-106 waste melter feeds.

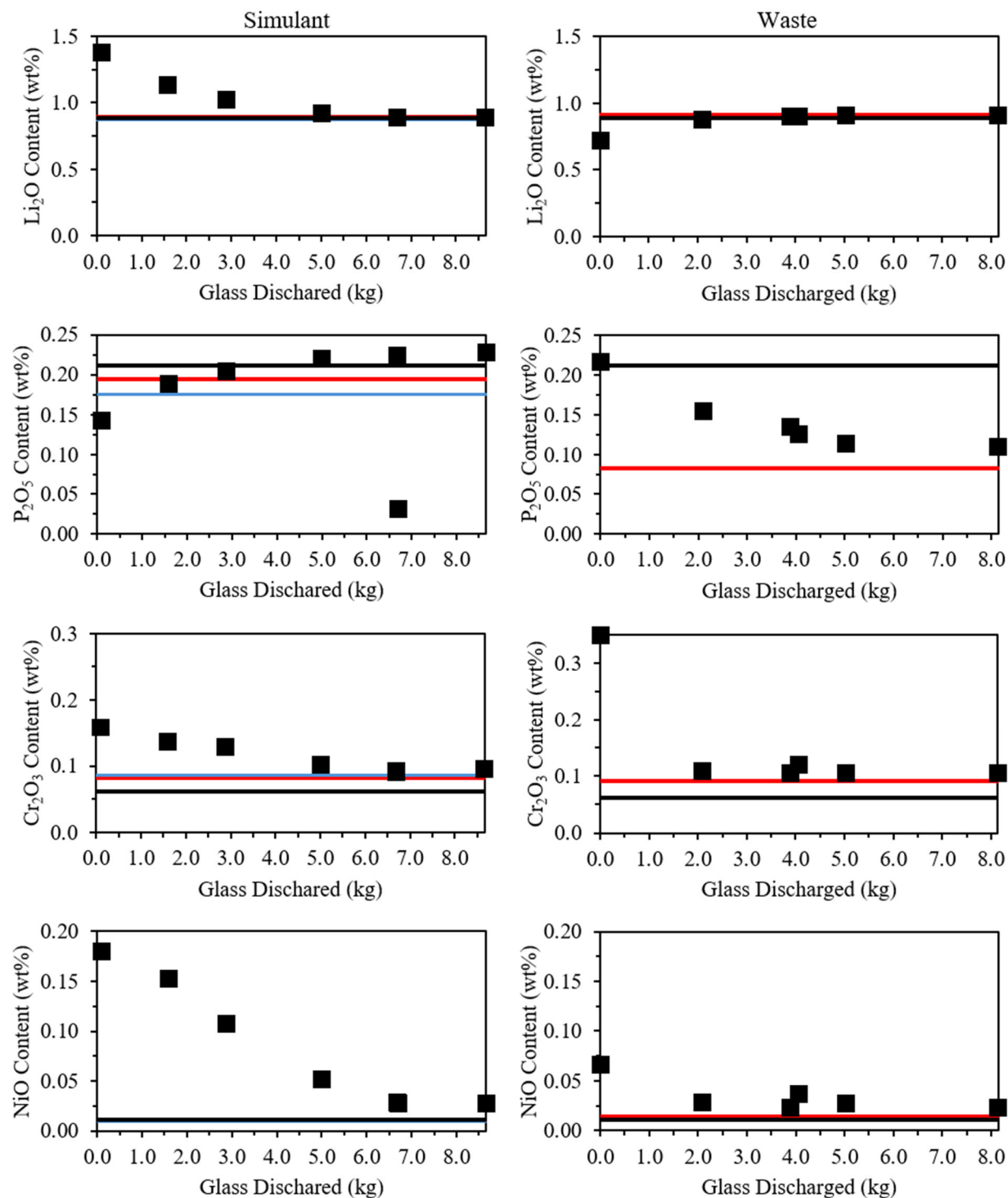


Figure B.4. Content of a set of components (Li_2O , P_2O_5 , Cr_2O_3 , and NiO) in the glass produced during CLSM runs with AW-106 simulant and AW-106 waste melter feeds.

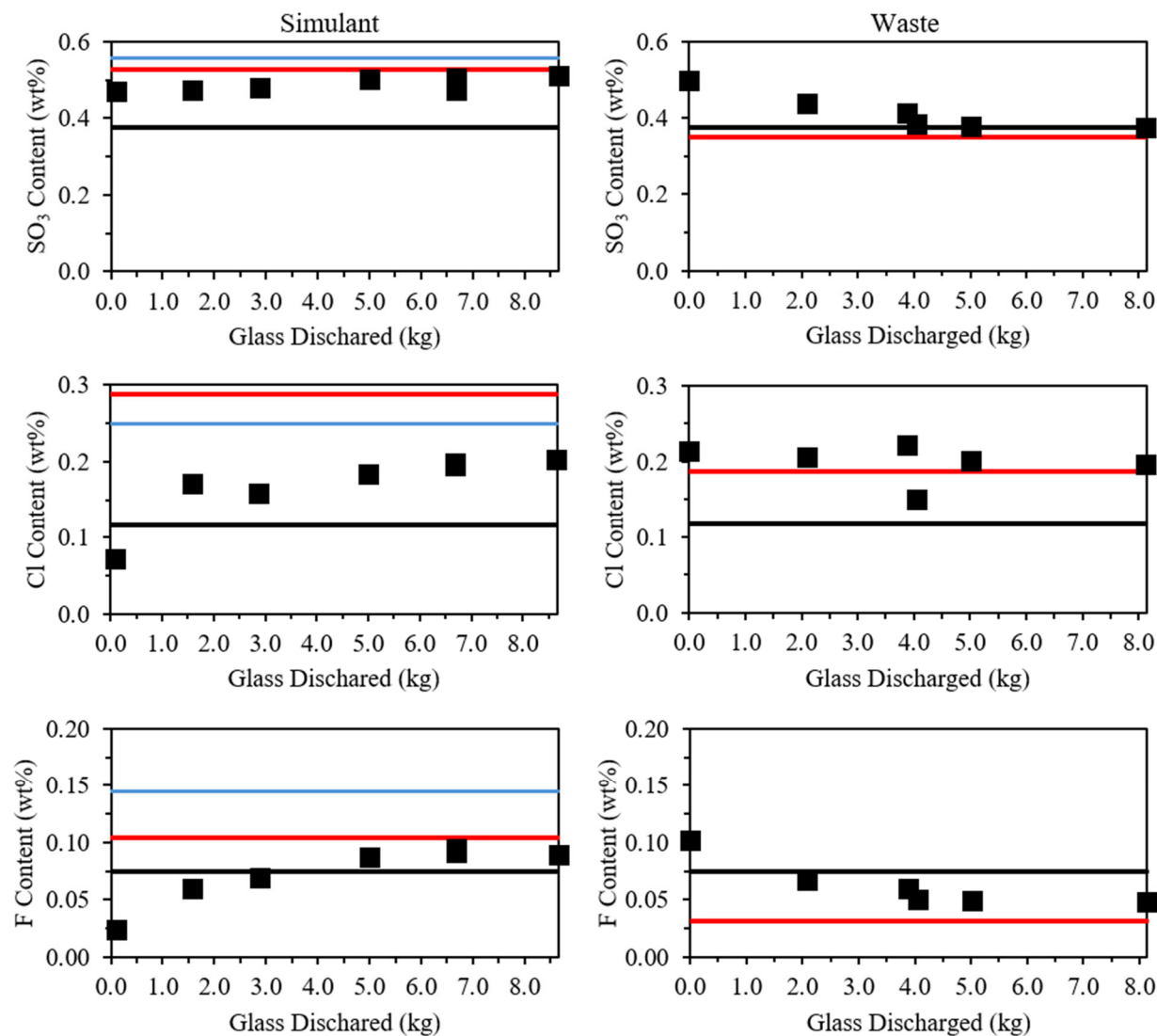


Figure B.5. Content of a set of components (SO_3 , Cl, and F) in the glass produced during CLSM runs with AW-106 simulant and AW-106 waste melter feeds.

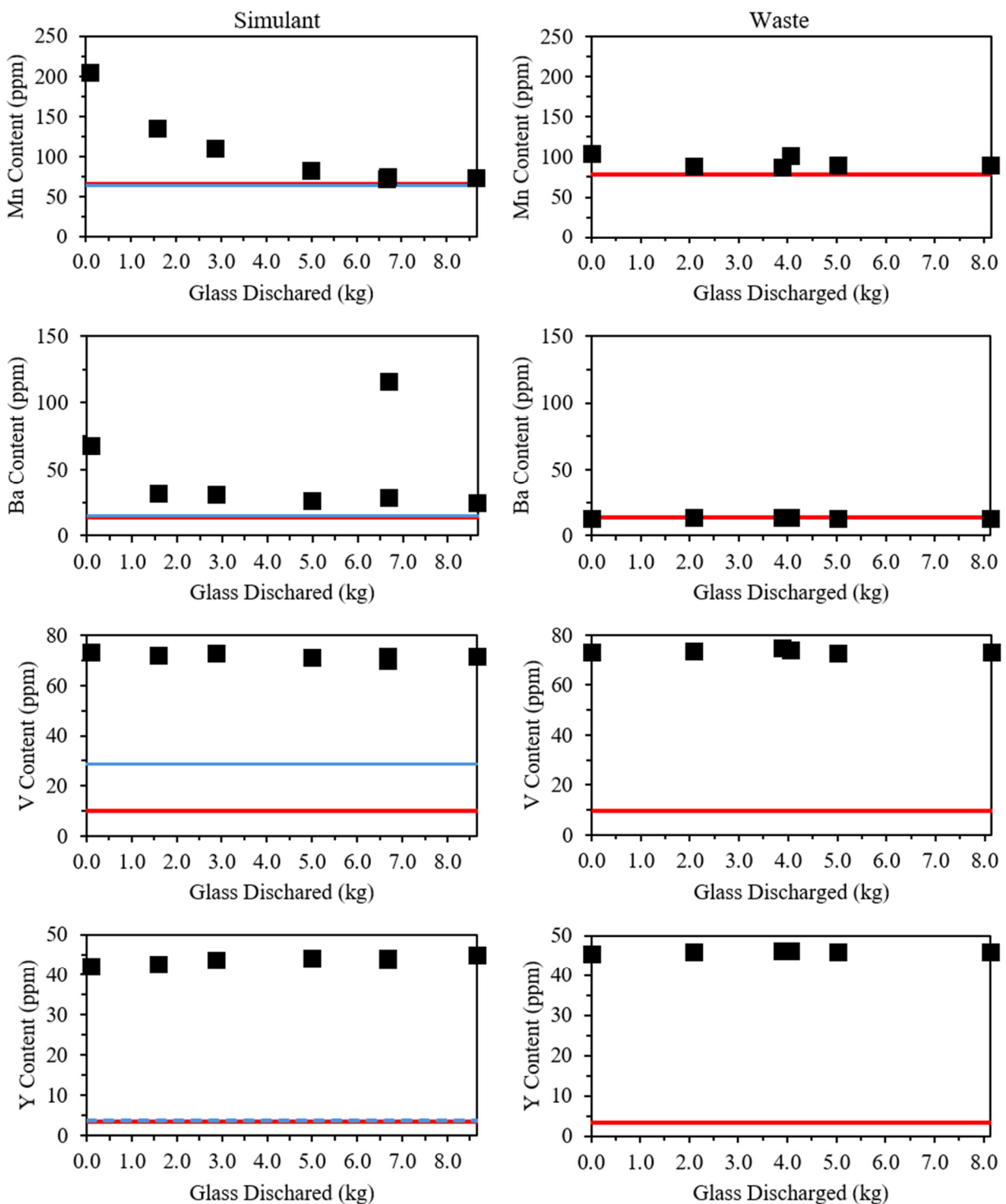


Figure B.6. Content of a set of impurities (Mn, Ba, V, and Y) in the glass produced during CLSM runs with AW-106 simulant and AW-106 waste melter feeds.

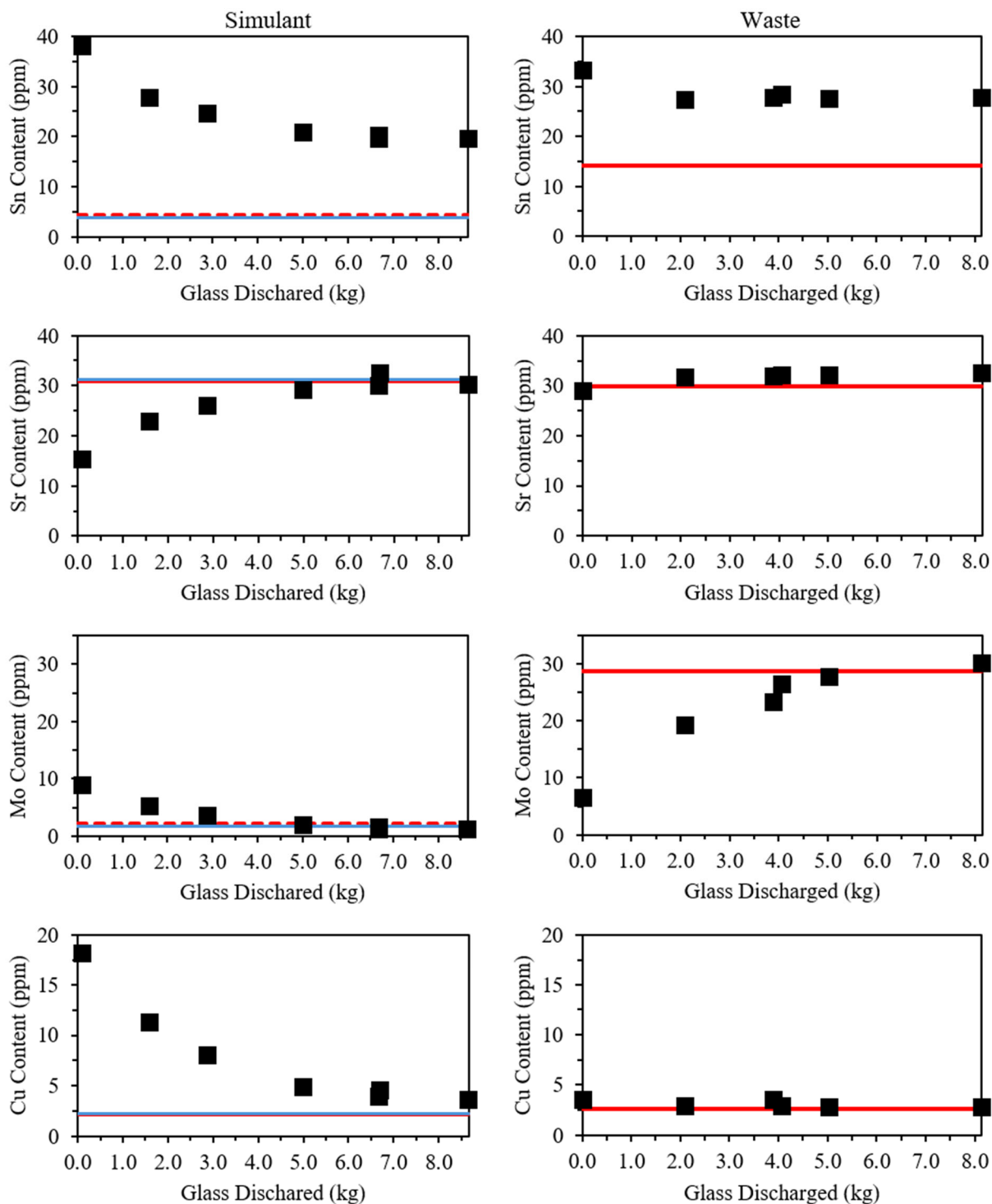


Figure B.7. Content of a set of impurities (Sn, Sr, Mo, and Cu) in the glass produced during CLSM runs with AW-106 simulant and AW-106 waste melter feeds.

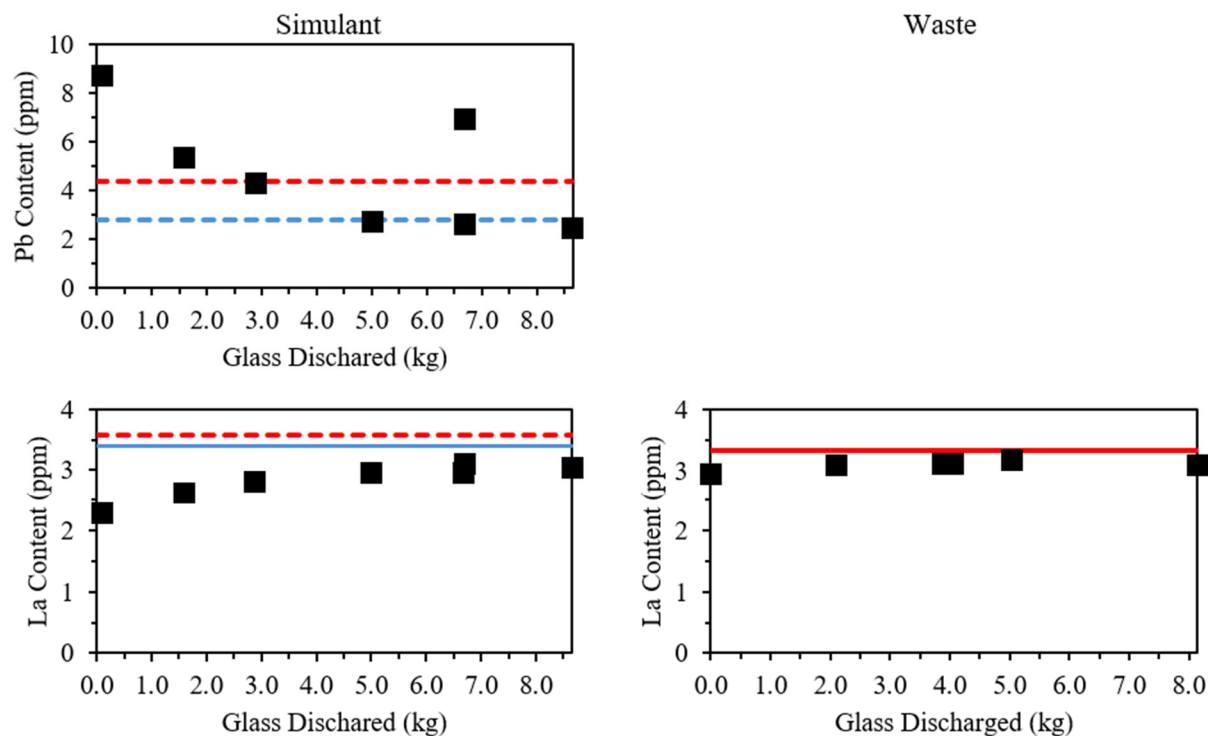


Figure B.8. Content of a set of impurities (Pb and La) in the glass produced during CLSM runs with AW-106 simulant and AW-106 waste melter feeds.

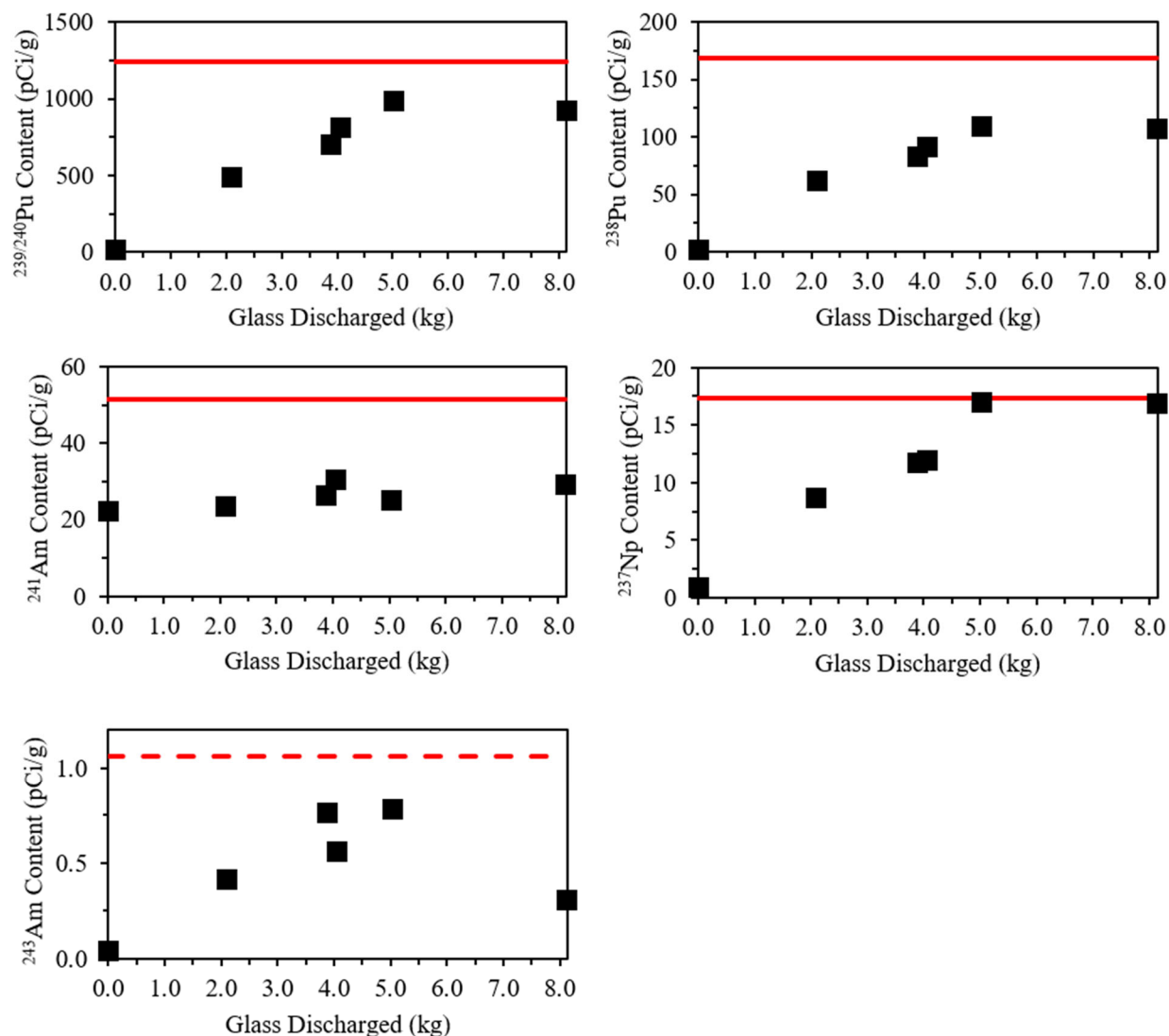


Figure B.9. Activity of measured radionuclides ($^{239/240}\text{Pu}$, ^{238}Pu , ^{241}Am , ^{237}Np , and ^{243}Am) in the glass produced during the CLSM run with AW-106 waste melter feeds.

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