PNNL-38189, Rev. 0
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Vitrification of Hanford Tank 241-AW-105 Waste and Equivalent Simulant

September 2025

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Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

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Richland, Washington 99354

Revision History

Revision Number	**Effective Date**	**Description of Change**
0	September 2025	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-105 (referred to herein as AW-105) waste was retrieved by Hanford Tank Waste Operations and Closure (H2C) and transferred to Pacific Northwest National Laboratory (PNNL). Compared to previously received and vitrified wastes (AP-107, AP-101, AN-107 and AP-105), the concentration of potassium in AW-105 was greater by an order of magnitude.

The AW-105 waste went through dilution in the laboratory 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. A glass composition and glass forming chemical (GFC) additions were calculated from the Kim et al. glass models[1] to satisfy the WTP baseline requirements based on analysis of the AW-105 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 based on the understood best-basis inventory of tank AW-105 and batched.

As preparation for the processing of the AW-105 waste melter feed, the simulant version of the melter feed had its properties tested and then was processed in a non-radioactive, continuous laboratory-scale melter (CLSM) system to understand production expectations. The AW-105 simulant melter feed was charged into the CLSM for 6.91 h of processing, which produced 6.59 kg of glass, for an average glass production rate of 2023 kg m^{-2} d^{-1} without any issues pumping the slurry or visual anomalous behavior during vitrification.

Since there were no processing issues with the AW-105 simulant melter feed, the actual AW-105 waste melter feed was then processed in a CLSM system built into a contamination area in a radioactive environment. The melting behavior characteristics appeared similar for both the simulant and waste melter feeds. The AW-105 waste melter feed was charged into the CLSM for 8.56 h of processing, which produced 5.36 kg of glass, for an average glass production rate of 1330 kg m^2 d^{-1}. The processing rates for both the AW-105 simulant and waste were within ranges expected with the CLSM, though the waste was at the bottom end of the range. Since the operations team observed that the AW-105 waste cold cap had appropriate coverage over the glass melt surface, the low production rate indicates that the cold cap was not as thick as previous runs with other compositions, but could be increased by increasing melter feed charging rate without any adverse effect on the cold cap.

Samples of the AW-105 simulant and melter feeds as well as selected glass and offgas liquid samples were analyzed to determine the concentration of certain chemical constituents. Based on this analysis, most of the primary components in the glass produced from the conversion of the AW-105 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 systems.

A constituent of interest present in low quantities in the AW-105 waste is ^{99}Tc or its non-radioactive surrogate, Re, added to the AW-105 simulant. Analysis for the quantities of ^{99}Tc and Re in the AW-105 glass product resulted in an average single-pass retention from the melter feed during relative chemical steady state of 23 ± 2 % for ^{99}Tc and 45 ± 1 % for Re. Compared to the processing of other melter feeds, the retention of ^{99}Tc in the AW-105 glass was as low as any previous, while the retention of Re in the

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[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.

AW-105 was in the middle of the retention range previously measured. The low glass production rate for the AW-105 waste run and suspected thin cold-cap could account for why the ^{99}Tc retention was also low.

A spike of iodine was added into the AW-105 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 I from the melter feed into the glass product was then measured to be 14 %. 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 condensate and demister solutions from the AW-105 simulant and waste runs were analyzed for acetonitrile and their concentrations were in the same range as previous melter feeds processed in the CLSM. Scaling the acetonitrile production during the AW-105 simulant and waste runs by the total amount of organic carbon in their respective melter feeds and performing the same calculation for all previous CLSM runs, yielded a range of production from 5 – 11 g-acetonitrile per kg-total organic carbon that was not strongly dependent on the CLSM plenum temperature.

Acknowledgements

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
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
LSL2	Life Sciences Laboratory 2
PNNL	Pacific Northwest National Laboratory
psia	pounds per square inch absolute
QA	quality assurance
R	retention
R&D	research and development
Rec	recovery
RPL	Radiochemical Processing Laboratory
RWTP	Radioactive Waste Test Platform
SBS	submerged-bed scrubber
sccm	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

Contents

Figures

Tables

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 approximately 56 million gallons of radioactive waste located 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. Currently, the first phase of the planned WTP startup and operation, called direct-feed low-activity waste (DFLAW), involves directly processing only the liquid supernatant portion of the waste by vitrification in electric melters in the WTP low-activity waste (LAW) facility without full pretreatment (Bernards et al. 2017). A second portion of the tank waste, called high-level waste (HLW), is set to contain most of the radioactivity inventory (Bernards et al. 2017).

To meet the acceptance criteria at the WTP LAW facility, H2C designed a Tank Side Cesium Removal (TSCR) system to remove suspended solids through filtration and cesium (Cs/^{137}Cs) by ion exchange from the supernatant (Bernards et al. 2017). 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 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

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

The samples of waste received for vitrification as described in this report were from Hanford tank 241-AW-105. Upon receipt, the tank 241-AW-105 waste (hereafter called AW-105) was diluted to a target sodium concentration of 5.5 M, filtered for solids removal, and passed through ion exchange for cesium removal. The purpose of vitrifying the AW-105 waste was to evaluate the processing of this high-potassium waste compared to other wastes at lower potassium levels. To accomplish this purpose, the objective was to process the AW-105 waste in the rad-CLSM until at least 1 offgas sample could be collected while the cold cap was steady. Samples of melter feed, glass, and offgas liquids/filters would then be collected so that a mass balance on ^{99}Tc could be performed.

To prepare for the processing of the AW-105 waste, given that this composition had not been processed in the CLSM previously, a simulant of the AW-105 melter feed was designed and processed in the sim-CLSM. Results from the AW-105 waste and simulant processing help demonstrate the ability of the CLSM system to support future WTP programmatic needs by providing information about melter feed production and processability with obtainable volumes of tank waste. These results will add to the growing database of cold-cap behavior under different melter feed compositions and the distribution of semi-volatile components between glass and offgas products.

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-105 simulant melter feed and the AW-105 waste melter feed from the actual Hanford tank 241-AW-105 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-105 waste was designed based on process knowledge about the liquid present in Hanford Tank 241-AW-105. The volume of supernatant in Tank 241-AW-105 was initially 2546 kL with a composition from the best-basis inventory (BBI) of the liquid (Stauffer 2023) while 687 kL of liquid based on the composition of liquid in Hanford Tank 241-AP-101 (Detrich 2015), were added into Tank 241-AW-105. The combined, volumetric composition of the liquid resulted in a sodium molarity of 5.95 M, which was reduced to a target dilution of 5.5 M Na.

Based on these assumptions, the estimated AW-105 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-105 waste simulant created from this composition is shown in Table 3.1. The amount of GFCs to be added per liter of AW-105 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 and these GFCs were estimated to increase the volume of the resultant AW-105 simulant melter feed by 0.3267 L per liter of waste simulant. Ultimately, 12.0 L of AW-105 simulant melter feed was batched, which weighed 18.72 kg for a measured melter feed density of 1.56 kg L^{-1} and water percentage of 45%, while the calculated glass yield was 652 g of glass per liter of melter feed. This melter feed was spiked with Re_2O_7, to a desired target of 8.1 ppm Re in the final glass if 100 % retained, and KI, to a desired target of 150 ppm I in the final glass if 100% retained, during batching.

Table 3.1. AW-105 Simulant and Waste Compositions

Analyte	AW-105 Simulant Composition (mg L^{-1})	AW-105 Waste Composition (mg L^{-1})	% Difference (%)
Al	9045	8612	5
Cl	2210	1329	66
Cr	327	318	3
F	1527	1100	39
K	20921	22059	-5
Na	126445	126839	0
P	446	--	--
S	1070	893	20
NO2	49217	35396	39
NO3	129666	81451	59
TOC	1823	1238	47
TIC	42060	7321	475
Oxalate	504	--	--
	M	M	
Na	5.5	5.5	--

Table 3.2. AW-105 Simulant Chemical Recipe and Melter Feed GFCs Additions

Chemicals	Amount (g L^{-1})	Assay
Re_2O_7 Solution (661 ppm-Re)	6.87	1
KI	0.13	0.99
$Al(NO_3)_3 \cdot 9H_2O$	96.72	0.98
NaOH	51.93	0.97
KOH	22.61	0.999
Na_2CrO_4	0.78	0.98
$Na_3PO_4 \cdot 12H_2O$	4.13	1
NaCl	2.77	0.99
NaF	2.56	0.99
Na_2SO_4	3.61	0.99
$NaC_2H_3O_2$ (sodium acetate)	1.58	0.99
$NaHCO_2$ (sodium formate)	2.65	0.98
$Na_2C_2O_4$ (sodium oxalate)	0.58	0.999
$C_2H_4O_3$ (glycolic acid)	1.48	0.98
$NaNO_2$	26.90	0.98
$NaNO_3$	106.13	0.995
Na_2CO_3	56.27	0.995
GFCs		Assay
$C_{12}H_{22}O_{11}$ (Sucrose)	47.71	1
H_3BO_3 (Boric Acid)	116.24	1.002
TiO_2 (Rutile)	8.89	0.954
Mg_2SiO_4 (Olivine)	19.61	0.9053
ZnO (Zinc Oxide)	22.98	0.999
$ZrSiO_4$ (Zircon)	29.55	0.990
Fe_2O_3 (Hematite)	34.32	0.994
Al_2SiO_5 (Kyanite)	44.69	0.9806
Ca_2SiO_4 (Wollastonite)	28.86	0.9778
SiO_2 (Silica)	236.25	0.995
Waste Loading (%)	25.34%	
Target Glass Yield (g L $feed^{-1}$)	652	

A portion of this AW-105 simulant melter feed was dried and powdered for property testing. First, ~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 seconds 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 seconds. 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. Second, ~1 g of 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) were used to normalize the signal intensities and calculate concentrations for particular gases over the experimental temperature range for this evolved gas analysis (EGA) test.

Actual supernatant from Hanford tank 241-AW-105 was collected by H2C and received by PNNL. Upon receipt, PNNL diluted the AW-105 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. 2025). The analyzed sodium molarity of the diluted AW-105 waste was 5.5 M. The approximately 9.23 L of resulting liquid were processed through an ion exchange column system at 16 °C, which collected ~100 % of the ^{137}Cs activity from the AW-105 waste, while >95% of all desired analytes (see Table 3.1) remained in the waste (Westesen et al. 2025).

The composition of the AW-105 waste was measured after ion exchange (Westesen et al. 2025) and four primary analyte values are shown in Table 3.1. The difference between the AW-105 composition used to batch the simulant compared to the actual AW-105 waste is also given in Table 3.1. Two batches of AW-105 waste melter feed were prepared, batch 1 used 7.631 kg of AW-105 waste and batch 2 used 2.947 kg of AW-105 waste. Given a composite density for the AW-105 waste of 1.2825 g mL^{-1}, the volume of waste in batch 1 was 5.950 L and batch 2 was 2.297 L.

The GFCs added per liter to each AW-105 waste batch were different than those used for the AW-105 simulant, shown in Table 3.2, because they were adjusted based on the best available AW-105 analysis at the time of calculation. This analysis showed that the amount of NO_2 and NO_3 in the waste were half of what was expected based on the BBI calculations, so half the amount of sucrose was added into the AW-105 waste melter feed. The final AW-105 waste melter feed in batch 1 weighed 12.097 kg with an estimated volume of 7.895 L and batch 2 weighed 4.671 kg with an estimated volume of 3.048 L. Both batches of AW-105 waste melter feed had an estimated resultant density of 1.53 kg L^{-1}.

The target glass composition expected from the vitrification of the AW-105 melter feed (referred to as AW-105), 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 are also displayed in Table A.1 of Appendix A.

Table 3.3. Target Glass Composition for the AW-105 Glass

Component	AW-105 (wt%)
Al_2O_3	6.13
B_2O_3	9.96
CaO	2.03
Cl	0.14
Cr_2O_3	0.06
F	0.13
Fe_2O_3	5.53
K_2O	2.82
Li_2O	0.00
MgO	1.49
Na_2O	19.55
NiO	0.01
P_2O_5	0.12
SO_3	0.26
SiO_2	43.84
TiO_2	1.41
ZnO	3.51
ZrO_2	3.02
Total	100.0

3.2 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.

3.2.1 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 melters, but to reproduce the feed-to-glass conversion process performed in the melters. A simplified flow diagram of both the radioactive and simulant CLSM systems is shown in Figure 3.1.

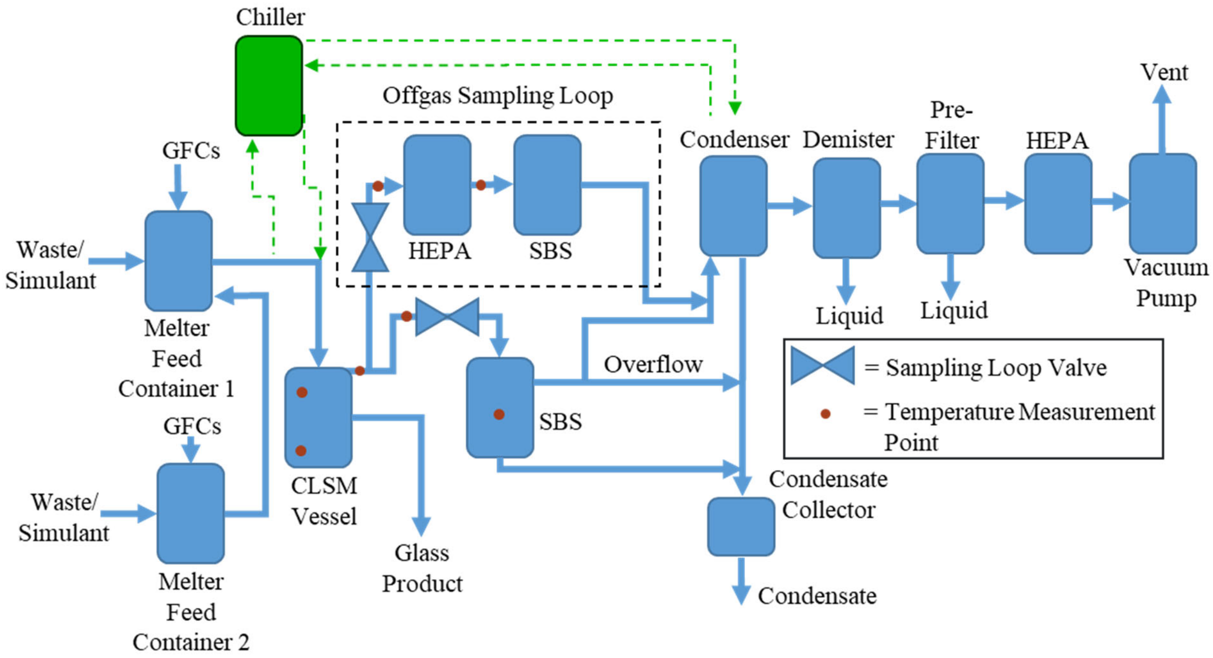

Figure 3.1. Simplified flow diagram of the CLSM systems.

The AW-105 simulant CLSM run used one container of melter feed, placed in the ‘Melter Feed Container 1’ position, while the AW-105 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 24 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 inches), resulting in a cross-section and glass surface area of 0.0113 m^2 with a plenum volume of 0.0018 m^3. 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 inches).

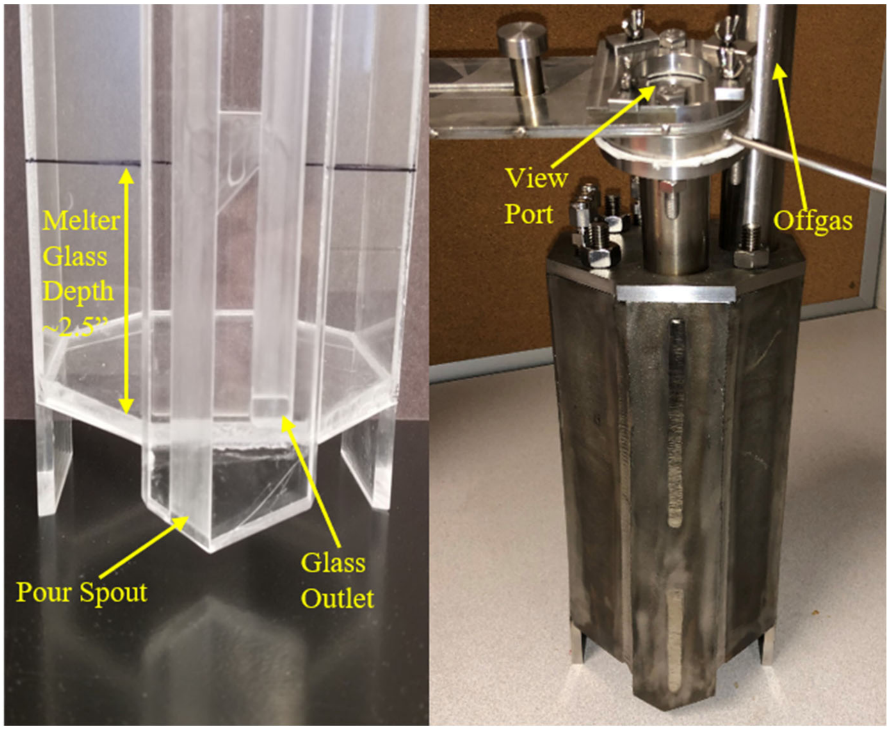

Figure 3.2. Acrylic CLSM vessel model (left) and actual CLSM vessel (right).

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.

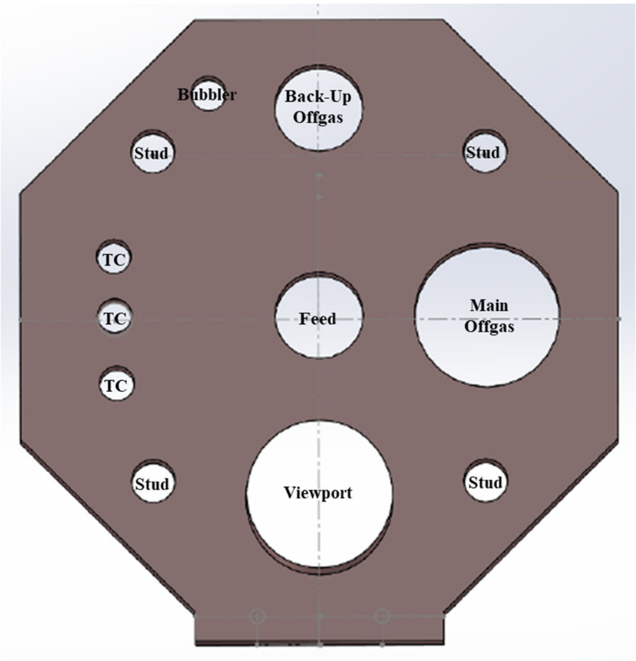

Figure 3.3. CLSM vessel lid and identified ports. The designation 'TC' stands for a thermocouple port.

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. After HEPA filtration, the offgas flowed through the vacuum pump and was released into the HCA fume hood ventilation system for the radioactive CLSM system or the top of the fume canopy for the simulant CLSM system. 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.

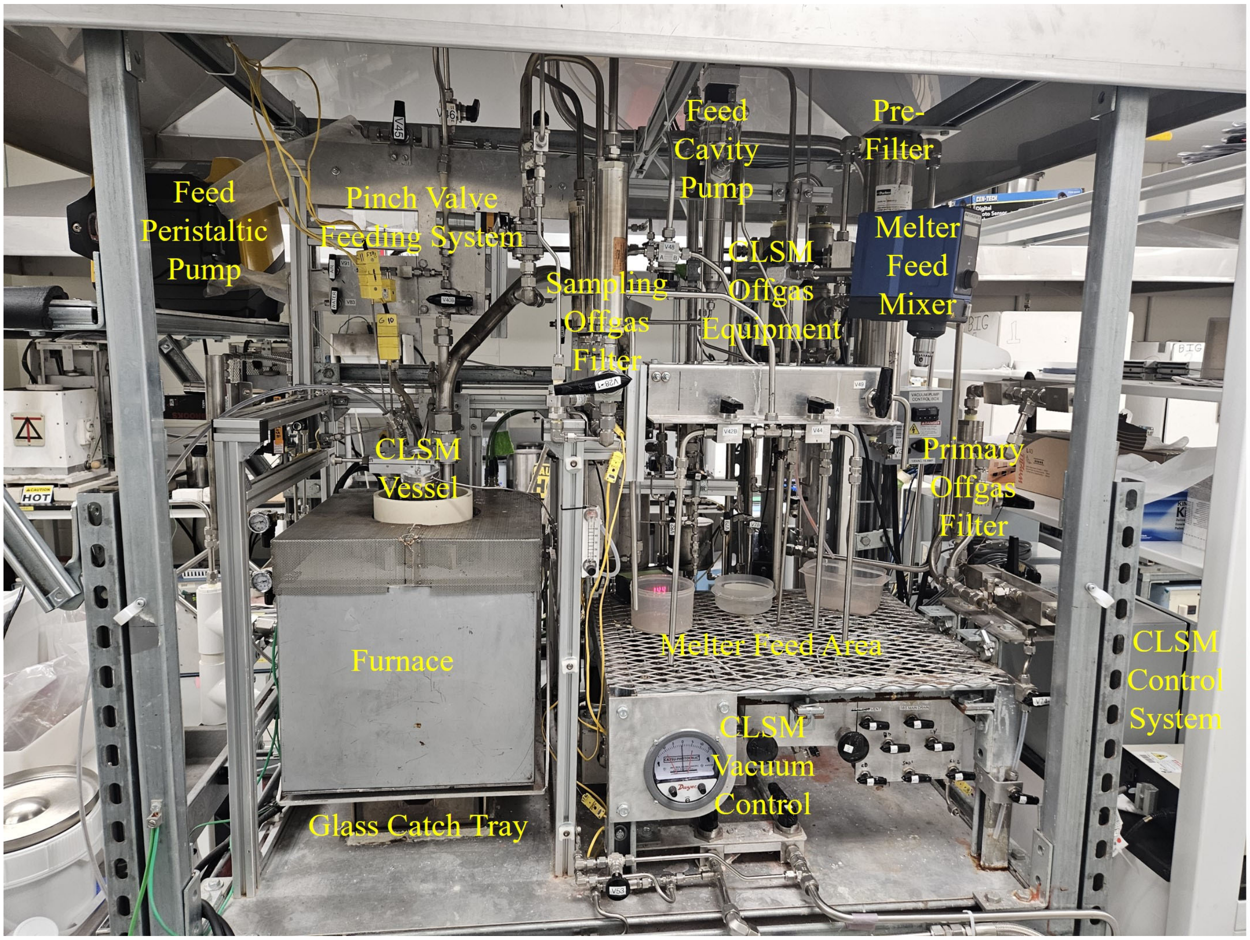

Figure 3.4. The sim-CLSM layout under the fume canopy in the LSL2.

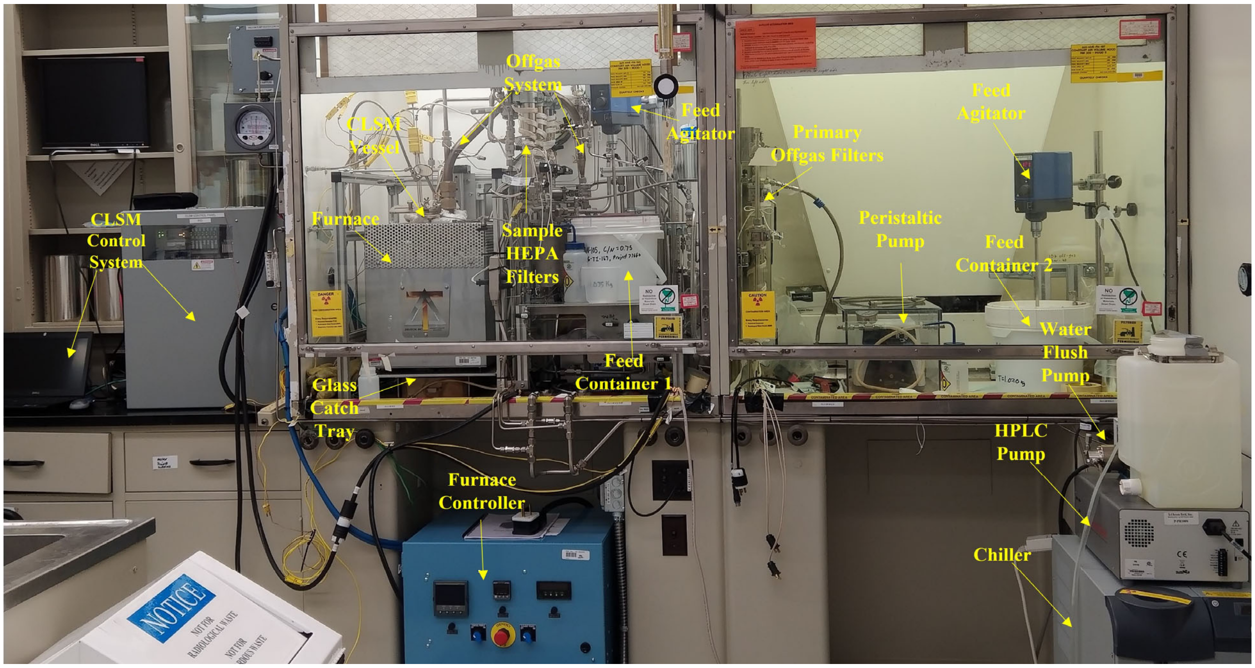

Figure 3.5. The rad-CLSM layout in the RPL HCA (left) and CA (right) fume hoods.

3.2.2 Test Conditions

The CLSM system was operated to maintain a glass melt pool temperature of 1150 °C (± 30 °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) 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 500-700 °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 were 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-105 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, and 2024), and are listed in Table 3.4. The general production range values did align with the designed operation rates at the WTP of 15 metric tons of glass per day [MTG d^{-1}] of immobilized LAW (Bernards et al. 2017).

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_2O	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-H_2O. As described in Section 3.2.1, 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.

3.3 Sample Analysis Methods

The mass of the container with the AW-105 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-105 waste melter feed, the masses of the AW-105 waste and each individual GFCs added to the two batches of AW-105 waste melter feed were measured and totaled to calculate the initial mass in each container before processing. The masses of the containers with the AW-105 waste melter feed were measured after processing for the final mass of melter feed processed through the CLSM.

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 (CH3CN)

4.0 CLSM Run Results

This section describes the operation of the CLSM for the AW-105 simulant run in the LSL2 on January 30, 2025, and the AW-105 waste run in the RPL on March 26, 2025. The feed property, production, and chemical analysis results are also detailed.

4.1 Melter Feed Properties

The FET results for the AW-105 simulant melter feed are shown in Figure 4.1. The spike in volume during ‘Run 1’ observed around 300 °C was a result of the analysis program mis-interpreting a change in the light source in the FET furnace and should not be considered as a low-temperature expansion of the melter feed. The initial expansion for Runs 1 and 2 occurred between 705 °C and 720 °C and their peaks reached an expansion of ~16 V/V_g. These values are both in the same range as those measured for AP-107 at the nominal sucrose ratio performed in Rigby et al. (2024).

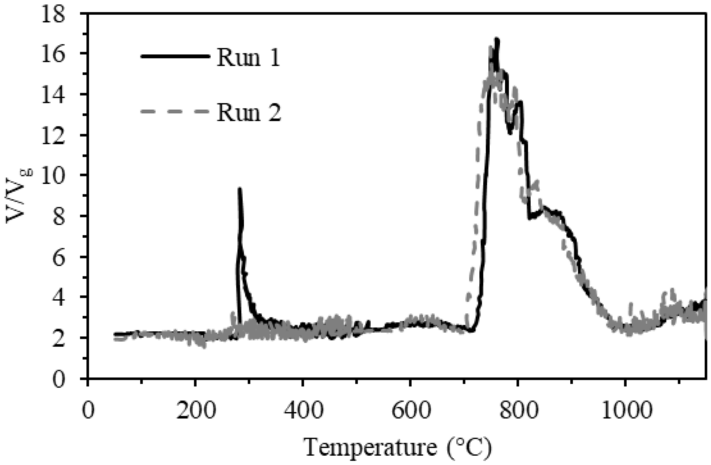

Figure 4.1. FET results for AW-105 simulant melter feed.

The EGA results for the AW-105 simulant melter feed are shown in Figure 4.2. The primary produced gases, CO_2, NO, N_2, and O_2, resemble the shape and temperature ranges measured by Rigby et al. (2024) for AP-107 at the nominal sucrose ratio, however the magnitude of the gases produced are different due to differences in equipment set-up and the flow-rate correlation calibration. The gases of CO, NO_2, SO_2, I, and acetonitrile were detectable with EGA at much lower magnitudes than the primary gases as demonstrated by their alignment with the x-axis of Figure 4.2.

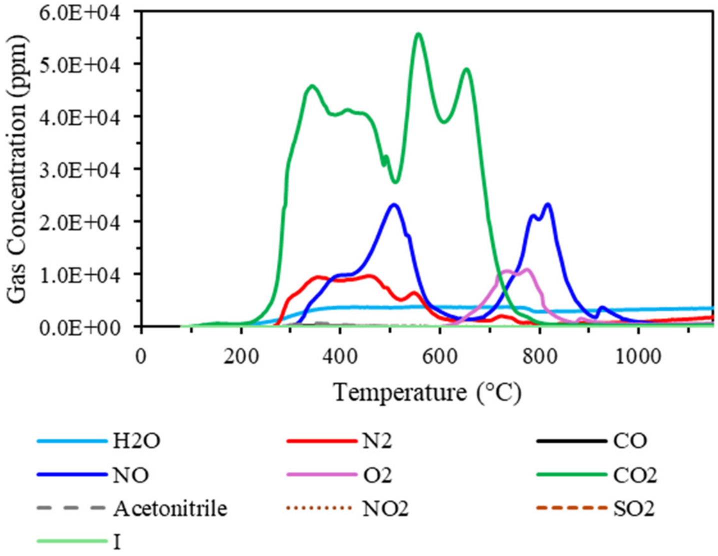

Figure 4.2. EGA results for AW-105 simulant melter feed. The CO, NO_2, SO_2, I, and acetonitrile gas concentrations all appear on the x-axis given the y-axis range.

4.2 Operational Description and Production Results

For the AW-105 simulant run, during set-up of the sim-CLSM, approximately 2.0 kg of AN-105 glass pieces, produced previously (Dixon et al. 2020a), 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}. The CLSM run then began by charging the AW-105 simulant melter feed into the CLSM vessel at 10:11 AM on January 30, 2025, when the glass temperature had reached its desired range, shown in Table 3.4. The time (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. 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) 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-105 simulant run was 6.59 kg, corresponding to over 3 turnovers of the 2.0 kg glass inventory.

For the AW-105 waste run performed on March 26, 2025, during set-up of the CLSM system, approximately 2.0 kg of AW-105 glass pieces, from the final pour of AW-105 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-105 waste melter feed into the CLSM vessel at 9:47 AM, when the glass temperature had reached its desired range, shown in Table 3.4. The time and mass of each individual glass pour of the AW-105 waste run, and the cumulative mass of total AW-105 waste glass poured, are given in Table 4.1. Following the termination of feeding, the cold cap burned off 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 total waste CLSM run was 5.36 kg, corresponding to slightly under 3 turnovers of the 2.0 kg glass inventory. It was also noted during the run that the transfer of AW-105 waste melter feed from ‘Melter Feed Container 2’ into ‘Melter Feed Container 1’, see Figure 3.5 for positioning, began at 1.32 h and ended after about 0.5 h when as much feed as possible had been transferred. After 8.56 h the objectives of the AW-105 waste run had been accomplished and feeding was stopped.

Table 4.1. Timing and Mass of Glass Pours During the AW-105 Simulant and Waste CLSM Runs

1-30-2025			3-26-2025		
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	1999.60	--	Load	1952.41	--
Initial	61.91	0.06	Initial	186.25	0.19
0.57	399.65	0.46	0.57	313.04	0.50
1.12	596.75	1.06	1.10	365.58	0.86
1.77	552.66	1.61	1.70	327.58	1.19
2.45	879.45	2.49	2.28	352.83	1.55
3.07	500.37	2.99	2.78	342.96	1.89
3.58	338.11	3.33	3.23	436.69	2.32
4.08	623.79	3.95	3.74	377.27	2.70
4.63	606.56	4.56	4.23	341.91	3.04
5.59	566.41	5.13	4.74	453.21	3.50
6.20	628.36	5.75	5.24	373.11	3.87
6.73	451.72	6.21	5.74	377.75	4.25
7.09	645.50	6.85	6.24	379.19	4.63
Final	1734.75	8.59	6.76	264.85	4.89
			7.22	319.05	5.21
			7.72	234.42	5.45
			8.23	424.77	5.87
			Final	1445.97	7.32
Total Produced		6.59	Total Produced		5.36

The production results from the AW-105 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 4.3 and those recorded during the waste CLSM run are displayed in Figure 4.4. 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 are shown in relation to the processing values in Figure 4.3 and Figure 4.4.

Table 4.2. CLSM Production Results During Both AW-105 CLSM Runs

Parameter	AW-105 Simulant CLSM Run	AW-105 Waste CLSM Run
Test Date	1/30/2025	3/26/2025
Feeding Duration, h	6.91	8.56
Low Flow Duration, h	0	0
Downtime, h	0.25	0
Glass Produced, kg	6.59	5.36
Melter Feed Consumed, kg	16.42	13.81
Average Glass Production Rate, kg m^{-2} d^{-1}	2023	1330
Average Feeding Rate, kg h^{-1}	2.38	1.61
Average Bubbling Flux Rate, L m^{-2} min^{-1}	59	78
Average Glass Temperature, °C	1146	1138
Average Plenum Temperature, °C	648	695

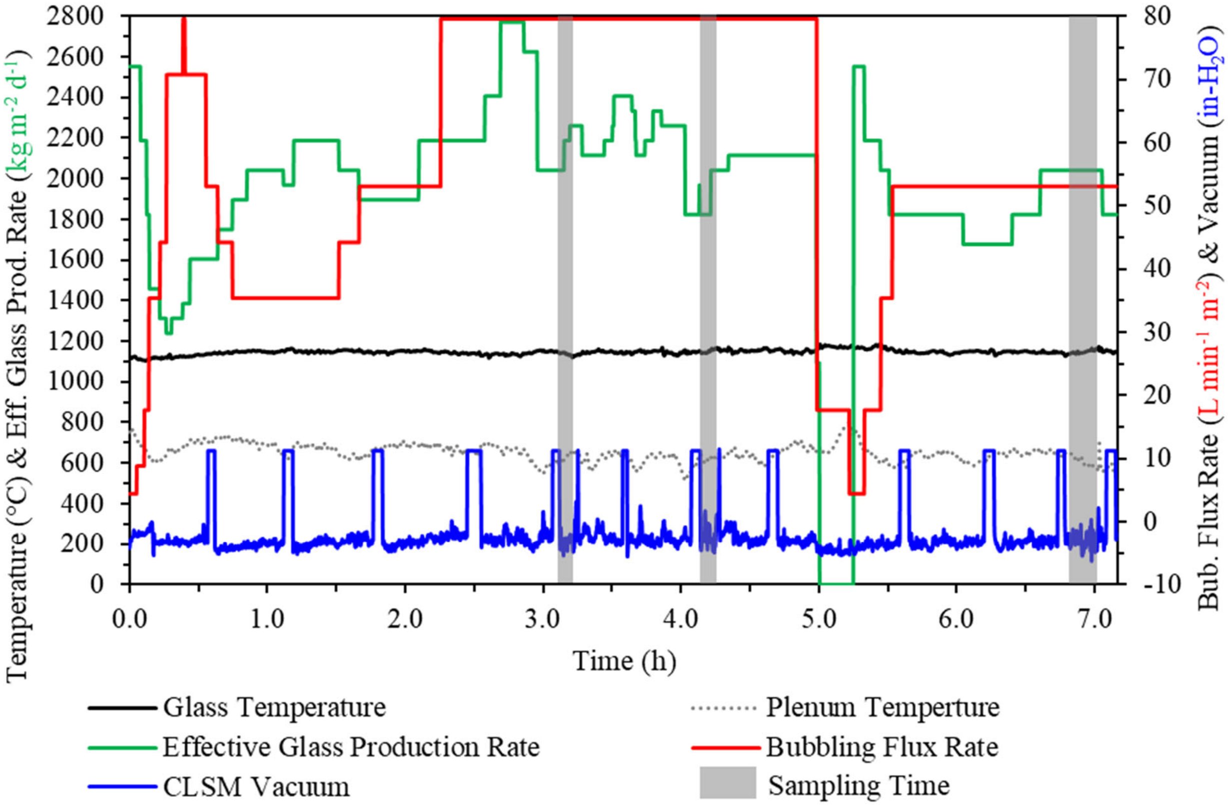

Figure 4.3. Processing values (glass and plenum temperatures, effective glass production rate, bubbling flux rate, and CLSM vacuum measurements) and offgas sample timing recorded during the AW-105 simulant CLSM run.

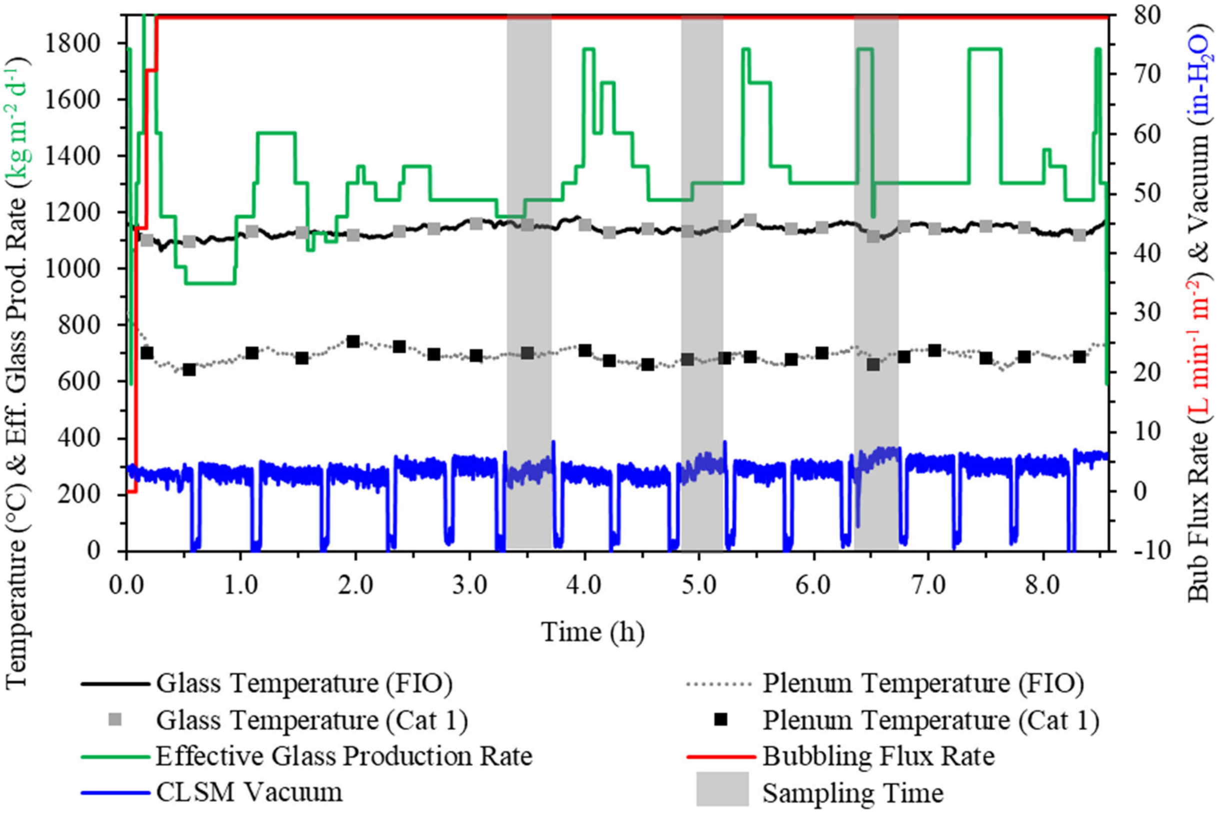

Figure 4.4. Processing values (glass and plenum temperatures, effective glass production rate, bubbling flux rate, and CLSM vacuum measurements) and offgas sample timing recorded during the AW-105 waste CLSM run.

The cold cap during the AW-105 simulant 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 closest to cold-cap behaviors while processing AP-107 and AN-107 melter feeds in the CLSM (Dixon et al. 2019, 2020b, 2022a, and 2024). At a point ~5.00 h into the AW-105 simulant CLSM run, feed charging was stopped, shown in Figure 4.3, so the melter feed could be transferred to a smaller diameter container for the remainer of the run. Charging began again once the transfer was complete, 0.25 h after it had stopped.

The cold cap during the AW-105 waste melter feed charging appeared to have appropriate coverage over the glass melt surface (90 – 100 %), but its thickness was never properly identified due to observational limitations with the rad-CLSM. However, the reduction in glass production rate from the AW-105 simulant CLSM run to the AW-105 waste CLSM run, see Table 4.2, indicates that the waste cold cap was thinner over the glass surface despite its adequate coverage of the surface area. Based on this, it is believed that the AW-105 waste melter feed could have been charged at a higher rate in the CLSM vessel with no adverse cold-cap effects. The potential effect of a thin cold cap and low glass production rate on semi-volatile retention into the glass product will be discussed in Section 5.4.

4.3 Sample Chemical Analysis

The samples selected for chemical analysis from the AW-105 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

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component listed in Table 3.5. Similarly, the samples selected for chemical analysis from the AW-105 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. 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 combined into two separate containers and subsampled. Similarly, the liquids that accumulated in the demister during the simulant run and the waste run were 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-105 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-105 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-105 simulant and AW-105 waste melter feeds and compares data to previous CLSM runs (Dixon et al. 2018, 2019, 2020a, 2020b, 2022a, 2022b, 2023, and 2024).

5.1 Glass Composition

Table 5.1 compares the average composition of the glass produced during the CLSM runs with the AW-105 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-105 Simulant and Waste CLSM Run Glass Products with Target Compositions

Component	Target AW-105-	Measured Average Simulant AW-105-	% Diff. Target to Average Simulant AW-105-	Measured Average Waste AW-105-	% Diff. Target to Average Waste AW-105-
	wt%	wt%	%	wt%	%
Al_2O_3	6.13	5.80	-5.4	5.55	-9.5
B_2O_3	9.96	10.62	6.7	10.75	7.9
CaO	2.03	1.93	-5.4	1.99	-2.1
Cl	0.14	0.27	--	0.20	--
Cr_2O_3	0.06	0.10	--	0.09	--
F	0.13	0.11	--	0.12	--
Fe_2O_3	5.53	5.44	-1.5	5.37	-2.8
K_2O	2.82	2.28	-19.4	2.89	2.3
Li_2O	0.00	0.00	--	0.00	--
MgO	1.49	1.42	-4.5	1.51	1.5
Na_2O	19.55	20.03	2.5	19.73	0.9
NiO	0.01	0.10	--	0.02	--
P_2O_5	0.12	0.14	--	0.13	--
SO_3	0.26	0.33	--	0.39	--
SiO_2	43.84	43.47	-0.8	43.28	-1.3
TiO_2	1.41	1.42	0.9	1.37	-2.3
ZnO	3.51	3.59	2.2	3.72	5.9
ZrO_2	3.02	2.96	-2.1	2.89	-4.3
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-105 simulant in column A and the AW-105 waste in column B. Most of the primary components measured in the AW-105 glass compositions produced from the AW-105 simulant and waste CLSM runs were within ±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-105 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-105 target. The components CaO, SO_3, P_2O_5, F, and Li_2O were above the AW-105 target and K_2O, MgO, TiO_2, and ZrO_2 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-105 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-105 glass. Three primary components, Al_2O_3, B_2O_3, and K_2O, differed by greater than 5 wt% in the expected AW-105 waste glass relative to the AW-105 simulant glass since the received AW-105 waste samples had lower concentrations of Al with greater concentrations of K and B than expected based on the AW-105 tank BBI.

The trends for Cr_2O_3 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 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-105 glass composition, three primary glass components, Cl, F, and SO_3, were calculated with retention factors less than 95%. Figure B.5 displays the composition trends during the AW-105 simulant and waste CLSM runs for these components where the trends show SO_3 and Cl were present in the glass at greater levels than the target anticipated while F was at the glass level expected. Such behavior has been measured with SO_3 and Cl in previous CLSM runs (Dixon et al. 2024, 2023, 2022a, and 2022b), but these previous runs had much less (or no measured) F concentrations in the waste compared to AW-105, so no compositional trends comparing the target to measured glass values had been observed for F in the CLSM before. The behavior of these components (along with other semi-volatiles) in the CLSM offgas treatment system will be discussed further in Section 5.3.

Several components were present as minor (2500 ppm or less) impurities in the melter feeds and glass product during the AW-105 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-105 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-105 melter feeds. This trend applied to V, Bi, Mn, Pb, Sn, and La in the AW-105 simulant CLSM run and Bi, Sn, Cu, Sr, and Mo in the AW-105 waste CLSM run. 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, remained relatively constant in all glass pours, but at a level greater than expected based on the AW-105 melter feeds. The Y (and V in CLSM runs without a spike in the initial glass) trend has been previously analyzed in CLSM glass products (Dixon et al. 2020a, and 2020b). 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 Cr_2O_3 and NiO content in the glass product.

The measured activity of each analyzed radionuclide in the glass products from the AW-105 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-105 simulant feed, so only the AW-105 waste CLSM run is shown. The activity of all the radionuclides for AW-105 displayed in Figure B.9 were in the ranges previously measured for the 7 M Na AP-105, AP-101, AP-107 2x recycle/AP-105 changeover, and AP-107 1x recycle (Dixon et al. 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 ~100% retention of the analyzed melter feed by two turnovers of the CLSM glass contents. However, the behavior of ^{241}Am in the AW-105 glass differed from previous CLSM runs 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):

$$\mathrm{DF}_i = \frac{\dot{m}_{i,feed}}{\dot{m}_{i,offgas}} \tag{5.1}$$

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):

$$R_i = \frac{\dot{m}_{i,glass}}{\dot{m}_{i,feed}} \tag{5.2}$$

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):

$$\text{Rec}_i = \frac{\dot{m}_{i,glass} + \dot{m}_{i,offgas}}{\dot{m}_{i,feed}} \tag{5.3}$$

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_{99Tc}, 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-105 simulant melter feed and AW-105 waste melter feed. For each component of the AW-105 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 6.91 h for the AW-105 simulant run and 8.56 h for the AW-105 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-105 simulant run of 6.59 kg and in the AW-105 waste run of 5.36 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-105 simulant run, the mass of each offgas unit can be found in Table A.2 of Appendix A and for the AW-105 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-105 simulant CLSM run are given in Table 5.2 and the mass flow rate data for the entire runtime of the AW-105 waste CLSM run are given in Table 5.3. Note that the chemical analysis results for Cs in both the AW-105 simulant and waste melter feeds, and the results for I in the AW-105 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-105 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-105 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	0.14	0.06	0.07	1.9	42	94
Total Cs[(a)]	--	--	0.00	--	--	--
Total I	2.05	0.28	1.67	1.2	14	95
Al	525	492	2	334	94	94
B	505	530	5	101	105	106
Ca	235	221	1	213	94	94
Cl	53	44	12	4	82	106
Cr	9	11	0	28	127	130
F	25	18	5	5	73	95
Fe	620	611	3	234	99	99
K	356	303	7	51	85	87
Li[(a)]	--	0	0	--	--	--
Mg	151	138	0	6223	91	91
Na	2477	2386	25	98	96	97
Ni	1	12	0	20	871	876
P	8	10	0	56	114	116
S	22	21	1	20	98	103
Si	3432	3262	2	1923	95	95
Ti	137	136	0	1855	99	99
Zn	438	463	2	236	106	106
Zr	359	351	0	1161	98	98
Total	9355	9010	68	138	96	97

(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-105 Waste 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}		%	%
^{99}Tc	0.04	0.01	0.02(b)	1.7	27	85
Total Cs(a)	--	--	0.00(b)	--	--	--
Total I(a)	--	--	0.06(b)	--	--	--
Al	324	300	0	1717	93	93
B	377	341	2	235	90	91
Ca	163	145	0	1387	89	89
Cl	31	20	7(b)	5	66	87
Cr	6	6	0	26	108	112
F	18	12	1(b)	21	65	70
Fe	414	384	1	654	93	93
K	279	245	4(b)	70	88	89
Li(a)	0	0	0	--	--	--
Mg	102	93	0	26712	92	92
Na	1686	1495	9	181	89	89
Ni	1	2	0	19	185	190
P	6	6	0	2818	103	103
S	17	16	1(b)	27	91	95
Si	2205	2066	0	5136	94	94
Ti	93	84	0	3708	90	90
Zn	326	305	0	958	94	94
Zr	236	218	0	5927	92	92
Total	6283	5736	25	250	91	92

(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-105 simulant and waste runs, most all component recoveries were within ±10 % of complete recovery. The Rec_i values for Cr and Ni (and I in the AW-105 waste run only) 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 5.2 for Cr_2O_3 and NiO, affected the calculations. The Rec_i values for K and P in the AW-105 simulant run were also outside of the desired range because the initial load glass in the CLSM vessel had much different amounts of those components than the melter feed.

In the AW-105 waste run, the Rec_i values for ^{99}Tc, Ca, Cl, F, K, and Na were also outside of the 90 – 110 % range. Except for Ca, these components were present in the AW-105 melter feed in the soluble phase and all fell below the desired range. This indicates that the analyzed melter feed samples had a greater ratio of liquids to solids than the actual AW-105 waste melter feed; a potential result from sampling methods and settling during transportation for analysis.

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, and 2024) were ^{99}Tc (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-105 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-105 Simulant and Waste CLSM Runs

AW-105 Simulant CLSM Run

	Re (mg)	Cs (mg)	I (mg)	Cl (mg)	F (mg)	K (mg)	S (mg)
Glass	23.3	--(a)	118	18213	7518	125676	8824
Sampling + Wash	5.96	--(a)	82.4(b)	888	472	542	84.5
SBS + Condensate + Demister	21.0	--(a)	598	4278	1759	2193	340
End Filters	2.19	--(a)	10.5	2.19	44.9	178	24.6

AW-105 Waste CLSM Run

	^{99}Tc (mg)	Cs (mg)	I (mg)	Cl (mg)	F (mg)	K (mg)	S (mg)
Glass	5.72	0.862(c)	1.33(c)	10393	6104	125598	8151
Sampling + Wash (d)	2.92 (1.10)	0.0815 (0.0397)	1.05 (1.03)	756 (237)	426 (17.5)	535 (107)	91.3 (16.9)
SBS + Condensate + Demister	7.78	0.717	30.86	2570	--(a)	1303	221
End Filters	1.40	0.127	0.342	14.4	15.5	222	22.5

(a) The component concentrations in AW-105 samples were below analytical reporting limits.

(b) The Sampling SBS sump was not analyzed for the AW-105 simulant run, so an expected amount of I that would be recovered in the Sampling SBS sump was calculated based on the AN-107 simulant run (Dixon et al. 2024).

(c) The concentrations of Cs and I in the AW-105 waste glass were below detection limits for most samples, so this value should be considered a best estimate calculation based on detection limits.

(d) 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-105 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 and 2022b), 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-105 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-105 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):

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

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-105 simulant CLSM run is displayed in Figure 5.1a and during the AW-105 waste CLSM run is displayed in Figure 5.1b.

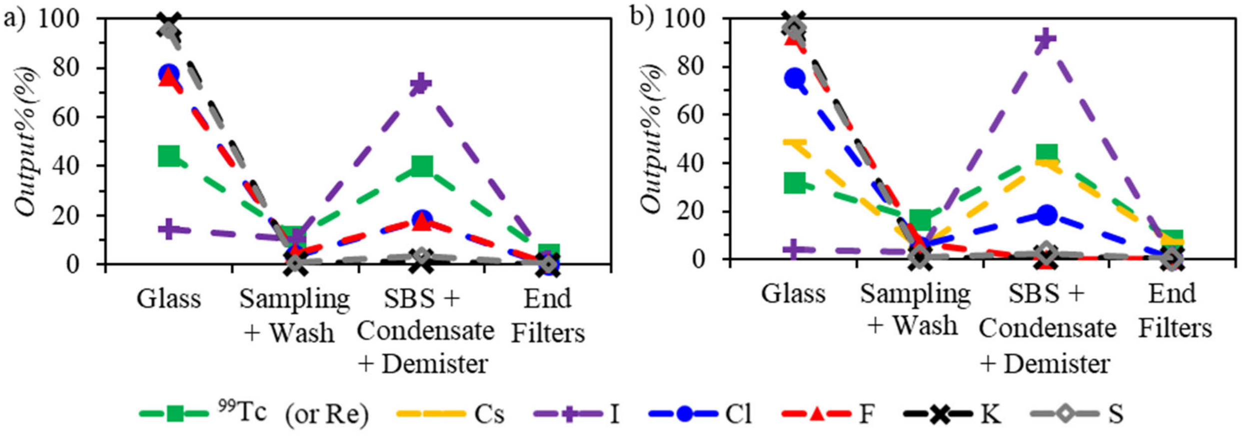

Figure 5.1. Percentage of the quantity of each component in the output stream (*Output%*) in the CLSM offgas treatment system during a) the AW-105 simulant run and, b) the AW-105 waste run.

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-105 simulant and waste runs were used to calculate retention values (R_{99Tc}, 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_{99Tc} and R_{Re}, calculated for each glass pour are also displayed as black squares (■) in Figure 5.2 with respect to the mass of glass discharged while the I retention value, R_I, is displayed as blue circled (●) in Figure 5.2a only, since I concentration was below the analytical reporting limit in the AW-105 waste melter feed. The characteristic relationships between Re or ^{99}Tc and I are shown in Table 5.5 for the AW-105 simulant CLSM run and in Table 5.6 for the AW-105 waste CLSM run. These tables include R_{99Tc} (or R_{Re}) values calculated exclusively during the sampling time periods, marked on Figure 4.3 for the AW-105 simulant CLSM run and on Figure 4.4 for the AW-105 waste CLSM run.

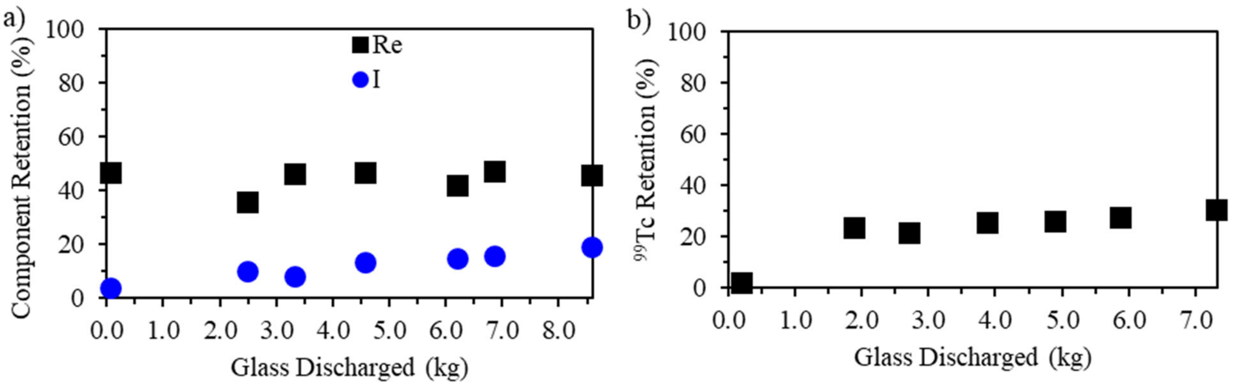

Figure 5.2. a) Re and I retention in the glass product from the AW-105 simulant CLSM run and b) ^{99}Tc retention in the glass product from the AW-105 waste CLSM run.

The 2.0 kg of glass pieces loaded into the CLSM vessel for the start of the AW-105 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-105 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 45 ± 1 %. Compared to the previous CLSM simulant runs, this value was equivalent to the single pass R_{Re} value when processing AP-101 (Dixon et al. 2022b), which was in the middle of the range for melter feeds that had been processed in the CLSM (Dixon et al. 2018, 2020a, 2022c, 2023, 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 > AP-101 = AW-105 > AP-105 = AN-105.

Table 5.5. Re and I Relationships During the AW-105 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[b] Retention (%)	Re Sampling[b] Recovery (%)
8.52	129	Initial	0.06	3.80	5.01	47	4		
8.52	129	2.45	2.49	2.97[a]	12.8	36[a]	10		
8.52	129	3.58	3.33	3.74[a]	9.86	46[a]	8	44	98
8.52	129	4.63	4.56	3.80[a]	16.8	47[a]	14	45	135
8.52	129	6.73	6.21	3.48[a]	19.1	42[a]	15		
8.52	129	7.09	6.85	3.90[a]	20.0	47[a]	16	46	83
8.52	129	Final	8.59	3.75[a]	24.0	46[a]	19		
					Total, R_i	42	14		
					Total, Rec_i	94	95		

[a] The Re glass analysis for samples 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 3.2.1.

Table 5.6. ^{99}Tc and I Relationships During the AW-105 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 (%)
3.89	2.48	Initial	0.19	0.0781	14.5	2		
3.89	2.48	2.78	1.89	0.846	3.3	24		
3.89	2.48	3.74	2.70	0.781	2.37	22	20	73
3.89	2.48	5.24	3.87	0.935	0.952	26	24	68
3.89	2.48	6.76	4.89	0.950	0.941	26	24	80
3.89	2.48	8.23	5.87	0.989	0.898	28		
3.89	2.48	Final	7.32	1.08	0.676	31		
					Total, R_i	27		
					Total, Rec_i	85(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 3.2.1.

(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-105 simulant melter feed of 129 ppm in the glass if 100% retained, I was detected above analytical limits in all analyzed glasses in the CLSM simulant run. The relative chemical steady state was then reached after two turnovers of the CLSM vessel glass inventory during the AW-105 simulant run and the total run R_I value was 14 %. The value was equivalent to the processing of 7 M Na AP-105 simulant melter feed (Dixon et al. 2023) and slightly greater than the processing of AN-107 simulant (R_I value = 10 %, Dixon et al. 2024). All these CLSM R_I values 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 in for single-pass retention when processing LAW melter feeds. The AW-105 simulant glass pieces loaded into the CLSM vessel for the AW-105 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-105 waste melter feed.

Following the trend discussed in Dixon et al. (2024), the behavior of I in the CLSM offgas treatment system was preferentially captured in liquid units over filter matrices. During the AW-105 simulant CLSM run, <1% of the total 691 mg I was captured on filters while in the AW-105 waste CLSM run, 1% of the total 32 mg I was captured on filters. Compared to other semi-volatile components, like Re (13% of the total 29 mg on filters) and Cl (5% of the total 5168 mg on filters) in the AW-105 simulant CLSM run and ^{99}Tc (19% of the total 12 mg on filters) and Cl (7% of the total 3340 mg on filters) in the AW-105 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-105 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-105 waste run did not contain any ^{99}Tc. 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 23 ± 2 %. Compared to the previous CLSM waste runs, this value was greater than only the AP-105 melter feed single pass R_{99Tc} value (Dixon et al. 2018).

The glass production rate for the AW-105 waste CLSM run was equivalent to the AP-105 waste CLSM run (Dixon et al. 2018), both of which were believed to have thin cold caps with the potential for increased thickness at greater charging rates. This increase was demonstrated for AP-105 waste melter feed when processing different portions of AP-105 waste (Dixon et al. 2022a and 2023), which showed corresponding increases in the single pass R_{99Tc} values. So, it is believed that a thin cold cap from low melter feed charging in the CLSM results in low ^{99}Tc retention that can be improved with thicker cold-cap conditions. 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 > AP-105 ≥ AP-107 > AW-105 (and thin cold-cap AP-105).

The Cs content in both the AW-105 simulant and waste melter feeds was below the analytical detection limits using ICP-MS. Subsequently, the Cs content was below analytical detection limits for all glasses produced during the AW-105 simulant and waste CLSM runs except for the first glass poured during the AW-105 waste CLSM run, 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.

5.5 Acetonitrile Analysis

The measured levels of acetonitrile in the condensate and demister liquids collected in the CLSM offgas system for the AW-105 simulant CLSM run are listed in Table A.2 of Appendix A and the AW-105 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 5.7 displays the total amount of acetonitrile collected in the simulant condensate, calculated from the acetonitrile concentration in the liquid, the liquid density, and the total mass of liquid collected. The 'Total Run Acetonitrile per Sucrose' column in Table 5.7 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 5.7. Acetonitrile in Liquids from the AW-105 Simulant CLSM Runs

Liquid		Acetonitrile Concentration (mg L^{-1})	Total Acetonitrile (mg)	Acetonitrile per Sucrose (g kg^{-1})	Total Run Acetonitrile per Sucrose (g kg^{-1})
Condensate	Simulant	130	922	2.43	2.69
Demister	Simulant	430	296		
Condensate	Waste	96	592	3.00	3.33
Demister	Waste	160	63		

In Dixon et al. (2024), the AN-107 simulant CLSM run produced a similar amount of total acetonitrile compared to previous runs (Dixon et al. 2022b and 2023) despite the AN-107 melter feed having an order of magnitude less sucrose in the melter feed. Thus, it was proposed that the amount of organic carbon in the wastes should be considered for acetonitrile generation along with the sucrose added into the melter feed. Table 5.8 displays the acetonitrile production calculated based on the total amount of organic carbon consumed from the melter feed vitrification during the AW-105 simulant and waste CLSM runs. The acetonitrile per total organic carbon values range from 5 to 11 g kg^{-1} for 4 melter feed compositions in 7 different runs, with no discernable relationship to the average plenum temperature as shown in Figure 5.3. While Dellinger et al. (1984) suggest 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.

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 TOC ($g\ kg^{-1}$)
AW-105 Simulant	648	1353	16.42	63.3	11500	7.17
AW-105 Waste	695	728	13.81	32.3	6908	7.63
AN-107 Simulant	593	1406	14.81	1.1	9060	10.48
7 M Na AP-105 Simulant	609	1889	14.37	74.4	24300	5.41
7 M Na AP-105 Waste	660	1788	13.99	74.4	24275	5.26
AP-101 Simulant	610	1104	13.86	71.1	12000	6.64
AP-101 Waste	695	2930	22.19	66.6	13800	9.57

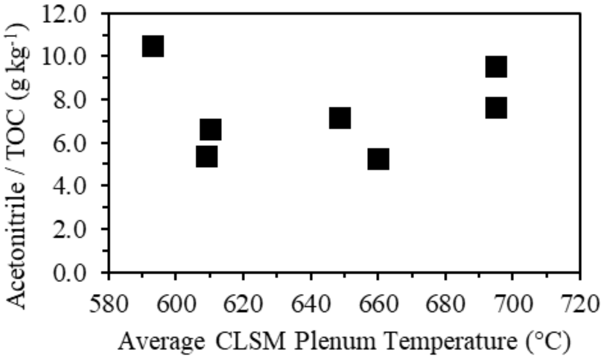

Figure 5.3. Acetonitrile production per TOC in the melter feed for all measured CLSM runs.

5.6 Production Comparison

Table 4.2 reported the production characteristics for both the AW-105 simulant and waste CLSM runs while Table 5.9 displays selected characteristics compared to previous, relevant CLSM runs (see Table 1.1 for references of each run). For the processing of AW-105, the simulant processed ~700 kg $m^{-2}\ d^{-1}$ faster than the waste in the CLSM. This pattern, that a simulant processes faster than the equivalent waste composition, has been the pattern with most feeds for which both a simulant and waste have been processed, except for 7 M Na AP-105. However, the fact that the AW-105 waste processed at the lowest end of expected CLSM glass production rates indicated that the cold cap was less thick than its maximum achievable size (without processing interruption) and that the glass production could have been increased by increasing the melter feed charging rate. The AW-105 waste was unique from all previous waste processed in the CLSM due to its concentration of potassium being one to two orders of magnitude greater. Despite this difference, the AW-105 waste has now been demonstrated to be able to be vitrified at a rate in the range expected based on other LAW processing, though it processed on the low end of the range.

Table 5.9. 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-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 ^{99}Tc retention while processing AP-105 melter feed during the changeover run is considered the best-case, single-pass retention.

As observed in Figure 5.4, 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 the AW-105 simulant melter feed had the hottest average plenum temperature of all previous simulant runs since the sim-CLSM was upgraded to a larger capacity furnace before the run.

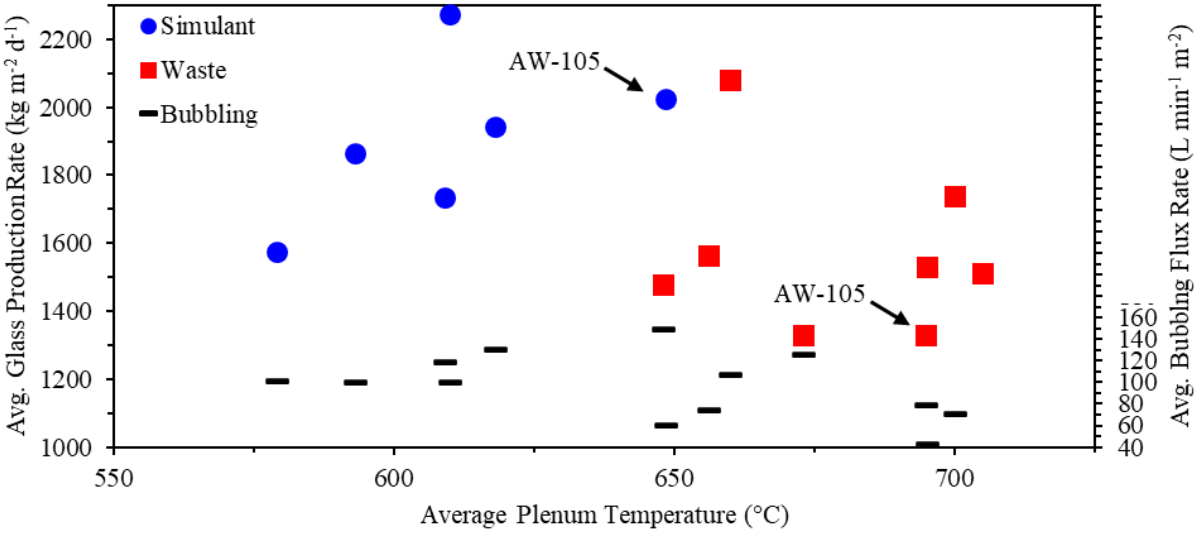

Figure 5.4. Comparison of average glass production rate vs plenum temperature for melter feeds processed in the CLSM.

6.0 Conclusions

A sample of AW-105 waste was procured by H2C and given to PNNL for processing through the RWTP. A simulant version of the AW-105 waste was designed based on the BBI of tank AW-105 (with the addition of a portion of AP-101 waste) and an assumed target dilution of the waste to a sodium molarity of 5.5 M. A glass composition was calculated for this AW-105 simulant from the Kim et al. (2012) glass models, GFCs were added to the simulant, and the resultant melter feed was processed in the sim-CLSM over a 6.91 h processing period, producing 6.59 kg of glass for an average glass production rate of 2023 kg m^2 d^{-1}. The simulant processing demonstrated that AW-105 melter feed could be vitrified without any aberrant behavior and defined the expected production ranges for waste processing.

The sample of AW-105 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-105 simulant were used for the formation of the AW-105 waste melter feed, except for sucrose addition since analysis of the AW-105 waste revealed it had lower NO_3 and NO_2 than estimated from the tank BBI. Over 8.56 h of processing, 5.36 kg of glass were produced for an average glass production rate of 1330 kg m^{-2} d^{-1} for AW-105 waste melter feed in the CLSM system. The average glass production rate for both the AW-105 simulant and waste melter feeds were in the range expected based on the processing of previous melter feeds, but the AW-105 waste melter feed was at the bottom of the range. It is suspected that while the AW-105 waste melter feed had adequate coverage over the glass melt surface (90 – 100 %), the cold cap was thinner than desired and that thickness could be increase by increasing charging rate without adverse effect to the cold cap. Overall, the objectives of the AW-105 vitrification were accomplished and through the offgas sampling and ^{99}Tc mass balance it was demonstrated that a high potassium concentration waste can be processed without an unexpected issue. Other conclusions from the AW-105 simulant and waste CLSM runs include:

- Most all the primary components in the glass produced during the CLSM runs were within 10 % of their targets based on the AW-105 glass compositions.

- Components recovered in the CLSM offgas system (Re, ^{99}Tc, Cs, I, S, K, Cl, and F) during the AW-105 simulant and waste runs were recovered in similar proportions and totals in each unit of the offgas system compared to previous CLSM runs.

- The relative chemical steady-state, single-pass retention of Re when processing the AW-105 simulant melter feed was 45 ± 1 %, which was equivalent to the retention of Re when processing AP-101 in the sim-CLSM.

- The relative chemical steady-state single-pass retention of ^{99}Tc when processing the AW-105 waste melter feed was 23 ± 2 %, which was equivalent to low-charging AP-105 processed in the rad-CLSM. It is believed that increased charging rate of AW-105 melter feed would increase the cold-cap thickness and ^{99}Tc retention would subsequently increase.

- The total retention of I when processing the AW-105 waste melter feed was 14 %, which was equivalent to the 7 M Na AP-105 run in the sim-CLSM.

- 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, $^{243/244}$Cm, ^{243}Am ^{238}Pu, and $^{239/240}$Pu) in the AW-105 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-105 waste reached ~100 % retention in the glass after 2 turnovers like what had been measured for previous wastes, the ^{241}Am differed from previous CLSM runs in that its retention was about 50%. This may indicate that the behavior of ^{241}Am is more susceptible to volatilization during a thin cold-cap situation than other radionuclides.

- Acetonitrile was detectable in the condensate and demister liquids collected from the CLSM system during the AW-105 simulant and waste runs in the same concentration ranges as previous CLSM runs. Considering the acetonitrile produced during CLSM runs with respect to the amount of total organic carbon in the melter feeds processed, instead of by sucrose in the melter feed as previously calculation, a range of production from 5 – 11 g-acetonitrile per kg-total organic carbon was identified.

7.0 References

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Appendix A – CLSM Glass Compositions and Chemical Analysis of Samples Collected from the AW-105 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-105 simulant and waste CLSM run that were sent to SwRI for analysis. Values colored 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	AN-107(a) (wt%)	AP-101-S(b) (wt%)	AP-101-W(b) (wt%)	AP-107-2R(c) (wt%)	AP-107-1R(d) (wt%)	AP-107(e) (wt%)	AP-105-7M(f) (wt%)	AP-105(g) (wt%)
Al_2O_3	6.12	6.13	6.12	6.13	6.13	6.12	6.13	6.13
B_2O_3	9.93	9.95	9.95	9.95	9.95	9.95	9.95	9.95
CaO	4.82	4.45	3.39	4.09	4.53	3.69	2.07	2.64
Cl	0.05	0.16	0.17	0.19	0.18	0.15	0.24	0.22
Cr_2O_3	0.02	0.09	0.08	0.08	0.07	0.08	0.06	0.06
F	0.00	0.01	0.00	0.03	0.03	0.00	0.00	0.00
Fe_2O_3	5.51	5.52	5.52	5.52	5.52	5.52	5.52	5.52
K_2O	0.09	0.39	0.47	0.49	0.36	0.47	0.51	0.49
Li_2O	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
Na_2O	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	0.02
P_2O_5	0.11	0.12	0.10	0.16	0.19	0.15	0.10	0.11
SO_3	0.40	0.39	0.36	0.38	0.39	0.37	0.29	0.33
SiO_2	45.68	45.49	46.45	45.60	45.36	46.08	44.73	45.76
TiO_2	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
ZrO_2	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

(a) Dixon et al. (2024)
(b) Dixon et al. (2022b)
(c) Dixon et al. (2022a)
(d) Dixon et al. (2020b)
(e) Dixon et al. (2019)
(f) Dixon et al. (2023)
(g) Dixon et al. (2018)

Table A.2. Chemical Analysis of Samples Produced During the AW-105 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-105 Melter Feed	16.42	3.42	0.190	51.8	0.950	13250	2.85	12750	3.86	0.950	9.50	5945
Glass Pour (Initial)	0.06	3.80	0.198	5.01	49.5	30200	4.76	29800	8.34	0.990	439	18800
Glass Pour (2.45 h)	2.43	2.97	0.198	12.8	49.4	30900	2.96	34900	8.54	0.988	206	15200
Glass Pour (3.58 h)	0.84	3.74	0.194	9.86	48.4	30300	2.91	30900	8.62	0.969	231	14700
Glass Pour (4.63 h)	1.23	3.80	0.193	16.8	48.3	30700	2.90	31200	8.80	0.966	199	14200
Glass Pour (6.73 h)	1.65	3.48	0.198	19.1	49.5	31300	2.97	33950	8.83	0.990	188	13950
Glass Pour (7.09 h)	0.65	3.90	0.199	20.0	49.8	31000	2.99	34600	9.05	0.995	123	14000
Glass Pour (Final)	1.73	3.75	0.197	24.0	49.2	31400	2.95	31300	8.73	0.984	135	13900
Primary HEPA Filter	0.016	3.79	0.392	4.70	0.978	11750	2.94	12100	17600	0.978	9.78	5135
Sampling HEPA Filter 1	0.016	27.5	0.370	4.78	1.21	11500	3.00	12400	17000	0.999	9.99	4960
Sampling HEPA Filter 2	0.016	47.9	0.364	4.31	1.17	11400	2.97	12400	17000	0.990	9.90	4920
Sampling HEPA Filter 3	0.017	26.0	0.351	27.8	2.25	11100	2.91	14500	16500	0.970	9.70	4720
Pre-Filter	0.28	7.35	0.0216	11.5	0.398	6.35	0.325	88.7	0.108	0.108	1.08	2.65
Condensate	7.14	2.28	0.0996	57.6	0.498	71.4	1.49	209	0.498	0.498	16.9	50.0
Primary Offgas Wash	0.25	15.1	0.0986	1.45	2.31	203	1.48	440	0.493	0.493	16.2	264
Sampling Offgas Wash	0.13	4.47	0.0997	2.01	0.499	83.3	1.50	185	0.499	0.499	4.99	29.4
Primary SBS Sump	1.20	2.61	0.0995	93.6	0.497	30.7	1.49	218	0.497	0.497	4.97	9.74
Demister	0.72	2.28	0.0958	104	0.479	57.2	1.44	225	0.479	0.479	35.8	25.0
Pre-Filter Fluid	0.03	5.10	0.0768	272	3.16	38.0	1.15	124	0.384	0.384	28.9	32.1

Table A.2. Chemical Analysis of Samples Produced During the AW-105 Simulant CLSM Run (cont.)

	Component Concentration (mg kg^{-1})											
Sample Name	Cd	Co	Cr	Cu	Fe	K	La	Li	Mg	Mn	Mo	Na
AW-105 Melter Feed	0.950	1.03	216	5.55	15650	8985	1.33	2.85	3800	54.4	2.50	62550
Glass Pour (Initial)	0.990	0.99	1700	17.5	39500	3690	2.13	256	7340	427	9.10	160000
Glass Pour (2.45 h)	0.988	0.988	997	15.9	38600	13300	2.76	67.5	8250	220	7.05	152000
Glass Pour (3.58 h)	0.969	0.969	889	15.8	38700	16200	2.92	44.1	8480	191	6.59	152000
Glass Pour (4.63 h)	0.966	0.966	745	15.6	38800	18600	3.02	25.9	8560	170	6.38	151000
Glass Pour (6.73 h)	0.990	0.990	661	14.9	38300	19500	3.09	14.6	8670	153	5.96	150500
Glass Pour (7.09 h)	0.995	0.995	662	15.0	38500	19600	3.15	12.9	8700	152	5.92	150000
Glass Pour (Final)	0.984	0.984	634	15.0	38300	20100	3.13	12.6	8670	149	6.03	151000
Primary HEPA Filter	0.978	0.978	93.3	2.49	303	9790	0.978	2.94	623	7.25	40.7	25850
Sampling HEPA Filter 1	0.999	0.999	137	1.79	518	11500	0.999	3.00	599	6.55	35.0	31500
Sampling HEPA Filter 2	0.990	0.990	143	1.34	384	11800	0.990	3.04	598	5.86	35.2	30800
Sampling HEPA Filter 3	0.970	2.80	278	6.18	1100	11200	0.970	4.59	589	32.4	35.7	30900
Pre-Filter	0.108	0.169	17.1	0.171	26.8	527	0.108	0.325	0.541	0.309	0.615	1380
Condensate	0.498	0.498	10.4	0.498	95.6	237	0.498	1.49	2.49	3.56	0.498	935
Primary Offgas Wash	0.493	0.493	44.6	0.493	556	1320	0.493	7.83	38.2	3.89	1.10	5230
Sampling Offgas Wash	0.499	0.499	21.6	0.531	293	446	0.499	1.50	3.44	2.06	0.503	2040
Primary SBS Sump	0.497	0.497	9.77	0.497	60.2	276	0.497	1.49	2.49	0.497	0.497	922
Demister	0.479	0.479	16.9	0.479	149	236	0.479	1.44	2.40	3.44	0.873	982
Pre-Filter Fluid	0.384	6.72	427	10.7	1930	279	0.384	2.44	3.03	40.3	50.4	996

Table A.2. Chemical Analysis of Samples Produced During the AW-105 Simulant CLSM Run (cont.)

	Component Concentration (mg kg^{-1})											
Sample Name	Ni	P	Pb	Pd	S	Sb	Se	Si	Sn	Sr	Th	Ti
AW-105 Melter Feed	35.9	212	1.90	2.85	551	2.85	3.80	86650	5.70	4.63	9.50	3470
Glass Pour (Initial)	3600	1010	160	29.7	2130	2.97	39.6	208000	48.0	9.25	9.90	5780
Glass Pour (2.45 h)	1640	690	50.7	29.6	1520	2.96	39.5	207000	30.9	10.2	9.88	8170
Glass Pour (3.58 h)	1370	659	32.0	29.1	1440	2.91	38.8	202000	26.3	10.7	9.69	8240
Glass Pour (4.63 h)	1030	638	19.5	29.0	1420	2.90	38.6	204000	22.6	10.8	9.66	8260
Glass Pour (6.73 h)	726	614	10.6	29.7	1360	2.97	39.6	208000	19.2	11.0	9.90	8425
Glass Pour (7.09 h)	682	616	9.50	29.9	1340	2.99	39.8	206000	19.0	10.9	9.95	8420
Glass Pour (Final)	593	614	8.85	29.5	1380	2.95	39.4	206000	18.9	11.0	9.84	8420
Primary HEPA Filter	25.2	15.1	7.23	2.94	234	2.94	3.91	399500	5.87	269	9.78	23.7
Sampling HEPA Filter 1	5.42	30.2	8.79	3.00	543	3.00	4.00	395000	5.99	259	9.99	27.7
Sampling HEPA Filter 2	3.89	28.8	7.12	2.97	528	2.97	3.96	397000	5.94	257	9.90	27.4
Sampling HEPA Filter 3	162	32.9	8.96	2.91	547	2.91	3.88	384000	5.82	247	9.70	29.5
Pre-Filter	2.32	1.08	0.276	0.325	77.6	0.325	0.433	1.08	0.649	0.108	1.08	0.123
Condensate	1.54	6.62	9.65	1.49	37.6	1.49	1.99	72.3	2.99	0.498	4.98	2.44
Primary Offgas Wash	7.16	18.6	10.9	1.48	228	1.48	1.97	412	2.96	0.493	4.93	22.0
Sampling Offgas Wash	34.6	8.24	2.185	1.50	72.9	1.50	2.00	106	2.99	0.499	4.99	10.4
Primary SBS Sump	0.497	4.97	0.995	1.49	35.5	1.49	1.99	53.3	2.98	0.497	4.97	3.24
Demister	5.55	11.8	11.8	1.44	40.6	1.44	1.92	60.7	2.88	0.479	4.79	3.52
Pre-Filter Fluid	256	6.48	11.4	1.15	66.3	1.15	1.54	6.91	2.30	0.384	3.84	2.09

Table A.2. Chemical Analysis of Samples Produced During the AW-105 Simulant CLSM Run (cont.)

	Component Concentration (mg kg^{-1})											
Sample Name	Tl	U	V	W	Y	Zn	Zr	Br	Cl	F	N as NO_3	N as NO_2
AW-105 Melter Feed	9.50	95.0	5.69	95.0	1.87	11050	9055	88.4	1345	631	18850	3725
Glass Pour (Initial)	99.0	99.0	2200	99.0	28.0	25900	14800	185	1700	1780	--	--
Glass Pour (2.45 h)	98.8	98.8	586	98.8	38.2	30400	21100	225	2920	1210	--	--
Glass Pour (3.58 h)	96.9	96.9	380	96.9	41.1	27600	21300	198	2490	1180	--	--
Glass Pour (4.63 h)	96.6	96.6	241	96.6	42.5	27000	21500	201	2670	1190	--	--
Glass Pour (6.73 h)	99.0	99.0	147	99.0	43.7	29800	21550	242	2595	1220	--	--
Glass Pour (7.09 h)	99.5	99.5	136	99.5	44.0	30000	21500	200	2500	1210	--	--
Glass Pour (Final)	98.4	98.4	129	98.4	43.8	27400	21400	245	2660	1220	--	--
Primary HEPA Filter	9.78	97.8	0.978	97.8	2.35	11850	78.2	9.76	9.76	44.3	643	9.76
Sampling HEPA Filter 1	9.99	99.9	0.999	99.9	2.31	11300	87.8	9.56	4760	777	2330	9.56
Sampling HEPA Filter 2	9.90	99.0	0.990	99.0	2.31	10900	82.3	9.89	5480	1170	1370	21.9
Sampling HEPA Filter 3	9.70	97.0	5.49	97.0	2.25	11700	84.8	9.68	5245	987	2620	9.68
Pre-Filter	1.08	1.08	0.247	1.08	0.108	7.82	0.325	10.8	13.1	136	6115	10.8
Condensate	4.98	4.98	8.36	4.98	0.498	69.6	10.3	96.8	450	200	4405	96.8
Primary Offgas Wash	4.93	4.93	12.8	4.93	0.493	446	143	96.6	2190	1590	1570	96.6
Sampling Offgas Wash	4.99	4.99	3.83	4.99	0.499	218	8.45	97.4	722	224	724	148
Primary SBS Sump	4.97	4.97	0.959	4.97	0.497	64.8	3.71	96.0	600	155	3620	96.0
Demister	4.79	4.79	14.4	4.79	0.479	73.7	17.7	94.2	481	201	19700	94.2
Pre-Filter Fluid	3.84	3.84	22.5	3.84	0.384	14.9	20.8	74.2	81.2	233	110000	74.2

Table A.2. Chemical Analysis of Samples Produced During the AW-105 Simulant CLSM Run (cont.)

	Component Concentration (mg kg^{-1})					Component Concentration (µg L^{-1})	Ash (%)	Loss on Ignition (%)
Sample Name	P as PO_4	Total S (Solids) or SO_4 (All Others)	TOC	TIC	Carbonate	Acetonitrile	--	--
AW-105 Melter Feed	88.4	1710	11500	10600	53000		42.28	57.72
Glass Pour (Initial)	--	2090	--	--	--		97.31	2.69
Glass Pour (2.45 h)	--	1600	--	--	--		97.08	2.92
Glass Pour (3.58 h)	--	1570	--	--	--		96.72	3.28
Glass Pour (4.63 h)	--	1460	--	--	--		96.92	3.08
Glass Pour (6.73 h)	--	1470	--	--	--		96.88	3.12
Glass Pour (7.09 h)	--	1400	--	--	--		96.39	3.61
Glass Pour (Final)	--	1450	--	--	--		96.69	3.31
Primary HEPA Filter	9.76	48.5	--	--	--		97.71	2.30
Sampling HEPA Filter 1	9.56	1010	--	--	--		96.06	3.94
Sampling HEPA Filter 2	9.89	1080	--	--	--		96.76	3.24
Sampling HEPA Filter 3	9.68	810	--	--	--		93.74	6.26
Pre-Filter	10.8	578	--	--	--	--	--	--
Condensate	96.8	154	175	--	--	130000	--	--
Primary Offgas Wash	96.6	754	22.3	--	--	--	--	--
Sampling Offgas Wash	97.4	219	20.1	--	--	--	--	--
Primary SBS Sump	96.0	113	204	--	--	--	--	--
Demister	94.2	141	300	--	--	430000	--	--
Pre-Filter Fluid	74.2	273	545	--	--	--	--	--

Table A.3. Chemical Analysis of Samples Produced During the AW-105 Waste CLSM Run

	Sample Mass	Component Concentration (mg kg^{-1})										
Sample Name	(kg)	^{99}Tc	Total Cs	Total I	Ag	Al	As	B	Ba	Be	Bi	Ca
AW-105 Melter Feed 1	13.81	1.54	0.188	0.943	0.940	12350	2.82	14100	4.96	0.940	9.40	6060
AW-105 Melter Feed 2	--	1.49	0.192	0.981	0.958	11700	2.87	13900	5.07	0.978	9.58	6090
Glass Pour (Initial)	0.19	0.0781	0.266	14.5	44.1	29900	2.64	32700	8.96	0.882	123	13900
Glass Pour (2.78 h)	1.70	0.846	0.174	3.30	43.4	29300	2.60	33400	9.72	1.90	54.7	13700
Glass Pour (3.74 h)	0.81	0.781	0.186	2.37	46.5	29200	2.79	33200	9.98	2.05	44.0	13800
Glass Pour (5.24 h)	1.17	0.935	0.166	0.952	41.4	29100	2.49	32200	10.5	2.44	32.3	14000
Glass Pour (6.76 h)	1.02	0.95	0.175	0.941	43.7	28800	2.62	32500	10.4	2.46	22.1	14000
Glass Pour (8.23 h)	0.98	0.989	0.179	0.898	44.7	28700	2.68	32100	10.6	2.50	21.1	14000
Glass Pour (Final)	1.45	1.08	0.178	0.676	44.4	27650	2.66	32150	10.6	2.66	18.1	13950
Primary HEPA Filter A	0.016	1.79	0.892	0.783	0.959	11200	2.88	14000	18400	0.959	9.59	5390
Sampling HEPA Filter 1	0.016	28.0	0.994	4.30	0.948	10600	2.85	13350	17200	0.948	9.48	5020
Sampling HEPA Filter 2	0.015	16.7	0.579	16.1	0.801	6310	2.40	8840	9470	0.801	8.01	2710
Sampling HEPA Filter 3	0.016	21.1	0.948	1.96	0.966	10800	2.90	12500	16900	0.966	9.66	4790
Pre-filter	0.25	4.77	0.312	0.459	0.173	2.99	0.217	129	0.0724	0.0724	0.724	2.84
Primary SBS Sump	1.00	1.61	0.0995	2.49	0.498	10.7	1.49	134	0.498	0.498	4.98	4.98
Sampling SBS Sump	1.29	0.0543	0.100	0.533	0.502	2.51	1.51	17.0	0.502	0.502	5.02	5.02
Condensate	6.21	0.913	0.108	4.23	0.496	12.6	1.49	93.0	0.496	0.496	4.96	8.85
Demister	0.41	1.21	0.112	5.05	0.475	14.4	1.42	114	0.475	0.475	4.75	10.9
Pre-filter fluid	0.03	6.22	1.27	8.49	0.399	39.9	1.17	391	0.389	0.389	3.89	10.1

Table A.3. Chemical Analysis of Samples Produced During the AW-105 Waste CLSM Run (cont.)

	Component Concentration (mg kg^{-1})											
Sample Name	Cd	Co	Cr	Cu	Fe	K	La	Li	Mg	Mn	Mo	Na
AW-105 Melter Feed 1	0.940	1.37	212	0.940	15500	10250	1.22	3.76	3930	50.1	9.04	62000
AW-105 Melter Feed 2	0.958	1.16	208	0.958	15300	10500	1.37	3.83	3620	48.7	9.37	63300
Glass Pour (Initial)	8.82	0.882	1020	19.4	36500	19700	3.06	12.8	8620	175	6.99	143000
Glass Pour (2.78 h)	8.68	0.868	686	7.35	36400	21800	3.05	6.28	8810	147	14.7	141000
Glass Pour (3.74 h)	9.30	0.930	630	6.11	36500	21600	3.08	4.77	8850	140	15.4	141000
Glass Pour (5.24 h)	8.29	0.829	661	5.17	37300	23300	3.06	4.49	8900	139	18.6	145000
Glass Pour (6.76 h)	8.75	0.875	632	3.65	36700	23300	2.97	3.50	8850	132	19.7	144000
Glass Pour (8.23 h)	8.94	0.894	641	3.36	36400	23500	3.01	3.58	8840	130	20.3	143000
Glass Pour (Final)	8.88	0.888	627	3.10	36850	24200	2.99	3.55	8980	130	21.4	145000
Primary HEPA Filter A	0.959	9.59	97.3	0.959	166	10200	0.959	3.83	633	6.26	36.8	26200
Sampling HEPA Filter 1	0.948	9.48	164	1.09	316	13050	0.948	3.80	572	7.17	41.8	32000
Sampling HEPA Filter 2	0.801	8.01	93.6	0.822	250	7050	0.801	3.20	313	5.26	15.2	18400
Sampling HEPA Filter 3	0.966	9.66	142	1.58	256	11400	0.966	3.86	545	5.07	21.4	29400
Pre-filter	0.0724	0.140	34.7	0.440	44.8	714	0.0724	0.290	0.944	0.581	1.30	1180
Primary SBS Sump	0.498	0.498	8.90	0.498	18.5	260	0.498	1.99	2.49	0.498	0.498	625
Sampling SBS Sump	0.502	0.502	3.47	0.502	16.5	10.0	0.502	2.01	2.51	0.520	0.502	22.6
Condensate	0.496	0.496	9.51	0.496	24.3	156	0.496	1.98	2.48	0.496	0.496	565
Demister	0.475	0.475	12.8	0.475	46.9	178	0.475	1.90	3.98	0.475	0.476	626
Pre-filter fluid	0.389	11.9	1000	21.2	3890	418	0.389	1.71	2.66	72.8	114	2690

Table A.3. Chemical Analysis of Samples Produced During the AW-105 Waste CLSM Run (cont.)

	Component Concentration (mg kg^{-1})											
Sample Name	Ni	P	Pb	Pd	S	Sb	Se	Si	Sn	Sr	Th	Ti
AW-105 Melter Feed 1	37.4	206	2.46	2.82	633	1.88	3.76	83300	31.5	7.97	9.40	3510
AW-105 Melter Feed 2	34.4	215	2.65	2.87	663	1.92	3.83	80600	32.8	8.15	9.58	3430
Glass Pour (Initial)	837	629	8.70	26.4	1380	1.76	35.3	194000	21.7	11.2	88.2	8260
Glass Pour (2.78 h)	402	576	7.03	26.0	1440	1.74	34.7	197000	54.7	15.9	86.8	8210
Glass Pour (3.74 h)	344	562	7.12	27.9	1420	1.86	37.2	199000	60.3	16.7	93.0	8220
Glass Pour (5.24 h)	259	580	6.77	24.9	1530	1.66	33.2	199000	68.9	18.3	82.9	8110
Glass Pour (6.76 h)	204	564	6.86	26.2	1530	1.75	35.0	198000	72.2	18.8	87.5	8030
Glass Pour (8.23 h)	176	563	6.99	26.8	1530	1.79	35.8	198000	74.6	19.0	89.4	8000
Glass Pour (Final)	186	570	6.65	26.6	1570	1.78	35.5	189500	75.8	19.1	88.8	7725
Primary HEPA Filter A	3.35	18.7	8.42	2.88	280	1.92	3.83	369000	5.75	285	9.59	25.4
Sampling HEPA Filter 1	9.34	43.7	7.07	2.85	630	1.90	3.80	358000	5.69	268	9.48	29.4
Sampling HEPA Filter 2	13.4	27.5	3.53	2.40	333	1.60	3.20	209000	4.80	146	8.01	18.6
Sampling HEPA Filter 3	9.52	39.9	8.17	2.90	582	1.93	3.86	366000	6.15	260	9.66	26.8
Pre-filter	5.45	3.29	0.145	0.217	63.1	0.145	2.90	0.752	0.435	0.0724	0.724	0.0814
Primary SBS Sump	0.498	4.98	0.995	1.49	33.7	0.995	1.99	33.0	2.99	0.498	4.98	1.77
Sampling SBS Sump	2.20	5.02	1.00	1.51	5.02	1.00	2.01	5.02	3.01	0.502	5.02	0.502
Condensate	0.778	4.96	0.992	1.49	28.2	0.992	1.98	28.2	2.98	0.496	4.96	1.60
Demister	2.19	4.75	0.950	1.42	30.0	0.950	1.90	29.1	2.85	0.475	4.75	2.71
Pre-filter fluid	591	7.59	0.779	1.17	177	0.779	1.56	4.95	2.34	0.389	3.89	2.98

Table A.3. Chemical Analysis of Samples Produced During the AW-105 Waste CLSM Run (cont.)

	Component Concentration (mg kg^{-1})											
Sample Name	Tl	U	V	W	Y	Zn	Zr	Br	Cl	F	N as NO_3	N as NO_2
AW-105 Melter Feed 1	9.40	9.40	4.98	94.0	1.39	12200	8955	141	1230	689	15200	8800
AW-105 Melter Feed 2	9.58	9.58	5.67	95.8	1.44	12000	8610	135	1050	665	13300	7930
Glass Pour (Initial)	441	88.2	132	88.2	43.9	29100	20900	241	2600	1140	--	--
Glass Pour (2.78 h)	434	86.8	90.4	86.8	44.2	29900	21100	224	1950	1100	--	--
Glass Pour (3.74 h)	465	93.0	83.8	93.0	44.3	29700	21100	244	2200	1140	--	--
Glass Pour (5.24 h)	414	82.9	76.4	82.9	45.5	28900	21100	238	2030	1130	--	--
Glass Pour (6.76 h)	437	87.5	70.5	87.5	45.1	29100	20900	235	2180	1160	--	--
Glass Pour (8.23 h)	447	89.4	67.8	89.4	44.9	28600	20800	224	1970	1150	--	--
Glass Pour (Final)	444	88.8	67.6	88.8	45.0	28750	20100	169	1865	1165	--	--
Primary HEPA Filter A	9.59	9.59	0.959	95.9	2.48	14100	83.5	8.71	8.71	19.1	940	8.71
Sampling HEPA Filter 1	9.48	9.48	0.948	94.8	2.38	12600	85.2	58.9	6460	549	1370	634
Sampling HEPA Filter 2	8.01	8.01	0.801	80.1	1.33	8140	52.8	28.6	3460	191	1720	1020
Sampling HEPA Filter 3	9.66	9.66	0.966	96.6	2.57	12800	83.8	37.9	5170	371	1700	345
Pre-filter	0.724	0.724	0.0724	0.724	0.0724	2.95	0.217	14.5	25.5	44.8	5010	14.5
Primary SBS Sump	4.98	4.98	0.498	4.98	0.498	19.9	2.78	97.0	473	97.0	4215	97.0
Sampling SBS Sump	5.02	5.02	0.502	5.02	0.502	2.90	1.51	97.3	97.3	97.3	611	97.3
Condensate	4.96	4.96	0.496	4.96	0.496	22.2	2.60	96.5	309	96.5	4490	96.5
Demister	4.75	4.75	0.475	4.75	0.475	25.4	3.47	91.4	430	91.4	23900	91.4
Pre-filter fluid	3.89	3.89	4.19	4.31	0.389	58.1	3.71	76.3	299	146	99600	76.3

Table A.3. Chemical Analysis of Samples Produced During the AW-105 Waste CLSM Run (cont.)

	Component Concentration (mg kg^{-1})					Component Concentration (µg L^{-1})	Component Concentration (pCi g^{-1})			
Sample Name	P as PO_4	Total S (Solids) or SO_4 (All Others)	TOC	TIC	Carbonate	Acetonitrile	^{241}Am	^{243}Am	^{242}Cm	^{244}Cm
AW-105 Melter Feed 1	141	2365	6945	5855	29500	--	7.61E+01	3.70E+00	8.22E-02	1.35E+00
AW-105 Melter Feed 2	135	2100	6870	5530	27700	--	5.96E+01	5.71E+00	0.00E+00	1.87E+00
Glass Pour (Initial)	--	2280	--	--	--	--	1.25E+00	2.24E-01	1.63E-01	0.00E+00
Glass Pour (2.78 h)	--	2110	--	--	--	--	6.56E+01	1.28E+00	3.16E-01	3.44E+00
Glass Pour (3.74 h)	--	2310	--	--	--	--	7.89E+01	7.27E+00	1.68E-01	1.27E+00
Glass Pour (5.24 h)	--	2000	--	--	--	--	8.57E+01	9.34E+00	3.09E-01	3.21E+00
Glass Pour (6.76 h)	--	1850	--	--	--	--	8.72E+01	6.74E+00	4.57E-01	2.02E+00
Glass Pour (8.23 h)	--	2250	--	--	--	--	8.70E+01	7.67E+00	4.82E-01	2.73E+00
Glass Pour (Final)	--	1585	--	--	--	--	9.85E+01	2.82E+00	4.12E-01	3.15E+00
Primary HEPA Filter A	8.71	151	--	--	--	--	6.66E-01	0.00E+00	0.00E+00	1.65E-01
Sampling HEPA Filter 1	19.2	1130	--	--	--	--	2.75E+00	4.84E-01	0.00E+00	3.98E-02
Sampling HEPA Filter 2	17.5	660	--	--	--	--	8.31E+00	1.40E-01	0.00E+00	-7.61E-02
Sampling HEPA Filter 3	19.1	1000	--	--	--	--	5.44E+00	6.57E-01	0.00E+00	0.00E+00
Pre-filter	14.5	505	--	--	--	--	1.39E-01	0.00E+00	0.00E+00	0.00E+00
Primary SBS Sump	97.0	108	111	--	--	--	1.43E+00	0.00E+00	9.22E-02	8.52E-02
Sampling SBS Sump	97.3	97.3	43.4	--	--	--	4.19E-02	1.71E-01	0.00E+00	-8.30E-02
Condensate	96.5	96.5	140	--	--	96000	4.40E+00	9.53E-01	0.00E+00	0.00E+00
Demister	91.4	102	226	--	--	160000	7.04E+00	2.43E-01	0.00E+00	1.66E-01
Pre-filter fluid	76.3	558	330	--	--	--	7.31E+00	9.05E-01	2.14E-01	4.41E-01

Table A.3. Chemical Analysis of Samples Produced During the AW-105 Waste CLSM Run (cont.)

	Component Concentration (pCi g^{-1})				Ash (%)	Loss on Ignition (%)
Sample Name	^{237}Np	^{238}Pu	$^{239/240}$Pu	^{244}Pu	--	--
AW-105 Melter Feed 1	9.53E-01	5.23E+00	2.77E+01	6.20E-01	41.13	58.88
AW-105 Melter Feed 2	1.91E+00	6.94E+00	3.17E+01	4.63E-01	40.99	59.01
Glass Pour (Initial)	0.00E+00	9.27E+00	1.52E+01	7.41E-01	97.08	2.92
Glass Pour (2.78 h)	2.44E+00	1.39E+01	3.95E+01	9.47E-01	96.38	3.62
Glass Pour (3.74 h)	3.19E+00	1.07E+01	4.62E+01	4.41E-01	98.19	1.81
Glass Pour (5.24 h)	3.09E+00	2.38E+01	5.15E+01	1.50E+00	97.70	2.30
Glass Pour (6.76 h)	3.33E+00	2.08E+01	5.59E+01	2.07E+00	96.71	3.29
Glass Pour (8.23 h)	4.36E+00	2.22E+01	6.72E+01	5.77E-01	95.97	4.03
Glass Pour (Final)	2.73E+00	1.05E+01	5.29E+01	5.65E-01	97.18	2.82
Primary HEPA Filter A	0.00E+00	-9.96E-02	1.89E+00	8.97E-01	96.26	3.74
Sampling HEPA Filter 1	4.13E-02	1.71E-01	6.22E-01	1.96E+00	95.84	4.16
Sampling HEPA Filter 2	-6.97E-02	3.22E-01	1.61E+00	4.83E-01	55.64	44.36
Sampling HEPA Filter 3	-2.70E-01	2.01E-01	1.01E+00	2.21E+00	96.50	3.50
Pre-filter	-6.31E-03	0.00E+00	4.78E-02	5.46E-02	--	--
Primary SBS Sump	-2.82E-02	3.02E-01	5.94E-01	9.24E-01	--	--
Sampling SBS Sump	1.63E-01	-5.18E-02	2.07E-01	9.33E-01	--	--
Condensate	0.00E+00	5.24E-02	8.91E-01	4.19E-01	--	--
Demister	0.00E+00	1.79E-01	1.62E+00	9.86E-01	--	--
Pre-filter fluid	3.66E-02	2.07E-01	1.17E+00	3.45E-01	--	--

Appendix B – Compositional Trends in Glass Pours from the AW-105 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-105 simulant CLSM run, and the label 'Waste' displays results from the AW-105 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 (▬), and the expected component content in the glass based on the analyzed melter feed samples as a red, solid line (–). 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.

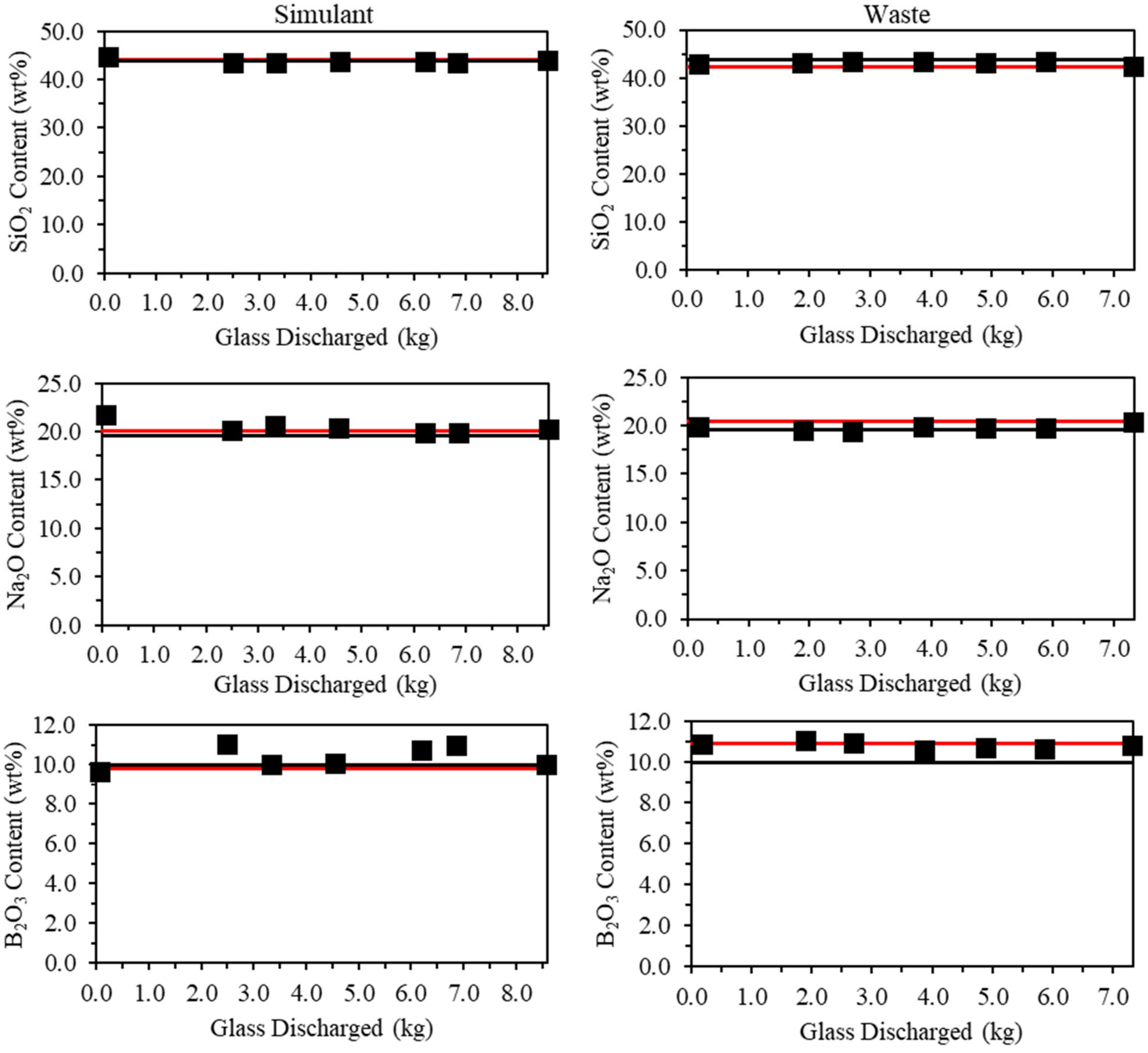

Figure B.1. Content of a set of components (SiO_2, Na_2O, and B_2O_3) in the glass produced during CLSM runs with AW-105 simulant and AW-105 waste melter feeds.

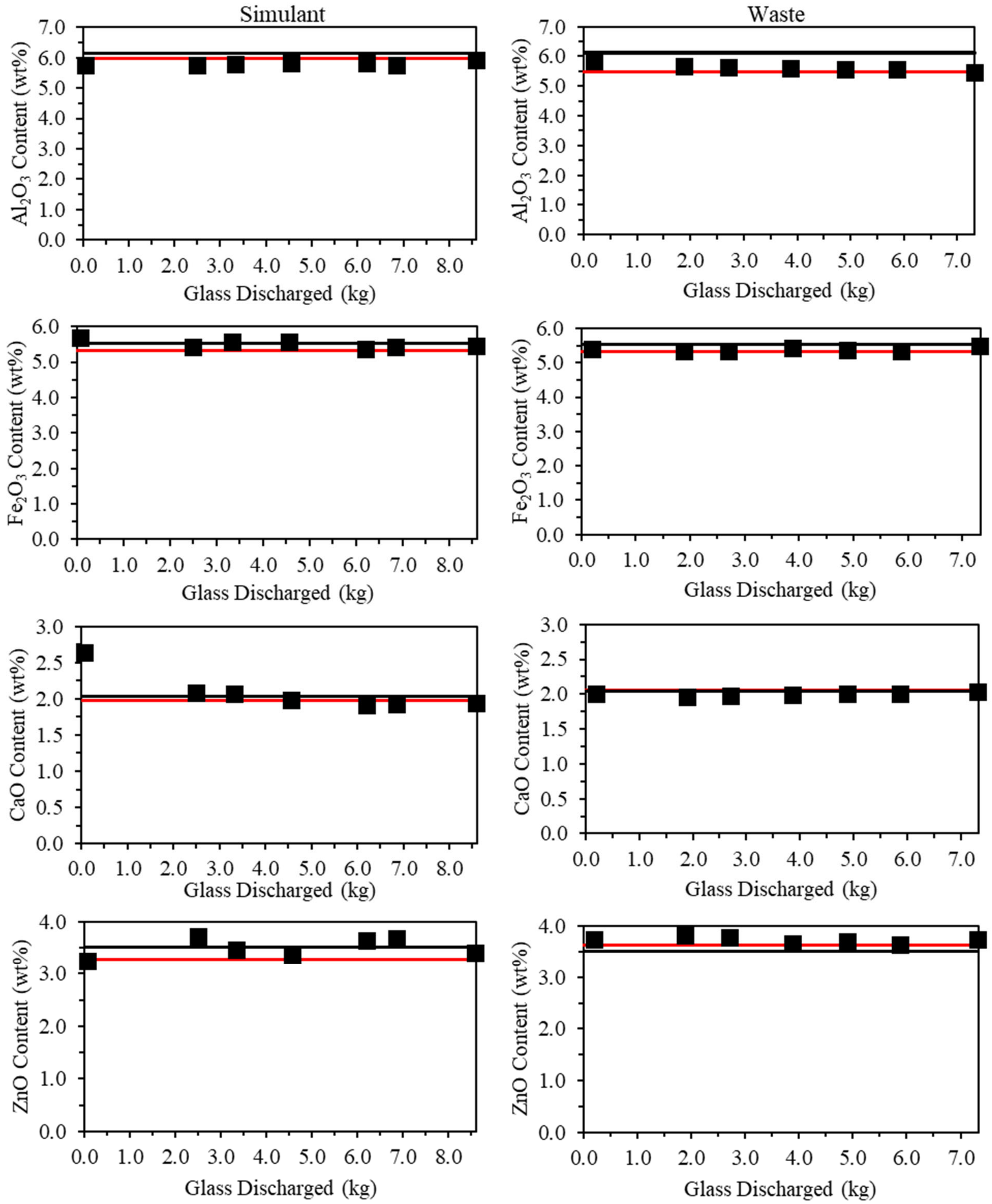

Figure B.2. Content of a set of components (Al_2O_3, Fe_2O_3, CaO, and ZnO) in the glass produced during CLSM runs with AW-105 simulant and AW-105 waste melter feeds.

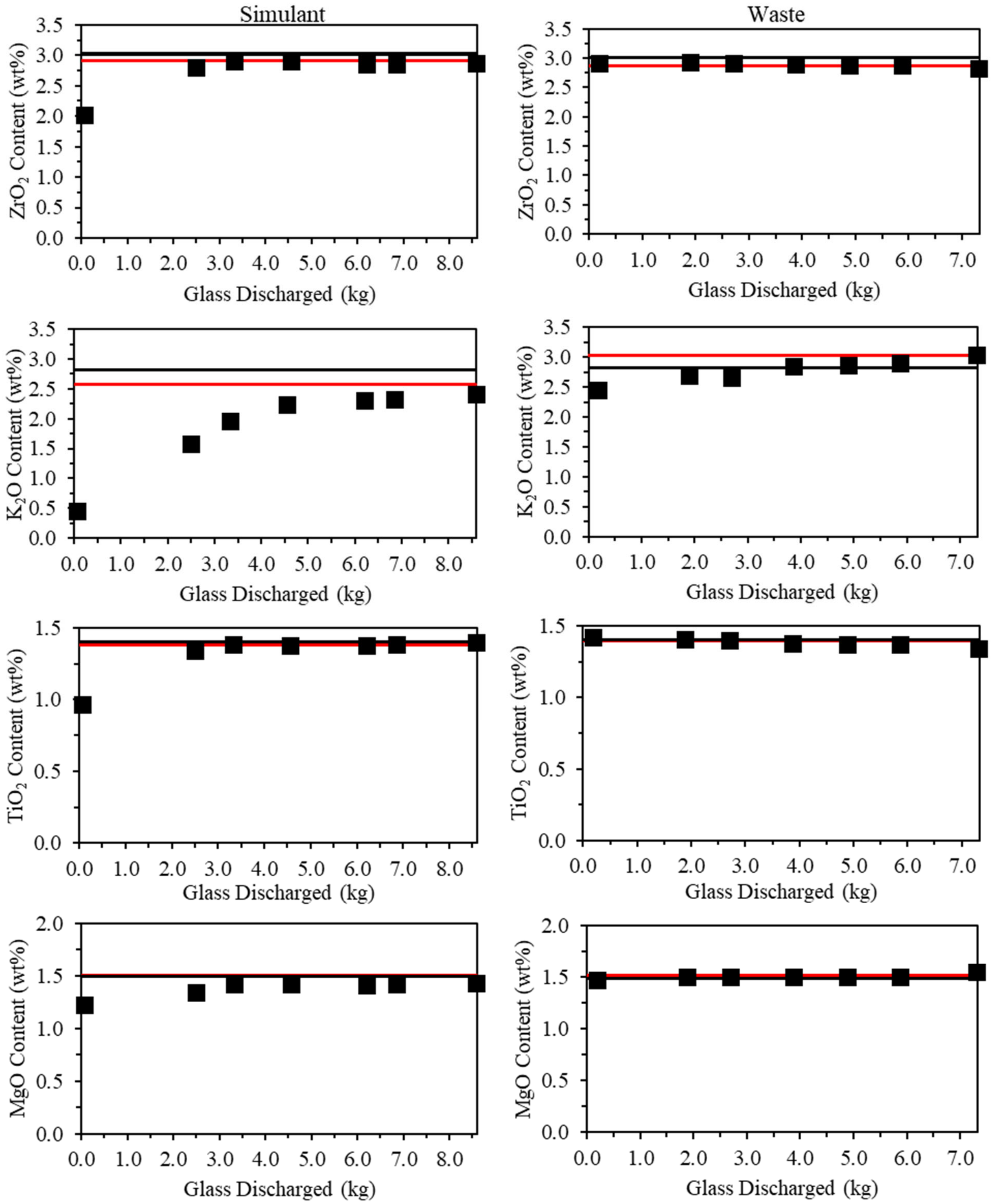

Figure B.3. Content of a set of components (ZrO_2, K_2O, TiO_2, and MgO) in the glass produced during CLSM runs with AW-105 simulant and AW-105 waste melter feeds.

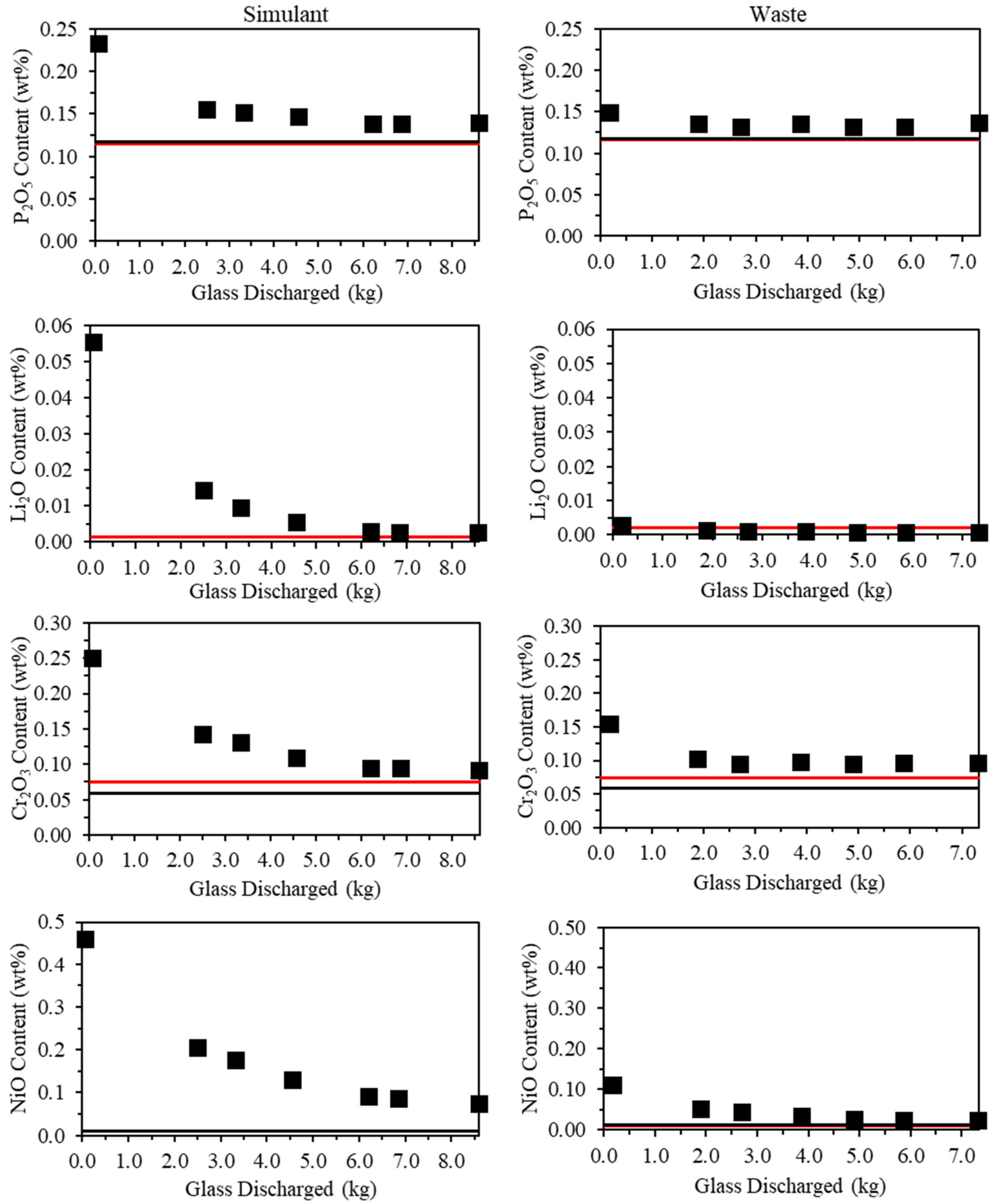

Figure B.4. Content of a set of components (P_2O_5, Li_2O, Cr_2O_3, and NiO) in the glass produced during CLSM runs with AW-105 simulant and AW-105 waste melter feeds.

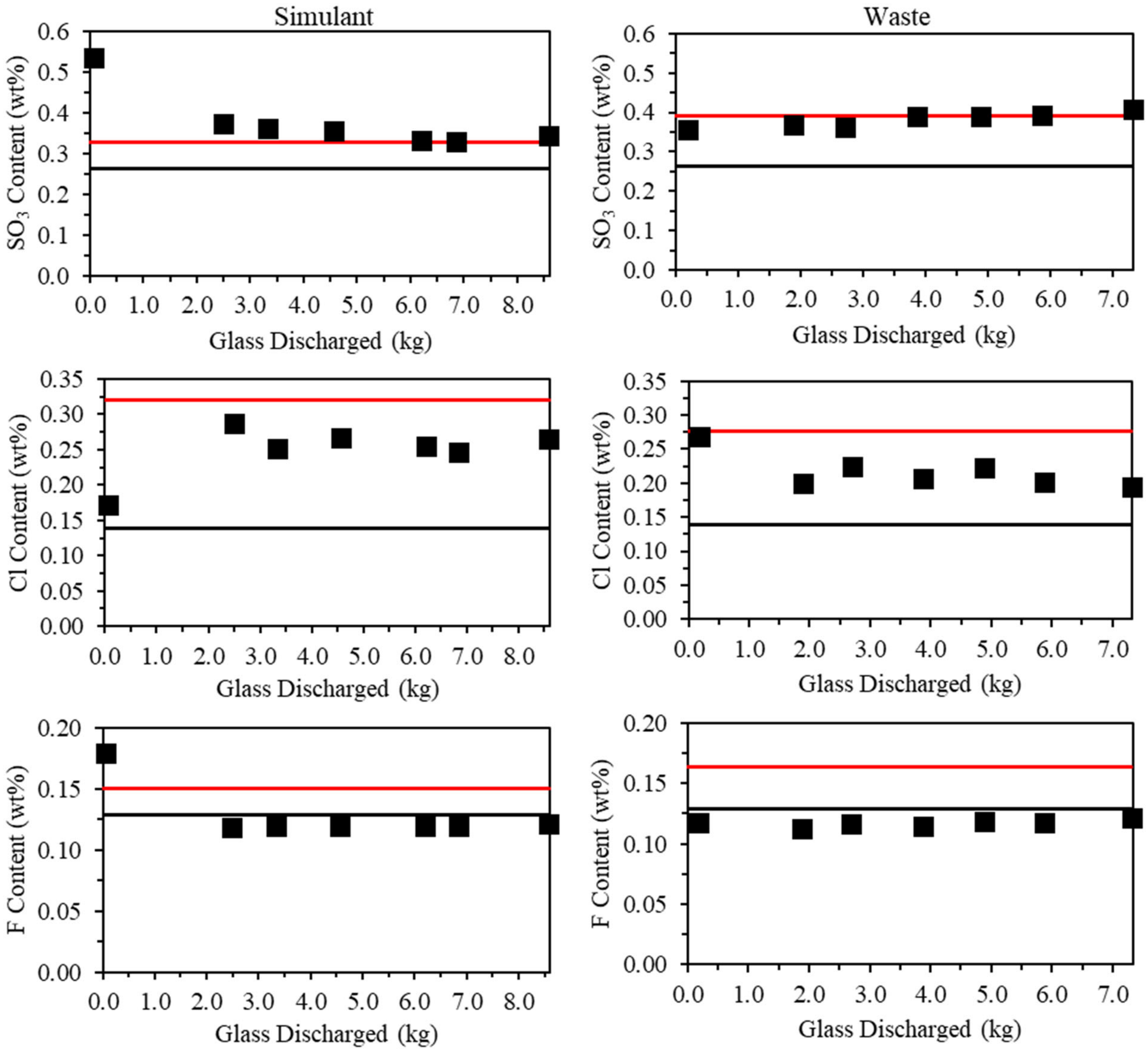

Figure B.5. Content of a set of components (SO_3, Cl, and F) in the glass produced during CLSM runs with AW-105 simulant and AW-105 waste melter feeds.

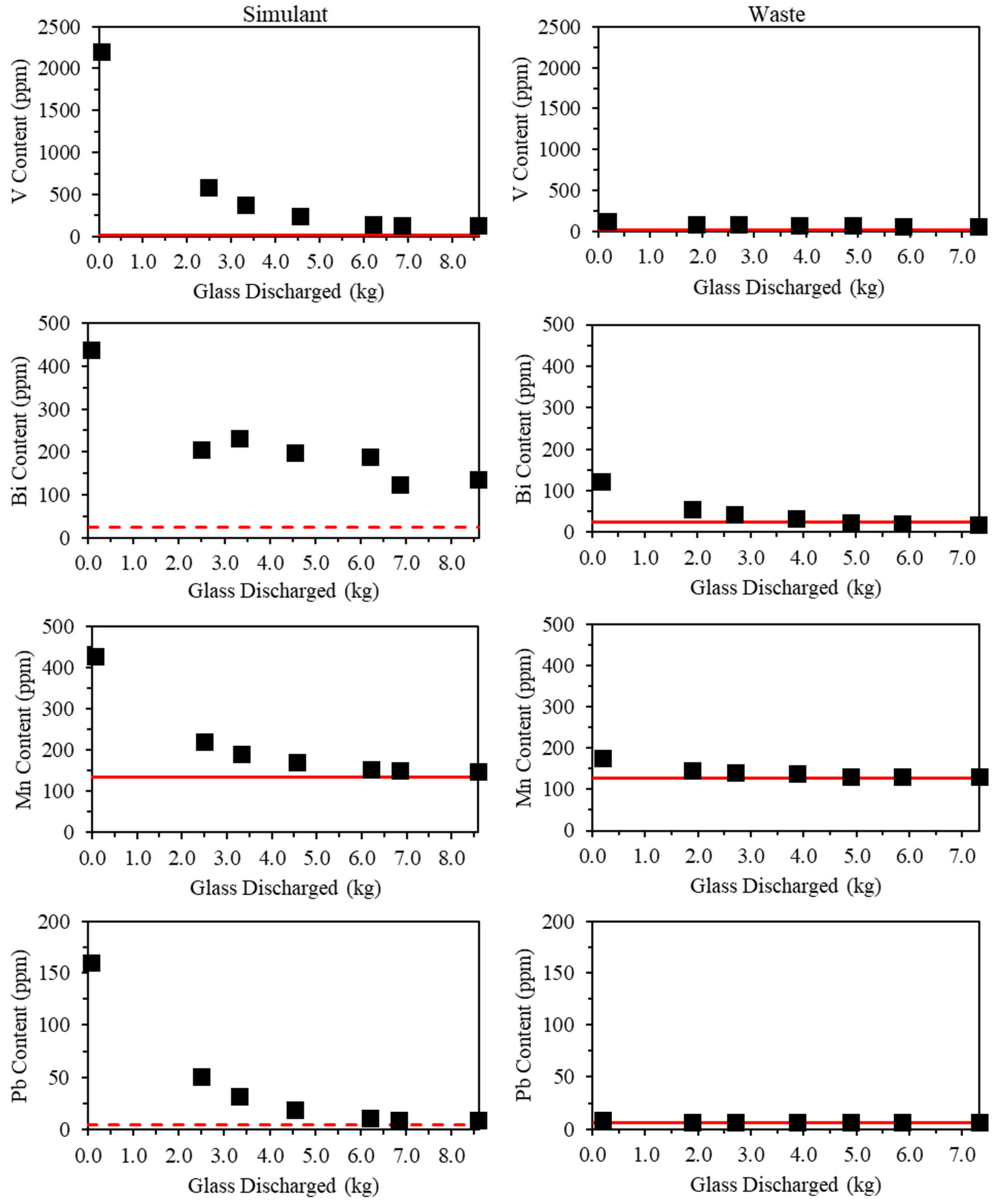

Figure B.6. Content of a set of impurities (V, Bi, Mn, and Pb) in the glass produced during CLSM runs with AW-105 simulant and AW-105 waste melter feeds.

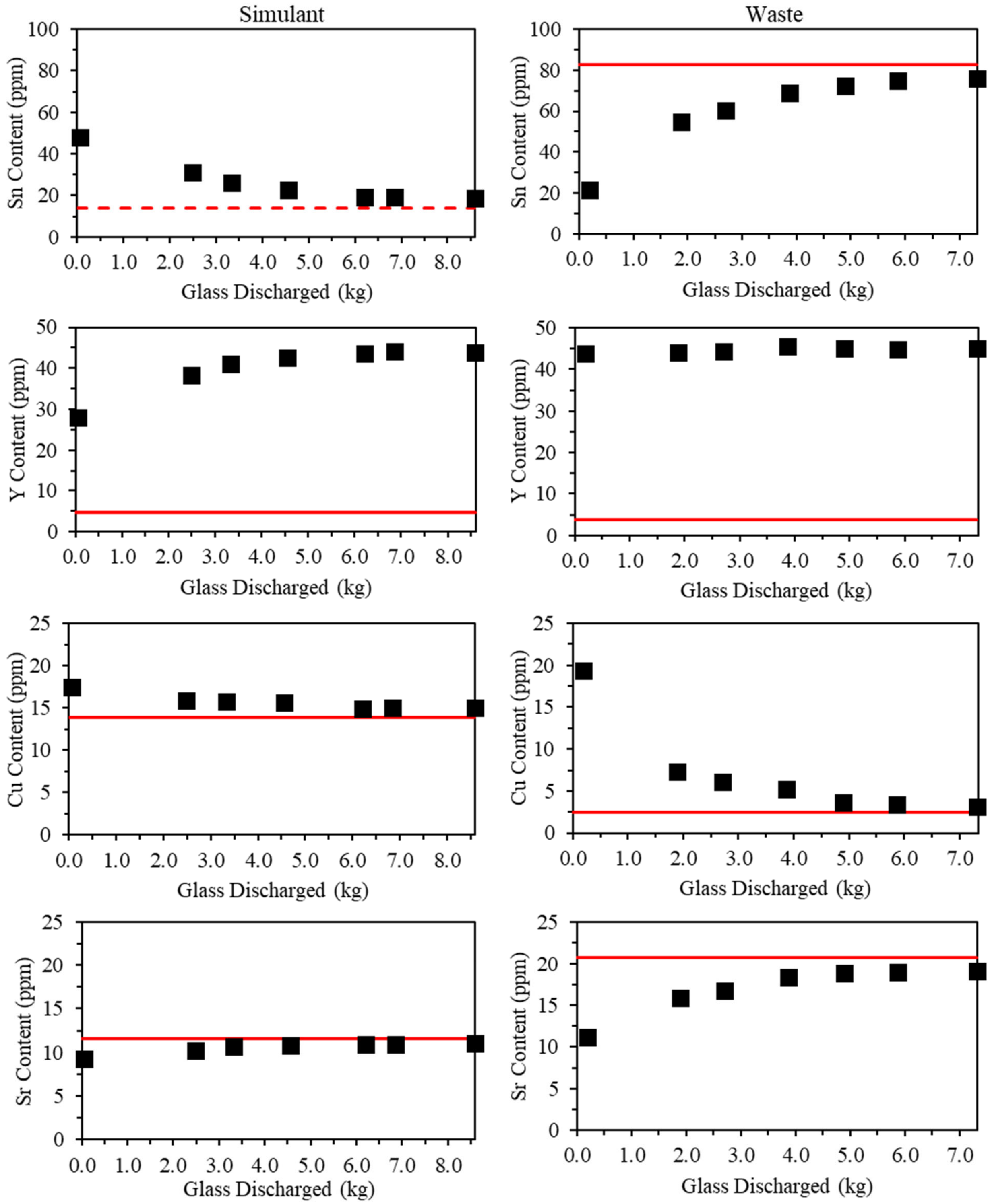

Figure B.7. Content of a set of impurities (Sn, Y, Cu, and Sr) in the glass produced during CLSM runs with AW-105 simulant and AW-105 waste melter feeds.

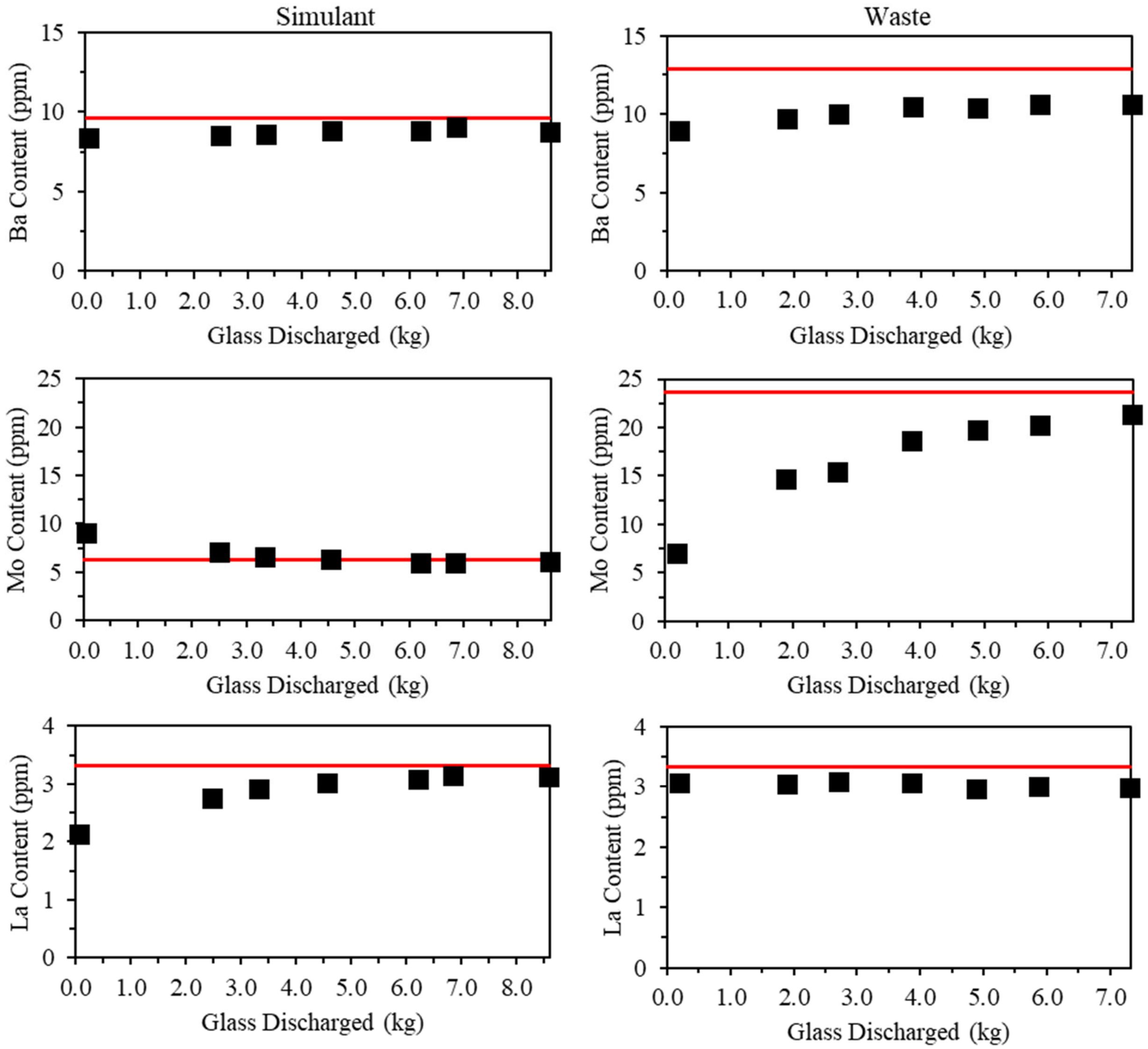

Figure B.8. Content of a set of impurities (Ba, Mo, and La) in the glass produced during CLSM runs with AW-105 simulant and AW-105 waste melter feeds.

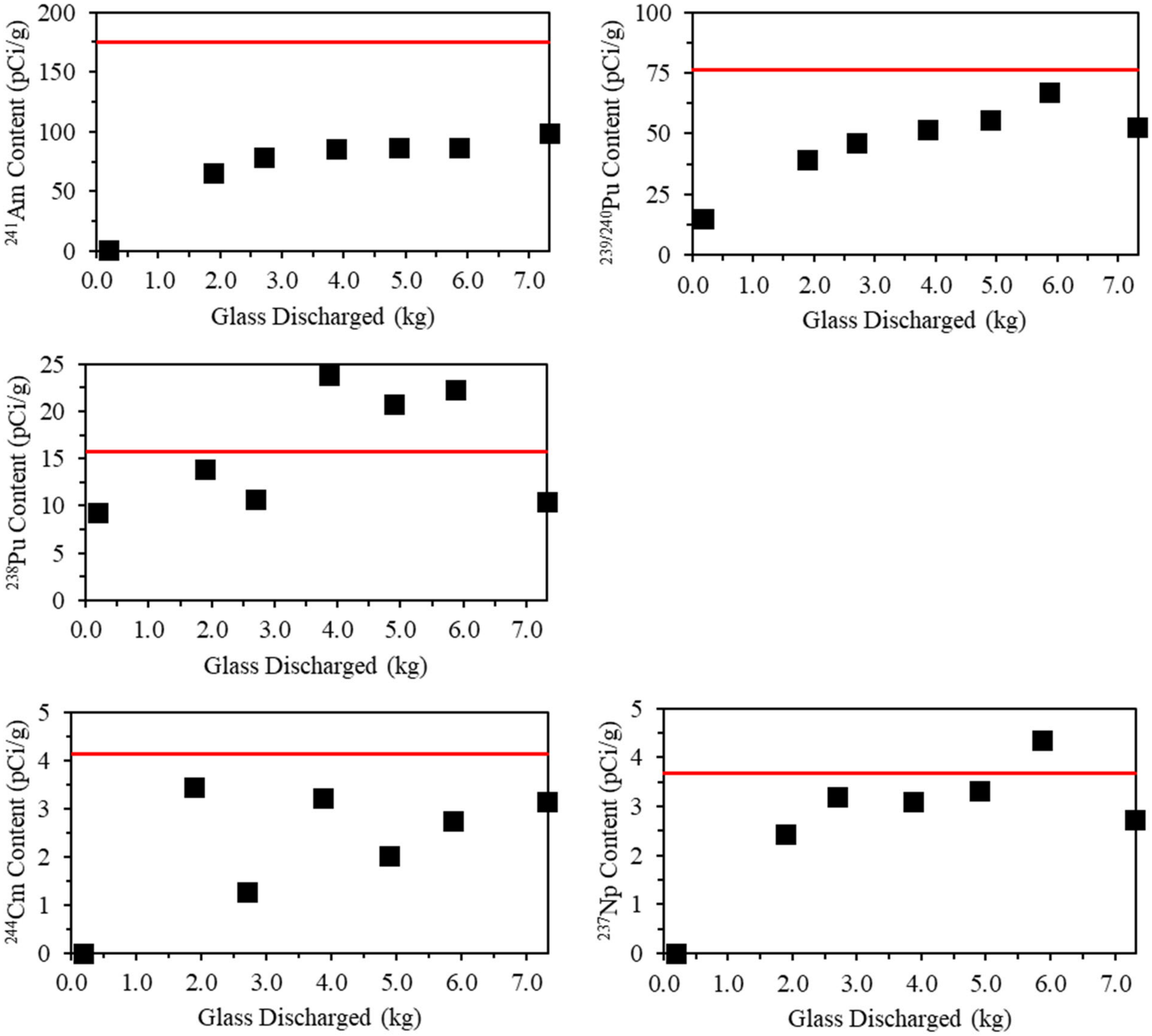

Figure B.9. Activity of measured radionuclides (^{241}Am, $^{239/240}$Pu, ^{238}Pu, ^{244}Cm, and ^{237}Np) in the glass produced during the CLSM run with AW-105 waste melter feeds.

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