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Technetium Retention in WTP LAW Glass with Recycle Flow-Sheet: DM10 Melter Testing, VSL-12R2640-1, Rev. 0

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
Office of River Protection under Contract DE-AC27-08RV14800



P.O. Box 850
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VSL-12R2640-1

Final Report

Technetium Retention in WTP LAW Glass with Recycle Flow-Sheet: DM10 Melter Testing

prepared by

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Completeness of Testing:

This report describes the results of work and testing specified by the referenced WRPS approved Test Plan(s). The work and any associated testing followed established quality assurance requirements and was conducted as authorized. The descriptions provided in this test report are an accurate account of both the conduct of the work and the data collected. Results required by the Test Plan are reported. Also reported are any unusual or anomalous occurrences that are different from the starting hypotheses. The test results and this report have been reviewed and verified.

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EXECUTIVE SUMMARY

In the WTP LAW vitrification facility, the extent to which technetium is incorporated into the LAW glass product and the fraction that is present in secondary waste streams that are disposed as non-glass waste forms are major factors in the Performance Assessment for the ILAW disposal facility at Hanford. The WTP flow sheet incorporates recycle of the liquid effluents from the primary off-gas treatment systems in order to increase the fraction of technetium in the glass and decrease that in the secondary waste streams. Previous expectations have been that partitioning of technetium to the glass versus the secondary waste streams would be very high. For example, the 2003 risk assessment supporting the evaluation of supplemental ILAW treatment technologies assumed "low," "best," and "high" estimates for the fraction of the technetium inventory reporting to the LAW glass product of 90%, 99.9%, and 100%, respectively, with the "best estimate" value used for the risk assessment calculations, while more recent flow sheet modeling in System Plan 6 for the WTP facility and the supplemental LAW facility provides estimates of 91.7% in the LAW glass and 0.36% in non-glass waste forms. However, these estimates were based on very limited data on the performance of the various WTP unit operations with respect to technetium retention factors and much of that information was based on the use of rhenium as a surrogate for technetium. Furthermore, prior to the present work, no testing had been performed on a test system that included recycle of the liquid effluents from the primary off-gas system. In the present work, tests were conducted to determine the retention of technetium and other volatiles in glass while processing simulated LAW feeds through a DM10 melter equipped with a prototypical off-gas treatment system that concentrates and recycles fluid effluents back to the melter feed. The tests were conducted with ^{99m}Tc, a gamma-emitting, short half-life isotope of technetium.

To support these tests, an existing DM10 system installed at VSL was modified to add the required recycle loop. Based on the WTP LAW off-gas system design, suitably scaled versions of the SBS, WESP, and TLP vacuum evaporator were designed, built, and installed into the DM10 system. Process modeling was used to support this design effort and to ensure that issues associated with the short half life of the ^{99m}Tc radioisotope that was used in this work were properly addressed and that the system would be capable of meeting the test objectives. In particular, this required that the overall time constant for the system was sufficiently short that a reasonable approach to steady state could be achieved before the ^{99m}Tc activity dropped below the analytical limits of detection. The conceptual design, detailed design, flow sheet development, process model development, P&ID development, control system design, software design and development, system fabrication, installation, procedure development, operator training, and Test Plan development for the new system were all conducted during this project. The new system was commissioned and subjected to a series of shake-down tests before starting the planned test program. Various system performance issues that arose during testing were addressed through a series of modifications in order to improve the performance and reliability of the system. Significant changes included modifications to the feed system to ensure reliable delivery of technetium to the melter and to minimize feed system clogs, WESP modifications to prevent arcing and improve performance, and addition of a transition line

spray to mobilize transition line deposits into the SBS to make them available for recycle. The resulting system provided a robust and reliable platform to address the test objectives.

Seven different LAW waste compositions were processed in nine nominally 72-hour tests. All feeds were spiked with a solution containing ^{99m}Tc in the pertechnetate form; the feeds used in these tests also contained measureable amounts of nonradioactive iodine and rhenium. In each test, a mass balance for technetium and other feed constituents of concern was measured across the glass pool, discharge glasses, throughout the off-gas system, evaporator overheads, and WESP exhaust. The nominal melter operating conditions employed for the majority of the tests were: an 1150°C glass pool temperature, sugar as an organic reductant at a stoichiometric sugar ratio of 0.5, and air bubbled through the glass pool at a rate to achieve a constant target glass production rate of 2,250 kg/m^2/day. Throughout the tests, enhancements were made to the feed system, WESP, evaporators, and operational procedures in order to optimize unit performance and minimize test interruptions. In addition to the mass balance for key constituents (Tc, Re, S, I, Cl, F), data collected from these tests were used to calculate retention factors across the melter and each of the various off-gas system components. These results were used as input into process models of the system which were used to calculate the predicted concentrations in the glass product for comparison to the measured values. The data were also used to quantify the amount of technetium that escapes the recycle loop through the WESP exhaust and the evaporator overheads.

In the WTP system, technetium can exit the recycle loop via two routes: In the off-gas stream exiting the WESP and in the liquid condensate from the vacuum evaporator. Constituents in the off-gas stream from the WESP are further removed in the PBS. The PBS effluent and evaporator condensate secondary waste from the WTP are directed ultimately to non-glass waste forms. Consequently, the fraction of technetium exiting the recycle loop via these routes is a significant factor in the Performance Assessment for the Hanford Integrated Disposal Facility. There have been no previous measurements of this fraction.

These tests have produced the first ever data on:

- Technetium retention factors for key WTP unit operations (SBS, WESP, vacuum evaporator).
- The effect of recycle on the incorporation of technetium and other key species in LAW glass.
- The distribution and fate of technetium throughout the vitrification system and recycle loop, and the extent of partitioning to secondary waste streams.

Key findings from this work include:

- With recycle, retentions of technetium and rhenium in the glass product are increased by factors of at least 2 to 3 over the corresponding single-pass values for almost all glass compositions. The average technetium and rhenium retentions in glass across all compositions tested were 68% and 79%, respectively. All but two compositions showed technetium retentions in glass of 68 to 84% and rhenium retentions in glass of 70 to 100%.

- The increase in glass retention was limited by holdup of material in the system, particularly in the WESP internals, the film cooler, and the transition line. Mobilization of this material in order to make it available for recycle would likely further increase the retention in glass.

- The technetium mass balance closure reached as high as 95% but averaged about 90% over the later tests, which is about 10% lower than that observed for rhenium. This difference likely contributed to the observed difference in the retentions in glass. In comparison, in 72 previously conducted single-pass DM10 tests (without recycle) the average mass balance closures were 97% for technetium and 102% for rhenium.

- The fraction of feed technetium exiting the recycle loop through the evaporator overheads was less than 0.03% during normal operations and much lower for many tests.

- The fraction of feed technetium exiting the recycle loop through the WESP exhaust ranged from 0.01 to 0.5% during normal operations.

- The fraction of feed technetium exiting the recycle loop through the WESP exhaust was critically dependent on the performance of the WESP and increased to above 10% (i.e., by a factor of about 500 or more) when the WESP was not functioning.

- Iodine retention in the glass also showed significant enhancements over the corresponding single-pass values but to a lesser extent than those for technetium and rhenium.

- The amount of technetium, iodine, and rhenium retained in the glass product showed similar variations across the seven LAW streams investigated (LAW from Hanford tanks AP-101, AN-105, AN-107, AN-104, AN-102, AZ-101, and AZ-102) to that observed in the tests without recycle, but the variation was somewhat less pronounced.

- For technetium, the system component retention factors averaged across all seven feed types were:
    - Single-pass melter: 35.2% (vs. 68% average with recycle)
    - SBS: 52.2%
    - WESP: 99.8%

- For rhenium, the system component retention factors averaged across all seven feed types were:
    - Single-pass melter: 43.1% (vs. 79% average with recycle)
    - SBS: 70.0%
    - WESP: 99.4%

- Overall, technetium and rhenium showed remarkably similar distribution across the various system sumps. However, as noted above, the retention factor for technetium in the SBS was

significantly lower than that for rhenium, both on average and in all but one of the individual tests.

- The steady state retention of technetium in the glass product showed a reasonable correlation to that for rhenium, with the average rhenium retention being roughly 10% absolute higher than that for technetium. The correlation between rhenium and technetium and the generally higher retention for rhenium is consistent with previous results for the single-pass retention, but with all values shifted higher with recycle.

- Technetium retention in the glass product was more sensitive to interruptions in the feed and recycle streams than was the case for rhenium suggesting that data from tests with technetium, rather than a rhenium surrogate, should be used in evaluating the potential impacts of such interruptions on the performance of the WTP.

- Testing with a high potassium feed showed higher emissions of both technetium and potassium in the WESP exhaust, suggesting that the presence of potassium may reduce the capture efficiency of technetium in the off-gas system.

- The single-pass melter retentions for technetium and rhenium calculated from the present test data show good agreement with the corresponding values measured previously on the DM10 and DM100 melter systems. The SBS and WESP retention factors measured for rhenium show excellent agreement with those measured previously on the DM1200 system, which represents a factor of 60 scale-up.

- Sulfur, chlorine, and fluorine also showed significant increases in retention in the glass product, often approaching 100%. The mass balance closure was generally good for sulfur but less so for chlorine and fluorine as a result of their very low levels in the feed and their ubiquity as contaminants.

- Sulfate salt phases were observed on the melt pool surface after two of the tests; these same LAW streams and glass formulations showed no evidence of secondary phase formation during previous single-pass tests. However, salt formation was consistent with the higher concentrations of sulfur and chlorine in the melter feeds for the present tests. The salt phase showed an approximate fifty-fold enrichment in technetium over the glass; rhenium and halides also showed significant enrichments.

- When the measured retention factors for Tc, Re, S, I, Cl, and F for each of the system components are input into the process model, reasonable agreement with measured glass data is seen.

Potential Implications for the WTP

In the present tests, technetium retentions in a variety of Hanford LAW glasses were determined with recycle using a flow sheet representative of the Hanford WTP LAW vitrification facility. With recycle, retention of technetium in the glass product increased by a factor of at least 2 to 3 over the corresponding single-pass values for almost all glass compositions. In the present tests with recycle, all but two compositions showed technetium retentions in glass of 68 to 84%.

While the measured technetium retention values for the LAW glass with recycle are much increased over the single-pass values, they are significantly lower than previous assumptions and estimates. For example, the 2003 risk assessment supporting the evaluation of supplemental ILAW treatment technologies assumed "low," "best," and "high" estimates for the fraction of the technetium inventory reporting to the LAW glass product of 90%, 99.9%, and 100%, respectively, with the "best estimate" value used for the risk assessment calculations. More recently, a baseline technetium mass balance has been generated as part of System Plan 6 for the WTP facility, which employs a flow sheet that includes WTP LAW and HLW vitrification, as well as vitrification for supplemental treatment of LAW. That flow sheet includes recycle back to the WTP pretreatment facility of liquid effluents from off-gas treatment in both the WTP LAW and HLW facilities; in contrast, the supplemental LAW vitrification facility is modeled with recycle internal to that facility. Per the assumptions used in that mass balance, of the total technetium inventory in the tank farms, 99.3% is retrieved for treatment, 91.6% reports to the LAW glass product (from both WTP and supplemental LAW), 5.6% reports to the HLW glass, 0.18% reports to solidified liquid effluent, and 0.18% reports to other solid wastes. Results from the present tests suggest that a value of around 0.18% may not be an unreasonable expectation for the liquid secondary waste streams since the fraction of feed technetium exiting the recycle loop through the WESP exhaust ranged from 0.01 to 0.5% during normal operations, while that exiting the recycle loop through the evaporator overheads was less than 0.03% during normal operations and much lower for many tests. As discussed below, it is expected that the time-averaged fraction of technetium exiting the WESP will be increased somewhat as a result of the downtime associated with the daily water washes of the WESP that are planned at the WTP.

In the present tests, the measured technetium retention in the product glass was limited by several factors. The test results showed that a significant amount of technetium was held up in the system during testing, particularly in the WESP internals, the film cooler, and the transition line. This material was therefore not available for recycle, which decreased the incorporation of technetium in the glass product. Mobilization of this material in order to make it available for recycle would likely further increase the retention in glass. In particular, significant holdup was found in the WESP. The WTP plans to employ periodic water washes ("deluges") of the WESP internals to mobilize this material and maintain WESP collection efficiency. Future testing should be conducted to assess the impact of this provision. It is also noted that power must be secured during the deluge operation, which results in essentially zero collection efficiency during that time, which is estimated to be in the rage of about ten to thirty minutes once every 24 hours. The present test results indicate that the fraction of technetium escaping the primary off-gas system would increase to about 15% during that downtime. Thus, the results from the present tests would suggest that the time-

averaged fraction of technetium exiting the WESP, including this downtime, may range from about 0.1% to about 0.8%.

Another factor in the measured technetium retention in glass is the shortfall in mass balance closure for technetium. In view of the complexity of the test system and the numerous samples and analyses that are required to complete the mass balance, the measured average technetium mass balance closure of about 90% is considered very good. However, the shortfall is significant with respect to the ability to measure retentions in glass nearing 100%. Additional studies are needed to evaluate potential reasons for the shortfall in the technetium mass balance. Nevertheless, these results serve to highlight the difficulties of measuring retentions in glass that approach 100%. From this perspective, measurement of the fraction of the technetium exiting the recycle loop provides a more direct and precise means of estimating the fraction of technetium reporting to liquid secondary waste and ultimately, to non-glass waste forms. As noted above, the results from the present work for this fraction are in the same general range as recent flow sheet estimates.

The performance of the various unit operations in the WTP flow sheet in terms of element-specific retention factors is critical input information into flow sheet modeling such as that employed for system planning. The results from the present work provide the first such direct measurements of retention factors for technetium for key unit operations including the SBS, WESP, and vacuum evaporator.

Recommendations for Future Work

Based on the results from the present work, it is recommended that future testing address:

- Testing and analysis to determine the origin of the remaining shortfall in the technetium mass balance relative to rhenium.

- Testing of the effects of system modifications to further minimize holdup in both the WESP and the film cooler/transition line in order to make more of that material available for recycle. This includes the addition of the daily and prototypic WESP deluge during testing and a transition line sprayer that rinses the film cooler area. In addition, methods to reduce the total volume of material removed for sampling during testing should be considered.

- All of the present testing has employed the baseline WTP LAW glass formulations. Since the tests showed a strong dependence of technetium retention in the glass on feed composition, testing should also be conducted with the higher waste loading LAW formulations developed at VSL for ORP. There are no comparable data presently available for these formulations, even for single-pass retention.

- Recycle testing with flow-sheet modifications that increase single-pass retention. Extensive single-pass testing has shown that using iron (II) oxalate as an additive significantly increases the single-pass technetium retention but the effects of recycle have not been tested.

- Testing with higher concentrations of halides, within the maximum projected concentrations for Hanford LAW, to facilitate improved mass balance closure and determination of retention factors, and the determination of the effect of increased concentrations of recycled halides and sulfur on the tendency to form secondary salt phases on the melt pool surface.

- Testing to support early operation of the LAW facility using the anticipated feed types to determine the expected system performance, secondary waste stream compositions, and fate of technetium. The feeds for early operation of the LAW facility have the potential to be significantly different from those tested for technetium retention to-date, and current testing has shown that technetium retention in the glass depends strongly on feed composition.

- Scale-up recycle testing on the DM100 with ^{99m}Tc and Re and on the DM1200 with Re.

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List of Abbreviations

AES	Atomic Emission Spectroscopy
ASME	American Society of Mechanical Engineers
CEM	Continuous Emissions Monitoring
CUA	Catholic University of America
DCP-AES	Direct Current Plasma – Atomic Emission Spectroscopy
DF	Decontamination Factors
DM	DuraMelter
DOE	Department Of Energy
DWPF	Defense Waste Processing Facility
EDTA	Ethylene Diamine Tetra-acetic Acid
EPA	Environmental Protection Agency
FTIR	Fourier Transform Infrared Spectroscopy
HEME	High Efficiency Mist Eliminator
HEPA	High-Efficiency Particulate Air Filter
HLW	High Level Waste
IHLW	Immobilized High Level Waste
IC	Ion Chromatography
ICP-MS	Inductively Coupled Plasma – Mass Spectroscopy
IDF	Integrated Disposal Facility
ILAW	Immobilized Low Activity Waste
JHCM	Joule Heated Ceramic Melter
LAW	Low Activity Waste
NIST	National Institute of Standards and Technology
NQA	Nuclear Quality Assurance
NTA	Nitro Triacetic Acid
ORP	Office of River Protection
P&IDs	Piping and Instrumentation Diagrams
PA	Performance Assessment
PNNL	Pacific Northwest National Laboratory
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QARD	Quality Assurance Requirements and Description
SBS	Submerged Bed Scrubber
SRNL	Savannah River National Laboratory
US NRC	United States Nuclear Regulatory Commission
VSL	Vitreous State Laboratory
W.C.	Water Column
WESP	Wet Electrostatic Precipitator
WTP	Hanford Tank Waste Treatment and Immobilization Plant
WRPS	Washington River Protection *Solutions*, LLC
WVDP	West Valley Demonstration Project
XRF	X-Ray Fluorescence Spectroscopy

SECTION 1.0
INTRODUCTION

1.1 Background

About 57 million gallons of high-level mixed waste is currently stored in underground tanks at The United States Department of Energy's (DOE's) Hanford site in the State of Washington. The Hanford Tank Waste Treatment and Immobilization Plant (WTP) will provide DOE's Office of River Protection (ORP) with a means of treating this waste by vitrification for subsequent disposal. The tank waste will be separated into low- and high-activity waste fractions, which will then be vitrified respectively into Immobilized Low Activity Waste (ILAW) and Immobilized High Level Waste (IHLW) products. The ILAW product will be disposed in an engineered facility on the Hanford site while the IHLW product is designed for acceptance into the national deep geological disposal facility for high-level nuclear waste. The ILAW and IHLW products must meet a variety of requirements with respect to protection of the environment before they can be accepted for disposal.

The Low Activity Waste (LAW) at Hanford will be vitrified in a Joule Heated Ceramic Melter (JHCM) to produce a stable product for safe disposal. Technetium is an important radioactive component in the Hanford waste and is typically one of the principal contributors to risk in performance assessments for the ILAW disposal facility. The distribution of technetium between the various product and secondary waste streams from the WTP and, in particular, between the LAW glass product and the secondary waste streams, both of which are planned for on-site disposal in the ILAW disposal facility, is a key factor in such assessments. The 2003 risk assessment supporting the evaluation of supplemental ILAW treatment technologies assumed "low," "best estimate," and "high" estimates for the fraction of the technetium inventory reporting to the LAW glass product of 90%, 99.9%, and 100%, respectively, with the "best estimate" value used for the risk assessment calculations [1]. More recently, a baseline technetium mass balance has been generated as part of System Plan 6 [2] for the WTP facility, which employs a flow sheet that includes WTP LAW and HLW vitrification, as well as vitrification for supplemental treatment of LAW. That flow sheet includes recycle back to the WTP pretreatment facility of liquid effluents from off-gas treatment in both the WTP LAW and HLW facilities; in contrast, the supplemental LAW vitrification facility is modeled with recycle internal to that facility. Per the assumptions used in that mass balance, of the total technetium inventory in the tank farms, 99.3% is retrieved for treatment, 91.6% reports to the LAW glass product (from both WTP and supplemental LAW), 5.6% reports to the HLW glass, 0.18% reports to solidified liquid effluent, and 0.18% reports to other solid waste forms. Thus, a total of about 0.36% of the inventory is projected to be sent to the ILAW disposal facility in non-glass waste forms. Since these waste forms are generally much less leach resistant than the LAW glass, the fraction of technetium in these waste forms can have significant effects on the overall performance assessment. Consequently, test data are crucial to assess and underpin the assumptions underlying such mass balance projections and, in particular, the effects of recycle on increasing the incorporation of technetium in the glass products and minimizing the fraction in non-glass waste forms.

Technetium is one of the more volatile radionuclides for which retention in LAW glass under the high temperature conditions during vitrification can vary depending on feed composition, feed chemistry, and melter operating parameters. High retention of technetium in the glass is desirable in order to minimize the fraction that is directed to secondary waste treatment and disposal in non-glass waste forms. Previous testing performed at the Vitreous State Laboratory (VSL) of The Catholic University of America (CUA) for Washington River Protection *Solutions*, LLC (WRPS) has focused on determination of the baseline "single-pass" retention over the range of WTP LAW feed compositions and glass formulations as well as the development of potential modifications to the baseline that could increase the single-pass retention [3, 4].

In practice, however, radioactive waste vitrification systems are typically designed in such a way that a significant fraction of the radionuclides and other contaminants of concern that exit the melter in the off-gas stream is captured in the off-gas system and recycled back to the melter feed. This is the case for the WTP melter systems, where the liquid waste streams from the primary off-gas system components are recycled back to the pretreatment facility and, ultimately, to subsequent melter feed batches. Such a recycle loop can greatly increase the overall retention of volatile constituents in the glass product over the single-pass value. However, such improvements for the WTP flow-sheet have not been previously demonstrated through testing on scaled systems. Accordingly, Washington River Protection Solutions (WRPS) commissioned a series of tests to investigate the effects of recycle using a suitably modified melter system (DM10) at VSL. The original plans for testing [5] also included scale-up testing ($\approx 60\times$) on the DM1200 vitrification system, which includes an off-gas treatment system that is prototypical of the WTP LAW system. However, the DM1200 testing was eliminated per WRPS direction leaving only DM10 testing in the final plans.

The recycle testing was performed on a suitably modified DM10 melter system and was conducted in two phases. The first phase ("FY11 testing") was performed under the initial Test Plan [5] that was responsive to the WRPS Task Plan [6], a WRPS Scope of Work [7], and the VSL Project Plan [8] for the overall technetium recycle project. The second phase ("FY12 testing") was performed under a Test Plan [9] revision and was responsive to the WRPS Task Plan [6], the revised WRPS Scope of Work [10], and the VSL Project Plan [8].

This report presents the results from both phases of DM10 melter testing. The tests were performed with recycle of the liquid effluents from the off-gas treatment system back to the melter feed in order to evaluate the retention of technetium and other species for a range of simulated LAW streams. These results are compared to single-pass retention results previously measured while processing the same waste streams. In addition to providing information on the effectiveness of the recycle flow sheet, such tests also provide important performance data for the unit operations in the primary off-gas system with respect to technetium capture and recycle. This information is crucial in assessing the amount of technetium that ultimately reports to non-glass waste forms.

1.1.1 Prior WTP Testing

In support of the WTP Project, the Vitreous State Laboratory (VSL) at The Catholic University of America (CUA) and Energy*Solutions* have developed and tested glass formulations for WTP waste envelopes to provide data to meet the WTP contract requirements and to support system design activities [11-16]. That work is based upon small-scale batch melts ("crucible melts") using waste simulants. Selected formulations have also been tested in small-scale, continuously-fed, joule-heated melters (DM10 and DM100 systems) [17-28] and, ultimately, in the LAW Pilot Melter [29-40]. Such melter tests provide information on key process factors such as feed processing behavior, dynamic effects during processing, sulfate incorporation, processing rates, off-gas amounts and compositions, foaming control, etc., that cannot be reliably obtained from crucible melts. This sequential scale-up approach in the vitrification testing program ensures that maximum benefit is obtained from the more costly melter tests and that the most effective use is made of those resources.

Under the WTP support effort, VSL and Energy*Solutions* have developed and identified glass compositions for processing the Phase I LAW tank waste streams for the WTP. These compositions have been tested for processing and product quality requirements at various scales ranging from crucible melts of about 400 g, up to the LAW Pilot Melter at processing rates in excess of 6600 kg/day (2000 kg/m^2/day). The testing included the nominal feed compositions and those with ±15% variations in the waste simulants added to the melter feeds. The melter testing provided high confidence that the selected WTP compositions are unlikely to cause accumulation of a separate sulfate phase in the melter even at high feed processing rates. Feed processing characteristics and off-gas characteristics have been determined at various melter scales and data have been collected to support engineering and permitting requirements. Furthermore, statistically designed composition matrices were generated, and crucible melts of those glass compositions were prepared and characterized to qualify the glass composition region covering the LAW glass compositions selected for WTP waste processing [15, 16]. The selected WTP compositions have also been tested to ensure their compatibility with melter materials of construction. Thus, the glass formulation development and melter testing work for the selected WTP compositions have reached a level of maturity where the compositions can be used for waste processing at the WTP with relatively high confidence. In addition, under a separate program for ORP, potential incremental improvements have been evaluated and tested for ORP in support of its evaluation of WTP LAW facility optimization [41]. Examples of such incremental improvements tested at VSL include significant increases in waste loading, increasing the processing temperature, and increasing the fraction of the sulfur in the feed that is partitioned to the off-gas stream to support evaluation of scenarios in which the off-gas recycle loop is broken [42-46]. While these higher loading formulations offer the prospects for significant cost savings, at present they are less well developed than the current WTP baseline formulations.

1.2 Overview of Technetium and Rhenium Behavior in LAW Vitrification

Technetium was introduced into the Hanford tanks as the pertechnetate anion, which was present in the high-nitrate liquid wastes that originated from nuclear fuel dissolution and separations processes. The preponderance of the available sampling data indicates that technetium is still found to be predominantly in the pertechnetate form in most of the Hanford tank waste. However, there is some evidence that in some waste types, years of thermal, chemical, and radiolytic digestion in the presence of organic material and complexants such as ethylene diamine tetra-acetic acid (EDTA), nitro triacetic acid (NTA), citrate, and oxalate, has transformed some of the TcO_4^- into stable, reduced, technetium complexes so that in high-organic tanks, such as AN-107 and AN-102, up to 50% of the technetium may be in this reduced form [47]. However, these waste types (LAW Envelope C) represent a small minority of the total LAW inventory. Thus, overall, most of the technetium is expected to be in the pertechnetate form. As a result of its high solubility, the majority of the technetium will be partitioned to the LAW fraction (as opposed to the HLW fraction) during the solid-liquid separation in pretreatment and, hence, to the LAW vitrification system.

Tc is one of three Group VIIa elements in the periodic table, with Mn and Re being the other two. Unlike MnO_4^-, TcO_4^- and ReO_4^- are stable in alkaline solution and both are much less oxidizing than MnO_4^-. More generally, technetium and rhenium are very similar chemically and differ significantly from manganese, which is the only other Group VIIa element [48]. Also unlike manganese, for which the II oxidation state is the most stable and Mn^{2+} is an important species, technetium and rhenium exhibit little cationic chemistry and form few compounds in the II state [48]. Instead, technetium and rhenium chemistry tends to be dominated by the most stable VII oxidation state and the next most stable IV state. In general, technetium and rhenium species with oxidation states of less than IV are rapidly oxidized and those with oxidation states between IV and VII tend to disproportionate into corresponding mixtures of IV and VII compounds [49]. For both elements, the VII oxides are more volatile than the IV oxides [49]; their stability fields have been mapped as a function of oxygen fugacity [50]. Tc_2O_7 boils at 311°C, Re_2O_7 boils at 363°C, and TcO_2 sublimes at 900°C [49]. Electrochemical measurements made in borosilicate glass melts have shown that technetium is more easily reduced than is rhenium [51], as also is the case in aqueous solutions. Similarities as well as important differences in the behavior of technetium and rhenium during vitrification of LAW simulants and subsequent vapor phase hydration testing of the resulting LAW glasses have also been reported [52 - 54]. In aggregate, however, for these and many other reasons, rhenium, while imperfect, remains the best known chemical surrogate for technetium [49].

The retention of technetium and rhenium during the formation of borosilicate glass melts has been reviewed previously [49]. A general finding is that retention is favored under more reducing conditions, which favor the IV oxidation state over the VII state. For example, in crucible melt studies, Freud et al. [51] found technetium retentions of 45% and 75% under oxidizing and reducing conditions, respectively, while Vida [55] found technetium retentions of between 47% and 70% under reducing conditions. Darab and Smith [49] found similar retentions (~65%) for rhenium in crucible melts with Hanford LAW simulants. Other crucible melt tests with LAW simulants showed comparable volatility for technetium and rhenium, little effect of redox on retention, and enhanced

volatility with sulfate [56]. Nine crucible melts performed in support of the WTP project at Pacific Northwest National Laboratory (PNNL) and Savannah River National Laboratory (SRNL) with samples of actual LAW showed technetium retentions of 12 – 63% (one was 99%), with an average of 38% [56]. Also in support of the WTP project, a continuously-fed small-scale melter test (using a simple crucible "melter" with an overflow) was performed with an actual LAW Envelope C sample at SRNL, which showed a technetium retention of about 28% [57]. Earlier, during the Hanford TWRS Privatization phase, nine small-scale JHCM tests were performed at VSL on a DM10 unit using LAW simulants that were spiked with ^{99m}Tc [58], which showed that 18 – 77% of the technetium was retained over a range of process conditions. Tests with LAW simulants performed at PNNL in one-sixth-scale Bulk Vitrification melters showed that 35 and 53% of the technetium was retained [59]. Technetium retentions of about 38% were observed in the PAMELA joule-heated ceramic melter campaigns in Mol, Belgium [49]. In this context, surprisingly high technetium retentions of around 99% have been reported at the Defense Waste Processing Facility (DWPF) high-level waste vitrification facility [60]. Overall, Tc retention in glass has been observed to vary widely depending on a number of factors including feed chemistry, redox, and process conditions such as melt temperature, cold-cap coverage, bubbling, etc.

Also of significance are results from studies reported in the literature that suggest that the volatility of cesium can be enhanced in the presence of technetium [61, 62]. While there are differences in the reported magnitudes of this effect, one of those studies suggests that the volatility of both species can be enhanced by as much as an order of magnitude [62]. However, when simulants contained both Cs and Tc, the volatilities varied greatly for experiments repeated under the same conditions, between about 0.7 – 19% for Cs and 0.9 – 40% for Tc [62]. This behavior is thought to be a result of the formation of cesium pertechnetate, $CsTcO_4$ [61 - 66]. Technetium itself is considerably more volatile than cesium during vitrification, particularly under oxidizing conditions [50, 61, 62]. Consequently, the formation of such a compound would be expected to increase the volatility of cesium. Cesium represents the largest contributor to the radiation dose from WTP LAW streams. Cesium removal efficiency is therefore one of the key design requirements of the WTP off-gas treatment systems. Significant departures from design expectations for the cesium flux from the WTP melters could adversely impact operation and maintenance, particularly for the LAW vitrification facility. An extensive series of melter tests was therefore conducted to assess the potential impacts of cesium pertechnetate formation on the WTP LAW vitrification facility [67]. Those tests were performed on a DM100 melter system at VSL using LAW simulants and rhenium as a surrogate for technetium [67]. The results showed an increase in cesium volatility as the Re:Cs ratio was increased. A rapid rise was observed above Re:Cs ratios of about 100 for LAW feeds. A WTP review of data collected during crucible vitrification of feeds made from actual waste samples (LAW and HLW) showed a similar increase in cesium volatility beginning at Tc:Cs ratios of about 10,000. As noted above, literature data show an order of magnitude increase in cesium volatility in the presence of technetium even at Tc:Cs ratios of about 0.3 [62, 65, 66]. Consequently, while the general trends exhibited by the literature data, the DM100 data, and the WTP actual waste crucible melt data are similar, there are large differences in the Tc:Cs (or Re:Cs) ratios at which large increases in cesium volatility are observed. It should be noted, however, that the actual cesium and technetium (or rhenium) concentrations differ greatly among these studies. Because of the way in

which the DM100 tests for the WTP were performed [67] and the primary focus on cesium volatility, it is not possible to assess whether any enhancement in rhenium volatility was caused by cesium. However, in view of the vast excesses of sodium and potassium as compared to cesium and the very high Tc:Cs ratios in the LAW streams, any such effect would likely be small. Nevertheless, for completeness, such effects were investigated in a previous series of single-pass tests with technetium on a DM10 system (without recycle); the results showed that any effect of cesium on technetium retention was small and probably within the reproducibility of the tests [4]. In view of these results, and the focus on the behavior of technetium, cesium was not added in the present tests in order to provide a direct comparison with the results from previous single-pass tests that also did not include cesium.

In JHCMs, waste and glass forming chemicals or glass frit are fed onto the surface of the molten glass pool to form a "cold cap," where a number of rate controlling physical and chemical reactions occur. As the feed materials travel downward through the cold cap, water is evaporated, salts are melted and decomposed, and the products combine to form molten glass that then becomes part of the underlying melt pool. The essential melt-rate limiting processes are the transport of heat to and through this zone to fuel the conversion reactions, and the mass transport of the reaction products away from this zone. In traditional JHCMs, such as those deployed at the West Valley Demonstration Project (WVDP) and the DWPF (prior to September, 2010) in the US as well as those deployed in Germany/Belgium and Japan, the electrical energy supplied to the molten glass pool by joule heating is transported to the cold cap region by natural thermal convection, which is relatively inefficient in the viscous glass melt, limiting heat and mass transport. In the early 1990s, VSL developed an active melt pool mixing technology that employed air sparging or "bubbling" to enhance heat and mass transport and thereby effect dramatic increases in glass production rates. This technology was licensed to Energy*Solutions* (then Duratek) for further development, demonstration, and commercialization and was subsequently incorporated into both the WTP LAW and HLW melters and more recently into the DWPF melter. The use of bubblers drastically increases the glass production rate but also has the potential to increase technetium volatilization. Without bubblers, under conditions of near-complete cold cap coverage, the principal source of technetium loss is from the cold cap. With bubblers, however, loss via direct evaporation of dissolved technetium species from the glass melt can become an important contributor to the overall technetium loss. The extent of this contribution will likely depend on such factors as the bubbling rate, bubbling gas composition, and the melt temperature [3, 4].

In the cold cap, it is likely that technetium species are first incorporated into low-melting salt phases, which, for LAW feeds are primarily nitrates (sodium nitrate, for example, melts at ~320°C). While such phases would promote the VII oxidation state over the IV state, which would increase technetium volatility, they are also likely to strongly favor the formation of the much less volatile sodium and potassium pertechnetates over the more volatile cesium pertechnetate. The WTP LAW flow sheet includes sugar additions to counter-balance the oxidizing effects of nitrates in the LAW feed in order to mitigate melt pool foaming. Sugar and other reductants can also be used to promote the formation of more reducing conditions in the cold cap in order to favor the IV oxidation state and thereby increase technetium retention. As the feed material travels downward through the cold cap

and the temperature rises, the molten nitrates react exothermically with any reductants that are present; any excess reductants would then tend to reduce technetium to its less volatile oxidation state. Thus, one strategy for improving technetium retention centers on promoting relatively reducing conditions in the cold cap at sufficiently high temperatures through the addition of combinations of reductants to the LAW feed [3, 4]. However, as noted above, to be viable, such an approach must also avoid the creation of overly reducing conditions that can lead to the formation of deleterious phases, such as molten metals and sulfides that can compromise melter life.

1.3 Overview of Single-Pass Tc Retention Tests Conducted at VSL

Tests were conducted at the crucible scale and three melter scales to investigate and develop methods for improving the retention of technetium in Hanford LAW glasses during the vitrification process [3, 4]. The largest scale test employed an off-gas treatment system that is prototypical of the WTP LAW system and a one-eighth scale melter producing glass at about 2.7 MT per day. Several strategies were evaluated for enhancing the retention of technetium and other volatiles in the glass product over a wide range of LAW waste compositions. Methods were developed and demonstrated that result in single-pass retentions of technetium and iodine of greater than 50%.

Eighty-five DM10 melter tests totaling about 1100 hours of testing, two DM100 melter tests totaling about 100 hours of testing, and one DM1200 test producing six metric tons of glass were conducted. The vast majority of the tests were performed at 1150°C and with a bubbling rate sufficient to achieve a constant glass production rate of about 2,250 kg/m^2/day; selected tests also investigated the effects of variation of these parameters. All DM10 and DM100 feeds were spiked with a solution containing ^{99m}Tc in the pertechnetate form and also contained measureable amounts of nonradioactive iodine and rhenium. In each DM10 and DM100 melter test, a mass balance for technetium and other feed constituents of concern was performed across the glass pool, discharge glasses, and melter exhaust. DM10 tests were performed to determine the effect of waste and glass composition, reductant type and concentration, and additive type on technetium retention in the product glass, as well as to determine the effectiveness of various technetium retention enhancement approaches over a range of waste compositions. The two most promising enhancement strategies were scaled up to the DM100 melter and one of those tests was further scaled up to the DM1200 melter. Rhenium was used as a surrogate for technetium during the DM1200 test and the fates of rhenium, iodine, and other constituents were monitored throughout the off-gas system such that a mass balance could be calculated across the melter and primary off-gas system from measurements on discharge glasses, melter exhaust, primary off-gas system components exhaust, and off-gas system sump solutions.

The principal findings from these tests were:

- The amount of technetium, iodine, and rhenium retained in the glass product varies widely across the seven LAW streams investigated (from Hanford tanks AP-101, AN-105, AN-107, AN-104, AN-102, AZ-101, and AZ-102).

- Technetium retention improved as the conditions were made more reducing with the addition of organic additives such as sugar. However, there are practical limits that are imposed by the increasing tendency for molten metal and sulfide formation under very reducing conditions, which can decrease melter life, and the decreased retention of sulfur in the glass melt. None of the many reductants evaluated performed significantly better than sugar in this regard. Nevertheless, modest improvements should be possible through judicious application of this approach.

- None of the more reducing bubbling gases tested gave any significant improvement in technetium retention during feeding (though there was some improvement during idling). Thus, while this would have been a relatively simple change to implement, on the basis of the test results, it does not appear to be effective.

- Processing at a lower glass pool temperature resulted in modestly increased technetium retention. The disadvantage of this approach is that the glass production rate decreases significantly with decreasing temperature. It is possible that this could provide one element of a practical strategy for the baseline LAW vitrification system, where the melter capacity is likely greater than what the balance of the facility can support. However, with the present emphasis on optimization and enhancement of the LAW facility over and above its baseline specifications, such an approach would appear to be undesirable.

- The primary factor underlying the observed variation of technetium, iodine, and rhenium retentions across waste types appears to be the nitrate content, with a lesser effect from the nitrite content. Retentions decrease as these species increase in the melter feed. As further corroboration of this effect, the retentions of technetium, iodine, and rhenium in the glass product decrease approximately linearly with increasing nitrogen oxide emissions.

- Of the various methods investigated, the most effective method for enhancement of technetium, iodine, and rhenium retention without excessive reduction of the glass melt is the use of iron (II) oxalate as an additive. Single-pass technetium retentions of up to 61% were demonstrated using this method.

- The primary mode of action of the iron (II) oxalate addition appears to be via reaction in the basic melter feed during which the divalent iron is oxidized by nitrate, destroying nitrate and thereby reducing its concentration in the melter feed. As noted above, the decreased nitrate content in the melter feed results in increased retention, presumably by decreasing the tendency to form the more volatile higher oxidation states of the species of concern. Iron (II) oxalate would therefore not be expected to provide an effective enhancement for wastes with very low concentrations of nitrates, as was observed experimentally in this work.

- Although the waste nitrate concentration was the most significant factor influencing technetium, iodine, and rhenium retention, other factors also influenced retention and additives other than iron (II) oxalate enhanced retention, albeit to a lesser degree.

- Overall, rhenium was shown to be reasonable surrogate for technetium although on average rhenium retention in the glass product was higher than technetium in tests without iron (II) oxalate; the difference was greater at low retentions and near zero at high retentions, averaging ~7 absolute %). Tests with iron (II) oxalate showed a much poorer correlation between technetium and rhenium retentions and a distinct shift towards higher technetium retentions.

- Tests to examine scale up from the DM10 to the DM100 (~5X) for melter feed with iron (II) oxalate as an additive showed remarkable consistency in the retentions of technetium, rhenium, and iodine across melter scales.

- Tests to examine scale up from the DM10 to the DM100 to the DM1200 (~60X) for melter feed with iron (II) oxalate as an additive showed remarkable consistency in the retentions of rhenium and iodine across melter scales.

- Testing on the DM1200 and prototypical off-gas system showed an excellent mass balance, with the amount of rhenium in the glass product and primary off-gas system sumps constituting greater than 99% of the feed rhenium. The efficient capture of volatilized rhenium in the DM1200 primary off-gas system suggests that recycle of the primary off-gas system effluents should be very effective in increasing the incorporation of technetium into the LAW glass product and minimizing the fraction reporting to secondary wastes.

1.4 Test Objectives

The primary objective of the present work was to perform testing to determine the retention of technetium in WTP LAW glasses during the vitrification process when recycle is included. In addition, information on the retention of other species, including iodine and rhenium (a standard surrogate for technetium), in LAW glasses was collected. Data were also collected on other volatile species, including sulfur, chlorine, and fluorine, to assess their potential accumulation in the recycle stream and any consequent effects on salt formation in the melter.

Testing was performed on one of the two DM10 melter systems currently installed at VSL. That system was modified to include the key components in the WTP LAW primary off-gas system (submerged bed scrubber (SBS) and wet electrostatic precipitator (WESP)) and a recycle loop with an evaporator for the effluents from these components. Four tests were performed on that system in FY11 [5] and five tests were performed in FY12 [9], with each run of nominal duration of 72 hours.

Per the WRPS Task Plan [6] and Statement of Work [10], specific objectives of these tests were to collect information to address the following:

- Recycle flow-sheet mass balance
- Technetium retention in the glass product
- Direct comparison of Re (common Tc surrogate) alongside Tc
- Retention and recycle concentration of sulfate, iodine, and other halides
- Implications of LAW recycle flow-sheet on process control and glass formulation
- Implications of LAW recycle on the secondary waste flow-sheet.

1.5 Quality Assurance

This work was performed under a quality assurance program compliant with the applicable criteria of 10 CFR 830.120; the American Society of Mechanical Engineers (ASME) Nuclear Quality Assurance NQA-1, 2004; and DOE Order 414.1C, Quality Assurance. These QA requirements are implemented through a Quality Assurance Project Plan (QAPP) for WRPS WTP work [68] that is conducted at VSL. Test and procedure requirements by which the testing activities are planned and controlled are also defined in this plan. The program is supported by VSL standard operating procedures that were used for this work [69]. This is LAW work and is therefore not subject to the requirements of DOE/RW-0333P, Office of Civilian Waste Management Quality Assurance Requirements and Description (QARD).

The waste simulants used in the tests were procured from Optima Chemicals according to VSL specifications. Optima Chemicals was required to provide completed batch sheets with identifications and weights of chemicals used in the preparation of each batch of simulant. The compositions of the simulants were confirmed by chemical analysis at VSL under the VSL QA program using VSL standard operating procedures.

1.6 Technetium Surrogates

In this work, a short-lived isotope of technetium, ^{99m}Tc (half-life = 6 hrs), was used in place of ^{99}Tc (half-life = 210,000 yrs). ^{99}Tc is a pure beta emitting isotope that would have required analysis by either beta counting or inductively coupled plasma-mass spectroscopy (ICP-MS). ^{99m}Tc, however, has easily detectable gamma emissions around 140 keV permitting analysis by gamma counting, which is fast, accurate, relatively inexpensive, and requires little sample preparation. A further significant benefit of ^{99m}Tc is that its short half-life means that all of the test systems and associated wastes are essentially decontaminated simply by allowing a short time (about three days) for decay (^{99m}Tc decays to ^{99}Tc but the ratio of their half-lives and, therefore, the residual activity due to the ^{99}Tc that is produced, is extremely small). Since ^{99m}Tc is routinely used in the medical

field for diagnostic and radiotherapy purposes, there is an extensive infrastructure already in place for providing calibrated doses at specified times at very modest cost. However, an obvious disadvantage with using such a short-lived isotope is that all of the analyses must be conducted soon after the samples are collected and decisions on any repeat analyses must be made quickly. ^{99m}Tc is a daughter of ^{99}Mo by beta decay (half-life 66 hours) with a branching ratio of 89%. ^{99}Mo and ^{99}Tc achieve equilibrium quickly enough such that doses of ^{99m}Tc can be obtained simply by elution from a ^{99}Mo column. Obviously, while ^{99m}Tc has different radiological properties from ^{99}Tc, their chemical behavior is identical. This isotope has previously been used successfully on the DM10 and DM100 melter system to investigate technetium partitioning while vitrifying LAW and HLW Hanford simulants [3, 4, 58, 70, 71]. However, in the present work, the inclusion of the recycle loop introduces additional timing considerations in both the design of the test systems and the execution of the testing. As discussed in Section 9, process models have been developed to address these issues and results from these models confirmed that such testing is practical [8].

Technetium in the form of pertechnetate best represents the likely form of technetium in the LAW melter feed since the majority of the technetium (perhaps >80%) in the waste tanks is present as pertechnetate. Exceptions are a limited number of tanks that are high in organics (e.g. AN-107 and AN-102), in which only about half the technetium is in the form of pertechnetate. However, the fact that Tc was originally added as pertechnetate, in combination with the high nitrate content, makes this the most likely species. Nevertheless, relatively little information from direct analysis is available on the speciation of technetium in the Hanford tanks.

There are no perfect non-radioactive surrogates for technetium. However, rhenium comes closest to meeting this need in many applications. Rhenium has frequently been used as a surrogate for technetium based on the general similarities in chemical and physical behavior, such as thermal stabilities, volatilities, and redox behavior, between analogous rhenium and technetium compounds expected in the waste [6]. However, it is also important to appreciate the differences [49, 52-54]. In previous work, tests were conducted on the DM100 with rhenium to study the synergistic effects of technetium and cesium on cesium volatility [67] and to assess likely technetium retention in a wide range of LAW glass compositions [72]. In the previous work [3], rhenium was shown to be a reasonable surrogate for technetium under the feed and melter conditions tested but important differences were evident. The relative volatilities of rhenium and technetium were further evaluated in subsequent tests conducted at the DM10 and DM100 scale [4]. Rhenium was included in the present tests to collect further information on the similarities and differences in the behavior of rhenium and technetium. Such data provide an important basis for interpretation of tests results that employ rhenium as a technetium surrogate, such as is typically the case at large scale.

1.7 Testing Overview

Six distinct feed compositions were used to determine the effect of feed composition on the retention of technetium and other species in nine nominally 72-hour tests. Key operating parameters such as the glass temperature (nominally 1150°C) were held constant to investigate the effect of each

feed composition on the retention of technetium. The processing rate was targeted at ≈ 2,250 kg/m^2/day of glass, which corresponds to the "stretch-goal" rate of 22.5 MT/day specified by ORP for the WTP LAW melter for all but one of the tests. The bubbling rate was adjusted to achieve a near-complete cold-cap (90-100% of melt surface covered with feed) while maintaining the target glass production rate. Quantitative measurements of glass production rates, melter operating conditions (temperatures, pressures, power, flows, etc.), gaseous emissions by Fourier Transform Infrared Spectroscopy (FTIR), and particulate emissions using Environmental Protection Agency (EPA) methods were made for each test. Discharged and melt pool glass samples were inspected for formation of any salt phases and analyzed for chemical composition, including technetium content. Samples of the process fluids from each of the off-gas treatment system components were collected and analyzed. Sampling and analysis during testing was sufficient to support a mass balance for all constituents of interest and particularly technetium, rhenium, iodine, sulfur, chlorine, and fluorine. Details of the DM10 recycle system design and sampling points are provided in Section 1.7.

1.8 DM10 Melter System with Recycle

The DM10 pilot scale melter was upgraded to include a wet off-gas treatment and recycle loop [8, 75]. An overview of the DM10 system showing system components and nominal process flows over the course of the tests is provided in Figures 1.1.a, 1.1.b, and 1.1.c. Also shown on the figures are locations of sampling points, labeled S0 through S10.

A more detailed schematic depiction of the modified DM10 system is provided in the Piping and Instrumentation Diagrams (P&IDs) for the system, Figures 1.2 – 1.10. For purposes of presentation in the P&ID format, the system has been conceptually broken down into the following eight subsystems (nodes):

- Node 1: Submerged Bed Scrubber (SBS)
- Node 2: Wet Electrostatic Precipitator (WESP)
- Node 3: Containment Tank
- Node 4: Vacuum Evaporator
- Node 5: Heating Water and Cooling Water Systems
- Node 6: DM10 Feed
- Node 7: DM10 Melter
- Node 8: Off-gas Exhaust

1.8.1 DM10 Melter

The DM10 unit is a ceramic refractory-lined melter fitted with two Inconel 690 plate electrodes that are used for joule-heating of the glass pool and a bubbler for stirring the melt. The melter P&ID is shown in Figure 1.3 and a schematic diagram of the DM10 is provided in Figure

1.11. Thermocouples installed in a thermowell provide temperature measurements at various locations within the glass pool and in the plenum space. The glass product is removed from the melter by means of an air-lift discharge system. The DM10 unit has a melt surface area of 0.021 m^2 and a glass inventory of about 8 kg. The off-gas system maintains the melter under slight negative pressure (typically about 2 inches W.C.) with respect to ambient. For comparison, each of the two WTP LAW melters has a melt surface area of 10 m^2 and a glass inventory of about 20 MT.

1.8.2 Feed System

For this testing the feed system consisted of three elements: the fresh feed supply, the recycle, and the ^{99m}Tc delivery. In the course of this series of tests, several design changes were made to the feed system to improve its performance and reliability [75]. The details of these changes are given below. Material impacts to the test conditions or test results due to these changes are discussed in subsequent sections of this report.

In the initial design [5], a small (400 mL) mixing vessel was used to combine the fresh feed, the recycle stream, and the ^{99m}Tc spike. This original design concept is shown in Figure 1.1.a and 1.4.a. The fresh feed was introduced in batches into a tank mounted on a load cell for weight monitoring. A speed-controlled agitator was lowered into the tank to stir the feed, and to prevent solids from settling. The feed was constantly recirculated through an external loop from the bottom to the top of the tank using a pneumatic diaphragm pump that provided continuous recirculation. The feed was introduced into the mixing tank by means of a peristaltic pump. The recirculation loop extended to the top of the melter where a tee diverted feed to the melter via the peristaltic pump. A photograph of this system is shown in Figure 1.12. The recycle stream flow to the mixing vessel was controlled via another peristaltic pump. The ^{99m}Tc spike was added to the mixing vessel using an automated syringe pump. A magnetic stirring bar was used for mixing. The mixing vessel was pneumatically sealed, and a dip tube inside the vessel allowed pressure from the compressed air displaced by the inlet liquid flows to drive the mixed feed into the melter. The fluid entered the melter through a water-cooled, Teflon-lined, vertical feed tube. A photograph of this is shown in Figure 1.13.a.

Upon completion of the first test, this vessel was found to have accumulated solids as well as a significant quantity of the ^{99m}Tc spike. Based on this result, it was determined that the best path forward was to remove the mixing vessel and inject the ^{99m}Tc spike directly into the recycle stream at a tee in the recycle line. This combined stream then mixed via a second tee with the fresh feed stream before entering the liquid cooled melter feed tube. While this new setup eliminated some of the issues from the previous test, it also had operational problems. The lines would clog, requiring manual operator intervention and feed system downtime. It is believed that these issues were the result of flow instabilities caused by the interaction between the feed and recycle pumps. These two pumps are both positive displacement, peristaltic pumps, and the fluids are all non-compressible. During the test, the recycle stream could be observed pulsing backwards in concert with the cycling of the fresh feed pump. This backward flow is believed to contribute to the line clogging during the

testing. This configuration was used during Tests 2 and 3. A photograph of the setup is shown in Figure 1.13.b.

Based on these observations, for the fourth test, a third feed delivery method was employed that decoupled the two pumps. This was done by injecting the ^{99m}Tc into the recycle line and injecting the mixture directly at the top of the water cooled melter feed tube. The fresh feed was introduced from the side of the tube, as before. Since the other end of the feed tube (in the melter) is open, this setup provided an open plenum between the two liquid entry points in the feed tube, which successfully decoupled the feed and recycle flows. This resulted in sample port S2 being moved upstream such that it sampled only the combined ^{99m}Tc spike and recycle stream. The P&ID for this feed system is shown in Figure 1.4.b, and a photograph of the setup is shown in 1.13.c.

Based on results of the first four tests conducted in FY11, several further feed system enhancements were implemented for the FY12 tests, prior to Test 5 [9, 75]. The primary change was to remove the technetium syringe pump delivery system and instead, the technetium spike was added directly to the fresh feed mixing tank. As done previously, the ^{99m}Tc was spiked into the melter feed at a constant rate of about 1 mCi/kg glass based on the activity at a reference time at the start of the test. The actual spiking rate is determined for each test based on the measured spike volume delivered and the measured specific activity of the spike solution. The ^{99m}Tc spike is added to the feed mixing tank at the start of the test and at the point where additional batches of fresh feed are added to the mixing tank. Four batches of feed were added to the mixing tank during a 72 hour test. Each time an individual batch of fresh feed is added to the tank, the appropriate portion of the ^{99m}Tc spike is added while the tank is being mixed using a mechanical agitator and the recirculation loop. To simplify the handling and introduction of the added spike, the spike solution was diluted to a larger volume of approximately 40 ml instead of the much smaller delivery volume used previously with the ^{99m}Tc syringe pump. In the previous design, the relatively small technetium spike pump and delivery system were contained in a locally shield box. In contrast, the addition of the technetium spike to the feed mixing tank results in a much more distributed source that required addition of features to the feed system to minimize operator radiological exposure and mitigate potential hazards due to leaks. Exposure is minimized by use of shield curtains placed around the mixing tank and recirculation loop. The curtain design eliminates shine paths to operators performing normal operational duties around the melter and off-gas system. However, the curtains allow for easy access for short duration operations such as introduction of the spike to the feed tank. Other changes include improved seals on the feed tank.

The feed to the melter was done in the same manner as the previous test, except for the addition of the technetium spike. This kept the plenum in the feed tube between the feed and recycle streams, which prevented the pumps from interacting. This is shown schematically in Figures 1.1.c and 1.4.c.

After Test 5, which employed an atypically high viscosity feed, one final change was made for the four remaining tests to further improve mixing of the technetium spike with the fresh feed. For these tests, instead of adding the spike directly to the feed tank, the spike was added to 1 liter of

water in a fixed vessel located above the feed tank. The solution from this vessel was then gravity fed into the feed tank concurrently with the fresh feed batch additions with mixing and recirculation. This final setup is shown in Figure 1.4.d.

1.8.3 Off-Gas System

Exhaust gas leaves the melter plenum through a film cooler device designed to minimize the formation of solid deposits. The film-cooler input air has a constant flow rate of ~10 SCFM and its temperature is thermostatically controlled to ~300°C. For operational simplicity, the original DM10 system (without recycle) was equipped with a dry off-gas treatment system involving gas filtration operations only. As part of the modifications to recycle liquid effluents from the off-gas system back into the feed, that system was replaced with a wet off-gas treatment system, as described in further detail below. Figures 1.5 through 1.9 show the P&IDs of the off-gas system unit operations that were added to implement the recycle loop; Figure 1.10 shows the P&ID for the final (original) dry filtration stage. The added components are the SBS (Node 1), WESP (Node 2), vacuum evaporator (Node 4), and associated tanks and piping (Nodes 3 and 5). Figure 1.14 shows the layout of these components and Figure 1.15 shows the internals in cross section. Figure 1.6 is a photograph of the installed wet off-gas components on a skid.

The off-gas pipe between the melter film cooler and the SBS is referred to as the transition line. Based on the results of the first four tests conducted in FY11, several enhancements were made in that area for the FY12 tests, as described below.

1.8.3.1 Film Cooler and Transition Line

As noted above, exhaust gases leave the melter plenum through a film cooler device that minimizes the formation of solid deposits. The connection between the melter and off-gas system is a transition line pipe that connects the film cooler to the SBS.

After FY11 Test 2, an accumulation of solids material was noticed in the transition line. Subsequent analysis of these solids showed that they were significantly enriched in rhenium but the material could not be analyzed for technetium because too much time had expired to allow accurate gamma counting. Immediately after Test 3, the transition line was dismounted and the accumulated solids were collected. The transition line and the film cooler were then rinsed and the rinsates were collected for analysis. Analysis of these samples provided an assessment of the accumulation of various feed species in these components. The results from Test 3 indicated significant accumulation of technetium (approximately 5%) in the transition line and film cooler. Similar sampling and analysis after Test 4 found approximately 4% technetium holdup in the transition line and film cooler.

In light of these observations several changes were implemented to reduce the solids accumulation and associated technetium holdup [75]. Originally, the transition line was a 3" schedule 10 SS pipe that ran horizontally out of the film cooler to a standard 90° elbow that flowed down into the submerged bed scrubber. The modified transition line implemented several changes: it exits the film cooler and reduces to a 2.5" pipe to increase the superficial gas velocity; it has a spray nozzle near the film cooler outlet to wash out solids deposited in the line; and it is run at a 10° downward angle to allow the spray water to drain into the SBS. These rinse features are generally consistent with the planned design and operation of the WTP melter off-gas system, although the exact mechanical design details differ.

Water for the nozzle spray comes from a small recirculation line and pump that draws water from the SBS sump. The supply for the spray is taken from the SBS sump in order to prevent disturbing the system water balance. The spray rate is about 1.5 gpm and is activated for about 1 minute every 12 hours. These changes were employed for the last five tests in order to reduce solids accumulation and technetium holdup. The modified transition line is shown in Figure 1.17 and the modified P&ID is shown in Figure 1.5.b.

1.8.3.2 Submerged Bed Scrubber

The SBS is the first unit operation in the upgraded DM10 off-gas system. The SBS serves multiple functions including: cooling the off-gas via contact with liquid water and condensing moisture in the gas; removing large particulates from the off-gas stream; scrubbing out soluble acid gases such as NO_X, HCl, and HF; and dissolving soluble particulates into the aqueous phase. The DM10 SBS consists of a vertically oriented, cylindrical, packed-bed column that is submerged in an outer tank that is partially filled with water. The water pool serves to quench the off-gas and collect particulates and soluble species. A gas plenum space above the packed bed serves as a disengagement volume to remove entrained liquid from the exiting gas stream.

The off-gas enters from the transition line through a down-comer at the top of the column that passes through the gas plenum, the packed bed, and discharges into the water pool. The flow then bubbles up through a diffuser plate that supports the bed packing, and evenly distributes the flow into the bed. The off-gas then flows through the gas plenum and exits through the top of the column. The water level and flow were controlled by an inlet nozzle and an outlet overflow nozzle located a few inches above the height of the packing. Water was filled to this level at the start of operation. As condensed water accumulated, it overflowed from the SBS into an external collection tank where it was combined with the aqueous WESP effluent. The combined fluid was then concentrated in the evaporator and recycled into the melter feed. In order to reduce the residence time in the sump, the SBS had a makeup water flow of about 10 L/hr for all of the tests.

The off-gas inlet temperature was typically 200-300°C and the off-gas outlet temperature was ~30°C for all of the tests. To handle this thermal duty, the SBS employed a submerged coil in the sump of the vessel and a cooling jacket around the SBS shell. Chilled water was used as the

cooling medium and the flow rate through the coil and external jacket was adjusted as needed to maintain a stable temperature in the SBS bed of ~30°C; this was set somewhat lower than the nominal WTP value of 50°C in order to reduce condensation in the downstream filtration system but the difference is not expected to affect the elemental scrubbing efficiencies. The DM10 SBS was constructed of 316 stainless steel. Figure 1.18 shows a photograph of the SBS with its makeup water line and sight glass for monitoring the liquid level. The original SBS configuration can be seen in Figure 1.5.a, which was used for the first four tests [5]. The SBS inlet was modified to accommodate the transition line slope and wash-down features used for the last five Tests [9]. The changes are shown in Figure 1.5.b.

1.8.3.3 Wet Electrostatic Precipitator

The DM10 WESP treats the off-gas exiting the SBS. Based on data from the DM1200 system, the WESP is particularly effective in capturing submicron particulates passing through the SBS. It is a vertical, 316 stainless steel vessel containing three star-spiked, high voltage rod electrodes located at the center of vertical, electrically grounded collection tubes that run the length of the vessel. High voltage (20-32 kV) applied to the electrodes produces corona discharge which ionizes aerosol particles flowing between the electrodes and the collection tubes. The high electric field causes any ionized particles to move and deposit onto the collector tube walls. A high-voltage power supply controls the voltage and current and prevents arcing between the rod electrodes and the grounded collection tubes.

The off-gas enters through a port near the bottom of the unit and flows vertically through the three tubes exiting at the top. A water spray introduced at the off-gas inlet ensures that the collection surfaces are coated in a wet film during operation, which prevents the collected particulates from permanently adhering to the collection tubes and allows the precipitated particles to be washed down into the containment tank through a port in the conical bottom of the vessel. Consequently, there is very little liquid hold up in the WESP sump and the effective sump volume is very small (of the order of a tenth of a liter).

During testing, the presence of condensation on the insulators for the rod electrodes was found to degrade their electrical resistivity over time. This prevented adequate voltage supply to the WESP resulting in a diminished decontamination factor. Similar issues were observed previously in some of the tests with the DM1200 WESP [82 – 85]. To resolve this issue, several modifications were implemented [75].

- The entire upper section of the WESP, which houses the electrical insulators, was heated via a band heater to limit condensation on the inner surface of the vessel near the insulators.

- Hot purge air was added through the top of the WESP and directed onto the insulators to reduce their contact with the wet off-gas stream.

- Holes were bored into the hollow ceramic insulators to allow hot air to be flowed through their interior in order to further assist in keeping them dry.

This approach, which is shown in the FY12 revision to the P&ID, Figure 1.6.b, stabilized the WESP performance and allowed it to function as designed for the remaining tests.

Periodically, if needed, the WESP can be flushed (deluged) from the top with fresh water in order to wash the particulate material that has built up on the electrodes and tubes into the vessel sump. Deluges were not performed during the tests but multiple deluges were performed at the conclusion of each test in an effort to recover all of the collected material, as required to support the mass balance around the system.

Figures 1.19 – 1.20 show the installed WESP. Figure 1.20 shows the top of the WESP, including two of the three electrical connection points to the electrodes inside the WESP. Figure 1.21 is a view looking down into the WESP from the top. The three channels, each with a single electrode down the center, are visible. A view near the bottom of one of the channels is shown in Figure 1.22.

Figure 1.23 shows schematic diagrams of the various modifications that were made to the WESP in successive tests, as described above.

1.8.3.4 Evaporator

Both commercial units and a custom design were considered for the DM10 vacuum evaporator. A custom design was selected due to the rather unique requirements of the recycle tests and the need for small sump volumes that could not be attained with commercial units. However, the vacuum pumping and condensation functions were provided by a parallel commercial unit. Figure 1.24 – 1.27 show photographs of these units.

The DM10 evaporator concentrates the effluents from the SBS and WESP by evaporation under reduced pressure, as is the case at the WTP. The concentrate is then recycled into the melter feed. The DM10 vacuum evaporator is a vertically oriented shell and tube heat exchanger that runs at a pressure of ~ 2.5 inches Hg, giving a saturation temperature of ~ 40°C. The evaporator, which is constructed of 316 stainless steel, is designed to have the process liquid on the tube side and hot water for heating on the shell side at 50 - 55°C. The vessel differs from a traditional shell and tube heat exchanger in that the vacuum evaporator has two tube sheets at the top of the exchanger and a third tube sheet at the bottom end of the exchanger. The feed liquid enters between the top two tube sheets and flows downwards through an array of 19 parallel tubes (3/8" NPS Sch 10) and boils as it is heated under vacuum by the hot water in the shell. The two-phase flow exits through the bottom tube sheet. The concentrated liquid remains in the sump while the vapor flows back up through an array of 8 parallel tubes (1" NPS Sch 10) that extend through all of the tube sheets and exits at the

top of the vessel. The vapor exits through a high efficiency mist eliminator (HEME) to reduce carryover of entrained water droplets. The vapor then flows through a pumping system, which maintains the vacuum on the system and condenses the vapor. Figure 1.24 is a photo of the evaporator showing the connection hoses to the recirculating water heater, which provides the energy source for evaporation. The vapor line exiting the top of the evaporator boiler is shown in Figure 1.25. The valve on the line allows isolation of the vacuum source.

To facilitate efficient heat exchange, the evaporator concentrate solution is recirculated from the sump to the top of V-400 using a flexible impeller pump, P-401. A peristaltic pump, P-400, pulls the recycle stream off of the discharge from P-401, as shown in Figure 1.28. This streams flows through a sampling port and flow meter and then on to the melter feed tube where it is combined with the spiked melter feed.

Vacuum generation and condensation of the vapor from V-400 is provided by a commercial vacuum evaporator (Evaled E700-AA3) unit, which has been modified to accept vapor input from the DM10 system. Figure 1.26 shows a photograph of the E700-AA3 as installed at the VSL. The E700-AA3 system typically operates as a self-contained vacuum evaporator with an internal refrigeration cycle that provides the heat for evaporation and condensation; however, in the current use, the E700 system provides a vacuum source and cooling for condensation of the vapor from the V-400 custom evaporator as well. In the adaptation into the DM10 off-gas system, a connection is made from the vapor line exiting the V-400 custom evaporator into the E700 commercial unit evaporator tank. Figure 1.27 shows the connection from the V-400 custom evaporator to the commercial unit via a bulkhead fitting on the Plexiglas window fitted onto the opening in the commercial unit tank. The modifications to the commercial evaporator affect the energy balance of the refrigeration cycle. To account for this, a parallel, brazed plate heat exchanger was added to remove additional heat from the water accumulating in the sump of the unit by recirculating it through the heat exchanger.

There are provisions throughout both units for sampling of the concentrates and condensates. These samples are collected and analyzed throughout testing, with the exception of the E700 sump fluid (which is essentially just the accumulated condensate from the V-400), which is sampled and analyzed only at the end of each test.

1.8.3.5 Off-Gas Control Considerations

Integration of the recycle loop with the wet and dry off-gas systems into the DM10 system required the design of a number of control schemes and associated software. The requirement of small sump volumes along with the need to provide a continuous recycle stream of evaporator concentrate to be mixed with fresh feed and technetium spike solution required careful control of evaporator heat transfer. The very small sump volume (~ 2.5 L typical operating level) in comparison to the inflow rates (~15 L per hour) meant that any small imbalance could lead rapidly to flooding of the evaporator or dry-out of the sump.

SBS and WESP sump liquid is collected in the containment tank, V-300, from which it is delivered to the evaporator for concentration and recycle to the melter. Figure 1.29 shows a photograph of the containment tank. The level in the containment tank is monitored by a liquid level transmitter (4-20 mA output). The control system opens pneumatic valve LV-3607 on a regular timed cycle and the vacuum in the V-400 evaporator draws the liquid into it. The length of time valve LV-3607 remains open is a function of the level in the tank. As the level rises above the set-point, the time the valve is open on each cycle increases, and vice versa. In this way, a pulsed but net steady average flow to the evaporator is maintained while the flow rate is adjusted to maintain the set-point level in the containment tank.

Since there is a fixed specified flow rate of the evaporator concentrate (recycle stream) from the evaporator sump and a varying inflow from the containment tank, the evaporation rate of the evaporator must be adjusted to compensate. This is accomplished by a control system that maintains the V-400 evaporator sump level essentially constant. This has the further advantage of maintaining a uniform recycle stream to the melter. The evaporator sump level is monitored by three level switches (high, middle and low) in the sump of the evaporator. The signals from these level switches are used to control the temperature of the heating water that is recirculated through the evaporator jacket. When the level rises above the middle switch, which is at the nominal set-point level, the heating water temperature is increased in order to increase the evaporation rate and reduce the sump level, and vice versa. The signals from high and low sensors are used to indicate that larger changes in temperature are required in order to rectify greater departure from the set-point. Although this system required some considerable tuning, it was ultimately extremely effective in controlling the evaporator sump level to the extent that operator intervention was rarely necessary.

Both the containment tank and V-400 evaporator sumps are fitted with level sight glasses for manual monitoring of their respective levels. In addition, a video camera is used to display the evaporator sight glass level on the operations control screen alongside all of the monitored process parameters.

All of the melter, feed, and off-gas system control, data acquisition, and display functions are provided by a custom-designed system operating on the LabVIEW platform.

1.8.3.6 Sampling Points

A variety of sampling points are provided in the DM10 system to support a mass balance determination for all constituents of interest. The sampling locations (S0 – S10) are shown in Figure 1.1.a –1.1.c. Based on initial test results, a number of revisions were made to the feed system in particular, as described above. The resultant sampling points used for the FY12 testing are described below and provided in Figure 1.1(c).

- *Melter Feed*: Confirmation of the melter feed composition is based on samples of the melter feed from the drum of as-received feed (S0), samples of the melter feed with technetium spike that are taken from the feed tank (S1), and samples from the recycle line (S2).

- *Glass Product*: Samples of the glass product are taken from glass that is air-lift discharged into steel cans (S4).

- *Glass Pool*: Glass samples are also taken directly from the glass pool ("dip" samples, S3), particularly for detection of any molten salt phases.

- *Off-Gas Vessel Sumps:* Liquid samples are collected from each of the vessel sumps in the off-gas treatment system (S5, S6, S9, and S10).

- *Off*-gas 1: Isokinetic sampling of melter exhaust is conducted at a point located immediately downstream of the WESP (S7).

- *Off-gas 2:* A sampling point located downstream of the HEPA filter is used for continuous emissions monitoring (CEM) by Fourier transform infra-red spectroscopy (FTIR) of a wide variety of gaseous species, including NO, NO_2, N_2O, CO, and SO_2 (S8).

For collection of many of these samples from process flows that are often under vacuum, a sampling apparatus was designed to allow collection of standard volumes [75]. In addition to the samples listed above, which are collected during the tests, at the end of each test, all of the sumps are sampled, sump and line flushes and rinses are performed, and the samples are collected for analysis. This includes samples generated from solids and rinsates collected from the film cooler and transition line. This suite of samples is used to support a mass balance over the entire test.

1.9 Summary of Experimental Methods

1.9.1 Glass Compositional Analysis

Sample preparation for chemical analysis typically involves size reduction and sieving. All samples were subjected to X-ray fluorescence spectroscopy (XRF) to determine the concentration of all elements except boron and lithium. A series of National Institute of Standards and Technology (NIST) reference materials were used for confirmation of the XRF data. Boron and lithium were determined by total acid dissolution of ground glass samples in HF/HNO_3 and subjecting the resulting solutions to direct current plasma-atomic emission spectroscopy (DCP-AES) analysis.

1.9.2 Melter Feed Analysis

Feed samples were taken directly from select drums of feed received from the vendor to confirm composition before use. Feed samples from the feed tank, recirculation line, or the feed line in the melter feed system were taken during the tests to determine ^{99m}Tc content by gamma spectroscopy. Feed samples from feed drums were analyzed for general properties and oxide composition. Feed samples were placed into platinum/gold crucibles that were transferred into a programmed furnace for drying and fusion to form a glass. The glass samples produced from this fusion were ground to less than 200 mesh and sealed in 20-ml vials for subsequent analysis by XRF, or by acid digestion followed by DCP-AES on the resulting solution. The feed samples were also characterized for their density, pH, water content, and glass yield. As-received feed samples were diluted and the solutions analyzed for anion content by ion chromatography (IC).

1.9.3 Gamma Counting

The activity of ^{99m}Tc in spike solutions and glass and off-gas samples was determined by measuring the activity of the samples using a germanium co-axial GC2020 crystal gamma spectrometer in which gamma pulses are pre-amplified with a 2002/C/CSL spectroscopy preamplifier. A high purity germanium detector coupled with Genie 2000 gamma spectroscopy analysis software from Canberra Industries, USA was used to collect and analyze the gamma spectrum. The system was calibrated using a NIST traceable mixed-gamma standard calibration source prepared by Eckert & Ziegler Analytics under a Measurement Assurance Program according to United States Nuclear Regulatory Commission (USNRC) Regulatory Guide 4.15 Rev.1, and compliant with ANSI N42.22-1995 for the traceability of radioactive sources to NIST.

Samples of the ^{99m}Tc spike solutions, melter glass samples, melter off-gas samples on filters, and melter off-gas sample solutions were collected and analyzed. Samples of glass and off-gas filters were analyzed in Petri dishes (~ 80 mm diameter). The glass samples were first ground, sieved, and glass powder in the 100 to 200 mesh range was glued to the Petri dish. ^{99m}Tc spike solutions and off-gas solutions were analyzed in 500 ml Marinelli beakers. The system was calibrated using NIST traceable mixed gamma sources in containers with the same sample geometry. The activities of the samples were measured and corrected for decay so that all activities are reported for the same reference time, which is 12:00 noon on the day of elution given by the nuclear pharmacy that prepared and delivered the ^{99m}Tc sources daily. The decay correction includes a correction for decay during the data acquisition as well as for decay from the sample elution time to the start of data acquisition.

Glass sample were ground inside a glove box and sieved into three size fractions: (1) retained on 100 mesh, (2) 100 to 200 mesh and (3) passing 200 mesh. Fraction (2) was used for gamma counting; fraction (3) was used for XRF and DCP-AES analyses; and fraction (1) was archived together with any unused part of (2). Gamma counting to determine Tc activity was done using 0.5 g of glass powder. About 1 g of glass powder was used for composition analysis by XRF and DCP.

Details of the Tc activity measurement are given below:

1. The detector was first calibrated for the energy range from 59.5 keV (^{241}Am) to 1836 keV (^{88}Y) using a 9-radionuclide mixed gamma standard in either of the two geometries used for the ^{99m}Tc samples: 1) 80 mm diameter glass fiber filter in Petri dish, or 2) 500 mL Marinelli beaker. For each of these two geometries, an energy calibration and a full detector efficiency calibration were performed. These calibrations were subsequently used to convert gamma counts to activity (in μCi).

2. The samples that were used in Tc activity measurements are either glass powders or off-gas filters in a Petri dish, or off-gas solutions and pertechnetate source solutions in 500 mL Marinelli beakers. Each of these samples was counted for 10 minutes, which was found to be sufficiently long to obtain a reasonable number of counts. ^{99m}Tc samples were generally analyzed within 60 hours of sample preparation, well within the nuclide identification algorithm limit of 15 half-lives decay, or 90 hours (see further discussion below).

3. After the spectral peak is identified at 140.6 keV, its area is determined by summing the counts under the peak and subtracting the underlying background determined by averaging the counts on either side of the peak. The spectral analysis was made using the NIST gamma peak library provided with the Canberra software. Generally, only the ^{99m}Tc peak at 140.6 keV was identified in the gamma spectrum. A few of the samples showed minor contamination from the ^{232}Th and ^{238}U decay chains, probably due to grinding the radioactive glass samples in a glove box previously used with glass containing thorium and uranium. These peaks, however, are well separated from the 140.6 keV ^{99m}Tc peak and caused no issues in the determination of Tc activity.

4. Gamma activities were calculated at a reference time of 12:00 noon on the day of the test. The solutions were introduced into the DM10 melter tests within 24 hours from preparation of the ^{99m}Tc spike solution. The decay correction is done using the following relation:

$$A = A_0 . \exp(-\lambda t_d)$$

where,

A_0 is the activity at the reference time (12:00 noon on the day of sample elution)

A is the activity measured at the time of spectrum acquisition

λ is the decay constant = $ln(2)/t_{½}$, with $t_{½}$ = half-life of the isotope (6.02 hours)

t_d is the decay time. For each sample analyzed, the date and time of reference (12:00 noon of the day of ^{99m}Tc elution) is an input, allowing the software (Genie-2000) to calculate decay time as the time elapsed between the reference time and the spectral acquisition start time.

Any nuclide that has decayed for more than fifteen half-lives from the reference time is eliminated from analysis, which limits the current method of evaluation for ^{99m}Tc to less than 90 hours from the reference time, as long as the activity is above the minimum detectable level.

5. In addition to correcting for decay from the reference time, a correction is made to the above activity for the decay of short lived nuclides during data acquisition by multiplying it by a factor *C*, which is calculated according to the following relation:

$$C = \frac{\lambda t_c}{(1 - \exp(-\lambda . t_c))}$$

For 600 second count time, the actual elapsed time (t_c) is typically 610 to 620 seconds. For a 600 second count time, λ_c its smaller than 0.009 and the magnitude of this correction is less than 0.5% of the calculated activity.

Examples of decay corrections have been provided earlier [3]. The ^{99m}Tc stock solutions with nominal activity of 20 mCi were delivered as a 1 ml pertechnetate solution packaged in a 3 mL syringe. ^{99m}Tc solutions prepared for DM10 melter tests that employed the syringe pump were diluted to 22 ml, adding an extra 1 ml of deionized water to account for the dead volume in the syringe used to deliver the ^{99m}Tc solutions into the slurry feed to the melter.

Gamma counting of stock solutions was done on diluted samples in a 500 ml Marinelli beaker. In a first dilution, 0.1 ml of ^{99m}Tc solution was diluted to 500 ml; a subsample of that solution was then further diluted by an additional factor of 500 or 5000, depending on the age of the sample. The remaining ^{99m}Tc solution (21.9 ml) was reserved for the tests. Gamma counting was done on the first day for the most dilute solution, or at decay times of up to 52 hours for the lower dilutions. Multiple activity measurements for a ^{99m}Tc solution at various dilutions showed a percent relative standard deviation (%RSD) of 3.1 [3].

Gamma counting of off-gas samples on filters was done in a Laxbro polystyrene non-vented Petri dish with an outside diameter of 90 mm. Calibration of the instrument for this sample geometry was done using a NIST traceable 1 μCi mixed-gamma calibration source in an 80 mm active diameter glass fiber filter covered with tape in the same type of Petri dish.

Gamma counting of glass samples used 0.5 g of glass powder in the size range between 100 and 200 mesh glued onto a Petri dish with a thin layer of glue that was previously sprayed. Again, calibration was done using the same 1 μCi NIST traceable mixed-gamma calibration source in a Petri dish. The amount of glass and the particle size range of the powder to be used in gamma counting were optimized from a study in which the weight of the glass, its particle size, and the amount of ^{99m}Tc spike solution added to the crucible melt glass were varied [3]: the mass of glass to be used in gamma counting was therefore set at 0.5 g per Petri dish.

1.9.4 Anion Analysis of Liquid Samples

Ion chromatography (IC) was employed to measure the concentrations of inorganic anions in solutions. A Dionex DX-120 ion chromatograph was used. The DX-120 consists of a CDM-3 conductivity detector and an anion self regenerating suppressor and was equipped with IonPac AS-14/AG-14 column/column guard for anion separation. Column elution was performed with a solution of $Na_2CO_3/NaHCO_3$. The instrument was controlled using the Chromeleon (version 6.50) data system software. Calibration standards for the analytes of interest were prepared with NIST traceable standards and were used to obtain a linear working range (typically 10 ppm). Separation of the common anions (e.g., F^-, Cl^- and SO_4^{2-}) was normally completed within 15 minutes. Integrated peak areas for each separated analyte were used to calculate their respective concentrations.

1.9.5 Mössbauer Spectroscopy

Mössbauer spectroscopy is an analytical technique that utilizes the recoil-free emission and resonant absorption of gamma rays by nuclei bound in solids. The energies of the gamma ray emitter (source) and absorber (sample) have to be closely matched and, therefore, the number of elements that can be studied using this technique is limited. One of the elements that has been studied extensively using Mössbauer spectroscopy is iron. In this work, Mössbauer spectroscopy was used to measure the fraction of iron in the Fe^{2+} and Fe^{3+} states, which can be used as a measure of the redox state of the glass sample.

Mössbauer spectra were collected using an American Magnetic/Ranger Scientific MS-1200 system equipped with a ^{57}Co source in a rhodium matrix with glass powder as the sample. Both divalent and trivalent iron show doublet peaks in the Mössbauer spectra, and the peak areas are proportional to the concentrations of the respective species in the glass. Even though the peaks overlap partially, software can be used to deconvolute the peaks and calculate the peak areas. The ratio of the areas of the Fe^{2+} and Fe^{3+} peaks is equal to the ratio of their concentrations in the glass. The redox measurements are calibrated using a set of six standard glass samples ranging in Fe^{2+} to Fe_{total} values from 7 to 90%. The standards include a NIST traceable Obsidian Rock (SRM 278), five standard glasses analyzed by Corning, Inc. for their redox state, and the SRL-EA glass. The NIST Standard iron foil (SRM 1541) was used to calibrate the instrument and determine the zero velocity channels. Since Doppler shifts in energy are measured in Mössbauer spectroscopy, the velocity is a measure of the shift in energy; knowing the zero velocity channel therefore helps in identifying the Fe^{2+} and Fe^{3+} peaks.

1.9.6 WESP Emission Samples

Under recycle conditions, the only exit points for feed components are via the glass product or via the gas stream exiting the WESP. Feed, glass, and sump solutions constitute the vast majority

of the overall mass balance but a very small fraction leave the system via the WESP exhaust. Consequently, WESP emission fluxes were measured to complete the mass balance for each melter test. Isokinetic melter exhaust samples (exhaust gas flow velocity equal to velocity through the gas sample probe tip) were combined with the FTIR continuous monitoring data for gaseous species to characterize fluxes from the WESP. Standard EPA isokinetic off-gas sampling trains and methods (EPA Methods 1A, 2, 4, 5, 26, 29), composed of particulate filters and liquid impingers, were used to collect materials that were subjected to chemical and physical analyses using the techniques described in Sections 1.8.1, 1.8.3 and 1.8.4. The sampling method includes the analysis of rinsate solution generated by the washing of the heated line from the sampling probe inserted into the melter exhaust immediately upstream of the particulate filter. The concentrations of off-gas species present as particulates and gaseous species that are collected in impinger solutions were derived from laboratory data on solutions extracted from air samples (filters and various solutions) together with measurements of the volume of air sampled. Particulate collection requires isokinetic sampling, which entails removing gas from the exhaust at the same velocity that the air is flowing in the duct (40-CFR-60, Methods 1-5). Total particulate loading is determined by combining gravimetric analysis of the standard particle filter and chemical analysis of probe rinse solutions. An additional impinger containing 2 N NaOH was added to the sampling train to ensure complete scrubbing of all acid gases and, particularly, iodine. The collected materials were analyzed using DCP-AES for the majority of the constituents and ion chromatography (IC) for anions. Particulate filter, rinses, and impinger solutions were gamma counted for ^{99m}Tc prior to wet chemical analysis.

At a sampling point located downstream of the HEPA, emissions were monitored in each test for a variety of gaseous components, most notably CO and nitrogen species, by Fourier Transform Infra-Red Spectroscopy (FTIR). The off-gas system temperature is maintained well above 100°C prior to the sampling port downstream of the DM10 HEPA filter to prevent analyte loss due to condensation prior to monitoring. The data, therefore, represent the relative concentrations of volatile gaseous species in the melter exhaust.

SECTION 2.0
WASTE SIMULANTS AND GLASS FORMULATIONS

The base glass compositions proposed for technetium recycle testing were originally provided in a WTP Test Specification [72] and were subjected to extensive previous testing on the DM100 melter system [72, 74] to determine sulfur solubility and waste loadings for a series of LAW compositions. More recently, several of the compositions were used to evaluate the single-pass retention of technetium and iodine over a range of feed and melter operating conditions [3, 4]. The associated waste compositions were provided in another WTP Test Specification [76]. In view of the extensive data collected on these waste compositions and glass formulations, they provide a natural basis for the present work. Of these seven simulants and glass formulations, three were used for testing in FY11 [5] and five for testing in FY12 [9] (one, LAWE4H, is common to both phases of the work).

2.1 Waste Simulants

The LAW waste simulants for DM10 melter testing are derived from compositional data provided in a WTP Test Specification [76]. The simulant compositions are based on the compositions of LAW in the following tanks, which are listed below together with the corresponding glass formulations:

- Tank AP-101, Glass LAWE3;
- Tank AN-105, Glass LAWE4H;
- Tank AN-107, Glass LAWE5H;
- Tank AN-104, Glass LAWE6H;
- Tank AN-102, Glass LAWE7H;
- Tank AZ-101, Glass LAWE9H;
- Tank AZ-102, Glass LAWE10H.

Tables 2.1 through 2.7 summarize the simulant compositions for each of these LAW tanks. These simulants have all been used in previous melter tests [3, 4, 72, 74]. However, in all of the previous tests, the effect of the recycle stream on key volatile constituents (S, Cl, and F) was included by increasing their concentrations based on projections at steady state using measured melter decontamination factors. Conversely, in the present tests, the recycle stream was generated during the testing and combined with the waste simulant as part of the process flow. Consequently, the projected steady-state recycle contribution that has been included in these waste simulants must be subtracted out for the present work. The included effect of recycle was based on the assumption of 85% retention of sulfur in the melter for waste Envelopes A and C and 70% for Envelope B [77]. At steady-state recycle, this gives rise to an increase in the sulfur content of the melter feed of 17.65% for Envelopes A and C and 42.86% for Envelope B. Similarly, the chlorine concentrations

were increased by 111% and fluorine concentrations by 19% for all melter feeds [77]. The amounts of sulfate, chloride, and fluoride have therefore been reduced (as sodium salts) accordingly in the simulants used for the present tests.

2.1.1 Waste Simulant Spikes

As in previous tests [3, 4] , iodine (as iodide) and rhenium (as perrhenate) were each spiked into the melter feed at levels corresponding to 0.1 wt% (as I and ReO_2, respectively) if all were retained in the glass. Similarly, ^{99m}Tc was spiked into the melter feed to target a concentration of about 1 mCi/kg glass assuming total retention in the glass and based on the activity at a reference time at the start of the test. The actual spike concentration was determined for each test based on the measured spike volume delivered and the measured specific activity of the spike solution. Calibrated ^{99m}Tc doses were received in the morning prior to each test; since the doses were calibrated for 12:00 noon, the actual dose on receipt was almost twice the reference dose. All of the ^{99m}Tc activities obtained from gamma counting data were referenced to the VSL calibration at 12:00 noon on the initial day of the test (i.e., they are the activities that would have been present at 12:00 noon and are therefore corrected for the effects of decay). Each dose received was diluted to 22 ml, of which 0.1 to 0.2 ml was counted to determine the total amount of ^{99m}Tc used in each test. The remaining volume of the ^{99m}Tc solution was loaded into a medical syringe pump which was attached to a line connecting to a port in the melter feed line adjacent to the feed tube in the first four tests or mixed directly into the feed tank in the last five tests.

2.2 Glass Formulations

The compositions of the base glasses that were tested for the LAW simulants are given in Tables 2.8 – 2.14, together with the waste loadings and contributions from the waste and glass formers. Crucible melts of these glasses have already been prepared and characterized at VSL for compliance with processing and product quality requirements; the base glasses meet all relevant processing and product quality requirements. Glass former additives [78] for one liter each of the waste simulant and selected feed properties are shown in Table 2.15.

As captured in the LAW glass formulation correlation that was developed for WTP process control [79], the relative sodium and sulfur content in the LAW material is a key factor in the determination of waste loadings and appropriate glass formulations. For some waste streams, potassium also plays a significant role. Consequently, it is instructive to display the LAW glass formulations on a plot of alkali content versus sulfur content, as shown in Figure 2.1. The line in the figure shows the glass formulations that would be produced by the baseline WTP LAW glass formulation correlation [79]; it is noted, however, that WTP LAW glasses with significantly higher waste loadings have been demonstrated [80]. This framework provides a useful basis for testing across the spectrum of LAW compositions. This approach was used in recent testing on technetium retention [3, 4] and also for the present work. The results from the previous testing show single-pass

technetium retention (i.e., without recycle) that vary significantly across LAW waste types, from a low of about 18% to a high of about 65% (without incorporation of any of the retention enhancements that have been developed). The most extensive technetium retention testing has been performed on the AN-105 LAW simulant and LAWE4H glass formulation, which was included in the present work. Overall, the tests address the variation across waste types and the ability of recycle to achieve high overall retention despite low single-pass retentions.

2.3 Organic Reductant Additions

With high nitrate feeds, the addition of reductants is necessary in order to control melt foaming. Sugar, which was used for this purpose at West Valley, has also been selected as the baseline reductant for the WTP. The amount of sugar required increases with the amount of nitrates present in the feed and decreases with the amount of waste organics present in the feed, which themselves act as reductants. Excessive additions of reductants can be deleterious, leading to over-reduction of the melt and formation of sulfides and molten metals. Melter testing while monitoring the iron redox state have shown that carbon additions greater than the targeted amount created overly reducing conditions in the glass [3, 17, 18, 25, 44]. Consequently, the oxidants and reductants in the feed must be suitably balanced. The basis for achieving this balance was developed by VSL and Energy*Solutions* for the vitrification of high-sodium-nitrate feeds at Savannah River's M-Area and has been successfully applied to the processing of a wide variety of simulated WTP feeds over many years [17-40]. In developing this approach, we elected to conservatively adopt the most reducing potential reaction as the basis for the *definition* of a "sugar ratio" of 1.0 as a result of concerns for over-reducing the melt. Such a reaction, using sodium salts as an example, is

$$C_{12}H_{22}O_{11} + 8NaNO_3 = 8CO_2 + 4CO + 4N_2 + 11H_2O + 4Na_2O$$

Fundamentally, the basis that is selected is simply a convention, since the precise stoichiometry of the reactions involved is neither known nor constant under the conditions prevailing in the melter. However, with this convention, a sugar ratio of 1.0 corresponds to one mole of sucrose per eight moles of nitrate or, more generally, 1.5 moles of organic carbon per mole of nitrate. It is then expected that significantly less sugar than this will be required in practice. The empirically determined amount required to successfully control melt foaming without significantly reducing the glass melt was found to correspond to a ratio of 0.5 when any nitrites present were counted as nitrates (i.e., 0.75 moles of organic carbon per mole of nitrate + nitrite). This approach has been employed for all WTP melter testing. It is, however, expected that slight variations around the nominal value of 0.5 may be necessary to account for differences in the reducing power of waste organics in comparison to sugar, particularly for LAW streams that are high in organics [3, 4, 25]. Testing with starch in place of sugar has shown that, like waste organics, starch has less reducing power than sugar [44].

The calculation of the amount of sugar needed to achieve a stoichiometric sugar ratio of 0.5 for LAWE4H proceeds as follows:

- One liter of simulant contains 126988 mg nitrate and 85428 mg nitrite (see Table 2.2), which corresponds to 2.048 moles of nitrate and 1.857 moles of nitrite, giving a total of 3.905 moles of NOx
- Required total amount of organic carbon for a sugar ratio of 0.5 is 3.905 x 0.75 = 2.929 moles
- One liter of simulant contains 2093 mg or 0.174 moles of organic carbon (see Table 2.2)
- Therefore, 2.929 - 0.174 = 2.755 moles of organic carbon must be added.
- The molecular weight of sucrose is 342 g per mole, 2.755 x 342/12 = 78.5 g sugar must be added per liter of simulant, as shown in Table 2.15.

2.4 Preparation of Melter Feed

Optima Chemicals, which has supplied all of the LAW simulants for the previous DM10, DM100, DM1200, and LAW Pilot Melter studies, prepared the simulants and added the glass forming chemicals before shipment to VSL in 55-gallon drums. Iodine in the form of sodium or potassium iodide, rhenium in the form of perrhenic acid, sugar, and the technetium spike were added to the feed at VSL.

2.5 Analysis of Melter Feed Samples

2.5.1 General Properties

Feed samples from melter tests were analyzed to confirm the physical properties and chemical composition. Samples were taken directly from feed drums prior to addition of technetium, iodine, rhenium, and sugar to verify the as-received feed composition for all tests. Feed samples were also taken from the line into the melter to verify the technetium concentration in the initial four tests and to again verify the composition of the feed for most inorganic components [10]. For several tests, the residual feed from the feed tank and mixing vessel were also sampled. Feed source, sample names, sampling dates, and measured properties are provided in Tables 2.16 and 2.17 for feed samples of as-received feed and feed samples taken from the feed system, respectively. The measured glass yield for all of the as-received feed samples deviated less than 10% from the target values and most deviated less than two and a half percent from the target values (on a mass per unit mass basis). Other measured parameters, including density, water content, and pH also indicate that the feed approximates the target solids content and show the consistency of the feed for each composition. Collectively, the measured values support the use of the target values for calculating glass production rates (this criterion is the same as was used extensively in all previous melter testing performed for the WTP and was adopted here for consistency). Feed samples from the feed system also indicate that the feed solids contents approximate the target values except for samples from the first test. The mixing vessel at the conclusion of Test 1 contained feed with a high concentration of solids. This observation and the measured inconsistency in feed solids content of samples from Test 1 prompted changes in the feed system for subsequent tests. The measured pH

varied from 8 to 13, depending on waste loading and the concentration of alkali hydroxides in waste: LAWE3, LAWE4H, and LAWE5H with the higher concentrations and pH as compared to LAWE7H, LAWE9H, and LAWE10H with lower concentrations and pH. Measured feed properties in the baseline feed compositions in the current tests are similar to those measured in previous tests with the same waste and glass formulations [3, 4, 72, 74].

2.5.2 Technetium Content

Various feed streams were sampled at different locations in the feed system throughout the tests to verify the technetium concentration. A listing of all the samples analyzed for technetium content is given in Table 2.18. During the first two tests, feed was sampled from a feed port downstream of the point at which the injected technetium, feed pumped from the feed tank, and the recycle stream were combined. The measured feed line Tc concentrations cover a range from 0.319 - 2.874 μCi/g, due mostly to the buildup in the recycle streams as the tests progress. However, some of the variation in the early tests is due to the issues with the technetium spiking system that led to subsequent feed system modifications. Also of note from the first test is the high concentration of technetium in the feed removed from the mixing vessel at the end of the first test.

Although the measured technetium concentrations included the range expected based on the feed and technetium injection rates, changes were made to the feed system to provide more consistent delivery to the melter. During Tests 3 and 4, the recycle stream was sampled during testing and the stream resulting from combining the three feed components was sampled directly from the feed tube at the end of the tests. High concentrations of technetium were measured in the recycle stream, between 5 and 12 μCi/g, as expected. Lower concentrations, between 0.4 and 1.1 μCi/g, were measured in feed sampled from the feed tube; these concentrations are consistent with the technetium injection, slurry feed, and recycle stream flow rates and concentrations.

In Tests 5 – 9, technetium was added directly to the feed tank. In these tests feed samples were collected from the feed line prior to blending with the recycle stream, from the residual feed remaining in the feed tank at the end of each test, and directly from the recycle line. The measured technetium concentration in the feed samples from the sampling port and taken from feed tank approximates the 0.5 μCi/g targeted for the five tests. The recycle stream contained higher and variable concentrations of technetium, as expected. For mass balance determinations, the amount of technetium fed to the melter is calculated from the amount of technetium injected into the feed stream for Tests 1 – 4 and the amounts measured in the feed samples for Tests 5 – 9.

2.5.3 Chemical Composition

The chemical compositions of the feed samples were determined by first making a glass from the feed sample via crucible melt. The glass was subsequently crushed and analyzed directly by XRF. All vitrified feed samples were also dissolved in acid (HF/HNO_3) with the aid of a microwave

oven and the resulting solutions analyzed by DCP-AES. The measured boron and lithium values from the DCP-AES analysis were used for normalizing the XRF data since their concentrations were not determined by XRF. Anion concentrations were determined by dilution of raw feed samples with de-ionized water followed by ion chromatography.

The analyzed compositions of feed sampled from as-received drums are provided in Table 2.19. The results generally show good agreement with the target composition for the major components. The most abundant constituent, silica, had deviations from target of less than 2.5% for all the as-received feed samples. Of the oxides with target concentrations of one weight percent or greater, the XRF values had relative deviations of less than 10% for most measured values for as-received feed samples with a few notable exceptions. A surplus of boron of about one absolute percent was measured in feed used for the first two tests and was confirmed by the analysis of the product glasses (see Section 5.1). This was corrected in subsequent batches of feed used in Test 7 with the same LAWE4H composition. Deficits in magnesium of up to a third of an absolute percent were evident in some samples from the initial tests due to olivine settling during sampling. As observed in previous tests with these compositions [3, 4], surpluses of titanium were observed in feed and glass samples due to its presence as a contaminant in the glass forming additives, most notably kyanite [81]. The absolute percent deviations from target are less than 0.35 wt% and therefore would not affect the outcome of the tests with respect to volatile retention in the product. Common elements such as chromium, lithium, potassium, and phosphorus, which are typical impurities in bulk chemicals, are over-represented when the constituent is a minor component. Higher measured concentrations for these common elements may also be attributable to measurement uncertainties at these low concentrations. Agreement between the two analytical methods was excellent, except for low sodium values obtained from the DCP analysis, which is due in part to a low-bias for sodium for that method [81]; previous experience indicates that the XRF results are more reliable in this regard. The concentrations of volatile minor elements such as sulfur and chlorine determined by XRF are, as expected, below target due to loss during crucible melting of the feed samples. Conversely, higher than target concentrations of sulfur and chlorine were measured on solutions from most feed samples prepared at room temperature and analyzed by ion chromatography. Many of the product glasses also have higher than target concentrations of sulfur and chlorine, supporting the ion chromatography analysis of the feed samples. In all but the LAWE5H and LAWE7H feed samples, analyzed fluorine concentrations were well below the low target value of 0.07 wt%.

Feed samples taken from a variety of locations within the DM10 feed system were also analyzed for oxide composition. In addition to analysis by XRF, vitrified feed samples were also dissolved in acid (HF/HNO_3) with the aid of a microwave oven and the resulting solutions analyzed by DCP-AES; results are provided in Table 2.20. Analyzed compositions of samples from Tests 1 and 2 show significant deviations from the target concentration for several oxides. Soluble components such as boron, alkali, and halides decreased in concentration over the course of the two tests while insoluble constituents, namely magnesium, zirconium, and titanium, increased in concentration. The largest concentration of these insoluble oxides in the form of olivine, zircon, and rutile sands were observed in the mixing vessel at the conclusion of Test 1. Given that the as-

received feed and product glasses were largely on target, the bias observed in Tests 1 and 2 feed samples were probably a result of the sampling system used in these tests. The analysis of the physical properties and chemical composition of feed prompted changes in the feed system, including the manner in which feed was sampled for subsequent tests. Feed samples taken from the feed tube at the conclusion of Tests 3 and 4, as well as residual feed from Test 8, show good agreement with the as-received feed analysis and their respective target compositions. Unlike the as-received feed samples, these feed samples contained the technetium, iodine and rhenium spikes. Rhenium and iodine like other volatile elements were measured at below target values due to loss during crucible melting of the feed samples.

SECTION 3.0
DM10 MELTER OPERATIONS

Melter tests were conducted on the modified DM10 system with LAW simulants from 8/30/11 to 3/9/12. These tests investigated the retention of technetium and other volatiles in glass produced from simulated LAW streams processed in a prototypical melter and off-gas system with recycle of the off-gas effluent solutions back to the melter feed. These tests produced over 1080 kg of glass from over 2200 kg of feed. Table 3.1 provide summaries of the DM10 tests, including run times and dates, the percent of feed technetium, rhenium, and iodine measured in the glass product, the amount of glass discharged, the amount of feed processed, the recycle stream feed rate, and target glass composition. A chronology of operational events for each test is provided in Tables 3.2.a – 3.2.i.

3.1 DM10 Tests

For these tests, the nominal melter operating conditions for testing were an 1150°C glass pool temperature, sugar as an organic reductant at a stoichiometric sugar ratio of 0.5, a recycle solution feed rate of 0.4 kg/hr, and air bubbled through the glass pool at a rate to achieve a constant glass production rate of 2,250 kg/m^2/day. This rate corresponds to the production of 142 kg glass over the targeted 72 hour test duration. All feeds were spiked with a solution containing ^{99m}Tc in the pertechnetate form; the feed used in these tests also contained measureable amounts of nonradioactive iodine and rhenium. In each test, a mass balance for technetium and other feed constituents of concern was measured across the glass pool, discharge glasses, off-gas and evaporators system components, and WESP exhaust. The tests, listed in the order in which they were performed, were as follows:

- Test 1: Target glass LAWE4H, system shakedown test – 63 hour duration (WESP malfunction)
- Test 2: Target glass LAWE4H, 1500 kg/m^2/day target production rate– 68 hour duration
- Test 3: Target glass LAWE5H– 54 hour duration (blower failure)
- Test 4: Target glass LAWE10H – 72 hour duration
- Test 5: Target glass LAWE6H– 62 hour duration (electrical malfunction)
- Test 6: Target glass LAWE3 – 72 hour duration
- Test 7: Target glass LAWE4H – 72 hour duration
- Test 8: Target glass LAWE7H – 72 hour duration
- Test 9: Target glass LAWE9H – 72 hour duration

Six of the nine tests approximated the target duration of 72. Abrupt failures in three critical components resulted in premature terminations of three of the tests, as indicated above. The retention in glass of technetium, iodine, and rhenium are provided in Table 3.1 for convenience;

detailed discussion of the partitioning of the volatiles is presented in the context of the glass analysis (Section 5.0), the mass balance (Section 7.0), and data modeling (Sections 8.0 and 9.0) in subsequent sections.

At the end of each test, dip samples were taken to provide samples for analysis of the glass pool, to detect the presence of separated sulfur phases on the glass pool surface, and to provide an indication of the amount of glass in the melter (via a rod extended to the melt pool floor). All discharge and dip glass samples were counted for ^{99m}Tc and subsequently analyzed by XRF for composition. If a sulfate layer was detected on the melt surface, the glass pool was bubbled until the dip samples indicated that the sulfate layer had dissipated prior to shutting down the melter. The only observations of significant secondary sulfate salt phases occurring on the surface of the glass pool was at the conclusion of Test 6, in which enough sulfate was extractable for technetium and chemical analysis, and Test 8 in which an amount insufficient for chemical analysis was present. The results of sulfate phase analysis are presented in Section 5.0. In both instances the melt pool was bubbled while idling for about three hours to eliminate the secondary phase from the glass surface. In view of the extent of the sulfate phase, a period of water feeding was also employed after Test 6 to fully remove the sulfate phase. Complete removal of sulfate phase from the melter after each test is necessary because they are highly corrosive to metallic components in the melter and incomplete removal could cause false indication of secondary sulfate phase formation in subsequent test.

3.2 DM10 Test Conditions

Nominal target processing conditions, including bubbling rate adjusted to maintain the target production rate of 2250 kg/m^2/day, a melt pool temperature of 1150°C, and a complete cold cap were targeted and achieved throughout the majority of the melter tests. The cold cap was monitored visually throughout the tests and controlled by varying the bubbling rate while keeping the feed rate fixed. Bubbling was decreased if the cold cap was observed to cover less than the majority of the melt pool surface and bubbling was increased if the cold cap was observed to cover the entire surface. The target glass production rate of 2250 kg/m^2/day (2 kg glass/hr on DM10) corresponds to 3.6 to 3.8 kg/hr as the target feed rate, depending on the glass conversion ratio for each feed (see Table 2.16). Feed rates for the slurry feed and recycle streams are shown for the nine tests in Figures 3.1.a – 3.1.i. Test average feed rates for all feeds other than the LAWE4H composition were within ten percent of this value on either a feed processed or glass discharged basis. The LAWE3, LAWE7H, and LAWE9H compositions were processed at slightly above the target rate. Small deviations are observed for feeds with higher or lower glass conversion ratios. The test average recycle stream feed rate met the target of 0.4 liters per hour for all but the first two tests.

Difficulties were experienced processing the LAWE4H composition at the target rate. During Test 1 with the LAWE4H composition, feeding was interrupted on several occasions to breakup the cold cap using a metal rod to compensate for cold cap bridging and adhering to melter walls; in one instance feeding was stopped to burn-off excessive cold cap material in the melter plenum. In this test, these problems were compounded by feed interruptions due to issues with delivery of the

evaporator recycle stream and the technetium spike stream to the mixing vessel and subsequently to the melter. During Test 2 with the LAWE4H composition, a lower production rate of 1500 kg/m^2/day was targeted and approximated while feeding with minimal interruptions resulting from cold cap bridging or other cold cap issues in the melter. Although improvements were made to the feed system after Test 1, interruptions in feed were experienced as a result of clogs in the feed and recirculation lines totaling 2.9 hours. Continued improvements to the feed system over the course of the tests eliminated interruptions from clogged feed lines; notice in Figures 3.1.f, 3.1.h, and 3.1.i that the only feed interruptions in Tests 6, 8, and 9 were those to transfer feed at regular planned intervals. During Test 7 with the LAWE4H composition, feed was not readily incorporated into the glass. The cold cap would completely cover the melter surface and require regular use of a metal rod to break it up. Perhaps as a result of the over-feeding at the target feed rate, feed on the melt pool surface foamed up, which resulted in material being deposited on the refractory bricks lining the glass pool. This material was removed, sampled, and analyzed for calculating mass balances for the test. Foaming of feed and cold cap material was associated with the rodding of the cold cap which can bring liquid feed and previously suspended feed deposits into sudden contact with the molten glass surface.

Temperatures across the melter system were measured and logged electronically every two minutes. Test average measured temperatures are given in Table 3.3; glass temperatures for each test are shown in Figures 3.2.a – 3.2.i and plenum temperatures in Figures 3.3.a – 3.2.i. The measured test average glass temperatures two inches from the melter floor were between 1146 - 1155°C, indicating that the target glass temperature of 1150°C was achieved. The glass temperature two inches higher in the melt pool (4" from bottom) was typically 5-15°C lower than the 2" temperature as result of being closer to the melt surface; it therefore varies as the level of the glass changes and the cold cap coverage fluctuates. The data at 2" from the melter bottom are most representative of the bulk glass temperature; these data are closely monitored to adjust electrode power to maintain the target of 1150°C.

Test average plenum temperatures were mostly at or below 500°C during most tests, indicating that a complete cold cap covered the melt pool surface throughout the tests. Plenum temperatures decreased from about 800°C at the start of each test as the cold cap insulating the plenum space from the glass pool developed. Stable plenum temperature profiles, as observed in all tests except for the first day of Test 1 and Test 5, are indications of consistent cold cap coverage. During the first day of Test 1 and in Test 5 the melter was likely over-fed for a period of time requiring stoppage or reductions of the feed to allow buildup in the cold cap to be incorporated into the glass. Unlike plenum temperature measurements on larger melters, the exposed thermocouple often gave a lower temperature reading than the thermocouple in the thermowell due to variable amounts of feed coating the exposed thermocouple. Downward spikes in plenum temperature were observed during Tests 5 and 7 while manually dislodging plenum deposits, which resulted in momentary coverage of all openings in the cold cap.

The electrode temperatures were about 75°C lower than the highest glass pool temperatures during Test 1 and decreased over the course of the test series to 180°C lower than the glass pool, in keeping with previous DM10 tests [3]. The discharge chamber temperature was maintained at around 1000°C during the vast majority of the testing to facilitate pouring. Melter exhausted from the plenum is diluted by film cooler air reducing the temperature by 175 to 250°C.

In addition to temperature, a variety of other melter system data are measured and recorded during testing, including glass melt pool bubbling rate, electrode power, glass electrical properties and melter vacuum; test average values are provided in Table 3.3. Bubbling used to agitate the melt pool is displayed in Figures 3.4.a – 3.4.i; the electrode current and voltage are shown in Figures 3.5.a – 3.5.i. Although bubbling rates were higher than for previous tests with the same feeds [3, 4], the same trends were observed with feed type. Test average bubbling rates were lowest for LAWE7H and LAWE9H glass compositions (1.3 and 0.8 lpm) and were highest for the LAWE4H glass composition, which also never reached the target production rate. Processing the LAWE4H composition at the lower rate of 1500 kg/m^2/day required an average bubbling rate of only 0.4 lpm. Intermediate bubbling rates between 1.2 and 2.6 lpm were required to process the glass compositions LAWE3, LAWE5H, and LAWE10H, while greater amounts of bubbling were required for LAWE6H. The higher amounts of bubbling and the inability to achieve the target rate for the LAWE4H composition, which was not observed in previous tests, is probably attributable to the longer durations of the current tests as compared to the 12 hour durations of the earlier tests [3, 4]. Nevertheless, it is worth noting that the LAWE4H feed has been processed extensively at 2250 kg/m^2/day on the DM100 [4, 72] and DM1200 [4] melters without difficulty, probably due to the diminishing effect of the melter walls on the larger melters.

Total power to the electrodes is calculated from the electrode voltage and current that is electronically recorded every two minutes during testing. Test average power usage ranged from 4.9 to 6.1 kW, which is within the range of previous DM10 tests with these glass formulations [3, 4]. Generally, the amount of power applied to the electrodes increases as bubbling decreases, consistent with previous tests [3]. The voltage, current, and power were relatively consistent throughout each test except at about 20 hours into Test 4 when the voltage tap was changed to accommodate the lower alkali feed.

A melter vacuum of about one and a half inches of water was maintained for most of the testing, with the instantaneous spikes toward ambient pressure associated with sampling in between tests and manual dislodging of deposits in the upper plenum area. "Bridging" of feed material between the melter walls (which can result in separation of the cold cap from the melt surface) tends to occur more frequently in melters with small surface areas and is mitigated as necessary by manual dislodging. For this purpose, the DM10 is equipped with a tool that allows removal of deposits without opening the viewports or flanges on the melter lid.

SECTION 4.0
OFF-GAS SYSTEM PERFORMANCE

The off-gas treatment system, shown schematically in Figure 1.1, consists of a submerged bed scrubber (SBS); a wet electrostatic precipitator (WESP); a high-efficiency particulate air filter (HEPA); and a vacuum evaporator. Data on the off-gas system performance collected over the course of nine technetium recycle tests are presented and discussed in this section. An overview of the complete test series including the test sequence, major post-test inspections and equipment modifications, and key operational events that affected the off-gas system is provided in Tables 3.1 and 3.2.a - 3.2.i.

4.1 Off-Gas System Test Results

Data for each of the off-gas system components, logged by the LabVIEW data acquisition and control software, were imported into MS Excel files for data analysis and plotting. Time "0" on the x-axis of each data plot corresponds to the start of feed into the melter at the beginning of each test. The timing for operational events discussed below is measured from this time "0". The test start and stop dates and times are listed in Tables 3.2.a through 3.2.i for tests 1 through 9, respectively. Where indicated, data were smoothed by time averaging instantaneous measurements logged at two-minute intervals to reduce data scatter and the number of data points for the plots. The average, minimum, and maximum values of the measured off-gas system parameters are given in Tables 4.1.a through 4.1.i for Tests 1 – 9, respectively. Plots of the average off-gas temperatures and the off-gas flows throughout the DM10 off-gas system are shown in Figures 4.1.a through 4.1.i.

The off-gas system parameters, performance, and key operational events are discussed below. However, over the course of the nine tests, the system evolved in order to improve reliability and performance and in response to operational events. As a result, the analysis is broken down by unit operation and test number in order to capture the dynamic nature of the system over the nine tests.

4.1.1 Transition Line

After the melter film cooler, the first component of the off-gas system is the transition line, which is exposed to the highest exhaust temperatures and the highest particle loading and concentrations of gaseous components. Test average temperatures of melter exhaust entering the transition line ranged from 246 to 294°C while exit temperatures ranged from 246 to 277°C. At the conclusion of most of the tests, inspections of the transition line and film cooler were conducted to document the amount of solids deposition and technetium accumulations. A listing of these deposits and the amount of associated technetium is provided in Table 4.2. At the conclusions of Tests 3 and

4, deposits with 5.0 and 4.4 mCi of technetium were observed accounting for 5.3 and 3.6 % of the total technetium fed into the system during Test 3 and 4, respectively.

After Test 4 the transition line was altered to include a spray nozzle to wash out the transition line periodically while testing. The line was run at a 10° slope so the water would drain out of the transition line into the SBS. Additionally, the line size was decreased from a 3" schedule 10 pipe to a 2.5" schedule 10 pipe to increase the velocity of the off-gas. The modified transition line design is shown in Figure 1.17. The P&ID for the modified system is shown in Figure 1.5.b. The new spray nozzle was run for 1 minute every 12 hours at a flow rate of ~5.7 lpm. The water was taken from the SBS sump in order to avoid disturbing the water balance of the system. The test time when the sprays were performed is given in Tables 3.2.e – 3.2.i. Spraying of the cold water into the hot transition line results in momentary downward spikes in temperature.

At the conclusions of Tests 5 - 9, deposits with 1.5 to 5.7 mCi of technetium were collected from the transition line accounting for 1.2 to 3.9 % of the total technetium fed into the system for a given test. The average percentage of the ^{99m}Tc fed that accumulated in the transition line and film cooler from the two tests done prior to the installation of the new transition line was 4.5%. The average of the 5 tests after the modification was 2.3%, showing that the modified transition line reduced accumulations in the transition line by a factor of about 2 but did not prevent them. However, it should be noted that a significant portion of the technetium was found in the film cooler during the tests, which was not affected by the spray. Unfortunately, the DM10 melter layout was not compatible with the use of a film cooler spray because the film cooler is offset from the glass pool and located above the refractory bricks. As a result, any solids removed during the wash down would fall onto the refractory rather than back into the melter. However, it is possible that modifications to surmount this issue could be implemented in future tests.

4.1.2 SBS

The SBS is the first component in the primary off-gas system and is designed to quench melter exhaust, remove particulate from the exhaust stream, and provide liquids with constituents removed from the melter exhaust to be recycled back to melter feed. Monitored and electronically recorded parameters from the SBS during testing were the temperature of the inlet and outlet exhaust streams, as shown in Figures 4.2.a – 4.2.i, the temperature of the sump fluids and cooling water, as shown in Figures 4.3.a – 4.3.i, the differential and vacuum pressures across the SBS, as shown in Figures 4.4.a – 4.4.i, and the liquid flow in and out of the SBS, as shown in Figures 4.5.a – 4.5.i.

The SBS effectively quenched the melter exhaust to the bed liquid temperature with no blockages over the course of the tests. The nominal operating temperature for the SBS was 50°C [5]; however, most of the tests were conducted at 30°C to avoid condensation in the dry off-gas system components that was observed at the higher temperature. The sump temperature in the first test was 40°C and resulted in some downstream condensation. For all subsequent tests, the operating temperature set point was 30°C.

During Test 1, there was little variation in SBS bed temperature measured four and ten inches below the surface of the bed at 37.8°C and 39.0°C, respectively. Over the eight subsequent tests, the test average sump temperatures ranged from 28.5 to 29.5°C at 4" from the bed surface and 29.5 to 31.0°C at 10" from the bed surface. During Test 1 the melter exhaust stream was fully cooled from 263°C, to the SBS bed temperature, to a test average temperature upon exiting the SBS of 38.4 °C. During the eight subsequent tests, the temperature of the exhaust stream entering the SBS averaged between 246 to 277°C and was cooled to the bed temperatures, averaging from 29.3 to 30.9°C.

The transition line was sprayed with SBS sump solutions every 12 hours for 1 minute at ~5.7 lpm to rinse solid deposits into the SBS sump during tests 5 – 9. Momentary dips in SBS inlet temperatures occurred every twelve hours in response to quenching the melter exhaust with the 30°C SBS solution. At the start of Test 5, the cooling water flow was not set correctly, and the sump temperature rose to 42°C about 1.8 hours into the test. Once corrected, the SBS sump quickly came to the 30°C set point. Several times during the tests the chiller for the SBS cooling water tripped off resulting in momentary losses of cooling water flow. During Test 9, the chiller operating temperature was increased to stabilize operation, resulting in minor SBS temperature fluctuations during the outages and changes in set point temperatures.

The test average pressure drop across the SBS ranged from 15.7" to 19.4 "W.C., which was approximately the height of the liquid in the SBS. The liquid level in the SBS generally decreased somewhat over the course of each test. Decreases in water level over the first approximately ten hours of many tests are associated with higher liquid temperatures as the system equilibrates with the hot melter exhaust. Test average vacuum at the SBS inlet ranged from 1.6 to 2.2" W.C, approximating the vacuum on the melter.

Liquids enter the SBS by the direct addition of makeup water and the condensation of moisture from feed in the melter exhaust. Liquids exit the SBS by overflow into the containment tank before entering the evaporator for recycling back to the melter. The makeup water flow rate to the SBS was set at 11 lph during Tests 1, 3, 4, and 6, 13 lph during Test 2, and 10 lph during Tests 5, 7, 8, and 9 while manipulating the total flow rate out of the SBS to the evaporator system to achieve a relatively constant volume in the SBS sump during steady state operation. Test average liquid flow from the SBS ranged from 10 to 12.9 lpm. The difference between the amount of make up water added to the SBS and the amount of liquid discharged to the recycle system ranged from a test average deficit of 0.4 kg/hr in the initial test to surpluses in the other eight tests of up to 1.5 kg/hr. During the first test, melter feeding was episodic and the SBS operated at a higher sump temperature, resulting in net loss of water to the exhaust stream. In all subsequent tests, there was a net accumulation of water from condensation of moisture in the melter exhaust. The water emission rate from the SBS associated with a saturated gas stream at 30°C is about 2 kg/hr, whereas water rates measured from the WESP exhaust ranged between 0.6 and 1.5 kg/hr. Since the gas temperature was fully equilibrated with the SBS bed temperature, suggesting that the gas should be saturated at that temperature, this difference may be the result of condensation in the WESP.

Disruptions to the makeup water occurred over the tests as follows:

- Test 2 between 53.2 and 54.0 hours run time the makeup water flow into the SBS was turned off to prevent backing up the containment tank when the commercial evaporator tripped off.
- Test 2 between 65.4 and 66.4 hours run time the makeup water flow into the SBS was turned off in response to high liquid levels in the SBS sump. The flow of water out of the SBS started to decrease at about 56 hours, which resulted in an increased liquid level in the SBS, increased differential pressure across the SBS, and increased pressure drop across the entire off-gas system.
- Test 3 between 46.4 and 46.52 hours run time the makeup water flow into the SBS was stopped briefly.
- Test 3 between 48.8 and 49.7 hours run time the data acquisition system malfunctioned and stopped taking data. The makeup water flow was maintained but several minutes of data were not recorded.
- Test 4 around 12.3 hours run time the makeup water flow into the SBS was stopped briefly in response to high liquid level in the evaporator sump.
- Test 4 around 14.1 hours run time the makeup water flow into the SBS was stopped briefly to compensate for a high, short duration liquid flow from the WESP.
- Test 6 around 28.8 hours run time the makeup water flow into the SBS was stopped briefly to compensate for a high, short duration liquid flow from the WESP.
- Test 6 around 35 hours run time the makeup water flow into the SBS was stopped as a result of the commercial evaporator shutting down due to high liquid level in its sump.

4.1.3 WESP

The WESP is the second component in the primary off-gas system and is designed to remove fine particulate from the exhaust stream and provide liquids with constituents removed from the melter exhaust to be recycled back to melter feed. The blower that provides vacuum on the melter and primary off-gas system immediately follows the WESP in the exhaust train and therefore is evaluated in conjunction with the WESP. Monitored parameters and electronically recorded parameters from the WESP during testing were the temperatures of the inlet makeup water, outlet exhaust stream, and blower outlet, as shown in Figures 4.6.a – 4.6.i; pressures around the blower and WESP differential, as shown in Figures 4.7.a – 4.7.i; WESP makeup water flow rate, as shown in Figures 4.8.a – 4.8.i; and WESP voltage and current, as shown in Figures 4.9.a – 4.9.i.

The WESP provides a high electric field between the electrodes to ionize particles in the gas stream, which are then accelerated and collected on the electrodes. To optimize the collection efficiency, the WESP voltage is increased to just below the point at which dielectric breakdown occurs and arcing begins. This voltage varies with the gas stream composition and water content, as well as the condition of the WESP itself.

At several points during the test sequence, the WESP hardware and method of operation were modified to improve WESP performance as indicated by sustainable voltage and current across the WESP elements. A description of these modifications and resulting test conditions is provided below.

Test 1: For the first 38 hours of the test, the set-point voltage and current were inadvertently recorded instead of the actual values, as displayed in Figure 4.9.a. The WESP began to arc from the rod electrodes to the WESP shell as the test progressed. The voltage was lowered from the initial set-point of 27 kV in steps as continued arcing began at each lower voltage setting. This process was continued until the power to the WESP was shut off at 45.25 hours. The WESP was deluged in an attempt to clean the collection plates and regain performance, but this was not effective; therefore the WESP was not powered for the remainder of the test. The WESP spray water was left on to keep the water balance the same. The malfunction of the WESP was one of the major factors that led to the early termination of this test. Post test analysis traced the cause of the WESP failure to a water film on the electrical insulators between the rod electrodes and the WESP shell. The water created a conductive path from the electrodes to the grounded shell, which resulted in increased arcing as the water film developed during the test.

Test 2: Purge air was added to keep the insulators dry with the provision to heat the air if necessary. The water spray flow into the WESP was reduced from 3.0 lph in the previous test to 0.5 lph in an attempt to reduce the water build up on the insulators. The WESP voltage during this test was maintained at ~10.4 kV for the first 38 hours of the test. Attempts to increase the voltage above this value resulted in arcing between the rod electrodes and the grounded collection plate. Because of this undesirable low voltage, heating of the insulator purge air was implemented. The purge air was run through a ¼" OD copper tube that was wound around the transition line prior to flowing into the WESP insulators. This created a heat exchanger between the off-gas in the transition line (temperature of 250-300 °C) and the purge air for the insulators. The hot air dried the insulators and allowed the WESP voltage to be gradually increased and held at an average value of 21.4 kV for the remainder of the test. At about 60 hours run time, the WESP blower suction pressure dropped, resulting in reduced flow out of the containment tank and rising liquid level in the SBS. The liquid also backed up into the sump of the WESP resulting in arcing between the liquid in the sump and the electrodes.

Test 3: Additional modifications were made to the system to keep the electrical isolators dry and prevent loss of WESP performance. Heated dilution air was injected downwards from the top of the WESP in the vicinity of the isolators to direct the wet process gas away from the isolators and to heat the isolators. This air served the additional role of heating the air leaving the WESP, lowering

its relative humidity, and preventing condensation in the filters downstream. A band heater was also added around the top of the WESP to heat that section of the WESP and aid in the removal of any moisture near the electrical isolators. The WESP spray flow was increased to 2 lph from 0.5 lph used in the previous test. As the test progressed, arcing across the WESP increased and the voltage was lowered from an initial setpoint of ~25 kV to ~19 kV. Set-point changes downwards were made in response to persistent arcing. Once the system had stabilized without arcing, the electrical set-point was gradually increased toward the initial values. The changes made to the WESP during and after the second test provided stable operation of the WESP electrodes for the majority of Test 3 and therefore were retained in subsequent tests.

At 54.13 hours into the test, P-200, the regenerative blower used to pull the air through the SBS bed and WESP, overheated and failed. This resulted in the early termination of the test. The blower was a new unit and was shipped back to the vendor for analysis. The vendor determined that the failure was due to a manufacturing defect and made the repair at not cost. However, this process took several months, which necessitated the installation of a different blower for subsequent tests.

Test 4: The WESP was initially set to an operating voltage of 25 kV, but within several hours after the start of the test, the voltage was decreased due to persistent arcing. The WESP voltage was continually adjusted, both up and down throughout the test to mitigate rapid arcing and to enhance performance during extended periods of stability, respectively. Overall, the voltage was maintained above 20 kV for the duration of the test.

Test 5: The WESP was initially set to an operating voltage of 25 kV but, as in previous tests, this set-point was reduced as regular arcing was observed. This occurred for the first time at ~10 hours into the test, after which, the WESP required periodic reductions in voltage to prevent arcing. However, a set-point of between 20-22 kV was maintained, with minor adjustments up and down, until ~54 hours into the test. At this point, persistent arcing required the WESP voltage be reduced to ~18 kV. This set-point was maintained until the end of the test.

Test 6: The WESP began arcing persistently about 27.45 hours into the test. Voltage adjustments did not rectify the problem, unlike previous tests. This was traced to the fact that the automatic controller for the power going to the WESP dilution air heaters was not functioning. As a result, 27.68 hours into the test, the heater power was set to a fixed value of 0.5 kW. The WESP discharge temperature, TIR-2102, increased and the arcing dissipated, allowing the WESP voltage to be slowly increased.

After a WESP liquid sample was taken 24 hours into the test, HV-2610 was inadvertently left closed. This was noticed ~5 hours later when the WESP began to arc between the electrodes and the sump water. This was similar to the Test 4 event where the same valve was left closed; however, because of the longer duration of closure, the accumulated water resulted in filling of the containment tank when valve HV-2610 was opened. To compensate, the SBS makeup water flow was reduced to 5 lph and the WESP spray water flow was reduced to 1.5 lph. Once the excess water was worked off, the flow rates were restored to their original set points.

Test 7: The WESP was set to an initial voltage of 24 kV and this was reduced to 21.2 kV at 1.62 hours into the test. The spray water flow rate was initially set to 2.0 lph but this was increased to 3.0 lph at 5.1 hours into the test. This increase was accompanied by a corresponding decrease in the SBS flow to maintain the same total flow to the evaporator system.

Test 8: The initial set-point for the WESP voltage was 26 kV and this was reduced to ~21 kV after the first few hours. As in previous tests, the voltage was adjusted throughout the test when persistent arcing was observed. When stable, the voltage was periodically increased to improve performance.

Test 9: The initial set-point for WESP voltage was 23 kV and, as in previous tests, this had to be reduced slightly after the first few hours. As in previous tests, the voltage was adjusted throughout the test to optimize performance of the WESP. When stable, the voltage was periodically increased to improve performance.

During parts of Tests 1 and 2, the WESP was not operational. During Tests 3 to 9, the average WESP voltage and current varied between 18.6 and 21 kV and 0.8 and 2.2 mA, respectively. Emission samples taken during Tests 1 and 2 when the WESP was not operational showed 11.0% and 14.8%, respectively, of Re and >0.47% and 12.7%, respectively, of Tc fed to the system in the WESP emissions. During Tests 3 to 9 when the WESP was operational, the Re emissions dropped to 0.43% or less and the Tc emissions dropped to 0.52 % or less. In all of the tests, the WESP voltage was adjusted periodically to the highest value possible without arcing.

Exhaust temperatures around the WESP reflect the changes in system operating parameters. In the first test the exhaust entered the WESP on average at 38.4°C dropped by less than a degree across the WESP and increased by about three degrees across the blower. In the second test the exhaust entered the WESP on average at 29.9°C increased by about thirteen degrees across the WESP and blower in response to added heated air. In the seven remaining seven tests, the off-gas entered the WESP at about 30°C, exited the WESP at average temperatures between 48 and 57°C, and exited the blower at average temperatures between 51 and 58°C. The temperature gradient of 25°C across the WESP and blower is attributable to the heated dilution air added to the WESP and a band heater around the top of the WESP. Changes to the blower (replaced after Test 3) and added air flow did not appreciably change the pressure and flows through the system. Test average suction pressure of the regenerative blower ranged from -18.8 to -22.9" W.C. and the test average pressure drop across the WESP ranged from 1.5 and 1.8" W.C. No evidence of occluded air flow was observed during testing.

4.1.4 Containment Tank

The containment tank functions to collect the sump water from the SBS and WESP, provide buffer capacity, and to deliver the blended solution to the custom evaporator. Monitored and

electronically recorded parameters during testing were the temperature of the liquid in the tank, as shown in Figures 4.10.a – 4.10.i; liquid flow rate out of the tank, as shown in Figures 4.11.a – 4.11.i; and tank liquid volumes, as shown in Figures 4.12.a – 4.12.i. The temperature of the liquid in the tank reflects that of the SBS solution from which it is primarily derived. Liquid temperatures were around 34°C in Test 1 and averaged between 28 and 30°C for the other eight tests. Sump temperatures were often a few degrees higher at the start of tests as the SBS equilibrated with the external cooling elements. After the initial test, the flow rates varied around the target of 15 lph; test average flow rates ranged between 13.8 and 15.8 lpm. Instantaneous flow rates typically varied over a larger range, between 5 and 20 lph, in response to similar fluctuations in the flow rate into the tank from the SBS and WESP.

The tank level was stable for the majority of testing, indicating that the control strategy discussed in Section 1.7.3.5 worked well. Deviations from the target operational volume of eleven liters were the result of issues with other off-gas system components that either rapidly reduced or increased the flow in or out of the tank. Examples are observed as spikes in the liquid level as a result of the valve on the WESP drain being closed after sampling then being opened later causing a sudden large flow to the tank in Tests 4 and 6, and brief interruptions in flow out of the tank due to problems with the evaporator in Tests 6 and 9. Near the end of Test 2, a clogged outlet control valve caused the containment tank to fill completely before the issue was noticed as a result of other operational issues at that time. Subsequently, a high level alarm was added to the containment tank level transducer which produced an audible alarm along with a visual display on the control station.

4.1.5 Evaporator Systems

The DM10 off-gas system includes two evaporators: the custom evaporator, which concentrates the continuous flow of liquid off-gas effluents produced in the SBS and WESP for recycling back to the melter feed, and the commercial evaporator, which provides vacuum and condenses the distillate exiting the custom evaporator. The custom evaporator is designed to function under conditions prototypical of the WTP TLP evaporator in concentrating the process solutions for recycle, whereas the commercial evaporator is unique to the VSL system and serves to provide vacuum and accumulate and concentrate the overheads from the custom evaporator for subsequent analysis and disposal. Monitored and electronically recorded parameters during testing were the temperature of the headspace vapor in the custom evaporator, as shown in Figures 4.13.a – 4.13.i; the vacuum on the custom evaporator, as shown in Figures 4.14.a – 4.14.h; and liquid flow rate out of the custom evaporator as recycle to the melter feed and the associated pump speed, as shown in Figures 4.15.a – 4.15.i.

During Test 1, the custom evaporator ran at an average headspace temperature of 39.0°C and an average vacuum of 26.7" Hg. The custom evaporator ran at an average headspace temperature ranging between 43.9 and 48.6 °C and an average vacuum between 27 and 27.6" Hg over the last eight tests. The test average recycle liquid flow rate approximated the target rate of 0.40 lph for all but the first two tests. The lower test average feed rates for Tests 1 and 2 of 0.30 and 0.36 lph were

mostly attributable to periods of feed interruptions, which required significant manual intervention. Minor clogs and interruptions were experienced in other tests, which did not significantly affect the overall recycle stream rate. To maintain the constant feed rate, changes in the pump speed were periodically required due to wear on the tubes that pass through the peristaltic pump.

The operation of the evaporators and the interactions between them and other components of the melter and off-gas system were complicated, requiring several system enhancements and operational changes, particularly during the first few tests. However, the final configuration that was employed for the later tests functioned very well. Descriptions of these operational issues and the modifications that were made to address them are summarized by test below.

Test 1: The system for controlling the level in the evaporator sump was based on pilot scale testing that showed the recirculation flow rate had a significant effect on the evaporation rate in the evaporator. Therefore, a single level switch was used to set the speed of the recirculation pump based on the liquid level in the sump. However, in actual operation, this proved problematic because the high vacuum in the evaporator meant that at higher speeds the pump would begin to cavitate, limiting the ability to adjust the recirculation flow rate and therefore controllability. To address this, the level was monitored manually and a video camera was installed giving the operators a live feed of the level gauge from the control station. Also, in order to overcome the undesirably high and low levels in the evaporator sump, both the speed of the recirculation pump (P-401) and the temperature of the heating water (V-501) were manually adjusted. P-401 and V-501 were variously both increased, decreased, and turned on and off in order to control the level in the evaporator. Improvements were made in subsequent tests to automate this control scheme to improve reliability and decrease the amount of manual intervention required.

In addition to the control system issues, a physical design oversight led to excessive liquid accumulation in the custom evaporator sump as well as sump liquid carryover into the commercial evaporator. This was rectified before the second test by adding a pressure equalization path from above the top tube sheet to the top of the level gauge.

Test 2: The control system was modified from the first test to use three level switches to control the speed of the recirculation water pump. This improved the controllability of the sump level but still required significant manual interaction. It was evident that control via the pump speed alone did not provide sufficient dynamic range, which necessitated frequent manual changes to the heating water temperature. Consequently, it was decided to switch over from a pump-speed based control system to a water-temperature based control system. In this system, the three level sensors were used to control the heating water temperature and the recirculation water pump was run at a low fixed speed.

At 53.18 hours run time, the commercial evaporator shut down as a result of the pressure switch on its refrigeration loop tripping. The outage of the evaporator continued until cognizant personnel arrived and reset the system. During this time, make-up water flow to the SBS was turned off to prevent an excessive buildup of water in the system.

Test 3: The changes to the control system significantly improved the stability of the evaporator sump level in this and subsequent tests. Figure 4.16 shows how the evaporator sump level varies with time using this new control scheme. The data were taken during Test 9 (the same control system was implemented for all of the remaining tests) where digital image processing of the live video feed was used to find the meniscus of the water inside the level gauge of the evaporator. An image from the video feed is shown in Figure 4.17. The height was controlled to between 1" and 3.5" on a tape measure placed next to the gauge. The evaporator sump setup can be seen in Figure 4.17. Two black marks were placed on the level gauge marking the high and middle level switches. The high level switch was at ~4" on the tape measure. The control system prevented the sump from reaching the high level switch and also prevented the level from dropping below the height of the level gauge. The black mark highlighting the location of the middle level switch is crossed several times, which creates a band of unreadable levels as the black mark disrupts the image of the meniscus. Figure 4.16 shows the ability of the system to control the level in the evaporator within the limits of the high and low level switch.

Test 4: The tubing on the peristaltic pump controlling the recycle flow becomes fatigued over time. As a result, the tube flattens and less volume per revolution is moved through the pump. This results in the pump speed increasing as the test progresses. To prevent eventual tube failure, the tube is adjusted periodically to move a new section of tube into the rollers. Figure 4.15.d shows the gradual increase of the pump speed with time. At test times ~26 hours and ~51 hours, the pump speed decreases as a result of the movement of the tube in the pump rollers. Similar adjustments were made during the remaining tests and the same trends can be observed in Figures 4.15.e through 4.15.i.

The average vacuum in the evaporator was lower during this test because the sensor, (PIR-4201) failed about 22 hours into the test, as seen in Figure 4.14.d. The failure resulted in an artificially high pressure reading in the evaporator. This sensor was not used for process control and had no safety function and was solely for process monitoring and troubleshooting purposes. A visual gauge on the commercial evaporator allowed for the pressure to be manually observed throughout the test and the test was not impacted by the sensor failure. The pressure sensor was replaced after the test.

Test 5: Prior to this test, the failed pressure sensor, PIR-4201, from Test 4 was replaced, but was not reading correctly at the start of the test. Failure of the data acquisition system necessitated the early termination of this test.

Test 6: At about 35 hours into the test, the commercial evaporator shut down due to high sump level, which was traced to the auxiliary heat exchanger, E-400, which is used to balance the heat load on the refrigeration cycle of the commercial evaporator, removing too much heat from the sump water. A loss of vacuum resulted, which is seen in Figure 4.14.e. In this condition the SBS and WESP water could not be evaporated so the flow from the containment tank into the evaporator was closed, causing the containment tank level to rise, as seen in Figure 4.12.f. The SBS makeup water was turned off to reduce the rate at which the containment tank filled, as shown in Figure 4.5.f. The

commercial evaporator was down for about 1.2 hours before the evaporators stabilized and makeup water was restored to the SBS. The recycle flow was not affected during this event. However, since the peristaltic pump on the recycle line was not pulling against a vacuum, it was much more efficient. Figure 4.15.f shows the decrease in the pump speed while the flow rate is unchanged during this event.

Later during the test, the fluid flowing in the custom evaporator recirculation line was observed to contain a large number of air bubbles, which was traced to a leak in the seals on the recirculation pump. Eventually the air in-leakage prevented the recirculation pump from generating enough pressure head to flow any liquid to the top of the evaporator. This necessitated replacement of the pump seals, which was performed without interrupting the test. In order to replace the pump seals, the pump was first isolated from the system. The vacuum in the system allowed for the lines to be broken without risk of contamination as all liquids were pulled into the evaporator. The lack of recirculation in the evaporator during the repairs required the evaporator to be manually controlled. The heating water temperature was increased to account for the lack of recirculation and the flow into the evaporator was manually adjusted to prevent overfilling of the evaporator sump. This resulted in a rise in the containment tank level, as shown in Figure 4.12.f. The pump was taken off line at about 40.8 hours into the test and rebuilt in about an hour and twenty minutes, allowing the system to be back on line without backing up water into the SBS or WESP and without any interruption in the recycle flow during the maintenance.

Test 7: During this test there were no significant operational issues with the custom or commercial evaporator. There were a few high and low level alarms, which were resolved by adjusting the set-points on the heating water controller. System operations were not affected by these incidents.

Test 8: At about 10.25 hours into the test the commercial evaporator tripped off due to high liquid level in the sump, as occurred in Test 6. As a result of the loss of vacuum, the level in the custom evaporator sump rose above the high level switch. The evaporator heating water temperature and the feed from the containment tank were manually controlled until the commercial evaporator came back on line. There were no other operational issues with the evaporator during the test.

Test 9: At 13.10 hours into the test the commercial evaporator tripped off due to high refrigerant pressure. When this occurred, feeding was briefly stopped (fresh and recycle), the evaporator heating water was shut off, and the water flow from the containment tank was stopped. The commercial evaporator was restarted and when it was operating stably the custom evaporator was brought back online. The same trip occurred in the commercial evaporator at about 30.27 hours into the test. However the unit was able to be restarted quickly with no affect on the custom evaporator or other unit operations.

4.1.6 Dry Off-Gas System

The dry off-gas exhaust system provides coarse filtration and HEPA filtration before release through the stack. Additional vacuum is drawn on the system and there is air dilution through the blower. The exhaust is monitored downstream of the final blower for gaseous species and stack flow rate. Monitored and electronically recorded parameters in the system are cyclone outlet temperatures, HEPA filter inlet and outlet temperatures, exhaust blower outlet temperature, and exhaust blower outlet air flow rate. Test average, minimum and maximum values for these parameters are provided in Tables 4.1.a – 4.1.i. The system contains a redundant line of cyclone and HEPA filtration units and therefore the temperature of one set of filters is indicative of ambient room temperature rather than the exhaust flow stream. Exhaust temperatures through the dry off-gas system reflect the changes in system operating modes of the SBS and WESP. In the first test, the exhaust entered at about 35°C and dropped a few degrees across the filters and associated piping. In subsequent tests, although the operating temperature of the SBS was decreased, the addition of heated air to the WESP and the external application of a band heater on the WESP resulted in progressively higher exhaust temperatures of up to about 49°C throughout the dry off-gas system. The temperature drop across the dry off-gas system was about 5 to 7°C. The temperature profile across the dry off-gas system for Test 3 is shown in Figure 4.18.a as an example. An atypical temperature is shown for Test 2 in Figure 4.18.b. In Test 2, the exhaust was directed from HEPA filter #2 to #1 and the cyclone filter from cyclone #2 to cyclone #1 to diagnose an increase in melter pressure. No blockages were discerned in the dry off-gas during Test 2 or observed in any other subsequent tests.

After Test 1, water was found in the HEPA filter and pre-filter units. This is believed to have been due primarily to spray water carryover from the WESP because the WESP spray water flow was left on while the WESP power was off as a result of the electrical shorts in the WESP. The HEPA filter and pre-filter units remained dry for all subsequent tests.

Test average stack gas flow measured at the exit of the system ranged from 116.1 to 140.8 scfm (FIR-8301). Stack flow rates decreased from about 140 scfm during the first five tests to about 120 scfm, suggesting that in-leakage into the system was reduced between Tests 5 and 6, probably due to tightening of the filter units. In-leakage through the dry off-gas system, chiefly the blower, resulted in a 3.5 to 4 fold dilution of the WESP exhaust stream.

4.2 SBS, WESP, and Evaporator Process Fluids and Collected Solids

Samples were collected from the SBS, WESP, and evaporator sumps every 12 hours of testing. Samples were subjected to complete chemical analysis, which included gamma counting, pH determination, DCP-AES analysis for metals, and ion chromatography for anions. Tables 4.3 – 4.6 list the SBS, WESP, and evaporator samples as well as the total volume of solution removed from each sump, pH analysis, and gamma counting results for technetium; the center letter in the sample name is “S”, “W”, “E1”, and “E2” for the SBS, WESP, custom evaporator, and commercial evaporator samples, respectively.

The pH of the sump solutions is affected by constituents removed from the exhaust and by dilution from the makeup water. The SBS sump solution pH varied between 8 and 8.5 for most samples except samples from Test 4, which were about 2 pH units more acidic due to the lower concentration of alkali in the feed. The pH values of the WESP solutions were generally one pH unit lower than those for the SBS solutions, ranging mainly between 7 and 8 as a result of higher concentration of acid anions, namely nitrate, sulfate, and chloride. Solutions from the custom evaporator also had pH values between 6.5 and 7.5 except for solutions from Test 4, which were considerably more acidic (pH 4.5 – 5.5). These values are consistent with the SBS and WESP solutions being concentrated by the evaporation of water. Solutions associated with the commercial evaporator are of two origins: the blown-down sump solutions taken at the end of tests and condensed vapor exiting the custom evaporator (Tests 4 - 9). End of test blow-down solutions are slightly more alkaline than the condensed vapor samples. These vapor samples have pH values between 6.5 and 7.5 except for Test 4 samples, which average a pH of about 3. Some solutions from the beginning of the tests do not follow these trends due to incomplete equilibration with the process or residual material remaining in the sump solution.

The chemical composition was measured on all solutions and the results are provided in Tables 4.7 -4.24. Included in these tables is the analysis of various rinse solutions from the transition line listed in Table 4.2 and identified with the center letter in the sample name as "O". The analysis is primarily of the dissolved fraction since previous tests on the DM1200 with LAW waste compositions have demonstrated that over 95% of the chemical species measured in off-gas system solutions were dissolved [4, 82-85]. Solution chemistry from samples from the end of Tests 4, 5, and 6 is depicted in Figures 4.19 – 4.21. As expected, the most abundant solids in the SBS solutions were soluble species such as nitrite, halogens, boron, alkali metals, sulfate, and rhenium. These species are readily volatilized from the glass and cold cap in the melter as soluble salts. The relative abundance of nitrate versus nitrite is a function of solution pH; acidic solutions favor nitrate and basic solutions favor nitrite. The low concentration of nitrogen oxides in the Test 4 solutions is attributable to the low concentrations in the feed.

The WESP solutions contain mainly volatile salts (alkali nitrates, halides, borates, sulfates, and perrhenates) carried over from the SBS and fine particulate not removed by the SBS. These particulates consist of a significant portion of the technetium, rhenium, and alkali. Notice the higher concentration of technetium (comparison of contemporaneous samples in Tables 4.3 and 4.4) and rhenium in the WESP solutions than in SBS solutions shown in Figures 4.19 – 4.21. High concentrations of technetium and rhenium were also present in many of the WESP post-deluge samples indicating that these constituents were coating the internal WESP components and constitute a significant portion of the mass balance (see Section 7.0).

The evaporator sump samples are generally reflective of the combined SBS and WESP solutions. One exception is the lower proportion of nitrite and nitrate due to volatilization during the evaporation process. Solutions indicative of moisture emitted from the custom evaporator ("E2" samples not depicted in Figures 4.19 – 4.21) mostly contain constituents that can be volatilized from aqueous solutions at sub-boiling temperatures, namely nitrogen oxides and acid anions. Since the

SBS and WESP employ tap water for makeup water, sprays, and deluges, and are initially charged with tap water, elements common in tap water, such as calcium, are over represented in the solutions as compared to the amounts in the target feed compositions.

The evolution of the SBS, WESP, and evaporator recycle solution chemistry during testing is illustrated for technetium, rhenium, halides, and sulfur in Figures 4.22.a – 4.45.b. All sumps are thoroughly rinsed after each test and the SBS and evaporator sump solutions are completely exchanged with fresh tap water; thus, the only constituents present in the solution at the start of the test were elements present in tap water at low concentrations and any residual contamination from previous tests in the sequence. The amount of contamination from preceding tests was significant in some cases, depending on the reservoir and the analyte. However, ^{99m}Tc was not present in any initial solutions due to the decay rate of the isotope used in these tests. Technetium concentrations increase over the course of each test in all SBS, custom evaporator, and some of the WESP solutions. The average rhenium concentrations from samples taken before each test were 15, 231, and 451 ppm in SBS, WESP, and custom evaporator sumps, respectively. Rhenium concentrations, mirroring the pattern of technetium concentrations, increase over the course of each test in all SBS, custom evaporator, and some of the WESP solutions. For most of the tests, and particularly those of longer duration, a decrease in the rate of increase of the concentrations of technetium and rhenium over time is evident as the concentrations approach a steady-state plateau. However, the effects of various operational events are also superimposed on this general trend. These same trends are also evident in the evaporator sump data, which is consistent with those solutions being dominated by the SBS fluids. The WESP solution concentrations do not always follow a consistent pattern, due in part to the manner in which the solutions are taken; unlike the SBS and custom evaporator in which solutions always contain a measurable amount of liquid, the WESP outlet valve is closed to allow sufficient volume of sprayed solution to accumulate for each sample since the WESP liquids are typically removed from the reservoir as they are generated.

Generally similar indications of the approach to steady-state to those found for rhenium and technetium are seen in the halide and sulfate concentrations in the SBS sump solutions; however, these trends are affected by the relatively high starting concentrations, particularly for sulfate and chloride. In all but one of the tests, all four analytes either exhibit stable concentrations throughout the test or show rapid early rises followed by stabilization at plateau values indicative of steady-state. The latter behavior is particularly evident in the iodide data, which also generally shows the lowest starting concentrations. Interestingly, these plateau values are reached earlier in the test than is the case for the respective rhenium and technetium data. The one exception is Test 4, for which chloride and fluoride follow the previously described trends whereas iodide and sulfate exhibit steep, nearly linear increases to the end of the test. As discussed in Section 9.3.2, the sulfur concentrations in the glass for Test 4 also behaved atypically; it is possible that this may have been due to variations in the sulfur concentrations in successive feed batches for this test. As with the rhenium and technetium data, these general trends are also evident in the halide and sulfate concentrations in the evaporator sump.

Samples from solid deposits around the transition line were taken and analyzed to determine the extent of potential volatile accumulation. The results of the XRF and DCP-AES analysis of these samples are provided in Table 4.25; the results from technetium analysis for all but the Test 2 sample are provided in Table 4.2. Samples were taken immediately after Tests 2, 3, or 4 prior to installation of an inline transition line spray system. Relatively high concentrations of technetium, rhenium, chlorine, and sulfur were measured in all samples from the transition line area. Average enrichments over the target glass concentration are factors of 38 for chlorine, 5 for iodine, 41 for rhenium, and 6 for sulfur. Smaller enrichments are also observed for sodium, boron, and potassium, which form soluble deposits, all at the expense of silica and alumina. Collectively these data indicate that spraying the transition line and film cooler should result in the mobilization of soluble deposits into either the SBS or the melter, thus increasing the effectiveness of recycling technetium and other volatiles in the feed. Also included in Table 4.25 is a sample from the emergency off-gas port, which was not in the exhaust flow path during the tests. The sample is similar in composition to the other deposits in some respects but contains a very high concentration of aluminum and very little boron, suggesting the deposit may be contaminated with melter insulation material.

SECTION 5.0
GLASS PRODUCTS

Over a metric ton of glass was discharged from the DM10 in these tests. The glass from the melter was poured periodically into square steel cans using an airlift system. The discharged product glass was sampled from each can by removing sufficient glass from the top of the cans for technetium and total inorganic analysis. No secondary phases were observed in the discharged glass in these tests. Product glass masses, discharge date, measured technetium concentration, and a listing of other analysis conducted are listed in Table 5.1. Glass samples were also obtained by dipping a rod into the glass pool at the beginning and end of each test. A complete list of all glass pool samples, sampling date, measured technetium concentrations, measured iron oxidation state, indications of secondary phases, and glass pool height are listed in Table 5.2. These "dip samples" were analyzed in the same manner as the discharge samples and also underwent visual examination to detect the presence of a separate sulfate phase on the glass pool surface.

5.1 General Compositional Analysis

Glass discharge samples were crushed and analyzed directly by XRF. The values for boron and lithium oxides, which are not determined by XRF, were calculated from the DCP-AES analysis of the initial glass sample of each test and the target concentration (the measured feed concentration was used for Tests 1 and 2 since the boron concentration was known to deviate from the target) and used for normalizing the XRF data to 100 wt%. Fluorine cannot be analyzed using the routine XRF procedure on powdered samples; for this purpose, polished solid monoliths were analyzed under vacuum by XRF for samples from the end of each test. The XRF-analyzed compositions of discharged glass samples are compared to the respective target compositions in Table 5.3. The majority of the XRF analysis results compare favorably to their corresponding target values and feed sample analyses (see Section 2.5.3). The results generally show good agreement with the target composition for the major components. The most abundant constituent, silica, showed deviations from target of less than 3% for all glass from the end of each test and much lower for most glasses. Of the oxides with target concentrations of one weight percent or greater, the XRF values had relative deviations of less than 10% for most measured values with limited exceptions. Surpluses of boron were measured in glass from Tests 1 and 2, similar to the results from feed sample analysis, resulting in relative deviations of between 10 and 11 percent. Also in glasses from Tests 1 and 2, deficits in magnesium yielding relative deviations of between -13 and -14 percent were observed. These deviations were not seen in the as-received feed and result from the segregation of the mineral olivine in the feed system, as also observed in some previous tests [3, 4]. Significant magnesium deviations were not observed in subsequent tests due to improvements made to the feed system (see Section 1.8.2). As in previous tests with these feeds [3, 4, 72, 74], surpluses of titanium were observed in feed and glass samples due to its presence as a contaminant in the glass forming additives, most notably kyanite [81]. Potassium was targeted at 4.99 wt% oxide in Test 6 and the

average measured concentration was 5.54 wt%, giving a relative deviation of 11%. The absolute deviations for magnesium, potassium, and titanium are less than 0.6 wt%, and therefore would not affect the outcome of the tests with respect to volatile retention in the product. Tests 1 and 2, which processed feed with an absolute surplus of boron of about one percent, were repeated in Test 7 with similar processing properties and volatile retention indicating a lack of effect of the boron surplus. Volatile species such as halides and rhenium were measured at significantly below the target and feed concentrations, whereas chromium is above its target concentration due to the contribution from corrosion of the high-chromium melter refractory and metallic components.

Samples of the initial glass discharged from each test were dissolved in acid (HF/HNO_3) with the aid of a microwave oven and the resulting solutions were analyzed by DCP-AES primarily for boron and lithium determination but also for total analysis. The values from boron and lithium analysis of the initial discharge were used to calculate the boron and lithium concentrations for the remaining discharges. The measured boron concentration of the initial discharge of Tests 2 and 3 confirm the high concentration in the feed used in Tests 1 and 2. Other boron concentrations and all lithium concentrations approximate their target concentrations, validating this approach for normalizing the XRF data. Agreement between the two analytical methods was excellent, except for low sodium values obtained from the DCP analysis, which is due in part to a low-bias for sodium for that method [81]; previous experience indicates that the XRF results are more reliable in this regard.

Compositional trends of the major and select oxides during the tests are shown in Figures 5.1.a - 5.7.c, which illustrate the differences between the tested compositions and the closeness to target over the course of the tests. The transitions between the glass compositions are best observed for sodium and magnesium, while other elements such as aluminum vary little over the course of the tests, as intended. The most obvious change in concentration is that for potassium around Test 6 where the concentration changes from about one-half to five and a half percent oxide. After Test 6, the melt pool was turned over with glass produced from the initial tests; the glass discharged during the turnover is not included here, hence the apparent abrupt change in the potassium concentration between Tests 6 and 7.

The relationship between measured concentrations of volatile constituents, rhenium, sulfur, and halogens and the target concentrations depend on the element, actual feed concentration, glass formulation, and position within the test. Sulfur and chlorine concentrations were equal to or above target values for all but sulfur in a portion of Test 4. Measured feed concentrations of sulfur and chlorine are all above the target concentrations and are therefore closer to the measured concentration in glass. Sulfur and chlorine glass concentrations that are higher than the analyzed feed concentrations suggest a low bias in feed sample analysis due in part perhaps to low concentrations of insoluble phases that may contain sulfate and/or chloride, which would not be detected by the IC procedure. Fluorine concentrations measured in glasses from the end of the tests were below the measured feed concentrations in six of the nine tests. Rhenium and iodine concentrations were below target values for all but a few rhenium concentrations in Tests 2, 7 and 9. Unlike sulfur and the halogens, iodine and rhenium were spiked into the feed at VSL with reagent chemicals after analysis of the as-received feed showed it to be free of contamination, yielding a

fixed and reliable feed concentration for these two elements. Rhenium and iodine concentrations range from at or near zero at the start of tests to close to the target concentration of 0.1 wt. % for some tests. The concentrations of chlorine, iodine, and rhenium significantly decrease during the idling periods in between tests, in contrast to sulfur which is not volatilized significantly from the melt pool during idling periods. Sulfur concentrations in the glass are also less sensitive to interruptions in the feed and recycle streams. The concentrations of the volatiles increase over the course of each test, often followed by the measured concentrations reaching a plateau characteristic of steady-state. These plateau concentrations used to estimate the steady state retention in glass by dividing by the target concentrations; the percent retentions determined in this way for rhenium and iodine are listed in Table 3.1. Steady state retentions in glass for the nine tests ranged from 59-100% and 9-80% for rhenium and iodine, respectively.

The measured technetium activities for all the discharged glasses are shown in Figures 5.8.a – 5.8.i. Technetium activities increased over each of the tests from zero to a concentration approaching steady state with the technetium feed rate and the recycle system. Similar to iodine and rhenium, technetium concentrations in glass were sensitive to interruptions in slurry feeding and the recycle stream. Examples include downward spikes in technetium activity at about 20 and 30 hours run time during Test 1 as compared to the lack of spikes in technetium activity during later tests which had few interruptions in feed or recycle flow to the melter. The technetium activities were converted to a percentage of technetium retention in glass by dividing by the theoretical activity in glass; that theoretical activity is taken to be the activity in glass that would be obtained if all of the technetium that was fed was evenly distributed throughout the sum total of all of the glass (discharged and in the melt pool) in that test with no loss. The results from that calculation are shown in Figures 5.9.a – 5.9.i. Averages over the points at the "high plateau" in each of these plots were taken as the steady state values that are reported in Table 3.1. It should be noted that these steady state values are higher than the values for percent technetium in glass in the mass balance (see Section 7.0) because the latter is necessarily cumulative over the entire test and includes all of the early glass that contains very little technetium, whereas the former is essentially an instantaneous value. The instantaneous value is more relevant for long-term continuous operations. Steady state technetium retention in glass for the nine tests ranged from 40-84%.

5.2 Glass Pool Samples

All glass "dip" samples taken directly from the melt pool were closely examined to assess the presence or absence of sulfate salt secondary phases and to provide samples for chemical analysis. Samples were also taken to ensure that the melt surface was free of secondary phases prior to starting each testing sequence, as well as after bubbling intended to volatilize sulfur from a previously formed sulfur layer. Data from these samples are also used to determine the amount of glass in the melter as well as the concentration of key constituents at the conclusion of each test. Glass pool sample names, sampling date and time, measured technetium activities, measured iron oxidation state, measured glass pool depth, and secondary phase observations are listed in Table 5.2. Compositional analysis of the dip samples is provided Table 5.5. Analyzed compositions in dip samples largely verify the measured concentrations of contemporaneous discharge samples. The

measured iron oxidation state confirms that the conditions in the melter are oxidizing with the majority of glasses containing less than 2.5% of the total iron as divalent and all but one containing less than 6% of the total iron as divalent. A sample from Test 4 was almost twelve percent divalent due presumably to the low oxidant (nitrate) concentration in that feed; glass produced previously from the same LAWE10H formulation contained about eight percent divalent iron [4].

Significant secondary phases were observed at the end of Test 6 and, to lesser extent, Test 8; both required over three hours of continuous bubbling for removal. Persistent sulfate phase was observed on repeated dip samples after Test 6, requiring the feeding of water on the surface of the melter for approximately half an hour. A picture of the secondary sulfate phase on one of these dip samples is provided as Figure 5.10. Sufficient secondary phase was available for technetium (Table 5.2) and compositional analysis, which is given in Table 5.6. The technetium activity in the secondary sulfate phase was 50 times higher than in the glass in the same sample. The secondary phase is composed of water soluble alkali sulfate, perrhenate, chromate, and chloride salts; the presence of perrhenate is consistent with the observed enrichment in technetium.

The glass formulations used in these tests have been extensively tested for the tendency to form secondary under a variety of conditions including varying halide concentrations [3, 4, 72, 74]. Results for the two formulations that resulted in secondary phases, LAWE7H and LAWE3, are compared with the results from previous tests with the same formulations in Tables 5.7 and 5.8, respectively. For both formulations, the concentration of sulfur fed into the melter was higher in the present tests than that in previous tests conducted on the DM10 and DM100 melters. The higher concentrations fed to the melter are due to a combination of the above-target sulfur concentrations based on the feed analysis (see Table 2.19) and the amount of sulfur in the recycle stream (calculated from solution analysis in Tables 4.17 and 4.21). In addition, the chlorine concentrations for both formulations were higher in the present tests than in the previous tests. Secondary sulfate phases were not observed when processing the nominal LAWE3 and LAWE7H formulations on the DM10 [4] or on the DM100 [72] but were observed on the DM100 when processed with elevated halide and/or chromate contents [72, 74]. The formation of a secondary sulfate phase in the current tests while processing the LAWE3 formulation may also be attributable in part to the higher than target concentration of potassium (4.98 vs. 5.30 wt% oxide); potassium constituted over twelve percent of the secondary sulfate salt phase (see Table 5.6). The secondary phases observed in the present tests are therefore attributable to the higher concentrations of sulfur, chlorine, and potassium which exceeded both the target concentrations and the nominal amounts processed in previous tests in which secondary phases were not observed.

5.3 Technetium, Rhenium and Iodine Retention (Single-pass vs. Recycle)

An extensive set of tests was conducted with a wide variety of LAW waste and glass compositions to determine the extent of technetium, rhenium, and iodine retention in the glass product for the single-pass [3, 4] and recycle flow sheet. The results show that with recycle, the technetium, rhenium, and iodine concentrations in the glass product were increased significantly from their single-pass values. The retention of the volatiles for single-pass and recycle testing is

provided in Table 5.9 and illustrated in Figures 5.11 – 5.13. The retention of technetium increased by factors of 2.1 to 3.4 over the single-pass values for all glass compositions except for LAWE10H, which had a single-pass technetium retention of 66%. Similar increases by factors of 2 to 3 in retention were also observed for rhenium. The extent of retention enhancement with the use of the recycle system is in part dependent on the single-pass retention; compositions with high single-pass retention have smaller increases in retention with recycle, whereas compositions with low single-pass retention have larger increases in retention. The net result is that all but two compositions have percent retentions in glass for technetium and rhenium of 68 to 85 and 70 to 100, respectively, using the recycle system. Absolute increases in iodine retention in glass with the recycle system were less than those for technetium and rhenium due to the much larger fraction of iodine passing through the WESP (see Section 6.0) and volatilized during evaporation (see Section 7.0). Less than half the feed iodine was retained in the glass product in all but the test processing the LAWE10H composition.

The retentions of technetium and rhenium in the glass products are shown in Figure 5.14 for the single-pass and recycle tests. In all but two of these tests, the rhenium retention was equal to or higher than the technetium retention. On average, rhenium retention was about ten absolute percent higher than the technetium retention. The outliers are the tests conducted with the LAWE10H waste/glass composition that had the highest technetium retention of any composition for single-pass and recycle tests. Although rhenium retention was higher than technetium retention, retention for the two elements trended in the same manner over the range of compositions for both single-pass and recycle tests. The same correlation between technetium and rhenium for both the single-pass and recycle flow sheet was observed in the current tests, suggesting that rhenium performs reasonably as a surrogate for technetium in this regard. However, in single-pass tests using iron (II) oxalate, a different correlation between technetium and rhenium was observed from that observed in tests with nominal additives [4].

SECTION 6.0
MONITORED OFF-GAS EMISSIONS

6.1 WESP Exhaust Particulate and Gas Sampling

The WESP exhaust was sampled for metals, particles, and acid gases during each test using the procedures described in Section 1.8.6. WESP emission fluxes are compared to feed fluxes in Table 6.1. Notice the distinction that is made between constituents sampled as particles and as "gas". The "gaseous" constituents are operationally defined as those species that are scrubbed in the impinger solutions after the air stream has passed through a 0.3 μm heated filter. This distinction is not made for samples from Test 1 due to the inadvertent combination of impinger solutions and the filter during recovery; only the elemental emission rates are given for these samples. All samples are well within the 90 – 110% limits for isokinetic sampling. The percent feed technetium in the emissions is also shown in Table 6.1 and is calculated from the air volume sampled, the air flow rate in the exhaust duct, the duration of technetium feeding, and the total activity fed to the melter in each test. The purpose of the emissions data is to determine the amounts of key volatile components (technetium, iodine and rhenium) that escape the recycle loop and which are not recycled to the melter, to complete the elemental mass balances (see Section 7.0), and to provide data for calculating elemental decontamination factors across the WESP (see Section 8).

Thirteen WESP exhaust samples were taken, with at least one from each test and two from Tests 1, 2, 5, and 6. The additional samples were taken to determine whether the observed changes in off-gas system parameters affected the performance of the WESP in removing particulate from the exhaust stream. In all but the first two tests, the measured particulate emission rate from the WESP ranged from 4 to 6 mg/hr, corresponding to a feed carryover through the melter and primary off-gas system of 0.01% (DF from 7000 to 9500). These values are calculated from a 5 mg weight gain over the course of the test, which approaches the detection limit of the method. The sum of the measured elementals for each test are significantly below the total emissions rate suggesting that the particulate emission rate may be lower than that indicated by the gravimetric analysis. Comparable DF values on the DM1200 for LAW high alkali wastes were considerably higher at about 500,000 [4, 83]; this is likely due in part to the longer sampling times (24 vs. 1 hour) which improves the resolution for determination of high DF values due to larger sample size.

The only elements detected in the particulate emissions are technetium, sodium, sulfur, potassium, calcium, silicon, and chlorine. During the first test and a portion of the second test, the WESP was not fully functional, which resulted in higher measured particulate and elemental emission rates. An extreme example is the second sample taken immediately before the end of Test 1, during which time there was no voltage on the WESP and excess moisture was being exhausted from the WESP. The sample from the end of Test 1 contained about five times the expected amount of water and high levels of water soluble species such as technetium, sodium, chlorine, and rhenium suggesting that liquid from the SBS sump was misting through the WESP.

Emissions of chlorine were mostly particulate, while those for sulfur were both particulate and gaseous, and iodine was mostly gaseous. No fluorine was detected in the WESP exhaust other than in the sample taken at the end of Test 1. Rhenium was detected in WESP emissions only in Test 1 and the initial portion of Test 2. In tests with the LAWE4H composition on the DM1200, enough rhenium was detected in the WESP exhaust to calculate a DF value for rhenium of 520; rhenium DF values in the current tests are less than about 250, thus longer sampling times would be required to determine a comparable DF. In keeping with numerous melter studies with iodine [3, 4, 19-23, 25, 82, 83, 86-88], iodine was detected almost exclusively in the basic impinger solution, suggesting that the emissions are in the form of gaseous I_2. Chlorine, sulfur, and iodine were the only elements detected in the impinger solutions collected downstream of the heated particle filter in the sampling train, which constitute the "gas" fraction of the melter emissions.

Technetium was detected in all but one sample particle filter permitting the rigorous determination of emission rates and DFs across the melter and primary off-gas system. Almost all the technetium activity detected was present in the filters and rinses, although in some samples, a small amount was detected in the acidic impinger solution. This technetium is probably very fine particulate that passed through the filter, thus only operationally defined as gaseous. From the middle of the second test the technetium emission rates ranged from 0.005 to 0.321 uCi/min, corresponding to 0.014 to 1.038 % of feed technetium carried over across the melter and primary off-gas system (DF across the melter, SBS, and WESP from 7143 to 96). The highest technetium emission rates were measured during Test 6 while a high potassium waste was processed and with potassium also being detected in the WESP exhaust. There are some indications that the retention of technetium in the glass product can decrease while processing high potassium wastes though the effect appear to be small [4]. However, potassium, which is inherently more volatile than sodium, may form finer particulate with technetium which could reduce the effectiveness of the SBS and WESP in removing it from the exhaust stream. The lowest technetium emission rates from the WESP were measured for LAWE4H, LAWE5H, LAWE9H, and LAWE10H with technetium emission rates of less than or equal to 0.012 uCi/min, which corresponds to less than 0.05 % of the feed technetium exiting through the WESP exhaust (DF of 2000).

6.2 Gases Monitored by FTIR

Melter emissions were monitored in each test for a variety of gaseous components, most notably CO and nitrogen species, by Fourier Transform Infra-Red Spectroscopy (FTIR), as described in Section 1.8.6. The sampling location is downstream of the primary and dry off-gas systems and therefore the measured concentrations are affected by any dilutions in the off-gas system and any removal of constituents by wet scrubbing. A summary of the average concentrations monitored during each test is provided in Table 6.2. The concentrations of monitored nitrogen oxides are plotted in Figures 6.1.a – 6.1.i. The analytes listed in Table 6.2 are those that were thought likely to be observed during the tests based on previous work; no other species were detected in the off-gas stream by FTIR. The test data depicted were collected while processing

different waste compositions over a wide range of nitrogen oxide and waste organic concentrations. In response to these changes in feed composition, observations from the measured volatile concentrations are as follows: significantly lower NO and NO_2 concentrations while processing the LAWE10H composition, which contained very low concentrations of nitrates and nitrites; relatively small changes in water concentration over the testing sequence due to the similar feed water contents and feed rates; and low carbon monoxide concentrations in proportion to feed concentrations of nitrate, nitrite and therefore added sugar. The most abundant nitrogen species monitored was NO, which is consistent with previous tests [3, 4, 17 - 28, 42 - 44, 72, 74, 82 - 87] in which nitrates and nitrites were present in the feed. The NO_2 concentration was about 3 to 8 times less than the NO concentration during tests with the LAWE3, LAWE4H, LAWE5H, LAWE6H, and LAWE7H compositions, while NO_2 concentrations were lower during tests with the LAWE9H and LAWE10H compositions. Another aspect of the emissions is the high degree of variation during testing, as can be observed for NO in Figures 6.1.a - 6.1.i. Notice that, even over short periods of time, NO emissions vary by as much as 200% from the mean in response to changes in the cold cap. No HF or HCl was detected by FTIR during testing due to the low halogen concentrations in the melter feed and their emissions being predominantly particulate and removal by the SBS and WESP. Ammonia is typically emitted while processing feeds with nitrates and sugar; however, it is effectively scrubbed from the exhaust stream in the SBS and therefore none was detected at the downstream monitoring point in these tests.

SECTION 7.0
MASS BALANCE FOR VOLATILE CONSTITUENTS

At the end of each test, all of the sumps were sampled, sump and line flushes and rinses were performed, and samples of all of these fluids were collected for analysis. In many cases two or three rinses were performed; the technetium activity typically dropped by about a factor of ten after each rinse. In addition, the film cooler and transition line were removed, any solids were collected, and the components were rinsed with dilute nitric acid and water. Samples were taken from the solids and rinsates collected from the film cooler and transition line for analysis. The results from analysis of this suite of samples were used to support a mass balance over each test.

For each test, the amount of technetium, rhenium, iodine, sulfur and halides fed into the melter was compared to the total amounts measured in the discharged glass and throughout the off-gas system and associated system components at the end of the test. The number of sampling locations was increased over the course of testing in order to identify other potential areas of technetium deposition during the tests. The mixing vessel was removed from the feed system after the first test and therefore data for the mixing vessel are given only for the first test. The amount of volatiles in the WESP exhaust is based on the rate measured from a one-hour sample taken after at least one day of processing. For tests with multiple WESP exhaust samples, the sample taken during conditions deemed indicative of the majority of the test interval was used for mass balance determination. The amount reported in the glass is the sum of the amounts measured in each discharge and the amount measured in the melt pool at the end of the test.

7.1 Technetium Mass Balance

The results of these mass balance calculations for technetium are provided in Table 7.1 and depicted in Figures 7.1.a – 7.1.h. Mass balance closure improved to 95% over the course of the tests due in part to added analysis of the transition line, containment tank, and inner parts of the WESP. Once the transition line inspection was added to post-test recovery in Test 3, the total recovery of technetium ranged between 85 and 95% for the last seven tests. Improvements to the feed system also resulted in less down time and elimination of holdup of technetium in the feed system. The fraction of feed technetium reporting to the glass was larger than that measured at any other location in all tests. The total amount of technetium reporting to the glass increased from 29 to 71 percent over the course of the tests due to improvements in the WESP resulting in more technetium being recycled back to the glass, and fewer feeding interruptions, thus preserving a complete cold cap, which in turn resulted in less technetium volatilization from the melt pool. Other locations with appreciable technetium accumulations were the mixing vessel in Test 1, which led to its removal for subsequent tests; WESP emissions during Test 2, resulting in continued modifications to the WESP; and the transition line in Test 3, resulting in continued inspections, sampling, and rinsing after subsequent tests; in addition, a water sprayer was added to the transition line and used in Tests 5 – 9. From 9 to 29% of the technetium was distributed between the SBS sump, containment tank, custom

evaporator sump, and associated transport lines, all of which would ultimately have been recycled back to the melter feed. The amount of recyclable technetium is increased to as high as 50.5% when the solutions generated from rinsing and deluging the WESP at the end of each test are included. During routine operation at the WTP (and on the DM1200 installed at VSL), the WESP is deluged daily to rinse material collected on the WESP internals into solutions pumped from the WESP; it is reasonable to conclude that the material in the deluges from the end of the DM10 tests would be recycled with periodic deluging of the WESP.

In the last seven tests, from 2 to 7% of the technetium fed to the melter was associated with the transition line, liquid samples taken during the tests, the commercial evaporator sump, and WESP emissions, all of which are not recycled back to the melter feed. Test samples represent from 16 to 47% of the amount of technetium that could not be recycled and is an artifact of the current testing protocol and thus is not indicative of WTP operations. Up to 84% of the technetium that could not be recycled is associated with transition line deposits; the amount was reduced with the implementation of inline spraying during Tests 5 – 9. The technetium exiting the WESP was no more than 7% of the fraction which could not be recycled to the melter feed and a half percent or less of the total technetium fed to the melter during Tests 5 - 9.

The amounts of technetium and rhenium contained in the glass, SBS solutions, WESP solutions generated from deluges, containment tank, custom evaporator, and WESP emissions are compared for Tests 2 – 9 in Figures 7.2 – 7.8. The amount of technetium reporting to glass ranges from 39 to 71% depending on the single-pass retention and the amount that is not recyclable during the test. The fraction of technetium shown in Figure 7.2 is the sum of all the technetium measured in discharged glass and the amount in the glass pool at the end of the test. Note that these values are lower than the steady state values (see Section 5.0) because the cumulative value is over the entire test and includes all of the early glass that contains very little technetium, whereas the steady state value is essentially an instantaneous value characteristic of long-term operations. The amount of technetium observed in transition line deposits ranged from 1.3 to 5.3% and decreased on average by about a factor of two with the installation of the inline spray. The amount of technetium observed in the SBS sump at the end of the tests ranged from 3.8 to 12% of feed and varied roughly inversely with the amount present in the discharged glass: the highest concentration of technetium in SBS and lowest in the glass was found for Tests 6 and 8, while the lowest concentration of technetium in SBS and the highest in the glass was found for Tests 4 and 9. The amount of technetium observed in the WESP solutions generated at the end of the each test ranged from 2 to 21.7% of feed technetium and followed a similar trend with technetium content in the glass as the SBS solutions. The amounts of technetium in the WESP also increased with the addition of the sprayer to the transition line, which washed deposits into the SBS. The amount of technetium observed collectively in the containment tank and custom evaporator sump at the end of the tests ranged from 4.9 to 16% of feed and reflects the relative amounts observed in the SBS and WESP solutions. The amount of technetium observed in the WESP exhaust ranged from 12.7% in Test 2 when the WESP was not fully functional to 0.014% of feed technetium in Test 9.

The low or below detectable levels of technetium in solutions from the sump of the commercial evaporator and in solutions condensed from the exhaust of the custom evaporator indicate that very little technetium exits the recycle loop through the evaporator. Except for Tests 1 and 6 in which there was overflow of liquid from the custom evaporator to the E-700 evaporator and trace amounts in Test 7, no technetium was detected in the E-700 sump solutions collected at the end of the tests. The percentage of feed technetium from Test 7 calculated to have exited the system via the evaporator is 0.013%. No technetium was detected in the commercial evaporator sump after Tests 2, 3, 4, 5, 8 and 9, which equates to < 0.03% of feed technetium (based on the analytical detection limit, the liquid volumes, and the amount of technetium fed to the melter). Since these solutions are the condensed (and further concentrated) vapor leaving the custom evaporator (which represents the WTP TLP evaporator), they represent the TLP evaporator condensate effluent from the WTP. Samples of condensed exhaust from the custom evaporator taken during the last five tests (See Table 4.6) also indicate that very little technetium was lost from the system via the evaporator. However, the cumulative nature of the condensate collection in the E-700 sump provides a more sensitive measure of this loss.

7.2 Rhenium Mass Balance

The results of the mass balance calculations for rhenium are provided in Tables 7.2 – 7.10 and compared to technetium in Figures 7.2 – 7.8. The total recovery for rhenium was higher than that for technetium, ranging from 90.5 to 119.6% for the nine tests with all but two tests within 10% of total recovery. Unlike technetium, residual rhenium from preceeding tests was present in the glass pool and throughout the off-gas system. To the extent possible, these amounts were quantified and used in the mass balance determinations. The total amount of rhenium reporting to the glass was higher than that for technetium, ranging from 52 to 94% in Tests 2-9. The differential between rhenium and technetium in the cumulative glass is more variable than that for the steady values (see Section 5.3) due to the greater sensitivity of technetium to feed interruptions, WESP performance, and operational issues during testing. In accordance with the higher rhenium retention in the glass, the amount of rhenium in the SBS solutions at the conclusions of the tests was less than that for technetium, ranging from 3.0 to 8.7%. In the WESP solutions generated from deluges at the conclusions of the tests, a greater proportion of feed rhenium than technetium was detected in solutions from five of the nine tests, indicating that the WESP may be more effective at removing rhenium particulate from the exhaust stream than technetium. In three of the tests, about 20 percent of feed rhenium was detected on the WESP internals, which would potentially be recycled back to the melter with the implementation of deluges during testing.

The amount of feed rhenium detected in the transition line deposits ranged from 0.8 to 5.3% and was lower than that for technetium in Tests 3 – 5 and higher in Tests 6 – 9. This transition roughly correlates with the addition of the sprayer to the transition line, suggesting that relatively more technetium is deposited in the lower portion of the transition line up to the SBS (which is accessible to the wash spray) while relatively less rhenium is deposited in the film cooler region. The containment tank and commercial evaporator solutions contained up to 12.3% of feed rhenium and reflect the combination and evaporation of SBS and WESP solutions. In all but the first two

tests, no rhenium was detected in the WESP emissions, indicating that less than one-third to two-thirds of a percent of feed rhenium was present in the WESP exhaust (based on the analytical detection limit, the liquid volume for the dissolved particulate filter, the exhaust air volume sampled and flow rate, and the amount of technetium fed to the melter). In samples taken from the commercial evaporator sump at the conclusion of Tests 5 – 9, rhenium was detected only in solutions from Tests 6 and 7 due to overflow from the custom evaporator during Test 6. Similar to technetium, the data indicate that little or no rhenium is exiting the recycle loop through the evaporator.

7.3 Halogen and Sulfur Mass Balances

The results of the mass balance calculations for chlorine, fluorine, iodine, and sulfur are provided in Tables 7.2 – 7.10 and illustrated in Figures 7.9 – 7.15. Mass balance for these constituents is complicated by the uncertainty in their feed concentrations (the analyzed feed concentrations for chlorine, fluorine, and sulfur did not match the target concentrations, as discussed in Section 2.5.3), the ubiquity of these constituents as contaminants, the low target and analyzed feed concentrations, the presence of chlorine and fluorine in tap water used in the WESP and SBS, and the inability to remove all these constituents from the off-gas system prior to the subsequent test. These issues were addressed by using analyzed feed concentrations, sampling the liquid reservoirs prior to each test to establish a baseline, and correcting for the amount of chlorine and fluorine in tap water (3 and 0.7 mg/l, respectively) for the mass balance determinations.

The total recovery for chlorine is greater than 100% for all tests, approximates 100% for sulfur, and is below 100% for iodine and fluorine for most tests. For the first four tests, chlorine has a total recovery ranging from 138 to 231%, has greater than total recovery of feed chlorine in the glass, is concentrated in the transition line deposits, and is present in the WESP exhaust from 30 to 90% of the analyzed feed amount. In contrast, in Tests 5-9, the total recoveries of chlorine are between 102 and 110% of the analyzed amount in the feed. Closer inspection of the exhaust data suggests that the surplus of chlorine in Tests 1-4 is associated with the gaseous component of the WESP exhaust, as shown in Table 7.11. Chlorine in the gaseous component of the exhaust stream was detected in significant quantities only in Tests 1-4 and the calculated emission rates were virtually identical in four consecutive samples. The gaseous chlorine emission rate is calculated from the analysis of impinger solutions, the volume of the impinger solutions, and the exhaust volume sampled and flow rate. The volumes and exhaust flow rates are relatively constant in all samples, as expected; however, the analyzed concentrations of chlorine are also very similar for the four samples, suggesting that the stock impinger solution used in the first four tests was contaminated with chlorine. The balance of the excess chlorine measured in the initial tests may be attributable to residual chlorine in portions of the melter systems that flushed out during testing and the various system modifications that were made. Above 100% total recovery of chlorine could also be associated with a possible low analytical bias for the very low concentrations of chlorine present in the feed samples.

Fluorine was anomalously high in total recovery and in glass for Test 5 suggesting that more fluorine was present in the feed than indicated by the analysis. A good mass balance was achieved for sulfur with total recoveries ranging between 89 and 114%. The overwhelming majority of the sulfur was contained in the glass with 91 to 109% of feed sulfur, except for Test 4 in which 84% of the feed sulfur was contained in the glass. Iodine recoveries ranged from 51 to 109% with only 8 to 64% reporting to the glass. As a result of the lower iodine retention in the glass, iodine was the most abundant of the four anions in the SBS solutions and most of the containment tank solutions expressed as percent of feed. In the custom evaporator, the relative proportion of iodine to chlorine changes due to the greater amount of chlorine contained in WESP deluge solutions and chlorine entering the system in the tap water sprays.

A tenth to a third of the feed iodine was exhausted from the WESP in all but Test 4. Large fractions of feed iodine have been observed in WESP exhaust and other locations downstream of the WESP during DM1200 tests [89] and therefore significant loss of iodine from the recycle stream was expected.

SECTION 8.0
RETENTION FACTORS FOR UNIT OPERATIONS

The data collected from each of the DM10 recycle tests was used to determine retention factors for each unit operation for several key components. Retention factors were calculated for the melter, SBS, and WESP for technetium, rhenium, iodine, sulfur, chlorine, and fluorine. The retention factors for technetium in glass are discussed in Section 5.0.

Each unit operation in the DM10 recycle system can be considered to have an input stream, a product stream, and an exhaust stream. In the case of the melter, these are the combined fresh feed and recycle streams, the discharged glass, and the melter off-gas, respectively. In the case of the SBS, these are the SBS input gas stream, the SBS liquid effluent, and the SBS exhaust gas stream, respectively. In the case of the WESP, these are the WESP input gas stream, the WESP liquid effluent stream, and the WESP exhaust stream, respectively. The retention factor for a particular constituent (Tc, Re, I, S, Cl, F) in a given unit operation (melter, SBS, WESP) is then defined as:

$$RF = \frac{F_p}{F_i} = \frac{F_i - F_e}{F_i} = 1 - \frac{F_e}{F_i} = 1 - TF \tag{8.1}$$

where F_i, F_p, and F_e are the flow rates of the particular constituent in the input, product, and exhaust streams, respectively, and TF is the transmission factor. This can be contrasted with the decontamination factor (DF), which is defined as:

$$DF = \frac{F_i}{F_e} = \frac{1}{1 - RF} = \frac{1}{TF}.$$

Note that whereas RF and TF range between zero and one, DF ranges between zero and infinity.

It is convenient to express the retention factors on a percentage basis where

$$\%RF = RF * 100.$$

Retention factors were calculated for each of the unit operations using the available test data. The general calculation scheme can be outlined as follows. Clearly, the retention factor can be calculated if any two of the three flow rates F_i, F_p, and F_e are known. In the case of the melter, F_i and F_p are measured but the melter exhaust is not directly measured; however, this can be determined as the difference between F_i and F_p. The melter exhaust flow rate is then the input flow rate into the SBS, which also was not directly measured. Since F_p for the SBS is measured, the SBS exhaust flow rate can again be obtained by difference from the input. The SBS exhaust flow rate is then the input flow rate for the WESP. For the WESP, both F_p and F_e are measured and therefore it is possible to calculate the WESP retention factors in two independent ways, which can be

compared. The general scheme is modified slightly by the holdup in the transition line and the WESP as is described in more detail below.

8.1 Technetium Retention Factors

8.1.1 Melter

For the melter, the technetium retention factor was calculated using Eq. 8.1 in the form:

$$RF_m = \frac{F_{p,m}}{F_{i,m}}$$

where $F_{i,m}$ is technetium flow rate into the melter at steady state, which is equal to the sum of the technetium flow rates in the fresh feed and in the recycle stream, and $F_{p,m}$ is the technetium flow rate out of the melter in the discharged glass.

The flow rate of technetium out of the melter in the off-gas stream is the difference between what is fed into the melter and what leaves the melter in the glass:

$$F_{e,m} = F_{i,m} - F_{p,m}.$$

8.1.2 SBS

The technetium flow rate into the SBS is calculated from the technetium flow rate in the melter exhaust minus the holdup in the transition line:

$$F_{i,s} = F_{e,m} - F_{TL},$$

where F_{TL} is the accumulation rate of technetium in the transition line. The retention factor for technetium in the SBS is then calculated using Eq. 8.1 in the form:

$$RF_s = \frac{F_{p,s}}{F_{i,s}},$$

where $F_{p,s}$ is the flow rate of technetium out of the SBS in the liquid effluent stream.

The flow of technetium out of the SBS in the off-gas stream is the difference between the flow rate in the input gas stream and the flow rate out of the SBS in the liquid effluent stream:

$$F_{e,s} = F_{i,s} - F_{p,s}.$$

8.1.3 WESP

The effective flow rate of technetium into the WESP was calculated as the flow rate of technetium in the gas stream leaving the SBS minus the rate of technetium accumulation on the WESP collection plates:

$$F_{i,w} = F_{e,s} - F_{WA},$$

where F_{WA} is the accumulation rate of technetium on the WESP internals. The retention factor for technetium in the WESP is then calculated using Eq. 8.1 in the form:

$$RF_w = 1 - \frac{F_{e,w}}{F_{i,w}},$$

where $F_{e,w}$ is the flow rate of technetium out of the WESP in the WESP off-gas stream, which is measured by off-gas sampling.

Since for the WESP, the technetium flow rates in both the exhaust stream and the liquid effluent stream are measured, the retention factor can be calculated in an alternative manner that is independent of the data for the upstream components (melter and SBS). Thus, the retention factor for technetium in the WESP can also be calculated using Eq. 8.1 in the form:

$$RF_w = \frac{F_{p,w}}{F_{i,w}} = \frac{F_{p,w}}{F_{e,w} + F_{p,w}}.$$

where $F_{p,w}$ is the flow rate of technetium out of the WESP in the liquid effluent stream. Retention factors for the WESP were calculated by both methods and compared.

8.1.4 Calculation of Technetium Retention Factors

To calculate the retention factors by the methods described above, the technetium flow rates throughout the system during each test need to be known. The technetium flow rates in the fresh feed, the recycle stream, and the SBS liquid effluent were calculated using the measured concentrations of technetium in samples from those streams together with the monitored stream flow rates. The technetium concentration was measured every 12 hours throughout the tests, while the instantaneous flow rates were recorded every 2 minutes. A linear interpolation between the 12 hour sample measurements was used to give a concentration for each flow measurement. The two were then multiplied together and multiplied by the time between measurements (2 minutes) to give the amount (in mCi) of technetium that flowed during that time interval. These amounts were then summed for each flow data point to give the cumulative amount of technetium that flowed in each

stream as a function of time throughout the test. Initially these sums are non-linear with time; however, as the tests progress, and the system reaches steady state, the change in mass with time becomes linear, and the slope of this line is flow rate of technetium (mCi/hr). This flow rate was used for the retention factor calculations.

To calculate the flow of technetium out of the melter in the off-gas, the flow rate of technetium leaving the melter in the glass must be known. Since the glass discharges are on a different schedule (approximately hourly) from other samples and measurements, this was done by first summing the amounts of technetium in the glass discharges and fitting a third order polynomial to the amount of technetium in the glass versus time. Then for each 2 minute time step, this calculated value was subtracted from the sum of the mass of the technetium in the fresh feed and the recycle for the corresponding time interval. This value provides the amount of technetium that flow out of the melter in the off-gas during those 2 minutes. By summing these masses over time, in a similar manner as was done for the feed, recycle, and SBS, the slope of the resulting line yields the flow rate of technetium in the melter off-gas stream. For example, Figure 8.1 shows the plots of technetium vs. time for the feed, recycle, off-gas from the melter, and the liquid effluent from the SBS during Test 9. Figure 8.2 shows the steady state region, with a line fit to the data. The slope of the equation for the fitted line provides the steady state flow rate that is used in the retention factor calculations.

For the WESP, the EPA Method 5 isokinetic sampling results were used to calculate the technetium emissions in the off-gas from the WESP. The technetium flow rate in the WESP liquid effluent was calculated in the same way as that for the SBS liquid effluent stream, using the measured concentrations of technetium in samples from those streams together with the monitored stream flow rates. This flow rate is used in the alternative calculation of the WESP retention factors.

The amount of technetium held up in the transition line and on the WESP collection plates was based on the end of test samplings performed at those locations. It is assumed that these accumulations are linear with time, and the rate was calculated as the total mass of technetium found in each location divided by the test time.

8.2 Retention Factors for Other Constituents

The same method as that used for technetium was used to calculate retention factors for rhenium, iodine, sulfur, chlorine, and fluorine, with mass-based concentrations replacing activity-based concentrations.

8.3 Retention Factor Results

The single-pass retention factors for technetium, rhenium, iodine and sulfur in the melter, SBS, and WESP were calculated for Tests 2 through 9. For chlorine and fluorine, the mass balance

was not sufficiently good to permit this method to be used for some of the tests. As a result, Tests 5, 6, 7 and 8 were analyzed for chlorine and Tests 6 and 7 were analyzed for fluorine. The results from all of these analyses are shown in Table 8.1. Note that there are two sets of retention factor results for the WESP corresponding to the two independent methods described in Section 8.1.3. Some of the retention factors have calculated values that are either less than zero or greater than 100%, which are non-physical. This is the case for some of the values for sulfur for Tests 3, 6, and 8 and for fluorine in Test 6. This behavior is associated with tests in which the WESP performance was changing significantly or where the mass balance for a particular constituent was greater than 100%. However, the majority of the calculated values are reasonable, showing fair consistency across tests and good consistency between the alternative methods of calculation used for the WESP.

Table 8.2.a shows the results of averaging the calculated single-pass retention values across all tests. It should be noted, however, that some test-to-test variation is expected, particularly at the melter, where the retention certainly depends on the feed composition. Table 8.2.b shows the same averages obtained after removal of values greater than 100% and removal of the WESP results for Test 2 since the WESP was unstable during that test. The average melter retention for rhenium is greater than that for technetium, as is the case for every test, which is consistent with previous observations [3, 4]. Interestingly, the average retention of technetium in the SBS is significantly lower than that for rhenium, which is also the case for every test except for Test 8. The average value for rhenium of about 70% is close to that for iodine, sulfur, and fluorine, whereas the average value for technetium of about 52% is close to that for chlorine. WESP retentions for technetium and rhenium are very high at around 99% or greater. WESP retentions are also high and generally in the 90% range for chlorine, fluorine, and sulfur. Iodine showed the lowest WESP retentions at around 20-30%, as would be expected for a species that is likely present as molecular iodine. Iodine retentions also showed some of the greatest test-to-test variations, which may reflect the change in distribution of iodine species as the composition of the off-gas changes, particularly as a result of changes in redox conditions. Test 4 (LAWE10H) showed the highest iodine retention in the WESP, which would suggest that a higher fraction was present as particulate rather than as molecular iodine. As discussed in Section 5.2, the glass from Test 4 was more reduced than that from any other test. Thus, it is possible that in the Test 4 off-gas, a greater fraction of the iodine was present as iodide salts that would be more effectively removed by the WESP.

In Table 8.3, the retention factors obtained in these tests for rhenium, sulfur, and iodine are compared with those obtained previously on the DM1200 system with the LAWE4H feed (with ferrous oxalate) [4]; the DM1200 system constitutes a factor of 60 scale up over the DM10 test system. The retention of rhenium in the SBS (average of 70.0%; 71.5% for Test 7 with LAWE4H feed) is in very good agreement with the value measured on the DM1200 melter system of 73.0%. Similarly, the retention of rhenium in the WESP (average values of 98.5% and 99.4%; values of 98.6% and 99.3% for Test 7 with LAWE4H feed) is also in very good agreement with the value measured on the DM1200 melter system of 98.5% [4]. The melter retention for rhenium in the DM10 tests (average of 43.1%; 41.6% for Test 7 with LAWE4H feed) cannot be directly compared to that for the DM1200 (62%) because of the use of ferrous oxalate in the DM1200 test, which increases rhenium and technetium retention in the melter [3, 4]. As shown in Table 8.3, there is also

reasonable agreement between the retention factors for sulfur in the SBS and the WESP from the DM10 and DM1200 tests. The comparison for iodine shows much poorer agreement, however, with the DM1200 test showing lower retention values than the DM10 for the SBS and higher values for the WESP. This is similar to the DM10 results for Test 4, discussed above, and may also be due to the more reducing conditions in the DM1200 tests as a result of the use of ferrous oxalate.

Figures 8.3 and 8.4 compare the single-pass melter retentions calculated from the data from the recycle tests with the single-pass melter retentions previously determined in DM10 tests without recycle for technetium and rhenium [3, 4], respectively. It should be noted that even with recycle, from its definition, the melter retention factor is still reflective of single-pass behavior; the addition of recycle simply increases the concentration in the feed and, thereby, also in the glass product. Thus, to a first approximation, the retention factor with respect to the *total* feed input is expected to remain the same; this could, of course change if the retention of a particular constituent was strongly dependent on its concentration in the feed, which is possible but would seem unlikely for most of these constituent since they are present at low concentrations. As shown in Figures 8.3 and 8.4, for both technetium and rhenium there is reasonable agreement between the single-pass melter retentions calculated from the recycle test data and the single-pass melter retentions previously determined in DM10 tests without recycle.

SECTION 9.0
PROCESS MODELING

Process modeling was used to support the design of the system modifications required to implement the recycle loop. Of particular concern were the residence time in each unit operation (SBS, WESP, Containment Tank, and Evaporator) in comparison to the half-life of ^{99m}Tc and the detection limits for its analysis in the process samples, including the glass product and liquid effluents. The interaction between these factors determines how closely compositional steady-state conditions can be approached and the upper limit on technetium retention in the glass product that can be reached. The process was modeled to capture these interactions and to provide a tool for the determination of key system parameters in the design of the off-gas system modifications required to implement the recycle loop.

As the testing was completed, the same model was used to analyze the data and to compare the concentrations of key species in the glass product with the models predictions. In this case, the actual operating conditions, flow rates, and measured decontamination factors for each unit operation were used as input into the model.

Further details and results from process modeling performed to support the system design and for analysis of the test data are provided in the following sections.

9.1 System Design

Process models of the DM10 flow diagram shown in Figure 1.1 have been implemented independently on two platforms in order to provide a means of cross-checking the results. One model employs Excel to implement the flow and mass balance conditions across each unit operation at each instant in time. The model was solved in successive time steps using Euler's Method to perform the numerical integration. Testing was conducted to ensure that the time step size was sufficiently small to yield results that were independent of the step size. A second model starts from the first-order differential equation governing each unit operation and solves the resulting set of coupled equations simultaneously; that model was implemented in Mathcad. For the same set of input parameters, there is good agreement between the two models. The principal input parameters are flow rates, sump volumes, and decontamination factors (DFs) for each unit operation. The Mathcad model was used primarily in the system design phase, whereas the Excel model was somewhat better suited for analysis of the test data.

Figure 9.1 shows the build up and decay of ^{99m}Tc activity for each unit operation as a function of run time calculated with the Mathcad model. Figure 9.2 shows the "activity" (proportional to the concentration) for the case in which the half-life is very long compared to the test duration, which is the case for ^{99}Tc and for stable elements (e.g., Re, I, S, Cl, F); all such species

would be expected to exhibit generally similar behavior, with differences in detail resulting from any differences in their DFs.

Of particular interest is the ^{99m}Tc activity in the glass product, shown in Figure 9.3, since this, in combination with the detection limit for the activity measurement, determines the maximum overall retention in glass that can be measured for the given set of input assumptions. In the design phase, a conservative estimate of the detection limit of 1 nCi/g was used and these results therefore show that the activity in the glass product would fall below that level after about 60 hours of run time; actual detection limits during testing were ten to twenty time smaller than this. The tests were therefore planned for a total duration of 72 hours and in all cases there was still sufficient activity in the product glasses for reliable measurements to be made.

Figure 9.4.a shows the technetium retention, which is the ratio of the activity in the product glass to that in the melter feed on a glass basis (excluding the contribution from recycle), as a function of time. Also shown is the effect of variations of the single pass-retention value from the 34% values used for all of the other figures; the effect of these variations on the glass activities at 60 hours is small. As discussed in Section 9.2, several aspects of the as-built system differed from those employed for original system design modeling; the effects of these changes on the projected technetium retention are shown in Figure 9.4.b.

Figure 9.5.a shows the driver sheet for the Excel version of the model where the adjustable process parameters (flow rates and decontamination factors) are highlighted in yellow and the unit operation volumes (in liters) are highlighted in purple. The parameter values shown in Figure 9.5.a are typical of those explored in the design phase. Note that, as discussed below, percent retentions are used in preference to decontaminations factors to characterize each unit operation. Figure 9.5.b shows the driver sheet used for analysis of the test data with parameter values used for Test 3. Note the addition of provisions for material holdup in the transition line and the WESP; these changes were made based on information collected during testing. Also note that there are some significant differences in the sump volumes, as discussed in Section 9.2.

9.2 Design versus As-Built

The liquid sump volumes were designed to be small in order to minimize the residence time in each unit operation. This was important in order to be able to reach steady state conditions during testing before the ^{99m}Tc activity fell below the detection limit. The initial estimates of the sump volumes were based on engineering judgment of the minimum sizes that could be fabricated that would meet the functional and operational requirements. During detailed design, however, it was recognized that a significantly larger SBS sump volume would be required to accommodate an adequate packed bed height, liquid vapor separation zone, and the internal cooling loop to ensure proper functioning. This was partially off-set by a significant reduction in the volume of the WESP sump and a more modest reduction in the volume of the containment tank. The WESP was modeled to have a liquid sump that drained into the containment tank; however, in the as-built system, the

WESP drained directly into the containment tank with no significant liquid holdup; a value of 0.1 liters was used for modeling to account for the liquid on the walls of the collection plates and in the piping between the WESP and the containment tank. In addition, during testing it was determined that the working level in the evaporator sump would have to be increased to ensure reliable control. The sump volumes used for the design modeling are compared to those for the as-built system in Table 9.1.

During the testing, the level in all of the vessels fluctuate; this can be seen for the containment tank in Figures 4.12.a through 4.12.i, for the Evaporator in Figure 4.17, and indirectly for the SBS in Figures 4.4.a through 4.4.i (the differential pressure across the SBS is proportional to the height of the water in the SBS). For modeling purposes, a fixed representative volume was used that approximates the operating volume during the tests. Similarly the flow rates are assumed to be constant and average values from the tests are used. Operational events, occasionally resulted in extended flow interruptions, as discussed in Sections 3 and 4. However, the model was not adjusted to account for these transients but rather the effects of these events are discussed below in terms of deviations from the model predictions.

In addition to the physical differences in the system, the design model assumed that technetium traveled unobstructed through the system. However, as discussed above in Section 7, during the testing it was determined that there was significant holdup of ^{99m}Tc in the transition line between the melter and SBS and on the WESP collection plates. In order for the model to more accurately describe the system, the holdup in these two locations was added in to the model. The driver sheet for the modified model, with the operating parameters for Test 3, is shown in Figure 9.5.b. Since there is no in-situ data for the accumulation as a function of time, it is assumed that the accumulation is linear with time and the activity found at the end of the test is divided by the test duration to obtain an accumulation rate that is used as input for the model.

9.3 Modeling of Test Data

The model for the as-built system was used in conjunction with the process data from the testing to predict the evolution of the concentrations of key species (Tc, Re, S, I, Cl, F) in the glass product throughout each of the tests and to compare the results with the measured values. As discussed above, the values for the flow rates were taken as the corresponding average values throughout the test, the values for the sump volumes are those listed in Table 9.1, and the holdups in the WESP and transition line were assumed to accumulate linearly based on the amounts determined from samples taken at the end of the test. The retention factors for each constituent in the melter, SBS, and WESP were calculated for each test as described in Section 8 and the values so determined were used as input into the model for that test. The model was then run using these test-specific parameters and the theoretical concentrations of Tc, Re, S, I, Cl, and F in the glass as a function of time were compared to the actual concentrations measured in the discharged glass. The results are discussed in the following sections.

The model results for the technetium concentrations in the product glass are compared to the measured values for Test 2 - 9 in Figures 9.6.a through 9.6.h, respectively. The results for rhenium in Tests 2 - 9 are shown in Figures 9.7.a through 9.7.h, respectively. The results for iodine in Tests 2 - 9 are shown in Figures 9.8.a through 9.8.h, respectively; and the results for sulfur in Tests 2 - 9 are shown in Figures 9.9.a through 9.9.h, respectively. For chlorine and fluorine, the mass balance was not sufficiently good to permit this method to be used for some of the tests. As a result, Tests 5, 6, 7 and 8 were analyzed for chlorine and Tests 6 and 7 were analyzed for fluorine. The results for chlorine are shown in Figures 9.10.a through 9.10.d, respectively, and those for fluorine are shown in Figures 9.11.a and 9.11.b, respectively.

9.3.1 Results for Technetium

Test 2: For Test 2, as discussed in Section 4, the WESP performed poorly for a significant portion of the test. As a result, the WESP retention factor was low and a significant fraction of the technetium and other volatiles were lost in the off-gas instead of being recycled. The modifications to the WESP performed at about 38 hours into the test improved WESP performance, which is shown in Figure 4.9.b. This may account for the rise in the measured technetium concentration towards the end of the test. This is shown in Figure 9.12 which plots the WESP voltage as well as the technetium concentrations in the glass (both model values and those measured discharged glass) for Test 2. The rise in glass concentration in the discharged samples corresponds with the increased WESP voltage. The model assumes the WESP performance is consistent throughout the test and does not account for these dynamic events. Additionally, since the holdup was not known for this test, the model assumed no holdup in the transition line, which would account in part for the low technetium concentration in the glass data as compared to the model.

Test 3: For Test 3, the data and model show good agreement for the majority of the test. There is a dip in the discharged glass technetium concentration from hour 37.8 through hour 46.5, which corresponds with significant down time in the syringe pump delivering the ^{99m}Tc to the melter inlet. The pump interruptions are listed in Table 3.2.c; in Figure 9.13, the period of frequent pump interruptions is overlaid on the glass technetium concentration data and the model from Figure 9.6.b.

Test 4: For Test 4, the model and the data show good agreement for the majority of the test. Towards the end of the test, the concentration of technetium in the glass discharged decreases, which is similar to what was seen in Test 3. The syringe pump supplying the fresh technetium stalled several times at around hour 41.5 and was problematic between hours 53.8 and 56, which led to its removal for subsequent tests, as discussed in Sections 1 and 4.

Test 5: For Test 5, the model and the data show good overall agreement. However, there were three areas where the concentration trends varied significantly from the model: first, roughly between hours 16-26, there is a dip followed by a rapid increase in the technetium concentration; second, this occurs again between hours 34 and 40; and third, from approximately hour 52 to the end of the test, there is a decrease in concentration. These changes do not correspond with any major

operational events during the tests. It is believed that they are associated with the changeover in feed batches, which evidently affected the feed technetium concentrations. This is illustrated by re-plotting Figure 9.6.d with the timing of the feed batch changes indicated in Figure 9.14, which clearly shows the correlation. This is also supported by the feed sample analysis data discussed in Section 2.5. The LAWE6H feed was the most viscous of all of the feeds that were tested, which may have resulted in poorer mixing; this was also the first test that employed the modified feed system with direct addition of technetium to the feed tank.

Test 6: For Test 6, there is a clear break in the trend predicted by the model and the measured data. This is most likely the result of hand valve HV-2610 between the WESP and the containment tank being left closed and the actions necessary to bring the system back to steady operating conditions that were discussed in Section 4. Figure 9.15 shows when the isolation of the WESP occurred and how that correlates with the decreased rate of increase of the technetium concentration in the glass as compared to the model. It is worth noting that the technetium concentration did not rebound once the problem was fixed. In contrast, while the same behavior is evident in the rhenium data, as can be seen in Figure 9.7.e, the concentration of rhenium increases after the WESP was reconnected to the containment tank. The reason for this difference is not clear.

Test 7: For Test 7, the model and measured glass concentrations correspond well for the first half of the test but the concentration in the discharged glass plateaus at a level below the steady state predicted by the model. There were no major operational issues with the off-gas system during this test that might explain this behavior. However, this discrepancy does correspond with the overall mass balance, which was 87% for technetium.

Test 8: For Test 8, the data and model show good agreement for the majority of the test. There are some deviations but these do not appear to correspond to any operational events. Near the end of the test, the measured data fall below the model predictions by an amount that is comparable to the technetium mass balance shortfall.

Test 9: For Test 9, the data and model show good agreement for the majority of the test. There are some deviations but these do not appear to correspond to any operational events. Near the end of the test, the measured data fall below the model predictions by an amount that is comparable to the technetium mass balance shortfall.

9.3.2 Results for Other Constituents

The data for the other key constituents (Re, S, I, Cl, and F) were analyzed in the same way as the data for technetium. However, unlike technetium, which decays rapidly, for these constituents it was possible for there to be non-zero sump and glass concentrations at the start of the test. This effect was accounted for in the model and was most prevalent for the sulfur, as discussed below. The data for Test 2 – 9 were analyzed for rhenium, sulfur, and iodine. For chlorine and fluorine, the mass

balance was not sufficiently good to permit this method to be used for some of the tests. As a result, Tests 5, 6, 7 and 8 were analyzed for chlorine and Tests 6 and 7 were analyzed for fluorine.

The model results for rhenium are compared to the concentrations measured in the product glass samples for Tests 2 - 9 in Figures 9.7.a through 9.7.h, respectively. The results show many of the same features observed in the technetium data. However, the agreement between the model predictions and the measured values is generally better and the deviation between the two at the end of the tests is significantly smaller. Since the mass balance closure was better for rhenium than for technetium, this would support the idea that part of the deviation of the technetium data from the model predictions is simply a result of the shortfall in the mass balance closure.

The model results for iodine are compared to the concentrations measured in the product glass samples for Tests 2 - 9 in Figures 9.8.a through 9.8.h, respectively. The measured data for iodine show considerable scatter due to the low concentrations that result from the low retention of iodine in the glass product. Despite this, the iodine data showed many of the same trends and responses to operational issues as the technetium and rhenium data. Overall, the general trends in the test data were reflected in the model predictions but the measured concentrations near the end of the tests were typically somewhat below the model predictions. This is almost certainly due to in part to the uniformly low mass balance for iodine, as discussed in Section 7. Test 4, which shows the highest iodine mass balance closure, shows the best agreement between the test-end model and measured iodine concentrations.

The model results for sulfur are compared to the concentrations measured in the product glass samples for Tests 2 - 9 in Figures 9.9.a through 9.9.h, respectively. Note that the initial sulfur concentration in the glass was non-zero for all of the tests except for Test 5. This resulted in a subdued initial concentration rise and, for some cases, the concentration actually decreased from its initial value. Overall, there was generally very good agreement between the model predictions and the measured data for sulfur. Unlike the case for technetium, iodine, and to a lesser extent, rhenium, there were a few cases for which the measured sulfur data were above the model predictions. The measured data for Test 4 are particularly atypical, showing an initial rise to a maximum followed by a decrease to a plateau, which is quite different from the behavior expected and predicted by the model. The reason for this is not clear but, as discussed in Section 4.2, atypical behavior for sulfur was also observed in the SBS sump solutions for Test 4. It is possible that this may have been due to variations in the sulfur concentrations in successive feed batches for this test.

The model results for chlorine are compared to the concentrations measured in the product glass samples for Tests 5 - 8 and are shown in Figures 9.10.a through 9.10.d, respectively. For the system model for chlorine, the makeup water was assumed to have a chlorine concentration of 3.0 ppm. This was added to the system based on the average makeup water flow rate for the SBS and WESP throughout the test. There is very good agreement between the model predictions and the measured discharged glass concentration for these tests.

The model results for fluorine are compared to the concentrations measured in the product glass samples for Tests 6 and 7 and are shown in Figures 9.11.a and 9.11.b, respectively. For the system model for fluorine, the makeup water was assumed to have a fluorine concentration of 0.7 ppm. This was added to the system based on the average makeup water flow rate for the SBS and WESP throughout the test. Only the last discharged glass sample from each test was analyzed for fluorine due to the time consuming nature of that analysis in order to obtain the necessary sensitivity; however, all of the samples have been archived for possible further testing in the future. Consequently, only the test-end values can be compared; the measured values are slightly lower than predicted for both tests.

9.3.3 Effect of Holdup

The effects of holdup in the transition line and the WESP is illustrated for technetium in Figures 9.16 and 9.17, which show the measured concentrations in the product glass and the model predictions with and without holdup. Clearly, the inclusion of the holdup in the model improves the agreement with the data. The magnitude of the effect depends on the measure amount of the holdup from samples taken at the end of the test. Generally, the holdup increased as the melter retention decreased and more technetium reported to the melter off-gas. In addition to technetium, the measured holdup in the transition line and WESP was included in the model for all of the constituents discussed above.

SECTION 10.0
SUMMARY AND CONCLUSIONS

Melter tests were conducted to determine the retention of technetium and other volatiles in glass while processing simulated LAW streams through a DM10 melter equipped with a prototypical off-gas system that concentrates and recycles fluid effluents back to the melter feed. To support these tests, an existing DM10 system installed at VSL was modified to add the required recycle loop. Based on the WTP LAW off-gas system design, suitably scaled versions of the SBS, WESP, and TLP vacuum evaporator were designed, built, and installed into the DM10 system. Process modeling was used to support this design effort and to ensure that issues associated with the short half life of the ^{99m}Tc radioisotope that was used in this work were properly addressed and that the system would be capable of meeting the test objectives. In particular, this required that the overall time constant for the system was sufficiently short that a reasonable approach to steady state could be achieved before the ^{99m}Tc activity dropped below the analytical limits of detection. The conceptual design, detailed design, flow sheet development, process model development, P&ID development, control system design, software design and development, system fabrication, installation, procedure development, operator training, and Test Plan development for the new system were all conducted during this project. The new system was commissioned and subjected to a series of shake-down tests before embarking on the planned test program. Various system performance issues that arose during testing were addressed through a series of modifications in order to improve the performance and reliability of the system. The resulting system provided a robust and reliable platform to address the test objectives.

Seven different LAW waste compositions were processed in nine nominally 72-hour tests. All feeds were spiked with a solution containing ^{99m}Tc in the pertechnetate form; the feeds used in these tests also contained measureable amounts of nonradioactive iodine and rhenium. In each test, a mass balance for technetium and other feed constituents of concern was measured across the glass pool, discharge glasses, throughout the off-gas system, evaporator overheads, and WESP exhaust. The nominal melter operating conditions employed for the majority of the tests were: an 1150°C glass pool temperature, sugar as an organic reductant at a stoichiometric sugar ratio of 0.5, and air bubbled through the glass pool at a rate to achieve a constant glass production rate of 2,250 kg/m^2/day. Throughout the tests, enhancements were made to the feed system, WESP, evaporators, and operational procedures in order to optimize unit performance and minimize test interruptions. In addition to the mass balance for key constituents (Tc, Re, S, I, Cl, F), data collected from these tests were used to calculate retention factors across the melter and each of the various off-gas system components. These results were used as input into process models of the system which were used to calculate the predicted concentrations in the glass product for comparison to the measured values. The data were also used to quantify the amount of technetium that escapes the recycle loop through the WESP exhaust and the evaporator overheads.

In the WTP system, technetium can exit the recycle loop via two routes: In the off-gas stream exiting the WESP and in the liquid condensate from the vacuum evaporator. Constituents in the off-gas stream from the WESP are further removed in the PBS. The PBS effluent and evaporator condensate secondary waste from the WTP are directed ultimately to non-glass waste forms. Consequently, the fraction of technetium exiting the recycle loop via these routes is a significant factor in the Performance Assessment (PA) for the Hanford Integrated Disposal Facility (IDF). There have been no previous measurements of this fraction. Data from the present tests permit such estimates to be made, as well as the relative contributions from the WESP and the evaporator.

These tests have produced the first ever data on:

- Technetium performance and retention factors for key WTP unit operations (SBS, WESP, vacuum evaporator)
- The effects of recycle on the incorporation of technetium and other key species
- The distribution and fate of technetium throughout the vitrification system and recycle loop, and the extent of partitioning to secondary waste streams

Key findings from this work include:

- With recycle, retentions of technetium and rhenium in the glass product are increased by factors of at least 2 to 3 over the corresponding single-pass values for almost all glass compositions. The average technetium and rhenium retentions in glass across all compositions tested were 68% and 79%, respectively. All but two compositions showed technetium retentions in glass of 68 to 84% and rhenium retentions in glass of 70 to 100%.

- The increase in glass retention was limited by holdup of material in the system, particularly in the WESP internals, the film cooler, and the transition line. Mobilization of this material in order to make it available for recycle would likely further increase the retention in glass.

- The technetium mass balance closure reached as high as 95% but averaged about 90% over the later tests, which is about 10% lower than that observed for rhenium. This difference likely contributed to the observed difference in the retentions in glass. In comparison, in 72 previously conducted single-pass DM10 tests (without recycle) the average mass balance closures were 97% for technetium and 102% for rhenium [3, 4].

- The fraction of feed technetium exiting the recycle loop through the evaporator overheads was less than 0.03% during normal operations and much lower for many tests.

- The fraction of feed technetium exiting the recycle loop through the WESP exhaust ranged from 0.01 to 0.5% during normal operations.

- The fraction of feed technetium exiting the recycle loop through the WESP exhaust was critically dependent on the performance of the WESP and increased to above 10% (i.e., by a factor of about 500 or more) when the WESP was not functioning.

- Iodine retention in the glass also showed significant enhancements over the corresponding single-pass values but to a lesser extent than those for technetium and rhenium.

- The amount of technetium, iodine, and rhenium retained in the glass product showed similar variations across the seven LAW streams investigated (LAW from Hanford tanks AP-101, AN-105, AN-107, AN-104, AN-102, AZ-101, and AZ-102) to that observed in the tests without recycle but the variation was somewhat less pronounced.

- For technetium, the system component retention factors averaged across all seven feed types were:
  - Single-pass melter: 35.2% (vs. 68% average with recycle)
  - SBS: 52.2%
  - WESP: 99.8%

- For rhenium, the system component retention factors averaged across all seven feed types were:
  - Single-pass melter: 43.1% (vs. 79% average with recycle)
  - SBS: 70.0%
  - WESP: 99.4%

- Overall, technetium and rhenium showed remarkably similar distribution across the various system sumps. However, as noted above, the retention factor for technetium in the SBS was significantly lower than that for rhenium, both on average and in all but one of the individual tests.

- The steady state retention of technetium in the glass product showed a reasonable correlation to that for rhenium, with the average rhenium retention being roughly 10% absolute higher than that for technetium. The correlation between rhenium and technetium and the generally higher retention for rhenium is consistent with previous results for the single-pass retention, but with all values shifted higher with recycle.

- Technetium retention in the glass product was more sensitive to interruptions in the feed and recycle streams than was the case for rhenium suggesting that data from tests with technetium, rather than a rhenium surrogate, should be used in evaluating the potential impacts of such interruptions on the performance of the WTP.

- Testing with a high potassium feed showed higher emissions of both technetium and potassium in the WESP exhaust, suggesting that the presence of potassium may reduce the capture efficiency of technetium in the off-gas system.

- The single-pass melter retentions for technetium and rhenium calculated from the present test data show good agreement with the corresponding values measured previously on the DM10 and DM100 melter systems. The SBS and WESP retention factors measured for rhenium show excellent agreement with those measured previously on the DM1200 system, which represents a factor of 60 scale-up.

- Sulfur, chlorine, and fluorine also showed significant increases in retention in the glass product, often approaching 100%. The mass balance closure was generally good for sulfur but less so for chlorine and fluorine as a result of their very low levels in the feed and their ubiquity as contaminants.

- Sulfate salt phases were observed on the melt pool surface after two of the tests; these same LAW streams and glass formulations showed no evidence of secondary phase formation during previous single-pass tests. However, salt formation was consistent with the higher concentrations of sulfur and chlorine in the melter feeds for the present tests. The salt phase showed an approximate fifty-fold enrichment in technetium over the glass; rhenium and halides also showed significant enrichments.

- When the measured retention factors for Tc, Re, S, I, Cl, and F for each of the system components are input into the process model, reasonable agreement with measured glass data is seen.

10.1 Potential Implications for the WTP

In the present tests, technetium retentions in a variety of Hanford LAW glasses were determined with recycle using a flow sheet representative of the Hanford WTP LAW vitrification facility. With recycle, retention of technetium in the glass product increased by a factor of at least 2 to 3 over the corresponding single-pass values for almost all glass compositions. In the present tests with recycle, all but two compositions showed technetium retentions in glass of 68 to 84%.

While the measured technetium retention values for the LAW glass with recycle are much increased over the single-pass values, they are significantly lower than previous assumptions and estimates. For example, the 2003 risk assessment supporting the evaluation of supplemental ILAW treatment technologies assumed "low," "best," and "high" estimates for the fraction of the technetium inventory reporting to the LAW glass product of 90%, 99.9%, and 100%, respectively, with the "best estimate" value used for the risk assessment calculations [1]. More recently, a baseline technetium mass balance has been generated as part of System Plan 6 [2] for the WTP facility, which employs a flow sheet that includes WTP LAW and HLW vitrification, as well as vitrification for supplemental treatment of LAW. That flow sheet includes recycle back to the WTP pretreatment

facility of liquid effluents from off-gas treatment in both the WTP LAW and HLW facilities; in contrast, the supplemental LAW vitrification facility is modeled with recycle internal to that facility. Per the assumptions used in that mass balance, of the total technetium inventory in the tank farms, 99.3% is retrieved for treatment, 91.6% reports to the LAW glass product (from both WTP and supplemental LAW), 5.6% reports to the HLW glass, 0.18% reports to solidified liquid effluent, and 0.18% reports to other solid wastes. Results from the present tests suggest that a value of around 0.18% may not be an unreasonable expectation for the liquid secondary waste streams since the fraction of feed technetium exiting the recycle loop through the WESP exhaust ranged from 0.01 to 0.5% during normal operations, while that exiting the recycle loop through the evaporator overheads was less than 0.03% during normal operations and much lower for many tests. As discussed below, it is expected that the time-averaged fraction of technetium exiting the WESP will be increased somewhat as a result of the downtime associated with the daily water washes of the WESP that are planned at the WTP.

In the present tests, the measured technetium retention in the product glass was limited by several factors. The test results showed that a significant amount of technetium was held up in the system during testing, particularly in the WESP internals, the film cooler, and the transition line. This material was therefore not available for recycle, which decreased the incorporation of technetium in the glass product. Mobilization of this material in order to make it available for recycle would likely further increase the retention in glass. In particular, significant holdup was found in the WESP. The WTP plans to employ periodic water washes ("deluges") of the WESP internals to mobilize this material and maintain WESP collection efficiency. Future testing should be conducted to assess the impact of this provision. It is also noted that power must be secured during the deluge operation, which results in essentially zero collection efficiency during that time, which is estimated to be in the range of about ten to thirty minutes once every 24 hours. The present test results indicate that the fraction of technetium escaping the primary off-gas system would increase to about 15% during that downtime. Thus, the results from the present tests would suggest that the time-averaged fraction of technetium exiting the WESP, including this downtime, may range from about 0.1% to about 0.8%.

Another factor in the measured technetium retention in glass is the shortfall in mass balance closure for technetium. In view of the complexity of the test system and the numerous samples and analyses that are required to complete the mass balance, the measured average technetium mass balance closure of about 90% is considered very good. However, the shortfall is significant with respect to the ability to measure retentions in glass nearing 100%. Additional studies are needed to evaluate potential reasons for the shortfall in the technetium mass balance. Nevertheless, these results serve to highlight the difficulties of measuring retentions in glass that approach 100%. From this perspective, measurement of the fraction of the technetium exiting the recycle loop provides a more direct and precise means of estimating the fraction of technetium reporting to liquid secondary waste and ultimately, to non-glass waste forms. As noted above, the results from the present work for this fraction are in the same general range as recent flow sheet estimates [2].

The performance of the various unit operations in the WTP flow sheet in terms of element-specific retention factors is critical input information into flow sheet modeling such as that employed for system planning [2]. The results from the present work provide the first such direct measurements of retention factors for technetium for key unit operations including the SBS, WESP, and vacuum evaporator.

10.2 Recommendations for Future Work

Based on the results from the present work, it is recommended that future testing address:

- Testing and analysis to determine the origin of the remaining shortfall in the technetium mass balance relative to rhenium.

- Testing of the effects of system modifications to further minimize holdup in both the WESP and the film cooler/transition line in order to make more of that material available for recycle. This includes the addition of the daily and prototypic WESP deluge during testing and a transition line sprayer that rinses the film cooler area. In addition, methods to reduce the total volume of material removed for sampling during testing should be considered.

- All of the present testing has employed the baseline WTP LAW glass formulations. Since the tests showed a strong dependence of technetium retention in the glass on feed composition, testing should also be conducted with the higher waste loading LAW formulation developed at VSL for ORP. There are no comparable data presently available for these formulations, even for single-pass retention.

- Recycle testing with flow-sheet modifications that increase single-pass retention. Extensive single-pass testing has shown that using iron (II) oxalate as an additive significantly increases the single-pass technetium retention but the effects of recycle have not been tested.

- Testing with higher concentrations of halides, within the maximum projected concentrations for Hanford LAW, to facilitate improved mass balance closure and determination of retention factors, and the determination of the effect of increased concentrations of recycled halides and sulfur on the tendency to form secondary salt phases on the melt pool surface.

- Testing to support early operation of the LAW facility using the anticipated feed types to determine the expected system performance, secondary waste stream compositions, and fate of technetium. The feeds for early operation of the LAW facility have the potential to be significantly different from those tested for technetium retention to-date, and current testing has shown that technetium retention in the glass depends strongly on feed composition.

- Scale-up recycle testing on the DM100 with ^{99m}Tc and Re and on the DM1200 with Re.

SECTION 11.0
REFERENCES

[1] "Risk Assessment Supporting the Decision on the Initial Selection of Supplemental Treatment Technologies," F.M. Mann, R.J. Puigh, R. Khaleel, S. Finfrock, B.P. McGrail, D.H. Bacon, R.J. Serne, RPP-17675, Rev. 0, CH2MHill Hanford Group Inc., Richland, WA, September, 2003.

[2] System Plan 6 Baseline Case – Final Candidate, HTWOS Run Name: 4MinTimestep(6Melters)-mmr-11-031, R.A. Kirkbride, Washington River Protection *Solutions*, Richland, WA, 3/17/11.

[3] "Improving Technetium Retention in Hanford LAW Glass – Phase 1," K.S. Matlack, I.S. Muller, I. Joseph, and I.L. Pegg, Final Report, VSL-10R1920-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 3/19/10.

[4] "Improving Technetium Retention in Hanford LAW Glass – Phase 2," K.S. Matlack, I.S. Muller, R. Callow, N. D'Angelo, T. Bardakci, I. Joseph, and I.L. Pegg, Final Report, VSL-11R2260-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 7/20/11.

[5] "Technetium Retention in WTP LAW Glass with Recycle Flow-Sheet: DM10 Melter Testing," W.K. Kot, H. Abramowitz, I.S. Muller, M. Brandys, K.S. Matlack, and I.L. Pegg, Test Plan, VSL-11T2460-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 7/19/11.

[6] "Task Plan for WP-5 Task 5.2.4 Recycle of Tc in LAW," WP5-5.2.4-FY2011, Rev. 0, Washington River Protection Solutions, Richland WA, May 2011.

[7] "Technetium Retention in WTP Immobilized Low Activity Waste (ILAW) with Recycle Flowsheet," Statement of Work, Requisition #: 231100, Rev. 0, Washington River Protection Solutions, Richland WA, 3/11/11.

[8] "Technetium Retention in WTP LAW Glass with Recycle Flow-Sheet," M. Brandys, H. Abramowitz, and I.L. Pegg, Project Plan, VSL-11E2460-1, Rev. A, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 5/5/11.

[9] "Technetium Retention in WTP LAW Glass with Recycle Flow-Sheet: DM10 Melter Testing: FY12 DM10 Melter Testing " W.K. Kot, H. Abramowitz, I.S. Muller, M. Brandys, K.S. Matlack, and I.L. Pegg, Test Plan, VSL-11T2640-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 12/7/11.

[10] "Technetium Retention in WTP Immobilized Low Activity Waste (ILAW) with Recycle Flowsheet," Statement of Work, Requisition #: 238425, Rev. 0, Washington River Protection Solutions, Richland WA, 10/10/11.

[11] "Glass Formulation and Testing with TWRS LAW Simulants," I.S. Muller and I.L. Pegg, Final Report, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 1/16/98.

[12] "Glass Formulation and Testing With RPP-WTP LAW Simulants," I.S. Muller, A.C. Buechele, and I.L. Pegg, Final Report, VSL-01R3560-2, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 2/23/01.

[13] "Baseline LAW Glass Formulation Testing," I.S. Muller and I.L. Pegg, Final Report, VSL-03R3460-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 8/8/03.

[14] "Glass Formulations to Support Melter Testing", I.S. Muller and I.L. Pegg, Final Report, VSL-03R3460-2, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 2/6/04.

[15] "Preparation and Testing of LAW Matrix Glasses to Support WTP Property-Composition Model Development," E. Reilly, I.S. Muller and I.L. Pegg, Final Report, VSL-04R4480-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 4/21/04

[16] "ILAW PCT, VHT, Viscosity, and Electrical Conductivity Model Development," G.F. Piepel, S.K. Cooley, I.S. Muller, H. Gan, I. Joseph and I.L. Pegg, Final Report, VSL-07R1230-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 6/28/07

[17] "Melter Tests with LAW Envelope B Simulants to Support Enhanced Sulfate Incorporation," K.S. Matlack, S.P. Morgan, and I.L. Pegg, Final Report, VSL-00R3501-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 11/27/00.

[18] "Melter Tests with LAW Envelope A and C Simulants to Support Enhanced Sulfate Incorporation," K.S. Matlack, S.P. Morgan, and I.L. Pegg, Final Report, VSL-01R3501-2, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 1/26/01.

[19] "Compositional Variation Tests on DuraMelter 100 with LAW Sub-Envelope A1 Feed (LAWA44 Glass) in Support of the LAW Pilot Melter," K.S. Matlack, W. Gong, and I.L. Pegg, Final Report, VSL-02R62N0-4, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 6/18/02.

[20] "Compositional Variation Tests on DuraMelter 100 with LAW Sub-Envelope A2 Feed (LAWA88) Glass in Support of the LAW Pilot Melter," K. S. Matlack, W. Gong and I.L. Pegg, Final Report, VSL-02R62N0-3, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 11/1/02.

[21] "Compositional Variation Tests on DuraMelter 100 with LAW Sub-Envelope A3 Feed in Support of the LAW Pilot Melter," K.S. Matlack, W. Gong, and I.L. Pegg, Final Report, VSL-01R62N0-1, Rev. 1, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 7/15/02.

[22] "Compositional Variation Tests on DuraMelter 100 with LAW Sub-Envelope B1 Feed in Support of the LAW Pilot Melter," K.S. Matlack, W. Gong, and I.L. Pegg, Final Report, VSL-02R62N0-5, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 5/8/03.

[23] "Compositional Variation Tests on DuraMelter 100 with LAW Sub-Envelope B2 Feed in Support of the LAW Pilot Melter," K.S. Matlack and I.L. Pegg, Final Report, VSL-03R3410-2, Rev. 0, The Catholic University of America, Vitreous State Laboratory, Washington, DC, 10/20/03.

[24] "Compositional Variation Tests on DuraMelter 100 with LAW Sub-Envelope C1 Feed (LAWC22 Glass) in Support of the LAW Pilot Melter," K.S. Matlack, W. Gong, and I.L. Pegg, Final Report, VSL-02R62N0-2, Rev. 1, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 9/23/02.

[25] "Compositional Variation Tests on DuraMelter 100 with LAW Sub-Envelope C2 Feed in Support of the LAW Pilot Melter," K.S. Matlack, W. Gong, R.A. Callow and I.L. Pegg, Final Report, VSL-04R4410-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 6/17/04.

[26] "DuraMelter 100 Sub-Envelope Changeover Testing Using LAW Sub-Envelope A1 and C1 Feeds in Support of the LAW Pilot Melter," K.S. Matlack, W. Gong, and I.L. Pegg, Final Report, VSL-02R62N0-6, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 9/9/03.

[27] "DuraMelter 100 Sub-Envelope Changeover Testing Using LAW Sub-Envelope A2 and B1 Feeds in Support of the LAW Pilot Melter," K.S. Matlack, W. Gong, and I.L. Pegg, Final Report, VSL-03R3410-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 8/22/03.

[28] "DuraMelter 100 Sub-Envelope Changeover Testing Using LAW Sub-Envelope A3 and C2 Feeds in Support of the LAW Pilot Melter," K.S. Matlack, W. Gong, and I.L. Pegg, Final Report, VSL-03R3410-3, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 10/17/03.

[29] "RPP-WTP Pilot Melter Envelope B Throughput Test Results Report," TRR-PLT-57, Duratek, Inc., Columbia, MD, 10/13/00.

[30] "RPP-WTP Pilot Melter Envelope A and C Throughput Test Results Report," TRR-PLT-54, Duratek, Inc., Columbia, MD, 10/13/00.

[31] "RPP-WTP Pilot Melter Sub-Envelope A1 Variation Test Results Report," TRR-PLT-071, Rev. 0, Duratek, Inc., Columbia, MD, 4/28/03.

[32] "RPP-WTP Pilot Melter Sub-Envelope C1-A1 Changeover Test Results Report," TRR-PLT-035, Rev. 0, Duratek, Inc., Columbia, MD, 9/29/03.

[33] "RPP-WTP Pilot Melter Sub-Envelope A2 Variation Test Results Report," TRR-PLT-070, Rev. 0, Duratek, Inc., Columbia, MD, 10/4/02.

[34] "RPP-WTP Pilot Melter Sub-Envelope A2-B1 Changeover Test Results Report," TRR-PLT-078, Rev. 0, Duratek, Inc., Columbia, MD, 11/3/03.

[35] "RPP-WTP Pilot Melter Sub-Envelope A3 Variation Test Results Report," TRR-PLT-060, Rev. 2, Duratek, Inc., Columbia, MD, 11/19/02.

[36] "RPP-WTP Pilot Melter Sub-Envelope C2-A3 Changeover Test Results Report," TRR-PLT-079, Rev. 0, Duratek, Inc., Columbia, MD, 11/11/03.

[37] "RPP-WTP Pilot Melter Sub-Envelope B1 Variation Test Results Report," TRR-PLT-074, Rev. 0, Duratek, Inc., Columbia, MD, 8/26/03.

[38] "RPP-WTP Pilot Melter Sub-Envelope B2 Variation Test Results Report," TRR-PLT-073, Rev. 0, Duratek, Inc., Columbia, MD, 10/27/03.

[39] "RPP-WTP Pilot Melter Sub-Envelope C1 Variation Test Results Report," TRR-PLT-069, Rev. 2, Duratek, Inc., Columbia, MD, 2/6/03.

[40] "RPP-WTP Pilot Melter Sub-Envelope C2 Variation Test Results Report," TRR-PLT-072, Rev. 1, Duratek, Inc., Columbia, MD, 3/12/03.

[41] LAW Pilot Melter Decommissioning and Testing, Letter Subcontract #DE-AC27-03RV14539.

[42] "Glass Formulation Testing to Increase Sulfate Incorporation," K. S. Matlack, M. Chaudhuri, H. Gan, I. S. Muller, W. Gong, and I. L. Pegg, Final Report, VSL-04R4960-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 2/28/05.

[43] "Small Scale Melter Testing with LAW Simulants to Assess the Impact of Higher Temperature Melter Operations," K.S. Matlack, W. Gong, and I.L. Pegg, Final Report, VSL-04R4980-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 2/13/04.

[44] "Glass Formulation Testing to Increase Sulfate Volatilization from Melter," K.S. Matlack, W. Gong, and I.L. Pegg, Final Report, VSL-04R4970-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 2/24/05.

[45] "Enhanced LAW Glass Formulation Testing," K.S. Matlack, I. Joseph, W. Gong, I.S. Muller, and I.L. Pegg, Final Report, VSL-07R1130-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 10/5/07.

[46] "Glass Formulation Development and DM10 Melter Testing with ORP LAW Glasses," K.S. Matlack, I. Joseph, W. Gong, I.S. Muller, and I.L. Pegg, Final Report, VSL-09R1510-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 6/12/09.

[47] "Feed Adjustment Chemistry for Hanford 101-SY and 103-SY Tank Waste: Attempts to Oxidize the Non-Pertechnetate Species", N.C. Schroeder, S.D. Radzinski, K.R. Ashley, A.P. Truong and G.D. Whitener, Journal of Radioanalytical and Nuclear Chemistry, Vol. 250, No. 2 (2001) 271–284.

[48] "Advanced Inorganic Chemistry," F.A. Cotton and G. Wilkinson, 3rd Ed., Wiley Interscience (1972).

[49] "Chemistry of Technetium and Rhenium Species during Low-Level Radioactive Waste Vitrification," J.G. Darab and P.A Smith, Chemistry of Materials, 8(5), pp. 1004-1021, (1996).

[50] "Thermochemical Comparison of the Systems Re-O and Tc-O," H. Migge, Mat. Res. Soc. Symp. Proc., 127, 205 (1989).

[51] E. Freud, W. Lutze, C. Russel, and H.A. Schaeffer, Scientific Basis for Nuclear Waste Management XIV, Materials Research Society, p. 199 (1990).

[52] "Tc and Re Behavior in Waste Glass Vapor Hydration Tests," D.A. McKeown, A.C. Buechele, W.W. Lukens, D.K. Shuh, and I.L. Pegg, Environ. Sci. Technol., 41, 431 (2007).

[53] "Dissimilar Behavior of Technetium and Rhenium in Borosilicate Waste Glass as Determined by X-Ray Absorption Spectroscopy," W.W. Lukens, D.A. McKeown, A.C. Buechele, I.S. Muller, D.K. Shuh, and I.L. Pegg, Chem. Mater., 19, 559 (2007).

[54] "Raman Studies of Technetium in Borosilicate Waste Glass," D.A. McKeown, A.C. Buechele, W.W. Lukens, I.S. Muller, D.K. Shuh, and I.L. Pegg, Radiochimica Acta, 95, 275 (2007).

[55] "The Chemical Behavior of Technetium During the Treatment of High-Level Radioactive Waste," J. Vida, Dissertation, TH Karlsruhe, 1989.

[56] "Tc Reduction Chemistry and Crucible Melting Studies with Simulated Hanford Low-Activity Waste," D.S. Kim et al., PNNL-15131, Pacific Northwest National Laboratory, Richland, WA (2005).

[57] "Large-Scale Vitrification of 241-AN-107 (Envelope C) Sample," J.R. Zemecnik, C.L. Crawford, D.C. Koopman, WSRC-TR-2002-00093, Rev. 0, Westinghouse Savannah River Company (2002).

[58] "Results of Melter Tests Using TWRS LAW Envelope B Simulants," K.S. Matlack, I.S. Muller, S.S. Fu, and I.L. Pegg, Final Report, Rev 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 10/24/97.

[59] "Progress of the Hanford Bulk Vitrification Project ICV Testing Program," K.S. Witwer, D.W. Woolery, E.J. Dysland, Waste Management '06 Conference Proceedings, Tucson, AZ (2006).

[60] "Tc-99 and Cs-137 Volatility from the DWPF Production Melter During Vitrification of the First Macrobatch of HLW Sludge at the Savannah River Site," N.E. Bibler, T.L. Fellinger, S.L. Marra, R.J. O'Driscoll, J.W. Ray, W.T. Boyce, Mat. Res. Soc. Symp., Proc., vol 608, p. 697 (2000).

[61] "Simultaneous Evaporation of Cs and Tc During Vitrification – A Thermochemical Approach," H. Migge, Mat. Res. Soc. Symp. Proc., 176, 411 (1990).

[62] "Volatilization of Ruthenium, Cesium and Technetium from Nitrate Systems in Nuclear Fuel Processing and Waste Solidification" P.W. Cains, K.C. Yewer and S. Waring, Radiochim. Acta 56, 99-104 (1992).

[63] H. Lammertz, E. Mertz, and S. Halaszovich, Scientific Basis for Nuclear Waste Management VIII, MRS Pittsburgh, PA, p. 823, 1985.

[64] J.K. Gibson, Radiochim. Acta, 62, 127, 1993.

[65] "Investigation of the Volatilization Behavior of Fission Products from High-Level Waste at Temperatures up to 1100°C," F. Baumgärtner, J. Heitz, K. Krebs, and B. Merte, Nukleare Entsorgung 3, 291-321, 1986.

[66] "On the Emission of Fission Products and Transuranium Nuclides from Highly Radioactive Waste between 200 and 1100°C," F. Baumgärtner, K. Krebs, and B. Merte, Kerntechnik, 51(3), 151-6, 1987

[67] "DM100 HLW and LAW Tests of the Influence of Technetium on Cesium Volatility Using Rhenium as a Technetium Surrogate," K.S. Matlack, W.K. Kot, and I.L. Pegg, Final Report, VSL-04R4710-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 9/28/04.

[68] "Quality Assurance Project Plan for WRPS Support Activities Conducted by VSL," VSL-QAPP-WRPS, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 3/26/10.

[69] "Master List of Controlled VSL Manuals and Standard Operating Procedures in Use," QA-MLCP, Rev. 61, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 3/31/11.

[70] "Results of Melter Tests Using TWRS HLW Envelope D Simulants," S.S. Fu, K.S. Matlack, and I.L. Pegg, Final Report, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 1/9/98.

[71] "Iron Mossbauer Redox and Relation to Technetium Retention during Vitrification," I.S. Muller, C. Viragh, H. Gan, K.S. Matlack, and I.L. Pegg, Hyperfine Interactions, 17, 191, (2009).

[72] "DuraMelter 100 Tests to Support LAW Glass Formulation Correlation Development," K. S. Matlack, W. Gong, I.S. Muller, and I. L. Pegg, Final Report, VSL-06R6480-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 3/21/06.

[73] "DM-100 Melter Testing to Support LAW Glass Formulation Correlation Development," K. Abel and J. Westsik, WTP Test Specification, 24590-WTP-TSP-RT-04-0004, Rev. 0, 01/12/05.

[74] "Small Scale Melter Testing of LAW Salt Phase Separation," K.S. Matlack, I.S. Muller, W. Gong, and I.L. Pegg, Final Report, VSL-07R7480-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 08/20/07.

[75] "DM10 Off-Gas System Upgrade Description," M. Brandys, H. Abramowitz, R.A. Callow, I.L. Pegg, Summary Report, VSL-11S2640-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 5/16/2012.

[76] "LAW Pilot Melter and DM-100 Sub-Envelope Changeover Testing," E.V. Morrey, WTP Test Specification, 24590-LAW-TSP-RT-02-012, Rev. 0.

[77] "Halide Recycle," e-mail message from E. Morrey to I. Joseph, 08/07/02.

[78] "Selection of HLW and LAW Glass Formers," E. Hansen and R. Schumacher, SRT-RPP-2002-00034, Rev. 0, Westinghouse Savannah River Co., Aiken, SC, 02/06/02.

[79] "Proposed Approach for Development of LAW Glass Formulation Correlation," I.S. Muller, G. Diener, I. Joseph, and I.L. Pegg, Final Report, VSL-04L4460-1, Rev. 2, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 10/29/04.

[80] "Waste Loading Enhancements for Hanford LAW Glasses," I.S. Muller, K.S. Matlack, H. Gan, I. Joseph, and I.L. Pegg, Final Report, VSL-10R1790-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 12/01/10.

[81] "Review of Properties of Simulated Feeds Used for Melter Testing," K.S. Matlack, W. Gong, and I.L. Pegg, Final Report, VSL-06R6410-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, Washington, D.C., 8/16/06.

[82] "Integrated Off-Gas System Tests on the DM1200 Melter with RPP-WTP LAW Sub-Envelope C1 Simulants," K.S. Matlack, W. Gong, T. Bardakci, N. D'Angelo, and I.L. Pegg, Final Report, VSL-02R8800-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 7/25/02.

[83] "Integrated Off-Gas System Tests on the DM1200 Melter with RPP-WTP LAW Sub-Envelope A1 Simulants," K.S. Matlack, W. Gong, T. Bardakci, D'Angelo, and I.L. Pegg, Final Report, VSL-02R8800-2, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 9/03/02.

[84] "Integrated Off-Gas System Tests on the DM1200 Melter with RPP-WTP LAW Sub-Envelope B1 Simulants," K.S. Matlack, W. Gong, T. Bardakci, N. D'Angelo, and I.L. Pegg, Final Report, VSL-03R3851-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 5/02/03.

[85] "Regulatory Off-Gas Emissions Testing on the DM1200 Melter System Using HLW and LAW Simulants," K.S. Matlack, W. Gong, T. Bardakci, N. D'Angelo, M. Brandys, W. Kot, and I.L. Pegg, Final Report VSL-05R5830-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 10/31/05.

[86] "LAW Envelope C Glass Formulation Testing to Increase Waste Loading," K.S. Matlack, W. Gong, I.S. Muller, I. Joseph, and I.L. Pegg, Final Report, VSL-05R5900-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 1/27/06.

[87] "LAW Envelope A and B Glass Formulation Testing to Increase Waste Loading," K.S. Matlack, H. Gan, I.S. Muller, I. Joseph, and I.L. Pegg, Final Report, VSL-06R6900-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 3/23/06.

[88] "Integrated DM1200 Melter Tests of Redox Effects Using HLW AZ-101 and C-106/AY-102 Simulants," K.S. Matlack, W. Gong, T. Bardakci, N. D'Angelo, W. Lutze, P. M. Bizot, R. A. Callow, M. Brandys, W. K. Kot and I.L. Pegg, Final Report, VSL-04R4800-1, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 5/6/04.

[89] "Summary of DM1200 Operation at VSL," K.S. Matlack, G. Diener, T. Bardakci, and I.L. Pegg, Final Report, VSL-06R6710-2, Rev. 0, Vitreous State Laboratory, The Catholic University of America, Washington, DC, 9/7/06.

Table 2.1. LAWE3 Simulant Recipe at 8 Molar Sodium Based on AP-101 Waste Composition [76].

Envelope Constituents	AP-101 Waste from 5.77 M to 8 M Na + recycles	Simulant AP-101 Modified for E3		Recycled addition	Glass Oxides	LAWE3 Simulant as Oxides (wt%)	Waste Contribution to Glass (wt%)	Source in Simulant	Order for Addition	Formula Weight	Assay*	Target[&] Weight (g)
-	mg/L	mg/L	Molarity	Molarity	Loading	100%	25.41%	In 494.3 ml estimated water add following compounds in the order listed below				
Al	9625	9625	0.357	-	Al_2O_3	5.33	1.34	$Al(NO_3)_3.9H_2O$, 60% sol.	1	375.14	0.61	220.51
B	12	12	0.001	-	B_2O_3	0.01	0.00	H_3BO_3	2	61.83	0.99	0.07
Cr	749	749	0.014	-	Cr_2O_3	0.32	0.08	$Na_2CrO_4*4H_2O$	8	234.04	0.99	3.42
K	56301	56301	1.440	-	K_2O	19.86	4.98	KOH	7	56.10	0.91	88.97
Na	183920	182357[&]	7.932[&]	0.068[$]	Na_2O	71.99	18.06+0.15[$]	NaOH, 50% sol. d=1.53	6	40.00	0.50	225.96[&]
Ni	82	82	0.001	-	NiO	0.03	0.01	NiO	3	74.69	1.00	0.10
Pb	95	95	0.0005	-	PbO	0.03	0.01	PbO	4	223.20	1.00	0.10
Si	157	157	0.006	-	SiO_2	0.10	0.02	SiO_2	5	60.09	0.99	0.34
Cl	2730	1294[&]	0.036[&]	0.041[$]	Cl	0.38	0.09+0.11[$]	NaCl	10	58.45	0.99	2.15[&]
F	1083	910[&]	0.048[&]	0.009[$]	F	0.27	0.07+0.01[$]	NaF	11	42.00	0.99	2.03[&]
PO_4	2251	2251	0.024	-	P_2O_5	0.49	0.12	$Na_3PO_4.12H_2O$	9	380.12	0.99	9.10
SO_4	5764	4899[&]	0.051[&]	0.009[$]	SO_3	1.20	0.30+0.05[$]	Na_2SO_4	12	142.06	0.99	7.32[&]
NO_2	58110	58110	1.263	-	-	-	-	$NaNO_2$	16	69.00	1.00	87.60
NO_3	183067	183067	2.953	-	-	-	-	$NaNO_3$	17	84.99	0.99	161.61
CO_3	44775	44775	0.746	-	-	-	-	Na_2CO_3	18	105.99	1.00	79.08
Org. Carbon	2718	2718	0.227	-	-	-	-	-	-	-	-	-
Acetate	3025	3025	0.051	-	-	-	-	Sodium Acetate (C2)	13	136.08	0.99	7.04
Formate	2213	2213	0.049	-	-	-	-	Sodium Formate (C1)	14	68.01	0.99	3.38
Oxalate	3321	3321	0.038	-	-	-	-	Sodium Oxalate (C2)	15	134.00	0.99	5.11
-	-	-	-	-	-	-	-	Target Glass Weight (with recycled off-gas solution to 8M Na)				1361.45
-	-	-	-	-	SUM	100.00	25.08+ 0.33[$]	Total simulant Weight				1398.22

- Empty data field.

* Assay refers to the purity of the raw material as specified by the vendor.

[&] Does not include the contribution from recycled off-gas streams.

[$] Addition due to off-gas recycle estimated to be 111% Cl^-, 19% F^- and 17.65% SO_4^{2-} as sodium salts.

Table 2.2. LAWE4H Waste Simulant Recipe at 8 Molar Sodium Based on AN-105 Waste Composition [76].

Envelope Constituents	AN-105 Waste from 10.4M to 8 M Na + recycles	Simulant AN-105 Modified for E4H		Recycled Additions	Glass Oxides	LAWE4H Simulant as Oxides (wt%)	Waste Contribution to Glass (wt%)	Source in Simulant	Order for Addition	Formula Weight	Assay*	Target Weight (g)
-	mg/L	mg/L	M	M	Loading	-	27.73%	In 270.42 ml water add following compounds in the order listed below				
Al	30554	30554	1.132	-	Al_2O_3	18.09	4.96	$Al(NO_3)_3.9H_2O$, 60% sol.	1	375.14	0.61	422.01
								$Al(OH)_3$	8	78.00	1.00	35.22
B	79	79	0.007	-	B_2O_3	0.08	0.02	H_3BO_3	2	61.83	0.99	0.45
Cr	624	624	0.012	-	Cr_2O_3	0.29	0.08	$Na_2CrO_4*4H_2O$	9	234.04	0.99	2.85
K	5223	5223	0.134	-	K_2O	1.97	0.54	KOH	7	56.10	0.91	8.25
Na	183920	182541[&]	7.94[&]	0.060[$]	Na_2O	77.10	21.11+0.16[$]	NaOH, 50% sol. d=1.53	6	40.00	0.50	458.03[&]
Ni	70	70	0.001	-	NiO	0.03	0.01	NiO	3	74.69	1.00	0.09
Pb	83	83	0.0004	-	PbO	0.03	0.01	PbO	4	223.20	1.00	0.09
Si	157	157	0.006	-	SiO_2	0.11	0.03	SiO2	5	60.09	0.99	0.34
Cl	2304	1092[&]	0.031[&]	0.034[$]	Cl	0.34	0.09+0.11[$]	NaCl	11	58.45	0.99	1.82[&]
F	912	766[&]	0.040[&]	0.008[$]	F	0.24	0.07+0.01[$]	NaF	12	42.00	0.99	1.71[&]
PO_4	1899	1899	0.020	-	P_2O_5	0.44	0.12	$Na_3PO_4.12H_2O$	10	380.12	0.99	7.68
SO_4	5764	4899[&]	0.051[&]	0.009[$]	SO_3	1.28	0.35+0.06[$]	Na_2SO_4	13	142.06	0.99	7.32[&]
NO_2	85428	85428	1.857	-	-	-	-	$NaNO_2$	17	69.00	0.995	128.79
NO_3	126988	126988	2.048	-	-	-	-	$NaNO_3$	-	84.99	0.99	0.00
TOC	2093	2093	0.174	-	-	-	-	Na_2CO_3	-	105.99	1.00	0.00
Acetate	2250	2250	0.038	-	-	-	-	Sodium Acetate (C2)	14	136.08	0.99	5.24
Formate	2135	2135	0.047	-	-	-	-	Sodium Formate (C1)	15	68.01	0.99	3.26
Glycolate	1936	1936	0.025	-	-	-	-	Glycolic Acid (C2)	16	76.05	0.71	2.73
-	-	-	-	-	-	-	-	Target Glass (with recycled off-gas solution to 8M Na)				1165.59
-	-	-	-	-	SUM	100.00	27.39+0.34[$]	Total simulant wt.				1356.30

- Empty data field.

* Assay refers to the purity of the raw material as specified by the vendor.

[&] Does not include the contribution from recycled off-gas streams.

[$] Addition due to off-gas recycle estimated to be 111% Cl^-, 19% F^- and 17.65% SO_4^{2-} as sodium salts.

Table 2.3. LAWE5H Simulant Recipe at Nominal 7 Molar Sodium Based on AN-107 Waste Composition [76].

Envelope Constituents	AN-107 Waste from 13.3M to 7 M Na + recycles	Simulant AN-107 Modified for E5H		Recycled Additions	Glass Oxides	LAWE5H Simulant As Oxides (wt%)	Waste Contribution To Glass (wt%)	Source in Simulant	Order for Addition	Formula Weight	Assay*	Target Weight (g)
-	mg/L	mg/L	M	M	Loading	-	20.64%	In 664 ml water add following compounds in the order listed below				
Al	140	140	0.005	-	Al_2O_3	0.11	0.02	$Al(NO_3)_3.9H_2O$ - 60% sol.	1	375.14	0.61	3.21
Ca	309	309	0.008	-	CaO	0.19	0.04	$Ca(NO_3)_2.4H_2O$	2	236.16	0.99	1.84
Cr	613	613	0.012	-	Cr_2O_3	0.39	0.08	$Na_2CrO_4.4H_2O$	7	234.04	0.99	2.80
Fe	936	936	0.017	-	Fe_2O_3	0.58	0.12	$Fe(NO_3)_3.9H_2O$	4	404.01	1.00	6.78
K	5122	5122	0.131	-	K_2O	2.66	0.54	KOH	6	56.10	0.91	8.09
Na	160930	159551[&]	6.94[&]	0.060[$]	Na_2O	92.70	18.81+0.16[$]	NaOH - 50% sol. d=1.53	5	40.00	0.50	297.28[&]
Ni	68	68	0.001	-	NiO	0.04	0.01	NiO	8	74.69	1.00	0.09
Pb	82	82	0.0004	-	PbO	0.04	0.01	PbO	9	223.20	1.00	0.09
Cl	2246	1064[&]	0.030[&]	0.033[$]	Cl	0.46	0.09+0.11[$]	NaCl	11	58.45	0.99	1.77[&]
F	887	745[&]	0.039[&]	0.007[$]	F	0.32	0.07+0.01[$]	NaF	12	42.00	0.99	1.66[&]
PO_4	1861	1861	0.020	-	P_2O_5	0.60	0.12	$Na_3PO_4.12H_2O$	10	380.12	0.99	7.53
SO_4	6310	5363[&]	0.056[&]	0.010[$]	SO_3	1.93	0.39+0.07[$]	Na_2SO_4	13	142.06	0.99	8.01[&]
NO_2	36013	36013	0.783	-	-	-	-	$NaNO_2$	23	69.00	1.00	54.29
NO_3	116010	116010	1.871	-	-	-	-	$NaNO_3$	24	84.99	0.99	153.65
Org.Carbon	21597	21597	1.800	-	-	-	-	-	-	-	-	-
EDTA	5123	5123	0.018	-	-	-	-	$Na_2EDTA.2H_2O$ (C10)	14	372.24	0.99	6.64
HEDTA	5123	5123	0.019	-	-	-	-	Na_3HEDTA (C10) - 41%sol.	15	344.20	0.42	15.44
Acetate	5123	5123	0.087	-	-	-	-	Sodium Acetate (C2)	16	136.08	0.99	11.92
Formate	5123	5123	0.114	-	-	-	-	Sodium Formate (C1)	17	68.01	0.99	7.82
Oxalate	2846	2846	0.032	-	-	-	-	Sodium Oxalate (C2)	18	134.00	0.99	4.38
Gluconate	4269	4269	0.022	-	-	-	-	Sodium Gluconate (C6)	3	218.14	0.99	4.82
Glycolic	11385	11385	0.150	-	-	-	-	Glycolic Acid (C2)	19	76.05	0.71	16.06
NTA	4554	4554	0.024	-	-	-	-	Nitrilotriacetic Acid (C6)	20	191.14	0.98	4.65
Citric	12524	12524	0.065	-	-	-	-	Citric Acid (C6)	21	192.12	0.99	12.65
Iminodiacetic	4013	4013	0.030	-	-	-	-	Iminodiacetic Acid (C4)	22	133.10	0.98	4.10
-	-	-	-	-	-	-	-	Target Glass (with recycled off-gas solution to 7M Na)				1143.54
-	-	-	-	-	SUM	100.00	20.29+0.35[$]	Total simulant weight				1299.46

- Empty data field.

* Assay refers to the purity of the raw material as specified by the vendor.

[&] Does not include the contribution from recycled off-gas streams.

[$] Addition due to off-gas recycle estimated to be 111% Cl^-, 19% F^- and 17.65% SO_4^{2-} as sodium salts.

Table 2.4. LAWE6H Simulant Recipe at Nominal 7 Molar Sodium Based on AN-104 Waste Composition [76].

Envelope Constituents	AN-104 Waste from 11.6M to 7 M Na + recycles	Simulant AN-104 Modified for E6H		Recycled Additions	Glass Oxides	LAWE6H Simulant As Oxides (wt%)	Waste Contribution To Glass (wt%)	Source in Simulant	Order for Addition	Formula Weight	Assay*	Target Weight (g)
-	mg/L	mg/L	Molarity	M	Loading	-	20.88%	In 380.21 ml water add following compounds in the order listed below				
Al	25069	25069	0.929	-	Al_2O_3	16.55	3.46	$Al(NO_3)_3.9H_2O$, 60% sol.	1	375.14	0.61	412.76
-	-	-	-	-	-	-	-	$Al(OH)_3$	4	78.00	1.00	20.47
Cr	734	734	0.014	-	Cr_2O_3	0.37	0.08	$Na_2CrO_4.4H_2O$	5	234.04	0.99	3.35
K	6140	6140	0.157	-	K_2O	2.58	0.54	KOH	3	56.10	0.91	9.70
Na	160930	159183[&]	6.924[&]	0.076[$]	Na_2O	75.81	15.66+0.17[$]	NaOH, 50% sol. d=1.53	2	40.00	0.50	294.59
Ni	84	84	0.001	-	NiO	0.04	0.01	NiO	6	74.69	1.00	0.11
Pb	99	99	0.001	-	PbO	0.04	0.01	PbO	7	223.20	1.00	0.11
Si	228	228	0.008	-	SiO_2	0.17	0.04	SiO_2	8	60.09	0.99	0.49
Cl	2688	1274[&]	0.036[&]	0.040[$]	Cl	0.94	0.09+0.11[$]	NaCl	10	58.45	0.99	2.12
F	1064	894[&]	0.047[&]	0.009[$]	F	0.37	0.07+0.01[$]	NaF	11	42.00	0.99	2.00
PO_4	2238	2238	0.024	-	P_2O_5	0.58	0.12	$Na_3PO_4.12H_2O$	9	380.12	0.99	9.05
SO_4	8708	7401[&]	0.077[&]	0.014[$]	SO_3	2.54	0.45+0.08[$]	Na_2SO_4	12	142.06	0.99	11.06
NO_2	78634	78634	1.709	-	NO_2	-	-	$NaNO_2$	15	69.00	1.00	118.54
NO_3	124203	124203	2.003	-	NO_3	-	-	$NaNO_3$		84.99	0.99	0.00
CO_3	31659	31659	0.528	-	CO_3	-	-	Na_2CO_3	16	105.99	1.00	55.92
Org.Carbon	2044	2044	0.170	-	-	-	-	-	-	-	-	-
Acetate	2284	2284	0.039	-	-	-	-	Sodium Acetate (C2)	13	136.08	0.99	5.31
Formate	4176	4176	0.093	-	-	-	-	Sodium Formate (C1)	14	68.01	0.99	6.37
-	-	-	-	-	-	-	-	Target Glass Weight(with recycled off-gas solution to 7M Na)				1370.37
-	-	-	-	-	SUM	100.00	20.51+0.37[$]	Total Simulant Weight				1332.16

- Empty data field.

* Assay refers to the purity of the raw material as specified by the vendor.

[&] Does not include the contribution from recycled off-gas streams.

[$] Addition due to off-gas recycle estimated to be 111% Cl^-, 19% F^- and 17.65% SO_4^{2-} as sodium salts.

Table 2.5. LAWE7H Simulant Recipe at 5 Molar Sodium Based on AN-102 Waste Composition [76].

Envelope Constituents	AN-102 Waste from 9.9M to 5 M Na + recycles	Simulant AN-102 Modified for E7H		Recycled Additions	Glass Oxides	LAWE7H Simulant As Oxides (wt%)	Waste Contribution To Glass (wt%)	Source in Simulant	Order for Addition	Formula Weight	Assay*	Target Weight (g)
-	mg/L	mg/L	Molarity	M	Loading	-	16.22%	In 689.14 ml water add following compounds in the order listed below				
Al	6201	6201	0.230	-	Al_2O_3	6.46	1.02	$Al(NO_3)_3.9H_2O$, 60% sol.	1	375.14	0.61	142.07
B	18	18	0.002	-	B_2O_3	0.03	0.01	H3BO3	3	61.83	0.99	0.11
Ca	248	248	0.006	-	CaO	0.19	0.03	$Ca(NO_3)_2$*$4H_2O$	2	236.16	0.99	1.47
Cr	608	608	0.012	-	Cr_2O_3	0.49	0.08	Na_2CrO_4*$4H_2O$	6	234.04	0.99	2.78
K	5137	5137	0.131	-	K_2O	3.41	0.54	KOH	5	56.10	0.91	8.12
Na	114950	114950[&]	4.934[&]	0.066[$]	Na_2O	84.30	13.35+0.18[$]	NaOH, 50% sol. D=1.53	4	40.00	0.50	102.76
Ni	70	70	0.001	-	NiO	0.05	0.01	NiO	7	74.69	1.00	0.09
Pb	83	83	0.0004	-	PbO	0.05	0.01	PbO	8	223.20	1.00	0.09
Si	46	46	0.002	-	SiO_2	0.05	0.01	SiO_2	9	60.09	0.99	0.10
Cl	2248	1065[&]	0.030[&]	0.033[$]	Cl	0.59	0.09+0.11[$]	NaCl	11	58.45	0.99	1.77[&]
F	893	750[&]	0.039[&]	0.008[$]	F	0.41	0.07+0.01[$]	NaF	12	42.00	0.99	1.68[&]
PO_4	1871	1871	0.020	-	P_2O_5	0.75	0.12	Na_3PO_4.12H2O	10	380.12	0.99	7.56
SO_4	8165	6940[&]	0.085[&]	0.013[$]	SO_3	3.19	0.50+0.09[$]	Na_2SO_4	13	142.06	0.99	10.37[&]
NO_2	43205	43205	0.939	-	NO_2	-	-	$NaNO_2$	18	69.00	1.00	65.13
NO_3	111873	111873	1.804	-	NO_3	-	-	$NaNO_3$	19	84.99	0.99	94.65
CO_3	27723	27723	0.462	-	CO_3	-	-	Na_2CO_3	20	105.99	1.00	48.96
Org.Carbon	14731	14731	1.228	-	-	-	-	-	-	-	-	-
Formate	16320	16320	0.363	-	-	-	-	Sodium Formate (C1)	14	68.01	0.99	24.91
Oxalate	938	938	0.011	-	-	-	-	Sodium Oxalate (C2)	15	134.00	0.99	1.44
Glycolate	21420	21420	0.282	-	-	-	-	Glycolic Acid (C2)	16	76.05	0.71	30.22
Citric Acid	8976	8976	0.047	-	-	-	-	Citric Acid (C6)	17	192.12	0.99	9.07
-	-	-	-	-	-	-	-	Target Glass Weight (with recycled off-gas solution to 5M Na)				1145.23
-	-	-	-	-	SUM	100.00	15.84+0.38[$]	Total Simulant Weight				1242.49

- Empty data field.

* Assay refers to the purity of the raw material as specified by the vendor.

[&] Does not include the contribution from recycled off-gas streams.

[$] Addition due to off-gas recycle estimated to be 111% Cl^-, 19% F^- and 17.65% SO_4^{2-} as sodium salts.

Table 2.6. LAWE9H Simulant Recipe at 4 Molar Sodium Based on AZ-101 Waste Composition [76].

Envelope Constituents	AZ-101 Waste from 5.1M to 4 M Na + recycles	Simulant AZ-101 Modified for E9H		Recycled Additions	Glass Oxides	LAW E9H Simulant as Oxides (wt%)	Waste Contribution to Glass (wt%)	Source in Simulant	Order for Addition	Formula Weight	Assay*	Target Weight (g)
-	mg/L	mg/L	M	M	Loading	-	11.34 %	In 805.15 ml water add following compounds in the order listed below				
Al	4761	4761	0.176	-	Al_2O_3	6.03	0.65	$Al(NO_3)_3.9H_2O$, 60% sol.	1	375.14	0.61	109.07
Ca	360	360	0.009	-	CaO	0.34	0.04	$Ca(NO_3)_2*4H_2O$	2	236.16	0.99	2.14
Cr	741	741	0.014	-	Cr_2O_3	0.73	0.08	$Na_2CrO_4.4H_2O$	5	234.04	0.99	3.39
K	6227	6227	0.159	-	K_2O	5.03	0.54	KOH	4	56.10	0.91	9.84
Na	91960	89178[&]	3.879[&]	0.121[$]	Na_2O	80.57	8.66+0.27[$]	NaOH, 50% sol. d=1.53	3	40.00	0.50	82.66[&]
Ni	85	85	0.002	-	NiO	0.07	0.01	NiO	6	74.69	1.00	0.11
Pb	101	101	0.001	-	PbO	0.07	0.01	PbO	7	223.20	1.00	0.11
Si	53	53	0.002	-	SiO_2	0.08	0.01	SiO_2	8	60.09	0.99	0.12
Cl	2723	1290[&]	0.0365[&]	0.0405[$]	Cl	0.86	0.09+0.11[$]	NaCl	10	58.45	0.99	2.15[&]
F	1078	906[&]	0.048[&]	0.009[$]	F	0.61	0.07+0.01[$]	NaF	11	42.00	0.99	2.02[&]
PO_4	2245	2245	0.024	-	P_2O_5	1.12	0.12	$Na_3PO_4.12H_2O$	9	380.12	0.99	9.08
SO_4	11485	8040[&]	0.084[&]	0.036[$]	SO_3	4.49	0.48+0.21[$]	Na_2SO_4	12	142.06	0.99	12.01[&]
NO_2	48214	48214	1.048	-	NO_2	-	-	$NaNO_2$	15	69.00	1.00	72.68
NO_3	41345	41345	0.667	-	NO_3	-	-	$NaNO_3$	16	84.99	0.99	10.26
CO_3	38740	38740	0.646	-	CO_3	-	-	Na_2CO_3	17	105.99	1.00	68.42
Org.Carbon	401	401	0.033	-	-	-	-	-	-	-	-	-
Formate	393	393	0.009	-	-	-	-	Sodium Formate (C1)	13	68.01	0.99	0.60
Oxalate	1085	1085	0.012	-	-	-	-	Sodium Oxalate (C2)	14	134.00	0.99	1.67
-	-	-	-	-	-	-	-	Target Glass Weight (with recycled off-gas solution to 4M Na)				1388.13
-	-	-	-	-	SUM	100.00	10.74+0.60[$]	Total Simulant Weight				1191.48

- Empty data field.

* Assay refers to the purity of the raw material as specified by the vendor.

[&] Does not include the contribution from recycled off-gas streams.

[$] Addition due to off-gas recycle estimated to be 111% Cl^-, 19% F^- and 42.86% SO_4^{2-} as sodium salts.

Table 2.7. LAWE10H Simulant Recipe at 2 Molar Sodium Based on AZ-102 Waste Composition [76].

Envelope Constituents	AZ-101 Waste from 3.5M to 2 M Na + recycles	Simulant AZ-102 Modified for E10H		Recycled Additions	Glass Oxides	LAWE10H Simulant as Oxides (wt%)	Waste Contribution to Glass (wt%)	Source in Simulant	Order for Addition	Formula Weight	Assay	Target Weight (g)
-	mg/L	mg/L	Molarity	M	Loading	-	6.20%	In 957.12 ml water add following compounds in the order listed.				
Al	123	123	0.005	-	Al_2O_3	0.26	0.02	$Al(NO_3)_3.9H_2O$, 60% sol.	2	375.14	0.61	2.82
Cr	760	760	0.015	-	Cr_2O_3	1.25	0.08	$Na_2CrO_4.4H_2O$	5	234.04	0.99	3.47
K	6412	6412	0.164	-	K_2O	8.70	0.54	KOH	4	56.098	0.91	10.13
Na	45980	42830[&]	1.863[&]	0.137	Na_2O	69.84	4.03+0.30[$]	NaOH, 50% sol. d=1.53	3	40.00	0.50	6.12 [&]
Ni	88	88	0.002	-	NiO	0.13	0.01	NiO	6	74.69	1.00	0.11
Pb	103	103	0.001	-	PbO	0.13	0.01	PbO	7	223.20	1.00	0.11
Si	171	171	0.006	-	SiO_2	0.41	0.03	SiO_2	8	60.09	0.99	0.37
Cl	2809	1331[&]	0.038[&]	0.042[$]	Cl	3.17	0.09+0.11[$]	NaCl	10	58.45	0.99	2.22[&]
F	1111	933[&]	0.049[&]	0.009[$]	F	1.25	0.07+0.01[$]	NaF	11	42.00	0.99	2.08[&]
PO_4	2323	2323	0.024	-	P_2O_5	1.96	0.12	$Na_3PO_4.12H_2O$	9	380.12	0.99	9.39
SO_4	13744	9621[&]	0.100[&]	0.043[$]	SO_3	12.91	0.56+0.24[$]	Na_2SO_4	12	142.06	0.99	14.37[&]
NO_2	23680	23680	0.515	-	NO_2	-	-	$NaNO_2$	14	69.00	1.00	35.70
NO_3	7837	7837	0.126	-	NO_3	-	-	$NaNO_3$	15	84.99	0.99	9.67
CO_3	23080	23080	0.385	-	CO_3	-	-	Na_2CO_3	1	105.99	1.00	40.76
Org.Carbon	608	608	0.051	-	-	-	-	-	-	-	-	-
Oxalate	2242	2242	0.025	-	-	-	-	Oxalic Acid (C2)	13	126.00	1.00	3.21
-	-	-	-	-	-	-	-	Target Glass (with recycled off-gas solution to 2M Na)				1431.41
-	-	-	-	-	SUM	100.00	5.55+0.65	Total simulant wt.				1097.66

- Empty data field.

* Assay refers to the purity of the raw material as specified by the vendor.

[&] Does not include the contribution from recycled off-gas streams.

[$] Addition due to off-gas recycle estimated to be 111% Cl^-, 19% F^- and 42.86% SO_4^{2-} as sodium salts.

Table 2.8. Oxide Composition of LAWE3 Simulant and Corresponding Glass Composition*.

	AP-101 in LAWE3 Glass at 18.21 wt% Na_2O	Glass Former Additives (wt%)	LAWE3 (wt%)
Loading	25.41%	74.59%	25.41%
Al_2O_3	1.34	4.76	6.10
B_2O_3	0.00	10.00	10.00
CaO	0.00	2.02	2.02
Cr_2O_3	0.08	0.00	0.08
Fe_2O_3	0.00	5.50	5.50
K_2O	4.98	0.00	4.98
Li_2O	0.00	0.00	0.00
MgO	0.00	1.48	1.48
Na_2O	18.06+0.15[$]	0.00	18.21
NiO	0.01	0.00	0.01
PbO	0.01	0.00	0.01
SiO_2	0.02	42.93	42.95
TiO_2	0.00	1.40	1.40
ZnO	0.00	3.50	3.50
ZrO_2	0.00	3.00	3.00
Cl	0.09+0.11[$]	0.00	0.20
F	0.07+0.01[$]	0.00	0.08
P_2O_5	0.12	0.00	0.12
SO_3	0.30+0.05[$]	0.00	0.35
Sum	25.41	74.59	100.00

[$] Addition due to off-gas recycle estimated to be 111% Cl^-, 19% F^- and 17.65% SO_4^{2-} as sodium salts.
* Used in Test 6

Table 2.9. Oxide Composition of LAWE4H Simulant and Corresponding Glass Composition*.

	AN-105 in LAWE4H Glass at 21.27 wt% Na_2O	Glass Former Additives (wt%)	LAWE4H (wt%)
Loading	27.72%	72.28%	27.72%
Al_2O_3	4.95	1.02	5.97
B_2O_3	0.02	9.77	9.79
CaO	0.00	2.46	2.46
Cr_2O_3	0.08	0.00	0.08
Fe_2O_3	0.00	5.38	5.38
K_2O	0.54	0.00	0.54
Li_2O	0.00	0.00	0.00
MgO	0.00	1.45	1.45
Na_2O	21.11+0.16[$]	0.00	21.27
NiO	0.01	0.00	0.01
PbO	0.01	0.00	0.01
SiO_2	0.03	44.47	44.50
TiO_2	0.00	1.37	1.37
ZnO	0.00	3.43	3.43
ZrO_2	0.00	2.94	2.94
Cl	0.09+0.11[$]	0.00	0.20
F	0.07+0.01[$]	0.00	0.08
P_2O_5	0.12	0.00	0.12
SO_3	0.35+0.06[$]	0.00	0.41
Sum	27.72	72.28	100.00

[$] Addition due to off-gas recycle estimated to be 111% Cl^-, 19% F^- and 17.65% SO_4^{2-} as sodium salts.
* Used in Tests 1, 2, and 7

Table 2.10. Oxide Composition of LAWE5H Simulant and Corresponding Glass Composition*.

	AN-107 in LAWE5H Glass at 18.97 wt% Na_2O	Glass Former Additives (wt%)	LAWE5H (wt%)
Loading	20.64%	79.36%	20.64%
Al_2O_3	0.02	5.97	5.99
B_2O_3	0.00	9.81	9.81
CaO	0.04	3.57	3.61
Cr_2O_3	0.08	0.00	0.08
Fe_2O_3	0.12	5.29	5.40
K_2O	0.54	0.00	0.54
Li_2O	0.00	0.49	0.49
MgO	0.00	1.45	1.45
Na_2O	18.81+0.16[$]	0.00	18.97
NiO	0.01	0.00	0.01
PbO	0.01	0.00	0.01
SiO_2	0.00	45.04	45.04
TiO_2	0.00	1.37	1.37
ZnO	0.00	3.43	3.43
ZrO_2	0.00	2.94	2.94
Cl	0.09+0.11[$]	0.00	0.20
F	0.07+0.01[$]	0.00	0.08
P_2O_5	0.12	0.00	0.12
SO_3	0.39+0.07[$]	0.00	0.46
Sum	20.64	79.36	100.00

[$] Addition due to off-gas recycle estimated to be 111% Cl^-, 19% F^- and 17.65% SO_4^{2-} as sodium salts.

* Used in Test 3

Table 2.11. Oxide Composition of LAWE6H Simulant and Corresponding Glass Composition*.

	AN-104 in LAWE6H Glass at 15.83 wt% Na_2O	Glass Former Additives (wt%)	LAWE6H (wt%)
Loading	20.88%	79.12%	20.88%
Al_2O_3	3.46	2.55	6.01
B_2O_3	0.00	9.85	9.85
CaO	0.00	5.46	5.46
Cr_2O_3	0.08	0.00	0.08
Fe_2O_3	0.00	5.42	5.42
K_2O	0.54	0.00	0.54
Li_2O	0.00	2.38	2.38
MgO	0.00	1.46	1.46
Na_2O	15.66+0.17[$]	0.00	15.83
NiO	0.01	0.00	0.01
PbO	0.01	0.00	0.01
SiO_2	0.04	44.21	44.25
TiO_2	0.00	1.38	1.38
ZnO	0.00	3.45	3.45
ZrO_2	0.00	2.95	2.95
Cl	0.09+0.11[$]	0.00	0.20
F	0.07+0.01[$]	0.00	0.08
P_2O_5	0.12	0.00	0.12
SO_3	0.45+0.08[$]	0.00	0.53
Sum	20.88	79.12	100.00

[$] Addition due to off-gas recycle estimated to be 111% Cl^-, 19% F^- and 17.65% SO_4^{2-} as sodium salts.

* Used in Test 5

Table 2.12. Oxide Composition of LAWE7H Simulant and Corresponding Glass Composition*.

	AN-102 in LAWE7H Glass at 13.53 wt% Na_2O	Glass Former Additives (wt%)	LAWE7H (wt%)
Loading	16.22%	83.78%	16.22%
Al_2O_3	1.02	5.00	6.02
B_2O_3	0.01	9.86	9.87
CaO	0.03	6.28	6.31
Cr_2O_3	0.08	0.00	0.08
Fe_2O_3	0.00	5.43	5.43
K_2O	0.54	0.00	0.54
Li_2O	0.00	3.17	3.17
MgO	0.00	1.49	1.49
Na_2O	13.35+0.18[$]	0.00	13.53
NiO	0.01	0.00	0.01
PbO	0.01	0.00	0.01
SiO_2	0.01	44.75	44.75
TiO_2	0.00	1.38	1.38
ZnO	0.00	3.46	3.46
ZrO_2	0.00	2.96	2.96
Cl	0.09+0.11[$]	0.00	0.20
F	0.07+0.01[$]	0.00	0.08
P_2O_5	0.12	0.00	0.12
SO_3	0.50+0.09[$]	0.00	0.59
Sum	16.22	83.78	100.00

[$] Addition due to off-gas recycle estimated to be 111% Cl^-, 19% F^- and 17.65% SO_4^{2-} as sodium salts

* Used in Test 8

Table 2.13. Oxide Composition of LAWE9H Simulant and Corresponding Glass Composition*.

Glass Oxides	AZ-101 in LAWE9H Glass at 8.93 wt% Na_2O	Glass Former Additives (wt%)	LAWE9H (wt%)
Loading	11.34%	88.66%	11.34%
Al_2O_3	0.65	5.41	6.05
B_2O_3	0.00	9.92	9.92
CaO	0.04	6.82	6.86
Cr_2O_3	0.08	0.00	0.08
Fe_2O_3 *	0.00	5.45	5.45
K_2O	0.54	0.00	0.54
Li_2O	0.00	4.08	4.08
MgO *	0.00	2.36	2.36
Na_2O	8.66+0.27$	0.00	8.93
NiO	0.01	0.00	0.01
PbO	0.01	0.00	0.01
SiO_2	0.01	46.79	46.79
TiO_2 *	0.00	1.39	1.39
ZnO*	0.00	3.47	3.47
ZrO_2	0.00	2.97	2.97
Cl	0.09+0.11$	0.00	0.20
F	0.07+0.01$	0.00	0.08
P_2O_5	0.12	0.00	0.12
SO_3 *	0.48+0.21$	0.00	0.69
Sum	11.34	88.66	100.00

$ Addition due to off-gas recycle estimated to be 111% Cl^-, 19% F^- and 42.86% SO_4^{2-} as sodium salts

* Used in Test 9

Table 2.14. Oxide Composition of LAWE10H Simulant and Corresponding Glass Composition*.

	AZ-102 in LAWE10H Glass at 4.33 wt% Na_2O	Glass Former Additives (wt%)	LAWE10H (wt%)
Loading	6.20%	93.80%	6.20%
Al_2O_3	0.02	6.05	6.07
B_2O_3	0.00	9.95	9.95
CaO	0.00	6.96	6.96
Cr_2O_3	0.08	0.00	0.08
Fe_2O_3	0.00	5.48	5.48
K_2O	0.54	0.00	0.54
Li_2O	0.00	4.26	4.26
MgO	0.00	2.94	2.94
Na_2O	4.03+0.30[$]	1.39	5.72
NiO	0.01	0.00	0.01
PbO	0.01	0.00	0.01
SiO_2	0.02	48.90	48.92
TiO_2	0.00	1.39	1.39
ZnO	0.00	3.48	3.48
ZrO_2	0.00	2.99	2.99
Cl	0.09+0.11[$]	0.00	0.20
F	0.07+0.01[$]	0.00	0.08
P_2O_5	0.12	0.00	0.12
SO_3	0.56+0.24[$]	0.00	0.80
Sum	6.20	93.80	100.00

[$] Addition due to off-gas recycle estimated to be 111% Cl^-, 19% F^- and 42.86% SO_4^{2-} as sodium salts

* Used in Test 4

Table 2.15. Glass Former Additives for 1 Liter of LAWE Waste Simulants and Corresponding Feed Properties.

Additive Source	Feed LAWE3	Feed LAWE4H	Feed LAWE5H	Feed LAWE6H	Feed LAWE7H	Feed LAWE9H	Feed LAWE10H
Additives in Glass (wt%)	74.59%	72.28%	79.36%	79.12%	83.78%	88.66%	93.80%
Kyanite (Al_2SiO_5) 325 Mesh (Kyanite Mining) (g)	111.67	18.15	117.42	56.86	96.64	126.86	147.13
H_3BO_3 (US Borax – Technical Granular) (g)	241.75	202.23	199.26	239.75	200.67	244.59	253.08
Wollanstonite NYAD 325 Mesh (NYCO Minerals) (g)	60.51	63.09	89.88	164.63	158.24	208.41	219.20
Fe_2O_3 (97% Alfa) (g)	71.35	60.14	57.43	71.07	59.21	70.04	71.22
Li_2CO_3 (Chemetall Foote Co. Technical grade) (g)	-	-	14.01	81.55	90.77	141.60	152.46
Olivine (Mg_2SiO_4) 325 Mesh (#180 Unimin) (g)	41.36	34.48	33.34	39.26	33.18	65.34	84.78
Na_2CO_3 (Technical grade) (g)	-	-	-	-	-	-	34.18
SiO_2 (Sil-co-Sil 75 US Silica) (g)	468.23	446.62	387.91	459.37	358.02	438.69	465.92
TiO_2 (Rutile Airfloated Chemaloy) (g)	20.20	16.92	16.60	20.04	16.75	20.45	21.08
ZnO (KADOX – 920 Zinc Corp. of America) (g)	47.65	39.98	39.22	47.28	39.63	48.17	49.81
Zircon $ZrSiO_4$ (Flour) Mesh 325 (AM. Mineral) (g)	61.60	51.69	50.71	60.97	51.13	62.18	64.55
Sucrose as Reductant (added only to actual melter feed) (g)	83.65*	78.50*	5.44*	74.50*	23.70*	35.71*	12.26*
Estimated Simulant Weight for 1 liter (g) &	1398	1356	1299	1332	1242	1191	1098
Sum of Additives (g)	1124	933	1006	1241	1104	1426	1563
Sum of Complete Batch (g)	2522	2289	2305	2573	2346	2617	2661
Final Volume (l)	1.45	1.36	1.38	1.49	1.42	1.57	1.61
Measured Density on crucible batch (g/ml)	1.74	1.69	1.67	1.73	1.65	1.67	1.65
Target Glass Produced (g/l simulant)	1361	1166	1144	1370	1145	1388	1431
Measured Weight % Water in Slurry Feed on crucible batch	35%	40%	41%	35%	40%	39%	40%
Target Weight % Additives in Slurry	45%	48%	44%	48%	47%	54%	59%
Target Glass Yield for crucible batch (g/kg of Feed)	539	508	495	532	487	529	539
Measured Glass Yield on crucible batch (g/kg of Feed)	500	480	495	510	479	514	536
Target Glass Yield (g/l of Feed)	938	859	827	920	804	883	989
Target Total Solids (g/l of Feed)	1126	1012	993	1127	988	1020	993
Target Additives (g/l of Feed)	774	688	727	833	775	907	969

- Empty data field
* Nominal concentrations. Sugar additions may be varied based on the organics content of the glass former additives.
& These do not include the contribution from recycled off-gas streams. All measured property values are for feed including estimated recycled off-gas.

Table 2.16. Characteristics of as Received Melter Feed Samples.

Test	Formulation	Date	Name	% Water	pH	Density (g/ml)	Glass Yield			
							(g/l)	Measured (kg/kg)	Target (kg/kg)	%Dev.
Test 1	LAWE4H		TcLoop4H	33.50	12.26	1.76	912	0.518	0.550	-5.82
Test 2	LAWE4H	8/16/11	10Q-F-68A	34.99	12.52	1.75	961	0.549	0.550	-0.18
Test 3	LAWE5H	9/6/11	10R-F-12B	38.50	12.07	1.71	881	0.515	0.527	-2.28
Test 3	LAWE5H	9/14/11	10R-F-90A	27.36	11.94	1.72	875	0.509	0.527	-3.45
Test 4	LAWE10H	9/8/11	10R-F-48A	38.97	8.64	1.68	929	0.553	0.563	-1.81
Test 5	LAWE6H	11/14/11	10S-F-95A	34.73	10.01	1.67	1360	0.532	0.528	0.78
Test 5	LAWE6H	11/16/11	10S-F-95B	35.42	10.09	1.64	888	0.528	0.528	0.06
Test 6	LAWE3H	12/1/11	10S-F-102A	32.85	12.19	1.82	999	0.549	0.549	-0.02
Test 7	LAWE4H	12/20/11	10T-F-37A	34.62	12.41	1.77	980	0.554	0.550	0.71
Test 7	LAWE4H	12/20/11	10T-F-37B	34.77	12.36	1.78	981	0.551	0.550	0.18
Test 8	LAWE7H	2/14/12	10U-F-69A	39.51	8.51	1.64	775	0.472	0.520	-9.15
Test 8	LAWE7H	2/16/12	10U-F-69B	35.51	8.51	1.72	904	0.526	0.520	1.12
Test 9	LAWE9H	4/3/12	10V-F-13A	39.14	8.53	1.69	895	0.530	0.520	1.85
Test 9	LAWE9H	4/3/12	10V-F-13B	39.80	8.57	1.66	871	0.525	0.520	0.92

Table 2.17. Characteristics of Feed Samples Taken from DM10 Feed System.

Test	Formulation	Location	Date	Name	% Water	pH	Density (g/ml)	Glass Yield			
								(g/l)	Measured (kg/kg)	Target (kg/kg)	%Dev.
Test 1	LAWE4H	Feed Line	8/31/11	10Q-F-102A	37.58	11.76	1.48	691	0.467	0.490*	-4.65
Test 1	LAWE4H	Feed Line	9/1/11	10Q-F-122A	32.31	11.95	NA	NA	0.532	0.490*	8.53
Test 1	LAWE4H	Feed Line	9/1/11	10Q-F-137A	31.97	11.96	NA	NA	0.552	0.490*	12.67
Test 1	LAWE4H	Feed Line	9/2/11	10Q-F-139A	33.25	11.96	NA	NA	0.530	0.490*	8.20
Test 1	LAWE4H	Residual Feed in Mixing Vessel	9/2/11	10R-F-12A	18.24	11.18	2.21	1724	0.780	0.490*	59.20
Test 2	LAWE4H	Feed Line	9/7/11	10R-F-40A	41.40	11.79	NA	NA	0.447	0.470*	-4.87
Test 2	LAWE4H	Feed Line	9/8/11	10R-F-48C	35.47	12.09	1.66	832	0.501	0.470*	6.66
Test 2	LAWE4H	Feed Line	9/8/11	10R-F-55A	37.78	11.98	NA	NA	0.494	0.470*	5.06
Test 2	LAWE4H	Feed Line	9/9/11	10R-F-68A	33.48	12.14	1.75	891	0.509	0.470*	-8.36
Test 3	LAWE5H	Feed Tube	9/21/11	10S-F-18A	43.76	11.69	1.53	684	0.447	0.480*	-6.90
Test 4	LAWE10H	Feed Tube	9/29/11	10S-F-93A	35.76	8.93	1.72	995	0.578	0.563	2.74
Test 8	LAWE7H	Residual from Feed tank	2/23/12	10U-F-137A	36.61	8.52	1.69	861	0.510	0.520	-2.00

*- Target calculated from the target for as received feed and the average slurry and recycle stream feed rates.
NA- Not analyzed.

Table 2.18. Listing of Feed Samples Analyzed for ^{99m}Tc Content.

Test	Location	Date	Time	Name	Weight (g)	^{99m}Tc (μCi/g)
1	Feed Line	8/31/2011	11:47	10Q-F-102A	37	0.319, 0.357
	Feed Line	9/1/2011	11:00	10Q-F-122A	31	0.911, 1.027
	Feed Line	9/1/2011	22:50	10Q-F-137A	14.35	0.658, 0.661
	Feed Line	9/2/2011	10:51	10Q-F-139A	26	0.469
	Residual Feed in Mixing Vessel	9/2/2011	20:00	10R-F-12A	296.61	84.216
2	Feed Line	9/7/2011	14:13	10R-F-40A	24.60	2.874
	Feed Line	9/8/2011	13:58	10R-F-48C	72	0.309, 0.450
	Feed Line	9/8/2011	16:30	10R-F-48B	10.70	0.875
	Feed Line	9/8/2011	18:06	10R-F-55A	25.82	0.803,0.838
	Feed Line	9/9/2011	14:19	10R-F-68A	48	0.574
3	Recycled Liquids	9/20/2011	3:43	10R-F-133A	8.96	7.643, 7.403
	Recycled Liquids	9/21/2011	3:35	10R-F-147A	20.36	11.579
	Feed Tube	9/21/2011	22:10	10S-F-18A	92	1.082, 1.106
4	Recycled Liquids	9/27/2011	4:45	10S-F-49A	18.64	6.742
	Recycled Liquids	9/28/2011	4:44	10S-F-62A	13.8	7.356, 7.373
	Recycled Liquids	9/29/2011	4:41	10S-F-81A	15.30	6.077, 5.674
	Feed Tube	9/29/2011	16:53	10S-F-93A	393.72	0.413
5	Upstream of Feed Tube	12/13/2011	19:00	10S-F-124A	48.79	0.542
	Recycled Liquids	12/14/2011	0:46	10S-F-127A	25.85	1.525
	Upstream of Feed Tube		12:52	10S-F-131A	30	0.692
	Recycled Liquids	12/15/2011	0:58	10S-F-147A	46.44	2.307
	Upstream of Feed Tube		9:37	10S-F-149A	28	0.591
	Recycled Liquids	12/16/2011	0:50	10T-F-14A	38.59	2.869
	Residual from Feed Tank		8:30	10T-F-20A	40.00, 25.30, 25.25, 27.00, 15.00, 10.70	0.143, 0.123, 0.139, 0.147, 0.134, 0.134
6	Upstream of Feed Tube	1/9/2012	18:16	10T-F-55A	43.72	0.515
	Recycled Liquids	1/10/2012	0:13	10T-F-58A	24.44	1.401
	Upstream of Feed Tube	1/10/2012	12:33	10T-F-68A	80	0.520
	Recycled Liquids	1/11/2012	0:09	10T-F-78A	19.54	3.99

Table 2.18 Listing of Feed Samples Analyzed for ^{99m}Tc Content (continued).

Test	Location	Date	Time	Name	Weight (g)	^{99m}Tc (μCi/g)
6	Upstream of Feed Tube	1/11/2012	12:24	10T-F-92A	60	0.519
	Recycled Liquids	1/12/2012	0:15	10T-F-102A	19.34	3.603
	Upstream of Feed Tube	1/12/2012	6:48	10T-F-105A	78	0.536
	Residual from Feed tank	1/12/2012	12:30	10T-F-106A	80	0.490, 0.530, 0.453, 0.492
7	Upstream of Feed Tube	1/17/2012	19:44	10T-F-145A	167.57	0.503
	Recycled Liquids	1/17/2012	23:37	10T-F-146A	24.24	0.939
	Upstream of Feed Tube	1/18/2012	18:14	10U-F-19A	225	0.485
	Recycled Liquids		23:16	10U-F-23A	24.23	2.31, 2.48
	Upstream of Feed Tube	1/19/2012	20:17	10U-F-40A	149	0.475
	Recycled Liquids		23:16	10U-F-47A	24.57	3.069
	Residual from Feed tank	1/20/2012	13:23	10U-F-56A	130	0.491, 0.490
8	Upstream of Feed Tube	2/20/2012	18:34	10U-F-93A	179.30	0.554
	Recycled Liquids		23:43	10U-F-95A	18.47	2.106
	Upstream of Feed Tube	2/21/2012	11:41	10U-F-101A	76	0.551
	Recycled Liquids		23:55	10U-F-109A	25.10	4.301
	Upstream of Feed Tube	2/22/2012	11:32	10U-F-119A	134	0.520
	Recycled Liquids		23:45	10S-F-127 A	33.27	6.434
	Upstream of Feed Tube	2/23/2012	7:48	10U-F-136A	162	0.502
	Residual from Feed tank		11:43	10U-F-137A	1620	0.513, 0.485
9	Upstream of Feed Tube	3/6/2012	18:49	10V-F-33A	231.26	0.503
	Recycled Liquids	3/7/2012	0:50	10V-F-39A	42.08	0.910
	Upstream of Feed Tube		12:31	10V-F-45A	164	0.508
	Recycled Liquids	3/8/2012	0:45	10V-F-61A	31	2.555
	Upstream of Feed Tube		12:31	10V-F-69A	184	0.533
	Upstream of Feed Tube		22:15	10V-F-78A	104	0.532
	Recycled Liquids		0:47	10V-F-79A	25.62	2.244
	Residual from Feed tank	3/9/2012	12:50	10V-F-88A	1780	0.530

Table 2.19. DCP and XRF Analyzed Composition for Vitrified as Received Feed Samples (wt%).

Test	1				2			3			
Sample	LAWE4H	TcLoop4H			10Q-F-68A			LAWE5H	10R-F-12B		
Oxide		XRF	% Dev.	DCP/IC	XRF	% Dev.	DCP/IC		XRF	% Dev.	DCP/IC
Al_2O_3	5.99	5.58	-6.92	5.56	5.39	-9.99	5.56	6.01	5.80	-3.59	6.07
B_2O_3*	9.82	10.98	11.77	10.98	10.85	10.45	10.85	9.84	9.91	0.66	9.91
CaO	2.47	2.33	-5.47	2.43	2.63	6.65	2.53	3.62	3.65	0.68	3.41
Cl	0.09	0.03	NC	0.10	0.04	NC	0.11	0.09	0.04	NC	0.14
Cr_2O_3	0.08	0.09	NC	0.11	0.13	NC	0.11	0.08	0.12	NC	0.10
F	0.07	NA	NC	0.04	NA	NC	0.03	0.07	NA	NC	0.11
Fe_2O_3	5.40	5.17	-4.30	5.27	5.48	1.55	5.31	5.42	5.36	-1.20	5.32
K_2O	0.54	0.60	NC	0.61	0.57	NC	0.59	0.54	0.75	NC	0.82
Li_2O*	§	0.02	NC	0.02	0.04	NC	0.04	0.49	0.59	NC	0.59
MgO	1.45	1.23	-15.48	1.40	1.54	6.09	1.61	1.46	1.42	-2.30	1.51
Na_2O	21.18	22.31	5.33	19.60	20.95	-1.11	19.79	18.87	19.37	2.65	17.38
NiO	0.01	0.02	NC	0.02	0.02	NC	0.03	0.01	0.01	NC	0.03
P_2O_5	0.12	0.16	NC	0.18	0.16	NC	0.01	0.12	0.19	NC	0.26
PbO	0.01	0.01	NC	<0.01	<0.01	NC	<0.01	0.01	0.01	NC	0.01
SiO_2	44.65	43.93	-1.60	45.24	44.17	-1.07	45.03	45.20	44.94	-0.58	42.97
SO_3	0.35	0.41	NC	0.41	0.31	NC	0.44	0.39	0.34	NC	0.42
TiO_2	1.37	1.36	-0.86	1.44	1.54	12.28	1.45	1.37	1.58	14.97	1.62
ZnO	3.44	3.10	-9.99	3.50	3.39	-1.39	3.34	3.44	3.27	-4.98	3.72
ZrO_2	2.95	2.67	-9.47	3.04	2.79	-5.41	3.02	2.95	2.66	-9.83	2.83
Sum	100.00	100.10	NC	99.95	100.00	NC	99.85	100.00	100.00	NC	97.22

* - DCP-AES analyzed values.
NA - Not Analyzed.
§ - Not a target constituent

Table 2.19. DCP and XRF Analyzed Composition for Vitrified as Received Feed Samples (wt%) (continued).

Test	3				4				5			
Sample	LAWE5H	10R-F-90A			LAWE10H	10R-F-48A			LAWE6H	10S-F-95A		
Oxide		XRF	% Dev.	DCP/IC		XRF	% Dev.	DCP/IC		XRF	% Dev.	DCP/IC
Al_2O_3	6.01	5.71	-4.95	5.97	6.11	5.53	-9.54	5.97	6.03	5.86	-2.85	6.18
B_2O_3*	9.84	10.36	5.23	10.36	10.02	9.85	-1.69	9.85	9.89	9.53	-3.61	9.53
CaO	3.62	3.79	4.49	3.41	7.01	7.14	1.90	6.54	5.48	5.70	4.00	5.19
Cl	0.09	0.04	NC	0.14	0.09	0.07	NC	0.12	0.09	0.03	NC	0.06
Cr_2O_3	0.08	0.12	NC	0.10	0.08	0.17	NC	0.11	0.08	0.12	NC	0.12
F	0.07	NA	NC	0.11	0.07	NA	NC	0.05	0.07	NA	NC	0.02
Fe_2O_3	5.42	5.59	3.17	5.31	5.52	5.53	0.20	5.42	5.44	5.86	7.66	5.30
K_2O	0.54	0.78	NC	0.84	0.54	0.60	NC	0.63	0.54	0.60	NC	0.58
Li_2O*	0.49	0.61	NC	0.61	4.29	4.41	2.83	4.41	2.39	2.38	-0.37	2.38
MgO	1.46	1.12	-23.23	1.24	2.96	3.17	7.24	2.98	1.47	1.41	-4.06	1.70
Na_2O	18.87	19.35	2.55	17.77	5.46	6.00	9.85	5.55	15.72	14.66	-6.73	13.77
NiO	0.01	0.01	NC	0.02	0.01	0.03	NC	0.04	0.01	0.03	NC	0.04
P_2O_5	0.12	0.18	NC	0.31	0.12	0.17	NC	0.40	0.12	0.17	NC	0.24
PbO	0.01	<0.01	NC	0.01	0.01	<0.01	NC	0.01	0.01	<0.01	NC	0.03
SiO_2	45.20	44.11	-2.43	42.86	49.25	49.14	-0.21	47.48	44.41	44.99	1.30	45.34
SO_3	0.39	0.35	NC	0.41	0.56	0.53	NC	0.68	0.45	0.31	NC	0.30
TiO_2	1.37	1.58	15.04	1.59	1.40	1.51	8.09	1.52	1.39	1.67	20.58	1.76
ZnO	3.44	3.52	2.24	3.81	3.50	3.37	-3.67	3.80	3.46	3.61	4.19	3.63
ZrO_2	2.95	2.77	-6.17	2.77	3.01	2.76	-8.19	2.98	2.96	3.10	4.57	2.93
Sum	100.00	100.00	NC	97.64	100.00	100.00	NC	98.54	100.00	100.00	NC	99.10

* - DCP-AES analyzed values.
NA - Not Analyzed.

Table 2.19. DCP and XRF Analyzed Composition for Vitrified as Received Feed Samples (wt%) (continued).

Test	5				6				7			
Sample	LAWE6H	10S-F-95B			LAWE3	10S-F-102A			LAWE4H	10T-F-37A		
Oxide		XRF	% Dev.	DCP/IC		XRF	% Dev.	DCP/IC		XRF	% Dev.	DCP/IC
Al_2O_3	6.03	5.79	-3.94	6.09	6.12	6.17	0.87	6.30	5.99	5.69	-5.01	5.78
B_2O_3*	9.89	9.51	-3.81	9.51	10.03	9.72	-3.12	9.72	9.82	9.44	-3.90	9.44
CaO	5.48	5.70	3.97	5.15	2.03	2.01	-0.93	1.97	2.47	2.46	-0.44	2.56
Cl	0.09	0.03	NC	0.09	0.10	0.05	NC	0.14	0.09	0.03	NC	0.07
Cr_2O_3	0.08	0.11	NC	0.12	0.08	0.12	NC	0.12	0.08	0.09	NC	0.12
F	0.07	NA	NC	0.02	0.07	NA	NC	0.03	0.07	NA	NC	0.03
Fe_2O_3	5.44	5.82	7.05	5.29	5.52	5.54	0.43	5.33	5.40	5.39	-0.06	5.20
K_2O	0.54	0.62	NC	0.61	5.00	5.30	6.11	4.70	0.54	0.57	NC	0.62
Li_2O*	2.39	2.37	-0.79	2.37	§	0.03	NC	0.03	§	0.04	NC	0.04
MgO	1.47	1.41	-4.07	1.72	1.48	1.43	-3.47	1.76	1.45	1.36	-6.41	1.61
Na_2O	15.72	15.50	-1.38	13.88	18.12	19.05	5.15	15.81	21.18	22.53	6.34	16.78
NiO	0.01	0.03	NC	0.03	0.01	0.02	NC	0.03	0.01	0.02	NC	0.03
P_2O_5	0.12	0.16	NC	0.40	0.12	0.16	NC	0.35	0.12	0.16	NC	0.13
PbO	0.01	0.02	NC	0.03	0.01	0.01	NC	0.02	0.01	0.01	NC	0.02
SiO_2	44.41	44.11	-0.68	45.42	43.09	42.46	-1.46	43.00	44.65	44.43	-0.49	44.63
SO_3	0.45	0.36	NC	0.46	0.30	0.30	NC	0.33	0.35	0.29	NC	0.14
TiO_2	1.39	1.66	19.64	1.75	1.40	1.53	9.23	1.82	1.37	1.51	9.72	1.63
ZnO	3.46	3.62	4.60	3.60	3.51	3.34	-4.88	3.59	3.44	3.20	-6.95	3.39
ZrO_2	2.96	3.17	7.12	2.95	3.01	2.75	-8.80	2.80	2.95	2.78	-5.60	2.91
Sum	100.00	100.00	NC	99.49	100.00	100.00	NC	97.85	100.00	100.00	NC	95.13

* - DCP-AES analyzed values.
NA - Not Analyzed.
§ - Not a target constituent

Table 2.19. DCP and XRF Analyzed Composition for Vitrified as Received Feed Samples (wt%) (continued).

Test	7				8				9			
Sample	LAWE4H	10T-F-37B			LAWE7H	10U-F-69B			LAWE9H	10V-F-13A		
Oxide		XRF	% Dev.	DCP/IC		XRF	% Dev.	DCP/IC		XRF	% Dev.	DCP/IC
Al_2O_3	5.99	5.80	-3.19	5.83	6.04	5.77	-4.56	5.83	6.09	5.71	-6.21	5.63
B_2O_3*	9.82	9.75	-0.75	9.75	9.91	9.60	-3.11	9.60	9.98	9.47	-5.11	9.47
CaO	2.47	2.48	0.65	2.52	6.33	6.36	0.40	6.23	6.90	7.04	2.00	6.45
Cl	0.09	0.03	NC	0.07	0.09	0.03	NC	0.13	0.09	0.02	NC	0.10
Cr_2O_3	0.08	0.10	NC	0.11	0.08	0.10	NC	0.11	0.08	0.12	NC	0.13
F	0.07	NA	NC	0.03	0.07	NA	NC	0.21	0.07	NA	NC	0.03
Fe_2O_3	5.40	5.38	-0.29	5.16	5.45	5.41	-0.72	5.28	5.48	5.82	6.23	5.52
K_2O	0.54	0.56	NC	0.61	0.54	0.67	NC	0.75	0.54	0.54	NC	0.64
Li_2O*	§	0.02	NC	0.02	3.18	3.30	3.70	3.30	4.10	4.13	0.63	4.13
MgO	1.45	1.31	-9.92	1.55	1.50	1.54	2.81	1.71	2.37	2.48	4.65	2.48
Na_2O	21.18	22.54	6.40	16.84	13.40	14.43	7.69	12.40	8.71	8.91	2.30	8.08
NiO	0.01	0.02	NC	0.02	0.01	0.02	NC	0.02	0.01	0.03	NC	0.03
P_2O_5	0.12	0.17	NC	0.18	0.12	0.17	NC	0.31	0.12	0.18	NC	0.13
PbO	0.01	0.01	NC	0.03	0.01	0.01	NC	0.02	0.01	0.01	NC	<0.01
SiO_2	44.65	44.14	-1.14	44.13	44.93	44.75	-0.39	45.31	47.07	47.46	0.82	46.41
SO_3	0.35	0.28	NC	0.14	0.51	0.37	NC	0.56	0.49	0.24	NC	0.52
TiO_2	1.37	1.41	2.33	1.55	1.39	1.50	8.31	1.64	1.40	1.63	16.43	1.72
ZnO	3.44	3.21	-6.87	3.34	3.47	3.19	-8.24	3.40	3.49	3.29	-5.80	3.33
ZrO_2	2.95	2.80	-5.06	2.88	2.97	2.78	-6.57	2.97	2.99	2.91	-2.61	2.84
Sum	100.00	100.00	NC	94.76	100.00	100.00	NC	98.78	100.00	100.00	NC	97.64

* - DCP-AES analyzed values.
NA - Not Analyzed.
§ - Not a target constituent

Table 2.19. DCP and XRF Analyzed Composition for Vitrified as Received Feed Samples (wt%) (continued).

Test	9			
Sample	LAWE9H	10V-F-13B		
Oxide		XRF	% Dev.	DCP/IC
Al_2O_3	6.09	5.63	-7.52	5.60
B_2O_3*	9.98	9.92	-0.60	9.92
CaO	6.90	6.98	1.22	6.36
Cl	0.09	0.03	NC	0.10
Cr_2O_3	0.08	0.12	NC	0.12
F	0.07	NA	NC	0.02
Fe_2O_3	5.48	5.21	-4.97	4.89
K_2O	0.54	0.63	NC	0.67
Li_2O*	4.10	4.45	8.43	4.45
MgO	2.37	2.27	-4.36	2.37
Na_2O	8.71	8.47	-2.76	8.24
NiO	0.01	0.03	NC	0.03
P_2O_5	0.12	0.19	NC	0.26
PbO	0.01	<0.01	NC	<0.01
SiO_2	47.07	47.62	1.17	46.11
SO_3	0.49	0.24	NC	0.54
TiO_2	1.40	1.57	12.58	1.62
ZnO	3.49	3.63	3.86	3.40
ZrO_2	2.99	3.00	0.53	2.77
Sum	100.00	100.00	NC	97.47

* - DCP-AES analyzed values.
NA - Not Analyzed.

Table 2.20. DCP and XRF Analyzed Composition for Vitrified Feed Samples from DM10 Melter Feed System (wt%).

Test	1									
Sample	Target	10Q-F-102A		10Q-F-122A		10Q-F-137A		10Q-F-139A		10R-F-12A	
Oxide		XRF	DCP	XRF	DCP	XRF	DCP	XRF	DCP	XRF	DCP
Al_2O_3	5.98	5.40	5.67	5.01	5.18	4.65	5.01	5.17	5.31	4.47	3.55
B_2O_3*	9.80	10.35	10.35	8.99	8.99	8.18	8.18	8.96	8.96	1.95	1.95
CaO	2.46	2.50	2.40	2.19	2.17	2.01	1.91	2.16	2.07	1.62	1.24
Cl	0.09	0.13	0.13	0.11	NA	0.08	NA	0.09	NA	0.03	NA
Cr_2O_3	0.08	0.14	0.11	0.23	0.12	0.44	0.11	0.48	0.17	0.36	0.06
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.39	5.59	5.20	5.64	5.58	6.54	6.20	5.70	5.39	8.59	8.48
I	0.10	0.042	NA	0.036	NA	0.033	NA	0.035	NA	<0.005	NA
K_2O	0.54	0.60	0.64	0.50	0.55	0.45	0.48	0.49	0.52	0.12	0.12
Li_2O*	§	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.05	0.05
MgO	1.45	2.22	2.19	4.62	4.21	8.36	7.59	4.36	3.93	16.46	13.18
Na_2O	21.14	19.83	18.28	17.88	15.99	15.46	14.41	16.88	15.85	3.91	3.16
NiO	0.01	0.02	0.03	0.03	0.05	0.06	0.07	0.04	0.05	0.11	0.12
P_2O_5	0.12	0.16	0.32	0.14	0.17	0.13	0.27	0.16	0.31	0.08	0.15
PbO	0.01	<0.01	0.01	<0.01	0.01	0.01	0.01	<0.01	0.01	<0.01	<0.01
ReO_2	0.10	0.096	0.010	0.112	0.117	0.088	0.090	0.091	0.099	0.026	0.045
SiO_2	44.56	44.62	42.02	44.33	42.12	42.76	40.94	42.82	40.47	50.35	42.24
SO_3	0.35	0.37	NA	0.29	NA	0.24	NA	0.26	NA	0.09	NA
TiO_2	1.37	1.55	1.55	2.48	2.49	2.98	2.89	3.44	3.39	3.42	2.11
ZnO	3.44	3.26	3.44	2.77	3.10	2.68	2.79	2.90	3.10	1.24	1.41
ZrO_2	2.94	3.07	3.05	4.60	5.04	4.83	5.10	5.93	6.33	7.12	0.84
Sum	100.00	100.00	95.44	100.00	95.92	100.00	96.08	100.00	95.99	100.00	78.71

* - DCP-AES analyzed values for boron and lithium used to normalize XRF results.
NA - Not Analyzed.
§ - Not a target constituent

Table 2.20. DCP and XRF Analyzed Composition for Vitrified Feed Samples from DM10 Melter Feed System (wt%) (continued).

Test	2								
Sample	Target	10R-F-40A		10R-F-48C		10R-F-55A		10R-F-68A	
Oxide		XRF	DCP	XRF	DCP	XRF	DCP	XRF	DCP
Al_2O_3	5.98	5.44	5.81	5.11	5.45	5.07	5.37	5.26	5.55
B_2O_3*	9.80	10.41	10.41	9.20	9.20	9.07	9.07	9.60	9.60
CaO	2.46	2.47	2.38	2.29	2.25	2.26	2.18	2.56	2.43
Cl	0.09	0.01	NA	0.05	NA	0.08	NA	0.03	NA
Cr_2O_3	0.08	0.12	0.10	0.28	0.18	0.22	0.13	0.12	0.10
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.39	5.53	5.50	5.55	5.41	5.93	5.85	5.72	5.54
I	0.10	0.006	NA	0.021	NA	0.031	NA	0.013	NA
K_2O	0.54	0.53	0.58	0.50	0.55	0.48	0.53	0.55	0.59
Li_2O*	§	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03
MgO	1.45	2.47	2.40	4.76	4.18	6.70	6.07	2.58	2.53
Na_2O	21.14	19.94	17.73	19.53	16.68	17.66	16.66	19.79	17.87
NiO	0.01	0.02	0.04	0.04	0.05	0.05	0.06	0.02	0.04
P_2O_5	0.12	0.18	0.30	0.15	0.20	0.16	0.13	0.14	0.24
PbO	0.01	0.01	0.01	<0.01	0.01	<0.01	0.01	<0.01	0.02
ReO_2	0.10	0.016	0.045	0.053	0.081	0.074	0.099	0.039	0.063
SiO_2	44.56	44.91	43.72	43.16	41.64	42.58	41.17	44.93	43.01
SO_3	0.35	0.16	NA	0.22	NA	0.25	NA	0.24	NA
TiO_2	1.37	1.62	1.67	2.30	2.30	2.48	2.47	1.85	1.77
ZnO	3.44	3.24	3.65	2.93	3.33	2.91	3.29	3.24	3.56
ZrO_2	2.94	2.91	3.15	3.83	4.05	3.96	4.27	3.28	3.41
Sum	100.00	100.00	97.52	100.00	95.59	100.00	97.39	100.00	96.35

* - DCP-AES analyzed values for boron and lithium used to normalize XRF results.
NA - Not Analyzed.
§ - Not a target constituent

Table 2.20. DCP and XRF Analyzed Composition for Vitrified Feed Samples from DM10 Melter Feed System (wt%) (continued).

Test	3			4			8		
Sample	Target	10S-F-18A		Target	10S-F-93A		Target	10U-F-137A	
Oxide		XRF	DCP		XRF	DCP		XRF	DCP
Al_2O_3	6.00	5.59	5.79	6.10	5.60	5.73	6.03	5.45	6.31
B_2O_3*	9.83	10.39	10.39	10.00	9.66	9.66	9.89	10.45	10.45
CaO	3.62	3.96	3.57	6.99	7.35	6.39	6.32	6.92	6.37
Cl	0.09	<0.01	NA	0.09	0.06	NA	0.09	0.01	NA
Cr_2O_3	0.08	0.11	0.09	0.08	0.17	0.1	0.08	0.10	0.11
F	0.07	NA	NA	0.07	NA	NA	0.07	NA	NA
Fe_2O_3	5.41	5.63	5.41	5.51	5.65	5.34	5.44	5.98	5.82
I	0.10	<0.005	NA	0.10	0.015	NA	0.10	<0.005	NA
K_2O	0.54	0.80	0.87	0.54	0.59	0.59	0.54	0.77	0.74
Li_2O*	0.49	0.62	0.62	4.28	4.01	4.01	3.18	3.41	3.41
MgO	1.45	0.40	0.53	2.95	3.14	3.05	1.49	1.42	1.7
Na_2O	18.84	19.10	17.95	5.45	5.39	5.22	13.38	11.77	13.34
NiO	0.01	0.01	0.02	0.01	0.03	0.04	0.01	0.02	0.03
P_2O_5	0.12	0.18	0.31	0.12	0.18	0.22	0.12	0.17	0.23
PbO	0.01	<0.01	0.02	0.01	<0.01	0.02	0.01	0.02	0.02
ReO_2	0.10	0.012	0.045	0.10	0.084	0.108	0.10	<0.005	0.009
SiO_2	45.11	45.29	42.66	49.15	49.89	47.57	44.84	44.73	42.87
SO_3	0.39	0.29	NA	0.56	0.44	NA	0.51	0.38	NA
TiO_2	1.37	1.45	1.47	1.40	1.56	1.56	1.38	1.69	1.71
ZnO	3.44	3.59	3.97	3.50	3.32	3.69	3.47	3.57	3.26
ZrO_2	2.94	2.57	2.67	3.00	2.87	2.89	2.97	3.15	3.18
Sum	100.00	100.00	96.39	100.00	100.00	96.19	100.00	100.00	99.56

* - DCP-AES analyzed values for boron and lithium used to normalize XRF results.
NA - Not Analyzed.

Table 3.1. Summary of DM10 Test Conditions and Results.

Test		1	2	3	4
Test Plan Number [5]		1	9	5	3
Time	Feed Start	8/30/11 22:50	9/7/11 1:59	9/19/11 15:30	9/26/11 16:40
	Feed End	9/2/11 13:50	9/9/11 22:00	9/21/11 21:38	9/29/11 16:40
	Interval	63.0 hr	68.0 hr	54.1 hr	72.0 hr
	Feed Interruptions	4.8 hr	2.9 hr	1.2 hr	0.7 hr
Glass	Target Glass	LAWE4H	LAWE4H	LAWE5H	LAWE10H
	Mass Poured	97.3 kg	79.3 kg	96.9 kg	138.9 kg
	Average Glass Production Rate	1765 kg/m^2/day	1332 kg/m^2/day	2046 kg/m^2/day	2205 kg/m^2/day
Feed	Mass Fed (excluding recycle)	189 kg	156 kg	210 kg	265 kg
	Average Recycle Feed Rate	0.30 l/h	0.36 l/h	0.40 l/h	0.40 l/h
	Average Glass Production Rate	1886 kg/m^2/day	1442 kg/m^2/day	2338 kg/m^2/day	2368 kg/m^2/day
System Operation Details	Feed	Feed mixing vessel used to combine all three feeds	Evaporator recycle tee-ed into fresh feed, then ^{99m}Tc added at another tee	^{99m}Tc tee-ed into evaporator recycle, then fed to top of feed tube. Fresh feed added in side of feed tube.	
	WESP	Not working beyond ~44 hours run-time	Improvements made after each test to reduce potential for shorting. Voltage adjusted periodically to reduce arcing.		
Measured % Feed in Glass at Steady-State	^{99m}Tc	40	75	81	84
	Rhenium	80	100	90	80
	Iodine	30	45	25	80

Table 3.1. Summary of DM10 Test Conditions and Results (continued).

Test		5	6	7	8	9
Test Plan Number [9]		5	8	7	6	9
Time	Feed Start	12/13/11 12:45	1/9/12 12:11	1/17/12 11:10	2/20/12 11:30	3/6/12 12:30
	Feed End	12/16/11 2:30	1/12/12 12:11	1/20/12 11:40	2/23/12 11:30	3/9/12 12:30
	Interval	61.8 hr	72.0 hr	72.5 hr	72.0	72.0
	Feed Interruption	1.4 hr	0.4 hr	0.7 hr	0.2 hr	0.4 hr
Glass	Target Glass	LAWE6H	LAWE3	LAWE4H	LAWE7H	LAWE9H
	Mass Poured	117.4 kg	143.4 kg	117.3 kg	147.6 kg	145.7 kg
	Average Glass Production Rate	2147 kg/m^2/day	2277 kg/m^2/day	1850 kg/m^2/day	2342 kg/m^2/day	2313 kg/m^2/day
Feed	Mass Fed (excluding recycle)	248 kg	294 kg	229 kg	293 kg	292 kg
	Average Recycle Feed Rate	0.40 l/h	0.39 l/h	0.40 l/h	0.41 l/h	0.40 l/h
	Average Glass Production Rate	2313 kg/m^2/day	2473 kg/m^2/day	1985 kg/m^2/day	2419 kg/m^2/day	2408 kg/m^2/day
System Operation Details	Feed	Tc spike was added to the feed mix tank				
	Transition line	Transition line spray added after Test 4.				
	WESP	Voltage adjusted periodically to reduce arcing.				
	Target SBS sump temperature	30°C	30°C	30°C	30°C	30°C
Measured % Feed in Glass at Steady-State	^{99m}Tc	68	53	72	45	72
	Rhenium	70	70	90	59	91
	Iodine	16	46	41	9	29

Table 3.2.a. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 1.

Run Time (hr)	Time	Operational Notes
0	08/30/2011 22:50	Feed Started: 8/30/2011 22:50
1.52	08/31/11 00:21	Stopped feeding to rod cold cap.
1.55	08/31/11 00:23	Resumed feeding.
9.25	08/31/11 08:05	Started evaporator recirculation pump (P-401)
9.42	08/31/11 08:15	Evaporator circulating water temperature controller (V-501) is tripped off, restarted V-501. Evaporator level high.
9.92	08/31/11 08:45	Evaporator circulating water temperature controller (V-501) is tripped off, restarted V-501.
11.13	08/31/11 09:58	Evaporator level is below the required level. Turned P-401 off.
12.95	08/31/11 11:47	Obtained Feed, SBS, WESP and evaporator concentrate samples.
13.53	08/31/11 12:22	Containment tank outlet flow meter (FIR-3301) rescaled from 0-15LPH to -50 to 50 LPH. Display not updated.
17.83	08/31/11 16:40	Transferred feed to tank. Net transferred mass is 64.84 kg.
18.00	08/31/11 16:50	Past 1-2 hrs flow is through evaporator outlet (FIR-4301).
18.72	08/31/11 17:33	Cleared clog in evaporator recycle flow meter (FIR-4301) tubing. Ran in reverse for 5mins @ 5rpm. This seemed to clear clog.
19.20	08/31/11 18:02	Evaporator level low. Turned off power to pump P-401.
19.30	08/31/11 18:08	Pump P-401 is turned back on.
20.53	08/31/11 19:22	Feed rate too high. Adjusted rpm: recycle feed pump from 15 to 12, fresh feed pump from 12.6 to 11.6.
21.00	08/31/11 19:50	Turned off power to pump P-401.
21.08	08/31/11 19:55	Reduced fresh feed pump from 11.6 to 4 rpm.
21.30	08/31/11 20:08	Stopped feeding due to too much feed on top of 100% cold cap
23.17	08/31/11 22:00	Raised feed tube 1" to remove it from the wet feed.
24.23	08/31/11 23:04	Obtained SBS, WESP and evaporator concentrate samples.
25.80	09/01/11 0:38	Feed restarted at a reduced rate.
26.60	09/01/11 1:26	Restarted V-501 Turned off power to P-401 to raise liquid level in E1 sump.
26.75	09/01/11 1:35	Restarted P-401.
27.83	09/01/11 02:40	Fresh feed pump set to 13 rpm; recycle feed pump set to 13 rpm.
34.42	09/01/11 9:15	Found discharge chamber clogged. Cleared most of the clog. Need to allow discharge chamber temperature to increase from 795 °C. Removed ~0.18 kg glass.

Table 3.2.a. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 1 (continued).

Run Time (hr)	Time	Operational Notes
36.27	09/01/11 11:06	Obtained WESP, SBS, evaporator concentrate, and feed samples.
37.67	09/01/11 12:30	Observed WESP arcing and lowered voltage to 13 kvolts.
38.25	09/01/11 13:05	Feed tube clogged-mixing vessel pressure interlock faulted. Reset interlock and restarted Tc-99 pump.
39.03	09/01/11 13:52	Started off gas sampling.
39.75	09/01/11 14:35	Tc99 pump is stopped.
39.97	09/01/11 14:48	Completed off gas sampling.
40.02	09/01/11 14:51	Started Tc-99 pump.
43.00	09/01/11 17:50	Transferred feed to feed tank. Total mass is 66.26 kg (didn't stop feeding).
43.67	09/01/11 18:30	WESP power is not working.
45.25	09/01/11 20:05	Collected a WESP sample post a 1 gallon deluge.
45.33	09/01/11 20:10	Collected a WESP sample post a 1 gallon deluge.
45.80	09/1/11 20:38	Collected a WESP sample post a 1 gallon deluge.
46.58	09/1/11 21:25	~12 gal deluge on WESP no sample taken. Power on WESP failed. Deluge flow clean for last 8 gal. WESP current is fine. Voltage is at 0 volt. Water flow rate 3 lph.
47.20	09/1/11 22:02	Tc-99 injection is stopped, had to restart syringe pump.
48.02	09/1/11 22:51	High pressure of refrigeration cycle on commercial evaporator E2 dropped to 200 psig; turned off cooling water flow and reduced sump recirculation flow to bring pressure to 250-280 psig.
48.17	09/1/11 23:00	Reintroduced cooling water flow to E2.
48.43	09/1/11 23:16	Obtained liquid samples from feed, SBS and evaporator concentrate.
50.40	09/2/11 1:14	Found V-501 to be off, was restarted.
51.28	09/2/11 2:07	Paused feeding to clear recycle water line, also flushed air and water to the feed system.
51.57	9/2/11 2:24	Resume feeding.
51.72	9/2/11 2:33	Recycle liquid is clear.
52.52	9/2/11 3:21	Observed water level to E1 continues to drop.
60.02	09/02/11 10:51	Obtained feed, SBS and evaporator concentrate samples.
60.68	09/2/11 11:31	Turned off pump P-401. Evaporator sump level is low.
60.83	09/2/11 11:40	Pump P-401 is restarted water level is between the required levels.
61.30	09/2/11 12:08	Turned off water flow to WESP.

Table 3.2.a. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 1 (continued).

Run Time (hr)	Time	Operational Notes
61.33	09/2/11 12:10	Tc-99 pump is faulted and stopped.
61.47	09/2/11 12:18	Restarted Tc-99 pump.
62.08	09/2/11 12:55	Stopped and raised feed tank agitator.
62.18	09/2/11 13:01	Tc-99 pump is stopped for no apparent reason.
62.20	09/2/11 13:02	Tc pump is restarted.
62.60	09/2/11 13:26	Started off gas testing.
62.93	09/2/11 13:46	Stopped off gas testing.
63.00	09/2/11 13:50	Stopped feeding Tc-99, recycle water pump, fresh feed pump and water to SBS.
63.20	9/2/11 14:02	SBS and evaporator concentrate samples are taken.
63.42	9/2/11 14:15	Dip sample is taken.
65.33	9/2/11 16:10	Removed liquid from evaporator E1.
66.35	9/2/11 17:11	Removed liquids from evaporator E2.
66.52	9/2/11 17:21	Removed rinse liquid from evaporator 2.
67.58	9/2/11 18:25	Started off-gas and wet-dry procedure shut-down.
68.93	9/2/11 19:46	Removed SBS liquids into two 5-gallon buckets.
69.67	9/2/11 20:30	Opened HEPA Train #1. Found it is completely soaked. It will be cleaned out and a new pre and HEPA filter will be installed. Collected a sample of wet mass. (10R-O-7A).
69.88	9/2/11 20:43	Removed liquid from containment tank.
69.92	9/2/11 20:45	Added ~ 3 gallons of 5% nitric acid to WESP. This will be recirculated through the top sprayer to clean the rods.
70.17	9/2/11 21:00	Net feed mass removed is 6.960 kg.
Post Test Inspections and Cleanings: Added ~ 3 gallons of 5% nitric acid to WESP. This was recirculated through the top sprayer to clean the rods overnight. All sump solutions sampled, drained and rinsed: SBS, WESP, Containment, E1 and E2. Film cooler and transition line removed, inspected and sampled (rinsed). Recycle line contents sampled and rinsed.		
Post Test Equipment Modifications: 1. Melter feed mixing vessel removed 2. WESP insulators purge air added 3. Increased the number of level sensors on the evaporator sump from 1 to 3 in order to improve controllability 4. Pneumatic path between inlet and outlet added to evaporator to prevent liquid carryover 5. Reduced spray water flow to WESP to reduce liquid build up in the HEPA filter.		

Table 3.2.b. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 2.

Run Time (hr)	Time	Operational Notes
0	09/07/11 01:59	Feed Started:9/07/2011 01:59
0.05	09/07/11 02:02	Started Tc-99 waited for feed to fill the tube.
0.10	09/07/11 02:05	Recycle feed water pump set from 12.4 to 11.9 rpm; target 0.4 lph.
4.93	09/07/11 06:55	Recycle feed water pump set from 13.0 to 13.1 rpm.
8.87	09/07/11 10:51	Had quick loss of power to building, as a result roof blower has been running like before. Had to increase exhaust blower from 15 to 19 Hz.
12.02	09/07/11 14:00	Samples are collected from wet off gas system plus feed sample. SBS, evaporator sump, WESP, and feed sample are collected.
14.15	09/07/11 16:08	Started off gas sampling.
15.03	09/07/11 17:01	Tc-99 syringe pump is stopped. Cleared the alarm, now all is satisfactory.
15.12	09/07/11 17:06	Off-gas sampling is completed.
15.15	09/07/11 17:08	Found recycled water has stopped flowing. Ran the peristaltic pump in reverse at full speed.
15.38	09/07/11 17:22	Found recycled water has stopped. Somewhere in the feed system there is a clog.
16.12	09/07/11 18:06	Stopped feeding all together to find clog and clear it.
17.87	09/07/11 19:51	Flushed water through recycled water line, unable to clear line. Took apart the Tee that has the Tc-99 injection line. The line was cleared with air. Reinstalled the Tee and flushed air back into melter with little or no flow. Released pressure off the system. Removed small Teflon line (jumper) that connects to the feed tube. Found line that goes into the feed tube blocked about 1-2". Flushed line with water. Reinstalled the lines. Resumed feeding.
18.43	09/07/11 20:25	Cleaned the blockage out of discharge chamber.
20.28	09/07/11 22:16	Feed tube jumper line was clogged after the peristaltic pump. Air was used to clear the line.
22.70	09/08/11 00:41	Initiated auto mode for fresh feed.
22.85	09/08/11 00:50	Restored fresh feed to manual mode.
24.00	09/08/11 01:59	SBS sump, WESP sump and evaporator sump samples were taken.

Table 3.2.b. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 2 (continued).

Run Time (hr)	Time	Operational Notes
24.77	09/08/11 02:45	Moved hose on evaporator recycle pump to a new position. Rpm set point from 13.0 to 11.2.
25.78	09/08/11 03:46	Observed some fresh feed slightly at the recycle water tubing Tee junction.
28.60	09/08/11 06:35	Added 66.592 kg feed (Batch E)
35.98	09/08/11 13:58	Obtained all samples; feed, SBS, evaporator concentrate and WESP.
38.02	09/08/11 16:00	A copper tube was wrapped around the transition line, to act as a heat exchanger, and heat up the WESP insulator purge air.
38.25	09/08/11 16:14	Obtained a feed sample due to low reading.
39.75	09/08/11 17:44	Recycle water pump from 12.5 to 13.5 rpm; flow average low,
40.12	09/08/11 18:06	Collected a feed sample for gamma count.
41.63	09/08/11 19:37	Tc-99 pump is stopped had to reset.
41.68	09/08/11 19:40	Tc-99 pump is stopped again had to reset.
41.75	09/08/11 19:44	All pumps are stopped. No more feeding.
42.27	09/08/11 20:15	No feed is flowing out of feed tube. A clog was found in stainless steel braided jumper line. It was not able to be cleared through flush air and water due to pinch valve is not holding. Jumper line was taken apart and was connected to supply air in order to blow out the clog. Just started feeding; now all is satisfactory.
48.40	09/09/11 02:23	SBS, WESP and evaporator concentrate samples are taken.
48.73	09/09/11 02:43	Observed a drip of liquid at the fitting (inlet) of Tee from recycled water, will be tightened and monitored.
49.23	09/09/11 03:13	Tc-99 delivery was stopped 3 consecutive times.
49.77	09/09/11 03:45	Tc-99 once again stopped and restarted. Found E1 camera for liquid level is frozen and was refreshed.
53.18	09/09/11 07:10	E700 is tripped off line. Attempted to reset and failed. Shut off make-up water to SBS to prevent a backup of water into the evaporator.
53.77	09/09/11 07:45	Found the reset switch for E-700. It was reset and it is online.
54.02	09/09/11 08:00	Restarted SBS make-up water at 10 lph.
54.77	09/09/11 08:45	Tc-99 pump is faulted.
54.85	09/09/11 08:50	Cleared blockage in feed line with air.
54.93	09/09/11 08:55	Restarted Tc-99 pump.
55.10	09/09/11 09:05	Tc-99 pump was stopped. Stopped fresh feed and recycle pumps.
55.22	09/09/11 09:12	Used air supply to blow out clog in feed tube. Restarted recycle, Tc-99 and fresh feed pumps.

Table 3.2.b. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 2 (continued).

Run Time (hr)	Time	Operational Notes
55.70	09/09/11 09:41	Stopped Tc-99 pump, blockage is suspected somewhere.
55.80	09/09/11 09:47	Stopped fresh feed and recycle pumps.
56.45	09/09/11 10:26	Resumed feeding. Restarted recycle, feed and Tc-99 pumps.
58.70	09/09/11 12:41	Transferred feed "Batch F". Net transferred mass is 66.00 kg.
59.85	09/09/11 13:50	SBS, evaporator concentrate, WESP and feed samples were taken.
60.68	09/09/11 14:40	It was noticed that melter pressure was rising because the containment tank had filled completely, which caused WESP and SBS to fill up. This increased liquid head that the off-gas had to flow through, and caused the pressure rise in the melter. The containment tank height was not noticed till 9/9/2011 19:30 (test time 65.52) roughly 6 hours after the problem occurred.
60.72	09/09/11 14:42	Off-gas sampling is started.
62.20	09/09/11 16:11	Switched from HEPA #2 to HEPA #1 and cyclone #2 to cyclone #1 in order to resolve the high melter pressure.
62.42	09/09/11 16:24	Moved the line in the evaporator recycle pump to a new location because the flow rate was high. This decreased evaporator pump speed from 13.5 to 11.7 rpm.
65.25	09/09/11 19:14	Turned off make up water to SBS due to high water level.
66.30	09/09/11 20:17	Restarted make up water to SBS at 13 lph.
66.38	09/09/11 20:22	Tc-99 syringe pump is stopped was reset.
68.02	09/09/11 22:00	Stopped feeding.
68.15	09/09/11 22:08	SBS, WESP and evaporator concentrate samples are taken.
68.35	09/09/11 22:20	Cold cap is gone.
68.43	09/09/11 22:25	Removed feed from feed tank. Net feed mass removed is 50.640 kg.
68.52	09/09/11 22:30	A dip sample was taken.
69.35	09/09/11 23:20	Collected containment liquid with 2 flushes through recycled line. Used 500 ml of deionized water for both flushes. Samples are taken.
70.02	09/10/11 00:00	Removed liquid completely from SBS. Samples are taken.
70.38	09/10/11 00:22	Performed WESP deluge #1. Sample is taken.
71.02	09/10/11 01:00	V-300 containment tank completely blown down. Sample is taken.
71.27	09/10/11 01:15	SBS rinse water completely blown down. Sample is taken.
71.43	09/10/11 01:25	V-300 containment tank is rinsed. Sample is taken.
71.52	09/10/11 01:30	E1 is completely blown down. Sample is taken.

Table 3.2.b. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 2 (continued).

Run Time (hr)	Time	Operational Notes
71.80	09/10/11 01:47	Performed WESP deluge #2. Sample is taken.
72.18	09/10/11 02:10	E1 is rinsed; sample is taken.
72.65	09/10/11 02:38	E1 is rinsed second time; sample is taken.
72.85	09/10/11 02:50	Feed-Tc-99-recycle water line is flushed. Sample is taken.
73.02	09/10/11 03:00	E2 is completely blown down.
133.52	09/12/11 15:30	Obtained a solid sample from transition line, a dry powder. Approximately 2 g additional lost. Obtained a second sample by washing duct with deionized water. Duct appeared mostly clean after washing.
Post Test Inspections and Cleanings: After the test the transition line was removed and inspected. Solids were deposited in the line, a sample was obtained a dry powder (approximately 2 g additional were lost). A second sample was obtained by washing duct with deionized water. All sump solutions sampled, drained and rinsed: SBS, WESP, Containment, E1 and E2. Film cooler and transition line removed, inspected and sampled (rinsed). Recycle line contents sampled and rinsed.		
Post Test Equipment Modifications: 1. Evaporator control changed so that the level sensors changed the setpoint of the heating water instead of the recirculation pump speed. 2. High level alarm added to containment tank level sensor. 3. Heated dilution air added to WESP electrodes. 4. Band heater positioned around the top of the WESP.		

Table 3.2.c. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 3.

Run Time (hr)	Time	Operational Notes
0	09/19/11 15:30	Feed Started: 9/19/2011 15:30
0.17	09/19/11 15:40	Started Tc-99 after it was loaded and primed (CUA #121599 and 121600).
0.38	09/19/11 15:53	WESP sprayer flow rate is adjusted to 2 lph, SBS makeup water is adjusted to 11 lph; WESP voltage is holding at 25 kV and current is at 5 mA.
1.55	09/19/11 17:03	Noticed that WESP power is at 25.3 kV and current is at 4.6 mA.
3.62	09/19/11 19:07	WESP power has been reduced from 25 to 22kV and current is at 2.21 mA due to persistent arcing.
12.00	09/20/11 03:30	Liquid samples are taken from SBS, WESP, evaporator and feed.
14.72	09/20/11 06:13	Transferred Batch "B" to feed tank. Net mass transferred is 75.550 kg.
17.33	09/20/11 08:50	Placed recycle pump in prime for 3 cycles of 10 seconds each to clear recycle feed line
21.95	09/20/11 13:27	Tc-99 pump is stopped and reset.
22.13	09/20/11 13:38	Performed a 10 second prime run for recycle condensate pump.
24.02	09/20/11 15:31	Liquid samples are taken from SBS, WESP, and evaporator.
24.60	09/20/11 16:06	Opened a small port on the EOG line between the gate valve and melter pressure relief valve to help prevent liquid from forming in the bottom of EOG line.
25.53	09/20/11 17:02	V-501 heater is tripped off. Restarted the heater.
27.33	09/20/11 18:50	Found heater V-501 tripped off, turned back on and stopped flow from containment tank until the level drops in evaporator.
27.45	09/20/11 18:57	Opened flow from containment tank to evaporator. Off-gas sampling has started.
28.45	09/20/11 19:57	Off-gas sampling ended.
28.92	09/20/11 20:25	Primed recycle peristaltic pump 3 times for about 10 seconds each time to clear any solids that have built up in the line.
33.50	09/21/11 01:00	Transferred Batch "C" to feed tank.
33.92	09/21/11 01:25	Tc-99 delivery pump is stalled twice. Primed recycle water pump 3 times for 10 seconds each.
35.15	09/21/11 02:39	Tc-99 pump is stopped and restarted.

Table 3.2.c. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 3 (continued).

Run Time (hr)	Time	Operational Notes
36.00	09/21/11 03:30	Liquid samples are taken from SBS, WESP, evaporator and feed.
36.35	09/21/11 03:51	Tc-99 pump is stopped and reset.
37.22	09/21/11 04:43	Primed recycle peristaltic pump for about 10 seconds to clear any solids that have built up.
37.38	09/21/11 04:53	Tc-99 pump is stalled and restarted.
37.40	09/21/11 04:54	Primed recycle peristaltic pump for about 10 seconds to clear any solids that have built up.
37.75	09/21/11 05:15	Tc-99 pump continue to stall (~8 times). The line is flushed completely including with 500 ml of tap water. Flushed with air and primed with recycle water before resuming. The feed was never stopped.
37.82	09/21/11 05:19	Tc-99 pump is stalled 4 times. Force level to the pump was increased.
37.88	09/21/11 05:23	Switching V-501 heater mode to manual.
41.87	09/21/11 09:22	Tc-99 pump is stalled 3 times.
44.00	09/21/11 11:30	Tc-99 pump is stalled and restarted.
44.25	09/21/11 11:45	Tc-99 pump is still having problems. Feed line will be replaced from Tc-99 pump.
44.87	09/21/11 12:22	Resumed feeding of Tc-99, replaced the line and primed down. Tc-99 was down for 37 minutes.
45.65	09/21/11 13:09	Noticed that WESP was arcing; was reduced to 19 kV.
46.15	09/21/11 13:39	Tc-99 pump is stopped and restarted.
46.20	09/21/11 13:42	Tc-99 pump is stopped 3 times; flushed recycle water pump.
46.40	09/21/11 13:54	Turned off SBS make up water and turned off recycle water pump.
46.52	09/21/11 14:01	Restarted SBS make up water and recycle water pump. Tc-99 pump was down for about 21 minutes.
48.00	09/21/11 15:30	Liquid samples were taken from SBS, WESP and evaporator. evaporator flow to melter is stopped.
48.80	09/21/11 16:18	Rebooted the computer. Operator has no control of the LabVIEW virtual instrument. Lost power to interlock. Operator could not reset computer. WESP air heaters were shut off.
49.70	09/21/11 17:12	LabVIEW virtual instrument could be controlled now.
50.00	09/21/11 17:30	Restarted feeding slurry, recycle water and Tc-99
52.53	09/21/11 20:02	LabVIEW data was lost for 1-2 minutes due to switching out of server.

Table 3.2.c. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 3 (continued).

Run Time (hr)	Time	Operational Notes
52.83	09/21/11 20:20	Switched to a new section of master flex through the peristaltic pump on feed.
54.13	09/21/11 21:38	Stopped feeding due to regenerative blower overheating.
54.17	09/21/11 21:40	Turned off power to WESP, heaters and shut flows off.
54.67	09/21/11 22:10	Collected feed sample from the feed tube. Collected liquid samples from SBS, WESP and evaporator.
55.60	09/21/11 23:06	Melter, feed systems and off gas shut downs continue.
55.60	09/21/11 23:06	Melter is switched from temperature to power control.
56.33	09/21/11 23:50	Completed feed removal. Net mass of feed removed is 7.68 kg.
58.33	09/22/11 01:50	A dip sample was taken.
60.83	09/22/11 04:20	WESP, SBS evaporators and recycle water line are rinsed.
71.33	09/22/11 14:50	Samples from transition line are taken.
72.00	09/22/11 15:30	Sample from EOG port is taken.
72.92	09/22/11 16:25	Collected build-up from the Tee that connects the film cooler to transition line.
73.50	09/22/11 17:00	Collected sample by washing down the film cooler.
74.85	09/22/11 18:21	Transition line is flushed with 0.75 % HNO3 and rinsed with DI water.
Post Test Inspections and Cleanings: Transition line is flushed with 0.75 % HNO3 and rinsed with DI water. All sump solutions sampled, drained and rinsed: SBS, WESP, Containment, E1 and E2. Film Cooler inspected and sampled (rinsed). Recycle Line contents sampled and rinsed.		
Post Test Equipment Modifications: 1. Regenerative Blower P-200 replaced with a new regenerative blower.		

Table 3.2.d. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 4.

Run Time (hrs)	Time	Operational Notes
0	09/26/11 16:40	Feed Started: 9/26/2011 16:40
0.03	09/26/11 16:42	Started Tc-99 syringe pump.
2.63	09/26/11 19:18	Reduced WESP power from 25 kV to 24 kV due to power tripping off.
2.87	09/26/11 19:32	Reduced WESP power to 22 kV. Power was tripping off.
6.25	09/26/11 22:55	Adjusted WESP power to 21.9 kV.
8.47	09/27/11 01:08	Noticed a leak on HV-1609, SBS water inlet.
9.10	09/27/11 01:46	Adjusting WESP power to 21.8 kV.
12.00	09/27/11 04:40	Liquid samples taken from SBS, WESP and evaporators.
12.33	09/27/11 05:00	Liquid level on E1 reached high level mark. Momentarily closed process water outlet valve HV-3606.
16.00	09/27/11 08:40	Transferred Batch "B" to feed tank. Net mass transferred is 69.66.
16.50	09/27/11 09:10	Rodded melter/shelf.
16.87	09/27/11 09:32	Rodded melter/shelf.
18.18	09/27/11 10:51	Rodded cold cap which was 100%, foamy and thick.
19.15	09/27/11 11:49	Rodded melter/shelf.
19.78	09/27/11 12:27	Rodded melter/shelf.
20.10	09/27/11 12:46	Rodded melter/shelf.
20.75	09/27/11 13:25	Stopped all feeding to change voltage taps. Stopped SBS make up water flow. All feeds are fresh feed, Tc-99 feed and recycled water feed.
20.83	09/27/11 13:30	Turned off power to electrodes.
20.87	09/27/11 13:32	Electrodes have been re-energized and resumed SBS make up water.
20.92	09/27/11 13:35	Resumed all feeding.
23.17	09/27/11 15:50	Switched jumper hose to a new section through peristaltic pump.
24.00	09/27/11 16:40	Liquid samples taken from SBS, WESP and evaporators.
24.43	09/27/11 17:06	Noticed air pockets in the recycle tubing; primed the line for about 20 seconds to clear.

Table 3.2.d. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 4 (continued).

Run Time (hrs)	Time	Operational Notes
25.67	09/27/11 18:20	WESP power was increased from 20 to 25 kV and current is 4.8 mA.
25.82	09/27/11 18:29	Reduced WESP power to 23 kV due to arcing.
25.93	09/27/11 18:36	Melter pressure is spiked due to port being opened for off-gas testing.
26.05	09/27/11 18:43	Moved the tubing to a new section through peristaltic pump for the recycle flow.
26.95	09/27/11 19:37	Melter pressure spiked due to off-gas sampling completion.
30.92	09/27/11 23:35	Increased recycled water feed rate for 2-3 minutes from 0.4 to 4.0 lph to flush line.
31.83	09/28/11 00:30	Briefly boosted Tc-99 delivery. It may clear any blocking. Gamma count on previous samples have plateaued or even perhaps gone down.
33.28	09/28/11 01:57	Observed WESP arc. Reduced WESP power to 22.3 kV.
33.63	09/28/11 02:18	Reduced WESP power to 22.0 kV from 22.3 kV.
34.58	09/28/11 03:15	Reduced WESP power to 21.0 kV from 22.0 kV.
35.35	09/28/11 04:01	Transferred Batch "C" to feed tank. Net mass transferred is 69.32 kg. Scraped solids on the mixing blade and inside wall of the feed tank.
36.00	09/28/11 04:40	Started off-gas sampling. Liquid samples taken from feed, SBS, WESP and evaporators.
39.67	09/28/11 08:20	Manually removed solids from the melter shelf.
41.52	09/28/11 10:11	Tc-99 pump is stopped was reset and turned the pump on.
41.55	09/28/11 10:13	Tc-99 pump continues to stall.
41.83	09/28/11 10:30	Tc-99 pump has been running for 5 minutes without any problems.
42.43	09/28/11 11:06	Took a WESP sample (10S-W-68A).
43.92	09/28/11 12:35	Cold cap is foamy with a hard crust. There is a buildup on the west wall. Removed shelf manually.
44.08	09/28/11 12:45	Reduced melter vacuum decreased the level in the SBS, reducing the overflow to the containment tank. U-501 was turned off to maintain minimum level in E1 evaporator. When melter vacuum was restored, the SBS level restored and U-501 was turned back on.
46.92	09/28/11 15:35	Moved fresh feed tubing to a new section through peristaltic pump. Fresh feed pump speed reduced from 13.8 to 12.8 rpm.
48.00	09/28/11 16:40	Liquid samples taken from SBS, WESP and evaporators.

Table 3.2.d. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 4 (continued).

Run Time (hrs)	Time	Operational Notes
50.98	09/28/11 19:39	Rodded melter shelf.
51.17	09/28/11 19:50	Moved the recycle line tubing to a new section through peristaltic pump.
53.83	09/28/11 22:30	Tc-99 pump is stalled and was reset.
53.87	09/28/11 22:32	Tc-99 pump is stalled and was reset two times.
53.95	09/28/11 22:37	Tc-99 pump is stalled and was reset three times.
54.03	09/28/11 22:42	Stop all feeding.
54.07	09/28/11 22:44	Started all feeds again. Tc-99 is not working yet. Replaced stainless steel jumper tubing on Tc-99 pump.
54.13	09/28/11 22:48	Started Tc-99 pump; now it is working. Pump was stalled four times.
54.42	09/28/11 23:05	Rodded melter shelf a few times.
54.43	09/28/11 23:06	Transferred Batch "D" to feed tank. Net mass transferred is 68.66 kg.
54.73	09/28/11 23:24	Stop all feeding.
54.83	09/28/11 23:30	Resumed all feeding.
55.30	09/28/11 23:58	Increased WESP power from 21 to 21.5 kV, its current is 2.3 mA.
55.48	09/29/11 00:09	Stop all feeding to replace Tc-99 delivery unit.
55.87	09/29/11 00:32	Resumed all feeding.
56.12	09/29/11 00:47	Increased WESP power from 21.0 kV to 21.5 kV.
57.07	09/29/11 01:44	Increased WESP power from 21.5 kV to 21.7 kV, its current is 2.3 mA. When WESP voltage is higher than 21.7 kV, it is unstable.
59.52	09/29/11 04:11	Reduced WESP power from 21.7 to 20.5 kV.
60.00	09/29/11 04:40	Liquid samples taken from feed, SBS, WESP and evaporators.
61.30	09/29/11 05:58	Increased recycle water flow to 4 lph to clear the line.
62.70	09/29/11 07:22	Rodded melter shelf.
65.45	09/29/11 10:07	Rodded melter shelf.
67.25	09/29/11 11:55	Cold cap ~90%, shelf and build up on all sides of melter.
68.17	09/29/11 12:50	Manually removed shelf.
70.92	09/29/11 15:35	Scraped down walls of the feed tank.
72.00	09/29/11 16:40	END OF TEST #4. Stopped feeding slurry, recycle water, Tc-99.
72.02	09/29/11 16:41	Collected liquid samples of feed, WESP, SBS and evaporators.

Table 3.2.d. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 4 (continued).

Run Time (hrs)	Time	Operational Notes
72.42	09/29/11 17:05	Removed feed from feed tank Net feed removed is 10.72 kg.
72.50	09/29/11 17:10	Cold cap is gone.
73.63	09/29/11 18:18	Collected a dip sample.
74.17	09/29/11 18:50	Collected first recycled sample.
74.72	09/29/11 19:23	Performed WESP deluge.
74.92	09/29/11 19:35	Drained SBS.
75.33	09/29/11 20:00	Drained containment tank.
75.52	09/29/11 20:11	Drained evaporator 1 and evaporator 2.
76.08	09/29/11 20:45	Collected a rinse of evaporator 1.
76.55	09/29/11 21:13	Collected additional WESP liquid that has drained from the deluge.
76.88	09/29/11 21:33	Collected dry powder from transition line.
77.42	09/29/11 22:05	Collected rinse of film cooler.
77.48	09/29/11 22:09	Performed rinse of SBS.
78.43	09/29/11 23:06	Transition line is rinsed and rinse water is collected.
78.50	09/29/11 23:10	Particles from the Tee between the transition line and the film cooler are collected.
78.70	09/29/11 23:22	Rinsed transition line second time and collected rinse water.
79.02	09/29/11 23:41	Containment tank is rinsed.
79.68	09/30/11 00:21	Sleeve inside SBS after film cooler and bellow are rinsed.
Post Test Inspections and Cleanings All sump solutions sampled, drained and rinsed: SBS, WESP, Containment, E1 and E2. Film Cooler and Transition Line removed, inspected and sampled (rinsed). Recycle Line contents sampled and rinsed.		
Post Test Equipment Modifications 1. Expansion tank added to evaporator heating water loop. 2. Transition line wash down installed. 3. Change in Tc delivery method. Dose added directly to fresh feed. Eliminated pump stalling issues. 4. Failed sensor PIR-4201 replaced.		

Table 3.2.e. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 5.

Run Time (hr)	Time	Operational Notes
0	12/13/11 12:45	Feed Started: 12/13/2011 12:45
4.17	12/13/11 16:55	Found feed tube is clogged.
5.82	12/13/11 18:34	Rodded to knock down build up underneath feed tube.
6.00	12/13/11 18:45	Transition line is sprayed 1 minute.
6.25	12/13/11 19:00	Took feed sample.
8.38	12/13/11 21:08	Rodded cold cap.
8.80	12/13/11 21:33	Rodded shelf left behind after discharge.
12.00	12/14/11 00:45	Took SBS, WESP, E1 and E2 samples.
13.75	12/14/11 02:30	Start of feed transfer of "Batch B" to feed tank. Net mass transferred is 73.335 kg (includes 2.50 kg water). Tc spike also added.
14.18	12/14/11 02:56	Resumed feeding.
14.70	12/14/11 03:27	Stopped feeding. Feeding problems, tube was clogged near the opening.
15.07	12/14/11 03:49	Resumed feeding.
18.22	12/14/11 06:58	Started transition line flush for 1 min.
18.58	12/14/11 07:20	Performed transition line flush for 1 min.
18.92	12/14/11 07:40	Sampled evaporator waste water. Found no contamination, switched discharge to sink.
24.00	12/14/11 12:45	Collected SBS sump, WESP sump, WESP sump, vacuum evaporator sump, feed upstream sample.
24.45	12/14/11 13:12	Paused feeding for ~5 min. to collect feed sample.
26.17	12/14/11 14:55	Rodded cold cap.
26.38	12/14/11 15:08	Feed pump lowered from 11 to 6 rpm to allow recovery from conditions in melter.
26.58	12/14/11 15:20	Rodded EOG line which is half open. (OG port was 100% blocked).
27.28	12/14/11 16:02	Rodded build up.
27.82	12/14/11 16:34	Feed pump raised from 6 to 10 rpm due to improving conditions in melter.
30.22	12/14/11 18:58	Started transition line flush for 1 min.
32.52	12/14/11 21:16	Rodded cold cap.
32.97	12/14/11 21:43	Paused feeding to transfer feed, recycle water rate increased from 0.4 lph to 3.0 lph for 3 minutes to clear possible clogs.
33.13	12/14/11 21:53	Resumed feeding.
36.42	12/15/11 01:10	Obtained SBS, WESP E1 and E2, feed samples.
42.20	12/15/11 06:57	Performed transition line flush for 1 min.

Table 3.2.e. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 5 (continued).

Run Time (hr)	Time	Operational Notes
44.85	12/15/11 09:36	Paused feeding for 2 min to take sample.
48.08	12/15/11 12:50	Pulled SBS, WESP, E1 samples.
50.32	12/15/11 15:04	Off gas sampling started.
51.32	12/15/11 16:04	Off gas sampling ended.
51.78	12/15/11 16:32	Paused feeding to transfer feed Net mass transferred is 75.405 kg. The Tc-99 added with syringe slowly as the feed was being transferred.
52.05	12/15/11 16:48	Resumed feeding, during transfer transformer taps changed from 60V to 40 V.
53.70	12/15/11 18:27	Rodding cold cap to open up.
54.02	12/15/11 18:46	Flushed transition line down for 1 minute.
55.87	12/15/11 20:37	Rodded shelf.
56.45	12/15/11 21:12	Melter pressure spiked to 0.1 "WC. It was a software glitch.
56.55	12/15/11 21:18	Rodded cold cap.
56.73	12/15/11 21:29	Rodded west side of the feed tube.
57.10	12/15/11 21:51	Rodded cold cap.
57.30	12/15/11 22:03	Rodded cold cap it is 100% now.
57.60	12/15/11 22:21	Rodding cold cap again. It is 100%.
57.90	12/15/11 22:39	Rodded cold cap, which is 100%, cold cap was up to feed tube.
60.02	12/16/11 00:46	Feed, SBS, WESP, E1 and E2 Sampling.
61.72	12/16/11 02:28	Alarm, failure in MD1 MOD4, National Instruments Analog input card. Pump still running. No reading on LabVIEW.
61.72	12/16/11 02:28	Problems with LabVIEW chassis. Paused feeding at 2:30, decided to go to EOG due to uncertain conditions of LabVIEW data. Testing on hold until further notice.

Table 3.2.e. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 5 (continued).

Run Time (hr)	Time	Operational Notes
61.75	12/16/11 02:30	Stopped feeding.
62.98	12/16/11 03:44	Completed off-gas and melter shutdowns.
63.07	12/16/11 03:49	It was determined that testing could no longer continue due to component failure. Accurate data recording was lost, as well as melter vacuum indications and containment tank auto switching.
63.08	12/16/11 03:50	Flushed feed line; checked discharge can.
66.08	12/16/11 06:50	Obtained a dip sample.
67.75	12/16/11 08:30	Stopped AOD; cleared recirculation line. Feed sample is taken.
68.25	12/16/11 09:00	Removed feed from feed tank 48.570 kg feed was removed.
Post Test Inspections and Cleanings: All sump solutions sampled, drained and rinsed: SBS, WESP, Containment, E1 and E2. Film cooler and transition line removed, inspected and sampled (rinsed). Recycle line contents sampled and rinsed.		
Post Test Equipment Modifications: Vessel for diluting Tc dose and gravity feeding Tc into feed tank added to system		

Table 3.2.f. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 6.

Run Time (hr)	Time	Operational Notes
0	01/09/12 12:11	Feed Started: 1/9/2012 12:11
3.07	01/09/12 15:15	Adjusted WESP voltage to down to 18 kV; current is at 0.6 mA, due to constant arcing.
4.77	01/09/12 16:57	Rodded cold cap after glass discharge.
5.05	01/09/12 17:14	Interlock alarmed due to software problem.
5.85	01/09/12 18:02	Performed transition line spraying.
6.08	01/09/12 18:16	Collected a feed sample.
6.52	01/09/12 18:42	Added 1 liter of water and syringe #2 to the holding tank above feed tank. (CUA #121862 and 121863).
12.27	01/10/12 00:27	Feed, SBS WESP, E1 and E2 samples are taken.
17.63	01/10/12 05:49	Alarms; LabVIEW spiked down on all graphs. Silenced horn. All satisfactory.
17.73	01/10/12 05:55	Feed rate dropped after the alarm. Stopped feeding, turned feed off with LabVIEW. Turned feed back on after moving hose.
17.98	01/10/12 06:10	Performed transition line spraying.
18.52	01/10/12 06:42	Paused feeding for feed transfer, (2 kg water included) 1 kg water for Tc-99 is included. Net mass added is 79.145. (CUA Ref #1892-11 041)Batch "B" Tc-99 CUA #121862, 121863 Syringe #2).
18.60	01/10/12 06:47	Continued feeding
19.98	01/10/12 08:10	Rodded cold cap.
22.82	01/10/12 11:00	Fresh feed pump target rate reduced from 4.00 kg/hr to 3.85 kg/hr
23.97	01/10/12 12:09	To 12:23 Feed, SBS WESP and E1 -samples are taken.
25.97	01/10/12 14:09	Off gas sampling started.
26.97	01/10/12 15:09	Melter pressure spike due to off-gas sampling.
27.45	01/10/12 15:38	WESP is arcing. Tried to adjust the voltage down with no improvement.
27.68	01/10/12 15:52	Found that controllers for WESP heaters are not working right. Leave the controller in manual mode; output set to 0.5 kW for now.

Table 3.2.f. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 6 (continued).

Run Time (hr)	Time	Operational Notes
28.58	01/10/12 16:46	Found that the isolation valve HV-2610 of WESP was closed. This allowed WESP to fill up with water and short out. Now in process of draining WESP into containment tank. WESP power now @21.5kW and 1.5 mA.
28.80	01/10/12 16:59	Due to too much water in the system, the SBS makeup water has been decreased from 11.0 to 5 lph and WESP from 2.0 to 1.5 lph.
29.05	01/10/12 17:14	Filled external syringe tank with 1 liter of water and spiked it with Tc-99m (CUA #121862 and 121863).
29.42	01/10/12 17:36	The level of the containment tank has come down. Restored SBS make-up water to 11.0 lph and WESP make-up to 2 lph.
29.85	01/10/12 18:02	Evaporator heater U-501 now being controlled by LabVIEW, still in manual mode at 60 °C, and switched to auto at 18:16.
31.52	01/10/12 19:42	Performed transition line spraying
31.70	01/10/12 19:53	Shifted tubing on peristaltic pump.
32.05	01/10/12 20:14	Evaporator high level alarm sounded. Increase temp setpoint from 60 to 65 °C also increase mid level setpoint to 65 from 55 °C.
34.42	01/10/12 22:36	WESP is arcing.
35.02	01/10/12 23:12	Lost function of E-700 evaporator unit. Also lost about 5 minutes of feeding due to alarm silence switch which was left on, securing power to fresh feed peristaltic pump.
35.72	01/10/12 23:54	Currently draining E-700 unit (17.44 kg)
35.73	01/10/12 23:55	Turned off SBS make up water until E-700 gets back in operation.
36.20	01/11/12 00:23	E-700 is now officially back up. SBS Make up water resuming at 11 lph.
36.23	01/11/12 00:25	Feed, SBS WESP, E1 and E2 samples are taken
38.33	01/11/12 02:31	Paused feeding for feed transfer, (2 kg additional water) Net mass added is 79.400. (CUA Ref #1892-11 Page 42 Batch "C" Tc-99 CUA #121862 , 121863 Syringe #3).
38.42	01/11/12 02:36	Resumed feeding.

Table 3.2.f. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 6 (continued).

Run Time (hr)	Time	Operational Notes
41.22	01/11/12 05:24	It appears that trouble getting liquid to properly flow across P-401 has been resolved without any feed interruption. Inlet to P-401 and recycle water pump have been reconfigured to other ports on the E1 vessel.
41.88	01/11/12 06:04	Performed transition line spraying.
43.82	01/11/12 08:00	Pulled residual water from P401 repair diluted to 500 ml. (10T-O-86A).
43.90	01/11/12 08:05	P401 evaporator recirculation pump has an air leak resulting in sporadic flow. P401 has been taken offline for repair. V-501 set point has been increased to compensate for the lack of recirculation.
45.90	01/11/12 10:05	P401 back in service. It has been rebuilt and U-501 is back in auto mode.
47.10	01/11/12 11:17	Recycle water feed dropped due to changing out feed tube on recycle pump for 8 minutes.
47.92	01/11/12 12:06	Feed, SBS WESP and E1 samples are taken.
50.05	01/11/12 14:14	Off-gas sampling started. 15:16 completed.
51.33	01/11/12 15:31	Moved jumper hose to a new section.
53.77	01/11/12 17:57	Filled external tank with 1 liter of water and syringe #4 (CUA #121862, 121863).
53.95	01/11/12 18:08	Started 54 hr spray of transition line.
56.22	01/11/12 20:24	Rodded inside melter.
57.02	01/11/12 21:12	Paused feeding for feed transfer, (includes 2 kg water; 1 kg for Tc 99m) Net mass added is 78.665. (CUA Ref #1892-11 Page 42 Batch "D" Tc-99 CUA #121862, 121863 Syringe #4). 1 kg water for flush.
57.12	01/11/12 21:18	Resumed feeding.
59.65	01/11/12 23:50	Discovered air pockets along P-401 cycling, will monitor.
60.42	01/12/12 00:36	Feed, SBS WESP, E1 and E2 samples are taken.
65.82	01/12/12 06:00	Performed transition line spraying.
66.62	01/12/12 06:48	Paused feeding for feed sample.
66.65	01/12/12 06:50	Resumed feeding.
68.23	01/12/12 08:25	Adjusted feed tube at peristaltic pump.
71.83	01/12/12 12:01	SBS WESP, E1 samples are taken.
72.00	01/12/12 12:11	STOP FEEDING. End of Test #6.

Table 3.2.f. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 6 (continued).

Run Time (hr)	Time	Operational Notes
72.03	01/12/12 12:13	12:16 Collected P-400 flush samples.
72.15	01/12/12 12:20	Dip sample, secondary phase observed
72.32	01/12/12 12:30	Removed feed from feed tank; 22.995 kg feed removed. Feed sample taken.
72.55	01/12/12 12:44	Second dip sample, secondary phase observed.
73.50	01/12/12 13:41	Dip sample taken, secondary phase observed.
74.12	01/12/12 14:18	Dip sample taken, secondary phase observed
74.48	01/12/12 14:40	Started feeding water to remove secondary phase/sulfates.
74.98	01/12/12 15:10	Stopped feeding water to melter.
75.32	01/12/12 15:30	Dip sample.
79.32	01/12/12 19:30	Finished melter and off-gas shut down.
Post Test Inspections and Cleanings: All sump solutions sampled, drained and rinsed: SBS, WESP, Containment, E1 and E2. Film cooler and transition line removed, inspected and sampled (rinsed). Recycle line contents sampled and rinsed.		

Table 3.2.g. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 7.

Run Time (hr)	Time	Operational Notes
0	01/17/12 11:10	Feed Started: 1/17/2012 11:10
1.62	01/17/12 12:47	WESP is arching. Reduced voltage to 21.2 kV from 24.0 kV, 2.2 mA.
3.42	01/17/12 14:35	Target feed rate changed from 4.0 kg/hr to 3.8 kg/hr.
4.32	01/17/12 15:29	Rodded melter.
4.63	01/17/12 15:48	Melter pressure spiked due to melter rodding.
5.20	01/17/12 16:22	Target feed rate changed from 3.8 kg/hr to 3.5 kg/hr.
5.37	01/17/12 16:32	Manually rodded cold cap and build up which caused spike in pressure and foaming of the feed on the melt pool surface (observed when rodding cold cap at times throughout the test).
5.60	01/17/12 16:46	Paused feeding due to liquid feed depositing high up in plenum area.
5.97	01/17/12 17:08	Resumed feeding slurry and recycled water. Had to clear EOG line and rod shelf which was touching the feed tube. Right after rodding through viewport, feeding was resumed.
7.32	01/17/12 18:29	Rodded cap after discharge.
8.42	01/17/12 19:35	Started 6 hr spray of transition line.
8.57	01/17/12 19:44	Collected a feed sample
8.83	01/17/12 20:00	Evaporator 1 below low level; alarm sounded. Reduced temperature to 40 °C.
9.08	01/17/12 20:15	Rodded cold cap.
10.97	01/17/12 22:08	Performed back air flush on feed recirculation system.
11.67	01/17/12 22:50	Slightly rodded 100% cold cap.
11.73	01/17/12 22:54	Performed manual dislodge of shelf cap.
12.00	01/17/12 23:10	Pulled SBS, WESP, E1 and E2 samples. Completed 23:37.
12.08	01/17/12 23:15	Large portion of shelf cap remains behind the feed tube, not able to reach during rodding.
12.30	01/17/12 23:28	E1 reaching high level, setting alarm off.
17.95	01/18/12 05:07	Started 18 hr spray of transition line.
20.17	01/18/12 07:20	Obtained E-700 waste water from waste drum. 389 gram, gamma count was low, switched from tank to drain.
20.43	01/18/12 07:36	Moved feed tube to a different section of tube.
21.07	01/18/12 08:14	Paused feeding for feed transfer, (2 kg water included) 1 kg water for Tc-99 is included. Net mass added is 77.455 kg. (CUA Ref #1892-11 P128 Batch "B"Tc-99 CUA #121881, 121882 Syringe #2).

Table 3.2.g. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 7 (continued).

Run Time (hr)	Time	Operational Notes
21.22	01/18/12 08:23	Continued feeding.
24.18	01/18/12 11:21	Pulled SBS, WESP, and E1 samples.
27.97	01/18/12 15:08	Found EOG 1/2 blocked. Rodded out EOG, mostly cleared. Also rodded build up that was above feed tube.
28.25	01/18/12 15:25	Rodded melter after discharge.
28.45	01/18/12 15:37	Off gas sampling to 16:36.
29.92	01/18/12 17:05	Replaced plunger tool sleeve due to hole in it. It was allowing too much air in. Causing plenum temps to stay low.
30.02	01/18/12 17:11	Started 30 hr spray of transition line.
30.55	01/18/12 17:43	External tank has 1 kg of water with Tc99m spiked using syringe #3. (CUA #121881 and 121882).
31.07	01/18/12 18:14	Paused feeding to collect feed sample.
31.98	01/18/12 19:09	Rodded cold cap after discharge, large amount of buildup on the walls.
33.00	01/18/12 20:10	Moved tubing to a new section through peristaltic pump.
34.22	01/18/12 21:23	Rodded cold cap which in turn closed the cap up.
35.28	01/18/12 22:27	Rodded EOG line it was 1/2 way blocked.
35.65	01/18/12 22:49	A brief alarm from feed recycle water pump.
36.08	01/18/12 23:15	Melter pressure spike occurrence appears to be from the computer server.
36.22	01/18/12 23:23	Cold cap after discharge is 80%; no separation, but left significant amount of buildup on south & east wall.
36.48	01/18/12 23:39	Pulled SBS, WESP, E1 and E2 samples.
36.60	01/18/12 23:46	High E1 alarm; adjusting “above mid” temp from 60 to 65 °C.
36.78	01/18/12 23:57	Increased chiller set point from 62 to 63 °C.
36.85	01/19/12 00:01	Reduced temp setting to “above mid" from 65 to 60 °C.
40.65	01/19/12 03:49	Prior to glass discharge slight separation observed. Rodded to dislodge along with existing build up accumulation on the walls.
42.02	01/19/12 05:11	Started 42 hr spray of transition line.
42.25	01/19/12 05:25	WESP voltage is reduced to 20.2 kV due to constant arcing. Current 1.0 -0.85 mA.
45.85	01/19/12 09:01	Moved feed tube to a different section.

Table 3.2.g. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 7 (continued).

Run Time (hr)	Time	Operational Notes
46.42	01/19/12 09:35	Paused feeding for feed transfer, (2 kg additional water). Net mass added is 77.440 kg. (CUA Ref #1892-11 Page 129 Batch "C". Tc-99 CUA #121881 , 121882 Syringe #3).
46.50	01/19/12 09:40	Resumed feeding.
47.92	01/19/12 11:05	Feed, SBS WESP and E1 samples are taken.
51.97	01/19/12 15:08	Found EOG line 3/4 blocked. Rodded EOG out 100% open. Also rodded build up inside melter.
53.47	01/19/12 16:38	Found two blockages in jumper line. Paused feeding to flush line out. All set now.
54.00	01/19/12 17:10	Started 54 hr spray of transition line.
55.37	01/19/12 18:32	Found another blockage in jumper hose; cleared the blockage.
56.07	01/19/12 19:14	Observed a sharp pressure spike due to fair amount of wet feed on the surface. Also observed that 7103, 7106 and feed rate for fresh feed all plummeted in conjunction with pressure spike.
57.12	01/19/12 20:17	Stopped feeding to collect fresh feed sample.
57.17	01/19/12 20:20	Resumed feeding slurry.
59.67	01/19/12 22:50	Observing P-401 head is grinding much harder than previously noted.
60.57	01/19/12 23:44	Feed, SBS WESP, E1 and E2 samples are taken.
60.72	01/19/12 23:53	Evaporator level high alarm. Switched to LV-3607 override to manual for a few minutes, till liquid level went down, switched back to automatic. All satisfactory.
65.67	01/20/12 04:50	Got low level alarm, liquid is at 2 1/2" in sight glass.
66.00	01/20/12 05:10	Started 66 hr spray of transition line.
71.12	01/20/12 10:17	Changed position of feed tube in pump.
72.50	01/20/12 11:40	END OF TEST #7.
72.87	01/20/12 12:02	Removed feed from tank. Net 5.0 kg feed was removed.
72.78	01/20/12 11:57	Feed, SBS WESP, E1 and E2 samples are taken.
73.50	01/20/12 12:40	Started off gas shut down.
77.00	01/20/12 16:10	Turned off mass flow controller.
77.33	01/20/12 16:30	Dip sample taken.
Post Test Inspections and Cleanings: All sump solutions sampled, drained and rinsed: SBS, WESP, Containment, E1 and E2. Film cooler and transition line removed, inspected and sampled (rinsed). Recycle line contents sampled and rinsed.		

Table 3.2.h. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 8.

Run Time (hr)	Time	Operational Notes
0	02/20/12 11:30	Feed Started: 2/20/2012 11:30
4.57	02/20/12 16:04	Loaded external tank with syringe #2 and 1 liter of water (CUA #122147 and 122148).
5.05	02/20/12 16:33	Performed transition line flush.
5.62	02/20/12 17:07	Feed pump speed changed from 7.3 to 7.0 rpm.
7.07	02/20/12 18:34	Feed sample from union. Feeding paused ~2 minutes.
7.92	02/20/12 19:25	Feed pump speed changed from 6.7 to 6.9 rpm.
10.25	02/20/12 21:45	Commercial evaporator is experiencing a high water condition. Investigating.
10.50	02/20/12 22:00	Evaporator 1 level is high.
10.53	02/20/12 22:02	Closed heater override.
10.57	02/20/12 22:04	Feed pump speed changed from 6.9 to 7.0 rpm
11.08	02/20/12 22:35	SBS, WESP, E1, E2 and feed samples are taken
16.53	02/21/12 04:02	Transferred feed "Batch B" to feed tank. Net mass transferred is 76.32 kg (includes 2.0 kg flush water), Syringe #1 Tc-99m (CUA #122147-148). No feed interruption. Fresh feed and recycled water never stopped.
18.12	02/21/12 05:37	Performed transition line flush.
24.02	02/21/12 11:31	SBS, WESP, E1, samples are taken.
24.18	02/21/12 11:41	Paused feeding to collect feed sample (2 min interruption).
26.80	02/21/12 14:18	Waste water drum sampled. No activity; shifted evaporator discharge to sink. Discharge shifted back to waste drum. Counter said there is Tc-99 in discharge water.
27.83	02/21/12 15:20	Up to 16:32 Off gas testing.
28.50	02/21/12 16:00	Feed pump speed changed from 7.5 to 7.6 rpm
29.63	02/21/12 17:08	Added 1L of water to external tank with Tc99M, syringe #3 (CUA#122147 & 122148).
30.02	02/21/12 17:31	Performed transition line flush.
30.67	02/21/12 18:10	Knocked down buildup on east wall.
33.70	02/21/12 21:12	Rodded build up left by discharge.
34.60	02/21/12 22:06	Transferred feed "Batch C" to feed tank. Paused feeding. Net mass transferred is 75.925 kg. (Ref. VSL-1904-12 P. 75). Net mass includes 2 kg of flush water and Syringe #3.
34.72	02/21/12 22:13	Resumed feeding.
36.43	02/21/12 23:56	SBS, WESP, E1, E2 and feed samples are taken.

Table 3.2.h. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 8 (continued).

Run Time (hr)	Time	Operational Notes
42.05	02/22/12 05:33	Performed transition line flush.
42.60	02/22/12 06:06	Rodded partial shelf cap that lingered all night.
48.02	02/22/12 11:31	SBS, WESP, E1 and feed samples are taken.
52.50	02/22/12 16:00	1 kg of water and Tc99m syringe #4 was loaded into the external tank above the feed tank (CUA #122147 and 122148).
52.95	02/22/12 16:27	Rodded melter.
53.17	02/22/12 16:40	Paused feeding to transfer feed "Batch D" to feed tank. Net mass transferred is 75.890 kg (includes 2.0 kg flush water). (Ref. VSL-1904-12 P. 75).
53.22	02/22/12 16:43	Resumed feeding.
54.02	02/22/12 17:31	Performed transition line flush.
56.60	02/22/12 20:06	Rodded shelf left behind after discharge.
57.98	02/22/12 21:29	Rodded shelf on melter to help feed go into melt pool. Again at 22:25.
59.92	02/22/12 23:25	SBS, WESP, E1, E2 and feed samples are taken.
60.18	02/22/12 23:41	Rodded patches of shelf along the walls.
40.27	02/22/12 03:46	Rodded shelf after discharge.
66.03	02/23/12 05:32	Performed transition line flush.
68.28	02/23/12 07:47	Fresh feed sample, 2 min pause in feeding.
71.83	02/23/12 11:20	SBS, WESP, E1, samples are taken.
72.00	02/23/12 11:30	END OF THE TEST.
72.20	02/23/12 11:42	Removed feed from tank. Net 10.90 kg feed was removed.
72.22	02/23/12 11:43	Feed sample taken
72.25	02/23/12 11:45	Dip sample taken; yellow phase observed.
72.60	02/23/12 12:06	Started off gas shut down.
75.07	02/23/12 14:34	Dip sample taken.
Post Test Inspections and Cleanings: All sump solutions sampled, drained and rinsed: SBS, WESP, Containment, E1 and E2. Film cooler and transition line removed, inspected and sampled (rinsed). Recycle line contents sampled and rinsed.		

Table 3.2.i. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 9.

Run Time (hr)	Time	Operational Notes
0	03/06/12 12:30	Feed Started: 3/6/2012 12:30
4.42	03/06/12 16:55	Added 1 kg of water to external tank and syringe #2 (CUA #122171) and #122172
6.03	03/06/12 18:32	Performed transition line flush.
6.13	03/06/12 18:38	Noticed feed is piling up underneath feed tube; knocked down with rodding tool.
6.32	03/06/12 18:49	Feed sample from union, feeding paused ~3 min.
7.53	03/06/12 20:02	Rodded cold cap.
9.70	03/06/12 22:12	Rodded shelf after left behind after discharge.
12.35	03/07/12 00:51	SBS, WESP, E1, E2 and feed samples are taken.
13.10	03/07/12 01:36	When E-700 unit stopped at this time feeding of both fresh feed and recycled water were paused for ~6 minutes.
15.52	03/07/12 04:01	Turned off heater U-501 to slow water dissipation; level is below low sensor.
15.60	03/07/12 04:06	Re-energized U-501 heater.
16.48	03/07/12 04:59	Turned off U-501 heater; level in sight glass is low.
16.55	03/07/12 05:03	Transferred feed "Batch B" to feed tank. Paused feeding. Net mass transferred is 76.15 kg includes 2.0 kg flush water. Syringe #2.
16.62	03/07/12 05:07	Start feeding.
16.63	03/07/12 05:08	Turned heater on U-501; level is OK.
17.00	03/07/12 05:30	Paused feeding for <1 min for air flush.
18.02	03/07/12 06:31	Performed transition line flush.
24.02	03/07/12 12:31	Paused 2 minutes to take feed sample.
24.10	03/07/12 12:36	SBS, WESP, E1, samples are taken.
24.45	03/07/12 12:57	Installed syringe #3, plus 1 liter water added to external tank.
26.38	03/07/12 14:53	Up to 15:53 Melter off gas sampling.
30.08	03/07/12 18:35	Performed transition line flush.
30.27	03/07/12 18:46	Evaporator 2 high pressure tripped. All satisfactory now.
31.42	03/07/12 19:55	Found SBS CW pump tripped off with alarm code AO8.

Table 3.2.i. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 9 (continued).

Run Time (hr)	Time	Operational Notes
32.00	03/07/12 20:30	Removed 10.44 kg liquid from E-700.
33.65	03/07/12 22:09	Transferred feed "Batch C" to feed tank. Paused feeding. Net mass transferred is 76.900 kg (includes 2.0 kg flush water). (Ref. VSL-1913-12 P. 18 Syringe #3).
33.73	03/07/12 22:14	Resumed feeding.
34.52	03/07/12 23:01	WESP is arching lowered its power.
36.28	03/08/12 00:47	SBS, WESP, E1, E2 and feed samples are taken.
42.00	03/08/12 06:30	Performed transition line flush.
44.08	03/08/12 08:35	SBS CW cooler U500 tripped off, it was reset.
48.02	03/08/12 12:31	Paused feeding for 2 minute to take feed sample.
48.08	03/08/12 12:35	SBS, WESP, E1 samples are taken.
51.28	03/08/12 15:47	Found some blockage in the jumper hose after peristaltic pump.
52.20	03/08/12 16:41	Since clearing blockage, feed pump setting lowered from 7.6 to 6.5 rpm.
52.33	03/08/12 16:50	Added syringe #4 and 1 kg water to external tank above feed tank in preparation.
53.08	03/08/12 17:35	Transferred feed "Batch D" to feed tank. Paused feeding. Net mass transferred is 77.230 kg (includes 2.0 kg flush water and 1 kg of syringe #4 flush water). (Ref. VSL-1913-12 P. 18). Introduced through peristaltic pump. Also air/water flush are not working.
53.17	03/08/12 17:40	Resumed feeding.
54.32	03/08/12 18:49	WESP kept tripping off; reduced from 21.5 kV to 21.0 kV, @1.1mA.
55.35	03/08/12 19:51	Rodded shelf left behind after discharge.
57.20	03/08/12 21:42	Performed transition line flush.
57.75	03/08/12 22:15	Took a feed sample with 1 min feed interruption.
60.30	03/09/12 00:48	SBS, WESP, E1, E2 and feed samples are taken.
66.02	03/09/12 06:31	Performed transition line flush.
71.87	03/09/12 12:22	SBS, WESP, E1 samples are taken.

Table 3.2.i. Summary of Off-Gas Operational Events and Equipment Inspections and Modifications during and after Test 9 (continued).

Run Time (hr)	Time	Operational Notes
72.00	03/09/12 12:30	END OF THE TEST.
72.25	03/09/12 12:45	Removed feed from tank. Net 14.50 kg feed was removed.
72.33	03/09/12 12:50	Feed sample taken.
72.38	03/09/12 12:53	Dip sample taken.
75.25	03/09/12 15:45	Removed and inspected OG transition line. Pictures: #3604 melter side of transition line, #3606 SBS side of transition line, #3607 transition line sprayer.
75.83	03/09/12 16:20	Obtained a picture of the film cooler and transition line Tee. Very little to no build up inside no sample taken. Picture #3611.
76.17	03/09/12 16:40	Completed melter shut down.
Post Test Inspections and Cleanings: All sump solutions sampled, drained and rinsed: SBS, WESP, Containment, E1 and E2. Film cooler and transition line removed, inspected and sampled (rinsed). Recycle line contents sampled and rinsed.		

Table 3.3. Measured Melter Parameters.

Test Segment		Test 1			Test 2			Test 3		
		Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
Temperature (°C)	Glass Pool (2" from floor)	1155	1140	1167	1151	1119	1167	1152	1142	1164
	Glass Pool (4" from floor)	1148	1103	1160	1142	1095	1159	1147	1129	1159
	Plenum (exposed)	445	116	895	505	339	760	470	354	744
	Plenum (thermowell)	494	300	738	512	401	762	520	398	772
	Electrode	1075	1058	1088	1072	1044	1101	1068	1057	1085
	Discharge Chamber	1058	733	1100	1062	635	1120	1025	750	1055
	Film Cooler Outlet	264	227	305	294	250	361	275	224	354
Bubbling (lpm)		3.9	0.2	7.6	0.4	0.1	1.3	2.3	0.4	3.9
Melter Pressure (inches water)		-1.67	-5.20	0.38	-1.56	-4.23	0.29	-1.51	-5.20	0.13
Electrode Voltage (Volts)		26	22	35	23	12	29	28	22	33
Electrode Current (Amps)		164	108	199	180	79	201	183	164	197
Melt Resistance (ohms)		0.162	0.120	0.225	0.131	0.119	0.162	0.154	0.128	0.185
Total Power (kW)		4.35	2.52	5.98	4.23	0.94	5.18	5.17	3.63	6.43

Table 3.3. Measured Melter Parameters (continued).

Test Segment		Test 4			Test 5			Test 6		
		Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
Temperature (°C)	Glass Pool (2" from floor)	1147	1064	1167	1152	1098	1167	1148	1120	1163
	Glass Pool (4" from floor)	1139	1062	1165	1137	1038	1197	1140	1117	1157
	Plenum (exposed)	451	343	753	349	49	716	449	368	741
	Plenum (thermowell)	514	438	798	420	208	759	500	444	782
	Electrode	1051	993	1088	993	968	1022	966	957	982
	Discharge Chamber	1026	916	1041	1000	886	1038	1040	952	1120
	Film Cooler Outlet	281	269	306	268	242	327	265	250	369
Bubbling (lpm)		1.2	0.1	4.8	3.9	0.4	6.3	2.6	1.0	5.4
Melter Pressure (inches water)		-1.71	-3.50	0.25	-2.14	-5.20	0.32	-1.68	-3.01	0.12
Electrode Voltage (Volts)		39	0	50	35	0	54	33	2	42
Electrode Current (Amps)		135	0	193	153	0	247	171	3	215
Melt Resistance (ohms)		0.290	0.153	3.000	0.235	0.171	3.211	0.192	0.166	0.707
Total Power (kW)		5.24	0.00	8.04	5.3	0.0	13.4	5.6	0.0	9.1

Table 3.3. Measured Melter Parameters (continued).

Test Segment		Test 7			Test 8			Test 9		
		Avg.	Min.	Max.	Avg.	Min.	Max.	Avg.	Min.	Max.
Temperature (°C)	Glass Pool (2" from floor)	1146	1133	1158	1149	1136	1164	1147	1123	1170
	Glass Pool (4" from floor)	1140	1118	1151	1144	1122	1156	1139	1109	1162
	Plenum (exposed)	480	384	800	447	297	779	446	278	748
	Plenum (thermowell)	393	131	738	513	447	794	493	404	764
	Electrode	979	972	999	977	967	991	967	952	992
	Discharge Chamber	1060	951	1088	1060	1001	1069	1001	954	1032
	Film Cooler Outlet	246	224	322	253	237	308	289	267	341
Bubbling (lpm)		3.4	1.0	7.3	1.3	0.5	2.2	0.8	0.3	1.6
Melter Pressure (inches water)		-1.76	-2.85	0.08	-1.90	-2.49	0.01	-1.76	-3.20	0.03
Electrode Voltage (Volts)		28	22	37	31	25	42	35	24	45
Electrode Current (Amps)		177	130	222	195	152	252	174	134	227
Melt Resistance (ohms)		0.157	0.130	0.212	0.161	0.138	0.197	0.201	0.154	0.243
Total Power (kW)		4.9	3.0	7.2	6.1	4.0	10.0	6.1	3.2	9.2

Table 4.1.a. Test 1 Off-Gas System Measured Parameters.

Unit	Monitored Constituent	ID	Avg.	Max.	Min.
SBS	Inlet Pressure ("WC)	PAIR-1201	-1.9	-0.1	-5.2
	Differential Pressure ("WC)	PDIR-1202	15.7	20.7	11.1
	Inlet Gas Temperature (°C)	TIR-1101	263.1	314.1	217.5
	Outlet Gas Temperature (°C)	TIR-1102	38.4	41.3	33.8
	Cooling Water Inlet Temperature (°C)	TIR-1104	23.2	25.5	20.5
	Cooling Water Jacket Outlet Temperature (°C)	TIR-1108	33.4	36.4	28.7
	Cooling Water Outlet Temperature (°C)	TIR-1109	29.6	31.8	26.6
	Sump Temperature 4" depth (°C)	TIR-1105	37.8	40.8	33.0
	Sump Temperature 10" depth (°C)	TIR-1106	39.0	42.0	33.6
	Makeup Water Inlet Temperature (°C)	TIR-1103	27.9	28.6	27.1
	Makeup Water Flow Into SBS (lph)	FIR-1302	10.4	20.5	6.4
	Water Flow Out of SBS (lph)	FIR-1304	10.0	19.9	1.0
WESP	Makeup Water Inlet Temperature (°C)	TIR-2101	28.3	31.1	27.1
	WESP Off-gas Outlet Temperature (°C)	TIR-2102	37.6	40.5	29.2
	Blower (P-200) Outlet Temperature (°C)	TIR-2103	40.9	45.3	35.0
	Off-gas dP across WESP (" WC)	PDIR-2201	1.5	3.0	1.1
	Blower (P-200) Suction Pressure("WC)	PIR-2202	-18.8	-14.8	-25.4
	Blower Outlet Pressure ("WC)	PAIR-2203	-2.9	-0.1	-5.0
	Makeup Water Flow into WESP (lph)	FIR-2303	3.0	5.0	0.0
	WESP Current (Amps)	IIR-2902	3.5	5.8	0.0
	WESP Voltage (kV)	EIR-2903	17.8	40.0	0.0
CONT TANK	Containment Tank Temperature (°C)	TIR-3101	34.3	36.1	31.2
	Tank Discharge Flow (lph)	FIR-3301	9.6	15.0	0.0
	Tank Level (l)	LAIRC-3402	10.8	15.2	8.1
EVAP	Head Space Vapor Temperature (°C)	TIR-4101	39.0	50.6	30.5
	Evaporator Vacuum (" Hg)	PIR-4201	26.7	28.8	9.7
	Recycle Flow Rate (lph)	FIR-4301	0.3	1.0	0.0
	Recycle Pump Speed (rpm)	SIR-4802	13.7	35.6	0.0
EXHAUST	Cyclone Filter 1 Outlet Temperature (°C)	TIR-8101	19.5	20.8	18.4
	Cyclone Filter 2 Outlet Temperature (°C)	TIR-8102	33.6	37.1	31.7
	HEPA Filter 2 Inlet Temperature (°C)	TIR-8103	33.5	36.5	31.1
	HEPA Filter Outlet Temperature (°C)	TIR-8104	36.7	41.4	31.6
	Exhaust Blower Outlet Temperature (°C)	TIR-8105	33.4	35.5	31.0
	HEPA Filter 1 Inlet Temperature (°C)	TIR-8107	31.0	33.2	29.3
	Exhaust Flow Rate (SCFM)	FIR-8301	140.8	155.9	130.1

Table 4.1.b. Test 2 Off-Gas System Measured Parameters.

Unit	Monitored Constituent	ID	Avg.	Max.	Min.
SBS	Inlet Pressure ("WC)	PAIR-1201	-1.8	-0.1	-4.4
	Differential Pressure ("WC)	PDIR-1202	17.5	24.8	14.0
	Inlet Gas Temperature (°C)	TIR-1101	276.7	330.2	250.8
	Outlet Gas Temperature (°C)	TIR-1102	29.9	33.3	27.0
	Cooling Water Inlet Temperature (°C)	TIR-1104	15.6	21.1	12.9
	Cooling Water Jacket Outlet Temperature (°C)	TIR-1108	20.1	26.4	17.2
	Cooling Water Outlet Temperature (°C)	TIR-1109	21.9	28.5	19.9
	Sump Temperature 4" depth (°C)	TIR-1105	28.5	32.7	25.5
	Sump Temperature 10" depth (°C)	TIR-1106	30.0	33.9	26.3
	Makeup Water Inlet Temperature (°C)	TIR-1103	27.3	31.4	26.6
	Makeup Water Flow Into SBS (lph)	FIR-1302	12.3	16.3	0.0
	Water Flow Out of SBS (lph)	FIR-1304	12.9	15.1	1.0
WESP	Makeup Water Inlet Temperature (°C)	TIR-2101	29.9	31.9	26.9
	WESP Off-gas Outlet Temperature (°C)	TIR-2102	30.8	34.7	27.9
	Blower (P-200) Outlet Temperature (°C)	TIR-2103	43.2	47.0	40.8
	Off-gas dP across WESP (" WC)	PDIR-2201	1.6	3.4	1.2
	Blower (P-200) Suction Pressure("WC)	PIR-2202	-20.5	-16.8	-28.1
	Blower Outlet Pressure ("WC)	PAIR-2203	-1.6	0.0	-4.6
	Makeup Water Flow into WESP (lph)	FIR-2303	0.5	2.2	0.0
	WESP Current (Amps)	IIR-2902	1.5	7.6	0.0
	WESP Voltage (kV)	EIR-2903	15.2	28.7	0.0
CONT TANK	Containment Tank Temperature (°C)	TIR-3101	29.3	31.0	28.3
	Tank Discharge Flow (lph)	FIR-3301	14.8	30.0	0.0
	Tank Level (l)	LAIRC-3402	11.5	16.9	9.8
EVAP	Head Space Vapor Temperature (°C)	TIR-4101	44.6	66.8	37.1
	Evaporator Vacuum (" Hg)	PIR-4201	27.6	28.6	22.4
	Recycle Flow Rate (lph)	FIR-4301	0.36	1.00	0.01
	Recycle Pump Speed (rpm)	SIR-4802	13.2	599.2	0.4
EXHAUST	Cyclone Filter 1 Outlet Temperature (°C)	TIR-8101	19.7	28.5	15.7
	Cyclone Filter 2 Outlet Temperature (°C)	TIR-8102	35.8	37.8	31.1
	HEPA Filter 2 Inlet Temperature (°C)	TIR-8103	33.8	35.4	29.8
	HEPA Filter Outlet Temperature (°C)	TIR-8104	38.0	41.4	33.8
	Exhaust Blower Outlet Temperature (°C)	TIR-8105	33.4	35.1	30.7
	HEPA Filter 1 Inlet Temperature (°C)	TIR-8107	30.6	37.5	27.4
	Exhaust Flow Rate (SCFM)	FIR-8301	138.5	156.6	113.7

Table 4.1.c. Test 3 Off-Gas System Measured Parameters.

Unit	Monitored Constituent	ID	Avg.	Max.	Min.
SBS	Inlet Pressure ("WC)	PAIR-1201	-1.8	-0.1	-5.2
	Differential Pressure ("WC)	PDIR-1202	16.5	22.4	13.8
	Inlet Gas Temperature (°C)	TIR-1101	269.7	322.8	234.8
	Outlet Gas Temperature (°C)	TIR-1102	30.8	37.3	26.5
	Cooling Water Inlet Temperature (°C)	TIR-1104	17.6	25.2	14.0
	Cooling Water Jacket Outlet Temperature (°C)	TIR-1108	21.5	34.4	16.5
	Cooling Water Outlet Temperature (°C)	TIR-1109	21.5	35.0	18.3
	Sump Temperature 4" depth (°C)	TIR-1105	29.5	36.8	25.0
	Sump Temperature 10" depth (°C)	TIR-1106	30.9	37.2	26.0
	Makeup Water Inlet Temperature (°C)	TIR-1103	25.4	28.9	24.6
	Makeup Water Flow Into SBS (lph)	FIR-1302	10.6	12.1	0.0
	Water Flow Out of SBS (lph)	FIR-1304	12.0	15.8	1.0
WESP	Makeup Water Inlet Temperature (°C)	TIR-2101	27.0	30.2	25.7
	WESP Off-gas Outlet Temperature (°C)	TIR-2102	55.6	61.8	36.4
	Blower (P-200) Outlet Temperature (°C)	TIR-2103	55.1	60.2	48.2
	Off-gas dP across WESP (" WC)	PDIR-2201	1.7	2.4	1.2
	Blower (P-200) Suction Pressure("WC)	PIR-2202	-19.6	-16.1	-25.2
	Blower Outlet Pressure("WC)	PAIR-2203	-1.4	-0.1	-4.8
	Makeup Water Flow into WESP (lph)	FIR-2303	2.1	2.6	0.0
	WESP Current (Amps)	IIR-2902	1.4	5.1	0.0
	WESP Voltage (kV)	EIR-2903	20.6	25.5	0.0
CONT TANK	Containment Tank Temperature (°C)	TIR-3101	29.3	31.9	26.8
	Tank Discharge Flow (lph)	FIR-3301	14.8	37.3	-9.2
	Tank Level (L)	LAIRC-3402	10.9	13.9	7.7
EVAP	Head Space Vapor Temperature (°C)	TIR-4101	45.5	49.2	40.3
	Evaporator Vacuum (" Hg)	PIR-4201	27.4	28.3	26.8
	Recycle Flow Rate (lph)	FIR-4301	0.40	1.0	0.0
	Recycle Pump Speed (rpm)	SIR-4802	15.8	599.7	0.0
EXHAUST	Cyclone Filter 1 Outlet Temperature (°C)	TIR-8101	31.1	34.5	27.9
	Cyclone Filter 2 Outlet Temperature (°C)	TIR-8102	29.0	31.4	25.3
	HEPA Filter 2 Inlet Temperature (°C)	TIR-8103	40.2	44.0	37.6
	HEPA Filter Outlet Temperature (°C)	TIR-8104	36.2	39.5	32.7
	Exhaust Blower Outlet Temperature (°C)	TIR-8105	35.6	39.2	31.3
	HEPA Filter 1 Inlet Temperature (°C)	TIR-8107	30.8	33.6	27.4
	Exhaust Flow Rate (SCFM)	FIR-8301	139.3	152.1	116.8

Table 4.1.d. DM10 Test 4 Off-Gas System Measured Parameters.

Unit	Monitored Constituent	ID	Avg.	Max.	Min.
SBS	Inlet Pressure ("WC)	PAIR-1201	-2.0	-0.1	-3.6
	Differential Pressure ("WC)	PDIR-1202	19.4	23.0	17.1
	Inlet Gas Temperature (°C)	TIR-1101	274.1	303.1	259.7
	Outlet Gas Temperature (°C)	TIR-1102	29.9	31.5	23.5
	Cooling Water Inlet Temperature (°C)	TIR-1104	18.7	20.9	14.2
	Cooling Water Jacket Outlet Temperature (°C)	TIR-1108	20.8	23.2	17.0
	Cooling Water Outlet Temperature (°C)	TIR-1109	20.6	22.5	16.7
	Sump Temperature 4" depth (°C)	TIR-1105	28.6	29.9	23.0
	Sump Temperature 10" depth (°C)	TIR-1106	29.6	31.2	23.4
	Makeup Water Inlet Temperature (°C)	TIR-1103	25.5	28.7	24.2
	Makeup Water Flow Into SBS (LPH)	FIR-1302	11.1	21.0	0.2
	Water Flow Out of SBS (LPH)	FIR-1304	12.6	15.1	1.0
WESP	Makeup Water Inlet Temperature (°C)	TIR-2101	28.3	29.6	24.7
	WESP Off-gas Outlet Temperature (°C)	TIR-2102	48.6	53.3	40.8
	Blower (P-200) Outlet Temperature (°C)	TIR-2103	51.0	53.2	45.4
	Off-gas dP across WESP (" WC)	PDIR-2201	1.8	2.4	1.3
	Blower (P-200) Suction Pressure("WC)	PIR-2202	-22.9	-19.1	-25.8
	Blower Outlet Pressure("WC)	PAIR-2203	-1.5	-0.6	-3.4
	Makeup Water Flow into WESP (lph)	FIR-2303	2.0	3.3	0.4
	WESP Current (Amps)	IIR-2902	2.2	5.1	0.0
	WESP Voltage (kV)	EIR-2903	20.8	26.3	1.3
CONT TANK	Containment Tank Temperature (°C)	TIR-3101	29.5	30.4	23.8
	Tank Discharge Flow (lph)	FIR-3301	15.8	50.0	-9.2
	Tank Level (l)	LAIRC-3402	10.7	15.3	9.8
EVAP	Head Space Vapor Temperature (°C)	TIR-4101	43.9	55.7	38.5
	Evaporator Vacuum (" Hg)	PIR-4201	8.1	29.9	-0.6
	Recycle Flow Rate (LPH)	FIR-4301	0.40	1.0	0.0
	Recycle Pump Speed (RPM)	SIR-4802	15.0	62.3	0.3
EXHAUST	Cyclone Filter 1 Outlet Temperature (°C)	TIR-8101	19.2	21.1	14.6
	Cyclone Filter 2 Outlet Temperature (°C)	TIR-8102	40.2	42.8	32.8
	HEPA Filter 2 Inlet Temperature (°C)	TIR-8103	37.9	40.0	29.8
	HEPA Filter Outlet Temperature (°C)	TIR-8104	35.8	37.1	32.8
	Exhaust Blower Outlet Temperature (°C)	TIR-8105	37.2	38.7	30.7
	HEPA Filter 1 Inlet Temperature (°C)	TIR-8107	31.4	32.8	26.7
	Exhaust Flow Rate (SCFM)	FIR-8301	127.8	143.6	91.9

Table 4.1.e. Test 5 Off-Gas System Measured Parameters.

Unit	Monitored Constituent	ID	Avg.	Max.	Min.
SBS	Inlet Pressure ("WC)	PAIR-1201	-2.8	-0.4	-5.1
	Differential Pressure ("WC)	PDIR-1202	17.1	23.8	14.7
	Inlet Gas Temperature (°C)	TIR-1101	264.7	302.0	52.5
	Outlet Gas Temperature (°C)	TIR-1102	30.7	42.0	27.0
	Cooling Water Inlet Temperature (°C)	TIR-1104	18.1	24.2	13.9
	Cooling Water Jacket Outlet Temperature (°C)	TIR-1108	21.9	40.3	17.8
	Cooling Water Outlet Temperature (°C)	TIR-1109	20.4	26.9	17.5
	Sump Temperature 4" depth (°C)	TIR-1105	29.5	41.8	26.4
	Sump Temperature 10" depth (°C)	TIR-1106	31.0	42.1	26.8
	Makeup Water Inlet Temperature (°C)	TIR-1103	16.4	17.3	15.6
	Makeup Water Flow Into SBS (lph)	FIR-1302	10.2	12.3	5.9
	Water Flow Out of SBS (lph)	FIR-1304	11.1	15.4	1.0
WESP	Makeup Water Inlet Temperature (°C)	TIR-2101	18.5	19.6	17.2
	WESP Off-gas Outlet Temperature (°C)	TIR-2102	53.8	58.1	52.2
	Blower (P-200) Outlet Temperature (°C)	TIR-2103	54.3	61.5	51.1
	Off-gas dP across WESP (" WC)	PDIR-2201	1.7	2.3	1.3
	Blower (P-200) Suction Pressure ("WC)	PIR-2202	-20.7	-17.1	-26.1
	Blower Outlet Pressure("WC)	PAIR-2203	-1.4	-0.2	-2.5
	Makeup Water Flow into WESP (lph)	FIR-2303	2.6	4.0	1.4
	WESP Current (Amps)	IIR-2902	1.5	5.2	0.0
	WESP Voltage (kV)	EIR-2903	21.0	25.7	1.3
CONT TANK	Containment Tank Temperature (°C)	TIR-3101	29.0	35.5	27.2
	Tank Discharge Flow (lph)	FIR-3301	14.2	32.3	-9.9
	Tank Level (l)	LAIRC-3402	10.8	11.7	9.0
EVAP	Head Space Vapor Temperature (°C)	TIR-4101	43.9	48.8	38.5
	Evaporator Vacuum (" Hg)	PIR-4201	NA	NA	NA
	Recycle Flow Rate (LPH)	FIR-4301	0.40	1.0	0.0
	Recycle Pump Speed (RPM)	SIR-4802	15.1	59.8	0.7
EXHAUST	Cyclone Filter 1 Outlet Temperature (°C)	TIR-8101	16.1	18.4	11.4
	Cyclone Filter 2 Outlet Temperature (°C)	TIR-8102	42.3	43.5	40.8
	HEPA Filter 2 Inlet Temperature (°C)	TIR-8103	39.2	40.1	36.8
	HEPA Filter Outlet Temperature (°C)	TIR-8104	35.4	36.7	32.6
	Exhaust Blower Outlet Temperature (°C)	TIR-8105	35.4	36.6	31.7
	HEPA Filter 1 Inlet Temperature (°C)	TIR-8107	28.7	30.0	25.3
	Exhaust Flow Rate (SCFM)	FIR-8301	140.4	148.1	132.2

Table 4.1.f. Test 6 Off-Gas System Measured Parameters.

Unit	Monitored Constituent	ID	Avg.	Max.	Min.
SBS	Inlet Pressure ("WC)	PAIR-1201	-1.6	5.0	-3.0
	Differential Pressure ("WC)	PDIR-1202	16.8	22.8	13.5
	Inlet Gas Temperature (°C)	TIR-1101	272.7	318.8	50.4
	Outlet Gas Temperature (°C)	TIR-1102	29.8	33.1	26.2
	Cooling Water Inlet Temperature (°C)	TIR-1104	17.5	20.0	14.0
	Cooling Water Jacket Outlet Temperature (°C)	TIR-1108	20.8	24.5	17.4
	Cooling Water Outlet Temperature (°C)	TIR-1109	19.7	22.0	17.5
	Sump Temperature 4" depth (°C)	TIR-1105	28.7	33.0	26.0
	Sump Temperature 10" depth (°C)	TIR-1106	30.2	34.9	26.1
	Makeup Water Inlet Temperature (°C)	TIR-1103	14.1	23.2	13.2
	Makeup Water Flow Into SBS (lph)	FIR-1302	10.7	11.9	0.0
	Water Flow Out of SBS (lph)	FIR-1304	11.4	17.2	1.1
WESP	Makeup Water Inlet Temperature (°C)	TIR-2101	17.2	23.4	15.7
	WESP Off-gas Outlet Temperature (°C)	TIR-2102	53.0	57.5	48.4
	Blower (P-200) Outlet Temperature (°C)	TIR-2103	56.2	61.7	46.2
	Off-gas dP across WESP (" WC)	PDIR-2201	1.6	4.9	0.8
	Blower (P-200) Suction Pressure ("WC)	PIR-2202	-19.9	-8.8	-25.1
	Blower Outlet Pressure("WC)	PAIR-2203	-1.1	-0.4	-4.3
	Makeup Water Flow into WESP (lph)	FIR-2303	2.0	3.2	0.0
	WESP Current (Amps)	IIR-2902	0.8	5.4	0.1
	WESP Voltage (kV)	EIR-2903	18.6	26.4	0.1
CONT TANK	Containment Tank Temperature (°C)	TIR-3101	27.9	29.4	22.3
	Tank Discharge Flow (lph)	FIR-3301	13.8	39.3	-10.9
	Tank Level (l)	LAIRC-3402	10.9	17.0	9.2
EVAP	Head Space Vapor Temperature (°C)	TIR-4101	46.2	60.0	34.9
	Evaporator Vacuum (" Hg)	PIR-4201	27.0	28.8	0.2
	Recycle Flow Rate (lph)	FIR-4301	0.39	1.0	0.0
	Recycle Pump Speed (rpm)	SIR-4802	18.8	599.7	1.6
EXHAUST	Cyclone Filter 1 Outlet Temperature (°C)	TIR-8101	14.8	19.0	3.9
	Cyclone Filter 2 Outlet Temperature (°C)	TIR-8102	47.5	51.5	43.4
	HEPA Filter 2 Inlet Temperature (°C)	TIR-8103	38.0	40.9	35.3
	HEPA Filter Outlet Temperature (°C)	TIR-8104	34.3	36.7	31.9
	Exhaust Blower Outlet Temperature (°C)	TIR-8105	39.0	42.3	30.2
	Exhaust Flow Rate (SCFM)	FIR-8301	117.9	126.0	102.6

Table 4.1.g. Test 7 Off-Gas System Measured Parameters.

Unit	Monitored Constituent	ID	Avg.	Max.	Min.
SBS	Inlet Pressure ("WC)	PAIR-1201	-1.7	0.2	-2.8
	Differential Pressure ("WC)	PDIR-1202	16.0	23.8	13.4
	Inlet Gas Temperature (°C)	TIR-1101	245.6	283.8	48.8
	Outlet Gas Temperature (°C)	TIR-1102	29.3	32.8	26.0
	Cooling Water Inlet Temperature (°C)	TIR-1104	18.2	21.2	14.6
	Cooling Water Jacket Outlet Temperature (°C)	TIR-1108	21.8	25.0	18.2
	Cooling Water Outlet Temperature (°C)	TIR-1109	20.5	23.3	17.9
	Sump Temperature 4" depth (°C)	TIR-1105	28.5	32.7	25.4
	Sump Temperature 10" depth (°C)	TIR-1106	29.5	35.4	25.8
	Makeup Water Inlet Temperature (°C)	TIR-1103	13.4	14.3	12.4
	Makeup Water Flow Into SBS (lph)	FIR-1302	10.1	11.7	5.4
	Water Flow Out of SBS (lph)	FIR-1304	10.6	14.4	1.0
WESP	Makeup Water Inlet Temperature (°C)	TIR-2101	15.6	16.6	14.5
	WESP Off-gas Outlet Temperature (°C)	TIR-2102	53.0	55.2	50.8
	Blower (P-200) Outlet Temperature (°C)	TIR-2103	53.2	57.0	50.5
	Off-gas dP across WESP (" WC)	PDIR-2201	1.5	2.0	1.1
	Blower (P-200) Suction Pressure ("WC)	PIR-2202	-19.0	-15.9	-25.8
	Blower Outlet Pressure("WC)	PAIR-2203	-1.1	-0.3	-2.0
	Makeup Water Flow into WESP (lph)	FIR-2303	2.9	4.5	1.3
	WESP Current (Amps)	IIR-2902	1.0	4.1	0.1
	WESP Voltage (kV)	EIR-2903	19.6	38.4	0.1
CONT TANK	Containment Tank Temperature (°C)	TIR-3101	28.2	29.7	24.1
	Tank Discharge Flow (lph)	FIR-3301	13.9	33.3	-3.4
	Tank Level (l)	LAIRC-3402	10.6	12.3	9.1
EVAP	Head Space Vapor Temperature (°C)	TIR-4101	46.3	50.9	40.1
	Evaporator Vacuum (" Hg)	PIR-4201	27.3	28.4	26.3
	Recycle Flow Rate (lph)	FIR-4301	0.40	1.0	0.0
	Recycle Pump Speed (rpm)	SIR-4802	16.8	581.7	1.3
EXHAUST	Cyclone Filter 1 Outlet Temperature (°C)	TIR-8101	15.9	18.1	11.1
	Cyclone Filter 2 Outlet Temperature (°C)	TIR-8102	49.3	51.9	44.7
	HEPA Filter 2 Inlet Temperature (°C)	TIR-8103	38.5	40.4	36.1
	HEPA Filter Outlet Temperature (°C)	TIR-8104	35.2	37.4	32.4
	Exhaust Blower Outlet Temperature (°C)	TIR-8105	42.3	45.3	35.6
	Exhaust Flow Rate (SCFM)	FIR-8301	119.9	131.3	112.1

Table 4.1.h. Test 8 Off-Gas System Measured Parameters.

Unit	Monitored Constituent	ID	Avg.	Max.	Min.
SBS	Inlet Pressure ("WC)	PAIR-1201	-1.8	0.0	-2.8
	Differential Pressure ("WC)	PDIR-1202	16.5	23.0	14.6
	Inlet Gas Temperature (°C)	TIR-1101	259.1	299.1	56.2
	Outlet Gas Temperature (°C)	TIR-1102	30.1	33.4	26.1
	Cooling Water Inlet Temperature (°C)	TIR-1104	16.8	21.4	13.8
	Cooling Water Jacket Outlet Temperature (°C)	TIR-1108	21.4	25.5	18.5
	Cooling Water Outlet Temperature (°C)	TIR-1109	19.9	23.3	18.1
	Sump Temperature 4" depth (°C)	TIR-1105	29.0	33.0	25.1
	Sump Temperature 10" depth (°C)	TIR-1106	30.3	36.4	25.3
	Makeup Water Inlet Temperature (°C)	TIR-1103	14.0	15.3	13.0
	Makeup Water Flow Into SBS (lph)	FIR-1302	10.1	10.8	5.8
	Water Flow Out of SBS (lph)	FIR-1304	11.0	16.4	4.7
WESP	Makeup Water Inlet Temperature (°C)	TIR-2101	16.0	18.0	14.9
	WESP Off-gas Outlet Temperature (°C)	TIR-2102	53.6	58.5	51.5
	Blower (P-200) Outlet Temperature (°C)	TIR-2103	53.7	60.1	51.6
	Off-gas dP across WESP (" WC)	PDIR-2201	1.5	2.0	1.1
	Blower (P-200) Suction Pressure ("WC)	PIR-2202	-19.7	-17.2	-25.5
	Blower Outlet Pressure("WC)	PAIR-2203	-1.3	-0.8	-2.0
	Makeup Water Flow into WESP (lph)	FIR-2303	3.0	3.7	1.7
	WESP Current (Amps)	IIR-2902	1.1	6.2	0.1
	WESP Voltage (kV)	EIR-2903	20.5	28.8	0.1
CONT TANK	Containment Tank Temperature (°C)	TIR-3101	28.7	30.9	25.6
	Tank Discharge Flow (lph)	FIR-3301	13.8	33.6	-6.0
	Tank Level (l)	LAIRC-3402	10.7	13.0	10.1
EVAP	Head Space Vapor Temperature (°C)	TIR-4101	47.7	63.9	42.4
	Evaporator Vacuum (" Hg)	PIR-4201	27.0	28.4	0.1
	Recycle Flow Rate (lph)	FIR-4301	0.41	1.0	0.0
	Recycle Pump Speed (rpm)	SIR-4802	17.5	61.4	1.3
EXHAUST	Cyclone Filter 1 Outlet Temperature (°C)	TIR-8101	16.2	19.4	13.0
	Cyclone Filter 2 Outlet Temperature (°C)	TIR-8102	49.8	53.1	46.5
	HEPA Filter 2 Inlet Temperature (°C)	TIR-8103	38.2	40.7	36.1
	HEPA Filter Outlet Temperature (°C)	TIR-8104	35.3	37.4	33.3
	Exhaust Blower Outlet Temperature (°C)	TIR-8105	43.2	46.5	37.8
	Exhaust Flow Rate (SCFM)	FIR-8301	116.1	122.7	106.3

Table 4.1.i. Test 9 Off-Gas System Measured Parameters.

Unit	Monitored Constituent	ID	Avg.	Max.	Min.
SBS	Inlet Pressure ("WC)	PAIR-1201	-1.7	0.2	-3.4
	Differential Pressure ("WC)	PDIR-1202	18.1	23.2	15.5
	Inlet Gas Temperature (°C)	TIR-1101	268.6	303.4	53.4
	Outlet Gas Temperature (°C)	TIR-1102	30.9	39.6	29.2
	Cooling Water Inlet Temperature (°C)	TIR-1104	18.2	24.9	14.1
	Cooling Water Jacket Outlet Temperature (°C)	TIR-1108	22.2	37.8	18.3
	Cooling Water Outlet Temperature (°C)	TIR-1109	20.7	34.8	18.2
	Sump Temperature 4" depth (°C)	TIR-1105	29.7	39.5	28.1
	Sump Temperature 10" depth (°C)	TIR-1106	30.9	39.6	29.2
	Makeup Water Inlet Temperature (°C)	TIR-1103	15.5	16.2	14.7
	Makeup Water Flow Into SBS (lph)	FIR-1302	10.2	11.7	6.5
	Water Flow Out of SBS (lph)	FIR-1304	11.4	16.0	1.0
WESP	Makeup Water Inlet Temperature (°C)	TIR-2101	17.5	19.0	16.1
	WESP Off-gas Outlet Temperature (°C)	TIR-2102	56.7	58.7	51.5
	Blower (P-200) Outlet Temperature (°C)	TIR-2103	57.7	61.3	55.2
	Off-gas dP across WESP (" WC)	PDIR-2201	1.5	2.1	1.1
	Blower (P-200) Suction Pressure ("WC)	PIR-2202	-21.2	-18.2	-25.7
	Blower Outlet Pressure("WC)	PAIR-2203	-1.1	-0.2	-1.7
	Makeup Water Flow into WESP (lph)	FIR-2303	3.0	3.4	1.7
	WESP Current (Amps)	IIR-2902	1.5	3.5	0.1
	WESP Voltage (kV)	EIR-2903	21.0	28.2	0.2
CONT TANK	Containment Tank Temperature (°C)	TIR-3101	29.6	34.0	26.1
	Tank Discharge Flow (lph)	FIR-3301	15.5	32.6	-2.0
	Tank Level (l)	LAIRC-3402	10.7	15.0	9.8
EVAP	Head Space Vapor Temperature (°C)	TIR-4101	48.6	64.5	42.0
	Evaporator Vacuum (" Hg)	PIR-4201	27.3	28.5	22.0
	Recycle Flow Rate (lph)	FIR-4301	0.40	0.8	0.0
	Recycle Pump Speed (rpm)	SIR-4802	18.6	27.9	1.4
EXHAUST	Cyclone Filter 1 Outlet Temperature (°C)	TIR-8101	18.0	22.2	12.1
	Cyclone Filter 2 Outlet Temperature (°C)	TIR-8102	45.6	52.6	24.7
	HEPA Filter 2 Inlet Temperature (°C)	TIR-8103	39.7	43.8	36.6
	HEPA Filter Outlet Temperature (°C)	TIR-8104	36.4	38.1	32.5
	Exhaust Blower Outlet Temperature (°C)	TIR-8105	37.7	44.8	18.1
	Exhaust Flow Rate (SCFM)	FIR-8301	117.1	126.4	108.0

Table 4.2. Transition Line Samples Taken at Conclusion of Tests.

	Description	Sample ID	Mass (g)	Tc Concentration (μCi/g)	Tc (μCi)
Test 3	Transition line	10S-O-28A	94	22.70	2134
	rinse	10S-O-28B	1491	0.64	949
	EOG	10S-O-28C	16	2.56	41
	FC/Transition flange	10S-O-28D	5	21.80	108
	Film cooler rinse	10S-O-28E	353	5.09	1799
	Film cooler Acid rinse	10S-O-28F	742	0.02	16
	Total				5046
Test 4	Transition line	10S-O-94E	46	28.89	1329
	rinse	10S-O-95A	432	3.62	1564
	rinse 2	10S-O-95C	2789	0.02	68
	FC/Transition flange	10S-O-95B	3	38.64	107
	Film cooler rinse	10S-O-94F	637	2.03	1294
	Total				4362
Test 5	Cake on transition line	10T-O-35E	4	35.00	140
	Film Cooler chunks	10T-O-36B	14	34.35	489
	Film Cooler outer sleeve rinse	10T-O-36C	506	0.18	90
	Film Cooler inner sleeve solid	10T-O-36D	51	1.89	96
	Film Cooler inner sleeve rinse	10T-O-36E	499	0.78	391
	Solids deposited in plenum	10T-O-36F	208	1.26	262
	Deposit in side view port	10T-O-36G	12	3.82	46
	Total				1513
Test 6	Film Cooler outer+inner rinse	10T-O-115C	624	4.82	3007
	Film Cooler & Transition Line	10T-O-115E	9	50.37	476
	Total				3483
Test 7	Film Cooler outer+inner rinse	10U-O-57D	1406	1.83	2578
	Solid deposited top of bricks	10U-O-57E	330	4.76	
	Solid deposited top of bricks	10U-O-57E-R	330	3.90	
	Average of solids deposited on top of bricks		330	4.33	1428
	Total				4006
Test 8	Solids on film cooler flange	10U-O-146D	12	70.53	844
	Film Cooler outer+inner rinse	10U-O-146E	572	7.90	4522
	Solids on brick-bottom film cooler	10U-O-146F	40	8.38	336
	Total				5702
Test 9	Film Cooler outer+inner rinse	10V-O-94B	491	4.76	2340
	Total				2340

Note: No samples were taken after Tests 1 and 2.

Table 4.3. Listing of SBS Effluents.

Test	Date	Time	Name	Weight (g)	^{99m}Tc (µCi/g)	pH
1	8/30/11	21:50	10Q-S-89A	291.55	BDL	8.84
	8/31/11	11:35	10Q-S-102A	24	0.020	8.64
		23:04	10Q-S-118A	69.78	0.024	8.35
	9/1/11	10:54	10Q-S-122A	32	0.057	8.65
		22:52	10Q-S-137A	30.05	0.074	8.58
	9/2/11	10:52	10Q-S-139A	32	0.066	8.63
		14:02	10Q-S-147A	34	0.069	8.64
		19:46 (blow down)	10R-S-7A	18000	0.119	NA
			10R-S-7B	16000	0.119	8.19
2	9/6/11	23:37	10R-S-12A	49.39	NA	8.63
	9/7/11	14:01	10R-S-40A	36	0.046	8.62
	9/8/11	1:59	10R-S-44A	94.16	0.029	8.48
		13:58	10R-S-48A	34	0.050	8.61
	9/9/11	2:23	10R-S-58A	39.64	0.053	8.38
		13:50	10R-S-68A	28	0.066	8.47
		22:08	10R-S-76A	68.14	0.069	8.57
	9/10/11	0:00 (blow down)	10R-S-77A	44300	0.116	8.61
			10R-S-77B	871	NA	8.62
		1:15 (rinse)	10R-S-77C	64020	0.008	NA
3	9/19/111	15:14	10R-S-120A	95.31	BDL	8.37
	9/20/11	3:44	10R-S-133A	129.48	0.041	8.21
		15:31	10R-S-143A	103.83	0.101, 0.116	8.27
	9/21/11	3:38	10R-S-147A	43.22	0.121, 0.139	8.31
		15:30	10S-S-12A	38.75	0.151	8.42
		22:10	10S-S-18A	43.52	0.119	8.30
	9/21/11	0:00 (blow down)	10S-S-19A	45280	0.155	8.35
		0:30 (rinse)	10S-S-19B	106360	0.012	NA
4	9/26/2011	13:30	10S-S-42A	34	BDL	8.12
	9/27/2011	4:47	10S-S-49A	34.78	0.029	6.35
		16:40	10S-S-58A	42.34	0.041	6.09
	9/28/2011	4:47	10S-S-62A	32.2	0.049	6.54
		16:40	10S-S-71A	55.18	0.055	6.62
	9/29/2011	4:43	10S-S-81A	25.93	0.056	6.28
		16:43	10S-S-93A	44.85	0.054	6.66
		19.35(blow down)	10S-S-94A	45040	0.082	3.18
		22:09 (rinse)	10S-S-95A	62380	0.009	NA
5	12/13/2011	10:15	10S-S-102A	50.0	0.073	7.83
	12/14/2011	0:48	10S-S-127A	36.26	0.073	8.21
		12:52	10S-S-131A	34	0.079	8.26
	12/15/2011	0:45	10S-S-147A	46.50	0.128	8.31
		12:50	10S-S-149A	30	0.097	8.32

NA- Not analyzed.
BDL- Below detection limit.

Table 4.3 Listing of SBS Effluents (continued).

Test	Date	Time	Name	Weight (g)	^{99m}Tc (μCi/g)	pH
5	12/16/11	0:56	10T-S-14A	53.52	0.155	8.26
		10:17 (blow down)	10T-S-35A	46598.05	0.073	8.40
		11:05 (rinse)	10T-S-35B	34053.37	0.027	7.99
6	01/09/12	10:24	10T-S-37A	32	BDL	8.18
	01/10/12	0:11	10T-S-58A	47.98	0.055	8.16
		12:09	10T-S-67A	54	0.089	8.12
	01/11/12	0:05	10T-S-78A	50.85	0.120	8.08
		12:06	10T-S-86A	34	0.156	8.12
	01/12/12	0:02	10T-S-102A	37.33	0.129	8.01
		12:01	10T-S-106A	56	0.095	8.12
		14:05 (blow down)	10T-S-112A	44740	0.236	8.28
		14:50 (rinse)	10T-S-112B	29448	0.061	8.53
7	1/17/2012	9:55	10T-S-139A	40	BDL	8.12
		23:10	10T-S-146A	55.10	0.034	8.41
	1/18/2012	11:21	10U-S-13A	36	0.056	8.51
		23:10	10U-S-23A	56.11	0.066	8.43
	1/19/2012	11:05	10U-S-33A	38	0.084	8.43
		23:10	10U-S-47A	51.33	0.086	8.44
	1/20/2012	11:57	10U-S-51A	58	0.099	8.52
		13:37 (blow down)	10U-S-56A	41624	0.109	8.49
		14:10 (rinse)	10U-S-56B	29176	0.024	8.38
8	2/20/2012	10:34	10U-S-69A	24	BDL	8.23
		23:34	10U-S-95A	55.92	0.068	7.72
	2/21/2012	11:32	10U-S-101A	28	0.096	7.98
		23:31	10U-S-109A	38.01	0.165	7.95
	2/22/2012	11:31	10U-S-119A	28	0.219	8.05
		23:30	10U-S-127A	86.35	0.246	7.91
	2/23/2012	11:21	10U-S-136A	32	0.237	7.96
		13:13 (blow down)	10U-S-137A	43400	0.323	8.01
		14:01 (rinse)	10U-S-137B	19674	0.104	8.29
9	3/6/2012	10:52	10V-S-22A	62	BDL	8.08
	3/7/2012	0:32	10V-S-39A	95.95	0.041	8.04
		12:31	10V-S-51A	26	0.062	8.33
	3/8/2012	0:31	10V-S-61A	47	0.071	8.13
		12:35	10V-S-69A	30	0.078	8.25
	3/9/2012	0:31	10V-S-79A	39.09	0.100	8.15
		12:30	10V-S-88A	30	0.107	8.25
		13:47 (blow down)	10V-S-93A	44170	0.119	8.35
		14:25 (rinse)	10V-S-93B	42350	0.020	7.98

BDL- Below detection limit.

Table 4.4. Listing of WESP Effluents.

Test	Date	Time	Name	Weight (g)	^{99m}Tc (μCi/g)	pH
1	8/30/2011	21:50	10Q-W-89A	17.68	BDL	9.78
	8/31/2011	12:57	10Q-W-102A	32	0.081	8.26
		23:04	10Q-W-118A	47.02	0.034	8.02
	9/1/2011	10:50	10Q-W-122A	32	0.062	8.27
		20:05	10Q-W-135A	25.78	0.028	8.01
		20:10	10Q-W-135B	31.47	0.014	7.98
		20:38	10Q-W-135C	31.08	0.012	8.04
	9/2/2011	10:57	10Q-W-139A	32	0.002	8.60
	9/1/2011	18:30	WESP was out.			
2	9/6/2011	23:37	10R-W-12A	9.04	BDL	1.99
	9/7/2011	14:07	10R-W-40A	22	0.094	7.43
	9/8/2011	1:59	10R-W-44A	33.52	0.238	7.93
		13:58	10R-W-48A	26	0.218	7.97
	9/9/2011	2:23	10R-W-58A	15.48	0.650	8.00
		14:02	10R-W-68A	26	0.663	7.89
		23:37	10R-W-76A	21.17	6.815	7.46
	9/10/2011	0:22 (deluge #1)	10R-W-77A	3380	0.579	7.38
		1:47 (deluge #2)	10R-W-89A	5260	0.037	NA
3	9/19/2011	15:14	10R-W-120A	30.03	BDL	7.70
	9/20/2011	3:47	10R-W-133A	25.71	0.284	7.51
		15:31	10R-W-143A	49.35	0.412, 0.567	7.65
	9/21/2011	3:30	10R-W-147A	11.91	0.814	7.63
		15:30	10S-W-12A	29.76	0.937	7.45
		22:10	10S-W-18A	50.49	0.087	7.47
	9/21/2011	23:30 (deluge)	10S-W-19A	4560	0.540	NA
4	9/26/2011	14:05	10S-W-42A	30	BDL	6.85
	9/27/2011	5:05	10S-W-49A	22.31	0.274	6.34
		16:45	10S-W-58A	36.49	0.729, 0.793	7.04
	9/28/2011	4:46	10S-W-62A	20.2	0.375	7.41
		11:06	10S-W-68A	32	0.365	7.85
		16:48	10S-W-71A	33.58	0.515	7.52
	9/29/2011	4:46	10S-W-81A	18.05	0.262	6.95
		16:56	10S-W -93A	33.71	0.314	7.59
		19:23 (deluge #1)	10S-W-94A	7900	0.647	7.29
		21:13 (deluge #2)	10S-W-94B	36.43	2.917	6.62
5	12/13/2011	10:24	10S-W-102A	54.0	BDL	7.39
	12/14/2011	0:50	10S-W-127A	17.18	0.521	7.63
		12:56	10S-W-131A	32	0.309	7.84
	12/15/2011	0:46	10S-W-147A	48.45	0.389	7.85
		12:52	10S-W-149A	28	0.597	7.91

NA- Not analyzed
BDL- Below detection limit.

Table 4.4. Listing of WESP Effluents (continued).

Test	Date	Time	Name	Weight (g)	^{99m}Tc (μCi/g)	pH
5	12/16/2011	1:04	10T-W-14A	25.99	0.620	7.78
		10:01 (deluge #1)	10T-W-35A	8201.41	2.271	7.10
		15:30 (deluge #2)	10T-W-36A	10351.29	0.016	7.50
6	1/9/2012	11:12	10T-W-37A	32	BDL	7.07
	1/10/2012	0:22	10T-W-58A	33.62	0.314	6.94
		12:12	10T-W-67A	36	0.337	6.81
	1/11/2012	0:12	10T-W-78A	29.79	0.426	7.03
		12:10	10T-W-86A	30	0.453	7.04
	1/12/2012	0:03	10T-W-102A	35.45	0.784	5.77
		12:03	10T-W-106A	40	0.498	6.97
		13:42 (deluge #1)	10T-W-112A	7214	2.863	8.30
		16:30 (deluge #2)	10T-W-115A	7935	0.196	7.48
7	1/17/2012	9:55	10T-W-139A	28	BDL	7.37
		23:12	10T-W-146A	54.72	0.105	7.74
	1/18/2012	11:24	10U-W-13A	26	0.267	7.50
		23:39	10U-W-23A	36.44	0.255	8.10
	1/19/2012	11:08	10U-W-33A	34	0.180	8.07
		23:43	10U-W-47A	35.62	0.263	8.02
	1/20/2012	11:58	10U-W-51A	36	0.244	8.25
		13:05 (deluge #1)	10U-W-56A	8046	0.600	7.55
		13:13 (deluge #2)	10U-W-56B	8084	0.032	7.68
8	2/20/2012	10:38	10U-W-69A	22	BDL	7.03
		23:57	10U-W-95A	23.98	0.252	7.12
	2/21/2012	11:34	10U-W-101A	30	0.250	5.82
		23:37	10U-W-109A	15.55	0.803	7.38
	2/22/2012	11:33	10U-W-119A	26	0.338	7.21
		23:39	10U-W-127A	69	0.585	7.21
	2/23/2012	11:23	10U-W-136A	26	0.799	6.19
		12:48 (deluge #1)	10U-W-137A	8270	3.567	7.39
		12:57 (deluge #2)	10U-W-137B	8078	0.304	7.63
		13:30 (deluge #3)	10U-W-137C	7486	0.017	7.45
9	3/6/2012	11:32	10V-W-22A	30.0	BDL	2.04
	3/7/2012	0:36	10V-W-39A	51.44	0.142	7.69
		12:35	10V-W-51A	18	0.281	7.72
	3/8/2012	0:34	10V-W-61A	58	0.279	8.00
		12:38	10V-W-69A	28	0.225	7.96
	3/9/2012	0:34	10V-W-79A	34.03	0.320	7.96
		12:30	10V-W-88A	28	0.412	7.97
		13:29 (deluge #1)	10V-W-88B	7970	0.745	7.86
		13:38 (deluge #2)	10V-W-88C	8144	0.013	7.64

BDL- Below detection limit.

Table 4.5. Listing of Concentrates from the Custom Evaporator (S9).

Test	Date	Time	Name	Weight (g)	^{99m}Tc (μCi/g)	pH
1	8/30/2011	21:50	10Q-E1-89A	22.15	BDL	8.33
	8/31/2011	11:42	10Q-E1-102A	14	0.804, 0.746	7.58
		23:04	10Q-E1-118A	30.30	1.732	7.10
	9/1/2011	10:56	10Q-E1-122A	12	3.070, 1.062	7.13
		23:03	10Q-E1-137A	45.80	NA	7.98
	9/2/2011	11:00	10Q-E1-139A	20	1.068	7.71
		14:42	10Q-E1-147A	6	1.724	7.43
		16:10 (blow down)	10R-E1-7A	2206	1.560	NA
2	9/6/2011	23:37	10R-E1-12A	10.13	NA	8.01
	9/7/2011	14:05	10R-E1-40A	20	1.155	7.84
	9/8/2011	1:59	10R-E1-44A	16.81	1.575	7.82
		13:58	10R-E1-48A	14	2.083	7.87
	9/9/2011	2:23	10R-E1-58A	26.06	3.797	7.62
		13:59	10R-E1-68A	16	2.871	7.62
		22:22	10R-E1-76A	55.72	2.454	7.49
	9/10/2011	1:30 (blow down)	10R-E1-89A	1695	3.612	NA
		2:10 (rinse #1)	10R-E1-89B	3160	0.200	NA
		2:38 (rinse #2)	10R-E1-89C	3540	0.022	NA
3	9/19/2011	15:14	10R-E1-120A	54.85	BDL	8.00
	9/20/2011	3:51	10R-E1-133A	24.81	1.098,1.224, 1.217	7.31
		15:31	10R-E1-143A	41.64	2.555, 2.763	7.02
	9/21/2011	3:46	10R-E1-147A	24.13	3.947	6.93
		15:30	10S-E1-12A	35.37	4.229	6.91
		22:10	10S-E1-18A	24.05	4.557	6.91
	9/22/2011	4:20 (blow down)	10S-E1-19A	2020	0.529	6.88
		4:20 (rinse)	10S-E1-19B	2880	0.365	NA
4	9/26/2011	13:50	10S-E1-42A	22	BDL	7.63
	9/27/2011	4:52	10S-E1-49A	25.82	0.788, 0.918	5.30
		16:42	10S-E1-58A	31.14	1.703	5.20
	9/28/2011	4:49	10S-E1-62A	25.1	2.169, 2.411	6.25
		16:42	10S-E1-71A	23.19	2.507	5.73
	9/29/2011	4:50	10S-E1-81A	21.75	2.561	5.70
		16:45	10S-E1-93A	35.12	2.031, 2.575	4.79
		20:11 (blow down)	10S-E1-94A	1942.9	2.148	4.90
		20:45 (rinse)	10S-E1-94B	1748	0.317	6.29
5	12/14/2011	0:54	10S-E1-127A	31.11	1.869	6.95
		13:00	10S-E1-131A	40	2.075	6.89
	12/15/2011	1:07	10-E1-147A	26.18	3.710	6.89
		12:57	10S-E1-149A	28	5.313	6.76

NA- Not analyzed.
BDL- Below detection limit.

Table 4.5. Listing of Concentrates from the Custom Evaporator (S9) (continued).

Test	Date	Time	Name	Weight (g)	^{99m}Tc (μCi/g)	pH
5	12/16/2011	0:58	10T-E1-14A	28.16	5.441	6.75
		9:36	10T-E1-35A	510.52	1.181	7.15
		9:43	10T-E1-35B	502.45	0.009	7.29
		9:48	10T-E1-35C	500.39	0.002	7.55
		11:55 (blow down)	10T-E1-35D	1352	8.478	6.95
		12:15 (rinse #1)	10T-E1-35E	3153.33	0.598	7.29
		17:42 (rinse #2)	10T-E1-36A	3852.26	0.198	7.63
		18:05 (rinse #3)	10T-E1-36B	4163.53	0.027	7.45
6	1/9/2012	12:29	10T-E1-54A	22	BDL	7.09
	1/10/2012	0:24	10T-E1-58A	26.91	1.823	7.85
		12:17	10T-E1-67A	24	3.042	7.01
	1/11/2012	0:19	10T-E1-78A	47.54	5.527	7.07
		12:17	10T-E1-86A	44	5.425	6.83
	1/12/2012	0:04	10T-E1-102A	49.31	2.761	7.31
		12:06	10T-E1-106A	36	4.476	6.84
		16:00 (blow down)	10T-E1-115A	1548	5.759	7.08
		17:00 (rinse #1)	10T-E1-115B	3086	0.415	7.66
		17:11 (rinse #2)	10T-E1-115C	3162	0.064	7.61
7	1/17/2012	10:01	10T-E1-139A	36	BDL	8.08
		23:14	10T-E1-146A	48.72	0.872	7.20
	1/18/2012	11:37	10U-E1-13A	36	1.523	7.22
		23:12	10U-E1-23A	48.64	1.891	7.04
	1/19/2012	11:13	10U-E1-33A	28	2.750	7.08
		23:12	10U-E1-47A	59.56	3.219	6.98
	1/20/2012	11:41	10U-E1-51A	34	3.157	6.90
		15:06 (blown down)	10U-E1-57A	1784	4.403	6.78
		15:15 (rinse #1)	10U-E1-57B	1600	0.698	7.33
		15:40 (rinse #2)	10U-E1-57C	3602	0.070	NA
8	2/20/2012	11:45	10U-E1-69A	22	BDL	7.34
		23:37	10U-E1-95A	22.82	2.098	6.83
	2/21/2012	11:38	10U-E1-101A	36	2.856	6.72
		23:45	10U-E1-109A	19.67	5.160	6.73
	2/22/2012	11:36	10U-E1-119A	34	6.058	6.69
		23:32	10U-E1-127A	56.91	7.438	6.57
	2/23/2012	11:24	10U-E1-136A	34	7.482	6.42
		14:15 (blow down)	10U-E1-137A	1570	3.567	6.43
		15:20 (rinse #1)	10U-E1-146A	2318.47	0.304	6.86
		15:45 (rinse #2)	10U-E1-146B	1951.23	0.017	7.40

NA- Not analyzed.
BDL- Below detection limit.

Table 4.5. Listing of Concentrates from the Custom Evaporator (S9) (continued).

Test	Date	Time	Name	Weight (g)	^{99m}Tc (µCi/g)	pH
9	3/6/2012	12:26	10V-E1-31A	44	BDL	7.65
	3/7/2012	0:38	10V-E1-39A	62.27	1.080	7.14
		12:38	10V-E1-51A	30	1.650	7.03
	3/8/2012	0:36	10V-E1-61A	42	2.907	6.74
		12:39	10V-E1-69A	32	2.754	6.95
	3/9/2012	0:35	10V-E1-79A	33.48	2.136	6.97
		12:30	10V-E1-88A	32	3.392	6.84
		15:20 (blow down)	10V-E1-93A	1620	3.923	6.73
		15:35 (rinse #1)	10V-E1-93B	3508	0.181	7.56
		15:52 (rinse #2)	10V-E1-93C	2618	0.056	7.31

BDL- Below detection limit.

Table 4.6. Listing of Samples around the Commercial Evaporator (S10).

Test	Date	Time	Name	Weight (g)	^{99m}Tc (μCi/g)	pH
1	9/2/2011	17:11 (blow down)	10R-E2-7A	119040	0.058	8.93
		17:21 (rinse)	10R-E2-7B	89680	BDL	8.19
2	9/10/2011	3:00 (blow down)	10R-E2-89A	32780	BDL	8.87
3	9/22/2011	4:00 (blow down)	10S-E2-19A	32620	BDL	NA
4	9/27/2011	5:00	10S-E2-49A	31.46	0.00059	6.42
		16:51	10S-E2-58A	34.38	0.00023	3.09
	9/28/2011	4:51	10S-E2-62A	16.7	0.00016	3.16
		16:45	10S-E2-71A	18.69	0.00026	2.73
	9/29/2011	4:52	10S-E2-81A	27.94	BDL	2.90
		16:51	10S-E2-93A	36.99	BDL	3.16
		20:23 (blow down)	10S-E2-94A	32620	BDL	NA
5	12/13/2011	10:25	10S-E2-102A	38	BDL	6.69
	12/14/2011	0:57	10S-E2-127A	24.38	0.00003	7.08
	12/15/2011	1:10	10S-E2-147A	28.07	BDL	6.85
	12/16/2011	1:06	10T-E2-14A	24.41	BDL	6.74
		12:23 (blow down)	10T-E2-35A	33161.63	BDL	7.64
6	1/10/2012	0:26	10T-E2-58A	26.17	0.00002	6.82
	1/11/2012	0:24	10T-E2-78A	31.62	0.002	6.60
	1/12/2012	1:05	10T-E2-102A	23.39	0.236	6.75
		17:22 (blow down)	10T-E2-115A	49792	0.043	7.34
7	1/17/2012	23:32	10T-E2-146A	26.76	0.00001	7.00
	1/18/2012	23:14	10U-E2-23A	25.85	BDL	6.78
	1/19/2012	23:14	10U-E2-47A	33.16	BDL	6.81
	1/20/2012	16:05 (blow down)	10U-E2-57A	45709	0.0003	7.33
8	2/20/2012	23:39	10U-E2-95A	32.76	0.00007	6.52
	2/21/2012	23:49	10U-E2-109A	23.44	0.024	7.62
	2/22/2012	23:36	10U-E2-127A	32.96	0.001	6.56
	2/23/2012	17:40 (blow down)	10U-E2-146A	48454	BDL	7.19
9	3/7/2012	0:42	10V-E2-39A	25.30	0.00001	7.31
	3/8/2012	0:40	10V-E2-61A	28	0.00013	7.15
		0:42	10V-E2-79A	25.98	0.00078	7.06
	3/9/2012	16:04 (blow down)	10V-E2-93A	31488	BDL	7.45

NA- Not analyzed.
BDL- Below detection limit.

Table 4.7. Anion Concentrations Measured by Ion Chromatography on Test 1 Process Solutions (ppm).

Sample ID	Chloride	Fluoride	Iodine	Nitrite	Nitrate	Sulfate
10Q-S-102A	112	9.69	85	338	15.5	117
10Q-S-118A	99.7	5.93	72.7	399	18.7	113
10Q-S-122A	154	21.7	99.9	291	14.6	127
10Q-S-137A	141	19	143	266	13.4	135
10Q-S-139A	124	19.3	126	320	13.9	130
10Q-S-147A	125	17.5	124	381	16.8	129
10Q-W-89A	239	12.1	5.06	130	22.6	150
10Q-W-101A	199	13.7	5.37	599	145	143
10Q-W-118A	120	4.44	22	254	142	101
10Q-W-122A	135	5	13.1	372	152	99.9
10Q-W-135A	77	13.7	3.85	299	121	96.2
10Q-W-135B	57.2	28.9	9.57	221	98.2	86.7
10Q-W-135C	62.8	19.9	15.6	227	172	85.5
10Q-W-139A	45.8	3.43	13.3	176	76.9	74.6
10Q-E1-89A	2700	85	887	2430	430	2860
10Q-E1-102A	5900	180	2600	7940	1190	4960
10Q-E1-118A	7900	121	3380	13900	2570	6810
10Q-E1-122A	8310	143	3580	13200	2760	6570
10Q-E1-137A	1850	162	871	2320	432	1710
10Q-E1-139A	2140	145	1420	3650	489	2290
10Q-E1-147A	3180	295	2470	6290	897	3180
10R-S-7B	181	28	160	562	24	184
10R-E2-7A	569	12.7	54.8	563	63.8	987

Table 4.8. Elemental Concentrations Measured by DCP-AES on Test 1 Process Solutions (ppm).

Sample ID	Al	B	Ba	Ca	Cr	Fe	K	Li	Mg	Mn	Na	Ni	P	Re	Si	Sr	Ti	Zn	Zr
10Q-S-102A	1.48	29.6	<0.01	40.6	0.656	0.277	16.2	0.407	14.2	<0.2	127	<0.2	3.21	44.2	<0.2	0.244	<0.1	1.31	<0.1
10Q-S-118A	0.972	20.8	<0.01	42.7	0.568	0.377	14.2	<0.25	14.5	<0.2	106	<0.2	<3.0	62.3	<0.2	0.243	<0.1	1.77	<0.1
10Q-S-122A	2.32	64	<0.01	40.4	1.28	0.473	24.9	0.264	13.9	<0.2	245	<0.2	<3.0	86.7	<0.2	0.182	<0.1	2.48	<0.1
10Q-S-137A	1.8	56.5	<0.01	40	1.02	0.365	24.4	<0.25	14.3	<0.2	209	<0.2	<3.0	96	<0.2	0.205	<0.1	1.91	<0.1
10Q-S-139A	2.24	53.7	<0.01	40.1	0.97	0.343	22.4	<0.25	14.1	<0.2	203	<0.2	<3.0	77.8	<0.2	0.194	<0.1	1.53	<0.1
10Q-S-147A	1.88	51.3	<0.01	42.1	0.955	0.429	22.4	<0.25	14.5	<0.2	195	<0.2	3.33	81.8	<0.2	0.213	<0.1	1.44	<0.1
10Q-W-89A	0.353	26.5	0.027	40.6	2.57	<0.25	34.4	1.29	13.4	<0.2	179	<0.2	<3.0	61.7	<0.2	0.252	<0.1	0.237	<0.1
10Q-W-101A	<0.15	9.09	0.035	39.4	1.34	<0.25	31.9	0.254	12.4	<0.2	175	<0.2	4.76	146	<0.2	0.237	<0.1	0.34	<0.1
10Q-W-118A	<0.15	8.91	0.04	41.1	0.555	<0.25	16.2	<0.25	13.3	<0.2	88.6	<0.2	3.26	76.4	<0.2	0.271	<0.1	0.384	<0.1
10Q-W-122A	0.174	9.49	0.035	42.4	0.666	<0.25	20.7	<0.25	11.8	<0.2	108	<0.2	<3.0	98	<0.2	0.277	<0.1	0.248	<0.1
10Q-W-135A	0.24	5.86	0.031	40.9	0.38	<0.25	11.3	<0.25	12.5	<0.2	60.2	<0.2	<3.0	34.3	<0.2	0.26	<0.1	0.438	<0.1
10Q-W-135B	0.658	3.81	0.03	40.2	0.79	1.09	11.4	<0.25	11.9	<0.2	42.5	<0.2	<3.0	19.8	<0.2	0.252	<0.1	0.899	<0.1
10Q-W-135C	0.531	3.85	0.034	42.1	0.423	0.566	9.38	<0.25	11.9	<0.2	44.4	<0.2	<3.0	22.3	<0.2	0.269	<0.1	0.511	<0.1
10Q-W-139A	0.389	2.97	0.048	41.6	<0.05	<0.25	4.66	<0.25	11.9	<0.2	29.4	<0.2	4.63	3.94	<0.2	0.239	<0.1	0.172	<0.1
10Q-E1-89A	1.74	635	0.237	499	22.2	0.409	395	53	315	<0.2	3220	0.361	<3.0	636	7.55	4.46	<0.1	0.571	<0.1
10Q-E1-102A	7.96	1270	0.692	1290	35.1	3.55	907	55.6	664	0.283	6440	0.395	6.63	2310	23.7	12	<0.1	8.56	0.283
10Q-E1-118A	5	1510	1.97	2450	49.3	2.9	1260	38.3	1290	0.732	9130	0.792	5.28	3930	50.7	25.7	0.101	25.1	0.28
10Q-E1-122A	5.43	1850	1.52	2000	63.8	3.1	1370	23	1120	0.606	9950	0.821	9.98	4870	60	20.6	<0.1	25.5	0.306
10Q-E1-137A	6.46	546	0.14	415	13.9	1.78	306	2.67	189	<0.2	2430	<0.2	3.64	1190	11.6	3.25	<0.1	5.56	0.159
10Q-E1-139A	5.73	745	0.235	591	16	1.95	352	3.48	269	<0.2	3030	<0.2	3.54	1290	13.9	4.87	<0.1	6.49	0.185
10Q-E1-147A	5.14	1100	0.318	812	22	1.13	589	3.68	453	<0.2	4810	<0.2	6.39	1880	19.6	6.4	<0.1	7.08	0.146
10R-S-7B	1	87.7	0.026	56.3	2.08	<0.25	34.1	<0.25	18.6	<0.2	287	<0.2	3.02	124	<0.2	0.327	<0.1	1.58	<0.1
10R-E2-7A	0.529	49.6	0.311	349	0.981	<0.25	58.1	1.28	149	<0.2	424	<0.2	3.06	80.6	18.1	2.95	<0.1	0.755	<0.1

Table 4.9. Anion Concentrations Measured by Ion Chromatography on Test 2 Process Solutions (ppm).

Sample ID	Chloride	Fluoride	Iodine	Nitrite	Nitrate	Sulfate
10R-S-12A	53.2	2.7	12.6	12.6	6.13	83.3
10R-S-40A	62.3	4.88	42.4	90.8	6.33	88.5
10R-S-44A	62.6	4.96	45.1	122	6.12	84.7
10R-S-48A	62.3	4.99	43.7	127	6.07	84.9
10R-S-58A	63.3	6.48	54.2	135	6.98	82.3
10R-S-68A	61.6	6.77	53.7	195	8.86	81.8
10R-S-76A	71.9	8.21	71.4	172	6.97	83.4
10R-W-12A	61.9	6.65	<0.5	<0.5	2540	83.4
10R-W-40A	78.1	4.84	9.55	364	204	93.1
10R-W-44A	116	8.25	13.7	474	99.6	100
10R-W-48A	129	9.15	11.5	618	146	100
10R-W-58A	317	31.5	14.6	1110	187	167
10R-W-68A	229	19.7	10.7	761	122	130
10R-E1-12A	742	82.3	543	1540	226	842
10R-E1-40A	2100	55.3	1060	3060	331	2500
10R-E1-44A	2000	51.9	1200	3050	281	2210
10R-E1-48A	2190	67.2	1460	3940	299	2260
10R-E1-58A	2090	87.1	1440	3960	314	2270
10R-E1-68A	2340	64	1560	4650	428	2280
10R-E1-76A	2340	68.9	1570	4680	406	2250
10R-R-77A	2430	57.4	1610	5040	503	2510
10R-S-77A	79	9.37	81.6	179	7.95	87.7
10R-S-77B	79	9.37	77.3	180	8.08	87.6
10R-W-77A	190	14.9	6.06	264	168	122
10R-O-77A	74.8	7.72	60.3	183	10.9	85.4
10R-E2-89A	1130	10.9	5.82	294	113	2080

Table 4.10. Elemental Concentrations Measured by DCP-AES on Test 2 Process Solutions (ppm).

Sample ID	Al	B	Ba	Ca	Cr	Fe	K	Li	Mg	Mn	Na	Ni	P	Re	Si	Sr	Ti	Zn	Zr
10R-S-12A	0.307	7	<0.01	39.9	0.217	<0.25	5.32	<0.25	12.4	<0.2	52.9	<0.2	<3.0	6.79	1.34	0.172	<0.1	0.147	<0.1
10R-S-40A	0.445	15.8	<0.01	37.8	0.344	<0.25	8.83	<0.25	12.3	<0.2	92.2	<0.2	<3.0	23.8	0.989	0.173	<0.1	0.128	<0.1
10R-S-44A	0.306	11	<0.01	41.4	0.25	<0.25	8.23	<0.25	12.3	<0.2	68.4	<0.2	<3.0	30.5	1.36	0.198	<0.1	0.202	<0.1
10R-S-48A	0.369	10.5	<0.01	40.8	0.242	<0.25	8.24	<0.25	12	<0.2	68	<0.2	<3.0	30.4	1.11	0.195	<0.1	0.195	<0.1
10R-S-58A	0.425	14.7	<0.01	40.7	0.284	<0.25	9.71	<0.25	11.8	<0.2	79.5	<0.2	<3.0	30.9	0.992	0.184	<0.1	0.219	<0.1
10R-S-68A	0.469	16	<0.01	38	0.262	<0.25	9.65	<0.25	11.7	<0.2	91.2	<0.2	<3.0	35.1	0.909	0.169	<0.1	0.22	<0.1
10R-S-76A	0.443	15.5	<0.01	37.9	0.332	<0.25	10.8	<0.25	11.4	<0.2	87.7	<0.2	<3.0	47.7	0.918	0.176	<0.1	0.233	<0.1
10R-W-12A	8.88	7.63	0.544	53	2.61	26	8.65	0.265	12.5	1.5	49.4	6.41	<3.0	16	13.6	0.244	0.274	8.57	<0.1
10R-W-40A	<0.15	5.66	<0.01	44.4	0.653	<0.25	12.3	<0.25	12.6	<0.2	84.3	<0.2	<3.0	55.2	4.92	0.236	<0.1	1.34	<0.1
10R-W-44A	<0.15	5.04	<0.01	44.5	0.599	<0.25	18	<0.25	12.8	<0.2	111	<0.2	<3.0	123	3.74	0.23	<0.1	0.452	<0.1
10R-W-48A	<0.15	6.2	<0.01	40.7	0.862	<0.25	20.1	<0.25	11.7	<0.2	125	<0.2	<3.0	147	3.67	0.209	<0.1	0.476	<0.1
10R-W-58A	<0.15	22.1	0.017	44.6	2.22	<0.25	70.7	<0.25	13.4	<0.2	383	<0.2	<3.0	502	5.3	0.262	<0.1	4.65	<0.1
10R-W-68A	<0.15	9.1	<0.01	40.1	1.26	<0.25	47.5	<0.25	12.2	<0.2	236	<0.2	<3.0	364	4.3	0.221	<0.1	0.711	<0.1
10R-E1-12A	0.588	317	0.027	145	5.67	<0.25	125	1.26	91.7	<0.2	1530	<0.2	<3.0	451	5.39	1.25	<0.1	0.959	<0.1
10R-E1-40A	1.03	318	0.473	1080	12.3	0.38	282	3.45	423	<0.2	2170	<0.2	<3.0	898	12.2	7.24	<0.1	1.79	<0.1
10R-E1-44A	0.932	263	0.584	1040	8.12	0.392	269	2.88	392	<0.2	1930	<0.2	<3.0	951	16.7	8.05	<0.1	1.85	<0.1
10R-E1-48A	1.03	362	0.696	1140	9.49	0.37	333	2.96	456	<0.2	2450	<0.2	<3.0	1140	18	8.79	<0.1	2.42	<0.1
10R-E1-58A	1.11	366	0.53	1060	9.32	0.382	292	2.83	354	<0.2	2430	<0.2	<3.0	1280	16.5	7.99	<0.1	4.63	<0.1
10R-E1-68A	1.17	364	0.623	1120	8.09	0.401	357	3.02	406	<0.2	2770	<0.2	<3.0	1580	16.5	8.83	<0.1	5.15	<0.1
10R-E1-76A	1.23	371	0.573	1090	6.88	0.436	350	2.89	365	<0.2	2880	<0.2	<3.0	1780	19.2	8.4	<0.1	7.98	<0.1
10R-R-77A	1.32	390	0.514	1070	7.15	0.439	363	2.9	382	<0.2	2870	<0.2	<3.0	2350	17	8.27	<0.1	6.85	<0.1
10R-S-77A	0.861	17	<0.01	39.9	0.415	<0.25	11.8	<0.25	11.5	<0.2	94.1	<0.2	<3.0	55.1	1.47	0.19	<0.1	0.174	<0.1
10R-S-77B	0.902	17.2	<0.01	38.5	0.431	<0.25	12	<0.25	11.8	<0.2	93.4	<0.2	<3.0	54.8	1.46	0.192	<0.1	0.159	<0.1
10R-W-77A	<0.15	10.1	<0.01	39.6	1.05	<0.25	51.5	<0.25	11.9	<0.2	192	<0.2	<3.0	351	4.13	0.206	<0.1	0.699	<0.1
10R-O-77A	0.342	13.8	<0.01	38.6	0.328	<0.25	11.8	<0.25	11.7	<0.2	84.5	<0.2	<3.0	53.5	1.25	0.187	<0.1	0.213	<0.1
10R-E2-89A	0.392	<1.0	0.272	477	0.114	<0.25	113	1.21	317	<0.2	724	<0.2	<3.0	5.26	46.7	4.75	<0.1	0.252	<0.1

Table 4.11. Anion Concentrations Measured by Ion Chromatography on Test 3 Process Solutions (ppm).

Sample ID	Chloride	Fluoride	Iodine	Nitrite	Nitrate	Sulfate
10R-S-120A	32.4	1.73	0.525	4.62	9.19	55.1
10R-S-133A	78.8	12.7	73.7	324	35.1	95.6
10R-S-143A	112	15.6	116	490	38.3	105
10R-S-147A	132	16.7	148	555	42.6	115
10S-S-12A	142	18.8	152	571	44	114
10S-S-18A	138	17.7	144	521	48	114
10R-W-120A	227	31.7	3.31	139	271	205
10R-W-133A	302	36.6	16.7	1030	203	268
10R-W-143A	420	42.9	17.5	1120	221	296
10R-W-147A	602	46.3	22.8	1390	307	359
10S-W-12A	685	54	23.4	1860	338	392
10S-W-18A	102	9.64	1.85	182	59.2	92.8
10R-E1-120A	803	49.4	410	1190	194	951
10R-E1-133A	1770	48.2	1280	7700	1130	2210
10R-E1-143A	2840	63.5	1830	8390	1540	2090
10R-E1-147A	5160	26.6	2740	12200	2100	2050
10S-E1-12A	2660	25.6	2480	5810	1610	1880
10S-E1-18A	4010	51.8	2220	7750	1780	2430
10S-S-19A	141	18.8	140	535	45.7	119
10S-E1-19A	4000	18	2240	7180	1880	2110
10S-O-28B	547	184	34	199	435	432
10S-O-19C	167	15.5	79.4	471	72.3	126
10S-O-19A	3940	49.6	2640	8510	2210	3160
10S-O-28E	3650	886	9.36	<0.5	426	2350
10S-O-28F	23.2	13.2	0.525	<0.5	3110	18.7

Table 4.12. Elemental Concentrations Measured by DCP-AES on Test 3 Process Solutions (ppm).

Sample ID	Al	B	Ba	Ca	Cr	Fe	K	Li	Mg	Mn	Na	Ni	P	Re	Si	Sr	Ti	Zn	Zr
10R-S-120A	0.155	4.18	<0.01	32.2	0.278	<0.25	4.2	<0.25	7.2	<0.2	37.7	<0.2	<3.0	2.34	2.45	0.121	<0.1	0.406	<0.1
10R-S-133A	<0.15	44.4	<0.01	30.7	1.79	0.351	22.5	1.94	7.64	<0.2	189	0.225	<3.0	46.5	5.63	0.131	<0.1	0.182	<0.1
10R-S-143A	<0.15	46.1	<0.01	30.1	1.72	<0.25	27	2.24	7.08	<0.2	215	<0.2	<3.0	86.3	5.65	0.124	<0.1	0.453	<0.1
10R-S-147A	<0.15	47.9	<0.01	31	1.96	0.297	33.4	2.48	7.24	<0.2	227	<0.2	<3.0	113	5.77	0.128	<0.1	0.56	<0.1
10S-S-12A	<0.15	52.1	<0.01	31	1.99	0.27	35	2.8	7.18	<0.2	257	0.226	<3.0	130	5.91	0.121	<0.1	0.396	<0.1
10S-S-18A	<0.15	51.6	<0.01	32.6	2.13	0.322	35.7	2.54	7.4	<0.2	250	<0.2	<3.0	130	6.23	0.125	<0.1	0.343	<0.1
10R-W-120A	0.384	42.7	0.012	37.7	3.05	0.333	55.7	<0.25	8.9	<0.2	336	0.436	<3.0	255	5.07	0.164	<0.1	2.11	<0.1
10R-W-133A	0.288	24.7	0.02	36.5	4.85	0.263	95.9	2.02	7.88	<0.2	419	0.446	<3.0	320	6.66	0.148	<0.1	1.57	<0.1
10R-W-143A	0.207	20.3	0.025	34.2	4.85	<0.25	112	2.7	7.77	<0.2	475	0.239	<3.0	439	6.89	0.146	<0.1	1.62	<0.1
10R-W-147A	0.192	18.8	0.036	33.8	5.86	0.343	156	3.56	7.78	<0.2	892	0.251	<3.0	690	8.34	0.152	<0.1	2.64	<0.1
10S-W-12A	0.17	23.8	0.027	33.8	7.33	<0.25	184	4.05	7.23	<0.2	914	<0.2	<3.0	787	9.65	0.141	<0.1	4.75	<0.1
10S-W-18A	<0.15	3.83	<0.01	31.1	0.716	<0.25	25.1	0.374	7.59	<0.2	105	<0.2	<3.0	99.3	4.88	0.123	<0.1	1	<0.1
10R-E1-120A	0.615	149	0.118	357	3.9	0.31	123	0.953	121	<0.2	1530	<0.2	<3.0	531	6.85	2.42	<0.1	2.59	<0.1
10R-E1-133A	1.29	1560	0.313	1050	71	0.638	1020	90.6	294	0.217	6470	0.491	<3.0	1690	30	6.65	<0.1	18.3	0.116
10R-E1-143A	1.36	1320	0.484	738	53.4	0.803	1090	82.9	270	0.3	5860	0.42	<3.0	3190	31	5.38	<0.1	64.4	0.113
10R-E1-147A	0.952	1330	0.224	682	59	0.924	1440	92	281	0.341	7430	0.359	<3.0	3620	39.3	4.8	<0.1	127	0.161
10S-E1-12A	0.685	1290	0.239	383	55.5	0.693	1240	85.4	220	0.279	6700	0.321	<3.0	3910	62.4	3.84	<0.1	96.1	0.134
10S-E1-18A	1	1250	0.255	474	59.9	0.669	1290	92.6	259	0.286	7250	0.48	5.66	4100	44.8	4.03	<0.1	88.4	0.16
10S-S-19A	<0.15	51.7	<0.01	31.4	2.22	<0.25	36.4	2.32	7.41	<0.2	233	<0.2	<3.0	137	7.01	0.132	<0.1	0.324	<0.1
10S-E1-19A	0.692	1440	0.218	399	68.3	0.616	1330	100	243	0.227	7670	0.409	<3.0	4400	76.4	4.1	<0.1	84.2	0.108
10S-O-28A	5.34	20.7	0.011	10.4	0.514	14.7	5.43	1.26	0.541	<0.04	65.5	0.057	<0.6	8.02	63.6	0.016	1.66	12	1.36
10S-O-28C	38.8	7.02	0.052	4.84	4.21	16.5	6.44	1.14	1.52	0.285	50.4	1.22	<0.6	12.5	74.9	0.076	1.27	5.71	2.15
10S-O-28D	4.57	21	0.018	10.1	0.558	15.1	5.37	1.29	0.5	<0.04	66.4	0.049	<0.6	7.43	59.2	0.016	1.39	12.3	1.25
10S-O-28B	<0.15	382	<0.01	7.35	14.4	1.23	199	24.1	0.641	<0.2	1630	<0.2	<3.0	839	22.4	<0.01	<0.1	1.1	<0.1
10S-O-19C	<0.15	36.6	<0.01	33.7	2.03	<0.25	45.7	2.1	7.74	<0.2	254	<0.2	<3.0	155	5.86	0.138	<0.1	1.15	<0.1
10S-O-19A	1.04	1540	0.236	545	73.7	0.83	1790	103	317	0.379	9020	0.392	3.87	5300	46.7	4.42	<0.1	80.7	0.132
10S-O-28E	<0.15	296	<0.01	1.4	126	0.4	837	60.4	0.575	<0.2	4870	<0.2	4.48	3310	41.2	0.019	<0.1	0.196	<0.1
10S-O-28F	14.4	33.3	0.065	22.7	2.17	16.6	9.47	1.53	1.73	0.424	110	0.447	<3.0	19.8	34.5	0.057	1.04	36.1	1.08

Table 4.13. Anion Concentrations Measured by Ion Chromatography on Test 4 Process Solutions (ppm).

Sample ID	Chloride	Fluoride	Iodine	Nitrite	Nitrate	Sulfate
10S-S-42A	38	1.96	6.83	26.5	11.7	59.6
10S-S-49A	90.6	29.5	187	3.97	15.8	205
10S-S-58A	98	29.9	247	2.67	13.4	255
10S-S-62A	102	29	308	7.53	11.2	317
10S-S-71A	103	28.9	378	6.03	10.9	368
10S-S-81A	117	34.9	463	1.4	9.75	396
10S-S-93A	115	31	504	5.17	9.94	418
10S-W-42A	190	17.7	6.46	70.4	1080	155
10S-W-49A	130	4.76	10.4	5.3	64.3	109
10S-W-58A	334	8.99	49.8	1.37	44.6	410
10S-W-62A	171	5.61	25	7.71	23.3	219
10S-W-68A	172	13.6	46.4	11	20.2	143
10S-W-71A	259	22.2	69.2	14.7	20.8	331
10S-W-81A	147	8.54	46.7	10.2	17.6	253
10S-W-93A	181	16	66	11.9	15.1	238
10S-E1-42A	638	46.9	258	1190	220	571
10S-E1-49A	2350	98.4	3230	20.6	502	4590
10S-E1-58A	3090	38.7	6080	<0.5	504	6410
10S-E1-62A	3640	36.9	9040	<0.5	443	8560
10S-E1-71A	3700	33.1	11900	<0.5	429	9670
10S-E1-81A	3690	33.5	13200	<0.5	356	10100
10S-E1-93A	3660	59.3	13600	<0.5	319	10500
10S-E2-49A	2.26	<0.05	<0.5	171	1.16	3.96
10S-E2-58A	3.24	0.0522	<0.5	<0.5	144	295
10S-E2-62A	<0.1	0.387	<0.5	<0.5	16.2	454
10S-E2-71A	<0.1	0.917	<0.5	<0.5	12.6	939
10S-E2-81A	<0.1	4.63	0.639	<0.5	4.93	460
10S-O-94A	3740	45.3	14100	<0.5	314	10300
10S-O-94D	123	28.7	371	0.564	11.5	478
10S-O-94F	102	9.39	<0.5	<0.5	<0.25	3940
10S-O-95A	1870	144	34.5	<0.5	6.35	1470
10S-O-95C	13.3	8.29	1.78	<0.5	0.369	16.3
10S-O-95E	25.6	39.1	7.22	<0.5	0.662	160
10S-S-94A	137	35.8	542	<0.5	9.42	476
10S-W-94A	144	9.38	9.47	<0.5	70	251
10S-W-94B	170	26.8	37.1	<0.5	206	194
10S-E1-94A	3500	53	13100	<0.5	311	9620
10S-E2-93A	<0.1	5.71	1.35	<0.5	7.4	652
10S-E2-94B	486	54.2	1810	<0.5	44.6	1420

Table 4.14. Elemental Concentrations Measured by DCP-AES on Test 4 Process Solutions (ppm).

Sample ID	Al	B	Ba	Ca	Cr	Fe	K	Li	Mg	Mn	Na	Ni	P	Re	Si	Sr	Ti	Zn	Zr
10S-S-42A	<0.15	4.16	<0.01	26.7	0.061	<0.25	5.96	0.419	6.92	<0.2	42.5	<0.2	<3.0	6.24	6.68	0.108	<0.1	0.362	<0.1
10S-S-49A	5.05	32.9	0.041	36.9	<0.05	<0.25	9.59	2.5	7.5	<0.2	45.1	<0.2	<3.0	30	18.8	0.175	<0.1	26.8	<0.1
10S-S-58A	4.35	33.9	0.03	36	<0.05	<0.25	9.61	2.87	6.74	<0.2	39.1	<0.2	<3.0	41.1	20.3	0.143	<0.1	11.5	<0.1
10S-S-62A	1.05	36.4	0.014	29.5	<0.05	<0.25	11.2	3.46	6.58	<0.2	41.5	<0.2	<3.0	53.9	18.8	0.122	<0.1	9.16	<0.1
10S-S-71A	1.52	41.6	0.025	27.4	<0.05	<0.25	12.1	3.69	6.37	<0.2	40.5	<0.2	<3.0	65.4	12.7	0.119	<0.1	6.27	<0.1
10S-S-81A	3.65	42.7	0.026	33.6	<0.05	<0.25	13.8	4.18	6.37	<0.2	43.4	<0.2	<3.0	75.6	21.9	0.13	<0.1	10.4	<0.1
10S-S-93A	2.05	46.7	0.018	28.2	<0.05	<0.25	14.5	4.46	6.54	<0.2	44.1	<0.2	<3.0	77.9	15.5	0.121	<0.1	7.46	<0.1
10S-W-42A	0.651	7.44	0.055	43.4	1.37	<0.25	52.6	1.08	10.4	0.263	209	1.16	<3.0	161	8.86	0.237	<0.1	20.4	<0.1
10S-W-49A	0.155	6.89	0.015	31.1	0.172	<0.25	45.6	7.07	8.19	<0.2	111	<0.2	<3.0	292	5.71	0.151	<0.1	0.94	<0.1
10S-W-58A	0.15	23.1	0.041	32.2	0.061	<0.25	114	26	8.3	<0.2	258	0.315	<3.0	769	9.24	0.166	<0.1	9.72	<0.1
10S-W-62A	<0.15	11.7	0.038	29.1	<0.05	<0.25	54.3	16	7.69	<0.2	133	0.228	<3.0	387	6.06	0.145	<0.1	2.74	<0.1
10S-W-68A	<0.15	15.1	0.02	28.8	<0.05	<0.25	55.9	17	7.75	<0.2	129	<0.2	<3.0	437	6.33	0.143	<0.1	2.81	<0.1
10S-W-71A	<0.15	28.4	0.03	28.3	0.062	<0.25	79.6	21.6	7.7	<0.2	184	0.23	<3.0	688	8.11	0.144	<0.1	6.94	<0.1
10S-W-81A	<0.15	14.5	0.023	27	<0.05	<0.25	44.6	13.1	7.23	<0.2	106	<0.2	<3.0	337	5.58	0.129	<0.1	4.5	<0.1
10S-W-93A	0.171	17.8	0.026	26.2	0.316	0.501	62.2	15.7	7.01	<0.2	140	0.333	<3.0	479	6.29	0.123	<0.1	6.35	<0.1
10S-E1-42A	0.274	176	0.04	80.2	7.75	0.264	146	11.6	41.5	<0.2	944	<0.2	<3.0	404	19.2	0.561	<0.1	3.94	<0.1
10S-E1-49A	62.3	905	0.334	756	1.25	0.709	416	75.6	333	3.47	1510	9.03	3.86	993	105	6.7	<0.1	470	0.112
10S-E1-58A	7.22	1060	0.229	711	0.557	0.858	498	121	322	2.26	1630	6.59	6.85	1790	128	5.63	<0.1	278	0.124
10S-E1-62A	1.42	1230	0.209	522	0.222	0.535	587	164	307	1.15	1840	3.34	3.17	2400	63.3	4.57	<0.1	296	<0.1
10S-E1-71A	1.51	1250	0.22	464	0.242	0.57	591	165	275	0.904	2190	2.43	4.59	2770	86	3.92	<0.1	186	<0.1
10S-E1-81A	1.55	1300	0.232	466	0.229	0.721	626	181	255	0.944	2400	2.11	4.56	3200	78.4	3.82	<0.1	242	<0.1
10S-E1-93A	2.31	1350	0.194	262	0.877	15.1	653	181	221	0.654	2100	1.53	9.48	3100	120	2.46	0.218	165	0.261
10S-E2-49A	<0.15	197	<0.01	0.504	<0.05	<0.25	<0.4	<0.25	0.072	<0.2	0.741	<0.2	<3.0	<5.25	0.586	0.016	<0.1	0.413	<0.1
10S-E2-58A	<0.15	338	0.021	0.306	<0.05	0.31	<0.4	<0.25	<0.05	<0.2	0.309	<0.2	<3.0	<10.250	0.307	0.015	<0.1	0.408	<0.1
10S-E2-62A	0.154	416	0.012	0.392	0.054	0.309	0.524	<0.25	<0.05	0.502	0.264	<0.2	<3.0	<1.25	0.388	0.015	<0.1	0.522	<0.1
10S-E2-71A	0.181	499	<0.01	0.451	0.066	1.31	0.474	<0.25	0.062	0.408	0.466	<0.2	<3.0	<1.25	0.555	0.021	<0.1	0.74	<0.1
10S-E2-81A	0.433	520	<0.01	0.377	0.098	1.82	<0.4	<0.25	<0.05	0.349	0.539	<0.2	<3.0	<1.25	0.843	0.011	<0.1	1.49	<0.1
10S-O-94A	1.02	1460	0.208	266	0.225	0.641	669	176	201	0.626	1830	1.57	4.8	3270	83	2.3	<0.1	119	<0.1
10S-O-94D	1.33	45.7	0.041	27.6	0.24	2.19	17.6	4.9	6.32	<0.2	47	<0.2	<3.0	105	8.43	0.121	0.155	7.97	0.235
10S-O-94F	0.294	40	0.056	77.3	15.8	0.338	512	157	5.04	1.46	1620	15.8	3.91	2750	27.3	6.85	0.12	18.7	<0.1
10S-O-95A	0.191	306	<0.01	5.72	1.48	0.317	561	238	2.61	<0.2	1330	<0.2	<3.0	3110	24.2	0.115	<0.1	0.544	<0.1
10S-O-95C	0.253	27.9	<0.01	2.85	0.234	<0.25	6.9	8.39	0.208	<0.2	28.1	<0.2	<3.0	23.6	3.46	<0.01	<0.1	0.524	<0.1
10S-O-95E	0.181	86.5	<0.01	10.4	0.28	<0.25	60.3	41	0.76	<0.2	205	<0.2	<3.0	330	7.17	0.021	<0.1	0.266	<0.1
10S-S-94A	2.23	45.4	0.063	30.8	0.392	4.47	17.6	5.82	6.8	<0.2	49.8	<0.2	<3.0	99.5	11.3	0.142	0.245	9	0.355
10S-W-94A	<0.15	6.5	0.017	28.5	0.075	<0.25	158	14.3	7.61	<0.2	128	0.974	<3.0	1200	10.3	0.137	<0.1	3.62	<0.1
10S-W-94B	1.67	13.4	0.104	48.9	0.112	0.441	1300	17.5	11.1	0.372	221	2.01	7.41	5750	56	0.271	<0.1	12.5	<0.1
10S-E1-94A	1.79	1200	0.211	228	0.56	2.84	607	168	208	0.494	2070	1.48	8.7	3020	118	2.21	0.131	163	0.107
10S-E2-93A	0.517	533	<0.01	0.289	0.095	0.609	<0.4	<0.25	<0.05	<0.2	0.26	<0.2	<3.0	<15.250	0.549	0.014	<0.1	0.654	<0.1
10S-E2-94B	0.496	156	0.025	52.1	0.062	<0.25	75.5	23.1	26.9	<0.2	229	<0.2	<3.0	407	37.7	0.275	<0.1	16.4	<0.1

Table 4.15. Anion Concentrations Measured by Ion Chromatography on Test 5 Process Solutions (ppm).

Sample ID	Chloride	Fluoride	Iodine	Nitrite	Nitrate	Sulfate
10S-S-102A	37	4.83	12.5	16.4	10.1	71
10S-S-127A	79.2	22.2	206	451	17.2	112
10S-S-131A	78	21	198	491	18.5	110
10S-S-147A	82.1	16.5	199	509	21.8	96.4
10S-S-149A	91.9	21.8	208	552	23.3	106
10T-S-14A	103	24.3	210	546	20.8	105
10S-W-102A	62.7	4.12	4.22	<0.5	54.9	104
10S-W-127A	285	19.8	14.1	681	148	225
10S-W-131A	204	13.7	14	479	205	171
10S-W-147A	307	15.8	17.7	883	232	177
10S-W-149A	298	17.1	19.7	600	264	150
10T-W-14A	326	20.1	20.4	725	300	195
10S-E1-127A	1840	58.6	2590	6000	552	2520
10S-E1-131A	2450	84.1	2930	7990	804	2650
10-E1-147A	2520	80.3	3250	8290	1190	2530
10S-E1-149A	3580	59.8	3810	9120	1490	3360
10T-E1-14A	4030	58.9	3610	9180	1610	3340
10S-E2-102A	3.88	3.95	33.6	45.5	16.1	242
10S-E2-127A	5.22	0.485	110	5010	3.09	15.5
10-E2-147A	4.72	0.281	163	7990	9.73	5.79
10T-E2-14A	4.29	0.232	220	9410	15.7	4.54
10T-E1-35A	660	65.3	637	1730	304	561
10T-E1-35B	27.8	16	2.78	14.3	15.6	54
10T-E1-35C	23.6	5.58	<0.5	2.21	12.7	49.6
10T-S-35A	115	28.4	195	460	23.6	123
10T-S-35B	37.2	6.25	23	67	12.4	62.3
10T-W-35A	759	43.2	5	248	650	362
10T-W-36A	26	2.94	<0.5	1.42	29.9	51.2
10T-O-35C	128	34.2	157	502	77.7	113
10T-E1-35D	4920	53.6	4640	8000	2440	6060
10T-E1-35E	370	23.2	249	484	146	451
10T-E1-36A	137	41.1	78.7	124	56.5	222
10T-E1-36B	45.1	27.3	15.1	20.1	17.6	84.1
10T-E2-35A	378	4.9	23.1	1530	145	863

Table 4.16. Elemental Concentrations Measured by DCP-AES on Test 5 Process Solutions (ppm).

Sample ID	Al	B	Ba	Ca	Cr	Fe	K	Li	Mg	Mn	Na	Ni	P	Re	Si	Sr	Ti	Zn	Zr
10S-S-102A	<0.15	2.11	<0.01	29.7	0.079	<0.25	3.68	0.562	7.2	<0.2	45	<0.2	<3.0	5.54	3.28	0.105	<0.1	0.284	<0.1
10S-S-127A	0.332	30.7	<0.01	29.2	0.975	<0.25	14.6	2.84	6.13	<0.2	89.7	<0.2	<3.0	66.1	1.2	0.105	<0.1	0.501	<0.1
10S-S-131A	0.346	28.9	<0.01	28.6	0.908	<0.25	14.6	2.68	6.05	<0.2	85.6	0.206	<3.0	67.8	1.29	0.106	<0.1	0.42	<0.1
10S-S-147A	0.393	25	<0.01	29	0.948	<0.25	16.5	2.7	6.08	<0.2	85	<0.2	<3.0	84.3	1.13	0.106	<0.1	0.442	<0.1
10S-S-149A	0.462	32.1	<0.01	30	1.09	<0.25	19.4	3.42	6.03	<0.2	104	<0.2	<3.0	99.9	1.05	0.103	<0.1	0.39	<0.1
10T-S-14A	0.452	32.3	<0.01	30.6	1.22	<0.25	21.1	3.53	6.12	<0.2	108	<0.2	<3.0	121	1.36	0.106	<0.1	0.444	<0.1
10S-W-102A	<0.15	2.88	<0.01	30.9	<0.05	<0.25	70	3.27	5.99	<0.2	50.4	0.361	<3.0	393	5.66	0.109	<0.1	0.605	<0.1
10S-W-127A	<0.15	10.7	0.012	31.4	3.34	<0.25	73.3	6.9	6.18	<0.2	259	<0.2	<3.0	406	5.28	0.115	<0.1	0.418	<0.1
10S-W-131A	<0.15	7.25	0.013	30.1	2.27	<0.25	50.3	4.56	5.86	<0.2	210	<0.2	<3.0	292	4.04	0.11	<0.1	0.268	<0.1
10S-W-147A	<0.15	6.68	0.021	29.8	3.34	<0.25	69.3	6.23	5.98	<0.2	247	<0.2	<3.0	465	5.14	0.116	<0.1	0.273	<0.1
10S-W-149A	<0.15	7.58	0.02	32	2.65	<0.25	60.8	5.33	6.3	<0.2	231	<0.2	<3.0	436	4.95	0.122	<0.1	0.275	<0.1
10T-W-14A	<0.15	7.98	0.016	33.2	3.32	<0.25	76.2	6.44	6.46	<0.2	283	0.22	<3.0	625	5.87	0.125	<0.1	0.305	<0.1
10S-E1-127A	1.12	570	0.29	633	14.8	<0.25	435	75.3	198	0.666	2590	0.847	5.73	1710	42.9	3.39	<0.1	30	<0.1
10S-E1-131A	1.37	694	0.255	684	20	0.302	618	97.2	183	0.212	3220	0.431	8.11	2610	51.8	3	<0.1	34.6	<0.1
10-E1-147A	1.53	583	0.254	718	21.2	0.378	750	99.3	195	0.203	3170	0.3	6.94	3300	64.7	3.26	<0.1	50.5	<0.1
10S-E1-149A	1.21	980	0.315	806	32.7	0.446	1100	153	264	0.237	3820	0.409	10.1	5630	82.1	3.61	<0.1	68.2	0.141
10T-E1-14A	1.04	1020	0.299	688	35.3	0.565	1050	160	244	0.233	4020	0.405	11.6	5910	70.8	3.45	<0.1	73.3	0.135
10S-E2-102A	<0.15	153	<0.01	4.18	0.059	<0.25	0.782	<0.25	0.475	<0.2	21.3	0.306	<3.0	<1.25	0.799	0.238	<0.1	0.594	<0.1
10S-E2-127A	<0.15	147	0.047	1.28	0.065	<0.25	0.451	<0.25	0.097	<0.2	1.8	0.227	<3.0	<1.25	<0.2	0.118	<0.1	0.715	<0.1
10-E2-147A	<0.15	181	0.064	0.762	<0.05	<0.25	0.469	<0.25	<0.05	<0.2	0.768	<0.2	<3.0	<1.25	<0.2	0.074	<0.1	0.43	<0.1
10T-E2-14A	<0.15	284	0.069	0.474	<0.05	<0.25	<0.4	<0.25	<0.05	<0.2	0.483	<0.2	<3.0	<1.25	<0.2	0.056	<0.1	0.425	<0.1
10T-E1-35A	0.704	150	0.027	118	4.94	<0.25	151	3.59	38.7	<0.2	714	<0.2	4.41	772	14.5	0.539	<0.1	7.94	<0.1
10T-E1-35B	<0.15	2.66	<0.01	32.8	0.072	<0.25	3.6	0.686	5.9	<0.2	25.6	<0.2	<3.0	6.4	3.77	0.11	<0.1	0.84	<0.1
10T-E1-35C	<0.15	<1.0	<0.01	29.6	<0.05	<0.25	2.35	0.325	5.61	<0.2	16.8	<0.2	3.51	1.38	2.24	0.098	<0.1	0.369	<0.1
10T-S-35A	0.64	33.6	<0.01	30.9	1.23	<0.25	24.7	4.86	6.24	<0.2	131	<0.2	<3.0	146	1.75	0.111	<0.1	0.32	<0.1
10T-S-35B	0.238	5.44	<0.01	30.8	0.237	<0.25	6.15	0.896	6.27	<0.2	34.2	<0.2	<3.0	23.6	1.82	0.111	<0.1	0.442	<0.1
10T-W-35A	0.494	7.29	0.021	40.2	5.85	<0.25	298	19.9	8.15	<0.2	585	0.604	<3.0	2530	17.4	0.156	<0.1	1.73	<0.1
10T-W-36A	<0.15	<1.0	0.013	31	0.128	<0.25	10.5	<0.25	6.27	<0.2	19.7	0.225	<3.0	39.3	2.36	0.119	<0.1	0.236	<0.1
10T-O-35C	0.372	27	<0.01	30.6	1.22	<0.25	27.2	4.05	6.28	<0.2	130	<0.2	<3.0	177	1.45	0.111	<0.1	0.233	<0.1
10T-E1-35D	1.61	1090	0.335	1280	24.2	0.825	1750	253	393	0.718	6570	1.26	13.2	11200	71.3	7.49	<0.1	57.2	0.18
10T-E1-35E	0.25	61.6	0.036	106	1.33	<0.25	103	10.6	26.5	<0.2	377	<0.2	<3.0	720	7.02	0.498	<0.1	2.8	<0.1
10T-E1-36A	0.205	30.1	<0.01	47.4	0.549	<0.25	42.3	3.45	11.9	<0.2	146	<0.2	3.03	275	4.15	0.181	<0.1	0.762	<0.1
10T-E1-36B	0.205	7.41	<0.01	31.4	0.12	<0.25	11.6	0.72	6.76	<0.2	49.6	<0.2	3.43	39.6	2.05	0.103	<0.1	0.392	<0.1
10T-E2-35A	0.768	25.3	0.179	548	0.15	<0.25	56.5	1.69	129	<0.2	251	<0.2	<3.0	<1.25	59	3.17	<0.1	0.204	<0.1

Table 4.17. Anion Concentrations Measured by Ion Chromatography on Test 6 Process Solutions (ppm).

Sample ID	Chloride	Fluoride	Iodine	Nitrite	Nitrate	Sulfate
10T-S-37A	55.9	12.9	80.3	214	14.7	74.7
10T-S-58A	92.8	16	61.2	522	43.8	79.9
10T-S-67A	144	25.7	82.4	697	58.8	88.5
10T-S-78A	179	31	97.2	809	62.3	99.8
10T-S-86A	193	34.3	99.4	852	63.6	99.9
10T-S-102A	153	21	81	745	60.7	83.5
10T-S-106A	178	27.5	94.7	909	66.9	92.6
10T-W-37A	38.6	5.69	<0.5	4.92	82.1	54
10T-W-58A	397	48.4	10.7	874	450	173
10T-W-67A	472	55.6	11.4	958	524	176
10T-W-78A	543	68.5	12.1	938	440	188
10T-W-86A	473	47.6	15.1	886	465	147
10T-W-102A	699	63.8	16.9	1190	779	198
10T-W-106A	501	45.7	15.3	911	593	139
10T-E1-54A	770	60.5	684	1330	940	887
10T-E1-58A	2650	75.6	1040	9260	1500	2010
10T-E1-67A	5200	59.1	1810	11500	3180	2490
10T-E1-78A	5910	60.7	1520	9970	3140	3280
10T-E1-86A	7810	50.8	2000	15300	3970	3750
10T-E1-102A	5310	70.7	1390	9750	2530	2180
10T-E1-106A	6520	51.2	2000	14400	3210	2570
10T-E2-58A	3.76	0.319	99	6180	14.1	3.43
10T-E2-78A	4.51	0.261	44.7	7940	18.9	4.92
10T-E2-102A	202	15.3	116	8060	113	124
10T-O-86A	459	14	109	744	217	250
10T-O-106A	2330	45.6	723	5790	1160	968
10T-O-106B	47.1	19	4.81	47.5	21.1	56.2
10T-O-112A	37.3	9.63	1.41	17.5	16	52.9
10T-O-112B	71.7	12.9	27.9	1360	4080	161
10T-S-112A	184	26	93.6	861	68.8	90.5
10T-S-112B	76.8	13	20.2	128	41.8	64.5
10T-O-115D	1400	513	495	1650	1610	805
10T-W-112A	2140	168	3	954	2380	620
10T-W-115A	54.1	7.49	<0.5	3.49	82.5	54.2
10T-O-112C	221	29	94.4	931	123	96.6
10T-O-115A	31.6	3.58	<0.5	2.55	13.3	46.9
10T-O-115B	31.9	1.93	<0.5	1.86	13.9	47.2
10T-O-115C	5990	1700	308	631	3230	3850
10T-O-115E	87.4	46	36.8	99.2	109	52.8
10T-E1-115A	8430	70	2500	14900	4020	3470
10T-E1-115B	611	36.6	168	1000	286	312
10T-E1-115C	113	24.2	16.3	164	49.3	95
10T-E2-115A	197	4.96	25.6	3080	85.7	329

Table 4.18. Elemental Concentrations Measured by DCP-AES on Test 6 Process Solutions (ppm).

Sample ID	Al	B	Ba	Ca	Cr	Fe	K	Li	Mg	Mn	Na	Ni	P	Re	Si	Sr	Ti	Zn	Zr
10T-S-37A	0.191	23.6	<0.01	41.9	0.464	<0.25	12.7	1.42	5.77	<0.2	90.6	<0.2	<3.0	57.6	1.19	0.045	<0.1	0.244	<0.1
10T-S-58A	0.19	56.8	<0.01	51.1	2.97	<0.25	8530	0.524	7.87	<0.2	167	<0.2	<3.0	75.1	2.04	0.089	<0.1	0.289	<0.1
10T-S-67A	0.287	83.2	<0.01	51.8	3.98	<0.25	11900	<0.25	8.23	<0.2	237	<0.2	<3.0	120	2.16	0.097	<0.1	0.39	<0.1
10T-S-78A	0.164	110	<0.01	54.1	4.89	<0.25	327	<0.25	8.21	<0.2	326	<0.2	<3.0	148	2.62	0.098	<0.1	0.447	<0.1
10T-S-86A	0.167	114	<0.01	52.1	5.22	<0.25	8540	<0.25	8.38	<0.2	310	<0.2	<3.0	173	2.66	0.104	<0.1	0.489	<0.1
10T-S-102A	<0.15	72.3	<0.01	52.5	3.25	<0.25	230	<0.25	7.91	<0.2	227	<0.2	<3.0	149	2.39	0.095	<0.1	0.567	<0.1
10T-S-106A	0.196	92.7	<0.01	58	3.92	<0.25	344	<0.25	8.05	<0.2	354	<0.2	<3.0	171	1.65	0.094	<0.1	0.47	<0.1
10T-W-37A	<0.15	<1.0	<0.01	45.4	<0.05	<0.25	17.2	0.343	7.2	<0.2	37.2	<0.2	<3.0	102	3.58	0.101	<0.1	<0.1	<0.1
10T-W-58A	0.245	102	<0.01	51.5	10.6	<0.25	606	1.3	9.25	<0.2	462	<0.2	<3.0	349	4.16	0.128	<0.1	1.16	<0.1
10T-W-67A	0.338	123	<0.01	51.8	10	<0.25	694	0.792	8.94	<0.2	499	<0.2	<3.0	369	3.81	0.126	<0.1	1.83	<0.1
10T-W-78A	<0.15	164	<0.01	49.7	10.5	<0.25	793	<0.25	8.83	<0.2	529	<0.2	<3.0	485	4.02	0.128	<0.1	1.45	<0.1
10T-W-86A	0.429	111	<0.01	48.8	6.74	<0.25	708	0.354	8.54	<0.2	482	<0.2	<3.0	480	4.18	0.116	<0.1	2.48	<0.1
10T-W-102A	0.19	149	<0.01	47.4	10.9	<0.25	964	<0.25	8.85	<0.2	668	<0.2	<3.0	858	6.91	0.134	<0.1	4.81	<0.1
10T-W-106A	0.23	86	<0.01	47.4	6.19	<0.25	712	<0.25	9	<0.2	468	<0.2	<3.0	558	4.75	0.127	<0.1	1.51	<0.1
10T-E1-54A	0.81	238	0.016	329	5.17	<0.25	280	33.4	104	<0.2	1220	0.215	<3.0	1040	23.5	1.02	<0.1	14	<0.1
10T-E1-58A	1.37	1290	0.435	1030	124	0.562	2920	31.4	353	0.354	3830	1.01	4.6	2020	48.1	5	<0.1	49.7	<0.1
10T-E1-67A	0.842	1570	0.368	946	160	0.838	7130	13.3	324	0.342	6020	1.08	6.63	3180	45.1	4.22	<0.1	48.2	<0.1
10T-E1-78A	0.711	2520	0.36	548	183	0.73	7870	8.76	296	0.284	6950	0.985	5.41	3250	48.8	4.27	<0.1	44.3	0.142
10T-E1-86A	0.901	3840	0.402	1080	267	0.893	10500	9.75	442	0.448	8680	1.07	6.37	2800	57.3	5.2	0.1	105	0.129
10T-E1-102A	0.485	1270	0.137	526	155	0.658	5960	3.3	207	<0.2	6420	0.468	6.07	3640	47.5	2.52	<0.1	20.5	<0.1
10T-E1-106A	0.668	2610	0.235	797	173	0.727	8050	2.65	284	0.238	7000	0.645	6.47	3230	56.2	3.82	<0.1	87.8	0.102
10T-E2-58A	<0.15	241	<0.01	1.78	0.091	<0.25	3.23	<0.25	<0.05	<0.2	12.3	<0.2	<3.0	<1.25	<0.2	<0.01	<0.1	1.24	<0.1
10T-E2-78A	<0.15	283	<0.01	0.918	<0.05	<0.25	2.67	<0.25	0.062	<0.2	5.83	<0.2	<3.0	3.03	<0.2	<0.01	<0.1	0.908	<0.1
10T-E2-102A	0.586	366	0.015	900	5.37	<0.25	397	<0.25	7.78	<0.2	297	<0.2	<3.0	254	4.04	0.126	<0.1	5.16	<0.1
10T-O-86A	<0.15	236	<0.01	54.2	13.7	<0.25	733	0.67	19.2	<0.2	645	<0.2	<3.0	473	4.66	0.207	<0.1	1.82	<0.1
10T-O-106A	0.283	845	0.082	358	68.2	0.304	3230	0.937	114	<0.2	3000	0.252	3.11	1790	35.9	1.43	<0.1	23.9	<0.1
10T-O-106B	<0.15	10.8	<0.01	49.4	0.362	<0.25	84.3	<0.25	10.9	<0.2	54.2	<0.2	<3.0	222	5.37	0.096	<0.1	0.81	<0.1
10T-O-112A	<0.15	5.02	<0.01	49.8	0.104	<0.25	53.6	<0.25	11	<0.2	36.4	<0.2	<3.0	152	3.74	0.089	<0.1	0.292	<0.1
10T-O-112B	9.43	1490	<0.01	37.3	24.2	<0.25	2310	1.34	11	<0.2	4640	<0.2	10.7	30.6	1.31	0.183	<0.1	<0.1	<0.1
10T-S-112A	0.235	87.2	<0.01	53.3	3.8	<0.25	304	<0.25	8.47	<0.2	279	<0.2	<3.0	250	2.66	0.103	<0.1	0.38	<0.1
10T-S-112B	0.309	39.8	<0.01	46.1	1.45	<0.25	112	<0.25	7.36	<0.2	131	<0.2	<3.0	60.4	2.07	0.077	<0.1	0.2	<0.1
10T-O-115D	5.44	2140	<0.01	6.15	122	0.295	3910	5.05	1.5	<0.2	5560	0.338	8.06	1700	13.2	<0.01	<0.1	0.779	0.105
10T-W-112A	<0.15	328	<0.01	10.8	56.9	0.27	3510	1.77	10.4	<0.2	2250	<0.2	4.15	3140	20.9	0.095	<0.1	0.587	<0.1
10T-W-115A	<0.15	8.78	<0.01	51.4	0.677	<0.25	99.6	<0.25	8.69	<0.2	55.8	<0.2	<3.0	213	2.72	0.107	<0.1	0.243	<0.1
10T-O-112C	0.225	96.4	<0.01	54.6	5.9	<0.25	321	<0.25	12	<0.2	307	<0.2	<3.0	257	3.81	0.112	<0.1	0.358	<0.1
10T-O-115A	<0.15	5.63	<0.01	39.5	<0.05	<0.25	12.7	<0.25	9.1	<0.2	38.8	<0.2	<3.0	2.33	2.82	0.047	<0.1	0.16	<0.1
10T-O-115B	<0.15	1.44	<0.01	46.2	<0.05	<0.25	7.47	<0.25	10	<0.2	26.4	<0.2	<3.0	1.92	2.76	0.069	<0.1	0.125	<0.1
10T-O-115C	<0.15	1620	0.04	2.79	272	0.35	8130	59.7	2.06	<0.2	9130	0.273	7.5	2740	32.7	0.077	<0.1	0.658	<0.1
10T-O-115E	3.64	128	<0.01	0.416	6.51	<0.25	232	<0.25	0.053	<0.2	375	<0.2	<3.0	92.8	1.81	<0.01	<0.1	0.574	<0.1
10T-E1-115A	0.711	2980	0.339	874	228	0.782	9990	3.22	431	0.337	9340	0.847	4.01	2500	51.6	4.32	<0.1	40.7	0.12
10T-E1-115B	0.165	204	<0.01	94.5	14.8	<0.25	849	0.253	32.9	<0.2	776	<0.2	<3.0	355	6.26	0.371	<0.1	1.67	<0.1
10T-E1-115C	<0.15	39.3	<0.01	46.4	2.3	<0.25	150	<0.25	12.7	<0.2	150	<0.2	<3.0	64.5	2.92	0.124	<0.1	0.538	<0.1
10T-E2-115A	0.588	52.8	0.74	4620	1.05	<0.25	76.4	1.55	85.6	<0.2	181	<0.2	<3.0	43.4	24.9	2.93	<0.1	0.474	<0.1

Table 4.19. Anion Concentrations Measured by Ion Chromatography on Test 7 Process Solutions (ppm).

Sample ID	Chloride	Fluoride	Iodine	Nitrite	Nitrate	Sulfate
10T-S-139A	42.3	4.46	5.12	51.4	17.4	52.1
10T-S-146A	66.2	12.7	61.9	371	20.1	65.1
10U-S-13A	40.7	14.8	80.1	461	22.6	61.2
10U-S-23A	45.6	15.2	99.8	483	23.5	80.3
10U-S-33A	48.2	16.8	102	451	23.6	75.6
10U-S-47A	51.7	18.2	104	481	22.1	78.3
10U-S-51A	47.2	16.6	97.2	454	22.7	75.4
10T-W-139A	36.1	2.59	<0.5	2.35	37.2	49.5
10T-W-146A	122	12.4	13.4	387	192	91.6
10U-W-13A	194	22.6	12.2	806	259	121
10U-W-23A	237	24.4	16.6	588	132	126
10U-W-33A	154	14.9	15	422	144	93.3
10U-W-47A	220	21.4	20.3	562	114	126
10U-W-51A	207	17.1	8.68	562	154	99.9
10T-E1-139A	738	31	69.6	392	393	1010
10T-E1-146A	1630	74.5	868	5610	637	1790
10U-E1-13A	2180	74.7	1370	7590	928	1960
10U-E1-23A	2450	57	1600	8100	1190	1800
10U-E1-33A	2700	54.7	1600	8060	1010	1810
10U-E1-47A	2950	51.4	1610	8170	1020	1950
10U-E1-51A	3230	49.9	1970	8500	1150	2250
10T-E2-146A	5.71	1.15	21.4	3560	3.52	3.84
10U-E2-23A	2.97	0.106	62	6350	6.03	2.76
10U-E2-47A	2.55	<0.05	49.7	5760	4.3	2.47
10U-O-51A	1040	61.1	711	2470	398	690
10U-O-57D	1460	489	38.4	242	761	1230
10U-S-56A	48.4	16	107	447	25	79.1
10U-S-56B	42	5.72	11.8	22.5	15.2	50
10U-O-57C	205	136	64.8	232	171	153
10U-W-56A	345	35.1	1.96	160	487	204
10U-W-56B	15.4	5.68	<0.5	7.06	46.3	50
10U-O-57A	103	14.9	89.8	72.8	43.1	78.3
10U-E1-57A	3200	60.6	2160	9300	1250	2710
10U-E1-57B	647	53.7	341	1470	222	468
10U-E2-57A	203	4.96	6.77	1350	80.6	373

Table 4.20. Elemental Concentrations Measured by DCP-AES on Test 7 Process Solutions (ppm).

Sample ID	Al	B	Ba	Ca	Cr	Fe	K	Li	Mg	Mn	Na	Ni	P	Re	Si	Sr	Ti	Zn	Zr
10T-S-139A	<0.15	13.3	<0.01	43.4	0.521	<0.25	25	<0.25	7.42	<0.2	51.8	<0.2	<3.0	13	2.02	0.071	<0.1	0.17	<0.1
10T-S-146A	0.494	51.2	<0.01	47.9	0.77	0.304	23.5	<0.25	7.3	<0.2	185	<0.2	<3.0	56.5	0.794	0.065	<0.1	0.154	<0.1
10U-S-13A	0.835	46.7	<0.01	32.7	0.937	<0.25	23.8	<0.25	8.07	<0.2	183	<0.2	<3.0	77.5	<0.2	0.066	<0.1	0.147	<0.1
10U-S-23A	0.684	41.8	<0.01	33.4	0.816	<0.25	22.7	<0.25	8.36	<0.2	171	<0.2	<3.0	107	<0.2	0.075	<0.1	0.229	<0.1
10U-S-33A	0.878	47.7	<0.01	33.6	0.841	<0.25	24.8	<0.25	8.32	<0.2	188	<0.2	<3.0	109	<0.2	0.07	<0.1	0.254	<0.1
10U-S-47A	0.784	46.2	<0.01	33.2	0.901	<0.25	23.9	<0.25	7.99	<0.2	195	<0.2	<3.0	120	<0.2	0.065	<0.1	0.233	<0.1
10U-S-51A	0.81	44	<0.01	33.9	0.825	<0.25	21.6	<0.25	7.59	<0.2	187	<0.2	<3.0	102	<0.2	0.068	<0.1	0.234	<0.1
10T-W-139A	<0.15	5.69	<0.01	43.4	0.152	<0.25	17.3	<0.25	7.87	<0.2	30.5	<0.2	<3.0	17.3	1.3	0.091	<0.1	<0.1	<0.1
10T-W-146A	<0.15	16.4	<0.01	44.6	1.19	<0.25	37.9	<0.25	8.16	<0.2	170	<0.2	<3.0	174	1.94	0.098	<0.1	0.452	<0.1
10U-W-13A	0.168	15.3	<0.01	37.6	2.05	<0.25	51.1	<0.25	8.69	<0.2	224	<0.2	<3.0	337	4.28	0.109	<0.1	0.639	<0.1
10U-W-23A	0.215	16.4	<0.01	35.7	2	<0.25	54.2	<0.25	8.45	<0.2	279	<0.2	<3.0	334	3.26	0.099	<0.1	0.165	<0.1
10U-W-33A	<0.15	8.42	<0.01	34.6	1.16	<0.25	35.2	<0.25	8.19	<0.2	164	<0.2	<3.0	219	2.25	0.096	<0.1	0.16	<0.1
10U-W-47A	0.257	11	<0.01	34.1	1.62	<0.25	49.6	<0.25	8.33	<0.2	229	<0.2	<3.0	312	2.59	0.1	<0.1	0.243	<0.1
10U-W-51A	0.163	8.16	<0.01	35	1.42	<0.25	45.5	<0.25	7.31	<0.2	207	<0.2	<3.0	299	2.54	0.091	<0.1	0.269	<0.1
10T-E1-139A	0.327	269	0.021	286	13	<0.25	1090	2.33	151	<0.2	986	<0.2	<3.0	1230	23.2	1.27	<0.1	0.512	<0.1
10T-E1-146A	2.31	745	0.223	684	29.1	0.377	871	4.08	275	<0.2	2730	0.223	4.44	1610	17.9	4.36	<0.1	21.1	<0.1
10U-E1-13A	3.19	920	0.199	559	31.2	0.538	895	3.77	258	0.207	3690	0.32	4.96	3010	22.6	3.4	<0.1	29.3	0.151
10U-E1-23A	3.19	873	0.21	657	23.2	0.466	816	3	273	0.217	4330	0.318	5.01	3350	25.8	3.67	<0.1	55.6	0.113
10U-E1-33A	2.63	999	0.205	668	18.8	0.449	812	2.52	277	0.297	4320	0.496	5.92	3500	27.4	3.61	<0.1	44.8	0.151
10U-E1-47A	2.57	910	0.236	584	17.5	0.511	803	2.29	272	0.384	4670	0.659	6.94	3690	30.2	3.92	<0.1	73.4	0.135
10U-E1-51A	2.64	1120	0.271	635	21.7	0.55	828	2.67	286	0.373	5140	0.704	7.01	4260	33.5	4.38	<0.1	75.6	0.152
10T-E2-146A	<0.15	122	<0.01	3.05	<0.05	<0.25	4.13	<0.25	1.69	<0.2	5.47	<0.2	<3.0	4.07	<0.2	0.012	<0.1	0.534	<0.1
10U-E2-23A	<0.15	123	<0.01	2.02	<0.05	<0.25	0.402	<0.25	0.094	<0.2	0.691	<0.2	<3.0	<1.25	<0.2	<0.01	<0.1	0.544	<0.1
10U-E2-47A	<0.15	133	<0.01	0.687	<0.05	<0.25	<0.4	<0.25	<0.05	<0.2	0.235	<0.2	<3.0	<1.25	<0.2	<0.01	<0.1	0.286	<0.1
10U-O-51A	<3.03	288	<0.2	185	5.34	<5.05	174	<5.05	63	<4.04	2690	<4.04	< 61	1270	<4.04	0.681	<2.02	8.18	<2.02
10U-O-57D	6.02	733	0.026	3.4	80.6	<0.25	849	11.5	0.344	<0.2	3540	<0.2	4.95	2790	15.5	0.033	<0.1	0.341	0.11
10U-S-56A	0.811	40.4	<0.01	33.8	0.859	<0.25	22.2	<0.25	7.56	<0.2	181	<0.2	<3.0	115	<0.2	0.077	<0.1	0.199	<0.1
10U-S-56B	0.578	13.7	<0.01	32.6	0.143	<0.25	7.25	<0.25	7.21	<0.2	69	<0.2	<3.0	24.6	<0.2	0.069	<0.1	0.138	<0.1
10U-O-57C	22.3	460	<0.01	2.76	4.98	<0.25	101	0.466	0.424	<0.2	1790	<0.2	<3.0	307	<0.2	<0.01	<0.1	0.139	<0.1
10U-W-56A	0.403	8.79	<0.01	40.7	2.76	<0.25	122	<0.25	8.41	<0.2	462	<0.2	<3.0	700	5.71	0.108	<0.1	0.352	<0.1
10U-W-56B	0.159	<1.0	<0.01	32.6	0.064	<0.25	11.7	<0.25	6.86	<0.2	36.7	<0.2	<3.0	47.1	1.03	0.076	<0.1	<0.1	<0.1
10U-O-57A	0.516	36	<0.01	34.9	0.902	<0.25	21.8	<0.25	7.65	<0.2	183	<0.2	<3.0	136	<0.2	0.131	<0.1	0.237	<0.1
10U-E1-57A	1.93	1240	0.413	678	27.2	0.639	869	3.17	281	0.393	6150	0.855	9.28	4670	64.3	5.33	<0.1	73.7	0.174
10U-E1-57B	1.13	193	0.019	149	3.88	<0.25	149	0.556	49.3	<0.2	1020	<0.2	<3.0	721	7.77	0.635	<0.1	7.55	<0.1
10U-E2-57A	0.656	18.8	0.324	491	0.055	<0.25	37.5	1.13	75.2	<0.2	142	<0.2	<3.0	62.3	24.8	2.24	<0.1	0.542	<0.1
10U-O-56A	31.3	889	<0.01	5.71	15.8	<0.25	159	0.752	0.094	<0.2	4870	<0.2	<3.0	25	<0.2	0.023	<0.1	<0.1	<0.1
10U-O-56B	0.709	73	<0.01	30.6	1.18	<0.25	16.5	0.58	3.09	<0.2	338	<0.2	<3.0	2.26	<0.2	0.121	<0.1	<0.1	<0.1

Table 4.21. Anion Concentrations Measured by Ion Chromatography on Test 8 Process Solutions (ppm).

Sample ID	Chloride	Fluoride	Iodine	Nitrite	Nitrate	Sulfate
10U-S-69A	4.92	31.9	12.3	62	12.8	56.1
10U-S-95A	14.7	85.3	77.8	629	35.1	126
10U-S-101A	16.7	88.9	69.4	510	34.8	116
10U-S-109A	19.9	123	111	664	40	139
10U-S-119A	24.8	135	124	691	40.6	142
10U-S-127A	20	138	120	727	42.3	144
10U-S-136A	26.8	149	132	759	45.5	150
10U-W-69A	42.3	7.4	<0.5	6.36	227	51.2
10U-W-95A	152	15.2	6.87	129	146	175
10U-W-101A	151	13.8	7.03	112	183	147
10U-W-109A	331	24	15.2	484	275	252
10U-W-119A	164	10.5	12.5	229	238	141
10U-W-127A	326	21.5	16.6	422	266	196
10U-W-136A	321	21	9.18	233	287	183
10U-E1-69A	1280	74.8	408	1140	1370	1570
10U-E1-95A	2930	50.7	774	8880	1310	4430
10U-E1-101A	3580	44.5	1070	9980	1960	4260
10U-E1-109A	4110	60.5	1440	9010	2030	3860
10U-E1-119A	4160	40.5	1660	8450	2370	4260
10U-E1-127A	4180	19.2	1400	7450	2280	4580
10U-E1-136A	4860	22.6	1850	7770	2380	4340
10U-E2-95A	0.148	<0.1	59.4	5970	9.06	2.41
10U-E2-109A	0.417	0.73	78.2	6690	7.75	14.6
10U-E2-127A	<0.05	0.218	107	8530	20.2	3.35
10U-O-137A	1060	44.7	413	2100	452	863
10U-O-137B	45.6	44.1	2.01	13.8	13.3	55.5
10U-O-137C	45.7	14.5	0.584	1.57	13.1	54.1
10U-O-146E	3620	351	3.26	<0.5	189	9300
10U-S-137A	29.5	167	130	724	53.7	169
10U-S-137B	11.3	84.8	17.6	104	31.5	106
10U-O-146C	615	309	11.6	18.6	525	1190
10U-W-137A	1150	57.1	0.958	48.4	977	618
10U-W-137B	71.9	7.41	<0.5	0.575	74.1	69.8
10U-W-137C	41.7	2.56	<0.5	<0.5	26.1	47
10U-O-146A	177	22.8	111	654	67.3	155
10U-O-146B	39.5	1.27	0.676	0.603	12.1	46.7
10U-E1-137A	5360	4.72	2100	7570	2730	5060
10U-E1-146A	585	49	214	1040	256	144
10U-E1-146B	104	46.1	18.3	105	40.1	112
10U-E2-146A	2.32	141	37.3	4020	52.4	274
10U-O-137D	120	30.6	108	12600	<0.25	762
10U-O-137E	76.6	12.2	34.2	3400	1100	276

Table 4.22. Elemental Concentrations Measured by DCP-AES on Test 8 Process Solutions (ppm).

Sample ID	Al	B	Ba	Ca	Cr	Fe	K	Li	Mg	Mn	Na	Ni	P	Re	Si	Sr	Ti	Zn	Zr
10U-S-69A	0.298	11.3	<0.01	26.4	0.359	<0.25	6.9	<0.25	6.65	<0.2	76.3	<0.2	<3.0	14.1	1.94	0.051	<0.1	<0.1	<0.1
10U-S-95A	0.353	42.2	<0.01	34.8	3.3	<0.25	28	4.95	8.37	<0.2	136	<0.2	<3.0	84.1	4.06	0.117	<0.1	0.385	<0.1
10U-S-101A	<0.15	38.9	<0.01	35.4	2.5	<0.25	26.7	5.24	8.4	<0.2	138	<0.2	<3.0	87.4	2.8	0.11	<0.1	0.133	<0.1
10U-S-109A	<0.15	37.8	<0.01	35.1	2.84	<0.25	36.9	6	8.45	<0.2	149	<0.2	<3.0	155	3.14	0.118	<0.1	0.352	<0.1
10U-S-119A	0.259	41.8	<0.01	34.8	2.85	<0.25	41.7	7.35	8.27	<0.2	167	<0.2	<3.0	185	2.63	0.11	<0.1	0.305	<0.1
10U-S-127A	<0.15	36.9	<0.01	34.4	2.83	<0.25	41.8	6.14	8.42	<0.2	154	<0.2	<3.0	192	3.27	0.117	<0.1	0.491	<0.1
10U-S-136A	<0.15	44.3	<0.01	36.1	3.27	<0.25	47	7.67	8.73	<0.2	180	<0.2	<3.0	209	3.06	0.121	<0.1	0.47	<0.1
10U-W-69A	<0.15	2.65	<0.01	36.3	0.235	<0.25	12.4	<0.25	7.99	<0.2	36.4	<0.2	<3.0	22.2	3.46	0.118	<0.1	1.22	<0.1
10U-W-95A	<0.15	11.5	<0.01	34.6	3.36	<0.25	57.9	4.66	8.88	<0.2	170	<0.2	<3.0	237	2.94	0.128	<0.1	0.827	<0.1
10U-W-101A	0.261	8.57	<0.01	35.2	2.55	<0.25	52.8	4.25	8.73	<0.2	158	<0.2	<3.0	241	2.58	0.129	<0.1	1.25	<0.1
10U-W-109A	<0.15	13.5	<0.01	38	4.57	<0.25	111	10.6	9.26	<0.2	337	<0.2	<3.0	612	5	0.162	<0.1	5.88	<0.1
10U-W-119A	<0.15	5.1	<0.01	35.6	1.76	<0.25	53.7	4.13	8.77	<0.2	151	<0.2	<3.0	273	3.04	0.129	<0.1	1.29	<0.1
10U-W-127A	<0.15	9.52	<0.01	35.5	3.6	<0.25	112	9.61	9	<0.2	323	<0.2	<3.0	649	4.85	0.139	<0.1	0.976	<0.1
10U-W-136A	<0.15	10.3	<0.01	36.2	3.36	<0.25	111	9.13	9.22	<0.2	273	<0.2	<3.0	600	4.49	0.143	<0.1	1.99	<0.1
10U-E1-69A	1.19	319	<0.01	330	10.8	<0.25	279	6.45	129	<0.2	1680	0.29	<3.0	1080	20.4	1.51	<0.1	9.09	<0.1
10U-E1-95A	1.95	1080	0.335	857	95.2	0.49	925	151	330	<0.2	3980	0.724	5.88	4520	45.1	6.13	<0.1	77.4	<0.1
10U-E1-101A	1.83	1120	0.327	805	94.8	0.456	1090	213	291	<0.2	4280	0.583	6.27	5130	45.5	5.42	<0.1	96	<0.1
10U-E1-109A	1.24	805	0.237	512	77.6	0.471	989	214	232	<0.2	4000	0.329	6.46	6370	52.3	4.07	<0.1	79.5	<0.1
10U-E1-119A	1.27	880	0.255	487	81.8	0.519	1100	229	252	<0.2	4630	0.362	8.17	6510	61.3	4.43	<0.1	94.1	<0.1
10U-E1-127A	0.859	1010	0.252	488	81.4	0.551	1290	232	259	<0.2	4660	0.398	8.83	6810	80.2	4.23	<0.1	98.5	<0.1
10U-E1-136A	0.778	1180	0.22	430	84.6	0.625	1380	294	252	<0.2	5050	0.346	10.6	7640	82.9	3.92	<0.1	111	<0.1
10U-E2-95A	<0.15	132	<0.01	1.23	<0.05	<0.25	1.64	<0.25	<0.05	<0.2	0.364	<0.2	<3.0	7.64	0.649	0.023	<0.1	0.206	<0.1
10U-E2-109A	<0.15	146	<0.01	3.11	0.144	<0.25	5.47	0.322	0.501	<0.2	16.7	<0.2	<3.0	23.5	0.428	<0.01	<0.1	4.71	<0.1
10U-E2-127A	<0.15	197	<0.01	0.621	<0.05	<0.25	0.449	<0.25	<0.05	<0.2	0.685	<0.2	<3.0	<1.25	<0.2	<0.01	<0.1	1.31	<0.1
10U-O-137A	0.294	191	<0.01	138	19	<0.25	299	52.3	55.2	<0.2	1050	<0.2	3.02	1480	24.4	0.807	<0.1	14.6	<0.1
10U-O-137B	<0.15	6.11	<0.01	41.5	0.173	<0.25	8.6	0.579	8.51	<0.2	43.4	<0.2	<3.0	12	6.3	0.062	<0.1	0.954	<0.1
10U-O-137C	<0.15	1.99	<0.01	39.3	<0.05	<0.25	4.52	<0.25	9.1	<0.2	28.9	<0.2	<3.0	3.59	1.53	0.076	<0.1	0.196	<0.1
10U-O-146E	0.639	382	<0.01	6.48	250	0.393	1670	295	1.21	<0.2	5530	0.322	9.14	6650	50.5	0.766	<0.1	0.695	<0.1
10U-S-137A	<0.15	45	<0.01	35.8	3.65	<0.25	52.9	8.35	8.91	<0.2	193	<0.2	<3.0	268	3.4	0.13	<0.1	0.604	<0.1
10U-S-137B	0.225	16.3	<0.01	33.5	1.34	<0.25	19.2	3.26	8.68	<0.2	97.4	<0.2	<3.0	72.5	1.41	0.115	<0.1	<0.1	<0.1
10U-O-146C	2.41	450	<0.01	5.2	29.8	<0.25	251	166	0.921	<0.2	2100	<0.2	<3.0	909	6.42	<0.01	<0.1	<0.1	<0.1
10U-W-137A	0.313	14.4	<0.01	42.7	14.5	<0.25	454	41.8	11	<0.2	900	0.331	3.47	2690	20	0.163	<0.1	2.01	<0.1
10U-W-137B	<0.15	<1.0	<0.01	34.7	0.572	<0.25	71.5	1.59	9.3	<0.2	72	<0.2	<3.0	366	2.76	0.13	<0.1	0.177	<0.1
10U-W-137C	<0.15	<1.0	<0.01	35.3	<0.05	<0.25	8.6	<0.25	8.77	<0.2	24.3	<0.2	<3.0	26.3	0.269	0.126	<0.1	<0.1	<0.1
10U-O-146A	<0.15	41.1	<0.01	34.8	3.23	<0.25	56.5	7.7	8.53	<0.2	200	<0.2	<3.0	284	3.2	0.083	<0.1	0.317	<0.1
10U-O-146B	<0.15	3.75	<0.01	32.4	<0.05	<0.25	2.77	<0.25	8.07	<0.2	23.5	<0.2	<3.0	2.41	0.86	0.063	<0.1	<0.1	<0.1
10U-E1-137A	0.753	1210	0.28	423	101	0.762	1410	294	281	<0.2	5580	0.439	10.6	7350	111	4.43	<0.1	113	<0.1
10U-E1-146A	0.179	109	<0.01	87	9.99	<0.25	171	27.6	32.4	<0.2	759	<0.2	<3.0	712	15.4	0.413	<0.1	6.54	<0.1
10U-E1-146B	<0.15	20.8	<0.01	39	1.16	<0.25	27.3	2.81	11.2	<0.2	106	<0.2	<3.0	80.5	6.29	0.094	<0.1	1.56	<0.1
10U-E2-146A	0.467	26.7	0.536	495	<0.05	<0.25	14	1.22	57	<0.2	108	<0.2	<3.0	<1.25	15.7	2.12	<0.1	0.397	<0.1
10U-O-137D	0.893	3460	<0.01	25	63	<0.25	923	1840	4.9	<0.2	6570	<0.2	6.45	104	1.54	<0.01	<0.1	17.9	0.592
10U-O-137E	0.942	1130	<0.01	34.5	20.1	<0.25	265	564	2.06	<0.2	2320	<0.2	<3.0	34.1	<0.2	0.197	<0.1	1.33	<0.1

Table 4.23. Anion Concentrations Measured by Ion Chromatography on Test 9 Process Solutions (ppm).

Sample ID	Chloride	Fluoride	Iodine	Nitrite	Nitrate	Sulfate
10V-S-22A	46.8	4.43	5.13	33.1	14.5	69.1
10V-S-39A	64.9	17.9	225	56.4	8.44	154
10V-S-51A	74.4	25.2	275	72.7	9.5	178
10V-S-61A	69.9	20	307	57.9	7.68	161
10V-S-69A	70.5	18.8	301	55	8.1	151
10V-S-79A	84.4	21.7	369	72.3	8.53	170
10V-S-88A	78.7	22.1	376	68	9.22	166
10V-W-22A	149	30.8	1.32	<0.5	2240	161
10V-W-39A	81.8	4.16	3.77	66.5	32.3	106
10V-W-51A	106	10	8.19	131	36.9	151
10V-W-61A	94.3	7.29	8.93	76.5	17.6	112
10V-W-69A	93.5	7.22	13.3	82.2	18	129
10V-W-79A	121	7.84	15.2	97.5	24.4	129
10V-W-88A	142	10.7	13.8	111	23.6	134
10V-E1-31A	587	56.7	114	527	376	766
10V-E1-39A	1380	86.9	2870	891	299	2270
10V-E1-51A	1840	82.4	5000	1100	279	3900
10V-E1-61A	2450	52.7	7500	963	313	4210
10V-E1-69A	2070	53.3	6550	880	255	3840
10V-E1-79A	1570	44.2	4820	752	186	2770
10V-E1-88A	2290	40.4	7310	864	281	3900
10V-E2-39A	0.678	2.19	43.3	1630	2.36	1.64
10V-E2-61A	1.19	1.78	313	1640	0.482	2.24
10V-E2-79A	1.38	0.44	341	1740	0.643	2.08
10V-O-88A	462	38.6	1500	210	73.4	931
10V-O-88B	34.8	9.96	4.25	0.599	7.06	48.6
10V-O-88C	34.9	4.41	<0.5	<0.5	7.1	48.4
10V-O-94B	185	25.4	10.9	<0.5	17.1	6550
10V-S-93A	88.2	22.3	373	64.1	10.5	183
10V-S-93B	40.7	2.75	28.1	3.61	8.26	59.7
10V-O-94A	490	65.9	62	<0.5	44.7	442
10V-W-88B	178	15.5	0.828	24	106	176
10V-W-88C	38	7.25	10.7	0.841	9.41	57.8
10V-O-93B	90.7	20.8	336	68.1	11.2	174
10V-O-93D	34.3	1.36	<0.5	<0.5	8.15	48.4
10V-E1-93A	2760	24	8310	886	334	4460
10V-E1-93B	151	29.4	308	39.7	21.1	244
10V-E1-93C	56.8	30.4	65.8	5.02	9.16	99.1
10V-E2-93A	59	1.67	113	422	14.7	91.3

Table 4.24. Elemental Concentrations Measured by DCP-AES on Test 9 Process Solutions (ppm).

Sample ID	Al	B	Ba	Ca	Cr	Fe	K	Li	Mg	Mn	Na	Ni	P	Re	Si	Sr	Ti	Zn	Zr
10V-S-22A	0.157	7.62	<0.01	31.7	0.455	<0.25	6.21	0.923	7.82	<0.2	44.3	<0.2	<3.0	14.9	2.23	0.112	<0.1	0.156	<0.1
10V-S-39A	<0.15	30.5	<0.01	27.6	0.209	<0.25	9.89	2.91	6.43	<0.2	55.9	<0.2	<3.0	48.3	3.07	0.102	<0.1	0.263	<0.1
10V-S-51A	0.154	45.1	<0.01	28	0.206	<0.25	12.9	4.89	6.1	<0.2	72.8	<0.2	3.04	61.2	3.31	0.097	<0.1	0.691	<0.1
10V-S-61A	0.189	32.8	<0.01	23.1	0.075	<0.25	12	3.11	5.44	<0.2	54	<0.2	<3.0	69	2.88	0.088	<0.1	0.608	<0.1
10V-S-69A	0.195	37.6	<0.01	25.4	0.135	<0.25	14.3	4.52	5.53	<0.2	66	<0.2	<3.0	69.7	3.11	0.087	<0.1	0.511	<0.1
10V-S-79A	0.157	40	<0.01	26.4	0.087	<0.25	14.6	4.3	6.15	<0.2	63.3	<0.2	<3.0	89.3	3.08	0.101	<0.1	0.739	<0.1
10V-S-88A	0.189	45.5	<0.01	27.1	0.126	<0.25	15	5.56	6.15	<0.2	72	<0.2	<3.0	88.6	2.92	0.097	<0.1	0.792	<0.1
10V-W-22A	17.6	9.74	0.466	43.2	21.8	46.3	209	5.73	9.07	0.518	218	1.82	8.99	885	10.9	0.275	0.536	8.48	0.247
10V-W-39A	<0.15	3.63	<0.01	27.1	0.303	<0.25	23.2	3.4	6.93	<0.2	69.9	<0.2	<3.0	146	2.37	0.113	<0.1	0.149	<0.1
10V-W-51A	<0.15	8.26	<0.01	26.3	0.236	<0.25	36.1	6.29	6.49	<0.2	95.4	<0.2	<3.0	221	3.64	0.108	<0.1	0.222	<0.1
10V-W-61A	0.17	5.02	<0.01	22.7	0.164	<0.25	29.6	4.56	5.62	<0.2	79.8	<0.2	<3.0	212	3.15	0.092	<0.1	<0.1	<0.1
10V-W-69A	<0.15	4.36	<0.01	23.3	0.137	<0.25	28.7	4.37	5.71	<0.2	76.7	<0.2	<3.0	208	3.29	0.096	<0.1	0.195	<0.1
10V-W-79A	<0.15	5.83	<0.01	26.2	0.198	<0.25	36.7	5.99	6.64	<0.2	93.9	<0.2	<3.0	267	3.34	0.112	<0.1	0.233	<0.1
10V-W-88A	<0.15	6.99	<0.01	26.7	0.283	<0.25	48.6	7.37	6.62	<0.2	110	<0.2	<3.0	347	3.5	0.112	<0.1	0.18	<0.1
10V-E1-31A	0.331	127	0.045	187	6.34	<0.25	166	16.9	74.6	<0.2	540	<0.2	3.09	492	14.6	1.19	<0.1	2.19	<0.1
10V-E1-39A	0.886	530	0.277	505	9.51	0.281	340	61.5	186	<0.2	1150	0.319	4.92	1110	44.1	3.5	<0.1	14.9	<0.1
10V-E1-51A	1.26	660	0.259	419	4.7	<0.25	420	94.5	174	0.26	1390	0.61	4.33	1740	33.2	3	<0.1	44.2	<0.1
10V-E1-61A	0.555	875	0.18	289	2.08	0.325	490	125	183	0.202	2050	0.352	6.5	2950	56	2.52	<0.1	69.2	<0.1
10V-E1-69A	0.507	718	0.158	280	1.15	<0.25	439	101	154	0.242	1510	0.4	4.9	3120	44.7	2.18	<0.1	62.1	<0.1
10V-E1-79A	0.419	529	0.159	191	0.946	<0.25	298	70.4	111	<0.2	1030	0.372	5.78	2050	40.9	1.66	<0.1	41.4	<0.1
10V-E1-88A	0.574	755	0.161	307	0.905	0.326	471	112	177	0.357	1510	0.82	6.29	3360	47.4	2.6	<0.1	75.8	<0.1
10V-E2-39A	<0.15	91.8	<0.01	4.48	<0.05	<0.25	0.505	<0.25	0.231	<0.2	0.583	<0.2	<3.0	<1.25	1.62	0.013	<0.1	0.887	<0.1
10V-E2-61A	<0.15	325	<0.01	4.04	<0.05	<0.25	<0.4	<0.25	0.109	<0.2	0.387	<0.2	<3.0	<1.25	1.3	<0.01	<0.1	0.826	<0.1
10V-E2-79A	<0.15	340	<0.01	1.39	<0.05	<0.25	0.84	<0.25	<0.05	<0.2	0.6	<0.2	<3.0	<1.25	0.304	<0.01	<0.1	0.486	<0.1
10V-O-88A	0.238	169	0.046	102	0.411	0.737	107	28.3	41.2	<0.2	423	<0.2	3.25	649	17.3	0.636	<0.1	6.82	<0.1
10V-O-88B	<0.15	2.56	<0.01	27.6	<0.05	<0.25	3.77	0.3	6.42	<0.2	22.3	<0.2	<3.0	3.84	3.73	0.117	<0.1	0.307	<0.1
10V-O-88C	<0.15	<1.0	<0.01	27.3	<0.05	<0.25	3.18	<0.25	6.54	<0.2	19.9	<0.2	<3.0	<1.25	1.66	0.119	<0.1	<0.1	<0.1
10V-O-94B	<0.15	124	0.051	75	33	<0.25	599	160	2.73	0.473	2050	1.89	6.13	3610	31.4	4.44	<0.1	0.898	<0.1
10V-S-93A	0.242	41.3	<0.01	25.8	0.156	<0.25	16.2	4.84	6.2	<0.2	70	<0.2	<3.0	99.2	2.37	0.101	<0.1	0.725	<0.1
10V-S-93B	<0.15	6.27	<0.01	26.9	<0.05	<0.25	4.52	0.916	6.55	<0.2	28.9	<0.2	<3.0	15.3	1.45	0.105	<0.1	0.413	<0.1
10V-O-94A	2.24	296	<0.01	12.4	2.36	<0.25	110	82.2	0.909	<0.2	757	<0.2	<3.0	426	3.97	0.028	<0.1	0.183	<0.1
10V-W-88B	<0.15	6.69	<0.01	28.7	0.63	<0.25	105	12.3	7.27	<0.2	148	<0.2	<3.0	704	5.93	0.12	<0.1	0.307	<0.1
10V-W-88C	<0.15	<1.0	<0.01	25.9	<0.05	<0.25	7.75	0.396	6.6	<0.2	20.5	<0.2	<3.0	25.5	1.5	0.111	<0.1	<0.1	<0.1
10V-O-93B	0.247	39	0.012	26.4	0.132	<0.25	17	4.98	6.05	<0.2	70.8	<0.2	<3.0	102	2.61	0.114	<0.1	0.62	<0.1
10V-O-93D	<0.15	3.95	0.01	25.9	<0.05	<0.25	3.68	0.567	6.09	<0.2	22.1	<0.2	<3.0	10.4	2.31	0.106	<0.1	0.248	<0.1
10V-E1-93A	0.571	864	0.174	341	1.23	0.411	530	134	205	0.429	2110	1.13	6.29	3660	64.8	3.01	<0.1	97.2	<0.1
10V-E1-93B	0.352	43.8	0.021	43.5	<0.05	0.439	26.5	5.65	13	<0.2	107	<0.2	<3.0	158	7.11	0.249	<0.1	2.64	<0.1
10V-E1-93C	<0.15	17.8	<0.01	26.8	<0.05	0.413	10.9	1.59	7.34	<0.2	46.3	<0.2	<3.0	26	8.73	0.127	<0.1	1.68	<0.1
10V-E2-93A	<0.15	39.4	0.146	127	<0.05	<0.25	4.68	0.301	15.8	<0.2	43.4	<0.2	<3.0	<1.25	5.07	0.542	<0.1	0.249	<0.1

Table 4.25. DCP and XRF Analyzed Composition of Deposits around the DM10 Transition Line (wt%).

Test	2	3			4	
Sampling Location	Transition Line	Transition Line	Emergency off Gas Port	Between Film Cooler and Transition Line	Transition Line	Between Film Cooler and Transition Line
Sample	10R-O-89B	10S-O-28A	10S-O-28C	10S-O-28D	10S-O-94E	10S-O-95B
Al_2O_3	5.32	3.48	14.99	3.37	3.91	3.63
B_2O_3	12.89*	13.36*	4.56*	13.56*	11.61*	12.45*
CaO	3.10	4.14	1.78	4.14	7.47	6.53
Cl	2.38	3.43	5.21	3.28	6.92	7.50
Cr_2O_3	0.20	0.30	2.44	0.34	0.23	0.27
Fe_2O_3	6.41	7.32	7.11	7.76	6.93	6.54
I	0.808	0.608	0.050	0.630	0.378	0.299
K_2O	1.04	1.84	2.06	1.85	1.62	1.89
Li_2O	0.09*	0.55*	0.50*	0.56*	3.52*	2.67*
MgO	<0.01	<0.01	0.25	<0.01	0.20	0.14
Na_2O	27.34	22.82	16.05	22.92	12.51	14.17
NiO	0.02	0.01	0.42	0.01	0.02	0.02
P_2O_5	0.19	0.21	0.31	0.22	0.19	0.19
PbO	0.01	0.02	0.06	0.02	0.02	0.01
ReO_2	1.946	3.967	5.070	3.706	3.894	7.012
SiO_2	27.14	25.69	32.31	24.83	29.88	26.73
SO_3	1.86	2.63	2.50	2.48	4.01	3.54
TiO_2	1.23	1.33	0.65	1.29	1.14	1.06
ZnO	4.44	4.90	1.81	5.37	2.71	2.72
ZrO_2	3.59	3.40	1.89	3.66	2.83	2.62
Sum	100.00	100.00	100.00	100.00	100.00	100.00

* DCP-AES analyzed values are used in normalization of XRF results
NA - Not analyzed.

Table 5.1. Listing of Glass Discharged, Masses, Measured Technetium Concentration, and Other Analysis Performed.

Test	Formulations	Date	Name	Analysis	Tc (μCi/g)	Mass (kg)	Cumulative (kg)
1	LAWE4H	8/31/2011	10Q-G-89A	XRF,DCP	0.006	2.02	2.02
			10Q-G-89B	XRF	0.025	1.66	3.68
			10Q-G-101A	XRF	0.037	1.78	5.46
			10Q-G-101B	XRF	0.063	1.50	6.96
			10Q-G-101C	XRF	0.100	2.20	9.16
			10Q-G-101D	XRF	0.158	1.42	10.58
			10Q-G-101E	XRF	0.186	1.38	11.96
			10Q-G-101F	XRF	0.180	1.46	13.42
			10Q-G-101G	XRF	0.215	1.64	15.06
			10Q-G-102A	XRF	0.192	1.34	16.40
			10Q-G-102B	XRF	0.174	1.36	17.76
			10Q-G-102C	XRF	0.219	1.30	19.06
			10Q-G-108A	XRF	0.172	1.98	21.04
			10Q-G-108B	XRF	0.246	1.60	22.64
			10Q-G-108C	XRF	0.225	2.22	24.86
			10Q-G-108D	XRF	0.234	2.16	27.02
			10Q-G-108E	XRF	0.173	2.46	29.48
			10Q-G-111A	XRF	0.127	2.04	31.52
			10Q-G-111B	XRF	0.058	0.90	32.42
		9/1/2011	10Q-G-118A	XRF	0.266	4.58	37.00
			10Q-G-119A	XRF	0.217	3.16	40.16
			10Q-G-120A	XRF	0.239	2.00	42.16
			10Q-G-120B	XRF	0.262	1.48	43.64
			10Q-G-120C	XRF	0.292	0.98	44.62
			10Q-G-121A	XRF	0.265	0.80	45.42
			10Q-G-121B	XRF	0.162	1.54	46.96
			10Q-G-121C	XRF	0.323	1.36	48.32
			10Q-G-121D	XRF	0.317	2.86	51.18
			10Q-G-121E	XRF	0.323	1.44	52.62
			10Q-G-122A	XRF	0.371	2.08	54.70
			10Q-G-122B	XRF	0.431	1.96	56.66
			10Q-G-129A	XRF	0.368	1.90	58.56
			10Q-G-129B	XRF	0.331	2.80	61.36
			10Q-G-129C	XRF	0.397	1.30	62.66
			10Q-G-129D	XRF	0.383	1.30	63.96
			10Q-G-129E	XRF	0.341	1.30	65.26
			10Q-G-135A	XRF	0.307	1.78	67.04
			10Q-G-135B	XRF	0.385	1.94	68.98
			10Q-G-135C	XRF	0.419	3.70	72.68
		9/2/2011	10Q-G-137A	XRF	0.341	0.90	73.58

Table 5.1. Listing of Glass Discharged, Masses, Measured Technetium Concentration, and Other Analysis Performed (continued).

Test	Formulations	Date	Name	Analysis	Tc (µCi/g)	Mass (kg)	Cumulative (kg)
1	LAWE4H	9/2/2011	10Q-G-137B	XRF	0.377	1.82	75.40
			10Q-G-138A	XRF	0.399	1.68	77.08
			10Q-G-138B	XRF	0.324	1.98	79.06
			10Q-G-138C	XRF	0.292, 0.304	2.58	81.64
			10Q-G-139A	XRF	0.285	2.08	83.72
			10Q-G-139B	XRF	0.245	1.80	85.52
			10Q-G-139C	XRF	0.257	1.68	87.20
			10Q-G-139D	XRF	0.273	2.06	89.26
			10Q-G-147A	XRF	0.315	2.02	91.28
			10Q-G-147B	XRF	0.285	2.00	93.28
			10Q-G-147C	XRF	0.221	2.00	95.28
			10R-G-7A	XRF	0.328	2.00	97.28
2		9/7/2011	10R-G-27A	XRF,DCP	BDL	2.52	99.80
			10R-G-27B	XRF	0.161	2.02	101.82
			10R-G-34A	XRF	0.285	2.08	103.90
			10R-G-34B	XRF	0.361	1.14	105.04
			10R-G-34C	XRF	0.382	1.36	106.40
			10R-G-34D	XRF	0.478	1.38	107.78
			10R-G-34E	XRF	0.562	1.46	109.24
			10R-G-40A	XRF	0.592	2.32	111.56
			10R-G-40B	XRF	0.674	1.22	112.78
			10R-G-40C	XRF	0.650	1.46	114.24
			10R-G-41A	XRF	0.562	2.78	117.02
			10R-G-41B	XRF	0.639	2.28	119.30
			10R-G-43A	XRF	0.541	2.20	121.50
		9/8/2011	10R-G-43B	XRF	0.537	1.18	122.68
			10R-G-44A	XRF	0.638	1.34	124.02
			10R-G-44B	XRF	0.763	1.78	125.80
			10R-G-44C	XRF	0.683	1.60	127.40
			10R-G-46A	XRF	0.785	1.62	129.02
			10R-G-46B	XRF	0.601	1.36	130.38
			10R-G-46C	XRF	0.679	1.16	131.54
			10R-G-46D	XRF	0.836	1.20	132.74
			10R-G-46E	XRF	0.895	1.24	133.98
			10R-G-46F	XRF	0.714	1.68	135.66
			10R-G-48A	XRF	0.744	2.66	138.32
			10R-G-48B	XRF	0.828	1.48	139.80
			10R-G-48C	XRF	0.937	2.26	142.06
			10R-G-55A	XRF	0.769	1.42	143.48
			10R-G-55B	XRF	0.845	1.36	144.84

Table 5.1. Listing of Glass Discharged, Masses, Measured Technetium Concentration, and Other Analysis Performed (continued).

Test	Formulations	Date	Name	Analysis	Tc (μCi/g)	Mass	Cumulative (kg)
2	LAWE4H	9/8/2011	10R-G-57A	XRF	0.955	1.68	146.52
			10R-G-57B	XRF	0.905, 0.996	1.18	147.70
			10R-G-57C	XRF	0.954	1.48	149.18
			10R-G-58A	XRF	1.102	1.94	151.12
		9/9/2011	10R-G-58B	XRF	0.969	1.64	152.76
			10R-G-58C	XRF	1.110	1.88	154.64
			10R-G-64A	XRF	1.146	1.70	156.34
			10R-G-64B	XRF	1.001	1.68	158.02
			10R-G-66A	XRF	0.994	1.62	159.64
			10R-G-67A	XRF	1.020	1.22	160.86
			10R-G-68A	XRF	1.053	2.44	163.30
			10R-G-68B	XRF	1.200	1.74	165.04
			10R-G-68C	XRF	1.144	2.62	167.66
			10R-G-68D	XRF	1.093	1.76	169.42
			10R-G-75A	XRF	1.077	1.88	171.30
			10R-G-76A	XRF	1.001	2.80	174.10
			10R-G-76B	XRF	1.006	2.46	176.56
3	LAWE5H	9/19/2011	10R-G-120A	XRF,DCP	0.022	2.42	178.98
			10R-G-127A	XRF	0.049	1.86	180.84
			10R-G-127B	XRF	0.068	1.30	182.14
			10R-G-127C	XRF	0.139	1.20	183.34
			10R-G-127D	XRF	0.195	2.18	185.52
			10R-G-127E	XRF	0.198	1.92	187.44
			10R-G-128A	XRF	0.253	2.32	189.76
		9/20/2011	10R-G-128B	XRF	0.292	1.50	191.26
			10R-G-128C	XRF	0.308	1.92	193.18
			10R-G-128D	XRF	0.321	1.74	194.92
			10R-G-133A	XRF	0.351	1.68	196.60
			10R-G-133B	XRF	0.376	2.28	198.88
			10R-G-133C	XRF	0.379	1.62	200.50
			10R-G-133D	XRF	0.392	1.38	201.88
			10R-G-136A	XRF	0.403	1.64	203.52
			10R-G-136B	XRF	0.455	2.04	205.56
			10R-G-136C	XRF	0.461	1.58	207.14
			10R-G-136D	XRF	0.480, 0.481, 0.455, 0.434	1.58	208.72
			10R-G-136E	XRF	0.413	1.52	210.24
			10R-G-136F	XRF	0.459	1.52	211.76
			10R-G-137A	XRF	0.455	2.42	214.18
			10R-G-137B	XRF	0.523	1.70	215.88
			10R-G-137C	XRF	0.575	2.44	218.32

Table 5.1. Listing of Glass Discharged, Masses, Measured Technetium Concentration, and Other Analysis Performed (continued).

Test	Formulations	Date	Name	Analysis	Tc (μCi/g)	Mass (kg)	Cumulative (kg)
3	LAWE5H	9/20/2011	10R-G-143A	XRF	0.620	1.82	220.14
			10R-G-143B	XRF	0.563	2.32	222.46
			10R-G-143C	XRF	0.574	1.98	224.44
			10R-G-144A	XRF	0.588	1.64	226.08
			10R-G-144B	XRF	0.576	1.84	227.92
			10R-G-144C	XRF	0.591	1.72	229.64
			10R-G-145A	XRF	0.577	1.70	231.34
			10R-G-145B	XRF	0.569	2.10	233.44
		9/21/2011	10R-G-145C	XRF	0.611	1.66	235.10
			10R-G-145D	XRF	0.666	1.86	236.96
			10R-G-147A	XRF	0.681	2.98	239.94
			10R-G-147B	XRF	0.673	2.20	242.14
			10R-G-148A	XRF	0.558	2.08	244.22
			10R-G-148B	XRF	0.579	2.24	246.46
			10R-G-148C	XRF	0.568	2.66	249.12
			10R-G-150A	XRF	0.549	2.02	251.14
			10R-G-150B	XRF	0.603	2.20	253.34
			10R-G-150C	XRF	0.618	2.12	255.46
			10R-G-150D	XRF	0.725, 0.731	2.64	258.10
			10S-G-12A	XRF	0.810	1.86	259.96
			10S-G-12B	XRF	0.770	3.04	263.00
			10S-G-17A	XRF	0.718	1.40	264.40
			10S-G-17B	XRF	0.696	1.56	265.96
			10S-G-17C	XRF	0.723	2.06	268.02
			10S-G-17D	XRF	0.751	2.54	270.56
			10S-G-18A	XRF	0.619	1.86	272.42
		9/22/2011	10S-G-19A	XRF	0.579	1.00	273.42
4	LAWE10H	9/26/2011	10S-G-42A	XRF,DCP	0.045	3.46	276.88
			10S-G-42B	XRF	0.095	2.32	279.20
			10S-G-43A	XRF	0.230	2.06	281.26
			10S-G-43B	XRF	0.198	1.38	282.64
			10S-G-43C	XRF	0.253	2.74	285.38
		9/27/2011	10S-G-43D	XRF	0.335	2.70	288.08
			10S-G-44A	XRF	0.372	2.44	290.52
			10S-G-44B	XRF	0.426	3.12	293.64
			10S-G-44C	XRF	0.492	1.00	294.64
			10S-G-49A	XRF	0.430	2.22	296.86
			10S-G-49B	XRF	0.443	1.44	298.30
			10S-G-49C	XRF	0.480	1.32	299.62
			10S-G-49D	XRF	0.507	2.94	302.56

Table 5.1. Listing of Glass Discharged, Masses, Measured Technetium Concentration, and Other Analysis Performed (continued).

Test	Formulations	Date	Name	Analysis	Tc (μCi/g)	Mass (kg)	Cumulative (kg)
4	LAWE10H	9/27/2011	10S-G-51A	XRF	0.522	1.68	304.24
			10S-G-51B	XRF	0.572	1.58	305.82
			10S-G-51C	XRF	0.606	1.20	307.02
			10S-G-51D	XRF	0.665	0.88	307.90
			10S-G-53A	XRF	0.648, 0.641	1.76	309.66
			10S-G-53B	XRF	0.656, 0.662	2.50	312.16
			10S-G-53C	XRF	0.658	2.38	314.54
			10S-G-58A	XRF	0.637	2.12	316.66
			10S-G-58B	XRF	0.680, 0.647, 0.655	1.64	318.30
			10S-G-58C	XRF	0.643	1.64	319.94
			10S-G-60A	XRF	0.625	1.82	321.76
			10S-G-60B	XRF	0.655	1.76	323.52
			10S-G-60C	XRF	0.600, 0.614	3.22	326.74
			10S-G-60D	XRF	0.711, 0.672, 0.668	2.92	329.66
		9/28/2011	10S-G-61A	XRF	0.726, 0.712, 0.728	2.48	332.14
			10S-G-61B	XRF	0.735, 0.725, 0.698	3.20	335.34
			10S-G-62A	XRF	0.711, 0.732, 0.692	2.96	338.30
			10S-G-62B	XRF	0.689, 0.674, 0.706	2.50	340.80
			10S-G-62C	XRF	0.743, 0.762, 0.691	2.08	342.88
			10S-G-62D	XRF	0.752, 0.776, 0.688	1.96	344.84
			10S-G-68A	XRF	0.683, 0.795, 0.717	1.92	346.76
			10S-G-68B	XRF	0.676	2.08	348.84
			10S-G-68C	XRF	0.661	2.04	350.88

Table 5.1. Listing of Glass Discharged, Masses, Measured Technetium Concentration, and Other Analysis Performed (continued).

Test	Formulations	Date	Name	Analysis	Tc (μCi/g)	Mass (kg)	Cumulative (kg)
4	LAWE10H	9/28/2011	10S-G-70A	XRF	0.689	1.92	352.80
			10S-G-70B	XRF	0.718	1.84	354.64
			10S-G-70C	XRF	0.704	2.38	357.02
			10S-G-70D	XRF	0.702	2.28	359.30
			10S-G-71A	XRF	0.712	2.38	361.68
			10S-G-71B	XRF	0.702	2.46	364.14
			10S-G-71C	XRF	0.670	2.64	366.78
			10S-G-76A	XRF	0.737	2.60	369.38
			10S-G-76B	XRF	0.661	2.58	371.96
			10S-G-76C	XRF	0.618	1.30	373.26
			10S-G-79A	XRF	0.811	2.30	375.56
			10S-G-79B	XRF	0.713	2.98	378.54
		9/29/2011	10S-G-80A	XRF	0.584	2.62	381.16
			10S-G-80B	XRF	0.602	2.86	384.02
			10S-G-81A	XRF	0.550	2.36	386.38
			10S-G-81B	XRF	0.575	2.80	389.18
			10S-G-81C	XRF	0.559, 0.566	2.10	391.28
			10S-G-86A	XRF	0.698	3.22	394.50
			10S-G-86B	XRF	0.695	3.16	397.66
			10S-G-86C	XRF	0.647	1.84	399.50
			10S-G-86D	XRF	0.629	3.12	402.62
			10S-G-86E	XRF	0.738	2.55	405.17
			10S-G-86F	XRF	0.662, 0.643	2.32	407.49
			10S-G-93A	XRF	0.588	2.44	409.93
			10S-G-93B	XRF	NA	2.42	412.35
5	LAWE6H	12/13/2011	10S-G-102A	XRF,DCP	0.159	2.92	415.27
			10S-G-123A	XRF	0.249	3.30	418.57
			10S-G-123B	XRF	0.314	2.62	421.19
			10S-G-124A	XRF	0.331	2.58	423.77
			10S-G-124B	XRF	0.305	2.20	425.97
			10S-G-124C	XRF	0.348	2.92	428.89
			10S-G-124D	XRF	0.380	2.10	430.99
			10S-G-125A	XRF	0.282	2.48	433.47
			10S-G-125B	XRF	0.371	2.94	436.41
		12/14/2011	10S-G-127A	XRF	0.320	2.36	438.77
			10S-G-127B	XRF	0.295	2.42	441.19
			10S-G-129A	XRF	0.337	1.58	442.77
			10S-G-129B	XRF	0.274	2.66	445.43
			10S-G-129C	XRF	0.286	1.50	446.93
			10S-G-130A	XRF	0.326	1.92	448.85
			10S-G-130B	XRF	0.376	1.56	450.41

NA – not analyzed.

Table 5.1. Listing of Glass Discharged, Masses, Measured Technetium Concentration, and Other Analysis Performed (continued).

Test	Formulations	Date	Name	Analysis	Tc (μCi/g)	Mass (kg)	Cumulative (kg)
5	LAWE6H	12/14/2011	10S-G-130C	XRF	0.396	2.16	452.57
			10S-G-130D	XRF	0.450	4.18	456.75
			10S-G-131A	XRF	0.515	2.68	459.43
			10S-G-131B	XRF	0.532	2.74	462.17
			10S-G-139A	XRF	0.522	2.90	465.07
			10S-G-139B	XRF	0.525	3.00	468.07
			10S-G-146A	XRF	0.551	2.12	470.19
			10S-G-146B	XRF	0.575	2.62	472.81
			10S-G-146C	XRF	0.513	2.18	474.99
		12/15/2011	10S-G-147A	XRF	0.408	2.00	476.99
			10S-G-147B	XRF	0.371	1.84	478.83
			10S-G-148A	XRF	0.412	2.68	481.51
			10S-G-148B	XRF	0.490	2.48	483.99
			10S-G-148C	XRF	0.481	2.60	486.59
			10S-G-148D	XRF	0.587	2.80	489.39
			10S-G-149A	XRF	0.567	3.18	492.57
			10S-G-149B	XRF	0.555	2.30	494.87
			10S-G-149C	XRF	0.581	2.14	497.01
			10S-G-149D	XRF	0.583	2.62	499.63
			10S-G-149E	XRF	0.531	3.42	503.05
			10S-G-151A	XRF	0.587, 0.605, 0.592	2.42	505.47
			10T-G-11A	XRF	0.482, 0.541	1.42	506.89
			10T-G-11B	XRF	0.481	2.08	508.97
			10T-G-11C	XRF	0.531	2.30	511.27
			10T-G-13A	XRF	0.346	2.30	513.57
			10T-G-13B	XRF	0.370	1.80	515.37
			10T-G-13C	XRF	0.479	2.02	517.39
			10T-G-14A	XRF	0.526	1.80	519.19
		12/16/2011	10T-G-14B	XRF	0.421	2.24	521.43
			10T-G-20A	XRF	0.430	2.48	523.91
			10T-G-36A	XRF	0.397	4.42	528.33
		12/19/2011	10T-G-37A	XRF	NA	1.42	529.75
6	LAWE3H	01/09/2012	10T-G-54A	XRF,DCP	0.033	2.68	532.43
			10T-G-54B	XRF	0.118	2.30	534.73
			10T-G-54C	XRF	0.161	1.54	536.27
			10T-G-55A	XRF	0.173	1.44	537.71
			10T-G-55B	XRF	0.198	1.44	539.15
			10T-G-57A	XRF	0.205	1.62	540.77
			10T-G-57B	XRF	0.246	1.88	542.65
			10T-G-57C	XRF	0.266	1.78	544.43
			10T-G-57D	XRF	0.247	2.00	546.43

NA – not analyzed.

Table 5.1. Listing of Glass Discharged, Masses, Measured Technetium Concentration, and Other Analysis Performed (continued).

Test	Formulations	Date	Name	Analysis	Tc (μCi/g)	Mass (kg)	Cumulative (kg)
6	LAWE3H	1/9/2012	10T-G-57E	XRF	0.295	1.80	548.23
			10T-G-57F	XRF	0.312	1.80	550.03
			10T-G-58A	XRF	0.324	1.56	551.59
		1/10/2012	10T-G-58B	XRF	0.317	1.76	553.35
			10T-G-58C	XRF	0.314	1.70	555.05
			10T-G-64A	XRF	0.329	1.16	556.21
			10T-G-64B	XRF	0.331	1.66	557.87
			10T-G-64C	XRF	0.363	1.74	559.61
			10T-G-64D	XRF	0.369	1.34	560.95
			10T-G-64E	XRF	0.383	2.04	562.99
			10T-G-66A	XRF	0.366	1.60	564.59
			10T-G-66B	XRF	0.374, 0.368	1.98	566.57
			10T-G-67A	XRF	0.412	2.12	568.69
			10T-G-67B	XRF	0.411	1.96	570.65
			10T-G-67C	XRF	0.388	2.86	573.51
			10T-G-67D	XRF	0.387	2.24	575.75
			10T-G-68A	XRF	0.383, 0.364, 0.367	2.68	578.43
			10T-G-68B	XRF	0.321	3.18	581.61
			10T-G-75A	XRF	0.327	2.04	583.65
			10T-G-75B	XRF	0.350	2.00	585.65
			10T-G-75C	XRF	0.334	2.48	588.13
			10T-G-75D	XRF	0.409	2.74	590.87
			10T-G-77A	XRF	0.403	2.66	593.53
			10T-G-77B	XRF	0.395	1.74	595.27
			10T-G-77C	XRF	0.392	1.94	597.21
		1/11/2012	10T-G-78A	XRF	0.416	2.84	600.05
			10T-G-79A	XRF	0.419	3.16	603.21
			10T-G-79B	XRF	0.422	2.38	605.59
			10T-G-79C	XRF	0.420	2.46	608.05
			10T-G-85A	XRF	0.441	3.54	611.59
			10T-G-85B	XRF	0.426	1.76	613.35
			10T-G-85C	XRF	0.439	1.76	615.11
			10T-G-86A	XRF	0.450	2.66	617.77
			10T-G-86B	XRF	0.474	2.56	620.33
			10T-G-86C	XRF	0.460	2.32	622.65
			10T-G-92A	XRF	0.483	2.70	625.35
			10T-G-92B	XRF	0.473	2.86	628.21
			10T-G-92C	XRF	0.473	1.90	630.11
			10T-G-92D	XRF	0.485	2.52	632.63
			10T-G-93A	XRF	0.518	2.42	635.05
			10T-G-93B	XRF	0.460	2.02	637.07

Table 5.1. Listing of Glass Discharged, Masses, Measured Technetium Concentration, and Other Analysis Performed (continued).

Test	Formulations	Date	Name	Analysis	Tc (μCi/g)	Mass (kg)	Cumulative (kg)
6	LAWE3H	1/11/2012	10T-G-93C	XRF	0.434	2.20	639.27
			10T-G-93D	XRF	0.493	1.96	641.23
			10T-G-95A	XRF	0.436	2.14	643.37
			10T-G-95B	XRF	0.495	2.74	646.11
			10T-G-95C	XRF	0.558	3.42	649.53
		1/12/2012	10T-G-102A	XRF	0.441	1.52	651.05
			10T-G-102B	XRF	0.437	1.56	652.61
			10T-G-103A	XRF	0.484	1.88	654.49
			10T-G-103B	XRF	0.521	2.06	656.55
			10T-G-103C	XRF	0.521	2.56	659.11
			10T-G-105A	XRF	0.506	2.62	661.73
			10T-G-105B	XRF	0.548	2.84	664.57
			10T-G-105C	XRF	0.557	2.98	667.55
			10T-G-106A	XRF	0.496	1.86	669.41
			10T-G-106B	XRF	0.538	2.18	671.59
			10T-G-106C	XRF	0.470	1.58	673.17
7	LAWE4H	1/17/2012	10T-G-139A	XRF,DCP	0.085	3.66	676.83
			10T-G-139B	XRF	0.185	1.48	678.31
			10T-G-142A	XRF	0.203	3.34	681.65
			10T-G-142B	XRF	0.281	0.92	682.57
			10T-G-143A	XRF	0.331	1.16	683.73
			10T-G-143B	XRF	0.292	1.10	684.83
			10T-G-145A	XRF	0.310	1.42	686.25
			10T-G-145B	XRF	0.306	1.16	687.41
			10T-G-145C	XRF	0.343	1.36	688.77
			10T-G-146A	XRF	0.369	1.42	690.19
			10T-G-146B	XRF	0.349	2.10	692.29
		1/18/2012	10T-G-147A	XRF	0.390	1.74	694.03
			10T-G-147B	XRF	0.423	1.74	695.77
			10U-G-8A	XRF	0.425	1.60	697.37
			10U-G-8B	XRF	0.424	1.44	698.81
			10U-G-8C	XRF	0.416	1.28	700.09
			10U-G-8D	XRF	0.440	1.66	701.75
			10U-G-10A	XRF	0.453	1.66	703.41
			10U-G-10B	XRF	0.499	1.30	704.71
			10U-G-11A	XRF	0.413, 0.459, 0.483	1.42	706.13
			10U-G-11B	XRF	0.456	1.64	707.77
			10U-G-11C	XRF	0.483	1.92	709.69
			10U-G-13A	XRF	0.497	1.90	711.59
			10U-G-13B	XRF	0.538	1.40	712.99
			10U-G-13C	XRF	0.543	1.60	714.59

Table 5.1. Listing of Glass Discharged, Masses, Measured Technetium Concentration, and Other Analysis Performed (continued).

Test	Formulations	Date	Name	Analysis	Tc (μCi/g)	Mass (kg)	Cumulative (kg)
7	LAWE4H	1/18/2012	10U-G-13D	XRF	0.580	2.24	716.83
			10U-G-18A	XRF	0.599	1.64	718.47
			10U-G-18B	XRF	0.547, 0.577, 0.584	1.90	720.37
			10U-G-18C	XRF	0.596	1.38	721.75
			10U-G-19A	XRF	0.631	1.34	723.09
			10U-G-19B	XRF	0.547	1.54	724.63
			10U-G-21A	XRF	0.581	1.54	726.17
			10U-G-21B	XRF	0.500	1.58	727.75
			10U-G-21C	XRF	0.553	1.54	729.29
			10U-G-21D	XRF	0.563	1.90	731.19
			10U-G-23A	XRF	0.575	1.72	732.91
		1/19/2012	10U-G-29A	XRF	0.546	1.94	734.85
			10U-G-29B	XRF	0.567	2.14	736.99
			10U-G-29C	XRF	0.579	1.78	738.77
			10U-G-30A	XRF	0.597	1.66	740.43
			10U-G-30B	XRF	0.629	1.66	742.09
			10U-G-30C	XRF	0.591, 0.575, 0.633	1.82	743.91
			10U-G-30D	XRF	0.552, 0.568	1.78	745.69
			10U-G-33A	XRF	0.589	2.06	747.75
			10U-G-33B	XRF	0.631	1.62	749.37
			10U-G-33C	XRF	0.644	1.98	751.35
			10U-G-33D	XRF	0.626	1.48	752.83
			10U-G-39A	XRF	0.604	1.54	754.37
			10U-G-39B	XRF	0.610	1.56	755.93
			10U-G-39C	XRF	0.600	1.48	757.41
			10U-G-39D	XRF	0.657	1.50	758.91
			10U-G-40A	XRF	0.604	1.36	760.27
			10U-G-40B	XRF	0.670	1.50	761.77
			10U-G-40C	XRF	0.669	1.56	763.33
			10U-G-40D	XRF	0.638	1.56	764.89
			10U-G-41A	XRF	0.599	1.62	766.51
			10U-G-41B	XRF	0.696	1.94	768.45
			10U-G-41C	XRF	0.682	1.50	769.95
		1/20/2012	10U-G-47A	XRF	0.623	1.80	771.75
			10U-G-47B	XRF	0.688	1.80	773.55
			10U-G-47C	XRF	0.659	1.36	774.91
			10U-G-48A	XRF	0.641	2.12	777.03
			10U-G-48B	XRF	0.666	1.90	778.93
			10U-G-48C	XRF	0.682	1.58	780.51

Table 5.1. Listing of Glass Discharged, Masses, Measured Technetium Concentration, and Other Analysis Performed (continued).

Test	Formulations	Date	Name	Analysis	Tc (μCi/g)	Mass (kg)	Cumulative (kg)
7	LAWE4H	1/20/2012	10U-G-48D	XRF	0.676	1.32	781.83
			10U-G-48E	XRF	0.645	1.44	783.27
			10U-G-51A	XRF	0.645	1.28	784.55
			10U-G-51B	XRF	0.605	1.60	786.15
			10U-G-51C	XRF	0.597	1.86	788.01
			10U-G-56A	XRF	0.654	2.50	790.51
8	LAWE7H		10U-G-91A	XRF,DCP	0.008	1.74	792.25
			10U-G-91B	XRF	0.066	1.68	793.93
			10U-G-91C	XRF	0.117	1.98	795.91
			10U-G-91D	XRF	0.128	2.48	798.39
			10U-G-92A	XRF	0.189	2.68	801.07
			10U-G-92B	XRF	0.186	2.18	803.25
			10U-G-93A	XRF	0.184	2.12	805.37
			10U-G-93B	XRF	0.187	2.12	807.49
			10U-G-93C	XRF	0.208	2.10	809.59
			10U-G-95A	XRF	0.194	2.22	811.81
			10U-G-95B	XRF	0.200	2.56	814.37
		2/21/2012	10U-G-96A	XRF	0.256	2.90	817.27
			10U-G-96B	XRF	0.256	2.56	819.83
			10U-G-96C	XRF	0.252	2.74	822.57
			10U-G-99A	XRF	0.280	3.00	825.57
			10U-G-99B	XRF	0.245	2.92	828.49
			10U-G-99C	XRF	0.297	2.78	831.27
			10U-G-99D	XRF	0.290, 0.234, 0.254	2.76	834.03
			10U-G-99E	XRF	0.262	2.44	836.47
			10U-G-101A	XRF	0.276	2.80	839.27
			10U-G-101B	XRF	0.314	2.60	841.87
			10U-G-101C	XRF	0.367	2.58	844.45
			10U-G-106A	XRF	0.368	2.50	846.95
			10U-G-106B	XRF	0.383	2.10	849.05
			10U-G-107A	XRF	0.401	2.18	851.23
			10U-G-107B	XRF	0.362	2.20	853.43
			10U-G-107C	XRF	0.390	2.04	855.47
			10U-G-107D	XRF	0.389	2.00	857.47
			10U-G-107E	XRF	0.456	2.10	859.57
			10U-G-109A	XRF	0.467	2.20	861.77
		2/22/2012	10U-G-109B	XRF	0.432	2.22	863.99
			10U-G-116A	XRF	0.455	2.18	866.17
			10U-G-116B	XRF	0.452	2.36	868.53
			10U-G-116C	XRF	0.467	2.36	870.89
			10U-G-116D	XRF	0.457	2.32	873.21
			10U-G-117A	XRF	0.462	2.50	875.71
			10U-G-117B	XRF	0.410	3.06	878.77

Table 5.1. Listing of Glass Discharged, Masses, Measured Technetium Concentration, and Other Analysis Performed (continued).

Test	Formulations	Date	Name	Analysis	Tc (μCi/g)	Mass (kg)	Cumulative (kg)
8	LAWE7H	2/22/2012	10U-G-117C	XRF	0.433	2.80	881.57
			10U-G-119A	XRF	0.489	2.36	883.93
			10U-G-119B	XRF	0.468, 0.467, 0.473	2.12	886.05
			10U-G-119C	XRF	0.413	1.96	888.01
			10U-G-119D	XRF	0.473	2.66	890.67
			10U-G-119E	XRF	0.498	2.62	893.29
			10U-G-125A	XRF	0.447	2.06	895.35
			10U-G-125B	XRF	0.417, 0.432, 0.464	2.86	898.21
			10U-G-126A	XRF	0.488	2.50	900.71
			10U-G-126B	XRF	0.440	2.24	902.95
			10U-G-126C	XRF	0.421	2.12	905.07
			10U-G-126D	XRF	0.409	2.26	907.33
			10U-G-127A	XRF	0.401	2.60	909.93
			10U-G-127B	XRF	0.430	2.46	912.39
		2/23/2012	10U-G-134A	XRF	0.448	2.44	914.83
			10U-G-134B	XRF	0.501	2.50	917.33
			10U-G-134C	XRF	0.510	3.06	920.39
			10U-G-134D	XRF	0.472	2.42	922.81
			10U-G-134E	XRF	0.462	2.30	925.11
			10U-G-136A	XRF	0.476, 0.552	3.36	928.47
			10U-G-136B	XRF	0.477	2.36	930.83
			10U-G-136C	XRF	0.576, 0.511	2.64	933.47
			10U-G-136D	XRF	0.466, 0.474	2.42	935.89
			10U-G-146A	XRF	0.422	2.18	938.07
9	LAWE9H	3/6/2012	10V-G-31A	XRF	0.118	1.42	939.49
			10V-G-31B	XRF	0.234	3.56	943.05
			10V-G-31C	XRF	0.289	1.72	944.77
			10V-G-33A	XRF	0.345	2.22	946.99
			10V-G-33B	XRF	0.412	2.10	949.09
			10V-G-34A	XRF	0.363	1.98	951.07
			10V-G-34B	XRF	0.447	1.72	952.79
			10V-G-34C	XRF	0.436	2.46	955.25
			10V-G-34D	XRF	0.489	2.24	957.49
		3/7/2012	10V-G-39A	XRF	0.477	1.92	959.41
			10V-G-39B	XRF	0.526	1.86	961.27
			10V-G-40A	XRF	0.524	1.62	962.89
			10V-G-40B	XRF	0.548	2.84	965.73

Table 5.1. Listing of Glass Discharged, Masses, Measured Technetium Concentration, and Other Analysis Performed (continued).

Test	Formulations	Date	Name	Analysis	Tc (μCi/g)	Mass (kg)	Cumulative (kg)
9	LAWE9H	3/7/2012	10V-G-41A	XRF	0.565	2.14	967.87
			10V-G-41B	XRF	0.520	2.10	969.97
			10V-G-44A	XRF	0.506, 0.526	1.80	971.77
			10V-G-44B	XRF	0.510	3.02	974.79
			10V-G-44C	XRF	0.474	3.16	977.95
			10V-G-45A	XRF	0.556	2.16	980.11
			10V-G-45B	XRF	0.531	2.04	982.15
			10V-G-45C	XRF	0.508	2.10	984.25
			10V-G-45D	XRF	0.555	1.98	986.23
			10V-G-51A	XRF	0.597	2.22	988.45
			10V-G-51B	XRF	0.559	2.04	990.49
			10V-G-51C	XRF	0.592	1.84	992.33
			10V-G-53A	XRF	0.641	1.90	994.23
			10V-G-53B	XRF	0.597	2.16	996.39
			10V-G-53C	XRF	0.632	2.08	998.47
			10V-G-54A	XRF	0.675	2.02	1000.49
			10V-G-54B	XRF	0.689	1.86	1002.35
			10V-G-54C	XRF	0.673	2.02	1004.37
			10V-G-60A	XRF	0.706	2.22	1006.59
			10V-G-60B	XRF	0.653, 0.701, 0.667, 0.667	2.52	1009.11
		3/8/2012	10V-G-61A	XRF	0.711	2.40	1011.51
			10V-G-61B	XRF	0.675	1.98	1013.49
			10V-G-61C	XRF	0.750	1.96	1015.45
			10V-G-61D	XRF	0.790	2.04	1017.49
			10V-G-63A	XRF	0.734	2.18	1019.67
			10V-G-63B	XRF	0.764	2.04	1021.71
			10V-G-63C	XRF	0.788	1.98	1023.69
			10V-G-63D	XRF	0.788	2.26	1025.95
			10V-G-69A	XRF	0.795, 0.747, 0.743	2.18	1028.13
			10V-G-69B	XRF	0.739	2.06	1030.19
			10V-G-69C	XRF	0.784	2.16	1032.35
			10V-G-69D	XRF	0.770, 0.664, 0.747, 0.747	2.12	1034.47
			10V-G-69E	XRF	0.705	2.36	1036.83
			10V-G-71A	XRF	0.721	2.22	1039.05
			10V-G-71B	XRF	0.772	2.08	1041.13

Table 5.1. Listing of Glass Discharged, Masses, Measured Technetium Concentration, and Other Analysis Performed (continued).

Test	Formulations	Date	Name	Analysis	Tc (μCi/g)	Mass (kg)	Cumulative (kg)
9	LAWE9H	3/8/2012	10V-G-71C	XRF	0.699	2.28	1043.41
			10V-G-73A	XRF	0.672	2.14	1045.55
			10V-G-73B	XRF	0.756	2.02	1047.57
			10V-G-73C	XRF	0.670	2.46	1050.03
			10V-G-78A	XRF	0.682	2.02	1052.05
			10V-G-78B	XRF	0.756, 0.736, 0.702	1.92	1053.97
			10V-G-78C	XRF	0.799	2.08	1056.05
		3/9/2012	10V-G-79A	XRF	0.713	2.28	1058.33
			10V-G-79B	XRF	0.700	2.16	1060.49
			10V-G-79C	XRF	0.786, 0.808	2.34	1062.83
			10V-G-79D	XRF	0.768	2.08	1064.91
			10V-G-81A	XRF	0.742	2.02	1066.93
			10V-G-81B	XRF	0.751	2.16	1069.09
			10V-G-81C	XRF	0.713	1.96	1071.05
			10V-G-81D	XRF	0.752, 0.711, 0.796	1.90	1072.95
			10V-G-81E	XRF	0.693	1.96	1074.91
			10V-G-81F	XRF	0.749	2.20	1077.11
			10V-G-88A	XRF	0.751	2.34	1079.45
			10V-G-88B	XRF	0.738	2.18	1081.63
			10V-G-93A	XRF	0.846	2.14	1083.77

Table 5.2. Listing of Glass Pool Samples, Secondary Phase Observations, Measured Iron Oxidation State, and Measured Tc Concentrations.

Test	Date	Time	Sample I.D.	Fe^{2+}/Σ Fe (%)	Tc (μCi/g)	Secondary Phases	Depth of Glass Pool (inches)
Before 1	8/30/2011	21:20	10Q-D-88A	NM	NM	No	6.75
End of 1	9/2/2011	14:15	10Q-D-147A	5.9	0.403	No	9.00
Before 2	9/6/2011	22:00	10R-D-12A	NM	NA	No	7.50
End of 2	9/9/2011	22:30	10R-D-77A	5.6	1.073	No	7.00
Before 3	9/19/2011	9:55	10R-D-120A	NM	NM	No	6.25
End of 3	9/22/2011	1:50	10S-D-19A	2.2	0.594	No	7.50
Before 4	9/26/2011	9:00	10S-D-42A	NM	NM	No	7.00
End of 4	9/29/2011	18:18	10S-D-93A	11.8	0.637	No	9.00
Before 5	12/13/2011	1:40	10S-D-102A	2.4	NM	No	NM
End of 5	12/16/2011	6:50	10T-D-20A	2.5	0.494	No	8.00
		19:32	10T-D-36A	NM	0.343	No	8.00
Before 6	1/9/2012	7:30	10T-D-37A	< 1	NM	No	7.00
End of 6	1/12/2012	12:20	10T-D-106A	2.30	0.868 (glass phase) 41.318 (yellow phase)	Yes	8.50
		12:44	10T-D-106B	NM	NM	Yes	8.50
		13:41	10T-D-112A	NM	NM	Yes	NM
		14:18	10T-D-112B	NM	NM	Yes	7.00
		15:30	10T-D-112C	NM	NM	No	NM
Before 7	1/13/2012	3:00	10T-D-124A	NM	NM	No	7.25
	1/17/2012	8:20	10T-D-139A	2.2	NM	No	7.25
End of 7	1/20/2012	12:21	10U-D-56A	2.2	0.722	No	9.00
		16:30	10U-D-57A	3.1	0.610	No	NM
Before 8	2/20/2012	7:34	10U-D-69A	1.1	NM	No	7.75
End of 8	2/23/2012	11:45	10U-D-137A	NM	0.444	Yes	7.25
		14:34	10U-D-137B	1.60	0.392	No	8.75
Before 9	3/6/2012	7:30	10V-D-22A	< 1	NM	No	6.00
End of 9	3/9/2012	12:53	10V-D-88A	< 1	0.739	No	8.00
		15:17	10V-D-93A	NM	0.808	No	6.50

NM –Not measured

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%).

Test	Target	1									
Mass (kg)		2.02	3.68	5.46	6.96	9.16	10.58	11.96	13.42	15.06	16.40
Sample		10Q-G-89A	10Q-G-89B	10Q-G-101A	10Q-G-101B	10Q-G-101C	10Q-G-101D	10Q-G-101E	10Q-G-101F	10Q-G-101G	10Q-G-102A
Al_2O_3	5.98	5.55	5.54	5.52	5.53	5.53	5.58	5.49	5.47	5.45	5.55
B_2O_3*	9.80	9.77[$]	9.96	10.12	10.24	10.39	10.47	10.53	10.59	10.65	10.69
CaO	2.46	2.76	2.77	2.79	2.65	2.66	2.62	2.61	2.66	2.65	2.60
Cl	0.09	0.12	0.14	0.16	0.15	0.17	0.17	0.17	0.17	0.17	0.17
Cr_2O_3	0.08	0.25	0.24	0.23	0.22	0.23	0.22	0.23	0.24	0.24	0.25
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.39	5.38	5.61	5.69	5.33	5.37	5.29	5.38	5.51	5.55	5.47
I	0.10	0.022	0.027	0.036	0.036	0.040	0.041	0.042	0.045	0.040	0.036
K_2O	0.54	0.74	0.73	0.75	0.70	0.70	0.70	0.68	0.69	0.67	0.67
Li_2O*	§	0.68[$]	0.58	0.48	0.41	0.33	0.29	0.25	0.22	0.18	0.16
MgO	1.45	1.64	1.56	1.34	1.24	1.20	1.19	1.12	1.18	1.18	1.14
Na_2O	21.14	20.16	20.15	19.75	21.38	20.89	21.24	21.44	21.04	21.02	20.76
NiO	0.01	0.07	0.06	0.05	0.04	0.05	0.04	0.03	0.03	0.03	0.03
P_2O_5	0.12	0.16	0.15	0.17	0.16	0.17	0.16	0.17	0.17	0.16	0.16
PbO	0.01	0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	0.01	<0.01
ReO_2	0.10	0.042	0.053	0.060	0.067	0.075	0.078	0.081	0.079	0.075	0.074
SiO_2	44.56	45.77	45.12	45.21	44.50	44.76	44.42	44.08	43.85	43.81	44.23
SO_3	0.35	0.37	0.39	0.42	0.42	0.44	0.45	0.46	0.45	0.45	0.46
TiO_2	1.37	1.08	1.15	1.20	1.19	1.24	1.26	1.31	1.36	1.37	1.38
ZnO	3.44	2.61	2.88	3.04	2.95	3.04	3.12	3.21	3.39	3.42	3.37
ZrO_2	2.94	2.83	2.89	2.97	2.77	2.72	2.68	2.72	2.86	2.86	2.79
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and feed sample using a simple well stirred tank model.
[$] - DCP-AES results
§ - Not a target constituent
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	1									
Mass (kg)		17.76	19.06	21.04	22.64	24.86	27.02	29.48	31.52	32.42	37.00
Sample		10Q-G-102B	10Q-G-102C	10Q-G-108A	10Q-G-108B	10Q-G-108C	10Q-G-108D	10Q-G-108E	10Q-G-111A	10Q-G-111B	10Q-G-118A
Al_2O_3	5.98	5.56	5.54	5.55	5.60	5.52	5.47	5.55	5.59	5.59	5.75
B_2O_3*	9.80	10.73	10.76	10.80	10.83	10.86	10.88	10.90	10.92	10.92	10.94
CaO	2.46	2.59	2.59	2.53	2.49	2.51	2.46	2.52	2.49	2.43	2.44
Cl	0.09	0.15	0.16	0.16	0.15	0.14	0.13	0.12	0.11	0.10	0.16
Cr_2O_3	0.08	0.24	0.24	0.24	0.24	0.23	0.22	0.23	0.23	0.24	0.23
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.39	5.43	5.56	5.32	5.28	5.35	5.21	5.37	5.29	5.17	5.11
I	0.10	0.035	0.047	0.033	0.037	0.033	0.033	0.030	0.018	0.021	0.022
K_2O	0.54	0.67	0.67	0.64	0.66	0.64	0.63	0.64	0.64	0.62	0.62
Li_2O*	§	0.14	0.12	0.10	0.09	0.07	0.06	0.04	0.04	0.03	0.02
MgO	1.45	1.19	1.16	1.17	1.22	1.22	1.21	1.24	1.24	1.21	1.19
Na_2O	21.14	21.29	21.10	21.26	21.35	21.57	22.06	21.01	21.28	21.69	21.72
NiO	0.01	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
P_2O_5	0.12	0.16	0.16	0.16	0.16	0.17	0.17	0.16	0.17	0.16	0.18
PbO	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
ReO_2	0.10	0.071	0.080	0.075	0.077	0.073	0.072	0.064	0.055	0.054	0.074
SiO_2	44.56	43.78	43.56	44.11	44.00	43.68	43.59	44.02	44.10	44.11	43.99
SO_3	0.35	0.44	0.44	0.45	0.43	0.43	0.42	0.41	0.42	0.42	0.43
TiO_2	1.37	1.37	1.41	1.37	1.38	1.41	1.40	1.47	1.45	1.41	1.35
ZnO	3.44	3.36	3.51	3.33	3.34	3.39	3.31	3.41	3.36	3.26	3.20
ZrO_2	2.94	2.76	2.86	2.67	2.65	2.68	2.65	2.80	2.60	2.55	2.55
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and feed sample using a simple well stirred tank model.
$ - DCP-AES results
§ - Not a target constituent
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	1									
Mass (kg)		40.16	42.16	43.64	44.62	45.42	46.96	48.32	51.18	52.62	54.70
Sample		10Q-G-119A	10Q-G-120A	10Q-G-120B	10Q-G-120C	10Q-G-121A	10Q-G-121B	10Q-G-121C	10Q-G-121D	10Q-G-121E	10Q-G-122A
Al_2O_3	5.98	5.62	5.59	5.52	5.57	5.62	5.60	5.54	5.59	5.59	5.50
B_2O_3*	9.80	10.95	10.96	10.96	10.96	10.96	10.97	10.97	10.97	10.97	10.97
CaO	2.46	2.51	2.50	2.66	2.56	2.49	2.49	2.49	2.51	2.49	2.55
Cl	0.09	0.15	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.13
Cr_2O_3	0.08	0.24	0.22	0.23	0.22	0.22	0.20	0.21	0.21	0.21	0.22
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.39	5.33	5.38	5.62	5.41	5.31	5.25	5.26	5.35	5.29	5.55
I	0.10	0.027	0.028	0.027	0.026	0.036	0.037	0.039	0.040	0.033	0.035
K_2O	0.54	0.63	0.63	0.65	0.63	0.63	0.63	0.61	0.62	0.62	0.65
Li_2O*	§	0.02	0.01	0.01	0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01
MgO	1.45	1.16	1.23	1.26	1.26	1.25	1.28	1.32	1.29	1.34	1.25
Na_2O	21.14	21.93	21.92	20.85	21.23	20.96	21.52	21.38	21.45	21.69	21.20
NiO	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
P_2O_5	0.12	0.15	0.15	0.17	0.16	0.16	0.16	0.17	0.17	0.16	0.15
PbO	0.01	<0.01	<0.01	0.01	<0.01	0.01	<0.01	<0.01	0.01	<0.01	0.01
ReO_2	0.10	0.078	0.076	0.075	0.080	0.082	0.085	0.082	0.082	0.080	0.079
SiO_2	44.56	43.25	43.15	43.40	43.70	44.22	43.78	43.86	43.54	43.44	43.31
SO_3	0.35	0.42	0.41	0.42	0.43	0.42	0.43	0.42	0.42	0.42	0.42
TiO_2	1.37	1.41	1.44	1.51	1.46	1.44	1.43	1.44	1.45	1.45	1.50
ZnO	3.44	3.41	3.45	3.63	3.47	3.38	3.32	3.35	3.40	3.37	3.58
ZrO_2	2.94	2.70	2.71	2.87	2.65	2.67	2.66	2.70	2.76	2.70	2.89
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and feed sample using a simple well stirred tank model.
$ - DCP-AES results
§ - Not a target constituent
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	1									
Mass (kg)		56.66	58.56	61.36	62.66	63.96	65.26	67.04	68.98	72.68	73.58
Sample		10Q-G-122B	10Q-G-129A	10Q-G-129B	10Q-G-129C	10Q-G-129D	10Q-G-129E	10Q-G-135A	10Q-G-135B	10Q-G-135C	10Q-G-137A
Al_2O_3	5.98	5.58	5.46	5.58	5.60	5.49	5.57	5.54	5.58	5.51	5.58
B_2O_3*	9.80	10.97	10.98	10.98	10.98	10.98	10.98	10.98	10.98	10.98	10.98
CaO	2.46	2.49	2.59	2.48	2.45	2.44	2.42	2.46	2.49	2.54	2.47
Cl	0.09	0.12	0.10	0.11	0.13	0.12	0.12	0.13	0.13	0.15	0.13
Cr_2O_3	0.08	0.20	0.23	0.21	0.22	0.22	0.20	0.20	0.22	0.21	0.20
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.39	5.26	5.66	5.32	5.28	5.21	5.20	5.27	5.32	5.42	5.18
I	0.10	0.028	0.022	0.028	0.029	0.028	0.030	0.035	0.029	0.039	0.029
K_2O	0.54	0.62	0.64	0.61	0.61	0.60	0.59	0.62	0.61	0.63	0.62
Li_2O*	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MgO	1.45	1.27	1.27	1.35	1.36	1.38	1.29	1.34	1.32	1.31	1.29
Na_2O	21.14	21.38	21.29	21.48	21.17	22.29	22.02	21.62	21.18	20.67	21.43
NiO	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01
P_2O_5	0.12	0.17	0.16	0.17	0.16	0.16	0.14	0.17	0.17	0.17	0.17
PbO	0.01	<0.01	0.01	0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
ReO_2	0.10	0.069	0.061	0.067	0.077	0.081	0.081	0.088	0.084	0.092	0.078
SiO_2	44.56	43.97	43.01	43.66	43.98	43.16	43.51	43.59	43.87	44.04	44.05
SO_3	0.35	0.42	0.40	0.40	0.41	0.40	0.41	0.42	0.42	0.43	0.42
TiO_2	1.37	1.46	1.54	1.46	1.47	1.46	1.44	1.46	1.47	1.49	1.44
ZnO	3.44	3.31	3.65	3.38	3.34	3.30	3.28	3.35	3.39	3.48	3.28
ZrO_2	2.94	2.64	2.90	2.71	2.71	2.66	2.68	2.72	2.71	2.82	2.64
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and feed sample using a simple well stirred tank model.
$ - DCP-AES results
§ - Not a target constituent
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	1									
Mass (kg)		75.40	77.08	79.06	81.64	83.72	85.52	87.20	89.26	91.28	93.28
Sample		10Q-G-137B	10Q-G-138A	10Q-G-138B	10Q-G-138C	10Q-G-139A	10Q-G-139B	10Q-G-139C	10Q-G-139D	10Q-G-147A	10Q-G-147B
Al_2O_3	5.98	5.52	5.61	5.52	5.55	5.54	5.55	5.56	5.58	5.56	5.55
B_2O_3*	9.80	10.98	10.98	10.98	10.98	10.98	10.98	10.98	10.98	10.98	10.98
CaO	2.46	2.54	2.57	2.59	2.51	2.52	2.47	2.50	2.47	2.50	2.54
Cl	0.09	0.11	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.10
Cr_2O_3	0.08	0.21	0.21	0.22	0.21	0.21	0.20	0.20	0.21	0.20	0.21
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.39	5.59	5.56	5.61	5.33	5.42	5.22	5.22	5.22	5.34	5.46
I	0.10	0.029	0.027	0.028	0.029	0.029	0.031	0.025	0.029	0.033	0.035
K_2O	0.54	0.64	0.64	0.63	0.63	0.63	0.61	0.62	0.63	0.62	0.63
Li_2O*	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MgO	1.45	1.29	1.27	1.26	1.20	1.17	1.14	1.12	1.09	1.08	1.08
Na_2O	21.14	20.87	20.88	20.69	21.47	21.58	22.07	21.70	21.65	21.45	21.17
NiO	0.01	0.02	0.02	0.01	0.02	0.02	0.01	0.01	0.01	0.01	0.02
P_2O_5	0.12	0.16	0.16	0.17	0.16	0.17	0.16	0.16	0.17	0.17	0.16
PbO	0.01	0.01	<0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
ReO_2	0.10	0.071	0.065	0.063	0.062	0.064	0.068	0.064	0.064	0.066	0.068
SiO_2	44.56	43.61	43.58	43.71	43.73	43.41	43.64	44.07	44.07	43.85	43.80
SO_3	0.35	0.41	0.40	0.41	0.40	0.40	0.41	0.40	0.42	0.42	0.41
TiO_2	1.37	1.51	1.51	1.54	1.47	1.48	1.41	1.43	1.40	1.45	1.47
ZnO	3.44	3.58	3.57	3.60	3.43	3.50	3.34	3.33	3.35	3.45	3.54
ZrO_2	2.94	2.86	2.84	2.87	2.74	2.79	2.59	2.51	2.56	2.71	2.79
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and feed sample using a simple well stirred tank model.
$ - DCP-AES results
§ - Not a target constituent
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

	Target	1				2						
Mass (kg)		95.28	97.28	Avg.	% Dev.	99.8	101.82	103.9	105.04	106.4	107.78	109.24
Sample		10Q-G-147C	10R-G-7A			10R-G-27A	10R-G-27B	10R-G-34A	10R-G-34B	10R-G-34C	10R-G-34D	10R-G-34E
Al_2O_3	5.98	5.52	5.60	5.56	-7.06	5.93	5.85	5.75	5.70	5.62	5.60	5.64
B_2O_3*	9.80	10.98	10.98	10.83	10.46	10.77$	10.78	10.80	10.80	10.81	10.81	10.82
CaO	2.46	2.47	2.42	2.54	3.07	2.46	2.46	2.57	2.48	2.51	2.63	2.52
Cl	0.09	0.11	0.10	0.13	NC	0.02	0.05	0.09	0.09	0.10	0.10	0.12
Cr_2O_3	0.08	0.21	0.22	0.22	NC	0.32	0.25	0.26	0.25	0.24	0.25	0.22
F	0.07	0.03	NA	NA	NC	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.39	5.34	5.19	5.37	-0.40	5.28	5.21	5.65	5.32	5.51	5.71	5.33
I	0.10	0.036	0.031	0.032	NC	0.006	0.015	0.025	0.021	0.023	0.026	0.025
K_2O	0.54	0.63	0.60	0.64	NC	0.59	0.61	0.63	0.61	0.63	0.64	0.62
Li_2O*	§	<0.01	<0.01	0.08	NC	0.06$	0.05	0.04	0.04	0.03	0.03	0.02
MgO	1.45	1.17	1.34	1.25	-14.13	1.20	1.22	1.11	1.26	1.22	1.12	1.16
Na_2O	21.14	21.55	21.82	21.30	0.77	21.30	21.31	20.99	21.93	21.60	20.63	21.32
NiO	0.01	0.02	0.02	0.02	NC	0.02	0.02	0.02	0.02	0.02	0.02	0.02
P_2O_5	0.12	0.16	0.17	0.16	NC	0.17	0.17	0.17	0.16	0.17	0.17	0.16
PbO	0.01	<0.01	<0.01	<0.01	NC	<0.01	0.01	0.01	<0.01	<0.01	0.01	<0.01
ReO_2	0.10	0.072	0.066	0.072	NC	0.017	0.039	0.050	0.052	0.056	0.058	0.061
SiO_2	44.56	43.69	43.60	43.88	-1.52	44.12	44.32	43.43	43.38	43.28	43.62	44.10
SO_3	0.35	0.40	0.40	0.42	NC	0.39	0.41	0.41	0.42	0.43	0.42	0.44
TiO_2	1.37	1.46	1.45	1.41	2.96	1.43	1.41	1.49	1.42	1.45	1.51	1.44
ZnO	3.44	3.42	3.30	3.35	-2.57	3.26	3.25	3.61	3.37	3.52	3.69	3.37
ZrO_2	2.94	2.74	2.70	2.73	-7.26	2.67	2.56	2.89	2.67	2.77	2.94	2.61
Sum	100.00	100.00	100.00	100.00	NC	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and feed sample using a simple well stirred tank model.
$ - DCP-AES results
§ - Not a target constituent
NA – Not analyzed
- Analyzed by XRF

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	2									
Mass (kg)		111.56	112.78	114.24	117.02	119.30	121.50	122.68	124.02	125.80	127.40
Sample		10R-G-40A	10R-G-40B	10R-G-40C	10R-G-41A	10R-G-41B	10R-G-43A	10R-G-43B	10R-G-44A	10R-G-44B	10R-G-44C
Al_2O_3	5.98	5.61	5.50	5.59	5.49	5.59	5.52	5.56	5.54	5.61	5.57
B_2O_3*	9.80	10.83	10.83	10.83	10.84	10.84	10.84	10.84	10.84	10.84	10.84
CaO	2.46	2.47	2.50	2.51	2.55	2.53	2.59	2.59	2.56	2.50	2.51
Cl	0.09	0.12	0.13	0.12	0.11	0.12	0.13	0.14	0.15	0.15	0.15
Cr_2O_3	0.08	0.22	0.23	0.22	0.22	0.22	0.23	0.23	0.22	0.21	0.21
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.39	5.25	5.39	5.40	5.49	5.39	5.53	5.53	5.48	5.35	5.40
I	0.10	0.025	0.026	0.026	0.024	0.022	0.027	0.034	0.035	0.040	0.036
K_2O	0.54	0.63	0.64	0.63	0.63	0.63	0.64	0.65	0.65	0.62	0.62
Li_2O*	§	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	<0.01	<0.01
MgO	1.45	1.21	1.13	1.23	1.24	1.13	1.13	1.11	1.10	1.14	1.14
Na_2O	21.14	21.95	21.84	21.37	21.34	22.04	21.20	21.29	21.80	22.13	21.76
NiO	0.01	0.02	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.02
P_2O_5	0.12	0.16	0.17	0.17	0.16	0.16	0.17	0.17	0.18	0.19	0.17
PbO	0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01
ReO_2	0.10	0.062	0.064	0.067	0.063	0.068	0.072	0.075	0.082	0.084	0.085
SiO_2	44.56	43.58	43.50	43.82	43.53	43.23	43.57	43.45	43.15	43.17	43.45
SO_3	0.35	0.42	0.42	0.43	0.42	0.42	0.42	0.43	0.43	0.43	0.44
TiO_2	1.37	1.42	1.45	1.44	1.49	1.44	1.50	1.46	1.45	1.40	1.41
ZnO	3.44	3.34	3.45	3.42	3.55	3.45	3.59	3.59	3.54	3.43	3.48
ZrO_2	2.94	2.65	2.70	2.68	2.81	2.69	2.80	2.82	2.77	2.69	2.69
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and feed sample using a simple well stirred tank model.
$ - DCP-AES results
§ - Not a target constituent
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	2									
Mass (kg)		129.02	130.38	131.54	132.74	133.98	135.66	138.32	139.80	142.06	143.48
Sample		10R-G-46A	10R-G-46B	10R-G-46C	10R-G-46D	10R-G-46E	10R-G-46F	10R-G-48A	10R-G-48B	10R-G-48C	10R-G-55A
Al_2O_3	5.98	5.55	5.58	5.58	5.54	5.43	5.53	5.45	5.45	5.43	5.55
B_2O_3*	9.80	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85
CaO	2.46	2.49	2.55	2.48	2.51	2.62	2.62	2.53	2.57	2.60	2.59
Cl	0.09	0.15	0.15	0.15	0.15	0.15	0.17	0.15	0.15	0.16	0.15
Cr_2O_3	0.08	0.20	0.22	0.21	0.21	0.22	0.24	0.20	0.20	0.20	0.20
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.39	5.36	5.47	5.24	5.30	5.63	5.58	5.31	5.49	5.53	5.44
I	0.10	0.043	0.035	0.033	0.040	0.041	0.036	0.044	0.045	0.040	0.042
K_2O	0.54	0.64	0.63	0.62	0.63	0.65	0.65	0.61	0.63	0.64	0.63
Li_2O*	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MgO	1.45	1.09	1.07	1.15	1.12	1.21	1.27	1.29	1.32	1.31	1.32
Na_2O	21.14	22.11	21.61	21.79	22.09	21.47	21.18	21.96	22.06	21.69	21.63
NiO	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.02
P_2O_5	0.12	0.16	0.18	0.16	0.17	0.16	0.17	0.17	0.16	0.17	0.17
PbO	0.01	<0.01	<0.01	<0.01	0.01	0.01	<0.01	0.01	0.01	<0.01	<0.01
ReO_2	0.10	0.085	0.085	0.085	0.087	0.092	0.091	0.095	0.093	0.093	0.089
SiO_2	44.56	43.23	43.35	43.81	43.32	43.06	43.42	43.37	42.79	43.08	43.19
SO_3	0.35	0.42	0.44	0.43	0.44	0.43	0.44	0.43	0.42	0.42	0.42
TiO_2	1.37	1.41	1.45	1.42	1.42	1.49	1.46	1.44	1.47	1.48	1.47
ZnO	3.44	3.45	3.53	3.33	3.40	3.63	3.49	3.39	3.50	3.51	3.45
ZrO_2	2.94	2.72	2.78	2.63	2.70	2.83	2.77	2.68	2.77	2.78	2.77
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and feed sample using a simple well stirred tank model.
$ - DCP-AES results
§ - Not a target constituent
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	2									
Mass (kg)		144.84	146.52	147.70	149.18	151.12	152.76	154.64	156.34	158.02	159.64
Sample		10R-G-55B	10R-G-57A	10R-G-57B	10R-G-57C	10R-G-58A	10R-G-58B	10R-G-58C	10R-G-64A	10R-G-64B	10R-G-66A
Al_2O_3	5.98	5.46	5.46	5.47	5.49	5.46	5.50	5.42	5.48	5.50	5.48
B_2O_3*	9.80	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85
CaO	2.46	2.60	2.67	2.60	2.58	2.64	2.57	2.63	2.65	2.67	2.60
Cl	0.09	0.15	0.15	0.15	0.15	0.14	0.16	0.16	0.16	0.16	0.16
Cr_2O_3	0.08	0.21	0.20	0.20	0.20	0.20	0.20	0.20	0.21	0.21	0.19
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.39	5.47	5.61	5.44	5.40	5.47	5.30	5.55	5.58	5.59	5.40
I	0.10	0.043	0.046	0.044	0.042	0.047	0.044	0.047	0.045	0.049	0.046
K_2O	0.54	0.64	0.65	0.64	0.63	0.63	0.62	0.65	0.64	0.64	0.64
Li_2O*	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MgO	1.45	1.39	1.38	1.22	1.30	1.35	1.30	1.26	1.32	1.33	1.45
Na_2O	21.14	21.47	20.85	21.43	22.03	21.43	22.14	21.38	21.16	21.23	21.81
NiO	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
P_2O_5	0.12	0.17	0.17	0.18	0.18	0.16	0.17	0.16	0.16	0.17	0.17
PbO	0.01	<0.01	0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
ReO_2	0.10	0.089	0.090	0.092	0.096	0.099	0.102	0.101	0.105	0.107	0.103
SiO_2	44.56	43.26	43.42	43.55	43.06	43.32	43.20	43.25	43.28	43.12	43.00
SO_3	0.35	0.43	0.43	0.44	0.42	0.43	0.43	0.44	0.43	0.42	0.42
TiO_2	1.37	1.47	1.52	1.44	1.46	1.45	1.43	1.48	1.48	1.51	1.47
ZnO	3.44	3.47	3.58	3.45	3.41	3.48	3.33	3.55	3.55	3.54	3.40
ZrO_2	2.94	2.79	2.90	2.77	2.66	2.79	2.65	2.84	2.86	2.88	2.78
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and feed sample using a simple well stirred tank model.
$ - DCP-AES results
§ - Not a target constituent
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	2									
Mass (kg)		160.86	163.30	165.04	167.66	169.42	171.30	174.10	176.56	Avg.	% Dev.
Sample		10R-G-67A	10R-G-68A	10R-G-68B	10R-G-68C	10R-G-68D	10R-G-75A	10R-G-76A	10R-G-76B		
Al_2O_3	5.98	5.39	5.47	5.46	5.42	5.42	5.48	5.48	5.39	5.54	-7.41
B_2O_3*	9.80	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.85	10.84	10.55
CaO	2.46	2.63	2.65	2.68	2.63	2.70	2.67	2.59	2.65	2.58	4.70
Cl	0.09	0.17	0.16	0.17	0.16	0.16	0.15	0.15	0.15	0.14	NC
Cr_2O_3	0.08	0.21	0.21	0.22	0.21	0.20	0.21	0.19	0.20	0.22	NC
F	0.07	NA	NA	NA	NA	NA	NA	NA	0.04#	NA	NC
Fe_2O_3	5.39	5.50	5.55	5.63	5.48	5.66	5.61	5.35	5.56	5.46	1.40
I	0.10	0.052	0.055	0.045	0.050	0.044	0.042	0.038	0.041	0.036	NC
K_2O	0.54	0.63	0.64	0.65	0.63	0.65	0.64	0.62	0.64	0.63	NC
Li_2O*	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.01	NC
MgO	1.45	1.46	1.36	1.45	1.43	1.44	1.39	1.44	1.50	1.26	-13.27
Na_2O	21.14	21.21	21.19	20.91	21.56	21.24	21.44	22.09	21.69	21.55	1.93
NiO	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	NC
P_2O_5	0.12	0.16	0.16	0.17	0.17	0.16	0.16	0.16	0.16	0.17	NC
PbO	0.01	0.01	0.01	0.01	0.01	0.01	<0.01	0.01	0.01	<0.01	NC
ReO_2	0.10	0.111	0.113	0.108	0.108	0.103	0.102	0.097	0.099	0.084	NC
SiO_2	44.56	43.30	43.22	43.20	43.03	42.91	42.95	42.89	42.74	43.33	-2.75
SO_3	0.35	0.41	0.43	0.43	0.41	0.42	0.41	0.42	0.41	0.43	NC
TiO_2	1.37	1.52	1.53	1.55	1.51	1.53	1.50	1.46	1.51	1.47	6.94
ZnO	3.44	3.45	3.47	3.54	3.43	3.59	3.53	3.37	3.47	3.47	1.12
ZrO_2	2.94	2.91	2.91	2.90	2.88	2.89	2.84	2.76	2.86	2.77	-5.83
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	NC

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and feed sample using a simple well stirred tank model.
$ - DCP-AES results
§ - Not a target constituent
NA – Not analyzed
- Analyzed by XRF

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	3									
Mass (kg)		178.98	180.84	182.14	183.34	185.52	187.44	189.76	191.26	193.18	194.92
Sample		10R-G-120A	10R-G-127A	10R-G-127B	10R-G-127C	10R-G-127D	10R-G-127E	10R-G-128A	10R-G-128B	10R-G-128C	10R-G-128D
Al_2O_3	6.00	5.83	5.72	5.74	5.78	5.69	5.77	5.75	5.79	5.73	5.72
B_2O_3*	9.83	10.27$	10.19	10.15	10.11	10.06	10.02	9.98	9.96	9.93	9.92
CaO	3.62	2.76	3.04	3.19	3.27	3.41	3.48	3.51	3.56	3.63	3.59
Cl	0.09	0.03	0.07	0.09	0.10	0.11	0.11	0.12	0.13	0.13	0.13
Cr_2O_3	0.08	0.34	0.29	0.26	0.24	0.24	0.23	0.23	0.23	0.21	0.21
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.41	5.49	5.58	5.44	5.40	5.52	5.65	5.61	5.56	5.63	5.58
I	0.10	<0.005	0.012	0.014	0.014	0.014	0.021	0.022	0.016	0.019	0.021
K_2O	0.54	0.61	0.66	0.71	0.72	0.75	0.77	0.78	0.77	0.79	0.78
Li_2O*	0.49	0.11$	0.17	0.21	0.24	0.29	0.33	0.36	0.38	0.40	0.41
MgO	1.45	1.26	1.20	1.23	1.20	1.23	1.26	1.33	1.30	1.35	1.45
Na_2O	18.84	21.21	20.36	20.76	20.55	20.00	19.35	19.74	19.43	19.13	19.83
NiO	0.01	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
P_2O_5	0.12	0.16	0.17	0.17	0.17	0.18	0.17	0.16	0.18	0.17	0.16
PbO	0.01	<0.01	0.01	0.01	0.01	0.01	<0.01	0.01	<0.01	0.01	0.01
ReO_2	0.10	0.016	0.032	0.039	0.045	0.049	0.051	0.049	0.054	0.054	0.057
SiO_2	45.11	43.88	44.32	44.02	44.20	44.30	44.33	44.00	44.35	44.40	43.78
SO_3	0.39	0.40	0.40	0.41	0.41	0.43	0.42	0.42	0.44	0.44	0.42
TiO_2	1.37	1.49	1.51	1.50	1.52	1.54	1.60	1.59	1.60	1.61	1.61
ZnO	3.44	3.37	3.44	3.35	3.33	3.43	3.56	3.53	3.46	3.50	3.48
ZrO_2	2.94	2.74	2.79	2.67	2.65	2.72	2.85	2.80	2.78	2.84	2.81
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
$ - DCP-AES results
§ - Not a target constituent
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	3									
Mass (kg)		196.60	198.88	200.50	201.88	203.52	205.56	207.14	208.72	210.24	211.76
Sample		10R-G-133A	10R-G-133B	10R-G-133C	10R-G-133D	10R-G-136A	10R-G-136B	10R-G-136C	10R-G-136D	10R-G-136E	10R-G-136F
Al_2O_3	6.00	5.75	5.87	5.68	5.71	5.71	5.71	5.71	5.69	5.70	5.77
B_2O_3*	9.83	9.90	9.89	9.88	9.87	9.86	9.86	9.85	9.85	9.84	9.84
CaO	3.62	3.68	3.39	3.79	3.82	3.78	3.83	3.80	3.86	3.75	3.66
Cl	0.09	0.13	0.14	0.14	0.15	0.15	0.16	0.17	0.16	0.17	0.17
Cr_2O_3	0.08	0.21	0.19	0.22	0.22	0.21	0.21	0.20	0.21	0.20	0.20
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.41	5.59	5.05	5.73	5.75	5.68	5.74	5.72	5.80	5.63	5.36
I	0.10	0.013	0.018	0.023	0.023	0.029	0.026	0.025	0.026	0.023	0.020
K_2O	0.54	0.79	0.76	0.83	0.82	0.82	0.83	0.85	0.84	0.83	0.81
Li_2O*	0.49	0.43	0.44	0.45	0.45	0.46	0.46	0.47	0.47	0.47	0.48
MgO	1.45	1.40	1.48	1.42	1.39	1.45	1.47	1.40	1.40	1.43	1.37
Na_2O	18.84	19.38	20.45	18.91	18.93	19.08	18.52	18.67	18.52	19.09	19.87
NiO	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
P_2O_5	0.12	0.18	0.18	0.17	0.17	0.18	0.18	0.18	0.18	0.17	0.17
PbO	0.01	0.01	<0.01	<0.01	<0.01	0.01	0.01	<0.01	0.01	0.01	<0.01
ReO_2	0.10	0.057	0.061	0.062	0.065	0.064	0.067	0.070	0.070	0.070	0.071
SiO_2	45.11	44.17	44.61	44.09	44.00	43.97	44.26	44.36	44.27	44.26	44.33
SO_3	0.39	0.45	0.43	0.44	0.42	0.45	0.46	0.47	0.46	0.46	0.45
TiO_2	1.37	1.62	1.49	1.66	1.69	1.65	1.68	1.66	1.66	1.62	1.56
ZnO	3.44	3.48	3.08	3.56	3.57	3.52	3.58	3.55	3.60	3.49	3.29
ZrO_2	2.94	2.74	2.44	2.94	2.94	2.91	2.93	2.84	2.90	2.76	2.57
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	3									
Mass (kg)		214.18	215.88	218.32	220.14	222.46	224.44	226.08	227.92	229.64	231.34
Sample		10R-G-137A	10R-G-137B	10R-G-137C	10R-G-143A	10R-G-143B	10R-G-143C	10R-G-144A	10R-G-144B	10R-G-144C	10R-G-145A
Al_2O_3	6.00	5.76	5.69	5.79	5.75	5.79	5.78	5.74	5.79	5.77	5.72
B_2O_3*	9.83	9.84	9.84	9.83	9.83	9.83	9.83	9.83	9.83	9.83	9.83
CaO	3.62	3.75	3.84	3.77	3.80	3.67	3.69	3.79	3.74	3.69	3.80
Cl	0.09	0.17	0.17	0.17	0.17	0.16	0.18	0.17	0.17	0.18	0.18
Cr_2O_3	0.08	0.20	0.20	0.19	0.19	0.19	0.20	0.20	0.20	0.19	0.21
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.41	5.61	5.74	5.51	5.61	5.41	5.37	5.60	5.47	5.42	5.63
I	0.10	0.023	0.028	0.018	0.022	0.023	0.022	0.024	0.022	0.029	0.028
K_2O	0.54	0.84	0.85	0.82	0.84	0.83	0.82	0.84	0.84	0.81	0.84
Li_2O*	0.49	0.48	0.48	0.48	0.48	0.49	0.49	0.49	0.49	0.49	0.49
MgO	1.45	1.40	1.27	1.37	1.34	1.42	1.39	1.36	1.42	1.34	1.40
Na_2O	18.84	19.07	18.64	18.99	18.86	19.57	19.64	19.02	19.05	19.73	19.18
NiO	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
P_2O_5	0.12	0.18	0.17	0.18	0.17	0.17	0.18	0.18	0.18	0.17	0.18
PbO	0.01	0.01	<0.01	<0.01	0.01	0.01	0.01	0.01	<0.01	<0.01	0.01
ReO_2	0.10	0.072	0.071	0.071	0.073	0.075	0.075	0.074	0.077	0.077	0.080
SiO_2	45.11	44.28	44.47	44.60	44.43	44.31	44.36	44.25	44.54	44.19	43.97
SO_3	0.39	0.48	0.47	0.45	0.47	0.47	0.46	0.46	0.47	0.46	0.46
TiO_2	1.37	1.61	1.64	1.61	1.65	1.59	1.58	1.65	1.61	1.59	1.65
ZnO	3.44	3.49	3.56	3.42	3.46	3.32	3.27	3.46	3.36	3.32	3.50
ZrO_2	2.94	2.71	2.84	2.69	2.80	2.65	2.64	2.82	2.71	2.70	2.83
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	3									
Mass (kg)		233.44	235.10	236.96	239.94	242.14	244.22	246.46	249.12	251.14	253.34
Sample		10R-G-145B	10R-G-145C	10R-G-145D	10R-G-147A	10R-G-147B	10R-G-148A	10R-G-148B	10R-G-148C	10R-G-150A	10R-G-150B
Al_2O_3	6.00	5.71	5.77	5.83	5.74	5.81	5.81	5.70	5.72	5.72	5.69
B_2O_3*	9.83	9.83	9.83	9.83	9.83	9.83	9.83	9.83	9.83	9.83	9.83
CaO	3.62	3.89	3.75	3.73	3.76	3.57	3.77	3.76	3.82	3.75	3.88
Cl	0.09	0.18	0.19	0.19	0.19	0.18	0.18	0.18	0.19	0.18	0.19
Cr_2O_3	0.08	0.21	0.20	0.20	0.19	0.18	0.19	0.19	0.20	0.19	0.20
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.41	5.76	5.58	5.52	5.50	5.23	5.55	5.56	5.66	5.52	5.73
I	0.10	0.024	0.023	0.024	0.025	0.024	0.018	0.021	0.025	0.027	0.024
K_2O	0.54	0.85	0.83	0.84	0.83	0.81	0.82	0.83	0.85	0.83	0.85
Li_2O*	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49
MgO	1.45	1.35	1.47	1.47	1.43	1.46	1.36	1.39	1.35	1.34	1.35
Na_2O	18.84	18.47	19.10	19.52	19.33	20.33	19.29	19.44	18.75	19.31	18.91
NiO	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
P_2O_5	0.12	0.18	0.18	0.17	0.17	0.18	0.18	0.18	0.18	0.17	0.17
PbO	0.01	0.01	<0.01	<0.01	0.01	0.01	0.01	0.01	<0.01	0.01	0.01
ReO_2	0.10	0.082	0.084	0.087	0.092	0.092	0.088	0.088	0.090	0.091	0.089
SiO_2	45.11	44.31	44.15	43.86	44.24	44.10	44.23	44.11	44.44	44.35	44.00
SO_3	0.39	0.47	0.45	0.47	0.47	0.47	0.48	0.46	0.47	0.47	0.46
TiO_2	1.37	1.70	1.64	1.62	1.63	1.55	1.62	1.62	1.64	1.60	1.66
ZnO	3.44	3.56	3.45	3.39	3.37	3.16	3.41	3.40	3.49	3.39	3.56
ZrO_2	2.94	2.91	2.80	2.75	2.70	2.51	2.64	2.71	2.80	2.71	2.89
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	3											
Mass (kg)		255.46	258.10	259.96	263.00	264.40	265.96	268.02	270.56	272.42	273.42	Avg.	% Dev.
Sample		10R-G-150C	10R-G-150D	10S-G-12A	10S-G-12B	10S-G-17A	10S-G-17B	10S-G-17C	10S-G-17D	10S-G-18A	10S-G-19A		
Al_2O_3	6.00	5.70	5.72	5.80	5.78	5.76	5.81	5.81	5.78	5.93	5.83	5.76	-4.02
B_2O_3*	9.83	9.83	9.83	9.83	9.83	9.83	9.83	9.83	9.83	9.83	9.83	9.83	NC
CaO	3.62	3.92	3.83	3.64	3.87	3.76	3.74	3.71	3.78	3.65	3.68	3.76	4.05
Cl	0.09	0.19	0.19	0.19	0.18	0.18	0.18	0.18	0.19	0.18	0.18	0.18	NC
Cr_2O_3	0.08	0.21	0.21	0.19	0.20	0.20	0.20	0.20	0.20	0.18	0.21	0.20	NC
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	0.05#	NA	NA	NC
Fe_2O_3	5.41	5.81	5.66	5.35	5.79	5.57	5.53	5.52	5.57	5.29	5.47	5.56	2.80
I	0.10	0.020	0.025	0.021	0.021	0.025	0.019	0.025	0.026	0.023	0.019	0.023	NC
K_2O	0.54	0.86	0.84	0.82	0.86	0.82	0.81	0.82	0.84	0.81	0.83	0.83	NC
Li_2O*	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	NC
MgO	1.45	1.36	1.38	1.56	1.41	1.47	1.44	1.50	1.54	1.54	1.56	1.42	-2.44
Na_2O	18.84	18.13	18.37	19.21	18.15	19.19	18.72	19.56	18.34	19.06	19.05	19.05	1.12
NiO	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	NC
P_2O_5	0.12	0.18	0.18	0.18	0.18	0.17	0.17	0.18	0.18	0.19	0.18	0.18	NC
PbO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	<0.01	0.01	0.01	NC
ReO_2	0.10	0.091	0.087	0.090	0.085	0.092	0.087	0.090	0.092	0.090	0.081	0.082	NC
SiO_2	45.11	44.51	44.73	44.69	44.39	44.09	44.69	43.75	44.78	44.78	44.42	44.33	-1.74
SO_3	0.39	0.47	0.47	0.46	0.46	0.45	0.46	0.46	0.48	0.47	0.47	0.47	NC
TiO_2	1.37	1.69	1.64	1.61	1.71	1.68	1.66	1.66	1.67	1.61	1.65	1.64	19.32
ZnO	3.44	3.61	3.53	3.27	3.63	3.42	3.37	3.41	3.40	3.22	3.32	3.43	-0.12
ZrO_2	2.94	2.90	2.80	2.58	2.93	2.78	2.77	2.79	2.78	2.59	2.71	2.76	-6.31
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	NC

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
# - Analyzed by XRF
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	4									
Mass (kg)		276.88	279.20	281.26	282.64	285.38	288.08	290.52	293.64	294.64	296.86
Sample		10S-G-42A	10S-G-42B	10S-G-43A	10S-G-43B	10S-G-43C	10S-G-43D	10S-G-44A	10S-G-44B	10S-G-44C	10S-G-49A
Al_2O_3	6.10	5.90	5.92	5.84	5.71	5.72	5.61	5.63	5.57	5.50	5.54
B_2O_3*	10.00	9.65[$]	9.72	9.77	9.80	9.85	9.89	9.91	9.93	9.94	9.95
CaO	6.99	4.40	4.87	5.25	6.03	6.01	6.31	6.35	6.66	6.85	6.82
Cl	0.09	0.05	0.06	0.07	0.08	0.08	0.09	0.10	0.09	0.10	0.11
Cr_2O_3	0.08	0.25	0.22	0.21	0.21	0.20	0.19	0.18	0.19	0.19	0.18
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.51	5.67	5.43	5.28	5.66	5.53	5.53	5.40	5.72	5.79	5.71
I	0.10	0.006	0.010	0.010	0.013	<0.005	0.015	0.019	0.025	0.024	0.023
K_2O	0.54	0.80	0.78	0.77	0.81	0.78	0.79	0.78	0.79	0.79	0.78
Li_2O*	4.28	1.44[#]	2.03	2.45	2.68	3.07	3.35	3.55	3.75	3.80	3.89
MgO	2.95	1.79	2.14	2.33	2.53	2.61	2.80	2.85	2.77	2.89	3.04
Na_2O	5.45	16.24	14.39	13.17	10.22	10.15	9.01	8.69	7.80	7.57	7.39
NiO	0.01	0.02	0.02	0.02	0.02	0.03	0.02	0.03	0.03	0.03	0.03
P_2O_5	0.12	0.18	0.18	0.19	0.18	0.18	0.18	0.17	0.18	0.18	0.18
PbO	0.01	0.01	0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.01	<0.01	<0.01
ReO_2	0.10	0.027	0.040	0.050	0.052	0.057	0.064	0.068	0.069	0.071	0.071
SiO_2	49.15	45.11	46.12	46.66	47.48	47.49	47.83	48.10	47.75	47.47	47.65
SO_3	0.56	0.49	0.54	0.57	0.61	0.61	0.63	0.65	0.65	0.66	0.64
TiO_2	1.40	1.65	1.56	1.51	1.59	1.55	1.53	1.51	1.56	1.57	1.55
ZnO	3.50	3.43	3.26	3.19	3.46	3.33	3.38	3.31	3.55	3.60	3.54
ZrO_2	3.00	2.90	2.71	2.66	2.84	2.77	2.78	2.71	2.90	2.97	2.90
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
$ - DCP-AES results
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	4									
Mass (kg)		298.30	299.62	302.56	304.24	305.82	307.02	307.90	309.66	312.16	314.54
Sample		10S-G-49B	10S-G-49C	10S-G-49D	10S-G-51A	10S-G-51B	10S-G-51C	10S-G-51D	10S-G-53A	10S-G-53B	10S-G-53C
Al_2O_3	6.10	5.52	5.51	5.50	5.52	5.53	5.48	5.51	5.48	5.52	5.51
B_2O_3*	10.00	9.96	9.96	9.97	9.98	9.98	9.98	9.98	9.99	9.99	9.99
CaO	6.99	7.02	7.08	7.05	7.05	7.07	7.11	7.11	7.31	7.18	7.18
Cl	0.09	0.11	0.12	0.12	0.12	0.12	0.12	0.13	0.14	0.12	0.12
Cr_2O_3	0.08	0.19	0.19	0.18	0.18	0.17	0.17	0.17	0.18	0.16	0.17
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.51	5.79	5.80	5.72	5.70	5.69	5.73	5.71	5.92	5.80	5.83
I	0.10	0.024	0.021	0.032	0.046	0.062	0.066	0.079	0.085	0.072	0.069
K_2O	0.54	0.79	0.81	0.80	0.76	0.74	0.74	0.71	0.72	0.70	0.69
Li_2O*	4.28	3.95	3.99	4.06	4.10	4.12	4.14	4.15	4.17	4.20	4.21
MgO	2.95	2.97	2.90	2.94	3.12	3.03	3.04	3.10	3.05	3.01	3.07
Na_2O	5.45	6.82	6.38	6.68	6.42	6.47	6.38	6.39	5.64	5.99	5.98
NiO	0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
P_2O_5	0.12	0.17	0.18	0.18	0.18	0.18	0.17	0.18	0.16	0.17	0.18
PbO	0.01	<0.01	0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01
ReO_2	0.10	0.072	0.073	0.075	0.077	0.077	0.079	0.080	0.085	0.082	0.080
SiO_2	49.15	47.86	48.14	48.02	48.13	48.16	48.11	48.11	48.10	48.29	48.17
SO_3	0.56	0.66	0.68	0.68	0.64	0.63	0.63	0.61	0.65	0.61	0.59
TiO_2	1.40	1.57	1.58	1.56	1.54	1.53	1.55	1.53	1.59	1.55	1.56
ZnO	3.50	3.58	3.57	3.50	3.50	3.50	3.57	3.53	3.72	3.62	3.63
ZrO_2	3.00	2.94	2.99	2.89	2.91	2.90	2.91	2.90	3.00	2.92	2.93
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	4									
Mass (kg)		316.66	318.30	319.94	321.76	323.52	326.74	329.66	332.14	335.34	338.30
Sample		10S-G-58A	10S-G-58B	10S-G-58C	10S-G-60A	10S-G-60B	10S-G-60C	10S-G-60D	10S-G-61A	10S-G-61B	10S-G-62A
Al_2O_3	6.10	5.51	5.48	5.46	5.51	5.48	5.42	5.51	5.51	5.50	5.46
B_2O_3*	10.00	9.99	9.99	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
CaO	6.99	7.22	7.20	7.23	7.26	7.25	7.33	7.30	7.35	7.29	7.42
Cl	0.09	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
Cr_2O_3	0.08	0.16	0.16	0.17	0.16	0.16	0.17	0.16	0.16	0.15	0.16
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.51	5.81	5.74	5.82	5.82	5.81	5.89	5.86	5.88	5.85	5.99
I	0.10	0.073	0.075	0.077	0.067	0.064	0.068	0.075	0.072	0.069	0.067
K_2O	0.54	0.69	0.68	0.68	0.69	0.68	0.68	0.68	0.67	0.65	0.66
Li_2O*	4.28	4.23	4.23	4.24	4.25	4.25	4.26	4.27	4.27	4.27	4.27
MgO	2.95	3.10	3.18	3.14	3.09	3.18	3.18	3.19	3.08	3.14	3.05
Na_2O	5.45	5.87	5.69	5.68	5.23	5.84	5.48	5.52	5.47	5.48	5.29
NiO	0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
P_2O_5	0.12	0.18	0.17	0.18	0.17	0.18	0.17	0.17	0.18	0.17	0.17
PbO	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01	0.01	0.01
ReO_2	0.10	0.077	0.077	0.078	0.078	0.078	0.078	0.076	0.078	0.080	0.075
SiO_2	49.15	48.27	48.47	48.35	48.79	48.42	48.35	48.32	48.41	48.52	48.35
SO_3	0.56	0.60	0.58	0.56	0.56	0.56	0.57	0.57	0.56	0.54	0.56
TiO_2	1.40	1.55	1.55	1.57	1.56	1.57	1.58	1.57	1.59	1.57	1.60
ZnO	3.50	3.62	3.65	3.68	3.69	3.58	3.72	3.67	3.69	3.64	3.74
ZrO_2	3.00	2.92	2.92	2.94	2.93	2.74	2.91	2.91	2.90	2.92	2.98
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	4									
Mass (kg)		340.80	342.88	344.84	346.76	348.84	350.88	352.80	354.64	357.02	359.30
Sample		10S-G-62B	10S-G-62C	10S-G-62D	10S-G-68A	10S-G-68B	10S-G-68C	10S-G-70A	10S-G-70B	10S-G-70C	10S-G-70D
Al_2O_3	6.10	5.59	5.54	5.49	5.59	5.47	5.53	5.51	5.46	5.49	5.48
B_2O_3*	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
CaO	6.99	7.24	7.24	7.32	7.20	7.33	7.15	7.37	7.28	7.22	7.28
Cl	0.09	0.12	0.12	0.13	0.12	0.12	0.12	0.12	0.12	0.11	0.12
Cr_2O_3	0.08	0.15	0.15	0.16	0.16	0.16	0.15	0.15	0.15	0.15	0.15
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.51	5.69	5.73	5.84	5.67	5.83	5.61	5.86	5.78	5.77	5.82
I	0.10	0.059	0.065	0.076	0.071	0.071	0.077	0.067	0.078	0.076	0.076
K_2O	0.54	0.65	0.65	0.65	0.64	0.64	0.64	0.65	0.65	0.63	0.66
Li_2O*	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28
MgO	2.95	3.21	3.21	3.08	3.20	3.13	3.24	3.16	3.17	3.24	3.19
Na_2O	5.45	5.80	5.52	5.56	5.71	5.52	5.71	5.51	5.64	5.78	5.62
NiO	0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
P_2O_5	0.12	0.17	0.18	0.17	0.17	0.18	0.18	0.18	0.19	0.18	0.18
PbO	0.01	<0.01	<0.01	0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01	<0.01
ReO_2	0.10	0.072	0.072	0.076	0.079	0.081	0.080	0.080	0.082	0.080	0.079
SiO_2	49.15	48.62	48.75	48.50	48.77	48.45	48.92	48.43	48.52	48.42	48.40
SO_3	0.56	0.54	0.53	0.52	0.55	0.55	0.56	0.54	0.56	0.56	0.55
TiO_2	1.40	1.51	1.54	1.56	1.51	1.59	1.52	1.58	1.55	1.55	1.55
ZnO	3.50	3.52	3.53	3.60	3.47	3.65	3.47	3.64	3.62	3.61	3.67
ZrO_2	3.00	2.75	2.85	2.94	2.77	2.92	2.73	2.83	2.82	2.83	2.87
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	4									
Mass (kg)		361.68	364.14	366.78	369.38	371.96	373.26	375.56	378.54	381.16	384.02
Sample		10S-G-71A	10S-G-71B	10S-G-71C	10S-G-76A	10S-G-76B	10S-G-76C	10S-G-79A	10S-G-79B	10S-G-80A	10S-G-80B
Al_2O_3	6.10	5.49	5.50	5.50	5.50	5.47	5.44	5.47	5.52	5.53	5.50
B_2O_3*	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
CaO	6.99	7.31	7.22	7.29	7.30	7.42	7.43	7.42	7.24	7.17	7.33
Cl	0.09	0.12	0.11	0.12	0.12	0.11	0.12	0.11	0.11	0.12	0.12
Cr_2O_3	0.08	0.15	0.15	0.15	0.16	0.16	0.16	0.16	0.15	0.15	0.15
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.51	5.89	5.72	5.91	5.85	5.99	6.01	5.93	5.73	5.65	5.80
I	0.10	0.079	0.074	0.078	0.069	0.070	0.076	0.078	0.067	0.052	0.060
K_2O	0.54	0.66	0.64	0.65	0.64	0.65	0.66	0.64	0.62	0.63	0.63
Li_2O*	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28
MgO	2.95	3.08	3.21	3.25	3.12	3.13	3.09	2.97	3.20	3.24	3.08
Na_2O	5.45	5.47	5.67	5.46	5.69	5.31	5.30	5.20	5.67	5.85	5.34
NiO	0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
P_2O_5	0.12	0.17	0.18	0.18	0.17	0.17	0.18	0.17	0.17	0.19	0.18
PbO	0.01	<0.01	0.01	<0.01	<0.01	<0.01	0.01	0.01	0.01	0.01	0.01
ReO_2	0.10	0.078	0.076	0.077	0.076	0.078	0.077	0.081	0.082	0.081	0.076
SiO_2	49.15	48.44	48.60	48.25	48.36	48.18	48.21	48.64	48.70	48.78	48.83
SO_3	0.56	0.55	0.55	0.54	0.53	0.51	0.52	0.56	0.54	0.54	0.54
TiO_2	1.40	1.57	1.54	1.56	1.57	1.60	1.61	1.60	1.55	1.53	1.57
ZnO	3.50	3.70	3.59	3.73	3.66	3.78	3.77	3.68	3.53	3.46	3.56
ZrO_2	3.00	2.92	2.83	2.93	2.87	3.05	3.03	2.97	2.82	2.70	2.92
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	4									
Mass (kg)		386.38	389.18	391.28	394.50	397.66	399.50	402.62	405.17	407.49	409.93
Sample		10S-G-81A	10S-G-81B	10S-G-81C	10S-G-86A	10S-G-86B	10S-G-86C	10S-G-86D	10S-G-86E	10S-G-86F	10S-G-93A
Al_2O_3	6.10	5.46	5.50	5.52	5.44	5.52	5.47	5.49	5.41	5.45	5.44
B_2O_3*	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
CaO	6.99	7.27	7.29	7.32	7.24	7.25	7.44	7.22	7.27	7.36	7.26
Cl	0.09	0.11	0.12	0.11	0.12	0.12	0.12	0.12	0.12	0.12	0.13
Cr_2O_3	0.08	0.16	0.16	0.16	0.15	0.15	0.16	0.15	0.16	0.15	0.15
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.03#
Fe_2O_3	5.51	5.75	5.78	5.81	5.76	5.68	5.94	5.73	5.83	5.81	5.77
I	0.10	0.061	0.073	0.083	0.086	0.075	0.079	0.079	0.078	0.084	0.080
K_2O	0.54	0.63	0.64	0.64	0.63	0.64	0.65	0.62	0.64	0.65	0.65
Li_2O*	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28	4.28
MgO	2.95	3.18	3.19	3.16	3.20	3.30	3.05	3.21	3.23	3.19	3.20
Na_2O	5.45	5.67	5.52	5.35	5.59	5.44	5.18	5.48	5.38	5.34	5.44
NiO	0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
P_2O_5	0.12	0.17	0.17	0.18	0.17	0.17	0.18	0.17	0.17	0.17	0.17
PbO	0.01	<0.01	0.01	0.01	<0.01	<0.01	<0.01	0.01	<0.01	<0.01	<0.01
ReO_2	0.10	0.073	0.077	0.079	0.079	0.081	0.079	0.079	0.080	0.080	0.078
SiO_2	49.15	48.65	48.59	48.61	48.65	48.80	48.51	48.76	48.65	48.60	48.69
SO_3	0.56	0.51	0.52	0.54	0.53	0.55	0.55	0.54	0.54	0.55	0.54
TiO_2	1.40	1.56	1.56	1.57	1.56	1.57	1.60	1.54	1.56	1.57	1.57
ZnO	3.50	3.56	3.59	3.62	3.58	3.54	3.72	3.59	3.63	3.64	3.58
ZrO_2	3.00	2.87	2.91	2.94	2.90	2.78	2.96	2.89	2.92	2.93	2.89
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
# - Analyzed by XRF
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	4				5							
Mass (kg)	Target	412.35	Avg.	% Dev.	Target	415.27	418.57	421.19	423.77	425.97	428.89	430.99
Sample		10S-G-93B				10S-G-102A	10S-G-123A	10S-G-123B	10S-G-124A	10S-G-124B	10S-G-124C	10S-G-124D
Al_2O_3	6.10	5.44	5.49	-9.96	6.02	6.88	6.62	6.46	6.25	6.30	6.25	5.98
B_2O_3*	10.00	10.00	10.00	NC	9.87	9.12$	9.33	9.45	9.55	9.61	9.68	9.71
CaO	6.99	7.39	7.27	3.95	5.47	6.60	6.34	6.26	6.23	6.17	5.99	6.02
Cl	0.09	0.11	0.12	NC	0.09	0.03	0.05	0.05	0.06	0.06	0.06	0.08
Cr_2O_3	0.08	0.15	0.16	NC	0.08	0.16	0.16	0.14	0.16	0.15	0.15	0.16
F	0.07	NA	NA	NC	0.07	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.51	5.88	5.80	5.44	5.43	5.52	5.58	5.62	5.62	5.71	5.73	5.88
I	0.10	0.056	0.072	NC	0.10	<0.003	<0.003	0.013	0.009	0.014	0.018	0.018
K_2O	0.54	0.64	0.66	NC	0.54	0.57	0.63	0.65	0.67	0.62	0.61	0.63
Li_2O*	4.28	4.28	4.26	-0.56	2.38	3.58$	3.24	3.05	2.90	2.79	2.69	2.63
MgO	2.95	3.20	3.15	6.60	1.46	2.58	2.32	2.16	1.98	1.84	1.79	1.77
Na_2O	5.45	5.20	5.62	3.11	15.68	9.01	10.20	11.21	11.67	12.62	12.83	13.10
NiO	0.01	0.03	0.03	NC	0.01	0.04	0.04	0.03	0.03	0.02	0.03	0.03
P_2O_5	0.12	0.18	0.17	NC	0.12	0.19	0.18	0.18	0.18	0.17	0.19	0.17
PbO	0.01	0.01	<0.01	NC	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
ReO_2	0.10	0.077	0.078	NC	0.10	0.019	0.017	0.026	0.036	0.041	0.032	0.038
SiO_2	49.15	48.69	48.48	-1.35	44.33	48.19	47.65	46.90	46.45	45.75	45.66	45.33
SO_3	0.56	0.53	0.56	NC	0.45	0.14	0.20	0.29	0.28	0.36	0.38	0.44
TiO_2	1.40	1.59	1.56	12.01	1.38	1.48	1.47	1.51	1.60	1.56	1.56	1.57
ZnO	3.50	3.61	3.62	3.54	3.46	2.94	3.01	3.08	3.25	3.23	3.34	3.39
ZrO_2	3.00	2.95	2.89	-3.65	2.96	2.92	2.95	2.93	3.06	2.99	3.02	3.06
Sum	100.00	100.00	100.00	NC	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
$ - DCP-AES results
NA – Not analyzed
NC – Not calculated

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	5									
Mass (kg)		433.47	436.41	438.77	441.19	442.77	445.43	446.93	448.85	450.41	452.57
Sample		10S-G-125A	10S-G-125B	10S-G-127A	10S-G-127B	10S-G-129A	10S-G-129B	10S-G-129C	10S-G-130A	10S-G-130B	10S-G-130C
Al_2O_3	6.02	5.98	5.88	5.86	5.95	5.80	5.79	5.77	5.88	5.70	5.75
B_2O_3*	9.87	9.75	9.78	9.80	9.81	9.82	9.83	9.84	9.84	9.84	9.85
CaO	5.47	5.95	5.81	5.61	5.74	5.86	5.79	5.74	5.67	5.71	5.69
Cl	0.09	0.08	0.07	0.08	0.07	0.07	0.07	0.08	0.08	0.08	0.09
Cr_2O_3	0.08	0.15	0.16	0.17	0.19	0.19	0.19	0.18	0.16	0.19	0.23
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.43	5.81	5.74	5.73	5.88	5.82	5.90	5.73	5.78	5.86	5.80
I	0.10	0.010	0.013	0.011	0.013	0.024	0.017	0.021	0.012	0.018	0.029
K_2O	0.54	0.68	0.65	0.61	0.63	0.65	0.65	0.71	0.67	0.63	0.64
Li_2O*	2.38	2.58	2.53	2.50	2.47	2.46	2.44	2.43	2.43	2.42	2.41
MgO	1.46	1.60	1.56	1.57	1.47	1.44	1.43	1.40	1.40	1.39	1.43
Na_2O	15.68	13.61	14.49	14.94	14.23	14.43	14.88	15.12	14.68	15.14	15.17
NiO	0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.03
P_2O_5	0.12	0.19	0.16	0.17	0.16	0.18	0.18	0.18	0.16	0.17	0.16
PbO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
ReO_2	0.10	0.048	0.040	0.040	0.036	0.039	0.035	0.048	0.047	0.071	0.069
SiO_2	44.33	45.08	44.73	44.57	44.70	44.44	44.01	44.03	44.56	43.96	43.95
SO_3	0.45	0.43	0.43	0.44	0.45	0.47	0.50	0.52	0.51	0.54	0.48
TiO_2	1.38	1.60	1.58	1.54	1.62	1.63	1.64	1.59	1.59	1.63	1.61
ZnO	3.46	3.38	3.37	3.35	3.48	3.53	3.51	3.52	3.46	3.55	3.52
ZrO_2	2.96	3.04	2.98	2.99	3.06	3.12	3.10	3.06	3.04	3.09	3.09
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	5									
Mass (kg)		456.75	459.43	462.17	465.07	468.07	470.19	472.81	474.99	476.99	478.83
Sample		10S-G-130D	10S-G-131A	10S-G-131B	10S-G-139A	10S-G-139B	10S-G-146A	10S-G-146B	10S-G-146C	10S-G-147A	10S-G-147B
Al_2O_3	6.02	5.66	5.84	5.74	5.81	5.81	5.80	5.72	5.78	5.73	5.75
B_2O_3*	9.87	9.86	9.86	9.86	9.86	9.86	9.86	9.86	9.87	9.87	9.87
CaO	5.47	5.81	5.75	5.63	5.73	5.61	5.63	5.64	5.56	5.63	5.65
Cl	0.09	0.08	0.08	0.09	0.09	0.10	0.09	0.09	0.09	0.08	0.09
Cr_2O_3	0.08	0.20	0.20	0.21	0.18	0.20	0.19	0.19	0.18	0.18	0.16
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.43	5.93	5.78	5.83	5.84	5.85	5.91	5.86	5.78	5.78	5.76
I	0.10	0.011	0.011	0.031	0.025	0.015	0.014	0.017	0.023	0.016	0.013
K_2O	0.54	0.68	0.64	0.66	0.67	0.64	0.66	0.66	0.64	0.64	0.65
Li_2O*	2.38	2.40	2.40	2.39	2.39	2.39	2.39	2.39	2.39	2.39	2.39
MgO	1.46	1.46	1.46	1.46	1.43	1.40	1.42	1.40	1.38	1.39	1.33
Na_2O	15.68	14.63	14.50	14.86	14.37	15.08	14.31	14.99	15.38	15.24	15.20
NiO	0.01	0.03	0.03	0.03	0.04	0.03	0.01	0.03	0.03	0.03	0.04
P_2O_5	0.12	0.17	0.18	0.15	0.17	0.17	0.18	0.16	0.18	0.17	0.17
PbO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
ReO_2	0.10	0.060	0.062	0.072	0.071	0.060	0.050	0.070	0.058	0.050	0.065
SiO_2	44.33	44.32	44.43	44.13	44.53	43.97	44.68	44.11	44.11	44.22	44.25
SO_3	0.45	0.50	0.51	0.51	0.53	0.55	0.53	0.53	0.50	0.51	0.50
TiO_2	1.38	1.60	1.67	1.68	1.62	1.63	1.58	1.61	1.58	1.58	1.58
ZnO	3.46	3.52	3.50	3.56	3.53	3.54	3.56	3.56	3.46	3.49	3.46
ZrO_2	2.96	3.08	3.09	3.09	3.10	3.07	3.12	3.11	3.03	3.01	3.05
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	5									
Mass (kg)		481.51	483.99	486.59	489.39	492.57	494.87	497.01	499.63	503.05	505.47
Sample		10S-G-148A	10S-G-148B	10S-G-148C	10S-G-148D	10S-G-149A	10S-G-149B	10S-G-149C	10S-G-149D	10S-G-149E	10S-G-151A
Al_2O_3	6.02	5.70	5.72	5.75	5.77	5.73	5.85	5.89	5.79	5.80	5.77
B_2O_3*	9.87	9.87	9.87	9.87	9.87	9.87	9.87	9.87	9.87	9.87	9.87
CaO	5.47	5.65	5.52	5.51	5.53	5.47	5.41	5.59	5.59	5.66	5.60
Cl	0.09	0.09	0.09	0.08	0.10	0.09	0.09	0.09	0.08	0.10	0.09
Cr_2O_3	0.08	0.18	0.16	0.17	0.19	0.19	0.19	0.17	0.16	0.17	0.15
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.43	5.92	5.81	5.78	5.75	5.52	5.53	5.69	5.75	5.91	5.85
I	0.10	0.009	0.017	0.008	0.007	0.014	0.009	0.010	0.012	0.015	0.007
K_2O	0.54	0.68	0.65	0.63	0.64	0.63	0.60	0.63	0.66	0.63	0.66
Li_2O*	2.38	2.39	2.39	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38
MgO	1.46	1.37	1.41	1.42	1.37	1.50	1.48	1.45	1.45	1.39	1.43
Na_2O	15.68	15.06	15.20	15.46	15.62	16.61	16.48	15.60	15.86	14.91	15.35
NiO	0.01	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.03	0.02
P_2O_5	0.12	0.18	0.18	0.17	0.16	0.17	0.16	0.17	0.17	0.16	0.16
PbO	0.01	0.01	0.02	0.02	0.01	0.01	0.02	0.01	0.01	0.01	0.01
ReO_2	0.10	0.065	0.069	0.067	0.069	0.059	0.068	0.075	0.059	0.067	0.060
SiO_2	44.33	44.04	44.16	44.05	43.95	43.47	43.58	43.95	43.62	44.07	43.97
SO_3	0.45	0.54	0.54	0.53	0.56	0.51	0.51	0.50	0.51	0.53	0.51
TiO_2	1.38	1.58	1.60	1.61	1.63	1.54	1.52	1.55	1.56	1.64	1.60
ZnO	3.46	3.53	3.53	3.48	3.41	3.36	3.36	3.38	3.47	3.57	3.46
ZrO_2	2.96	3.11	3.02	3.00	2.95	2.88	2.87	2.96	2.97	3.08	3.07
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	5									
Mass (kg)		506.89	508.97	511.27	513.57	515.37	517.39	519.19	521.43	523.91	528.33
Sample		10T-G-11A	10T-G-11B	10T-G-11C	10T-G-13A	10T-G-13B	10T-G-13C	10T-G-14A	10T-G-14B	10T-G-20A	10T-G-36A
Al_2O_3	6.02	5.75	5.76	5.79	5.77	5.81	5.77	5.63	5.76	5.75	5.81
B_2O_3*	9.87	9.87	9.87	9.87	9.87	9.87	9.87	9.87	9.87	9.87	9.87
CaO	5.47	5.68	5.60	5.77	5.74	5.71	5.67	5.75	5.67	5.65	5.69
Cl	0.09	0.08	0.09	0.08	0.09	0.10	0.11	0.10	0.10	0.10	0.08
Cr_2O_3	0.08	0.20	0.17	0.19	0.19	0.20	0.19	0.18	0.17	0.19	0.22
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	0.04#	NA
Fe_2O_3	5.43	5.80	5.80	5.91	5.80	5.87	5.91	6.00	5.87	5.82	5.74
I	0.10	0.017	0.021	0.023	0.016	0.018	0.013	0.016	0.018	0.008	0.017
K_2O	0.54	0.67	0.65	0.62	0.64	0.65	0.64	0.68	0.66	0.64	0.63
Li_2O*	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38	2.38
MgO	1.46	1.39	1.44	1.38	1.42	1.47	1.45	1.36	1.41	1.40	1.41
Na_2O	15.68	15.05	15.39	14.50	15.13	14.59	15.28	14.40	15.02	15.19	15.03
NiO	0.01	0.04	0.03	0.03	0.03	0.04	0.03	0.03	0.04	0.04	0.03
P_2O_5	0.12	0.17	0.18	0.17	0.18	0.18	0.17	0.18	0.16	0.16	0.17
PbO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
ReO_2	0.10	0.058	0.053	0.055	0.051	0.066	0.081	0.077	0.072	0.077	0.061
SiO_2	44.33	44.19	43.92	44.38	43.94	44.38	43.75	44.42	44.04	44.00	44.27
SO_3	0.45	0.50	0.52	0.52	0.51	0.49	0.54	0.57	0.50	0.55	0.55
TiO_2	1.38	1.59	1.60	1.60	1.68	1.59	1.60	1.64	1.64	1.59	1.64
ZnO	3.46	3.53	3.50	3.60	3.51	3.51	3.51	3.58	3.54	3.49	3.45
ZrO_2	2.96	3.02	3.02	3.11	3.05	3.07	3.04	3.12	3.07	3.04	2.96
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
# - Analyzed by XRF
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	5				6							
Mass (kg)	Target	529.75	Avg.	% Dev.	Target	532.43	534.73	536.27	537.71	539.15	540.77	542.65
Sample		10T-G-37A				10T-G-54A	10T-G-54B	10T-G-54C	10T-G-55A	10T-G-55B	10T-G-57A	10T-G-57B
Al_2O_3	6.02	5.88	5.77	-4.11	6.11	6.32	6.17	6.13	6.14	6.01	6.08	5.95
B_2O_3*	9.87	9.87	9.86	NC	10.01	10.06[$]	10.05	10.05	10.04	10.04	10.03	10.03
CaO	5.47	5.77	5.66	3.43	2.02	5.01	4.21	3.76	3.45	3.26	3.13	2.94
Cl	0.09	0.03	0.09	NC	0.10	0.03	0.05	0.07	0.06	0.08	0.07	0.09
Cr_2O_3	0.08	0.30	0.19	NC	0.08	0.45	0.36	0.30	0.27	0.24	0.26	0.23
F	0.07	NA	NA	NC	0.07	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.43	5.92	5.82	7.12	5.51	5.55	5.49	5.60	5.57	5.66	5.78	5.75
I	0.10	<0.003	0.015	NC	0.10	<0.003	0.019	0.016	0.028	0.028	0.024	0.025
K_2O	0.54	0.64	0.65	NC	4.99	1.21	2.30	2.99	3.29	3.73	4.07	4.25
Li_2O*	2.38	2.38	2.39	NC	§	2.25[$]	1.79	1.53	1.33	1.15	0.98	0.81
MgO	1.46	1.42	1.42	-3.08	1.48	1.50	1.47	1.50	1.50	1.46	1.52	1.47
Na_2O	15.68	14.82	15.10	-3.75	18.08	16.13	16.89	16.99	17.22	17.38	17.13	17.04
NiO	0.01	0.04	0.03	NC	0.01	0.05	0.04	0.04	0.04	0.03	0.04	0.04
P_2O_5	0.12	0.17	0.17	NC	0.12	0.17	0.17	0.17	0.16	0.16	0.16	0.17
PbO	0.01	0.01	0.01	NC	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
ReO_2	0.10	<0.005	0.060	NC	0.10	<0.005	<0.005	0.014	0.041	0.021	0.025	0.023
SiO_2	44.33	43.80	44.10	-0.51	43.01	43.25	43.05	42.81	42.91	42.62	42.45	42.83
SO_3	0.45	0.56	0.52	NC	0.30	0.35	0.36	0.36	0.33	0.36	0.33	0.34
TiO_2	1.38	1.61	1.61	16.19	1.40	1.54	1.52	1.57	1.56	1.59	1.62	1.60
ZnO	3.46	3.62	3.50	1.37	3.51	3.28	3.28	3.32	3.29	3.39	3.45	3.52
ZrO_2	2.96	3.15	3.05	3.17	3.00	2.84	2.78	2.80	2.79	2.79	2.85	2.88
Sum	100.00	100.00	100.00	NC	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
[$] - DCP-AES result
§ - Not a target constituent
NC – Not calculated
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	6									
Mass (kg)		544.43	546.43	548.23	550.03	551.59	553.35	555.05	556.21	557.87	559.61
Sample		10T-G-57C	10T-G-57D	10T-G-57E	10T-G-57F	10T-G-58A	10T-G-58B	10T-G-58C	10T-G-64A	10T-G-64B	10T-G-64C
Al_2O_3	6.11	6.04	6.02	5.89	6.00	6.01	6.12	6.04	5.90	5.96	5.96
B_2O_3*	10.01	10.03	10.02	10.02	10.02	10.02	10.02	10.02	10.02	10.02	10.02
CaO	2.02	2.76	2.66	2.67	2.54	2.48	2.39	2.35	2.30	2.28	2.22
Cl	0.10	0.09	0.09	0.11	0.10	0.11	0.09	0.11	0.12	0.11	0.11
Cr_2O_3	0.08	0.21	0.21	0.23	0.21	0.21	0.20	0.20	0.19	0.18	0.18
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.51	5.77	5.54	5.80	5.66	5.78	5.63	5.66	5.70	5.81	5.88
I	0.10	0.031	0.045	0.031	0.032	0.041	0.047	0.045	0.024	0.034	0.046
K_2O	4.99	4.43	4.53	4.75	4.88	4.94	4.90	5.06	5.16	5.17	5.25
Li_2O*	§	0.68	0.55	0.46	0.39	0.33	0.28	0.23	0.21	0.18	0.15
MgO	1.48	1.49	1.51	1.52	1.48	1.47	1.53	1.46	1.46	1.46	1.49
Na_2O	18.08	17.45	17.31	17.13	17.21	17.39	17.38	17.22	17.46	17.30	17.33
NiO	0.01	0.04	0.04	0.04	0.03	0.04	0.03	0.04	0.03	0.04	0.03
P_2O_5	0.12	0.17	0.18	0.16	0.18	0.17	0.17	0.19	0.18	0.18	0.19
PbO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	<0.01	0.01	0.01
ReO_2	0.10	0.030	0.037	0.040	0.040	0.057	0.040	0.038	0.044	0.033	0.049
SiO_2	43.01	42.65	43.14	42.63	42.97	42.65	42.98	43.08	42.90	42.82	42.82
SO_3	0.30	0.34	0.36	0.39	0.36	0.40	0.41	0.36	0.39	0.40	0.37
TiO_2	1.40	1.56	1.57	1.64	1.61	1.61	1.58	1.63	1.64	1.60	1.60
ZnO	3.51	3.42	3.39	3.56	3.43	3.44	3.41	3.44	3.46	3.52	3.46
ZrO_2	3.00	2.79	2.78	2.91	2.83	2.85	2.79	2.82	2.83	2.92	2.85
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
§ - Not a target constituent
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	6									
Mass (kg)		560.95	562.99	564.59	566.57	568.69	570.65	573.51	575.75	578.43	581.61
Sample		10T-G-64D	10T-G-64E	10T-G-66A	10T-G-66B	10T-G-67A	10T-G-67B	10T-G-67C	10T-G-67D	10T-G-68A	10T-G-68B
Al_2O_3	6.11	6.12	5.91	5.95	5.96	6.07	6.03	5.98	5.93	5.98	5.83
B_2O_3*	10.01	10.02	10.02	10.01	10.01	10.01	10.01	10.01	10.01	10.01	10.01
CaO	2.02	2.19	2.20	2.20	2.17	2.17	2.13	2.13	2.15	2.17	2.12
Cl	0.10	0.12	0.11	0.13	0.11	0.13	0.13	0.12	0.12	0.11	0.13
Cr_2O_3	0.08	0.19	0.19	0.17	0.18	0.19	0.18	0.18	0.17	0.18	0.19
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.51	5.71	5.76	5.78	5.77	5.75	5.97	5.87	5.85	5.83	6.04
I	0.10	0.037	0.043	0.034	0.044	0.036	0.039	0.042	0.055	0.033	0.028
K_2O	4.99	5.20	5.26	5.47	5.45	5.52	5.48	5.45	5.57	5.45	5.60
Li_2O*	§	0.13	0.11	0.09	0.07	0.06	0.05	0.04	0.03	0.02	0.02
MgO	1.48	1.43	1.46	1.43	1.43	1.48	1.42	1.45	1.46	1.48	1.45
Na_2O	18.08	17.78	17.69	17.52	17.40	17.23	17.21	17.25	17.52	17.68	17.11
NiO	0.01	0.03	0.04	0.02	0.04	0.03	0.03	0.03	0.04	0.03	0.03
P_2O_5	0.12	0.17	0.17	0.17	0.19	0.19	0.17	0.17	0.16	0.16	0.18
PbO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
ReO_2	0.10	0.044	0.054	0.047	0.052	0.051	0.045	0.051	0.045	0.042	0.036
SiO_2	43.01	42.62	42.65	42.57	42.51	42.77	42.57	42.77	42.43	42.39	42.53
SO_3	0.30	0.38	0.38	0.39	0.39	0.37	0.40	0.38	0.39	0.39	0.38
TiO_2	1.40	1.62	1.59	1.62	1.65	1.59	1.64	1.65	1.62	1.62	1.66
ZnO	3.51	3.39	3.50	3.49	3.59	3.49	3.53	3.50	3.53	3.51	3.67
ZrO_2	3.00	2.81	2.86	2.88	2.96	2.85	2.93	2.91	2.92	2.90	2.97
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
§ - Not a target constituent
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	6									
Mass (kg)		583.65	585.65	588.13	590.87	593.53	595.27	597.21	600.05	603.21	605.59
Sample		10T-G-75A	10T-G-75B	10T-G-75C	10T-G-75D	10T-G-77A	10T-G-77B	10T-G-77C	10T-G-78A	10T-G-79A	10T-G-79B
Al_2O_3	6.11	6.07	5.98	5.87	6.03	6.08	6.06	6.07	5.98	6.01	5.98
B_2O_3*	10.01	10.01	10.01	10.01	10.01	10.01	10.01	10.01	10.01	10.01	10.01
CaO	2.02	2.08	2.11	2.11	2.06	2.06	2.09	2.08	2.02	2.08	2.05
Cl	0.10	0.12	0.11	0.13	0.13	0.13	0.13	0.12	0.13	0.12	0.14
Cr_2O_3	0.08	0.16	0.18	0.18	0.17	0.17	0.19	0.17	0.18	0.19	0.19
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.51	5.84	5.80	5.70	5.82	5.63	5.73	5.69	5.83	5.78	5.79
I	0.10	0.026	0.029	0.031	0.052	0.047	0.047	0.048	0.040	0.034	0.041
K_2O	4.99	5.57	5.47	5.50	5.56	5.49	5.66	5.56	5.53	5.53	5.65
Li_2O*	§	0.01	0.01	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MgO	1.48	1.48	1.48	1.48	1.41	1.43	1.48	1.45	1.50	1.45	1.45
Na_2O	18.08	17.52	17.47	17.44	17.39	17.69	17.28	17.62	17.41	17.27	17.60
NiO	0.01	0.03	0.03	0.04	0.03	0.03	0.04	0.04	0.03	0.04	0.03
P_2O_5	0.12	0.17	0.17	0.17	0.17	0.18	0.19	0.20	0.19	0.16	0.17
PbO	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
ReO_2	0.10	0.037	0.044	0.037	0.045	0.048	0.057	0.052	0.045	0.047	0.062
SiO_2	43.01	42.55	42.68	42.91	42.76	42.68	42.60	42.57	42.75	42.68	42.34
SO_3	0.30	0.37	0.35	0.42	0.39	0.40	0.39	0.38	0.39	0.42	0.39
TiO_2	1.40	1.58	1.61	1.66	1.62	1.65	1.58	1.64	1.63	1.71	1.64
ZnO	3.51	3.48	3.54	3.46	3.46	3.43	3.54	3.47	3.46	3.54	3.52
ZrO_2	3.00	2.87	2.91	2.85	2.87	2.84	2.91	2.82	2.86	2.92	2.92
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
§ - Not a target constituent
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	6									
Mass (kg)		608.05	611.59	613.35	615.11	617.77	620.33	622.65	625.35	628.21	630.11
Sample		10T-G-79C	10T-G-85A	10T-G-85B	10T-G-85C	10T-G-86A	10T-G-86B	10T-G-86C	10T-G-92A	10T-G-92B	10T-G-92C
Al_2O_3	6.11	5.92	5.99	5.92	6.07	5.98	5.96	5.96	6.06	6.04	5.94
B_2O_3*	10.01	10.01	10.01	10.01	10.01	10.01	10.01	10.01	10.01	10.01	10.01
CaO	2.02	2.11	2.17	2.08	2.09	2.06	2.15	2.13	2.06	2.05	2.11
Cl	0.10	0.15	0.13	0.15	0.14	0.14	0.15	0.14	0.14	0.14	0.15
Cr_2O_3	0.08	0.15	0.16	0.18	0.17	0.17	0.18	0.15	0.16	0.17	0.16
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.51	5.98	5.77	5.77	5.90	5.75	5.84	5.83	5.64	5.89	5.82
I	0.10	0.033	0.035	0.047	0.033	0.035	0.034	0.067	0.047	0.048	0.051
K_2O	4.99	5.56	5.58	5.48	5.57	5.49	5.61	5.54	5.56	5.49	5.58
Li_2O*	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MgO	1.48	1.53	1.50	1.51	1.47	1.46	1.45	1.52	1.54	1.47	1.51
Na_2O	18.08	17.29	17.15	17.86	17.57	18.03	17.60	17.65	17.66	17.22	17.29
NiO	0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.03
P_2O_5	0.12	0.18	0.18	0.16	0.19	0.20	0.18	0.16	0.16	0.17	0.17
PbO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
ReO_2	0.10	0.053	0.060	0.052	0.055	0.056	0.061	0.058	0.061	0.051	0.048
SiO_2	43.01	42.46	42.59	42.42	42.12	42.08	42.14	42.31	42.54	42.82	42.66
SO_3	0.30	0.37	0.38	0.42	0.36	0.39	0.40	0.38	0.37	0.38	0.39
TiO_2	1.40	1.64	1.69	1.61	1.67	1.65	1.68	1.64	1.67	1.59	1.61
ZnO	3.51	3.58	3.59	3.45	3.62	3.54	3.58	3.51	3.47	3.51	3.53
ZrO_2	3.00	2.95	2.96	2.84	2.92	2.92	2.94	2.89	2.81	2.91	2.90
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
§ - Not a target constituent
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	6									
Mass (kg)		632.63	635.05	637.07	639.27	641.23	643.37	646.11	649.53	651.05	652.61
Sample		10T-G-92D	10T-G-93A	10T-G-93B	10T-G-93C	10T-G-93D	10T-G-95A	10T-G-95B	10T-G-95C	10T-G-102A	10T-G-102B
Al_2O_3	6.11	5.83	5.97	5.95	6.04	5.99	5.93	5.87	5.78	5.99	5.90
B_2O_3*	10.01	10.01	10.01	10.01	10.01	10.01	10.01	10.01	10.01	10.01	10.01
CaO	2.02	2.14	2.12	2.07	2.12	2.12	2.17	2.14	2.09	2.14	2.15
Cl	0.10	0.15	0.14	0.15	0.15	0.16	0.14	0.14	0.15	0.14	0.13
Cr_2O_3	0.08	0.15	0.16	0.18	0.19	0.17	0.20	0.18	0.17	0.18	0.19
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.51	5.98	5.93	5.92	6.19	5.84	5.88	6.04	6.20	5.81	5.90
I	0.10	0.042	0.051	0.059	0.041	0.047	0.045	0.034	0.054	0.048	0.041
K_2O	4.99	5.58	5.70	5.61	5.74	5.64	5.55	5.55	5.55	5.58	5.49
Li_2O*	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MgO	1.48	1.48	1.47	1.49	1.46	1.47	1.45	1.47	1.43	1.49	1.47
Na_2O	18.08	17.21	17.05	17.13	16.96	17.36	17.37	17.14	17.34	17.05	17.58
NiO	0.01	0.03	0.04	0.03	0.03	0.03	0.04	0.04	0.04	0.03	0.04
P_2O_5	0.12	0.19	0.18	0.17	0.18	0.18	0.18	0.17	0.17	0.17	0.18
PbO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
ReO_2	0.10	0.071	0.061	0.050	0.053	0.051	0.058	0.072	0.078	0.070	0.059
SiO_2	43.01	42.64	42.45	42.53	42.02	42.25	42.08	42.33	42.00	42.85	42.28
SO_3	0.30	0.38	0.40	0.40	0.36	0.40	0.39	0.38	0.34	0.38	0.37
TiO_2	1.40	1.66	1.69	1.67	1.66	1.72	1.70	1.70	1.74	1.59	1.62
ZnO	3.51	3.55	3.59	3.59	3.72	3.60	3.71	3.67	3.73	3.54	3.62
ZrO_2	3.00	2.90	2.98	2.98	3.07	2.95	3.07	3.05	3.12	2.91	2.95
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
§ - Not a target constituent
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	6											
Mass (kg)	Target	654.49	656.55	659.11	661.73	664.57	667.55	669.41	671.59	673.17	Avg.	% Dev.
Sample		10T-G-103A	10T-G-103B	10T-G-103C	10T-G-105A	10T-G-105B	10T-G-105C	10T-G-106A	10T-G-106B	10T-G-106C		
Al_2O_3	6.11	6.06	5.87	5.91	5.91	5.95	5.93	5.96	5.99	6.03	5.97	-2.25
B_2O_3*	10.01	10.01	10.01	10.01	10.01	10.01	10.01	10.01	10.01	10.01	10.01	NC
CaO	2.02	2.07	2.14	2.09	2.10	2.06	2.16	2.09	2.07	2.06	2.11	4.48
Cl	0.10	0.14	0.14	0.16	0.17	0.15	0.15	0.15	0.14	0.12	0.14	NC
Cr_2O_3	0.08	0.17	0.16	0.17	0.17	0.18	0.17	0.16	0.17	0.17	0.17	NC
F	0.07	NA	NA	NA	NA	NA	NA	NA	0.03#	NA	NA	NC
Fe_2O_3	5.51	5.84	6.10	5.93	6.07	5.90	5.64	5.87	5.80	5.73	5.85	6.26
I	0.10	0.040	0.050	0.049	0.044	0.047	0.041	0.045	0.032	0.049	0.043	NC
K_2O	4.99	5.42	5.57	5.56	5.62	5.64	5.70	5.64	5.57	5.55	5.54	11.03
Li_2O*	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	0.02	NC
MgO	1.48	1.51	1.46	1.46	1.43	1.42	1.42	1.45	1.49	1.47	1.47	-1.07
Na_2O	18.08	17.47	17.20	17.20	17.23	16.95	17.37	17.02	17.21	17.50	17.38	-3.86
NiO	0.01	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	NC
P_2O_5	0.12	0.19	0.17	0.17	0.17	0.17	0.18	0.18	0.17	0.17	0.18	NC
PbO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	NC
ReO_2	0.10	0.050	0.067	0.070	0.068	0.070	0.051	0.074	0.051	0.063	0.055	NC
SiO_2	43.01	42.73	42.32	42.45	42.17	42.60	42.89	42.72	42.82	42.64	42.52	-1.13
SO_3	0.30	0.37	0.39	0.37	0.38	0.40	0.37	0.38	0.41	0.40	0.39	NC
TiO_2	1.40	1.60	1.66	1.67	1.65	1.68	1.63	1.66	1.62	1.64	1.64	17.26
ZnO	3.51	3.45	3.63	3.65	3.73	3.67	3.43	3.60	3.49	3.47	3.55	1.23
ZrO_2	3.00	2.85	3.02	3.04	3.04	3.05	2.82	2.95	2.88	2.86	2.92	-2.71
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	NC

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
§ - Not a target constituent
# - Analyzed by XRF
NA – Not analyzed
NC – Not calculated

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	7									
Mass (kg)		676.83	678.31	681.65	682.57	683.73	684.83	686.25	687.41	688.77	690.19
Sample		10T-G-139A	10T-G-139B	10T-G-142A	10T-G-142B	10T-G-143A	10T-G-143B	10T-G-145A	10T-G-145B	10T-G-145C	10T-G-146A
Al_2O_3	5.98	5.87	5.87	5.65	5.81	5.72	5.78	5.72	5.58	5.65	5.66
B_2O_3*	9.80	10.69$	10.57	10.35	10.30	10.25	10.20	10.15	10.11	10.07	10.04
CaO	2.46	2.63	2.58	2.66	2.56	2.61	2.66	2.62	2.65	2.67	2.58
Cl	0.09	0.03	0.04	0.05	0.06	0.07	0.07	0.07	0.07	0.09	0.09
Cr_2O_3	0.08	0.33	0.27	0.25	0.24	0.24	0.22	0.21	0.23	0.20	0.22
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.39	5.63	5.77	5.86	5.61	6.00	5.83	5.63	5.84	5.80	5.82
I	0.10	0.015	0.027	0.025	0.039	0.030	0.043	0.033	0.022	0.032	0.032
K_2O	0.54	1.50	1.15	1.12	0.98	0.91	0.92	0.90	0.88	0.81	0.82
Li_2O*	§	0.15$	0.13	0.09	0.08	0.08	0.07	0.06	0.05	0.05	0.04
MgO	1.45	1.10	1.14	1.20	1.19	1.24	1.24	1.15	1.28	1.22	1.26
Na_2O	21.14	20.47	20.82	20.75	21.22	20.54	20.64	20.96	20.70	20.85	20.62
NiO	0.01	0.08	0.07	0.05	0.04	0.05	0.05	0.05	0.05	0.04	0.04
P_2O_5	0.12	0.16	0.17	0.16	0.19	0.16	0.16	0.18	0.17	0.17	0.17
PbO	0.01	0.01	<0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
ReO_2	0.10	0.015	0.032	0.044	0.035	0.054	0.060	0.053	0.054	0.054	0.061
SiO_2	44.56	42.97	42.85	43.18	43.59	43.50	43.38	43.91	43.57	43.57	43.80
SO_3	0.35	0.38	0.42	0.39	0.37	0.37	0.43	0.42	0.41	0.44	0.41
TiO_2	1.37	1.49	1.48	1.48	1.45	1.50	1.50	1.45	1.53	1.51	1.50
ZnO	3.44	3.50	3.56	3.61	3.35	3.59	3.64	3.48	3.59	3.62	3.65
ZrO_2	2.94	2.99	3.05	3.06	2.86	3.09	3.10	2.97	3.18	3.14	3.18
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
$ - DCP-AES result
§ - Not a target constituent
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	7									
Mass (kg)		692.29	694.03	695.77	697.37	698.81	700.09	701.75	703.41	704.71	706.13
Sample		10T-G-146B	10T-G-147A	10T-G-147B	10U-G-8A	10U-G-8B	10U-G-8C	10U-G-8D	10U-G-10A	10U-G-10B	10U-G-11A
Al_2O_3	5.98	5.76	5.67	5.58	5.51	5.59	5.56	5.58	5.66	5.55	5.48
B_2O_3*	9.80	9.99	9.96	9.94	9.92	9.90	9.89	9.88	9.87	9.86	9.85
CaO	2.46	2.65	2.68	2.70	2.74	2.71	2.70	2.73	2.65	2.70	2.72
Cl	0.09	0.08	0.09	0.10	0.08	0.08	0.09	0.09	0.09	0.10	0.08
Cr_2O_3	0.08	0.22	0.22	0.20	0.19	0.18	0.20	0.17	0.19	0.17	0.18
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.39	5.84	5.93	5.91	5.84	5.94	5.94	5.84	5.96	5.76	5.94
I	0.10	0.025	0.035	0.022	0.032	0.035	0.049	0.031	0.026	0.026	0.037
K_2O	0.54	0.83	0.77	0.74	0.75	0.71	0.70	0.69	0.73	0.68	0.67
Li_2O*	§	0.03	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01
MgO	1.45	1.28	1.28	1.26	1.31	1.29	1.36	1.41	1.36	1.34	1.35
Na_2O	21.14	20.99	20.91	20.70	20.53	20.52	20.36	20.28	20.39	20.42	20.35
NiO	0.01	0.04	0.05	0.04	0.04	0.04	0.03	0.04	0.03	0.04	0.03
P_2O_5	0.12	0.16	0.16	0.19	0.17	0.19	0.18	0.16	0.18	0.17	0.18
PbO	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.02
ReO_2	0.10	0.059	0.062	0.058	0.062	0.060	0.067	0.069	0.070	0.082	0.072
SiO_2	44.56	43.43	43.44	43.89	44.11	44.01	43.99	44.25	44.09	44.43	44.20
SO_3	0.35	0.41	0.45	0.41	0.41	0.41	0.41	0.42	0.41	0.42	0.46
TiO_2	1.37	1.51	1.54	1.45	1.54	1.51	1.53	1.53	1.53	1.54	1.53
ZnO	3.44	3.60	3.59	3.63	3.62	3.59	3.67	3.62	3.63	3.59	3.65
ZrO_2	2.94	3.07	3.11	3.17	3.12	3.18	3.23	3.19	3.12	3.11	3.20
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
§ - Not a target constituent
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	7									
Mass (kg)		707.77	709.69	711.59	712.99	714.59	716.83	718.47	720.37	721.75	723.09
Sample		10U-G-11B	10U-G-11C	10U-G-13A	10U-G-13B	10U-G-13C	10U-G-13D	10U-G-18A	10U-G-18B	10U-G-18C	10U-G-19A
Al_2O_3	5.98	5.52	5.62	5.60	5.58	5.68	5.59	5.50	5.61	5.56	5.58
B_2O_3*	9.80	9.84	9.84	9.83	9.83	9.82	9.82	9.82	9.82	9.81	9.81
CaO	2.46	2.74	2.63	2.63	2.74	2.74	2.60	2.62	2.70	2.68	2.71
Cl	0.09	0.09	0.09	0.09	0.10	0.12	0.10	0.11	0.11	0.12	0.12
Cr_2O_3	0.08	0.19	0.19	0.17	0.19	0.19	0.17	0.17	0.18	0.17	0.18
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.39	5.87	5.79	5.81	5.95	5.90	5.81	5.86	5.77	5.77	5.82
I	0.10	0.044	0.040	0.037	0.042	0.048	0.045	0.044	0.048	0.049	0.044
K_2O	0.54	0.70	0.68	0.68	0.73	0.69	0.67	0.66	0.69	0.66	0.70
Li_2O*	§	0.01	0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MgO	1.45	1.36	1.39	1.36	1.33	1.32	1.28	1.28	1.23	1.26	1.23
Na_2O	21.14	20.36	20.83	20.87	20.49	20.40	20.94	20.62	20.78	20.97	20.84
NiO	0.01	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04
P_2O_5	0.12	0.15	0.18	0.18	0.16	0.18	0.17	0.19	0.17	0.18	0.18
PbO	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.01
ReO_2	0.10	0.073	0.078	0.075	0.084	0.096	0.092	0.095	0.079	0.079	0.087
SiO_2	44.56	44.42	43.90	43.95	43.87	43.92	44.07	44.29	44.00	44.06	43.80
SO_3	0.35	0.42	0.42	0.41	0.42	0.45	0.42	0.43	0.42	0.43	0.46
TiO_2	1.37	1.51	1.51	1.52	1.58	1.54	1.51	1.55	1.60	1.54	1.60
ZnO	3.44	3.54	3.60	3.59	3.67	3.67	3.54	3.58	3.59	3.51	3.64
ZrO_2	2.94	3.12	3.17	3.12	3.18	3.18	3.10	3.12	3.16	3.10	3.15
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
§ - Not a target constituent
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	7									
Mass (kg)		724.63	726.17	727.75	729.29	731.19	732.91	734.85	736.99	738.77	740.43
Sample		10U-G-19B	10U-G-21A	10U-G-21B	10U-G-21C	10U-G-21D	10U-G-23A	10U-G-29A	10U-G-29B	10U-G-29C	10U-G-30A
Al_2O_3	5.98	5.61	5.67	5.55	5.65	5.60	5.58	5.61	5.81	5.67	5.64
B_2O_3*	9.80	9.81	9.81	9.81	9.81	9.81	9.81	9.81	9.81	9.81	9.81
CaO	2.46	2.68	2.65	2.73	2.75	2.65	2.60	2.68	2.64	2.63	2.60
Cl	0.09	0.12	0.12	0.10	0.10	0.09	0.12	0.09	0.09	0.11	0.10
Cr_2O_3	0.08	0.19	0.20	0.18	0.18	0.18	0.18	0.19	0.16	0.17	0.17
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.39	5.88	5.82	5.99	5.74	5.81	5.83	5.66	5.58	5.64	5.74
I	0.10	0.045	0.044	0.047	0.042	0.035	0.036	0.042	0.039	0.038	0.050
K_2O	0.54	0.70	0.64	0.70	0.69	0.66	0.72	0.64	0.66	0.60	0.67
Li_2O*	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MgO	1.45	1.41	1.28	1.34	1.36	1.31	1.35	1.31	1.32	1.34	1.37
Na_2O	21.14	20.34	20.75	20.59	20.56	20.89	20.64	21.09	21.40	21.72	21.23
NiO	0.01	0.04	0.03	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.04
P_2O_5	0.12	0.18	0.17	0.18	0.18	0.19	0.17	0.17	0.18	0.16	0.16
PbO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
ReO_2	0.10	0.094	0.086	0.093	0.087	0.091	0.080	0.065	0.072	0.071	0.079
SiO_2	44.56	44.00	44.00	43.81	44.25	43.97	44.11	44.15	43.93	43.72	43.88
SO_3	0.35	0.43	0.41	0.43	0.42	0.43	0.43	0.44	0.41	0.40	0.43
TiO_2	1.37	1.59	1.54	1.58	1.51	1.53	1.56	1.52	1.46	1.48	1.51
ZnO	3.44	3.66	3.58	3.63	3.56	3.62	3.62	3.50	3.41	3.44	3.46
ZrO_2	2.94	3.19	3.18	3.18	3.07	3.09	3.14	2.99	2.98	2.95	3.05
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
§ - Not a target constituent
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	7									
Mass (kg)		742.09	743.91	745.69	747.75	749.37	751.35	752.83	754.37	755.93	757.41
Sample		10U-G-30B	10U-G-30C	10U-G-30D	10U-G-33A	10U-G-33B	10U-G-33C	10U-G-33D	10U-G-39A	10U-G-39B	10U-G-39C
Al_2O_3	5.98	5.74	5.50	5.64	5.63	5.56	5.71	5.56	5.61	5.61	5.58
B_2O_3*	9.80	9.81	9.81	9.80	9.80	9.80	9.80	9.80	9.80	9.80	9.80
CaO	2.46	2.65	2.58	2.64	2.65	2.68	2.72	2.63	2.66	2.62	2.64
Cl	0.09	0.11	0.10	0.10	0.10	0.10	0.12	0.10	0.10	0.12	0.10
Cr_2O_3	0.08	0.17	0.17	0.16	0.17	0.18	0.18	0.17	0.21	0.18	0.16
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.39	5.63	5.86	5.71	5.74	5.76	5.67	5.64	5.79	5.70	5.75
I	0.10	0.030	0.045	0.036	0.031	0.041	0.056	0.048	0.043	0.040	0.030
K_2O	0.54	0.63	0.67	0.68	0.68	0.65	0.64	0.65	0.65	0.66	0.70
Li_2O*	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MgO	1.45	1.43	1.45	1.38	1.38	1.35	1.36	1.36	1.30	1.34	1.34
Na_2O	21.14	21.30	20.94	21.03	21.16	20.59	20.62	21.32	20.68	20.79	20.71
NiO	0.01	0.03	0.04	0.03	0.04	0.03	0.03	0.03	0.04	0.03	0.03
P_2O_5	0.12	0.16	0.16	0.16	0.17	0.16	0.16	0.15	0.18	0.18	0.19
PbO	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01
ReO_2	0.10	0.064	0.076	0.076	0.068	0.092	0.083	0.098	0.089	0.076	0.093
SiO_2	44.56	44.11	44.11	44.15	44.13	44.29	44.39	44.08	44.36	44.49	44.38
SO_3	0.35	0.39	0.42	0.42	0.41	0.42	0.43	0.42	0.43	0.41	0.38
TiO_2	1.37	1.45	1.51	1.48	1.48	1.53	1.51	1.50	1.49	1.51	1.52
ZnO	3.44	3.35	3.49	3.47	3.39	3.57	3.48	3.44	3.51	3.46	3.50
ZrO_2	2.94	2.93	3.06	3.03	2.95	3.17	3.05	2.99	3.04	2.99	3.09
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
§ - Not a target constituent
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	7									
Mass (kg)		758.91	760.27	761.77	763.33	764.89	766.51	768.45	769.95	771.75	773.55
Sample		10U-G-39D	10U-G-40A	10U-G-40B	10U-G-40C	10U-G-40D	10U-G-41A	10U-G-41B	10U-G-41C	10U-G-47A	10U-G-47B
Al_2O_3	5.98	5.59	5.71	5.55	5.73	5.65	5.63	5.57	5.63	5.55	5.61
B_2O_3*	9.80	9.80	9.80	9.80	9.80	9.80	9.80	9.80	9.80	9.80	9.80
CaO	2.46	2.46	2.65	2.73	2.71	2.62	2.65	2.68	2.69	2.74	2.67
Cl	0.09	0.11	0.12	0.10	0.10	0.10	0.10	0.10	0.11	0.10	0.11
Cr_2O_3	0.08	0.19	0.20	0.18	0.17	0.19	0.19	0.18	0.18	0.17	0.17
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.39	5.54	5.84	5.89	5.68	5.79	5.81	5.75	6.00	5.81	5.88
I	0.10	0.036	0.045	0.045	0.033	0.049	0.052	0.046	0.043	0.040	0.048
K_2O	0.54	0.67	0.64	0.68	0.67	0.69	0.68	0.64	0.64	0.65	0.63
Li_2O*	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
MgO	1.45	1.38	1.33	1.32	1.32	1.30	1.28	1.34	1.30	1.34	1.36
Na_2O	21.14	22.04	20.32	20.26	20.45	20.56	20.17	20.26	20.10	20.35	20.40
NiO	0.01	0.03	0.04	0.05	0.03	0.03	0.03	0.04	0.04	0.04	0.03
P_2O_5	0.12	0.18	0.15	0.18	0.19	0.18	0.16	0.17	0.16	0.17	0.17
PbO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.02	0.01
ReO_2	0.10	0.078	0.077	0.105	0.077	0.097	0.105	0.094	0.078	0.083	0.109
SiO_2	44.56	43.99	44.42	44.36	44.57	44.27	44.62	44.76	44.65	44.58	44.47
SO_3	0.35	0.44	0.45	0.41	0.40	0.43	0.42	0.42	0.42	0.41	0.41
TiO_2	1.37	1.39	1.55	1.54	1.50	1.58	1.57	1.54	1.47	1.51	1.51
ZnO	3.44	3.24	3.54	3.60	3.51	3.54	3.54	3.53	3.57	3.57	3.51
ZrO_2	2.94	2.83	3.11	3.19	3.06	3.12	3.17	3.07	3.10	3.07	3.11
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
§ - Not a target constituent
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	7											
Mass (kg)		774.91	777.03	778.93	780.51	781.83	783.27	784.55	786.15	788.01	790.510	Avg.	% Dev.
Sample		10U-G-47C	10U-G-48A	10U-G-48B	10U-G-48C	10U-G-48D	10U-G-48E	10U-G-51A	10U-G-51B	10U-G-51C	10U-G-56A		
Al_2O_3	5.98	5.63	5.73	5.71	5.64	5.70	5.64	5.70	5.65	5.71	5.65	5.63	-5.88
B_2O_3*	9.80	9.80	9.80	9.80	9.80	9.80	9.80	9.80	9.80	9.80	9.80	9.81	NC
CaO	2.46	2.54	2.55	2.55	2.66	2.61	2.69	2.59	2.62	2.63	2.62	2.70	9.62
Cl	0.09	0.10	0.09	0.09	0.10	0.12	0.09	0.10	0.12	0.09	0.11	0.10	NC
Cr_2O_3	0.08	0.18	0.14	0.17	0.16	0.16	0.18	0.19	0.19	0.19	0.18	0.18	NC
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	0.03#	NA	NA	NC
Fe_2O_3	5.39	5.45	5.30	5.44	5.49	5.51	5.73	5.62	5.91	5.64	5.79	5.76	6.95
I	0.10	0.041	0.035	0.050	0.035	0.034	0.037	0.035	0.028	0.038	0.046	0.041	NC
K_2O	0.54	0.64	0.66	0.63	0.61	0.62	0.63	0.65	0.66	0.63	0.66	0.66	NC
Li_2O*	§	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	NC
MgO	1.45	1.39	1.42	1.40	1.43	1.39	1.36	1.31	1.40	1.40	1.39	1.35	-7.30
Na_2O	21.14	21.37	22.28	21.94	21.66	21.48	20.89	21.02	20.73	21.12	20.62	20.74	-1.88
NiO	0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	NC
P_2O_5	0.12	0.17	0.17	0.16	0.17	0.16	0.17	0.17	0.17	0.15	0.17	0.17	NC
PbO	0.01	0.01	0.00	0.01	0.01	0.01	0.01	0.00	0.01	0.01	0.01	0.01	NC
ReO_2	0.10	0.099	0.079	0.079	0.088	0.070	0.103	0.090	0.110	0.094	0.094	0.085	NC
SiO_2	44.56	44.46	44.03	43.93	44.12	44.25	44.33	44.32	43.82	44.14	44.23	44.20	-0.81
SO_3	0.35	0.42	0.37	0.42	0.41	0.43	0.41	0.41	0.42	0.40	0.40	0.42	NC
TiO_2	1.37	1.50	1.39	1.49	1.47	1.48	1.50	1.50	1.56	1.52	1.54	1.52	10.96
ZnO	3.44	3.31	3.18	3.24	3.27	3.28	3.39	3.45	3.61	3.37	3.49	3.51	2.27
ZrO_2	2.94	2.86	2.73	2.84	2.85	2.87	3.00	3.01	3.16	2.99	3.15	3.07	4.25
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	NC

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
§ - Not a target constituent
# - Analyzed by XRF
NA – Not analyzed
NC – Not calculated

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	8									
Mass (kg)		792.25	793.93	795.91	798.39	801.07	803.25	805.37	807.49	809.59	811.81
Sample		10U-G-91A	10U-G-91B	10U-G-91C	10U-G-91D	10U-G-92A	10U-G-92B	10U-G-93A	10U-G-93B	10U-G-93C	10U-G-95A
Al_2O_3	6.03	6.38	6.13	6.21	6.06	5.98	5.83	5.68	5.64	5.63	5.65
B_2O_3*	9.89	10.38$	10.30	10.23	10.15	10.09	10.05	10.02	10.00	9.97	9.96
CaO	6.32	2.72	3.53	4.08	4.52	4.92	5.14	5.66	5.72	5.97	6.17
Cl	0.09	0.01	0.03	0.05	0.07	0.07	0.07	0.09	0.08	0.09	0.10
Cr_2O_3	0.08	0.46	0.43	0.39	0.34	0.29	0.27	0.26	0.26	0.23	0.20
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.44	5.62	5.83	5.86	5.76	5.85	5.80	6.06	5.99	5.96	6.11
I	0.10	<0.005	<0.003	<0.005	<0.005	0.005	0.003	0.007	0.003	0.008	0.005
K_2O	0.54	0.62	0.66	0.65	0.68	0.71	0.73	0.74	0.73	0.75	0.77
Li_2O*	3.18	0.18$	0.64	1.10	1.55	1.94	2.18	2.37	2.52	2.65	2.75
MgO	1.49	1.59	1.52	1.48	1.51	1.46	1.51	1.50	1.44	1.49	1.45
Na_2O	13.38	20.37	18.33	17.34	16.61	15.82	15.72	13.94	14.58	13.83	13.07
NiO	0.01	0.07	0.07	0.06	0.05	0.05	0.04	0.05	0.05	0.04	0.05
P_2O_5	0.12	0.17	0.18	0.17	0.19	0.17	0.18	0.18	0.17	0.17	0.19
PbO	0.01	0.01	0.01	<0.01	0.01	0.01	0.01	0.01	0.01	0.01	<0.01
ReO_2	0.10	<0.005	0.012	0.020	0.025	0.026	0.033	0.039	0.026	0.030	0.034
SiO_2	44.84	43.52	43.97	43.90	44.03	44.01	44.00	44.50	43.93	44.25	44.57
SO_3	0.51	0.26	0.31	0.37	0.43	0.50	0.49	0.51	0.49	0.55	0.55
TiO_2	1.38	1.51	1.56	1.59	1.60	1.61	1.62	1.68	1.68	1.64	1.63
ZnO	3.47	3.13	3.33	3.37	3.34	3.40	3.28	3.49	3.54	3.53	3.54
ZrO_2	2.97	2.98	3.15	3.15	3.08	3.09	3.03	3.20	3.16	3.17	3.19
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
$ - DCP-AES results
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	8									
Mass (kg)		814.37	817.27	819.83	822.57	825.57	828.49	831.27	834.03	836.47	839.27
Sample		10U-G-95B	10U-G-96A	10U-G-96B	10U-G-96C	10U-G-99A	10U-G-99B	10U-G-99C	10U-G-99D	10U-G-99E	10U-G-101A
Al_2O_3	6.03	5.42	5.61	5.46	5.45	5.48	5.34	5.45	5.45	5.50	5.45
B_2O_3*	9.89	9.94	9.93	9.92	9.91	9.91	9.90	9.90	9.90	9.89	9.89
CaO	6.32	6.37	6.42	6.55	6.65	6.57	6.63	6.77	6.72	6.84	6.78
Cl	0.09	0.10	0.10	0.11	0.10	0.13	0.12	0.12	0.12	0.12	0.13
Cr_2O_3	0.08	0.20	0.21	0.18	0.19	0.19	0.19	0.17	0.16	0.17	0.17
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.44	6.02	6.01	6.05	5.98	6.09	6.13	6.00	5.96	6.01	6.04
I	0.10	<0.005	<0.005	0.007	0.008	0.006	0.012	0.008	0.009	0.006	0.005
K_2O	0.54	0.77	0.78	0.81	0.77	0.76	0.81	0.78	0.77	0.77	0.83
Li_2O*	3.18	2.85	2.93	2.99	3.03	3.07	3.10	3.12	3.13	3.14	3.15
MgO	1.49	1.45	1.46	1.44	1.47	1.44	1.45	1.48	1.42	1.48	1.44
Na_2O	13.38	13.19	13.21	12.42	13.04	12.58	12.66	12.32	12.24	11.95	12.50
NiO	0.01	0.03	0.04	0.03	0.03	0.04	0.03	0.04	0.04	0.04	0.04
P_2O_5	0.12	0.20	0.18	0.18	0.16	0.17	0.17	0.19	0.18	0.18	0.18
PbO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	<0.01	0.02	0.01	0.01
ReO_2	0.10	0.032	0.043	0.039	0.052	0.049	0.049	0.042	0.053	0.050	0.044
SiO_2	44.84	44.45	44.13	44.65	44.03	44.52	44.35	44.50	44.77	44.77	44.17
SO_3	0.51	0.51	0.56	0.56	0.58	0.61	0.60	0.62	0.62	0.59	0.65
TiO_2	1.38	1.68	1.67	1.73	1.69	1.66	1.64	1.68	1.68	1.64	1.65
ZnO	3.47	3.59	3.55	3.63	3.65	3.55	3.59	3.62	3.57	3.61	3.65
ZrO_2	2.97	3.17	3.19	3.22	3.19	3.16	3.23	3.19	3.21	3.23	3.22
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	8									
Mass (kg)		841.87	844.45	846.95	849.05	851.23	853.43	855.47	857.47	859.57	861.77
Sample		10U-G-101B	10U-G-101C	10U-G-106A	10U-G-106B	10U-G-107A	10U-G-107B	10U-G-107C	10U-G-107D	10U-G-107E	10U-G-109A
Al_2O_3	6.03	5.44	5.39	5.34	5.42	5.39	5.44	5.44	5.50	5.49	5.35
B_2O_3*	9.89	9.89	9.89	9.89	9.89	9.89	9.89	9.89	9.89	9.89	9.89
CaO	6.32	6.86	6.86	6.96	6.79	6.75	6.72	6.76	6.79	6.83	6.72
Cl	0.09	0.13	0.13	0.13	0.13	0.12	0.14	0.12	0.13	0.13	0.12
Cr_2O_3	0.08	0.16	0.16	0.17	0.17	0.17	0.16	0.17	0.15	0.16	0.21
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.44	6.11	6.12	6.15	6.09	5.96	5.99	5.91	5.93	5.91	5.91
I	0.10	0.035	0.025	0.008	0.007	0.005	0.008	0.008	0.025	0.016	0.007
K_2O	0.54	0.77	0.78	0.78	0.80	0.83	0.79	0.79	0.81	0.79	0.76
Li_2O*	3.18	3.16	3.16	3.16	3.17	3.17	3.17	3.17	3.17	3.17	3.17
MgO	1.49	1.44	1.41	1.39	1.39	1.38	1.46	1.45	1.40	1.37	1.39
Na_2O	13.38	11.97	12.63	11.90	12.06	12.56	12.64	12.52	12.35	12.45	12.92
NiO	0.01	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.03	0.03	0.03
P_2O_5	0.12	0.19	0.17	0.18	0.18	0.19	0.17	0.18	0.17	0.19	0.18
PbO	0.01	0.01	<0.01	0.01	0.01	0.01	<0.01	0.01	0.01	0.01	<0.01
ReO_2	0.10	0.056	0.050	0.058	0.050	0.063	0.063	0.054	0.050	0.071	0.063
SiO_2	44.84	44.53	44.06	44.51	44.53	44.32	44.39	44.52	44.57	44.51	44.35
SO_3	0.51	0.64	0.64	0.68	0.74	0.70	0.62	0.70	0.65	0.68	0.69
TiO_2	1.38	1.69	1.70	1.71	1.69	1.70	1.63	1.63	1.64	1.63	1.62
ZnO	3.47	3.67	3.59	3.67	3.64	3.57	3.55	3.51	3.59	3.53	3.55
ZrO_2	2.97	3.23	3.20	3.27	3.22	3.19	3.14	3.12	3.15	3.14	3.05
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	8									
Mass (kg)		863.99	866.17	868.53	870.89	873.21	875.71	878.77	881.57	883.93	886.05
Sample		10U-G-109B	10U-G-116A	10U-G-116B	10U-G-116C	10U-G-116D	10U-G-117A	10U-G-117B	10U-G-117C	10U-G-119A	10U-G-119B
Al_2O_3	6.03	5.36	5.36	5.42	5.45	5.56	5.47	5.44	5.41	5.60	5.43
B_2O_3*	9.89	9.89	9.89	9.89	9.89	9.89	9.89	9.89	9.89	9.89	9.89
CaO	6.32	6.76	6.80	6.92	6.66	6.61	6.69	6.76	6.52	6.58	6.64
Cl	0.09	0.15	0.12	0.14	0.14	0.13	0.13	0.15	0.13	0.12	0.14
Cr_2O_3	0.08	0.17	0.16	0.15	0.16	0.15	0.15	0.15	0.17	0.16	0.15
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.44	6.00	6.00	6.18	5.90	5.78	5.91	5.96	5.79	5.84	5.83
I	0.10	0.011	0.009	<0.005	<0.005	<0.005	0.016	0.008	0.006	0.013	0.013
K_2O	0.54	0.77	0.77	0.80	0.77	0.78	0.75	0.78	0.79	0.80	0.78
Li_2O*	3.18	3.17	3.17	3.17	3.17	3.18	3.18	3.18	3.18	3.18	3.18
MgO	1.49	1.45	1.42	1.42	1.46	1.41	1.48	1.47	1.44	1.39	1.44
Na_2O	13.38	12.59	12.06	11.91	12.95	12.98	12.27	12.37	13.62	12.89	12.82
NiO	0.01	0.03	0.04	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.03
P_2O_5	0.12	0.17	0.19	0.18	0.20	0.17	0.18	0.18	0.18	0.19	0.17
PbO	0.01	0.01	0.01	0.01	0.01	0.01	<0.01	0.02	0.01	0.01	0.01
ReO_2	0.10	0.049	0.076	0.061	0.053	0.052	0.061	0.069	0.059	0.058	0.053
SiO_2	44.84	44.28	44.66	44.46	44.34	44.56	44.82	44.57	44.17	44.48	44.56
SO_3	0.51	0.67	0.69	0.69	0.64	0.62	0.64	0.69	0.66	0.65	0.69
TiO_2	1.38	1.67	1.71	1.70	1.64	1.66	1.67	1.64	1.55	1.63	1.66
ZnO	3.47	3.65	3.63	3.66	3.45	3.40	3.54	3.53	3.40	3.46	3.48
ZrO_2	2.97	3.16	3.22	3.22	3.08	3.03	3.12	3.10	2.99	3.04	3.06
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	8									
Mass (kg)		888.01	890.67	893.29	895.35	898.21	900.71	902.95	905.07	907.33	909.93
Sample		10U-G-119C	10U-G-119D	10U-G-119E	10U-G-125A	10U-G-125B	10U-G-126A	10U-G-126B	10U-G-126C	10U-G-126D	10U-G-127A
Al_2O_3	6.03	5.49	5.50	5.51	5.33	5.43	5.52	5.55	5.52	5.50	5.43
B_2O_3*	9.89	9.89	9.89	9.89	9.89	9.89	9.89	9.89	9.89	9.89	9.89
CaO	6.32	6.62	6.62	6.61	6.59	6.68	6.75	6.73	6.73	6.82	6.67
Cl	0.09	0.13	0.13	0.12	0.12	0.14	0.15	0.14	0.13	0.13	0.14
Cr_2O_3	0.08	0.15	0.18	0.15	0.16	0.17	0.16	0.16	0.14	0.17	0.15
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.44	5.74	5.79	5.90	5.65	5.88	5.99	5.97	5.96	6.01	5.89
I	0.10	0.007	0.012	0.011	0.012	0.008	0.008	0.005	0.013	0.004	0.008
K_2O	0.54	0.74	0.78	0.80	0.80	0.76	0.85	0.82	0.81	0.77	0.81
Li_2O*	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18
MgO	1.49	1.43	1.40	1.44	1.38	1.45	1.42	1.48	1.38	1.36	1.42
Na_2O	13.38	12.79	13.43	13.38	13.11	12.77	12.14	11.96	12.04	11.88	12.75
NiO	0.01	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.04	0.04	0.03
P_2O_5	0.12	0.17	0.18	0.18	0.21	0.18	0.18	0.17	0.17	0.21	0.18
PbO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
ReO_2	0.10	0.054	0.048	0.057	0.060	0.052	0.052	0.052	0.062	0.051	0.059
SiO_2	44.84	44.88	44.23	44.08	44.66	44.47	44.54	44.88	44.79	44.90	44.44
SO_3	0.51	0.65	0.65	0.66	0.66	0.66	0.70	0.65	0.68	0.67	0.64
TiO_2	1.38	1.63	1.60	1.56	1.63	1.64	1.69	1.69	1.69	1.69	1.62
ZnO	3.47	3.39	3.38	3.41	3.48	3.51	3.59	3.52	3.60	3.58	3.53
ZrO_2	2.97	3.02	2.97	3.03	3.04	3.09	3.16	3.14	3.17	3.16	3.13
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	8									
Mass (kg)		912.39	914.83	917.33	920.39	922.81	925.11	928.47	930.83	933.47	935.89
Sample		10U-G-127B	10U-G-134A	10U-G-134B	10U-G-134C	10U-G-134D	10U-G-134E	10U-G-136A	10U-G-136B	10U-G-136C	10U-G-136D
Al_2O_3	6.03	5.53	5.40	5.42	5.44	5.42	5.48	5.46	5.46	5.36	5.47
B_2O_3*	9.89	9.89	9.89	9.89	9.89	9.89	9.89	9.89	9.89	9.89	9.89
CaO	6.32	6.86	6.67	6.66	6.80	6.81	6.75	6.86	6.78	6.76	6.82
Cl	0.09	0.16	0.14	0.16	0.14	0.13	0.13	0.15	0.14	0.13	0.15
Cr_2O_3	0.08	0.17	0.16	0.16	0.15	0.16	0.15	0.15	0.18	0.15	0.16
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.02#
Fe_2O_3	5.44	5.98	5.86	6.07	5.91	5.86	5.97	5.95	6.06	5.96	5.99
I	0.10	0.012	0.009	0.014	<0.005	0.014	0.003	0.004	0.009	0.008	<0.005
K_2O	0.54	0.78	0.81	0.80	0.81	0.75	0.82	0.78	0.82	0.83	0.82
Li_2O*	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18	3.18
MgO	1.49	1.40	1.42	1.40	1.40	1.38	1.38	1.43	1.41	1.34	1.42
Na_2O	13.38	12.12	12.68	12.62	12.06	12.03	12.53	12.02	12.45	12.45	11.78
NiO	0.01	0.03	0.03	0.04	0.04	0.04	0.04	0.03	0.03	0.04	0.03
P_2O_5	0.12	0.18	0.19	0.19	0.17	0.18	0.20	0.20	0.17	0.18	0.19
PbO	0.01	0.01	0.01	<0.01	0.01	0.01	0.01	0.01	<0.01	0.01	0.01
ReO_2	0.10	0.054	0.066	0.084	0.060	0.064	0.052	0.062	0.075	0.064	0.067
SiO_2	44.84	44.51	44.68	44.45	44.83	45.00	44.36	44.77	44.43	44.57	44.73
SO_3	0.51	0.66	0.71	0.67	0.68	0.69	0.63	0.68	0.62	0.66	0.67
TiO_2	1.38	1.69	1.62	1.59	1.68	1.66	1.67	1.66	1.64	1.68	1.74
ZnO	3.47	3.60	3.45	3.51	3.56	3.58	3.58	3.59	3.52	3.58	3.65
ZrO_2	2.97	3.19	3.02	3.10	3.18	3.14	3.17	3.13	3.14	3.17	3.23
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
# - Analyzed by XRF
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

	8				9							
Mass (kg)	Target	938.07	Ave.	% Dev.	Target	939.49	943.05	944.77	946.99	949.09	951.07	952.79
Sample		10U-G-146A				10V-G-31A	10V-G-31B	10V-G-31C	10V-G-33A	10V-G-33B	10V-G-34A	10V-G-34B
Al_2O_3	6.03	5.47	5.45	-9.66	6.08	6.26	6.01	6.02	5.89	5.81	5.92	5.82
B_2O_3*	9.89	9.89	9.89	NC	9.96	9.39$	9.56	9.62	9.69	9.74	9.78	9.81
CaO	6.32	6.84	6.73	6.50	6.89	6.73	6.93	7.05	6.99	7.14	7.17	7.18
Cl	0.09	0.13	0.13	NC	0.09	0.03	0.04	0.05	0.07	0.07	0.08	0.08
Cr_2O_3	0.08	0.17	0.16	NC	0.08	0.34	0.29	0.25	0.23	0.20	0.19	0.18
F	0.07	NA	NA	NC	0.07	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.44	5.97	5.96	9.51	5.47	5.90	5.91	6.08	6.17	6.12	6.04	5.92
I	0.10	0.009	0.010	NC	0.10	<0.005	0.012	0.019	0.013	0.018	0.006	0.013
K_2O	0.54	0.81	0.79	NC	0.54	0.75	0.73	0.69	0.71	0.71	0.67	0.66
Li_2O*	3.18	3.18	3.16	NC	4.10	3.39$	3.60	3.68	3.76	3.83	3.87	3.91
MgO	1.49	1.39	1.42	-4.81	2.37	1.70	1.94	1.86	1.92	2.12	2.13	2.25
Na_2O	13.38	11.77	12.47	-6.78	8.69	12.55	11.23	10.70	10.21	9.69	9.59	9.48
NiO	0.01	0.03	0.03	NC	0.01	0.05	0.04	0.04	0.05	0.04	0.04	0.05
P_2O_5	0.12	0.19	0.18	NC	0.12	0.16	0.19	0.17	0.17	0.17	0.20	0.17
PbO	0.01	<0.01	0.01	NC	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
ReO_2	0.10	0.049	0.057	NC	0.10	0.018	0.025	0.037	0.033	0.044	0.055	0.054
SiO_2	44.84	44.99	44.53	-0.68	46.98	44.19	44.92	45.23	45.44	45.64	45.64	45.88
SO_3	0.51	0.65	0.66	NC	0.49	0.53	0.54	0.50	0.54	0.52	0.57	0.56
TiO_2	1.38	1.68	1.66	19.96	1.40	1.69	1.64	1.63	1.63	1.65	1.66	1.61
ZnO	3.47	3.59	3.55	2.55	3.48	3.31	3.37	3.40	3.41	3.41	3.40	3.40
ZrO_2	2.97	3.19	3.14	5.94	2.98	3.00	3.02	2.96	3.05	3.07	2.99	2.97
Sum	100.00	100.00	100.00	NC	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
$ - DCP-AES results
NA – Not analyzed
NC – Not calculated

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	9									
Mass (kg)		955.25	957.49	959.41	961.27	962.89	965.73	967.87	969.97	971.77	974.79
Sample		10V-G-34C	10V-G-34D	10V-G-39A	10V-G-39B	10V-G-40A	10V-G-40B	10V-G-41A	10V-G-41B	10V-G-44A	10V-G-44B
Al_2O_3	6.08	5.77	5.76	5.72	5.61	5.77	5.66	5.85	5.76	5.75	5.77
B_2O_3*	9.96	9.84	9.87	9.88	9.90	9.91	9.92	9.93	9.93	9.94	9.94
CaO	6.89	7.19	7.25	7.36	7.18	7.23	7.22	7.22	7.32	7.30	7.27
Cl	0.09	0.08	0.08	0.09	0.09	0.09	0.09	0.10	0.09	0.09	0.09
Cr_2O_3	0.08	0.19	0.17	0.15	0.16	0.17	0.17	0.17	0.15	0.16	0.15
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.47	6.19	6.18	6.18	6.32	6.09	6.12	6.11	6.24	6.01	5.97
I	0.10	0.013	0.032	0.017	0.026	0.033	0.021	0.014	0.024	0.029	0.028
K_2O	0.54	0.69	0.68	0.69	0.66	0.65	0.66	0.63	0.70	0.67	0.71
Li_2O*	4.10	3.95	3.98	4.00	4.02	4.03	4.04	4.05	4.06	4.07	4.08
MgO	2.37	2.25	2.23	2.29	2.24	2.27	2.34	2.28	2.25	2.29	2.29
Na_2O	8.69	9.05	9.00	8.93	9.03	8.87	8.83	8.85	8.46	8.46	8.62
NiO	0.01	0.03	0.04	0.04	0.03	0.03	0.03	0.04	0.03	0.04	0.04
P_2O_5	0.12	0.16	0.18	0.17	0.18	0.17	0.17	0.17	0.18	0.16	0.19
PbO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
ReO_2	0.10	0.054	0.070	0.062	0.061	0.060	0.072	0.069	0.079	0.061	0.065
SiO_2	46.98	45.80	45.79	45.80	45.86	45.90	45.92	45.94	46.06	46.33	46.24
SO_3	0.49	0.53	0.55	0.52	0.52	0.55	0.53	0.53	0.55	0.54	0.53
TiO_2	1.40	1.67	1.60	1.65	1.67	1.70	1.68	1.63	1.65	1.68	1.66
ZnO	3.48	3.44	3.46	3.42	3.41	3.42	3.48	3.41	3.43	3.40	3.37
ZrO_2	2.98	3.10	3.06	3.04	3.04	3.04	3.03	3.00	3.04	3.00	3.00
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	9									
Mass (kg)		977.95	980.11	982.15	984.25	986.23	988.45	990.49	992.33	994.23	996.39
Sample		10V-G-44C	10V-G-45A	10V-G-45B	10V-G-45C	10V-G-45D	10V-G-51A	10V-G-51B	10V-G-51C	10V-G-53A	10V-G-53B
Al_2O_3	6.08	5.69	5.76	5.82	5.77	5.76	5.72	5.72	5.71	5.69	5.81
B_2O_3*	9.96	9.95	9.95	9.95	9.95	9.95	9.96	9.96	9.96	9.96	9.96
CaO	6.89	7.19	7.20	7.00	7.18	7.04	7.19	7.18	7.34	7.39	7.21
Cl	0.09	0.08	0.09	0.09	0.09	0.09	0.09	0.11	0.10	0.10	0.10
Cr_2O_3	0.08	0.15	0.16	0.16	0.15	0.15	0.13	0.16	0.15	0.17	0.13
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.47	6.10	6.14	5.97	6.02	6.12	6.11	6.08	6.30	6.14	6.28
I	0.10	0.032	0.020	0.030	0.030	0.030	0.040	0.023	0.032	0.028	0.041
K_2O	0.54	0.71	0.67	0.63	0.65	0.66	0.65	0.67	0.66	0.66	0.64
Li_2O*	4.10	4.08	4.08	4.09	4.09	4.09	4.09	4.09	4.09	4.09	4.09
MgO	2.37	2.34	2.39	2.47	2.39	2.34	2.33	2.41	2.34	2.33	2.33
Na_2O	8.69	8.42	8.28	8.90	8.85	9.08	8.67	8.68	8.15	8.32	8.48
NiO	0.01	0.04	0.03	0.03	0.03	0.05	0.04	0.04	0.04	0.04	0.03
P_2O_5	0.12	0.17	0.16	0.17	0.18	0.17	0.17	0.19	0.17	0.15	0.16
PbO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
ReO_2	0.10	0.067	0.056	0.064	0.069	0.073	0.072	0.067	0.077	0.066	0.078
SiO_2	46.98	46.24	46.44	46.26	46.03	45.96	46.15	45.97	46.11	46.05	45.92
SO_3	0.49	0.54	0.52	0.50	0.54	0.48	0.53	0.53	0.53	0.56	0.54
TiO_2	1.40	1.66	1.62	1.66	1.61	1.63	1.60	1.69	1.65	1.66	1.66
ZnO	3.48	3.46	3.42	3.27	3.37	3.34	3.42	3.40	3.52	3.53	3.47
ZrO_2	2.98	3.07	3.01	2.93	2.99	2.98	3.03	3.01	3.09	3.08	3.04
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	9									
Mass (kg)		998.47	1000.49	1002.35	1004.37	1006.59	1009.11	1011.51	1013.49	1015.45	1017.49
Sample		10V-G-53C	10V-G-54A	10V-G-54B	10V-G-54C	10V-G-60A	10V-G-60B	10V-G-61A	10V-G-61B	10V-G-61C	10V-G-61D
Al_2O_3	6.08	5.76	5.56	5.63	5.78	5.72	5.78	5.67	5.70	5.64	5.66
B_2O_3*	9.96	9.96	9.96	9.96	9.96	9.96	9.96	9.96	9.96	9.96	9.96
CaO	6.89	7.06	7.35	7.27	7.18	7.18	7.28	7.11	7.16	7.10	7.11
Cl	0.09	0.09	0.10	0.12	0.10	0.10	0.11	0.11	0.10	0.10	0.11
Cr_2O_3	0.08	0.17	0.16	0.15	0.14	0.16	0.14	0.14	0.14	0.14	0.15
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.47	6.13	6.13	6.21	6.21	6.05	6.00	5.98	5.76	5.78	5.83
I	0.10	0.014	0.038	0.039	0.033	0.021	0.033	0.030	0.025	0.026	0.039
K_2O	0.54	0.70	0.70	0.66	0.67	0.66	0.66	0.67	0.66	0.63	0.66
Li_2O*	4.10	4.09	4.09	4.09	4.09	4.10	4.10	4.10	4.10	4.10	4.10
MgO	2.37	2.35	2.38	2.29	2.41	2.40	2.28	2.35	2.45	2.31	2.34
Na_2O	8.69	8.82	8.58	8.20	8.44	8.53	8.50	8.70	8.51	8.71	8.37
NiO	0.01	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.05	0.05
P_2O_5	0.12	0.17	0.16	0.18	0.18	0.18	0.17	0.18	0.16	0.17	0.18
PbO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
ReO_2	0.10	0.074	0.078	0.085	0.084	0.088	0.080	0.082	0.095	0.098	0.096
SiO_2	46.98	45.89	45.87	46.27	45.99	46.12	46.21	46.38	46.60	46.60	46.54
SO_3	0.49	0.56	0.53	0.55	0.54	0.54	0.56	0.56	0.56	0.56	0.60
TiO_2	1.40	1.67	1.69	1.68	1.65	1.66	1.67	1.58	1.66	1.61	1.62
ZnO	3.48	3.41	3.47	3.48	3.46	3.47	3.42	3.41	3.38	3.44	3.55
ZrO_2	2.98	3.03	3.10	3.09	3.01	3.03	3.00	2.96	2.95	2.98	3.04
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	9									
Mass (kg)		1019.67	1021.71	1023.69	1025.95	1028.13	1030.19	1032.35	1034.47	1036.83	1039.05
Sample		10V-G-63A	10V-G-63B	10V-G-63C	10V-G-63D	10V-G-69A	10V-G-69B	10V-G-69C	10V-G-69D	10V-G-69E	10V-G-71A
Al_2O_3	6.08	5.68	5.77	5.69	5.69	5.67	5.80	5.75	5.69	5.70	5.59
B_2O_3*	9.96	9.96	9.96	9.96	9.96	9.96	9.96	9.96	9.96	9.96	9.96
CaO	6.89	7.19	7.03	7.17	7.15	7.15	7.04	7.07	7.23	7.23	7.25
Cl	0.09	0.11	0.11	0.13	0.10	0.11	0.11	0.11	0.10	0.10	0.11
Cr_2O_3	0.08	0.16	0.16	0.15	0.15	0.14	0.13	0.16	0.13	0.16	0.15
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.47	5.77	5.74	5.69	5.85	5.62	5.64	5.54	5.76	5.69	5.57
I	0.10	0.030	0.031	0.027	0.035	0.028	0.033	0.029	0.027	0.026	0.028
K_2O	0.54	0.71	0.66	0.66	0.68	0.64	0.67	0.69	0.70	0.67	0.67
Li_2O*	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10
MgO	2.37	2.40	2.36	2.35	2.27	2.42	2.40	2.37	2.34	2.26	2.25
Na_2O	8.69	8.30	8.58	8.70	8.32	8.78	8.75	8.25	8.86	8.46	8.71
NiO	0.01	0.04	0.04	0.04	0.05	0.05	0.04	0.04	0.05	0.05	0.04
P_2O_5	0.12	0.19	0.17	0.18	0.19	0.17	0.17	0.18	0.17	0.19	0.18
PbO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	<0.01	0.01	<0.01
ReO_2	0.10	0.096	0.087	0.099	0.100	0.084	0.088	0.091	0.097	0.078	0.081
SiO_2	46.98	46.64	46.69	46.63	46.56	46.47	46.58	47.13	46.06	46.62	46.64
SO_3	0.49	0.58	0.56	0.57	0.58	0.56	0.57	0.58	0.51	0.56	0.55
TiO_2	1.40	1.59	1.60	1.56	1.67	1.62	1.58	1.59	1.66	1.62	1.62
ZnO	3.48	3.45	3.42	3.39	3.55	3.48	3.42	3.43	3.53	3.53	3.52
ZrO_2	2.98	3.00	2.93	2.92	3.00	2.94	2.94	2.92	3.02	3.02	2.99
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	9									
Mass (kg)		1041.13	1043.41	1045.55	1047.57	1050.03	1052.05	1053.97	1056.05	1058.33	1060.49
Sample		10V-G-71B	10V-G-71C	10V-G-73A	10V-G-73B	10V-G-73C	10V-G-78A	10V-G-78B	10V-G-78C	10V-G-79A	10V-G-79B
Al_2O_3	6.08	5.62	5.70	5.65	5.63	5.66	5.67	5.67	5.71	5.64	5.59
B_2O_3*	9.96	9.96	9.96	9.96	9.96	9.96	9.96	9.96	9.96	9.96	9.96
CaO	6.89	7.29	7.22	7.08	7.19	7.27	7.10	7.16	7.21	7.19	7.29
Cl	0.09	0.11	0.11	0.11	0.11	0.12	0.12	0.12	0.11	0.10	0.13
Cr_2O_3	0.08	0.16	0.16	0.17	0.16	0.16	0.14	0.14	0.15	0.15	0.16
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Fe_2O_3	5.47	5.76	5.78	5.72	5.64	5.64	5.58	5.53	5.49	5.74	5.54
I	0.10	0.032	0.024	0.028	0.033	0.011	0.027	0.026	0.030	0.017	0.038
K_2O	0.54	0.69	0.69	0.69	0.70	0.70	0.65	0.69	0.70	0.65	0.69
Li_2O*	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10
MgO	2.37	2.28	2.19	2.18	2.18	2.22	2.19	2.17	2.20	2.28	2.26
Na_2O	8.69	8.55	8.44	9.32	8.85	8.49	8.92	8.70	8.45	8.52	8.37
NiO	0.01	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.03
P_2O_5	0.12	0.17	0.18	0.18	0.17	0.18	0.18	0.18	0.18	0.17	0.18
PbO	0.01	0.01	0.01	0.01	0.01	<0.01	0.01	0.01	0.01	0.01	0.01
ReO_2	0.10	0.089	0.100	0.081	0.090	0.091	0.093	0.090	0.098	0.089	0.094
SiO_2	46.98	46.32	46.51	45.97	46.27	46.61	46.43	46.80	46.80	46.54	46.67
SO_3	0.49	0.57	0.56	0.56	0.61	0.56	0.55	0.56	0.59	0.58	0.58
TiO_2	1.40	1.65	1.66	1.61	1.60	1.60	1.63	1.56	1.63	1.69	1.63
ZnO	3.48	3.58	3.55	3.55	3.61	3.59	3.59	3.53	3.56	3.56	3.63
ZrO_2	2.98	3.03	3.02	2.99	3.06	2.98	3.01	2.97	2.99	2.99	3.07
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	9									
Mass (kg)		1062.83	1064.91	1066.93	1069.09	1071.05	1072.95	1074.91	1077.11	1079.45	1081.63
Sample		10V-G-79C	10V-G-79D	10V-G-81A	10V-G-81B	10V-G-81C	10V-G-81D	10V-G-81E	10V-G-81F	10V-G-88A	10V-G-88B
Al_2O_3	6.08	5.70	5.75	5.66	5.67	5.67	5.67	5.65	5.62	5.65	5.60
B_2O_3*	9.96	9.96	9.96	9.96	9.96	9.96	9.96	9.96	9.96	9.96	9.96
CaO	6.89	7.11	7.06	7.11	7.07	7.14	7.15	7.14	7.10	7.19	7.18
Cl	0.09	0.11	0.13	0.11	0.13	0.11	0.11	0.11	0.12	0.11	0.12
Cr_2O_3	0.08	0.15	0.16	0.14	0.14	0.14	0.15	0.17	0.16	0.15	0.15
F	0.07	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.02
Fe_2O_3	5.47	5.48	5.38	5.47	5.57	5.54	5.50	5.47	5.54	5.41	5.56
I	0.10	0.021	0.018	0.035	0.036	0.022	0.031	0.033	0.035	0.032	0.016
K_2O	0.54	0.72	0.67	0.69	0.69	0.68	0.68	0.63	0.67	0.69	0.71
Li_2O*	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10	4.10
MgO	2.37	2.31	2.24	2.32	2.28	2.40	2.27	2.26	2.26	2.36	2.22
Na_2O	8.69	8.69	8.79	8.72	8.61	8.71	8.61	8.64	8.78	8.67	8.72
NiO	0.01	0.03	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.05
P_2O_5	0.12	0.17	0.17	0.17	0.19	0.17	0.18	0.17	0.17	0.17	0.19
PbO	0.01	0.01	<0.01	0.01	0.01	0.01	<0.01	<0.01	0.01	<0.01	0.01
ReO_2	0.10	0.075	0.078	0.090	0.096	0.088	0.077	0.098	0.091	0.095	0.088
SiO_2	46.98	46.68	47.04	46.70	46.67	46.45	46.66	46.67	46.61	46.75	46.66
SO_3	0.49	0.54	0.54	0.58	0.57	0.57	0.59	0.60	0.57	0.57	0.60
TiO_2	1.40	1.60	1.61	1.63	1.62	1.64	1.61	1.66	1.60	1.60	1.60
ZnO	3.48	3.56	3.47	3.55	3.61	3.57	3.59	3.59	3.58	3.53	3.55
ZrO_2	2.98	2.99	2.80	2.92	2.96	3.00	3.03	3.00	2.98	2.93	2.91
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
# - Analyzed by XRF
NA – Not analyzed

Table 5.3. XRF Analyzed Compositions of Discharged Glass (wt%) (continued).

Test	Target	9		
Mass (kg)		1083.77	Ave.	% Dev.
Sample		10V-G-93A		
Al_2O_3	6.08	5.71	5.70	-6.25
B_2O_3*	9.96	9.96	9.96	NC
CaO	6.89	7.16	7.18	4.21
Cl	0.09	0.11	0.11	NA
Cr_2O_3	0.08	0.16	0.15	NC
F	0.07	NA	NA	NC
Fe_2O_3	5.47	5.50	5.81	6.12
I	0.10	0.022	0.028	NC
K_2O	0.54	0.71	0.67	NC
Li_2O*	4.10	4.10	4.09	NC
MgO	2.37	2.31	2.31	-2.43
Na_2O	8.69	8.61	8.61	-0.99
NiO	0.01	0.04	0.04	NC
P_2O_5	0.12	0.18	0.17	NC
PbO	0.01	0.01	0.01	NC
ReO_2	0.10	0.105	0.084	NC
SiO_2	46.98	46.54	46.41	-1.22
SO_3	0.49	0.58	0.56	NC
TiO_2	1.40	1.62	1.63	16.85
ZnO	3.48	3.58	3.49	0.18
ZrO_2	2.98	2.98	3.00	0.49
Sum	100.00	100.00	100.00	NC

* Values calculated from B_2O_3 and Li_2O analysis by DCP-AES on the first discharged glass sample and the target concentration using a simple well stirred tank model.
NA – Not analyzed
NC – Not calculated

Table 5.4. DCP and XRF Analyzed Composition for Initial Glass Discharge Samples (wt%).

Test	1		2	
Sample	10Q-G-89A		10R-G-27A	
Oxide	XRF	DCP	XRF	DCP
Al_2O_3	5.55	5.78	5.93	6.14
B_2O_3	9.77[$]	9.77	10.77[$]	10.77
CaO	2.76	2.74	2.46	2.43
Cl	0.12	NA	0.02	NA
Cr_2O_3	0.25	0.21	0.32	0.27
F	NA	NA	NA	NA
Fe_2O_3	5.38	5.09	5.28	4.98
I	0.022	NA	0.006	NA
K_2O	0.74	0.79	0.59	0.64
Li_2O	0.68[$]	0.68	0.06[$]	0.06
MgO	1.64	1.75	1.20	1.35
Na_2O	20.16	17.79	21.30	19.18
NiO	0.07	0.07	0.02	0.03
P_2O_5	0.16	0.18	0.17	0.29
PbO	0.01	0.01	0.00	0.01
ReO_2	0.042	NA	0.017	NA
SiO_2	45.77	43.85	44.12	42.04
SO_3	0.37	NA	0.39	NA
TiO_2	1.08	1.11	1.43	1.45
ZnO	2.61	2.79	3.26	3.45
ZrO_2	2.83	3.06	2.67	2.82
Sum	100.00	95.72	100.00	95.94

[$] - DCP-AES analyzed values are used in normalization of XRF results
NA – Not Analyzed

Table 5.4. DCP and XRF Analyzed Composition for Initial Glass Discharge Samples (wt%) (continued).

Test	3		4	
Sample	10R-G-120A		10S-G-42A	
Oxide	XRF	DCP	XRF	DCP
Al_2O_3	5.83	6.08	5.90	6.21
B_2O_3	10.27[$]	10.27	9.65[$]	9.65
CaO	2.76	2.65	4.40	3.86
Cl	0.03	NA	0.05	NA
Cr_2O_3	0.34	0.27	0.25	0.20
F	NA	NA	NA	NA
Fe_2O_3	5.49	5.00	5.67	5.11
I	<0.005	NA	0.006	NA
K_2O	0.61	0.65	0.80	0.85
Li_2O	0.11[$]	0.11	1.44[$]	1.44
MgO	1.26	1.36	1.79	1.81
Na_2O	21.21	19.03	16.24	15.30
NiO	0.03	0.03	0.02	0.03
P_2O_5	0.16	0.27	0.18	0.42
PbO	<0.01	0.01	0.01	0.01
ReO_2	0.016	NA	0.027	NA
SiO_2	43.88	42.09	45.11	43.17
SO_3	0.40	NA	0.49	NA
TiO_2	1.49	1.48	1.65	1.64
ZnO	3.37	3.51	3.43	3.50
ZrO_2	2.74	2.77	2.90	2.85
Sum	100.00	95.62	100.00	96.10

[$] - DCP-AES analyzed values are used in normalization of XRF results
NA – Not Analyzed

Table 5.4. DCP and XRF Analyzed Composition for Initial Glass Discharge Samples (wt%) (continued).

Test	5		6	
Sample	10S-G-102A		10T-G-54A	
Oxide	XRF	DCP	XRF	DCP
Al_2O_3	6.88	6.52	6.32	6.27
B_2O_3	9.12[$]	9.12	10.06[$]	10.06
CaO	6.60	5.99	5.01	4.65
Cl	0.03	NA	0.03	NA
Cr_2O_3	0.16	0.14	0.45	0.46
F	NA	NA	NA	NA
Fe_2O_3	5.52	5.11	5.55	5.14
I	<0.003	NA	<0.003	NA
K_2O	0.57	0.62	1.21	1.26
Li_2O	3.58[$]	3.58	2.25[$]	2.25
MgO	2.58	2.68	1.50	1.70
Na_2O	9.01	7.89	16.13	12.89
NiO	0.04	0.04	0.05	0.05
P_2O_5	0.19	0.28	0.17	0.30
PbO	0.01	0.03	0.01	0.03
ReO_2	0.019	NA	<0.005	NA
SiO_2	48.19	46.41	43.25	43.33
SO_3	0.14	NA	0.35	NA
TiO_2	1.48	1.6	1.54	1.63
ZnO	2.94	3.03	3.28	3.35
ZrO_2	2.92	3.01	2.84	2.88
Sum	100.00	96.05	100.00	96.25

[$] - DCP-AES analyzed values are used in normalization of XRF results
NA – Not Analyzed
§ - Not a target constituent.

Table 5.4. DCP and XRF Analyzed Composition for Initial Glass Discharge Samples (wt%) (continued).

Test	7		8	
Sample	10T-G-139A		10U-G-91A	
Oxide	XRF	DCP	XRF	DCP
Al_2O_3	5.87	6.12	6.38	7.26
B_2O_3	10.69[$]	10.69	10.38[$]	10.38
CaO	2.63	2.46	2.72	2.81
Cl	0.03	NA	0.01	NA
Cr_2O_3	0.33	0.33	0.46	0.46
F	NA	NA	NA	NA
Fe_2O_3	5.63	5.10	5.62	5.70
I	0.015	NA	<0.005	NA
K_2O	1.50	1.48	0.62	0.61
Li_2O	0.15[$]	0.15	0.18[$]	0.18
MgO	1.10	1.40	1.59	1.76
Na_2O	20.47	16.77	20.37	19.15
NiO	0.08	0.06	0.07	0.06
P_2O_5	0.16	0.03	0.17	0.23
PbO	0.01	0.02	0.01	0.02
ReO_2	0.015	NA	<0.005	NA
SiO_2	42.97	42.86	43.52	43.17
SO_3	0.38	NA	0.26	NA
TiO_2	1.49	1.49	1.51	1.64
ZnO	3.50	3.42	3.13	3.12
ZrO_2	2.99	2.74	2.98	3.17
Sum	100.00	95.12	100.00	99.73

[$] - DCP-AES analyzed values are used in normalization of XRF results
NA – Not Analyzed
§ - Not a target constituent.

Table 5.4. DCP and XRF Analyzed Composition for Initial Glass Discharge Samples (wt%) (continued).

Test	9	
Sample	10V-G-31A	
Oxide	XRF	DCP
Al_2O_3	6.26	6.06
B_2O_3	9.39[$]	9.39
CaO	6.73	5.97
Cl	0.03	NA
Cr_2O_3	0.34	0.35
F	NA	NA
Fe_2O_3	5.90	5.27
I	<0.005	NA
K_2O	0.75	0.78
Li_2O	3.39[$]	3.39
MgO	1.70	1.88
Na_2O	12.55	11.06
NiO	0.05	0.05
P_2O_5	0.16	0.18
PbO	0.01	<0.01
ReO_2	0.018	NA
SiO_2	44.19	44.59
SO_3	0.53	NA
TiO_2	1.69	1.67
ZnO	3.31	3.17
ZrO_2	3.00	2.77
Sum	100.00	96.61

[$] - DCP-AES analyzed values are used in normalization of XRF results
NA – Not Analyzed

Table 5.5. XRF Analyzed Composition for Dip Samples (wt%).

Test Constituent	Target	Before 1 10Q-D-88A	After 1 10Q-D-147A	Before 2 10R-D-12A	After 2 10R-D-77A	Before 3 10R-D-120A	Target	After 3 10S-D-19A	Before 4 10S-D-42A	Target	After 4 10S-D-93A
Al_2O_3	5.98	5.44	5.63	5.87	5.42	5.84	6.00	5.70	6.03	6.10	5.57
B_2O_3*	9.80	9.77	10.77	10.77	10.27	10.27	9.83	9.65	9.65	10.00	9.12
CaO	2.46	2.82	2.46	2.51	2.67	2.59	3.62	3.64	3.71	6.99	7.52
Cl	0.09	0.13	0.10	0.02	0.16	0.02	0.09	0.17	0.04	0.09	0.12
Cr_2O_3	0.08	0.24	0.21	0.29	0.20	0.30	0.08	0.20	0.24	0.08	0.15
F	0.07	NA	NA	NA	NA	NA	0.07	NA	NA	0.07	NA
Fe_2O_3	5.39	5.48	5.21	5.34	5.58	5.28	5.41	5.42	5.53	5.51	5.92
I	0.10	0.028	0.029	NA	0.039	0.006	0.10	0.021	NA	0.10	0.070
K_2O	0.54	0.76	0.62	0.59	0.63	0.59	0.54	0.82	0.82	0.54	0.67
Li_2O*	§	0.68	0.06	0.06	0.11	0.11	0.49	1.44	1.44	4.28	3.58
MgO	1.45	1.78	1.24	1.32	1.58	1.31	1.45	1.65	1.55	2.95	3.13
Na_2O	21.14	19.61	21.49	21.11	21.03	21.90	18.84	19.30	18.18	5.45	5.42
NiO	0.01	0.07	0.01	0.02	0.02	0.02	0.01	0.02	0.02	0.01	0.03
P_2O_5	0.12	0.16	0.20	0.16	0.17	0.17	0.12	0.16	0.18	0.12	0.18
PbO	0.01	0.01	<0.01	<0.01	0.01	<0.01	0.01	0.01	0.01	0.01	0.01
ReO_2	0.10	0.034	0.061	<0.005	0.097	<0.005	0.10	0.081	0.011	0.10	0.079
SiO_2	44.56	46.07	44.08	44.01	43.65	43.87	45.11	43.54	44.33	49.15	49.27
SO_3	0.35	0.37	0.41	0.40	0.43	0.38	0.39	0.45	0.45	0.56	0.94
TiO_2	1.37	1.05	1.47	1.47	1.53	1.44	1.37	1.64	1.66	1.40	1.61
ZnO	3.44	2.49	3.27	3.25	3.48	3.20	3.44	3.33	3.32	3.50	3.64
ZrO_2	2.94	2.99	2.68	2.79	2.92	2.69	2.94	2.76	2.82	3.00	2.98
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

§ - Not a target constituent.
* - Values from DCP-AES analysis of adjacent discharge glass samples.
NA – Not analyzed by XRF.

Table 5.5. XRF Analyzed Composition for Dip Samples (wt%) (continued).

Test		After 5		Before 6		After 6		
Constituent	Target	10T-D-20A	10T-D-36A	10T-D-37A	Target	10T-D-106A	10T-D-106B	10T-D-112A
Al_2O_3	6.02	5.95	5.83	6.35	6.11	5.84	5.83	5.78
B_2O_3*	9.87	10.06	10.06	10.06	10.01	10.69	10.69	10.69
CaO	5.47	5.38	5.66	5.21	2.02	2.13	2.08	2.09
Cl	0.09	0.09	0.10	0.01	0.10	0.15	0.15	0.16
Cr_2O_3	0.08	0.17	0.21	0.43	0.08	0.17	0.17	0.20
F	0.07	NA	NA	NA	0.07	NA	NA	NA
Fe_2O_3	5.43	5.46	5.93	5.41	5.51	5.87	5.85	5.97
I	0.10	0.010	0.011	<0.003	0.10	0.056	0.052	0.046
K_2O	0.54	0.64	0.70	0.59	4.99	5.49	5.75	5.49
Li_2O*	2.38	2.25	2.25	2.25	§	0.15	0.15	0.15
MgO	1.46	1.43	1.41	1.56	1.48	1.45	1.40	1.42
Na_2O	15.68	16.72	14.95	16.40	18.08	17.14	17.03	17.17
NiO	0.01	0.04	0.03	0.07	0.01	0.03	0.02	0.04
P_2O_5	0.12	0.17	0.16	0.15	0.12	0.16	0.18	0.16
PbO	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
ReO_2	0.10	0.076	0.064	<0.005	0.10	0.079	0.081	0.064
SiO_2	44.33	43.67	43.86	44.05	43.01	42.05	41.88	41.75
SO_3	0.45	0.49	0.53	0.36	0.30	0.39	0.49	0.57
TiO_2	1.38	1.46	1.63	1.43	1.40	1.63	1.65	1.65
ZnO	3.46	3.17	3.52	3.00	3.51	3.57	3.57	3.63
ZrO_2	2.96	2.76	3.08	2.67	3.00	2.93	2.95	2.97
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

§ - Not a target constituent.
* - Values from DCP-AES analysis of adjacent discharge glass samples.
NA – Not analyzed by XRF.

Table 5.5. XRF Analyzed Composition for Dip Samples (wt%) (continued).

Test	Target	After 6		Target	Before 7		After 7		Before 8
Constituent		10T-D-112B	10T-D-112C		10T-D-124A	10T-D-139A	10U-D-56A	10U-D-57A	10U-D-69A
Al_2O_3	6.11	5.77	5.88	5.98	5.86	5.99	5.73	5.66	6.46
B_2O_3*	10.01	10.69	10.69	9.80	10.69	10.69	10.38	10.38	10.38
CaO	2.02	1.99	2.12	2.46	2.25	2.61	2.43	2.72	2.55
Cl	0.10	0.14	0.10	0.09	0.08	0.02	0.10	0.10	0.01
Cr_2O_3	0.08	0.34	0.18	0.08	0.18	0.32	0.17	0.22	0.44
F	0.07	NA	NA	0.07	NA	NA	NA	NA	NA
Fe_2O_3	5.51	5.87	5.96	5.39	4.95	5.84	5.30	5.81	5.55
I	0.10	0.043	0.031	0.10	0.026	<0.003	0.028	0.035	<0.003
K_2O	4.99	5.76	5.51	0.54	1.21	1.45	0.60	0.64	0.71
Li_2O*	§	0.15	0.15	§	0.15	0.15	0.18	0.18	0.18
MgO	1.48	1.41	1.46	1.45	1.17	1.13	1.43	1.41	1.52
Na_2O	18.08	17.22	17.11	21.14	22.68	19.78	22.05	20.11	20.52
NiO	0.01	0.03	0.03	0.01	0.03	0.09	0.03	0.04	0.08
P_2O_5	0.12	0.18	0.19	0.12	0.16	0.18	0.15	0.16	0.16
PbO	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
ReO_2	0.10	0.057	0.043	0.10	<0.005	<0.005	0.077	0.078	<0.005
SiO_2	43.01	41.03	41.87	44.56	43.46	43.19	43.66	43.63	43.73
SO_3	0.30	1.34	0.43	0.35	0.39	0.45	0.39	0.41	0.26
TiO_2	1.40	1.62	1.59	1.37	1.31	1.51	1.41	1.57	1.48
ZnO	3.51	3.48	3.62	3.44	2.93	3.53	3.13	3.56	3.07
ZrO_2	3.00	2.88	3.02	2.94	2.48	3.07	2.75	3.26	2.89
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

§ - Not a target constituent.
* - Values from DCP-AES analysis of adjacent discharge glass samples.
NA – Not analyzed by XRF.

Table 5.5. XRF Analyzed Composition for Dip Samples (wt%) (continued).

Test	After 8			Before 9	After 9		
Constituent	Target	10U-D-137A	10U-D-137B	10V-D-22A	Target	10V-D-88A	10V-D-93A
Al_2O_3	6.03	5.47	5.45	6.21	6.08	6.87	5.75
B_2O_3	9.89	9.39*	9.39*	9.39*	9.96	9.96**	9.96**
CaO	6.32	6.74	6.73	6.58	6.89	6.72	7.12
Cl	0.09	0.15	0.11	0.00	0.09	0.12	0.11
Cr_2O_3	0.08	0.17	0.17	0.40	0.08	0.15	0.17
F	0.07	NA	NA	NA	0.07	NA	NA
Fe_2O_3	5.44	5.91	5.93	5.75	5.47	5.06	5.36
I	0.10	0.012	0.007	<0.003	0.10	0.024	0.026
K_2O	0.54	0.80	0.82	0.73	0.54	0.73	0.67
Li_2O*	3.18	3.39*	3.39*	3.39*	4.10	4.10**	4.10**
MgO	1.49	1.35	1.47	1.55	2.37	2.17	2.26
Na_2O	13.38	12.75	13.04	13.37	8.69	9.19	8.54
NiO	0.01	0.03	0.04	0.06	0.01	0.04	0.04
P_2O_5	0.12	0.17	0.16	0.17	0.12	0.17	0.16
PbO	0.01	0.01	0.01	0.01	0.01	0.01	0.01
ReO_2	0.10	0.094	0.050	<0.005	0.10	0.096	0.086
SiO_2	44.84	44.05	44.23	44.06	46.98	46.50	46.98
SO_3	0.51	1.16	0.70	0.60	0.49	0.57	0.59
TiO_2	1.38	1.66	1.69	1.58	1.40	1.49	1.63
ZnO	3.47	3.55	3.54	3.26	3.48	3.31	3.53
ZrO_2	2.97	3.13	3.10	2.90	2.98	2.73	2.91
Sum	100.00	100.00	100.00	100.00	100.00	100.00	100.00

* - Values from DCP-AES analysis of adjacent discharge glass samples.
** - Target values are used.
NA – Not analyzed by XRF.

Table 5.6. DCP Analyzed Composition of Leached Secondary Phase on Dip Sample from the End of Test 6 (wt% Recovered Solids).

Element	Wt.%
B	0.89
Ca	0.19
Cr	6.08
K	13.41
Na	24.38
Re	7.53
Zn	0.05
SO_4	43.44
I	0.14
Cl	3.80
F	0.09
Total	100.00

Table 5.7. Secondary Phase Formation While Processing LAWE7H.

Test Segment		DM100 [74]	DM100 [72]	DM100 [74]	DM10 recycle (this work)
Feed	wt% Cl as glass	0.23	0.2	0.23	0.13 – measured in feed 0.11 – measured in recycle stream **0.24 – total in feed to melter**
	wt% SO_3	0.59	0.59	0.59	0.56 – measured in feed 0.08 – measured in recycle stream **0.64 – total in feed to melter**
Product	Secondary Sulfate on Dip Samples	2 of 3	None	1 of 3	Minor
	Measured wt% SO_3	0.52	0.53	0.57	0.67

Table 5.8. Secondary Phase Formation While Processing LAWE3.

Test Segment		DM100 [72]	DM10 Single Pass [4]	DM10 recycle (this work)
Feed	wt% Cl as glass	0.20	0.20	0.14 – measured in feed 0.17 – measured in recycle stream **0.31 – total in feed to melter**
	wt% K_2O as glass	4.98	4.98	5.30 – measured in feed
	Wt% SO_3	0.35	0.35	0.33 – measured in feed 0.06 – measured in recycle stream **0.39 – total in feed to melter**
Product	Secondary Sulfate on Dip Samples	None	None	Major
	Measured wt% K_2O	4.78	4.59	5.57
	Measured wt% SO_3	0.33	0.40	0.41

Table 5.9. Comparison of Volatile Retention in the Glass Product from Single-Pass Tests and Tests with Recycle.

Feed / Test		^{99m}Tc	Rhenium	Iodine
LAWE5H Test 3	Single-pass [4]	31	45	21
	Recycle	81	90	25
	Enhancement	X 2.6	X 2.0	X 1.2
LAWE10H Test 4	Single-pass [4]	66	57	51
	Recycle	84	80	80
	Enhancement	X 1.3	X 1.4	X 1.6
LAWE6H Test 5	Single-pass [4]	20	36	5
	Recycle	68	70	16
	Enhancement	X 3.4	X 1.9	X 3.2
LAWE3 Test 6	Single-pass [4]	18	25	22
	Recycle	53	70	46
	Enhancement	X 2.9	X 2.8	X 2.1
LAWE4H Test 7	Single-pass [3]	34	43	19
	Recycle	72	90	41
	Enhancement	X 2.1	X 2.1	X 2.2
LAWE7H Test 8	Single-pass [4]	19	27	< 1
	Recycle	45	59	9
	Enhancement	X 2.4	X 2.2	X >9
LAWE9H Test 9	Single-pass [3]	35	NM	35
	Recycle	72	91	29
	Enhancement	X 2.1	NC	X 1.2

NC - Not Calculated
NM – Not Measured. Re was not a constituent in the LAWE9H feed in Single-pass tests

Table 6.1. Results from WESP Outlet Emission Samples and Feed Carryover across the Melter and Primary Off-gas System.

		Test 1-LAWE4H 9/1/2011 13:52 – 14:52 6.1% Moisture, 106% Isokinetic ^{99m}Tc emission rate – 0.134 uCi/min ^{99m}Tc carryover – 0.47%				Test 1-LAWE4H 9/2/2011 13:31 – 13:51 21% Moisture, 109% Isokinetic ^{99m}Tc emission rate – 260.8 uCi/min ^{99m}Tc carryover – 913%			
		Feed[#] mg/min	Output (mg/min)	% Emitted	DF	Feed[#] mg/min	Output (mg/min)	% Emitted	DF
Particulate	Al	881	1.20	0.14	732	881	16.2	1.83	54.5
	B	847	0.93	0.11	909	847	976	115	0.9
	Ca	490	7.83	1.60	62.6	490	69.2	14.13	7.1
	Cl	28	115	411	0.2	28	3814	13689	< 0.1
	Cr	15	< 0.10	< 0.66	> 153	15	24.4	160	0.6
	F	8	< 0.10	< 1.20	> 84	8	109	1308	0.1
	Fe	1050	< 0.10	< 0.01	> 10502	1050	1.05	0.10	1000
	I	28	5.67	20.36	4.9	28	29.88	106.7	0.94
	K	125	3.69	2.96	33.8	125	583	467	0.2
	Li	0	< 0.10	NC	NC	0	4.88	NC	NC
	Mg	244	2.02	0.83	121	244	21.0	8.61	11.6
	Na	4370	NA	NC	NC	4370	3478	79.6	1.3
	Ni	2.2	< 0.10	< 4.57	> 22	2.2	192	8793	< 0.1
	P	15	< 0.10	< 0.68	> 146	15	< 0.10	< 0.68	> 146
	Pb	2.6	0.51	19.9	5.0	2.6	4.45	172	0.6
	Re	24	1.43	6.03	16.6	24	3529	14874	< 0.1
	S	47	11.1	23.6	4.2	47	576	1229	0.1
	Si	5804	9.36	0.16	620	5804	71.7	1.23	81.0
	Ti	229	< 0.10	< 0.04	> 2288	229	< 0.10	< 0.04	> 2288
	Zn	770	0.15	0.02	5131	770	25.5	3.31	30.2
	Zr	606	< 0.10	< 0.02	> 6064	606	0.68	0.11	895

[#] - Feed rate calculated from target composition and total glass production rate
NC – Not Calculated
NA – Not Analyzed due to contamination from sodium hydroxide impinge solution

Table 6.1. Results from WESP Outlet Emission Samples and Feed Carryover across the Melter and Primary Off-gas System (continued).

		Test 2-LAWE4H 9/7/2011 16:13 – 17:13 4.2% Moisture, 96.0% Isokinetic ^{99m}Tc emission rate – 4.1 uCi/min ^{99m}Tc carry-over – 12.7%				Test 2-LAWE4H 9/9/2011 14:49 – 15:49 3.8% Moisture, 102% Isokinetic ^{99m}Tc emission rate – <0.1 uCi/min ^{99m}Tc carry-over – <0.01%			
		Feed[#] mg/min	Output (mg/min)	% Emitted	DF	Feed[#] mg/min	Output (mg/min)	% Emitted	DF
Particulate	Total[$]	25964	20.96	0.08	1239	25964	4.24	0.02	6130
	Al	642	< 0.10	< 0.02	> 6423	642	< 0.10	< 0.02	> 6423
	B	617	< 0.10	< 0.02	> 6175	617	< 0.10	< 0.02	> 6175
	Ca	357	< 0.10	< 0.03	> 3570	357	< 0.10	< 0.03	> 3570
	Cl*	20	4.32	21.3	4.7	20	< 0.10	< 0.49	> 203
	Cr	11	< 0.10	< 0.90	> 111	11	< 0.10	< 0.90	> 111
	F*	6	< 0.10	< 1.64	> 61	6	< 0.10	< 1.64	> 61
	Fe	765	< 0.10	< 0.01	> 7652	765	< 0.10	< 0.01	> 7652
	I*	20	< 0.10	< 0.49	> 203	20	< 0.10	< 0.49	> 203
	K	91	0.16	0.17	578	91	< 0.10	< 0.11	> 910
	Li	0	< 0.10	NC	NC	0	< 0.10	NC	NC
	Mg	178	< 0.10	< 0.06	> 1775	178	< 0.10	< 0.06	> 1775
	Na	3184	1.12	0.04	2854	3184	< 0.10	< 0.00	> 31843
	Ni	1.6	< 0.10	< 6.27	> 16	1.6	< 0.10	< 6.27	> 16
	P	11	< 0.10	< 0.94	> 106	11	< 0.10	< 0.94	> 106
	Pb	1.9	< 0.10	< 5.31	> 19	1.9	< 0.10	< 5.31	> 19
	Re	17	2.55	14.8	6.8	17	< 0.10	< 0.58	> 173
	S*	34	0.71	4.66	21.5	34	0.19	0.55	182
	Si	4229	< 0.10	< 0.01	> 42290	4229	< 0.10	< 0.00	> 42290
	Ti	167	< 0.10	< 0.06	> 1667	167	< 0.10	< 0.06	> 1667
	Zn	561	< 0.10	< 0.02	> 5611	561	< 0.10	< 0.02	> 5611
	Zr	442	< 0.10	< 0.02	> 4419	442	< 0.10	< 0.02	> 4419
Gas	B	617	< 0.10	< 0.02	> 6175	617	< 0.10	< 0.02	> 6175
	Cl	20	14.3	70.3	1.4	20	12.5	61.3	1.6
	F	6	< 0.10	< 1.64	> 61	6	< 0.10	< 1.64	> 61
	I	20	6.83	33.6	3.0	20	4.75	23.4	4.3
	S	34	1.17	4.01	25.0	34	0.90	2.62	38.1

[$] - From gravimetric analysis of filters and particulate nitric acid rinses
[#] - Feed rate calculated from target composition and total glass production rate
* - Calculated from direct analysis of nitric-acid rinse only
NC – Not Calculated

Table 6.1. Results from WESP Outlet Emission Samples and Feed Carryover across the Melter and Primary Off-gas System (continued).

		Test 3-LAWE5H 9/20/2011 19:03 – 20:03 3.0% Moisture, 96.1% Isokinetic ^{99m}Tc emission rate – 0.012 uCi/min ^{99m}Tc carry-over – 0.042%				Test 4-LAWE10H 9/27/2011 18:42 – 19:42 3.0% Moisture, 99.4% Isokinetic ^{99m}Tc emission rate – 0.007 uCi/min ^{99m}Tc carry-over – 0.024%			
		Feed[#] mg/min	Output (mg/min)	% Emitted	DF	Feed[#] mg/min	Output (mg/min)	% Emitted	DF
Particulate	Total[$]	40690	4.39	0.01	9275	37805	4.24	0.01	8923
	Al	969	< 0.10	< 0.01	> 9687	1048	< 0.10	< 0.01	> 10478
	B	931	< 0.10	< 0.01	> 9314	1008	< 0.10	< 0.01	> 10076
	Ca	790	< 0.10	< 0.01	> 7900	1622	0.11	0.01	14538.2
	Cl*	43	< 0.10	< 0.23	> 427	39	< 0.10	< 0.26	> 390
	Cr	17	< 0.10	< 0.60	> 167	18	< 0.10	< 0.56	> 178
	F*	34	< 0.10	< 0.30	> 336	23	< 0.10	< 0.44	> 227
	Fe	1155	< 0.10	< 0.01	> 11549	1251	< 0.10	< 0.01	> 12510
	I*	31	< 0.10	< 0.33	> 305	32	< 0.10	< 0.31	> 325
	K	137	< 0.10	< 0.07	> 1369	146	< 0.10	< 0.07	> 1455
	Li	69	< 0.10	< 0.14	> 695	646	< 0.10	< 0.02	> 6455
	Mg	267	< 0.10	< 0.04	> 2669	578	< 0.10	< 0.02	> 5775
	Na	4267	< 0.10	< 0.00	> 42674	1313	0.13	0.01	9937
	Ni	2.4	< 0.10	< 4.17	> 24	2.6	< 0.10	< 3.92	> 26
	P	16	< 0.10	< 0.63	> 160	17	< 0.10	< 0.59	> 170
	Pb	2.8	< 0.10	< 3.53	> 28	3.0	< 0.10	< 3.32	> 30
	Re	26	< 0.10	< 0.38	> 261	28	< 0.10	< 0.36	> 277
	S*	51	< 0.10	< 0.19	> 514	86	< 0.10	< 0.12	> 859
	Si	6438	< 0.20	< 0.01	40650	7460	< 0.10	< 0.00	> 74599
	Ti	251	< 0.10	< 0.04	> 2507	273	< 0.10	< 0.04	> 2725
	Zn	844	< 0.10	< 0.01	> 8437	913	< 0.10	< 0.01	> 9130
	Zr	664	< 0.10	< 0.02	> 6645	721	< 0.10	< 0.01	> 7211
Gas	B	931	< 0.10	< 0.01	> 9314	1008	< 0.10	< 0.01	> 10076
	Cl	43	12.88	30.15	3.3	39	12.84	32.95	3.0
	F	34	< 0.10	< 0.30	> 336	23	< 0.10	< 0.44	> 227
	I	31	4.75	15.57	6.4	32	0.35	1.08	92.6
	S	51	0.92	1.79	55.8	86	0.88	1.03	97.4

[$] - From gravimetric analysis of filters and particulate nitric acid rinses
[#] - Feed rate calculated from target composition and total glass production rate
* - Calculated from direct analysis of nitric-acid rinse only
NC – Not Calculated

Table 6.1. Results from WESP Outlet Emission Samples and Feed Carryover across the Melter and Primary Off-gas System (continued).

		Test 5-LAWE6H 12/14/2011 16:13 – 17:13 3.1% Moisture, 104% Isokinetic ^{99m}Tc emission rate – 0.095 uCi/min ^{99m}Tc carry-over – 0.306%				Test 5-LAWE6H 12/15/2011 15:04 – 16:04 3.3% Moisture, 105% Isokinetic ^{99m}Tc emission rate – 0.036 uCi/min ^{99m}Tc carry-over – 0.102%			
		Feed[#] mg/min	Output (mg/min)	% Emitted	DF	Feed[#] mg/min	Output (mg/min)	% Emitted	DF
Particulate	Total[$]	44430	5.87	0.01	7574	44430	4.80	0.01	9260
	Al	1032	< 0.10	< 0.01	> 10317	1032	< 0.10	< 0.01	> 10317
	B	992	< 0.10	< 0.01	> 9923	992	< 0.10	< 0.01	> 9923
	Ca	1267	0.14	0.01	9107	1267	0.12	0.01	10247
	Cl*	29	< 0.10	< 0.34	> 292	29	< 0.10	< 0.34	> 292
	Cr	18	< 0.10	< 0.56	> 177	18	< 0.10	< 0.56	> 177
	F*	23	< 0.10	< 0.44	> 227	23	< 0.10	< 0.44	> 227
	Fe	1230	< 0.10	< 0.01	> 12300	1230	< 0.10	< 0.01	> 12300
	I*	32	< 0.10	< 0.31	> 324	32	< 0.10	< 0.31	> 324
	K	145	< 0.10	< 0.07	> 1452	145	< 0.10	< 0.07	> 1452
	Li	358	< 0.10	< 0.03	> 3582	358	< 0.10	< 0.03	> 3582
	Mg	285	< 0.10	< 0.04	> 2852	285	< 0.10	< 0.04	> 2852
	Na	3769	< 0.10	< 0.01	> 37687	3769	0.29	0.01	12778
	Ni	2.5	< 0.10	< 3.93	> 25	2.5	< 0.10	< 3.93	> 25
	P	17	< 0.10	< 0.59	> 170	17	< 0.10	< 0.59	> 170
	Pb	3.0	< 0.10	< 3.33	> 30	3.0	< 0.10	< 3.33	> 30
	Re	28	< 0.10	< 0.36	> 276	28	< 0.10	< 0.36	> 276
	S*	60	0.12	0.20	507	60	0.31	0.52	190.8
	Si	6713	< 0.10	< 0.01	> 67132	6713	0.24	0.00	28511
	Ti	268	< 0.10	< 0.04	> 2680	268	< 0.10	< 0.04	> 2680
	Zn	900	< 0.10	< 0.01	> 9005	900	< 0.10	< 0.01	> 9005
	Zr	710	< 0.10	< 0.01	> 7099	710	< 0.10	< 0.01	> 7099
Gas	B	992	< 0.10	< 0.01	> 9923	992	< 0.10	< 0.01	> 9923
	Cl	29	< 0.10	< 0.34	> 292	29	< 0.10	< 0.34	> 292
	F	23	< 0.10	< 0.44	> 227	23	< 0.10	< 0.44	> 227
	I	32	1.81	5.59	17.9	32	8.62	26.61	3.8
	S	60	0.72	1.20	83.2	60	0.71	1.18	84.5

[$] - From gravimetric analysis of filters and particulate nitric acid rinses
[#] - Feed rate calculated from target composition and total glass production rate
* - Calculated from direct analysis of nitric-acid rinse only
NC – Not Calculated

Table 6.1. Results from WESP Outlet Emission Samples and Feed Carryover across the Melter and Primary Off-gas System (continued).

		Test 6 -LAWE3 1/10/2012 14:09 – 15:09 3.2% Moisture, 107% Isokinetic ^{99m}Tc emission rate – 0.321 uCi/min ^{99m}Tc carry-over – 1.038%				Test 6-LAWE3 1/11/2012 14:14 – 15:14 3.2% Moisture, 108% Isokinetic ^{99m}Tc emission rate – 0.162 uCi/min ^{99m}Tc carry-over – 0.519%			
		Feed[#] mg/min	Output (mg/min)	% Emitted	DF	Feed[#] mg/min	Output (mg/min)	% Emitted	DF
Particulate	Total[$]	45955	5.09	0.01	9030	45955	6.00	0.01	7654
	Al	1079	< 0.10	< 0.01	> 10789	1079	< 0.10	< 0.01	> 10789
	B	1037	< 0.10	< 0.01	> 10370	1037	< 0.10	< 0.01	> 10370
	Ca	482	< 0.10	< 0.02	> 4820	482	< 0.10	< 0.02	> 4820
	Cl*	43	1.05	2.43	41.2	43	0.61	1.41	70.9
	Cr	18	< 0.10	< 0.55	> 183	18	< 0.10	< 0.55	> 183
	F*	10	< 0.10	< 0.01	> 100	10	< 0.10	< 0.01	> 100
	Fe	1286	< 0.10	< 0.01	> 12861	1286	< 0.10	< 0.01	> 12861
	I*	33	< 0.10	< 0.01	> 330	33	< 0.10	< 0.01	> 330
	K	1383	0.37	0.03	3727.0	1383	0.16	0.01	8863.7
	Li	0	< 0.10	NC	NC	0	< 0.10	NC	NC
	Mg	298	< 0.10	< 0.03	> 2979	298	< 0.10	< 0.03	> 2979
	Na	4478	0.27	0.01	16736.4	4478	0.14	0.00	31568.9
	Ni	2.6	< 0.10	< 3.81	> 26	2.6	< 0.10	< 3.81	> 26
	P	17	< 0.10	< 0.57	> 175	17	< 0.10	< 0.57	> 175
	Pb	3.1	< 0.10	< 3.23	> 31	3.1	< 0.10	< 3.23	> 31
	Re	28	< 0.10	< 0.35	> 285	28	< 0.10	< 0.35	> 285
	S*	44	0.20	0.46	216.7	44	< 0.10	< 0.23	> 441
	Si	6711	< 0.10	< 0.00	> 67113	6711	< 0.10	< 0.00	> 67113
	Ti	280	< 0.10	< 0.04	> 2802	280	< 0.10	< 0.04	> 2802
	Zn	941	< 0.10	< 0.01	> 9413	941	< 0.10	< 0.01	> 9413
	Zr	741	< 0.10	< 0.01	> 7413	741	< 0.10	< 0.01	> 7413
Gas	B	1037	< 0.10	< 0.01	> 10370	1037	< 0.10	< 0.01	> 10370
	Cl	43	< 0.10	< 0.23	> 434	43	< 0.10	< 0.23	> 434
	F	10	< 0.10	< 1.00	> 100	10	< 0.10	< 1.00	> 100
	I	33	10.23	30.65	3.3	33	11.20	33.54	3.0
	S	44	0.58	1.32	75.6	44	0.73	1.65	60.8

[$] - From gravimetric analysis of filters and particulate nitric acid rinses
[#] - Feed rate calculated from target composition and total glass production rate
* - Calculated from direct analysis of nitric-acid rinse only
NC – Not Calculated

Table 6.1. Results from WESP Outlet Emission Samples and Feed Carryover across the Melter and Primary Off-gas System (continued).

		Test 7-LAWE4H 1/18/2012 15:35 – 16:35 2.7% Moisture, 105% Isokinetic ^{99m}Tc emission rate – 0.012 uCi/min ^{99m}Tc carry-over – 0.045%				Test 8-LAWE7H 2/21/2012 15:20 – 16:20 3.1% Moisture, 98.1% Isokinetic ^{99m}Tc emission rate – 0.058 uCi/min ^{99m}Tc carry-over – 0.17%			
		Feed[#] mg/min	Output (mg/min)	% Emitted	DF	Feed[#] mg/min	Output (mg/min)	% Emitted	DF
Particulate	Total[$]	34714	4.96	0.01	6992	42501	5.77	0.01	7365
	Al	861	< 0.10	< 0.01	> 8614	1093	< 0.10	< 0.01	> 10929
	B	828	< 0.10	< 0.01	> 8281	1052	< 0.10	< 0.01	> 10516
	Ca	479	0.10	0.02	4635	1548	0.32	0.02	4803
	Cl*	27	< 0.10	< 0.37	>270	45	< 0.10	< 0.22	> 450
	Cr	15	< 0.10	< 0.67	> 149	19	< 0.10	< 0.53	> 188
	F*	8	< 0.10	< 1.25	> 80	72	< 0.10	< 0.14	> 720
	Fe	1026	< 0.10	< 0.01	> 10262	1303	< 0.10	< 0.01	> 13033
	I*	27	< 0.10	< 0.37	> 270	34	< 0.10	< 0.29	> 340
	K	122	< 0.10	< 0.08	> 1221	154	< 0.10	< 0.07	> 1536
	Li	0	< 0.10	NC	NC	506	< 0.10	< 0.02	> 5061
	Mg	238	< 0.10	< 0.04	> 2381	308	< 0.10	< 0.03	> 3078
	Na	4271	0.12	< 0.01	35655	3401	0.47	0.01	7229
	Ni	2.1	< 0.10	< 4.67	> 21	2.7	< 0.10	< 3.71	> 27
	P	14	< 0.10	< 0.70	> 143	18	< 0.10	< 0.56	> 180
	Pb	2.5	< 0.10	< 3.96	> 25	3.2	< 0.10	< 3.14	> 32
	Re	23	< 0.10	< 0.43	> 232	29	< 0.10	< 0.34	> 292
	S*	46	< 0.10	< 0.22	> 458	78	0.12	0.16	635.7
	Si	5672	< 0.10	< 0.00	> 56717	7182	0.38	0.01	18971
	Ti	224	< 0.10	< 0.04	> 2236	283	< 0.10	< 0.04	> 2835
	Zn	753	< 0.10	< 0.01	> 7525	955	< 0.10	< 0.01	> 9551
	Zr	593	< 0.10	< 0.02	> 5926	753	< 0.10	< 0.01	> 7533
Gas	B	828	< 0.10	< 0.01	> 8281	1052	< 0.10	< 0.01	> 10516
	Cl	27	< 0.10	< 0.37	> 272	45	0.39	0.87	115
	F	8	< 0.10	< 1.22	> 82	72	< 0.10	< 0.14	> 719
	I	27	8.41	30.9	3.2	34	9.14	26.7	3.7
	S	46	0.58	1.27	78.5	78	0.78	1.00	100

[$] - From gravimetric analysis of filters and particulate nitric acid rinses
[#] - Feed rate calculated from target composition and total glass production rate
* - Calculated from direct analysis of nitric-acid rinse only
NC – Not Calculated

Table 6.1. Results from WESP Outlet Emission Samples and Feed Carryover across the Melter and Primary Off-gas System (continued).

		Test 9-LAWE9H 3/7/2012 14:52 – 15:52 3.1% Moisture, 98.8% Isokinetic ^{99m}Tc emission rate – 0.005 uCi/min ^{99m}Tc carry-over – 0.014%			
		Feed[#] mg/min	Output (mg/min)	% Emitted	DF
Particulate	Total[$]	41142	4.71	0.01	8738
	Al	1091	< 0.10	< 0.01	> 10909
	B	1048	< 0.10	< 0.01	> 10483
	Ca	1670	< 0.10	< 0.01	> 16703
	Cl*	34	< 0.10	< 0.01	> 340
	Cr	19	< 0.10	< 0.54	> 186
	F*	7	< 0.10	< 1.42	> 70
	Fe	1297	< 0.10	< 0.01	> 12972
	I*	34	< 0.10	< 0.01	> 340
	K	152	< 0.10	< 0.07	> 1520
	Li	646	< 0.10	< 0.02	> 6459
	Mg	485	< 0.10	< 0.02	> 4847
	Na	2187	< 0.10	< 0.00	> 21867
	Ni	2.7	< 0.10	< 3.75	> 27
	P	18	< 0.10	< 0.56	> 178
	Pb	3.1	< 0.10	< 3.18	> 31
	Re	29	< 0.10	< 0.35	> 289
	S*	72	< 0.10	< 0.14	> 720
	Si	7448	< 0.10	< 0.00	> 74483
	Ti	285	< 0.10	< 0.04	> 2847
	Zn	948	< 0.10	< 0.01	> 9482
	Zr	748	< 0.10	< 0.01	> 7482
Gas	B	1048	< 0.10	< 0.01	> 10483
	Cl	34	0.39	1.14	87.9
	F	7	< 0.10	< 1.47	> 68
	I	34	3.51	10.35	9.7
	S	72	0.64	0.89	112

[$] - From gravimetric analysis of filters and particulate nitric acid rinses
[#] - Feed rate calculated from target composition and total glass production rate
* - Calculated from direct analysis of nitric-acid rinse only
NC – Not Calculated

Table 6.2. Concentrations [ppmv] of Species Measured by FTIR Spectroscopy from DM10 Off-gas System Exhaust.

	1		2		3	
	Avg.	Range	Avg.	Range	Avg.	Range
N_2O	40.2	<1.0 – 433	30.8	<1.0 – 192	23.8	<1.0 – 69.6
NO	223	10.0 – 1021	177	1.0 – 629	247	4.3 – 529
NO_2	37.1	2.5 – 319	21.4	<1.0 – 167	44.4	4.3 – 154
NH_3	<1.0	<1.0 – 1.6	<1.0	<1.0 – 1.8	<1.0	NA
H_2O [%]	2.1	1.8 – 2.6	1.9	1.7 – 2.1	1.8	1.7 – 2.4
CO_2	1041	370 - 5671	847	364 - 2869	894	373 - 1952
Nitrous Acid	2.0	<1.0 – 9.9	<1.0	<1.0 – 6.3	1.2	<1.0 – 4.2
Nitric Acid	1.0	<1.0 – 2.5	1.0	<1.0 – 2.3	<1.0	<1.0 – 2.0
HCN	<1.0	NA	<1.0	NA	<1.0	NA
Acetonitrile	<1.0	NA	<1.0	NA	<1.0	NA
CO	8.0	<1.0 – 61.5	4.8	<1.0 – 27.2	6.4	<1.0 – 19.0
HCl	<1.0	NA	<1.0	NA	<1.0	NA
HF	<1.0	NA	<1.0	NA	<1.0	NA

NA : Not applicable.

Table 6.2. Concentrations [ppmv] of Species Measured by FTIR Spectroscopy from DM10 Off-gas System Exhaust (continued).

	4		5		6	
	Avg.	Range	Avg.	Range	Avg.	Range
N_2O	8.7	<1.0 – 25.2	32.5	<1.0 – 145	44.9	<1.0 – 133
NO	45.0	<1.0 – 149	304	<1.0 – 905	382	25.6 – 674
NO_2	1.7	<1.0 – 10.0	55.1	<1.0 – 372	90.9	5.7 – 256
NH_3	<1.0	NA	<1.0	NA	<1.0	NA
H_2O [%]	2.0	1.8 – 2.2	1.4	1.0 – 1.8	1.4	1.0 – 1.7
CO_2	947	414 - 2124	1261	393 - 4392	1373	454 - 2851
Nitrous Acid	<1.0	NA	1.4	1.0 – 9..4	2.1	<1.0 – 7.2
Nitric Acid	<1.0	NA	<1.0	<1.0 – 2.6	1.0	<1.0 – 2.3
HCN	<1.0	NA	<1.0	NA	<1.0	NA
Acetonitrile	<1.0	NA	<1.0	<1.0 – 15.1	<1.0	NA
CO	2.1	<1.0 – 7.8	9.8	<1.0 – 51.9	12.9	<1.0 – 27.4
HCl	<1.0	NA	<1.0	NA	<1.0	NA
HF	<1.0	NA	<1.0	NA	<1.0	NA

NA : Not applicable.

Table 6.2. Concentrations [ppmv] of Species Measured by FTIR Spectroscopy from DM10 Off-gas System Exhaust (continued).

	7		8		9	
	Avg.	Range	Avg.	Range	Avg.	Range
N_2O	46.0	<1.0 - 428	39.1	<1.0 - 111	22.8	1.0 - 94.9
NO	276	24.9 - 1096	332	6.6 - 732	142	13.3 - 383
NO_2	52.6	2.7 - 548	72.3	2.6 - 306	12.0	1.2 – 77.2
NH_3	<1.0	NA	<1.0	NA	<1.0	<1.0 – 1.8
H_2O [%]	1.2	1.0 – 1.7	1.3	1.0 – 1.7	1.5	1.0 – 1.8
CO_2	1057	455 - 4827	1395	444 - 3341	1202	461 - 2878
Nitrous Acid	1.0	<1.0 – 14.4	1.4	<1.0 – 8.1	<1.0	<1.0 – 1.1
Nitric Acid	<1.0	<1.0 – 3.3	1.0	<1.0 – 2.1	<1.0	NA
HCN	<1.0	NA	<1.0	NA	<1.0	NA
Acetonitrile	<1.0	NA	<1.0	NA	<1.0	NA
CO	9.3	<1.0 – 60.0	14.6	<1.0 – 43.5	4.7	<1.0 – 16.0
HCl	<1.0	NA	<1.0	NA	<1.0	NA
HF	<1.0	NA	<1.0	NA	<1.0	NA

NA : Not applicable.

Table 7.1. Measured Cumulative Technetium Distribution.

	Test 1		Test 2		Test 3		Test 4	
Technetium Fed to System	99.70 mCi		125.83 mCi		95.26 mCi		122.63 mCi	
	mCi	%	mCi	%	mCi	%	mCi	%
Feed Mixing Vessel	25.75	25.8%	NA	NA	NA	NA	NA	NA
Glass	28.68	28.8%	69.28	55.1%	53.53	56.2%	87.27	71.2%
Transition Line	NM	NM	NM	NM	5.05	5.3%	4.36	3.6%
SBS Sump	4.03	4.0%	5.77	4.6%	8.32	8.7%	4.72	3.8%
WESP Collection Tubes	NM	NM	2.46	2.0%	2.74	2.9%	5.56	4.5%
Containment Tank	NM	NM	1.59	1.3%	2.52	2.6%	1.24	1.0%
Custom Evaporator	3.44	3.5%	6.82	5.4%	11.75	12.3%	4.73	3.9%
E-700 Evaporator	6.93	6.950%	<0.012	<0.010%	<0.01	<0.005%	<0.032	<0.026
Recycle Line	0.18	0.2%	0.27	0.2%	0.97	1.0%	0.77	0.6%
Test Samples	0.22	0.2%	0.69	0.5%	1.12	1.2%	0.82	0.7%
WESP Emissions	0.47	>0.471%	16.02	12.73%	0.04	0.042%	0.03	0.024%
Total	69.70	>69.87%	102.91	81.8%	86.03	90.3%	109.51	89.3%

NM – Not Measured

Table 7.1. Measured Cumulative Technetium Distribution (continued).

	Test 5		Test 6		Test 7		Test 8		Test 9	
Technetium Fed to System	112.49 mCi		133.04 mCi		111.20 mCi		147.76 mCi		139.33	
	mCi	%	mCi	%	mCi	%	mCi	%	mCi	%
Glass	53.87	47.9%	64.21	48.3%	68.05	61.2%	57.23	38.7%	97.23	69.8%
Transition Line	1.51	1.3%	3.48	2.6%	4.01	3.6%	5.70	3.9%	2.34	1.7%
SBS Sump	8.29	7.4%	14.17	10.7%	5.64	5.1%	17.69	12.0%	6.62	4.8%
WESP Collection Tubes	18.79	16.7%	22.21	16.7%	5.09	4.6%	32.08	21.7%	6.04	4.3%
Containment Tank	2.88	2.6%	4.27	3.2%	2.01	1.8%	5.37	3.6%	2.23	1.6%
Custom Evaporator	9.20	8.2%	10.40	7.8%	9.22	8.3%	18.26	12.4%	7.14	5.1%
E-700 Evaporator	<0.005	<0.004%	2.14	1.608%	0.01	0.013%	<0.015	<0.010%	<0.007	<0.005
Recycle Line	0.61	0.5%	1.19	0.9%	0.48	0.4%	1.21	0.8%	0.51	0.4%
Test Samples	0.95	0.8%	3.07	2.3%	1.82	1.6%	2.87	1.9%	2.05	1.5%
WESP Emissions	0.115	0.10%	0.69	0.52%	0.05	0.045%	0.25	0.17%	0.02	0.014%
Total	96.22	85.5%	125.83	94.6%	96.38	86.7%	140.66	95.2%	124.17	89.1%

Table 7.2. Measured Test-End Volatile Distributions for Test 1.

Constituent	ReO_2		Iodine		Chlorine		Fluorine		Sulfate	
mg fed	97300		97300		103950		29190		523530	
Measured Distribution	mg	%	mg	%	mg	%	mg	%	mg	%
Feed mixing vessel	148	0.2%	<30	< .03%	NM	NM	NM	NM	NM	NM
Glass	74254	76.3%	31279	32.1%	124734	120.0%	31884	109.2%	501390	95.8%
Transition line	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
SBS sump	2766	2.8%	462	0.5%	-1349	-1.3%	-11595	-39.7%	-424	-0.1%
WESP tube walls	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Containment tank	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Evaporator (custom)	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
E-700 Evaporator	11239	11.6%	6520	6.7%	66432	63.9%	1510	5.2%	117544	22.5%
Recycle line	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Test Samples	356	0.4%	303	0.3%	648	0.6%	103	0.4%	579	0.1%
WESP Emissions	10460	11%	23839	25%	69335	67%	<350	<1.2%	33035	6%
Makeup water	NA	NA	NA	NA	-2457	-2.4%	-573	-2.0%	NA	NA
Total	88764	102.0%	62402	64.1%	257343	247.6%	21329	73.1%	652124	124.6%

NM – Not Measured.
NA – Not Applicable

Table 7.3. Measured Test-End Volatile Distributions for Test 2.

Constituent	ReO_2		Iodine		Chlorine		Fluorine		Sulfate	
mg fed	79300		79300		85800		28860		432120	
Measured Distribution	mg	%	mg	%	mg	%	mg	%	mg	%
Glass	74126	93.5%	31938	40.3%	114802	133.8%	34512	119.6%	392631	90.9%
Transition line	891	1.1%	729	0.9%	2142	2.5%	NM	NM	2009	0.5%
SBS sump	2562	3.2%	3129	3.9%	1202	1.4%	303	1.0%	255	0.1%
WESP tube walls	1596	2.0%	24	0.03%	739	0.9%	58	0.2%	472	0.1%
Containment tank	734	0.9%	638	0.8%	256	0.3%	66	0.2%	-29	-0.01%
Evaporator (custom)	2653	3.3%	1745	2.2%	2723	3.2%	-22	-0.1%	2387	0.6%
E-700 Evaporator	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Recycle line	269	0.3%	157	0.2%	237	0.3%	6	0.02%	245	0.1%
Test Samples	276	0.3%	214	0.3%	348	0.4%	13	0.05%	356	0.1%
WESP Emissions	11736	14.8%	26645	34%	78593	92%	<473	<1.64%	37465	8.7%
Makeup water	NA	NA	NA	NA	-2652	-3.1%	-619	-2.1%	NA	NA
Total	83108	119.6%	65218	82.2%	198390	231.2%	34317	118.9%	435791	100.8%

NM – Not Measured.
NA – Not Applicable

Table 7.4. Measured Test-End Volatile Distributions for Test 3.

Constituent	ReO_2		Iodine		Chlorine		Fluorine		Sulfate	
mg fed	96900		96900		153300		119700		541800	
Measured Distribution	mg	%	mg	%	mg	%	mg	%	mg	%
Glass	77070	79.5%	21867	22.6%	167871	109.5%	52221	43.6%	533379	98.4%
Transition line	3801	3.9%	663	0.7%	5036	3.3%	275	0.2%	4239	0.8%
SBS sump	7172	7.4%	6300	6.5%	4959	3.2%	773	0.6%	2947	0.5%
WESP tube walls	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Containment tank	2227	2.3%	983	1.0%	1621	1.1%	169	0.1%	785	0.1%
Evaporator (custom)	9377	9.7%	3828	4.0%	6725	4.4%	-47	-0.04%	2667	0.5%
E-700 Evaporator	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Recycle line	768	0.8%	327	0.3%	487	0.3%	6	0.005%	392	0.1%
Test Samples	742	0.8%	381	0.4%	631	0.4%	20	0.02%	460	0.1%
WESP Emissions	<368	<0.38%	15087	16%	46220	30%	<359	<0.30%	9698	2%
Makeup water	NA	NA	NA	NA	-2110	-1.4%	-492	-0.4%	NA	NA
Total	101158	104.4%	49437	51.0%	231441	151.0%	52925	44.2%	554565	102.4%

NM – Not Measured.
NA – Not Applicable

Table 7.5. Measured Test-End Volatile Distributions for Test 4.

Constituent	ReO_2		Iodine		Chlorine		Fluorine		Sulfate	
mg fed	138900		138900		169600		68900		1152750	
Measured Distribution	mg	%	mg	%	mg	%	mg	%	mg	%
Glass	109352	78.7%	88765	63.9%	162964	96.1%	44529	64.6%	962107	83.5%
Transition line	5209	3.8%	203	0.1%	4316	2.5%	111	0.2%	5600	0.5%
SBS sump	4928	3.5%	24116	17.4%	4474	2.6%	1526	2.2%	18787	1.6%
WESP tube walls	11815	8.5%	80	0.1%	1212	0.7%	79	0.1%	2120	0.2%
Containment tank	1814	1.3%	5683	4.1%	1384	0.8%	420	0.6%	6610	0.6%
Evaporator (custom)	6089	4.4%	25000	18.0%	5728	3.4%	24	0.03%	17732	1.5%
E-700 Evaporator	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Recycle line	397	0.3%	1461	1.1%	388	0.2%	5	0.01%	1071	0.1%
Test Samples	602	0.4%	1640	1.2%	630	0.4%	20	0.03%	1543	0.1%
WESP Emissions	<500	<0.36%	1500	1%	55883	33%	<303	<0.44%	11873	1%
Makeup water	NA	NA	NA	NA	-2808	-1.7%	-655	-1.0%	NA	NA
Total	140207	100.9%	148447	106.9%	234170	138.1%	46058	66.8%	1027444	89.1%

NM – Not Measured.
NA – Not Applicable

Table 7.6. Measured Test-End Volatile Distributions for Test 5.

Constituent	ReO_2		Iodine		Chlorine		Fluorine		Sulfate	
mg fed	117400		117400		121520		32240		721680	
Measured Distribution	mg	%	mg	%	mg	%	mg	%	mg	%
Glass	68770	58.6%	17978	15.3%	94722	77.9%	49596	153.8%	664369	92.1%
Transition line	940	0.8%	785	0.7%	1267	1.0%	213	0.7%	2120	0.3%
SBS sump	7686	6.5%	8543	7.3%	3721	3.1%	1110	3.4%	2554	0.4%
WESP tube walls	24805	21.1%	41	0.03%	6492	5.3%	385	1.2%	3499	0.5%
Containment tank	2689	2.3%	1918	1.6%	1187	1.0%	390	1.2%	505	0.1%
Evaporator (custom)	14076	12.0%	4712	4.0%	5617	4.6%	377	1.2%	7220	1.0%
E-700 Evaporator	< 48	<0.04%	591	0.5%	12183	10.0%	-4	0.001%	18115	2.5%
Recycle line	466	0.4%	326	0.3%	363	0.3%	44	0.01%	338	0.1%
Test Samples	791	0.7%	550	0.5%	501	0.4%	18	0.01%	506	0.1%
WESP Emissions	<423	<0.36%	31240	27%	<413	<0.34%	<110	<0.34%	12269	2%
Makeup water	NA	NA	NA	NA	-2438	-2.0%	-569	-1.8%	NA	NA
Total	120224	102.4%	66684	56.8%	123615	101.7%	51560	159.9%	711495	98.6%

NM – Not Measured.
NA – Not Applicable

Table 7.7. Measured Test-End Volatile Distributions for Test 6.

Constituent	ReO_2		Iodine		Chlorine		Fluorine		Sulfate	
mg fed	143420		143420		217560		49980		637980	
Measured Distribution	mg	%	mg	%	mg	%	mg	%	mg	%
Glass	74470	51.9%	58803	41.0%	189137	86.9%	45132	90.3%	655742	102.8%
Transition line	4173	2.9%	1113	0.8%	3727	1.7%	920	1.8%	2742	0.4%
SBS sump	10085	7.0%	617	0.4%	5750	2.6%	589	1.2%	724	0.1%
WESP tube walls	28526	19.9%	22	0.02%	15885	7.3%	1272	2.5%	4901	0.8%
Containment tank	3661	2.6%	301	0.2%	2890	1.3%	280	0.6%	880	0.1%
Evaporator (custom)	3995	2.8%	3280	2.3%	13998	6.4%	196	0.4%	5144	0.8%
E-700 Evaporator	2536	1.8%	1277	0.9%	8578	3.9%	247	0.5%	16425	2.6%
Recycle line	1329	0.9%	378	0.3%	1255	0.6%	40	0.1%	561	0.1%
Test Samples	1013	0.7%	414	0.3%	1456	0.7%	34	0.1%	701	0.1%
WESP Emissions	<502	<0.35%	48103	34%	3068	1.4%	<175	<0.35%	10527	2%
Makeup water	NA	NA	NA	NA	-2808	-1.3%	-655	-1.3%	NA	NA
Total	129787	90.5%	114307	79.7%	239869	111.7%	48055	96.1%	698348	109.5%

NM – Not Measured.
NA – Not Applicable

Table 7.8. Measured Test-End Volatile Distributions for Test 7.

Constituent	ReO_2		Iodine		Chlorine		Fluorine		Sulfate	
mg fed	117340		117340		125950		42365		634330	
Measured Distribution	mg	%	mg	%	mg	%	mg	%	mg	%
Glass	98060	83.6%	48641	41.5%	119010	94.5%	37902	89.5%	587413	92.6%
Transition line	5990	5.1%	783	0.7%	3592	2.9%	1060	2.5%	3422	0.5%
SBS sump	4933	4.2%	4245	3.6%	-2692	-2.1%	470	1.1%	975	0.2%
WESP tube walls	7044	6.0%	16	0.01%	2901	2.3%	328	0.8%	2045	0.3%
Containment tank	2085	1.8%	1224	1.0%	885	0.7%	152	0.4%	389	0.1%
Evaporator (custom)	8684	7.4%	4289	3.7%	5492	4.4%	142	0.3%	3882	0.6%
E-700 Evaporator	3339	2.8%	310	0.3%	9280	7.4%	227	0.5%	17069	2.7%
Recycle line	NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Test Samples	1105	0.9%	410	0.3%	722	0.6%	25	0.1%	572	0.1%
WESP Emissions	<505	<0.43%	36258	31%	<466	<0.37%	<517	<1.22%	8056	1%
Makeup water	NA	NA	NA	NA	-2828	-2.2%	-660	-1.6%	NA	NA
Total	131240	111.8%	96176	82.0%	136363	108.3%	39645	93.6%	623823	98.3%

NM – Not Measured.
NA – Not Applicable

Table 7.9. Measured Test-End Volatile Distributions for Test 8.

Constituent	ReO_2		Iodine		Chlorine		Fluorine		Sulfate	
mg fed	147560		147560		196310		319370		1034290	
Measured Distribution	mg	%	mg	%	mg	%	mg	%	mg	%
Glass	80740	54.7%	12043	8.2%	188126	95.8%	30826	9.7%	1125858	108.9%
Transition line	7787	5.3%	59	0.04%	3248	1.7%	2350	0.7%	9249	0.9%
SBS sump	12880	8.7%	17362	11.8%	1063	0.5%	5826	1.8%	4255	0.4%
WESP tube walls	29720	20.1%	8	0.005%	10424	5.3%	552	0.2%	6030	0.6%
Containment tank	4617	3.1%	1446	1.0%	2993	1.5%	-107	- 0.03%	2038	0.2%
Evaporator (custom)	13520	9.2%	3136	2.1%	7810	4.0%	85	0.03%	5859	0.6%
E-700 Evaporator	< 71	< 0.05%	1807	1.2%	113	0.1%	6817	2.1%	13287	1.3%
Recycle line	1039	0.7%	246	0.2%	679	0.3%	57	0.02%	569	0.1%
Test Samples	1672	1.1%	323	0.2%	903	0.5%	37	0.01%	983	0.1%
WESP Emissions	<502	<0.34%	39399	27%	1708	1%	<447	<0.14%	10343	1%
Makeup water	NA	NA	NA	NA	-2808	-1.4%	-655	-0.2%	NA	NA
Total	151975	103.0%	75829	51.4%	214258	109.1%	45787	14.3%	1178470	113.9%

NM – Not Measured.
NA – Not Applicable

Table 7.10. Measured Test-End Volatile Distributions for Test 9.

Constituent	ReO_2		Iodine		Chlorine		Fluorine		Sulfate	
mg fed	145700		145700		148920		35040		981120	
Measured Distribution	mg	%	mg	%	mg	%	mg	%	mg	%
Glass	119354	81.9%	39619	27.2%	151620	101.8%	30450	86.9%	952021	97.0%
Transition line	3233	2.2%	1244	0.9%	2202	1.5%	181	0.5%	6095	0.6%
SBS sump	4360	3.0%	16268	11.2%	1814	1.2%	786	2.2%	5001	0.5%
WESP tube walls	6815	4.7%	94	0.1%	1728	1.2%	183	0.5%	1873	0.2%
Containment tank	1639	1.1%	4816	3.3%	1065	0.7%	256	0.7%	2129	0.2%
Evaporator (custom)	6702	4.6%	14521	10.0%	4153	2.8%	126	0.4%	7050	0.7%
E-700 Evaporator	<46	<0.03%	3554	2.4%	1859	1.2%	53	0.2%	2874	0.3%
Recycle line	464	0.3%	916	0.6%	316	0.2%	31	0.1%	614	0.1%
Test Samples	746	0.5%	1352	0.9%	511	0.3%	25	0.1%	888	0.1%
WESP Emissions	<510	<0.35%	15080	10%	1698	1%	<49	<0.14	8732	1%
Makeup water	NA	NA	NA	NA	-2808	-1.9%	-655	-1.9%	NA	NA
Total	143314	98.4%	97464	66.9%	164156	110.2%	31436	89.7%	987277	100.6%

NM – Not Measured.
NA – Not Applicable

Table 7.11. Chlorine Recovery and Measured Emission Rates from the WESP.

Test		% Chlorine Measured in Glass	% Chlorine in WESP Exhaust	% Chlorine Total Recovery	Measured Chlorine Particulate Emission Rate mg/min	Measured Chlorine Gaseous Emission Rate mg/min
2	LAWE4H	134	92	231	21.3	14.3*
3	LAWE5H	110	30	151	< 0.1	12.88
4	LAWE10H	96	33	138	< 0.1	12.84
5	LAWE6H	78	< 0.4	102	< 0.1	< 0.34
6	LAWE3	87	1	112	0.6	< 0.23
7	LAWE4H	95	< 0.4	108	< 0.1	< 0.37
8	LAWE7H	96	1	109	< 0.1	0.39
9	LAWE9H	102	1	110	< 0.1	0.39

* - The second sample taken during the test had gaseous Chlorine emissions of 12.5 mg/min.

Table 8.1. Percent Single Pass Retention Factors in the Melter, SBS, and WESP for Tests 2 - 9.

	Test 2, LAWE4H						Test 3, LAWE5H					
	Tc	Re	I	S	Cl	F	Tc	Re	I	S	Cl	F
Melter	56.4%	67.6%	30.7%	83.8%	NA	NA	25.7%	43.4%	16.1%	101.3%	NA	NA
SBS	66.4%	86.4%	54.9%	93.1%	NA	NA	49.9%	75.1%	68.8%	<0%	NA	NA
WESP-1*	18.8%	<0%	21.2%	<0%	NA	NA	100.0%	98.5%	58.8%	112.5%	NA	NA
WESP-2	55.0%	54.0%	1.6%	16.9%	NA	NA	99.9%	99.5%	12.7%	79.0%	NA	NA
	Test 4, LAWE10H						Test 5, LAWE6H					
	Tc	Re	I	S	Cl	F	Tc	Re	I	S	Cl	F
Melter	47.5%	50.4%	21.9%	67.6%	NA	NA	22.0%	31.3%	8.8%	87.8%	51.0%	NA
SBS	43.5%	61.1%	97.9%	69.9%	NA	NA	29.2%	45.3%	79.5%	76.9%	62.4%	NA
WESP-1	99.9%	98.8%	75.5%	90.7%	NA	NA	99.9%	99.5%	10.4%	47.2%	98.9%	NA
WESP-2	100.0%	99.4%	79.7%	74.7%	NA	NA	99.8%	99.4%	7.6%	70.3%	99.1%	NA
	Test 6, LAWE3H						Test 7, LAWE4H					
	Tc	Re	I	S	Cl	F	Tc	Re	I	S	Cl	F
Melter	25.3%	33.7%	33.6%	94.2%	52.4%	68.4%	38.2%	41.6%	29.5%	86.6%	59.8%	63.3%
SBS	54.2%	92.3%	60.1%	195.6%	76.6%	151.2%	52.1%	71.5%	65.8%	65.4%	44.2%	78.2%
WESP-1	99.3%	96.0%	3.7%	128.2%	93.1%	105.4%	99.9%	98.6%	3.6%	70.3%	99.0%	87.8%
WESP-2	99.1%	99.5%	4.3%	70.2%	96.3%	95.1%	99.9%	99.3%	8.5%	73.0%	99.0%	90.6%
	Test 8, LAWE7H						Test 9, LAWE9H					
	Tc	Re	I	S	Cl	F	Tc	Re	I	S	Cl	F
Melter	20.1%	23.6%	7.7%	103.1%	63.7%	NA	46.4%	53.4%	12.9%	76.1%	NA	NA
SBS	66.4%	60.9%	52.4%	<0%	15.4%	NA	55.6%	67.4%	91.9%	53.3%	NA	NA
WESP-1	99.7%	99.5%	51.7%	107.6%	97.8%	NA	100.0%	98.5%	32.3%	91.7%	NA	NA
WESP-2	99.8%	99.6%	6.9%	77.5%	96.4%	NA	100.0%	99.1%	14.2%	74.1%	NA	NA

* WESP-1 and WESP-2 refer to two different methods of calculating the WESP retention; the former uses the input and output gas streams, while the latter uses the output gas stream and the liquid effluent stream.

Table 8.2.a. Averages of Percent Single Pass Retention Factors in the Melter, SBS, and WESP Over All Tests.

	Tc	Re	I	S	Cl	F
Melter	35.2%	43.1%	20.1%	87.6%	56.7%	65.8%
SBS	52.2%	70.0%	71.4%	92.4%	49.7%	114.7%
WESP-1*	89.7%	98.5%	32.1%	92.6%	97.2%	96.6%
WESP-2	94.2%	93.7%	16.9%	67.0%	97.7%	92.9%

* See Table 8.1.

Table 8.2.b. Averages of Percent Single Pass Retention Factors in the Melter, SBS, and WESP Over All Tests After Excluding Values Greater than 100% and Values for Test 2.

	Tc	Re	I	S	Cl	F
Melter	35.2%	43.1%	20.1%	87.2%	56.7%	65.8%
SBS	52.2%	70.0%	71.4%	71.7%	49.7%	78.2%
WESP-1*	99.8%	98.5%	33.7%	92.6%	97.2%	87.8%
WESP-2	99.8%	99.4%	19.1%	74.1%	97.7%	92.9%

* See Table 8.1.

Table 8.3. Comparison of Percent Retention Factors in the SBS and WESP Determined on the DM10 and DM1200 Melter Systems.

	Re			S			I		
	DM10 Test 7	DM10 Average	DM1200	DM10 Test 7	DM10 Average	DM1200	DM10 Test 7	DM10 Average	DM1200
SBS	71.5%	70.0%	73.0%	65.4%	71.7%	76.3%	65.8%	71.4%	52.8%
WESP-1*	98.6%	98.5%	98.5%	70.3%	92.6%	86.0%	3.6%	33.7%	95.2%
WESP-2	99.3%	99.4%		73.0%	74.1%		8.5%	19.1%	

* See Table 8.1.

Table 9.1. Initial Sump Volume Estimates and As-Built Sump Volumes.

	Volume (L)	
	Conceptual Design Estimate	As-Built
SBS	15	45
WESP	5	0.1
Containment Tank	10	11
Evaporator	1	2.5

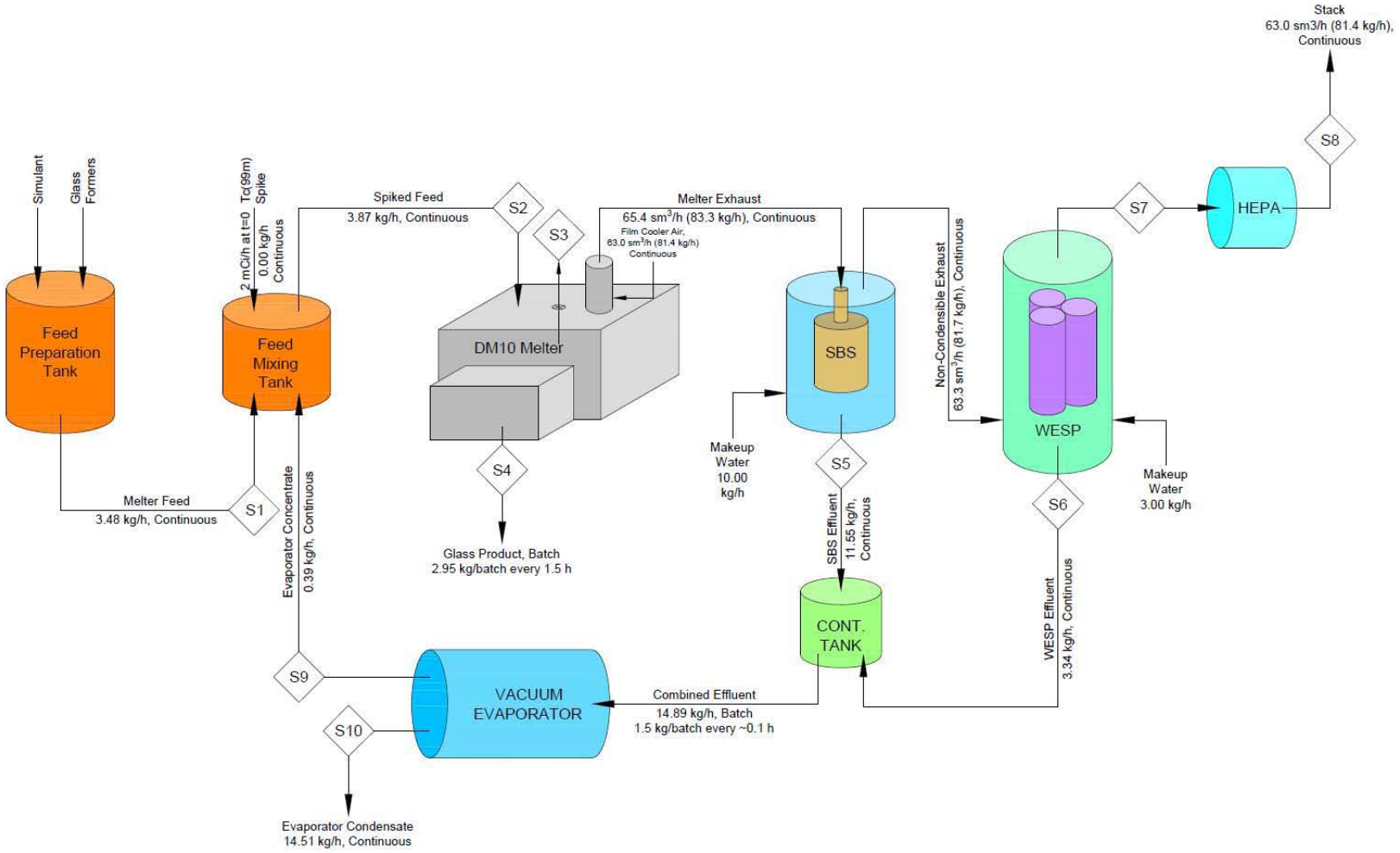


Figure 1.1.a. Schematic diagram (original) showing DM10 system components and process flows to implement recycle loop. Also shown are the sampling point (S1 – S10) and the approximate process flow rates.

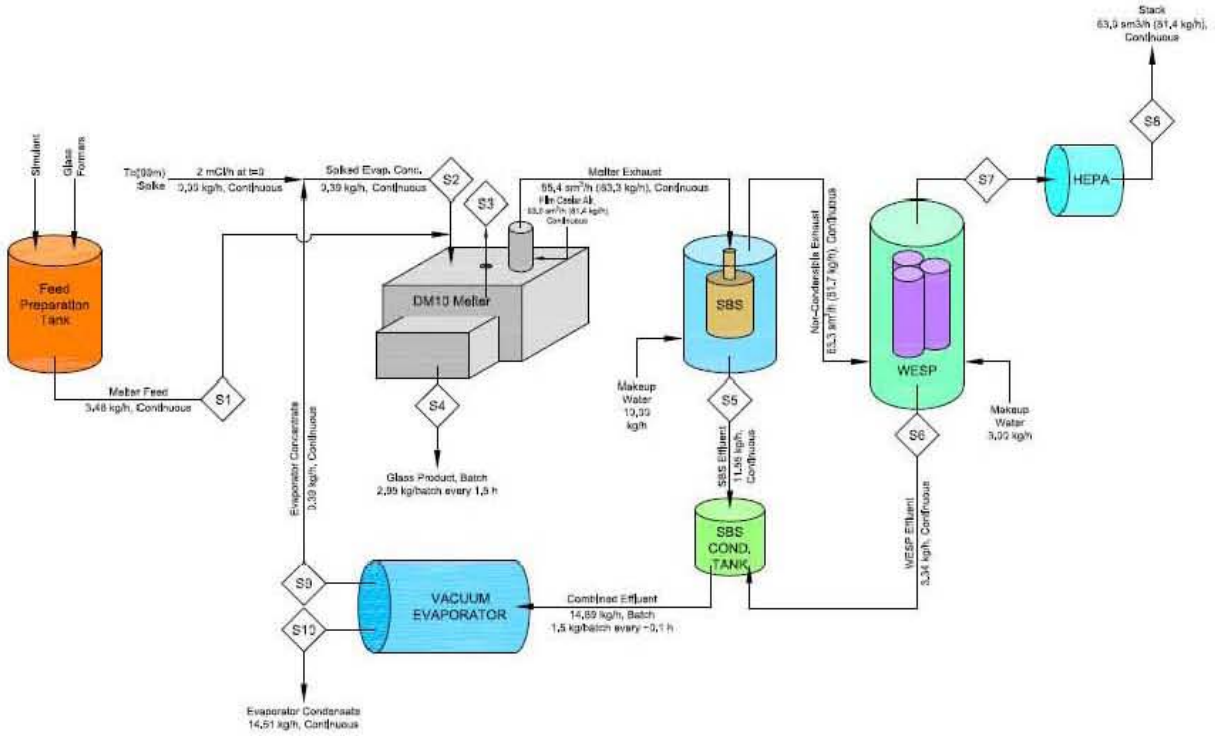


Figure 1.1.b. Schematic diagram (second revision) showing DM10 system components and process flows to implement recycle loop. Also shown are the sampling point (S1 – S10) and the approximate process flow rates.

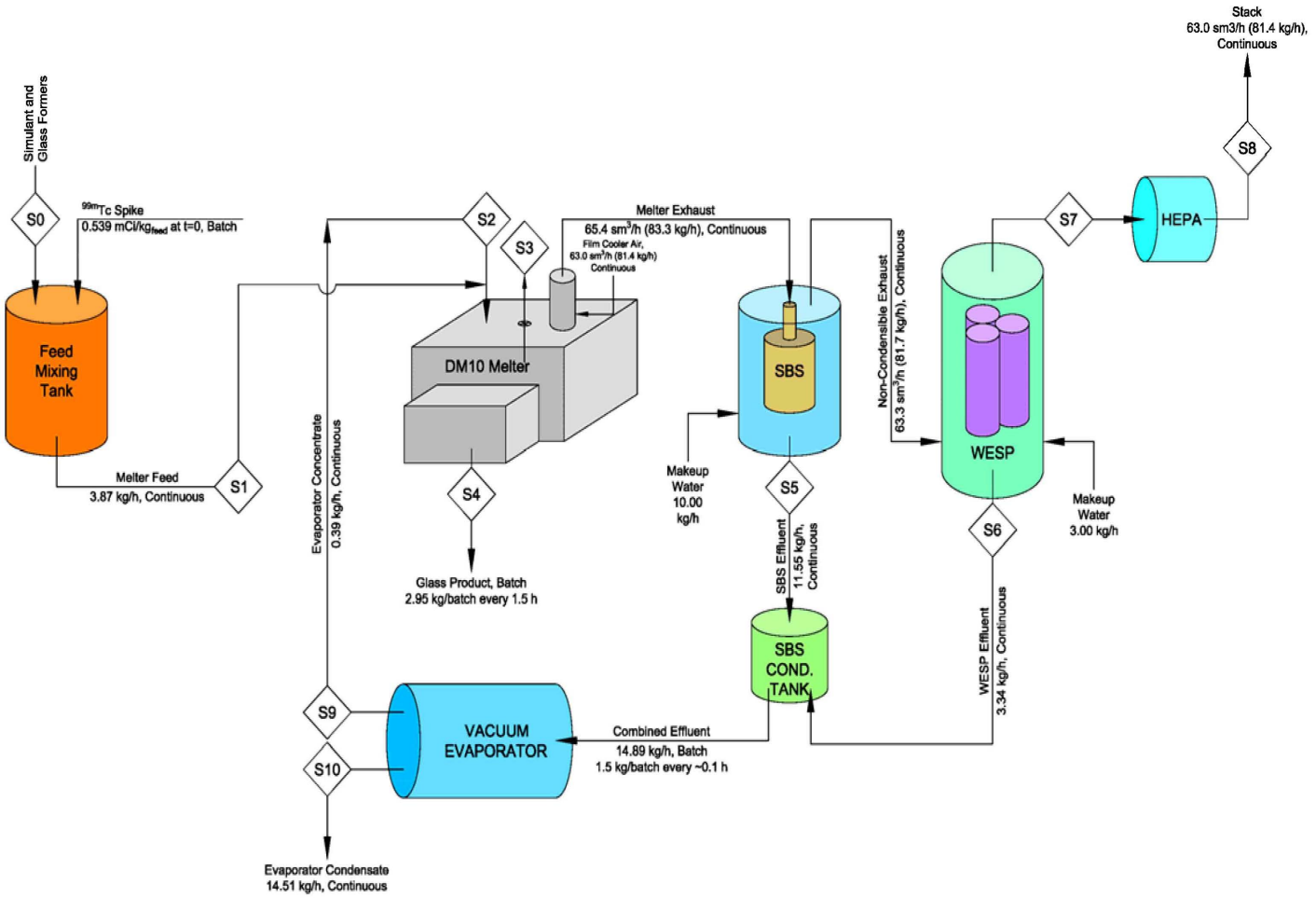
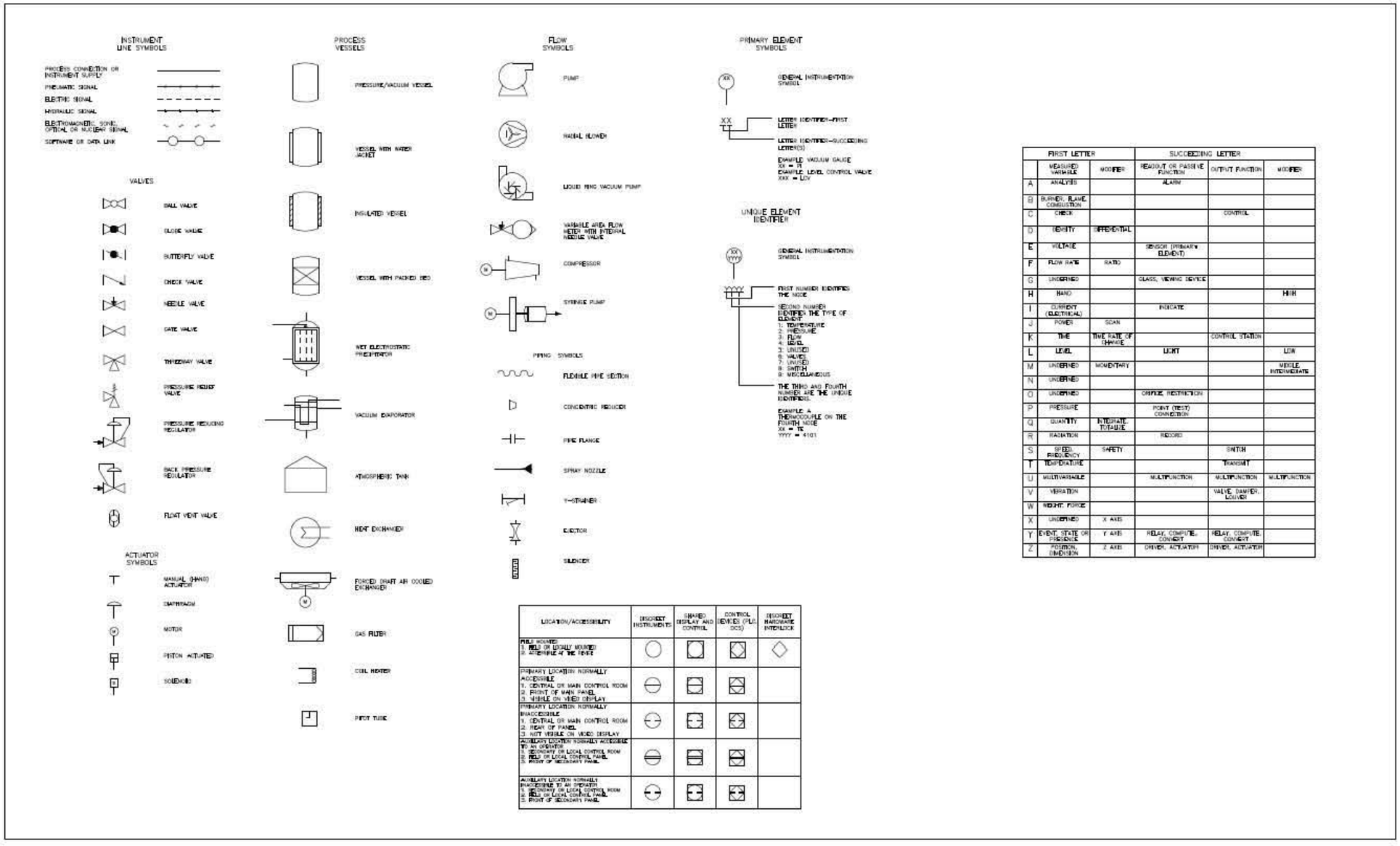


Figure 1.1.c. Schematic diagram (Final) showing DM10 system components and process flows to implement recycle loop. Also shown are the sampling point (S0 – S10) and the approximate process flow rates.



FIRST LETTER			SUCCEEDING LETTER		
	MEASURED VARIABLE	MODIFIER	READOUT OR PASSIVE FUNCTION	OUTPUT FUNCTION	MODIFIER
A	ANALYSIS		ALARM		
B	BURNER, FLAME, COMBUSTION				
C	CHECK			CONTROL	
D	DENSITY	DIFFERENTIAL			
E	VOLTAGE		SENSOR (PRIMARY ELEMENT)		
F	FLOW RATE	RATIO			
G	UNDEFINED		GLASS, VIEWING DEVICE		
H	HAND				HIGH
I	CURRENT (ELECTRICAL)		INDICATE		
J	POWER	SCAN			
K	TIME	TIME RATE OF CHANGE		CONTROL STATION	
L	LEVEL		LIGHT		LOW
M	UNDEFINED	MOMENTARY			MIDDLE, INTERMEDIATE
N	UNDEFINED				
O	UNDEFINED		ORIFICE, RESTRICTION		
P	PRESSURE		POINT (TEST) CONNECTION		
Q	QUANTITY	INTEGRATE, TOTALIZE			
R	RADIATION		RECORD		
S	SPEED, FREQUENCY	SAFETY		SWITCH	
T	TEMPERATURE			TRANSMIT	
U	MULTIVARIABLE		MULTIFUNCTION	MULTIFUNCTION	MULTIFUNCTION
V	VIBRATION			VALVE, DAMPER, LOUVER	
W	WEIGHT, FORCE				
X	UNDEFINED	X AXIS			
Y	EVENT, STATE OR PRESENCE	Y AXIS	RELAY, COMPUTE, CONVERT	RELAY, COMPUTE, CONVERT	
Z	POSITION, DIMENSION	Z AXIS	DRIVER, ACTUATOR	DRIVER, ACTUATOR	

Figure 1.2. P&ID Legend and Symbols.

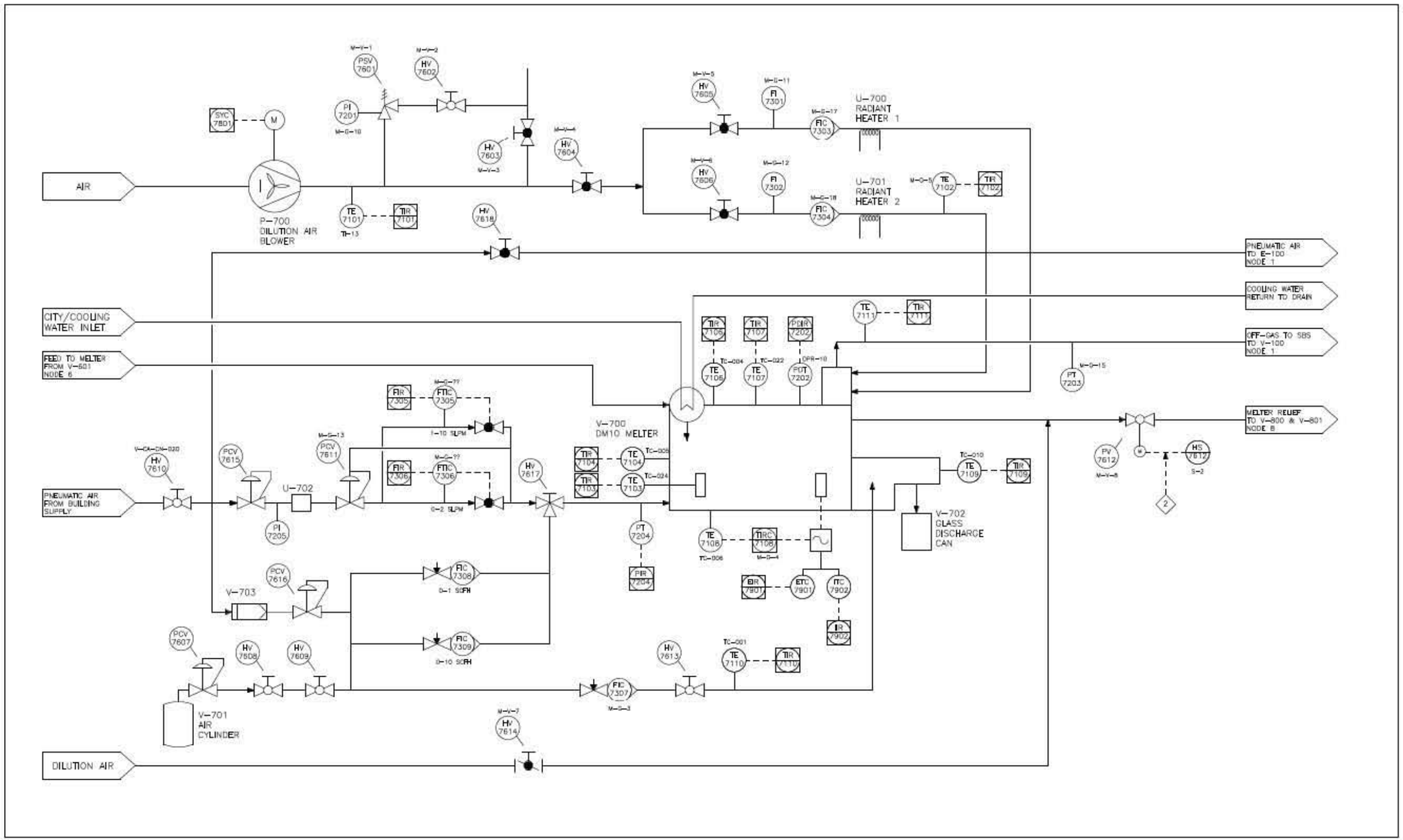


Figure 1.3. P&ID Node 7: DM10 Melter.

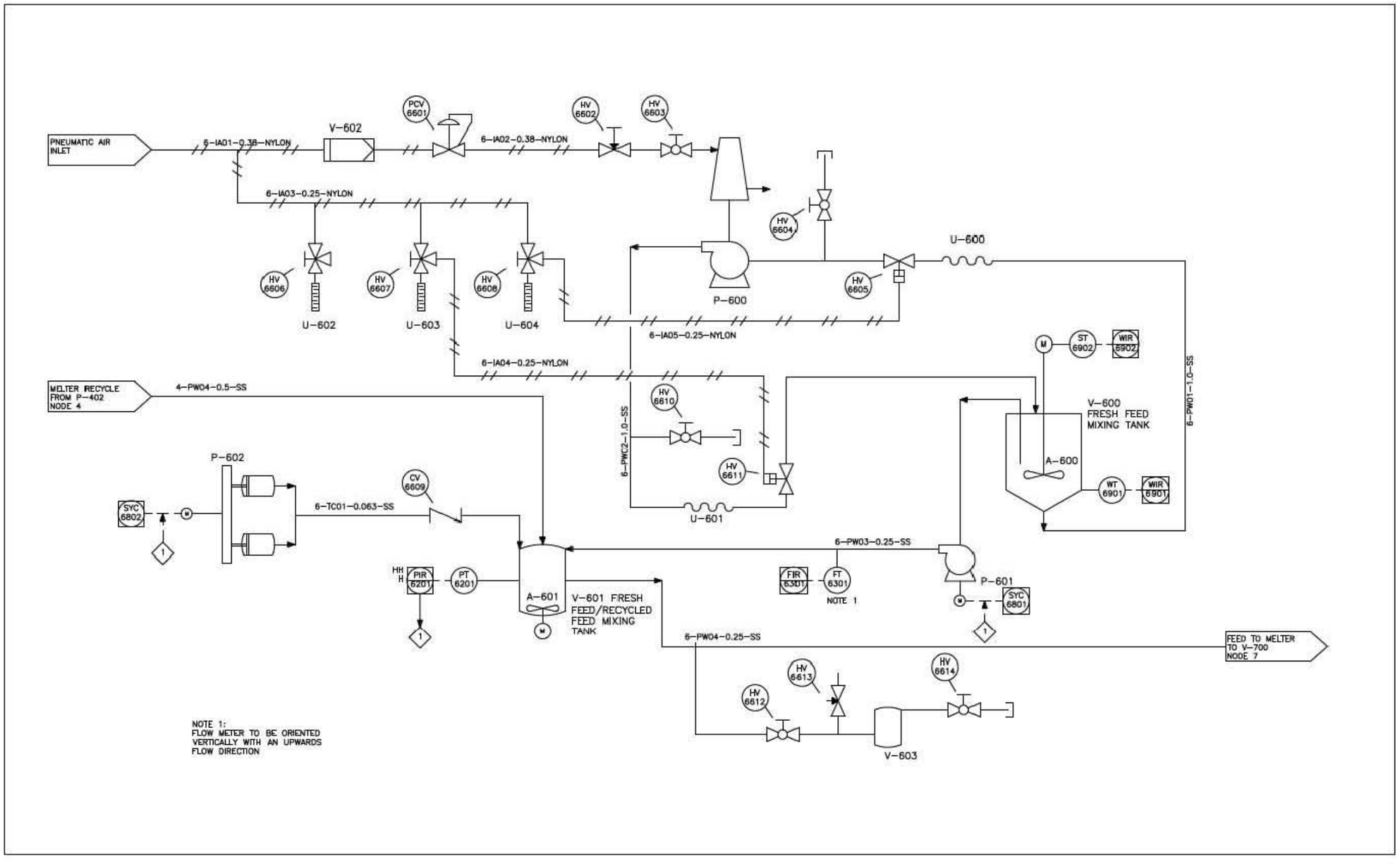


Figure 1.4.a. P&ID Node 6: DM10 Feed (original, Test 1).

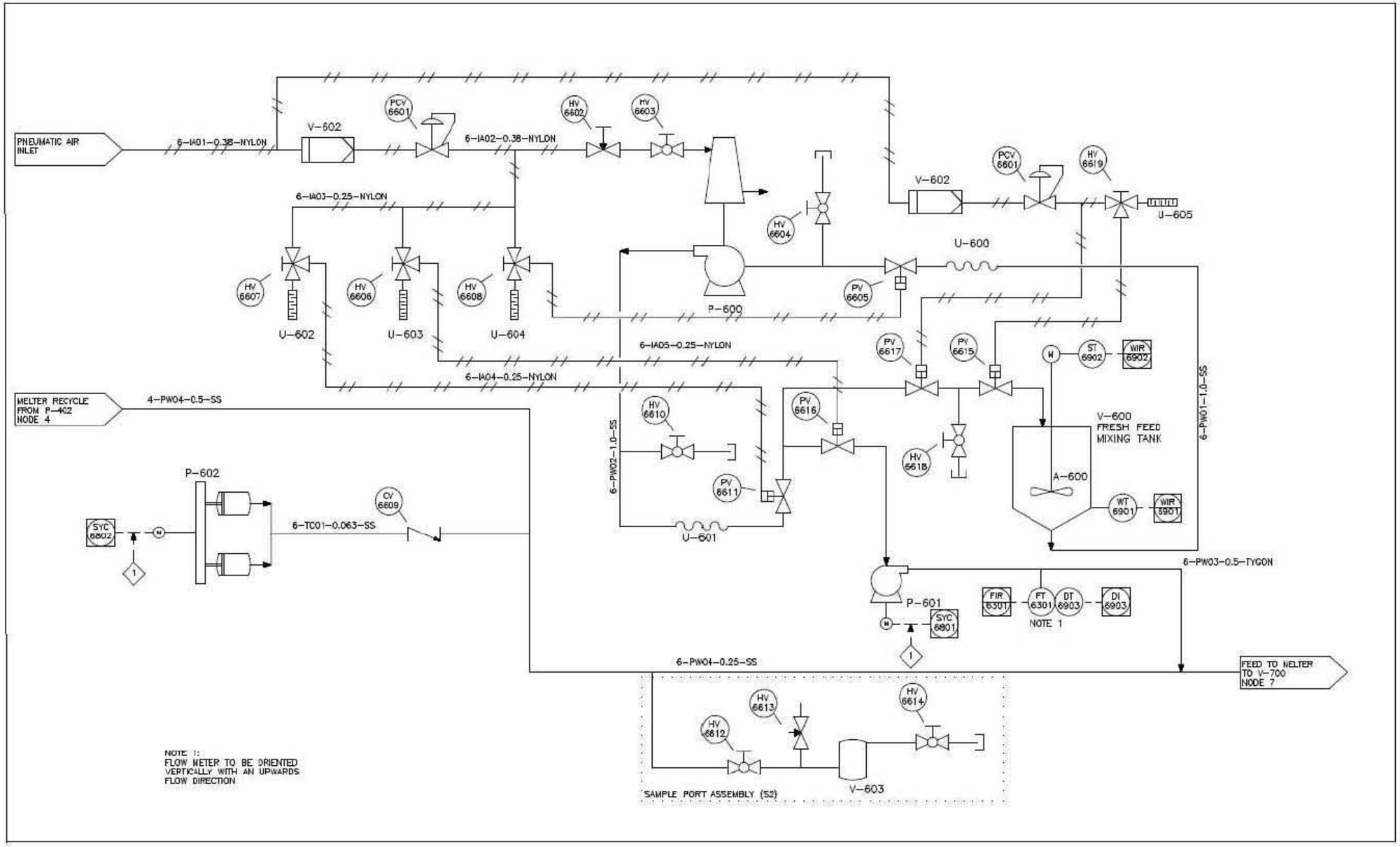


Figure 1.4.b. P&ID Node 6: DM10 Feed (Tests 2-4).

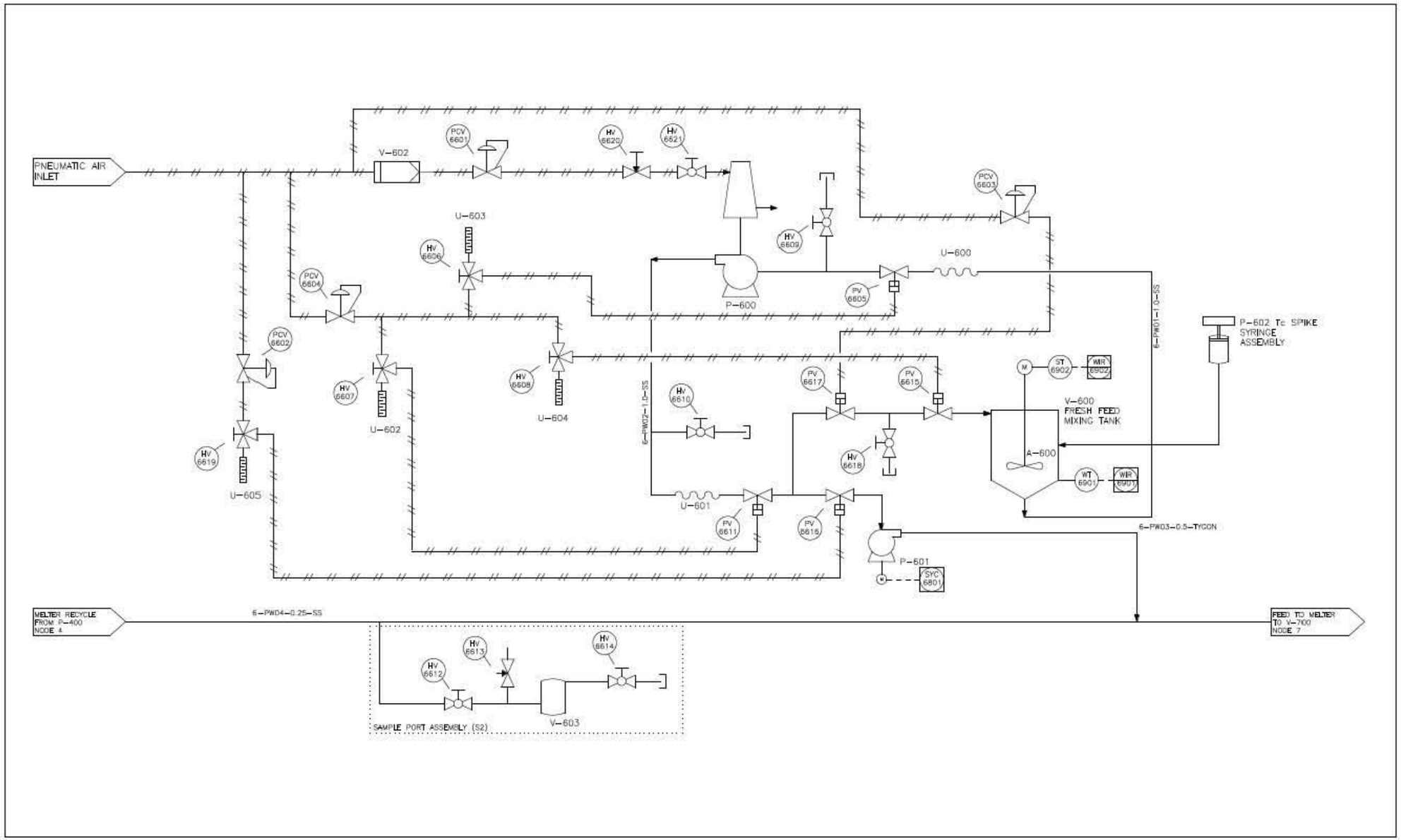


Figure 1.4.c. P&ID Node 6: DM10 Feed (Test 5).

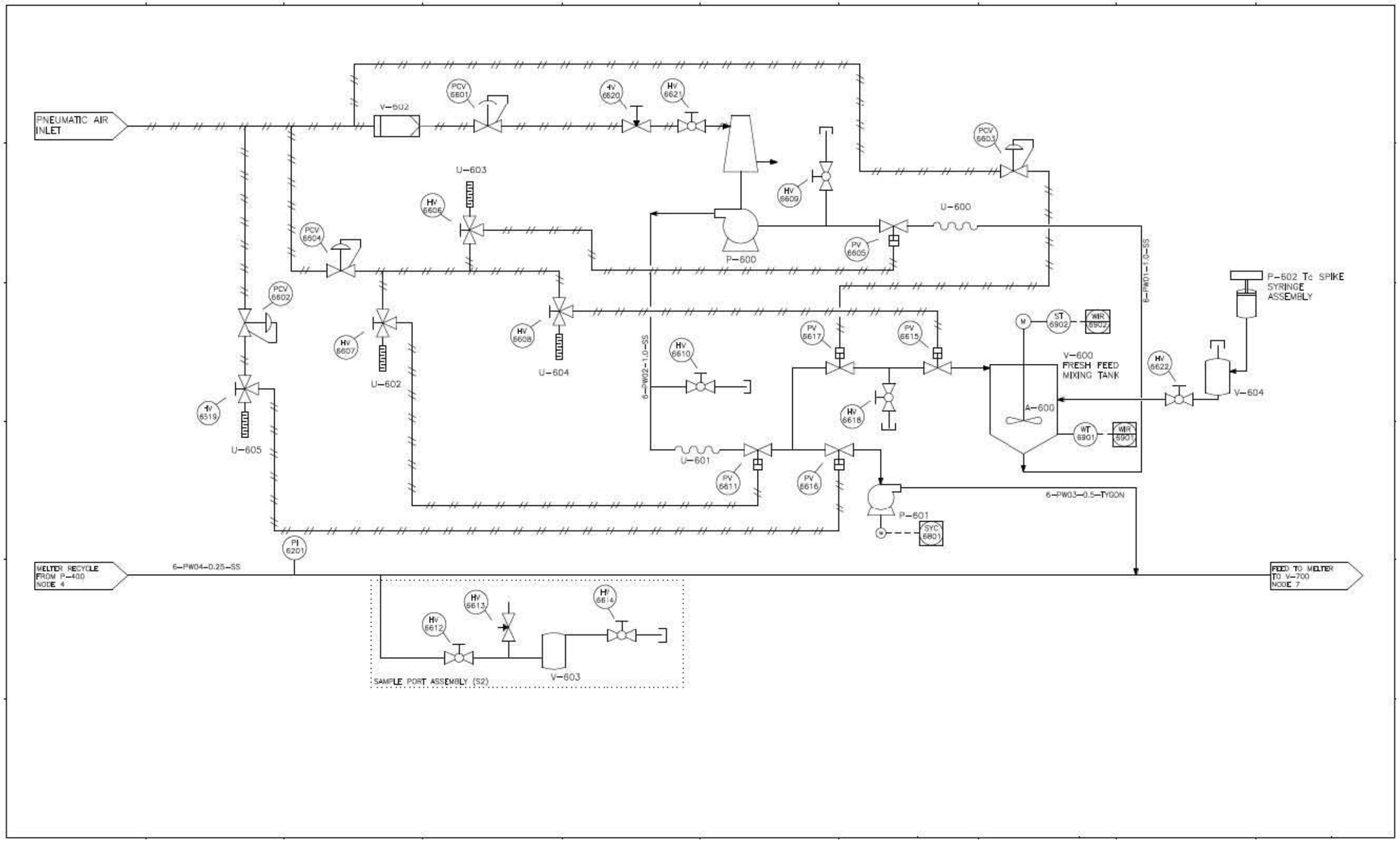


Figure 1.4.d. P&ID Node 6: DM10 Feed (Tests 6-9).

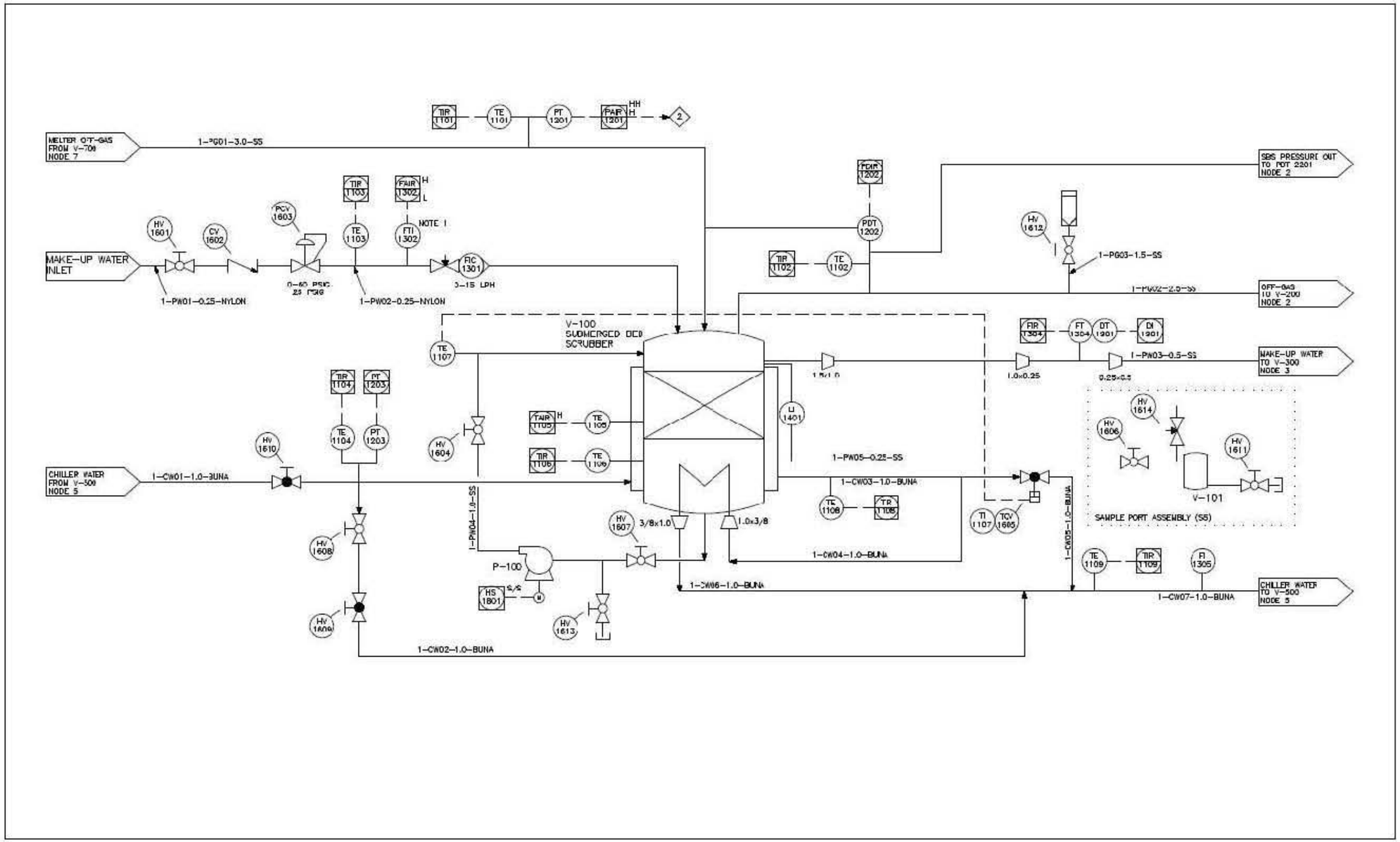


Figure 1.5.a. P&ID Node 1: DM10 Submerged Bed Scrubber (SBS), Tests 1-4.

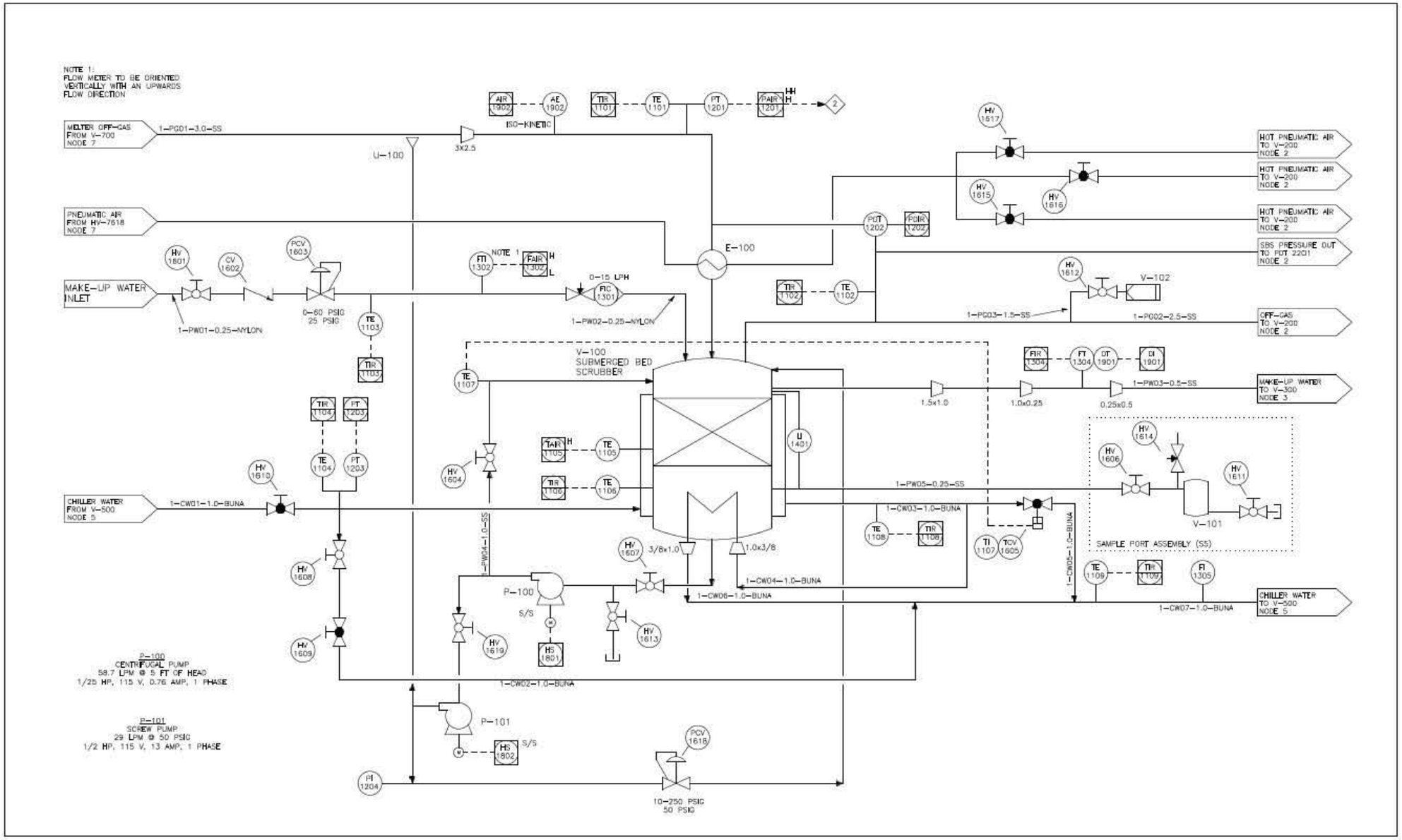


Figure 1.5.b. P&ID Node 1: DM10 Submerged Bed Scrubber (SBS), Tests 5-9.

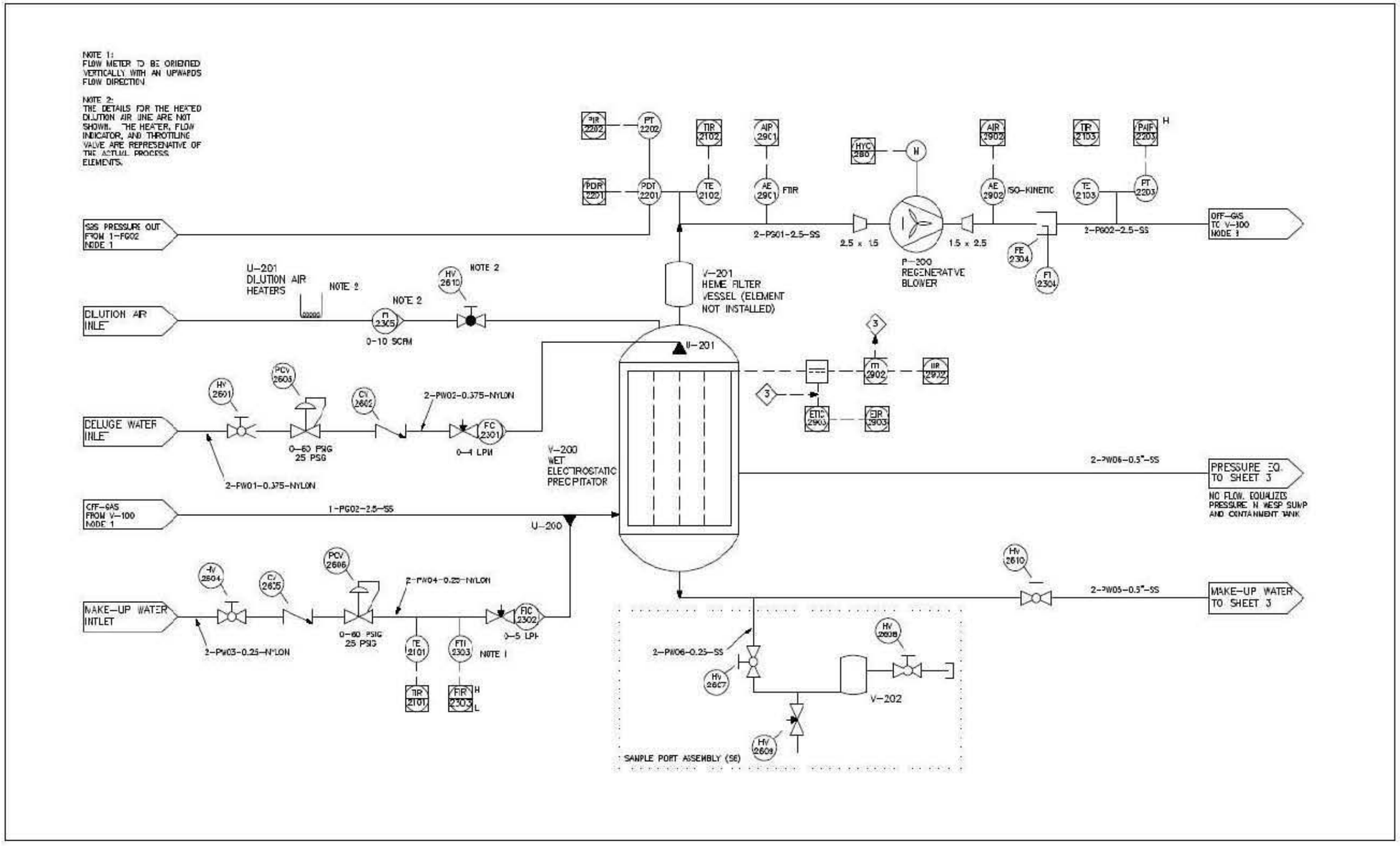


Figure 1.6.a. P&ID Node 2: DM10 Wet Electrostatic Precipitator (WESP).

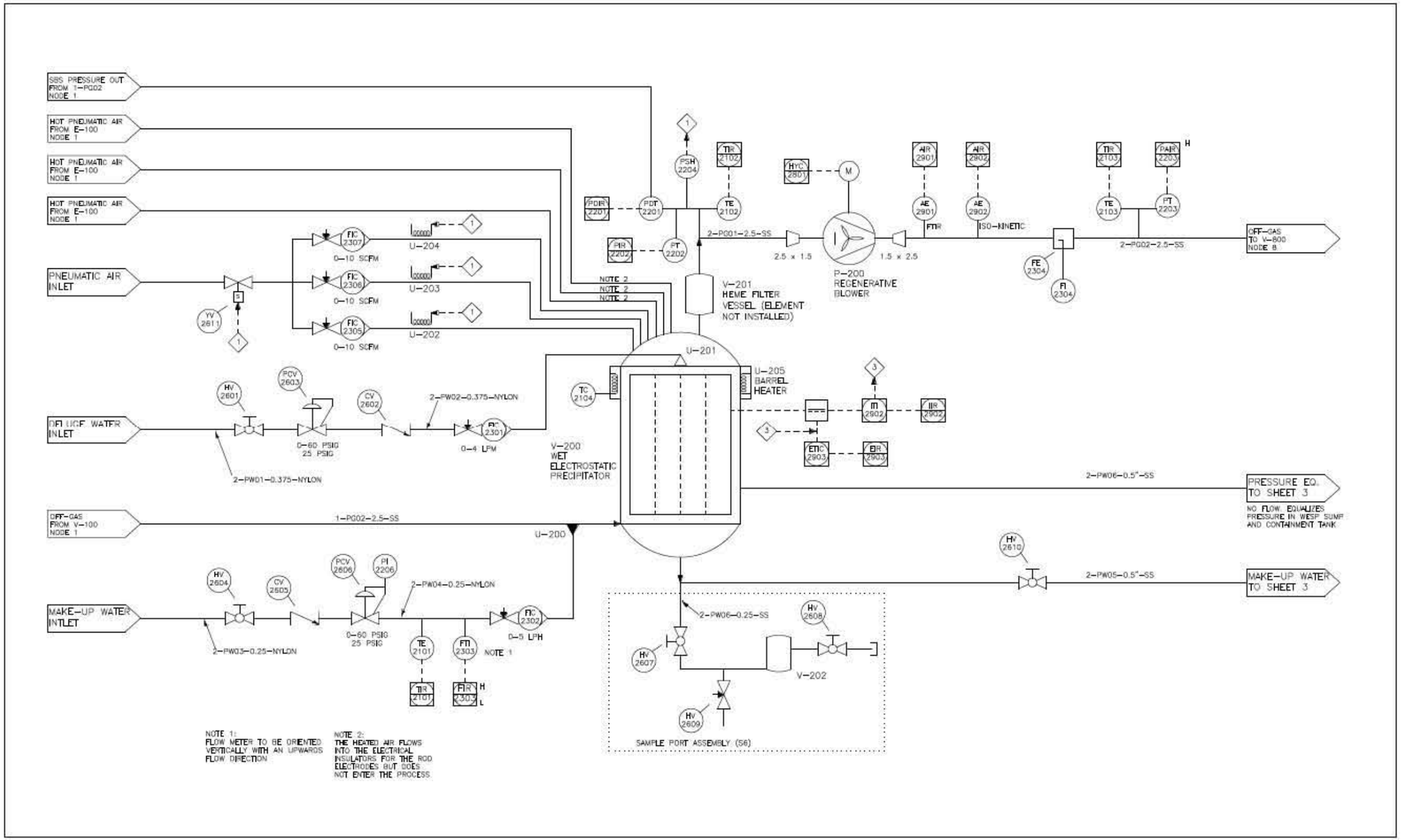


Figure 1.6.b. P&ID Node 2: DM10 Wet Electrostatic Precipitator (WESP), Final Configuration.

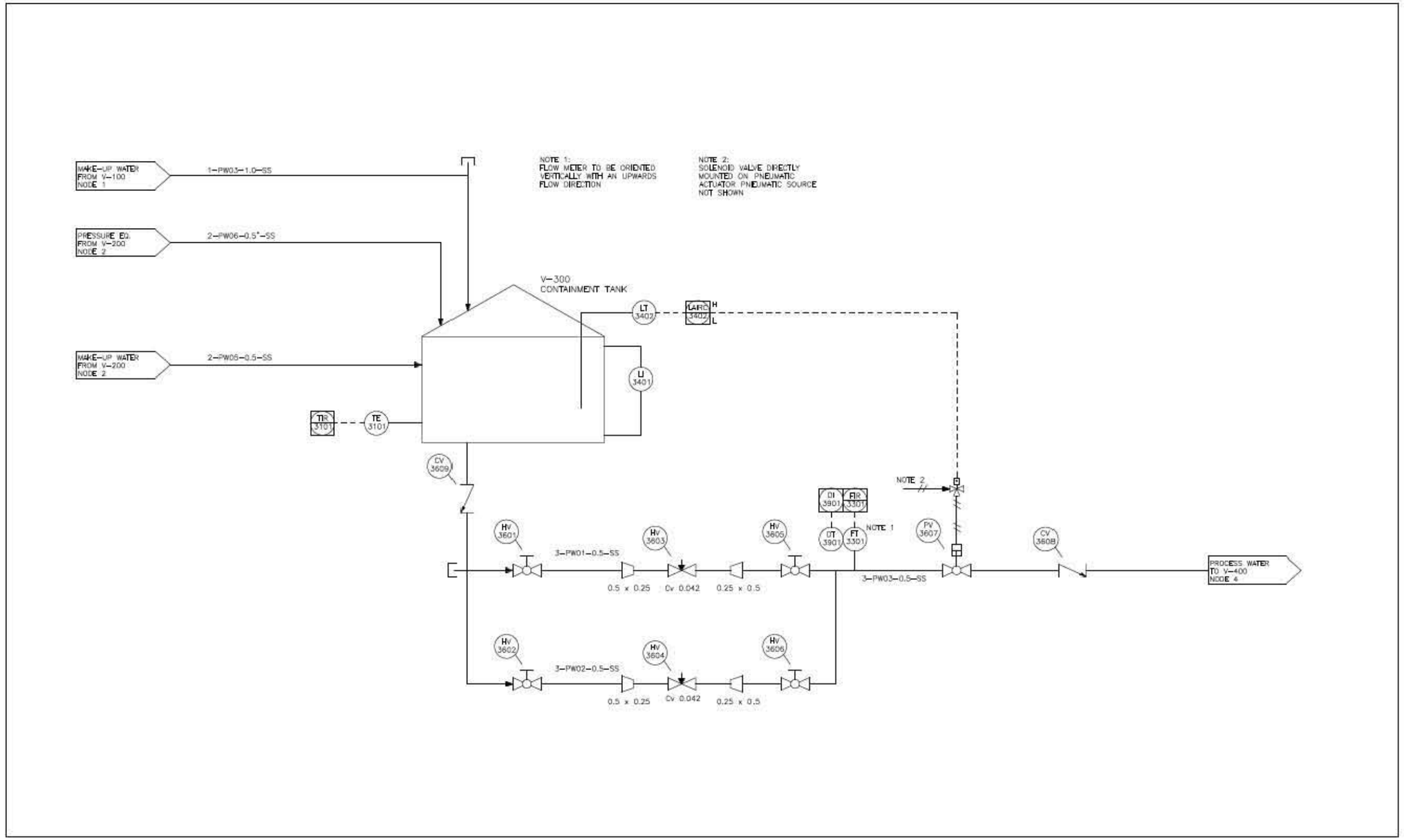


Figure 1.7. P&ID Node 3: DM10 Containment Tank.

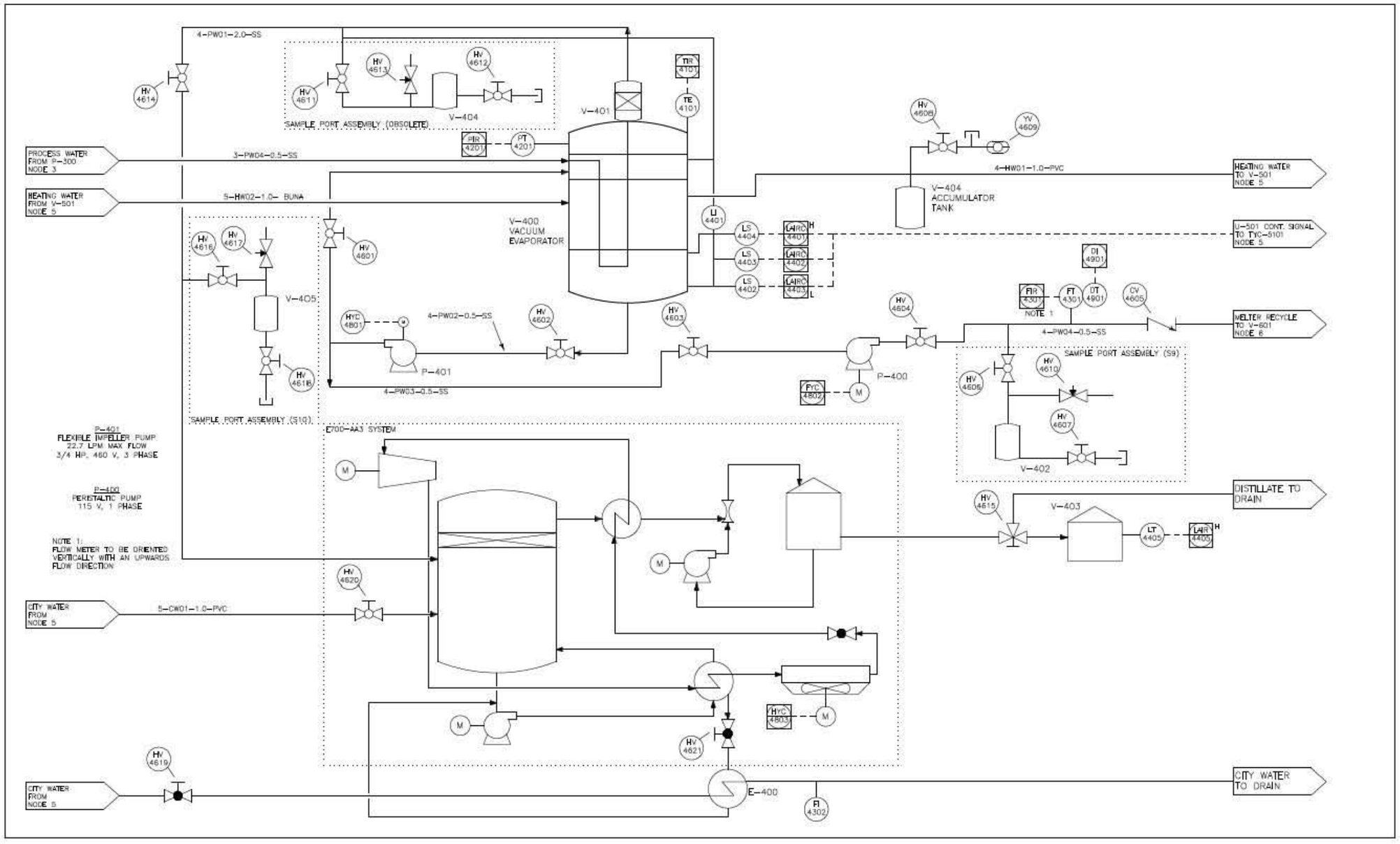


Figure 1.8. P&ID Node 4: DM10 Vacuum Evaporator.

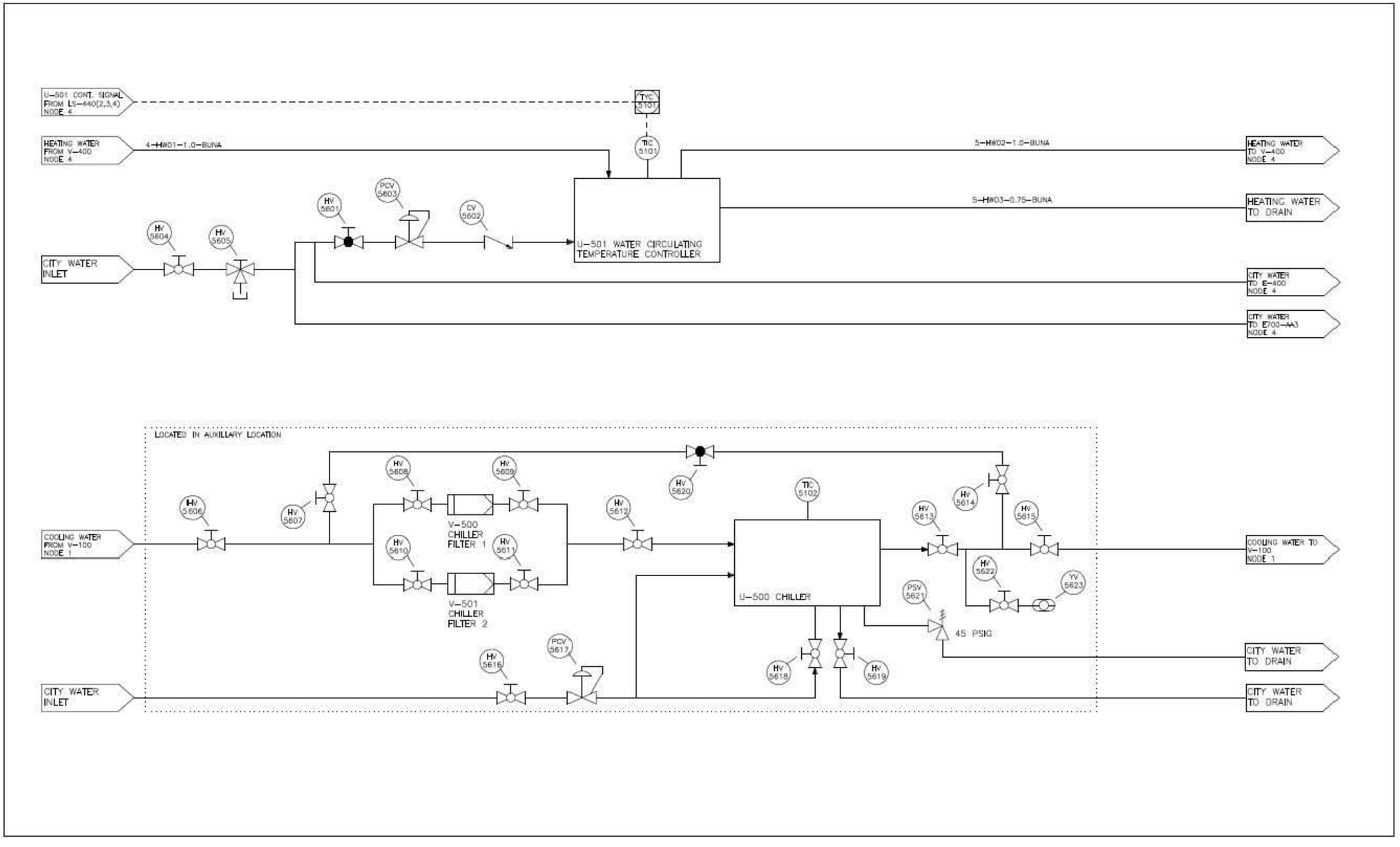


Figure 1.9. P&ID Node 5: DM10 Heating Water and Cooling Water Systems.

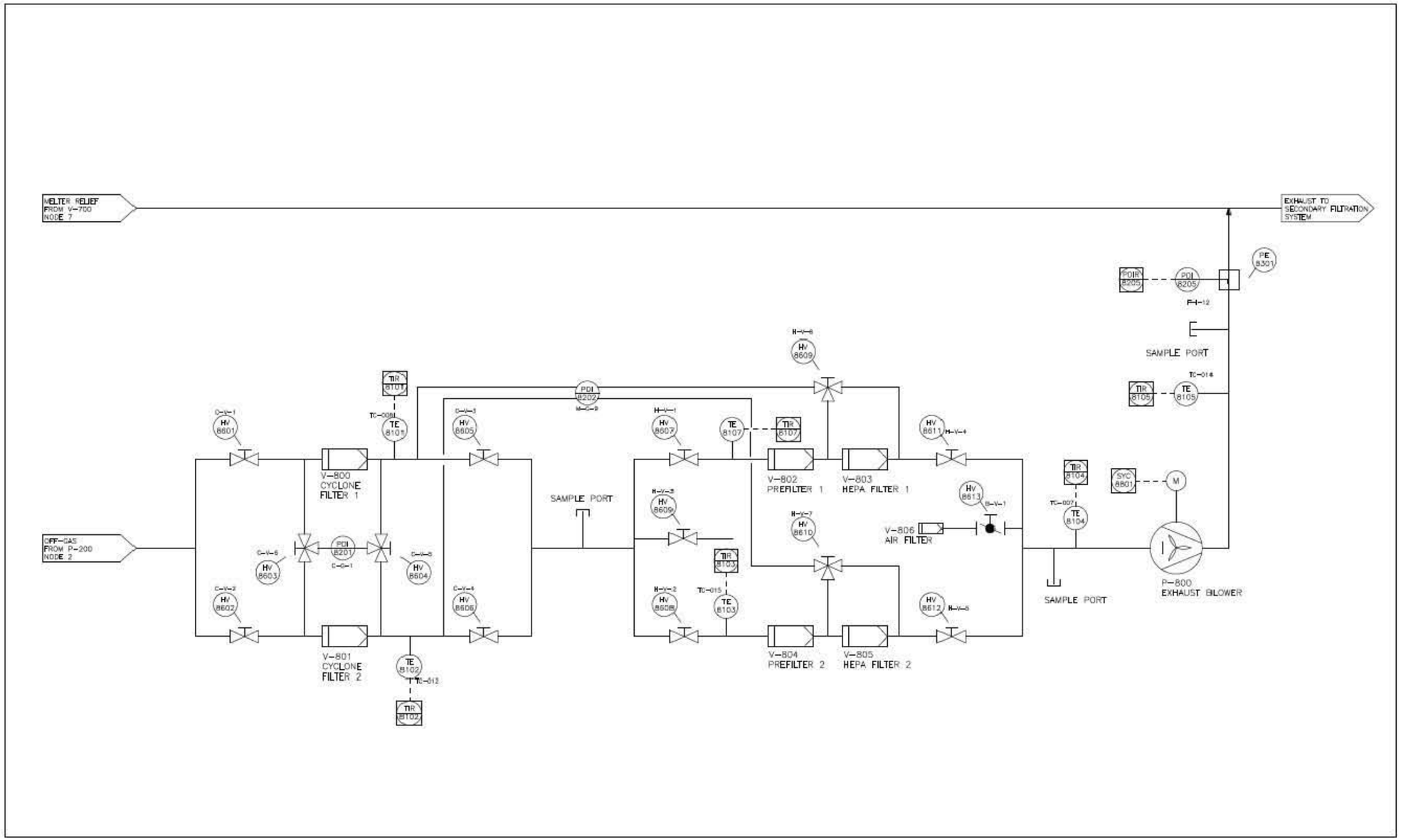


Figure 1.10. P&ID Node 8: DM10 Off-Gas Dry Exhaust.

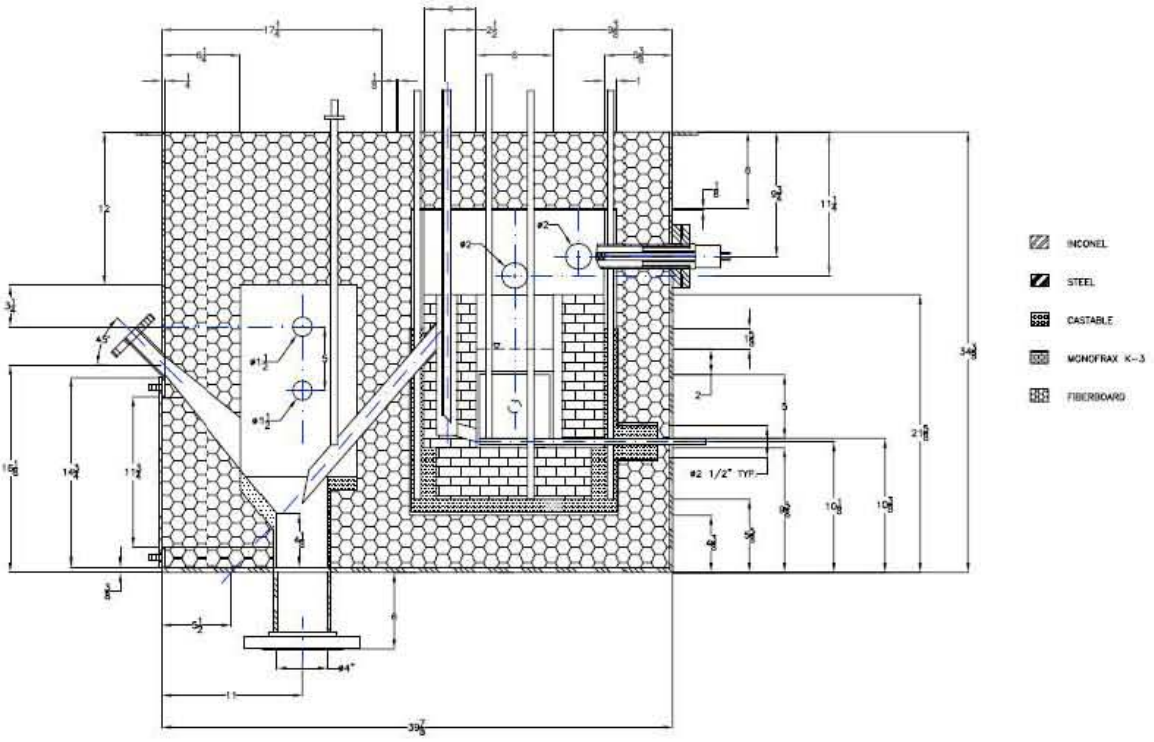


Figure 1.11. Schematic diagram showing cross-section through the DM10 melter.

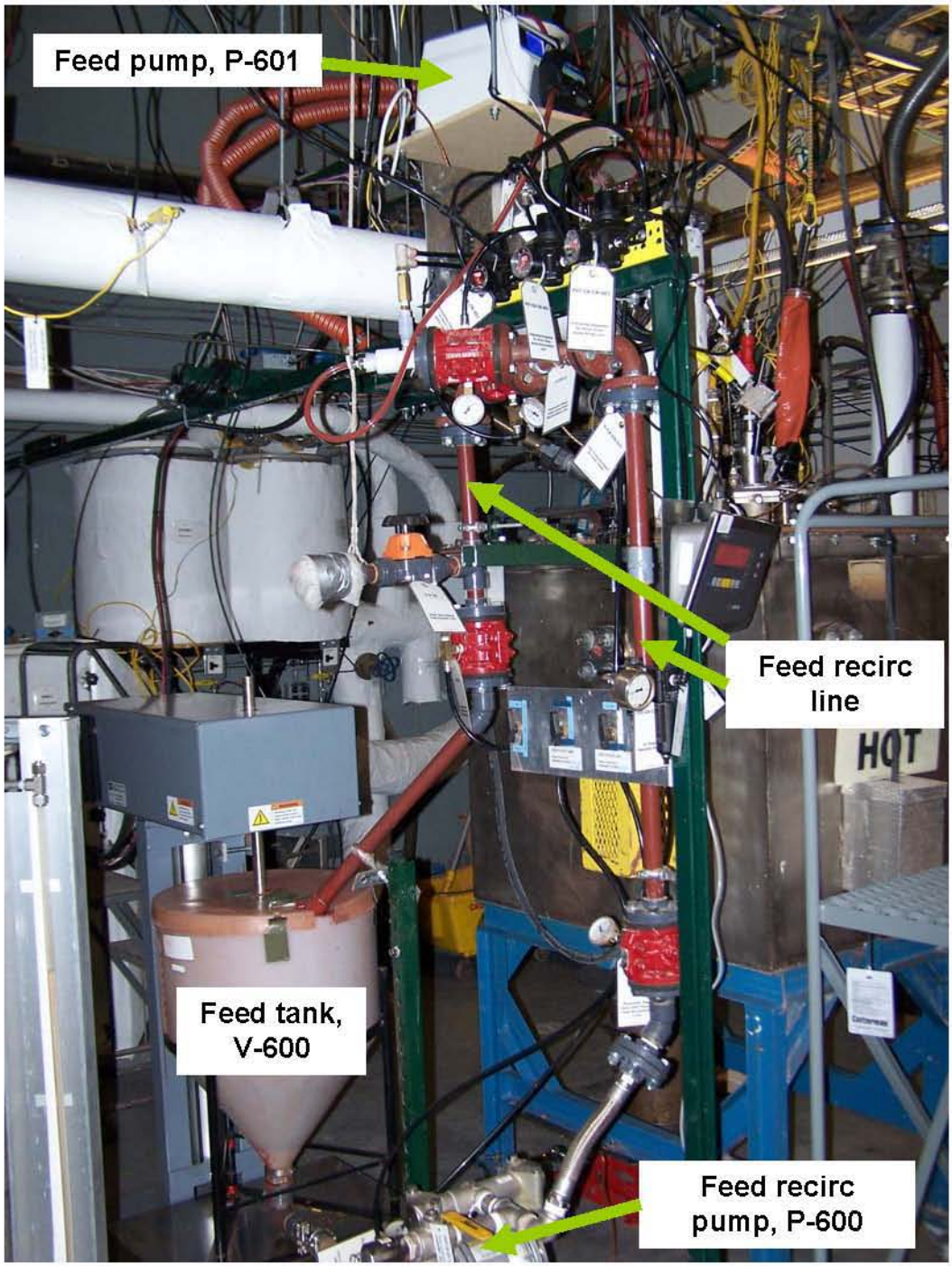


Figure 1.12. Photo of the feed recirculation line and peristaltic pump, P-601.

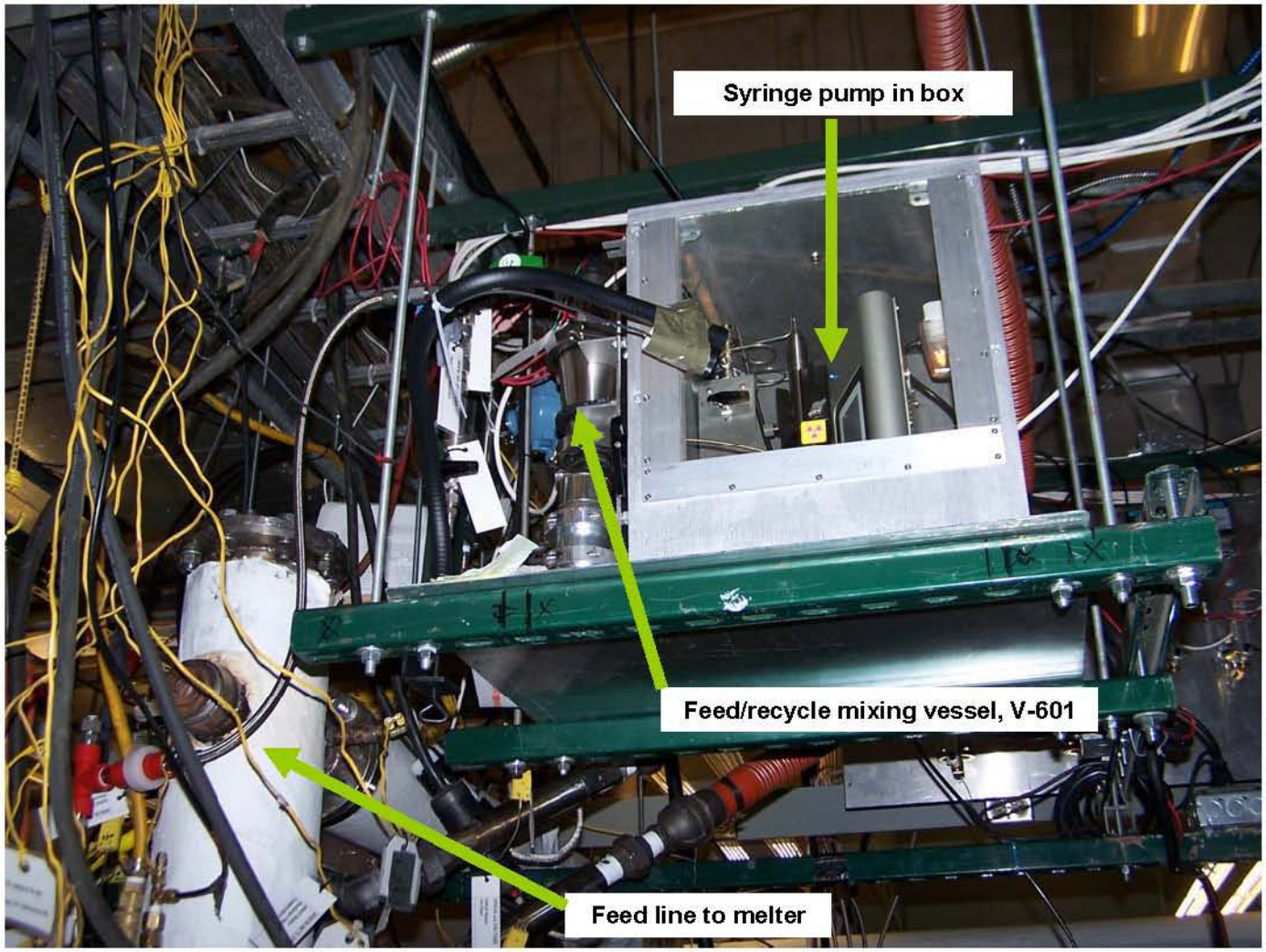


Figure 1.13.a. Original Feed line: Photo of the syringe pump inside shielded box, and feed input lines.

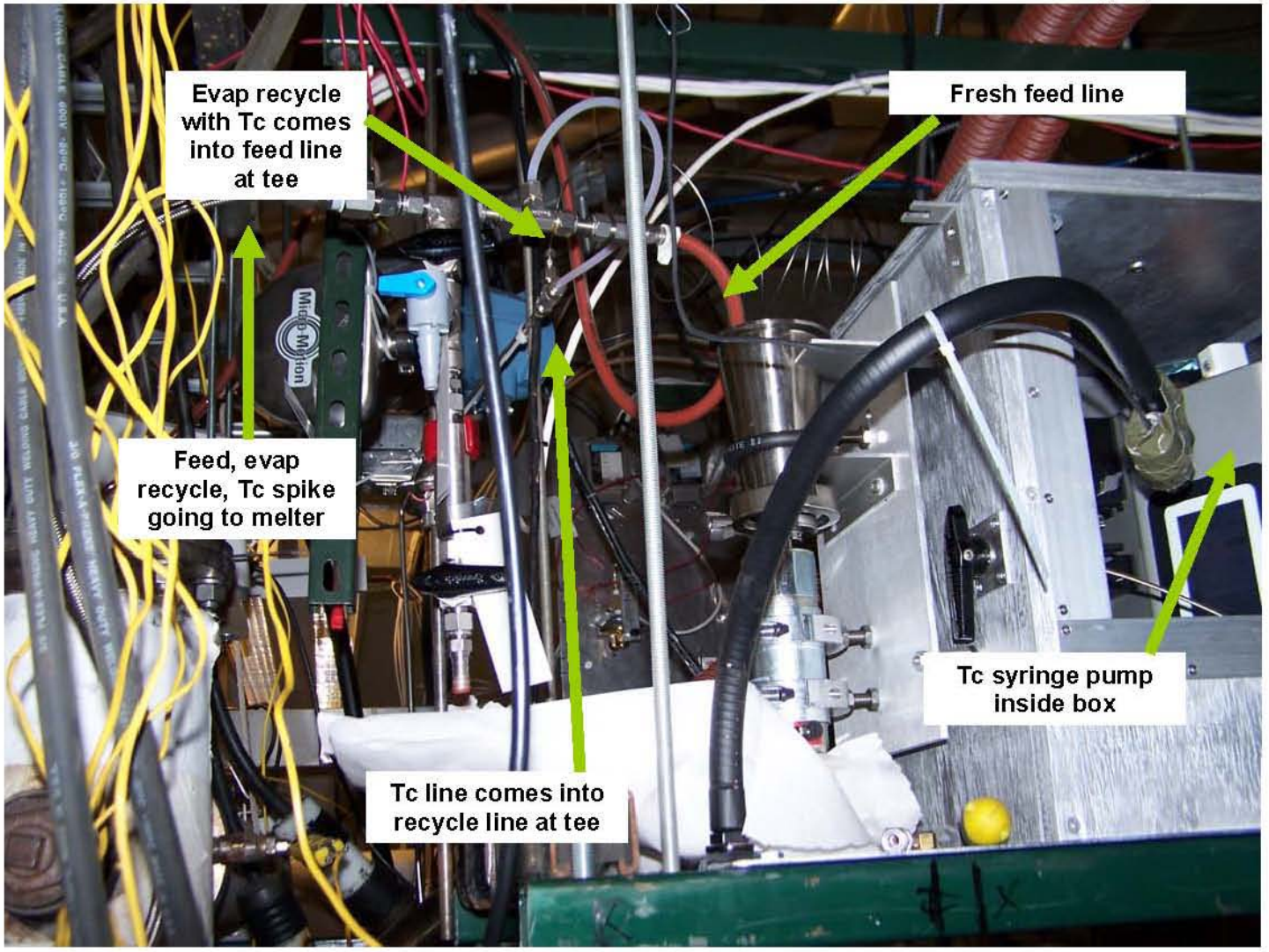


Figure 1.13.b. First Revised Feed line: Photo of the syringe pump inside shielded box, and feed input lines with two tees.

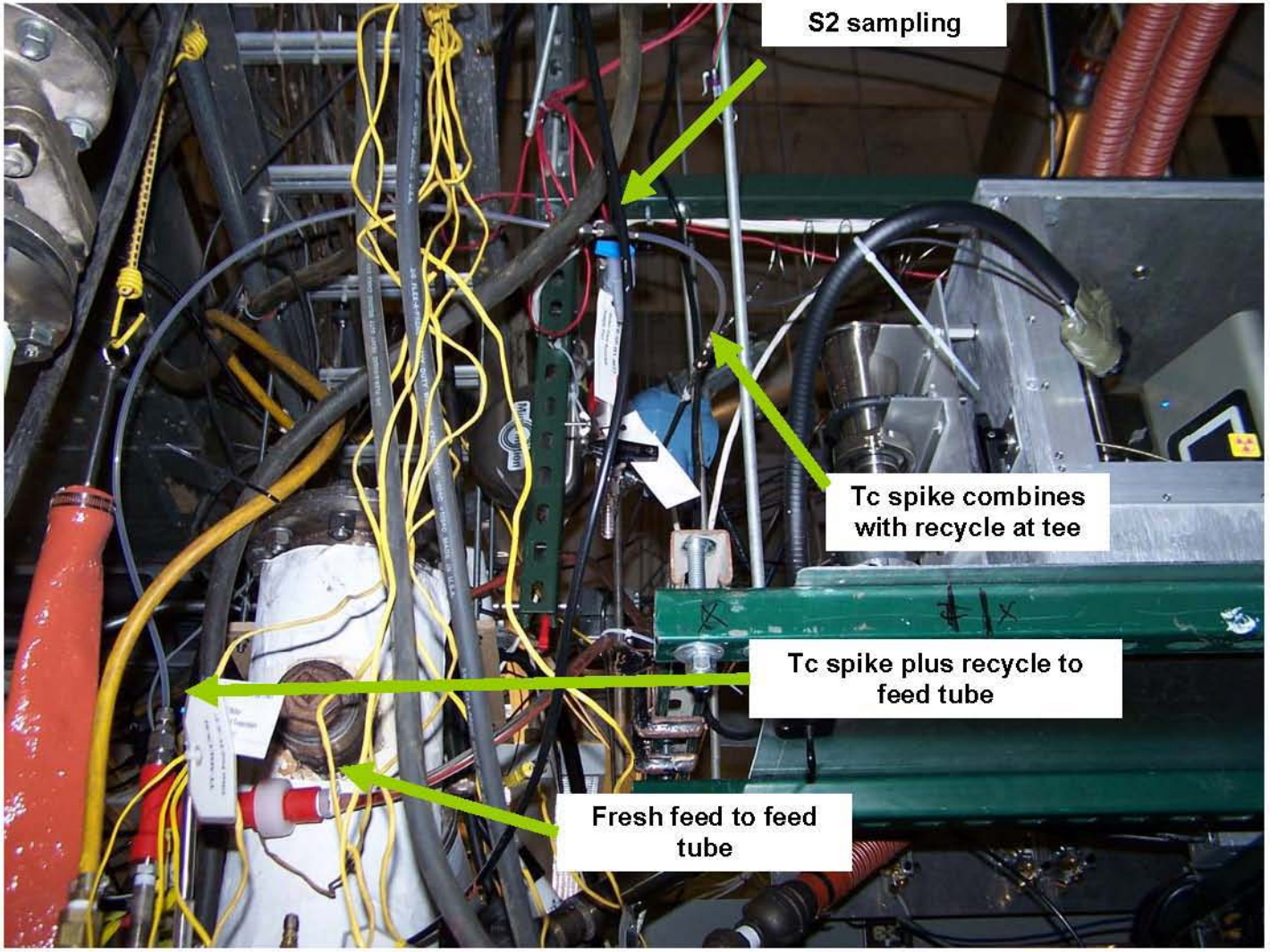


Figure 1.13.c. Second Revised Feed line: Photo of the syringe pump inside shielded box, and feed input lines which come together at melter feed tube.

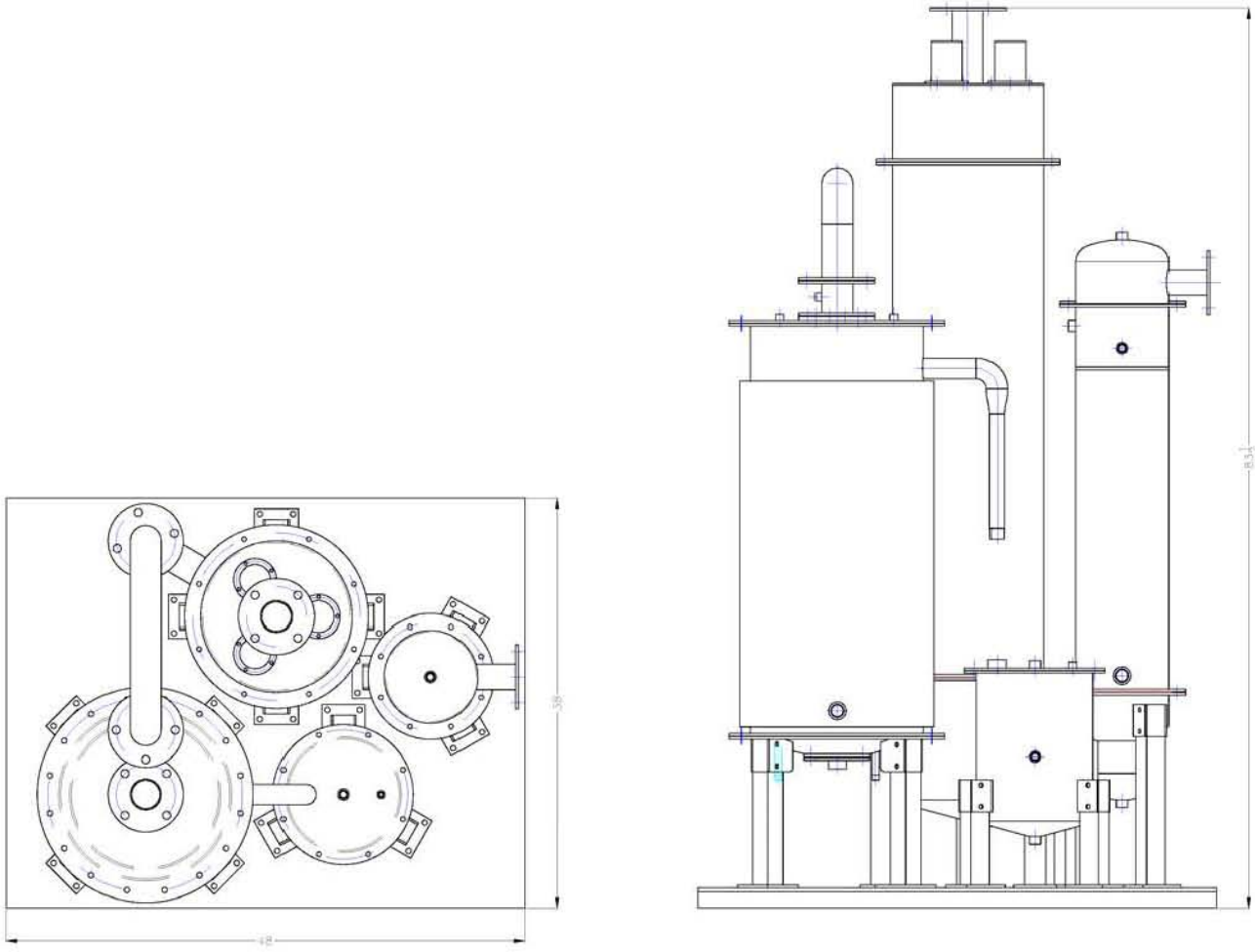


Figure 1.14. Plan and elevation views of arrangements of new DM10 off-gas system components. SBS is on the left, WESP is in the center, and vacuum evaporator is on the right. Small vessel in front is the effluent collection tank.

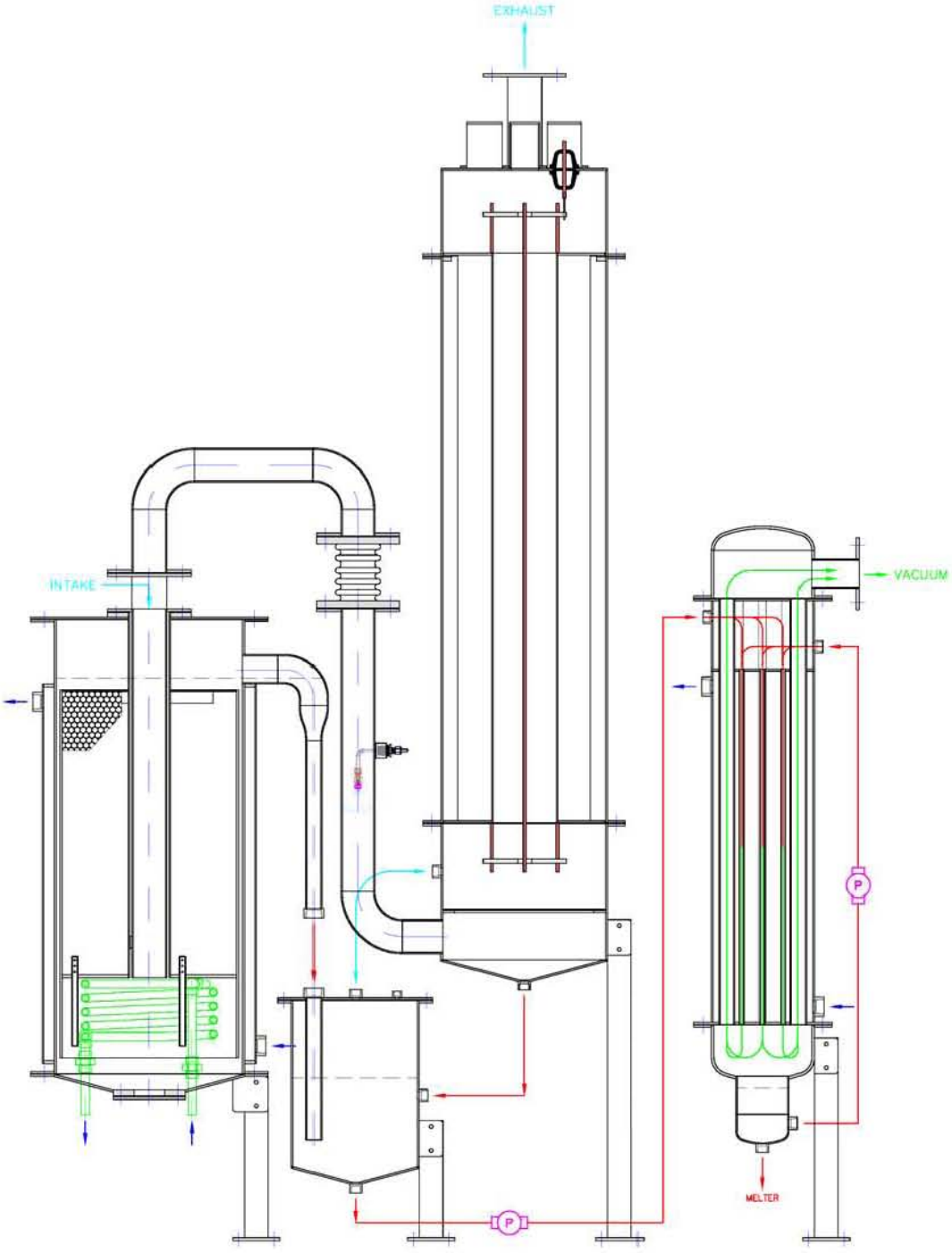


Figure 1.15. Cross section through new DM10 off-gas system components showing internals. SBS is on the left, WESP is in the center, and vacuum evaporator is on the right.

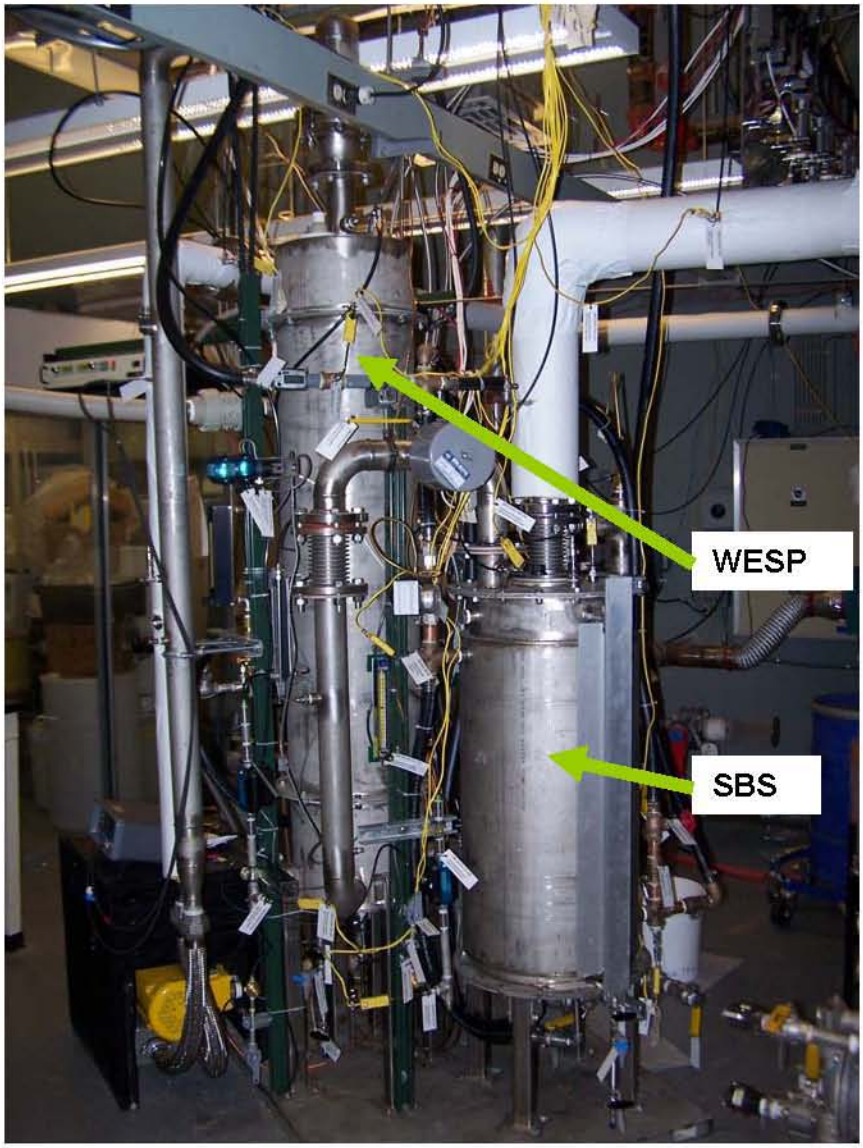


Figure 1.16. Photo of the wet off-gas system skid.

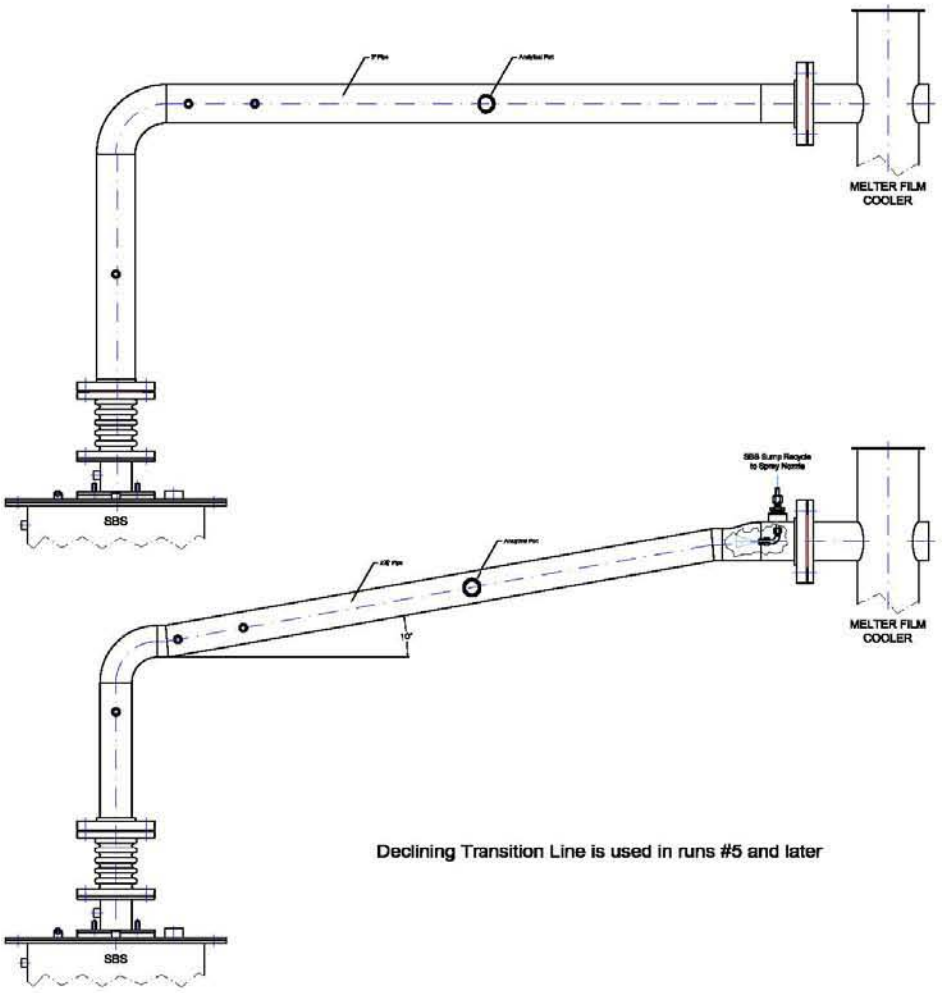


Figure 1.17. Original (top) and modified (bottom) transition lines. Melter is to the right, SBS is to the bottom left.

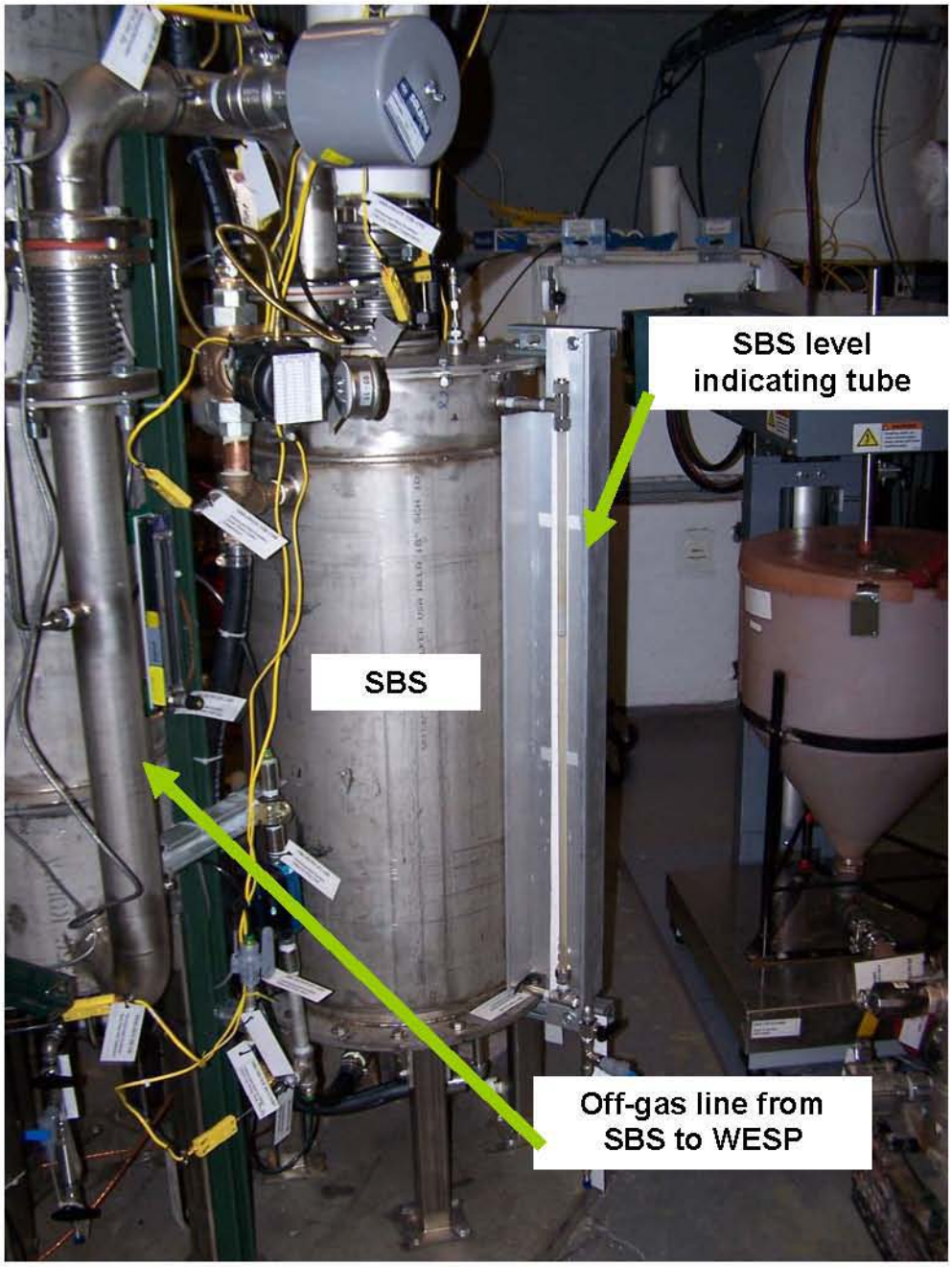


Figure 1.18. Photo of the SBS.

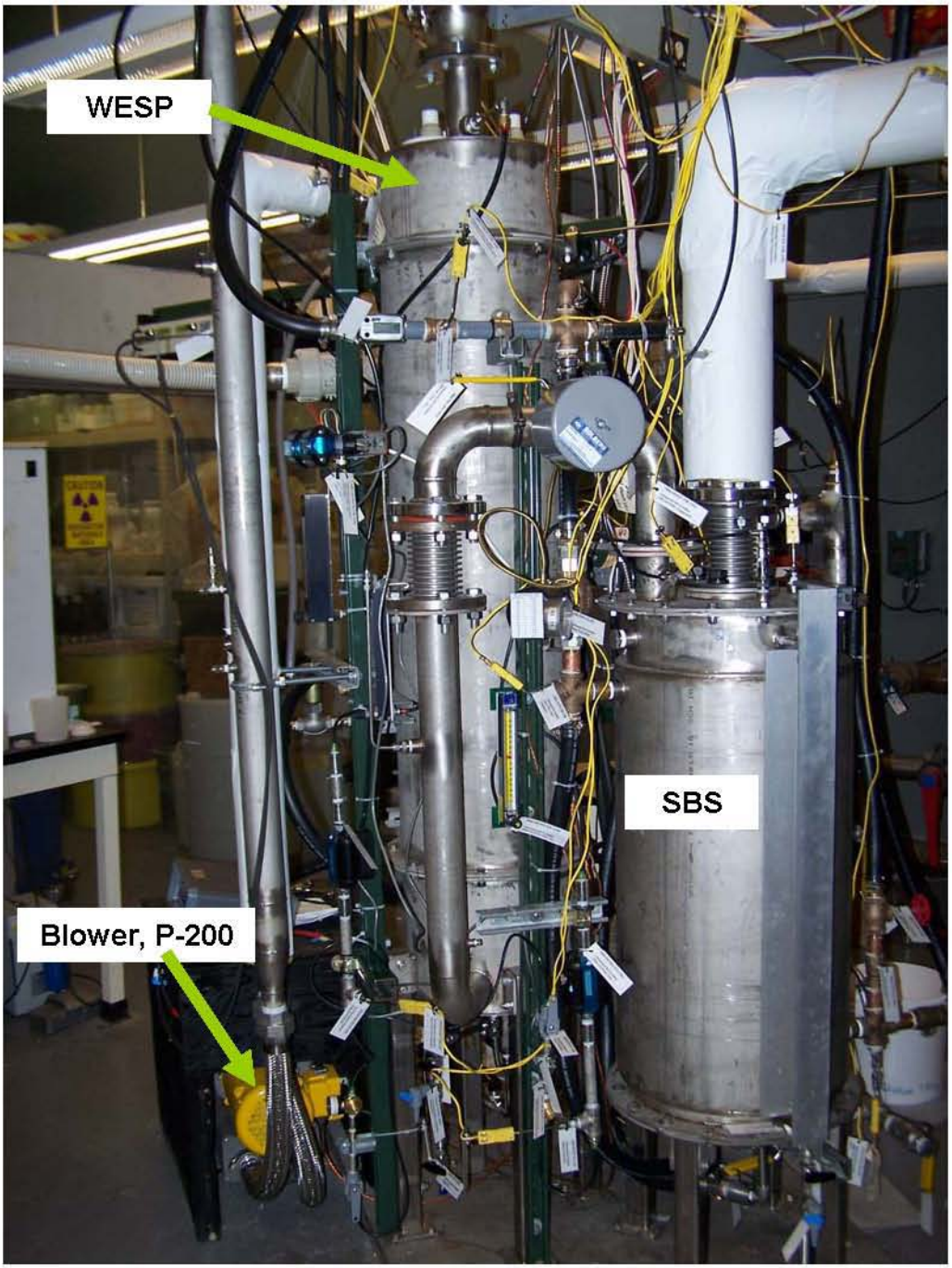


Figure 1.19. Photo of the WESP.

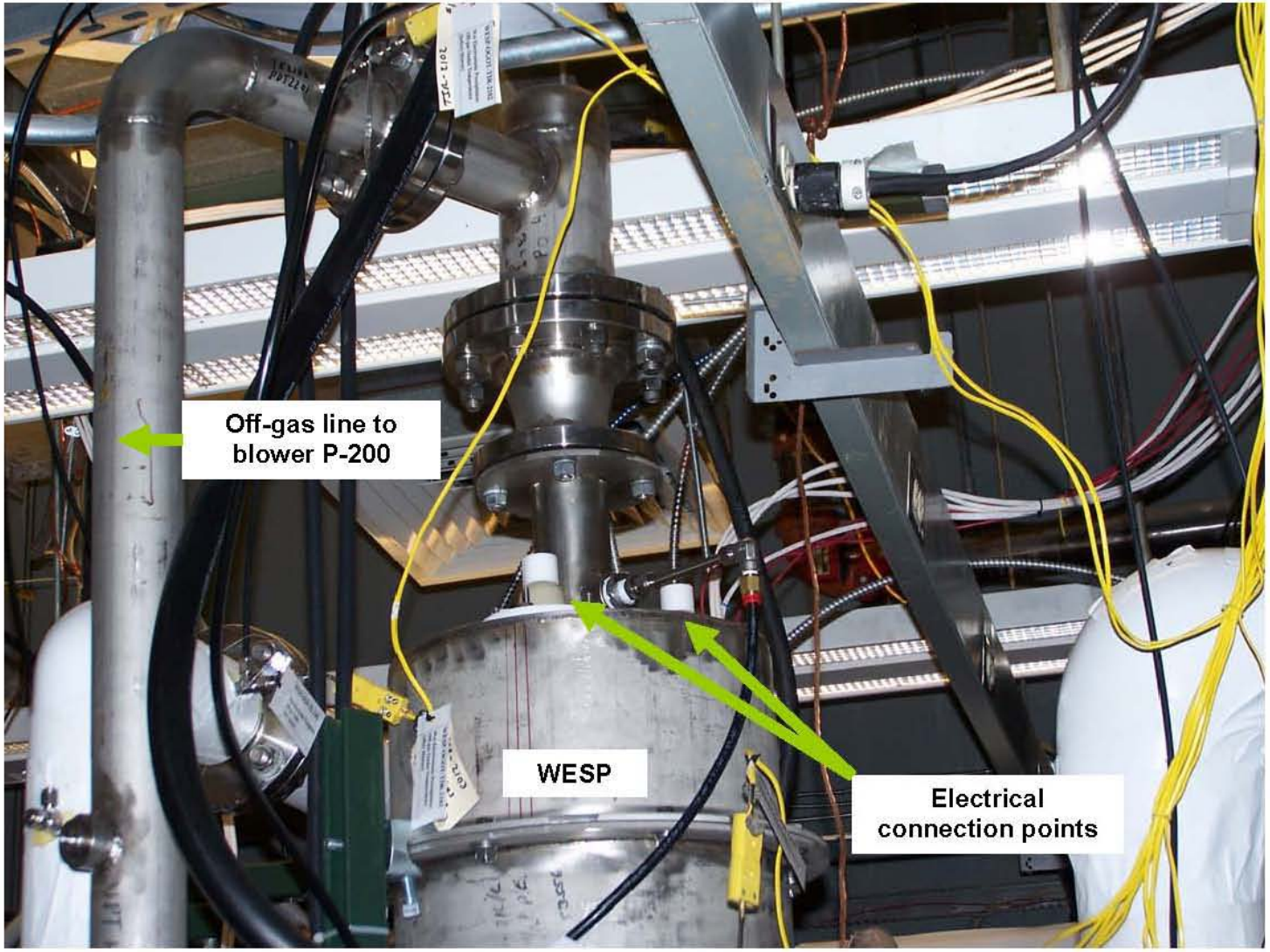


Figure 1.20. Photo of the top of the WESP.



Figure 1.21. Photo looking down into the WESP from the top. The three channels with electrodes are visible.



Figure 1.22. Photo looking down one channel near the bottom of the electrode.

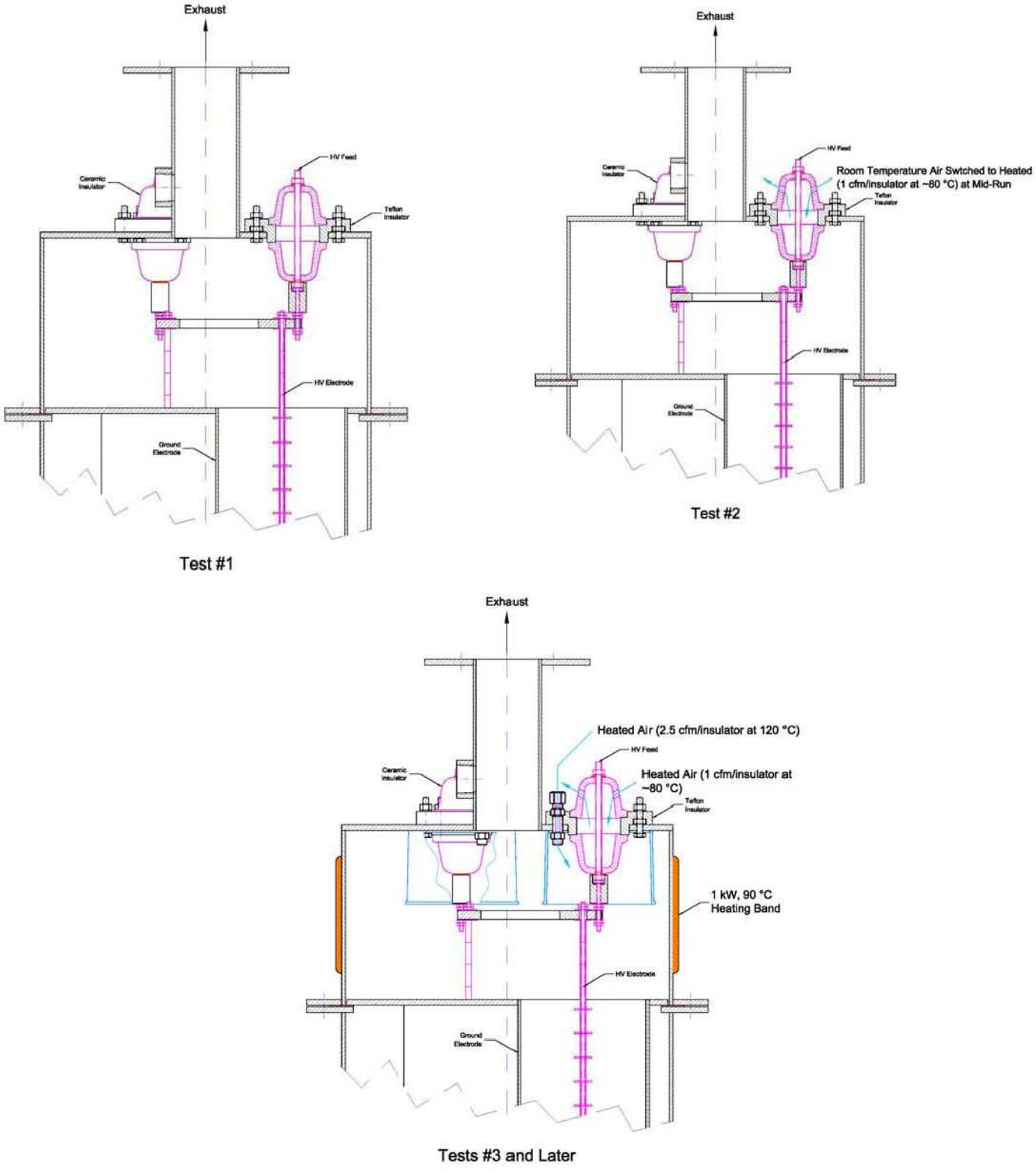


Figure 1.23. Modifications made to WESP in successive tests.

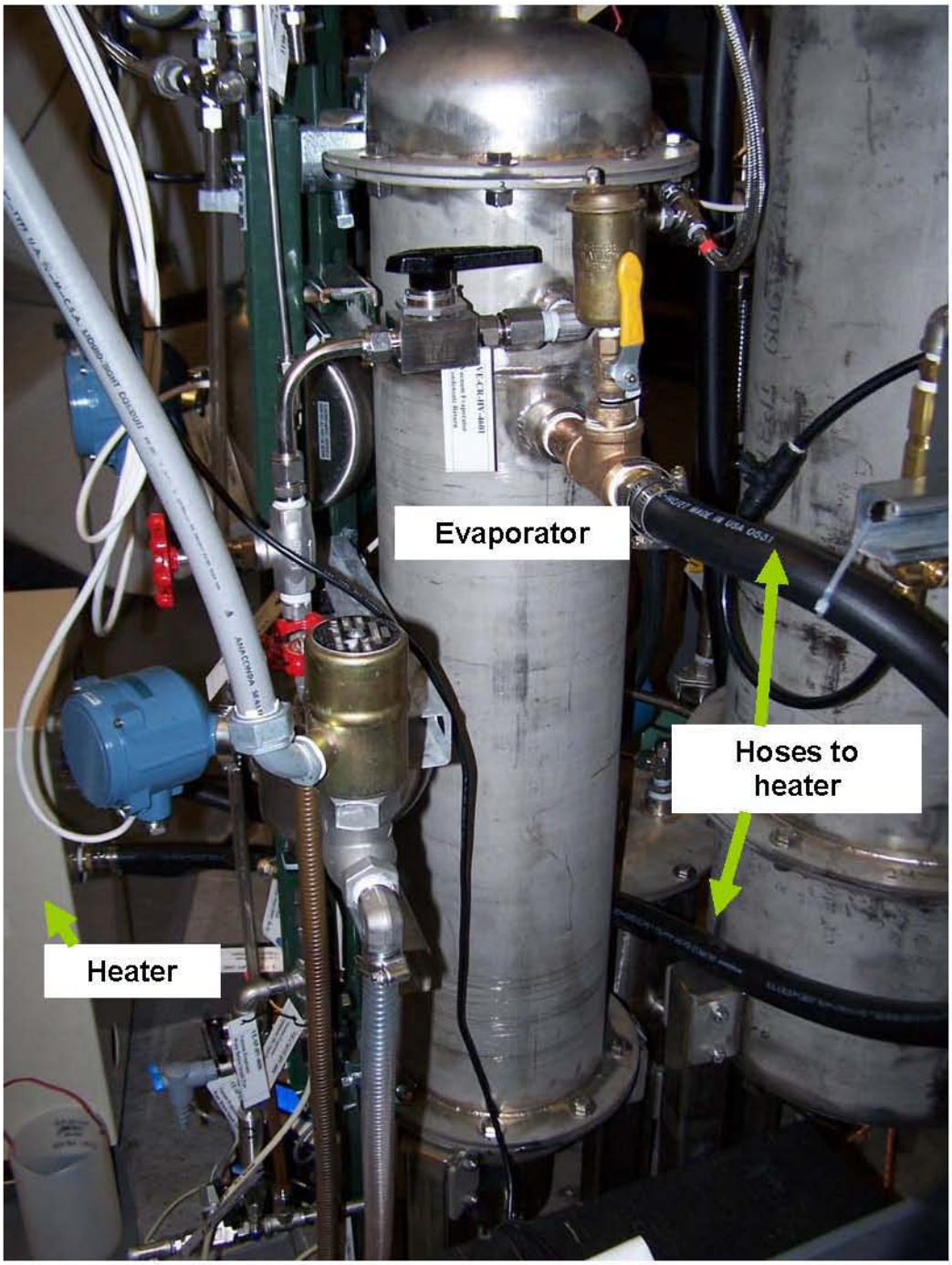


Figure 1.24. Photo of evaporator.

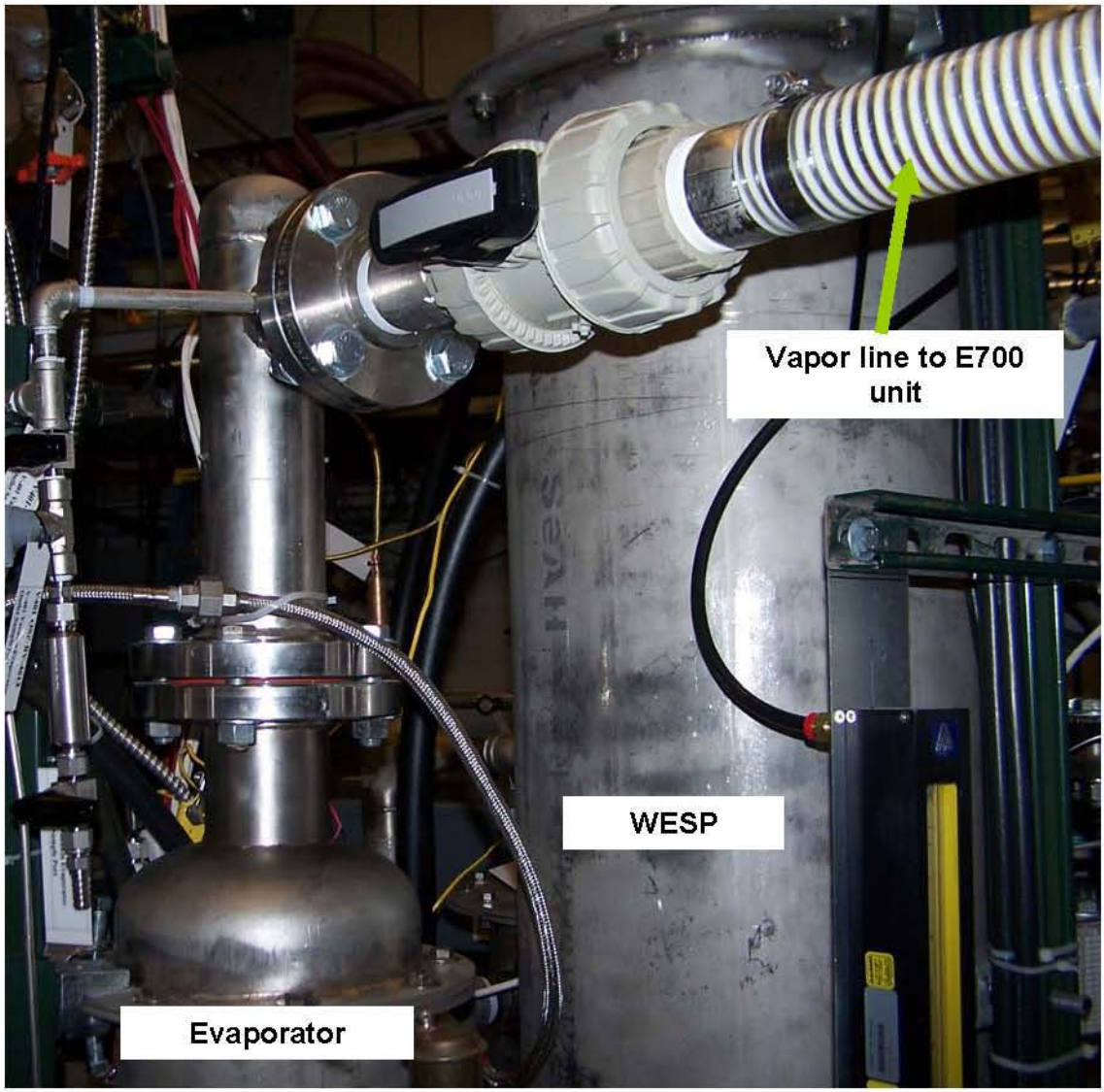


Figure 1.25. Photo of vapor line exiting evaporator.

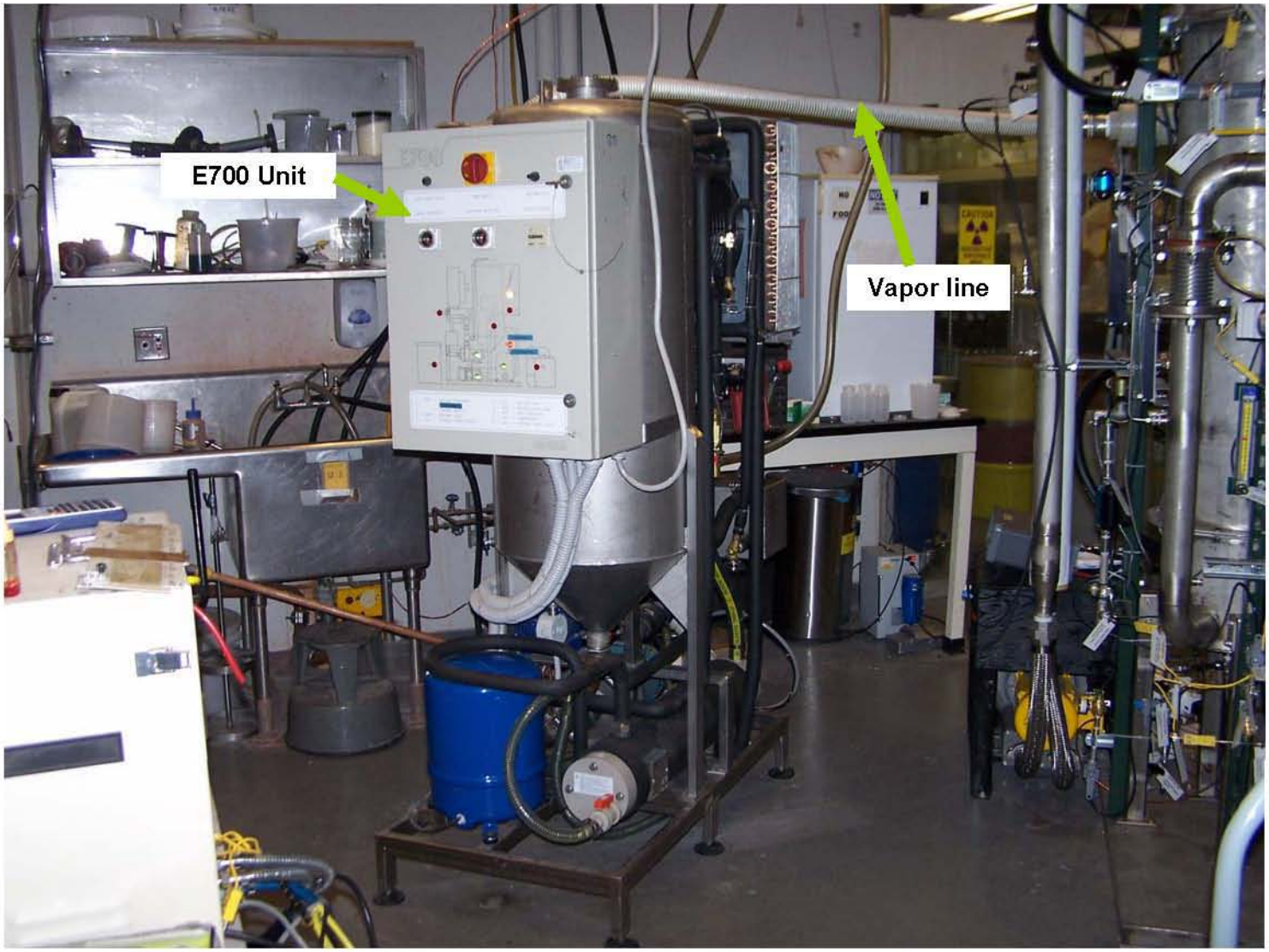


Figure 1.26. Photo of E700 commercial evaporator.

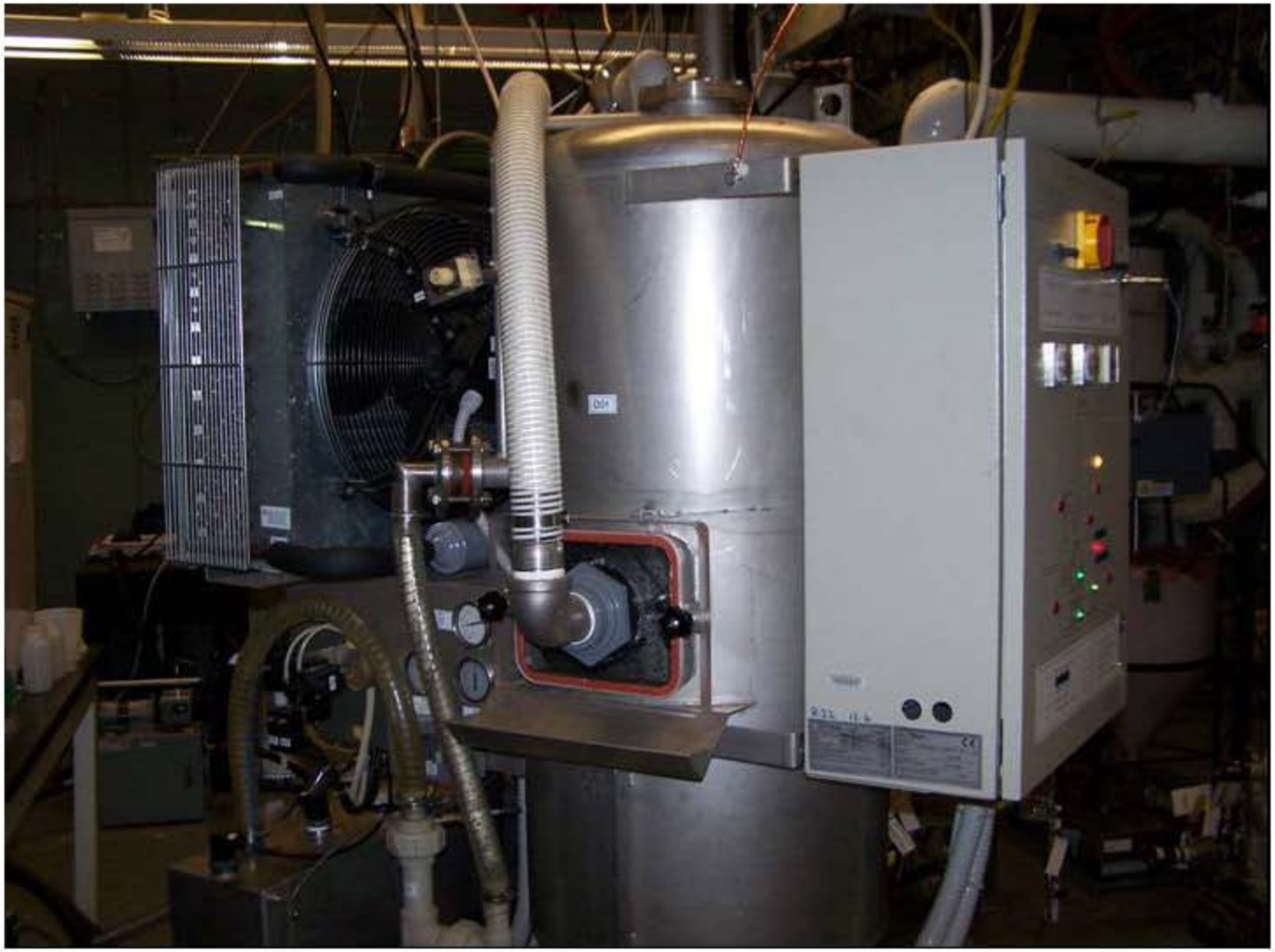


Figure 1.27. Photo of E700 evaporator connection at the plexiglass window.

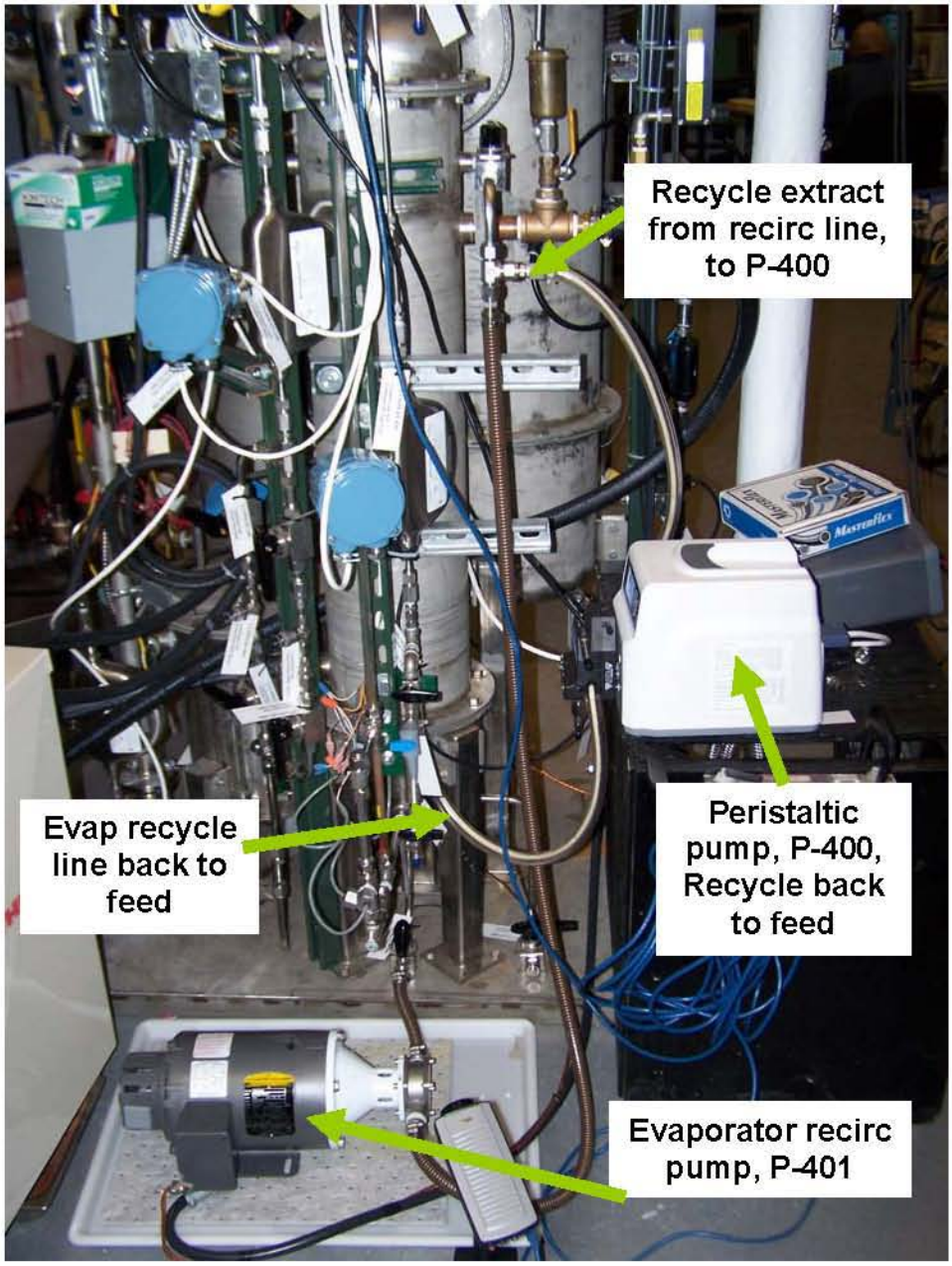


Figure 1.28. Photo of the peristaltic pump, P-400, for recycled concentrate.

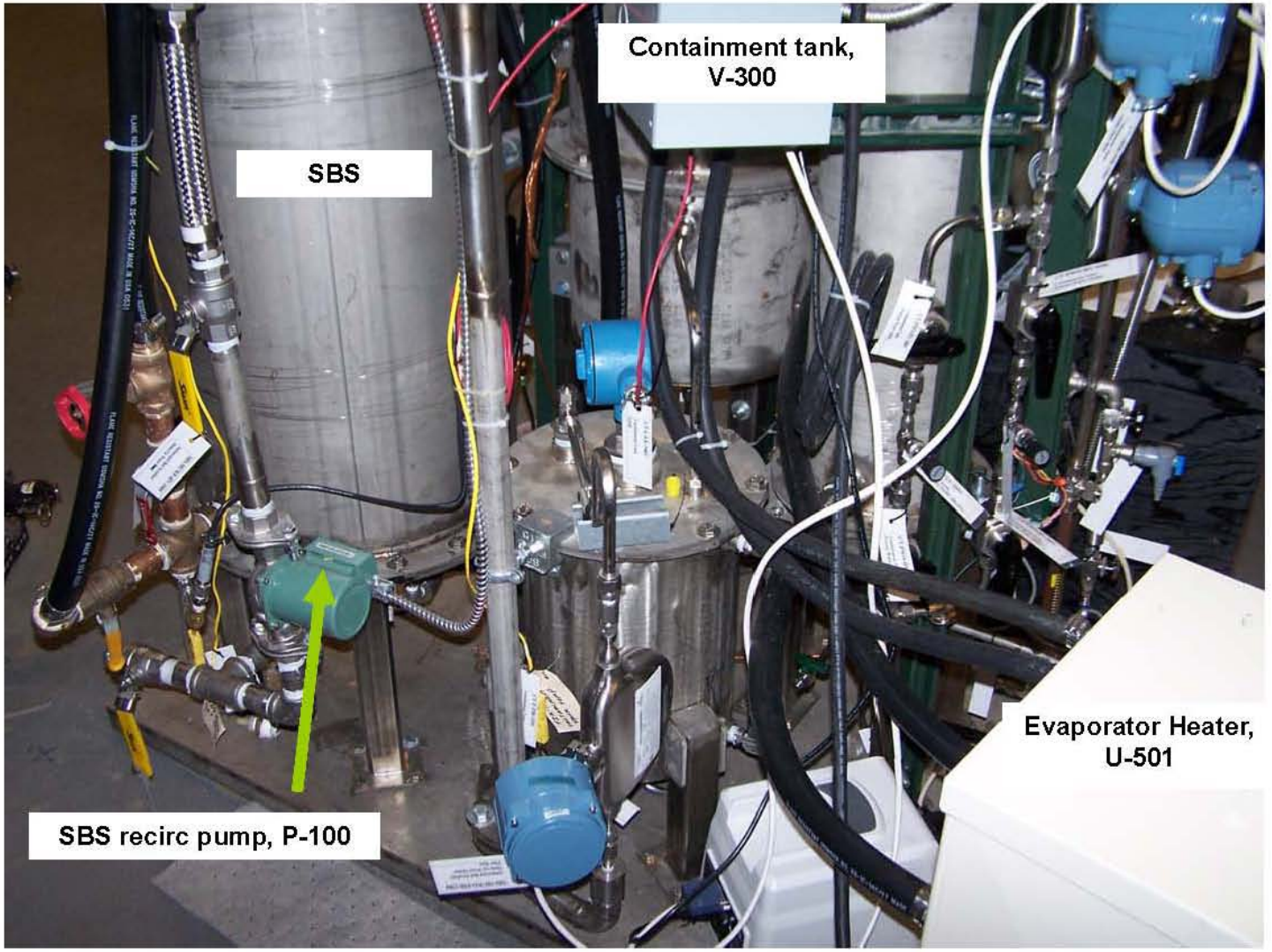


Figure 1.29. Photo of containment tank, V-300.

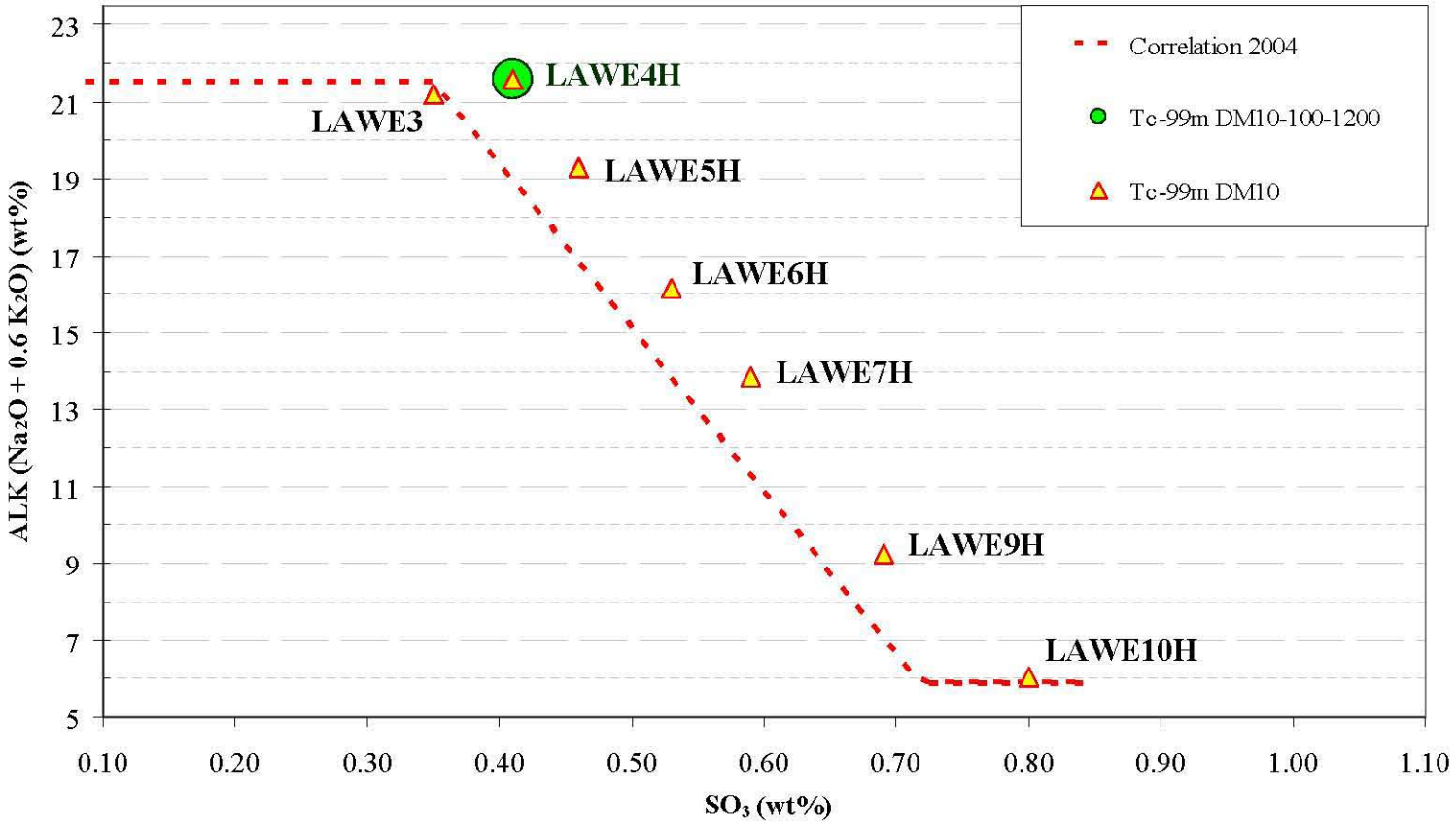


Figure 2.1. Plot showing glass compositions used for previous technetium retention testing at various scales (DM10, DM100, and DM1200) [3, 4] and relationship to the baseline WTP LAW glass formulation correlation (red dashed line).

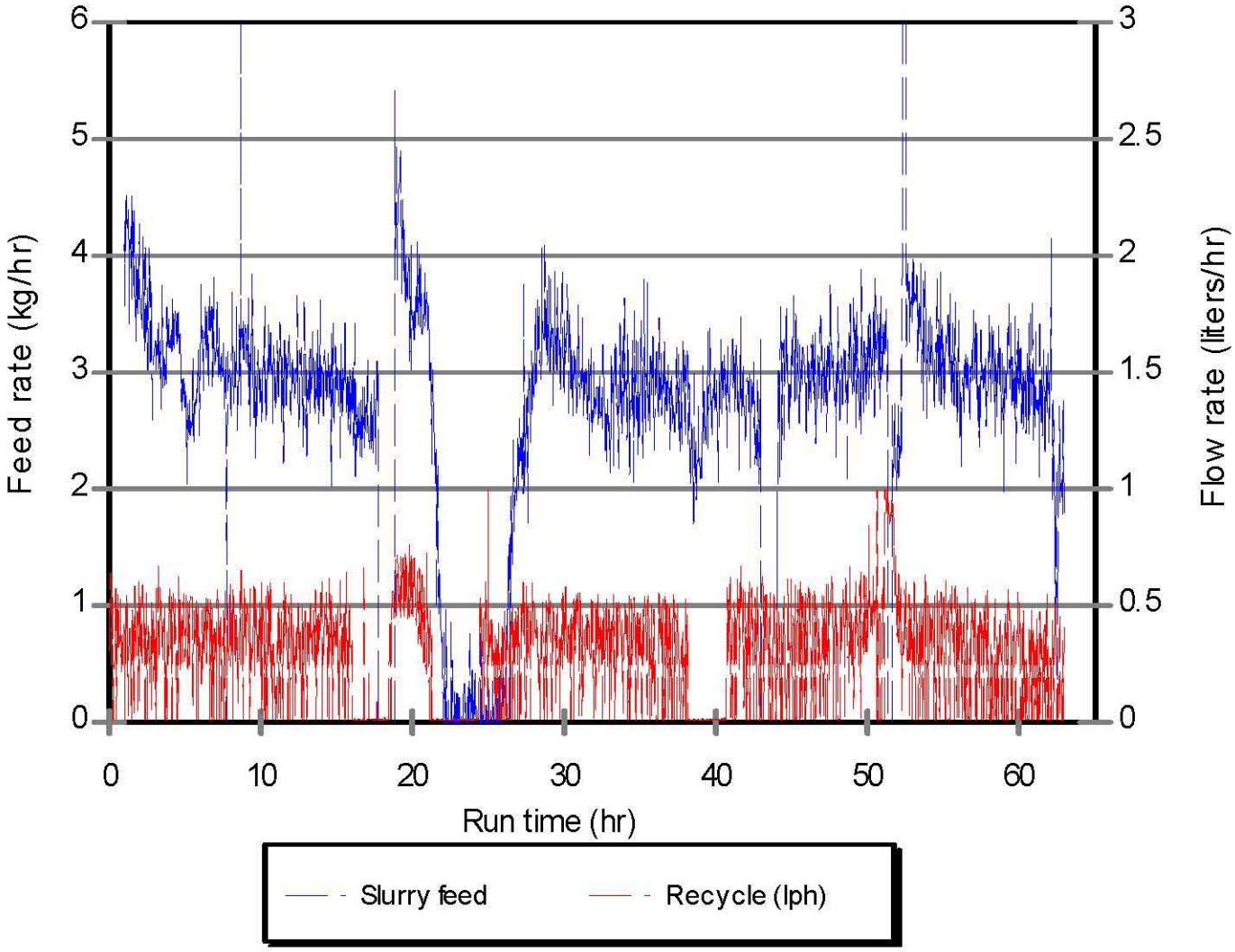


Figure 3.1.a. Slurry feed and recycle flow rates to the melter during Test 1.

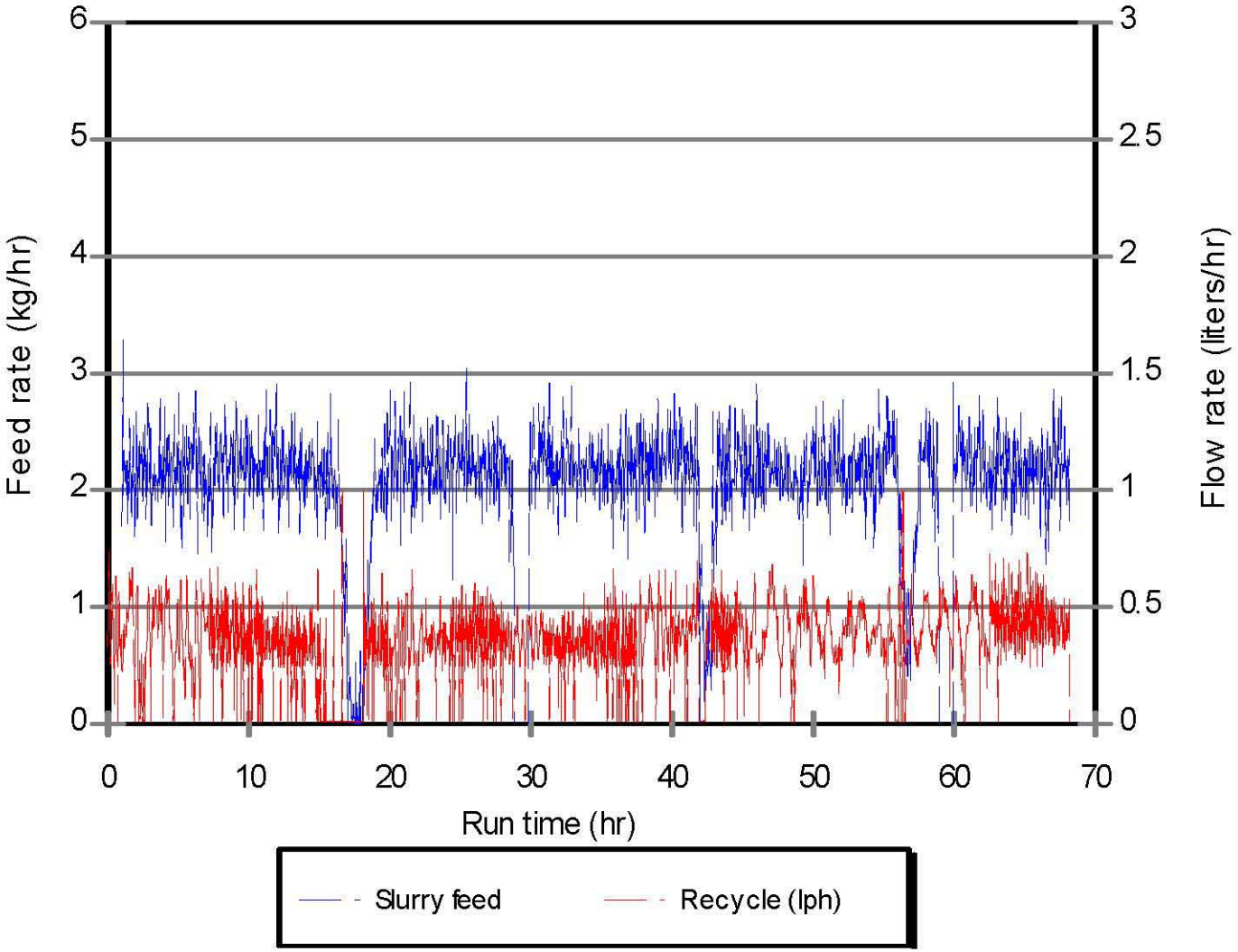


Figure 3.1.b. Slurry feed and recycle flow rates to the melter during Test 2.

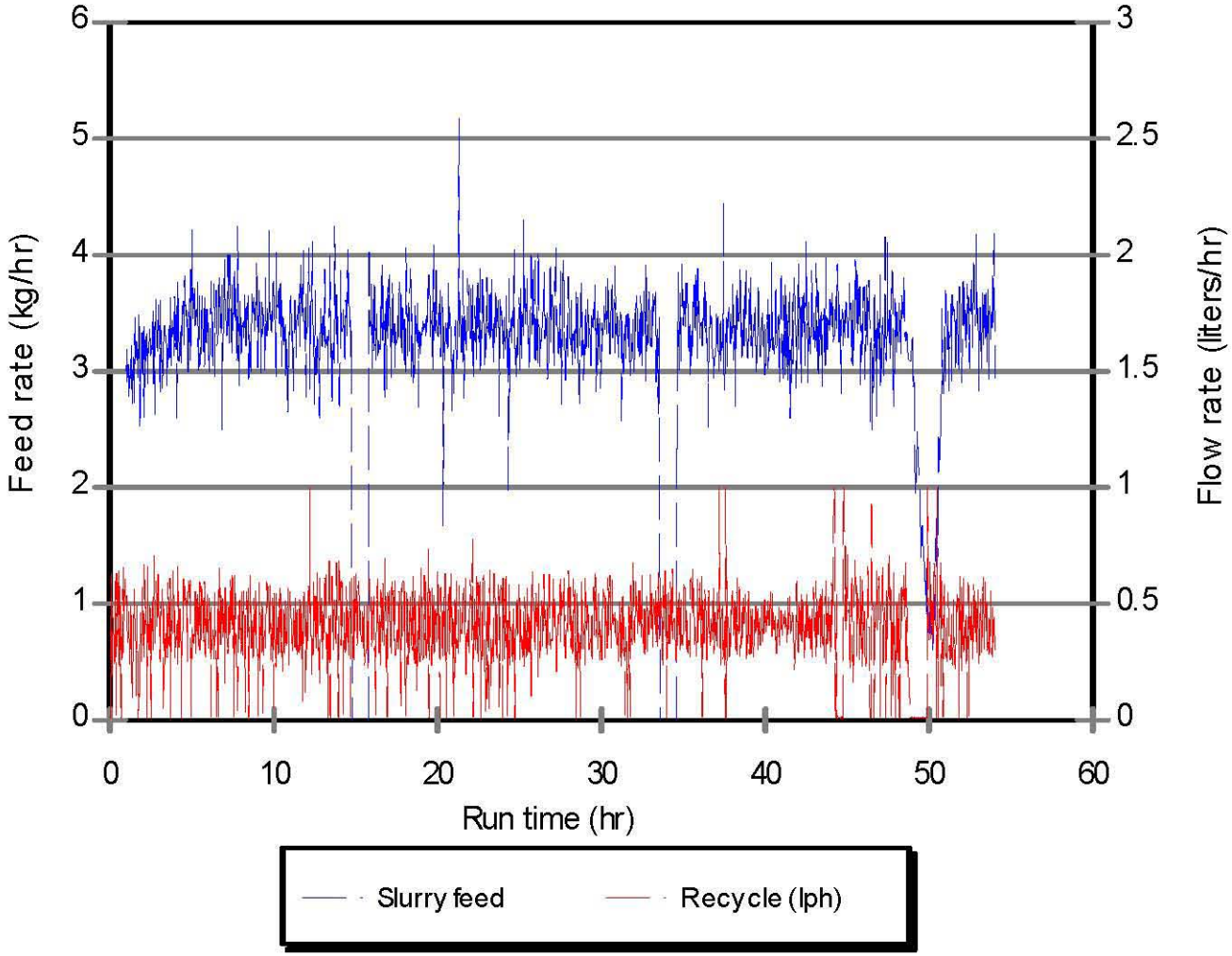


Figure 3.1.c. Slurry feed and recycle flow rates to the melter during Test 3.

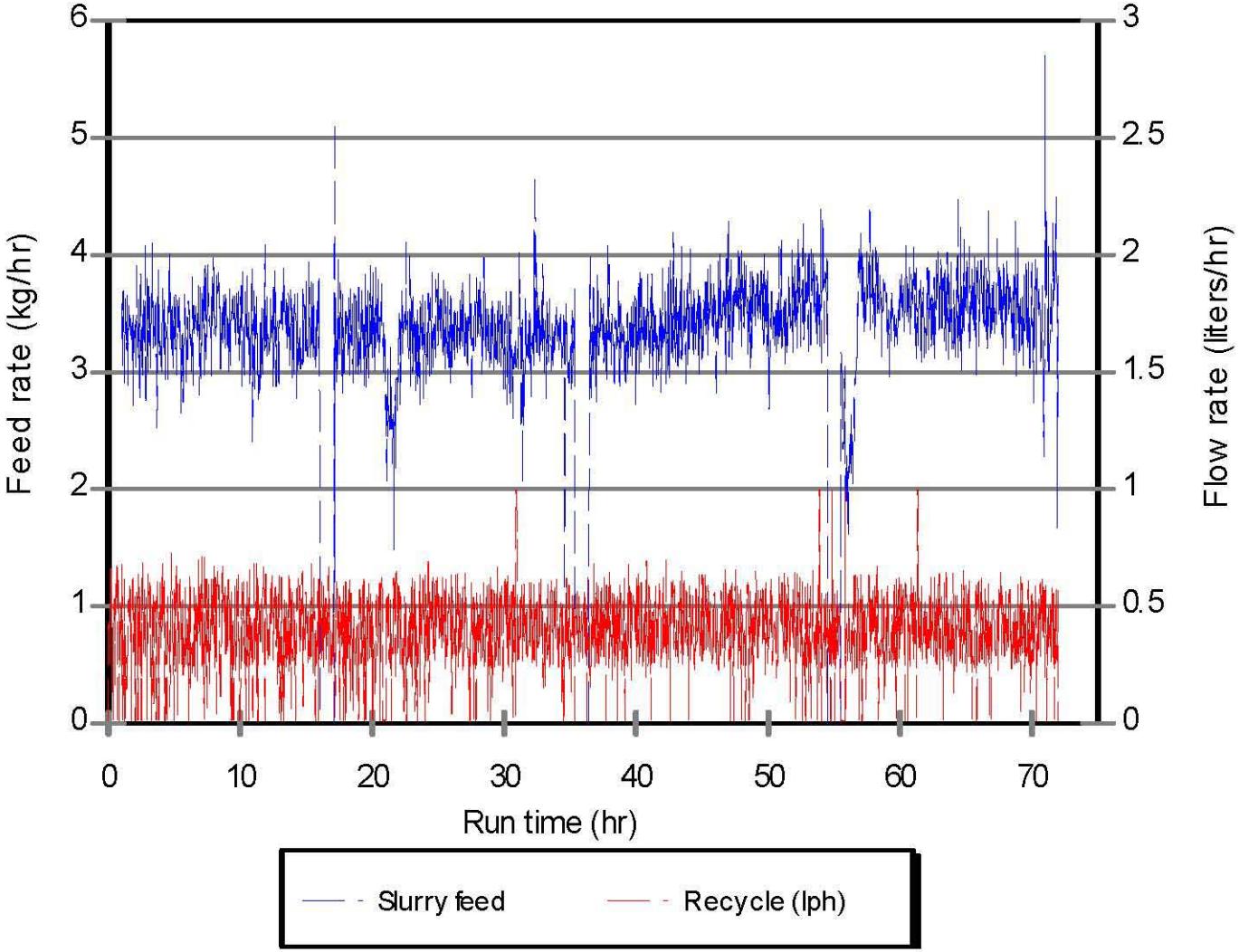


Figure 3.1.d. Slurry feed and recycle flow rates to the melter during Test 4.

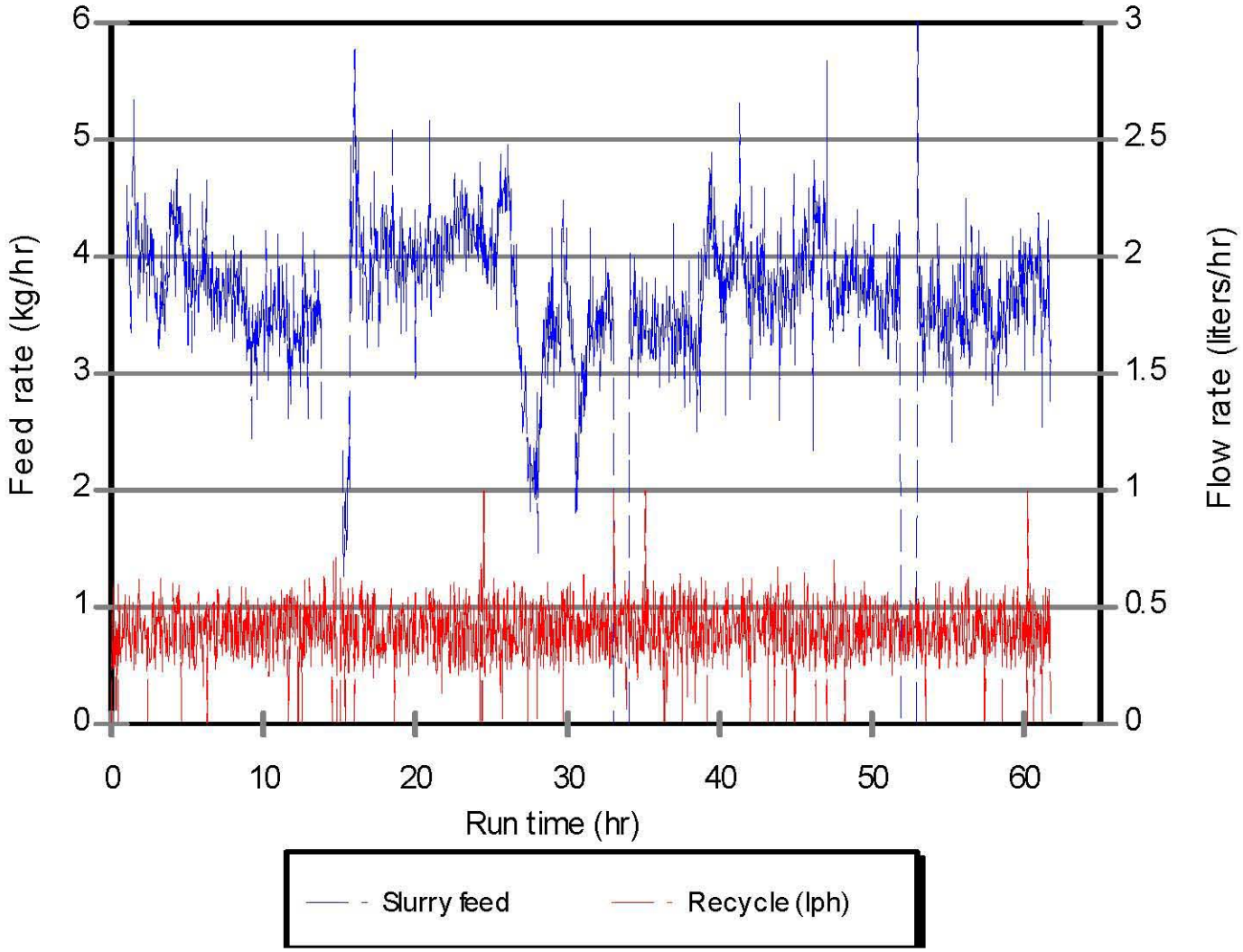


Figure 3.1.e. Slurry feed and recycle flow rates to the melter during Test 5.

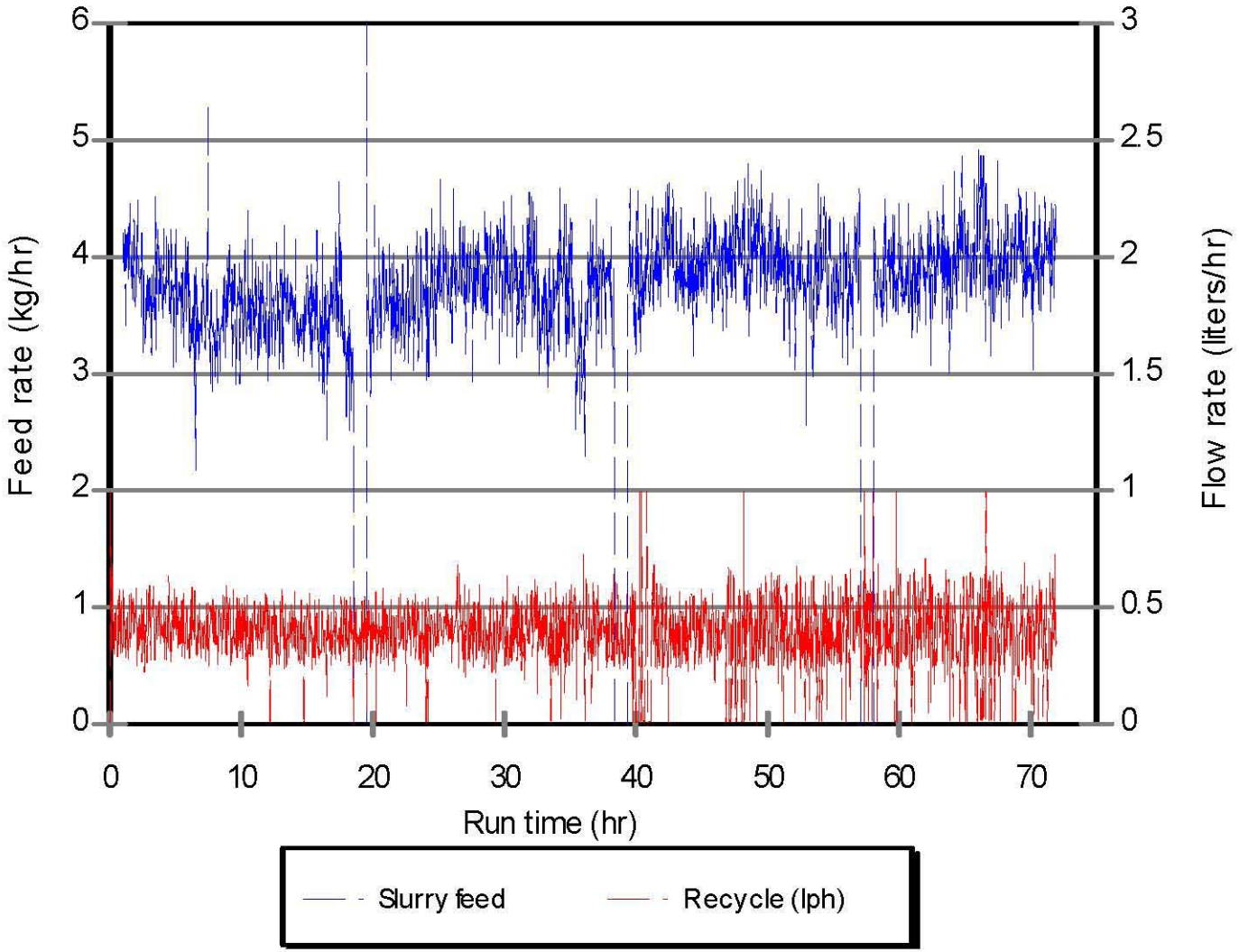


Figure 3.1.f. Slurry feed and recycle flow rates to the melter during Test 6.

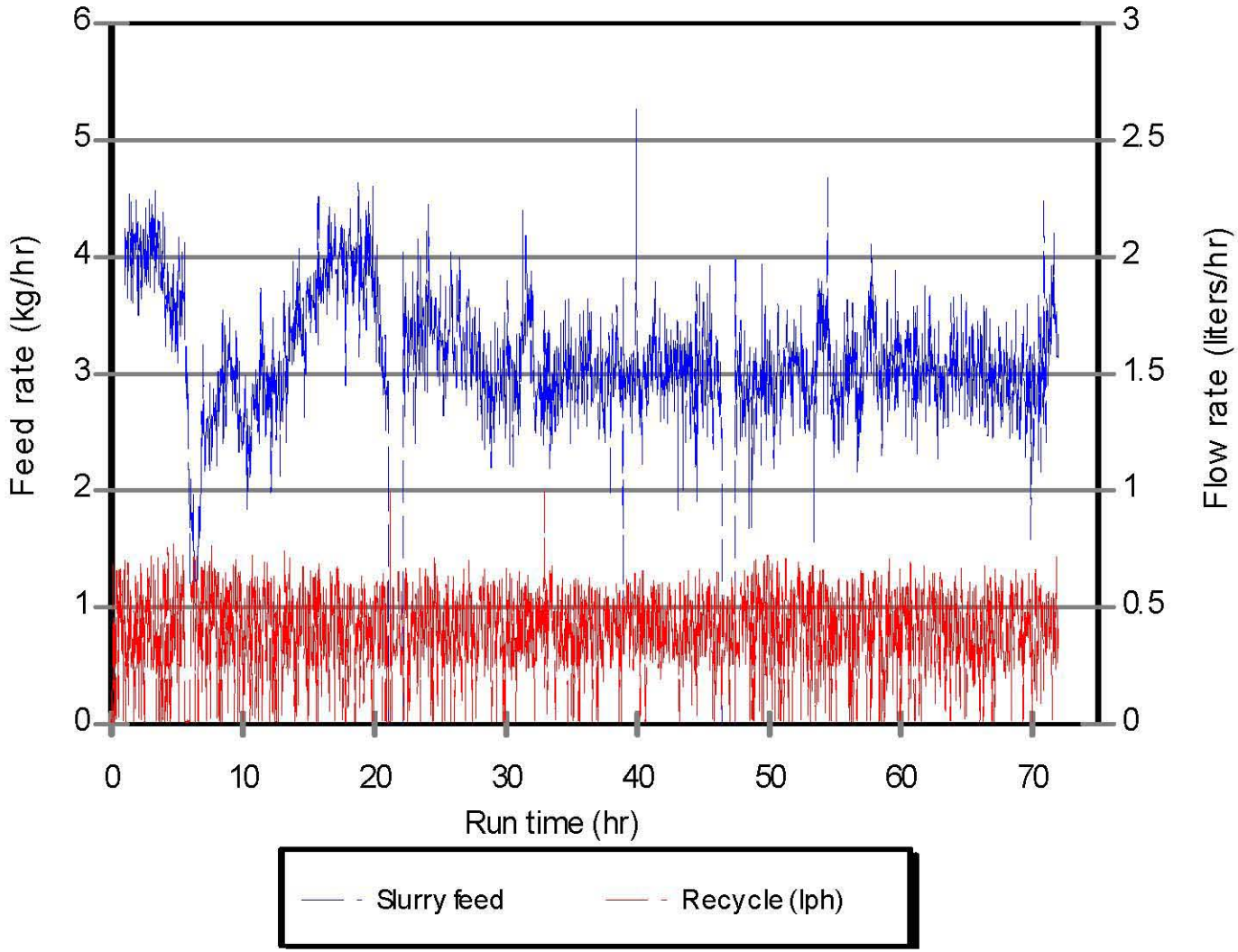


Figure 3.1.g. Slurry feed and recycle flow rates to the melter during Test 7.

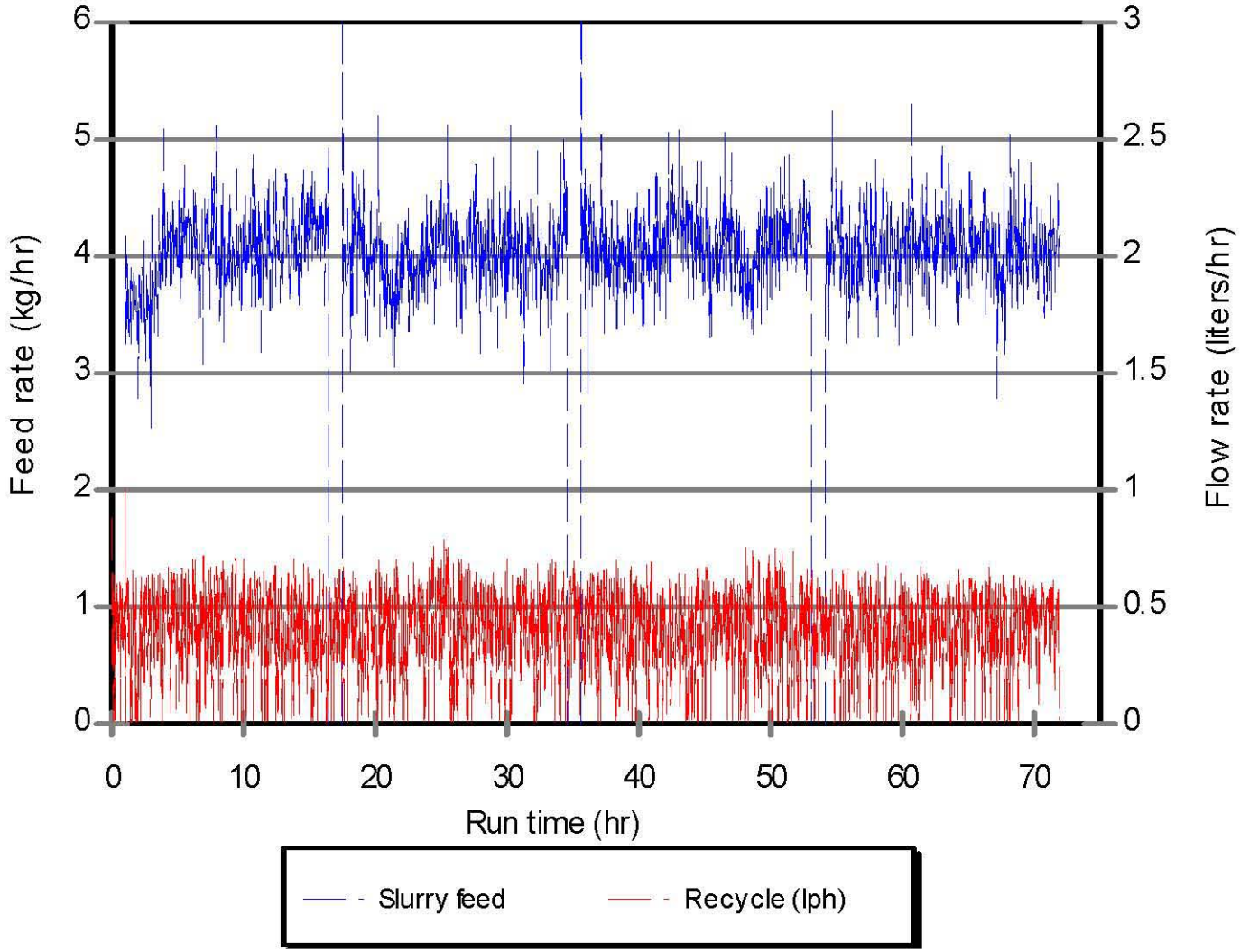


Figure 3.1.h. Slurry feed and recycle flow rates to the melter during Test 8.

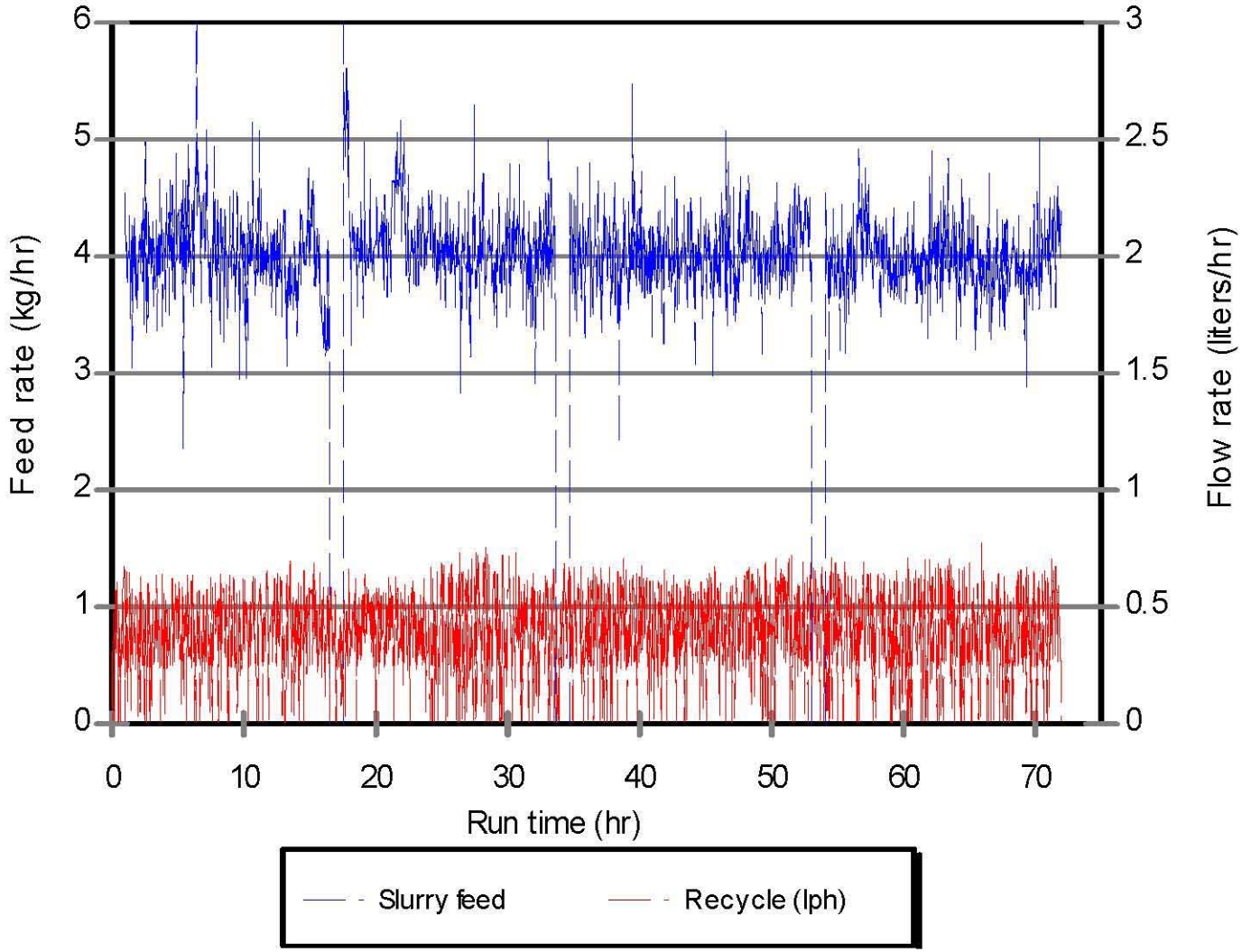


Figure 3.1.i. Slurry feed and recycle flow rates to the melter during Test 9.

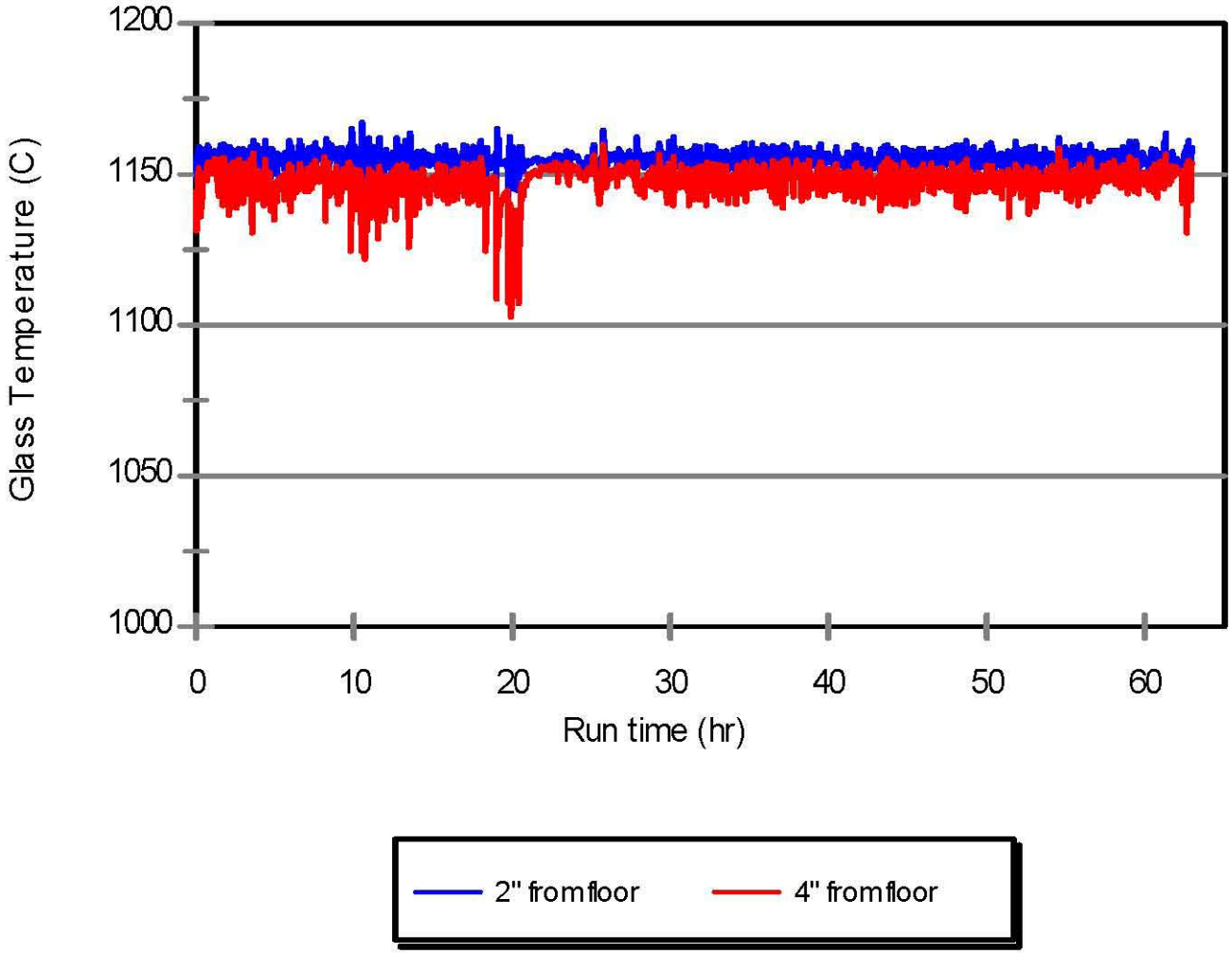


Figure 3.2.a. Glass pool temperatures during Test 1.

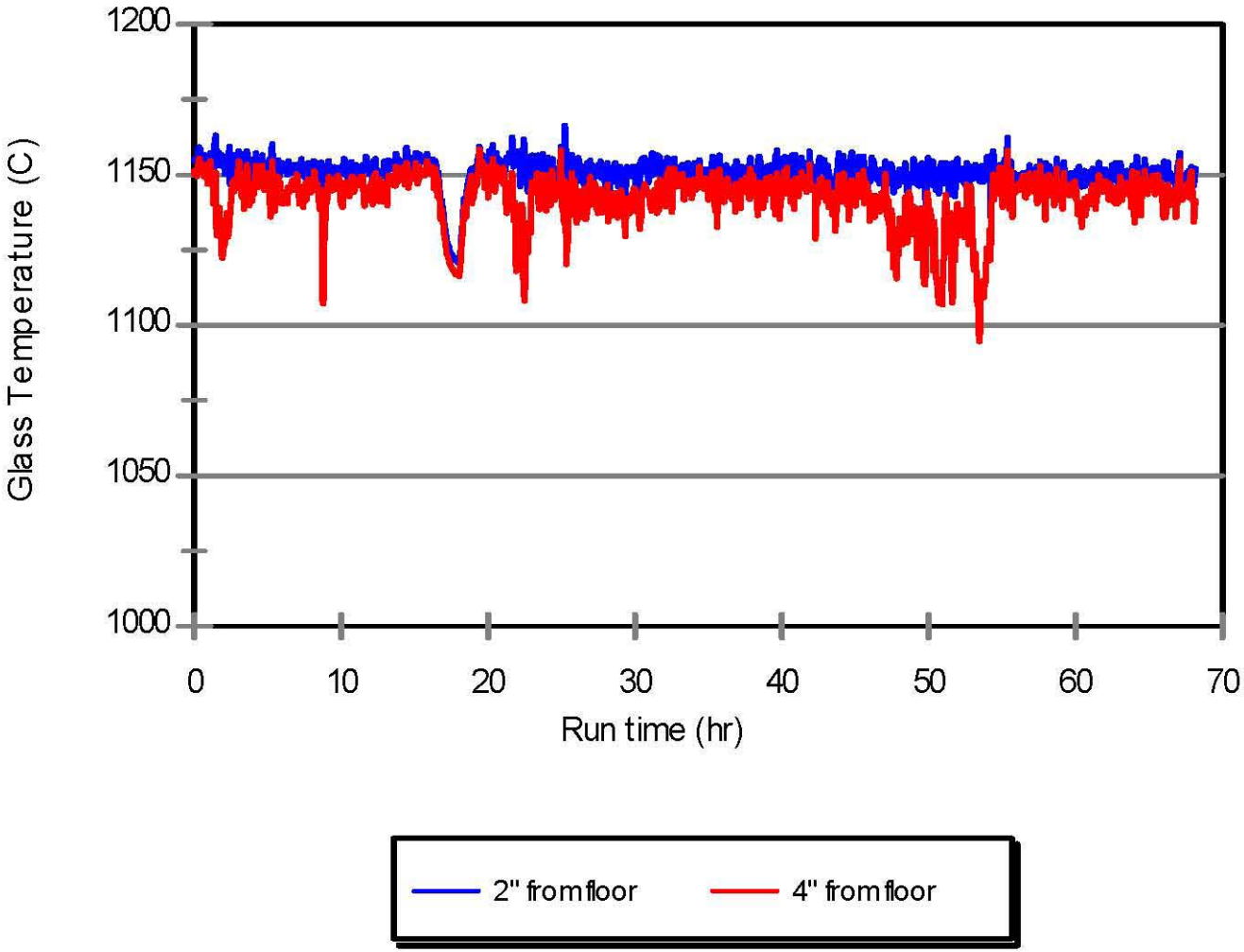


Figure 3.2.b. Glass pool temperatures during Test 2.

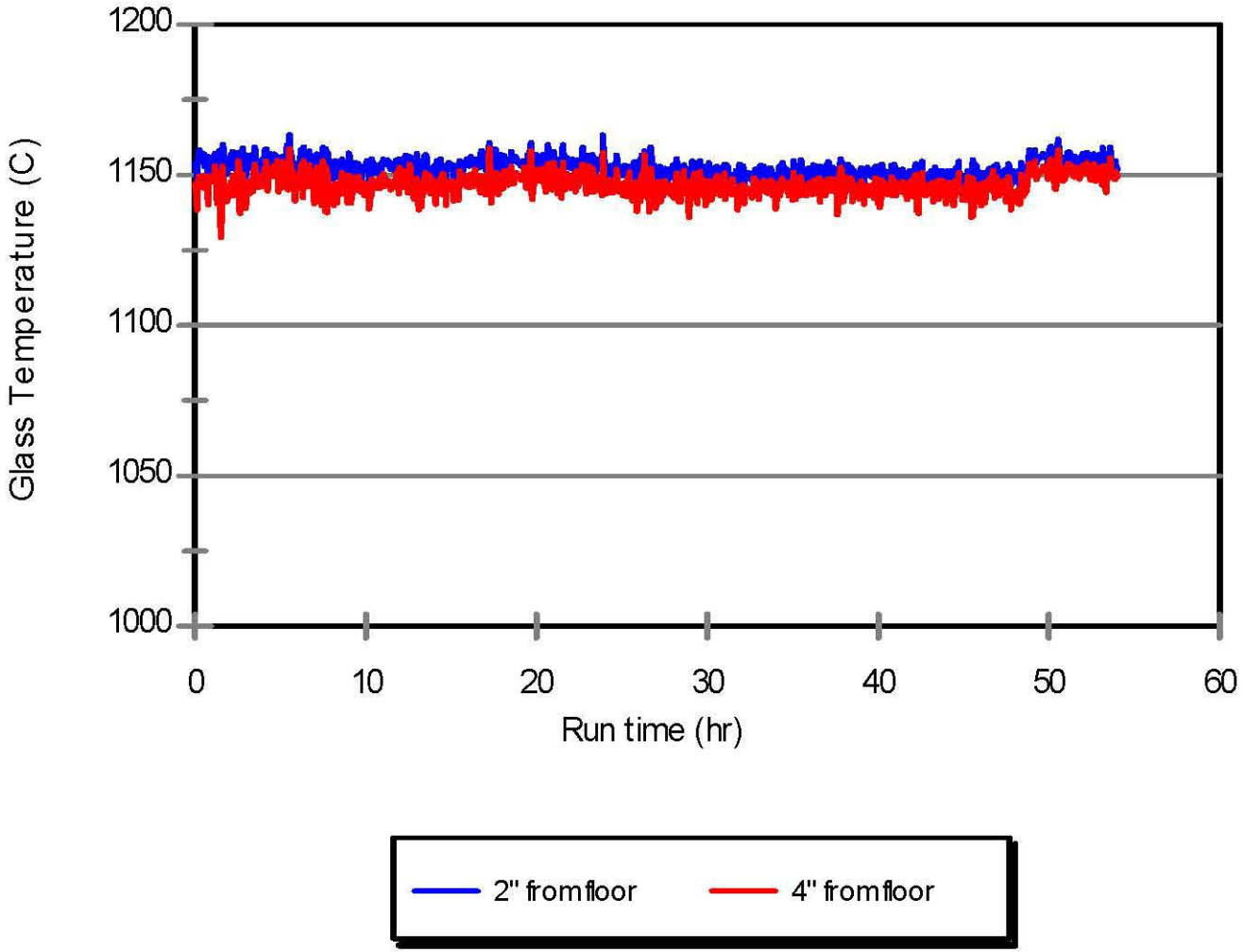


Figure 3.2.c. Glass pool temperatures during Test 3.

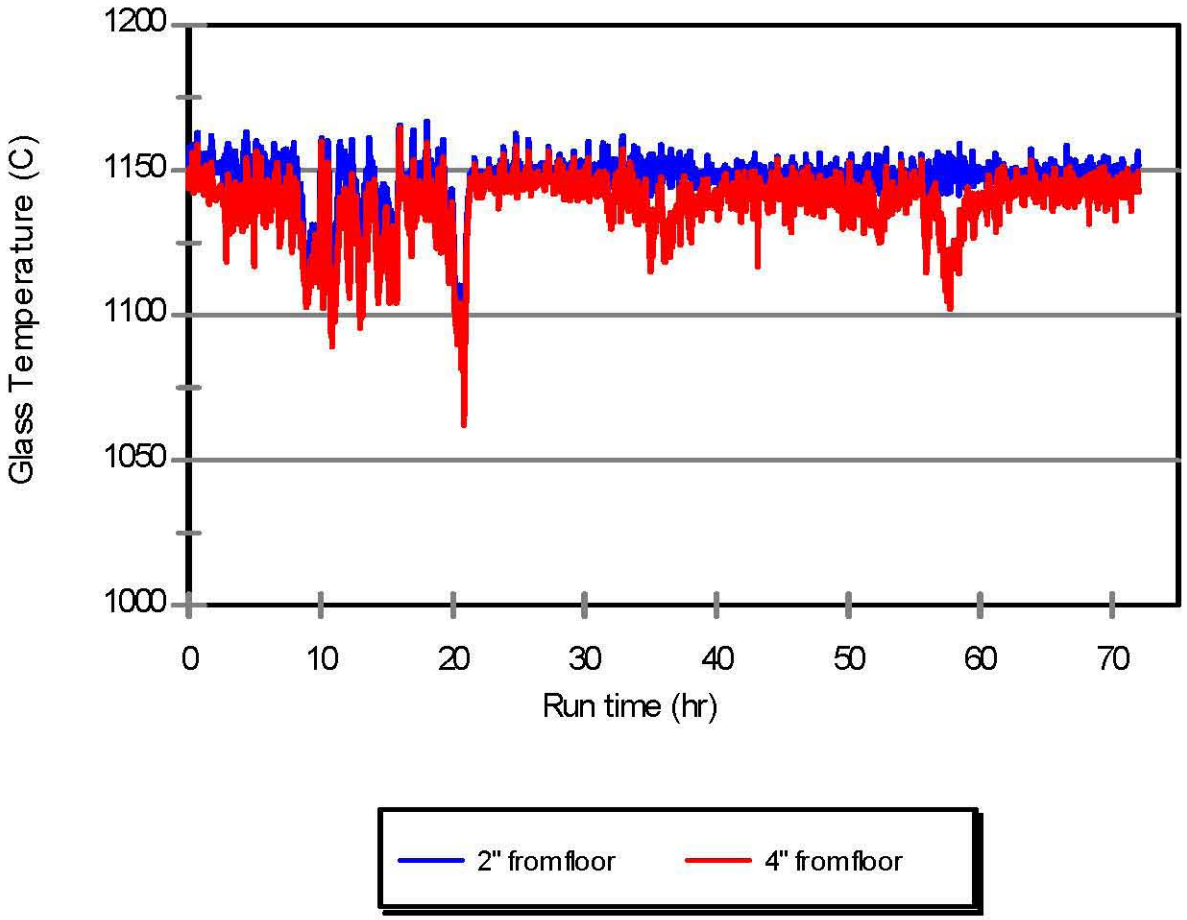


Figure 3.2.d. Glass pool temperatures during Test 4.

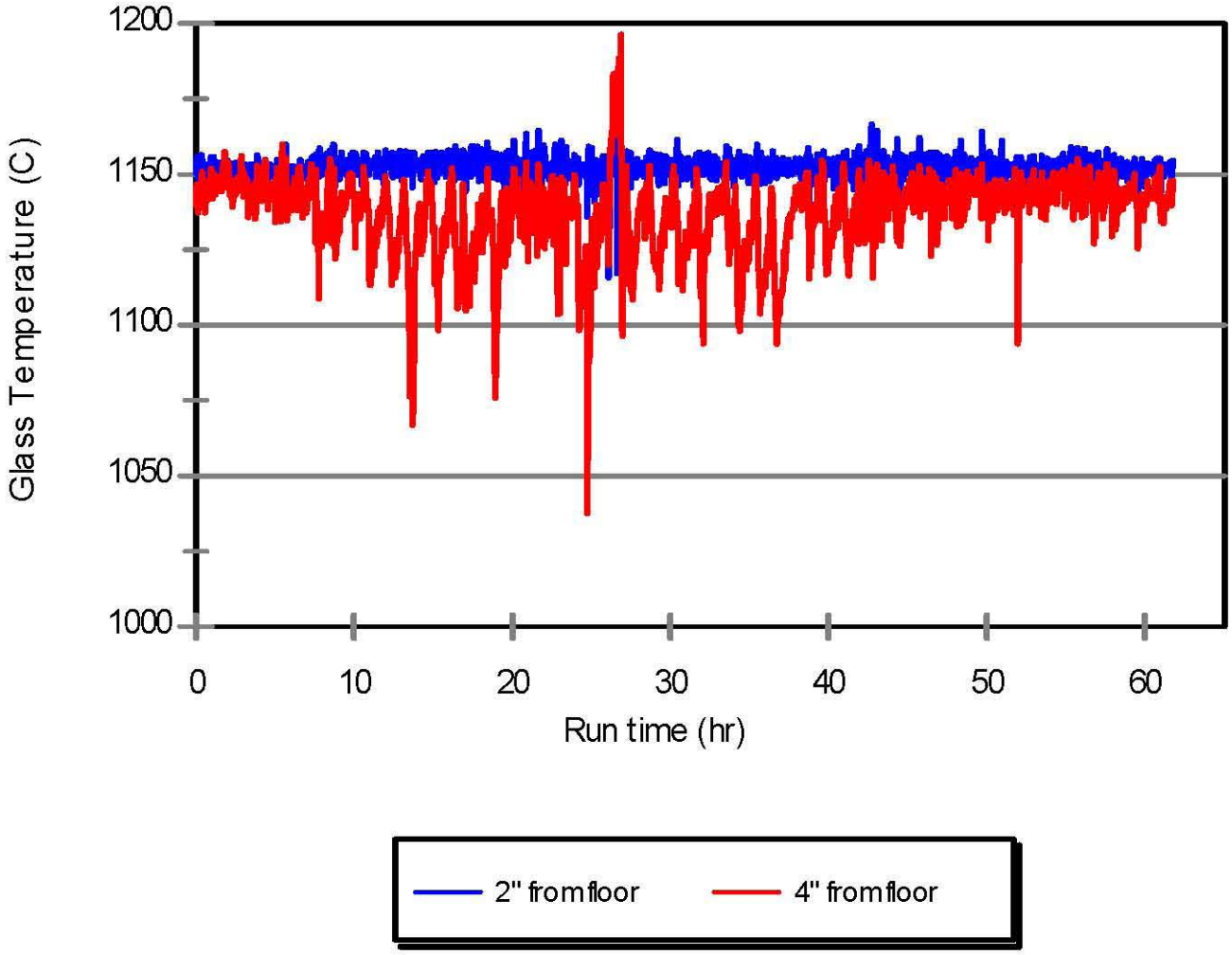


Figure 3.2.e. Glass pool temperatures during Test 5.

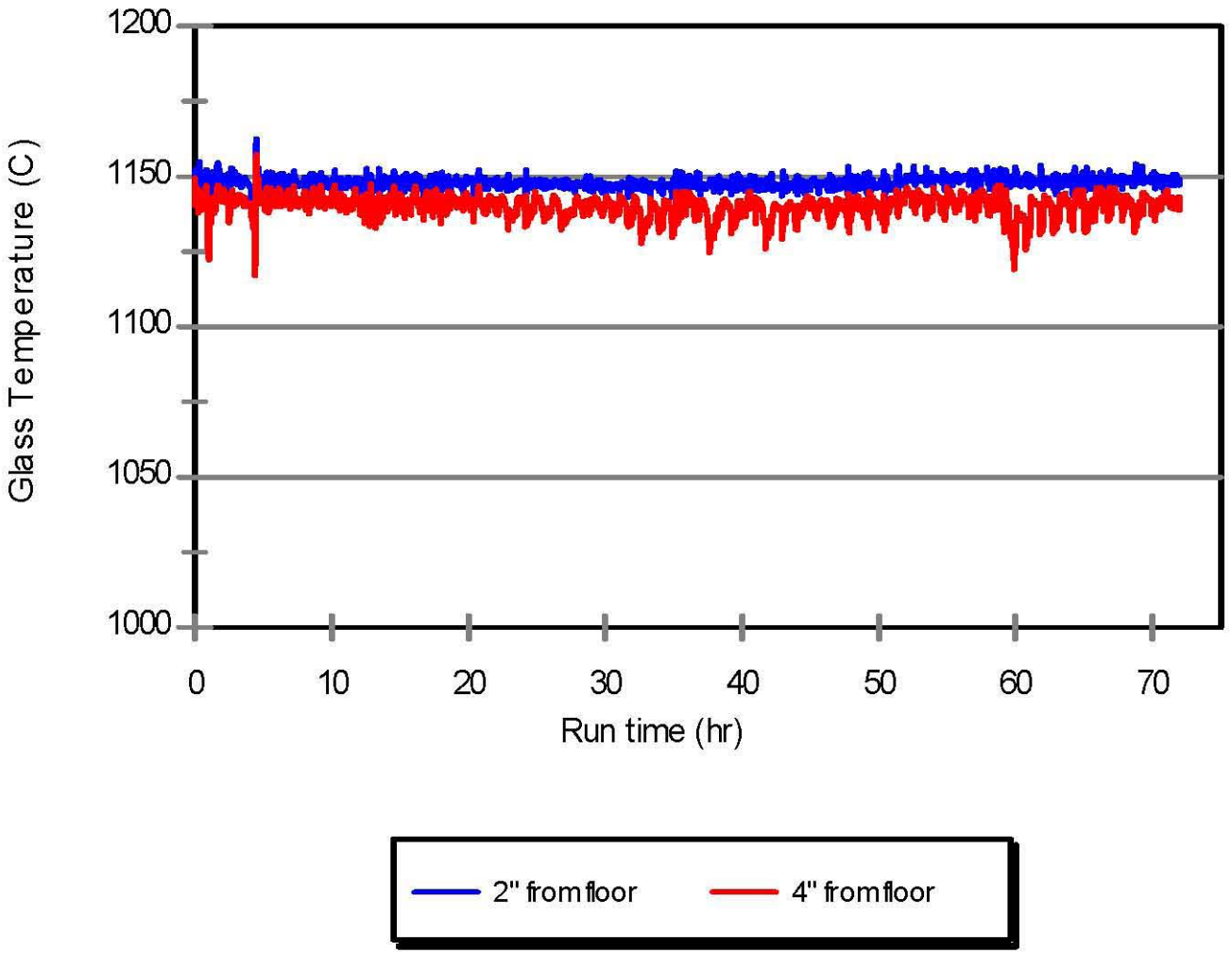


Figure 3.2.f. Glass pool temperatures during Test 6.

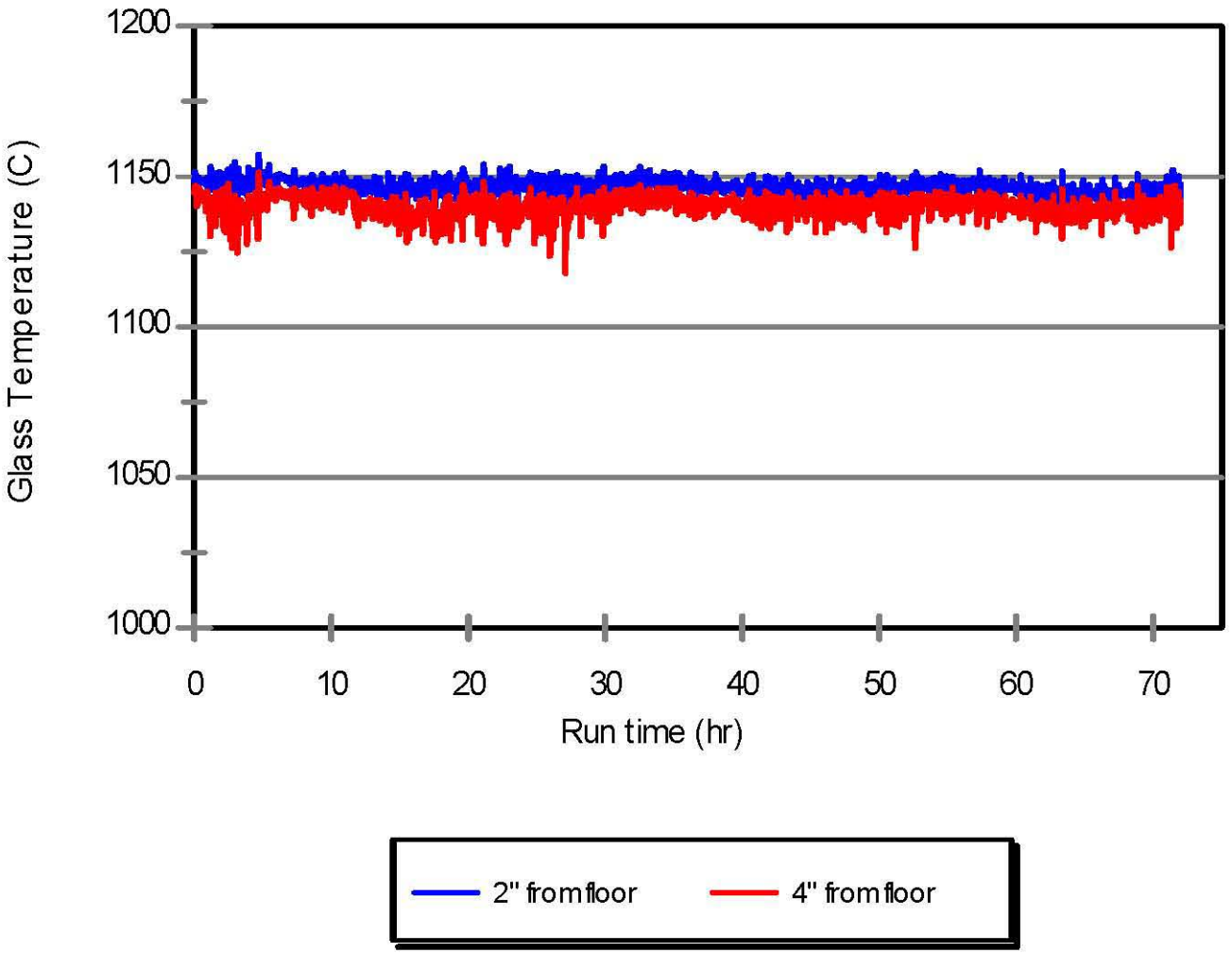


Figure 3.2.g. Glass pool temperatures during Test 7.

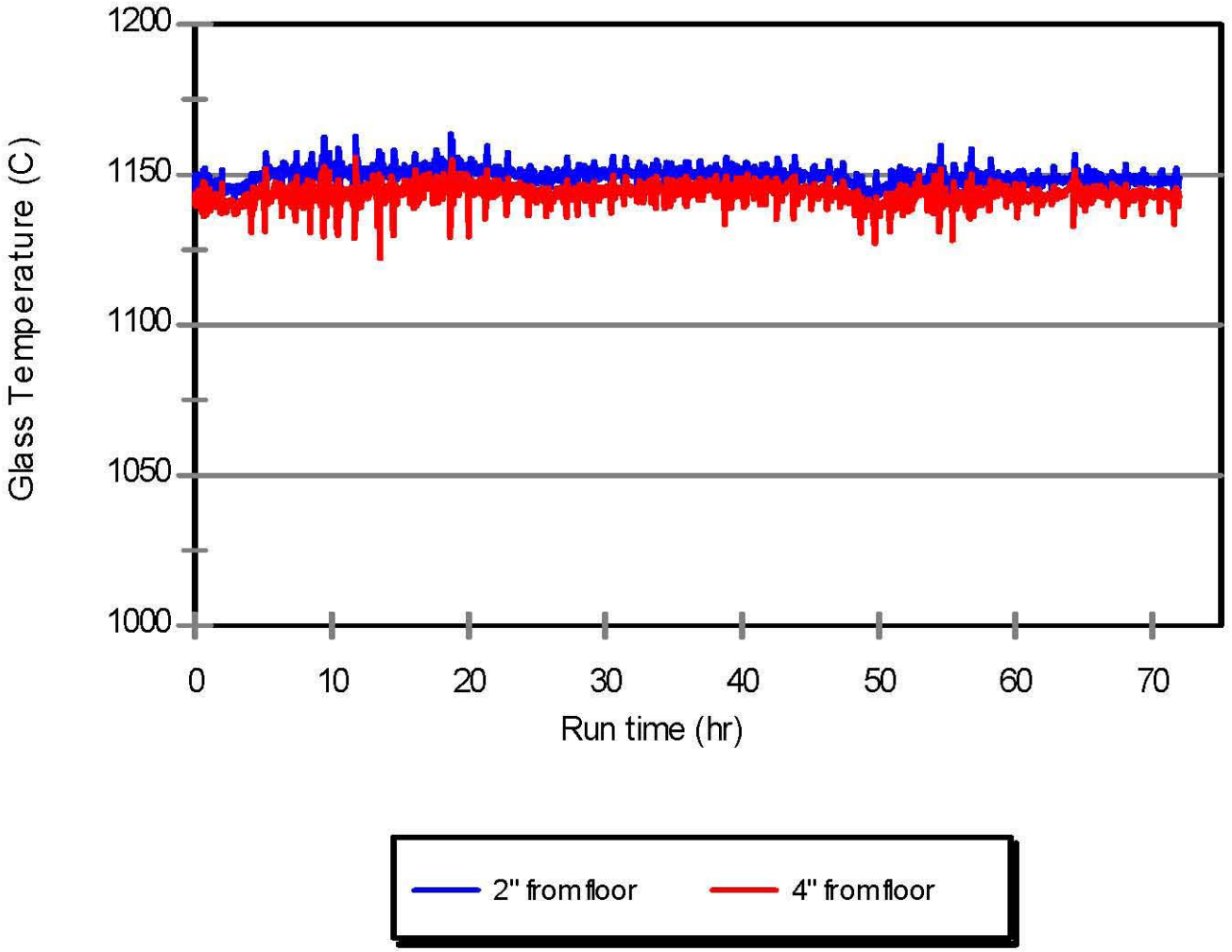


Figure 3.2.h. Glass pool temperatures during Test 8.

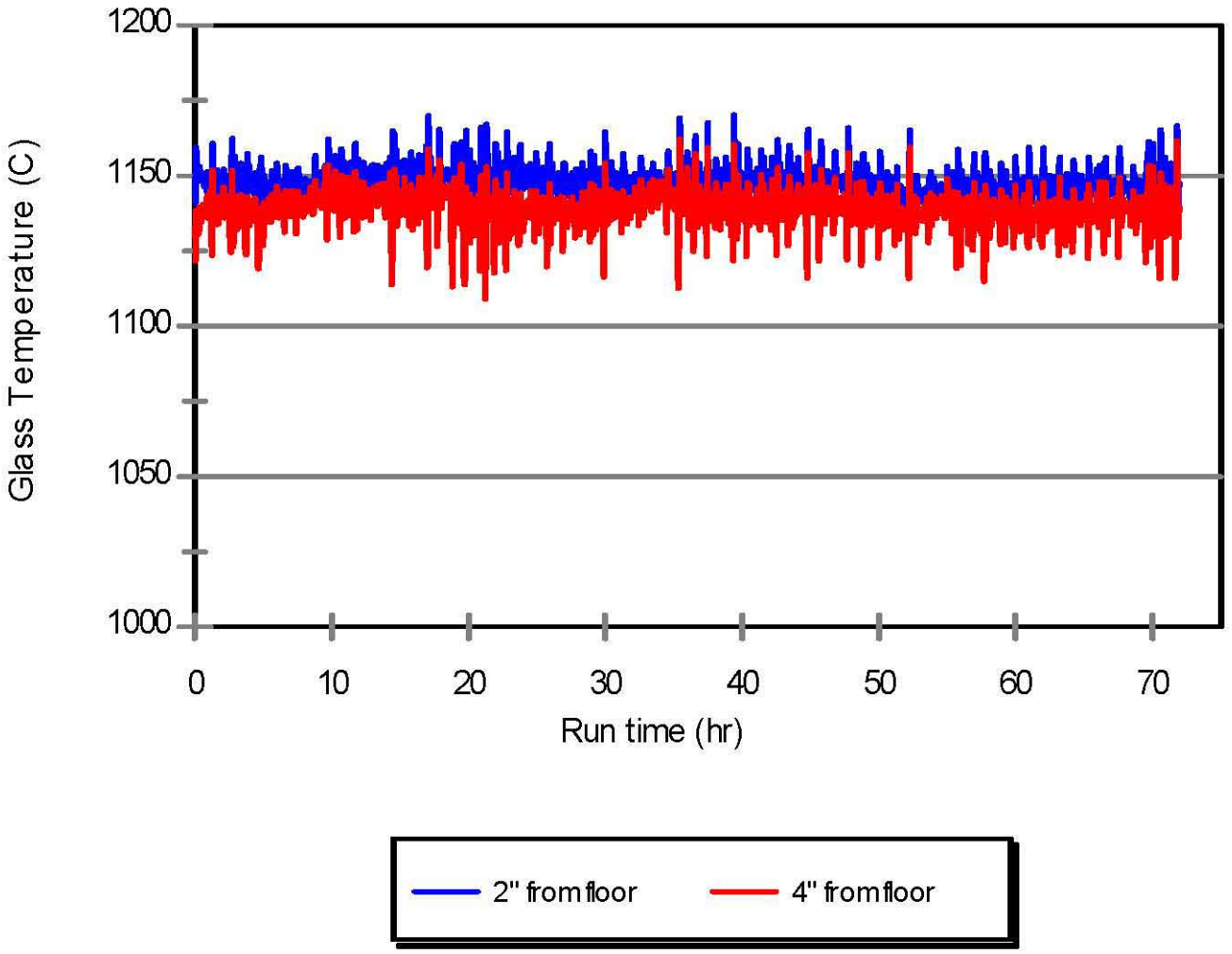


Figure 3.2.i. Glass pool temperatures during Test 9.

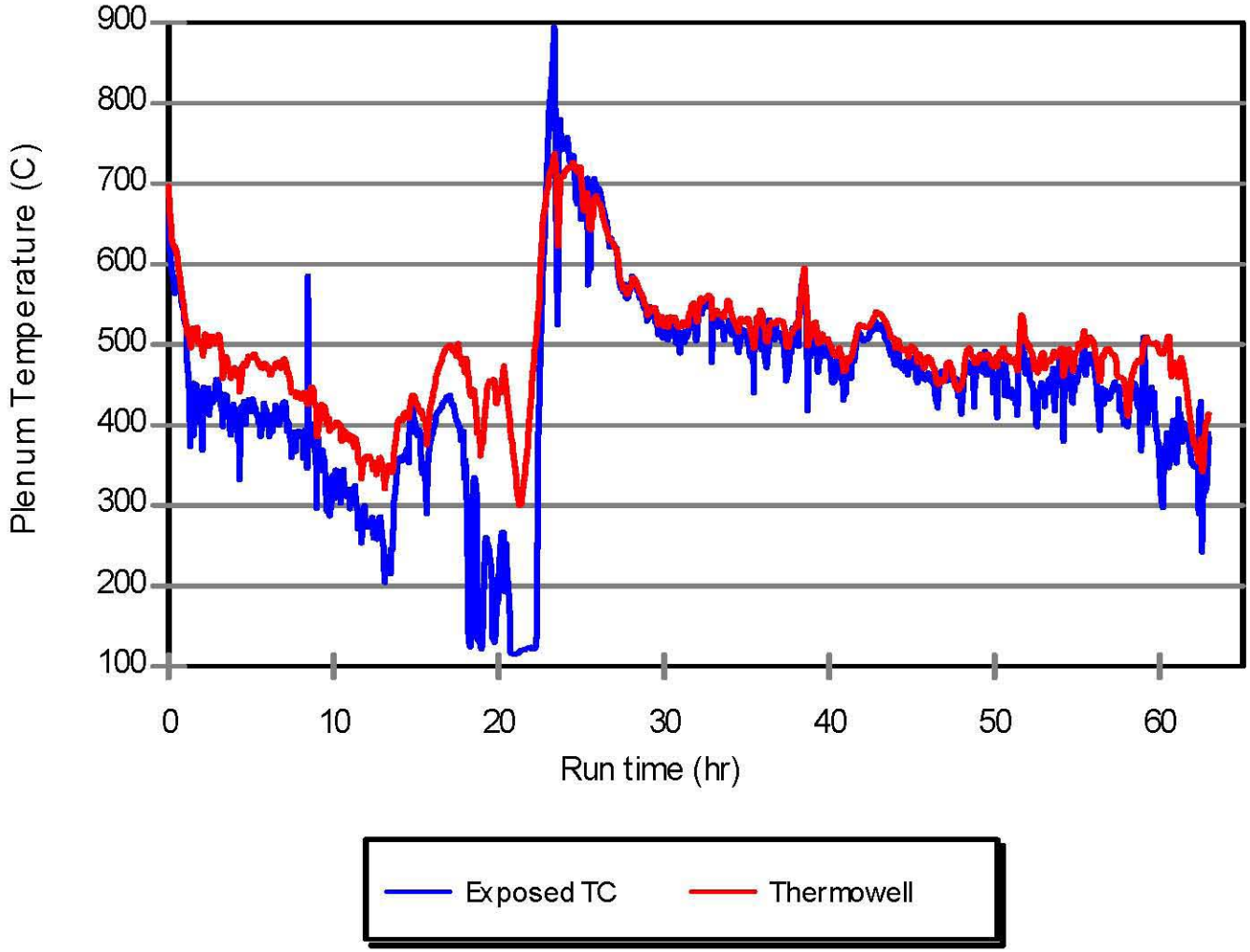


Figure 3.3.a. Plenum temperatures during Test 1.

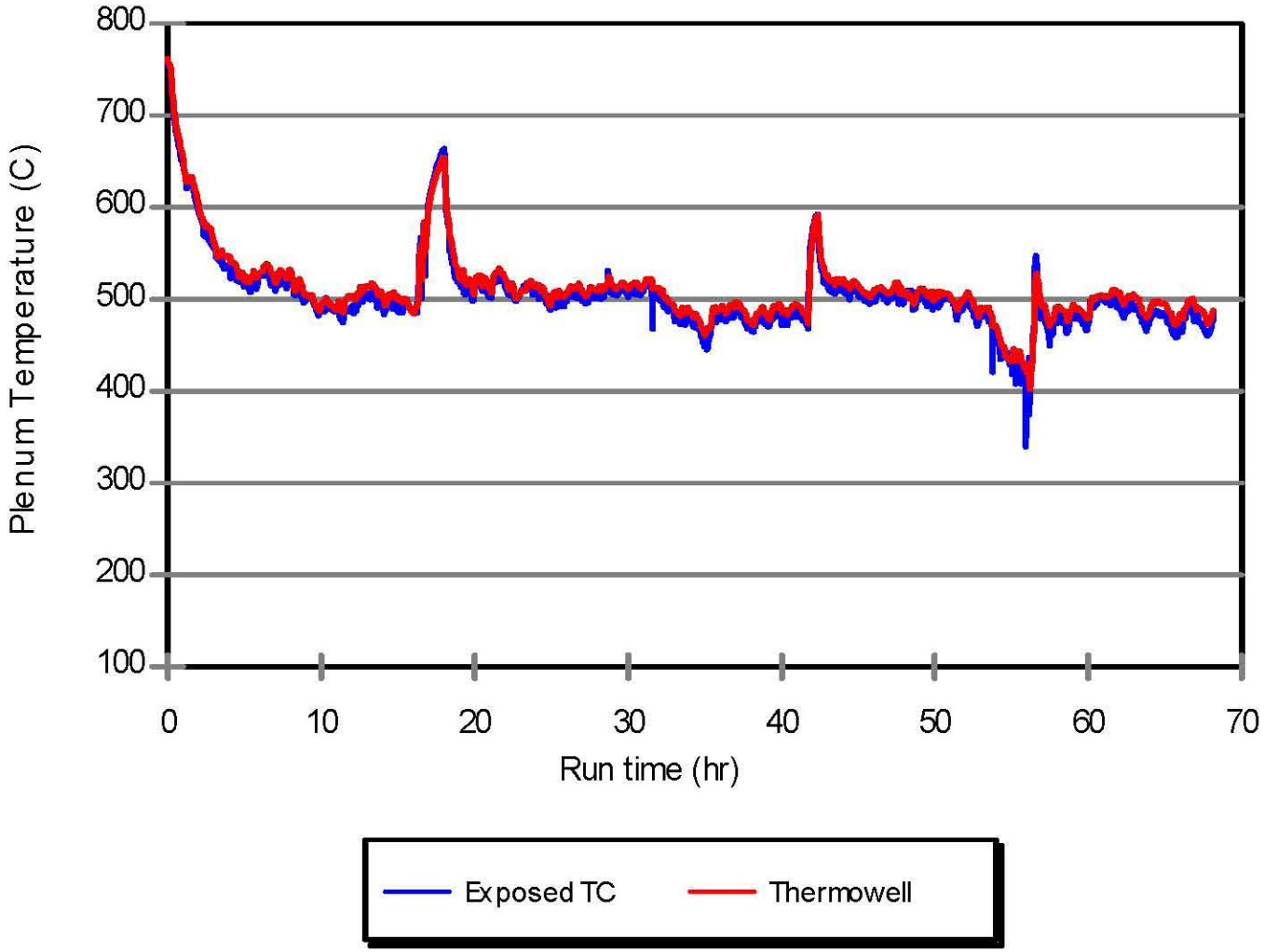


Figure 3.3.b. Plenum temperatures during Test 2.

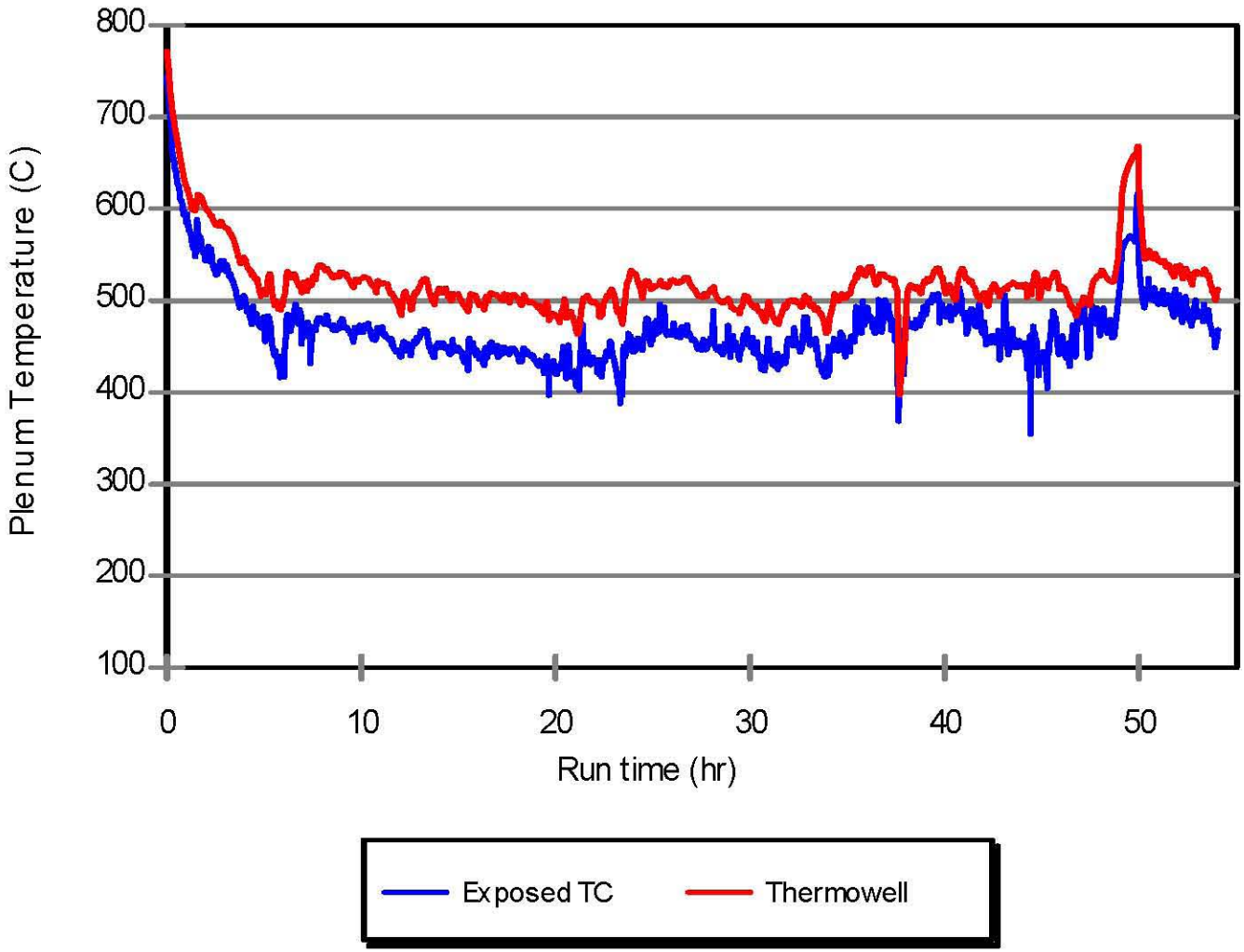


Figure 3.3.c. Plenum temperatures during Test 3.

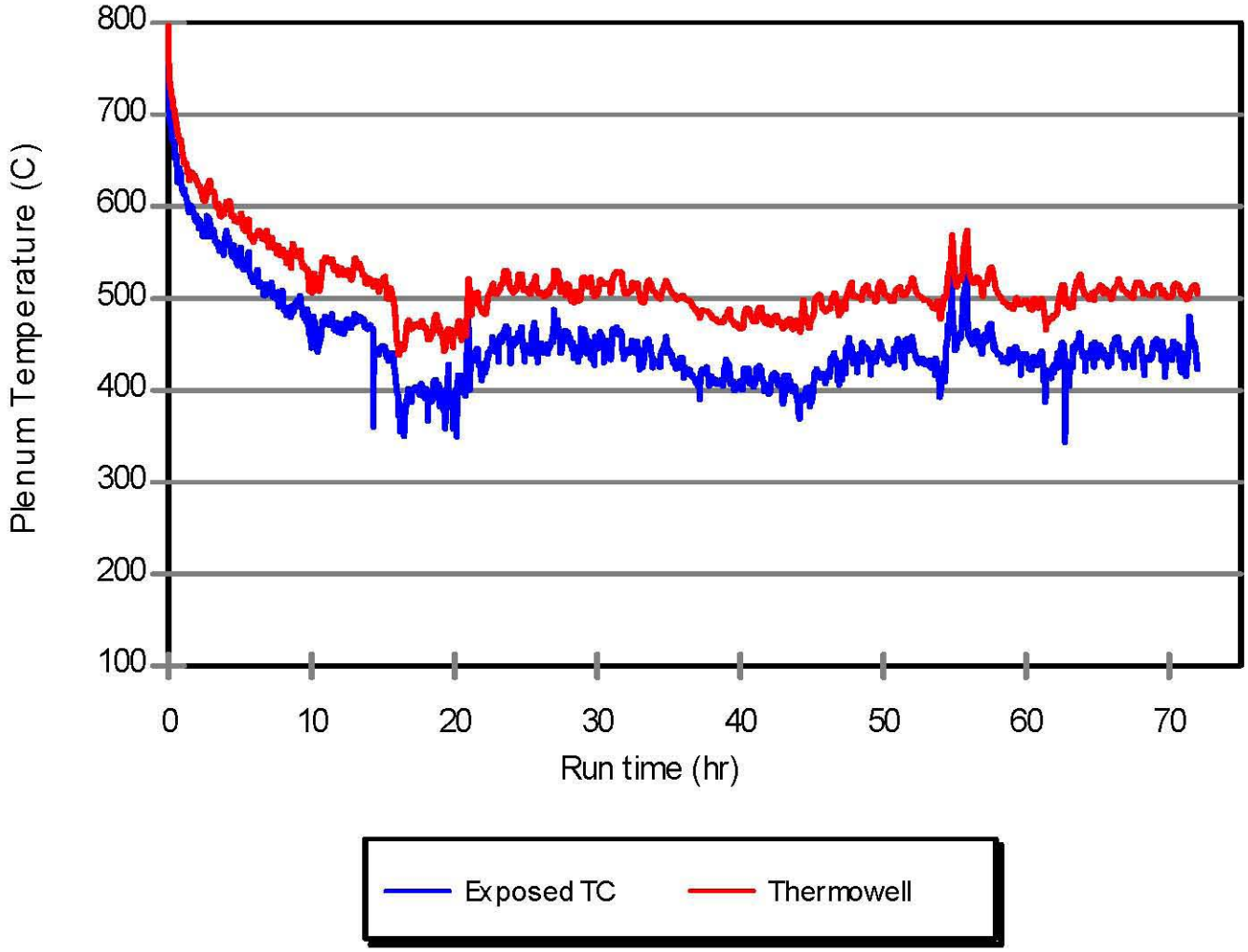


Figure 3.3.d. Plenum temperatures during Test 4.

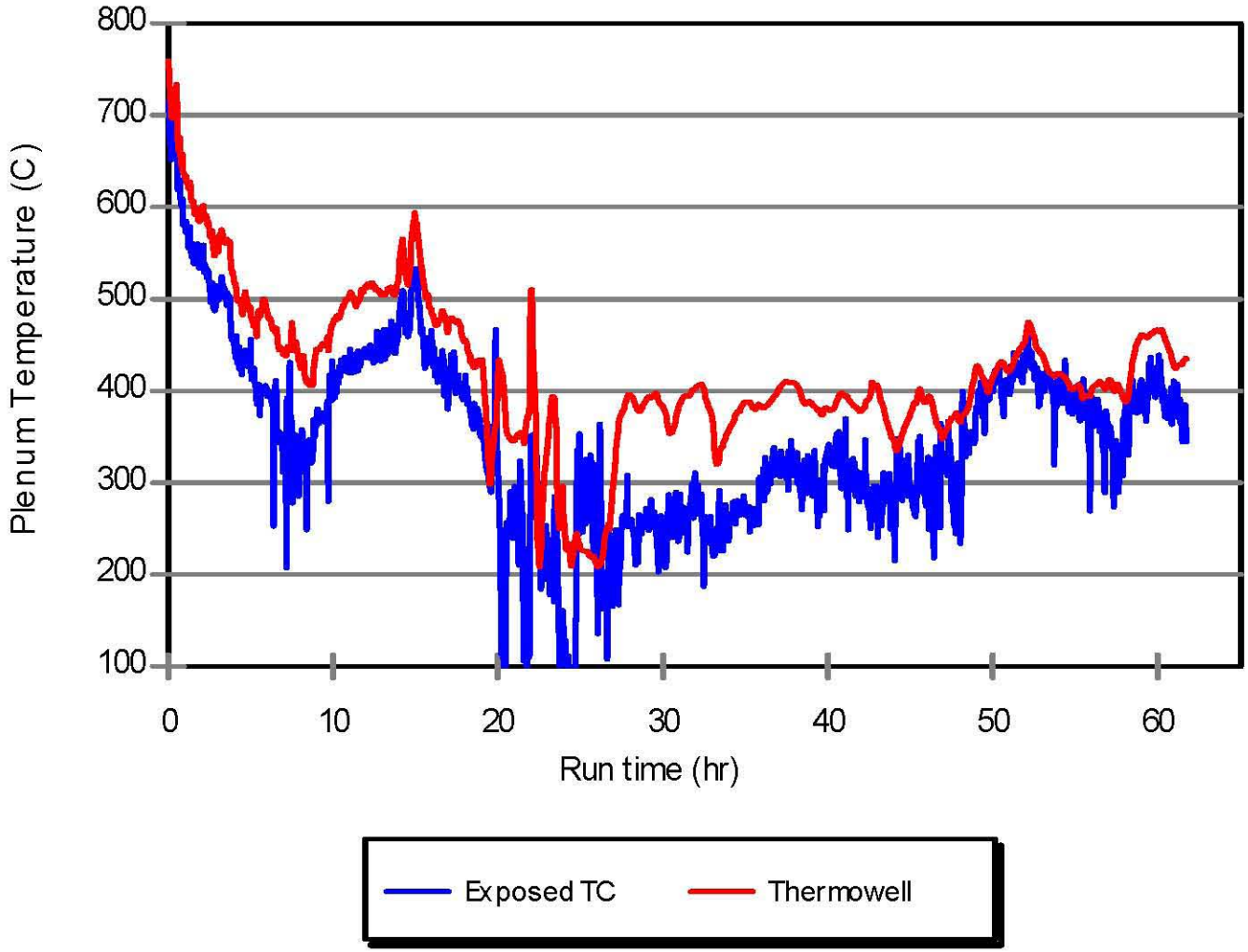


Figure 3.3.e. Plenum temperatures during Test 5.

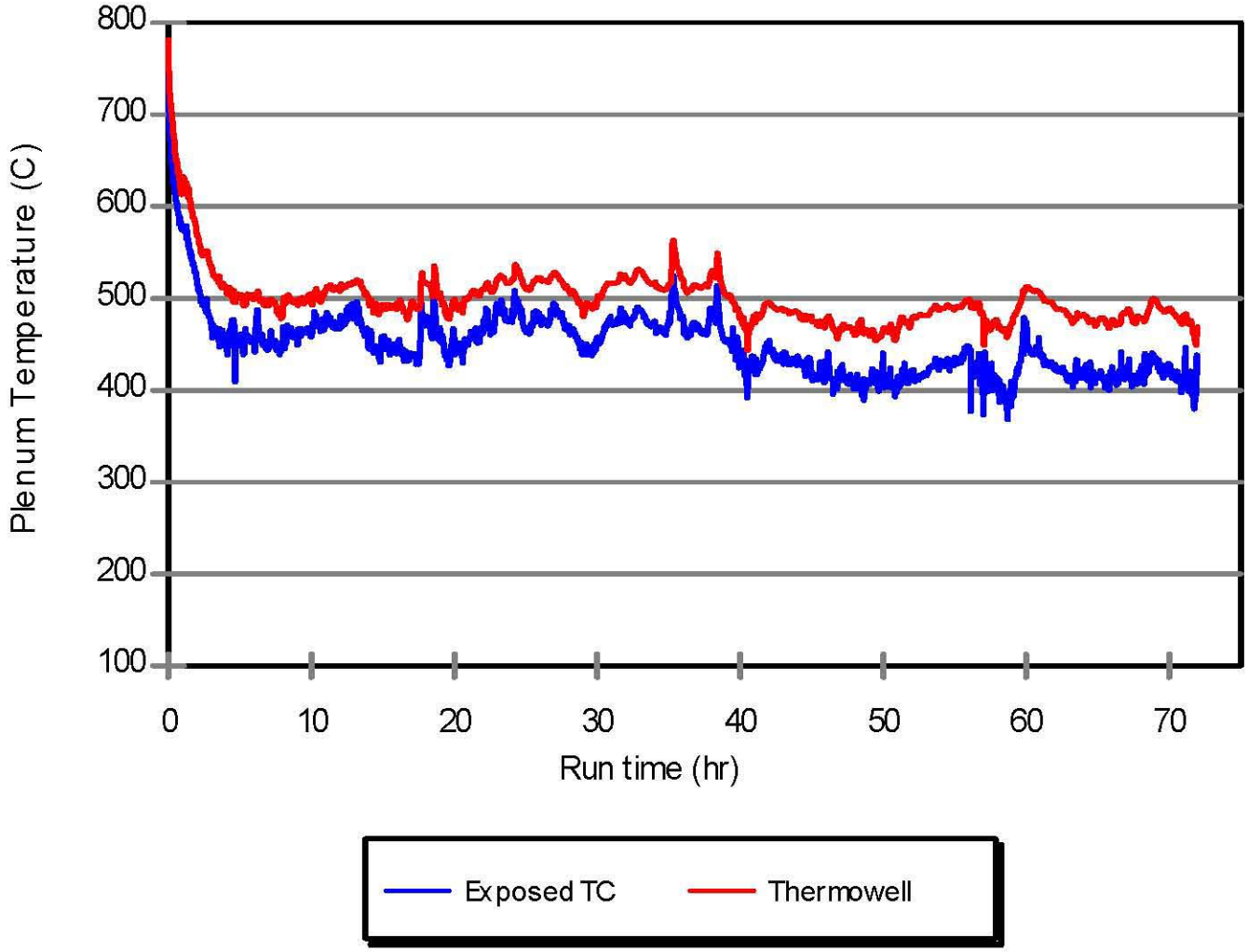


Figure 3.3.f. Plenum temperatures during Test 6.

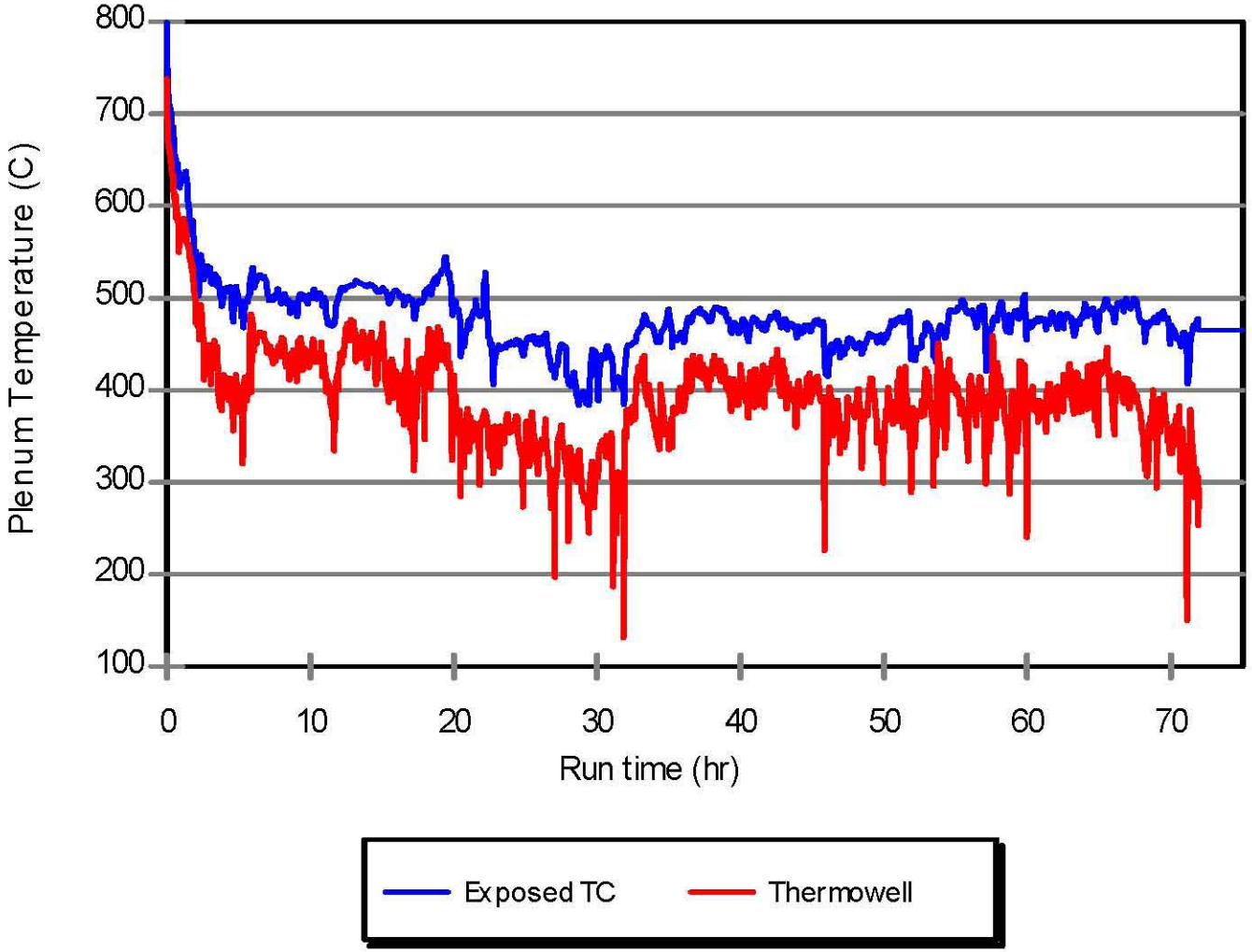


Figure 3.3.g. Plenum temperatures during Test 7.

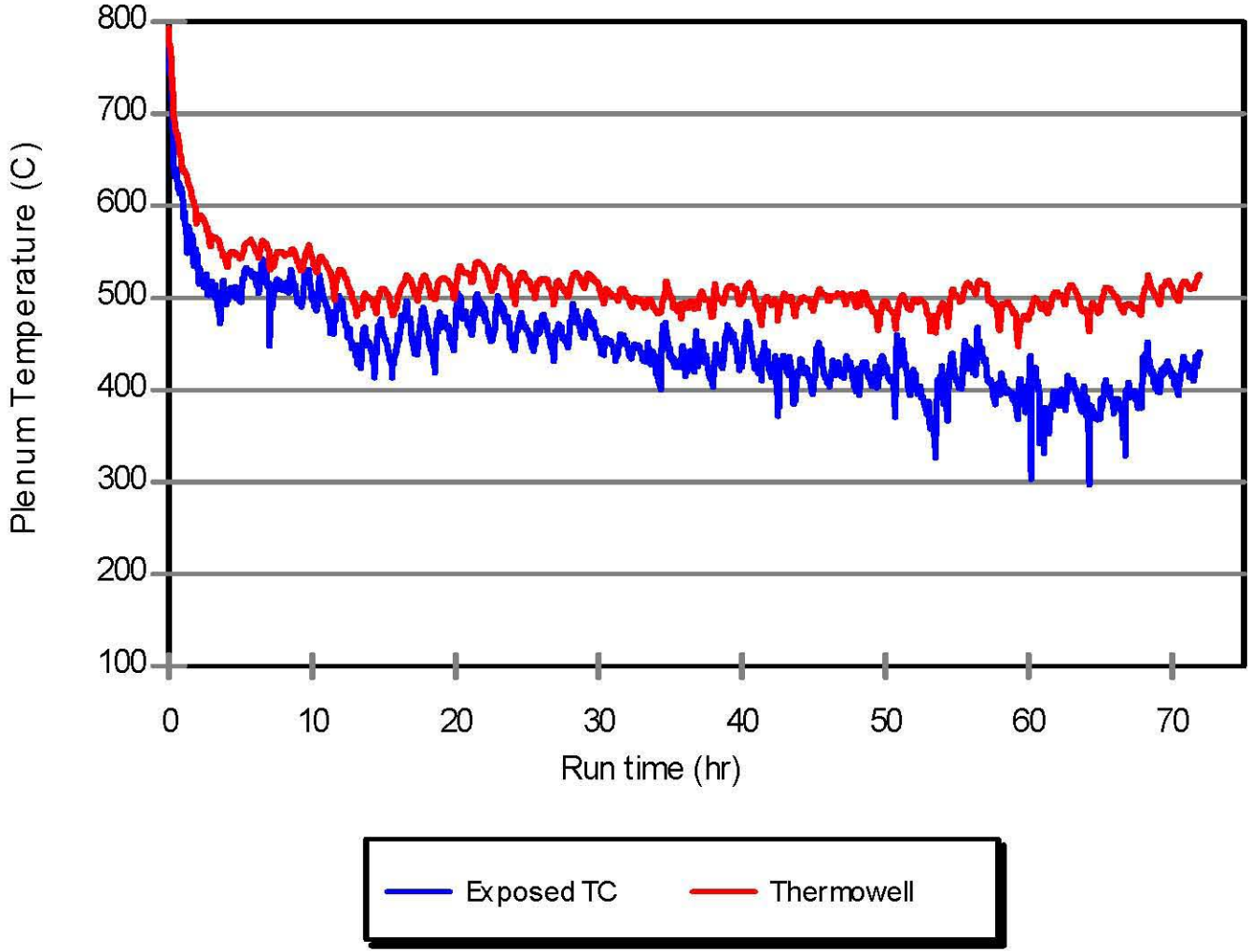


Figure 3.3.h. Plenum temperatures during Test 8.

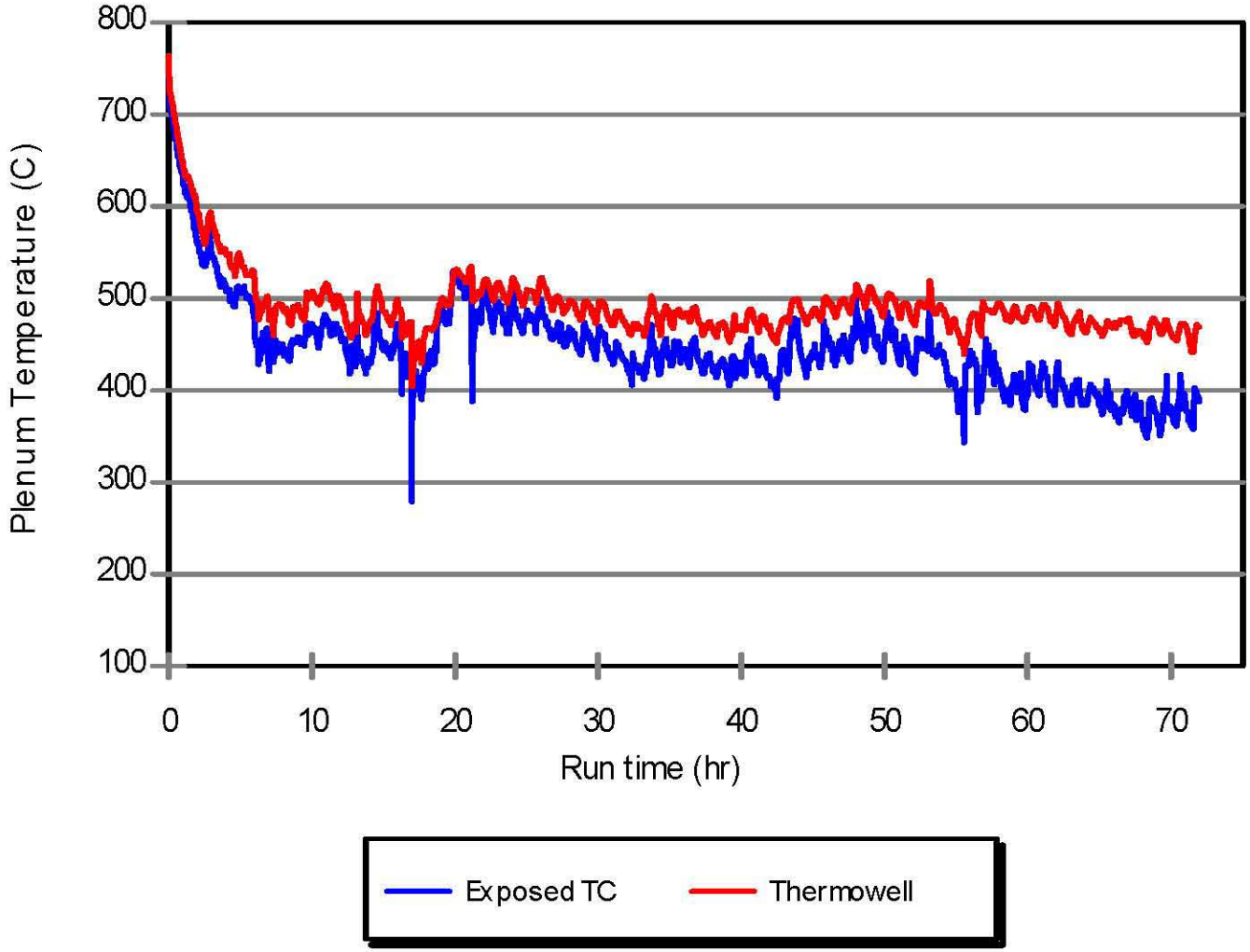


Figure 3.3.i. Plenum temperatures during Test 9.

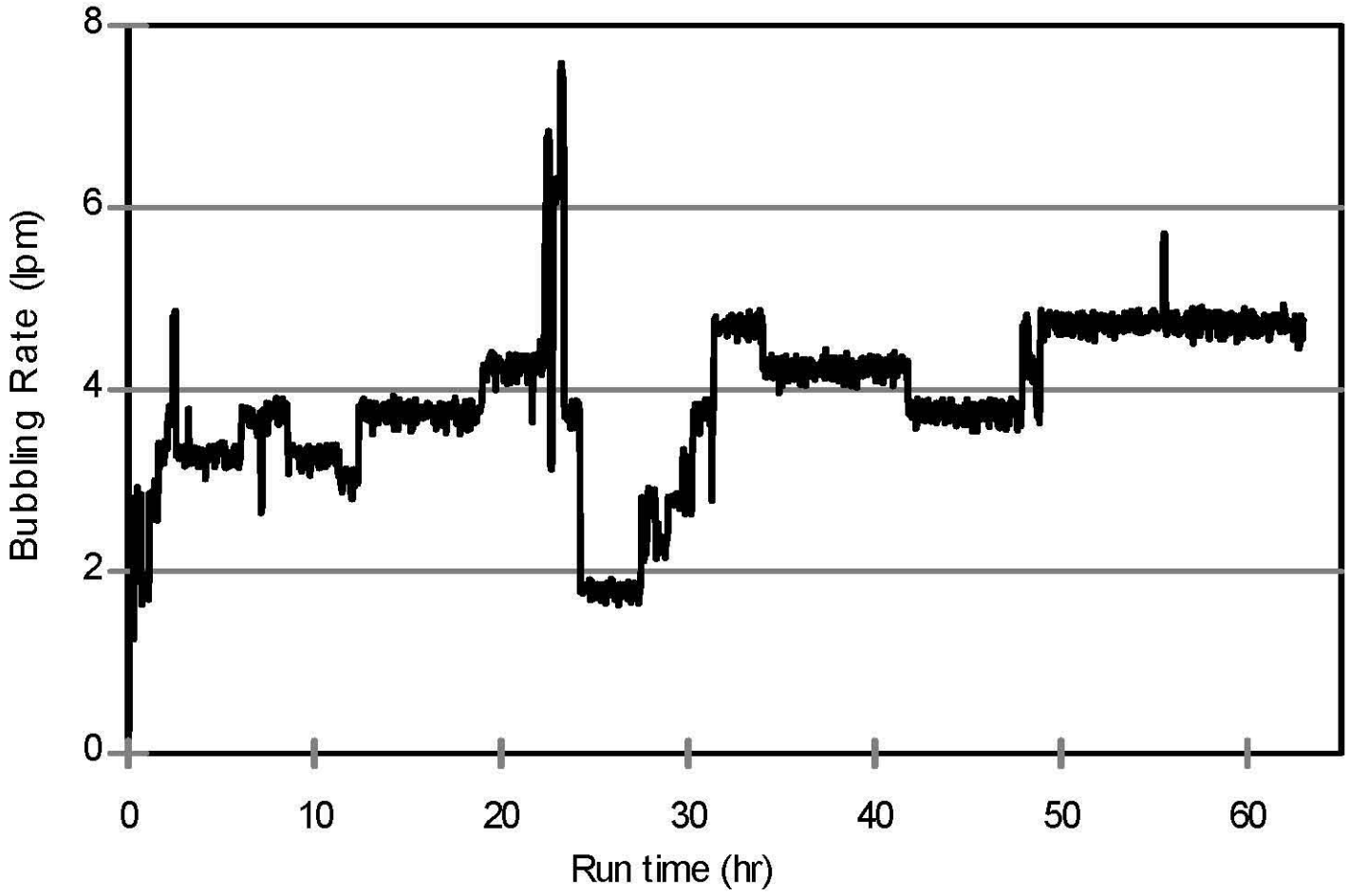


Figure 3.4.a. Glass pool bubbling rates during Test 1.

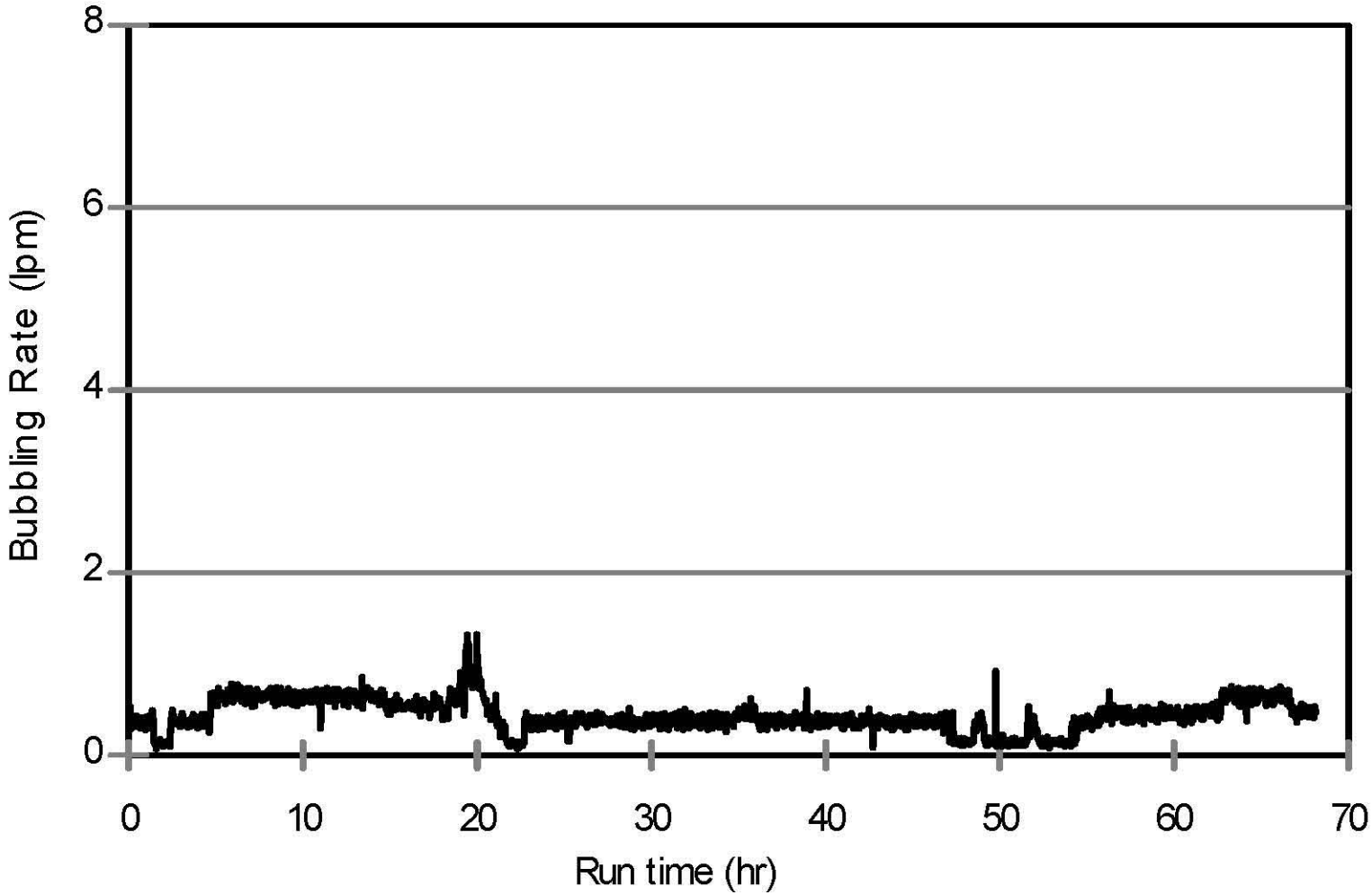


Figure 3.4.b. Glass pool bubbling rates during Test 2.

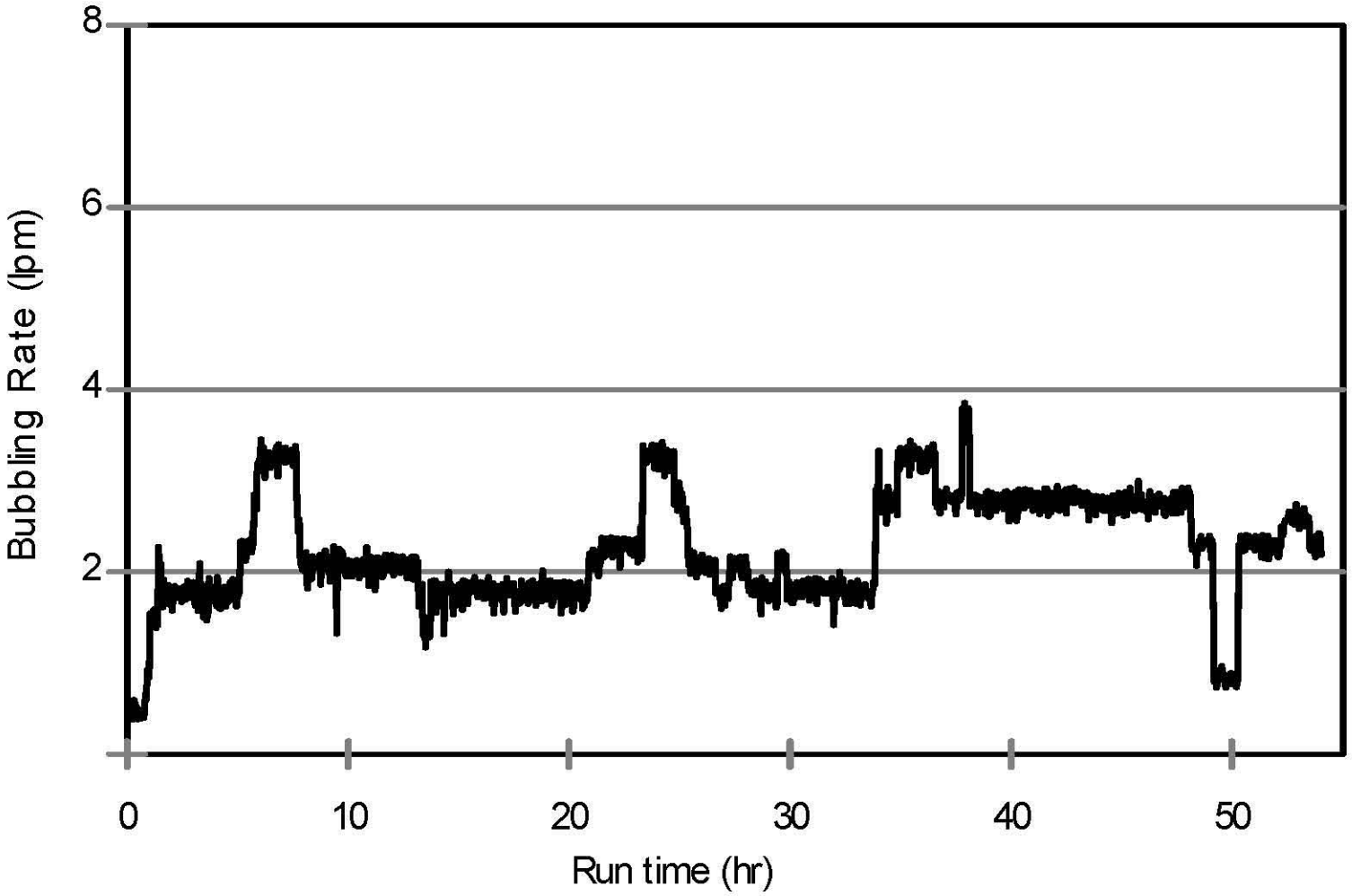


Figure 3.4.c. Glass pool bubbling rates during Test 3.

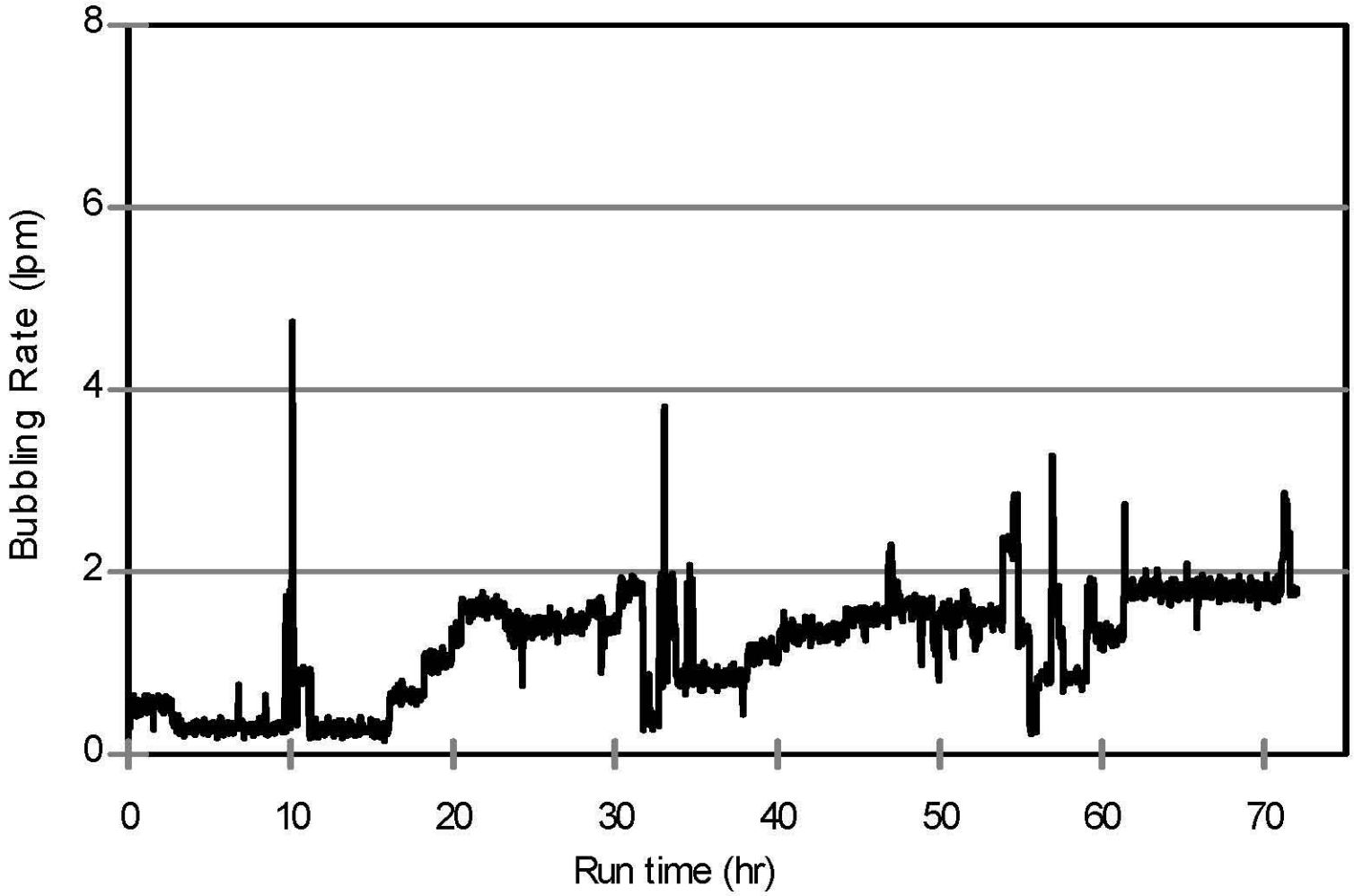


Figure 3.4.d. Glass pool bubbling rates during Test 4.

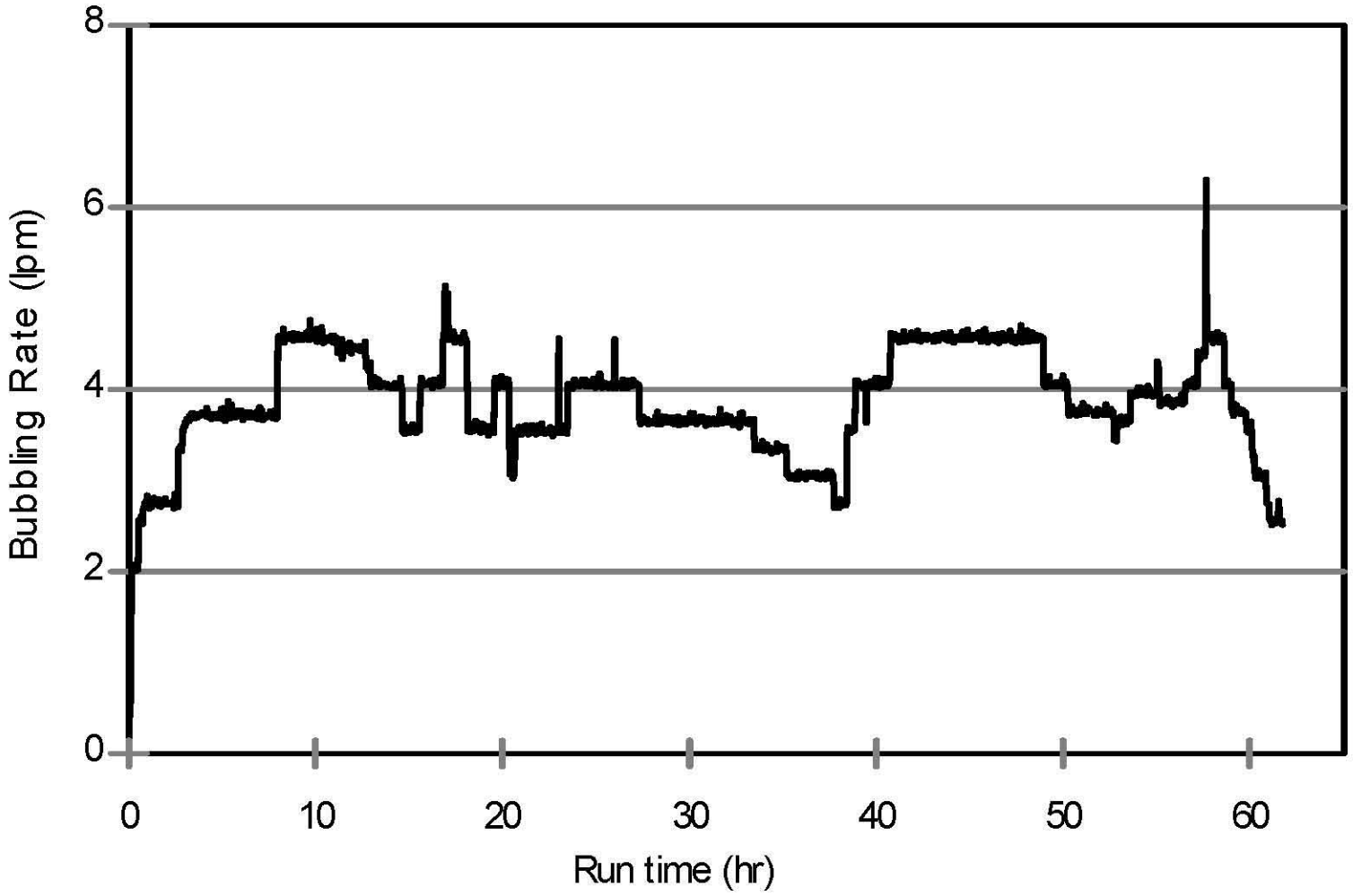


Figure 3.4.e. Glass pool bubbling rates during Test 5.

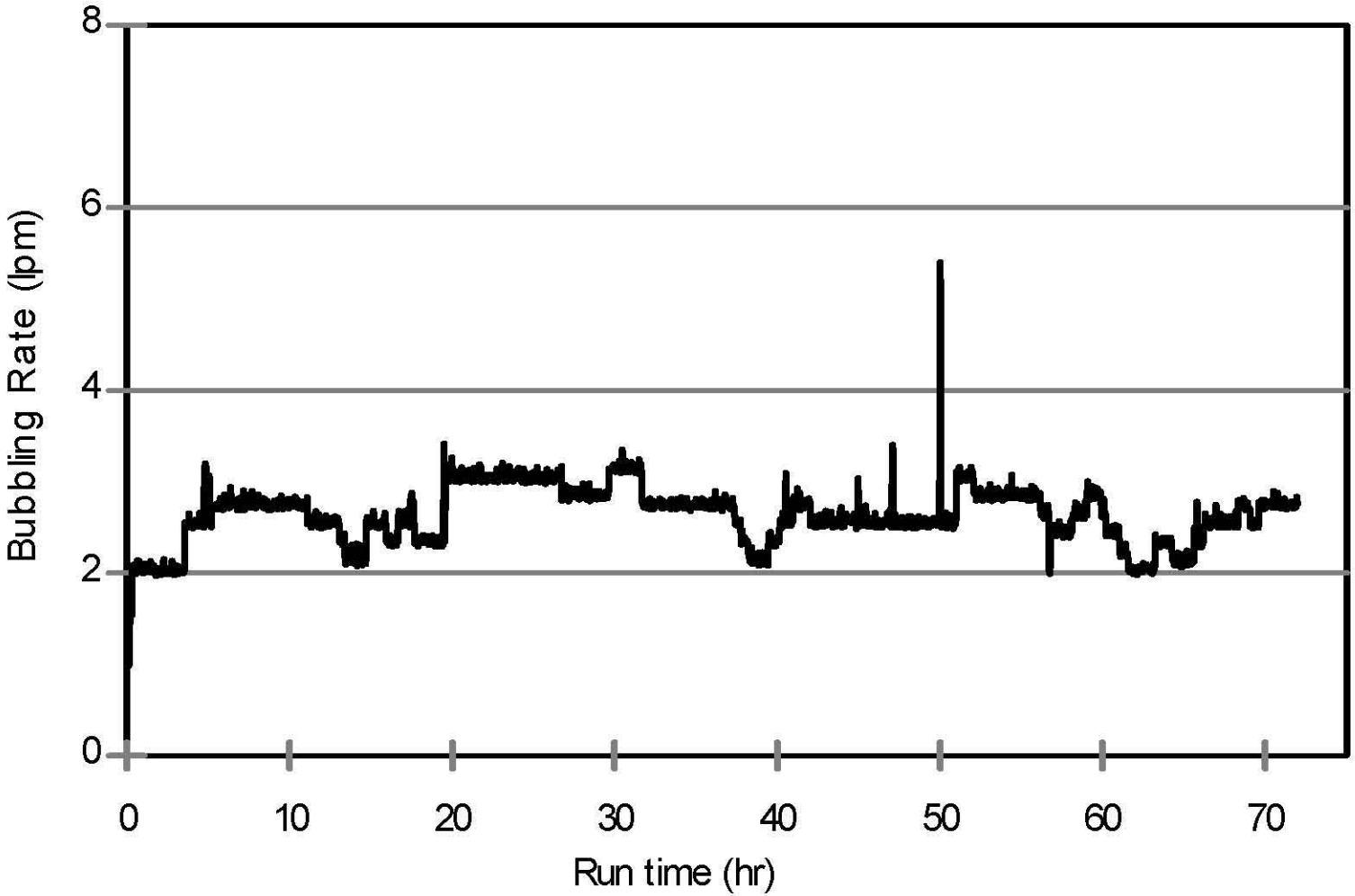


Figure 3.4.f. Glass pool bubbling rates during Test 6.

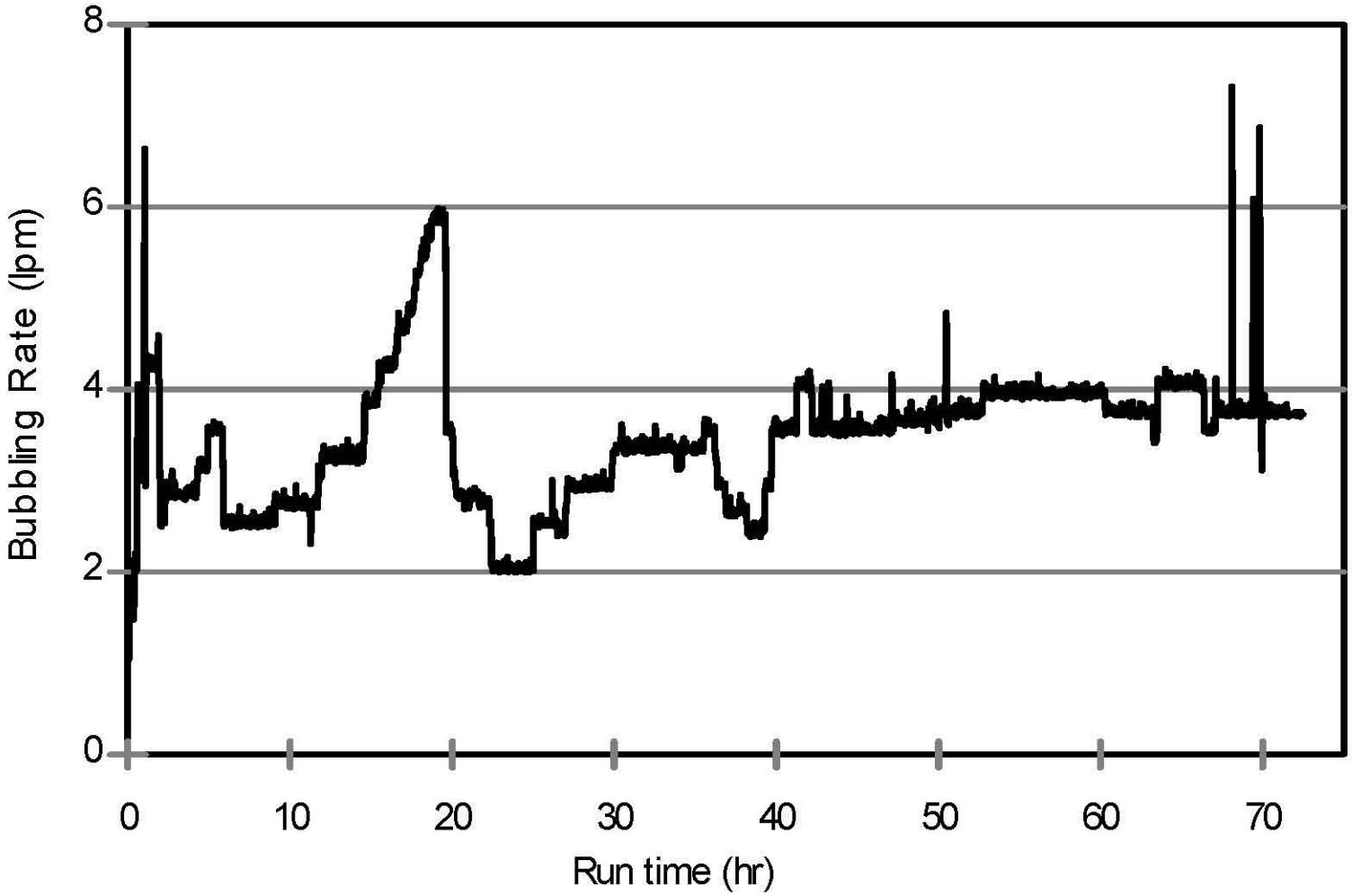


Figure 3.4.g. Glass pool bubbling rates during Test 7.

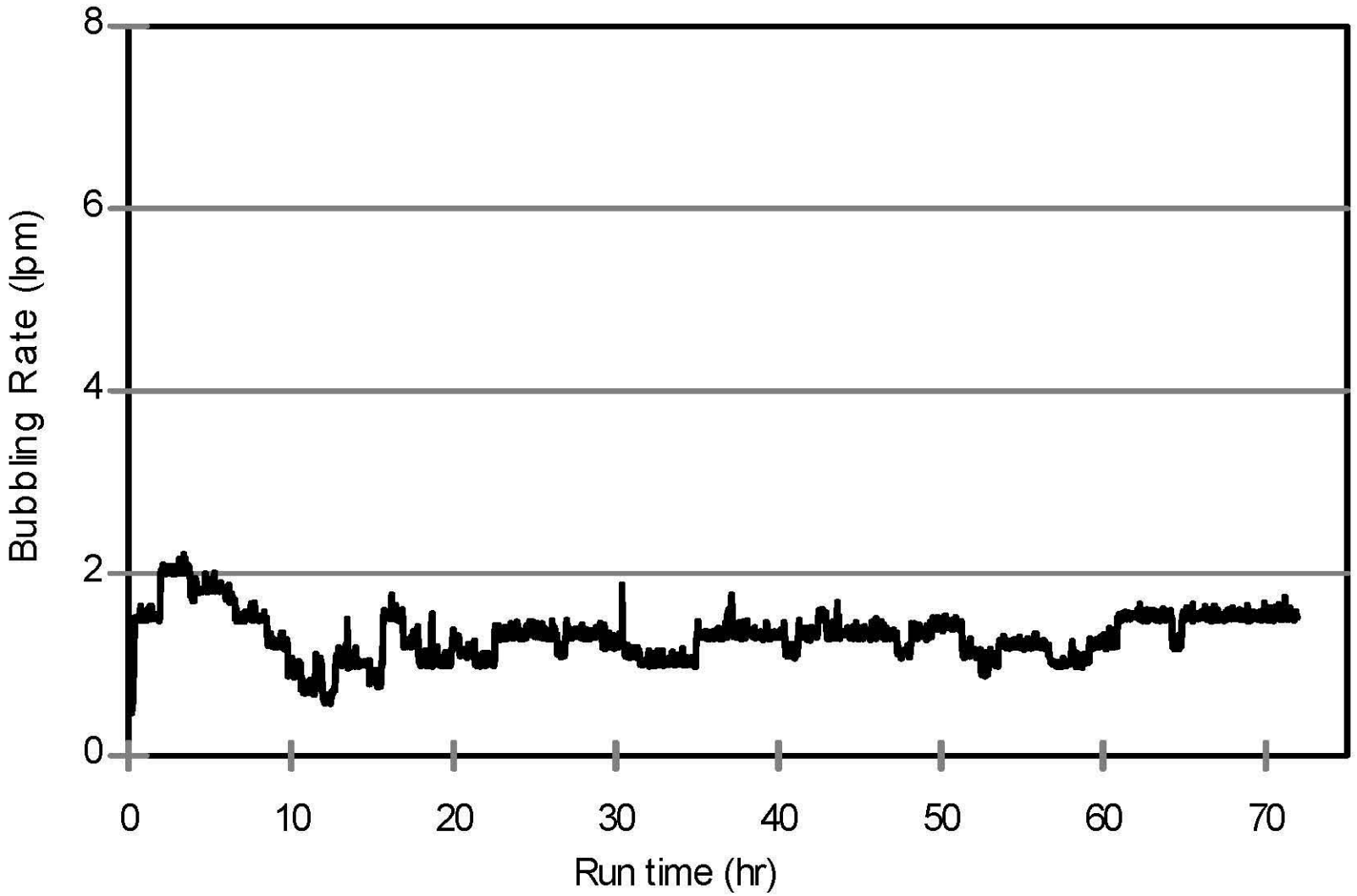


Figure 3.4.h. Glass pool bubbling rates during Test 8.

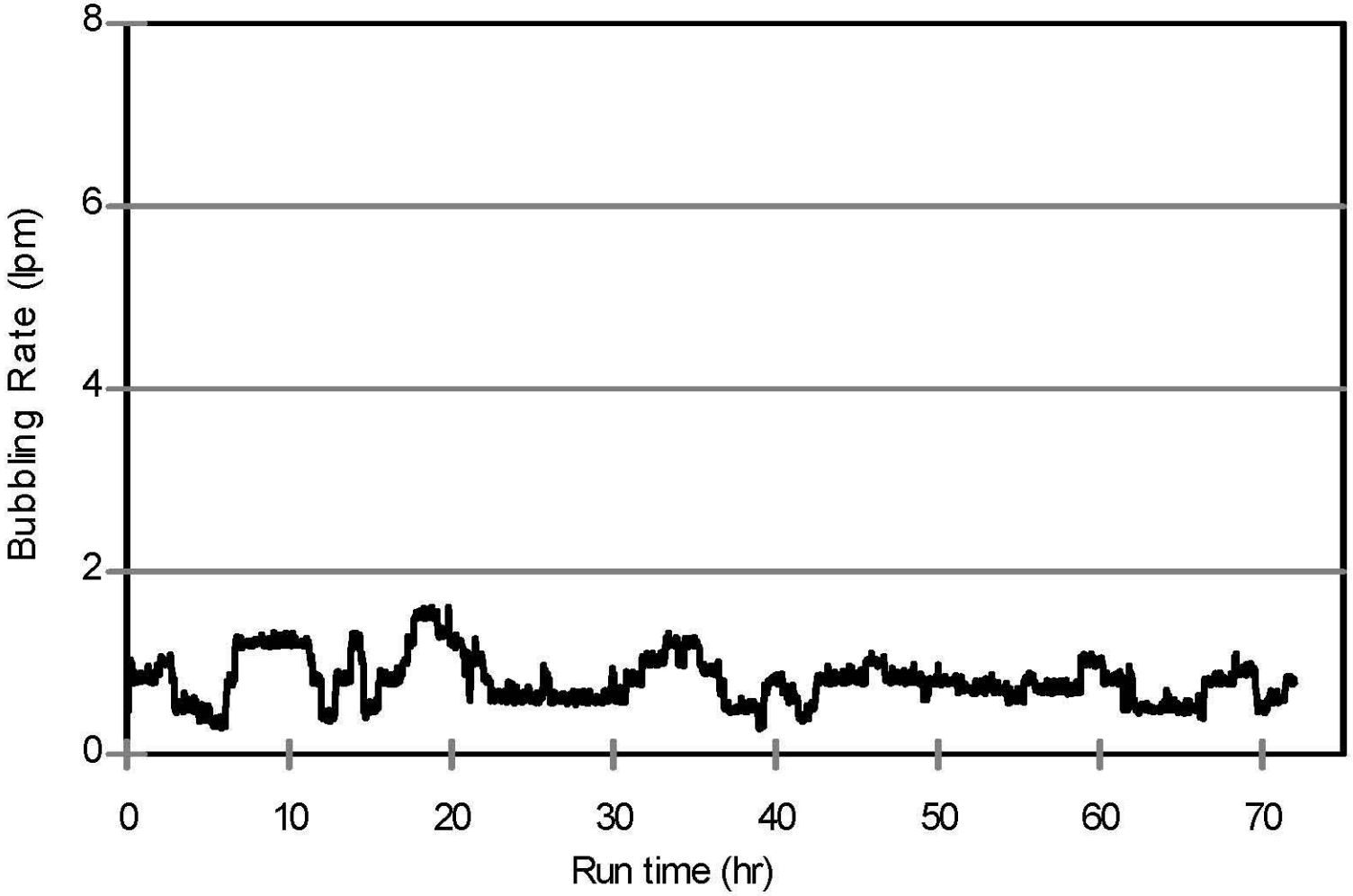


Figure 3.4.i. Glass pool bubbling rates during Test 9.

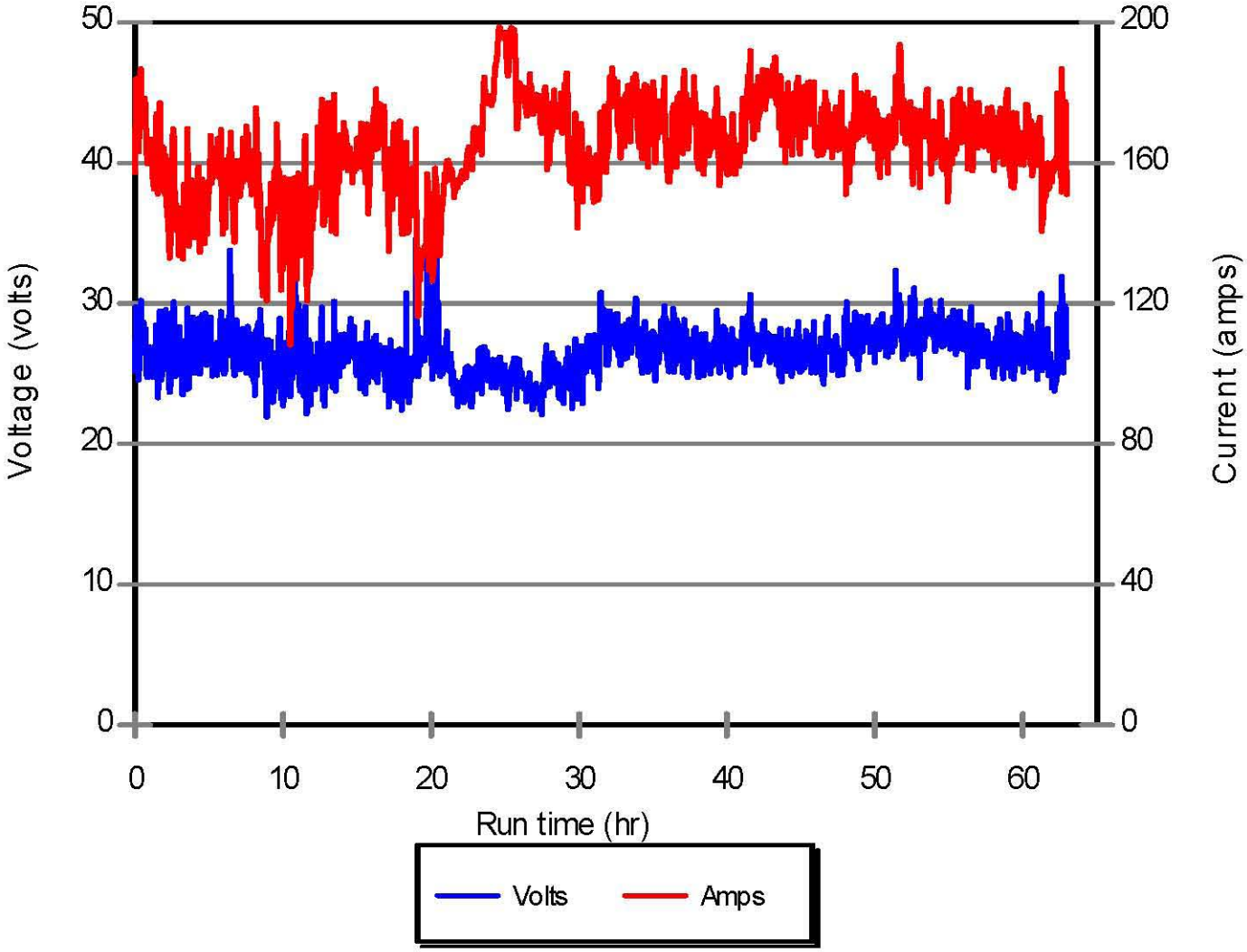


Figure 3.5.a. Electrode voltage and current during Test 1.

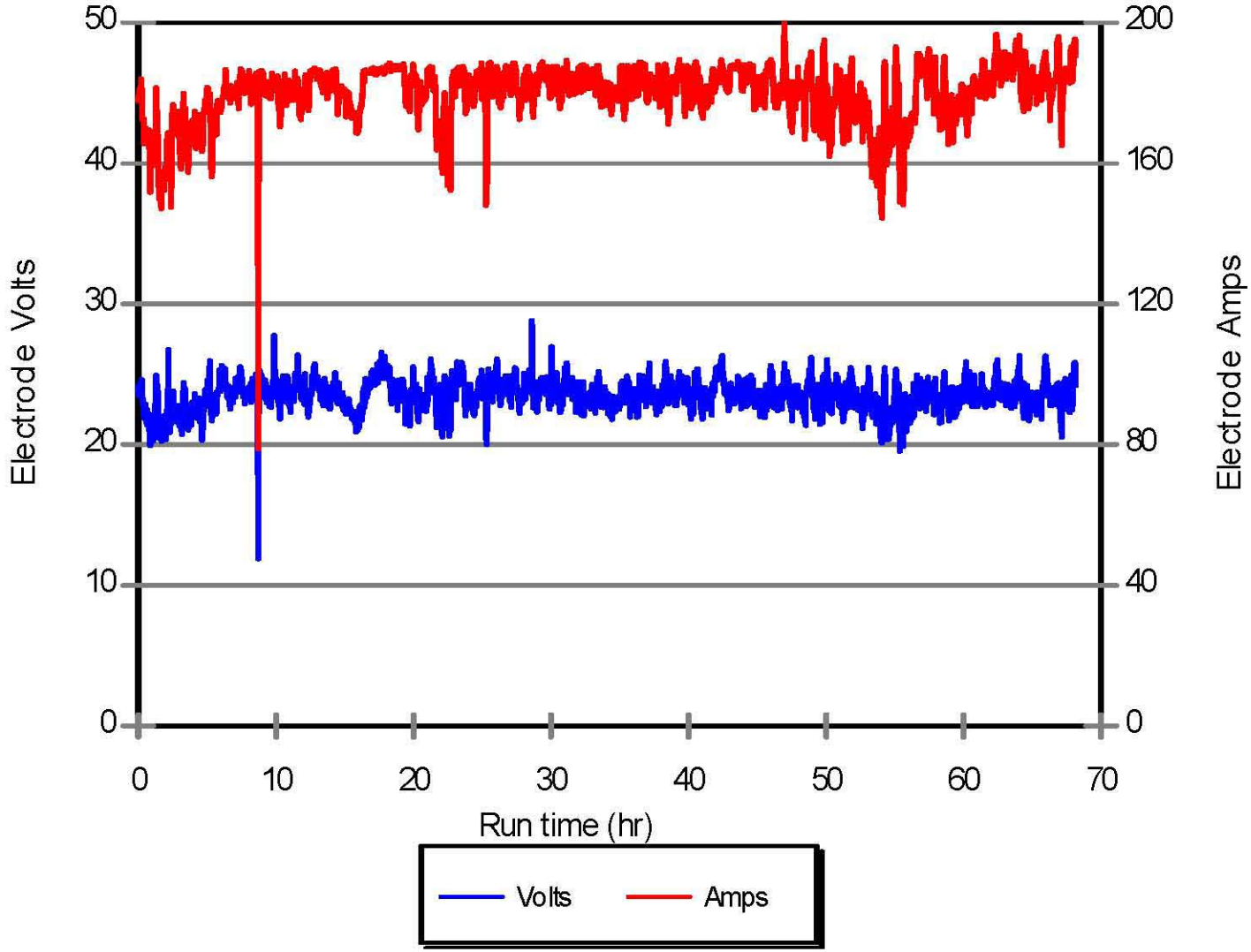


Figure 3.5.b. Electrode voltage and current during Test 2.

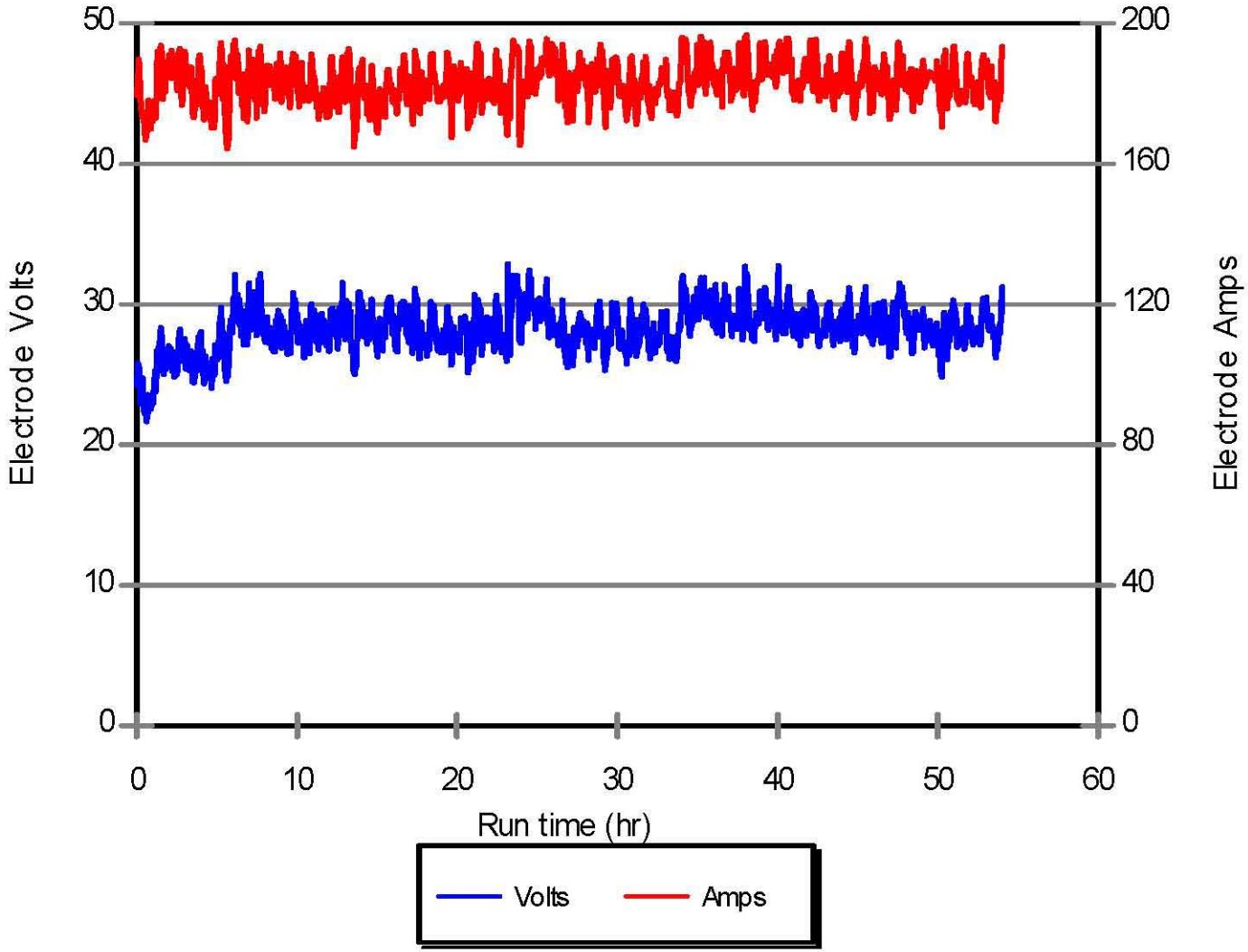


Figure 3.5.c. Electrode voltage and current during Test 3.

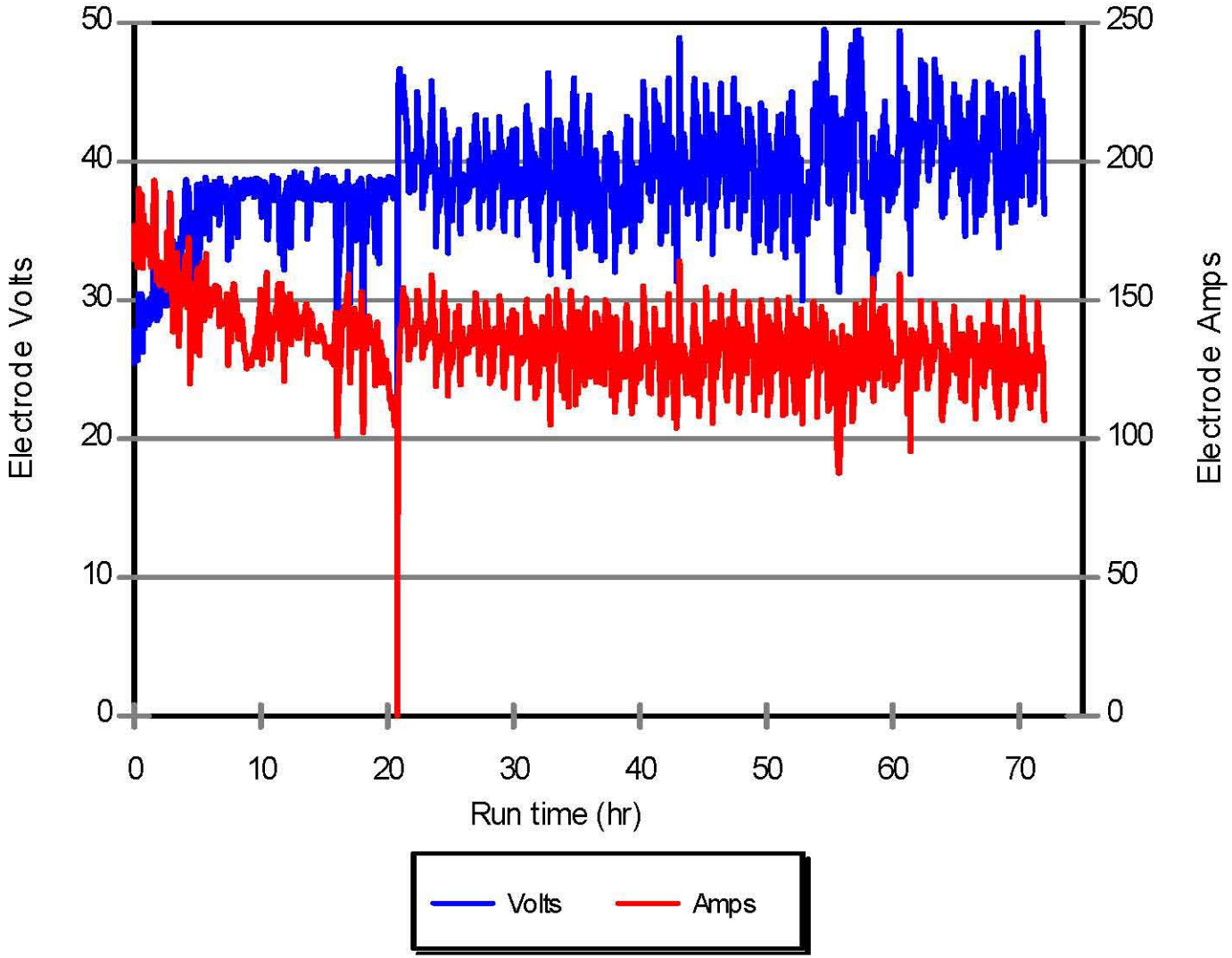


Figure 3.5.d. Electrode voltage and current during Test 4.

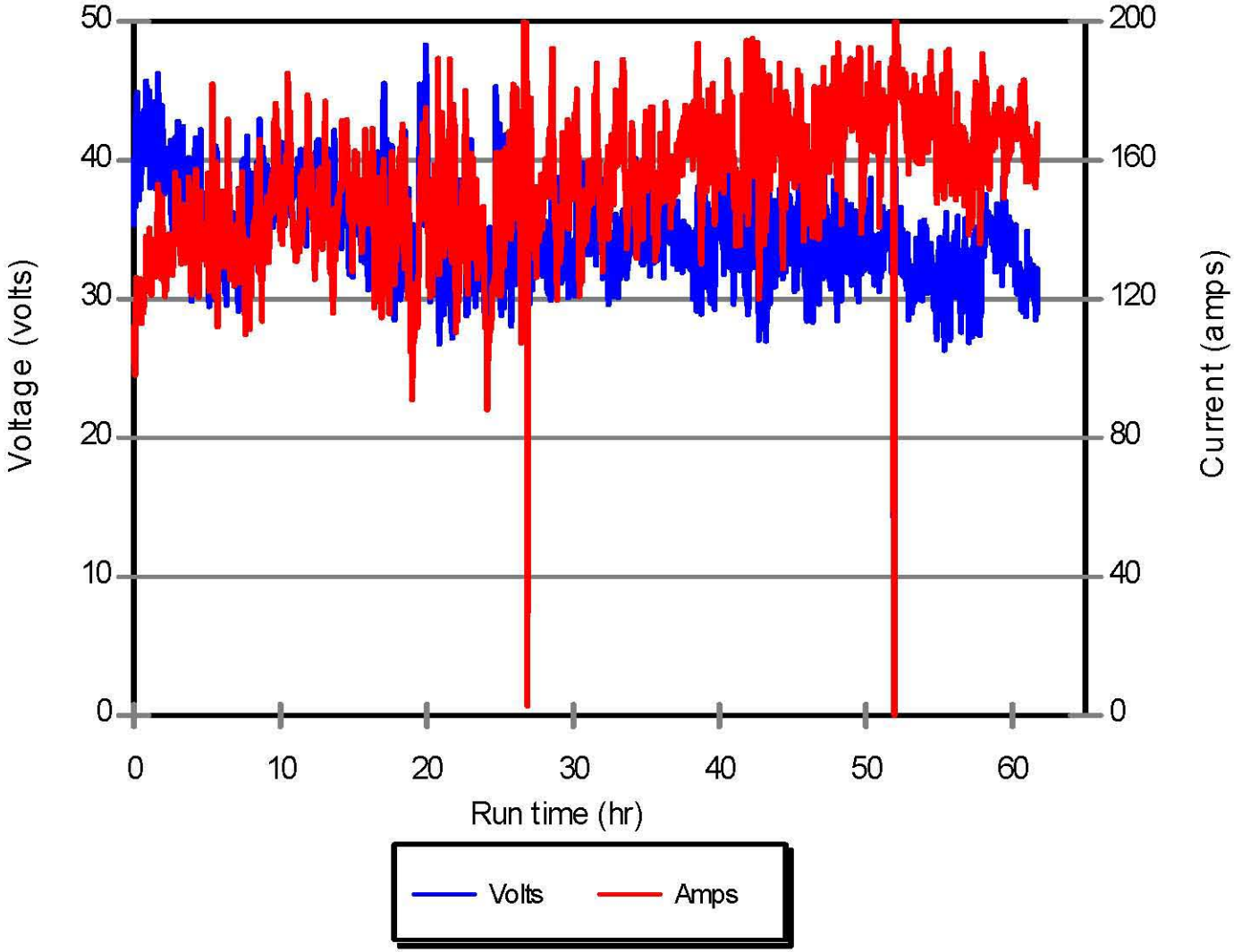


Figure 3.5.e. Electrode voltage and current during Test 5.

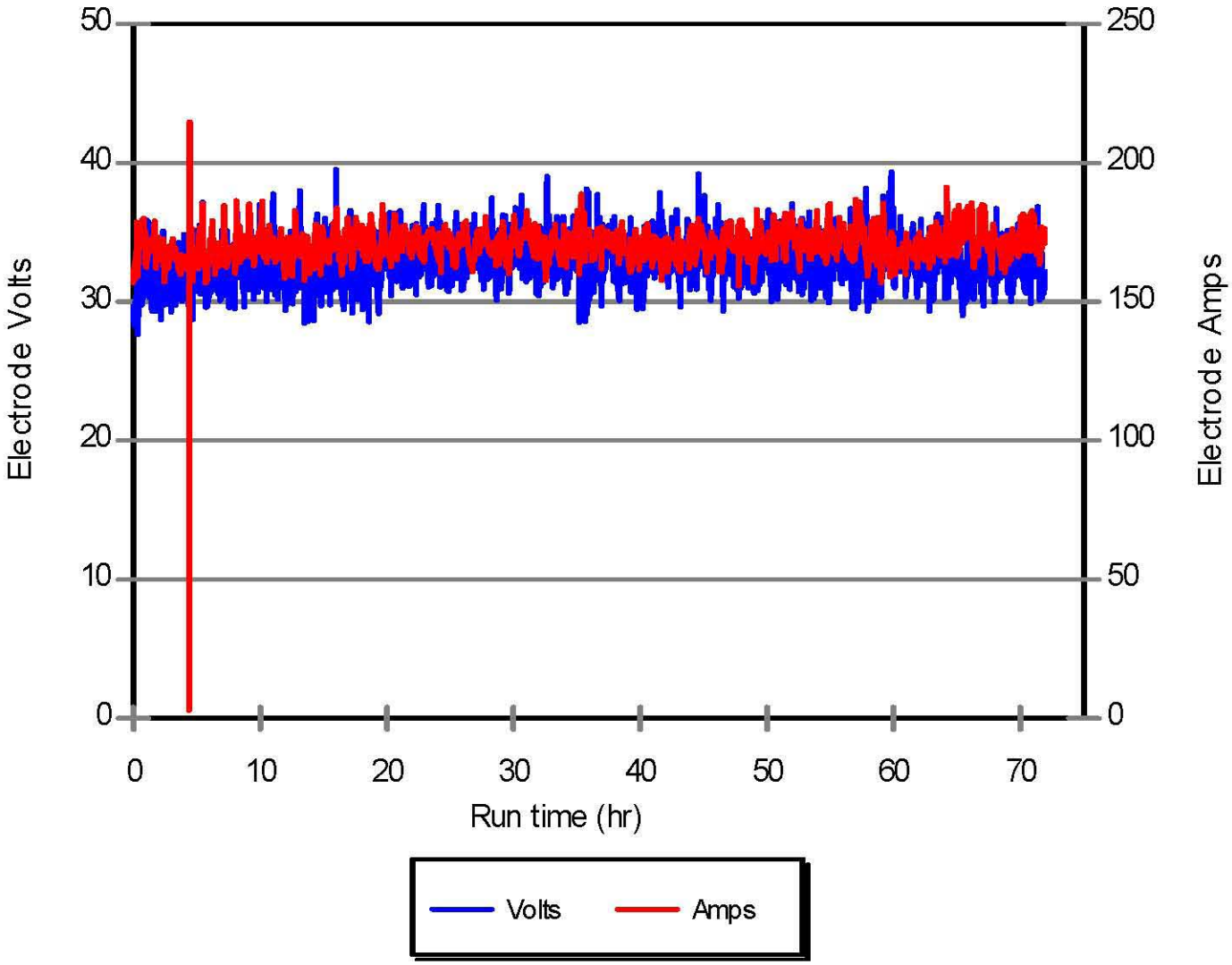


Figure 3.5.f. Electrode voltage and current during Test 6.

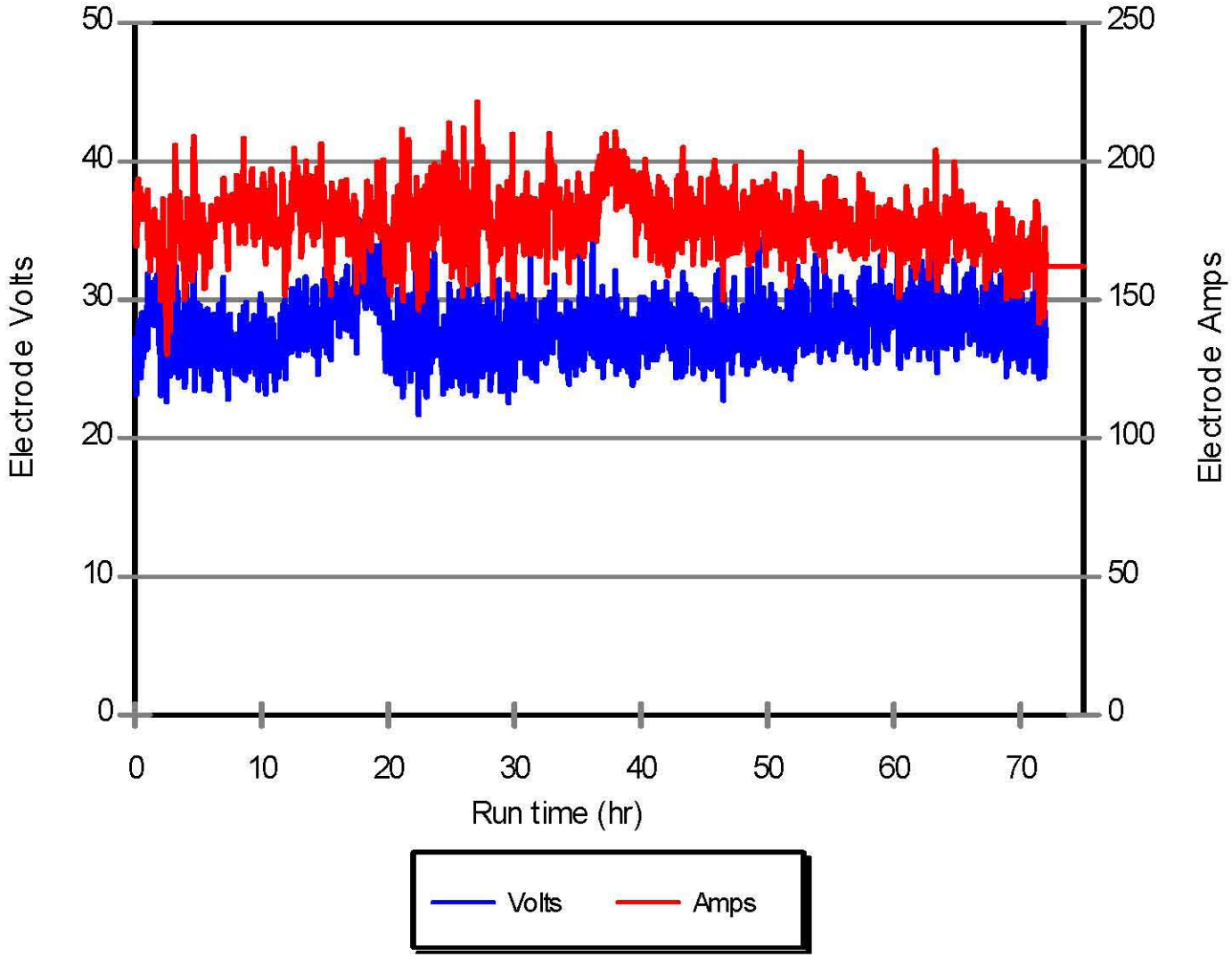


Figure 3.5.g. Electrode voltage and current during Test 7.

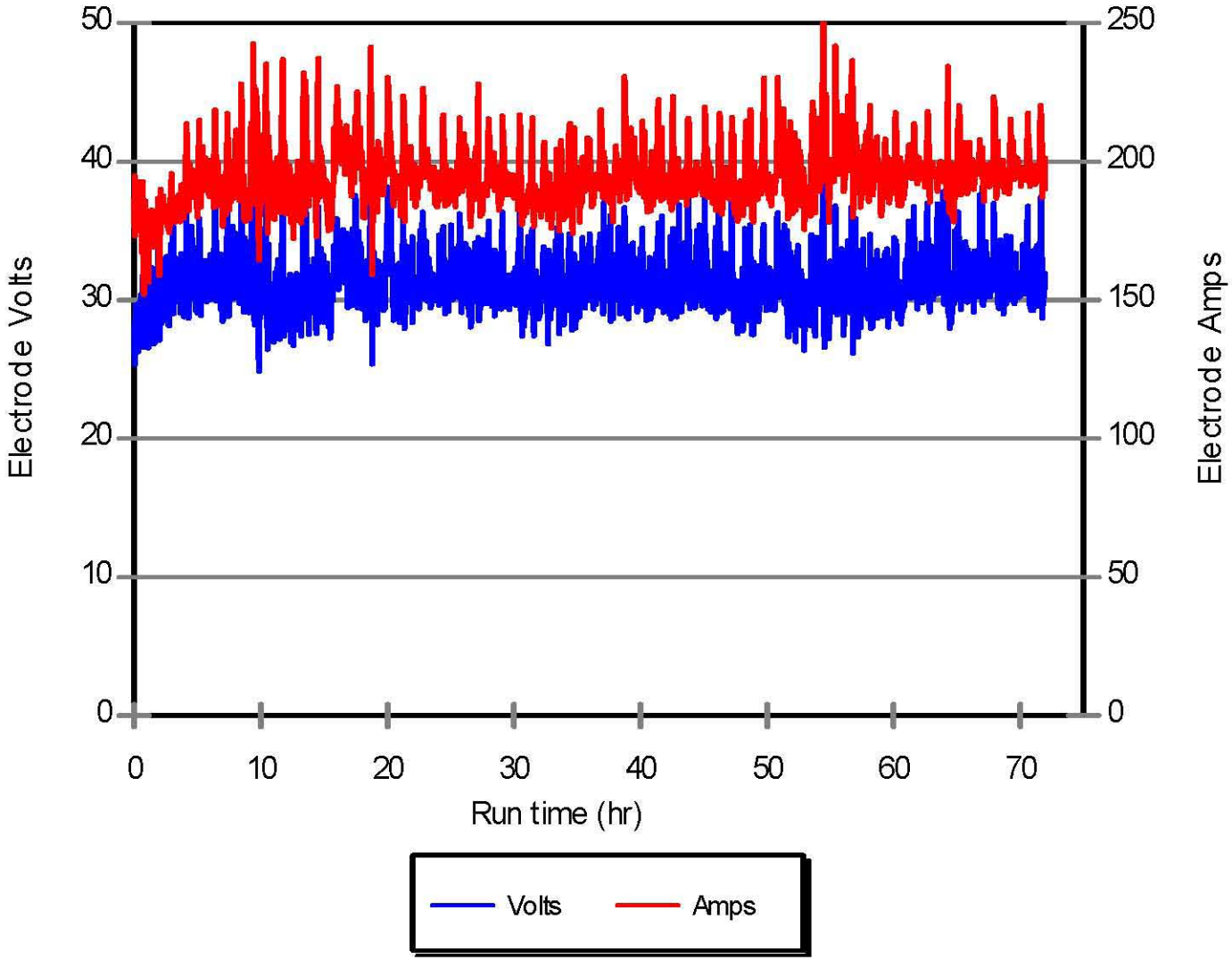


Figure 3.5.h. Electrode voltage and current during Test 8.

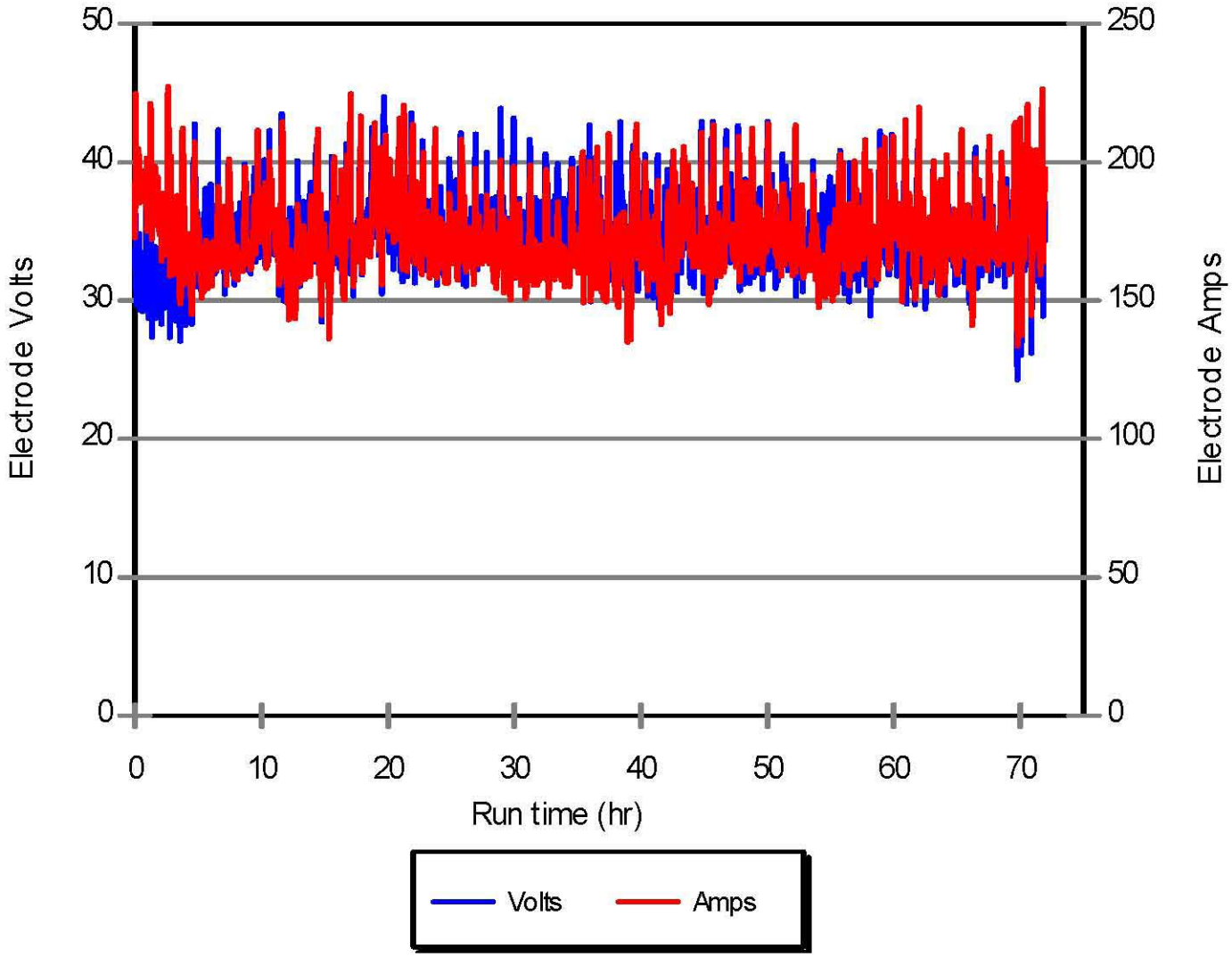


Figure 3.5.i. Electrode voltage and current during Test 9.

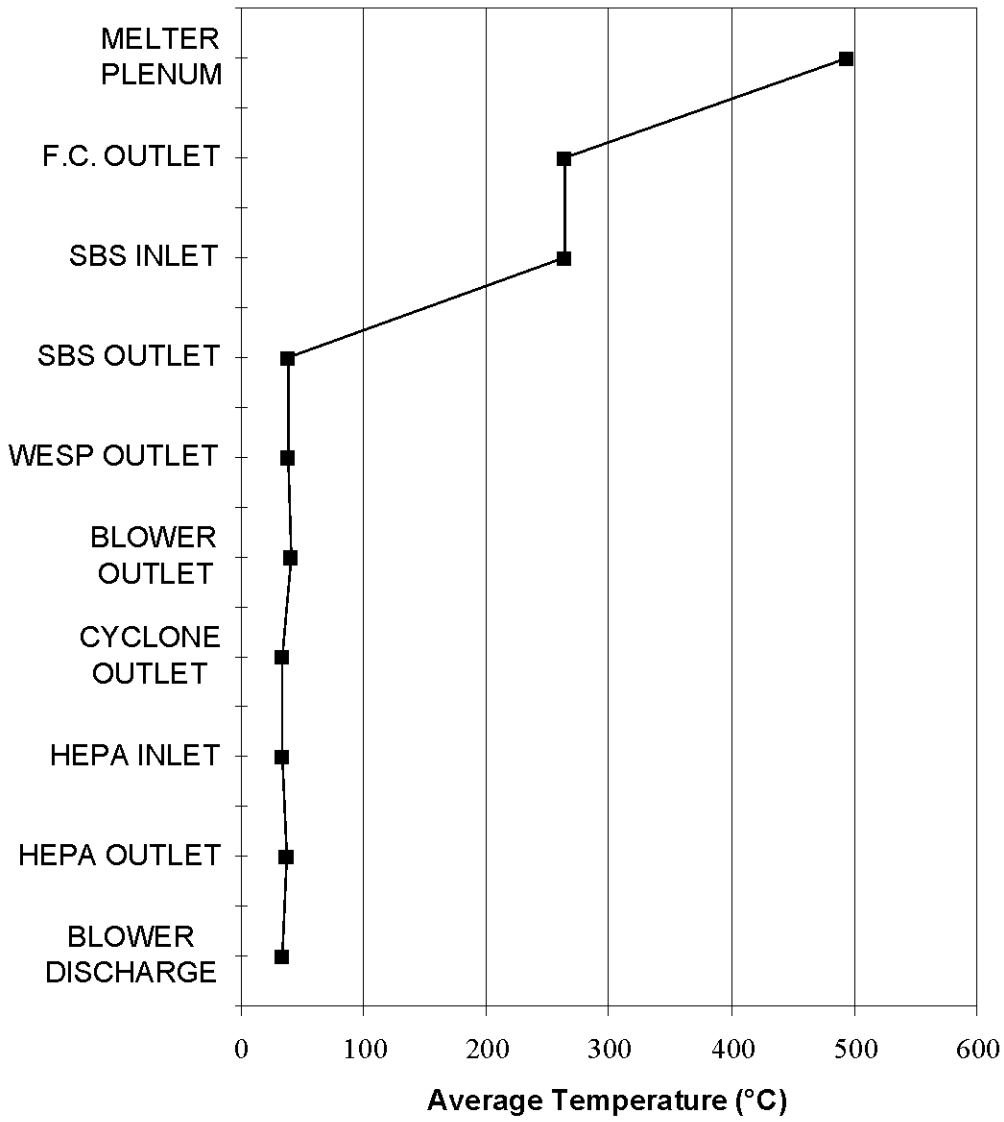


Figure 4.1.a. Average gas temperature along the DM10 off-gas train during Test 1.

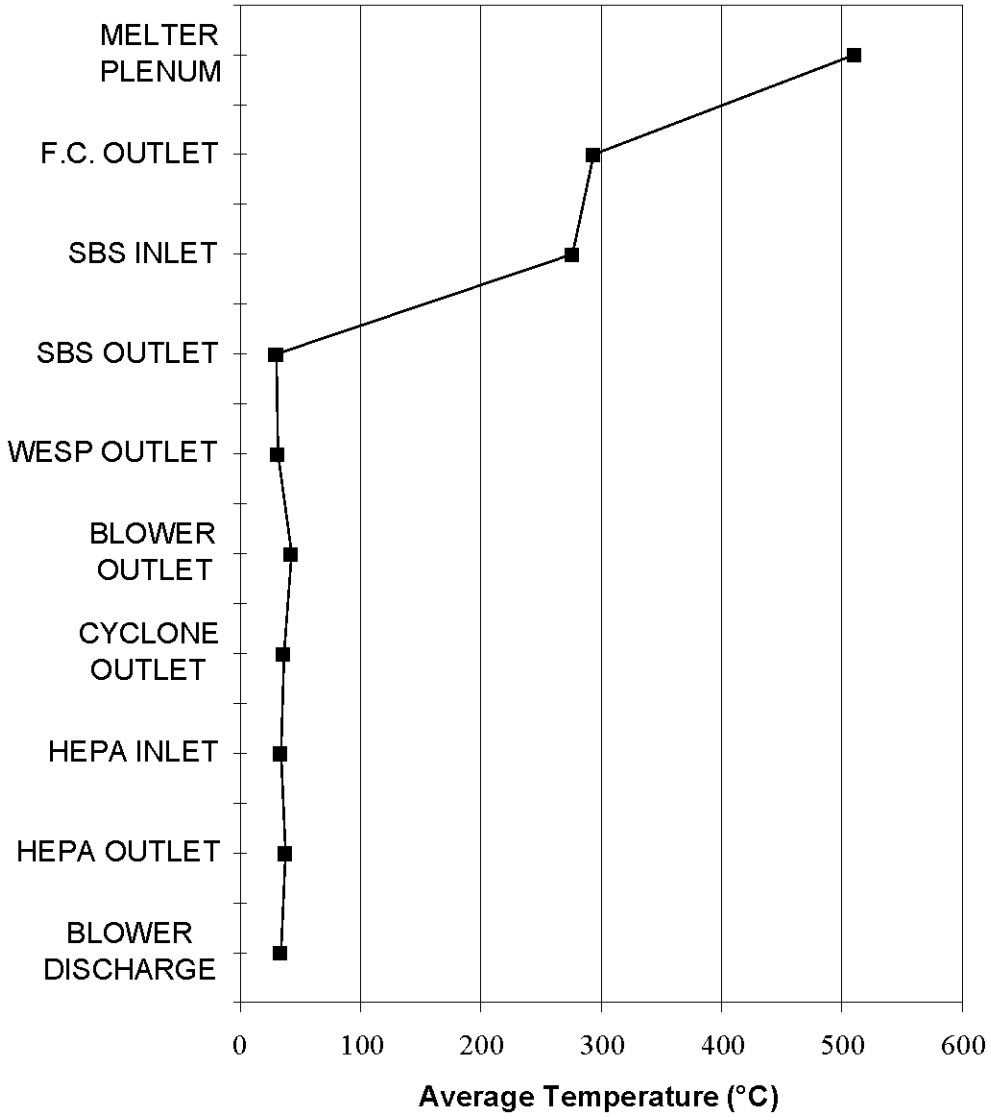


Figure 4.1.b. Average gas temperature along the DM10 off-gas train during Test 2.

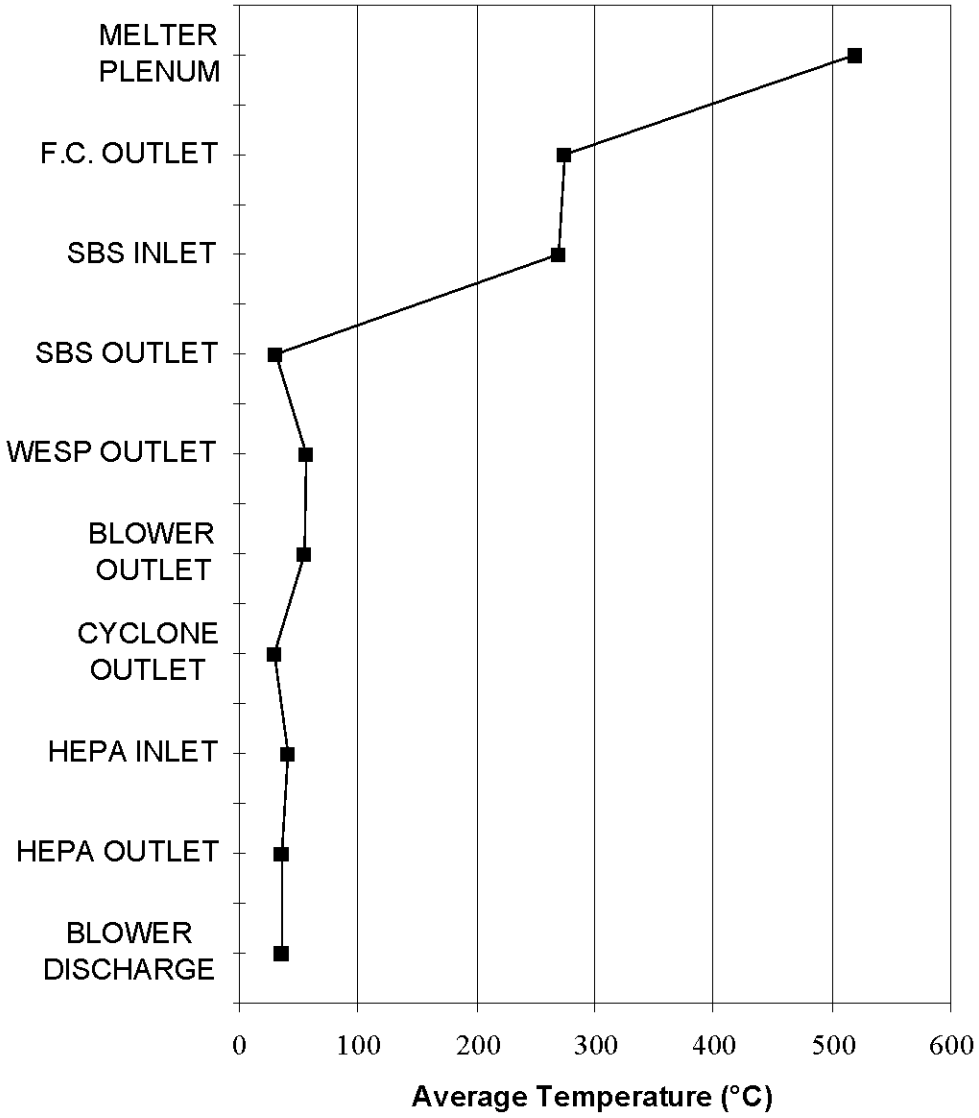


Figure 4.1.c. Average gas temperature along the DM10 off-gas train during Test 3.

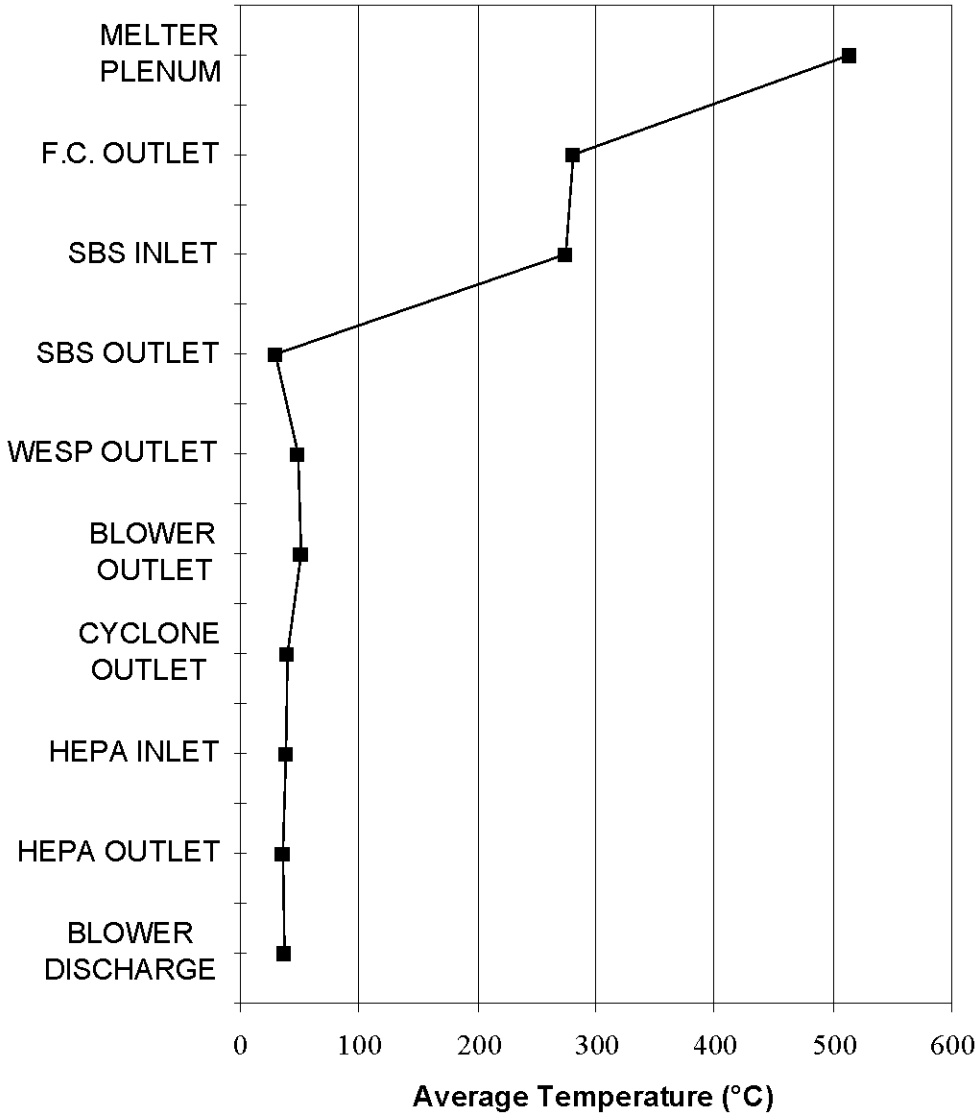


Figure 4.1.d. Average gas temperature along the DM10 off-gas train during Test 4.

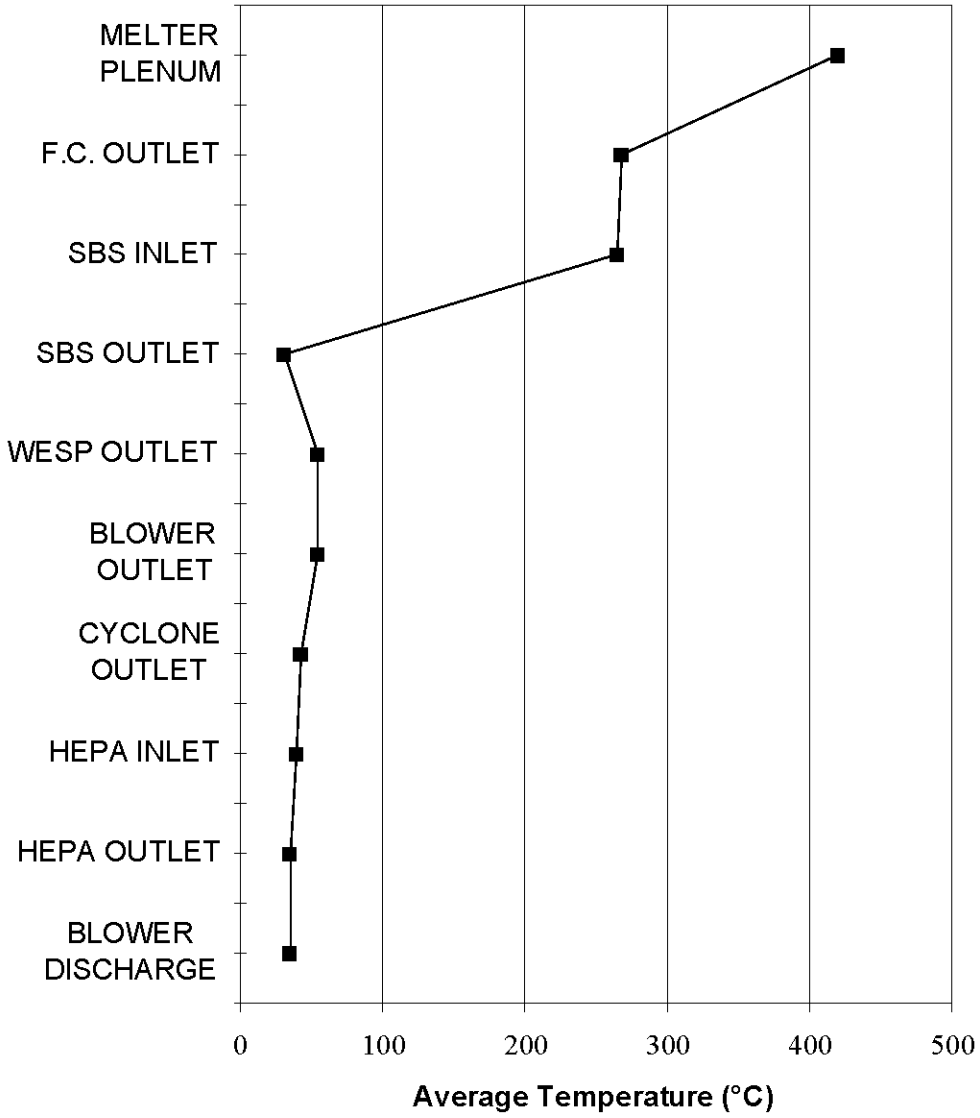


Figure 4.1.e. Average gas temperature along the DM10 off-gas train during Test 5.

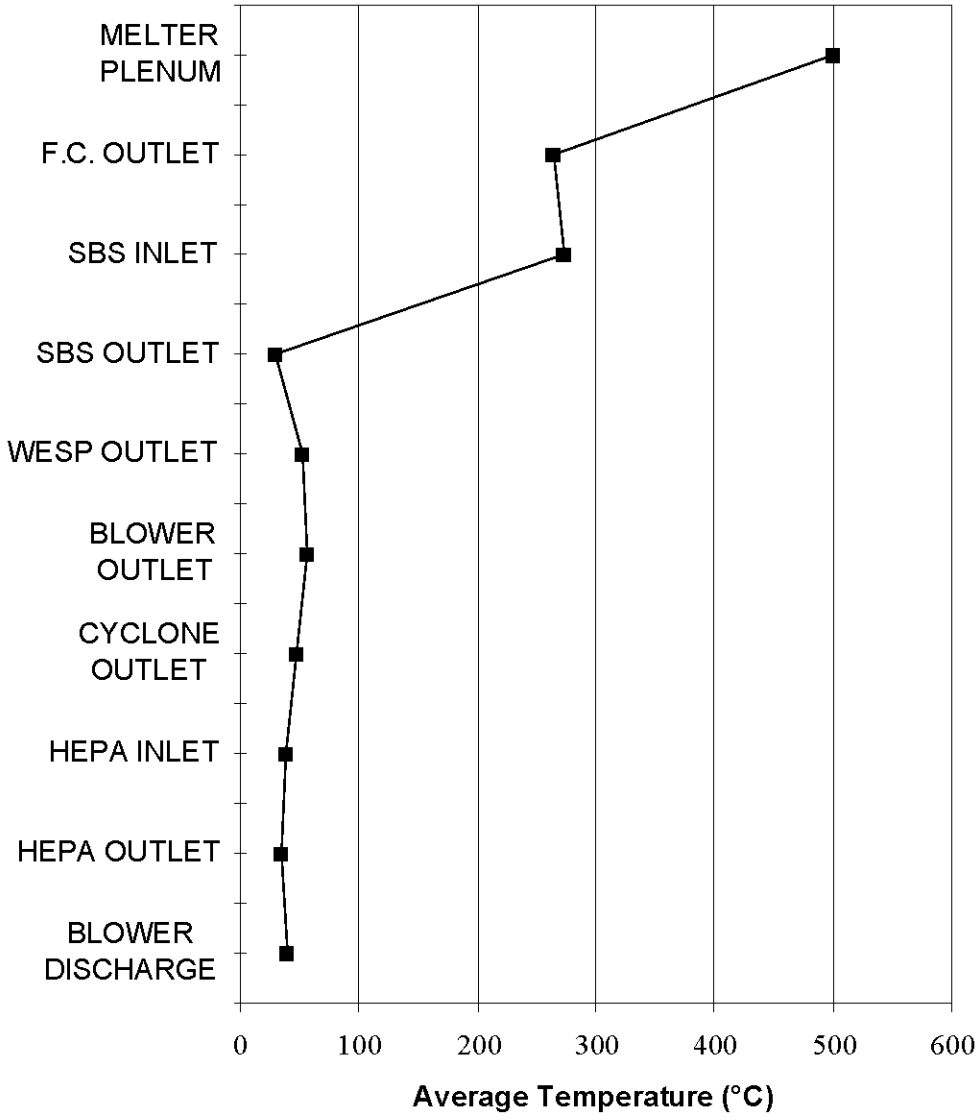


Figure 4.1.f. Average gas temperature along the DM10 off-gas train during Test 6.

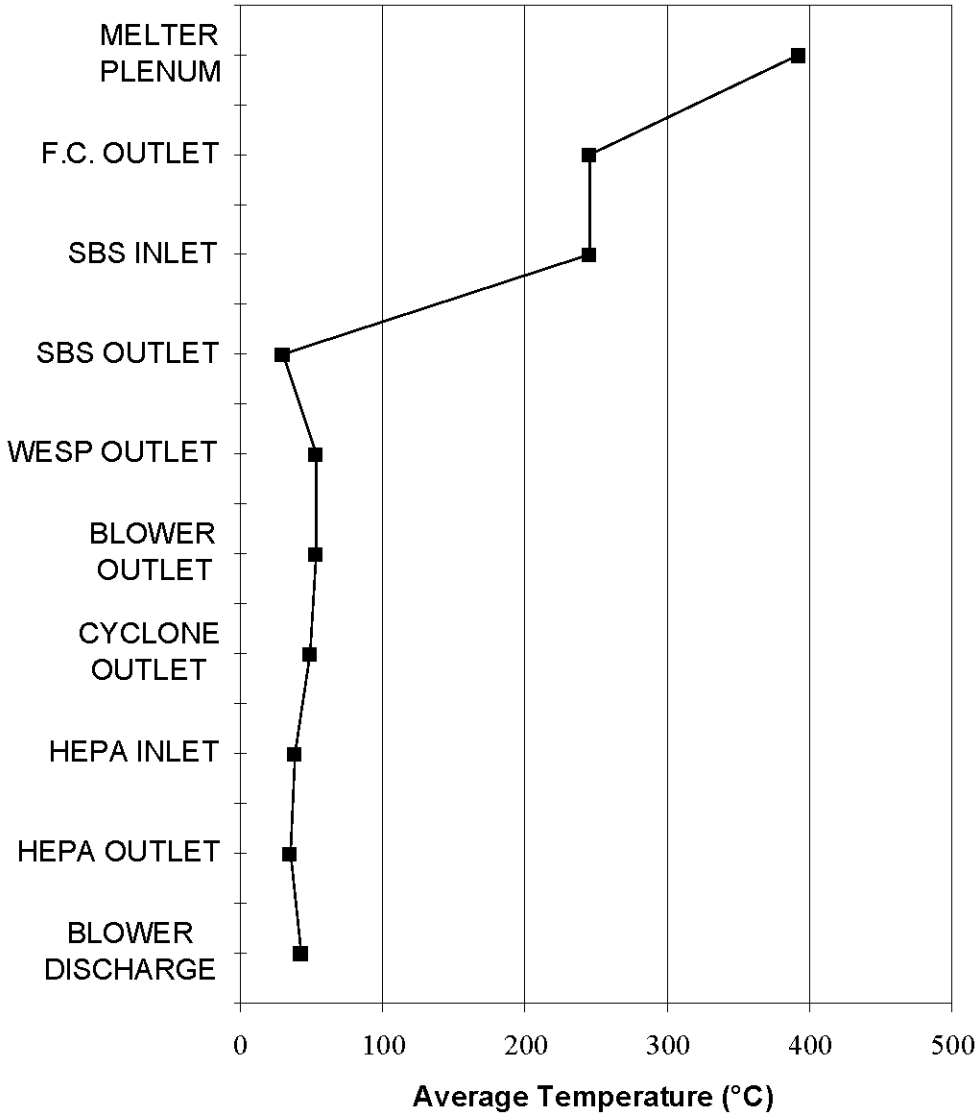


Figure 4.1.g. Average gas temperature along the DM10 off-gas train during Test 7.

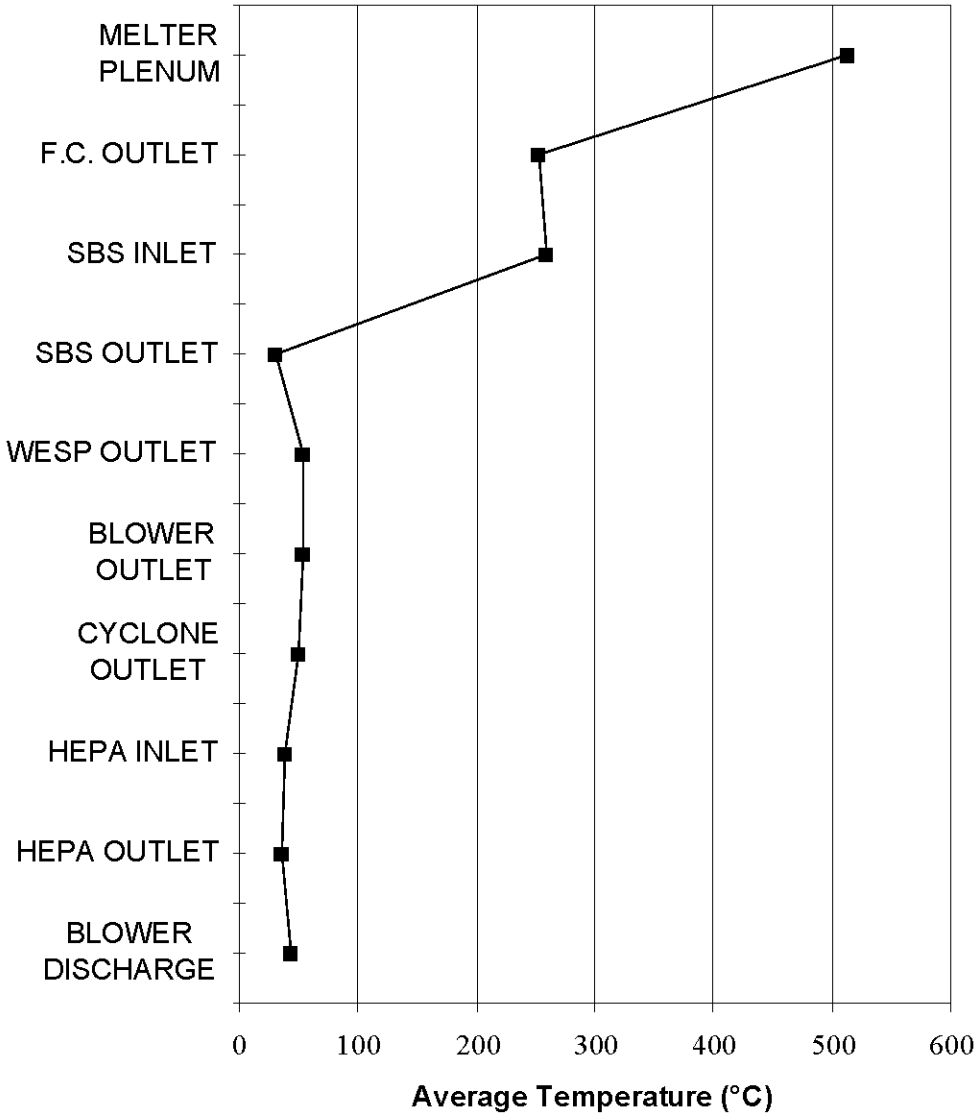


Figure 4.1.h. Average gas temperature along the DM10 off-gas train during Test 8.

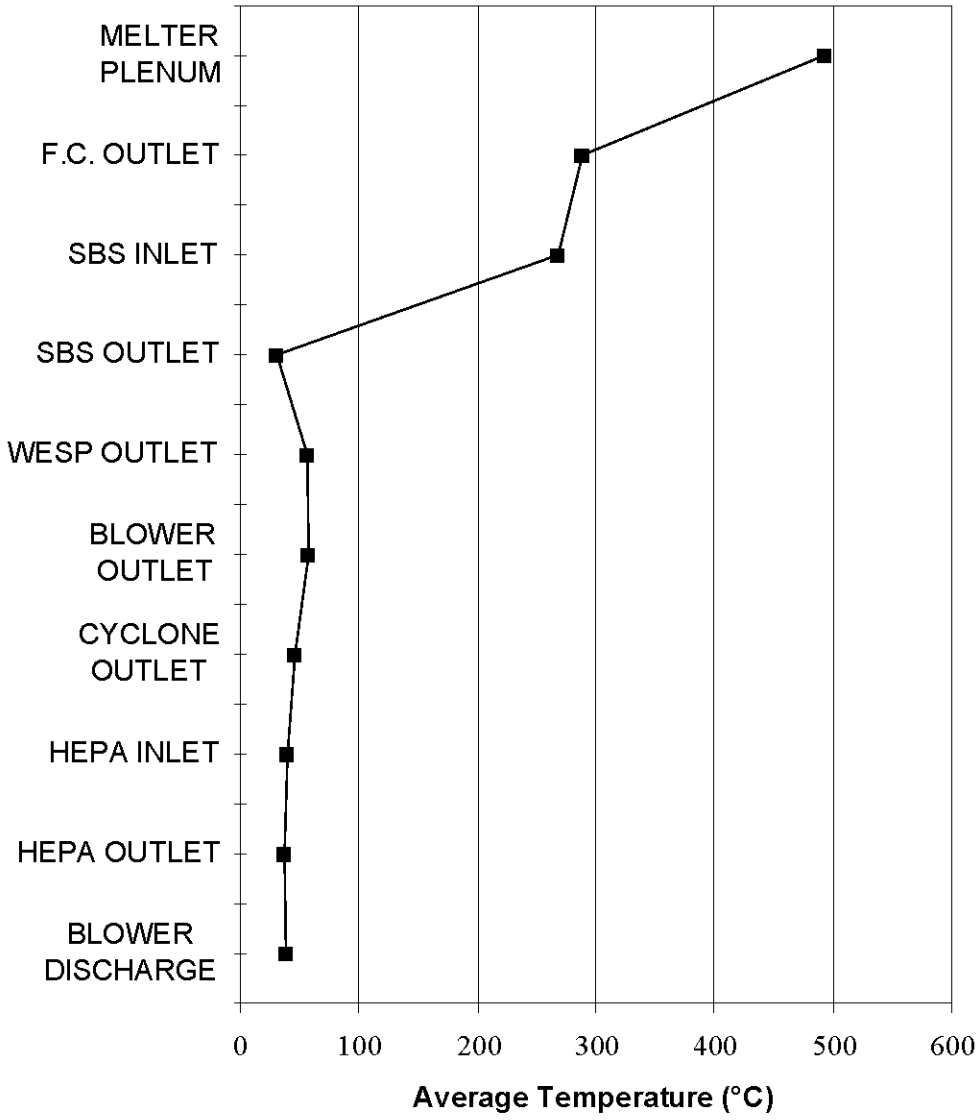


Figure 4.1.i. Average gas temperature along the DM10 off-gas train during Test 9.

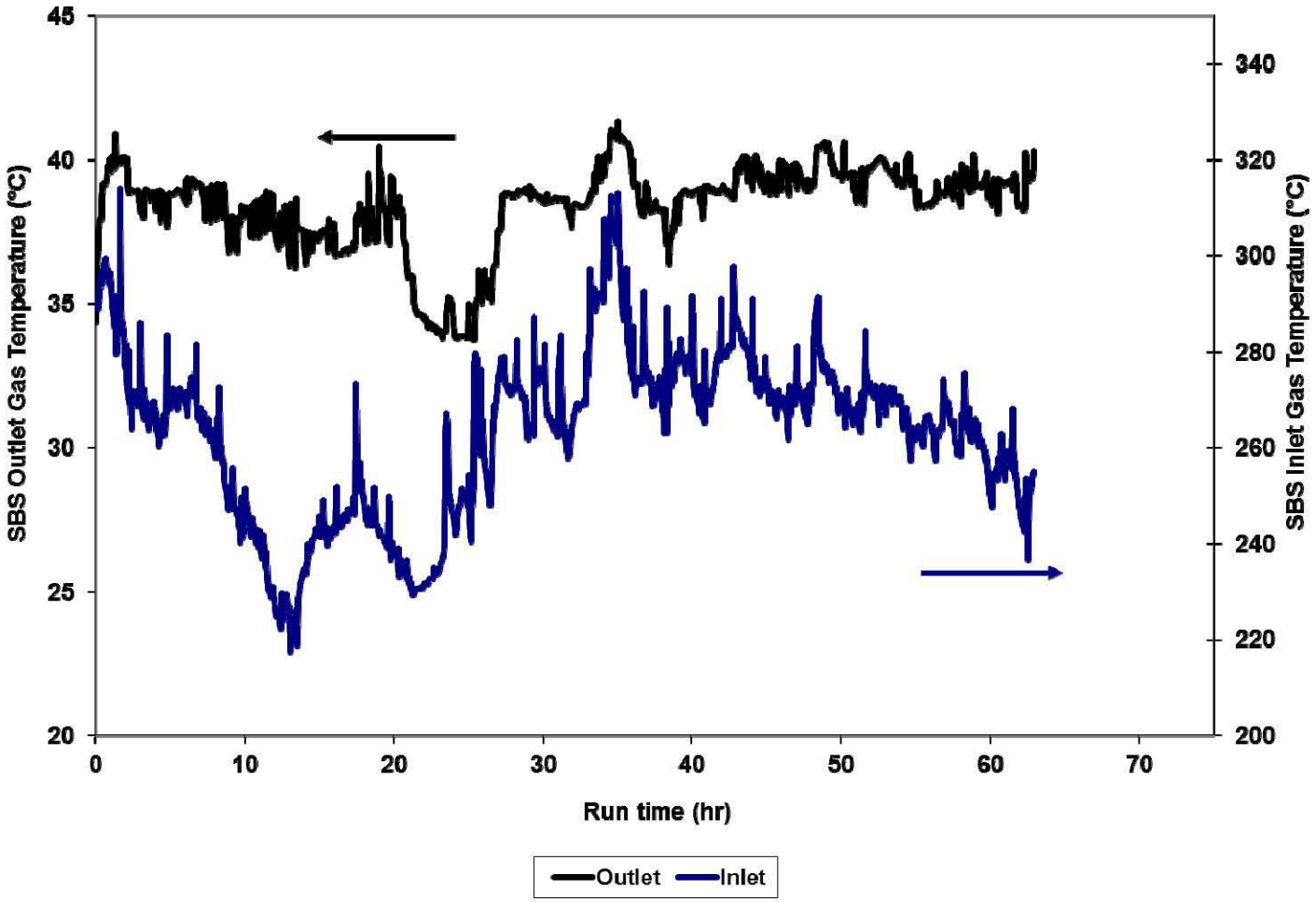


Figure 4.2.a. Test 1 SBS inlet and outlet gas temperatures.

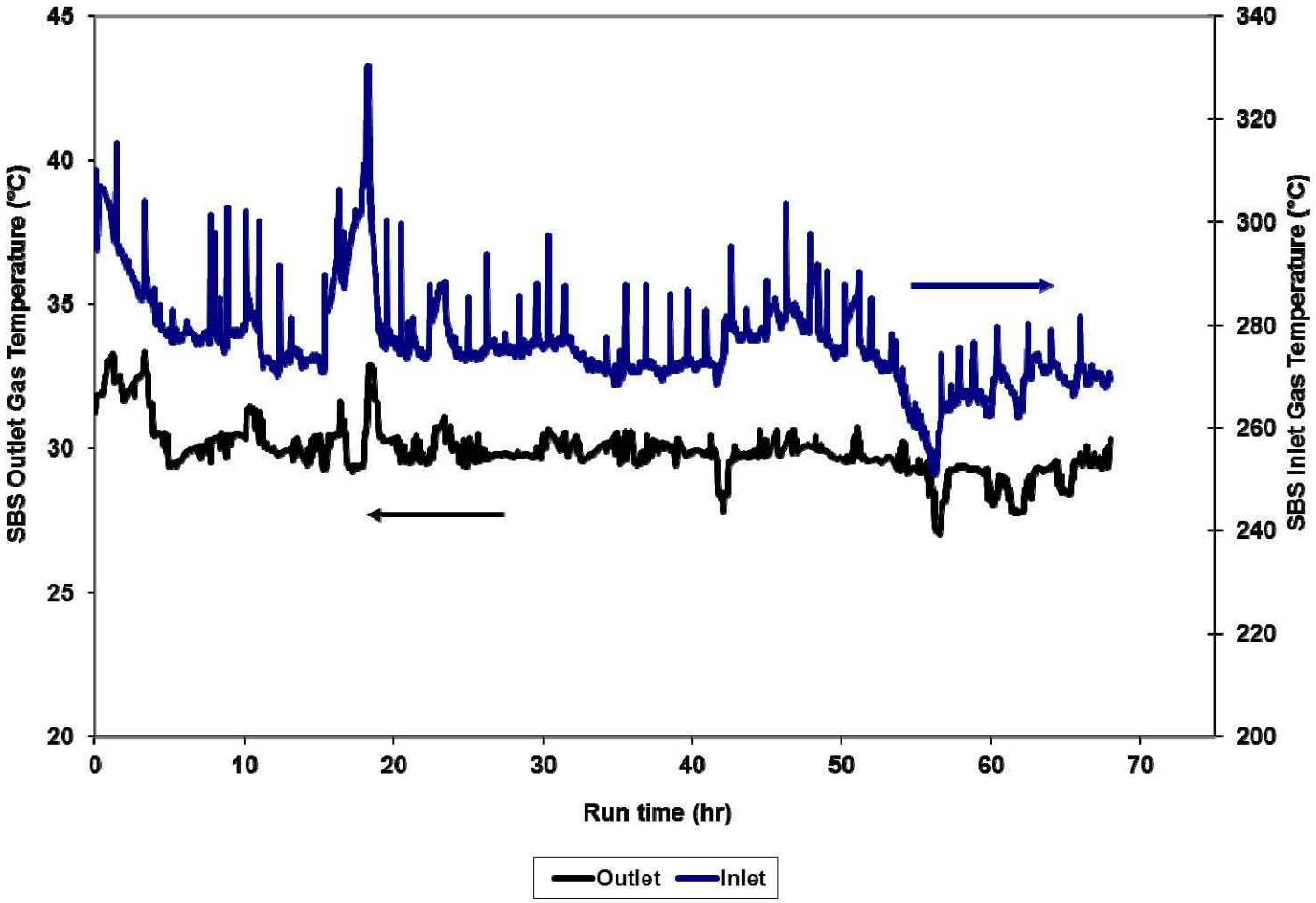


Figure 4.2.b. Test 2 SBS inlet and outlet gas temperatures.

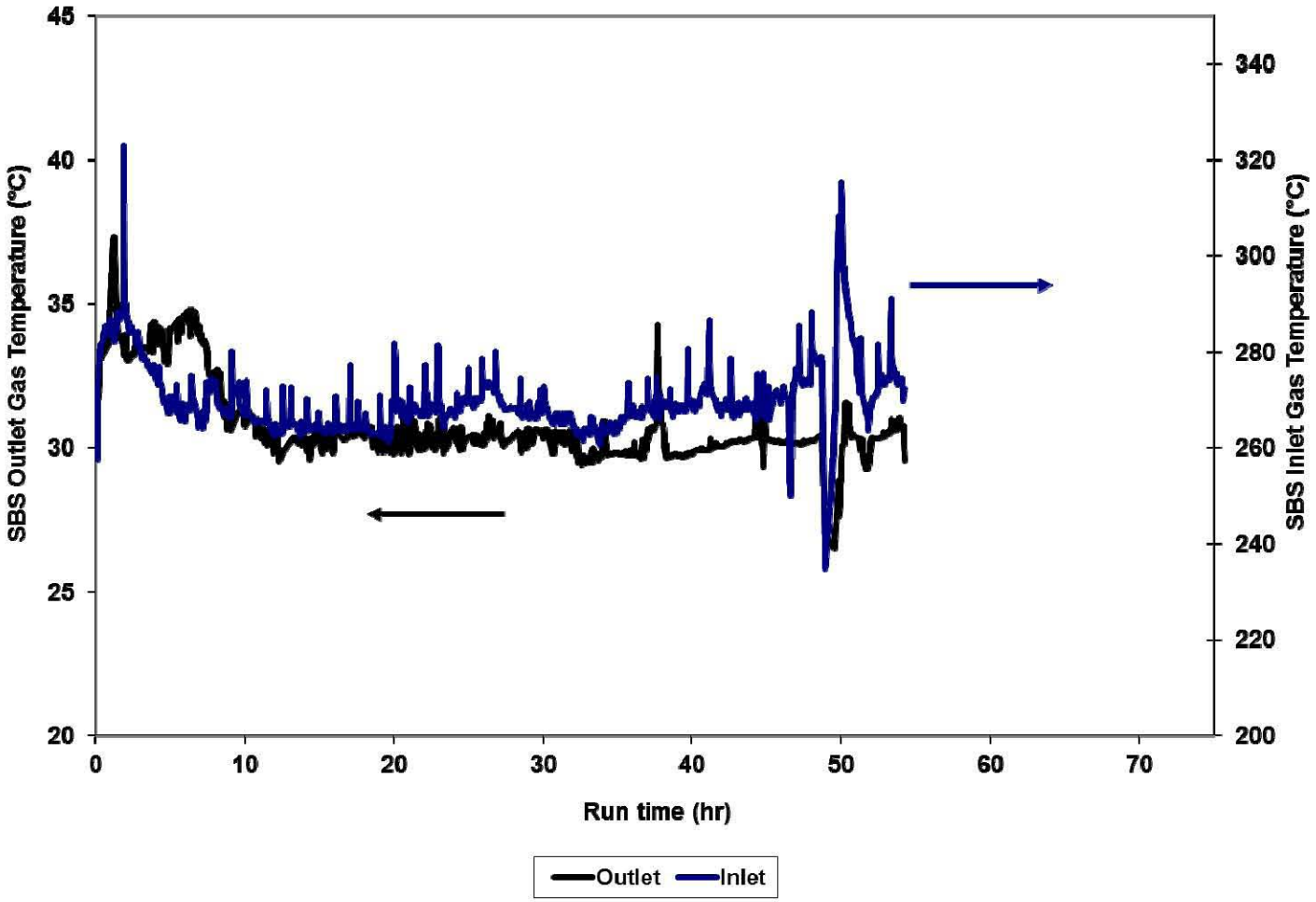


Figure 4.2.c. Test 3 SBS inlet and outlet gas temperatures.

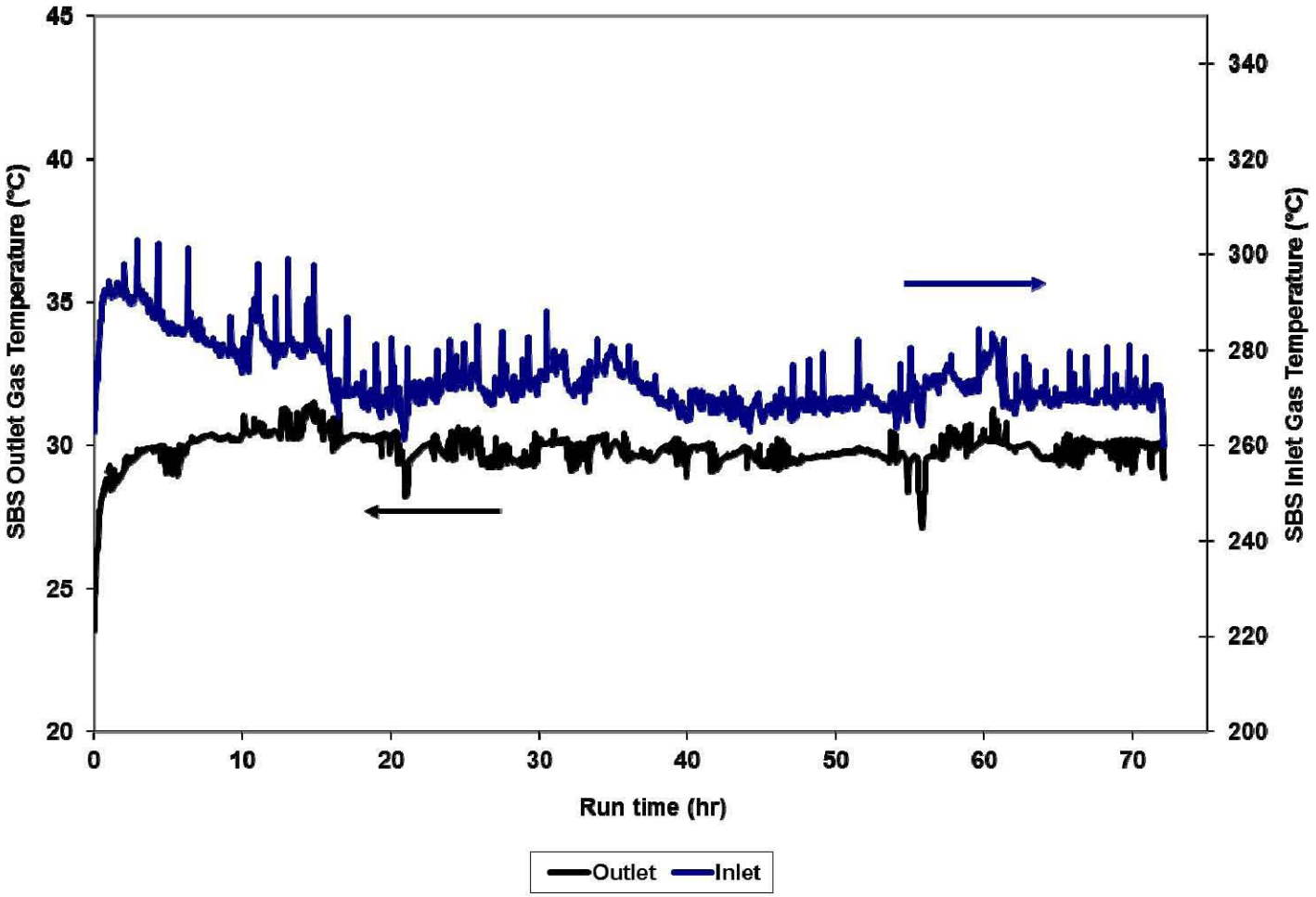


Figure 4.2.d. Test 4 SBS inlet and outlet gas temperatures.

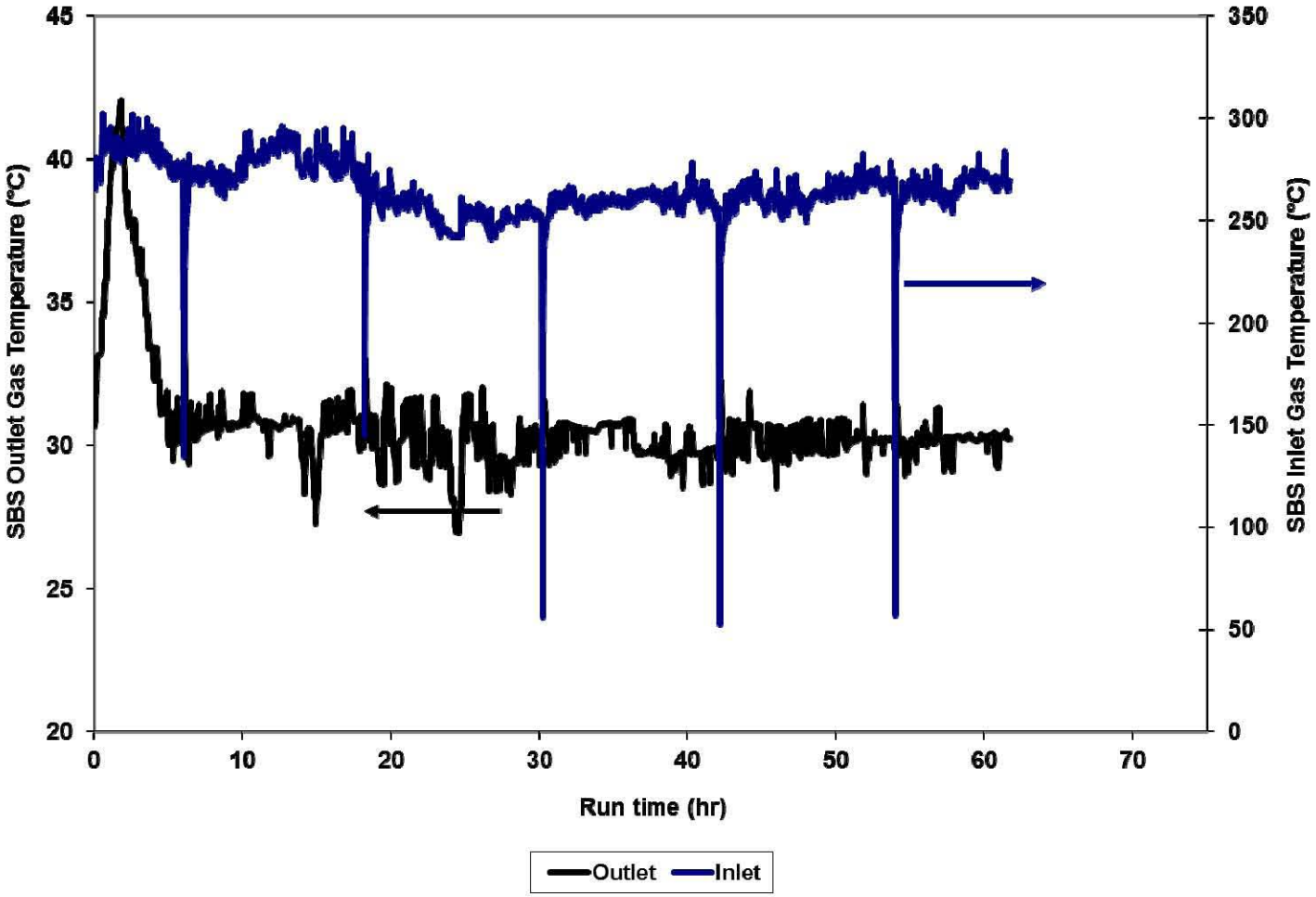


Figure 4.2.e. Test 5 SBS inlet and outlet gas temperatures.

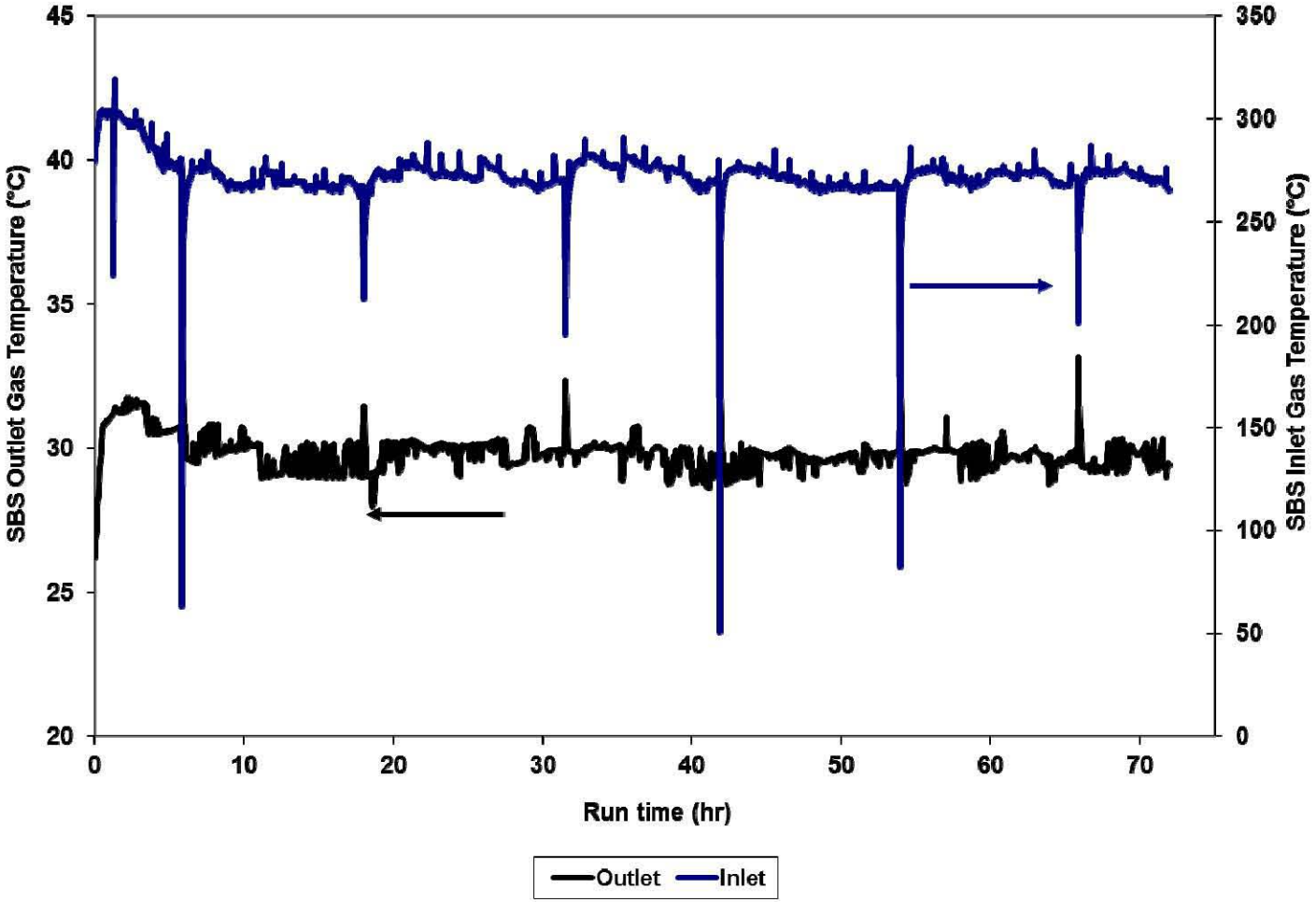


Figure 4.2.f. Test 6 SBS inlet and outlet gas temperatures.

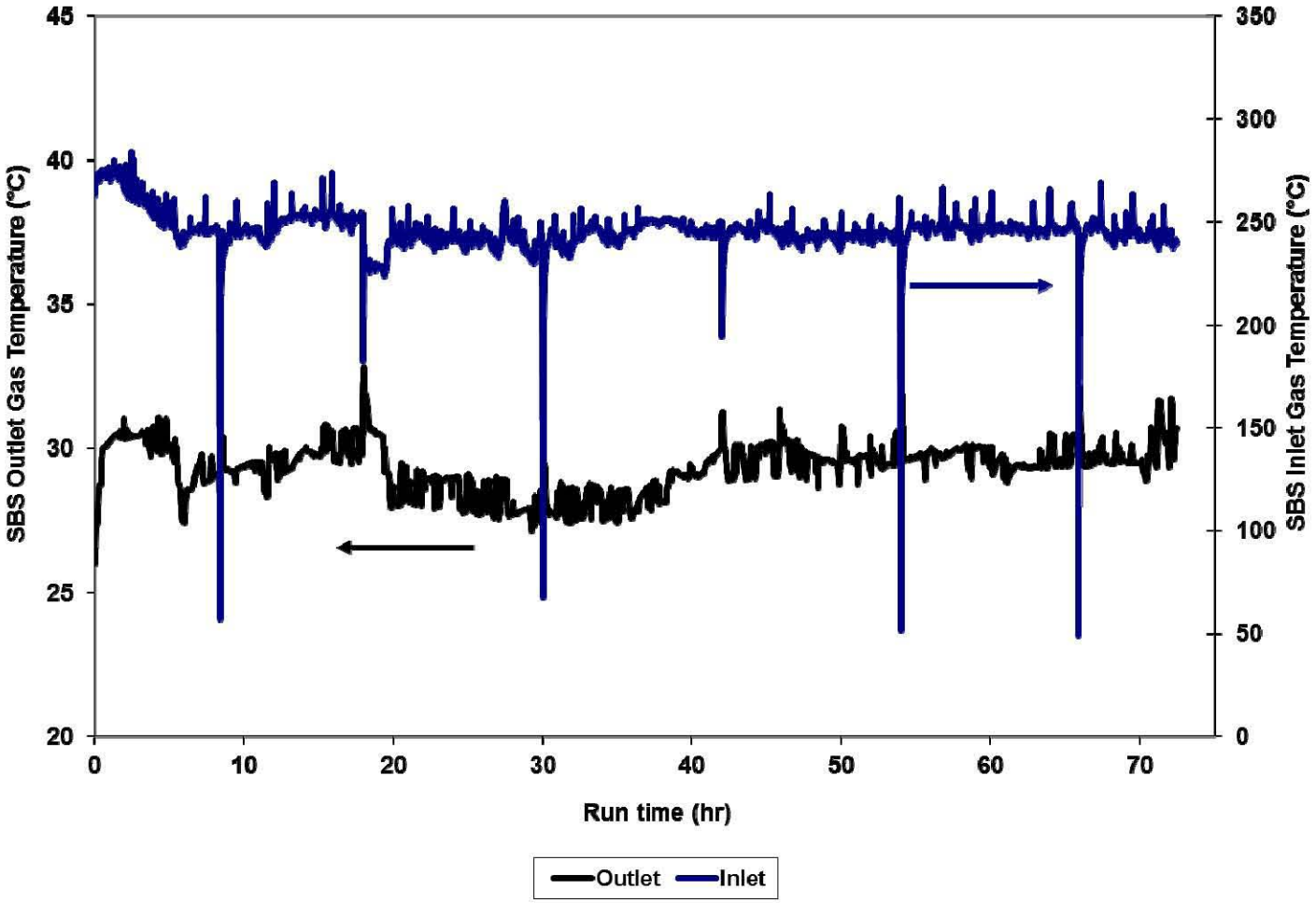


Figure 4.2.g. Test 7 SBS inlet and outlet gas temperatures.

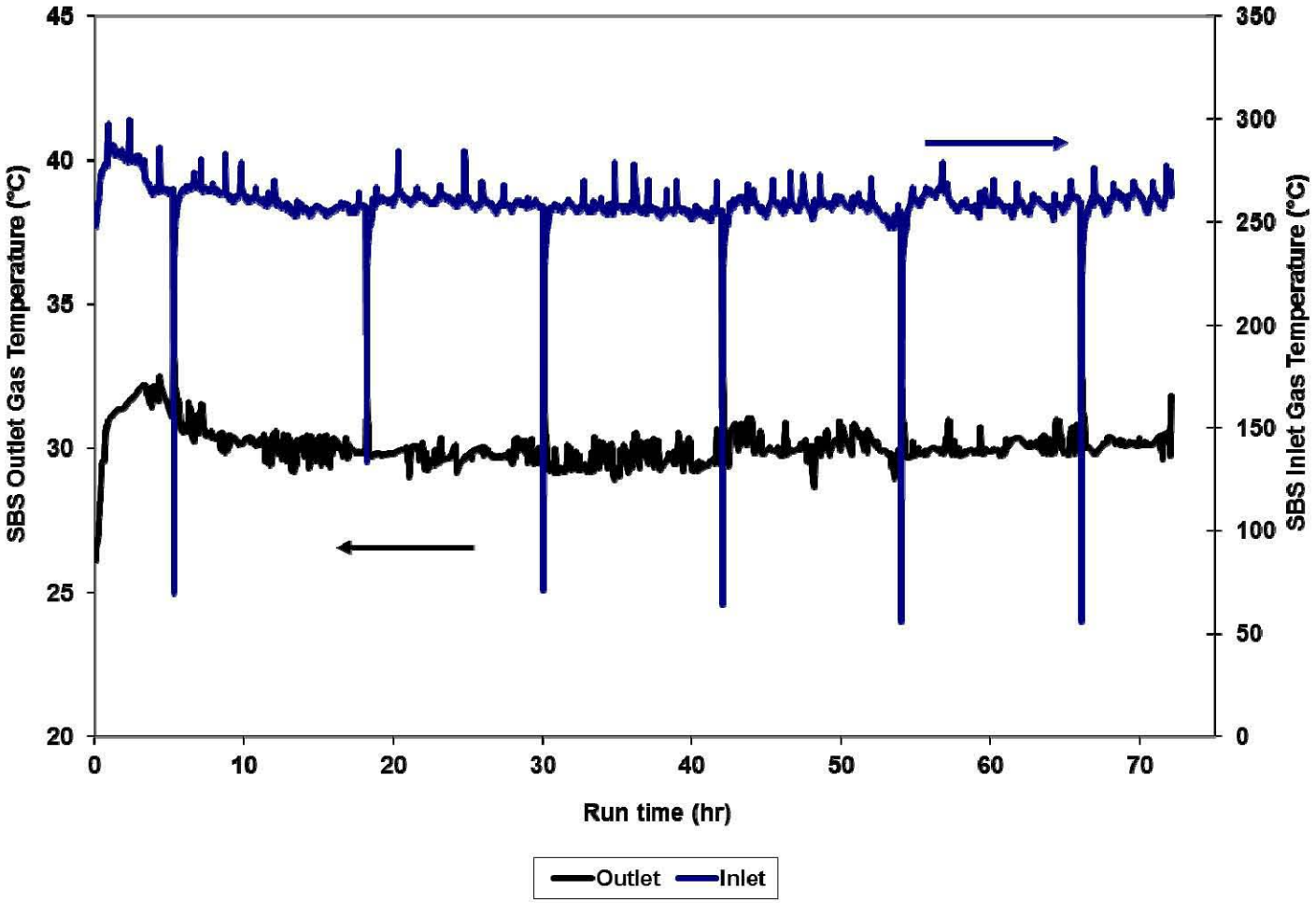


Figure 4.2.h. Test 8 SBS inlet and outlet gas temperatures.

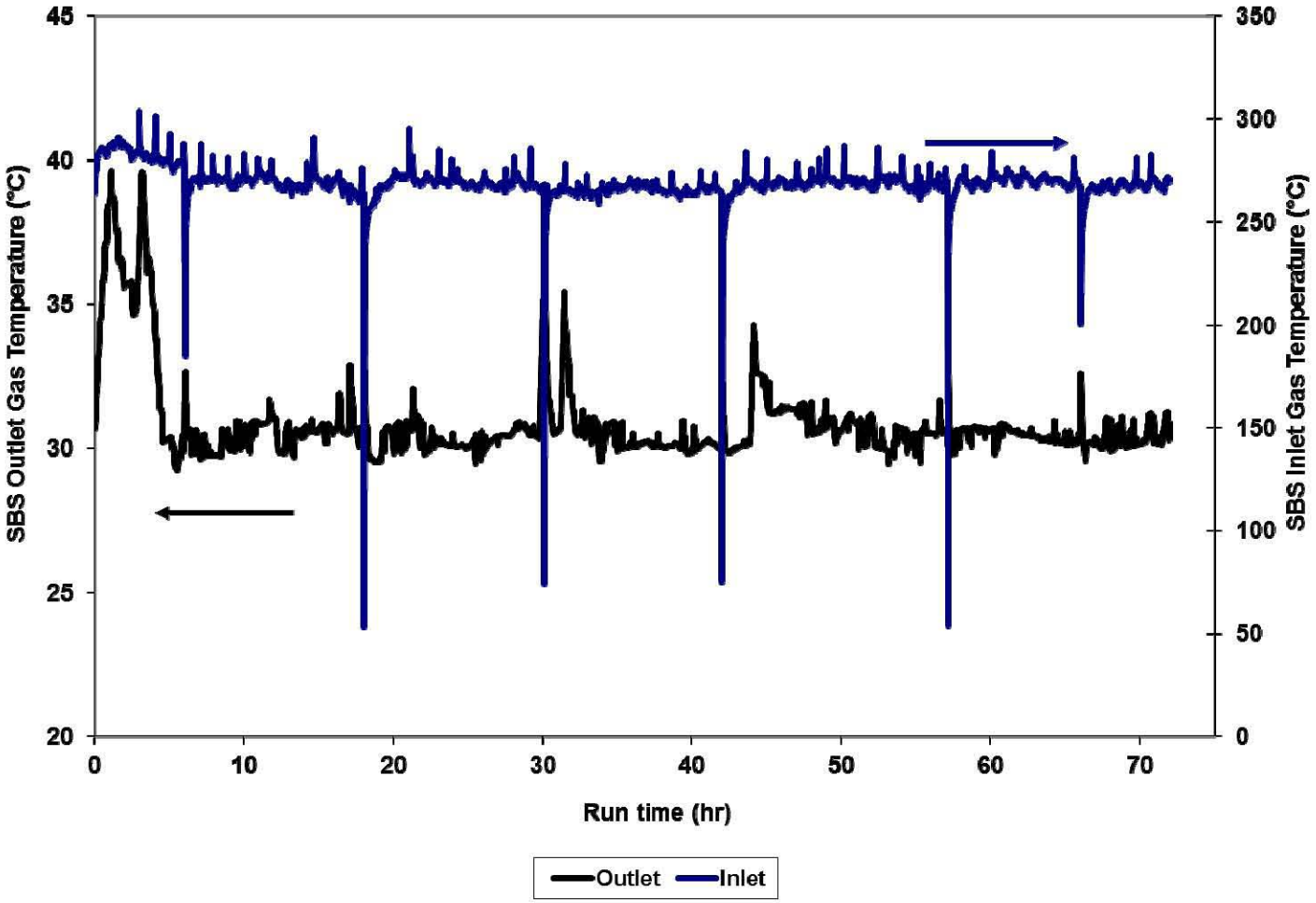


Figure 4.2.i. Test 9 SBS inlet and outlet gas temperatures.

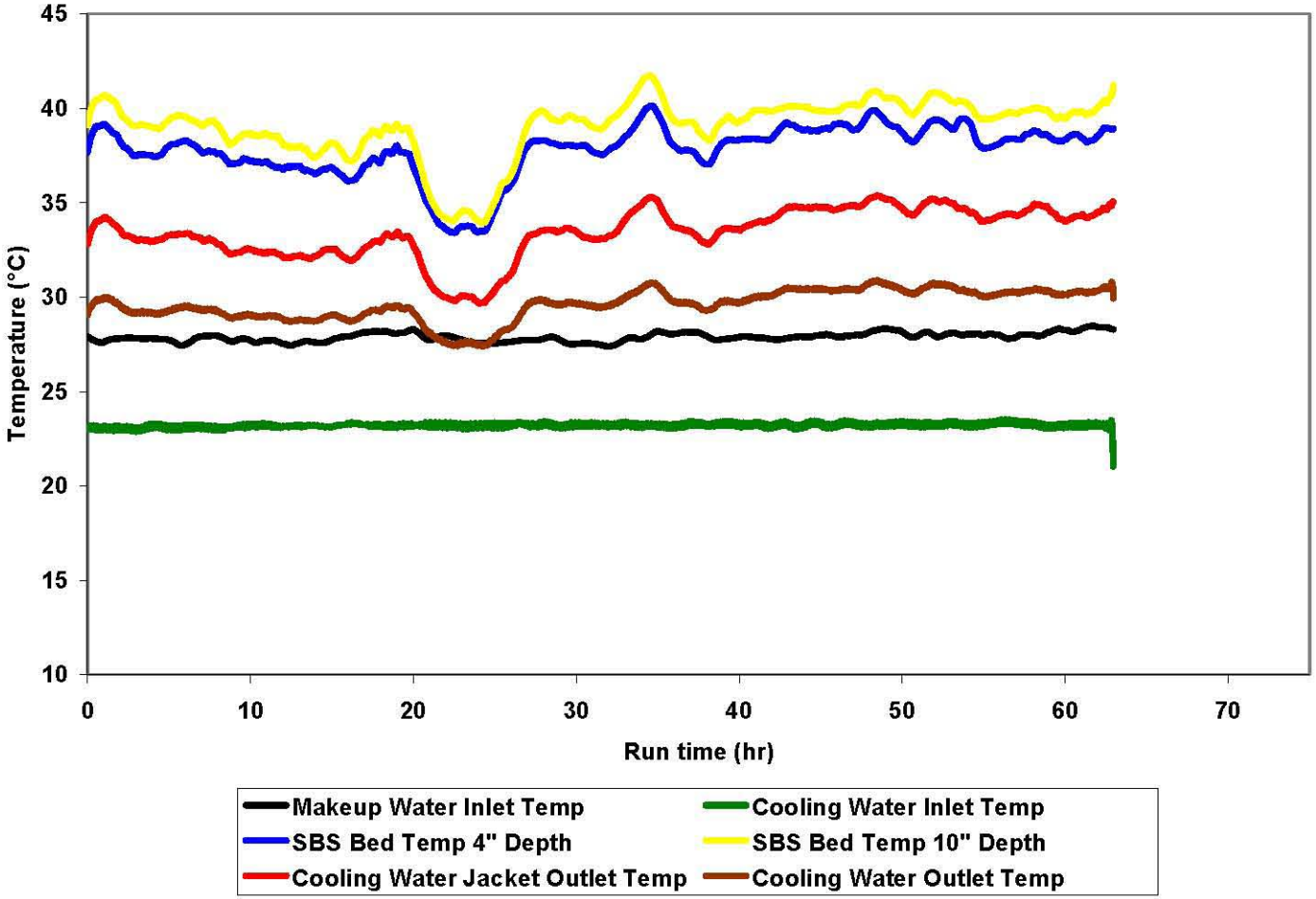


Figure 4.3.a. Test 1 SBS liquid sump and cooling water temperatures (1 hour running average used to reduce noise).

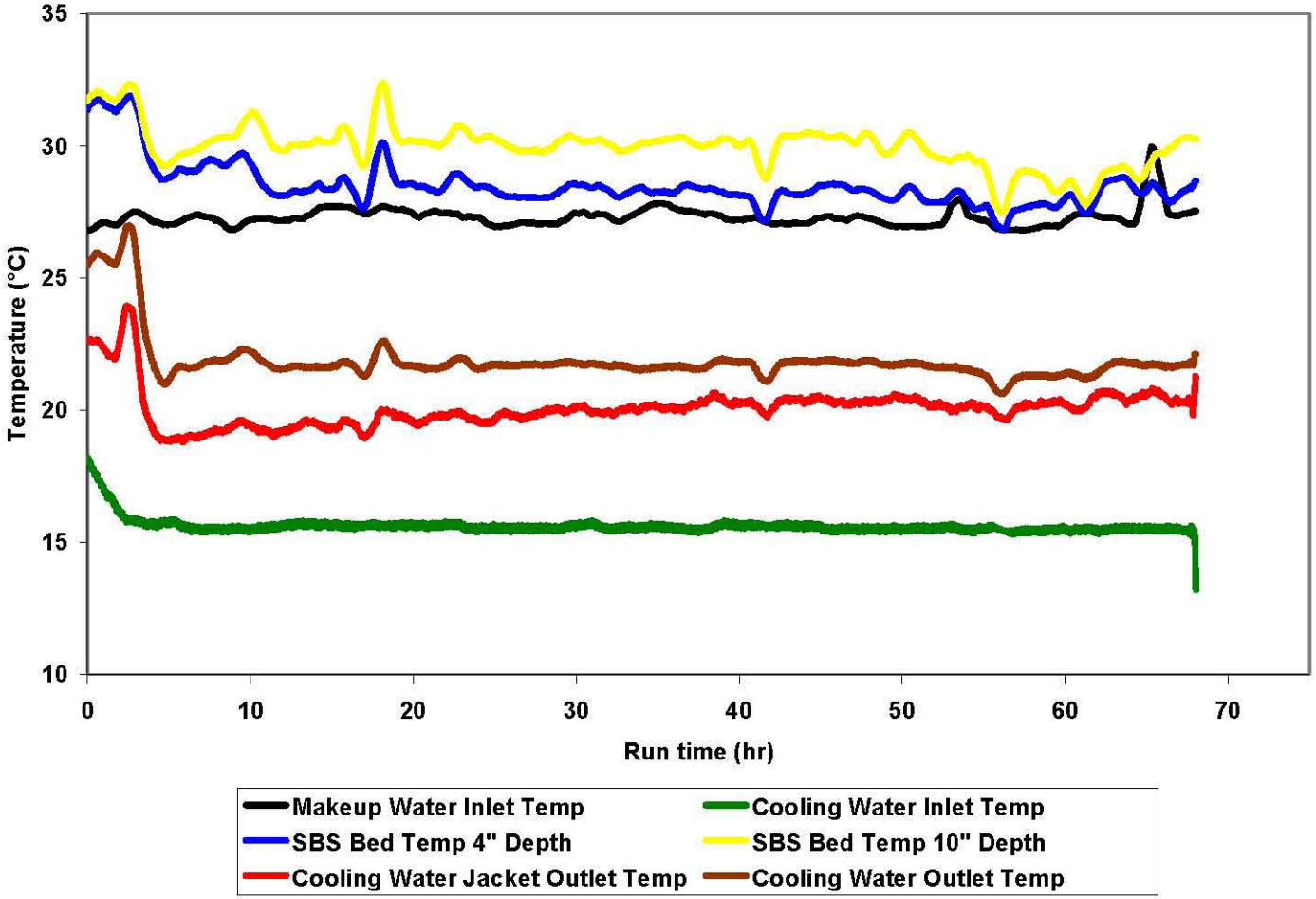


Figure 4.3.b. Test 2 SBS liquid sump and cooling water temperatures (1 hour running average used to reduce noise).

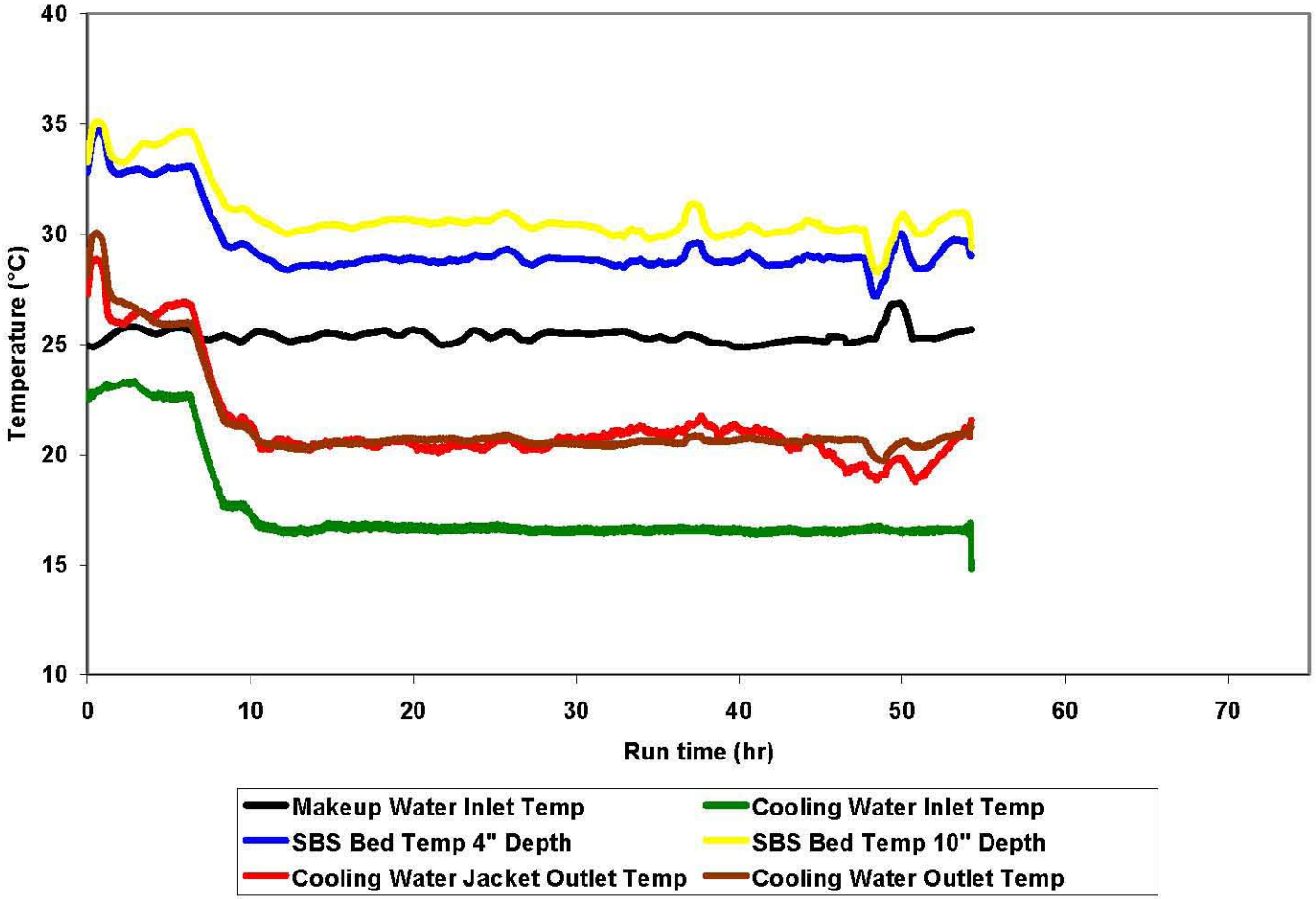


Figure 4.3.c. Test 3 SBS liquid sump and cooling water temperatures (1 hour running average used to reduce noise).

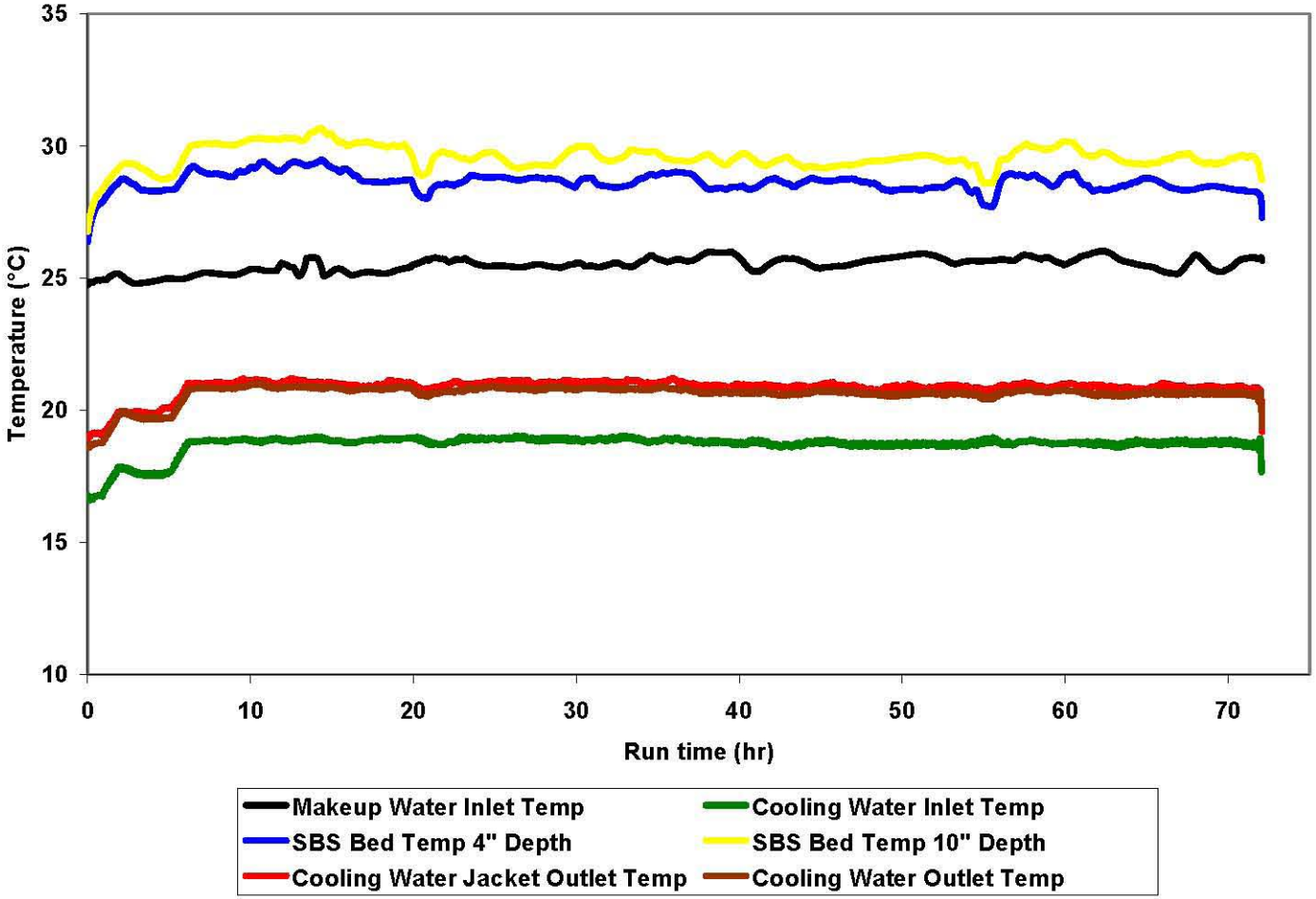


Figure 4.3.d. Test 4 SBS liquid sump and cooling water temperatures (1 hour running average used to reduce noise).

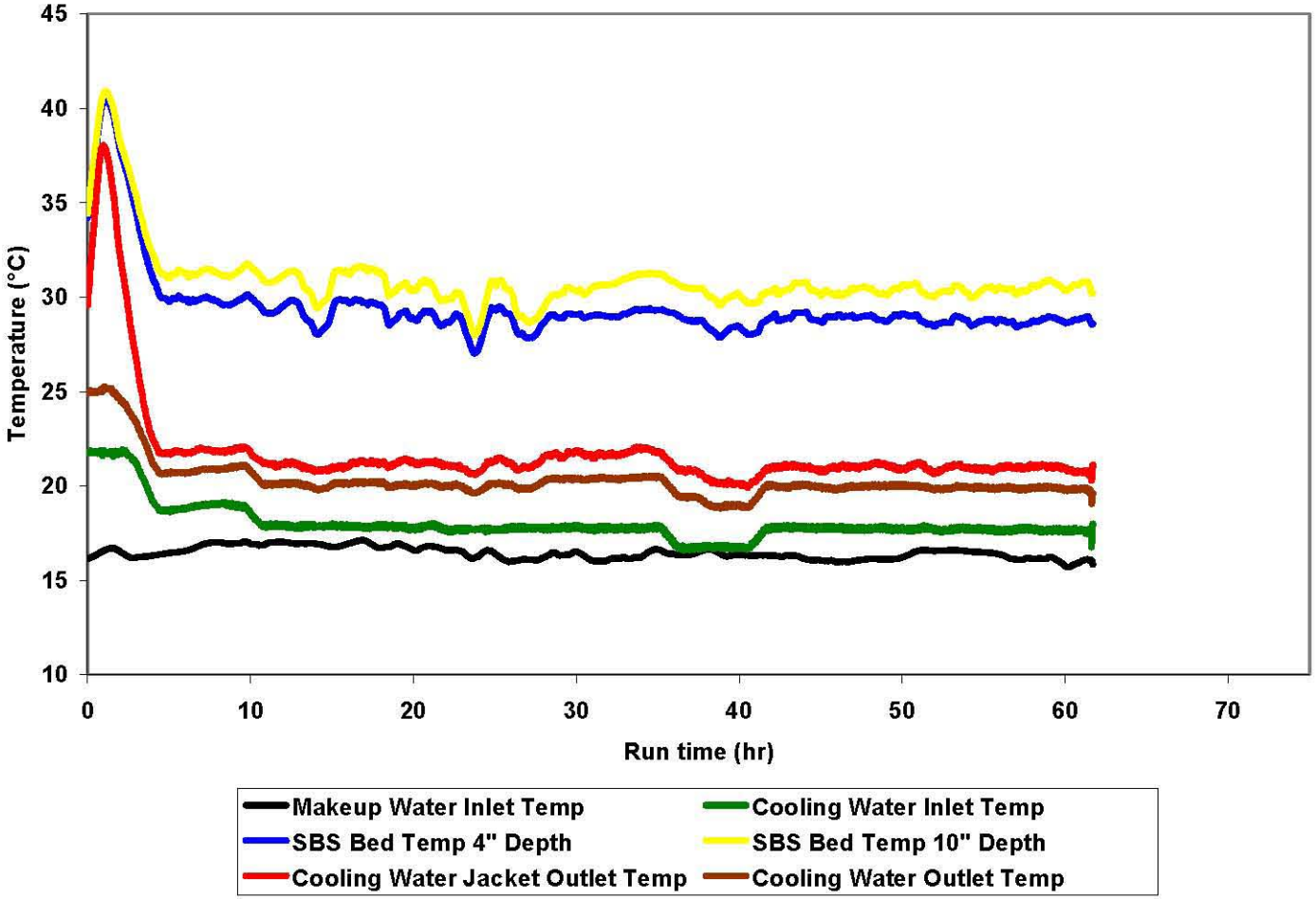


Figure 4.3.e. Test 5 SBS liquid sump and cooling water temperatures (1 hour running average used to reduce noise).

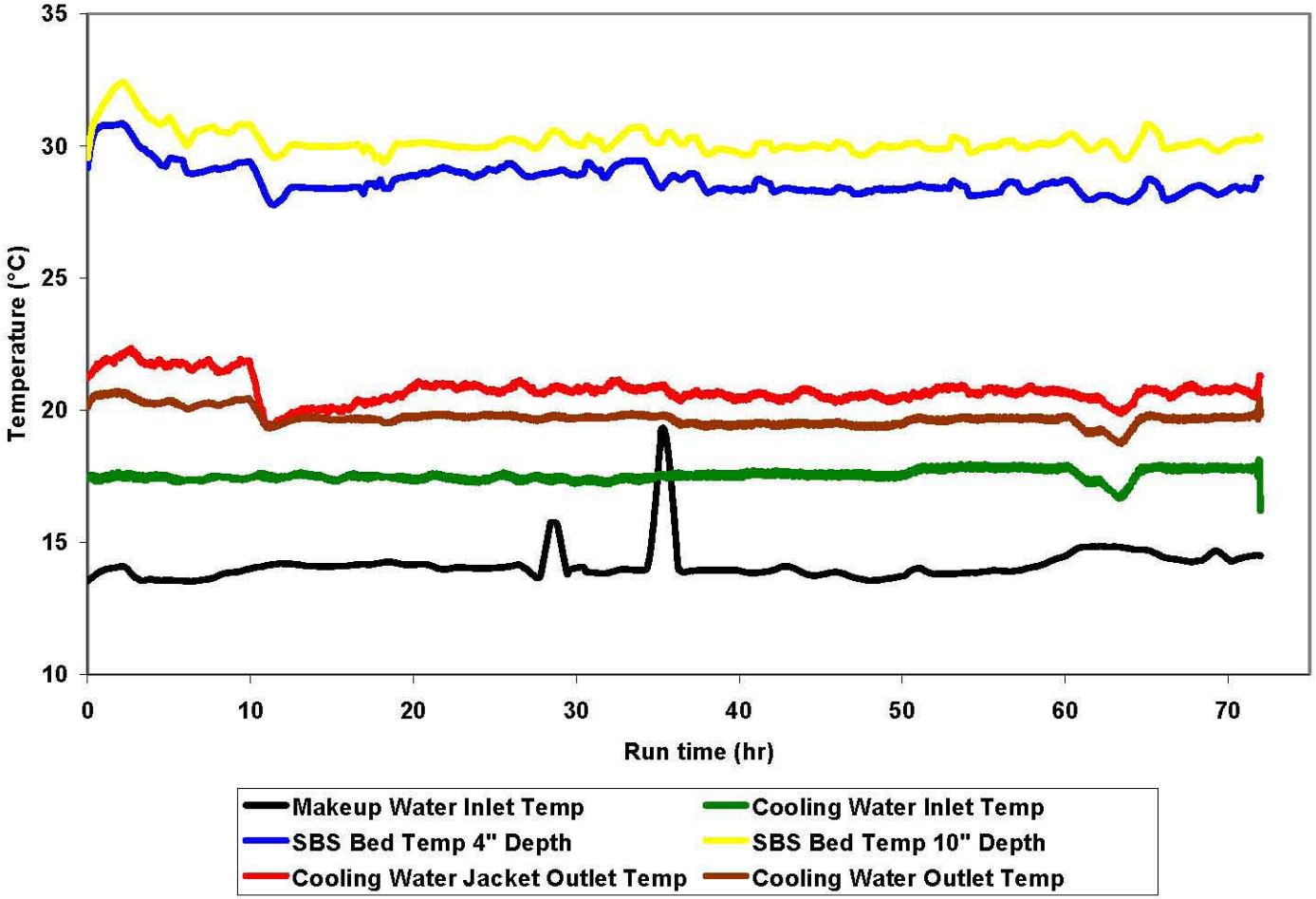


Figure 4.3.f. Test 6 SBS liquid sump and cooling water temperatures (1 hour running average used to reduce noise).

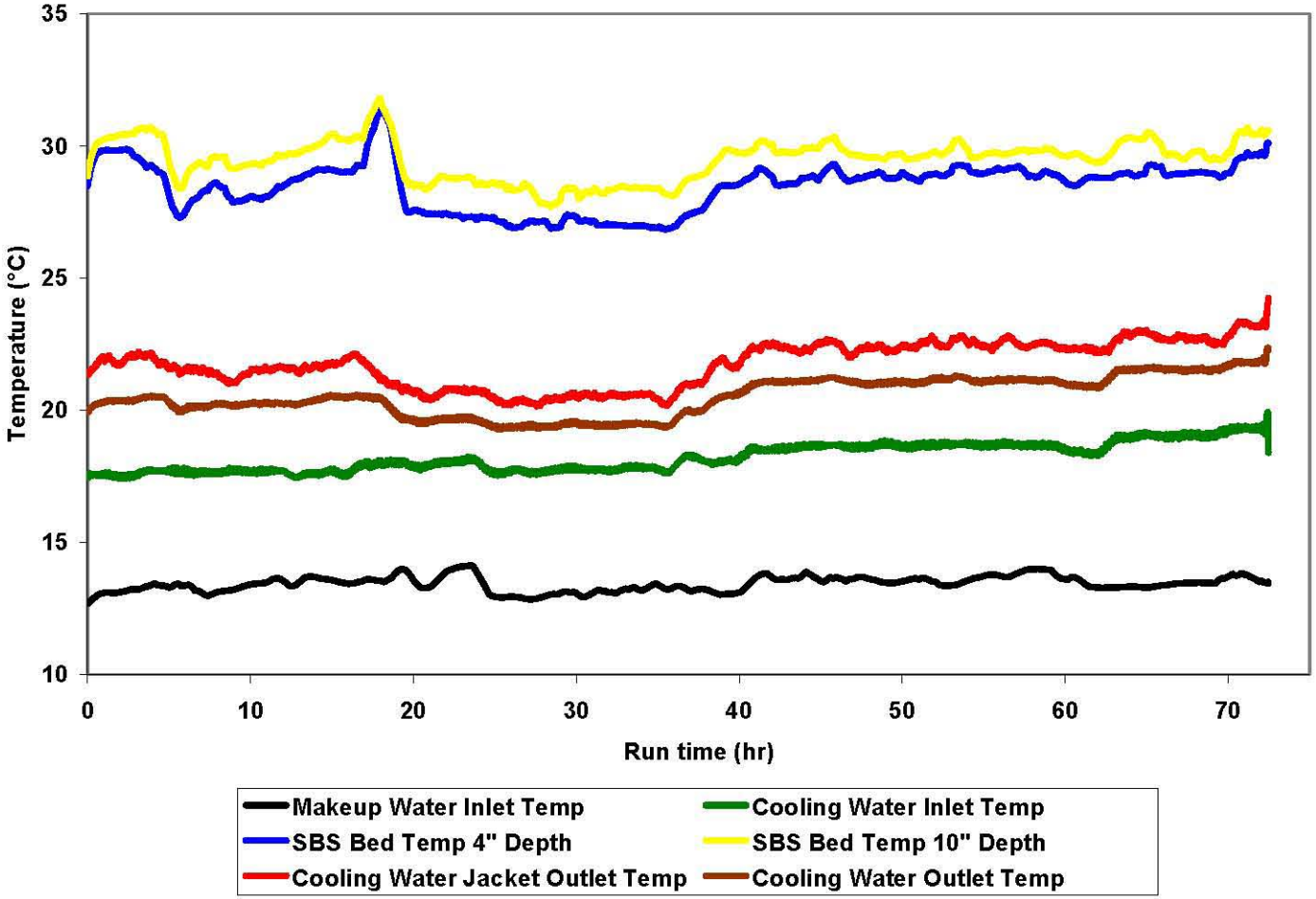


Figure 4.3.g. Test 7 SBS liquid sump and cooling water temperatures (1 hour running average used to reduce noise).

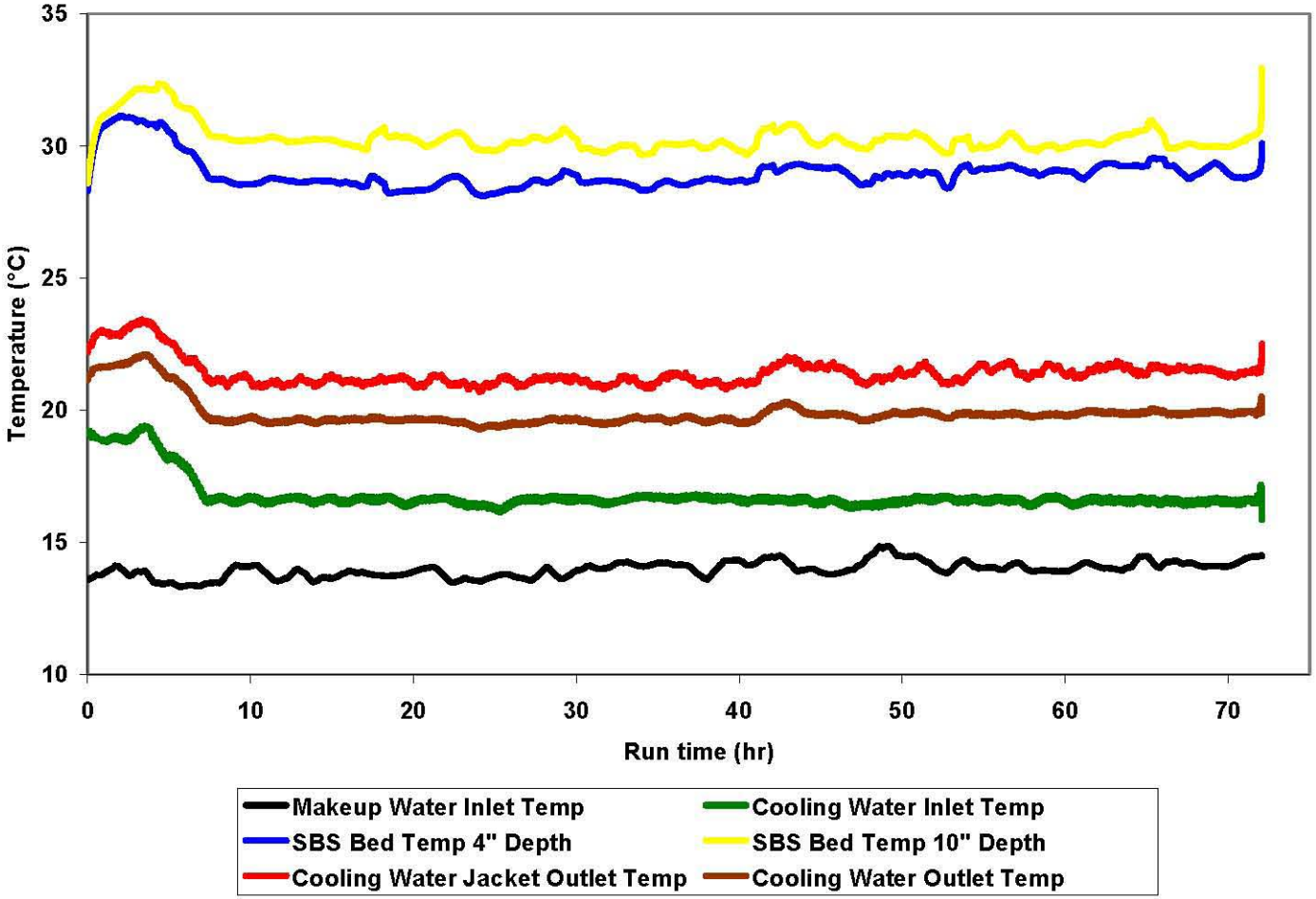


Figure 4.3.h. Test 8 SBS liquid sump and cooling water temperatures (1 hour running average used to reduce noise).

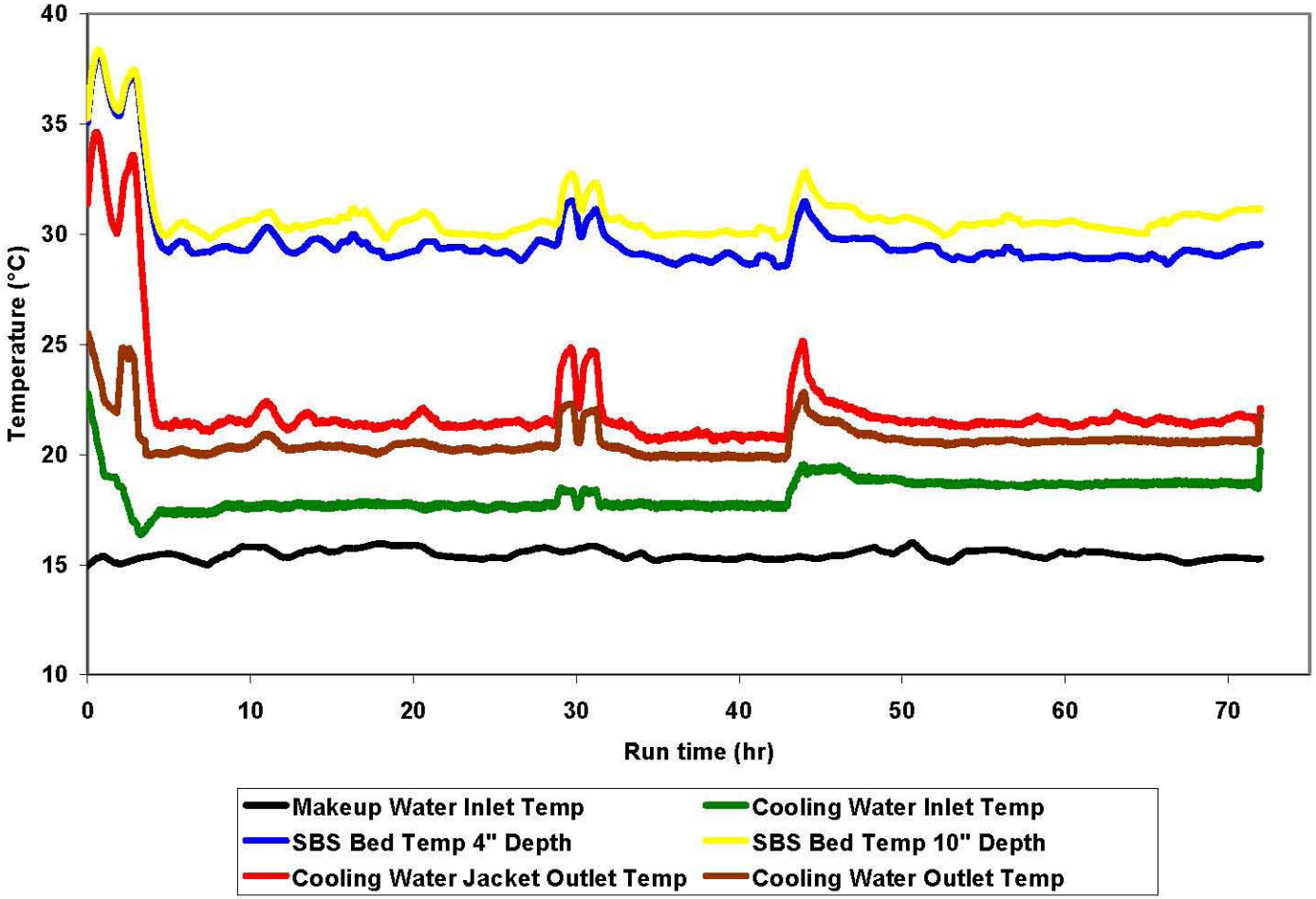


Figure 4.3.i. Test 9 SBS liquid sump and cooling water temperatures (1 hour running average used to reduce noise).

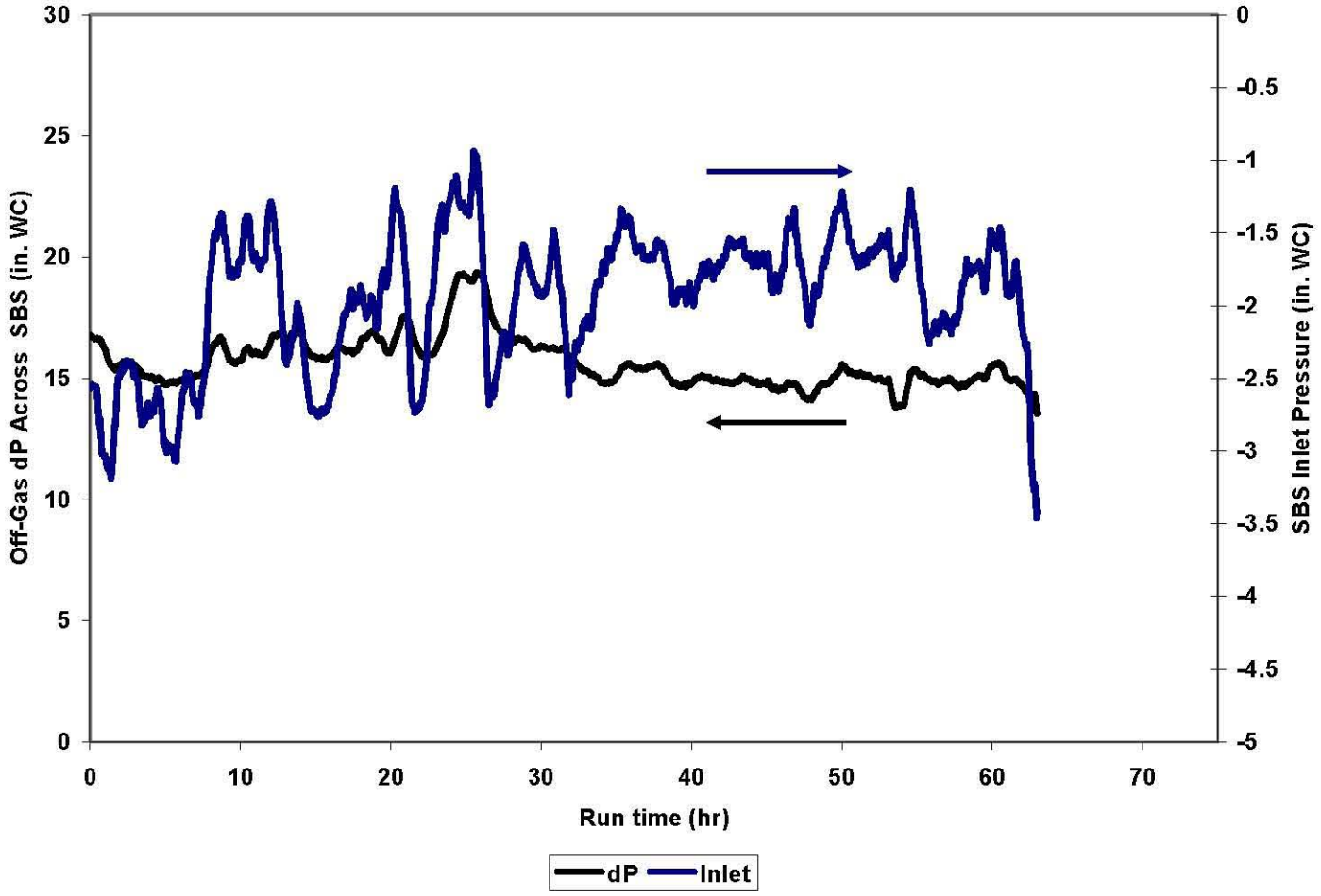


Figure 4.4.a. Test 1 SBS inlet pressure and differential pressure across the SBS (1 hour running average used to reduce noise).

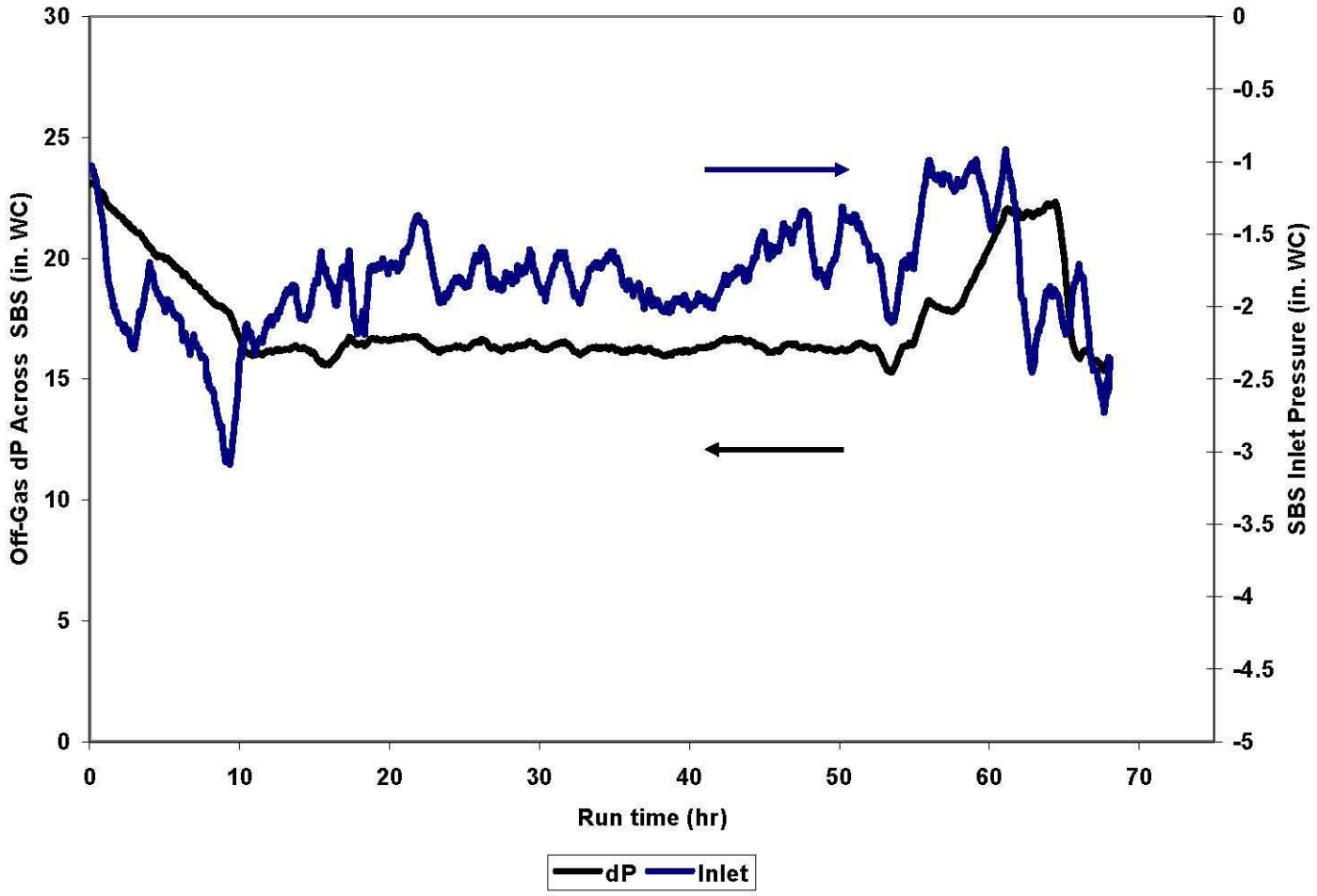


Figure 4.4.b. Test 2 SBS inlet pressure and differential pressure across the SBS (1 hour running average used to reduce noise).

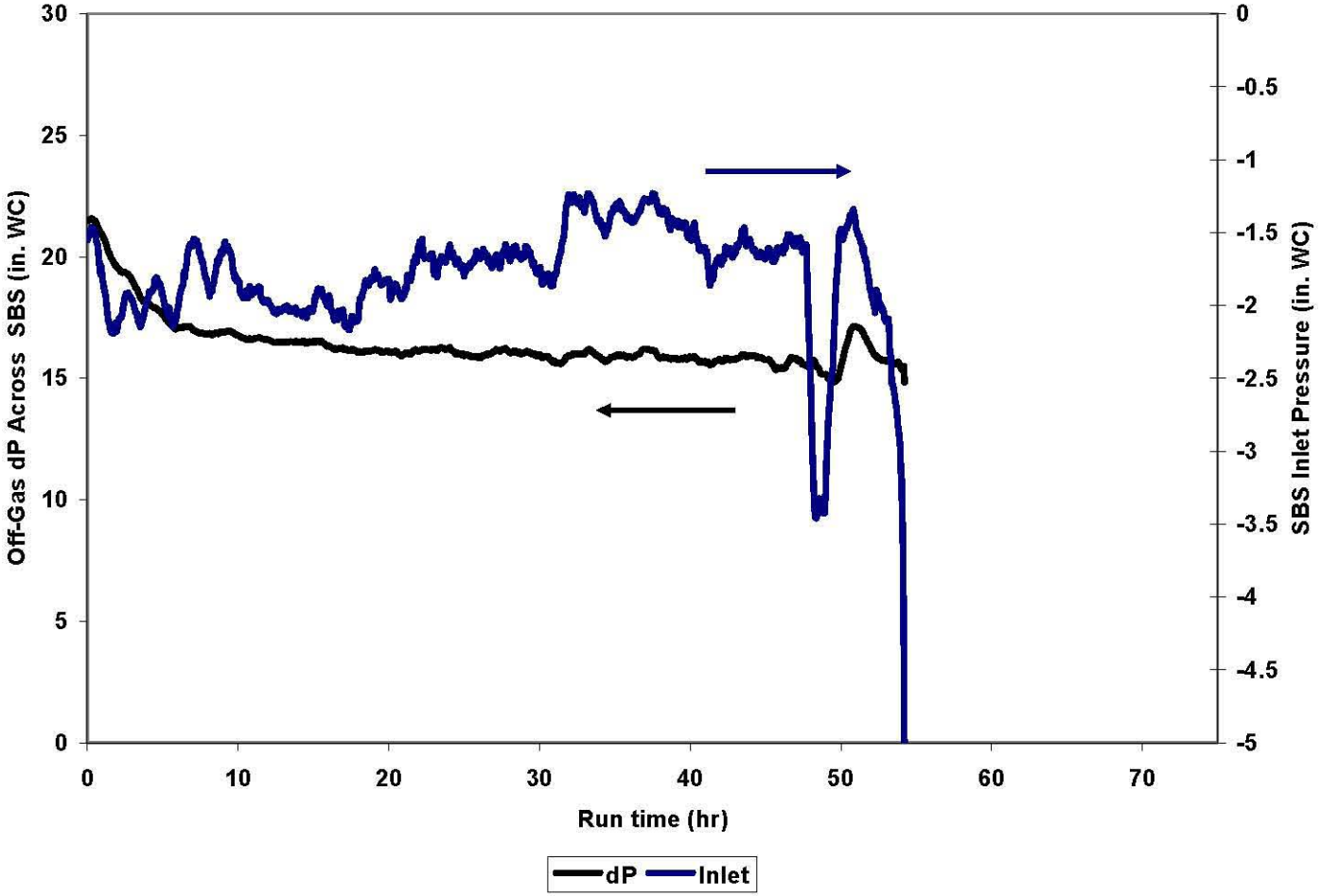


Figure 4.4.c. Test 3 SBS inlet pressure and differential pressure across the SBS (1 hour running average used to reduce noise).

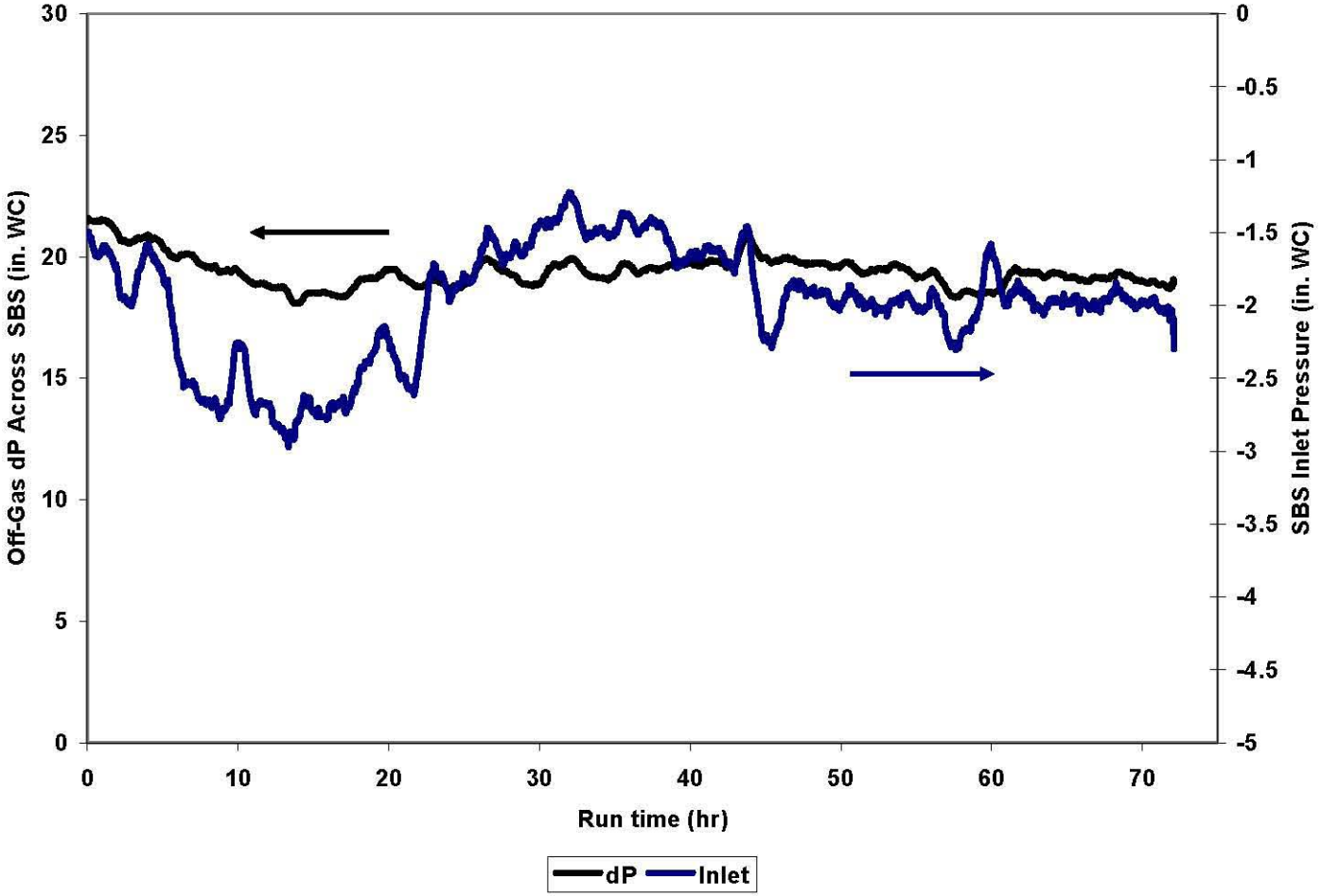


Figure 4.4.d. Test 4 SBS inlet pressure and differential pressure across the SBS (1 hour running average used to reduce noise).

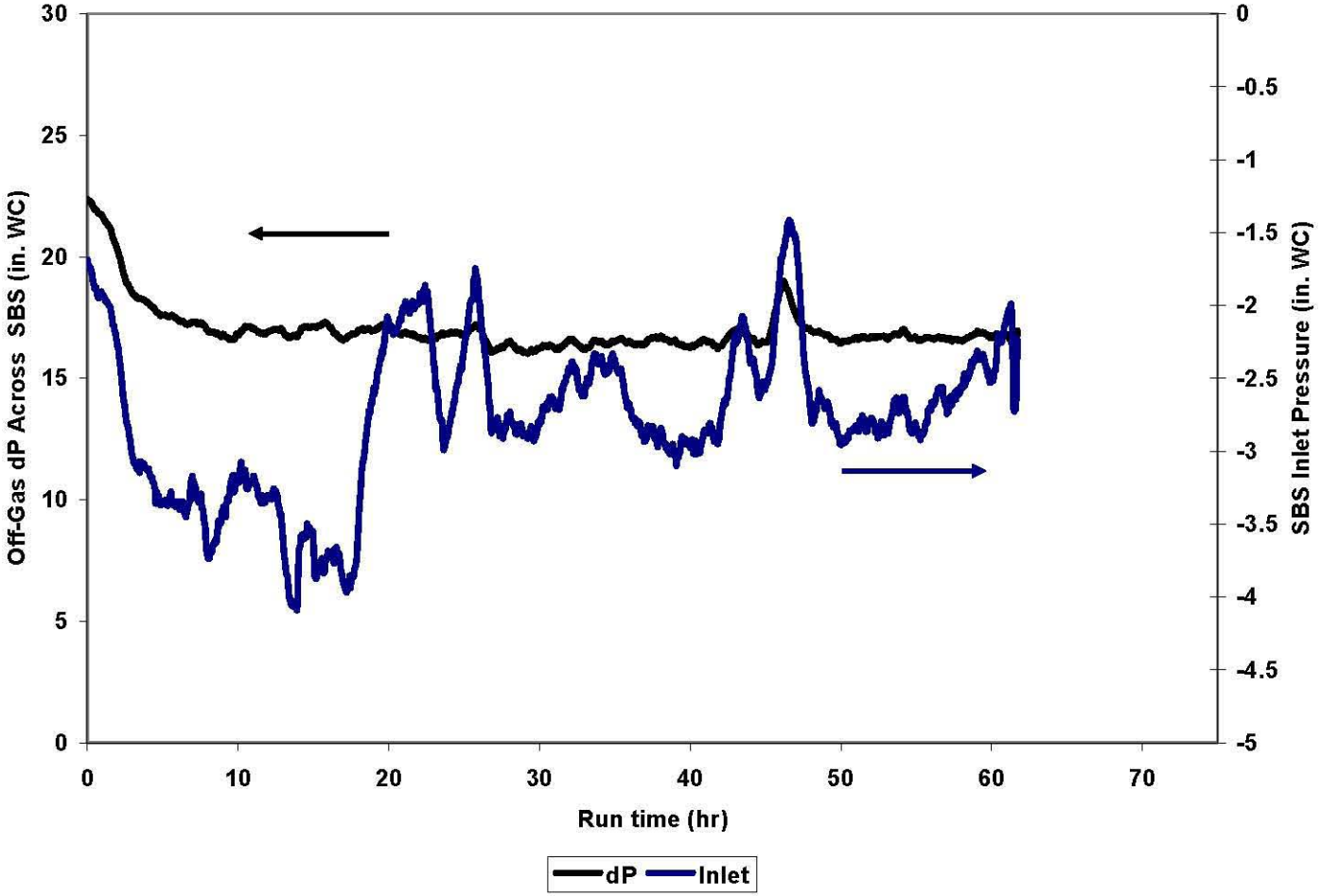


Figure 4.4.e. Test 5 SBS inlet pressure and differential pressure across the SBS (1 hour running average used to reduce noise).

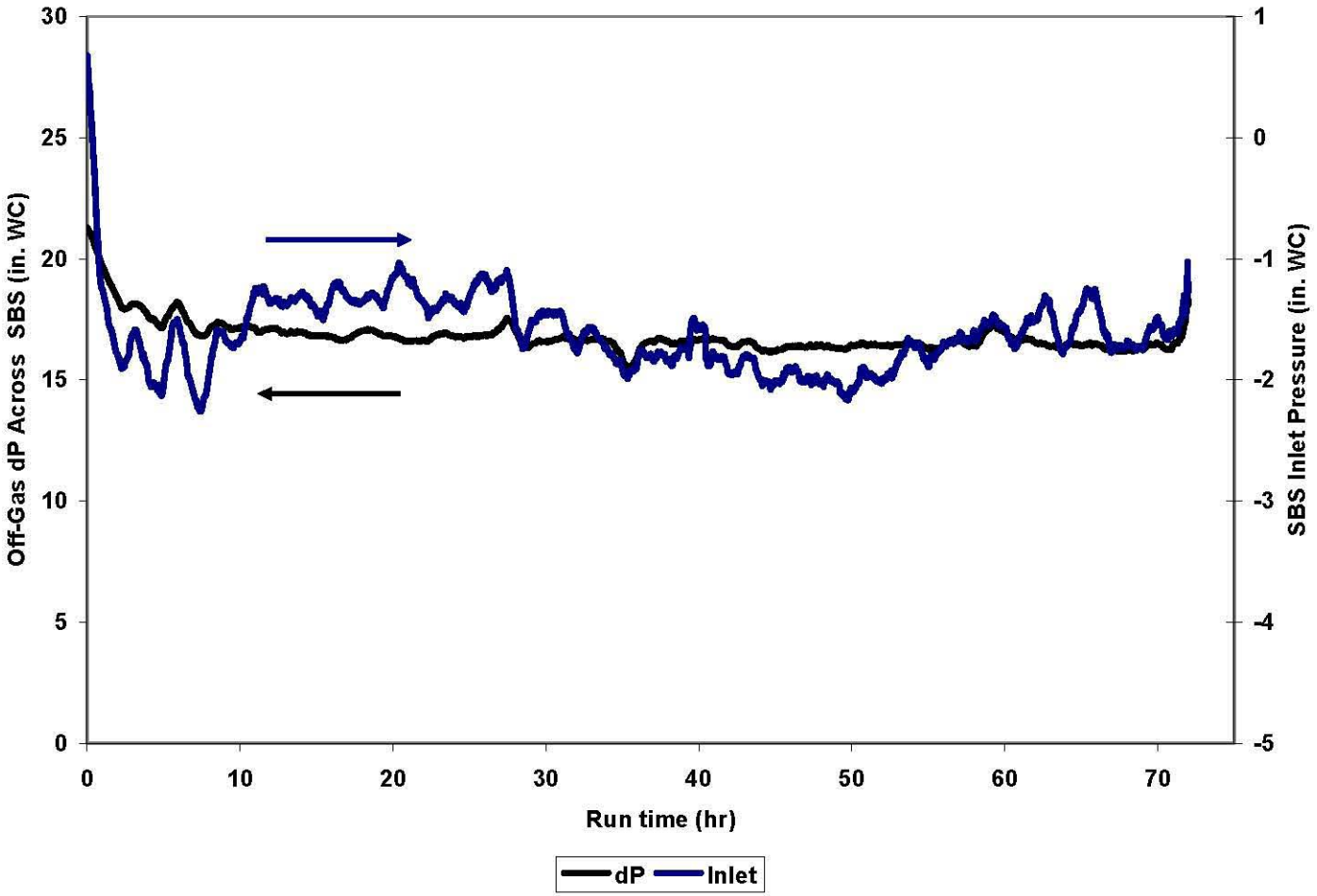


Figure 4.4.f. Test 6 SBS inlet pressure and differential pressure across the SBS (1 hour running average used to reduce noise).

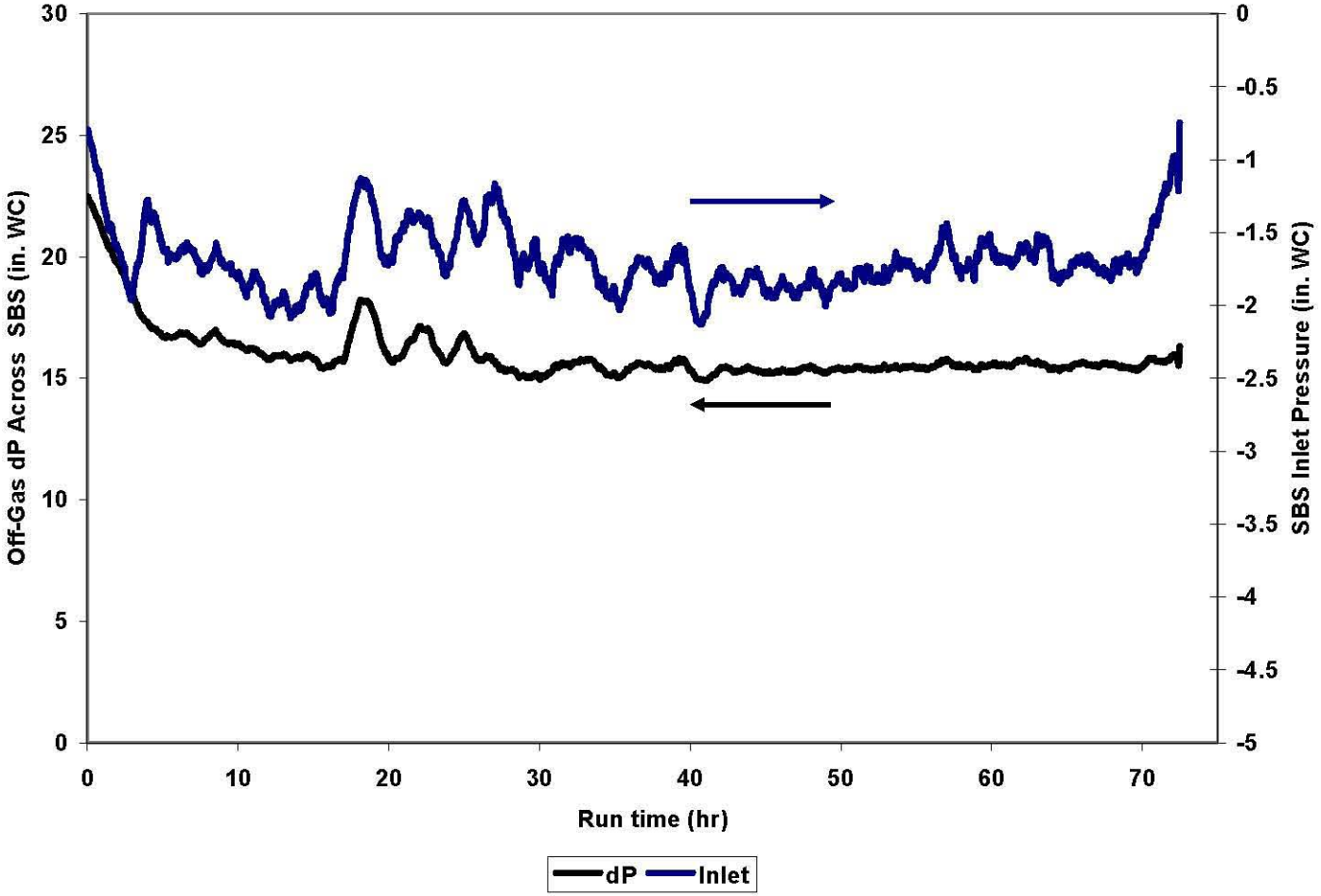


Figure 4.4.g. Test 7 SBS inlet pressure and differential pressure across the SBS (1 hour running average used to reduce noise).

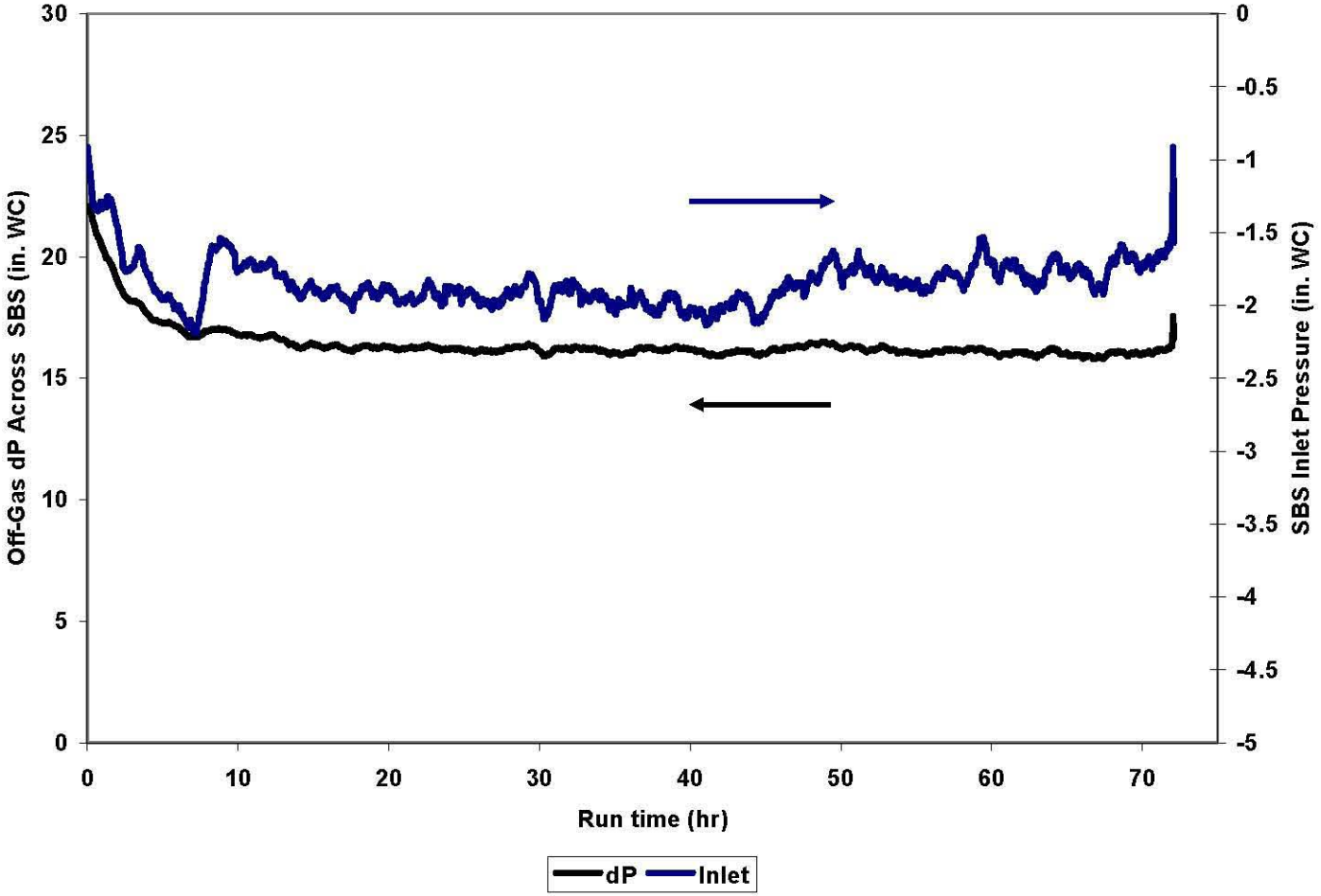


Figure 4.4.h. Test 8 SBS inlet pressure and differential pressure across the SBS (1 hour running average used to reduce noise).

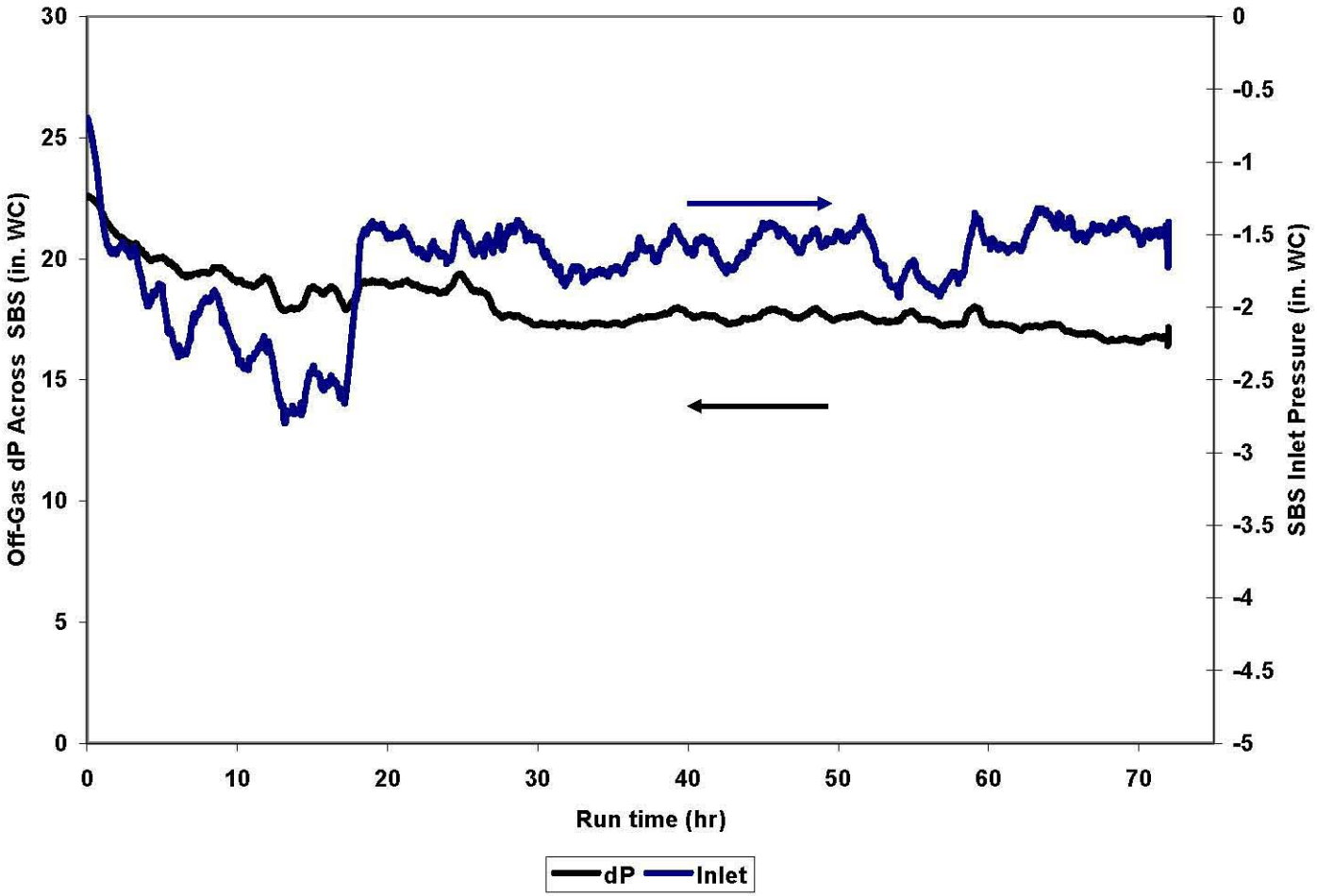


Figure 4.4.i. Test 9 SBS inlet pressure and differential pressure across the SBS (1 hour running average used to reduce noise).

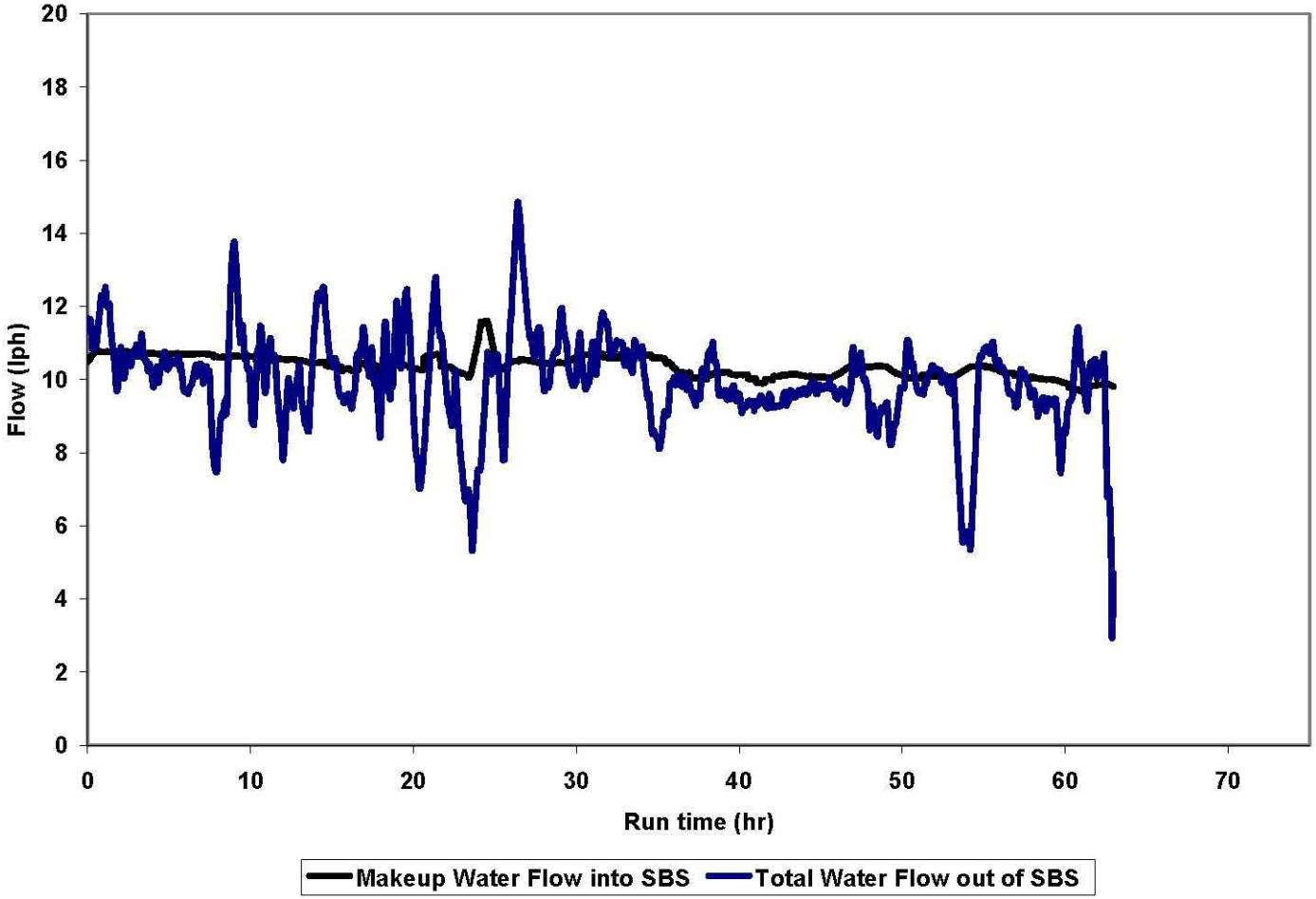


Figure 4.5.a. Test 1 makeup water flow rate into and total water flow out of the SBS (1 hour running average used to reduce noise).

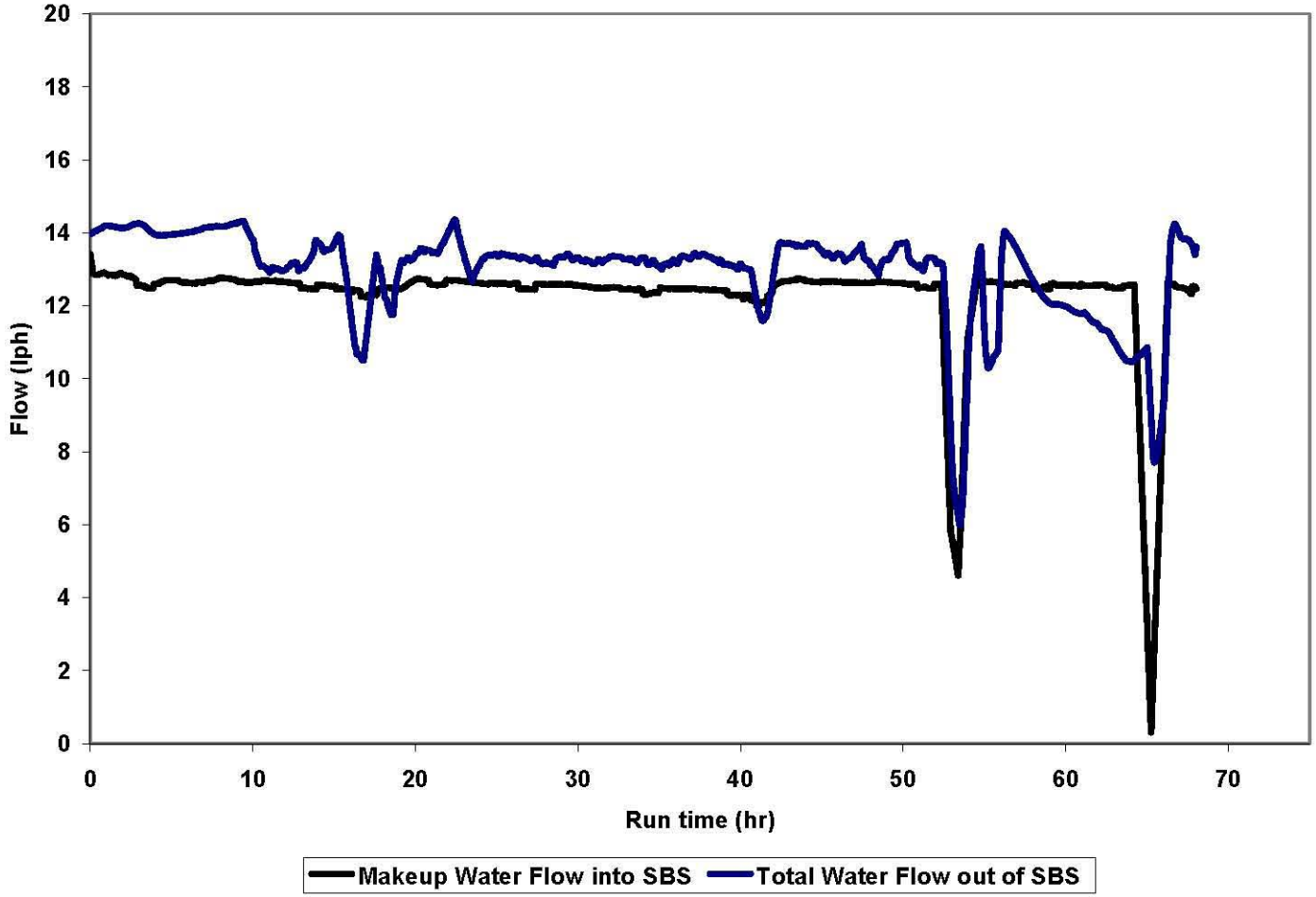


Figure 4.5.b. Test 2 makeup water flow rate into and total water flow out of the SBS (1 hour running average used to reduce noise).

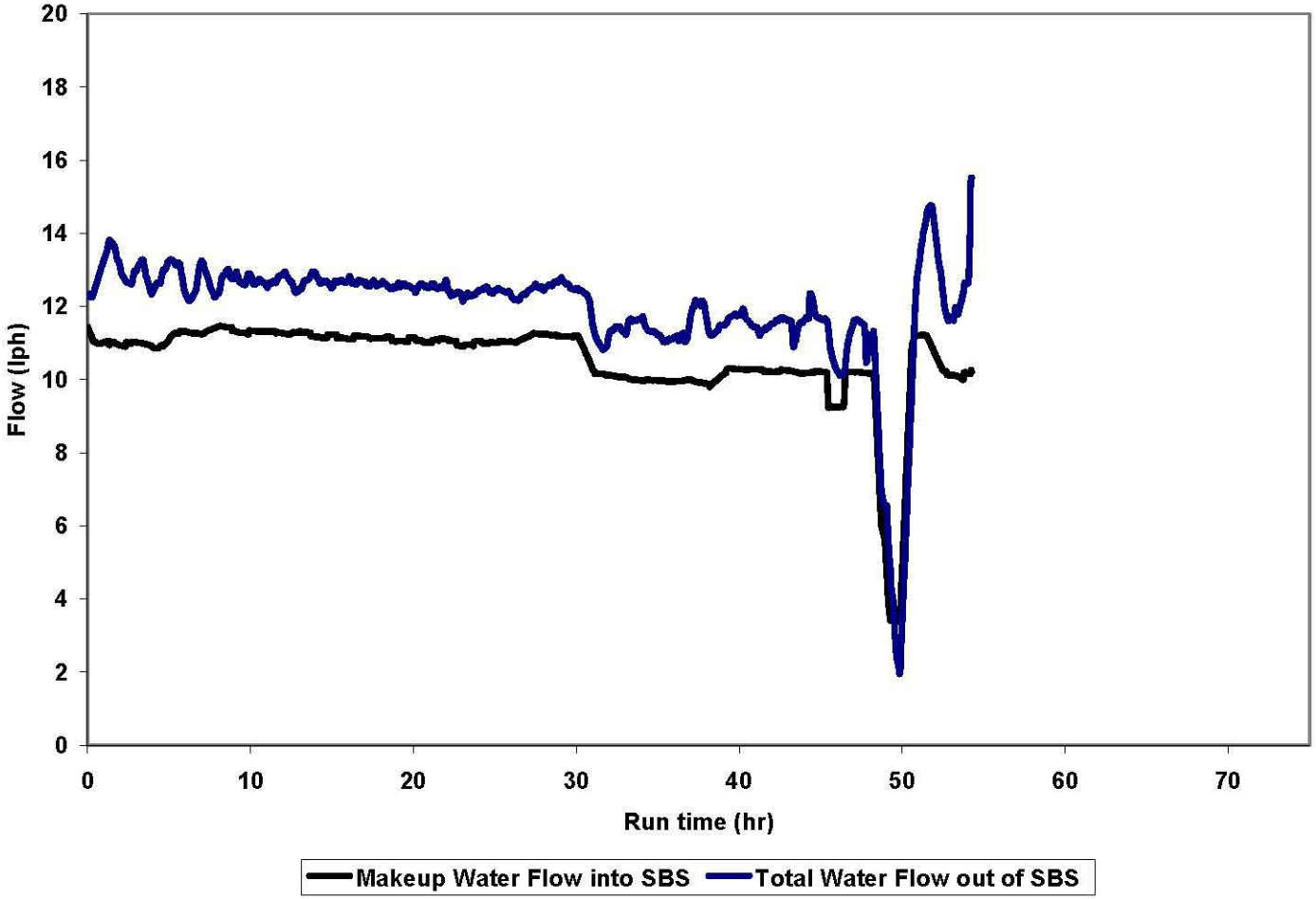


Figure 4.5.c. Test 3 makeup water flow rate into and total water flow out of the SBS (1 hour running average used to reduce noise).

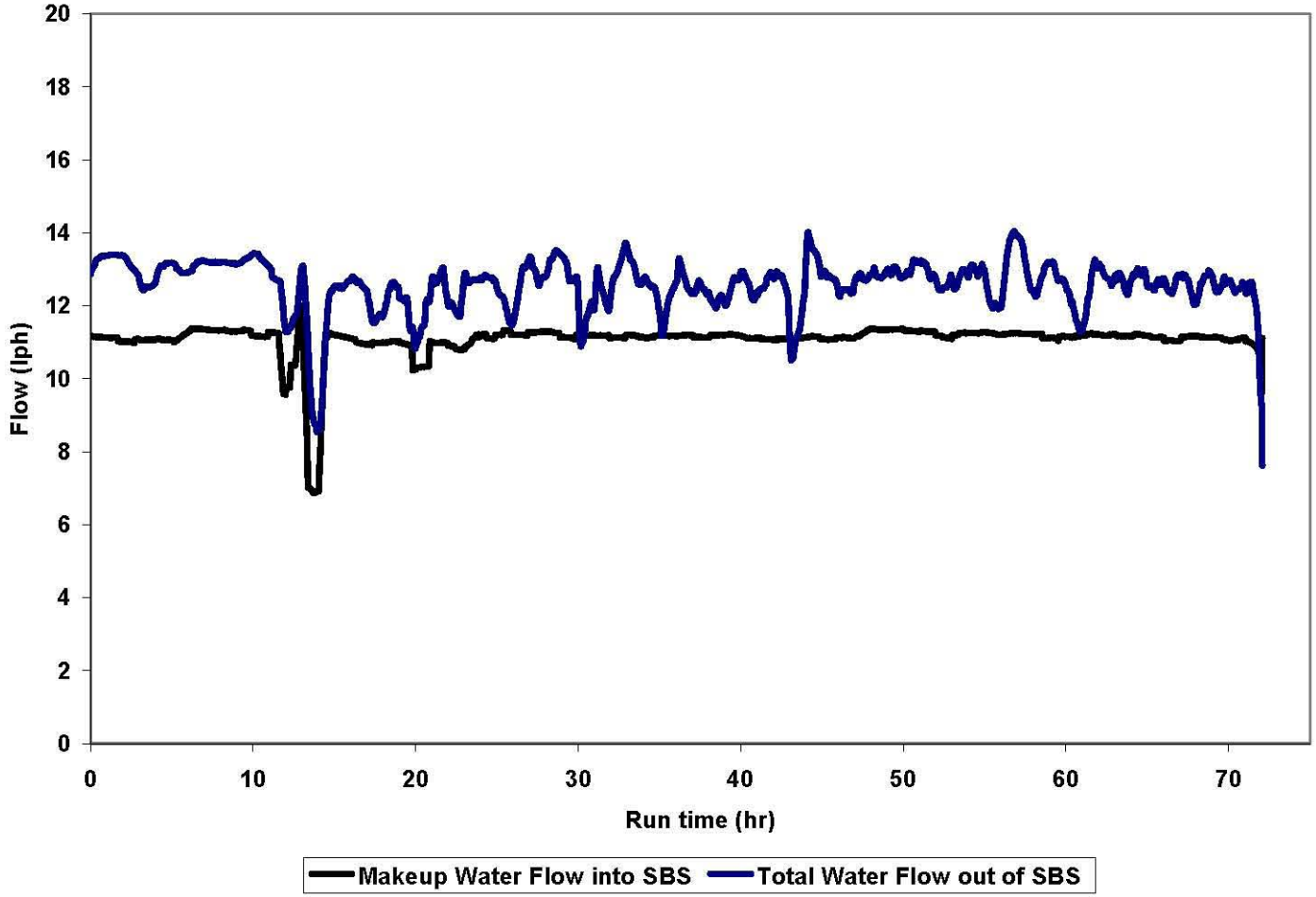


Figure 4.5.d. Test 4 makeup water flow rate into and total water flow out of the SBS (1 hour running average used to reduce noise).

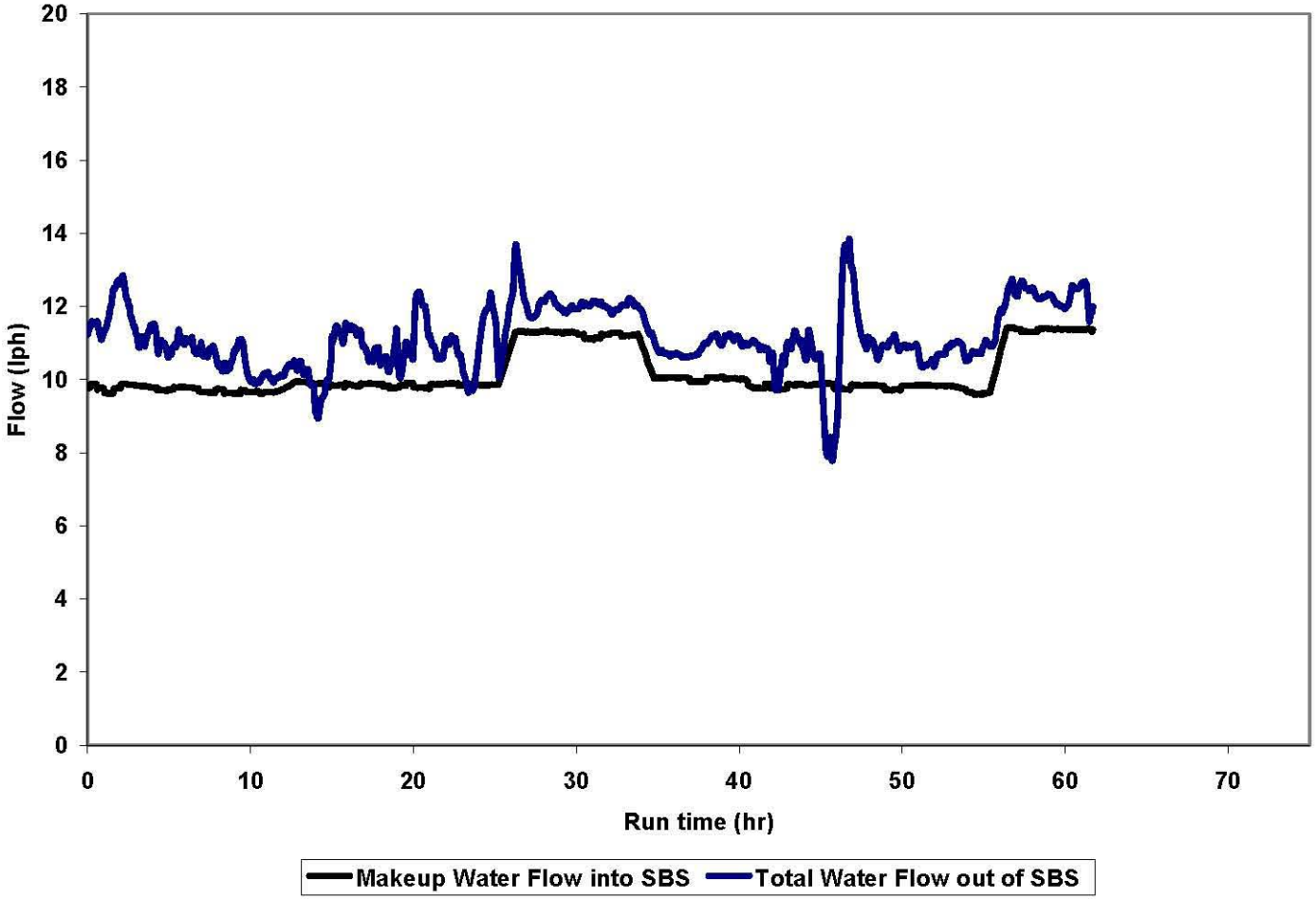


Figure 4.5.e. Test 5 makeup water flow rate into and total water flow out of the SBS (1 hour running average used to reduce noise).

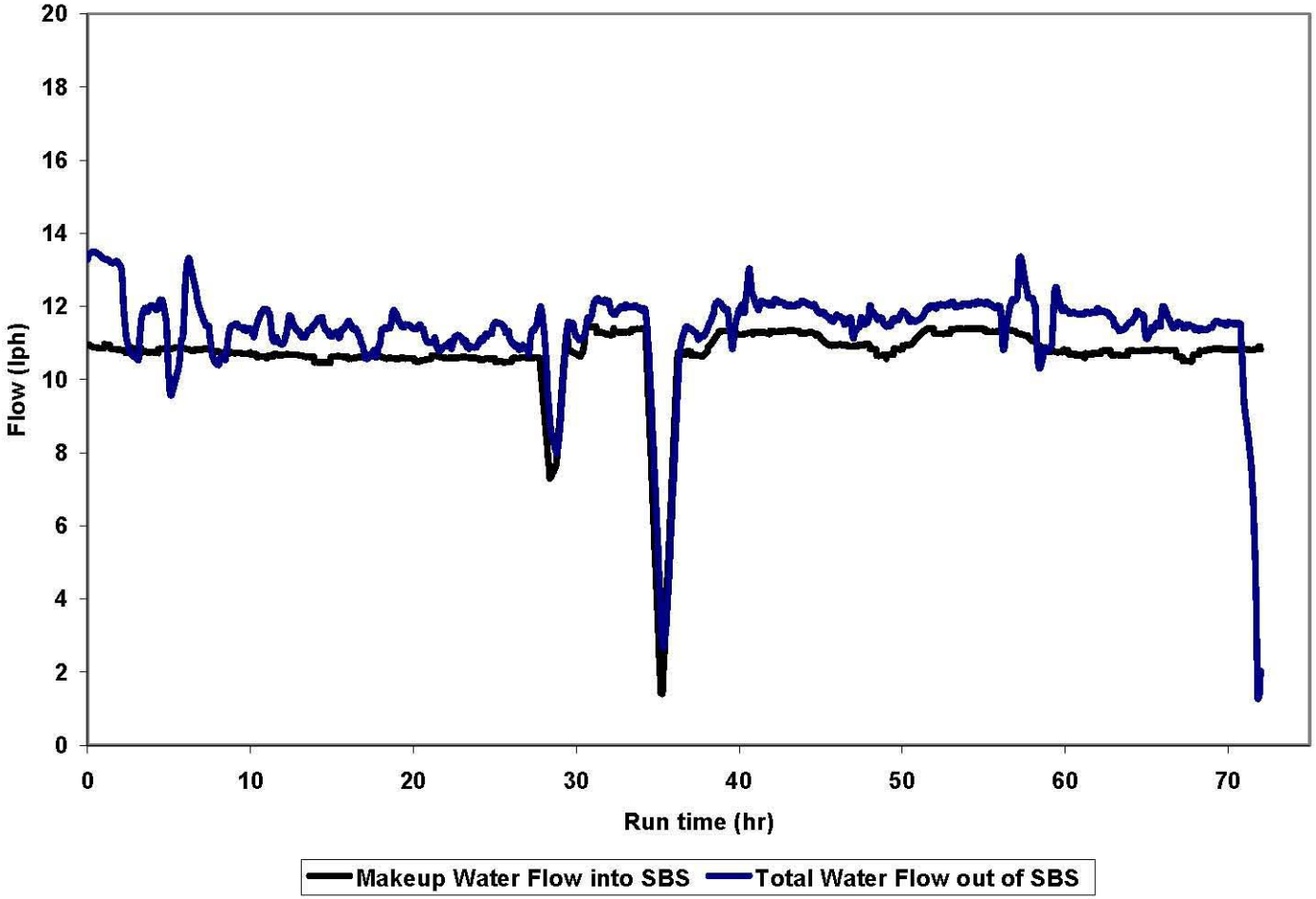


Figure 4.5.f. Test 6 makeup water flow rate into and total water flow out of the SBS (1 hour running average used to reduce noise).

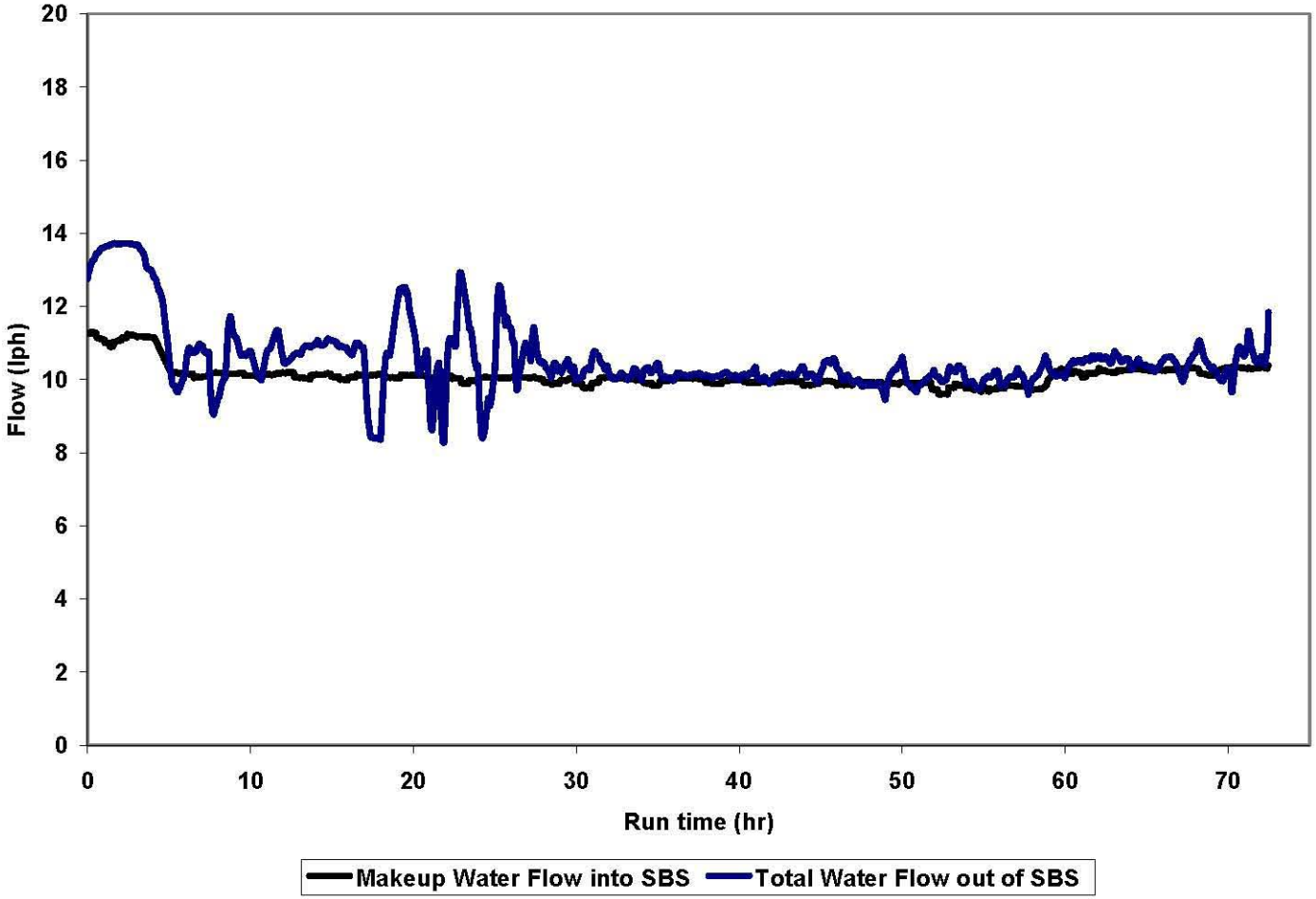


Figure 4.5.g. Test 7 makeup water flow rate into and total water flow out of the SBS (1 hour running average used to reduce noise).

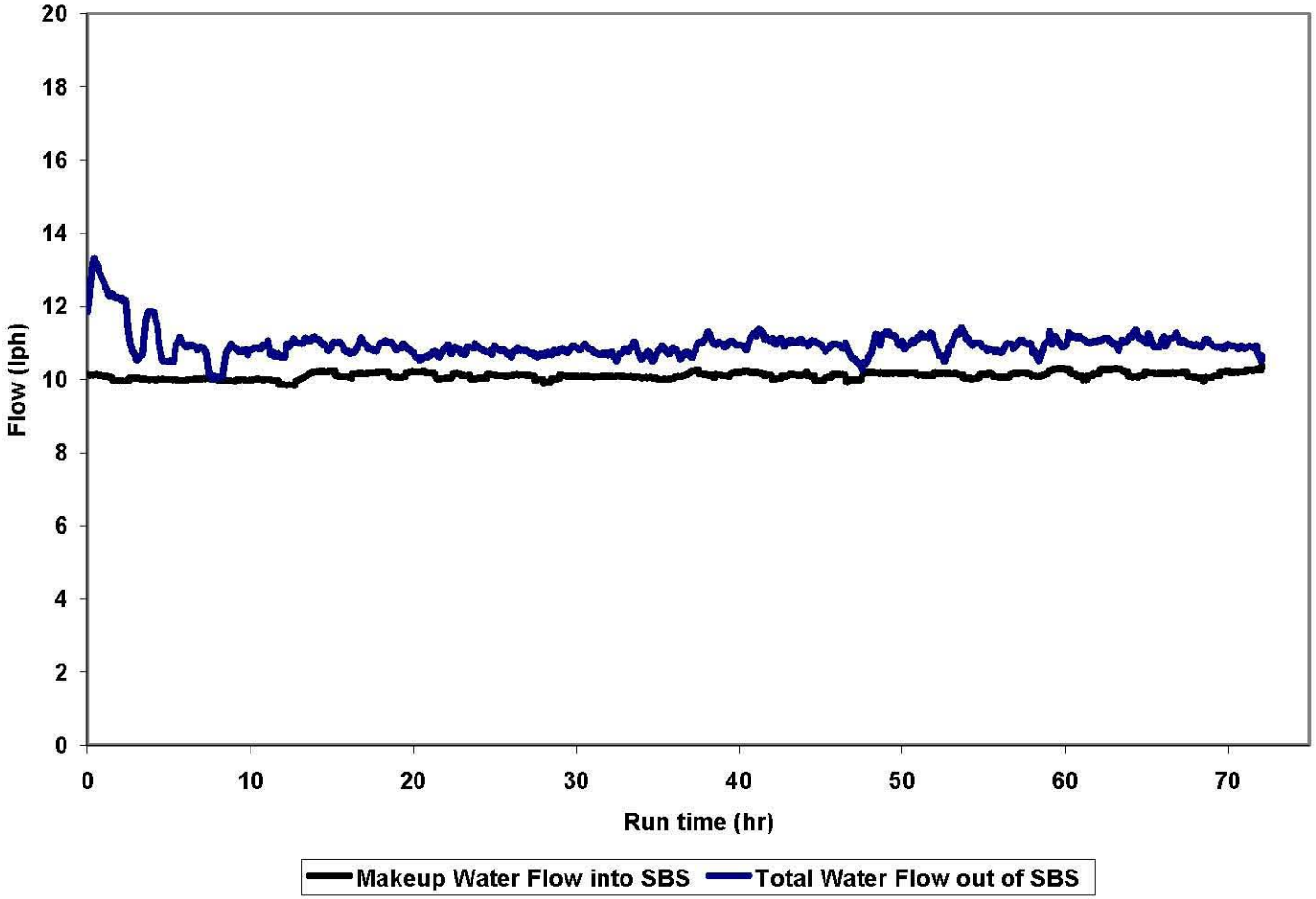


Figure 4.5.h. Test 8 makeup water flow rate into and total water flow out of the SBS (1 hour running average used to reduce noise).

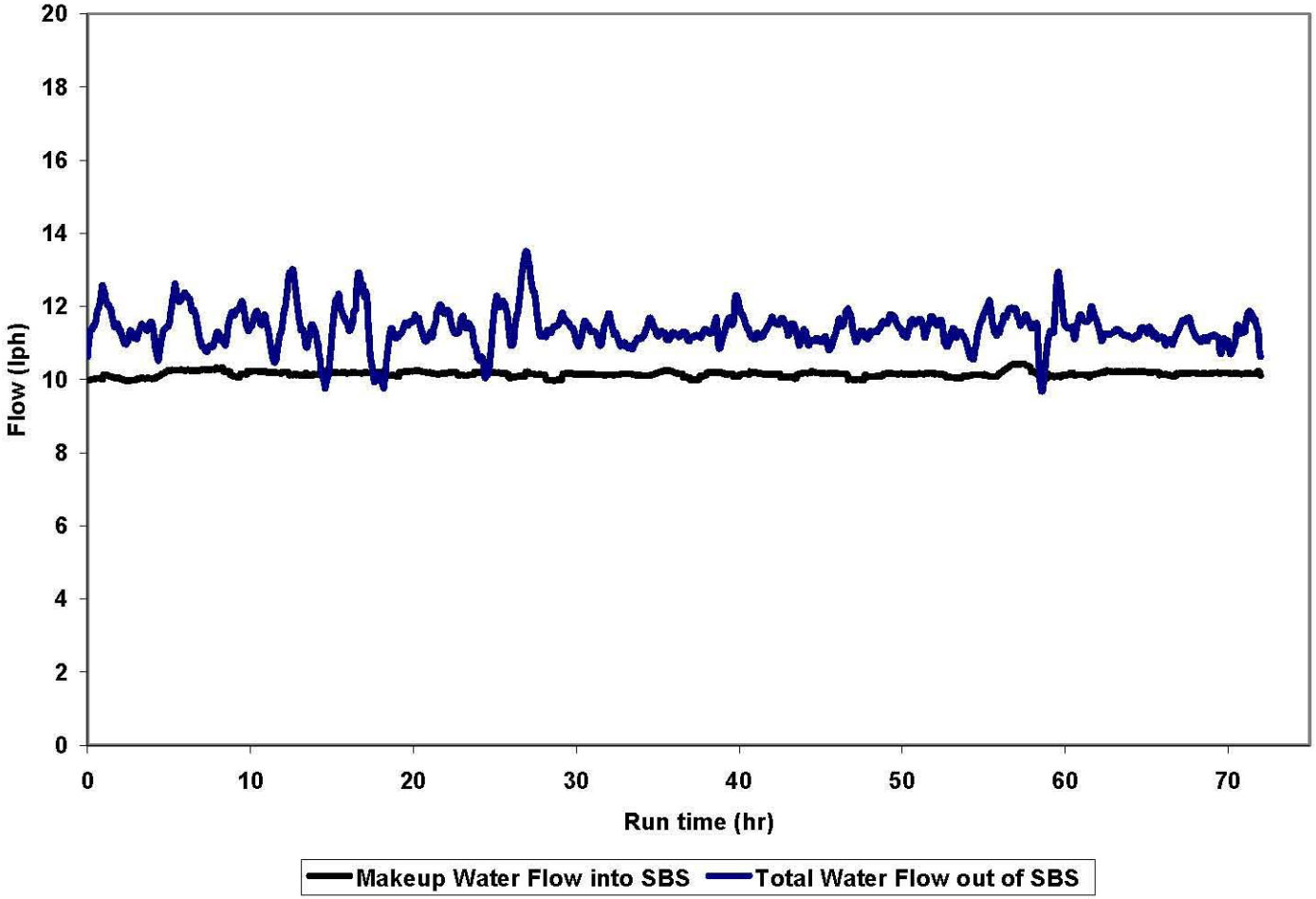


Figure 4.5.i. Test 9 makeup water flow rate into and total water flow out of the SBS (1 hour running average used to reduce noise).

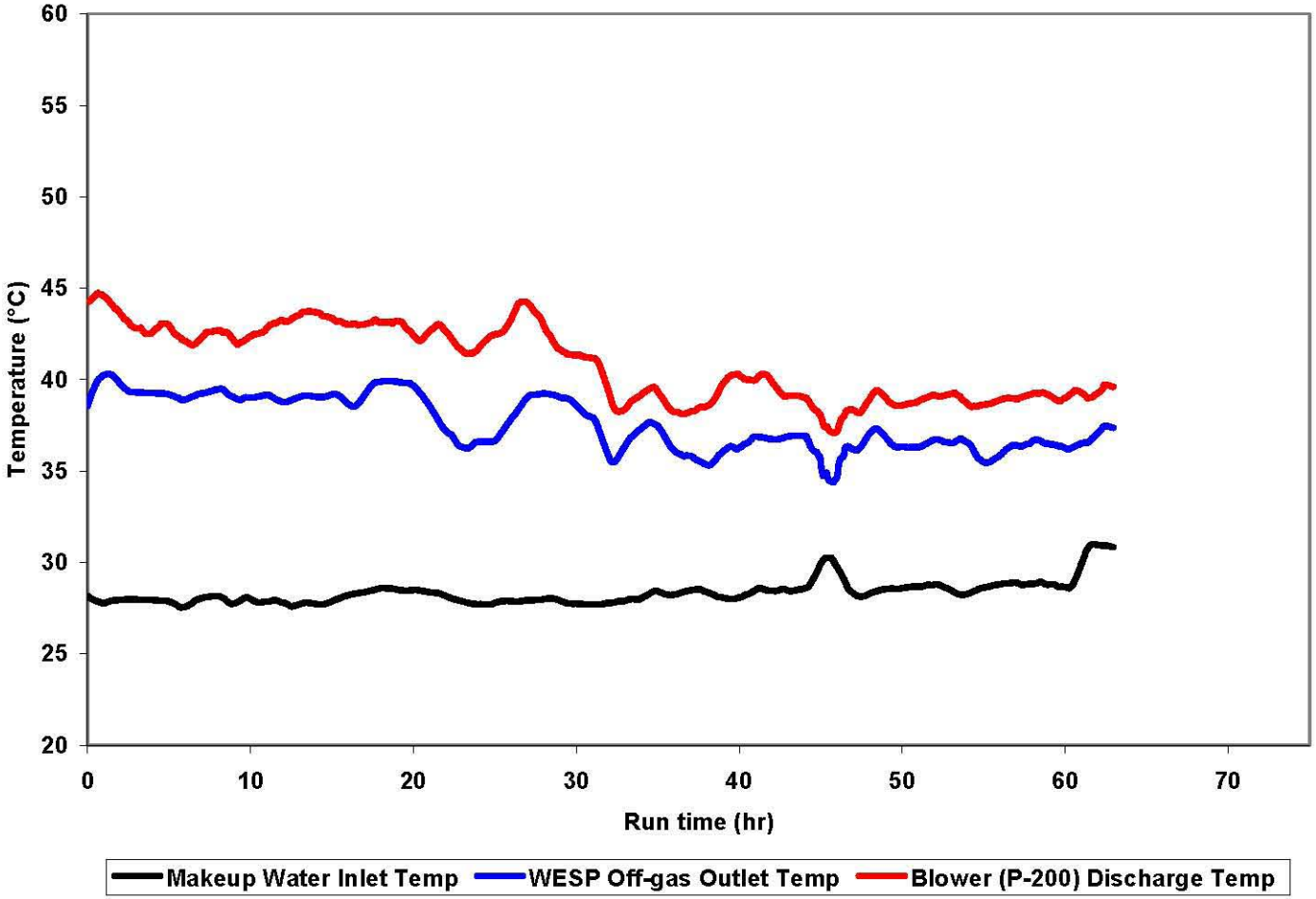


Figure 4.6.a. Test 1 WESP makeup water temperature, WESP outlet temperature, and P-200 discharge temperature (1 hour running average used to reduce noise).

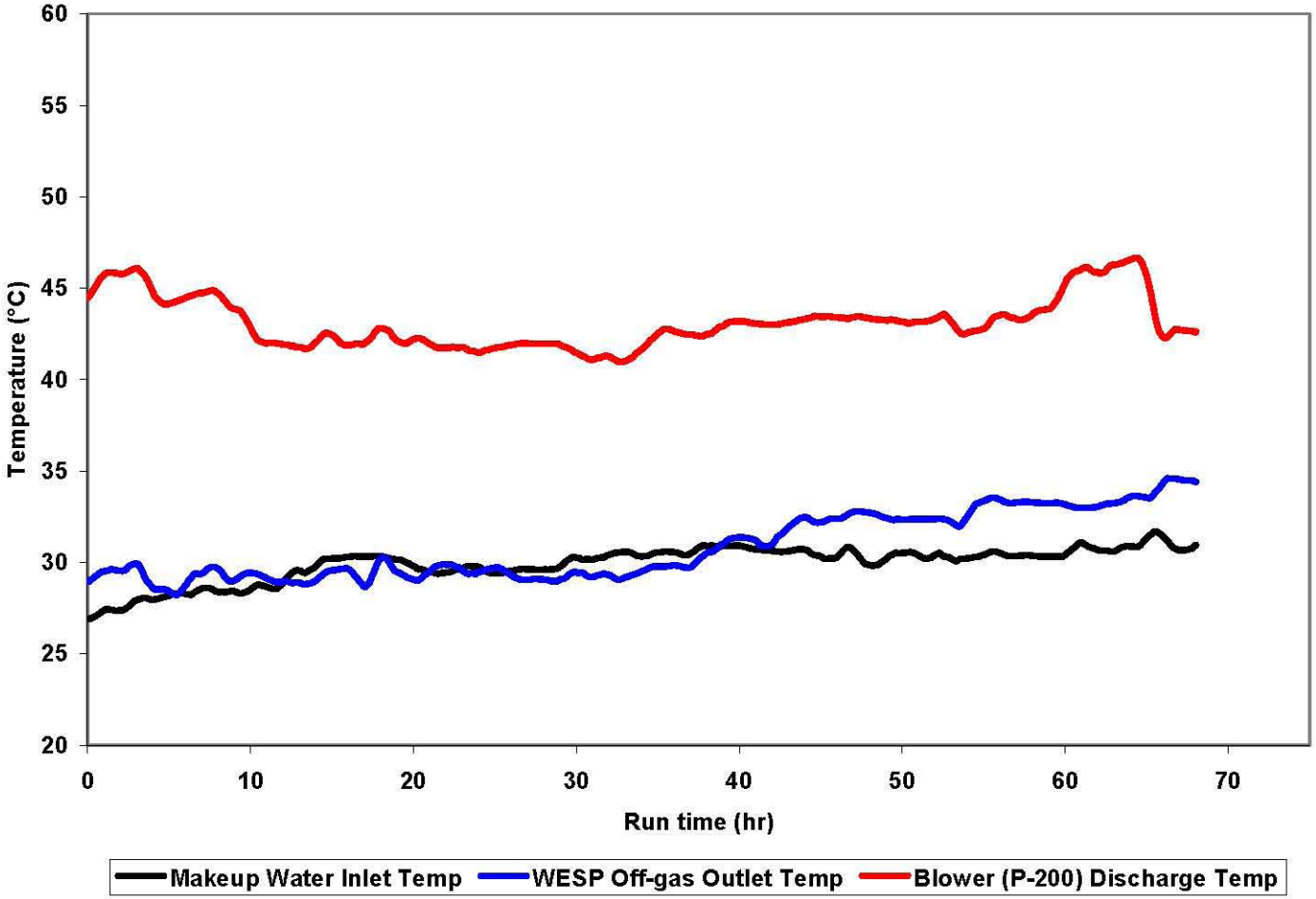


Figure 4.6.b. Test 2 WESP makeup water temperature, WESP outlet temperature, and P-200 discharge temperature (1 hour running average used to reduce noise).

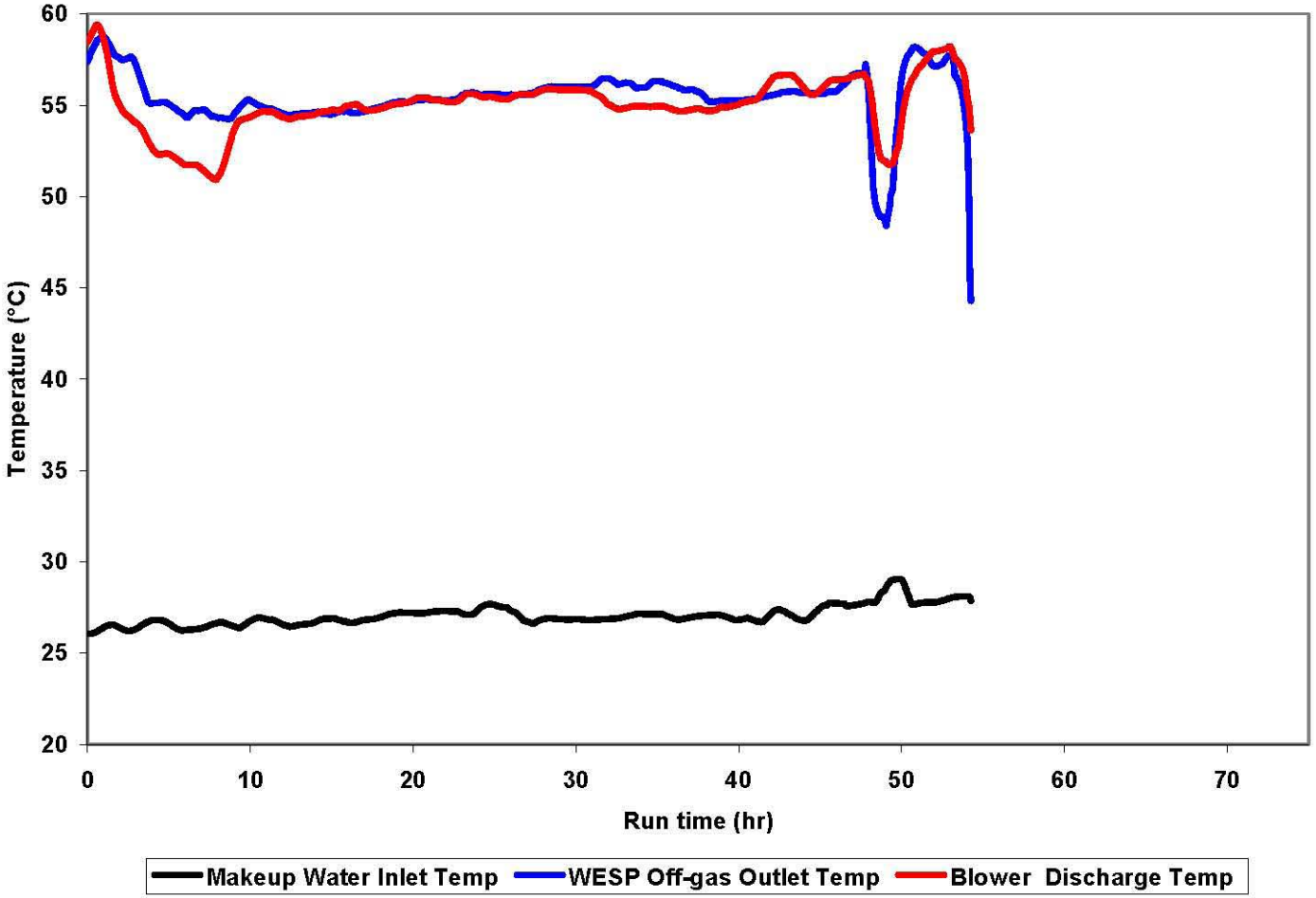


Figure 4.6.c. Test 3 WESP makeup water temperature, WESP outlet temperature, and P-200 discharge temperature (1 hour running average used to reduce noise).

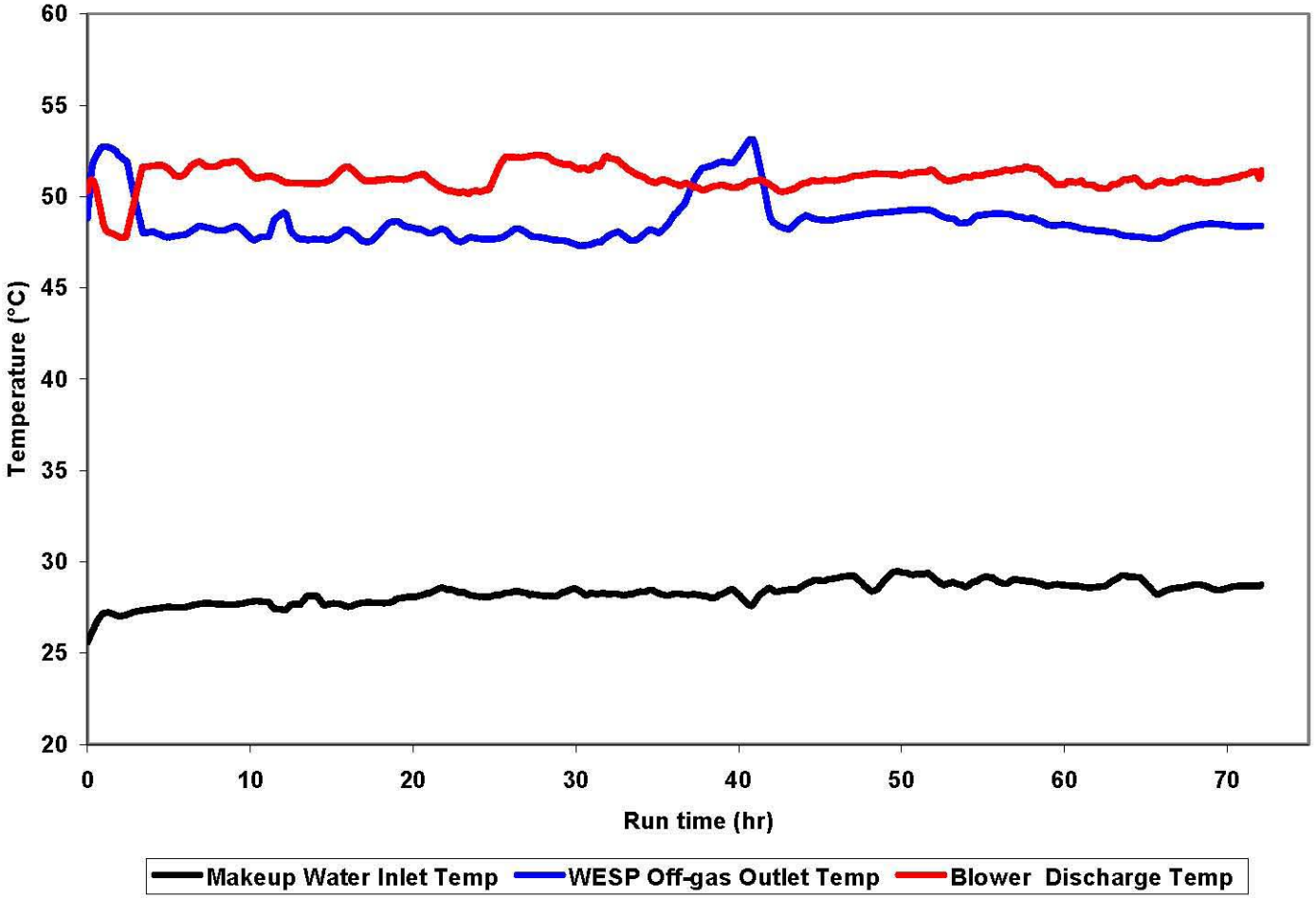


Figure 4.6.d. Test 4 WESP makeup water temperature, WESP outlet temperature, and P-200 discharge temperature (1 hour running average used to reduce noise).

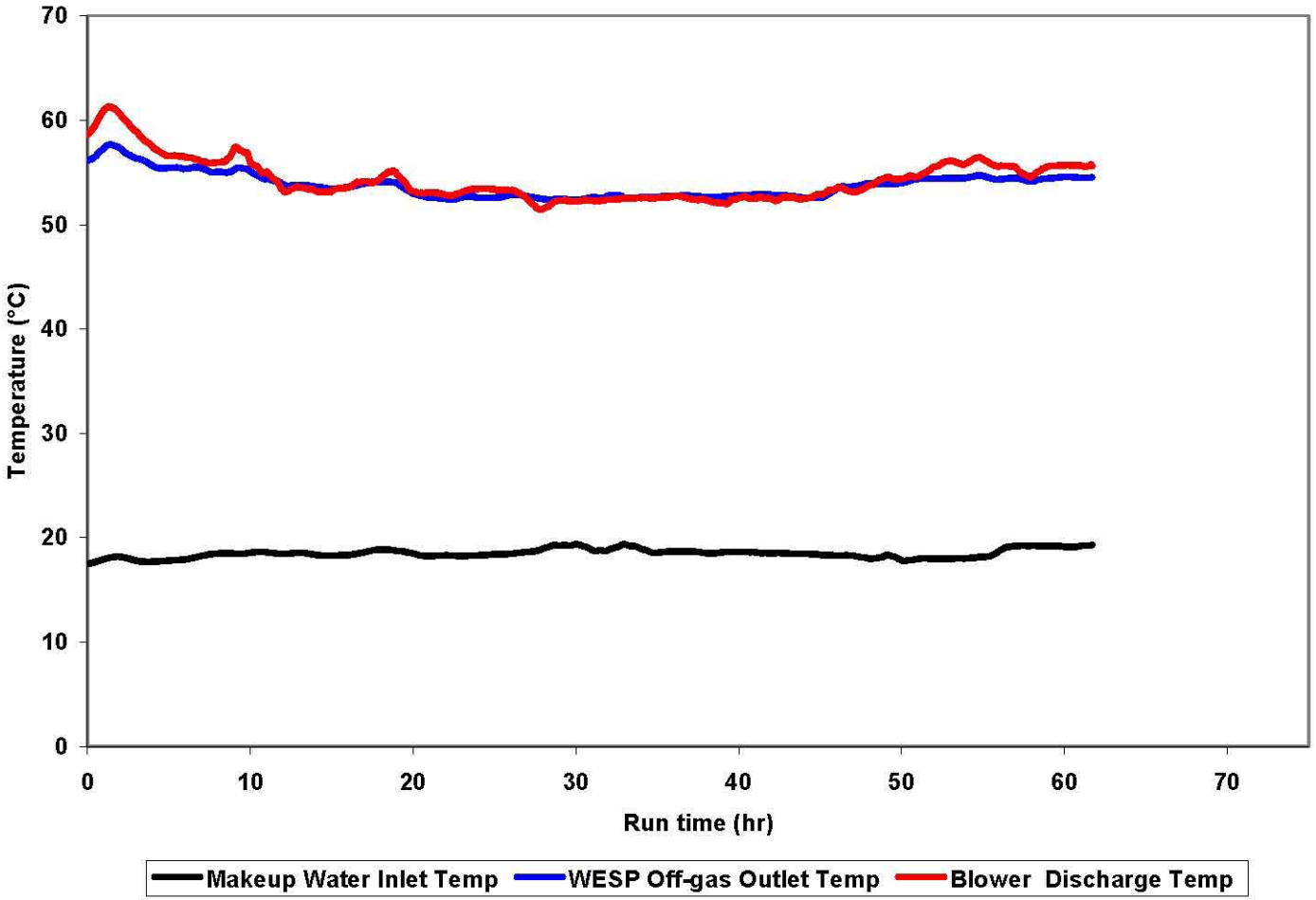


Figure 4.6.e. Test 5 WESP makeup water temperature, WESP outlet temperature, and P-200 discharge temperature (1 hour running average used to reduce noise).

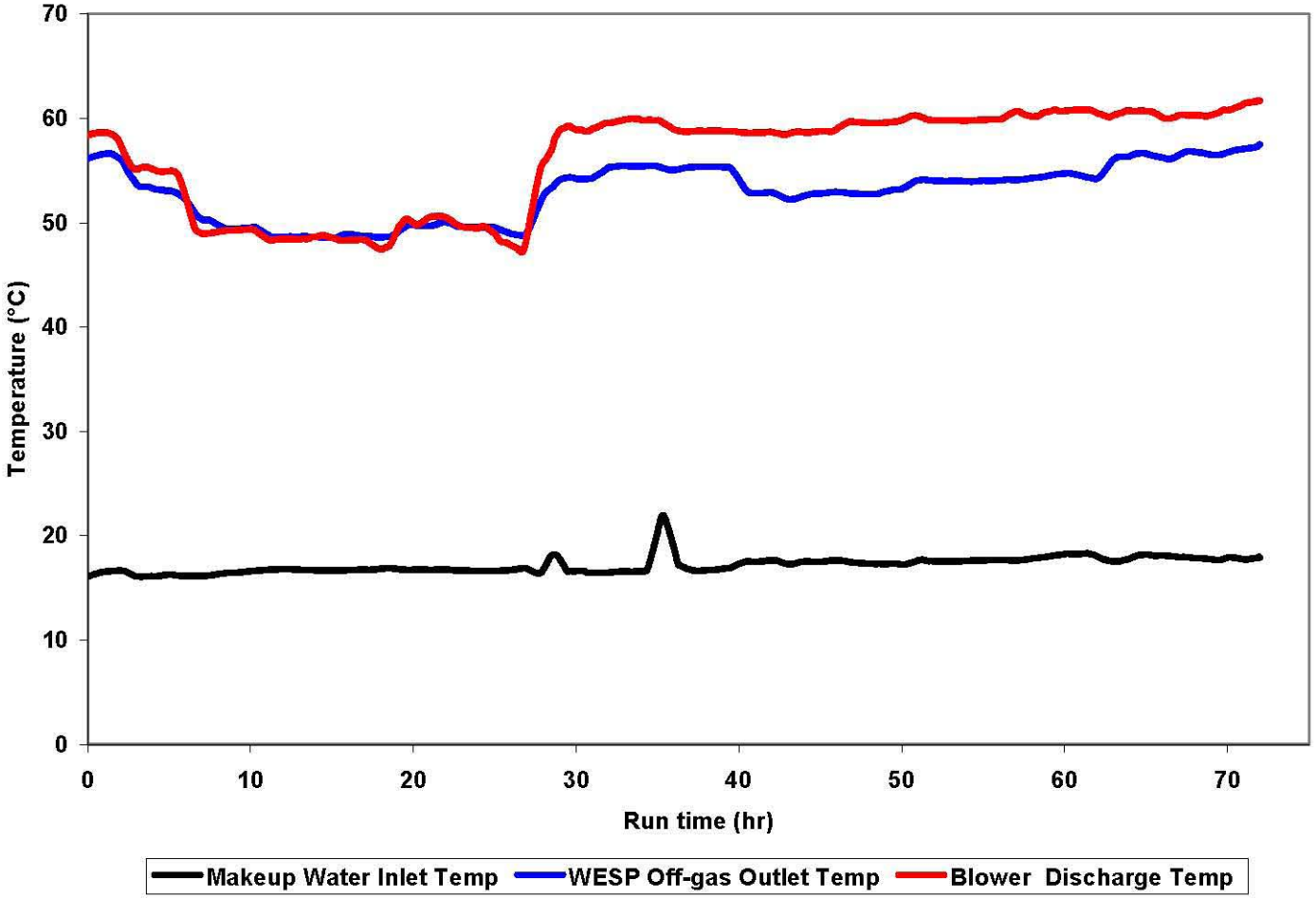


Figure 4.6.f. Test 6 WESP makeup water temperature, WESP outlet temperature, and P-200 discharge temperature (1 hour running average used to reduce noise).

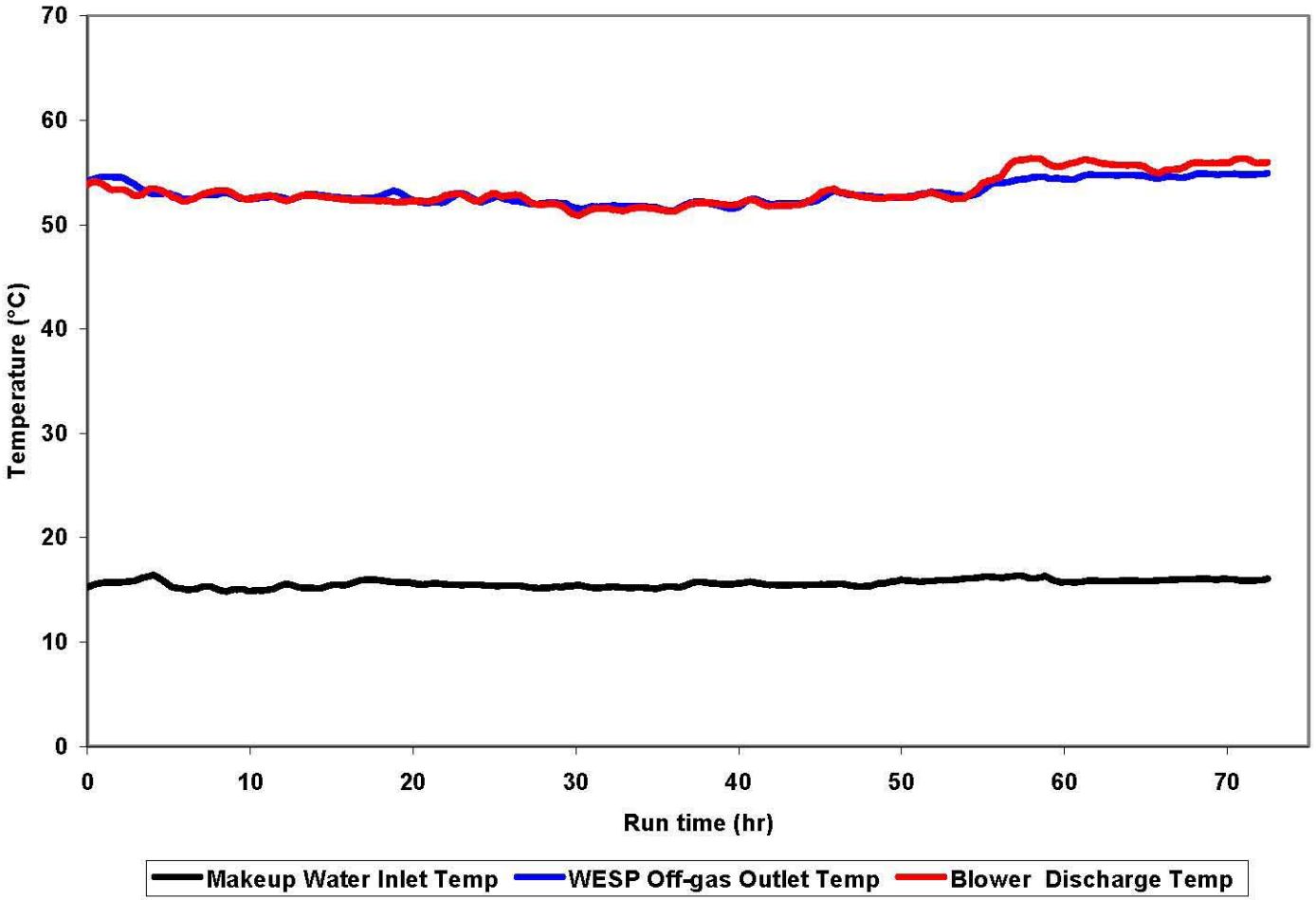


Figure 4.6.g. Test 7 WESP makeup water temperature, WESP outlet temperature, and P-200 discharge temperature (1 hour running average used to reduce noise).

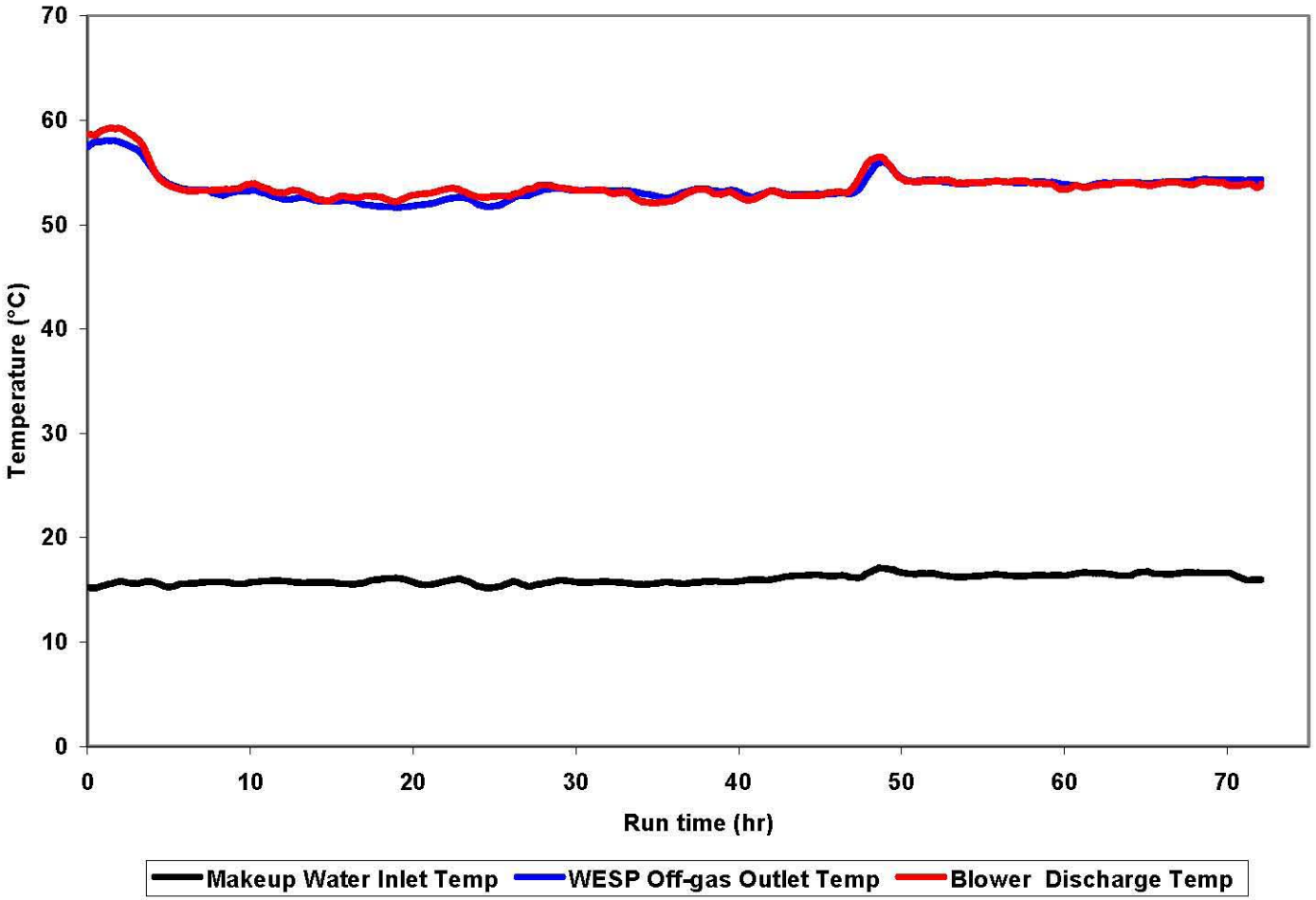


Figure 4.6.h. Test 8 WESP makeup water temperature, WESP outlet temperature, and P-200 discharge temperature (1 hour running average used to reduce noise).

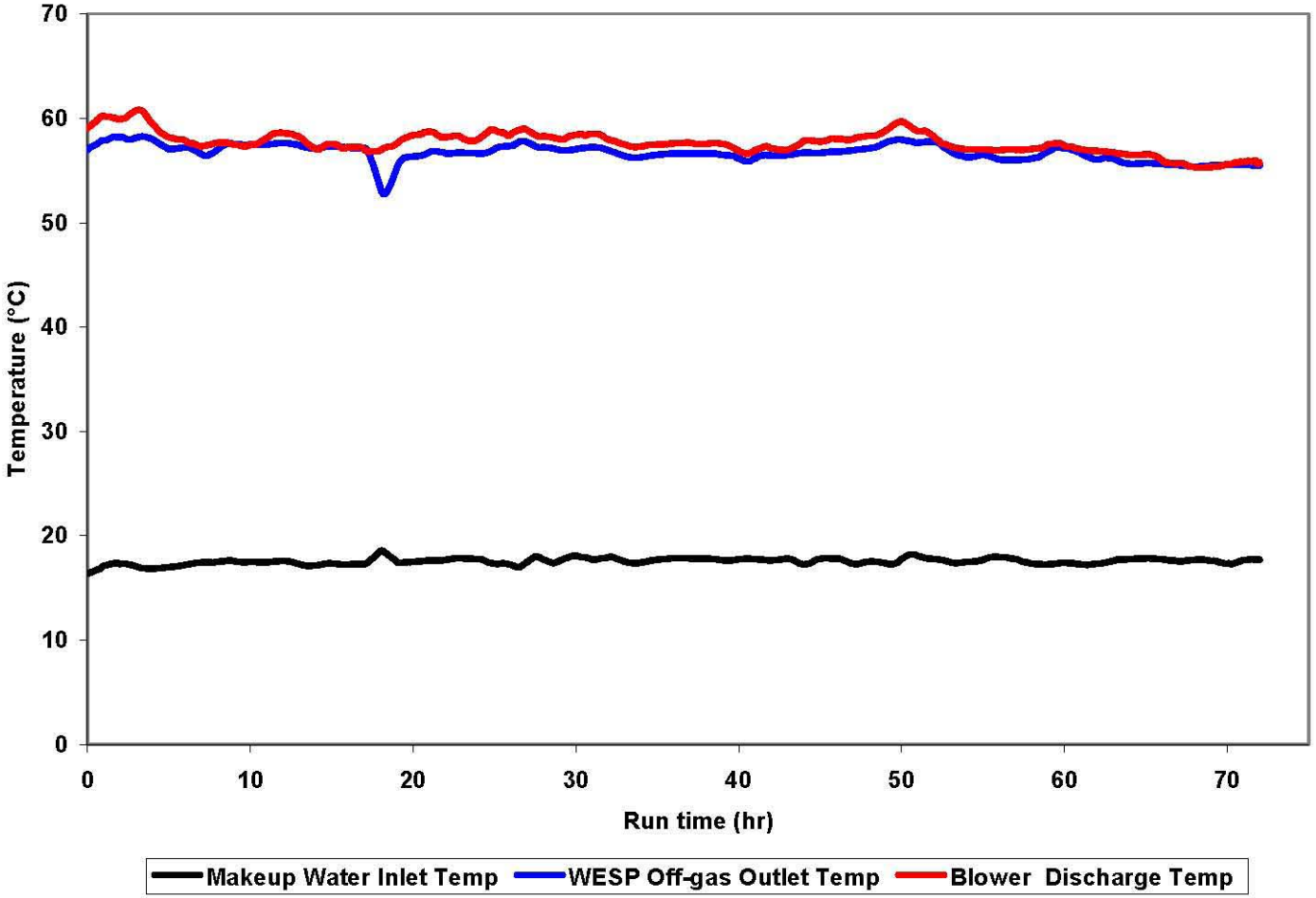


Figure 4.6.i. Test 9 WESP makeup water temperature, WESP outlet temperature, and P-200 discharge temperature (1 hour running average used to reduce noise).

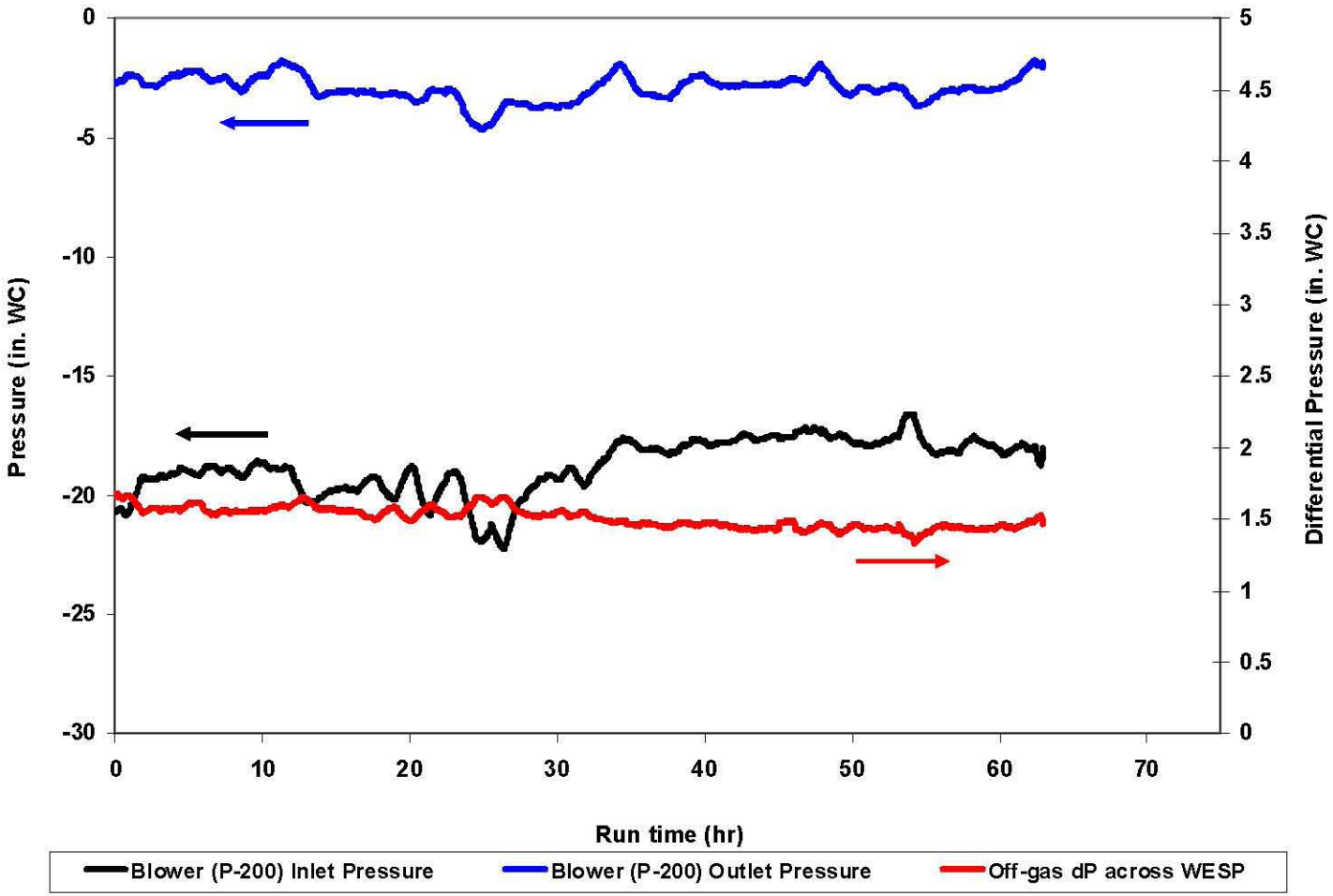


Figure 4.7.a. Test 1 pressure upstream and downstream from P-200, and differential pressure across the WESP (1 hour running average used to reduce noise).

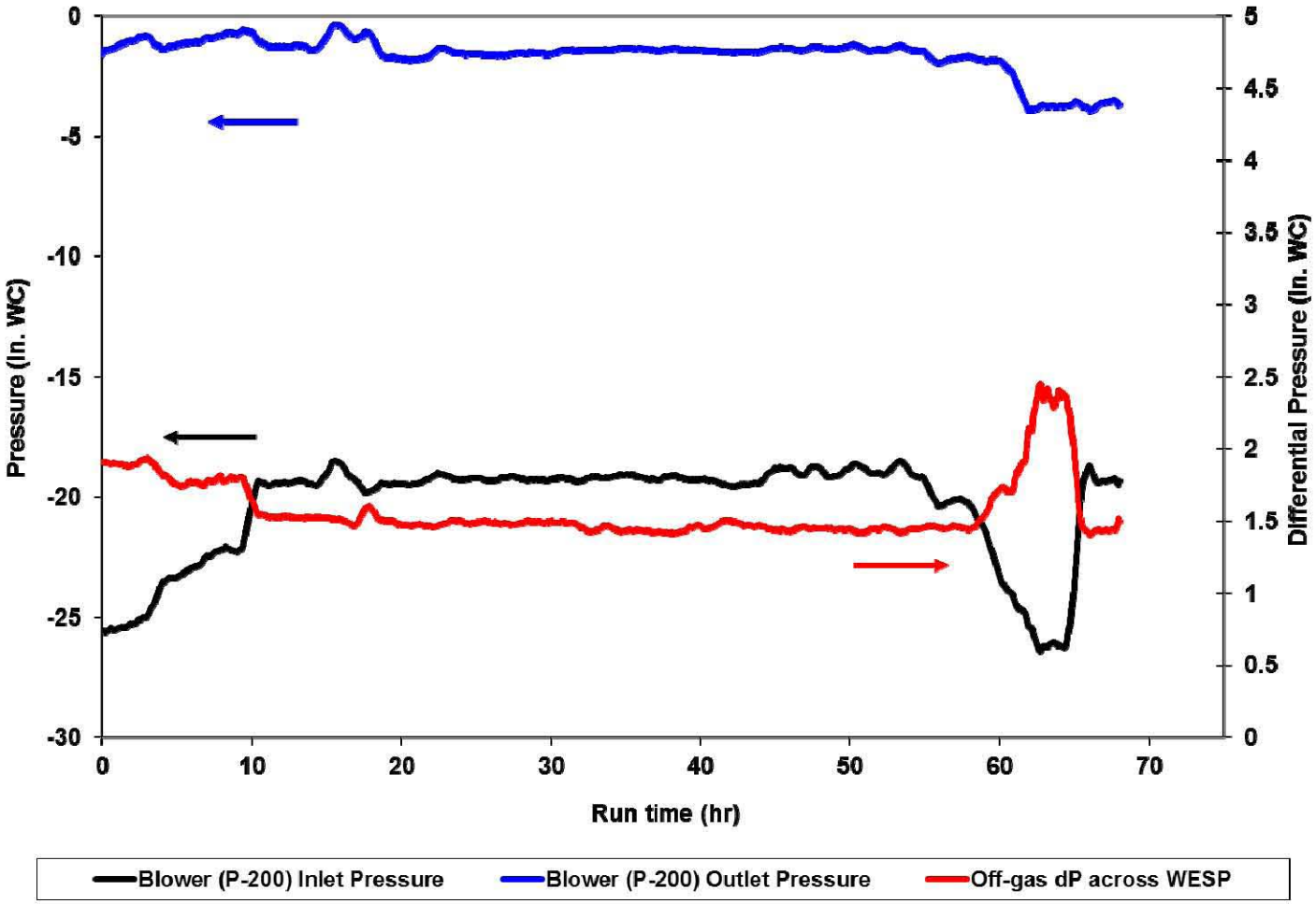


Figure 4.7.b. Test 2 pressure upstream and downstream from P-200, and differential pressure across the WESP (1 hour running average used to reduce noise).

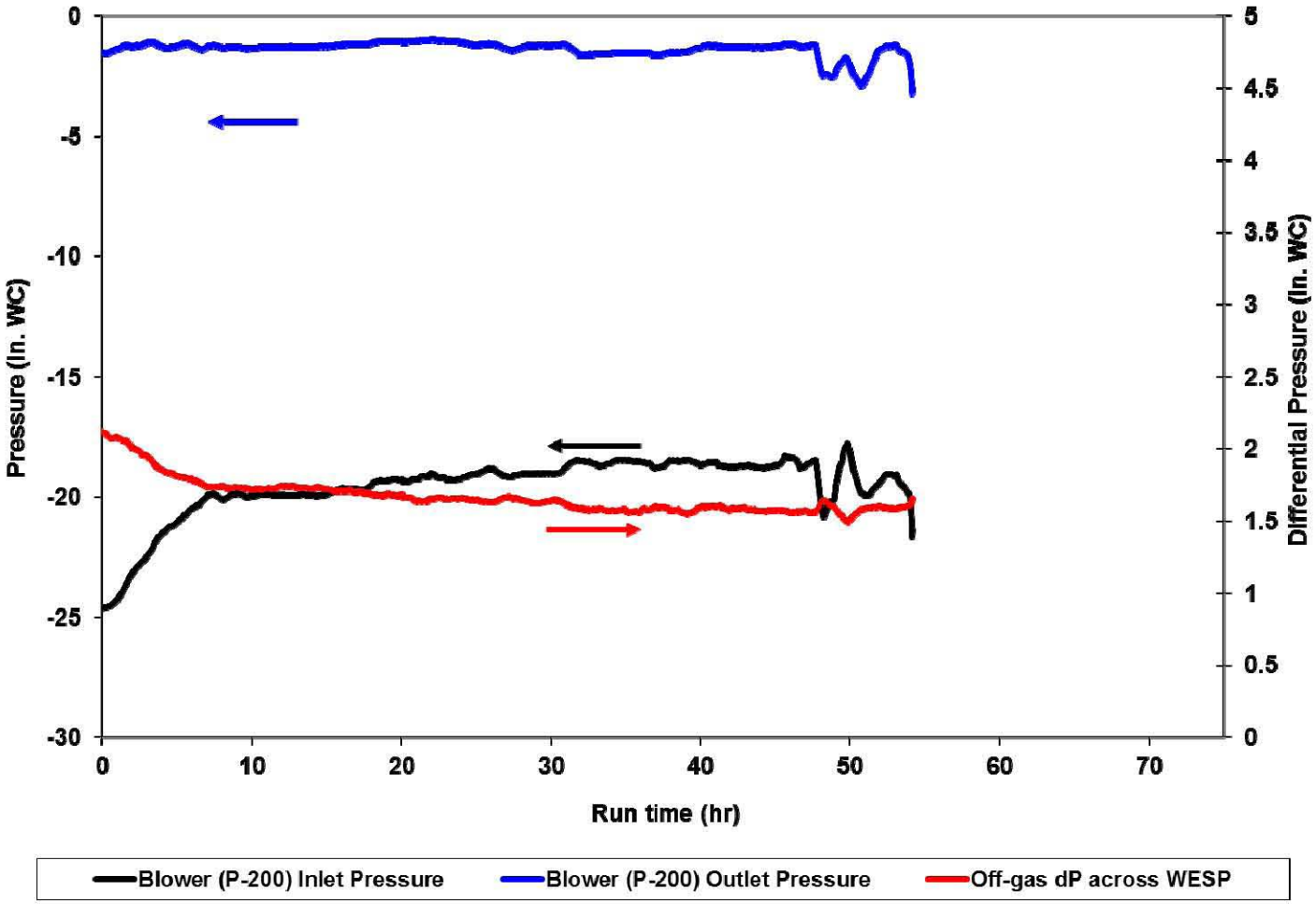


Figure 4.7.c. Test 3 pressure upstream and downstream from P-200, and differential pressure across the WESP (1 hour running average used to reduce noise).

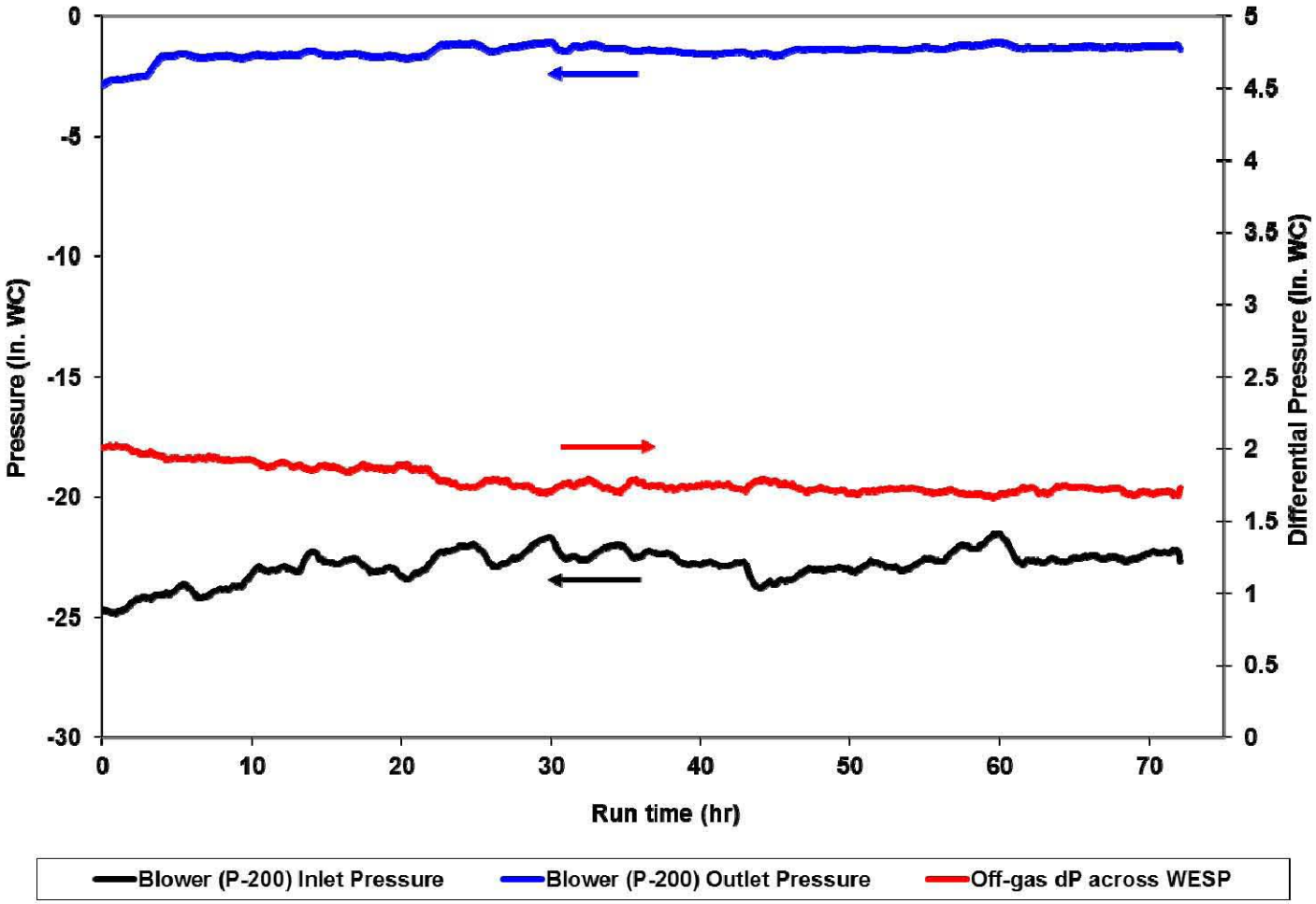


Figure 4.7.d. Test 4 pressure upstream and downstream from P-200, and differential pressure across the WESP (1 hour running average used to reduce noise).

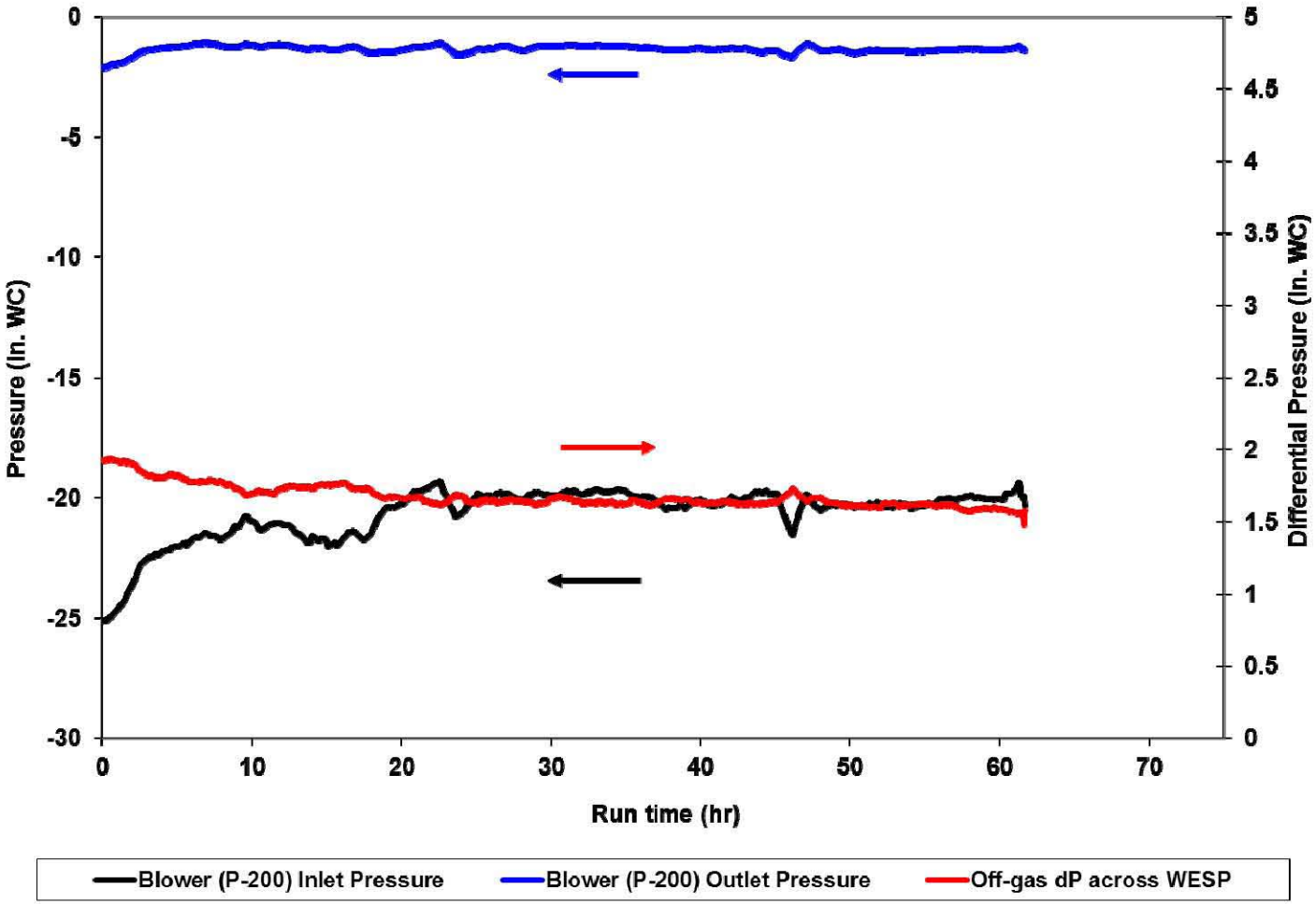


Figure 4.7.e. Test 5 pressure upstream and downstream from P-200, and differential pressure across the WESP (1 hour running average used to reduce noise).

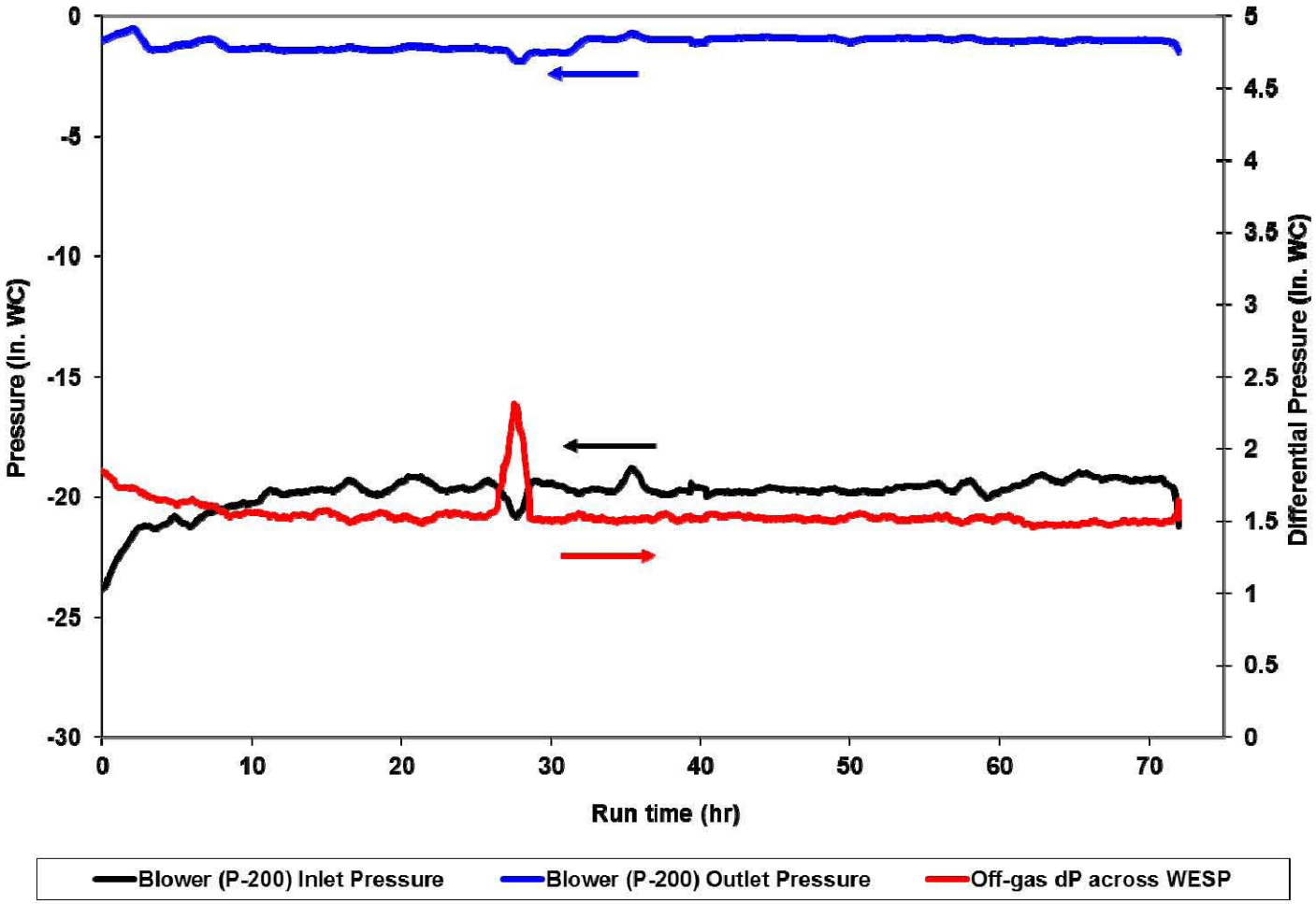


Figure 4.7.f. Test 6 pressure upstream and downstream from P-200, and differential pressure across the WESP (1 hour running average used to reduce noise).

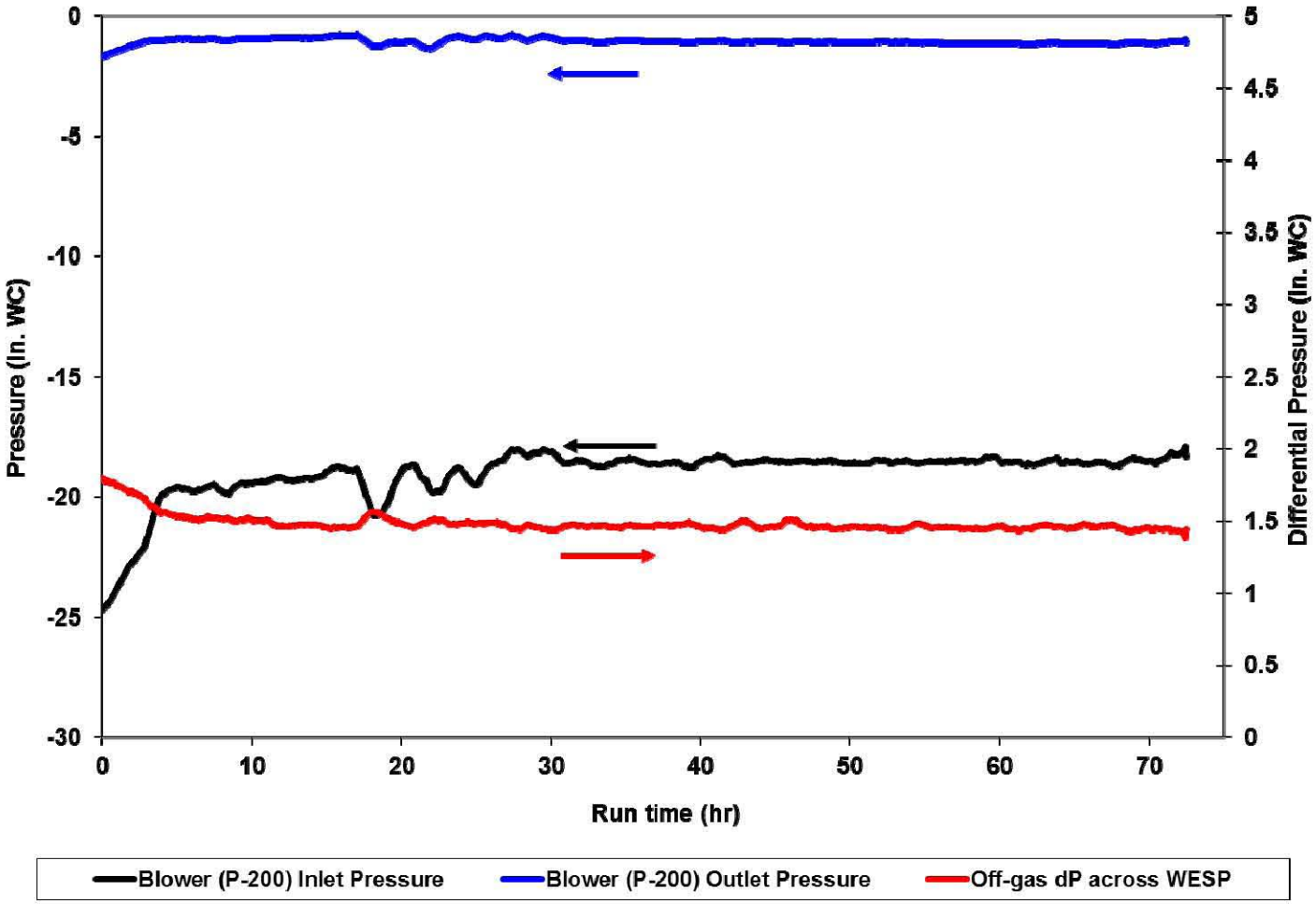


Figure 4.7.g. Test 7 pressure upstream and downstream from P-200, and differential pressure across the WESP (1 hour running average used to reduce noise).

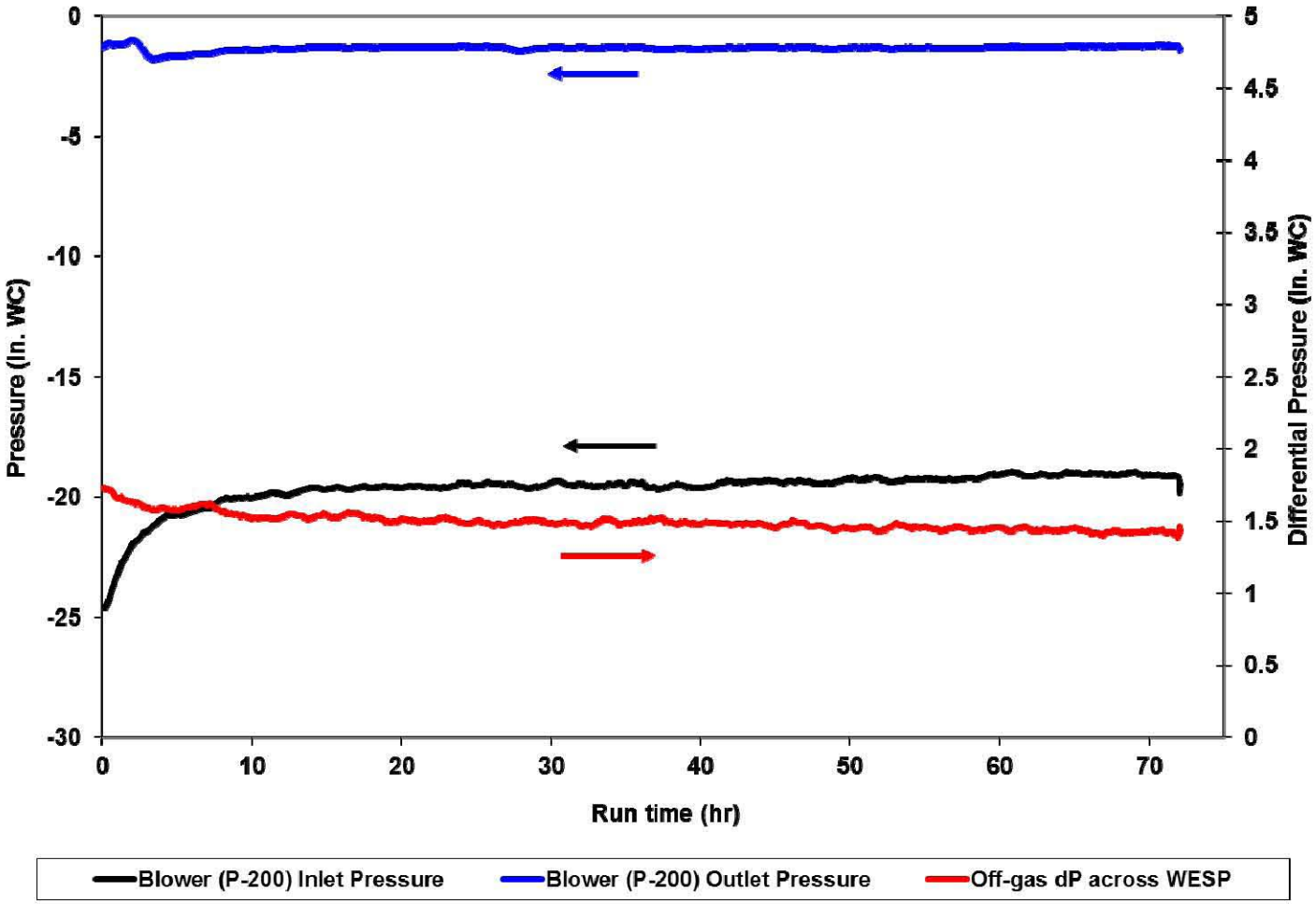


Figure 4.7.h. Test 8 pressure upstream and downstream from P-200, and differential pressure across the WESP (1 hour running average used to reduce noise).

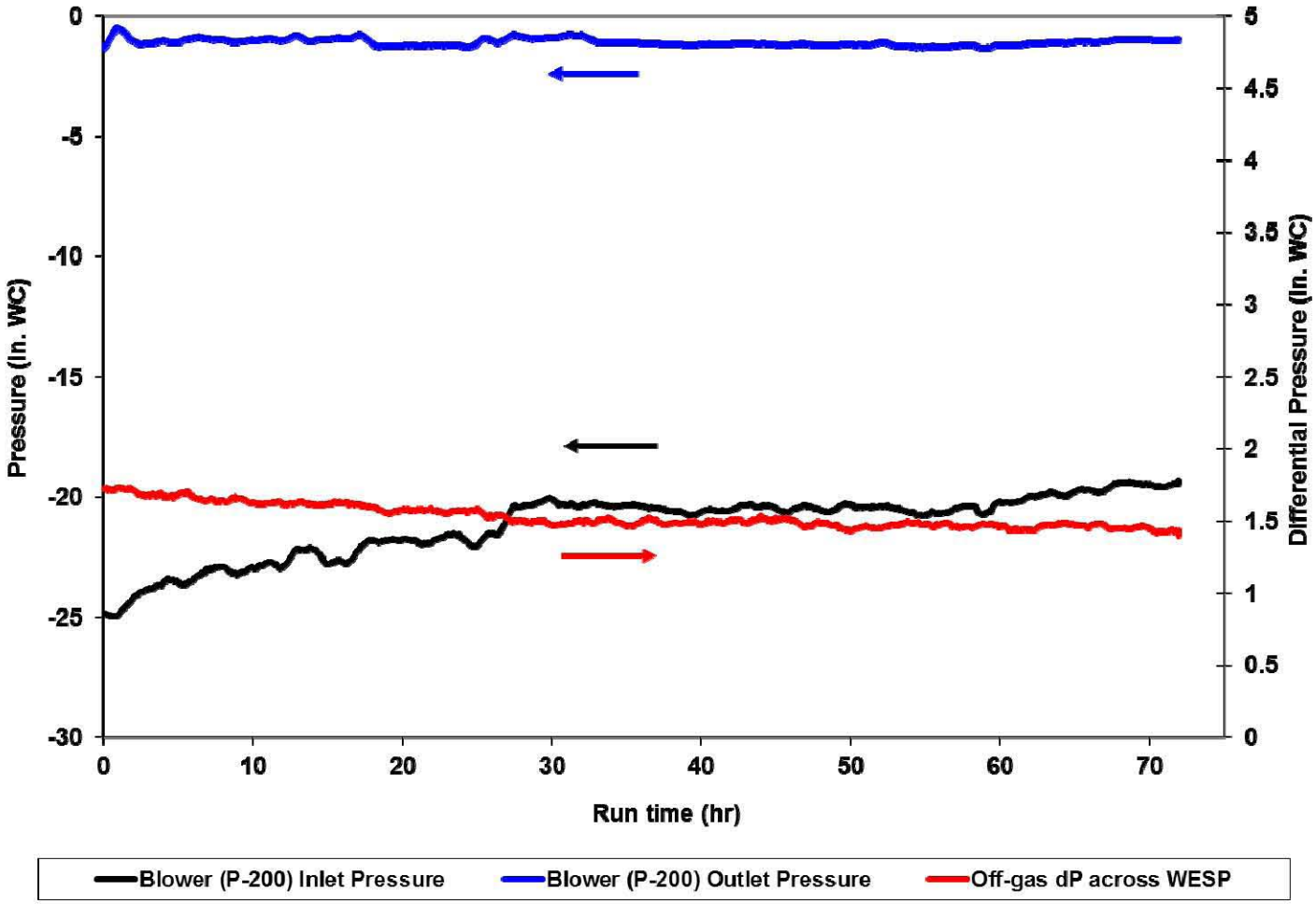


Figure 4.7.i. Test 9 pressure upstream and downstream from P-200, and differential pressure across the WESP (1 hour running average used to reduce noise).

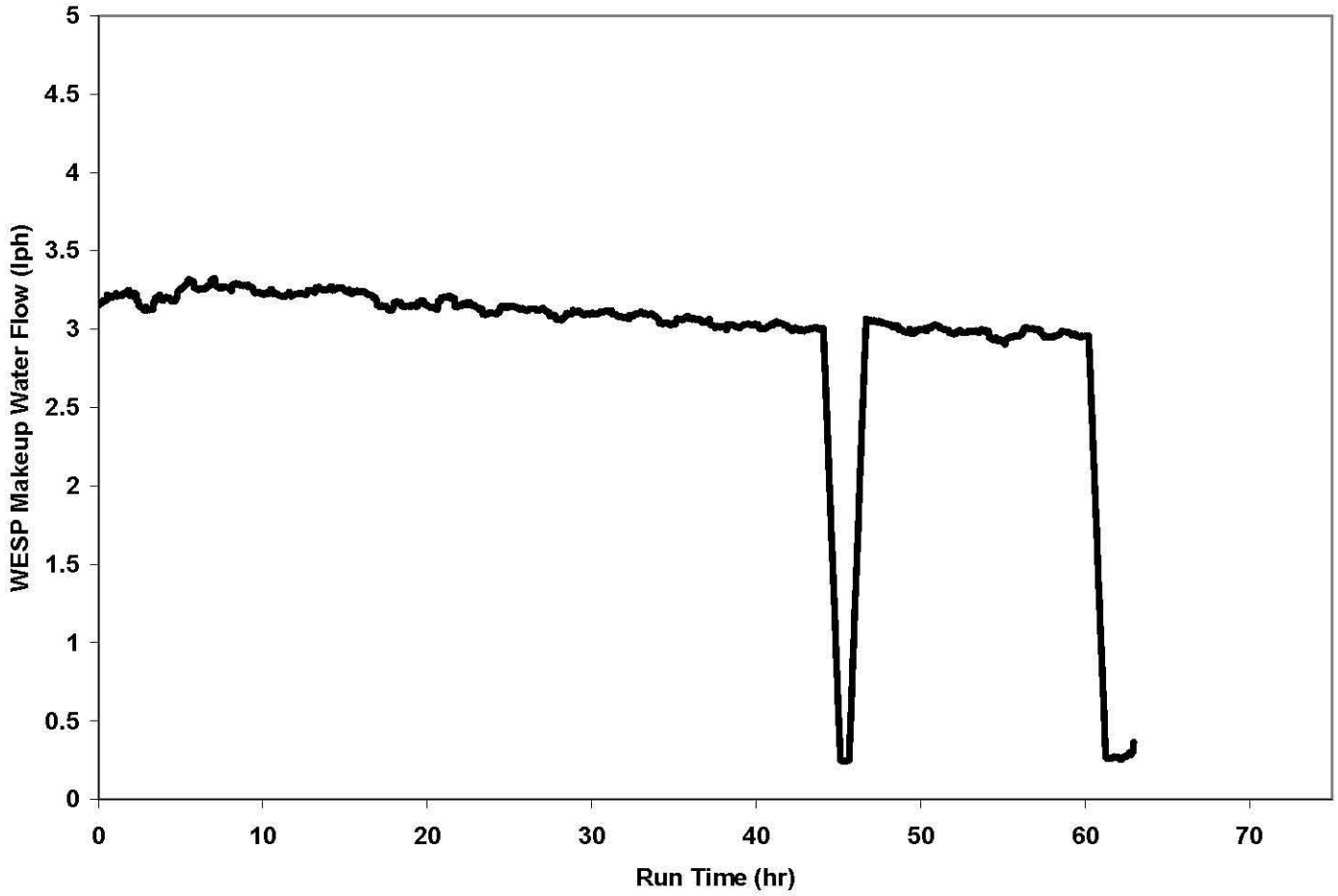


Figure 4.8.a. Test 1 WESP makeup water flow rate (1 hour running average used to reduce noise).

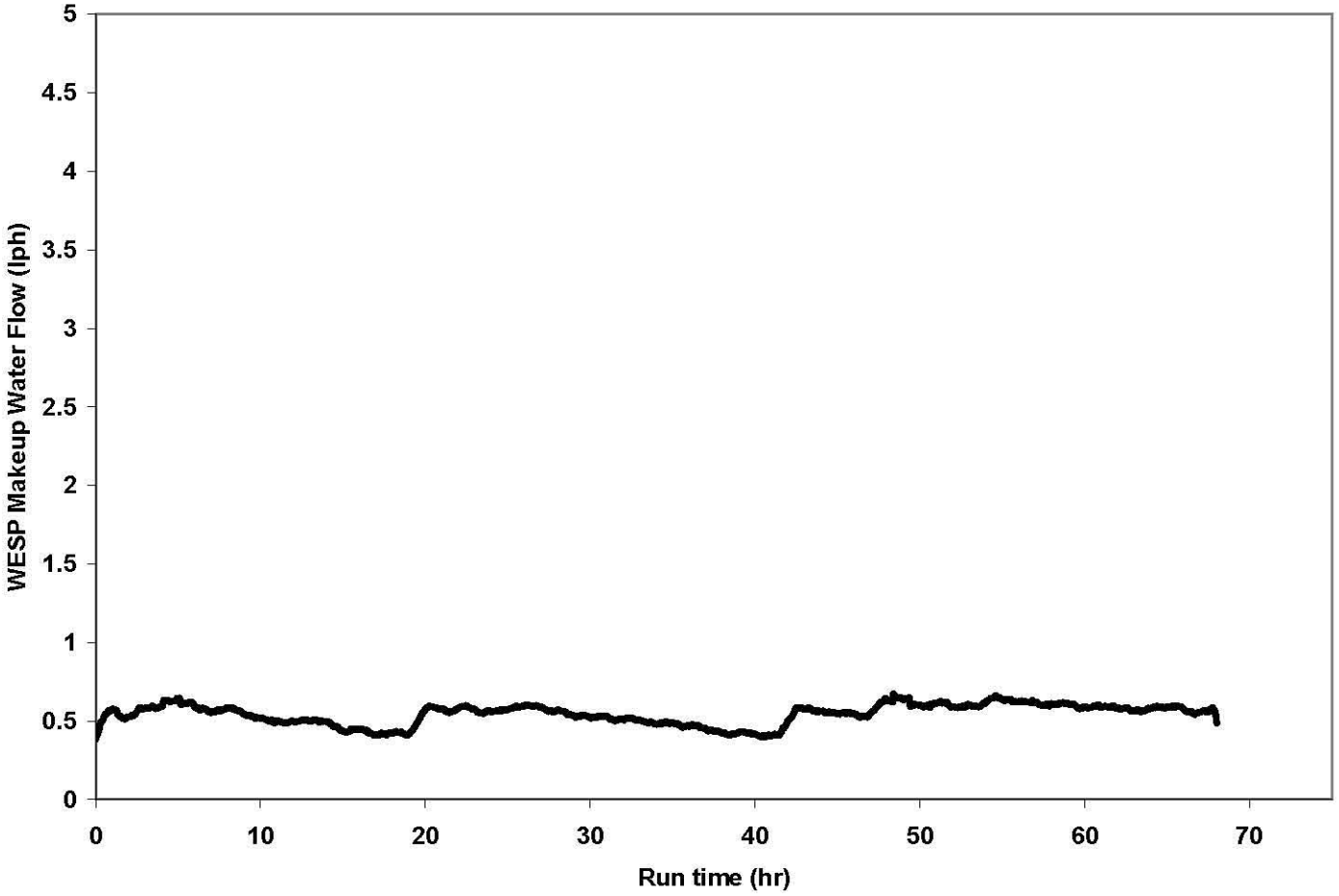


Figure 4.8.b. Test 2 WESP makeup water flow rate (1 hour running average used to reduce noise).

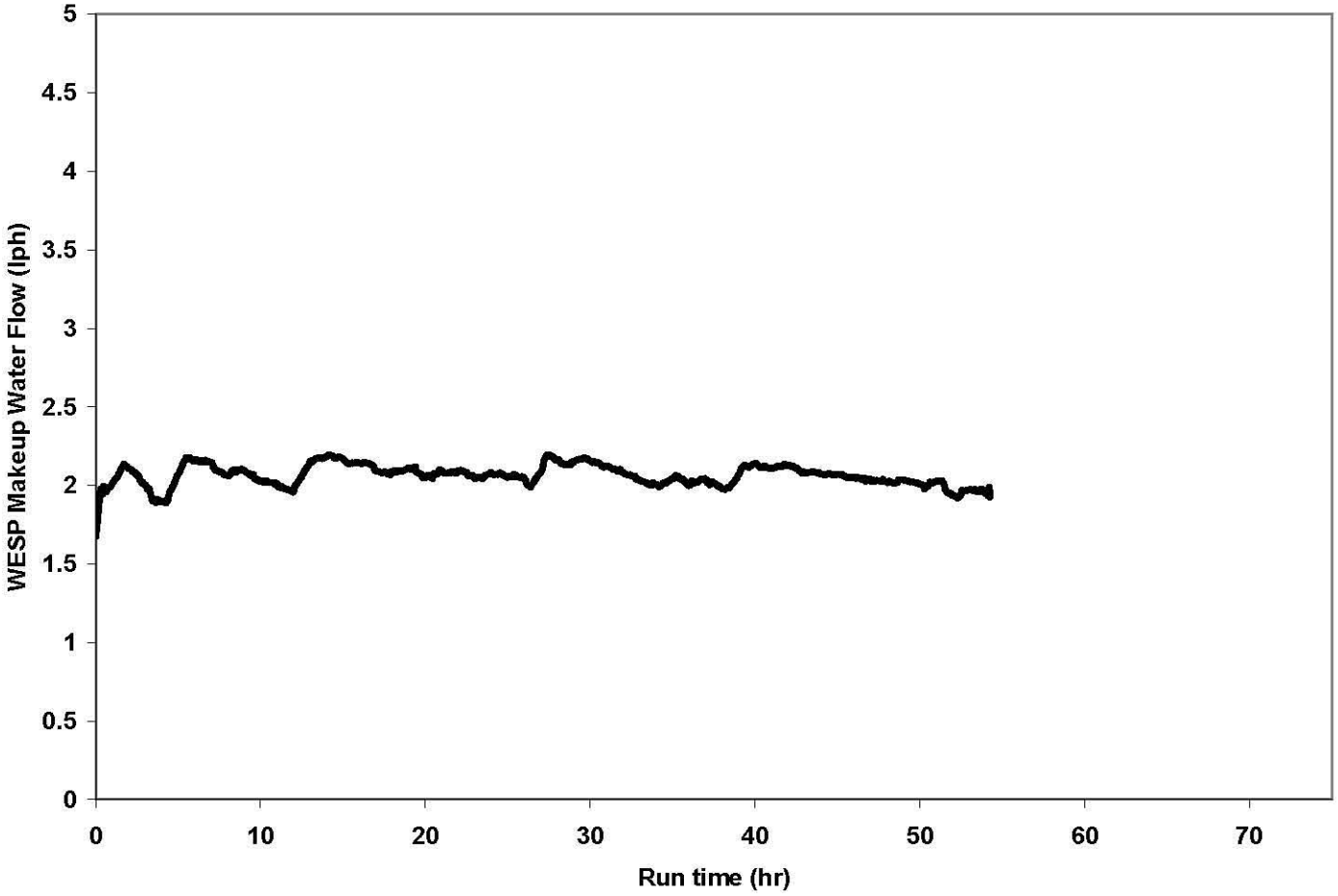


Figure 4.8.c. Test 3 WESP makeup water flow rate (1 hour running average used to reduce noise).

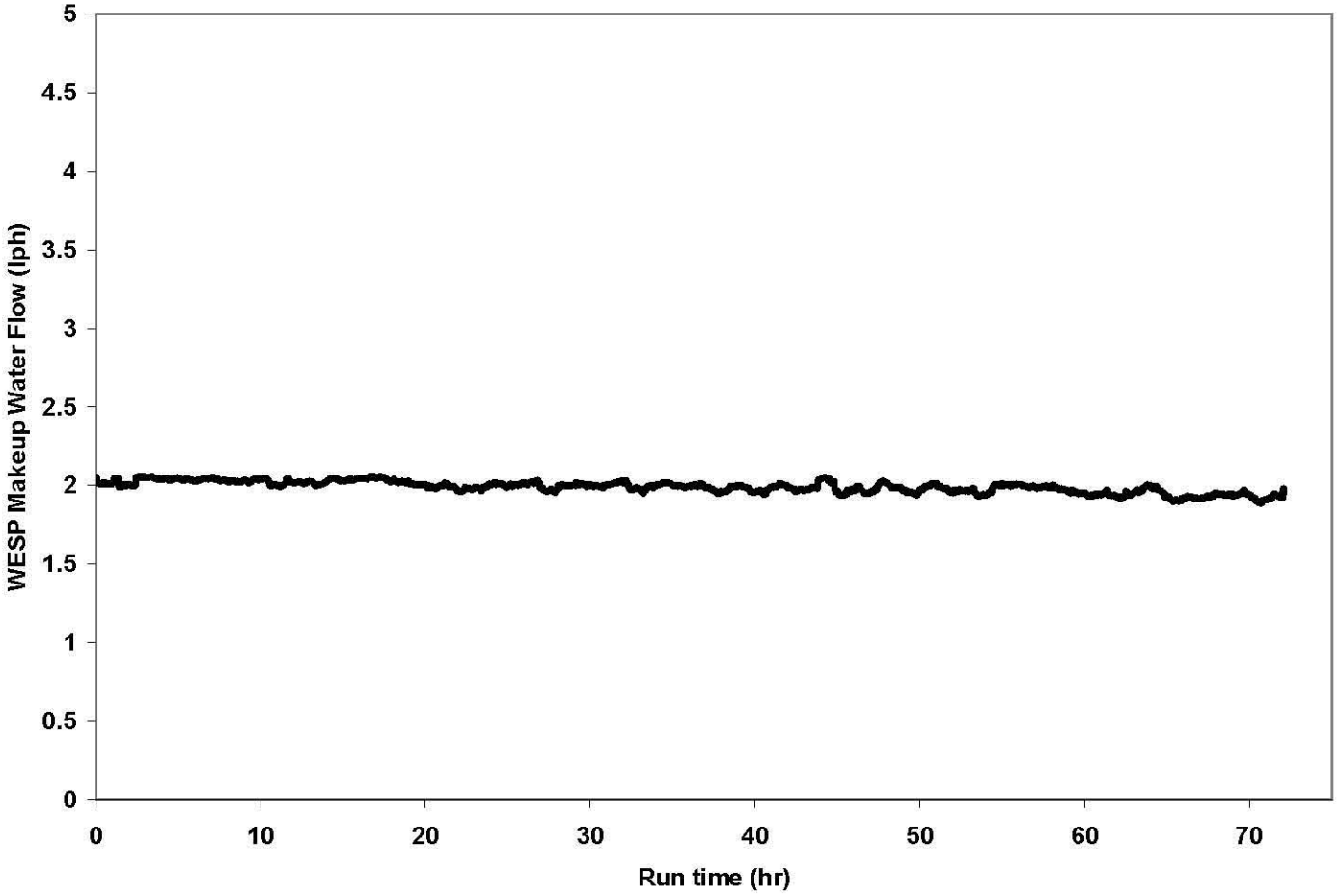


Figure 4.8.d. Test 4 WESP makeup water flow rate (1 hour running average used to reduce noise).

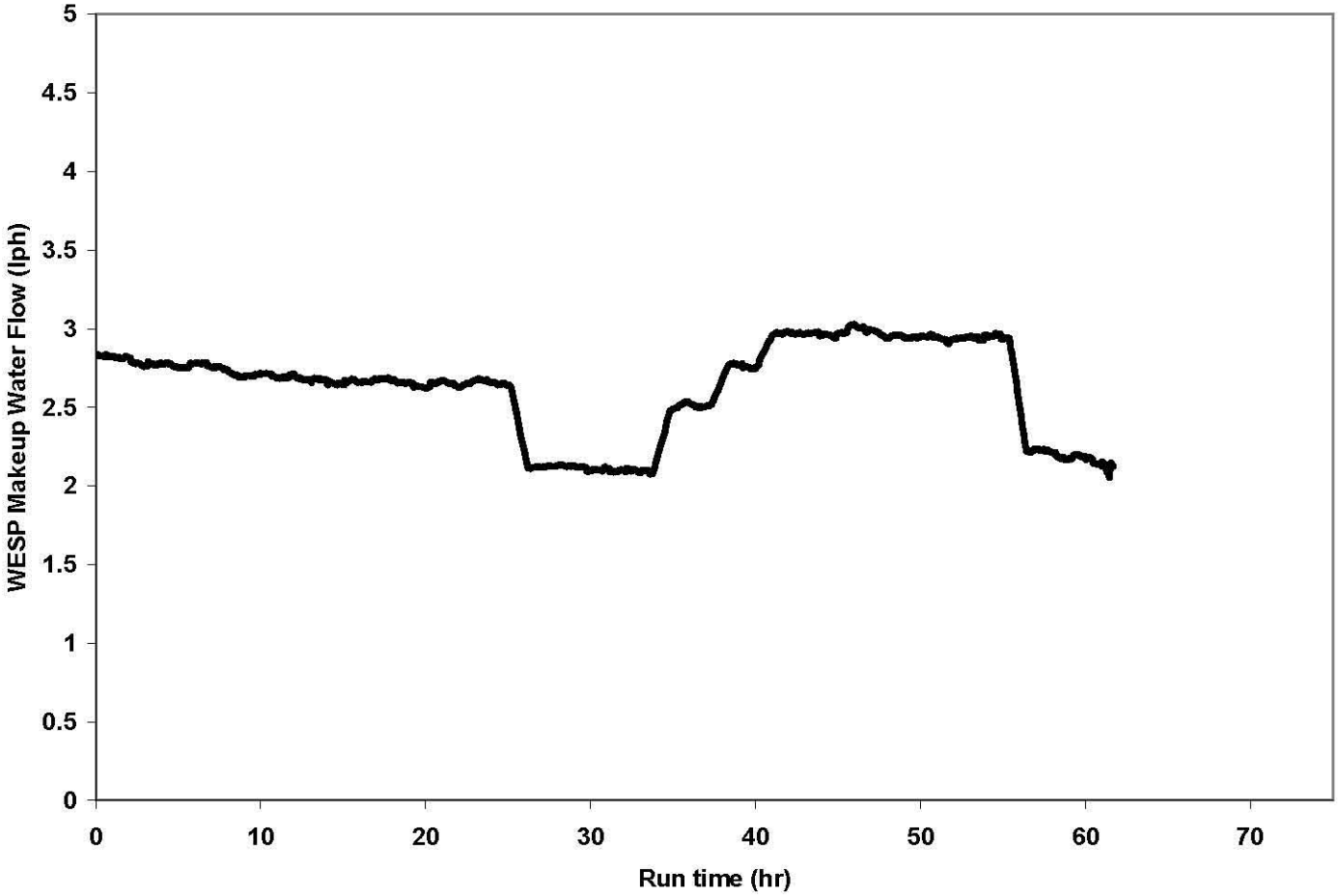


Figure 4.8.e. Test 5 WESP makeup water flow rate (1 hour running average used to reduce noise).

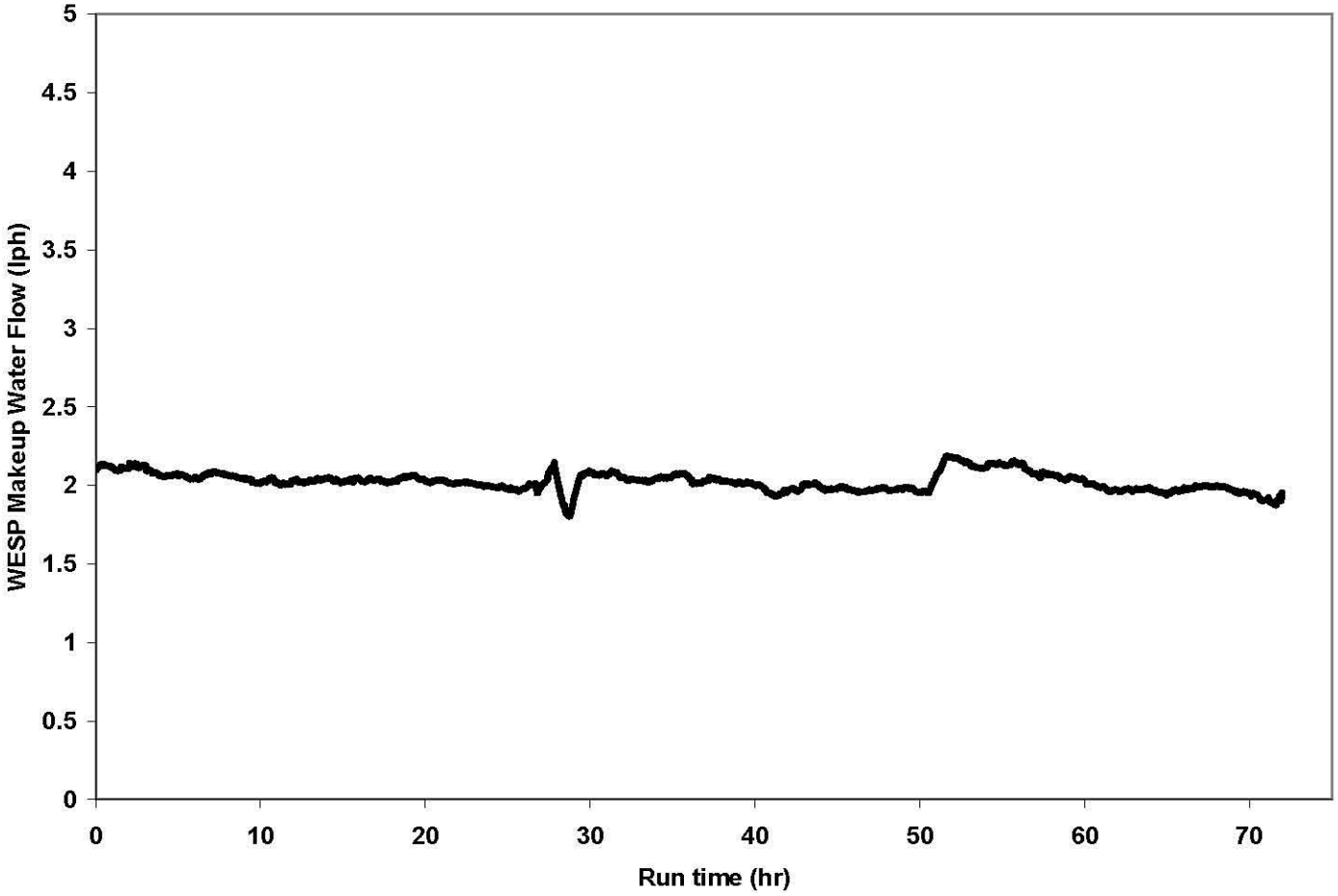


Figure 4.8.f. Test 6 WESP makeup water flow rate (1 hour running average used to reduce noise).

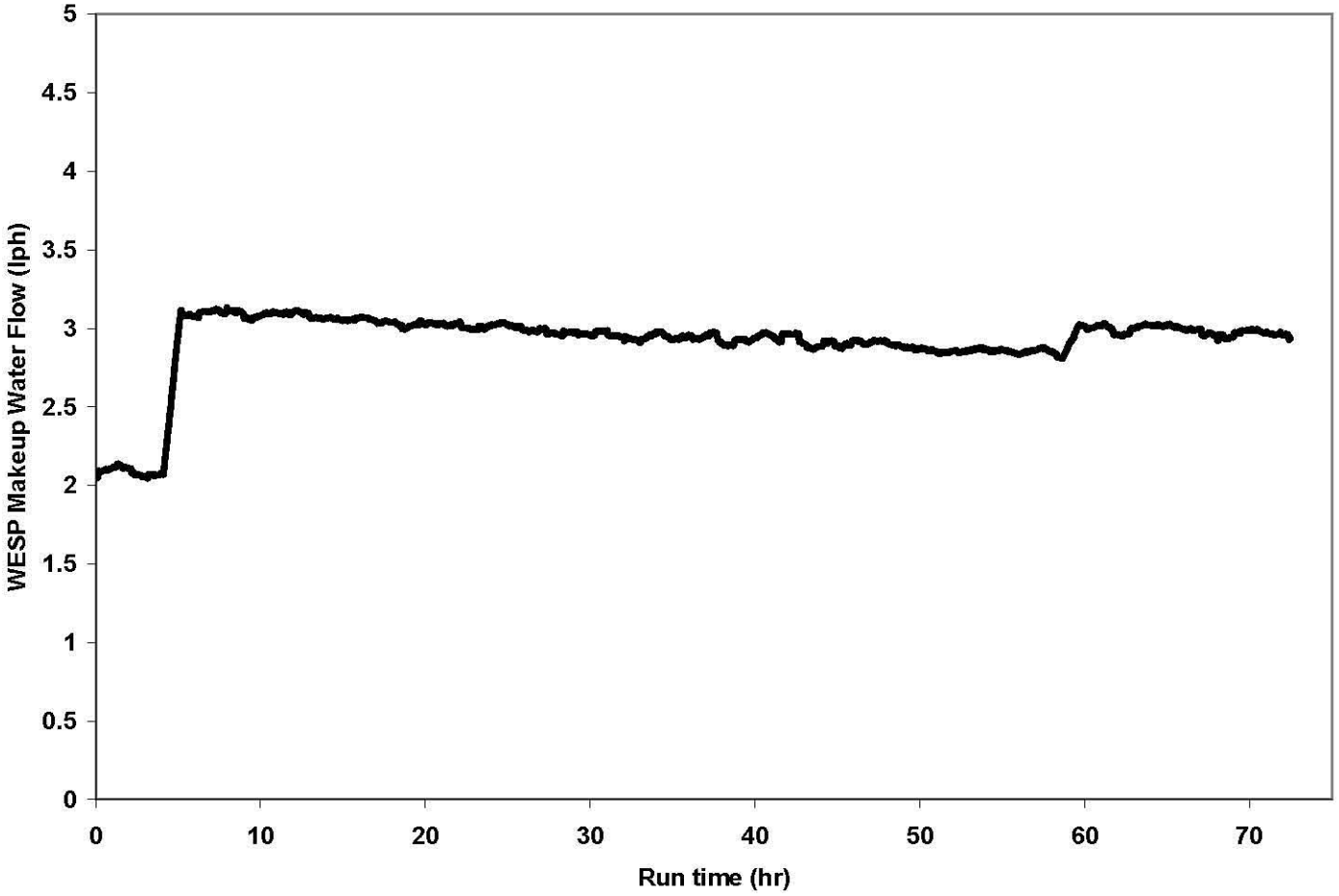


Figure 4.8.g. Test 7 WESP makeup water flow rate (1 hour running average used to reduce noise).

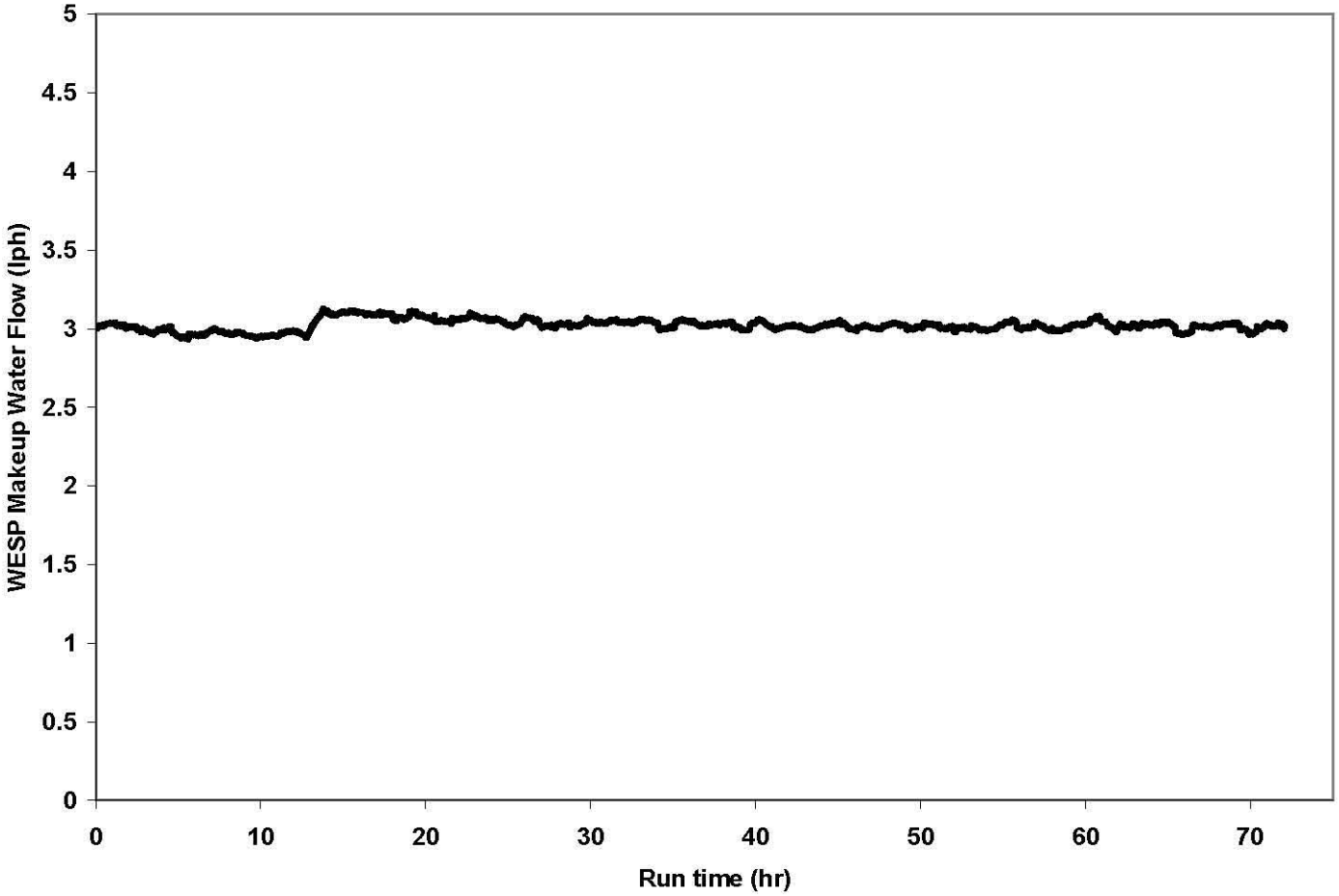


Figure 4.8.h. Test 8 WESP makeup water flow rate (1 hour running average used to reduce noise).

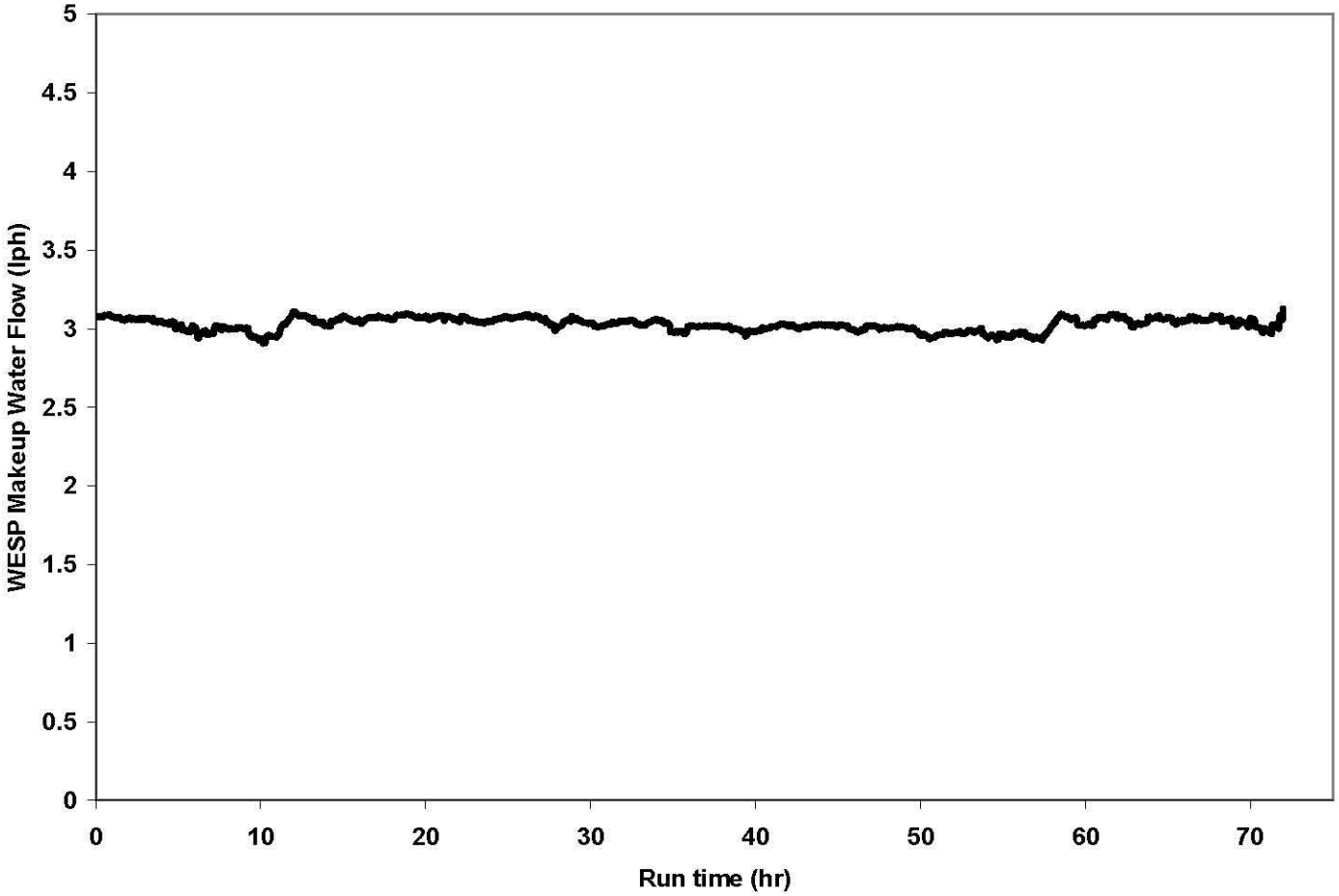


Figure 4.8.i. Test 9 WESP makeup water flow rate (1 hour running average used to reduce noise).

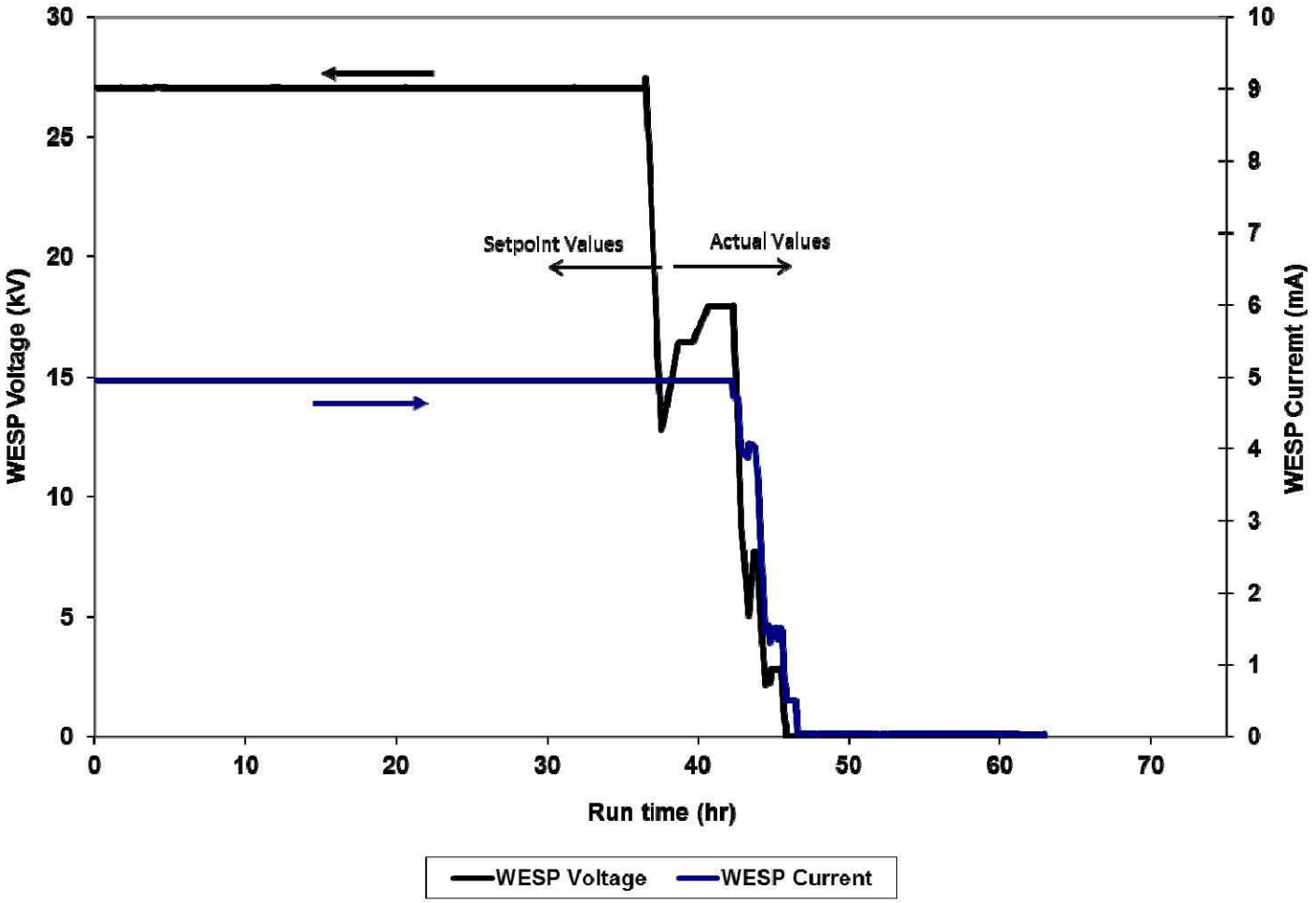


Figure 4.9.a. Test 1 WESP voltage and current (1 hour running average used to reduce noise).

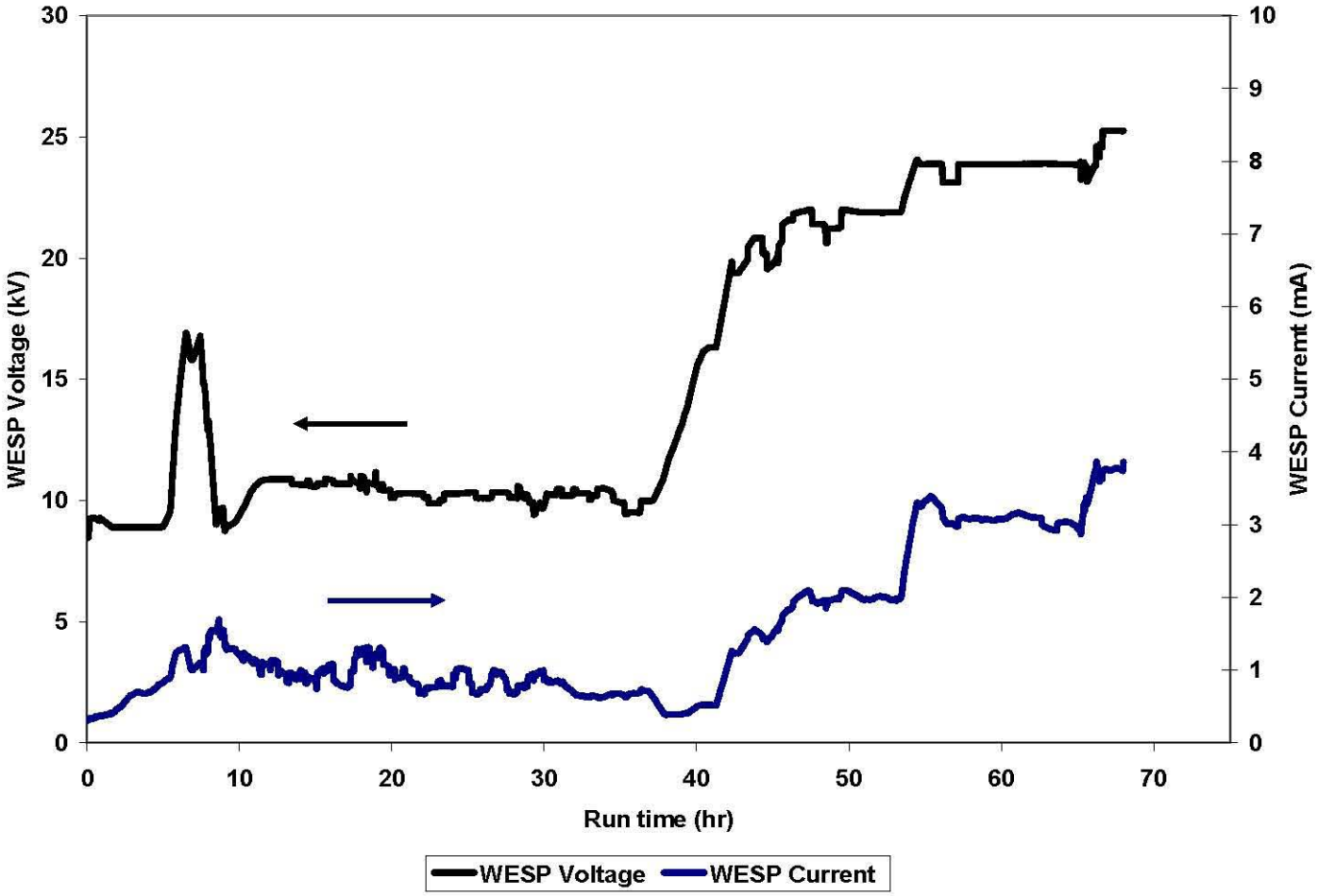


Figure 4.9.b. Test 2 WESP voltage and current (1 hour running average used to reduce noise).

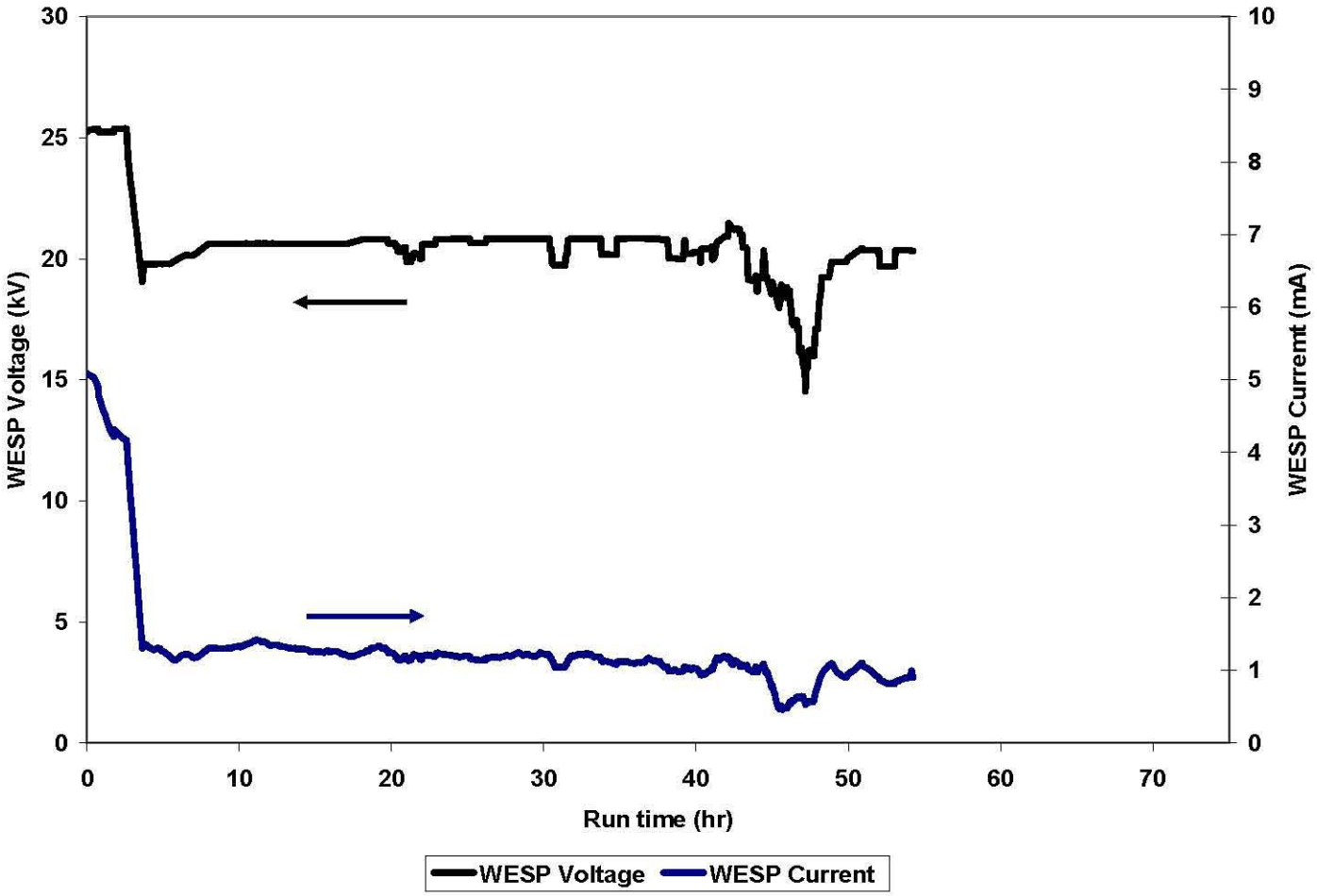


Figure 4.9.c. Test 3 WESP voltage and current (1 hour running average used to reduce noise).

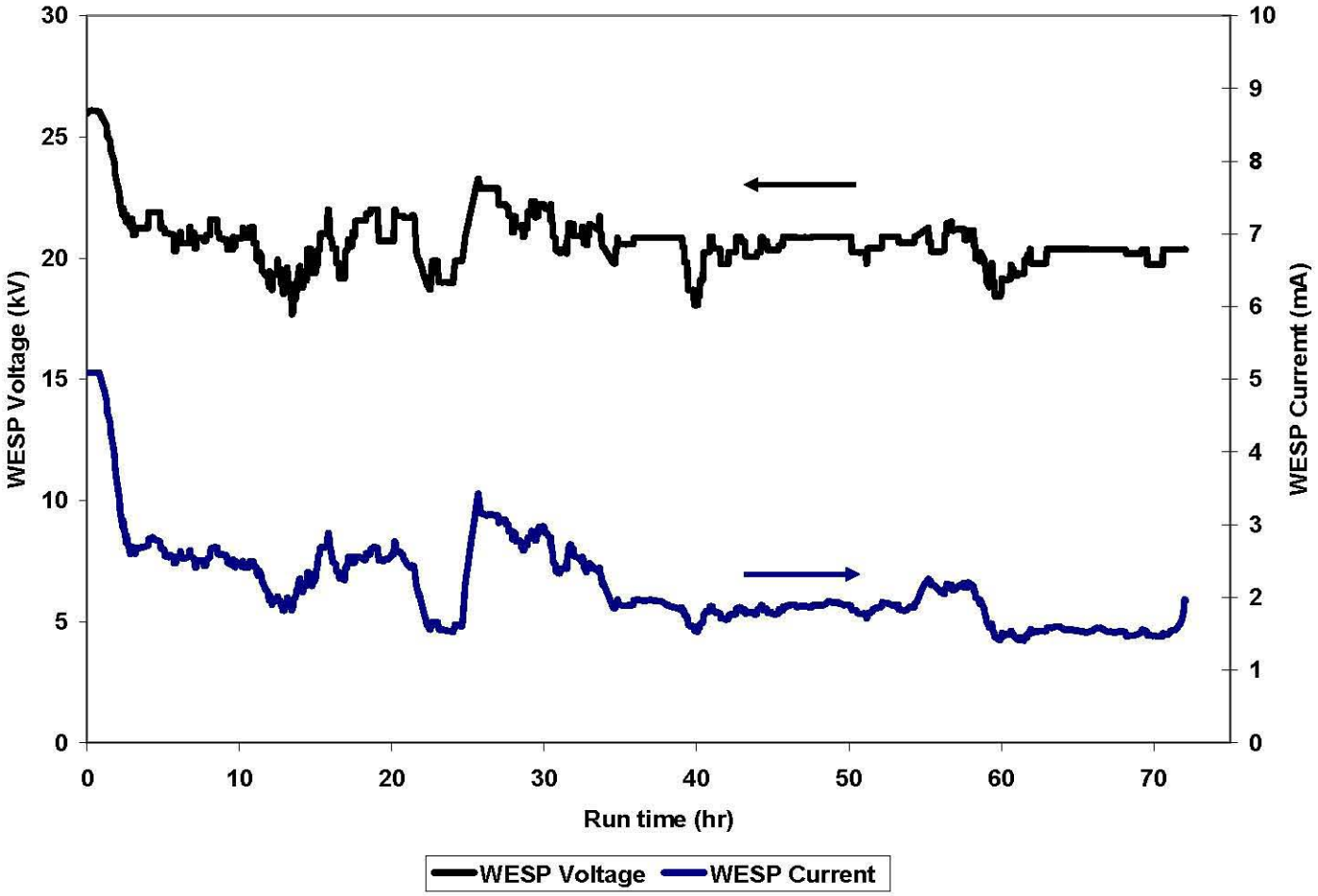


Figure 4.9.d. Test 4 WESP voltage and current (1 hour running average used to reduce noise).

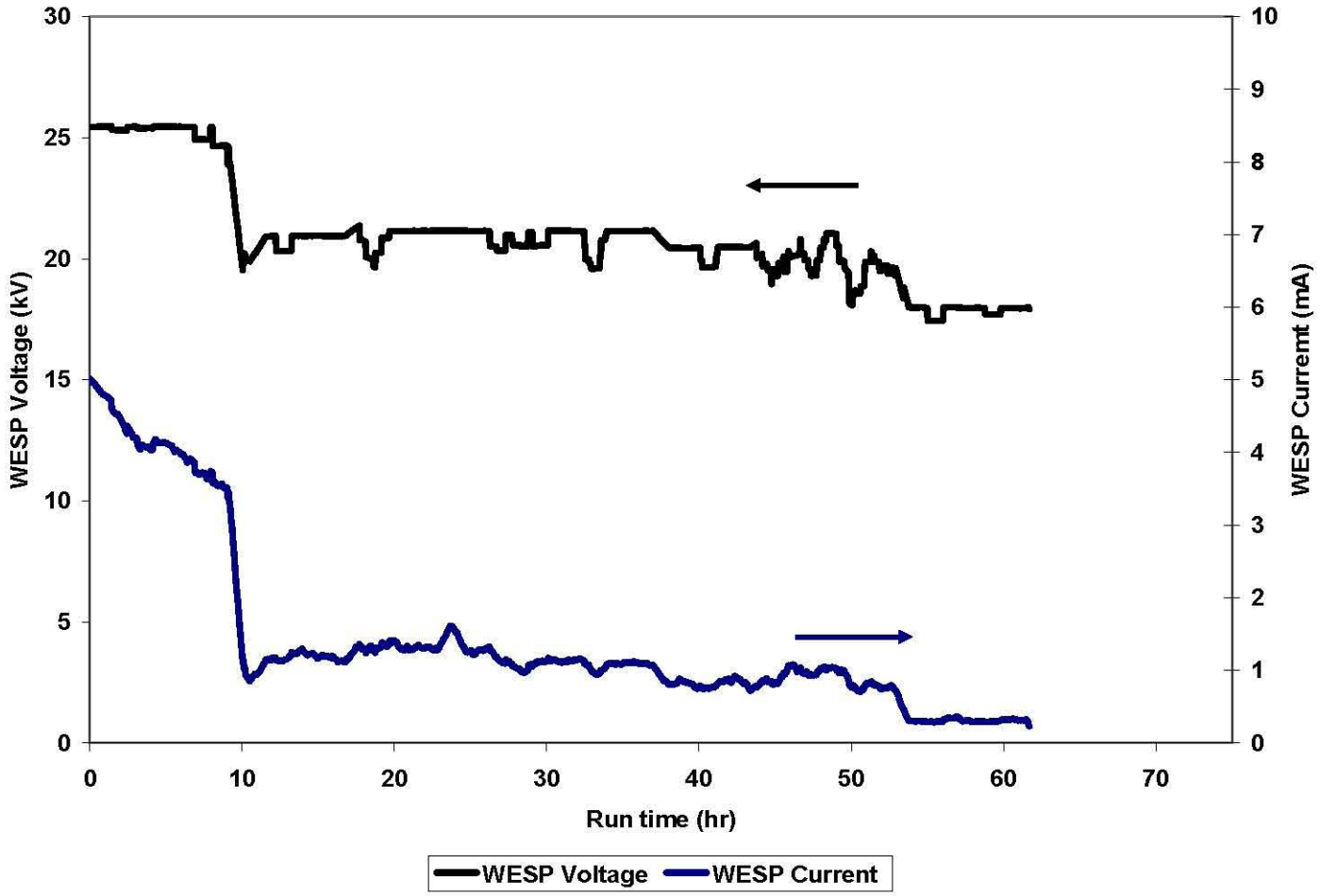


Figure 4.9.e. Test 5 WESP voltage and current (1 hour running average used to reduce noise).

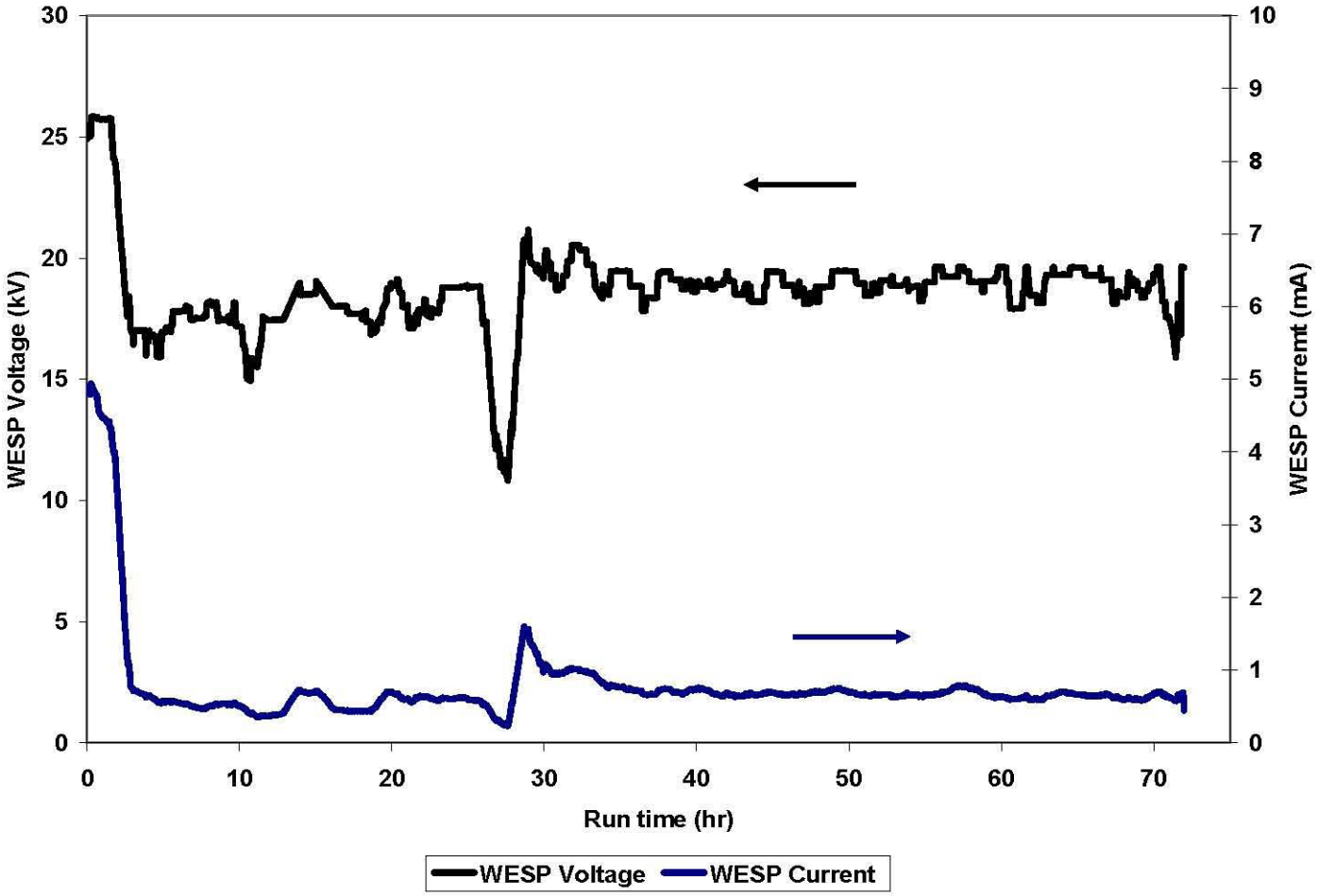


Figure 4.9.f. Test 6 WESP voltage and current (1 hour running average used to reduce noise).

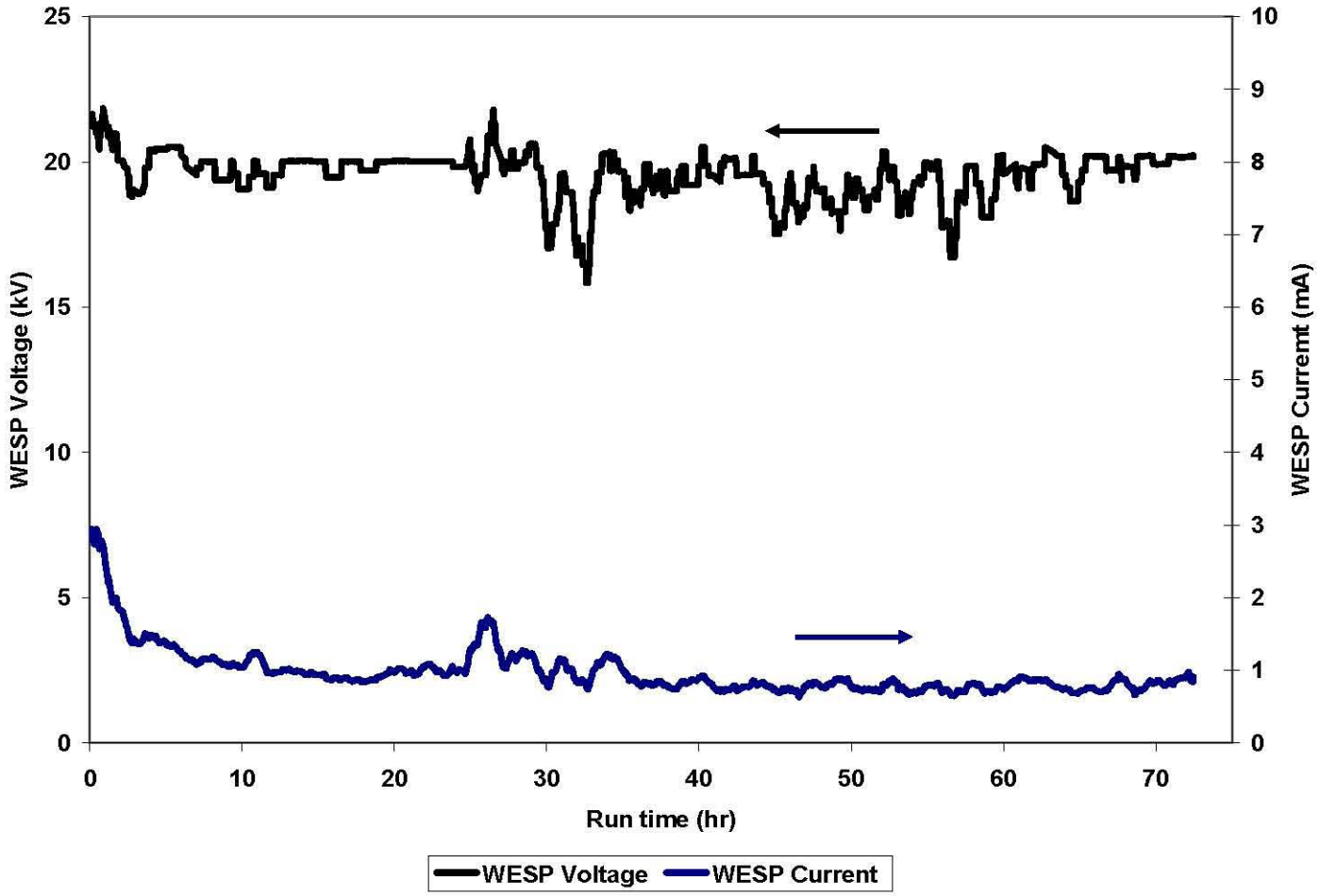


Figure 4.9.g. Test 7 WESP voltage and current (1 hour running average used to reduce noise).

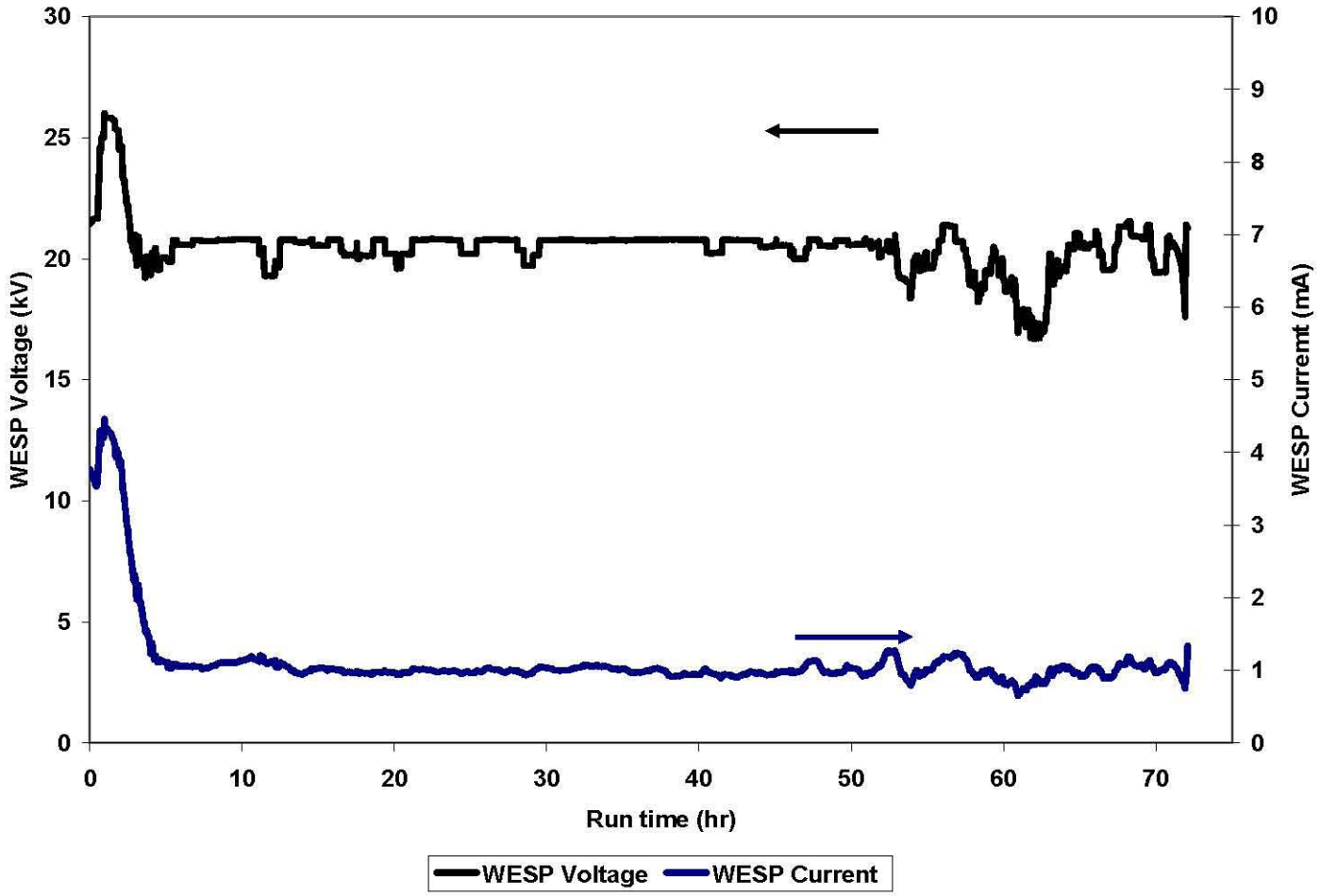


Figure 4.9.h. Test 8 WESP voltage and current (1 hour running average used to reduce noise).

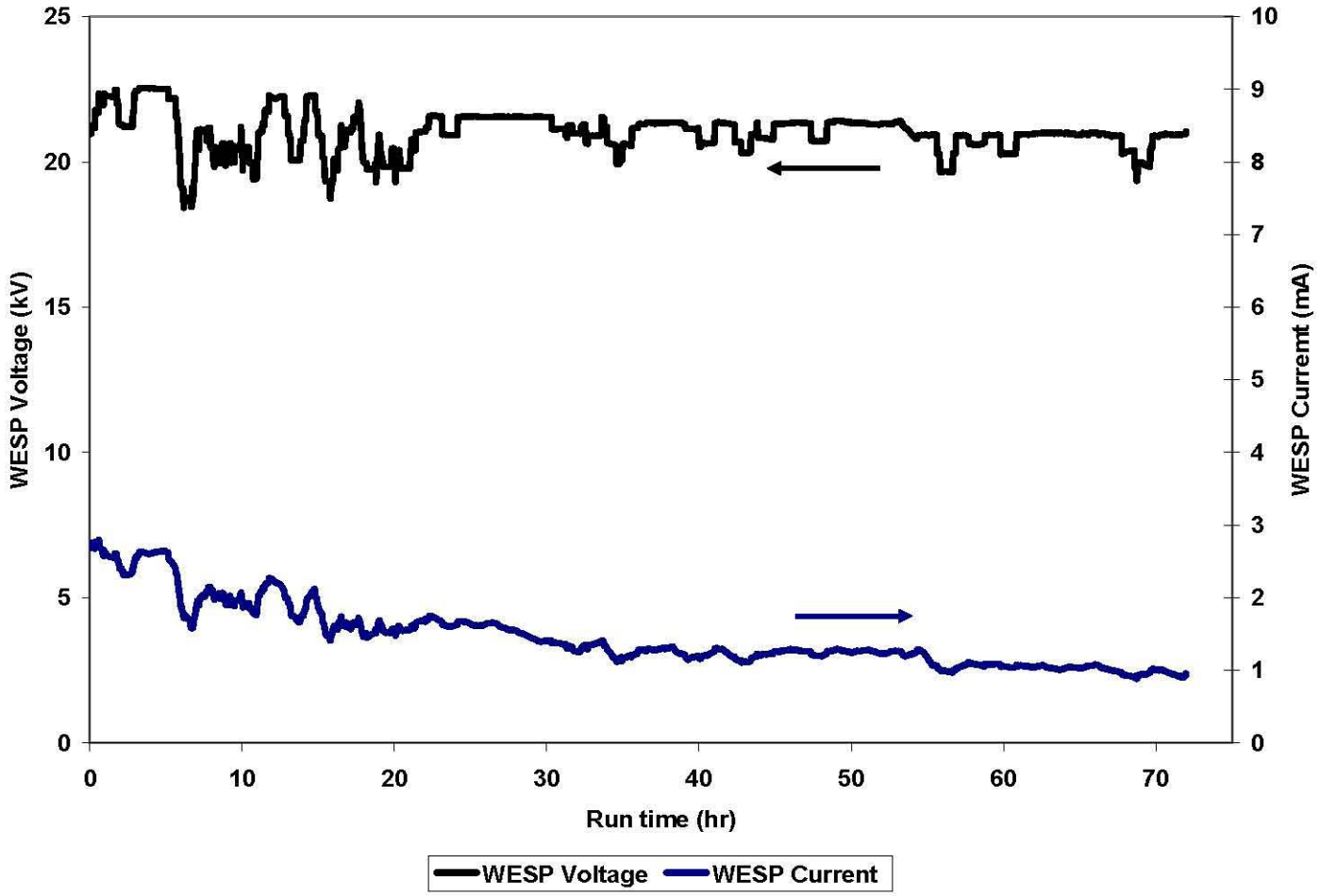


Figure 4.9.i. Test 9 WESP voltage and current (1 hour running average used to reduce noise).

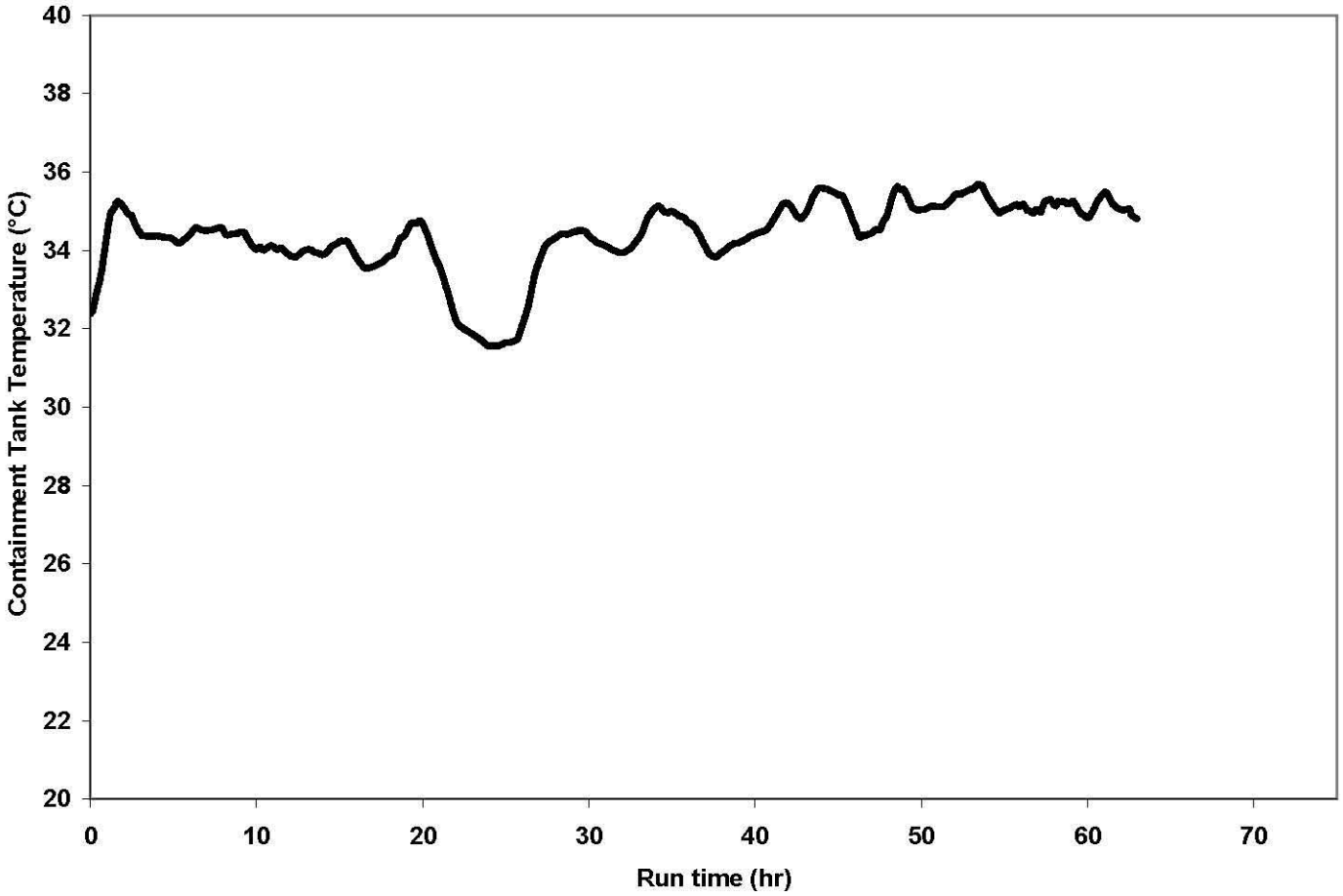


Figure 4.10.a. Test 1 Containment Tank temperature (1 hour running average used to reduce noise).

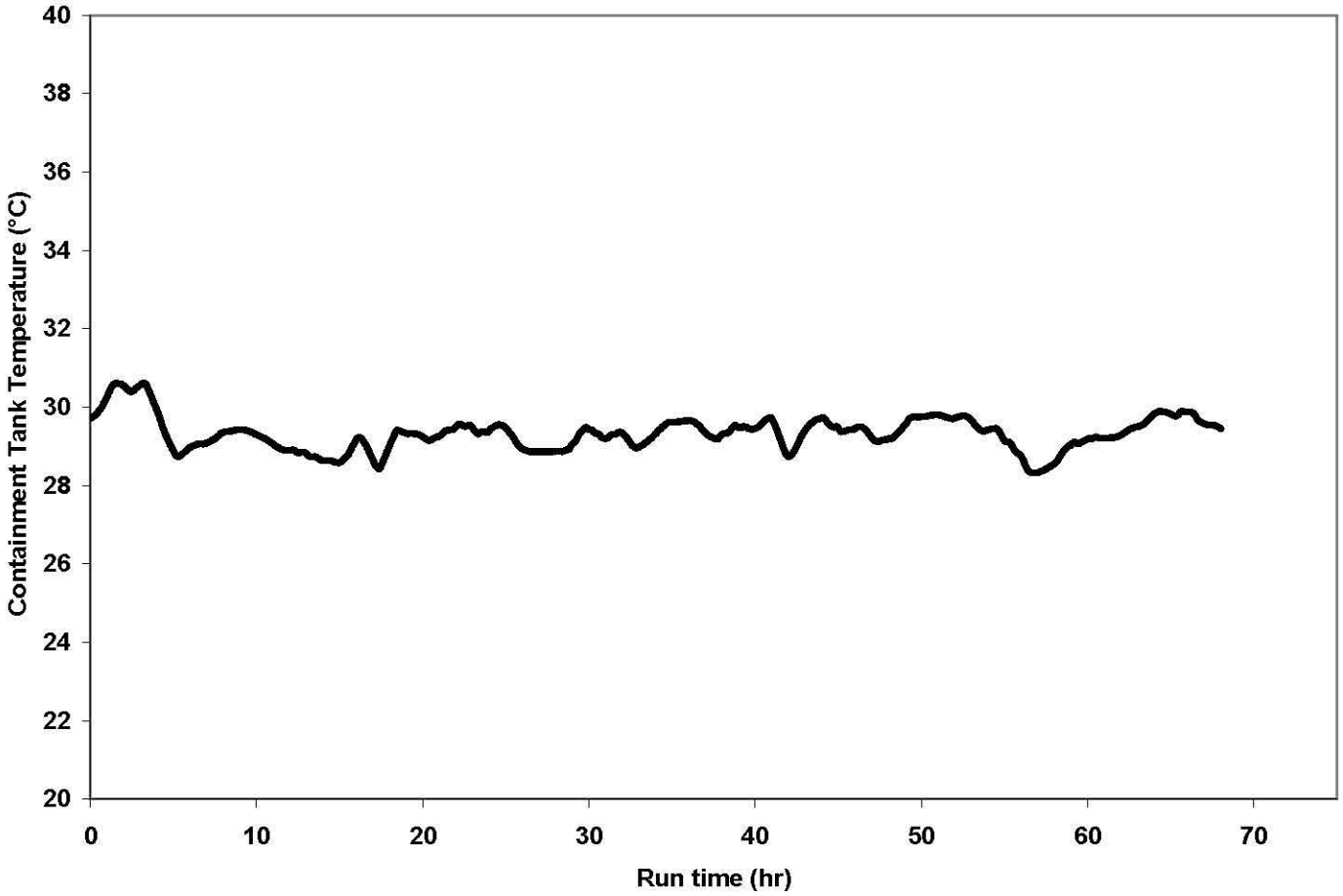


Figure 4.10.b. Test 2 Containment Tank temperature (1 hour running average used to reduce noise).

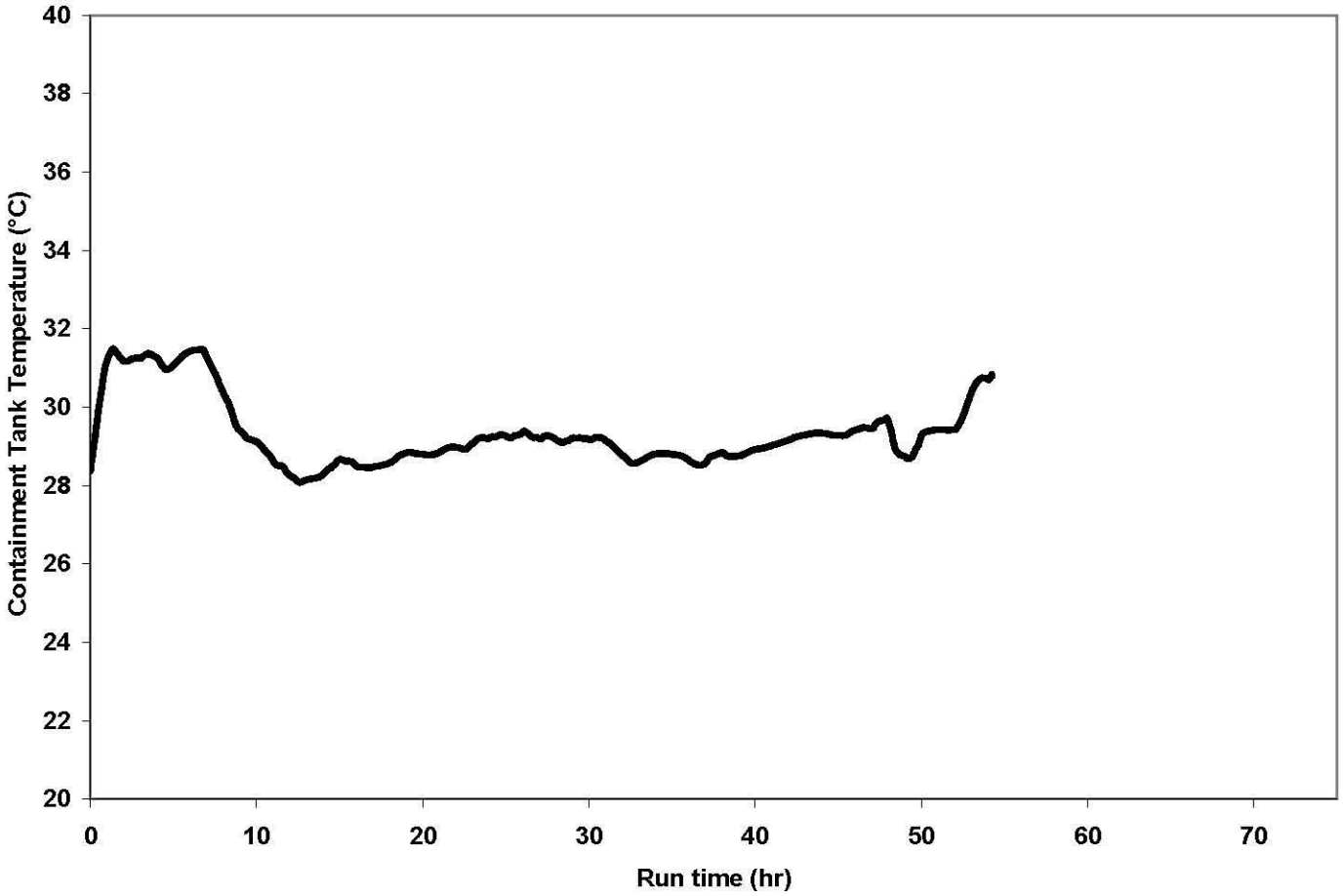


Figure 4.10.c. Test 3 Containment Tank temperature (1 hour running average used to reduce noise).

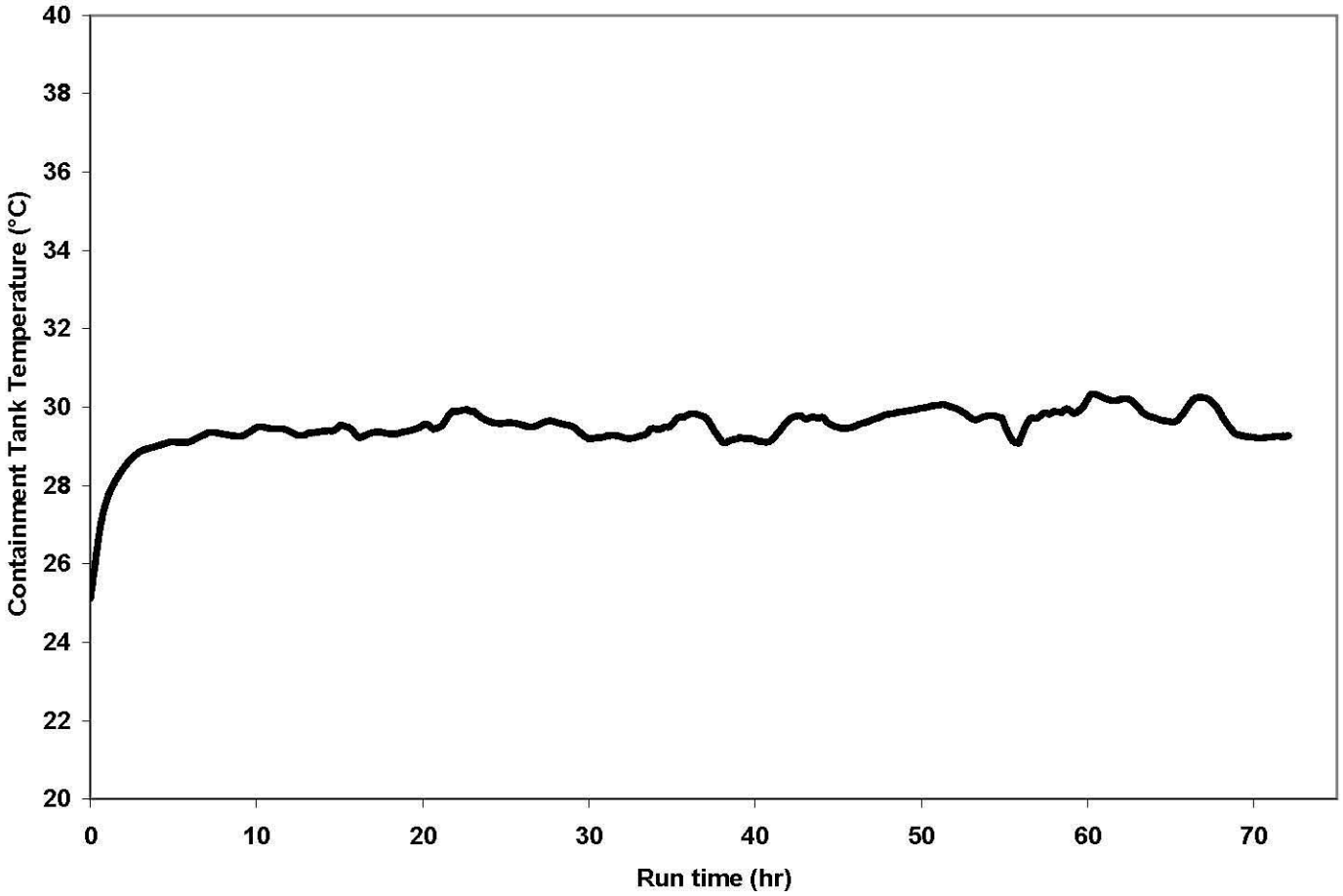


Figure 4.10.d. Test 4 Containment Tank temperature (1 hour running average used to reduce noise).

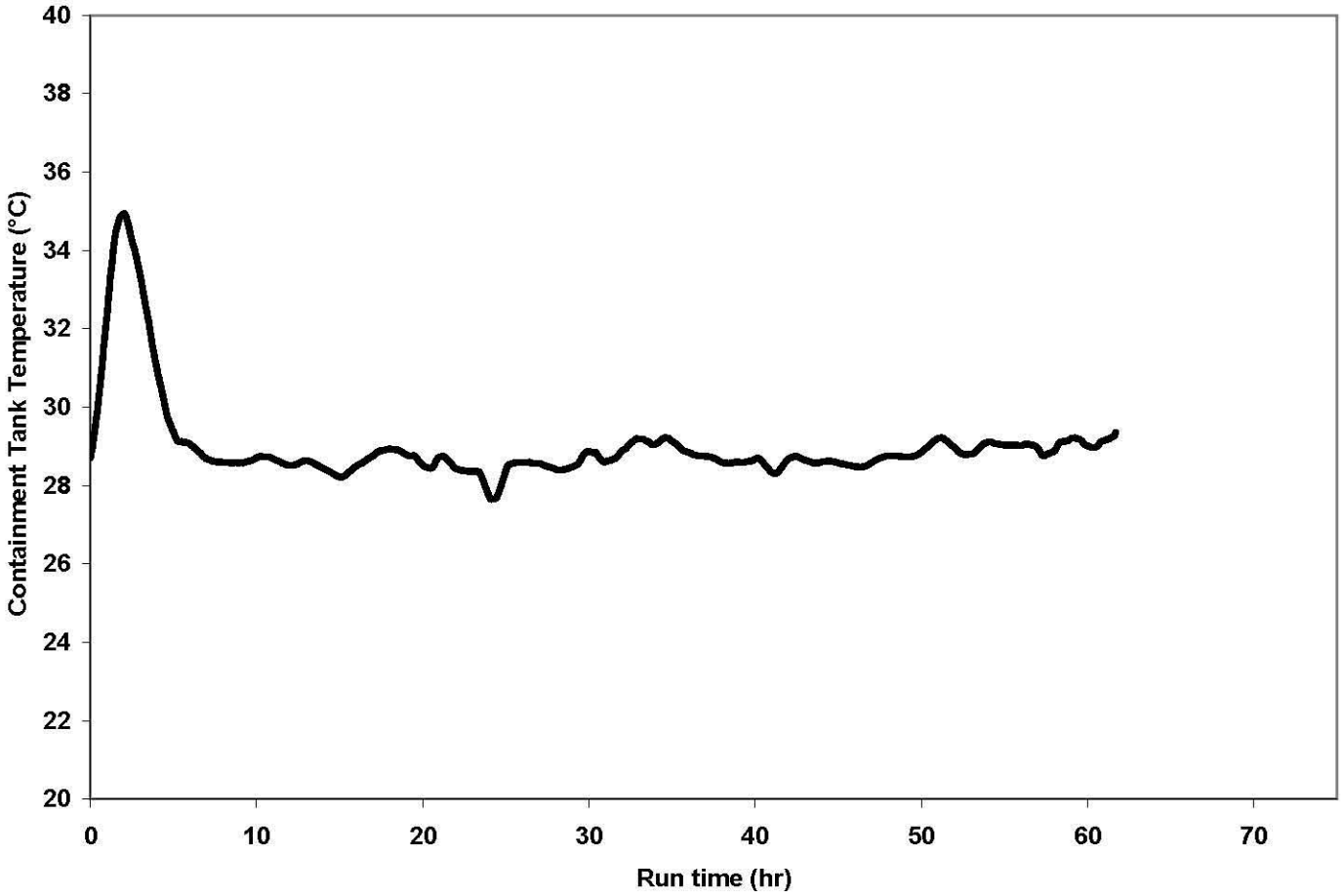


Figure 4.10.e. Test 5 Containment Tank temperature (1 hour running average used to reduce noise).

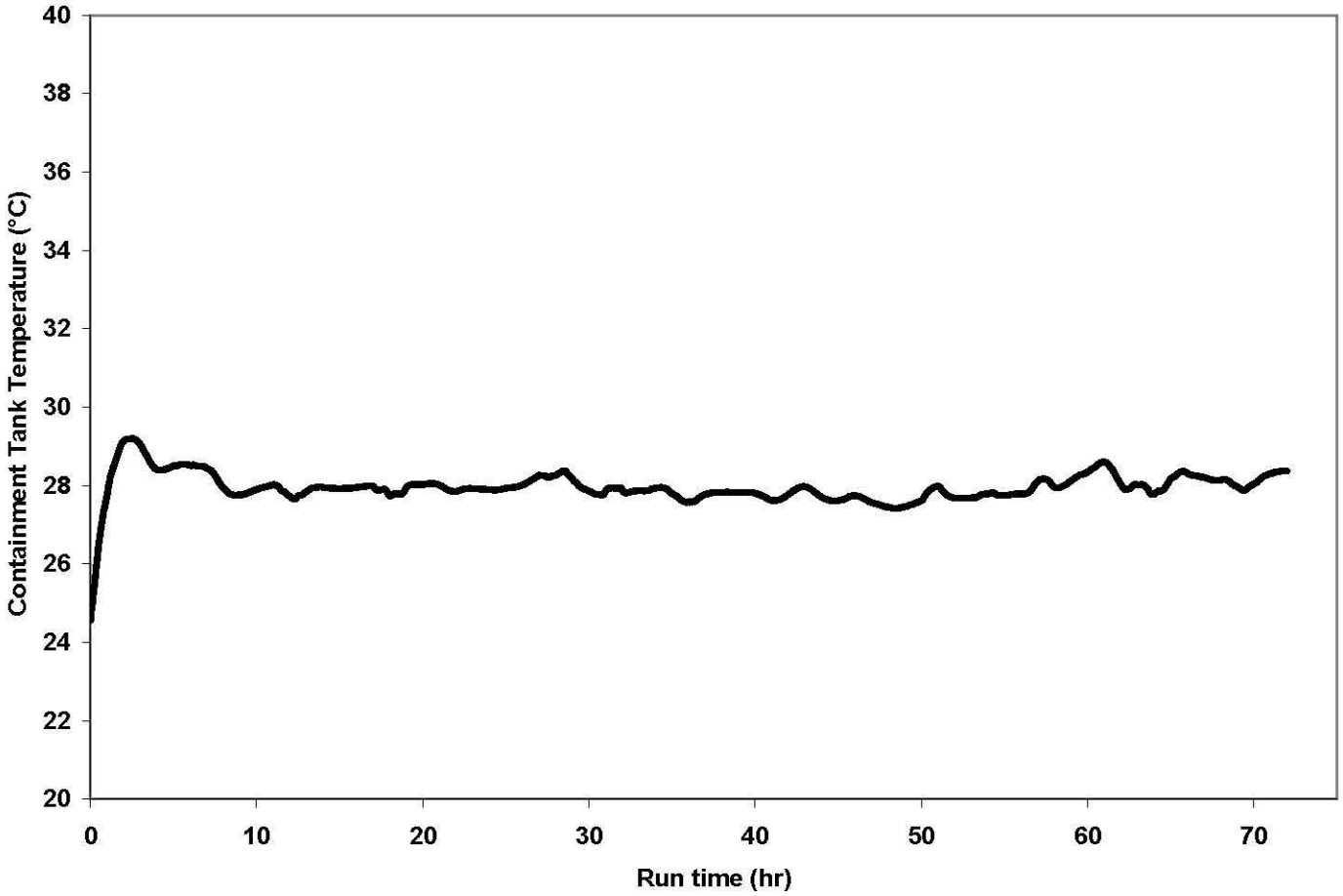


Figure 4.10.f. Test 6 Containment Tank temperature (1 hour running average used to reduce noise).

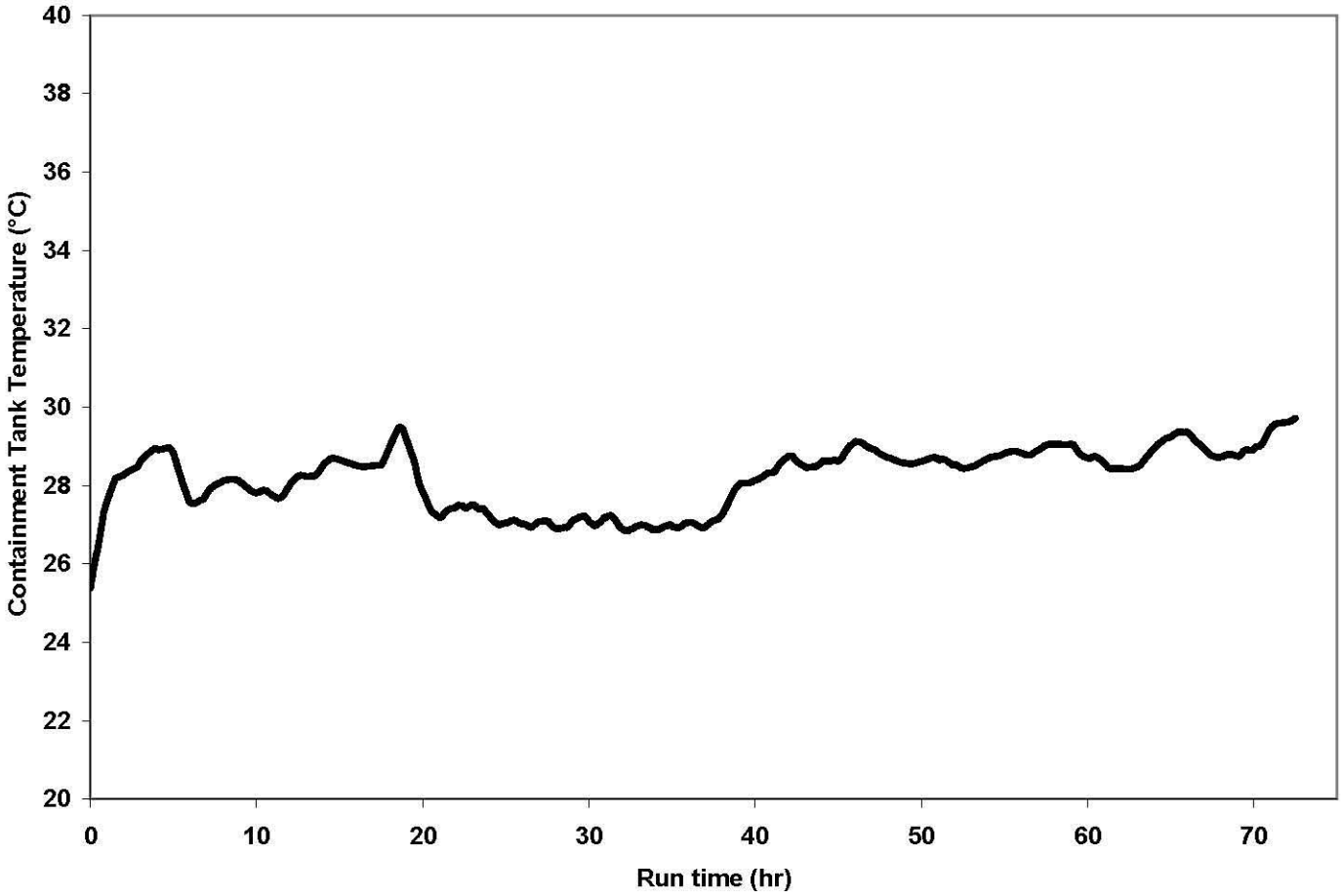


Figure 4.10.g. Test 7 Containment Tank temperature (1 hour running average used to reduce noise).

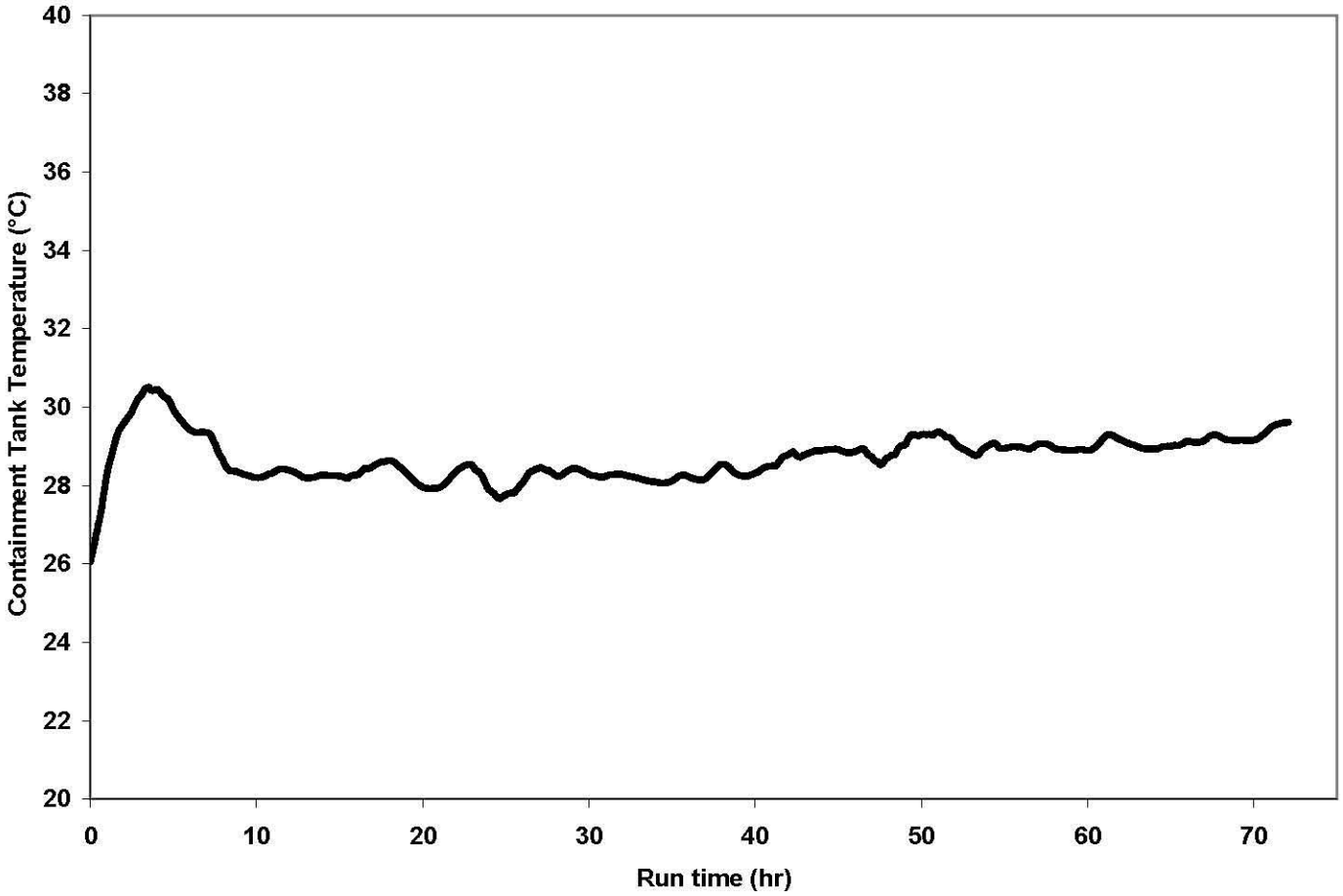


Figure 4.10.h. Test 8 Containment Tank temperature (1 hour running average used to reduce noise).

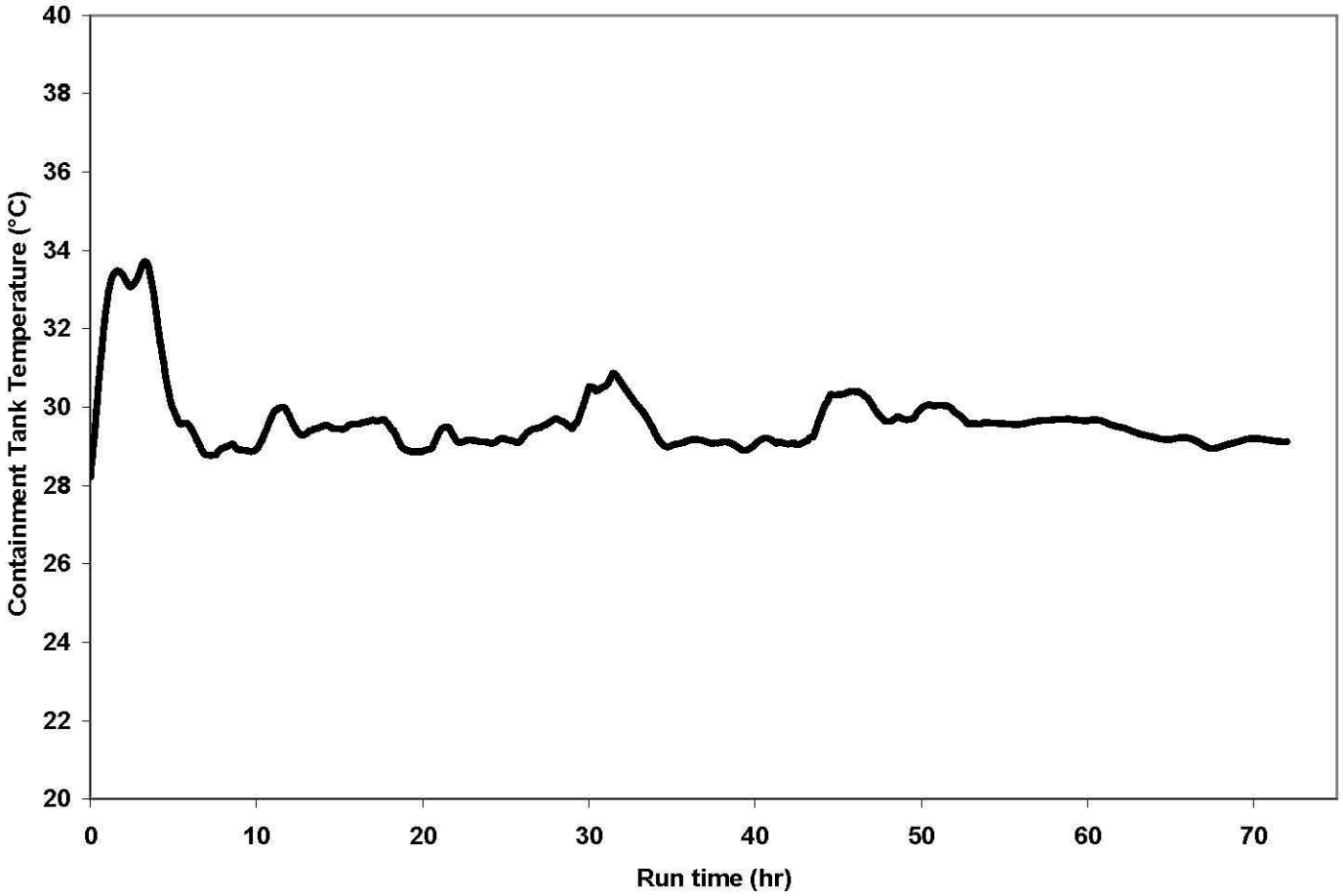


Figure 4.10.i. Test 9 Containment Tank temperature (1 hour running average used to reduce noise).

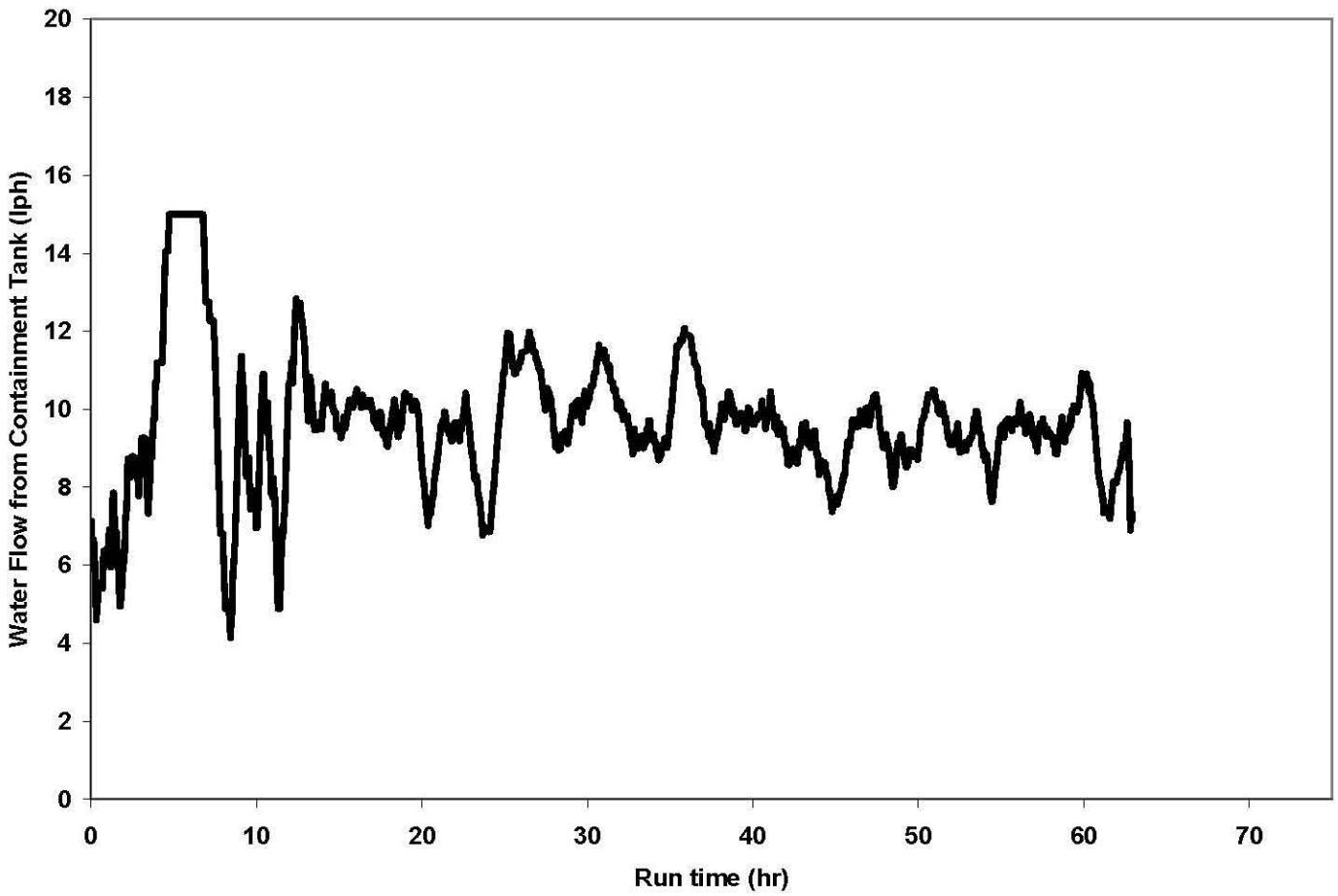


Figure 4.11.a. Test 1 flow rate out of Containment Tank (1 hour running average used to reduce noise).

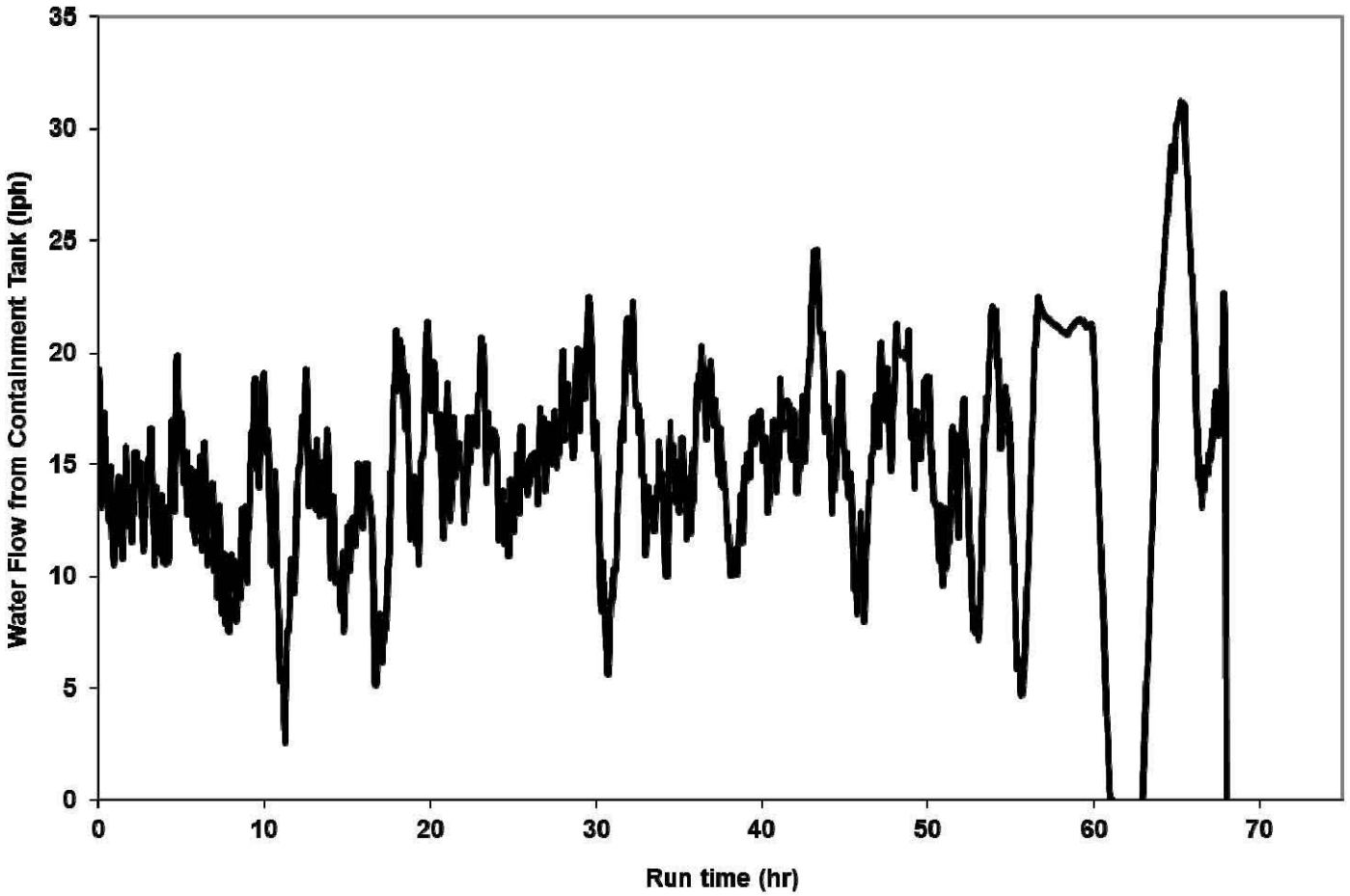


Figure 4.11.b. Test 2 flow rate out of Containment Tank (1 hour running average used to reduce noise).

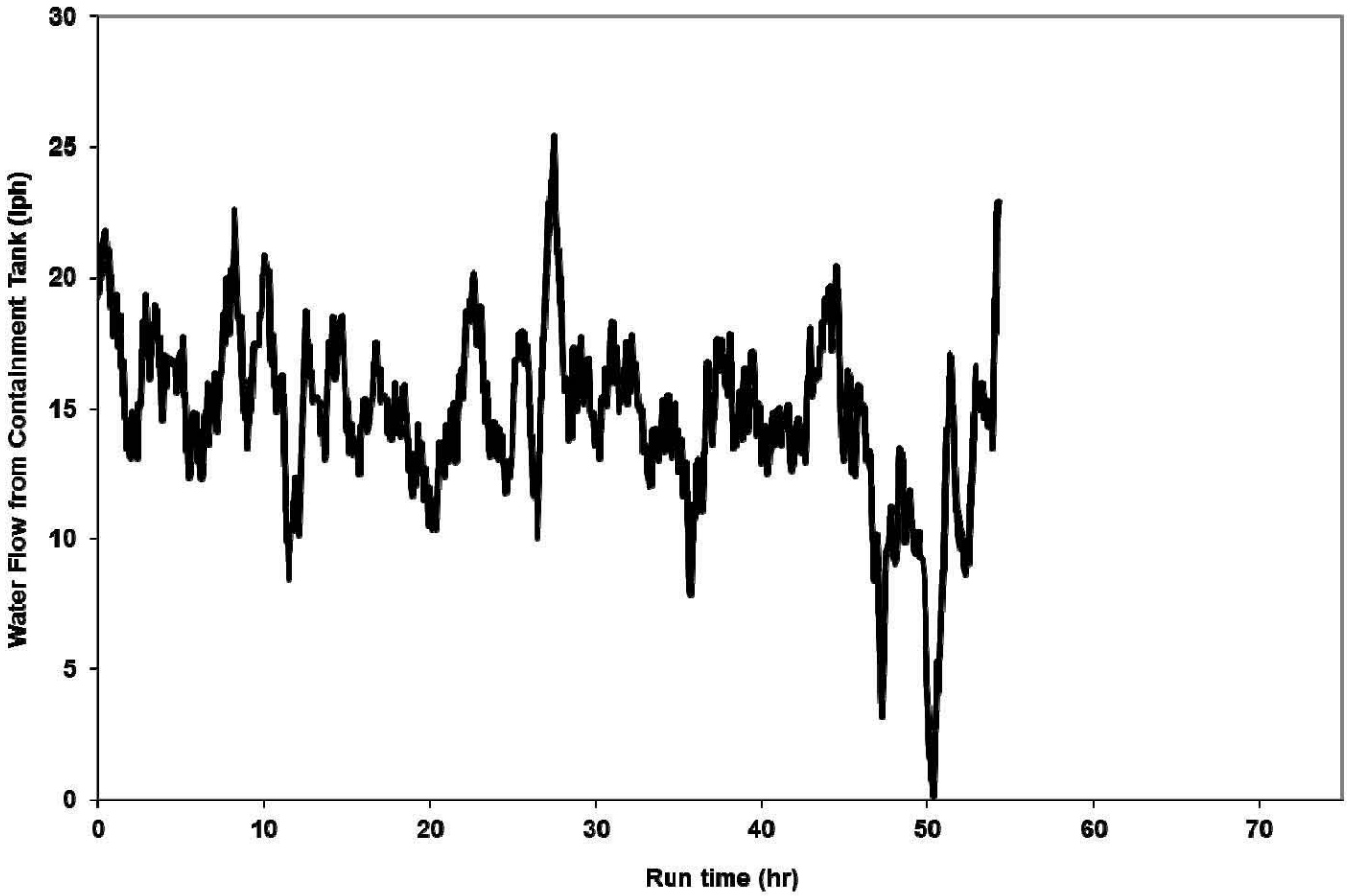


Figure 4.11.c. Test 3 flow rate out of Containment Tank (1 hour running average used to reduce noise).

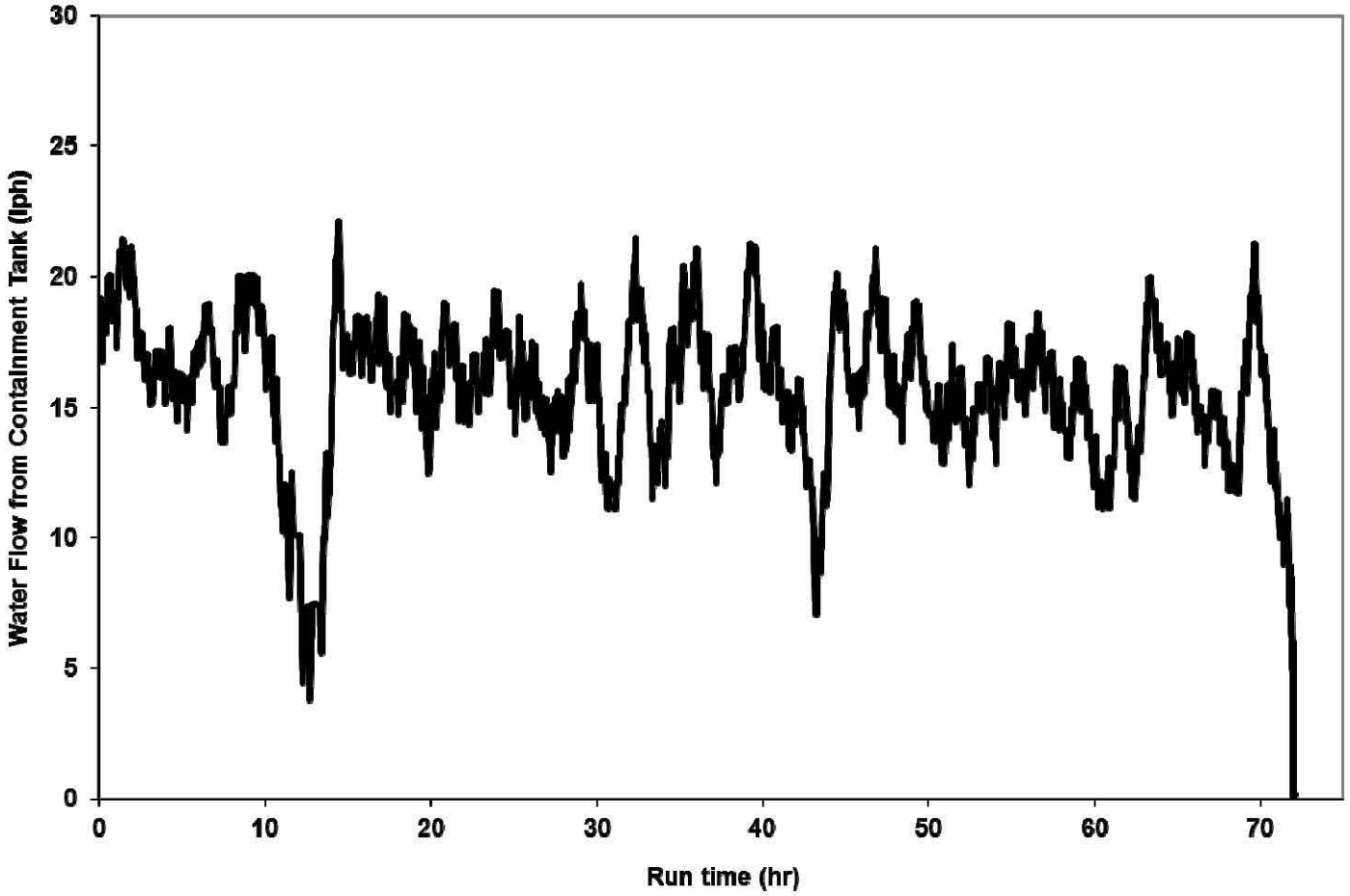


Figure 4.11.d. Test 4 flow rate out of Containment Tank (1 hour running average used to reduce noise).

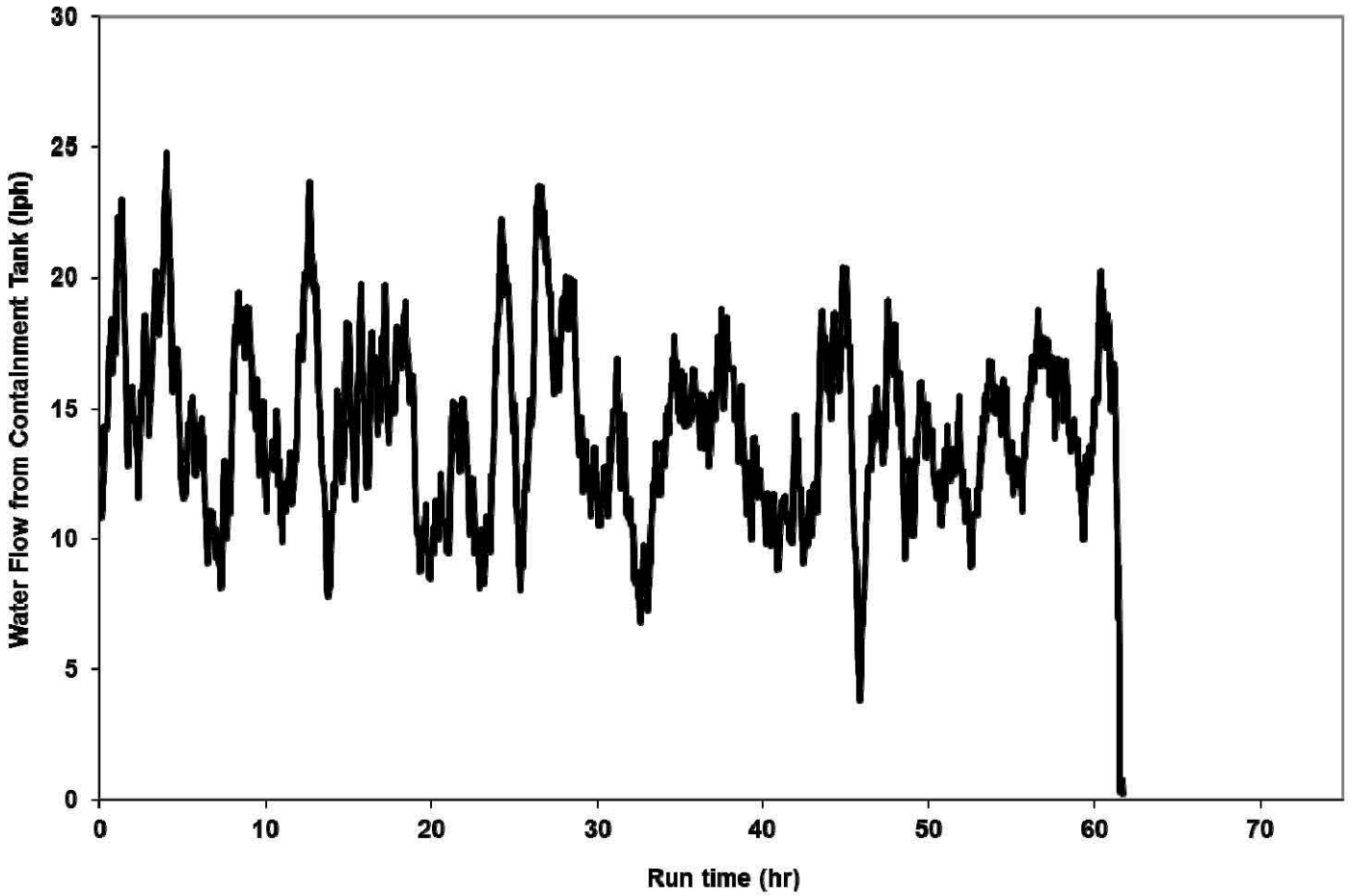


Figure 4.11.e. Test 5 flow rate out of Containment Tank (1 hour running average used to reduce noise).

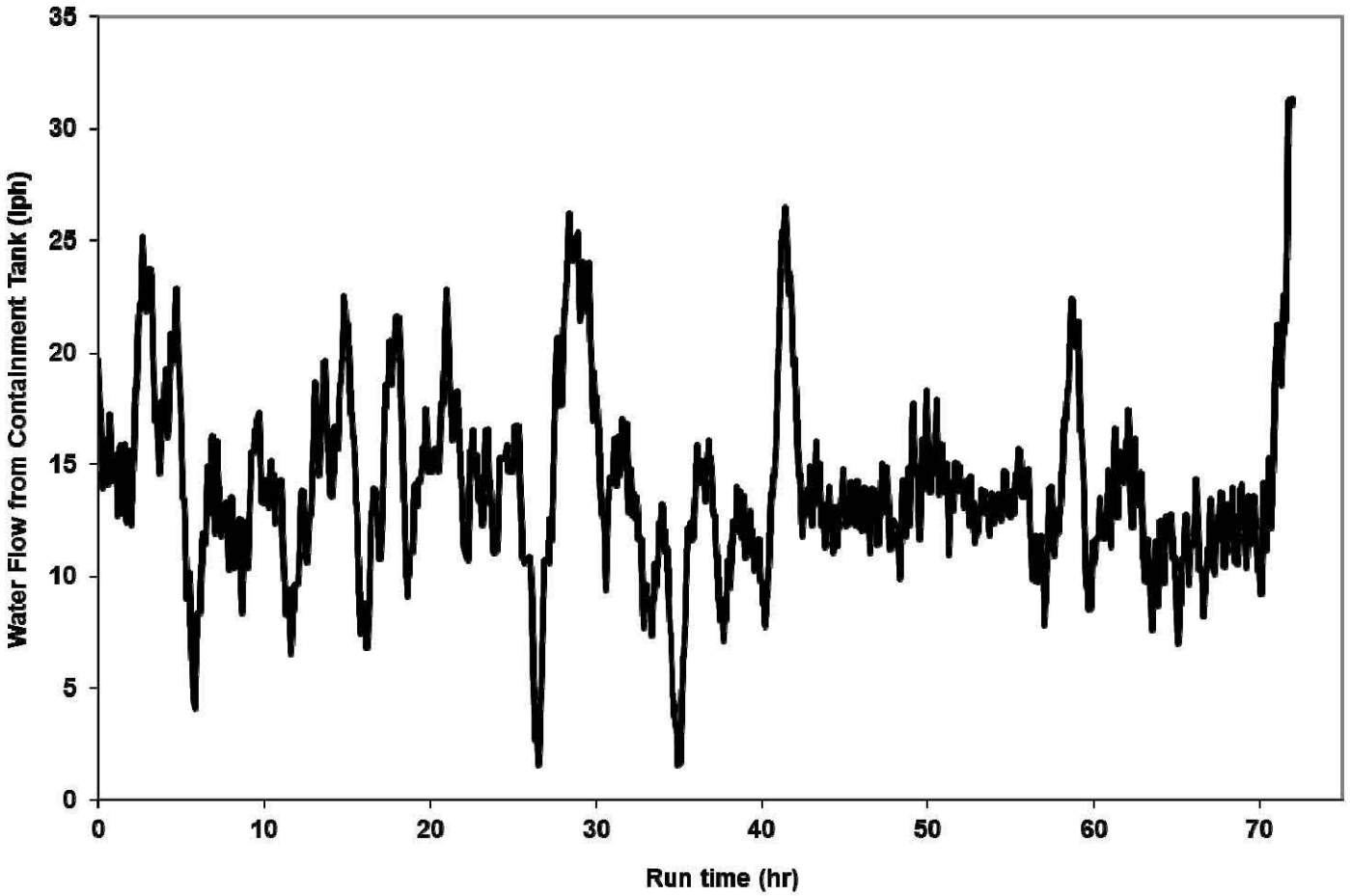


Figure 4.11.f. Test 6 flow rate out of Containment Tank (1 hour running average used to reduce noise).

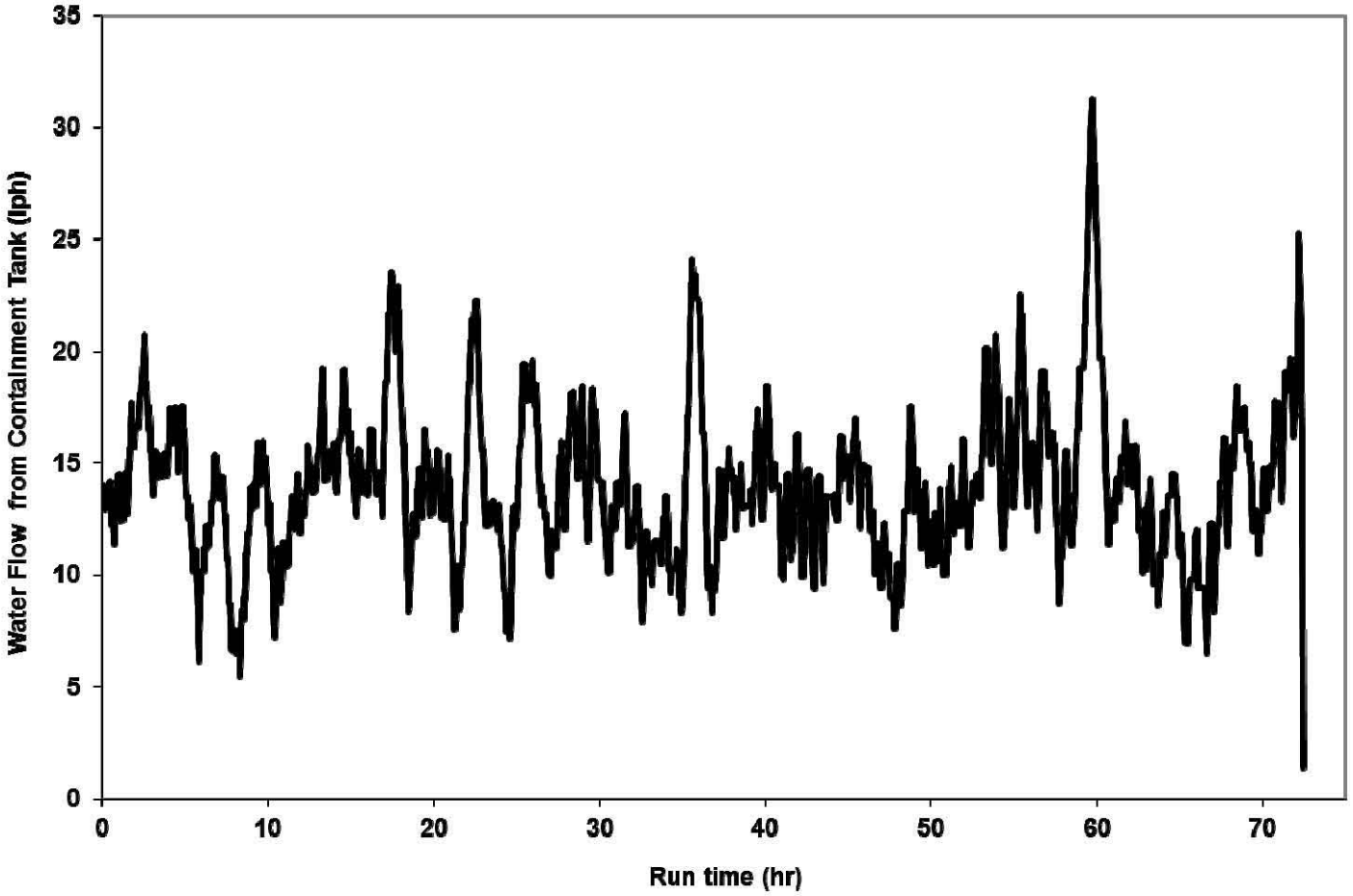


Figure 4.11.g. Test 7 flow rate out of Containment Tank (1 hour running average used to reduce noise).

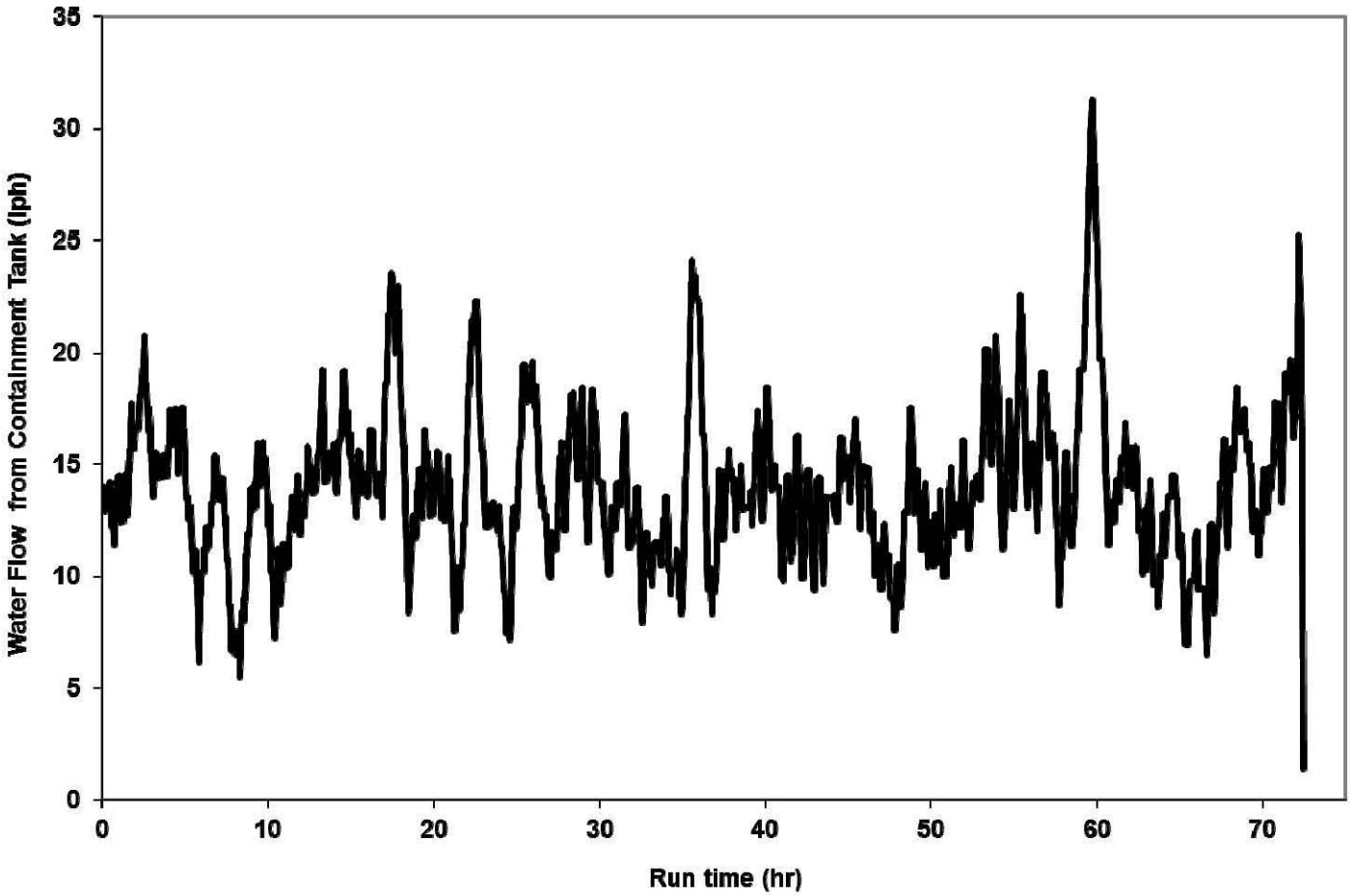


Figure 4.11.h. Test 8 flow rate out of Containment Tank (1 hour running average used to reduce noise).

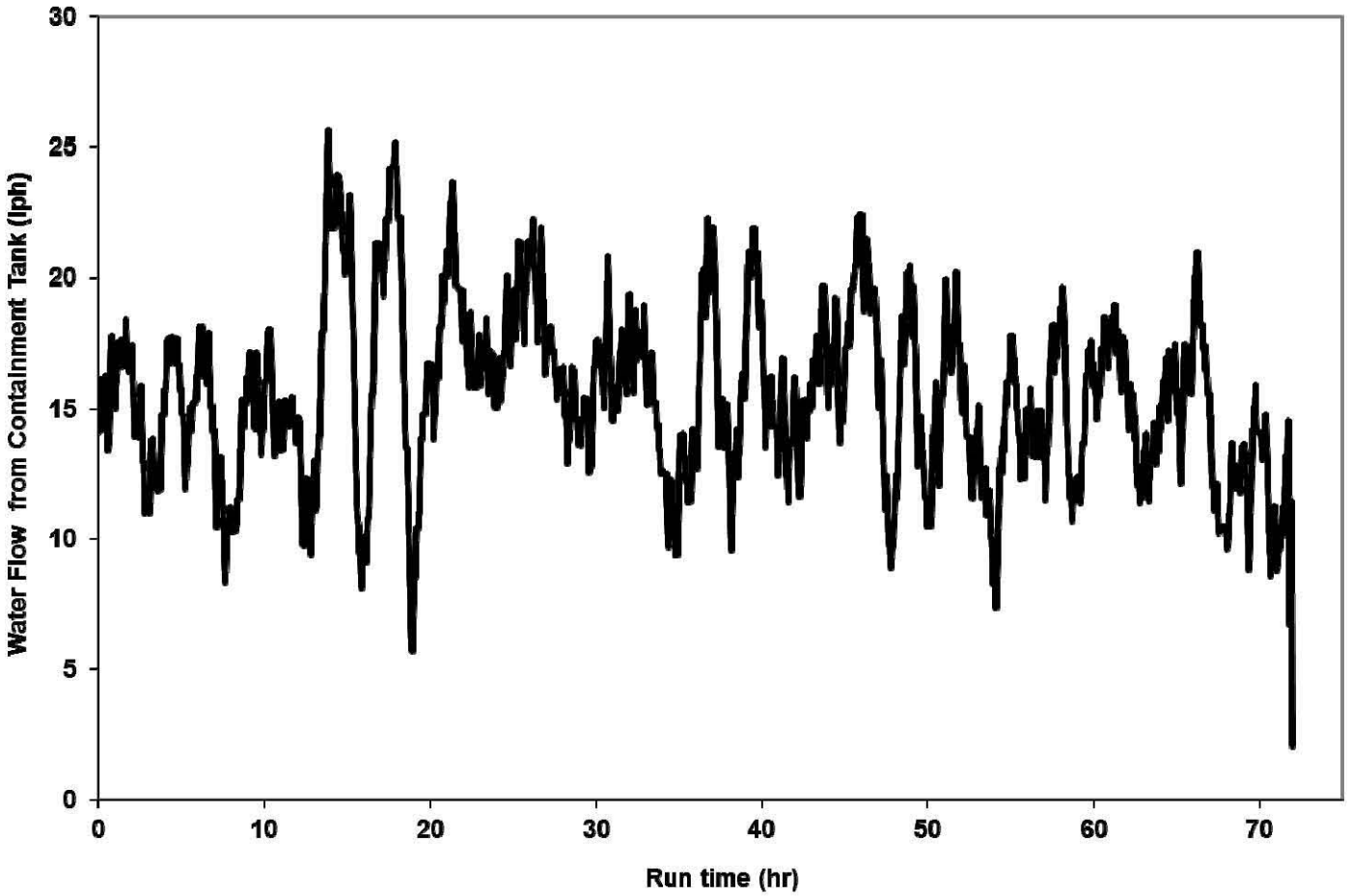


Figure 4.11.i. Test 9 flow rate out of Containment Tank (1 hour running average used to reduce noise).

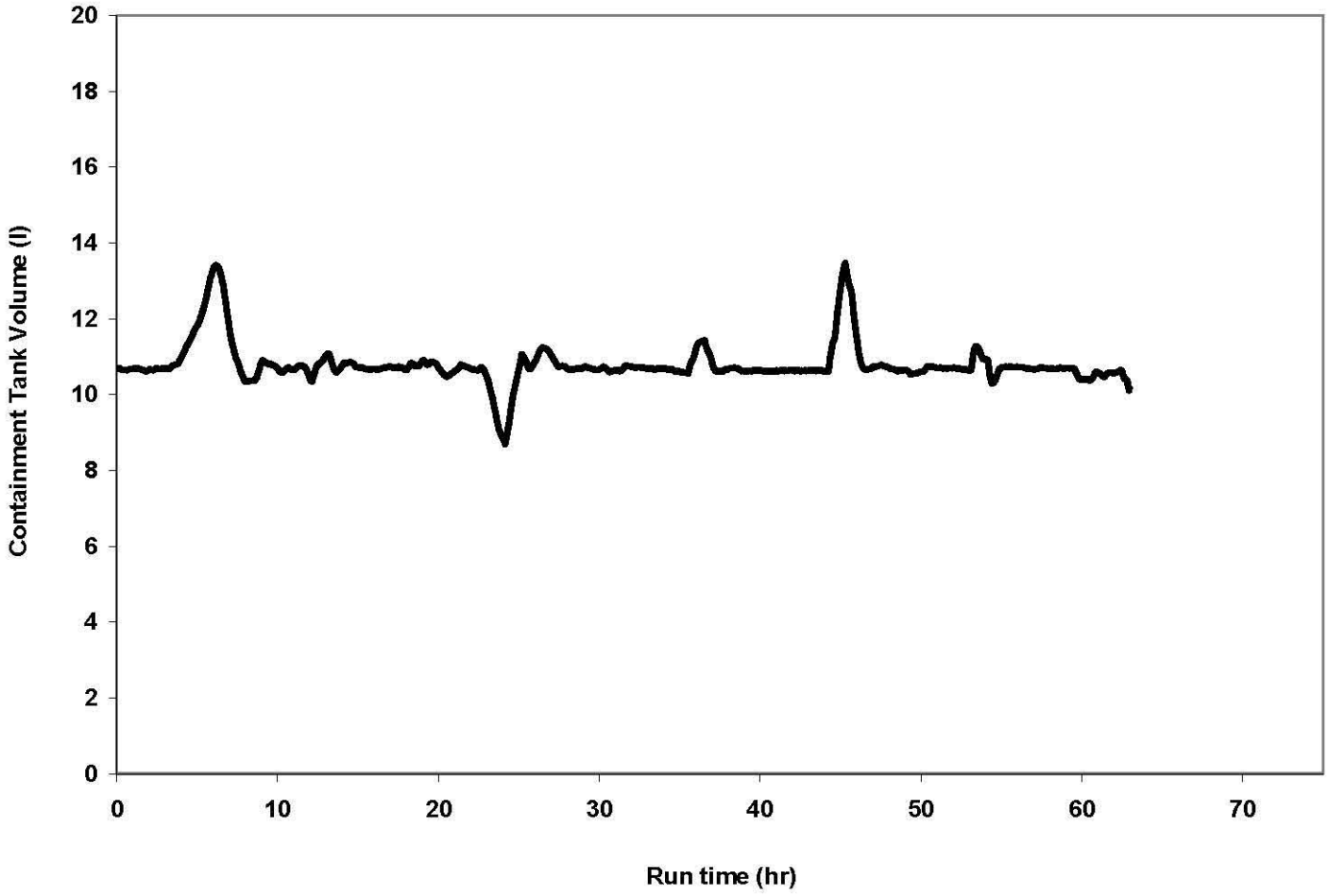


Figure 4.12.a. Test 1 Containment Tank level (1 hour running average used to reduce noise).

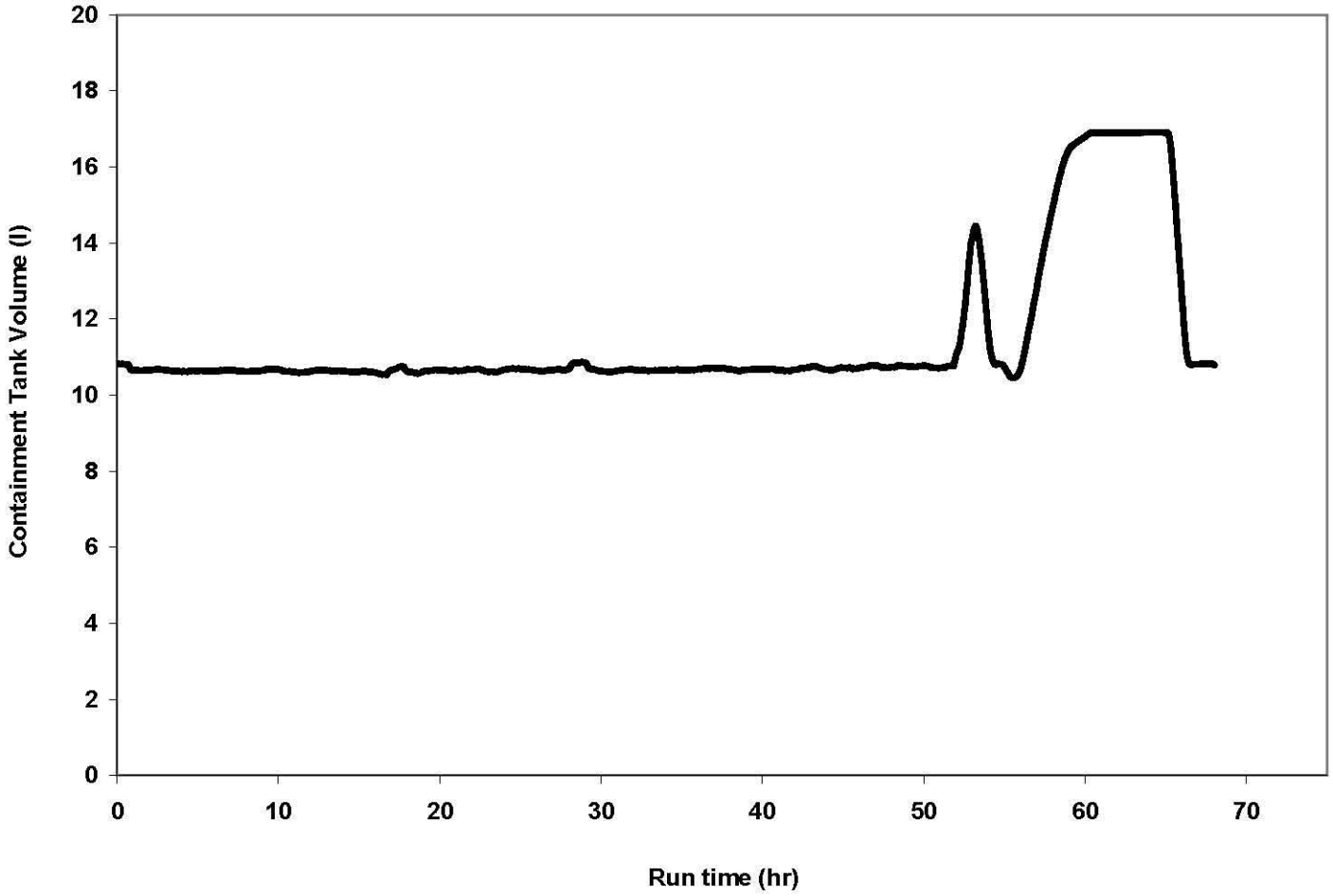


Figure 4.12.b. Test 2 Containment Tank level (1 hour running average used to reduce noise).

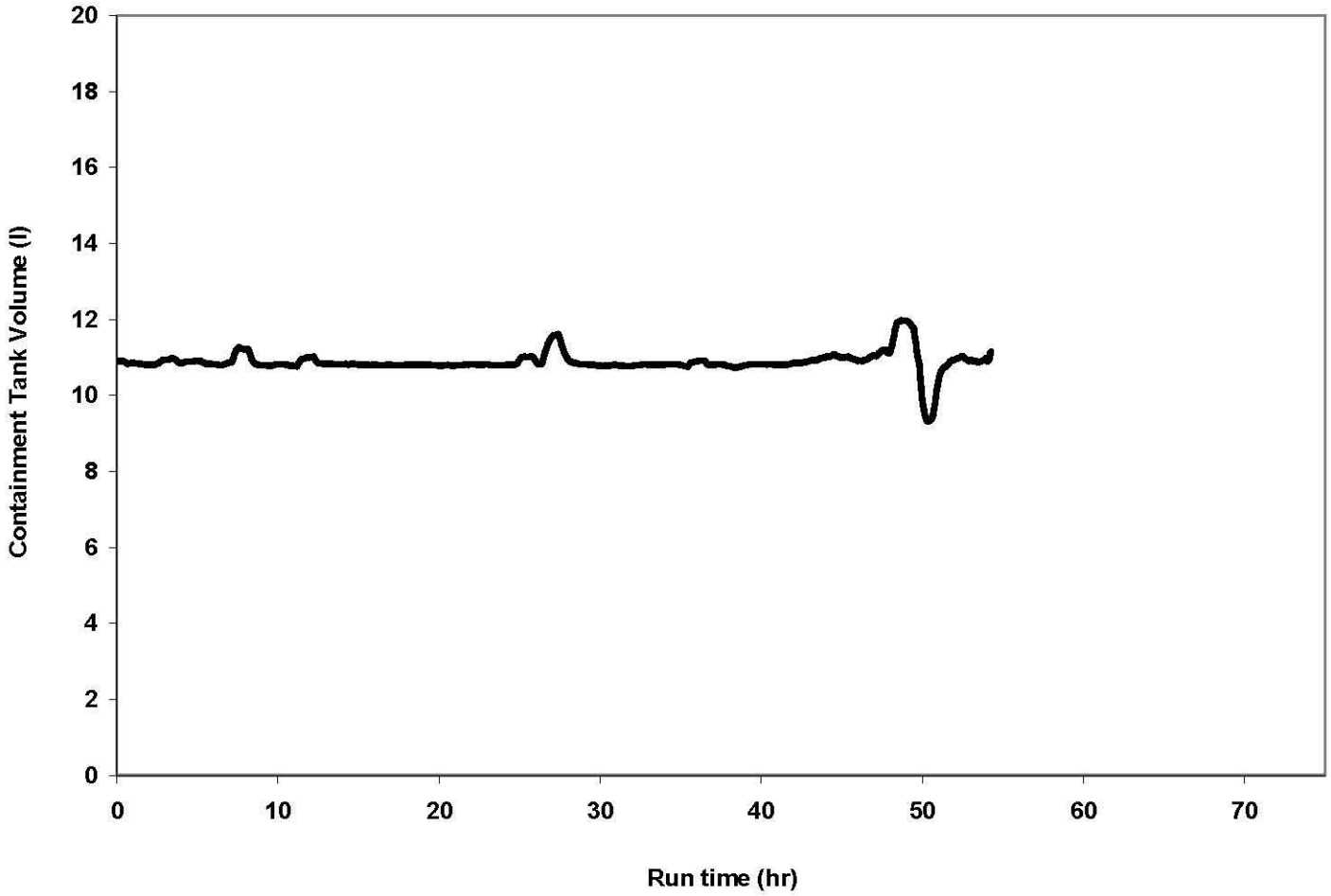


Figure 4.12.c. Test 3 Containment Tank level (1 hour running average used to reduce noise).

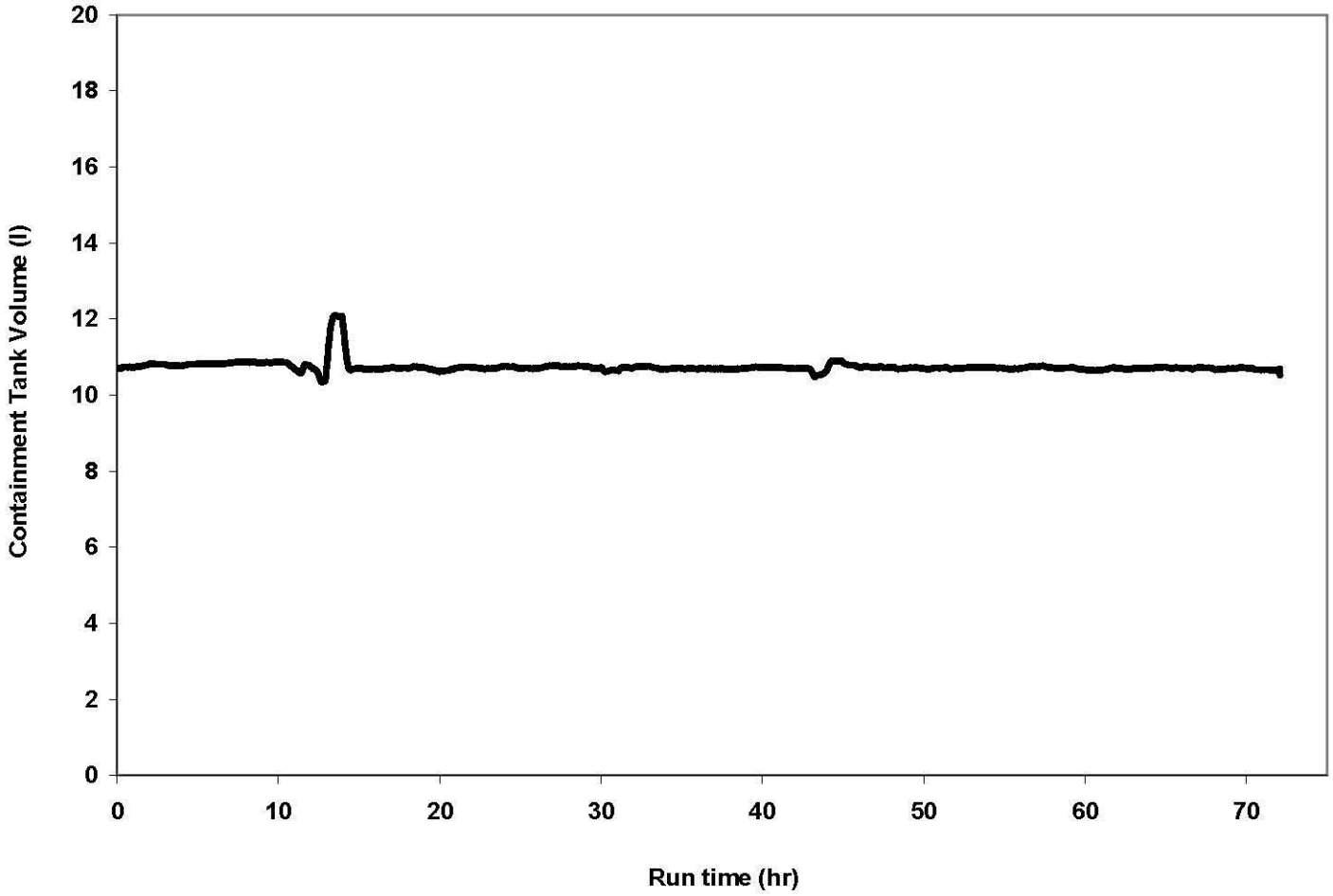


Figure 4.12.d. Test 4 Containment Tank level (1 hour running average used to reduce noise).

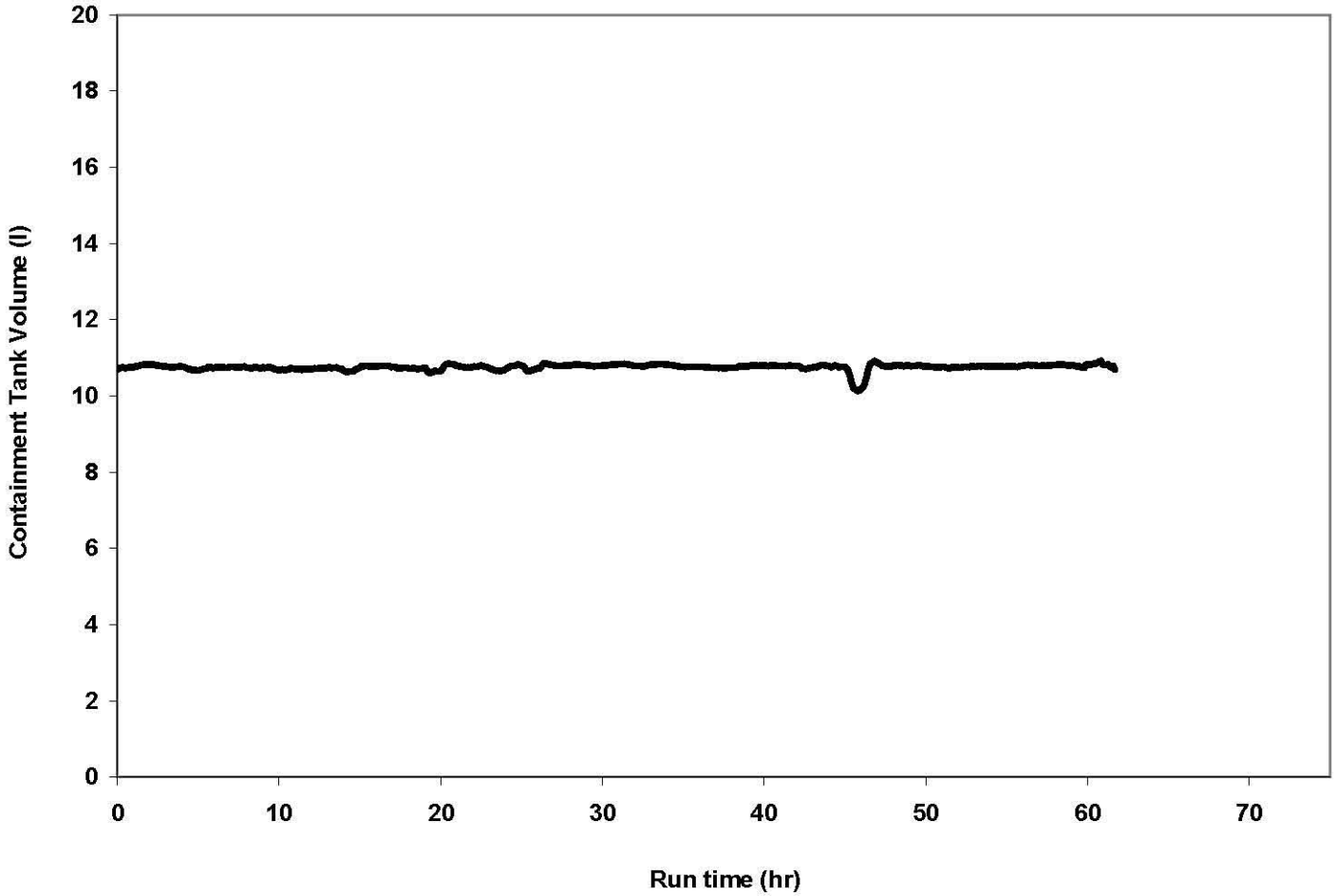


Figure 4.12.e. Test 5 Containment Tank level (1 hour running average used to reduce noise).

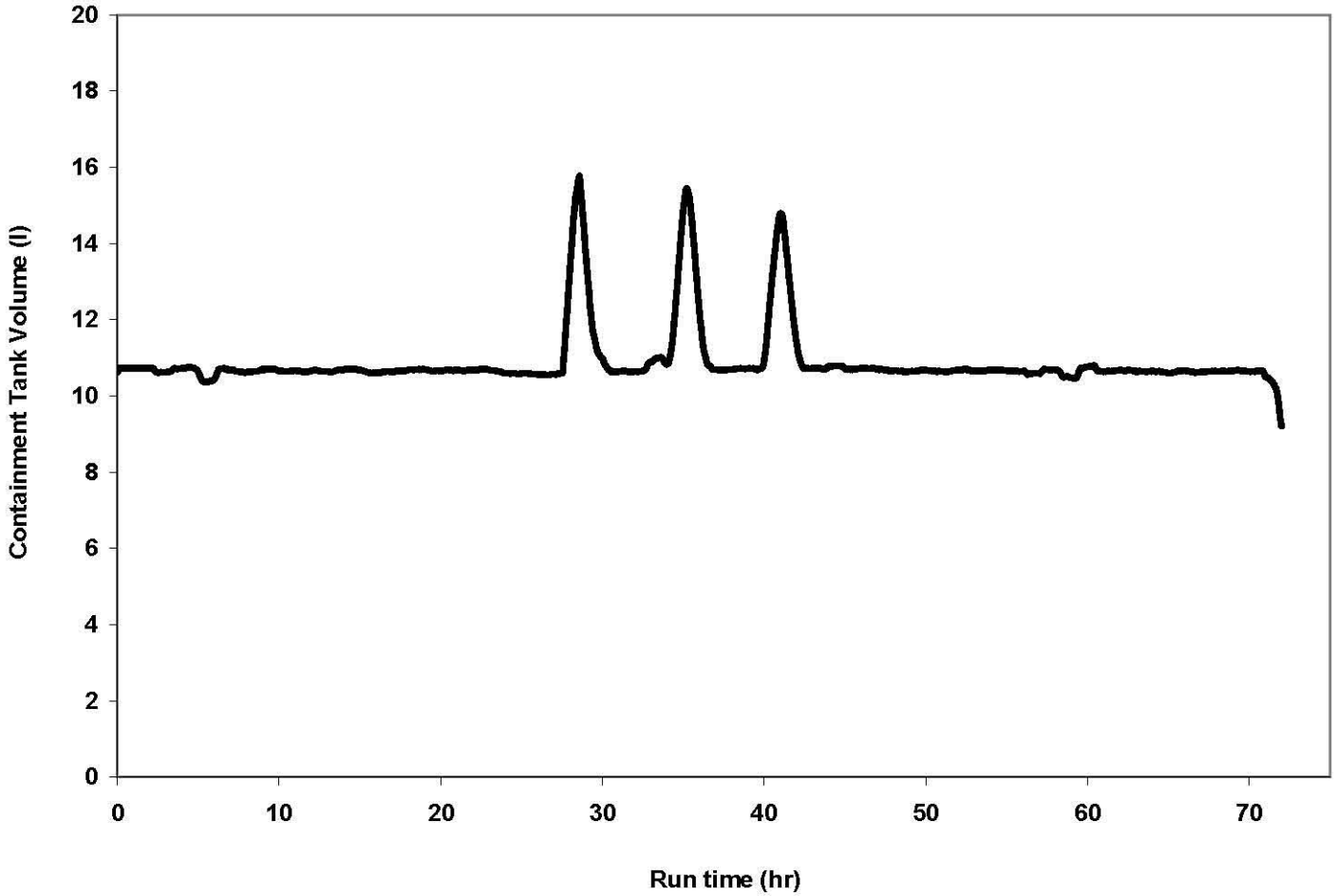


Figure 4.12.f. Test 6 Containment Tank level (1 hour running average used to reduce noise).

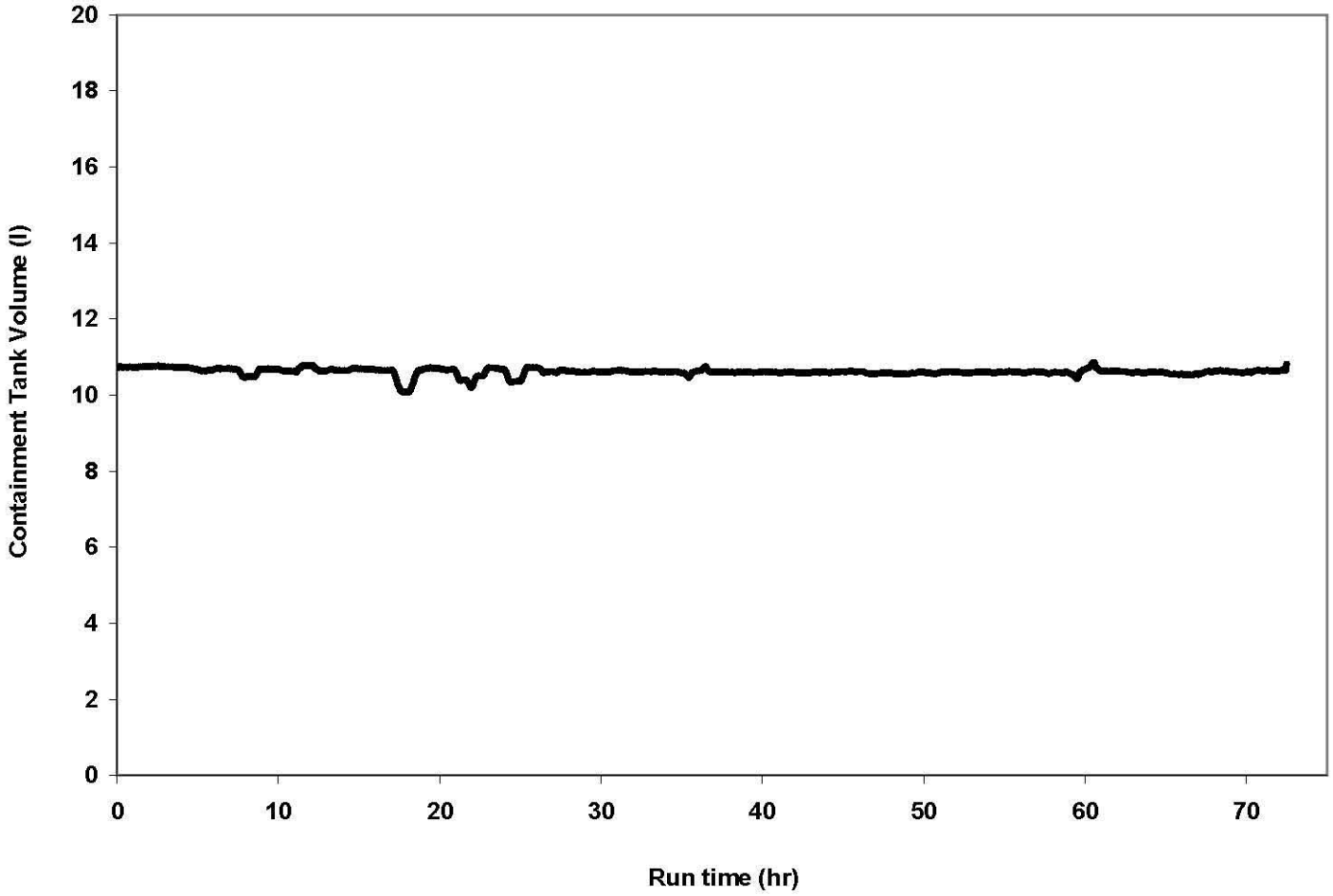


Figure 4.12.g. Test 7 Containment Tank level (1 hour running average used to reduce noise).

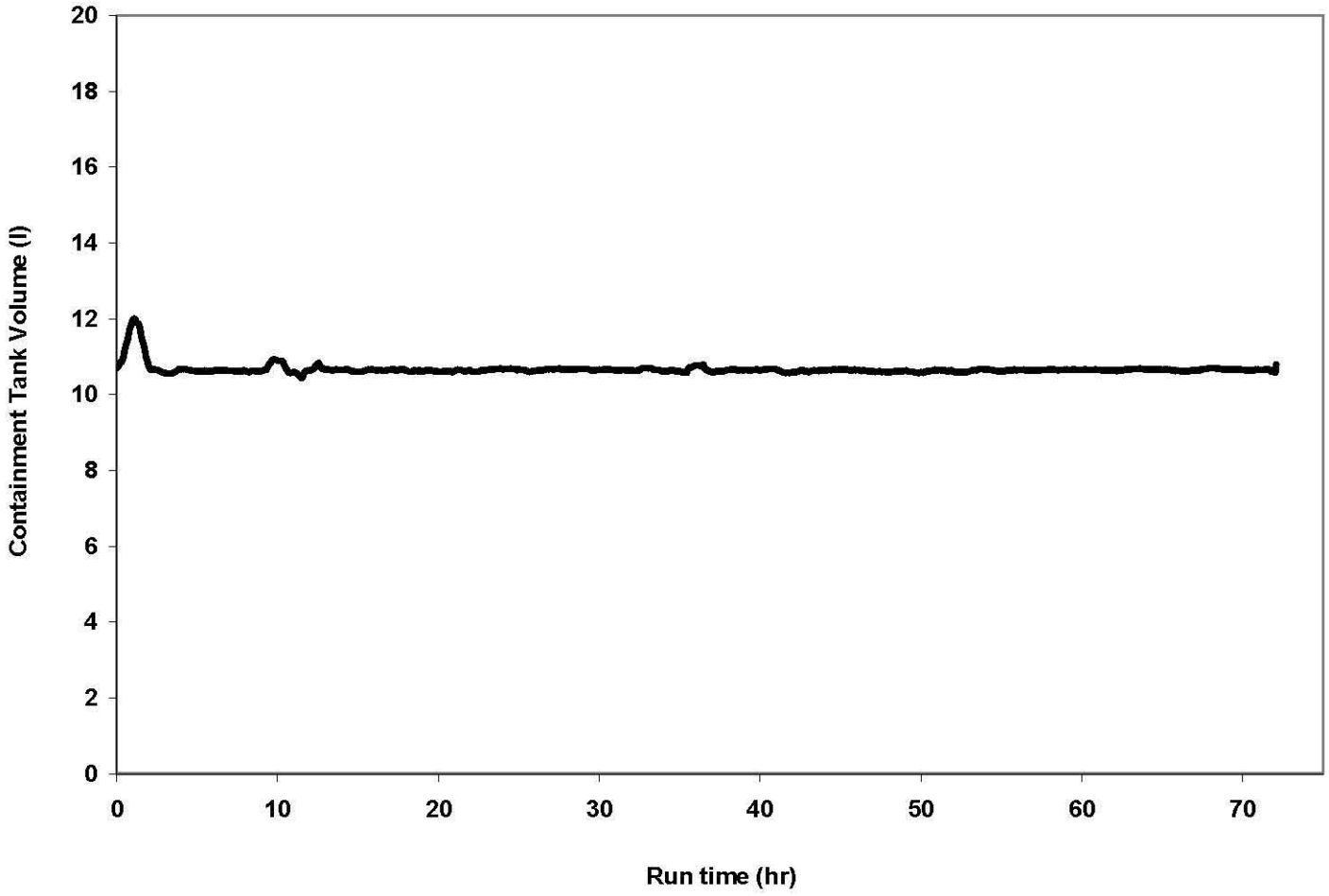


Figure 4.12.h. Test 8 Containment Tank level (1 hour running average used to reduce noise).

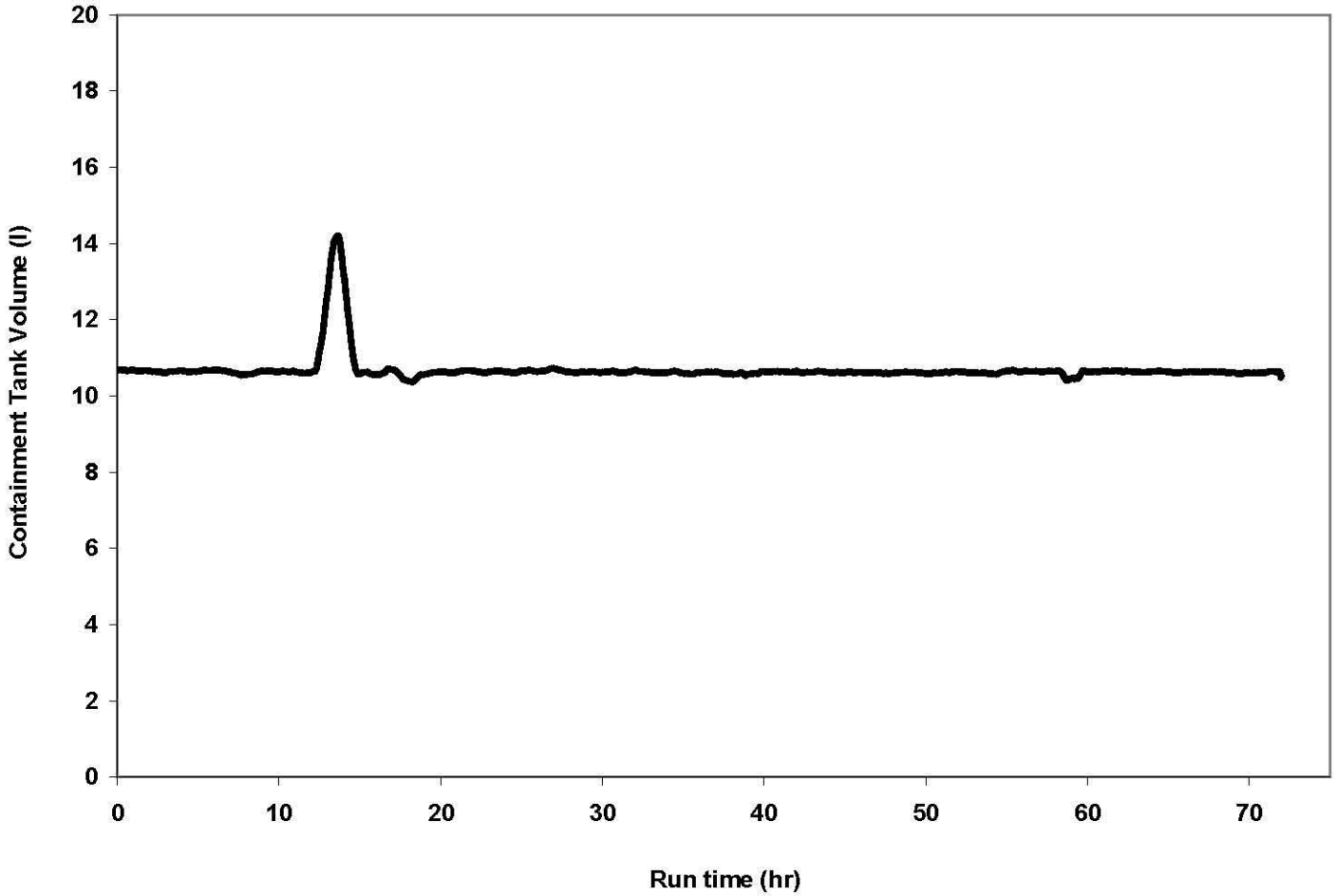


Figure 4.12.i. Test 9 Containment Tank level (1 hour running average used to reduce noise).

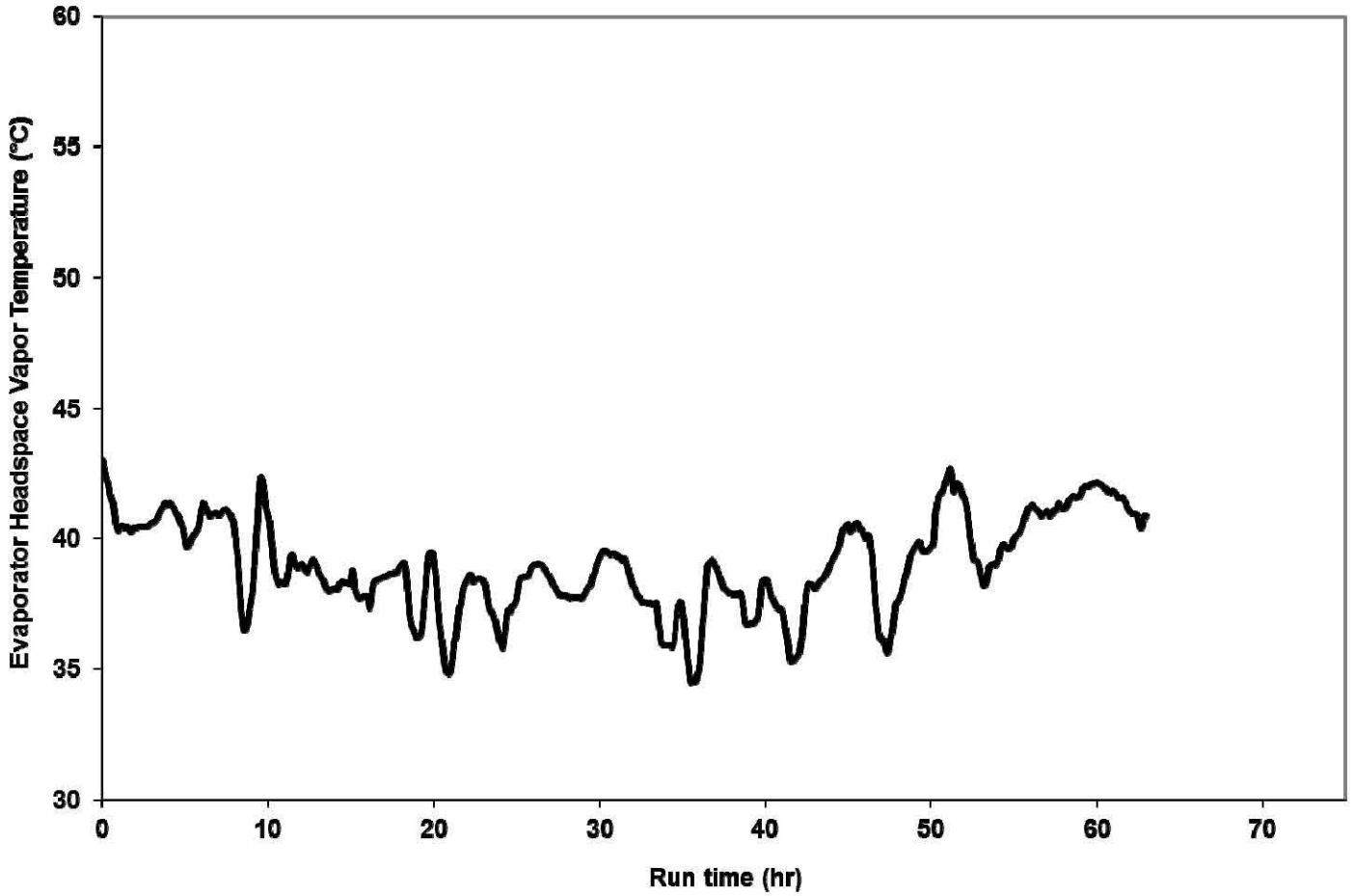


Figure 4.13.a. Test 1 headspace vapor temperature leaving the custom evaporator (1 hour running average used to reduce noise).

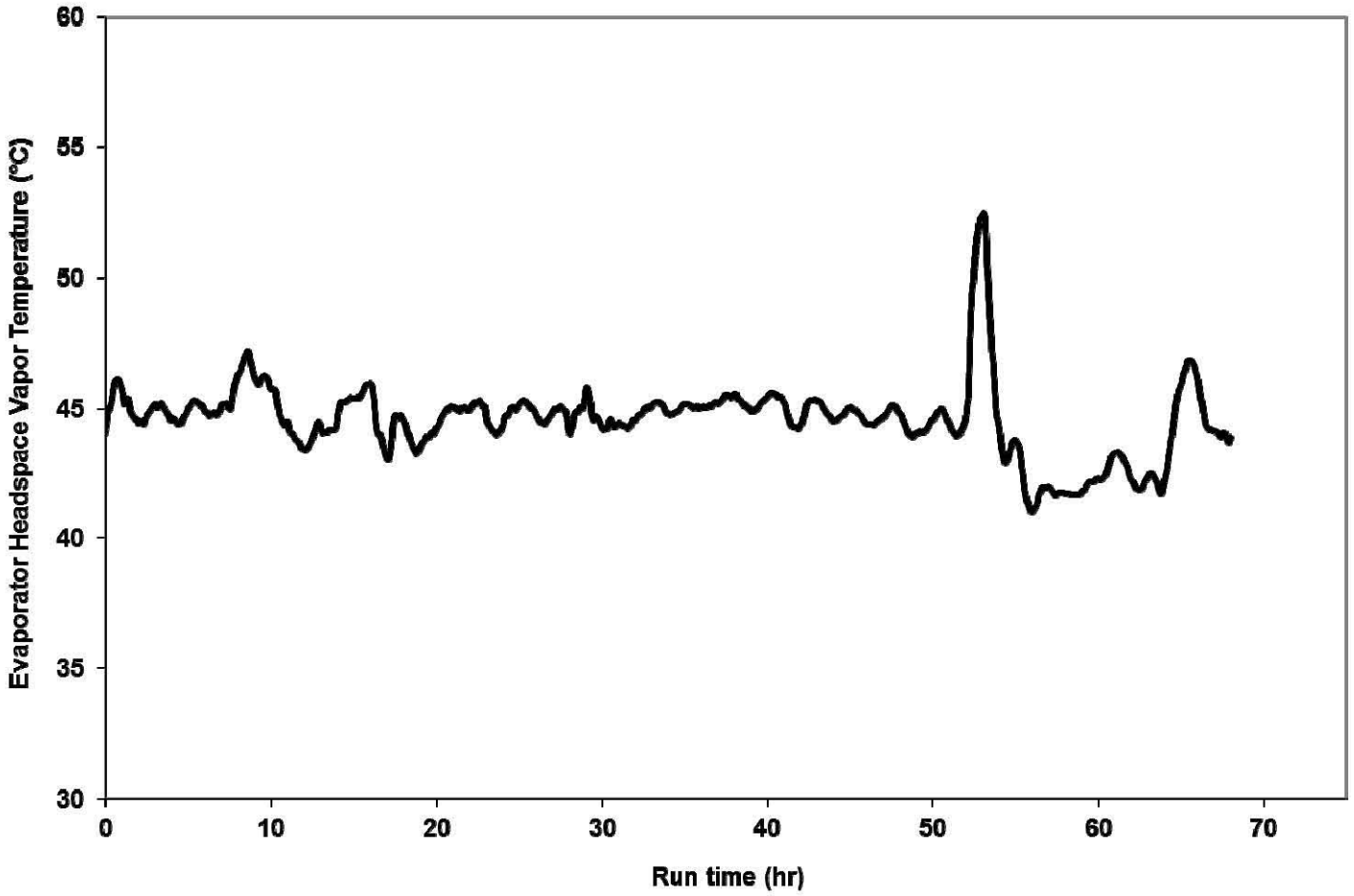


Figure 4.13.b. Test 2 headspace vapor temperature leaving the custom evaporator (1 hour running average used to reduce noise).

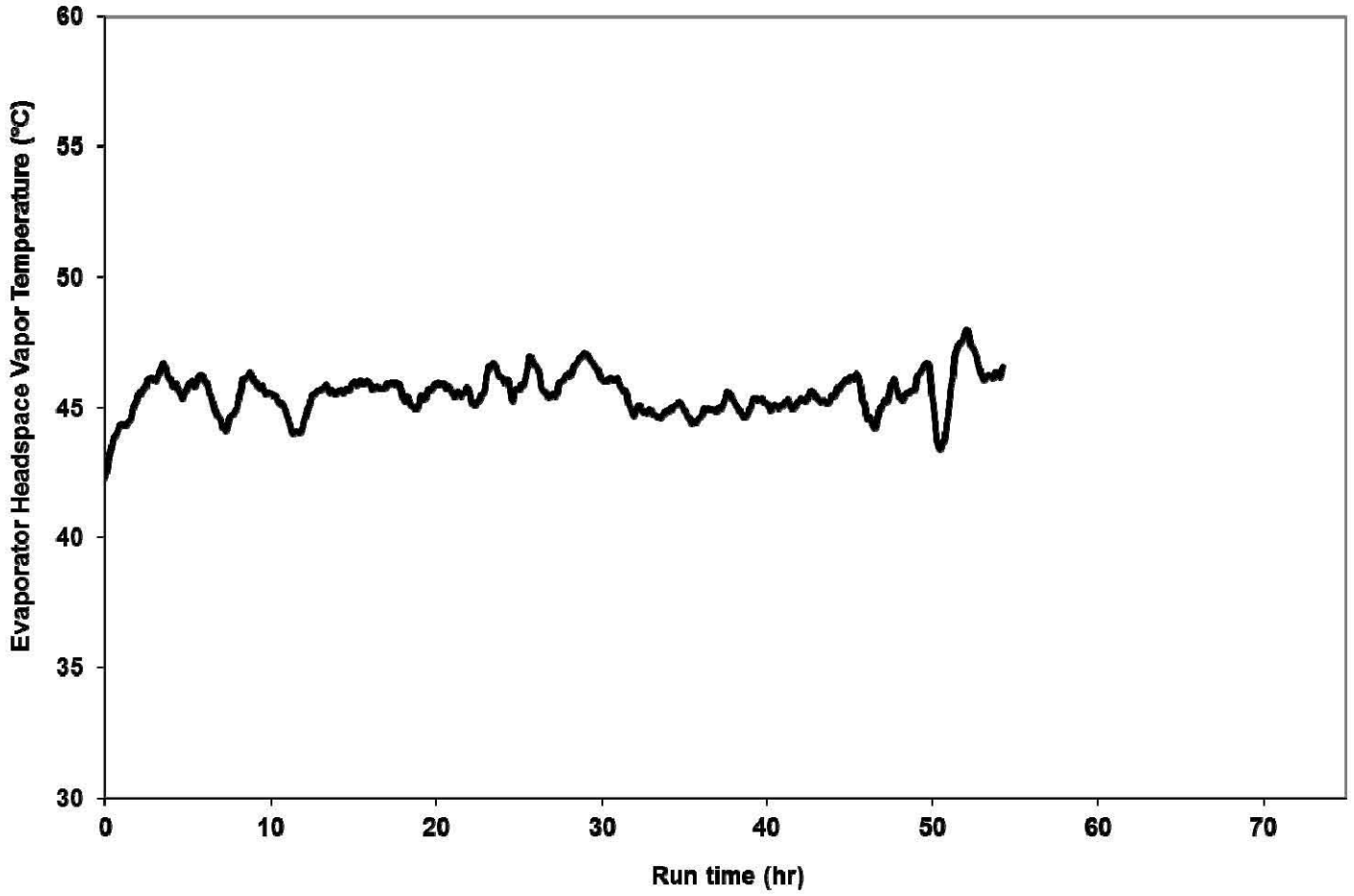


Figure 4.13.c. Test 3 headspace vapor temperature leaving the custom evaporator (1 hour running average used to reduce noise).

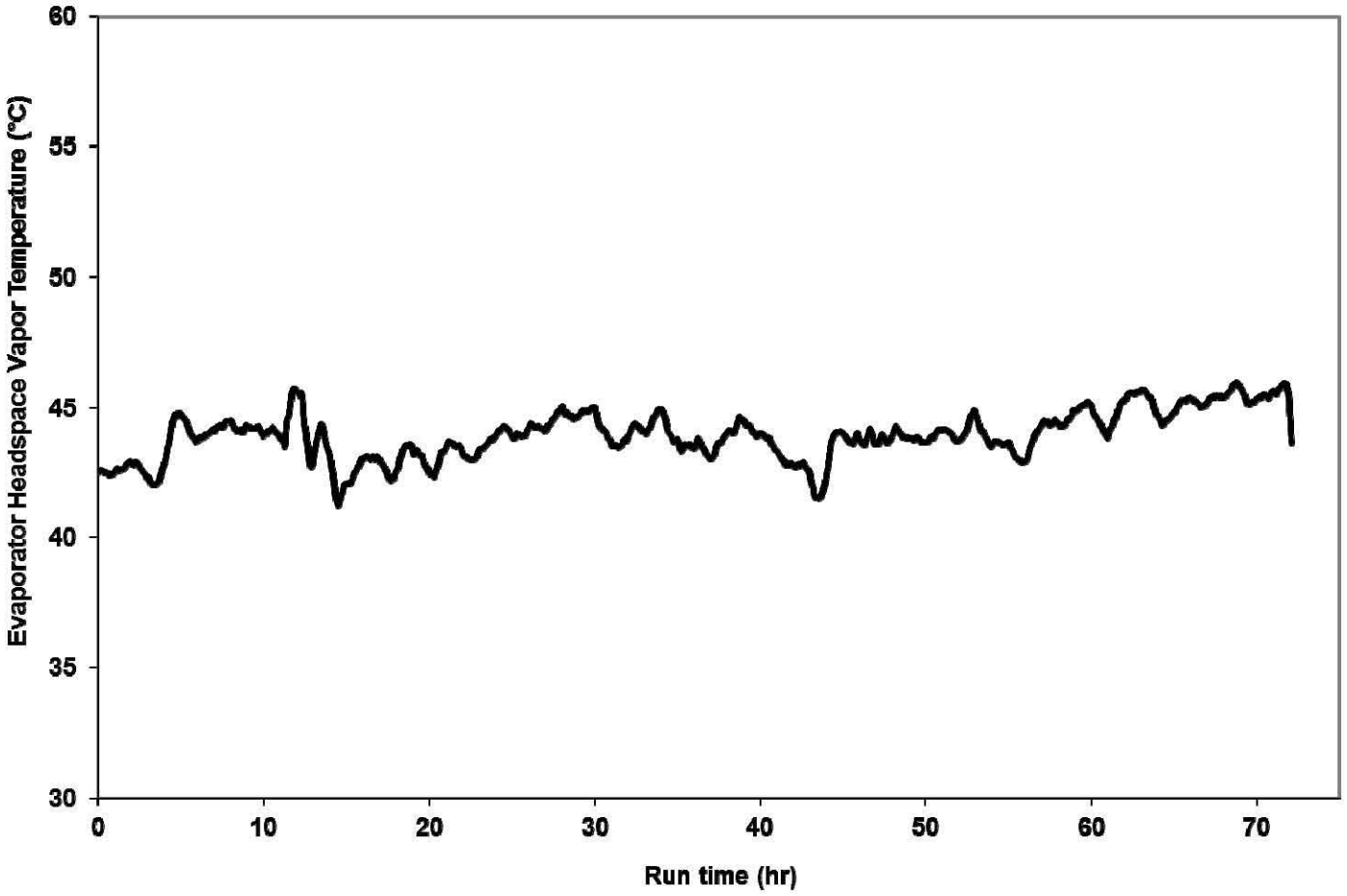


Figure 4.13.d. Test 4 headspace vapor temperature leaving the custom evaporator (1 hour running average used to reduce noise).

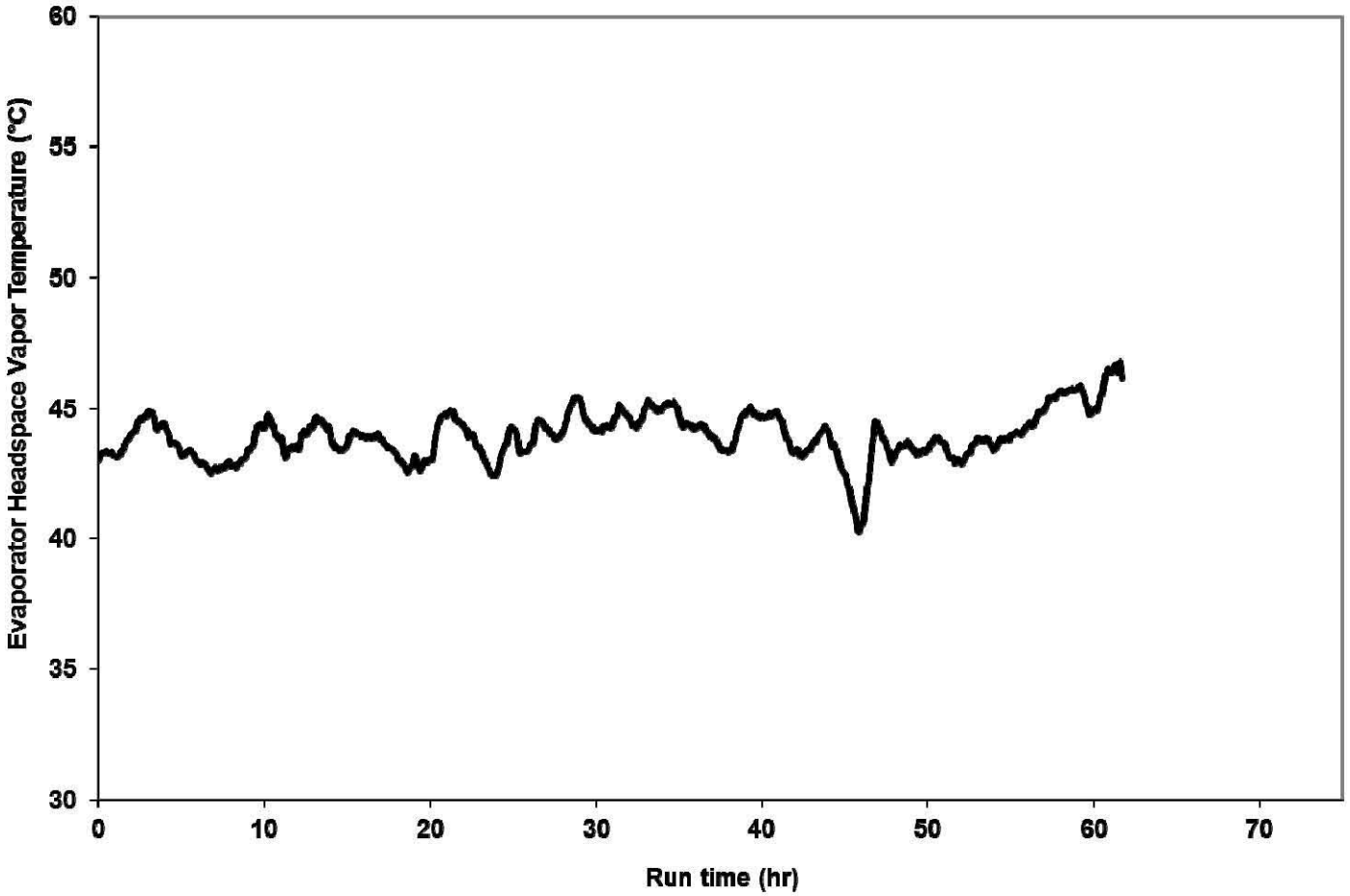


Figure 4.13.e. Test 5 headspace vapor temperature leaving the custom evaporator (1 hour running average used to reduce noise).

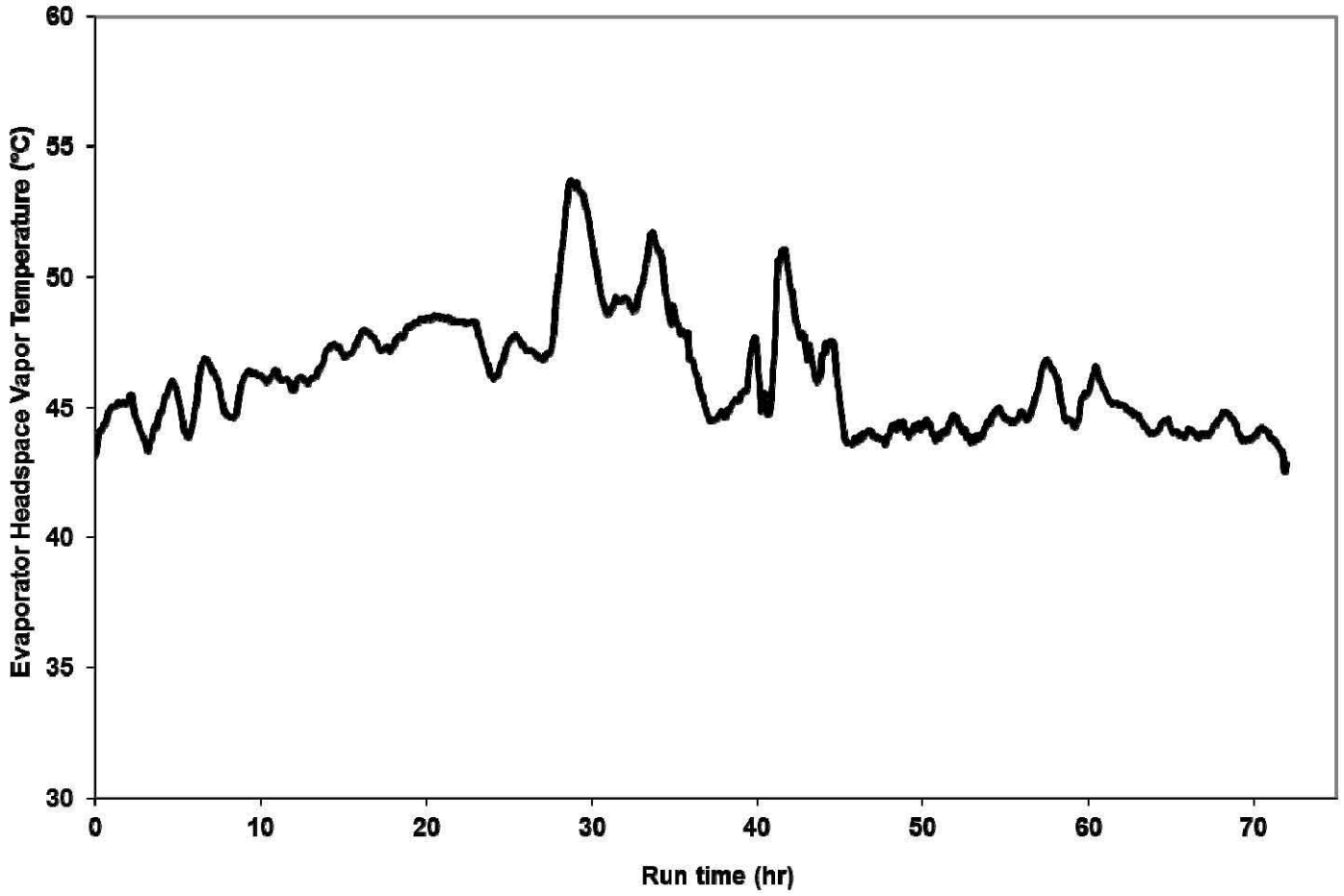


Figure 4.13.f. Test 6 headspace vapor temperature leaving the custom evaporator (1 hour running average used to reduce noise).

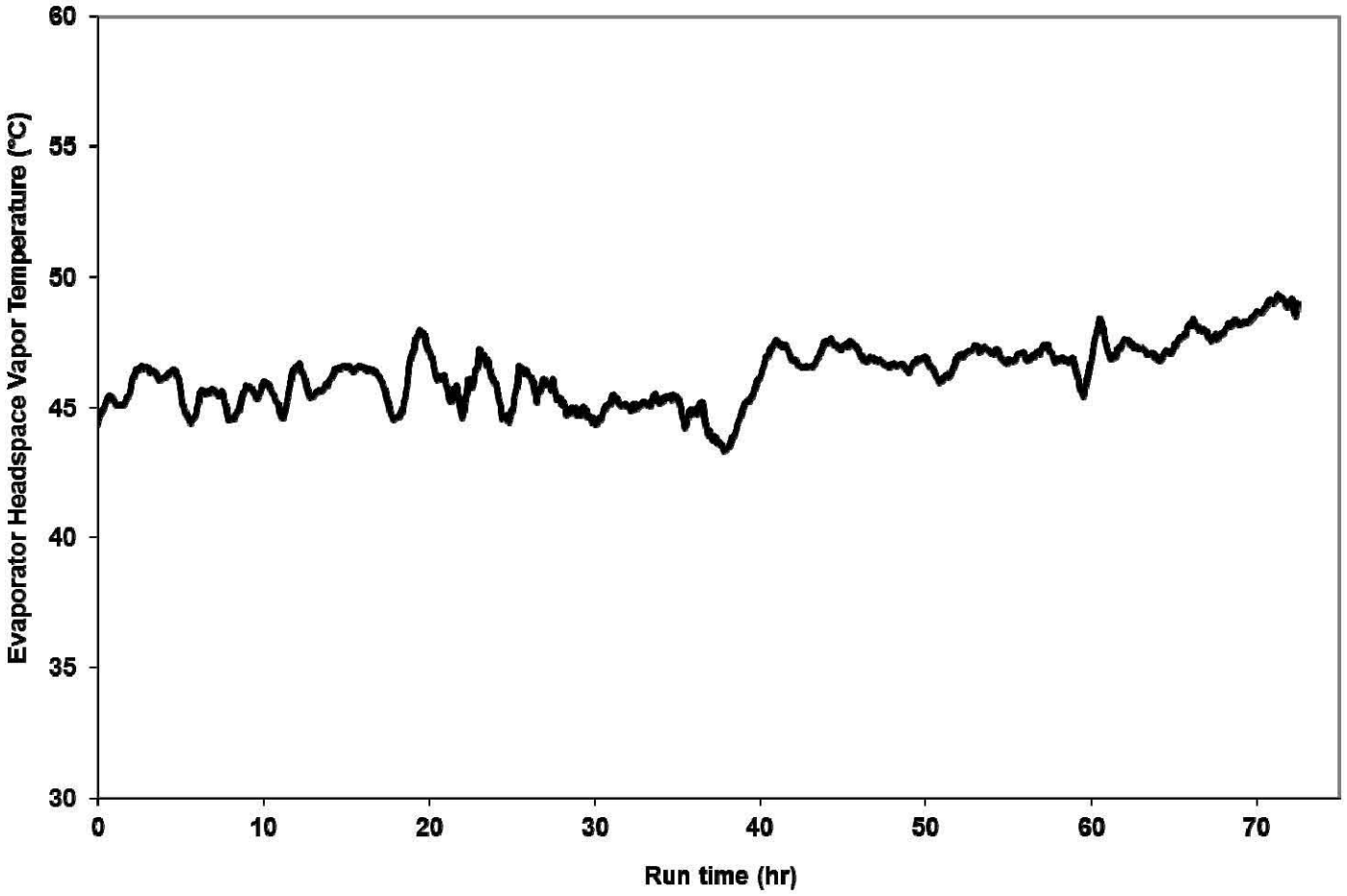


Figure 4.13.g. Test 7 headspace vapor temperature leaving the custom evaporator (1 hour running average used to reduce noise).

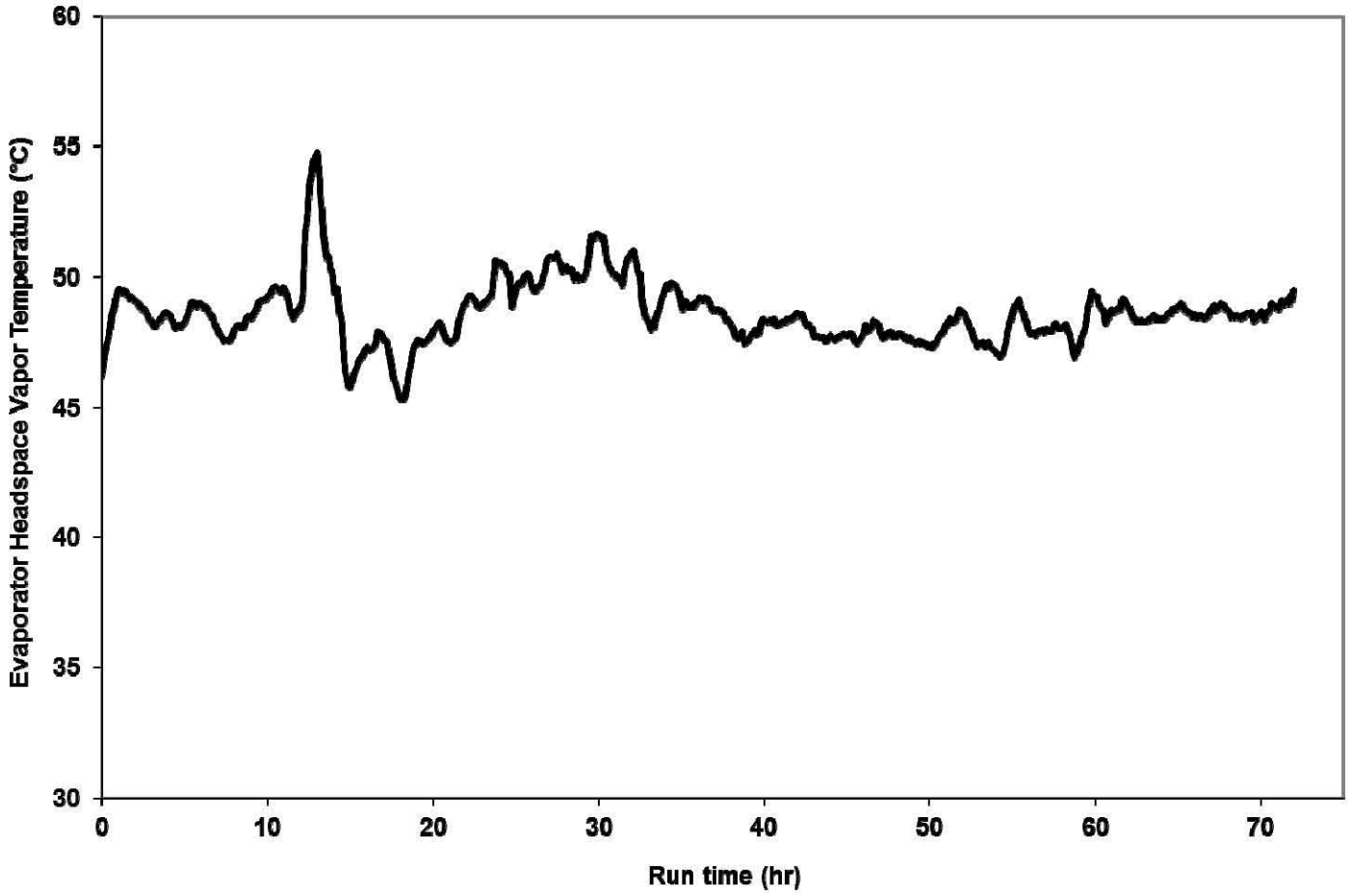


Figure 4.13.h. Test 8 headspace vapor temperature leaving the custom evaporator (1 hour running average used to reduce noise).

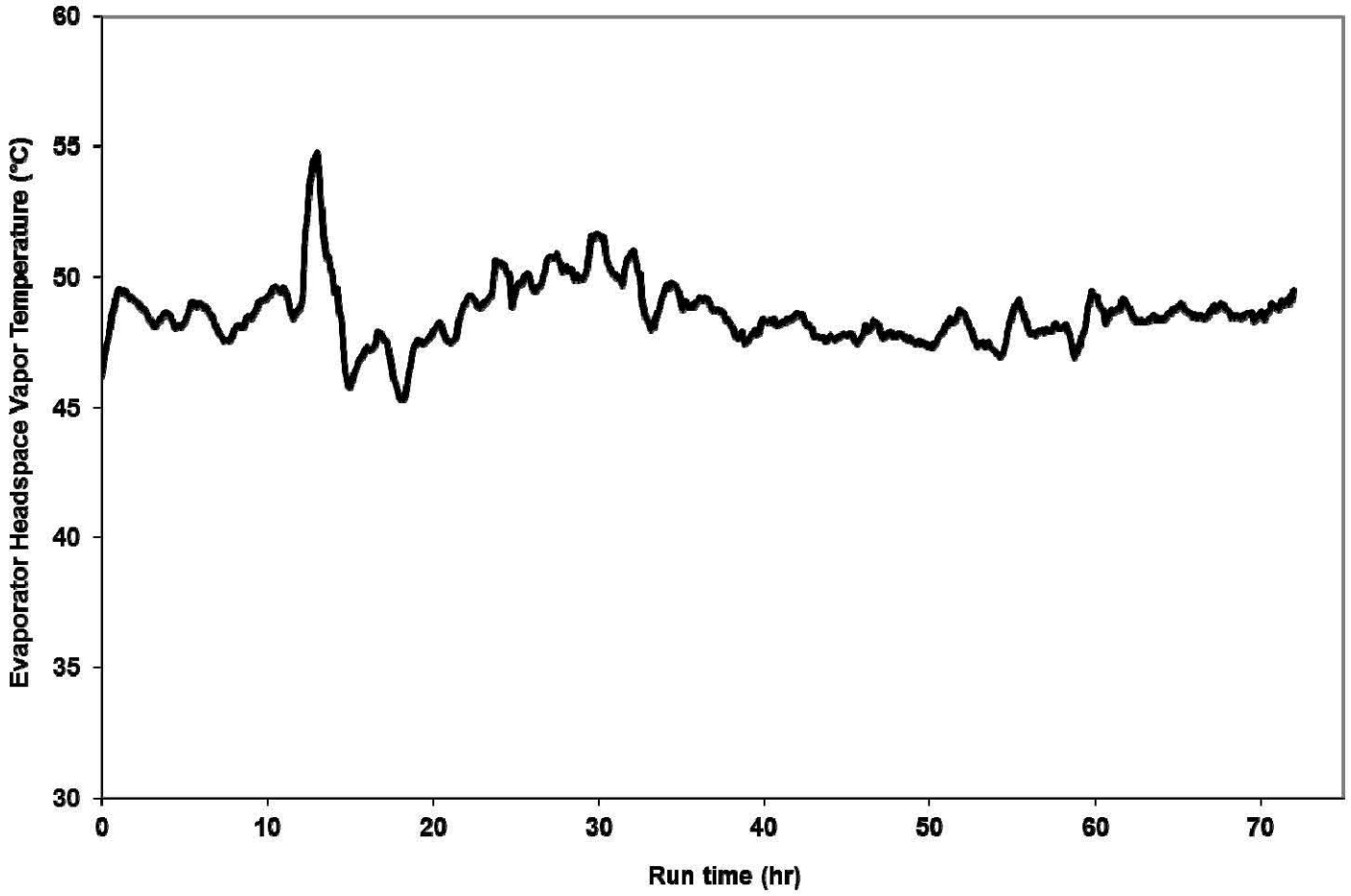


Figure 4.13.i. Test 9 headspace vapor temperature leaving the custom evaporator (1 hour running average used to reduce noise).

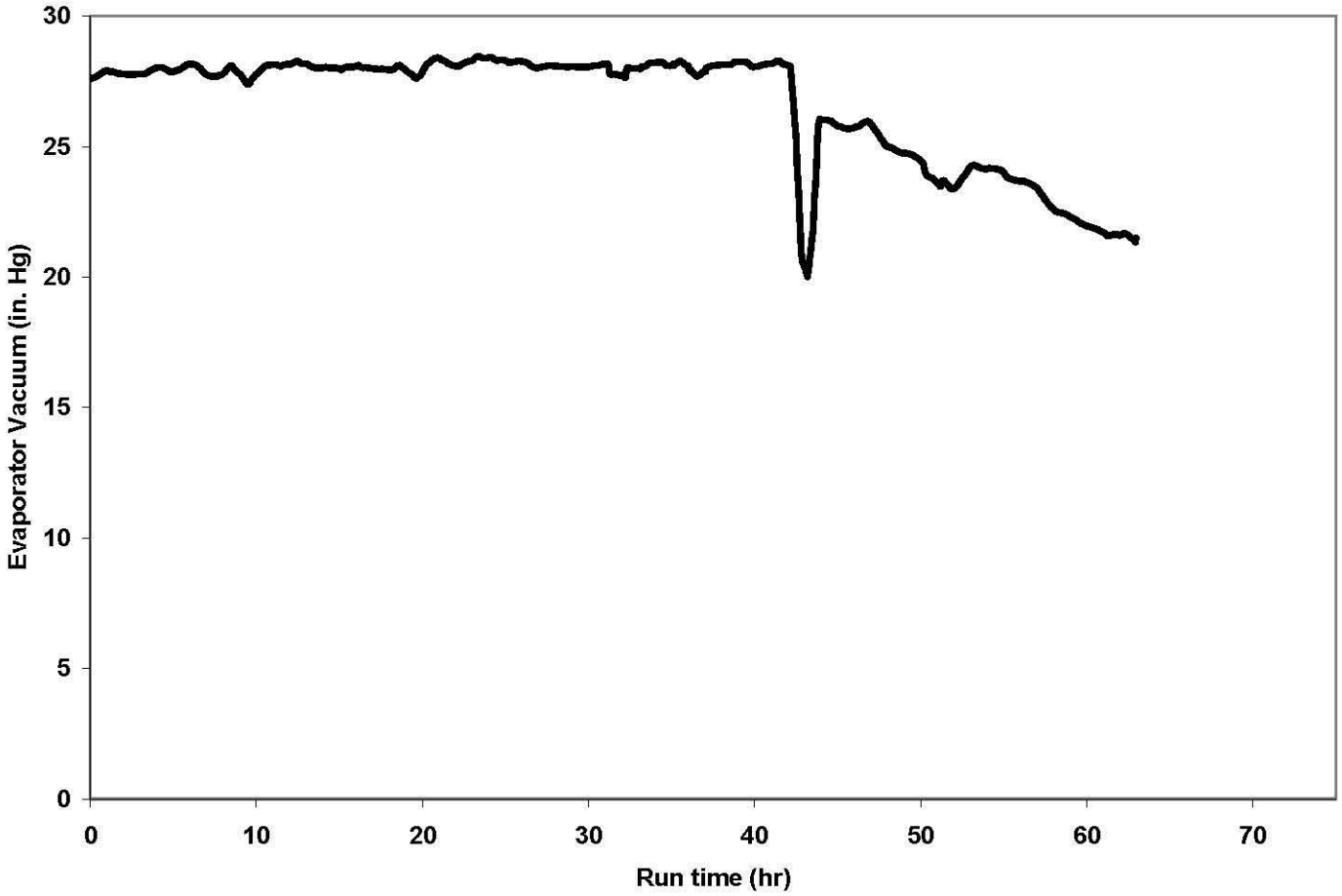


Figure 4.14.a. Test 1 Evaporator vacuum (1 hour running average used to reduce noise).

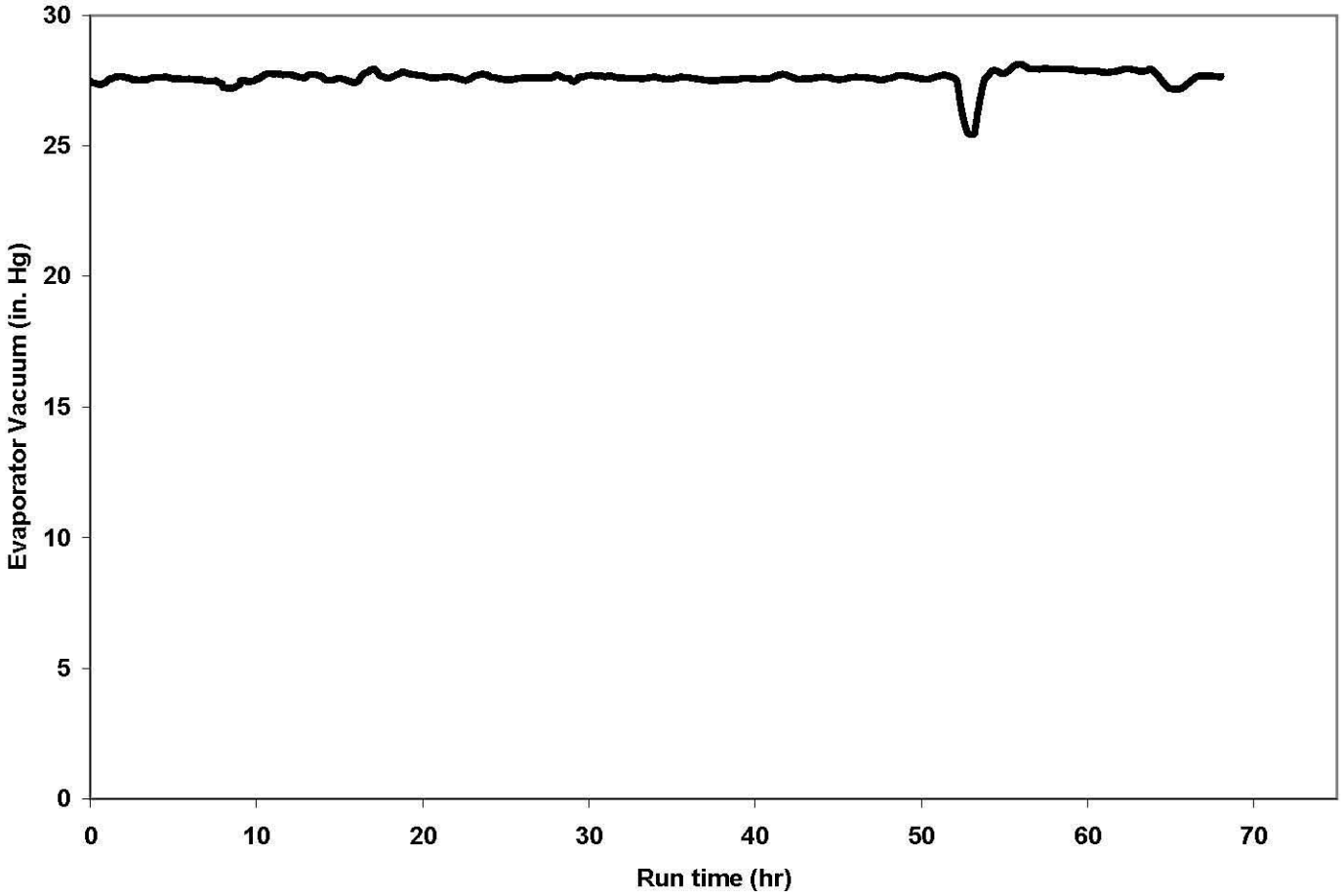


Figure 4.14.b. Test 2 Evaporator vacuum (1 hour running average used to reduce noise).

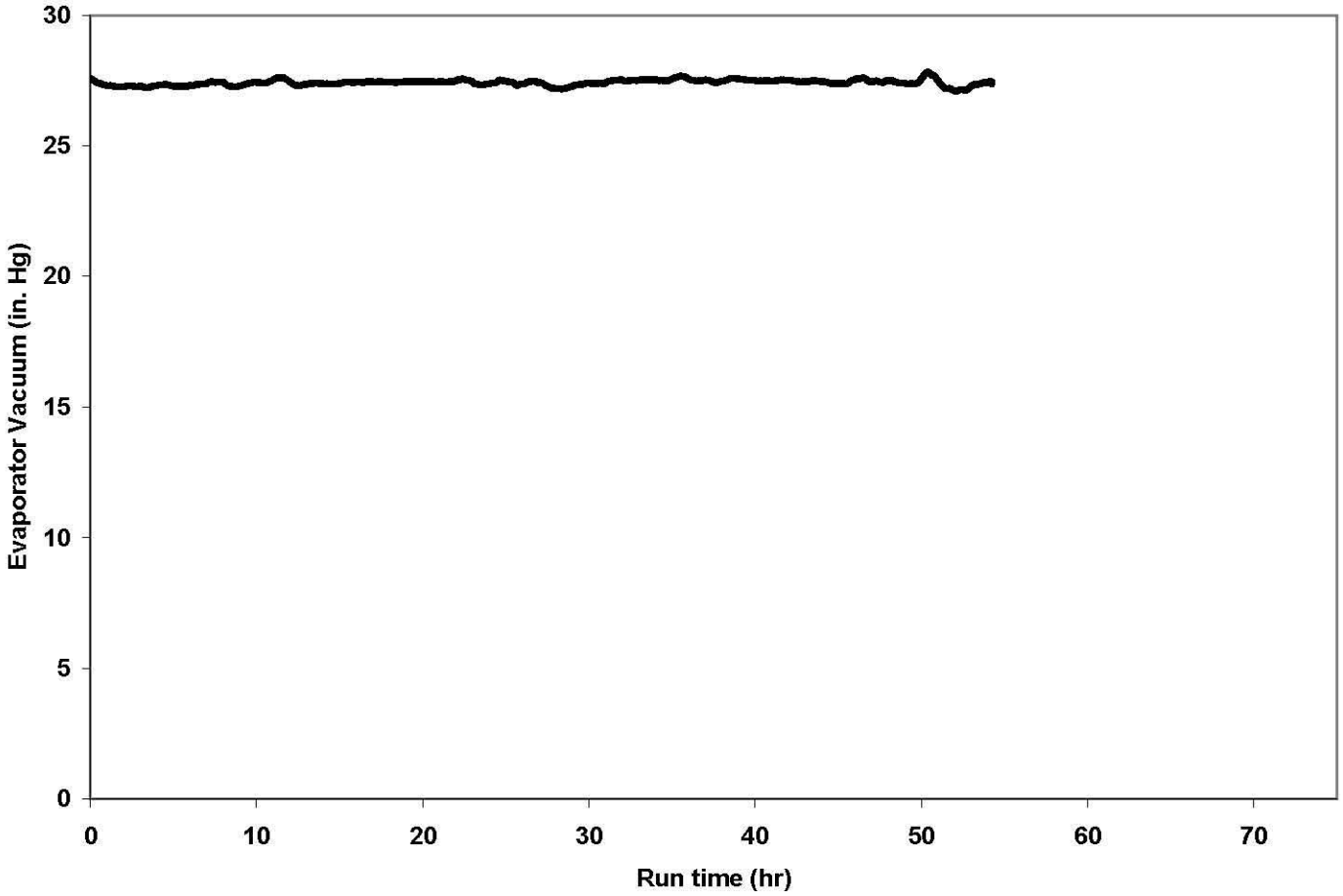


Figure 4.14.c. Test 3 Evaporator vacuum (1 hour running average used to reduce noise).

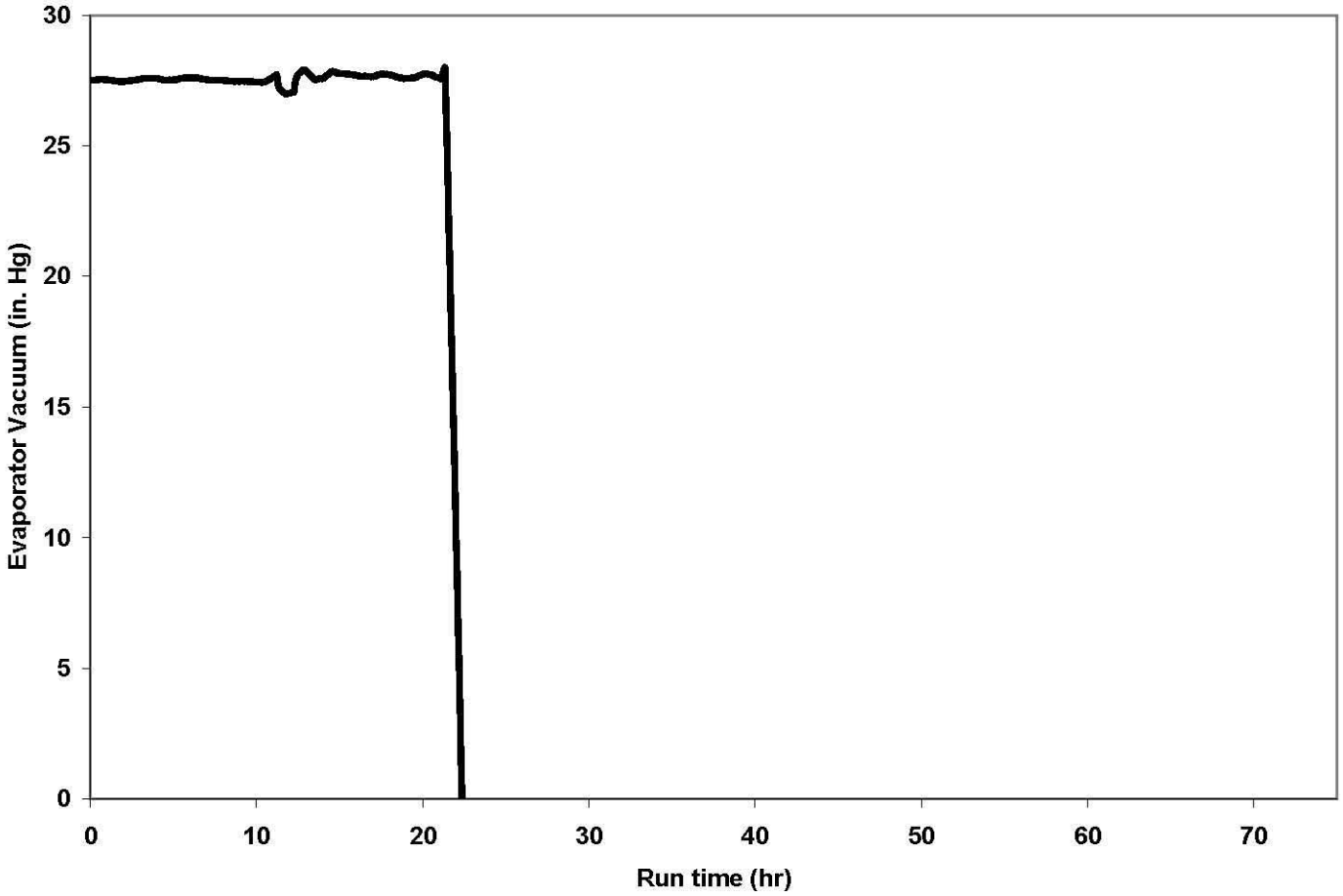


Figure 4.14.d. Test 4 Evaporator vacuum (1 hour running average used to reduce noise).

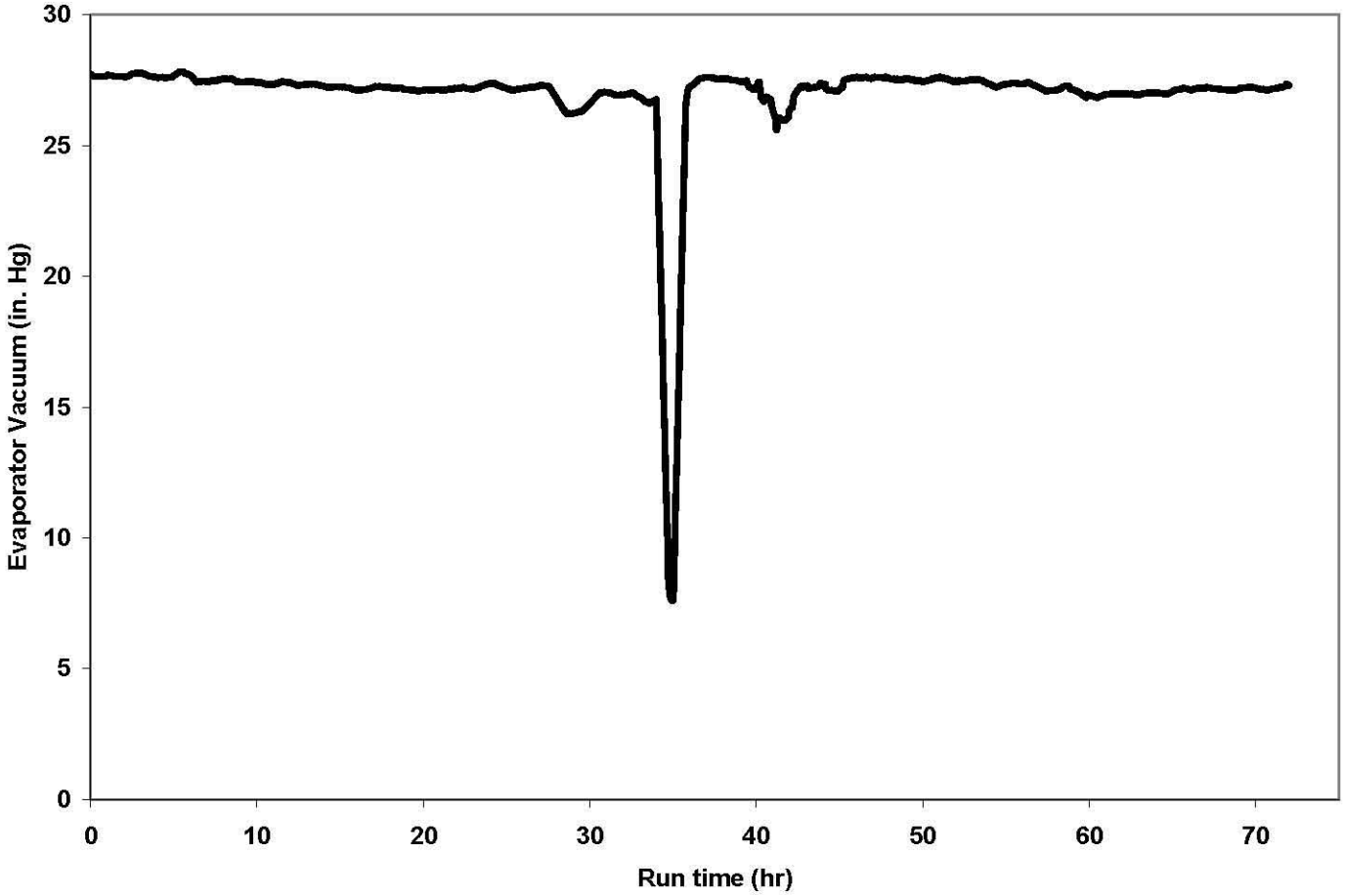


Figure 4.14.e. Test 6 Evaporator vacuum (1 hour running average used to reduce noise).

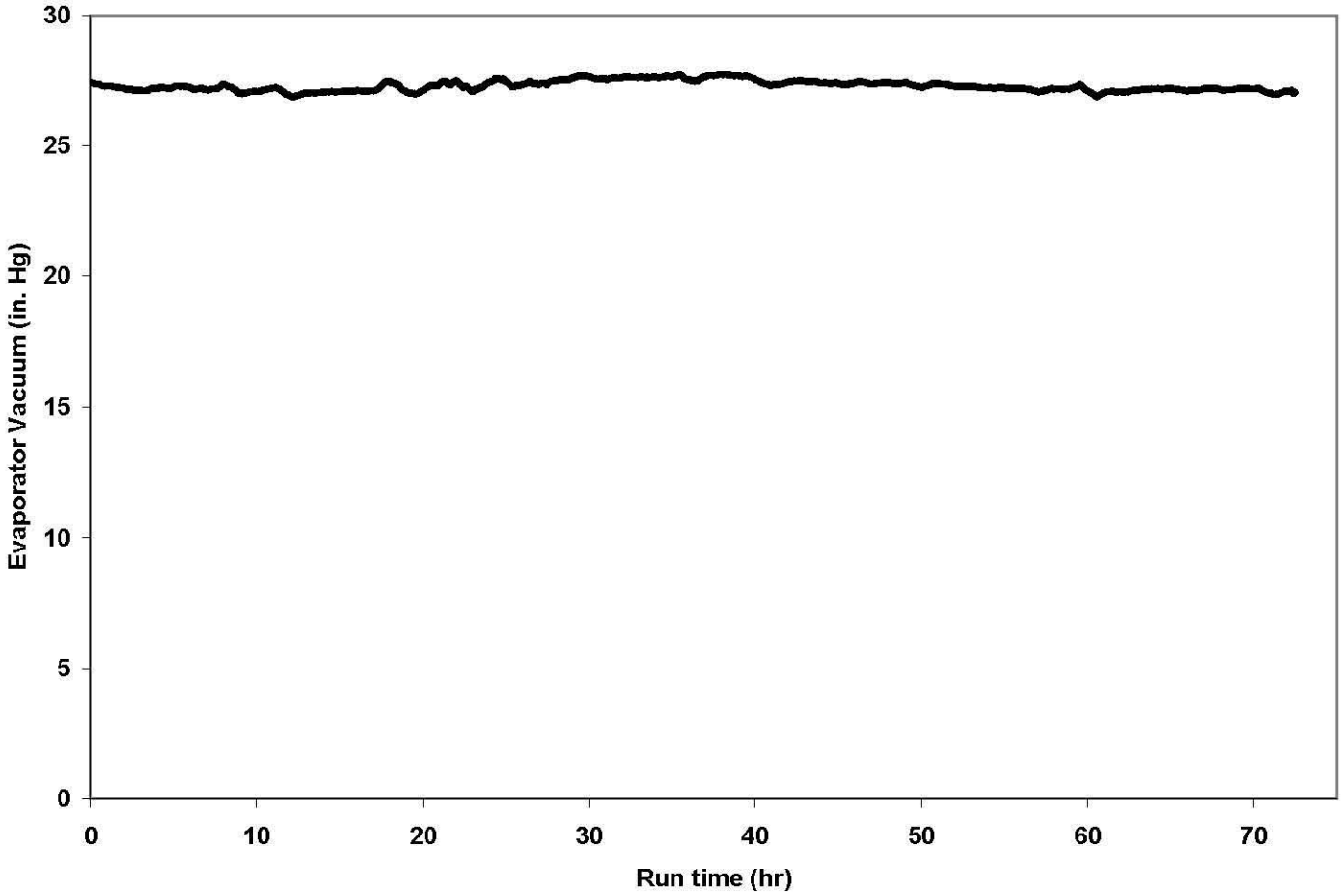


Figure 4.14.f. Test 7 Evaporator vacuum (1 hour running average used to reduce noise).

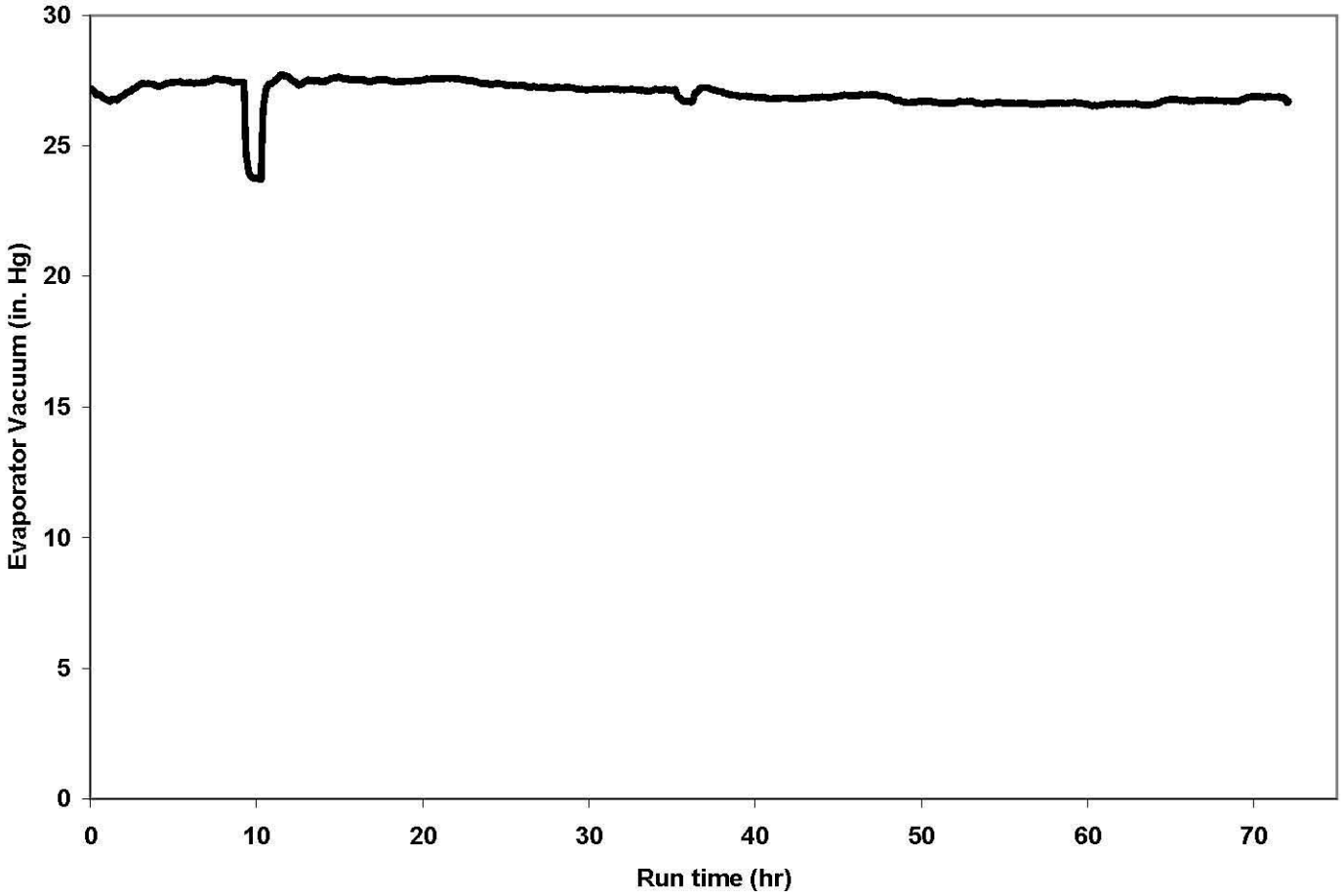


Figure 4.14.g. Test 8 Evaporator vacuum (1 hour running average used to reduce noise).

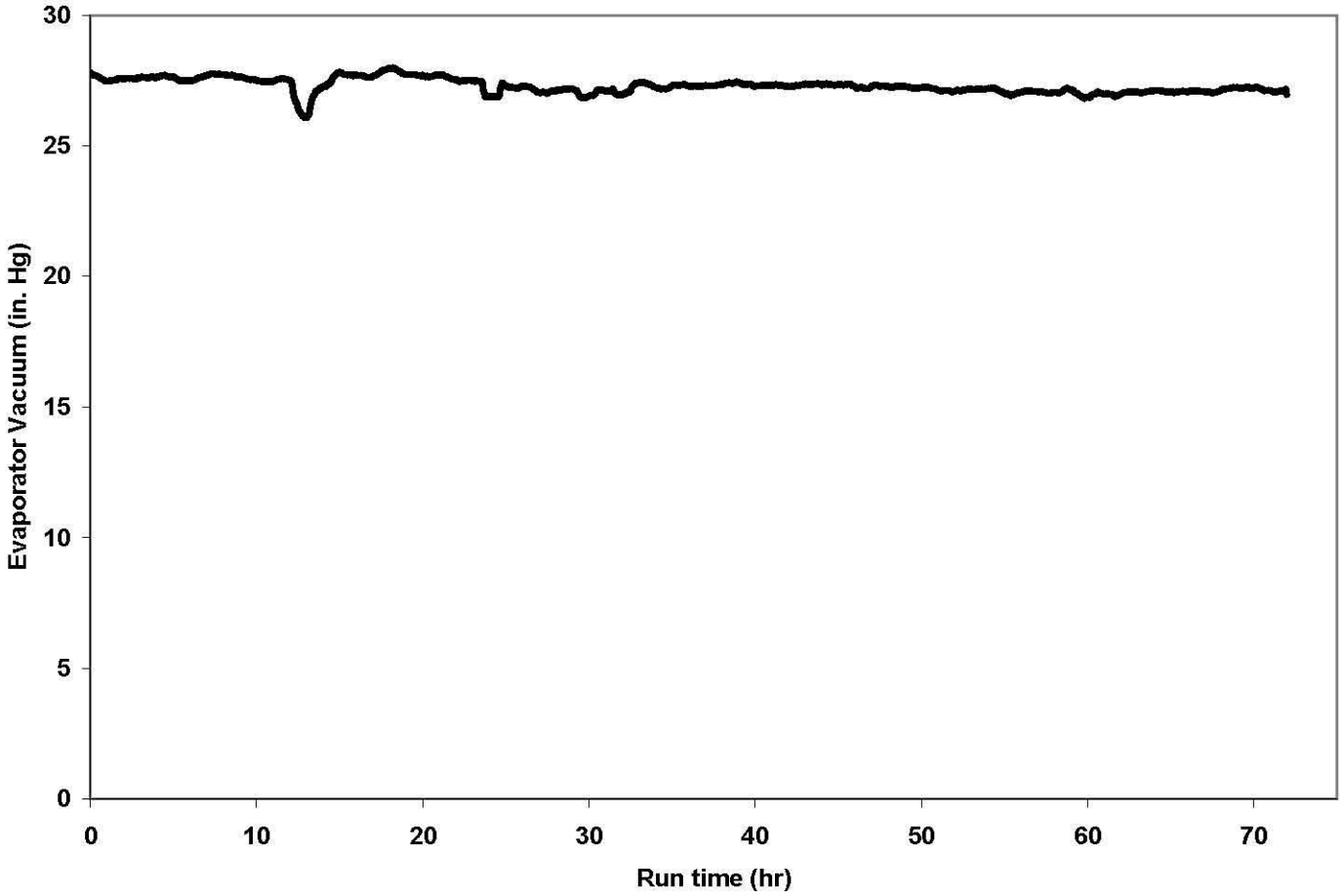


Figure 4.14.h. Test 9 Evaporator vacuum (1 hour running average used to reduce noise).

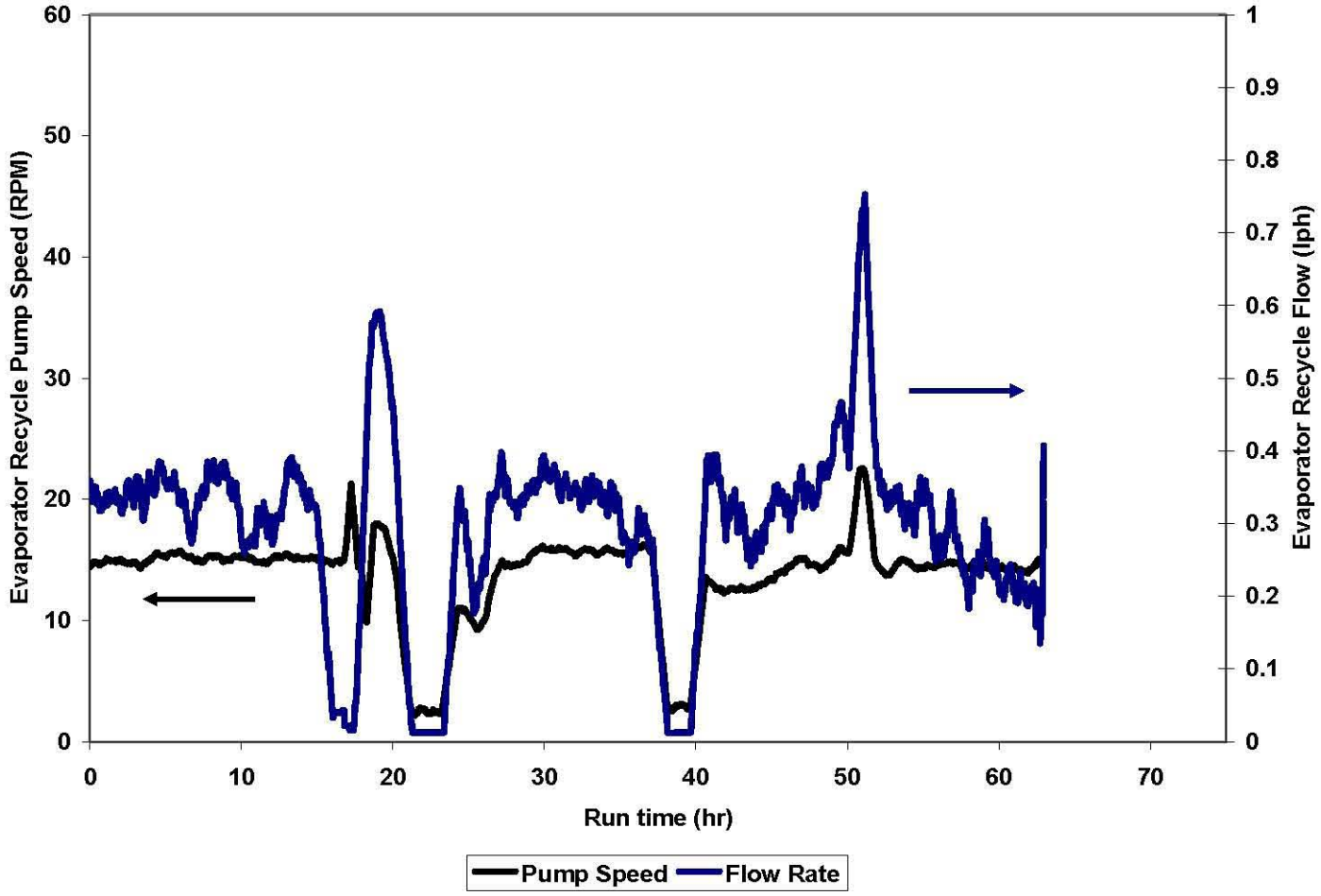


Figure 4.15.a. Test 1 recycle water flow rate and pump speed (1 hour running average used to reduce noise).

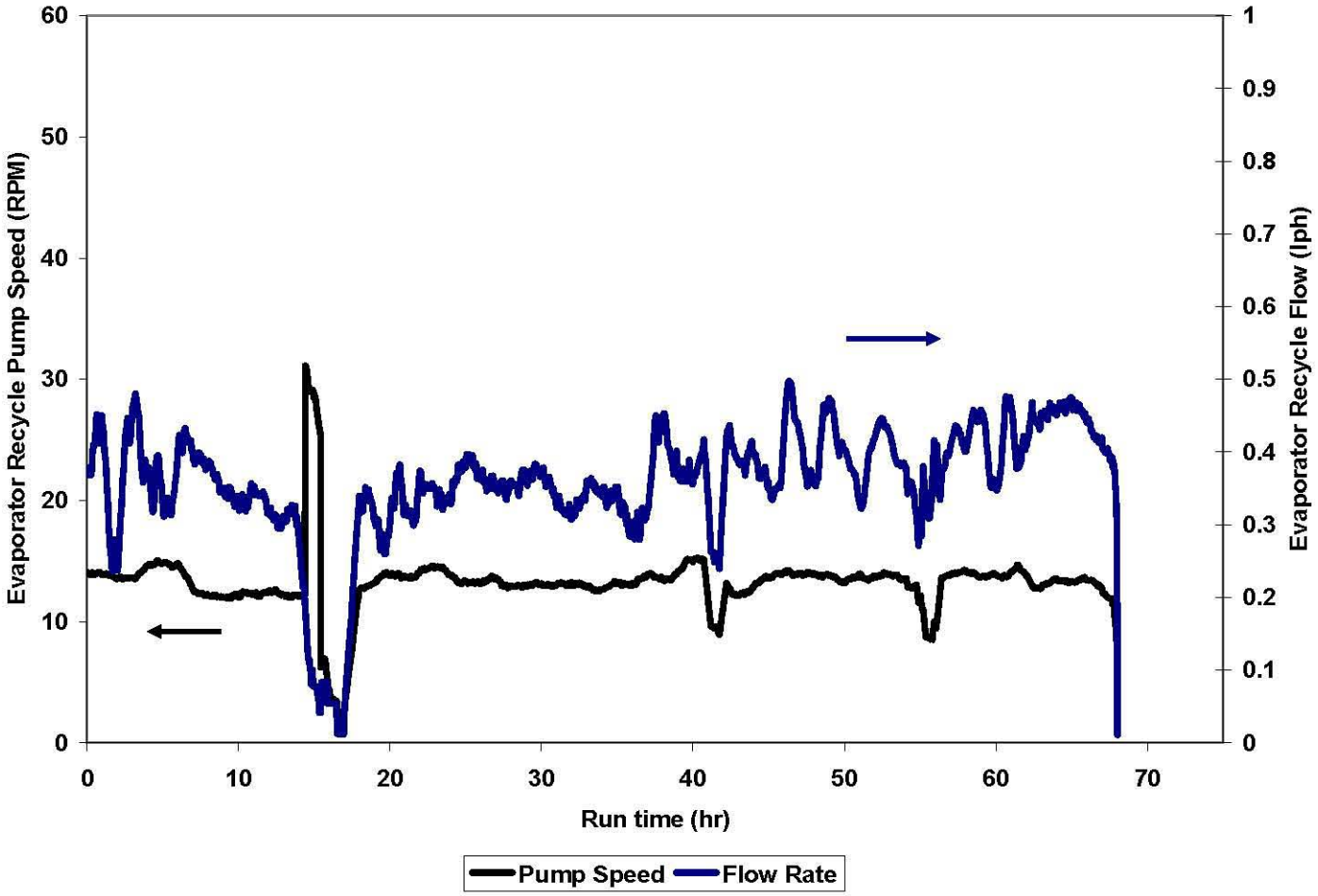


Figure 4.15.b. Test 2 recycle water flow rate and pump speed (1 hour running average used to reduce noise).

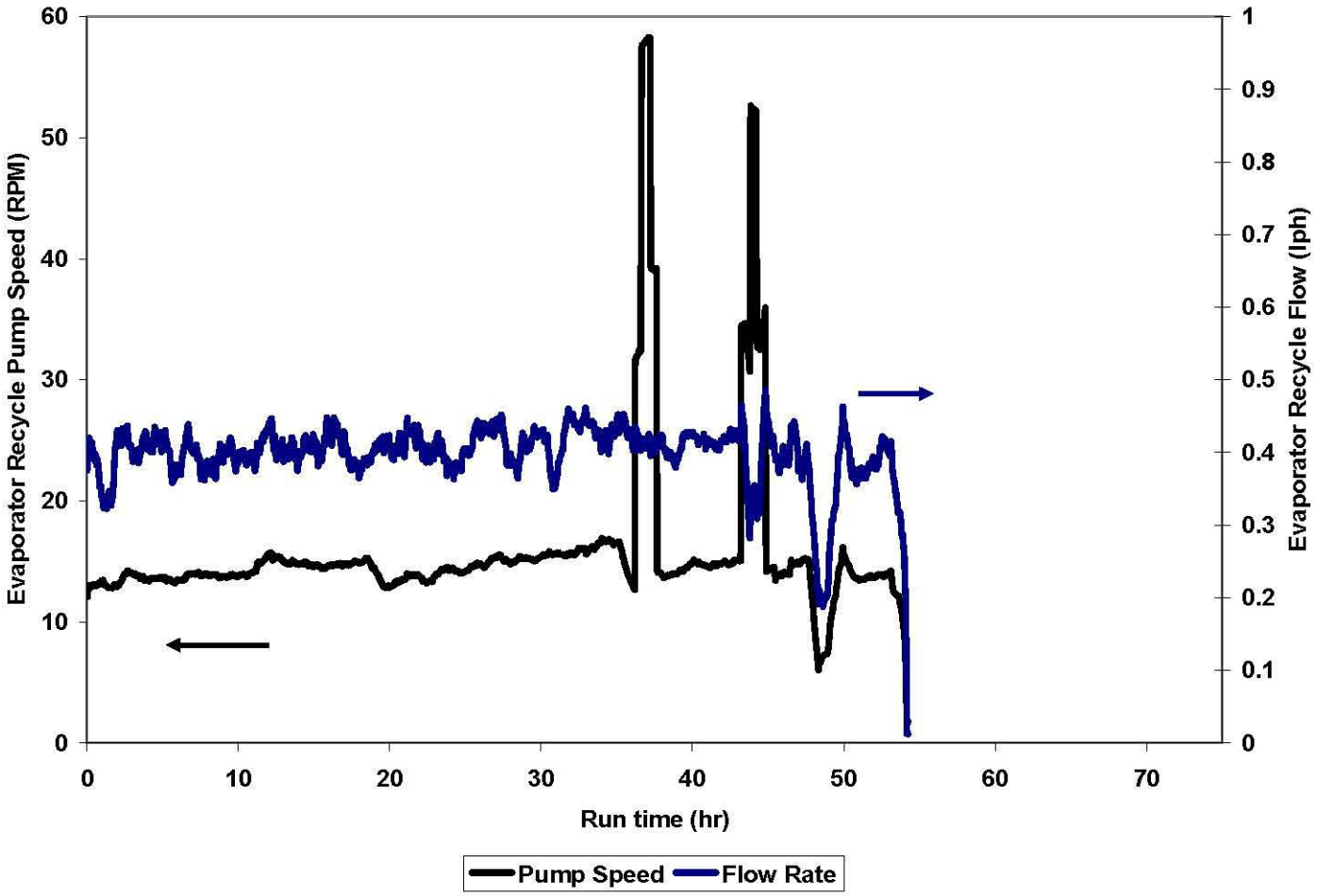


Figure 4.15.c. Test 3 recycle water flow rate and pump speed (1 hour running average used to reduce noise).

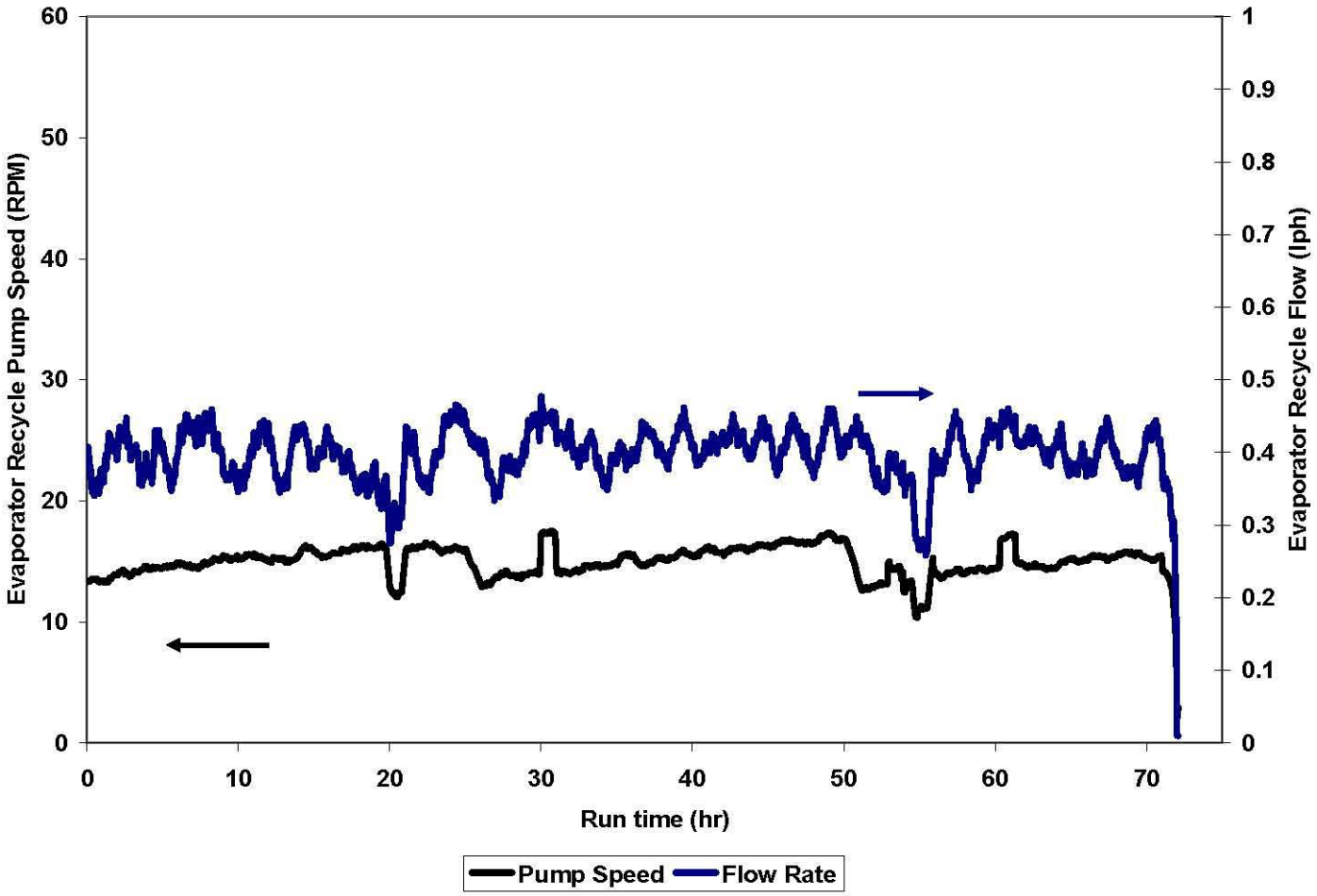


Figure 4.15.d. Test 4 recycle water flow rate and pump speed (1 hour running average used to reduce noise).

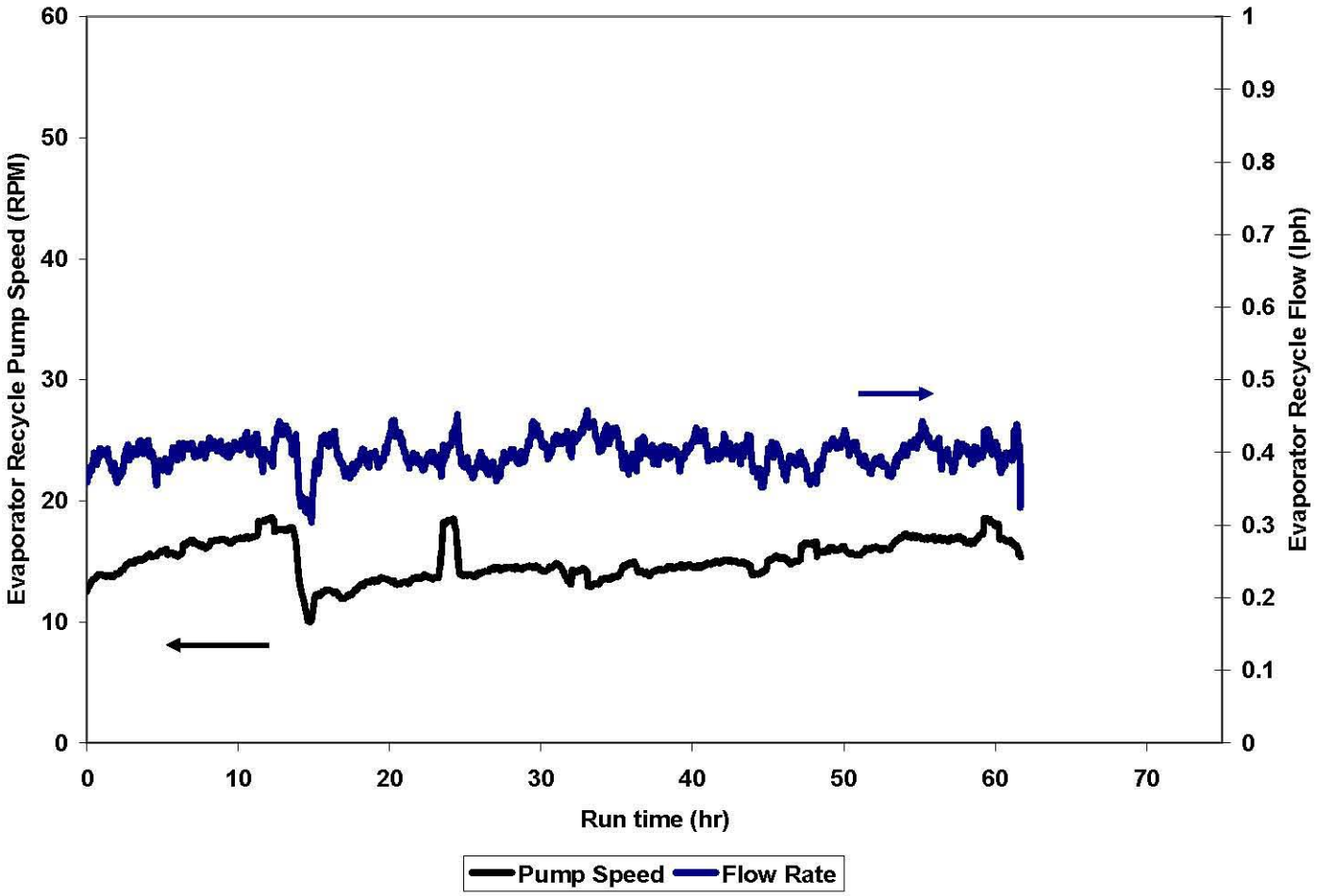


Figure 4.15.e. Test 5 recycle water flow rate and pump speed (1 hour running average used to reduce noise).

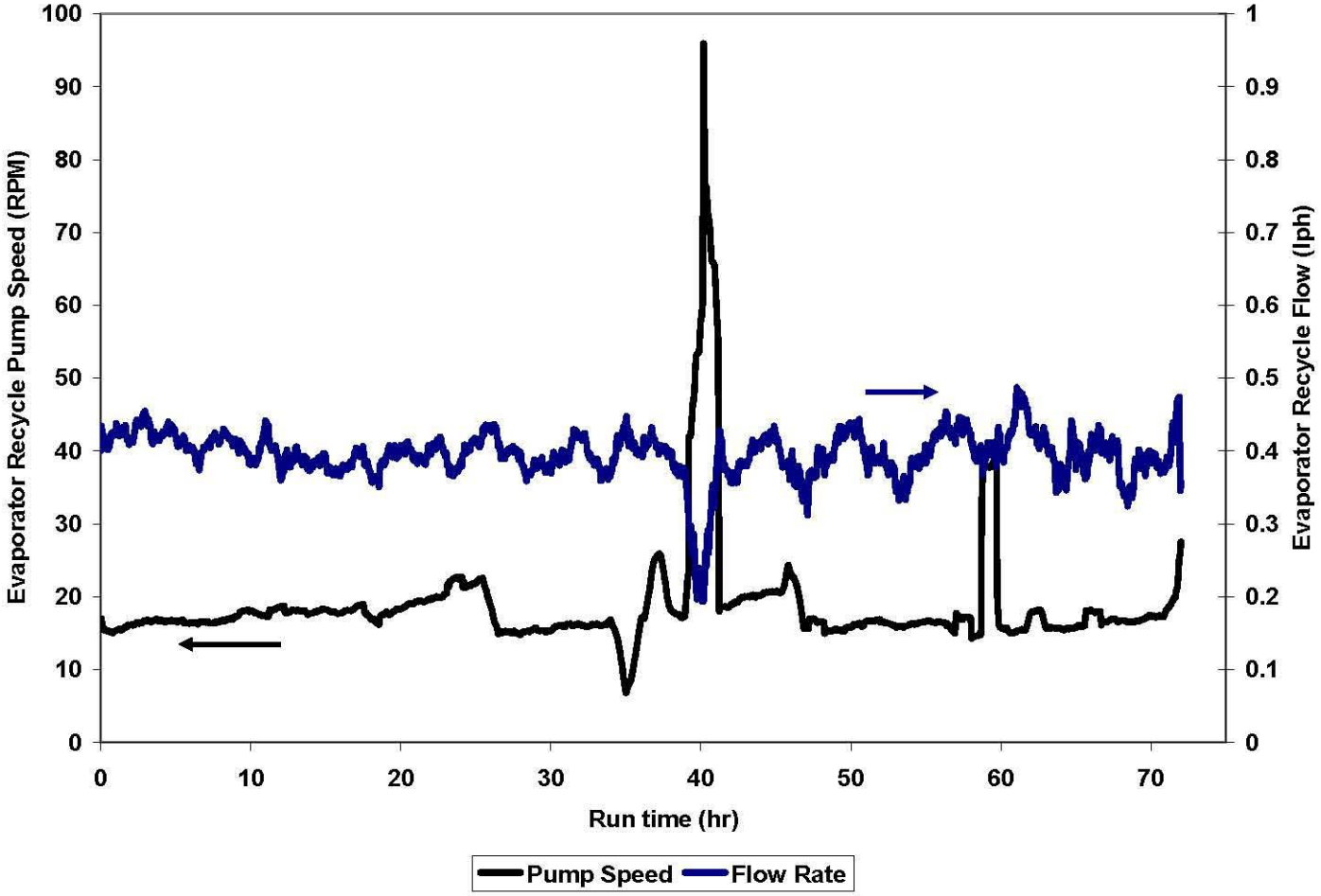


Figure 4.15.f. Test 6 recycle water flow rate and pump speed (1 hour running average used to reduce noise).

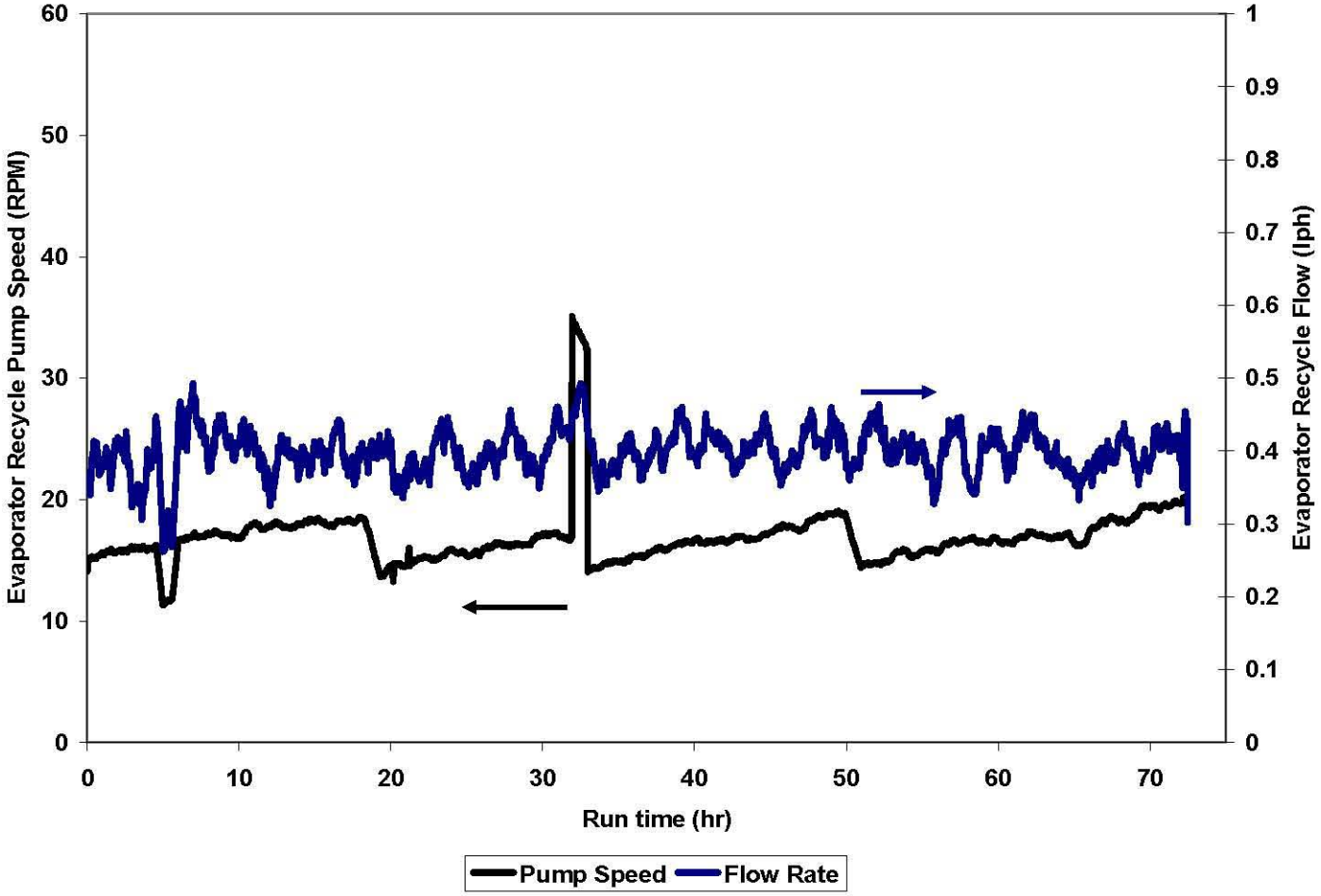


Figure 4.15.g. Test 7 recycle water flow rate and pump speed (1 hour running average used to reduce noise).

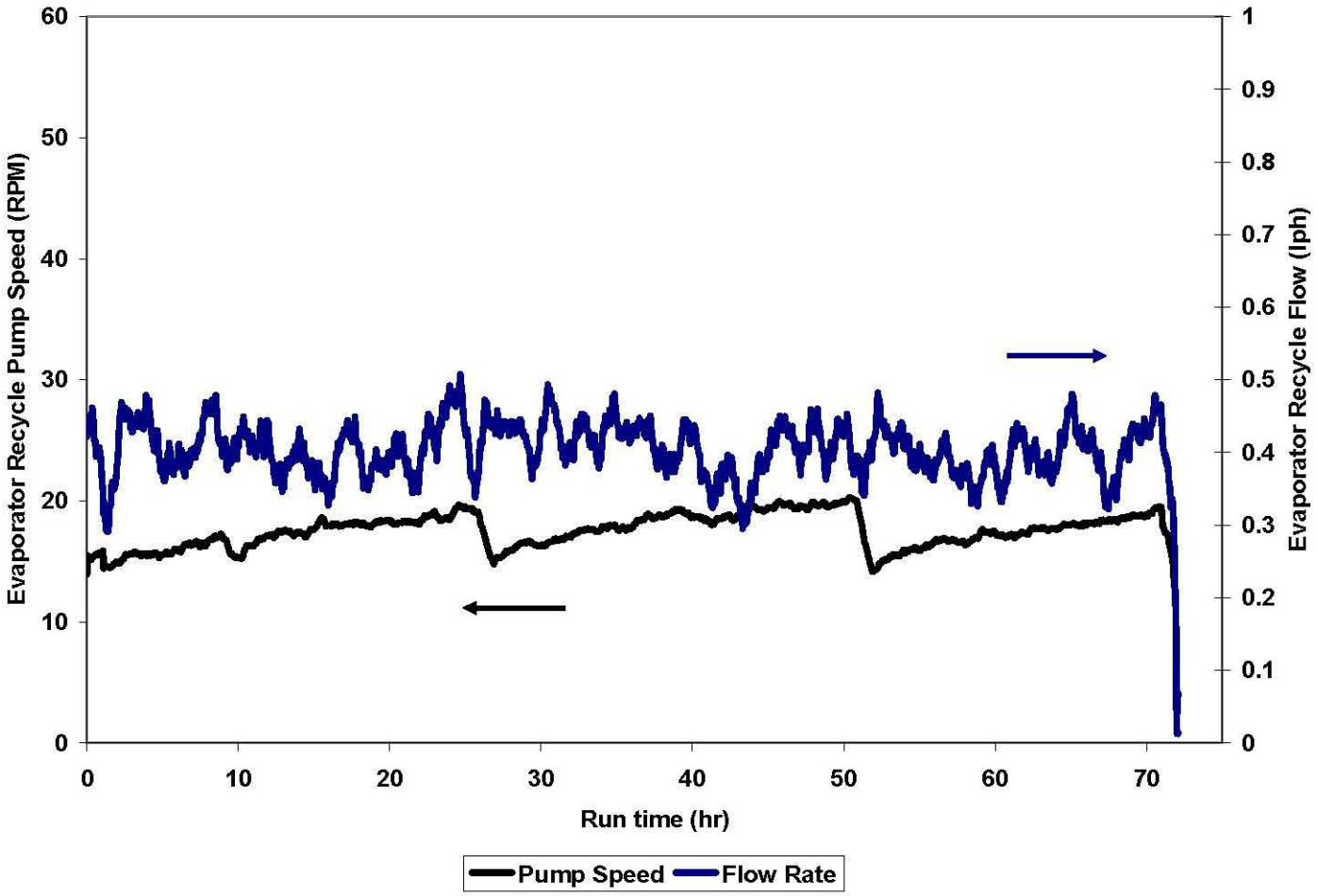


Figure 4.15.h. Test 8 recycle water flow rate and pump speed (1 hour running average used to reduce noise).

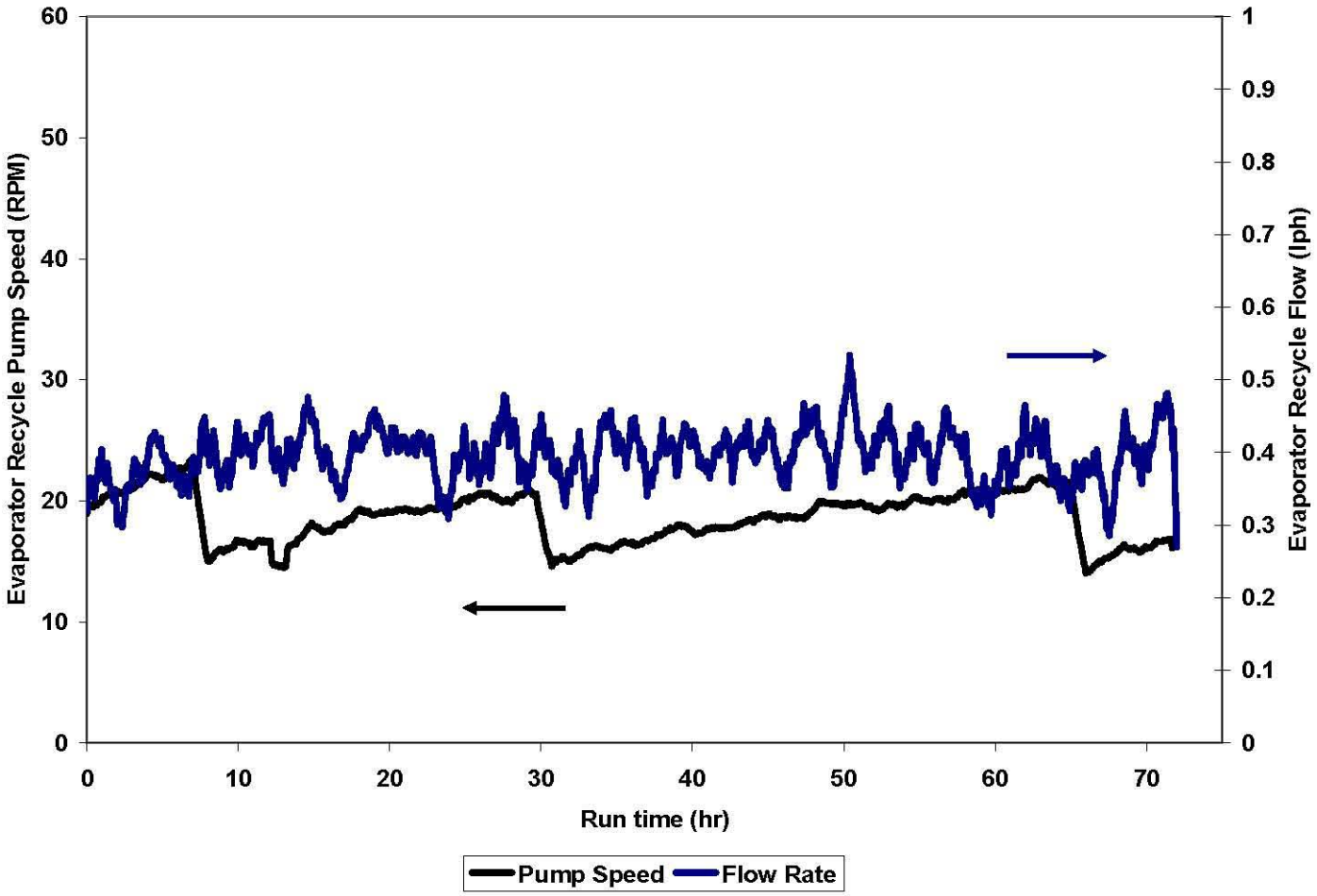


Figure 4.15.i. Test 9 recycle water flow rate and pump speed (1 hour running average used to reduce noise).

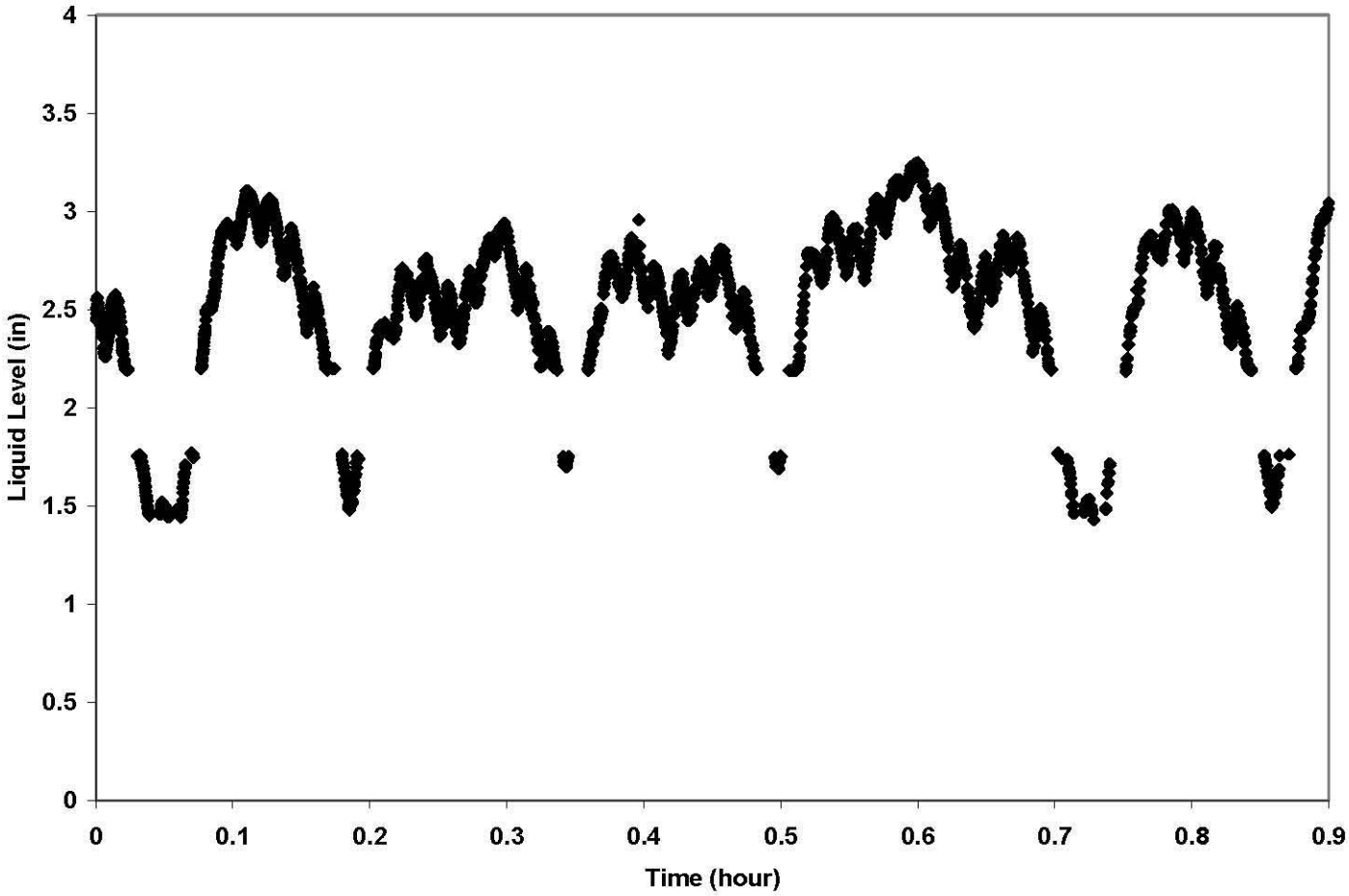


Figure 4.16. Digital image processing of the evaporator sump level, based on the height of the meniscus in the column. Data collected during Test 9.

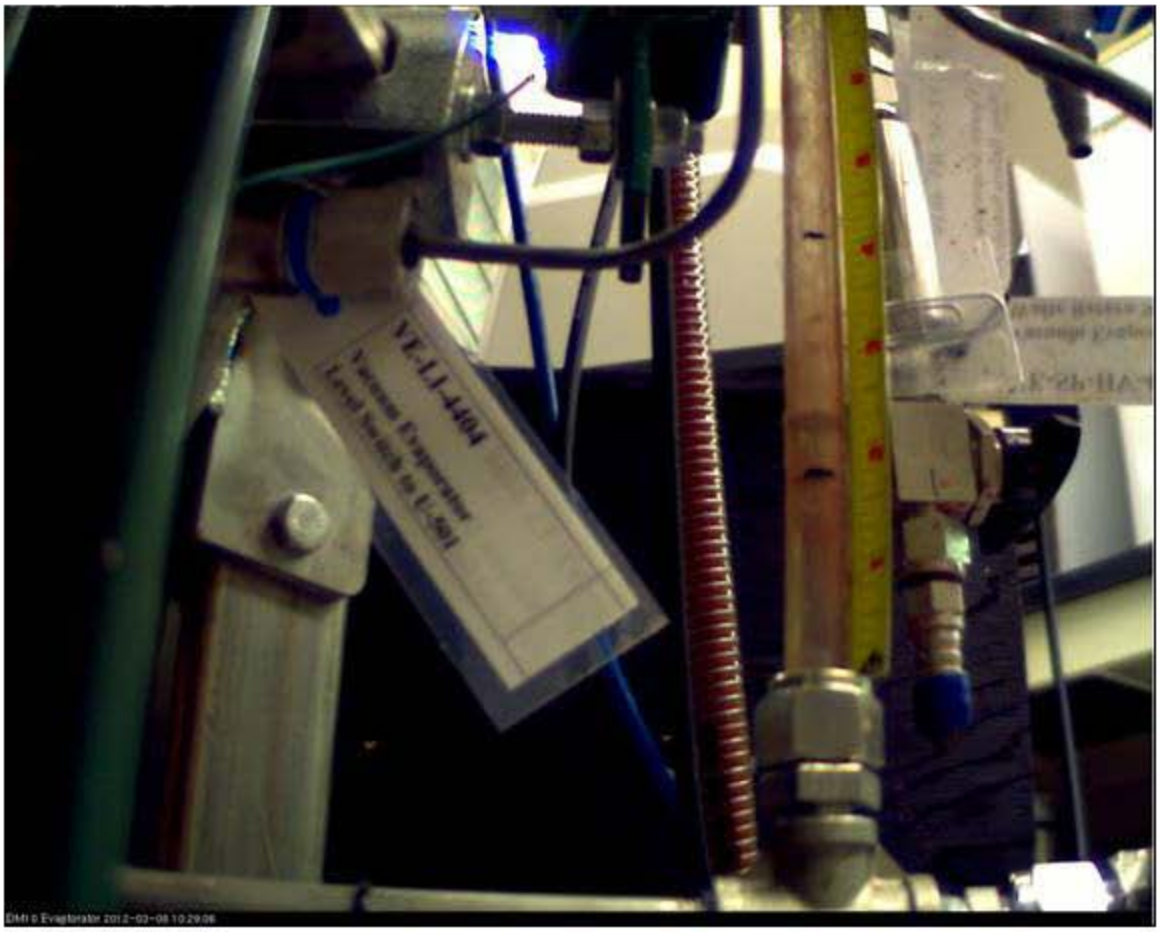


Figure 4.17. Still image from the video feed of the evaporator sump. The meniscus is clearly visible between the black marks on the vertical tube next to the tape measure.

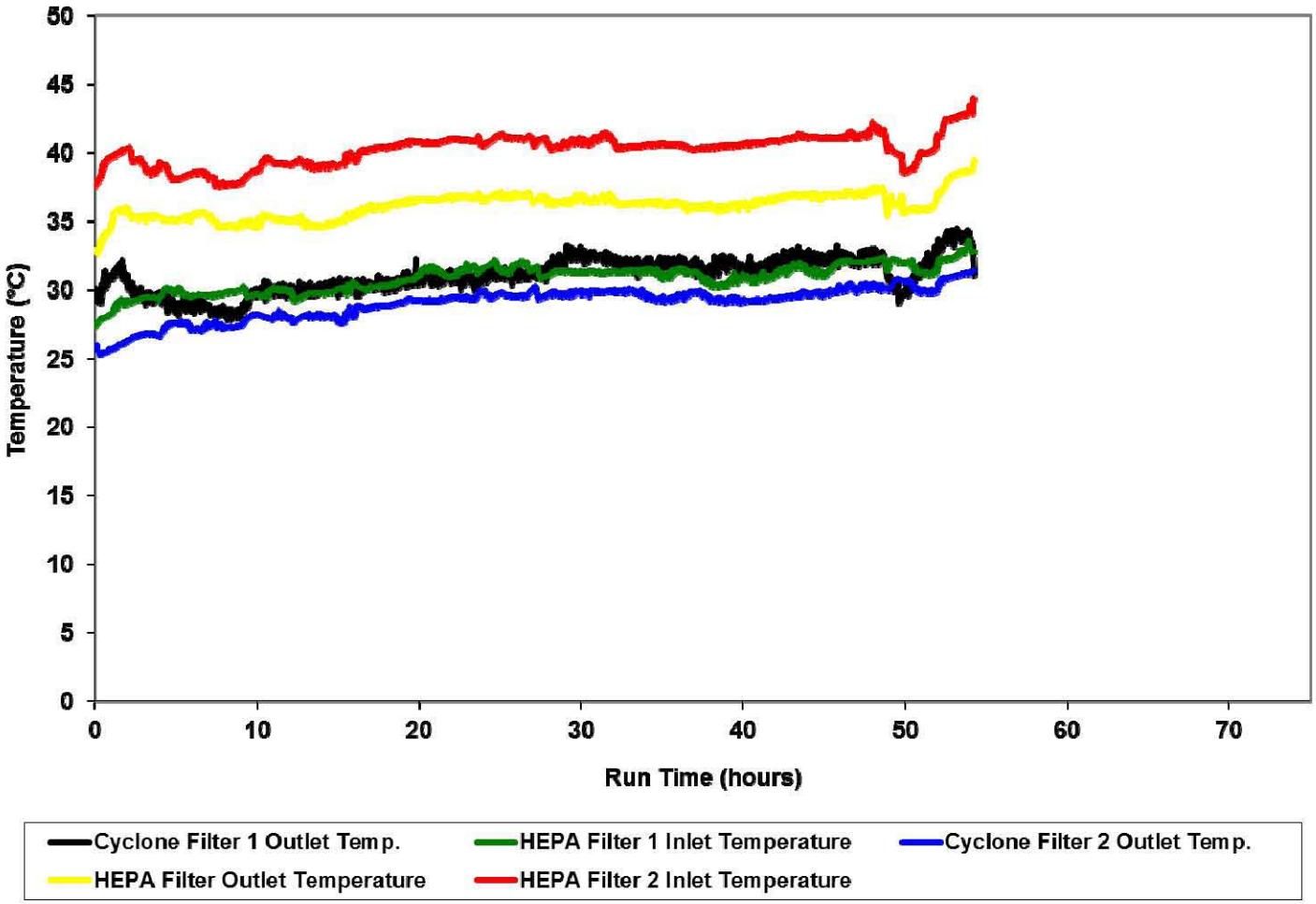


Figure 4.18.a. Test 3 exhaust system temperatures.

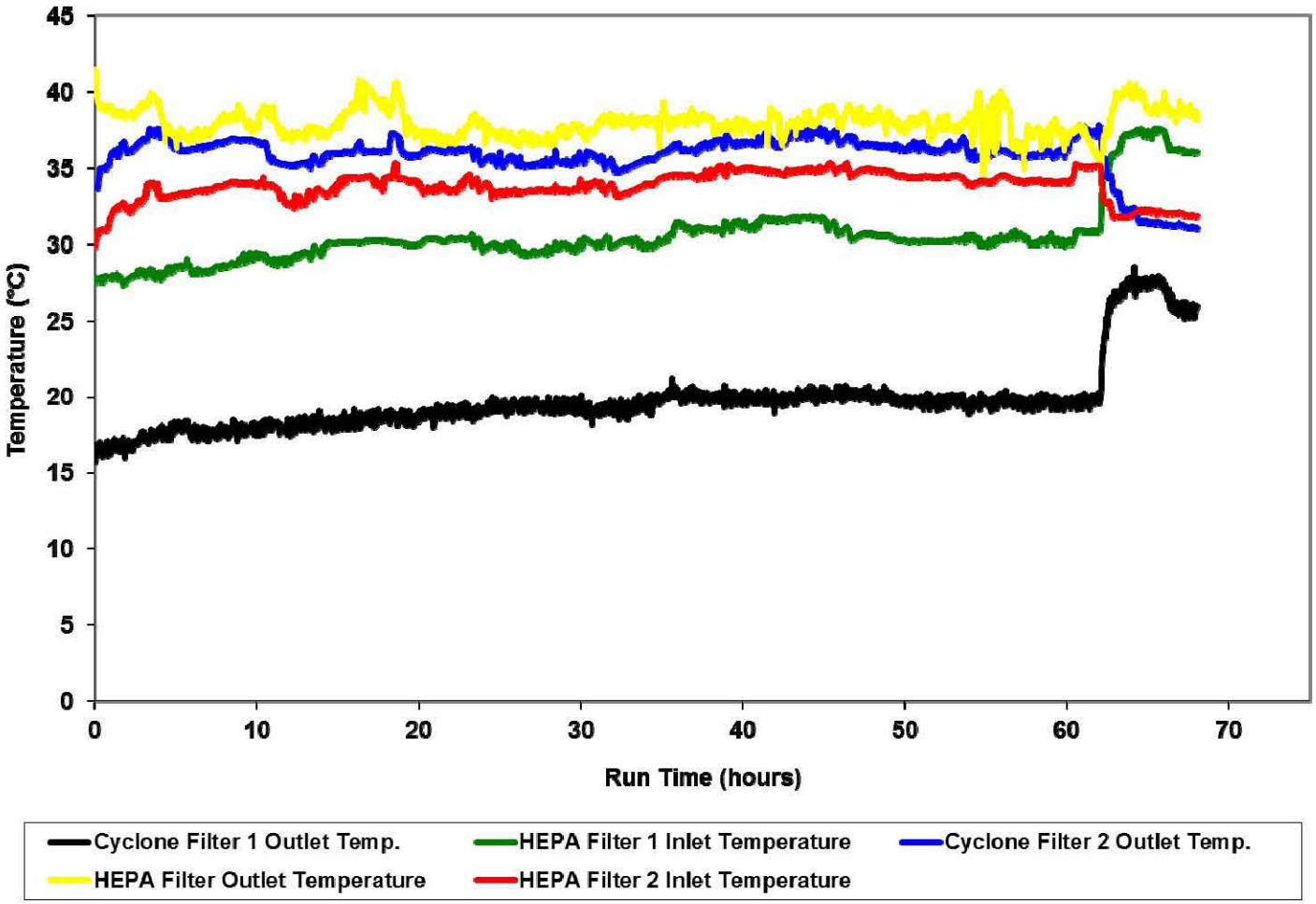


Figure 4.18.b. Test 2 exhaust system temperatures.

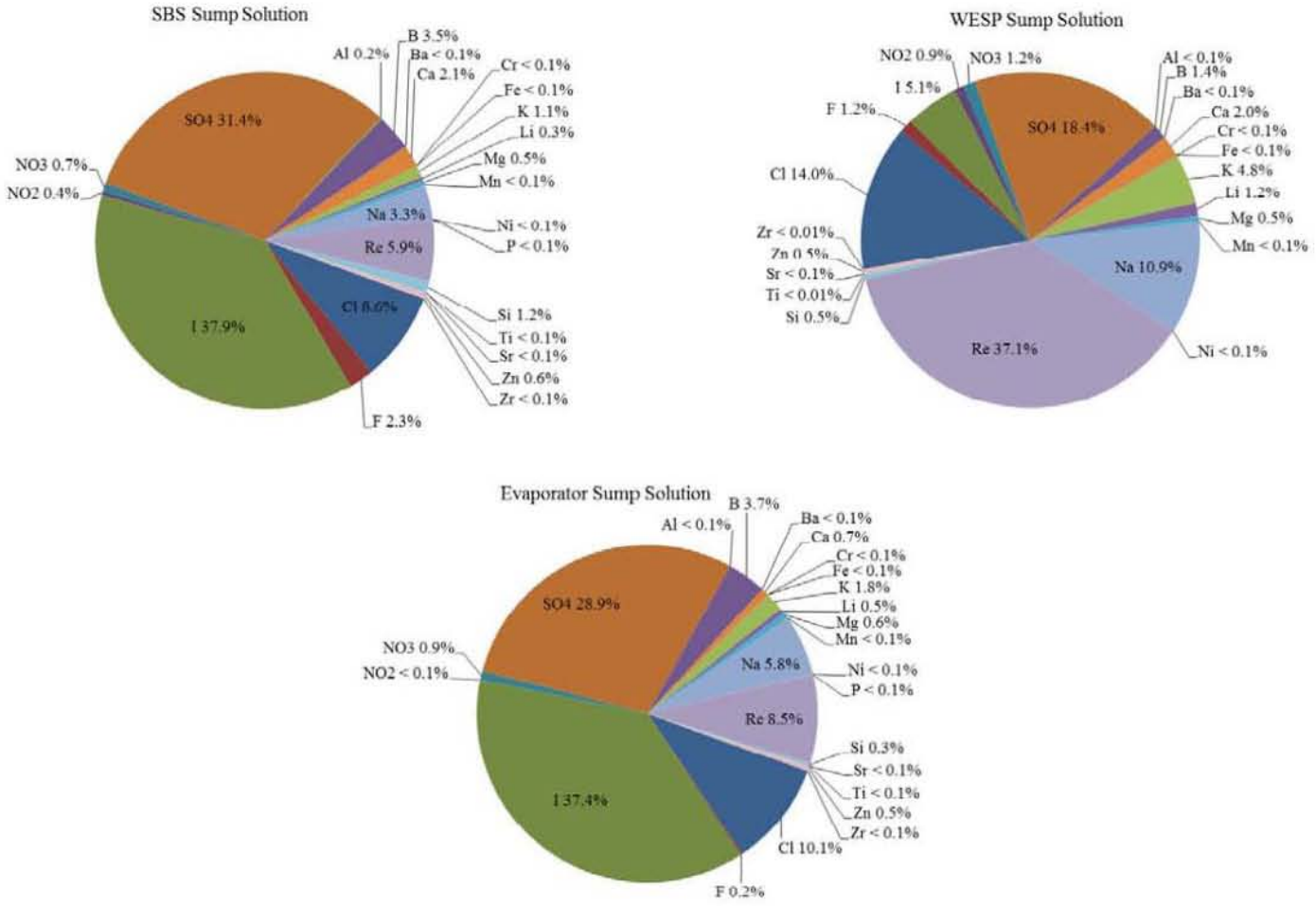


Figure 4.19. Analyzed compositions of sump solutions from the end of Test 4, LAWE10H.

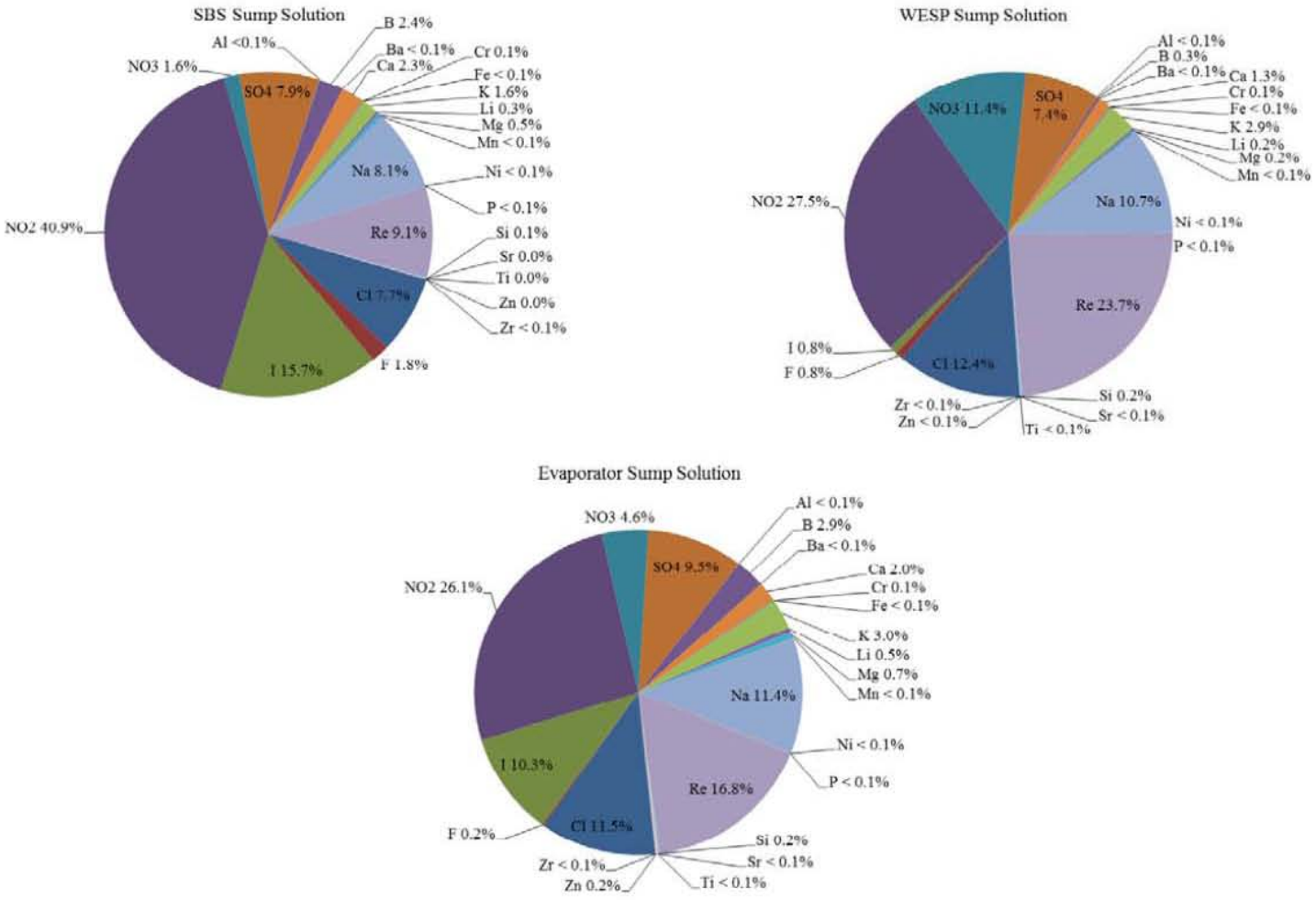


Figure 4.20. Analyzed compositions of sump solutions from the end of Test 5, LAWE6H.

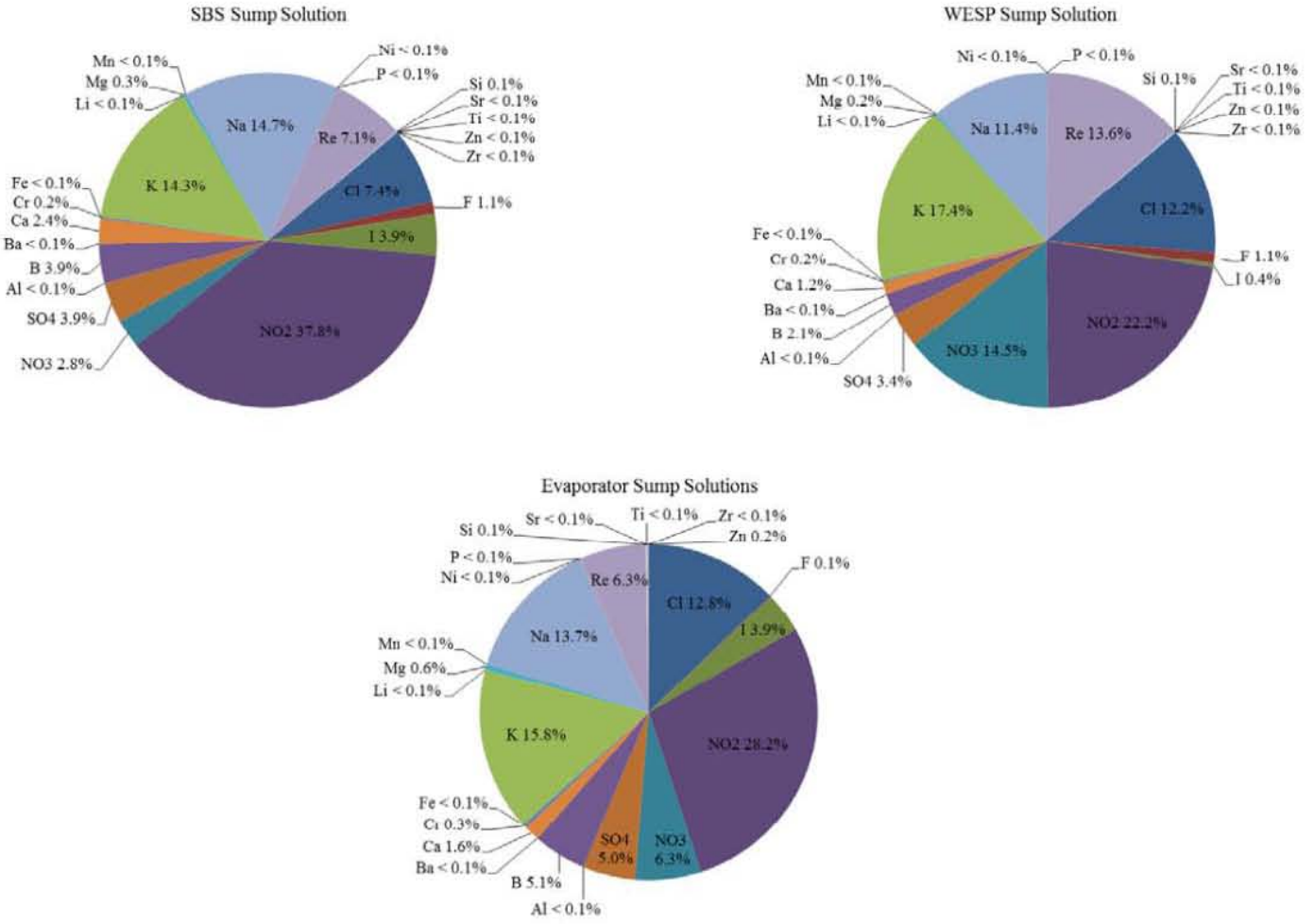


Figure 4.21. Analyzed compositions of sump solutions from the end of Test 6, LAWE3.

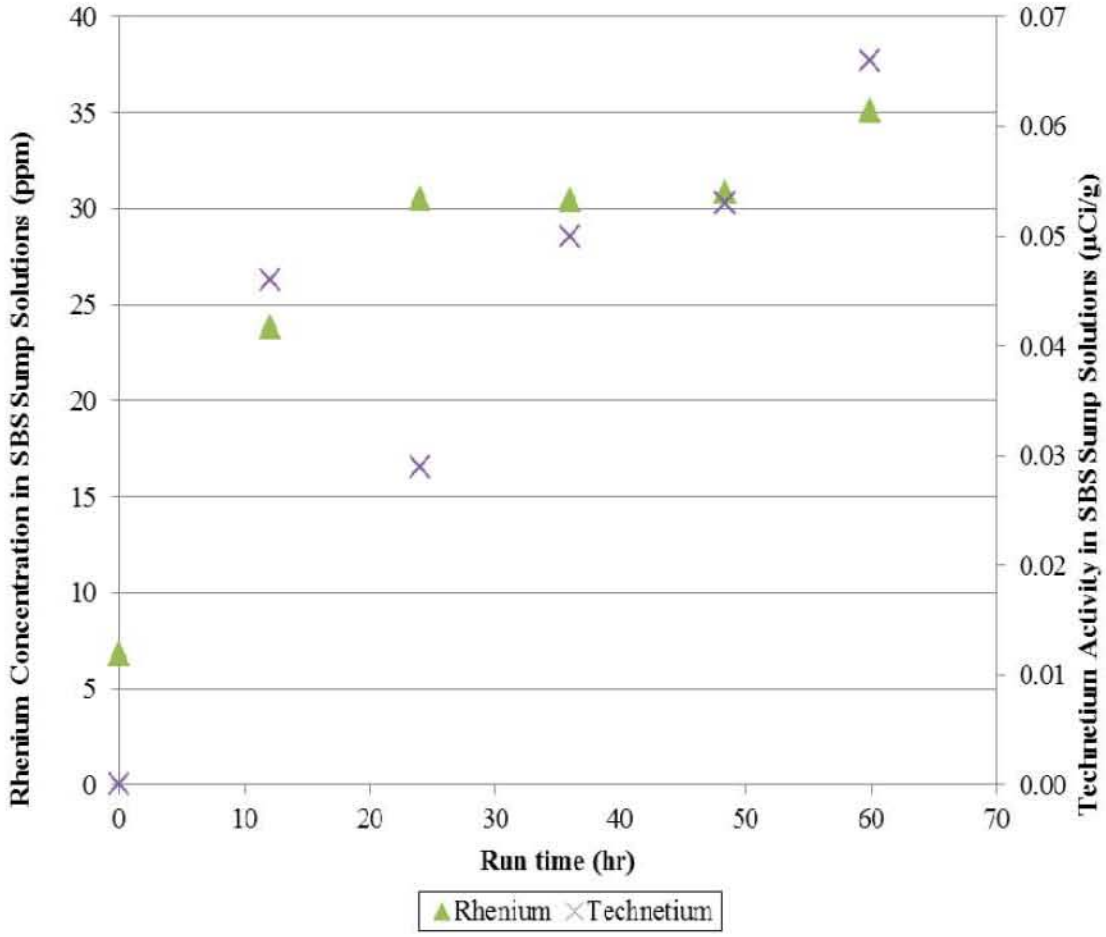


Figure 4.22.a. Technetium and rhenium concentrations in SBS solutions for Test 2.

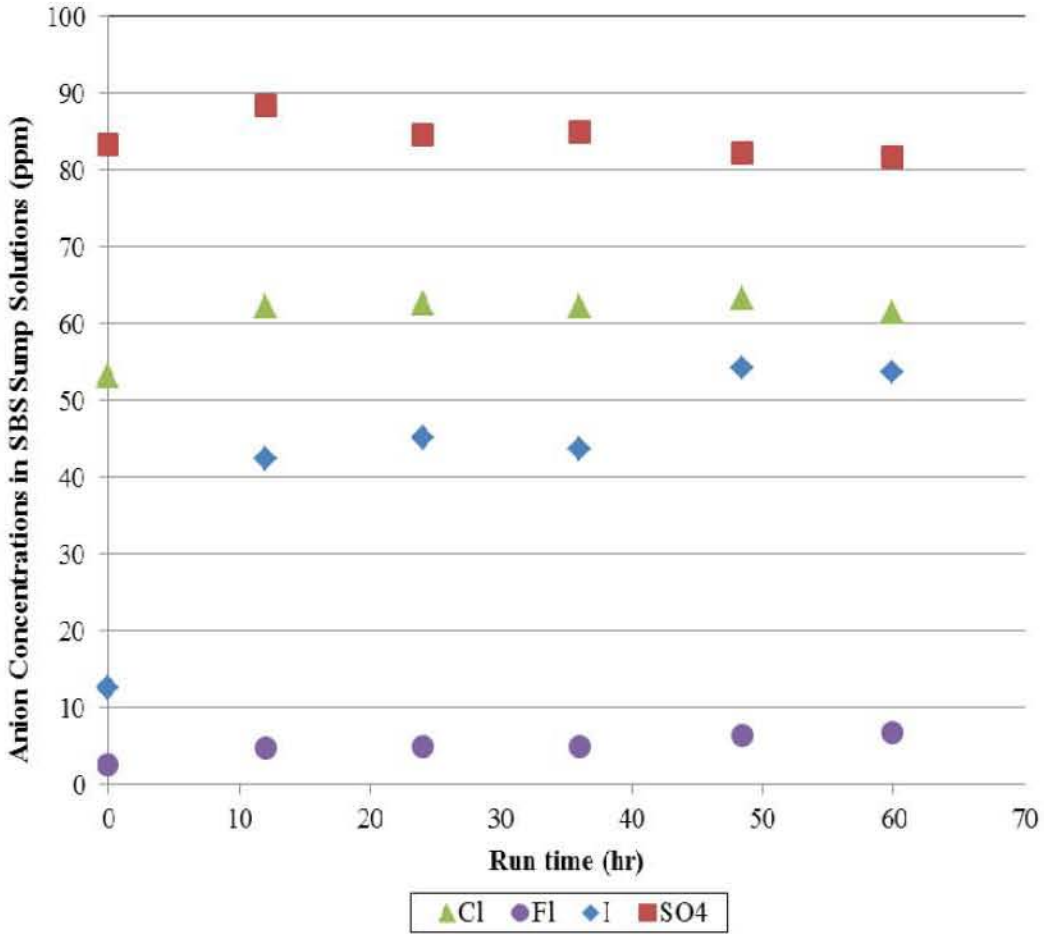


Figure 4.22.b. Anion concentrations in SBS solutions for Test 2.

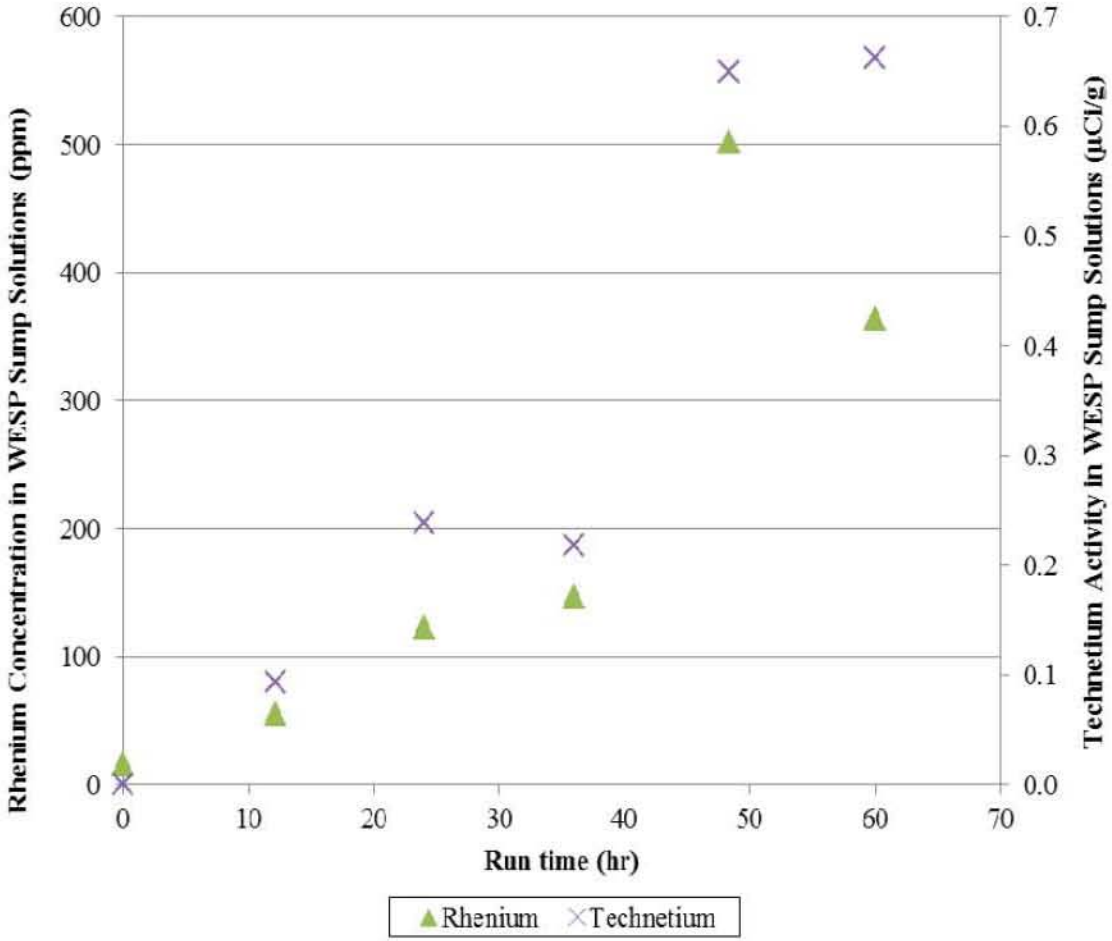


Figure 4.23.a. Technetium and rhenium concentrations in WESP solutions for Test 2.

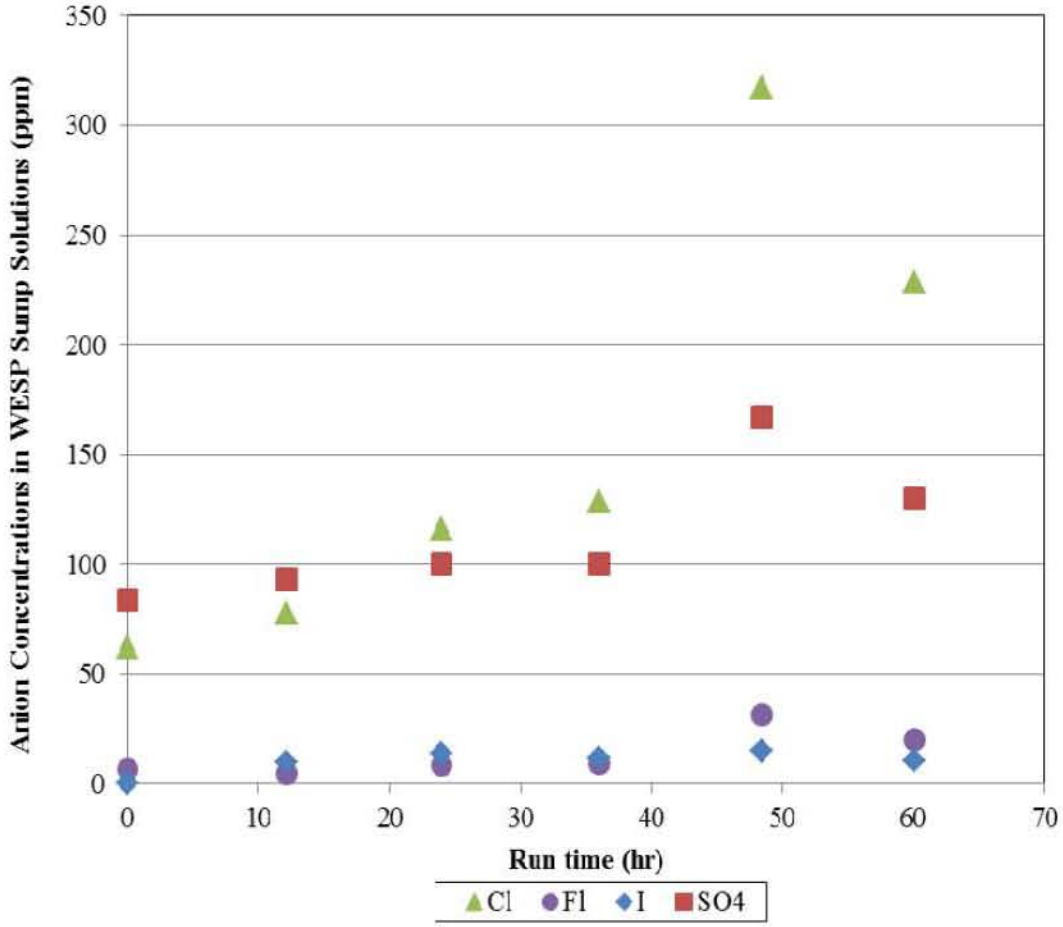


Figure 4.23.b. Anion concentrations in WESP solutions for Test 2.

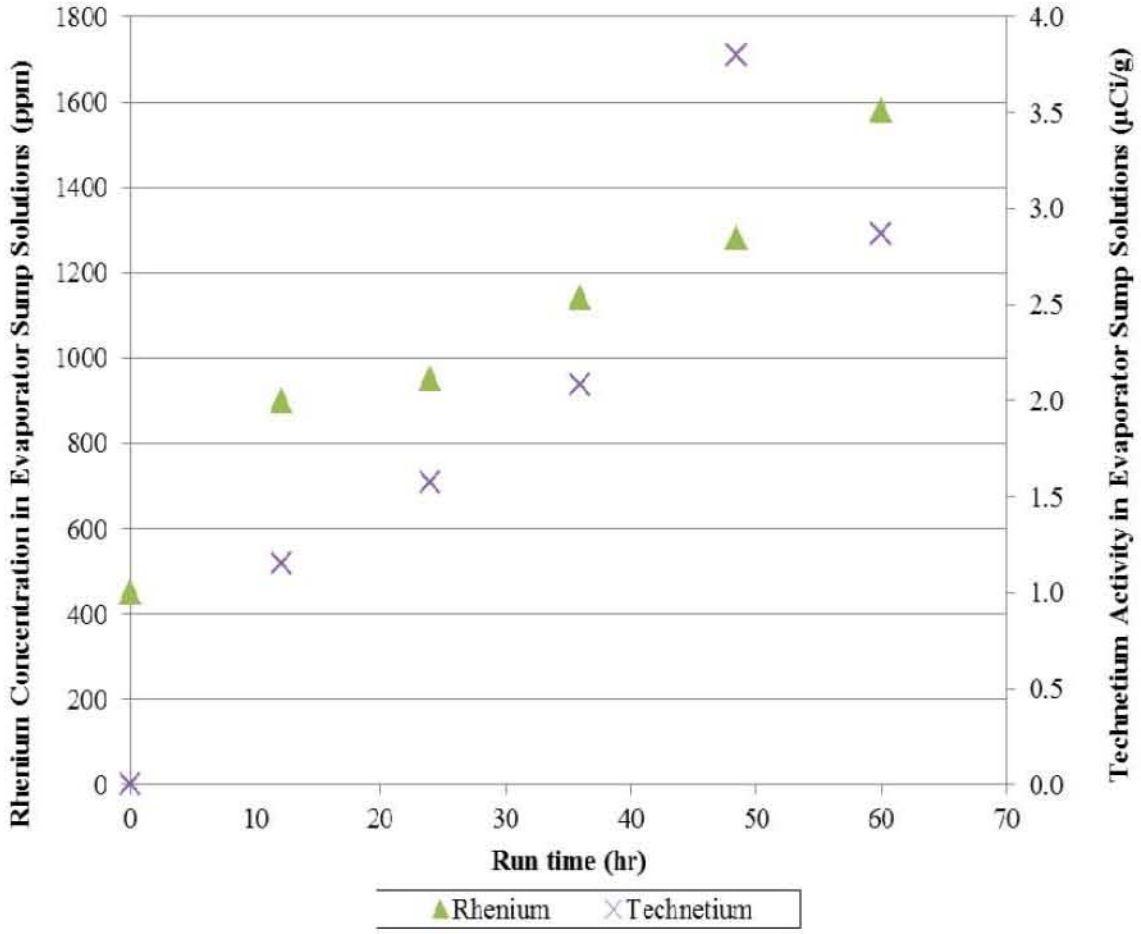


Figure 4.24.a. Technetium and rhenium concentrations in evaporator solutions for Test 2.

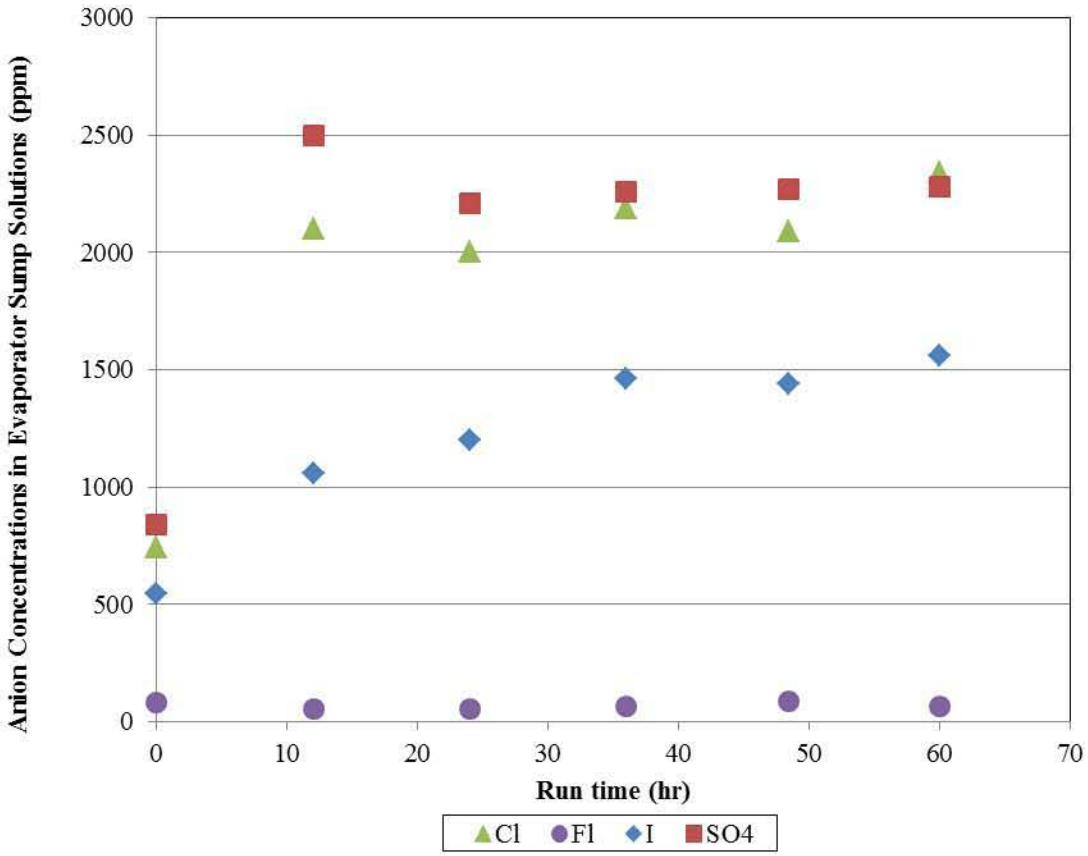


Figure 4.24.b. Anion concentrations in evaporator solutions for Test 2.

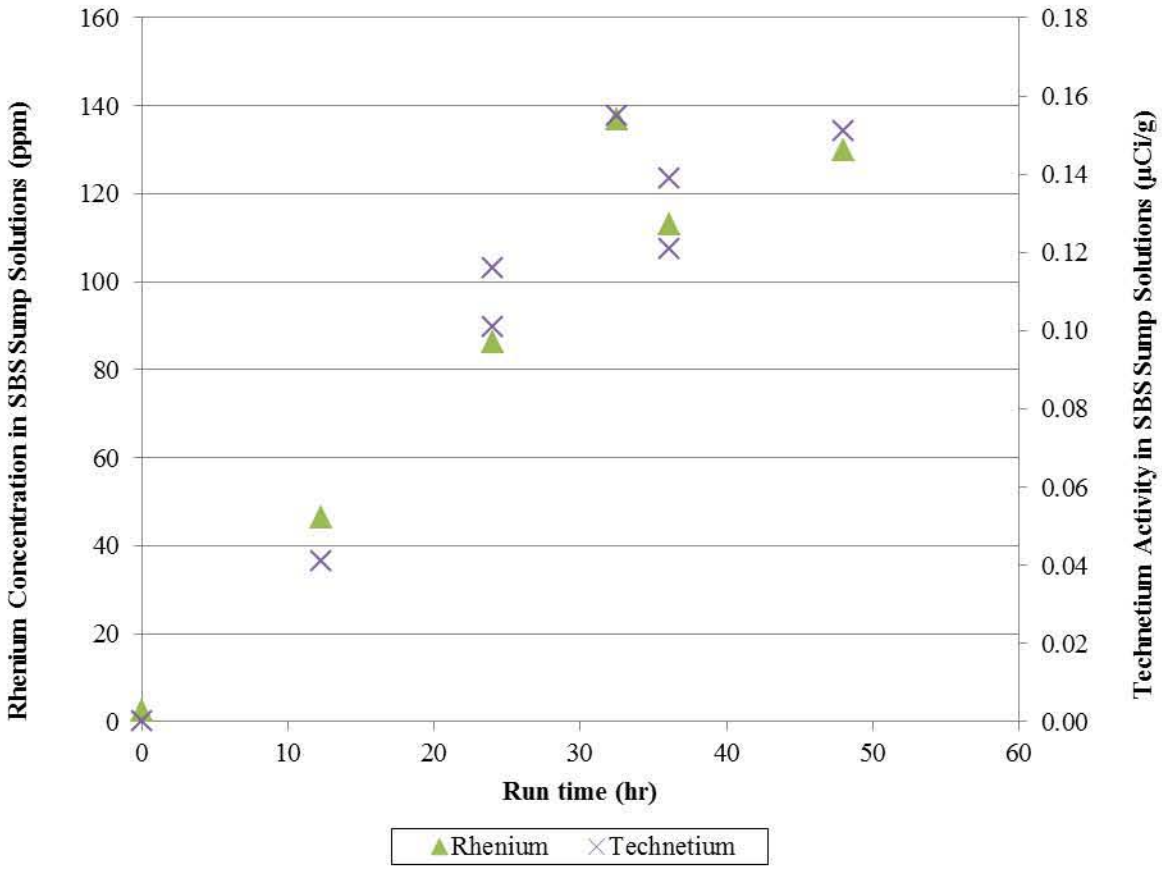


Figure 4.25.a. Technetium and rhenium concentrations in SBS solutions for Test 3.

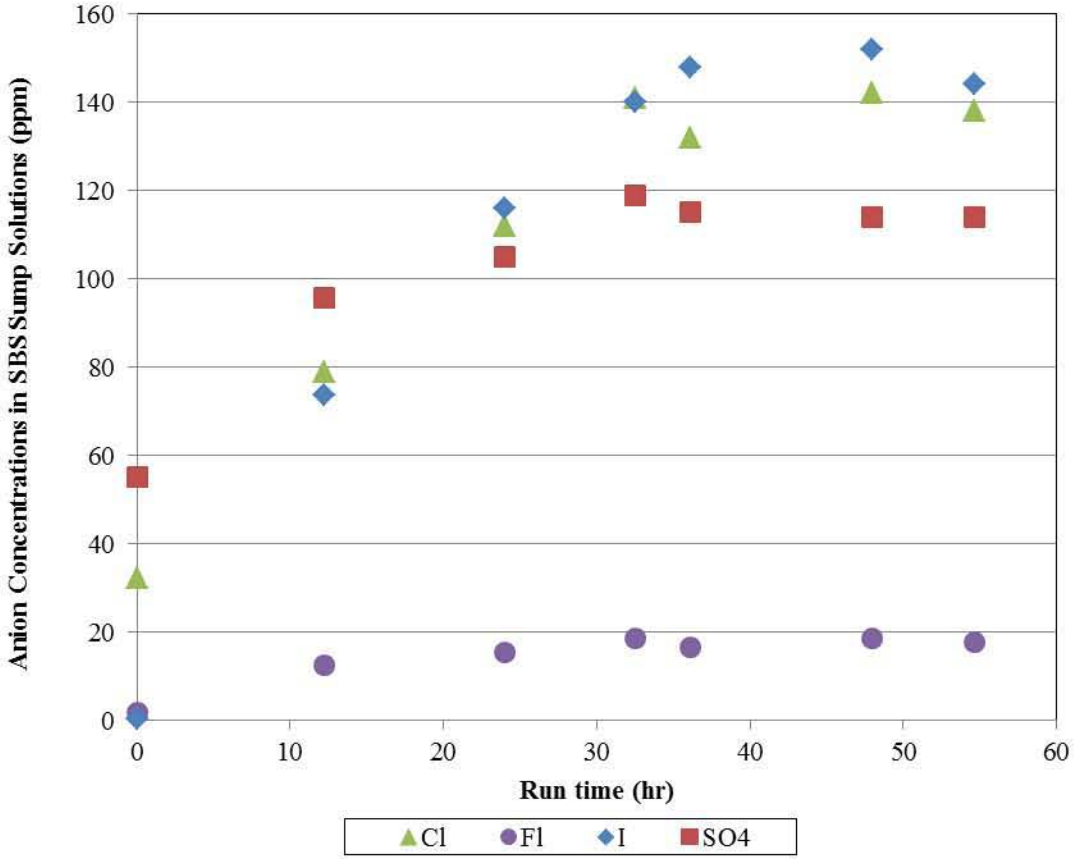


Figure 4.25.b. Anion concentrations in SBS solutions for Test 3.

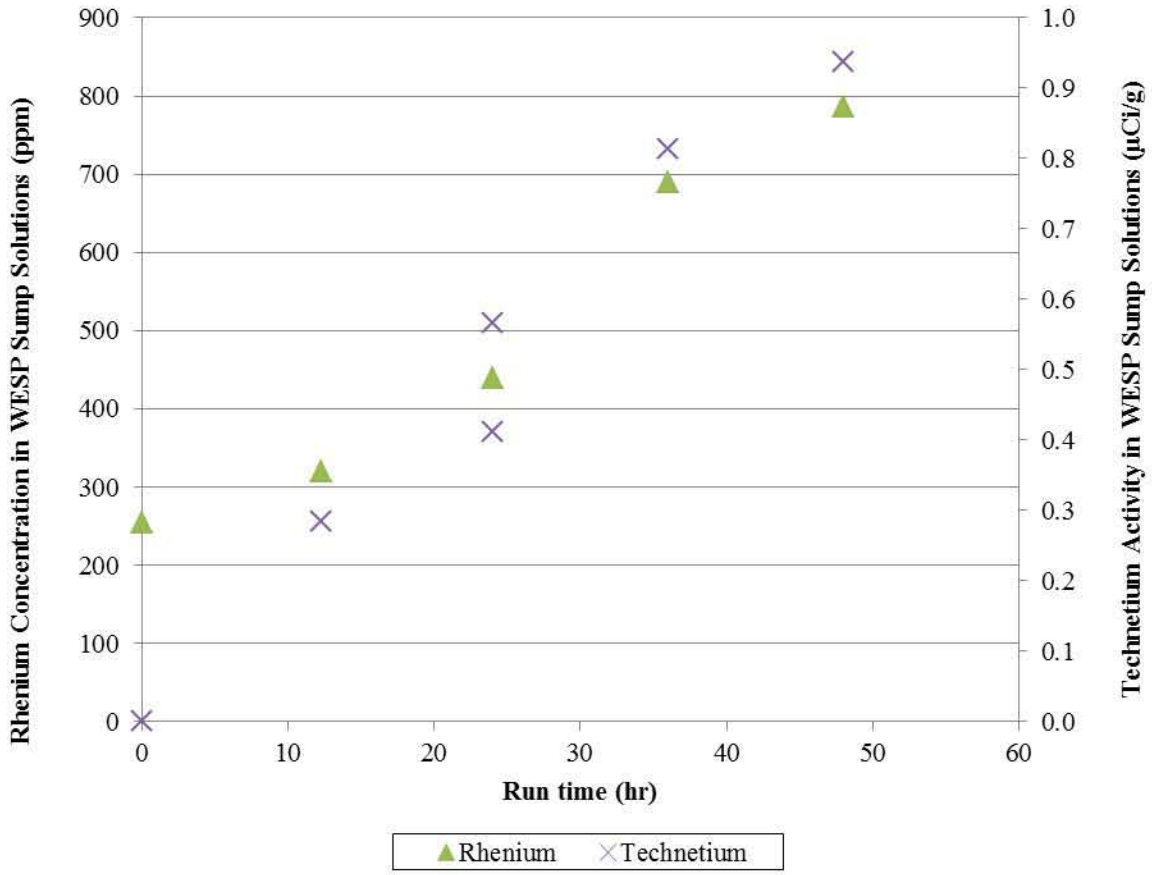


Figure 4.26.a. Technetium and rhenium concentrations in WESP solutions for Test 3.

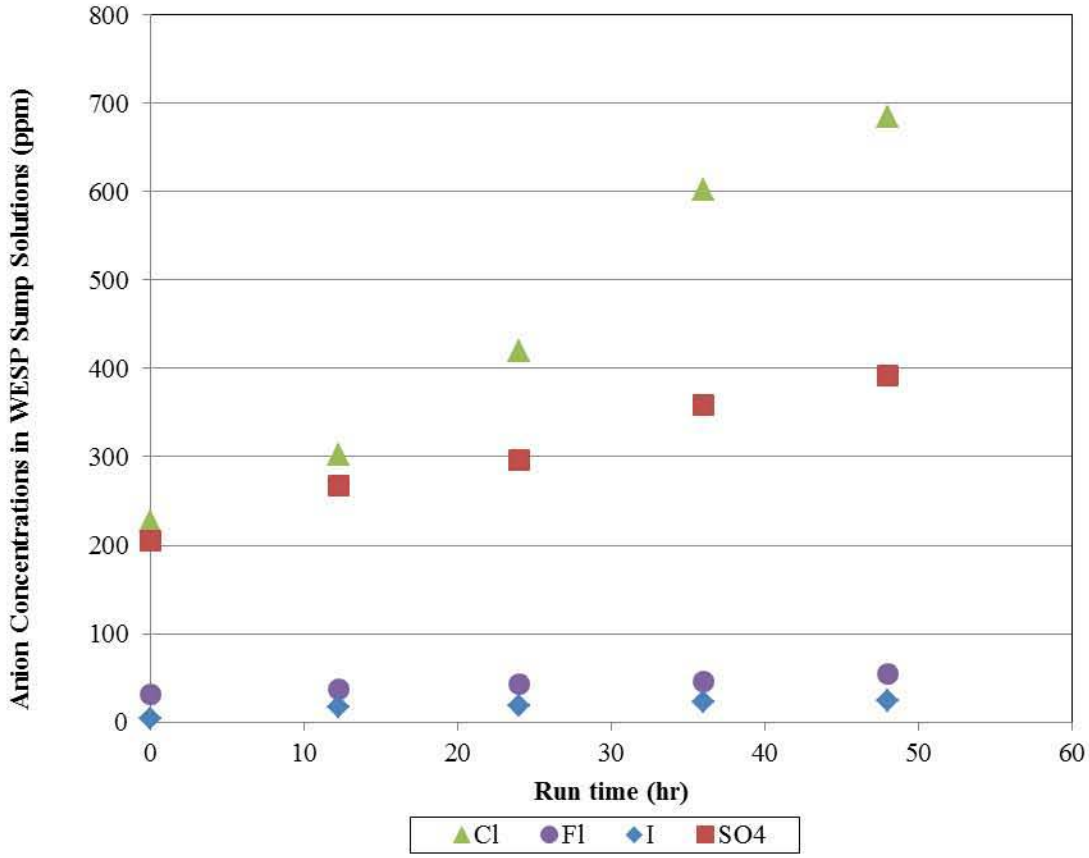


Figure 4.26.b. Anion concentrations in WESP solutions for Test 3.

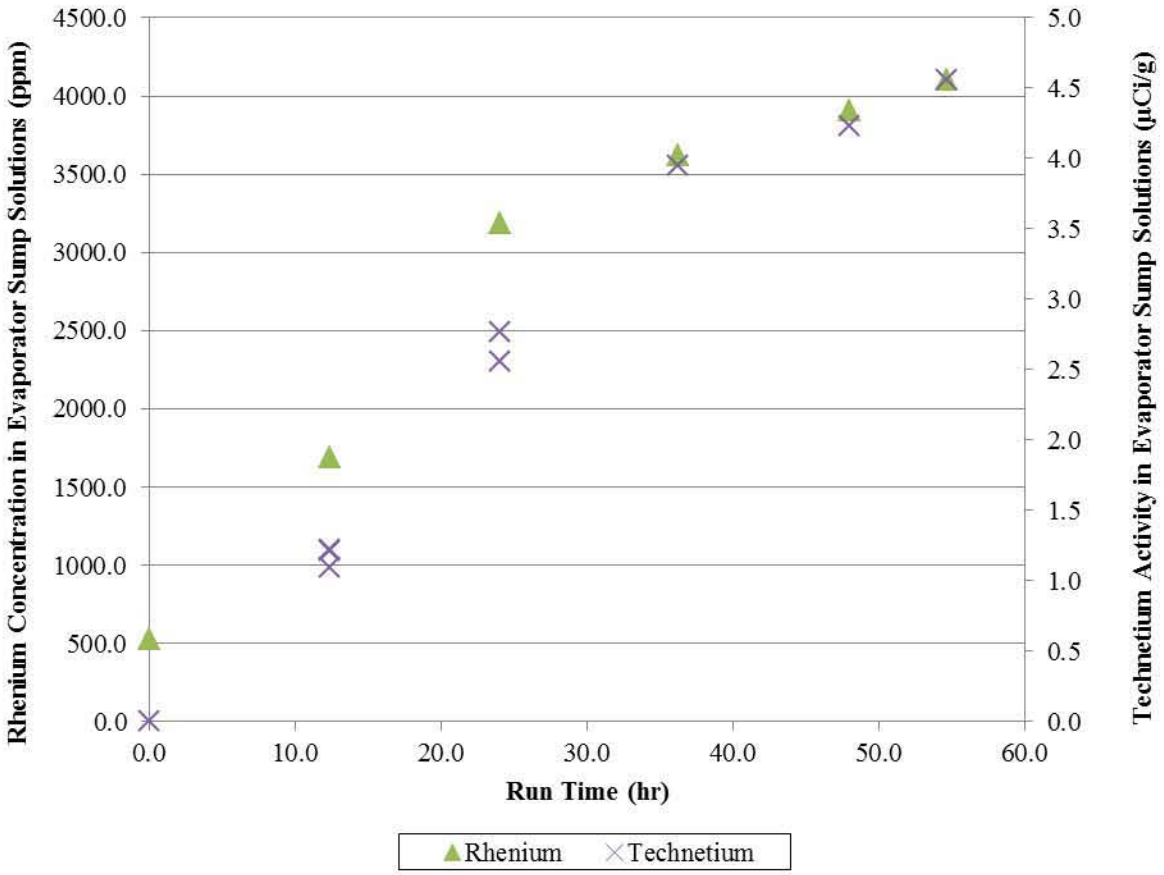


Figure 4.27.a. Technetium and rhenium concentrations in evaporator solutions for Test 3.

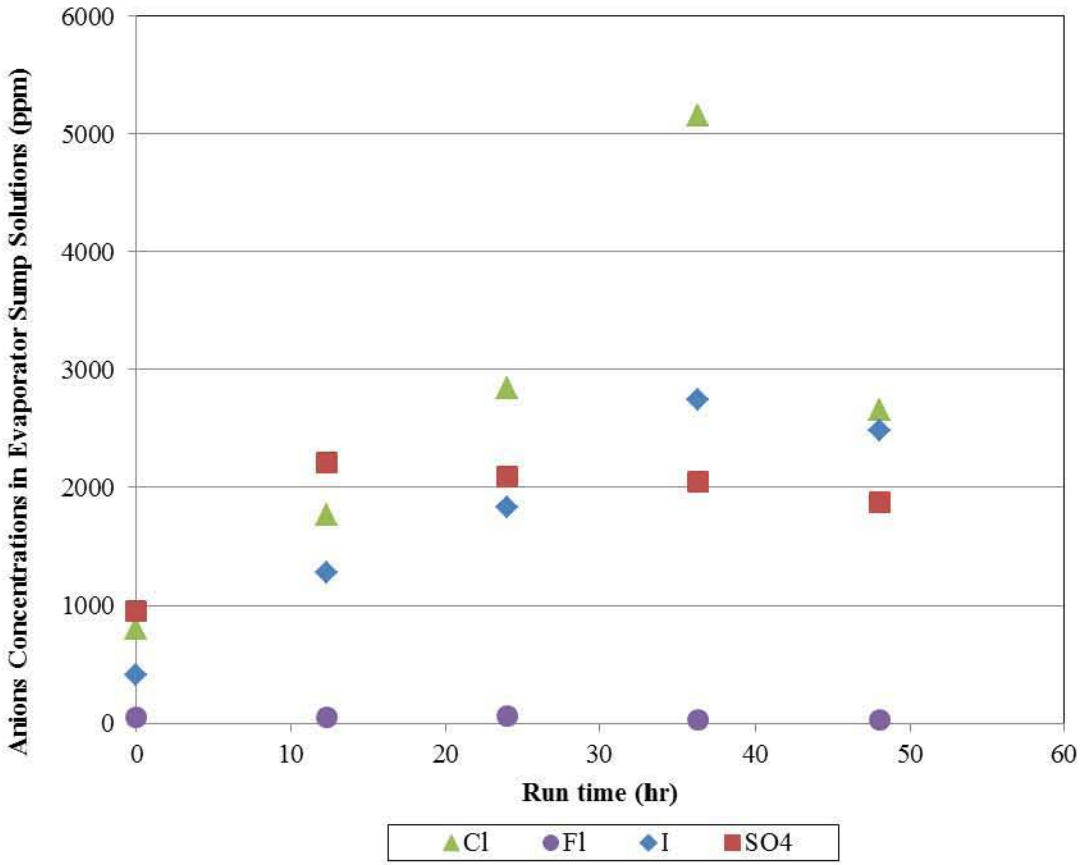


Figure 4.27.b. Anion concentrations in evaporator solutions for Test 3.

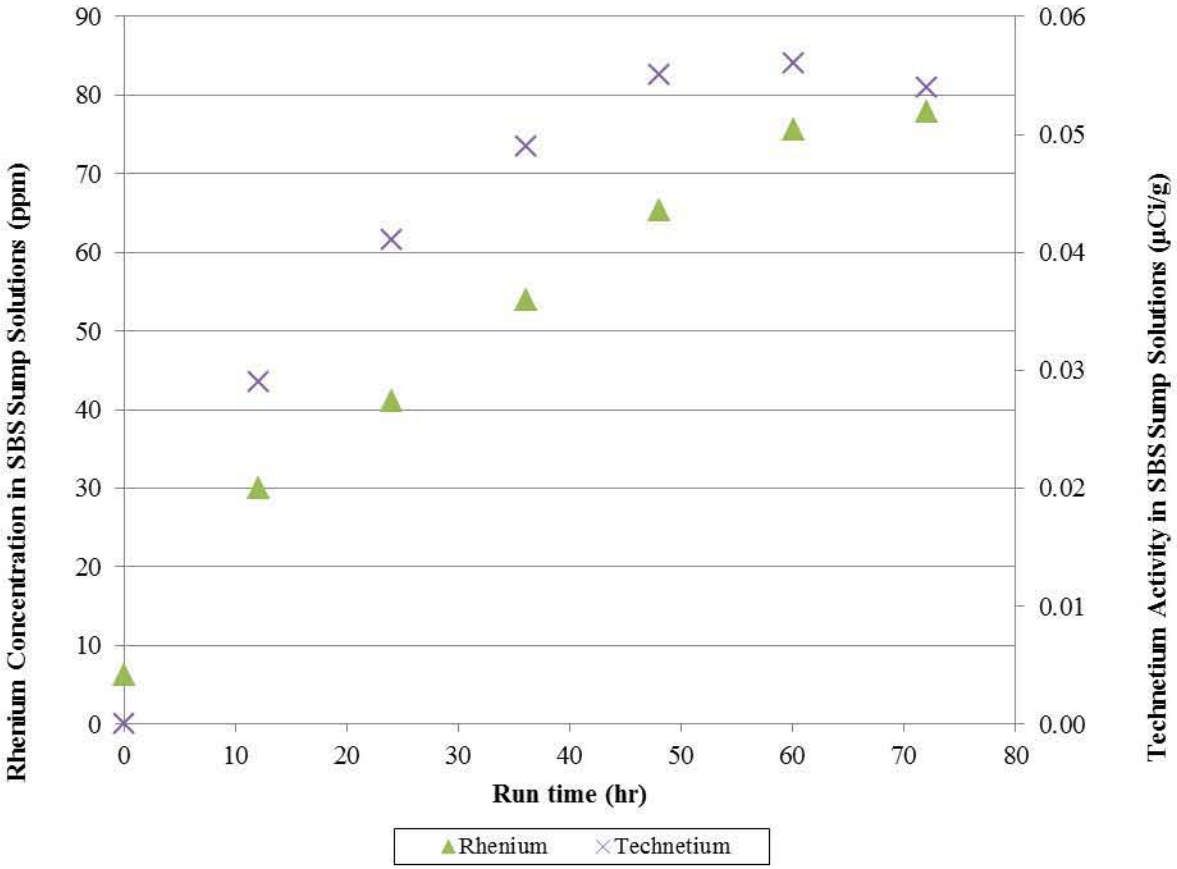


Figure 4.28.a. Technetium and rhenium concentrations in SBS solutions for Test 4.

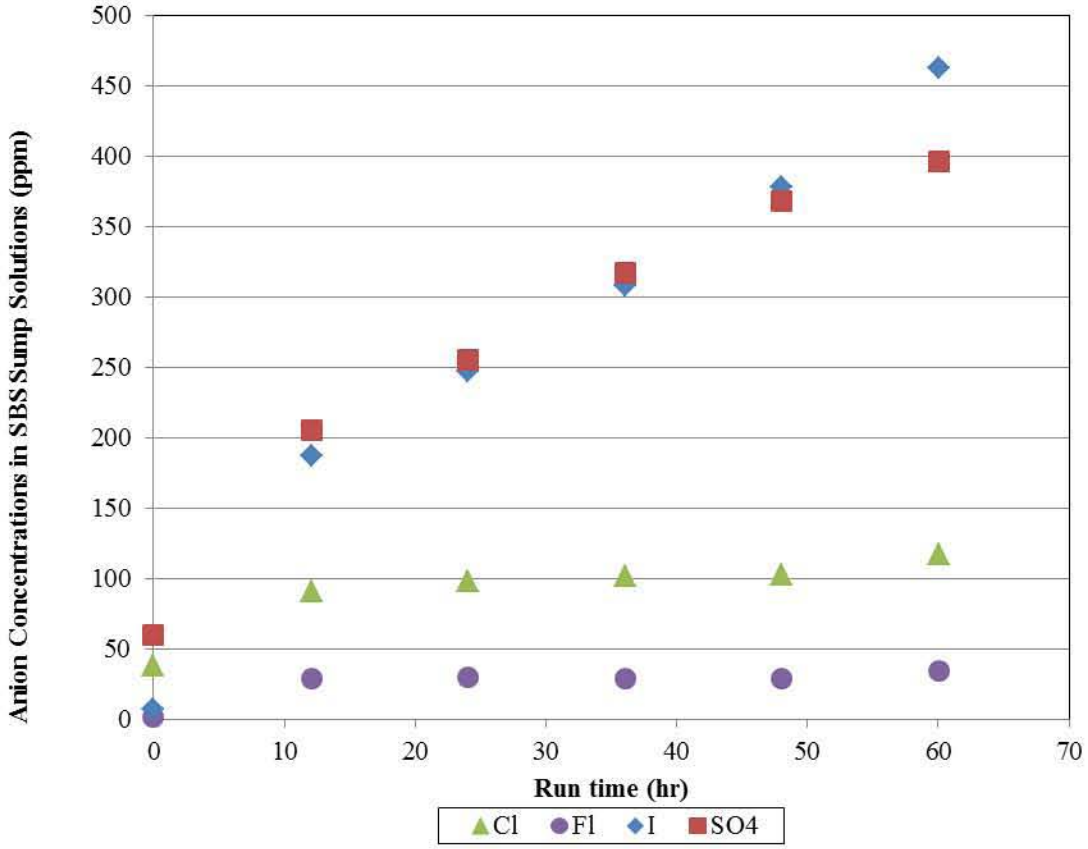


Figure 4.28.b. Anion concentrations in SBS solutions for Test 4.

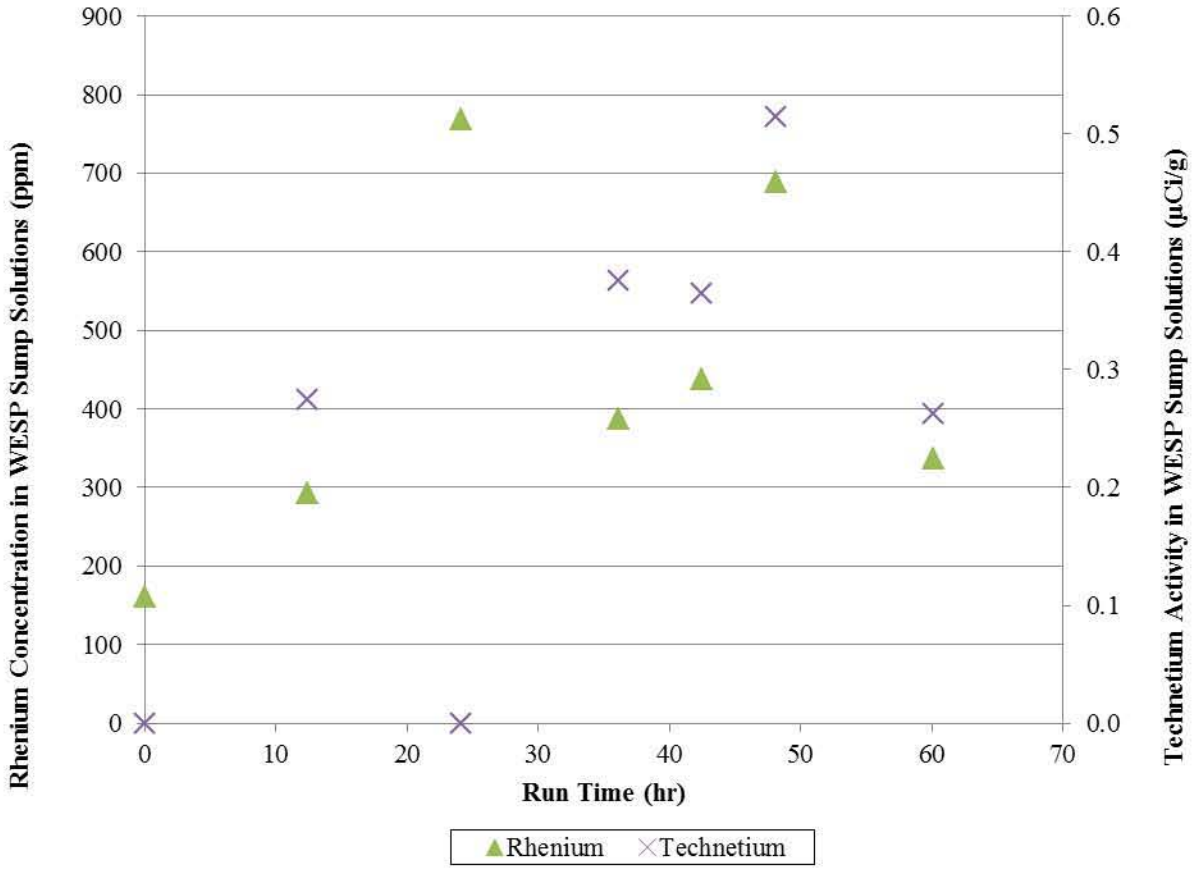


Figure 4.29.a. Technetium and rhenium concentrations in WESP solutions for Test 4.

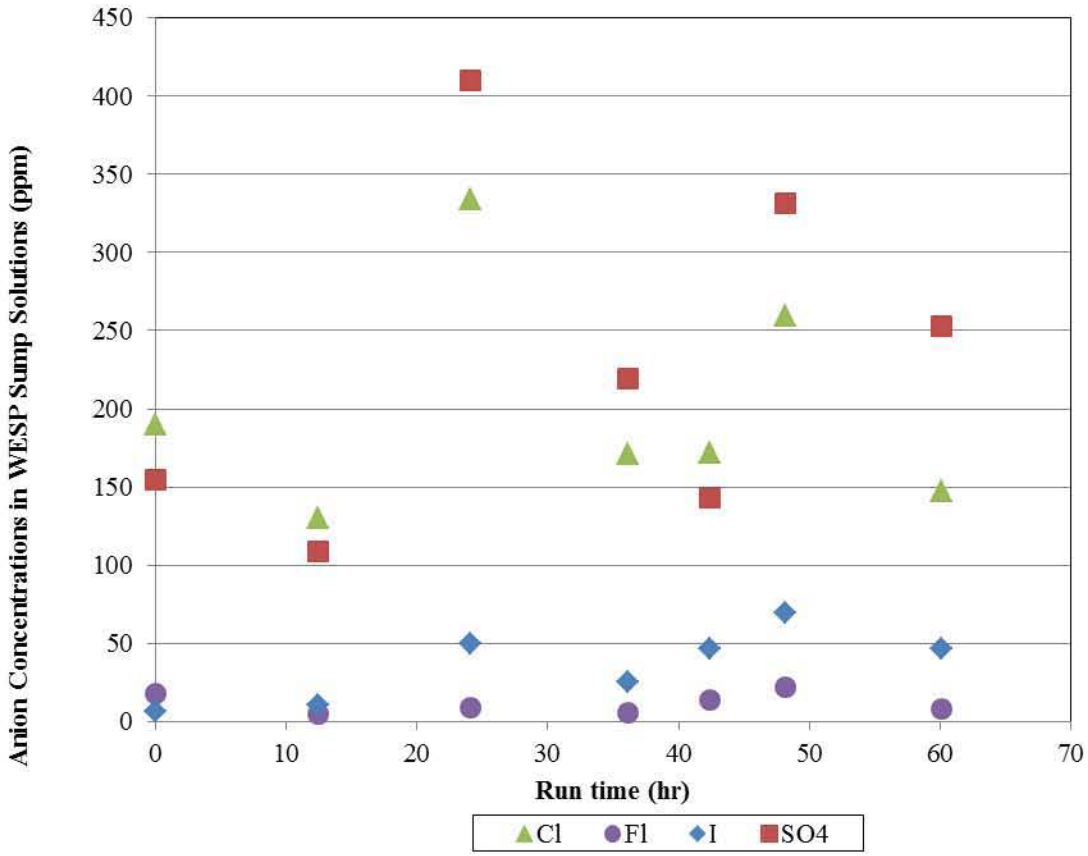


Figure 4.29.b. Anion concentrations in WESP solutions for Test 4.

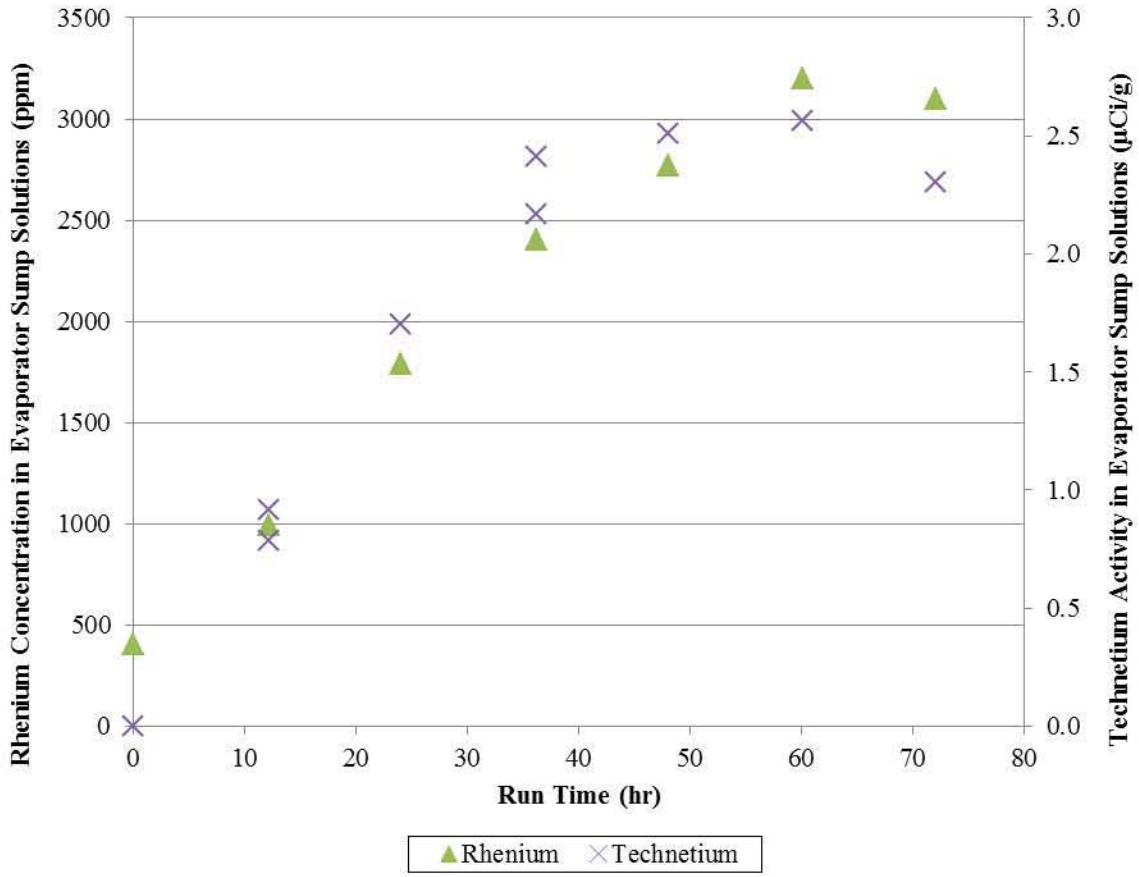


Figure 4.30.a. Technetium and rhenium concentrations in evaporator solutions for Test 4.

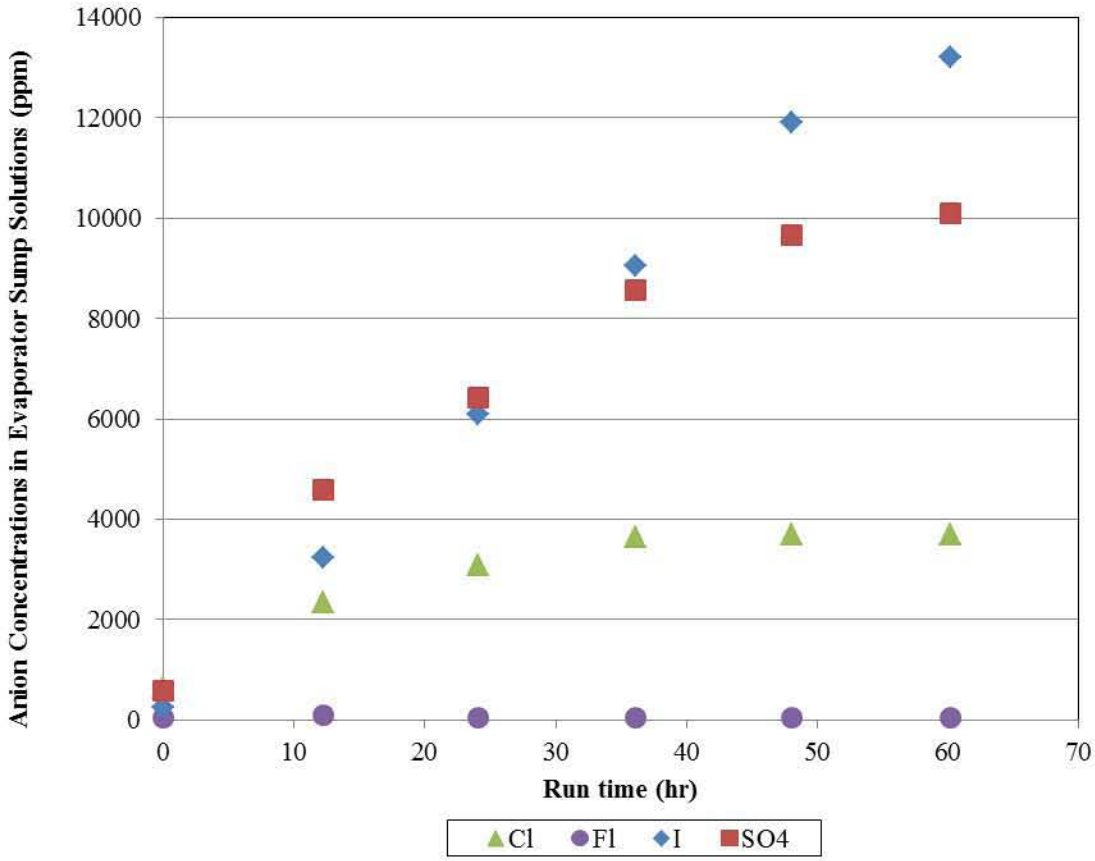


Figure 4.30.b. Anion concentrations in evaporator solutions for Test 4.

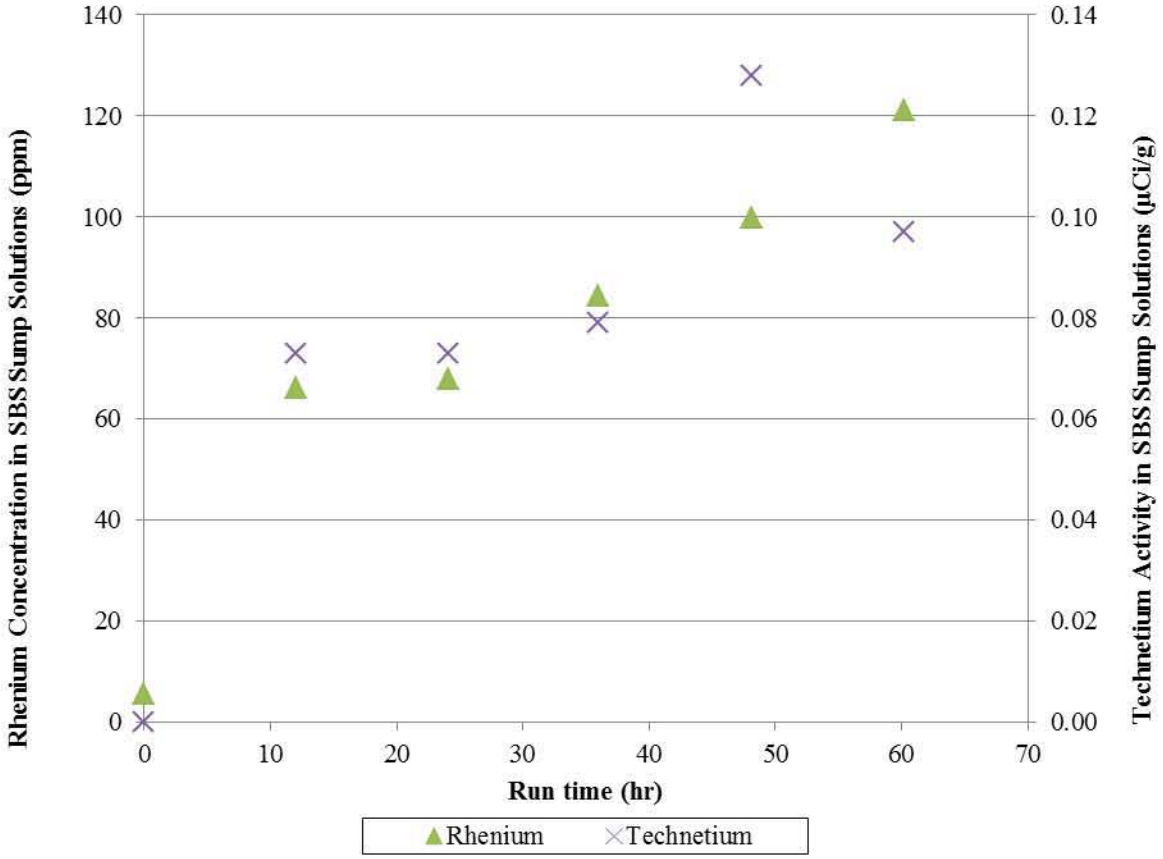


Figure 4.31.a. Technetium and rhenium concentrations in SBS solutions for Test 5.

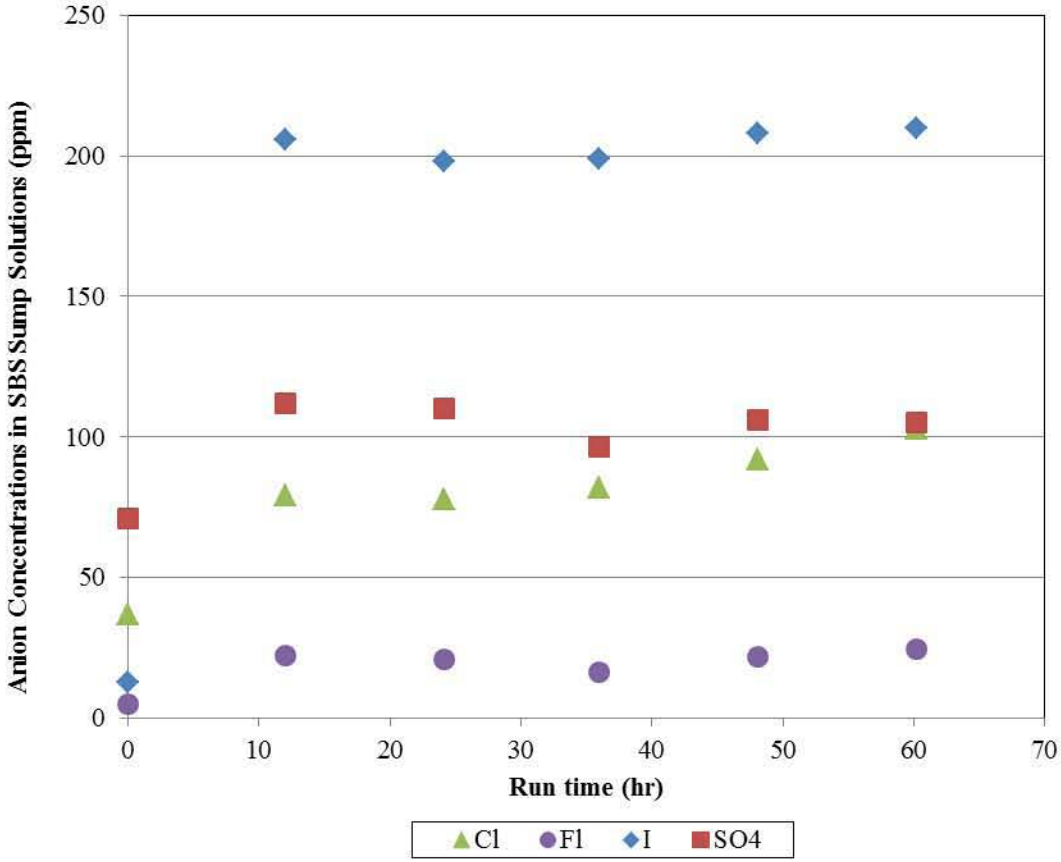


Figure 4.31.b. Anion concentrations in SBS solutions for Test 5.

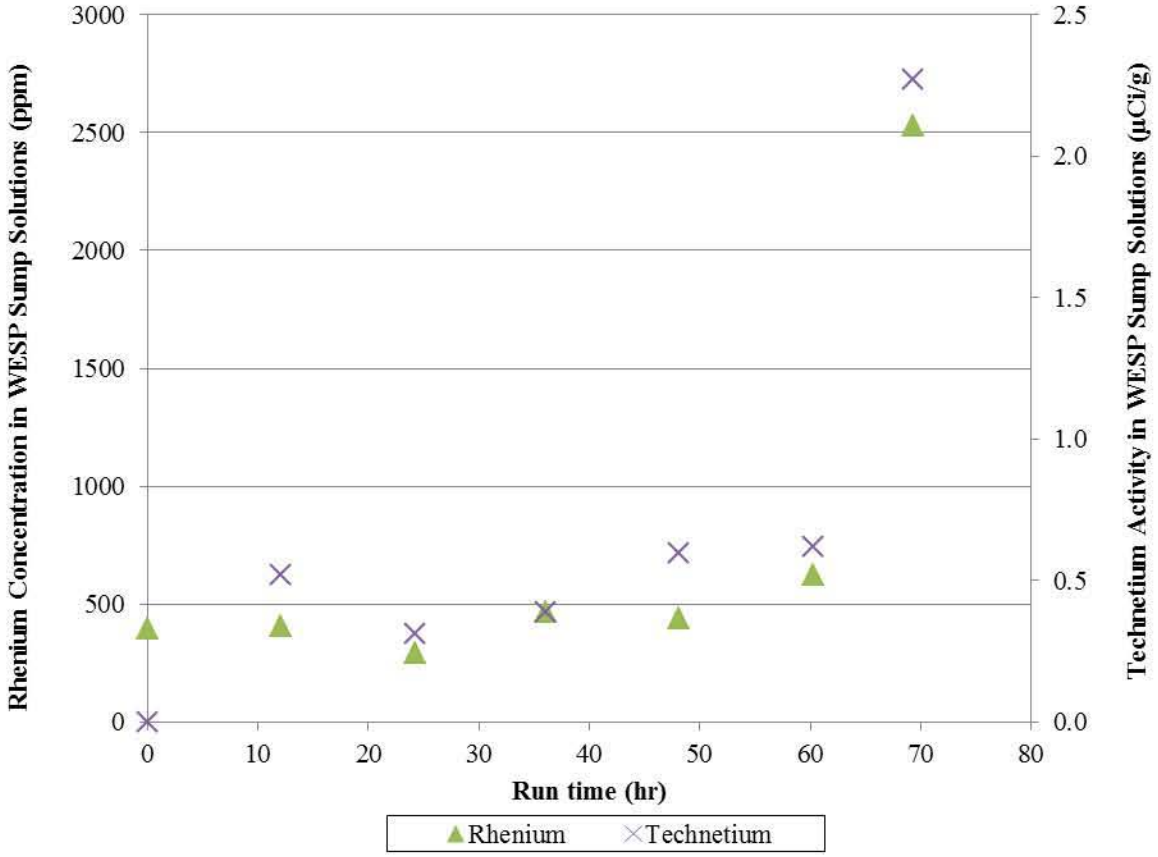


Figure 4.32.a. Technetium and rhenium concentrations in WESP solutions for Test 5.

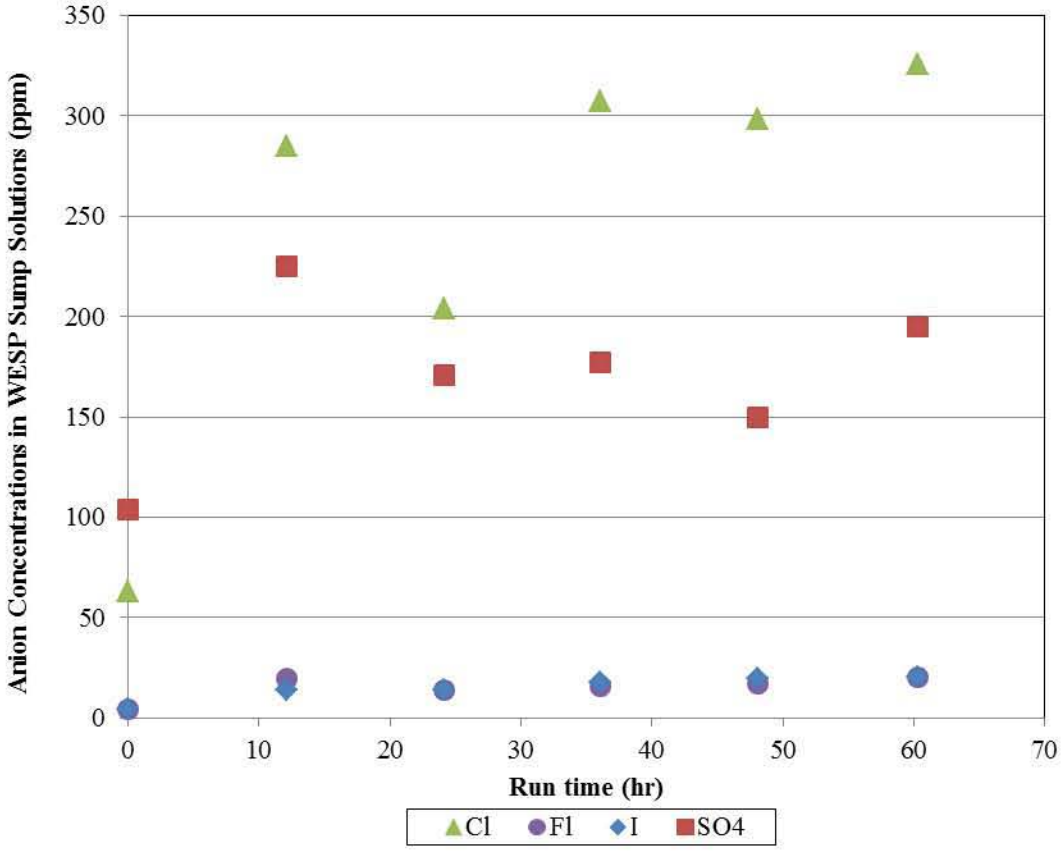


Figure 4.32.b. Anion concentrations in WESP solutions for Test 5.

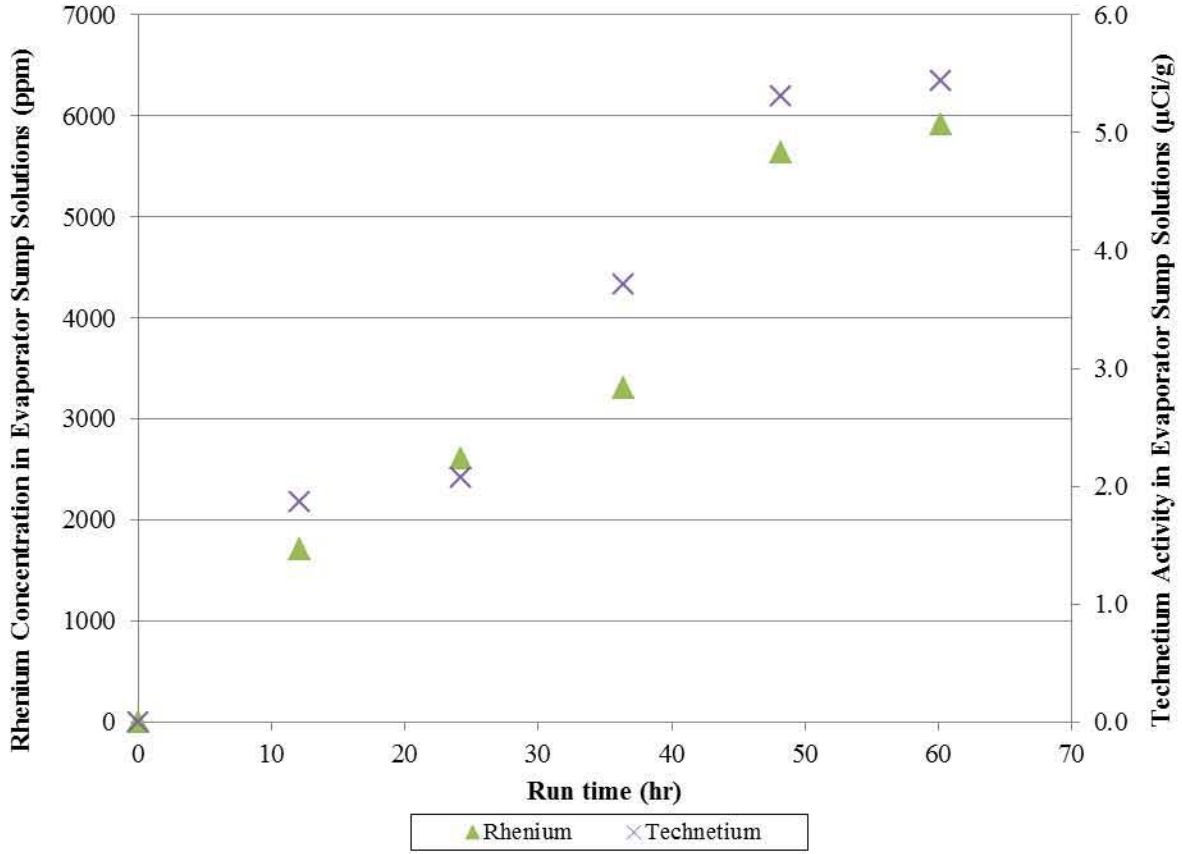


Figure 4.33.a. Technetium and rhenium concentrations in evaporator solutions for Test 5.

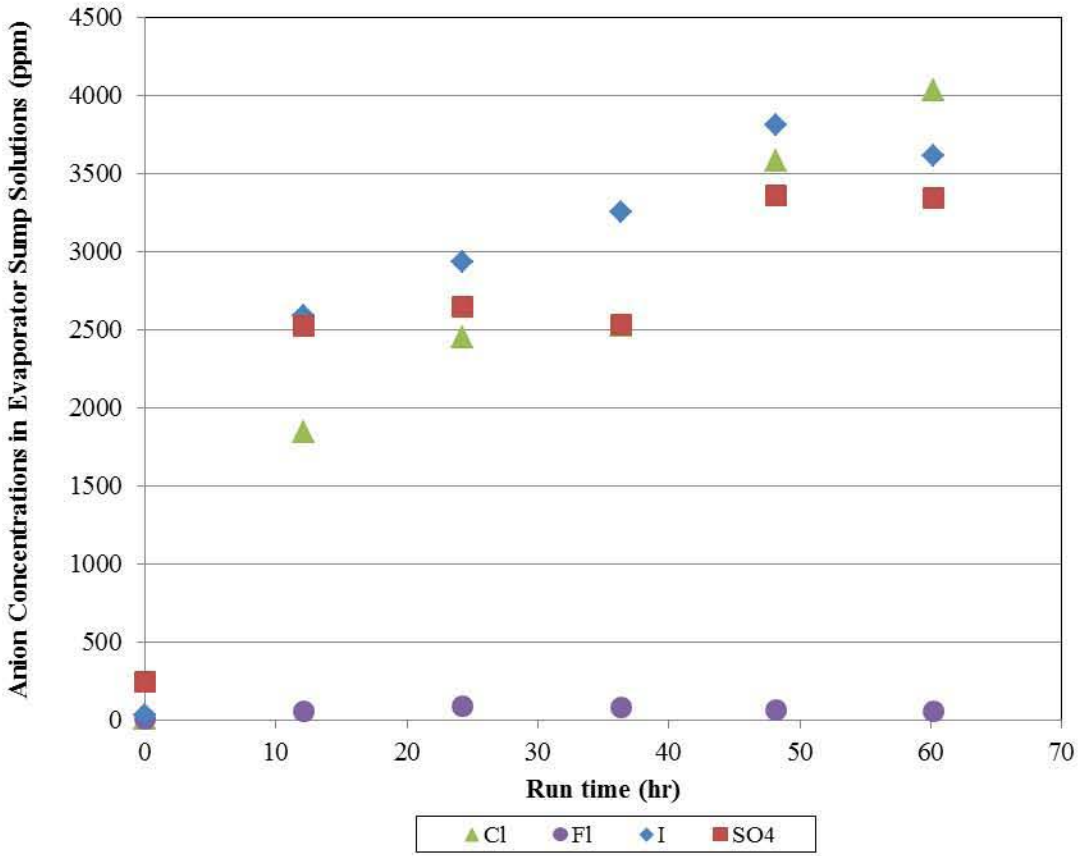


Figure 4.33.b. Anion concentrations in evaporator solutions for Test 5.

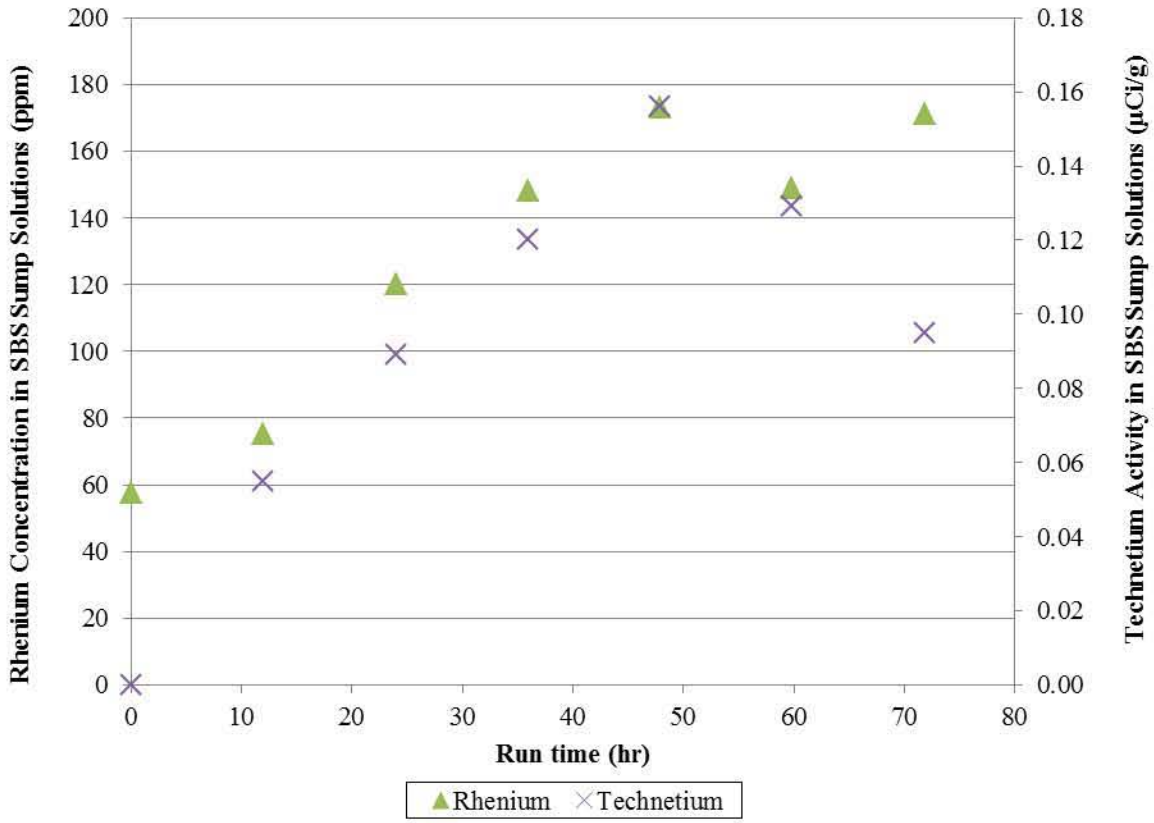


Figure 4.34.a. Technetium and rhenium concentrations in SBS solutions for Test 6.

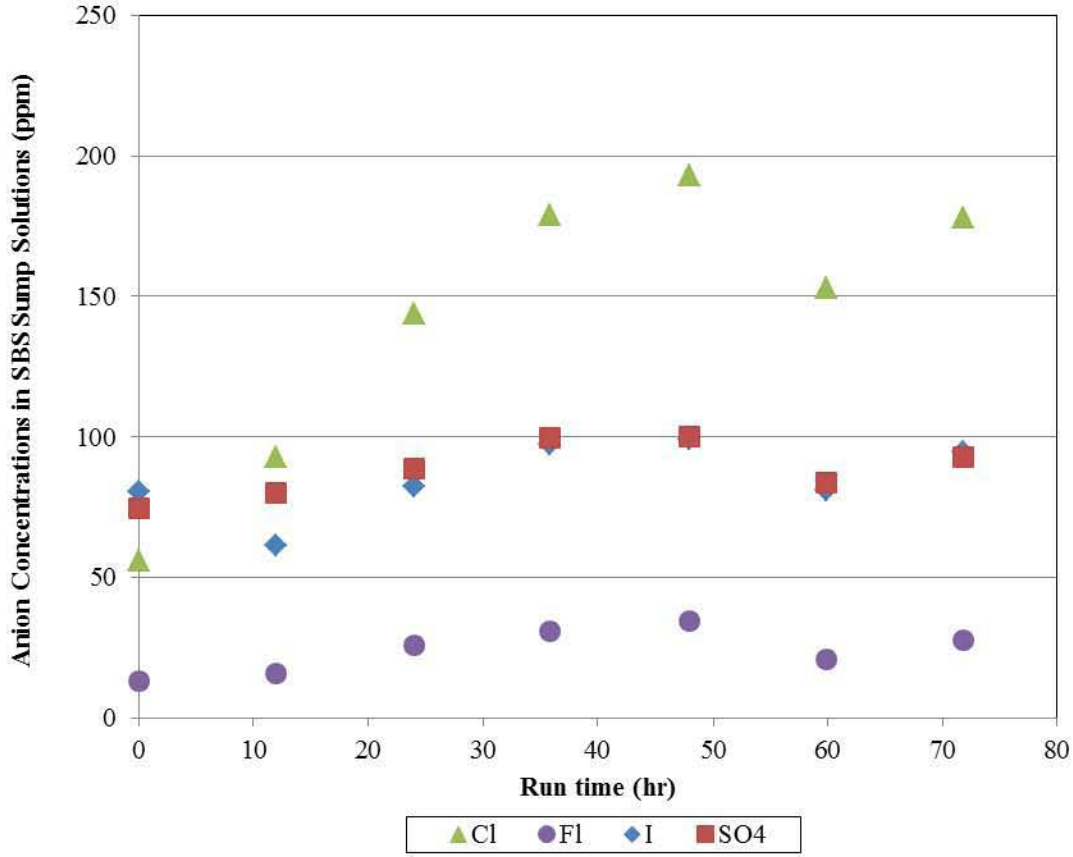


Figure 4.34.b. Anion concentrations in SBS solutions for Test 6.

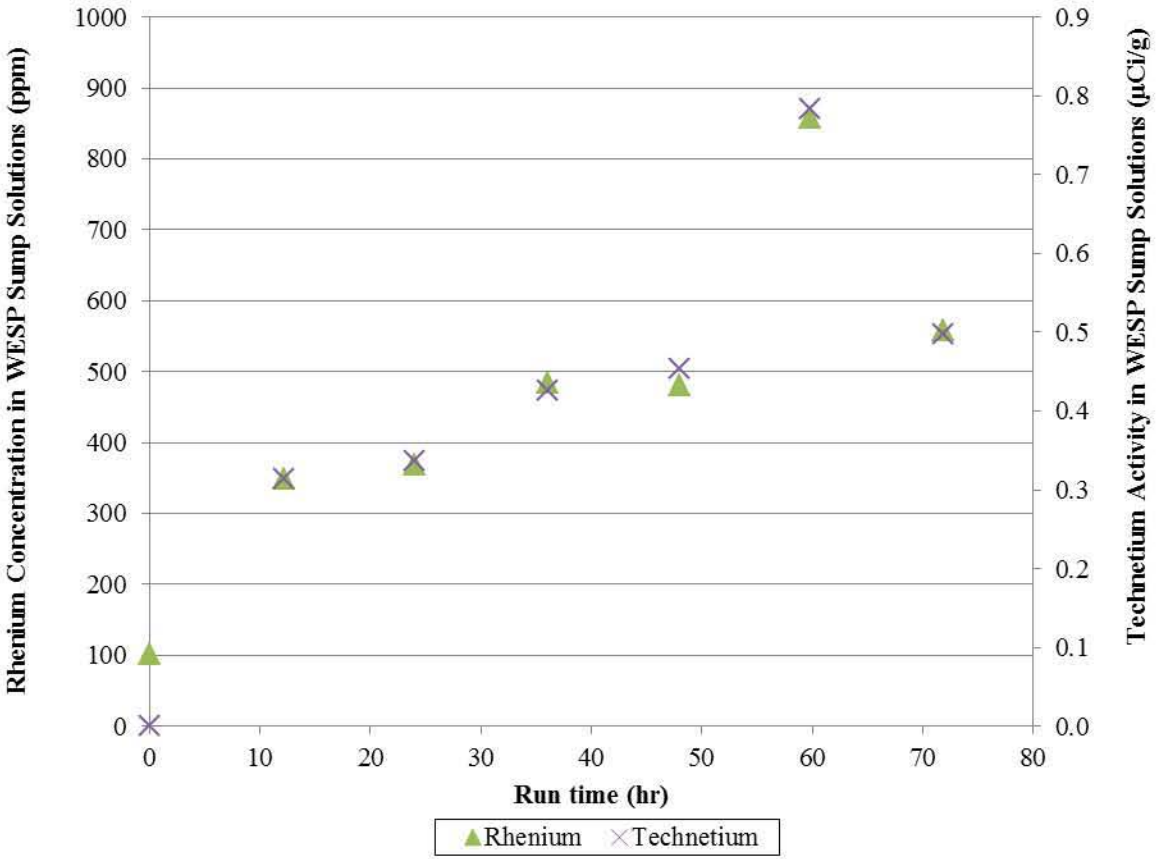


Figure 4.35.a. Technetium and rhenium concentrations in WESP solutions for Test 6.

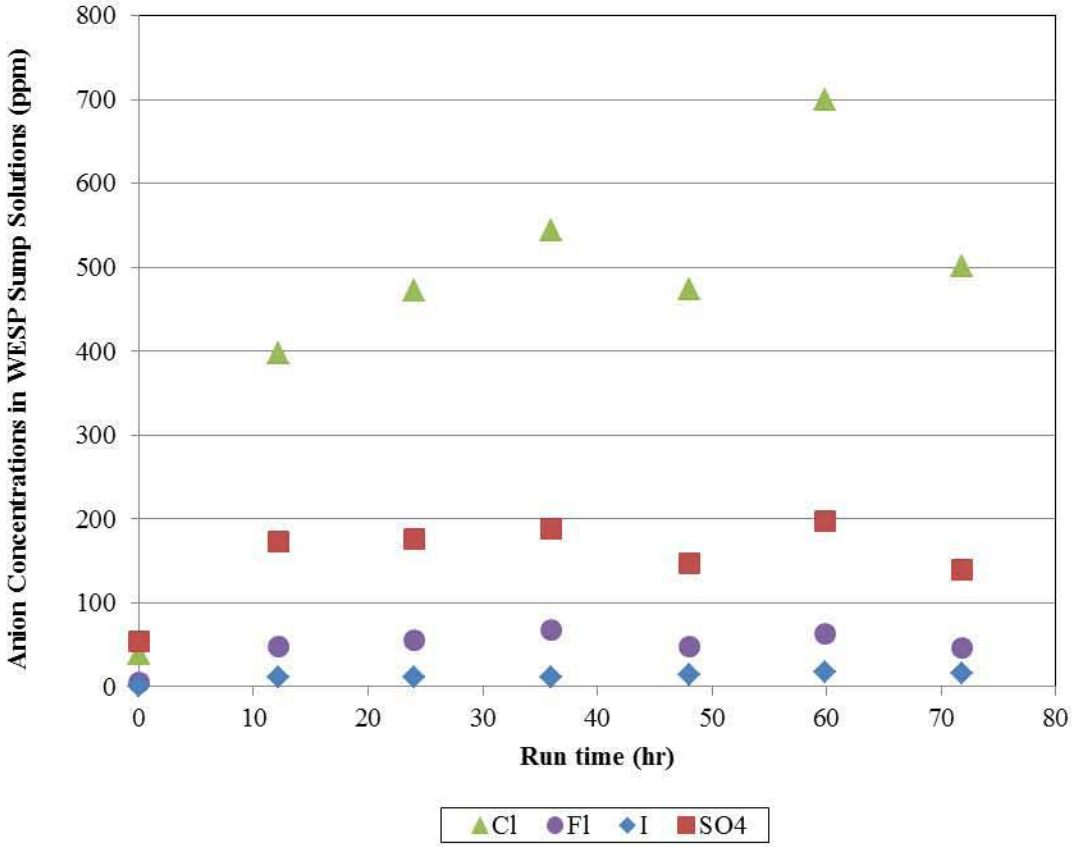


Figure 4.35.b. Anion concentrations in WESP solutions for Test 6.

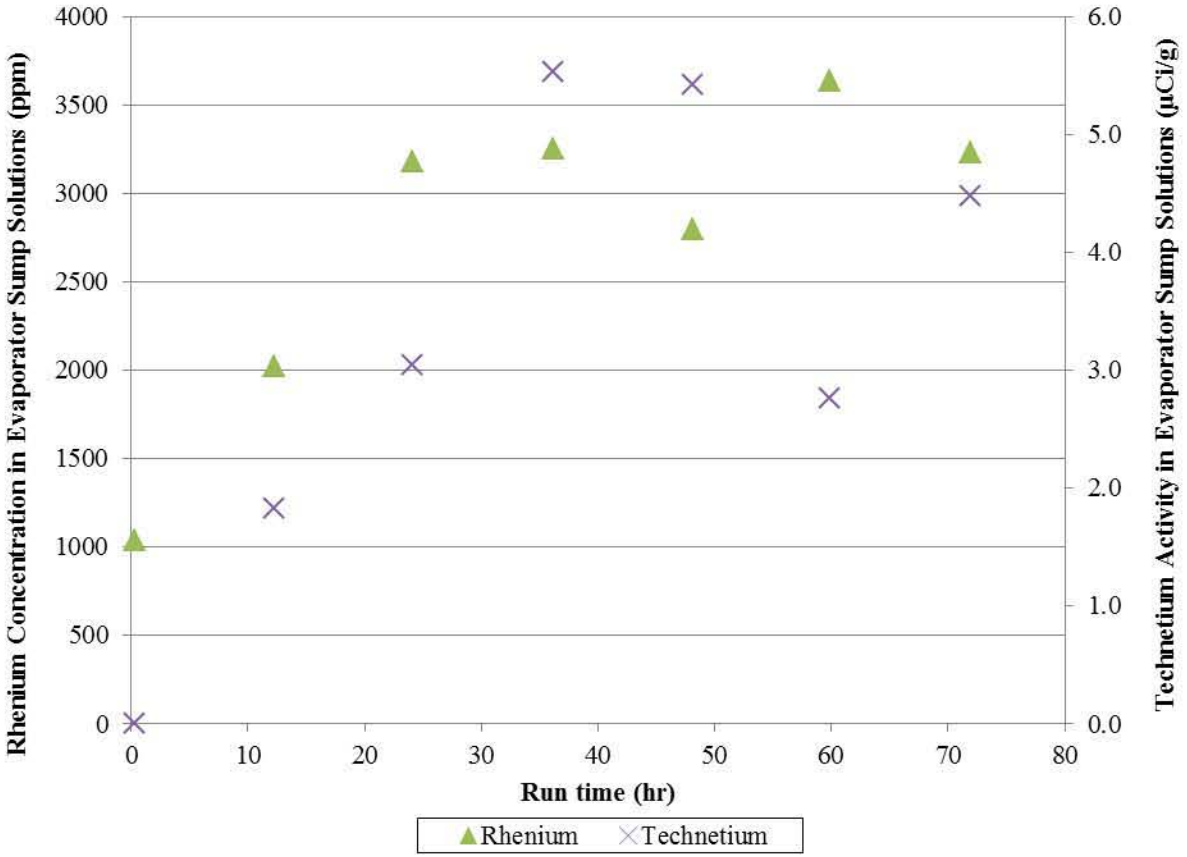


Figure 4.36.a. Technetium and rhenium concentrations in evaporator solutions for Test 6.

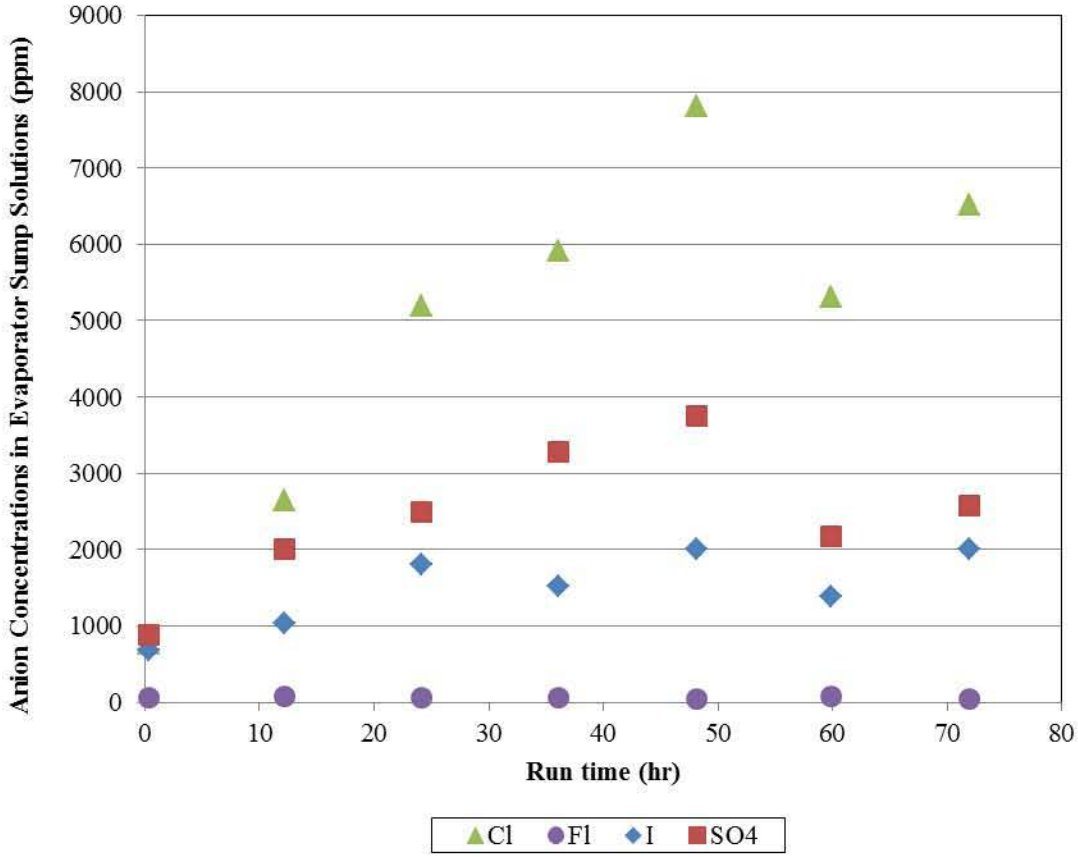


Figure 4.36.b. Anion concentrations in evaporator solutions for Test 6.

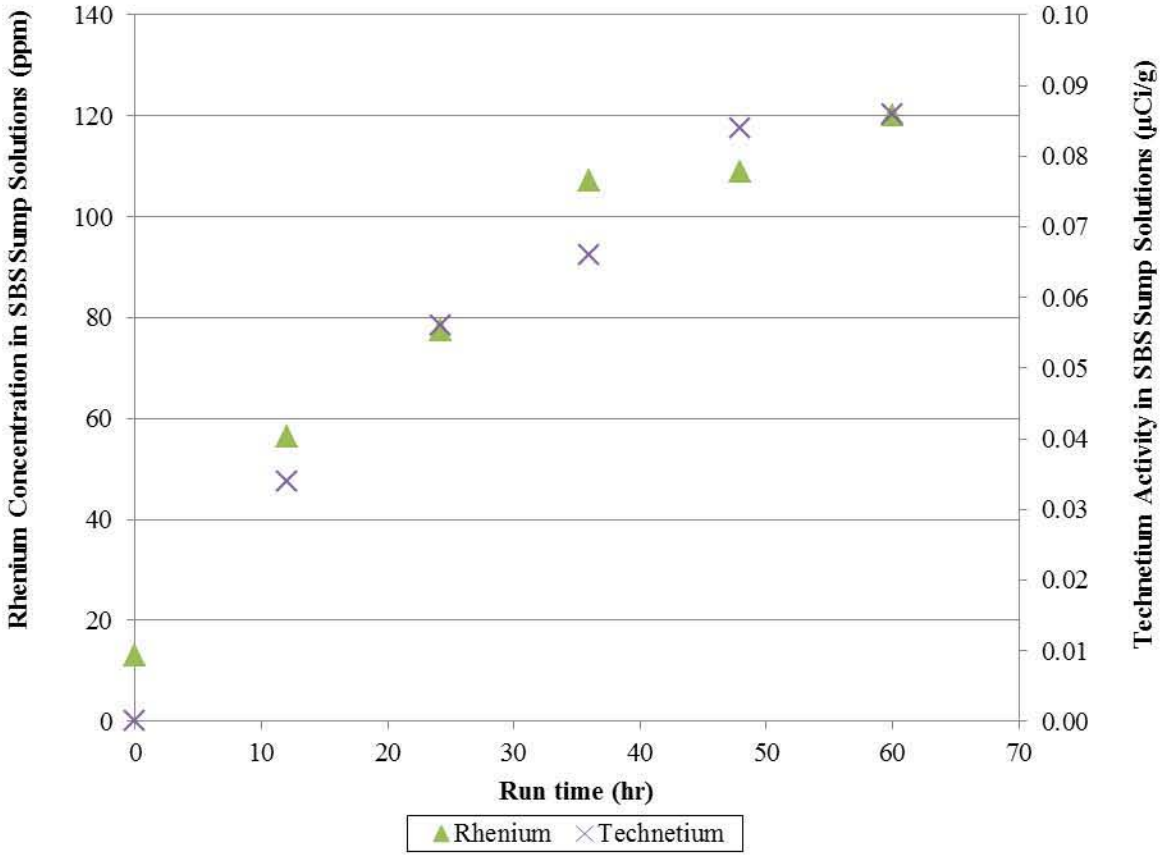


Figure 4.37.a. Technetium and rhenium concentrations in SBS solutions for Test 7.

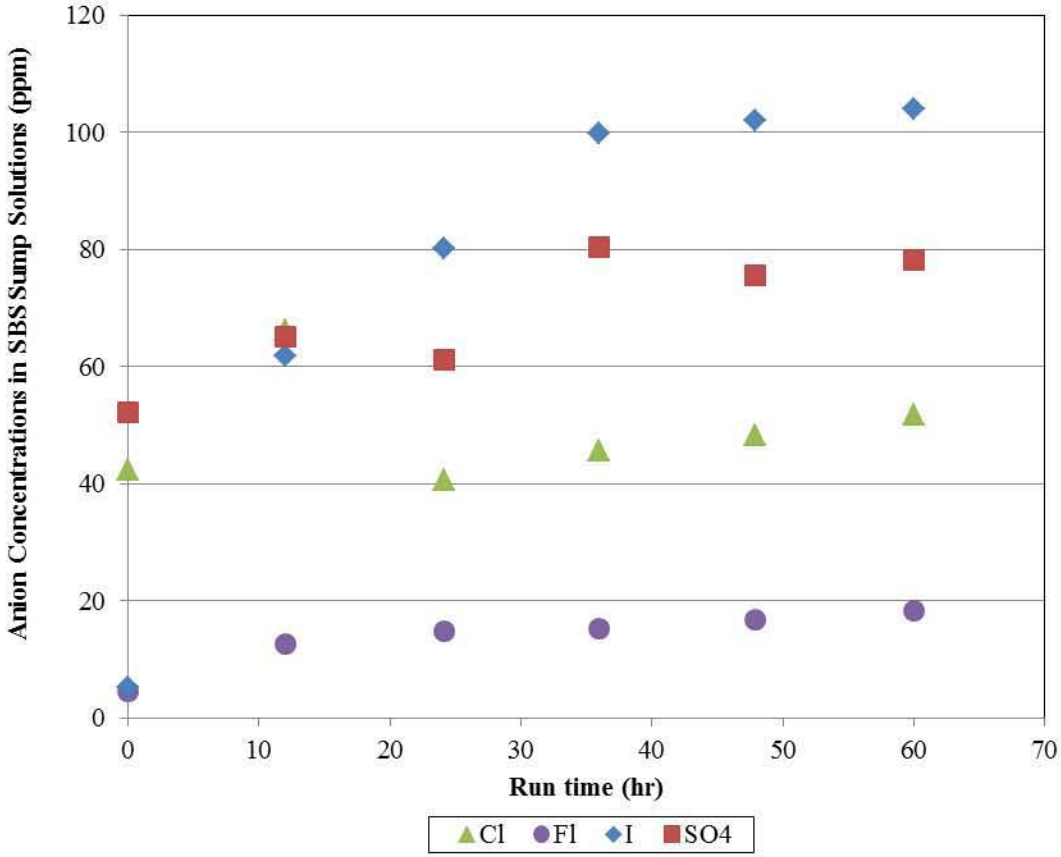


Figure 4.37.b. Anion concentrations in SBS solutions for Test 7.

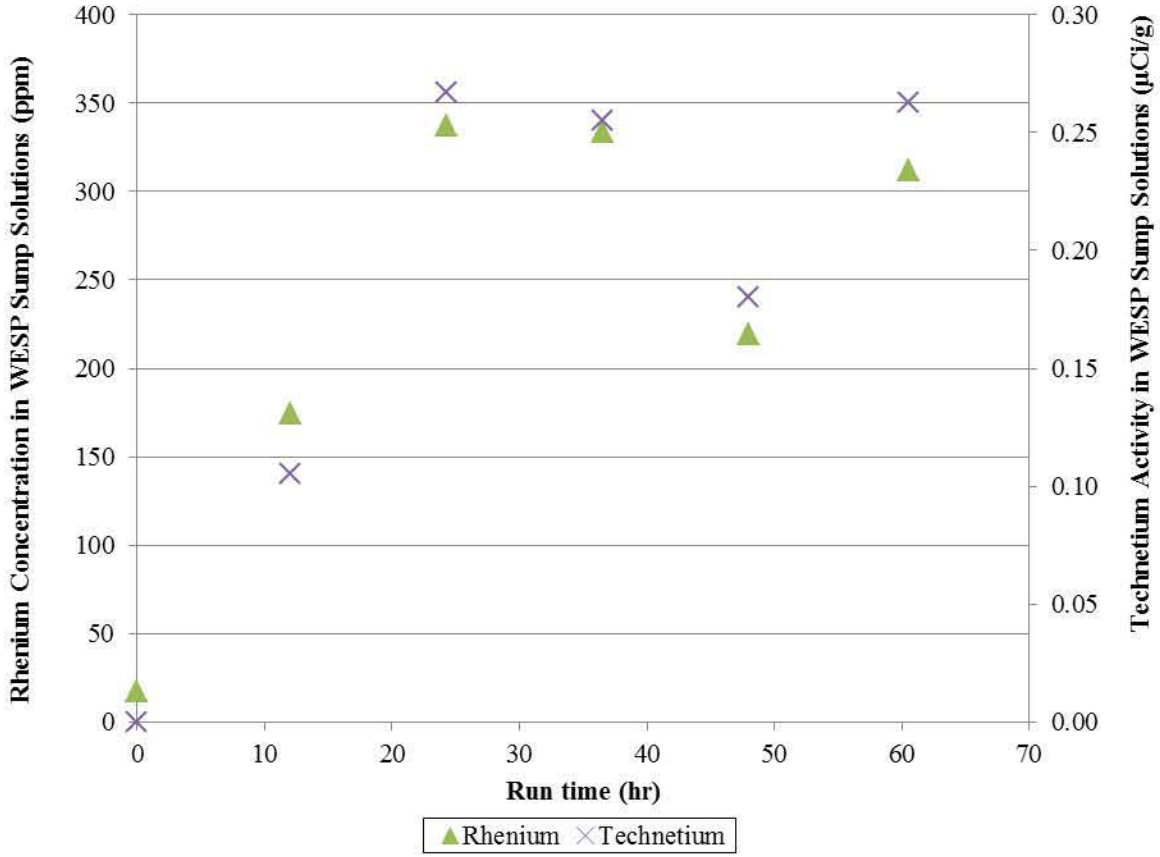


Figure 4.38.a. Technetium and rhenium concentrations in WESP solutions for Test 7.

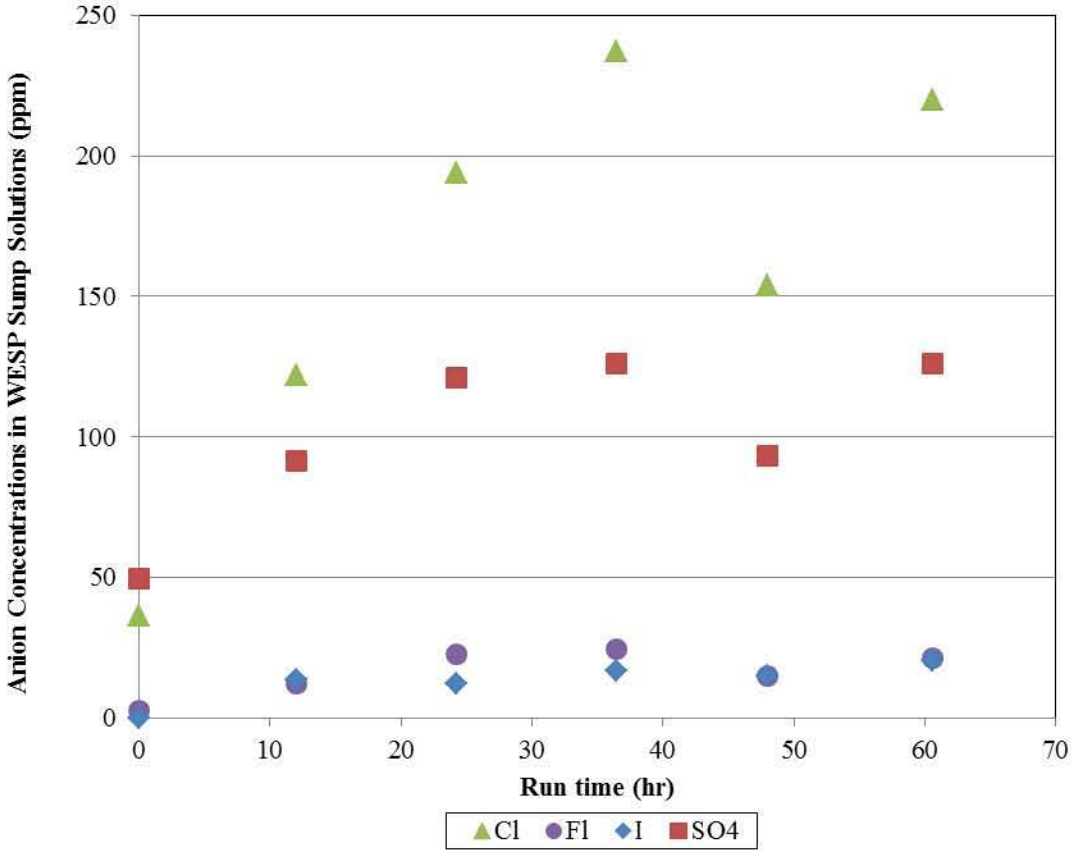


Figure 4.38.b. Anion concentrations in WESP solutions for Test 7.

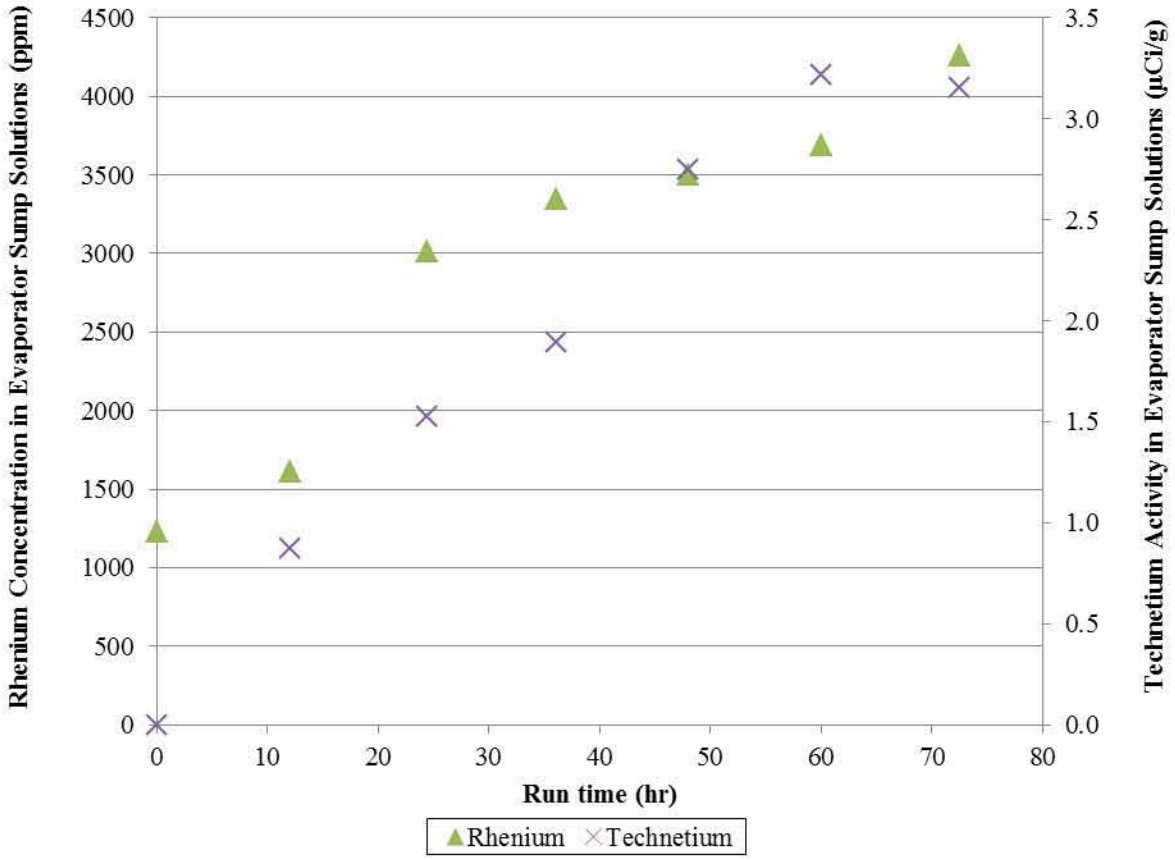


Figure 4.39.a. Technetium and rhenium concentrations in evaporator solutions for Test 7.

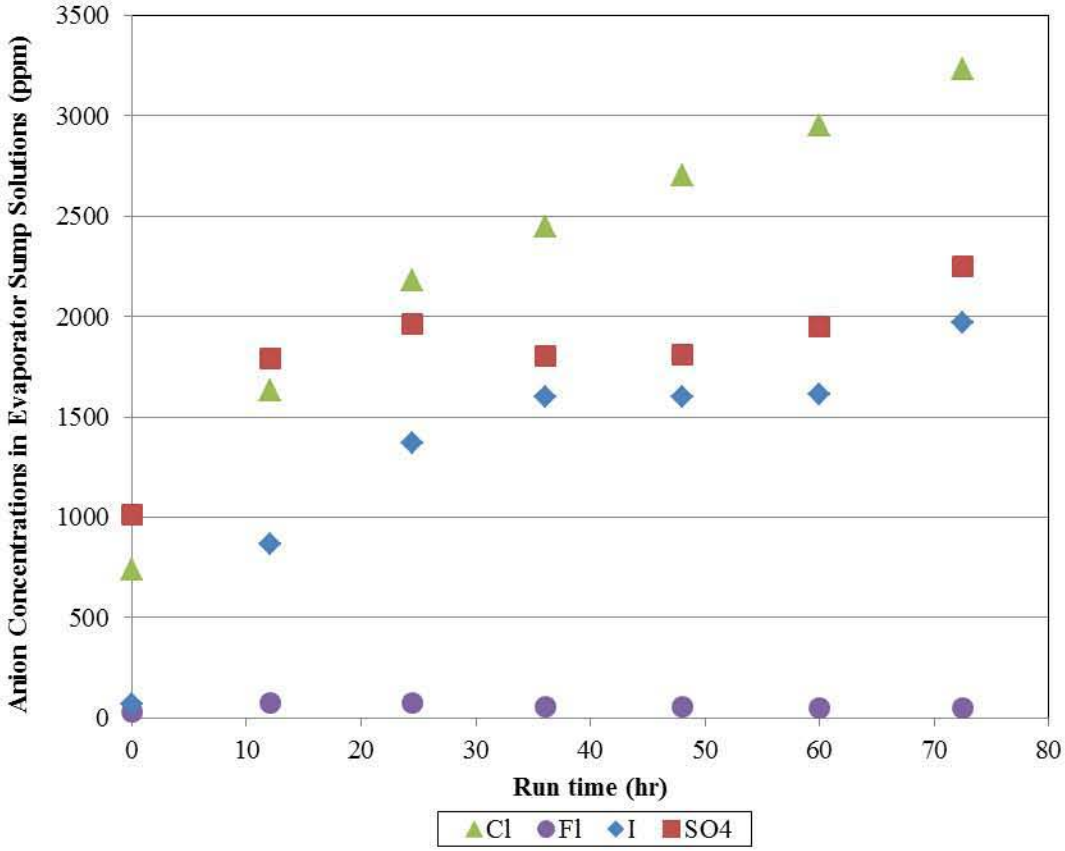


Figure 4.39.b. Anion concentrations in evaporator solutions for Test 7.

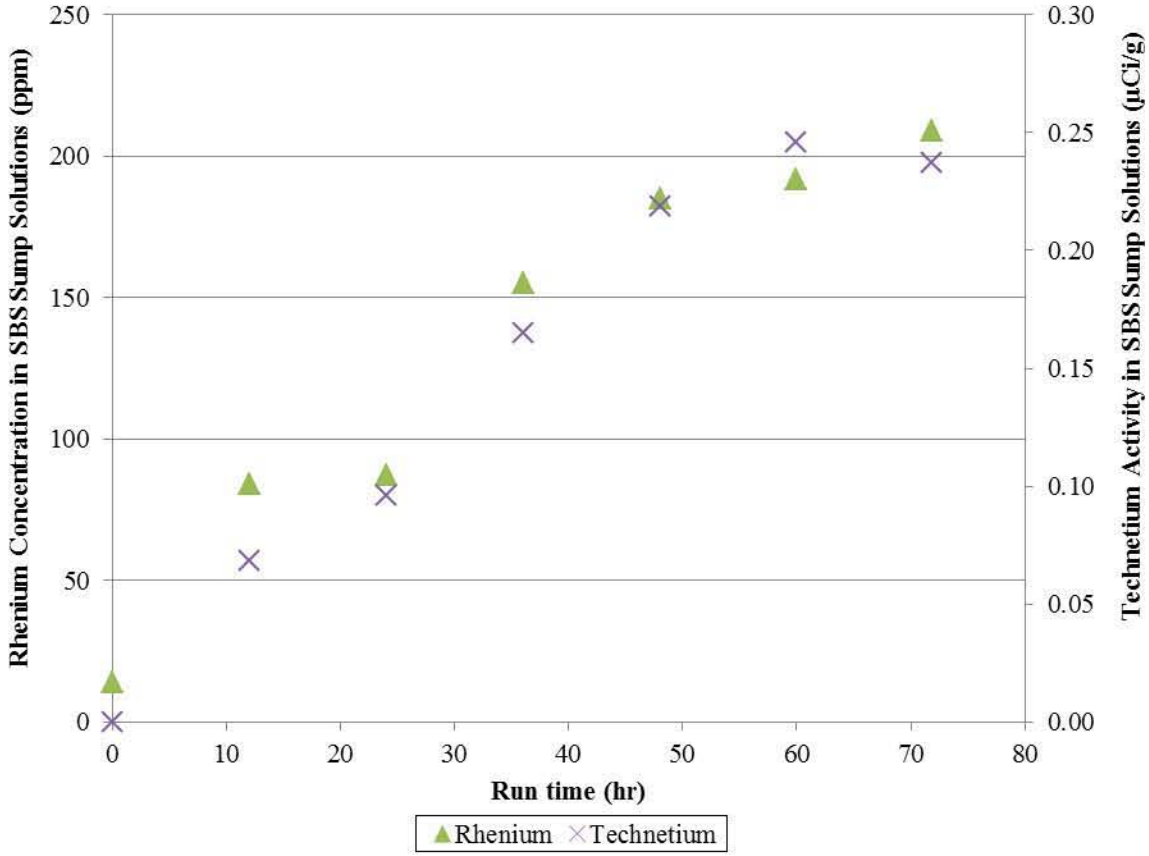


Figure 4.40.a. Technetium and rhenium concentrations in SBS solutions for Test 8.

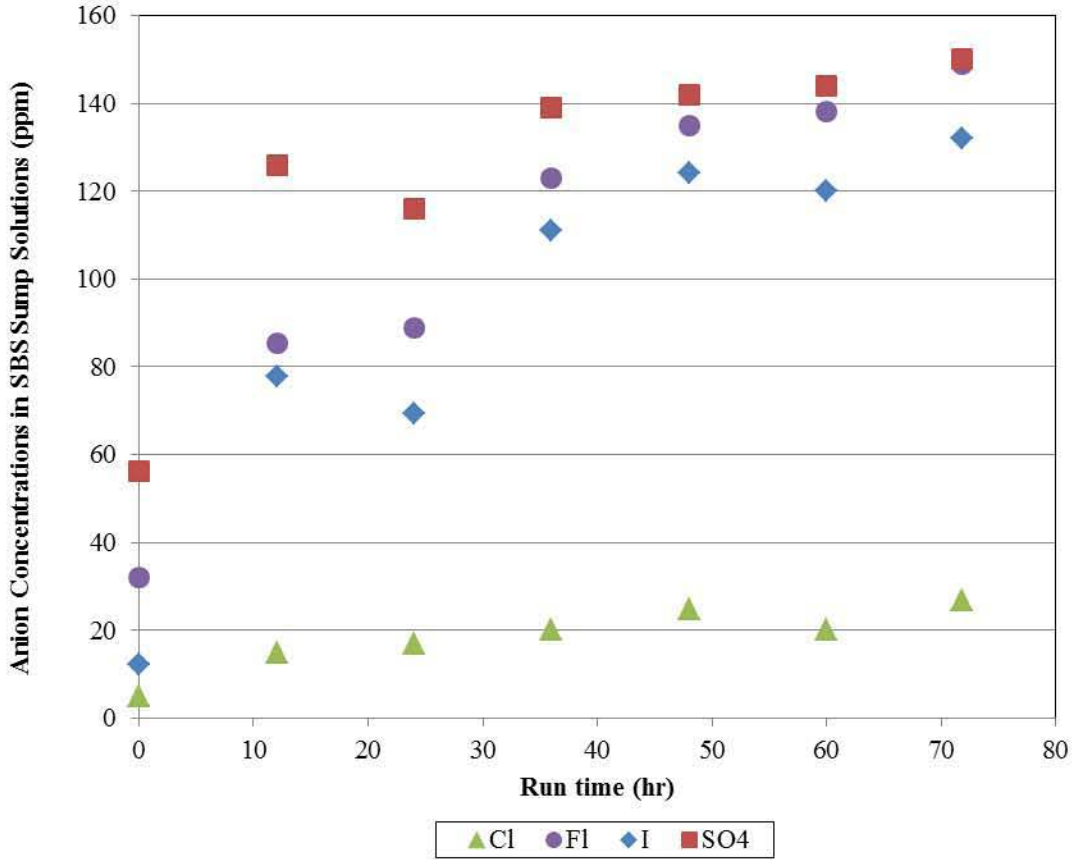


Figure 4.40.b. Anion concentrations in SBS solutions for Test 8.

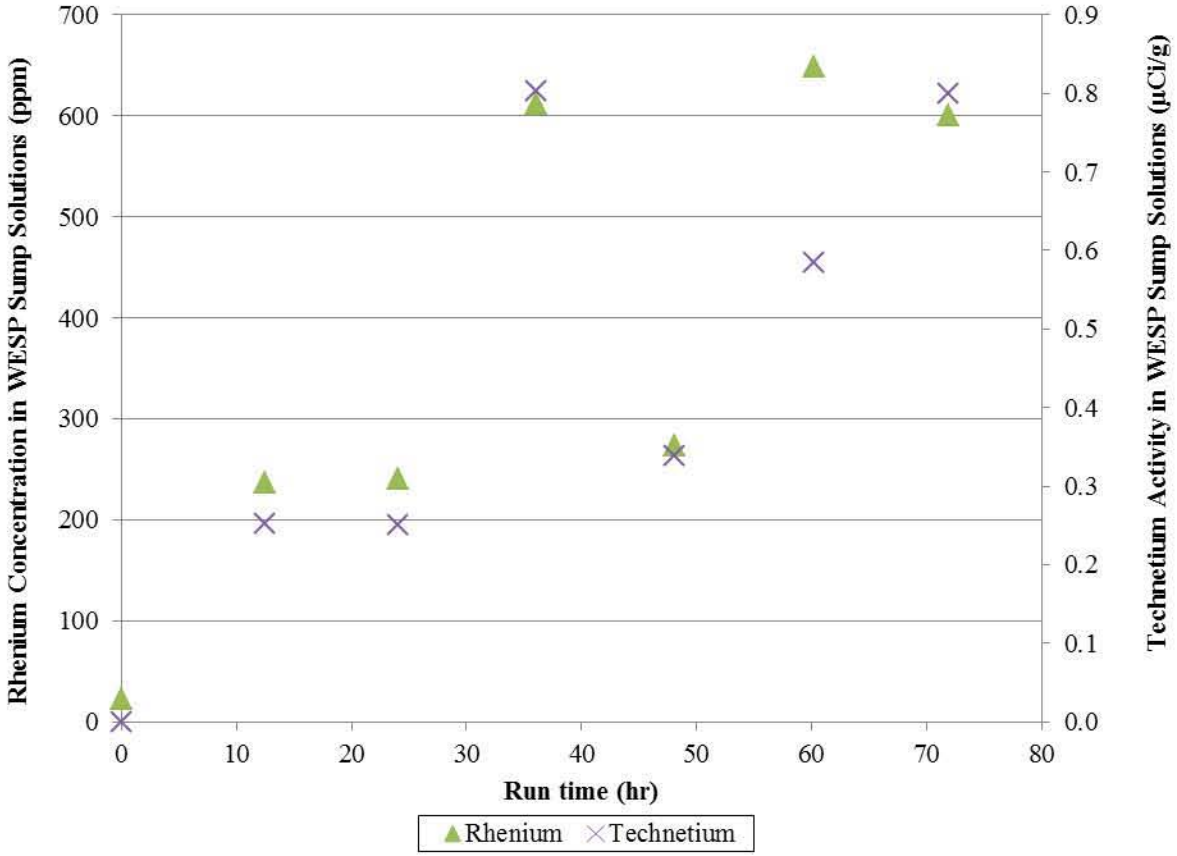


Figure 4.41.a. Technetium and rhenium concentrations in WESP solutions for Test 8.

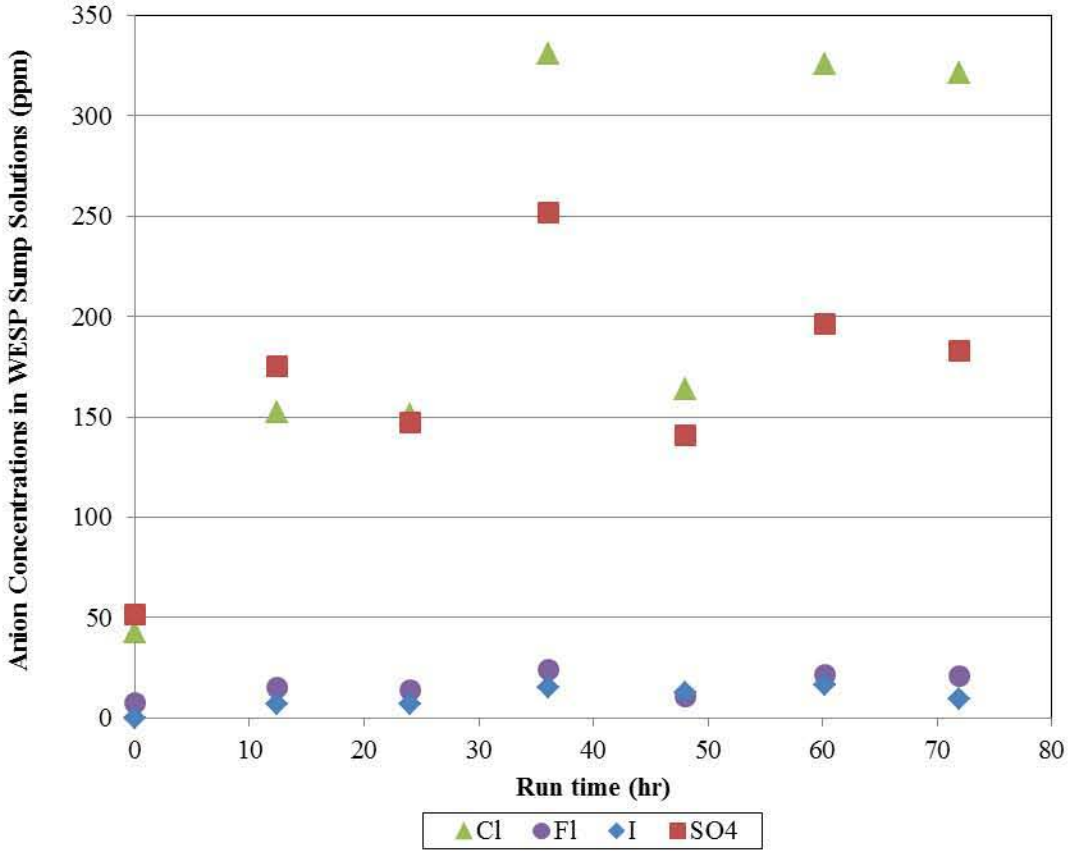


Figure 4.41.b. Anion concentrations in WESP solutions for Test 8.

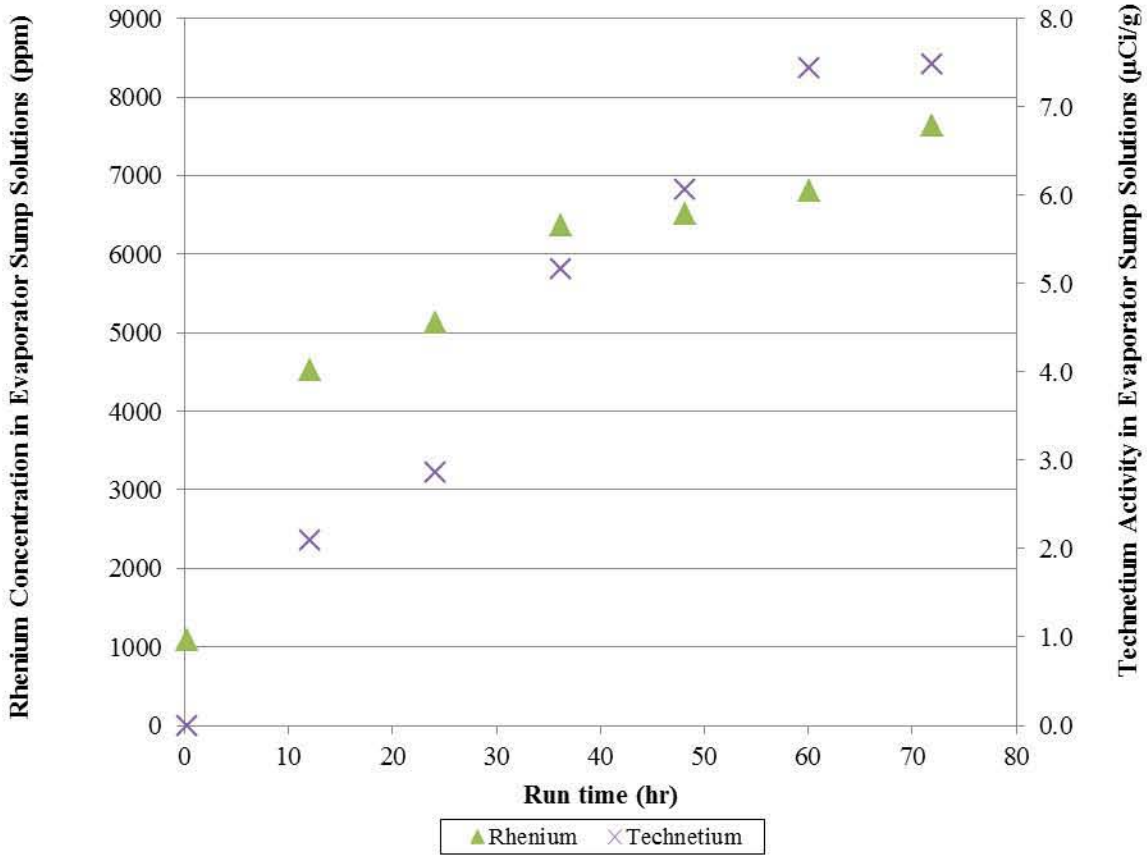


Figure 4.42.a. Technetium and rhenium concentrations in evaporator solutions for Test 8.

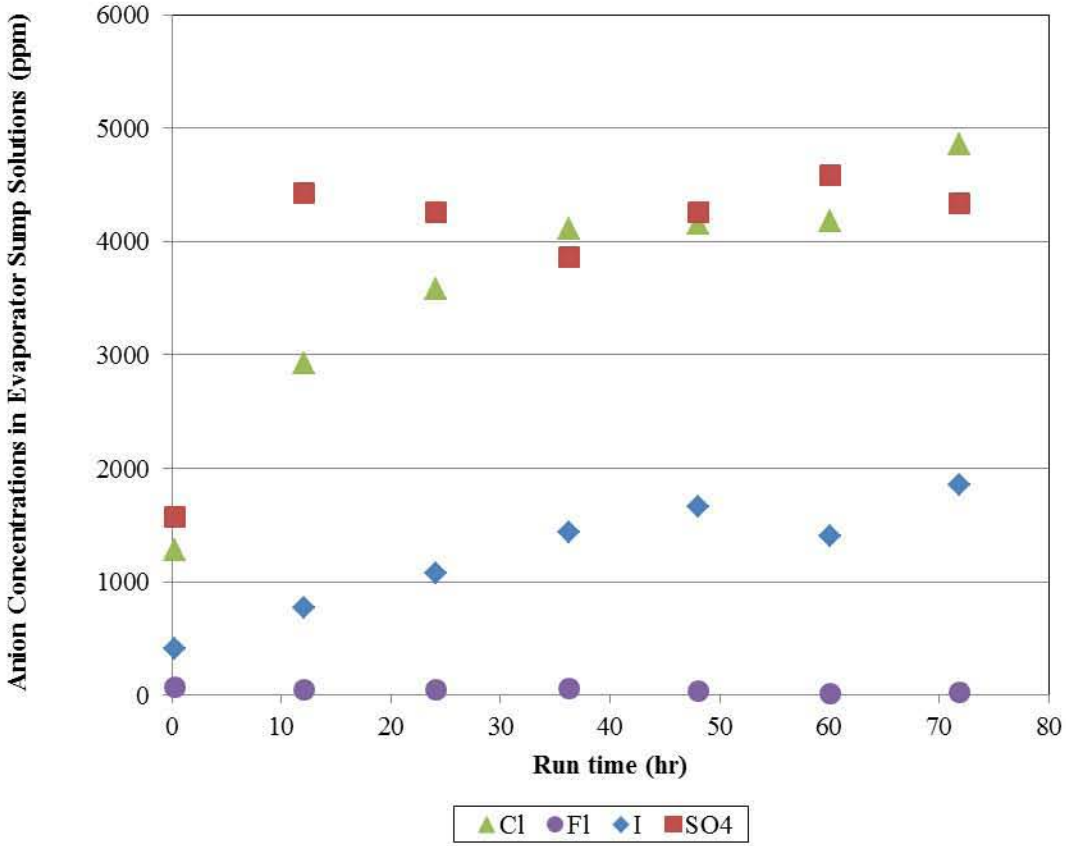


Figure 4.42.b. Anion concentrations in evaporator solutions for Test 8.

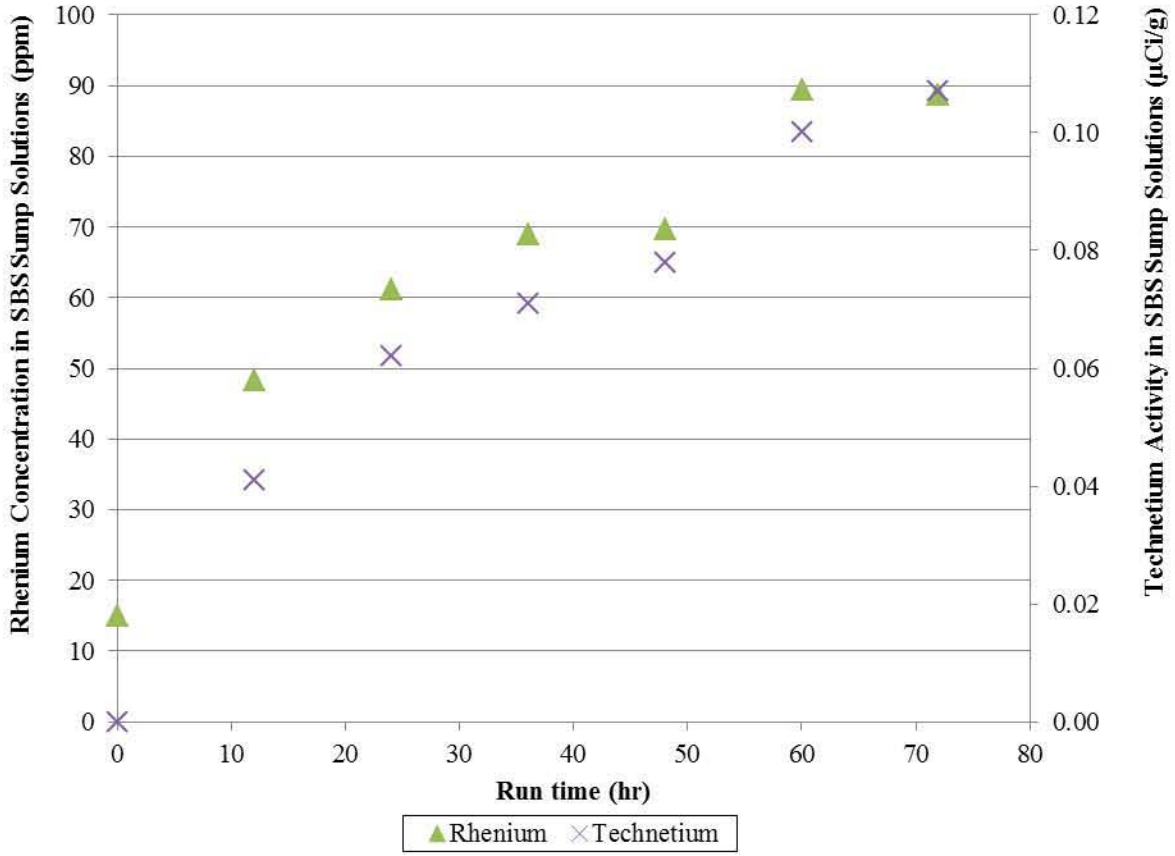


Figure 4.43.a. Technetium and rhenium concentrations in SBS solutions for Test 9.

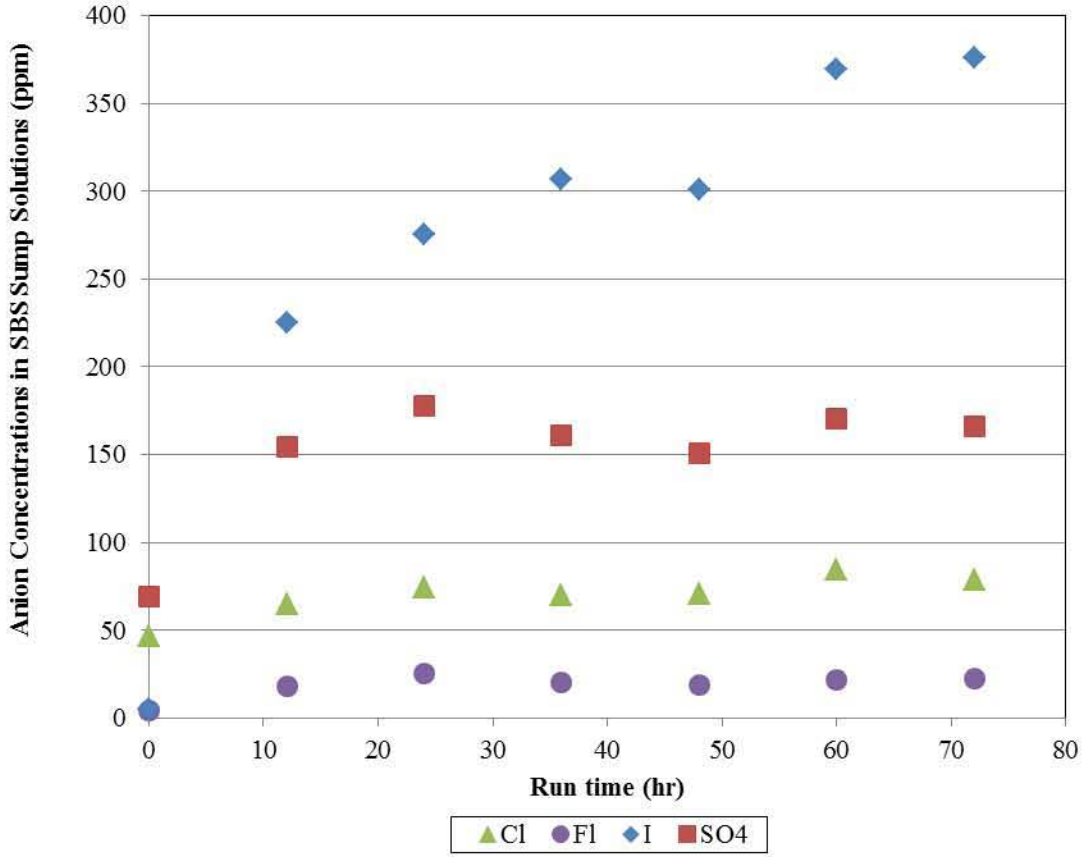


Figure 4.43.b. Anion concentrations in SBS solutions for Test 9.

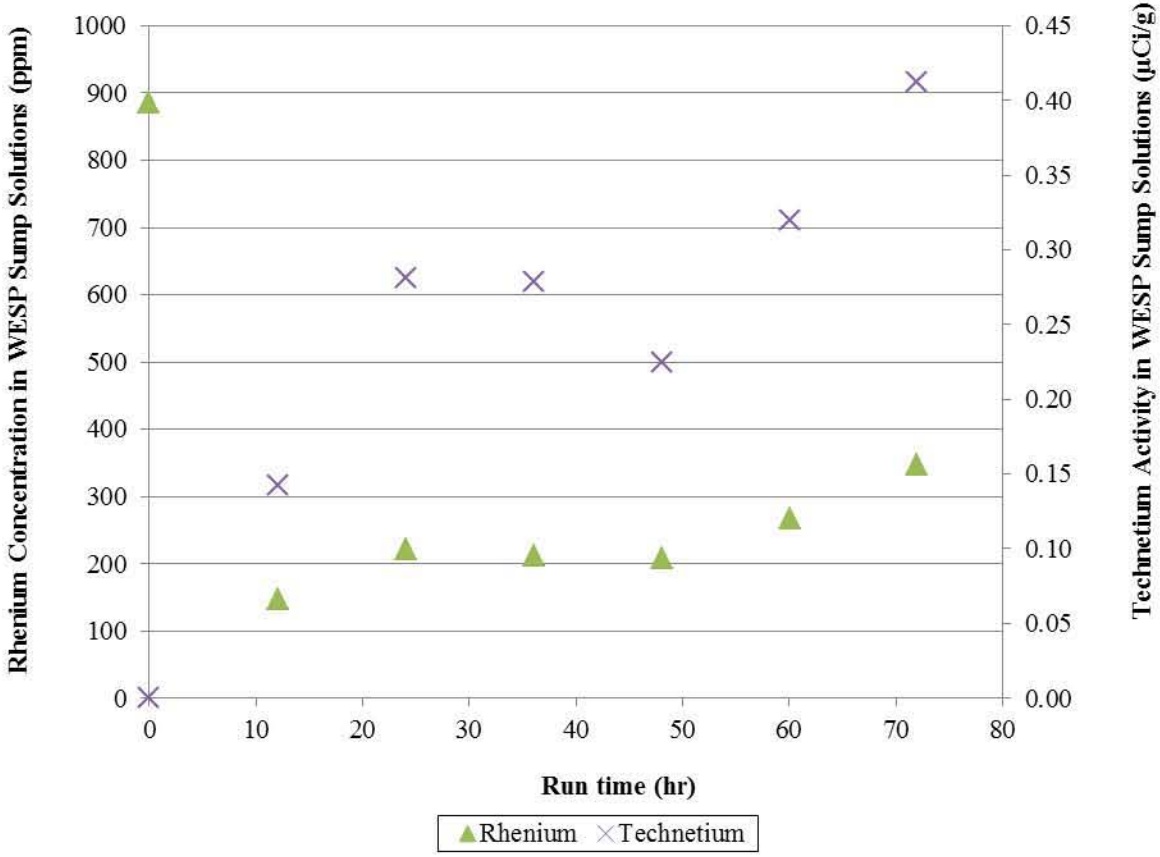


Figure 4.44.a. Technetium and rhenium concentrations in WESP solutions for Test 9.

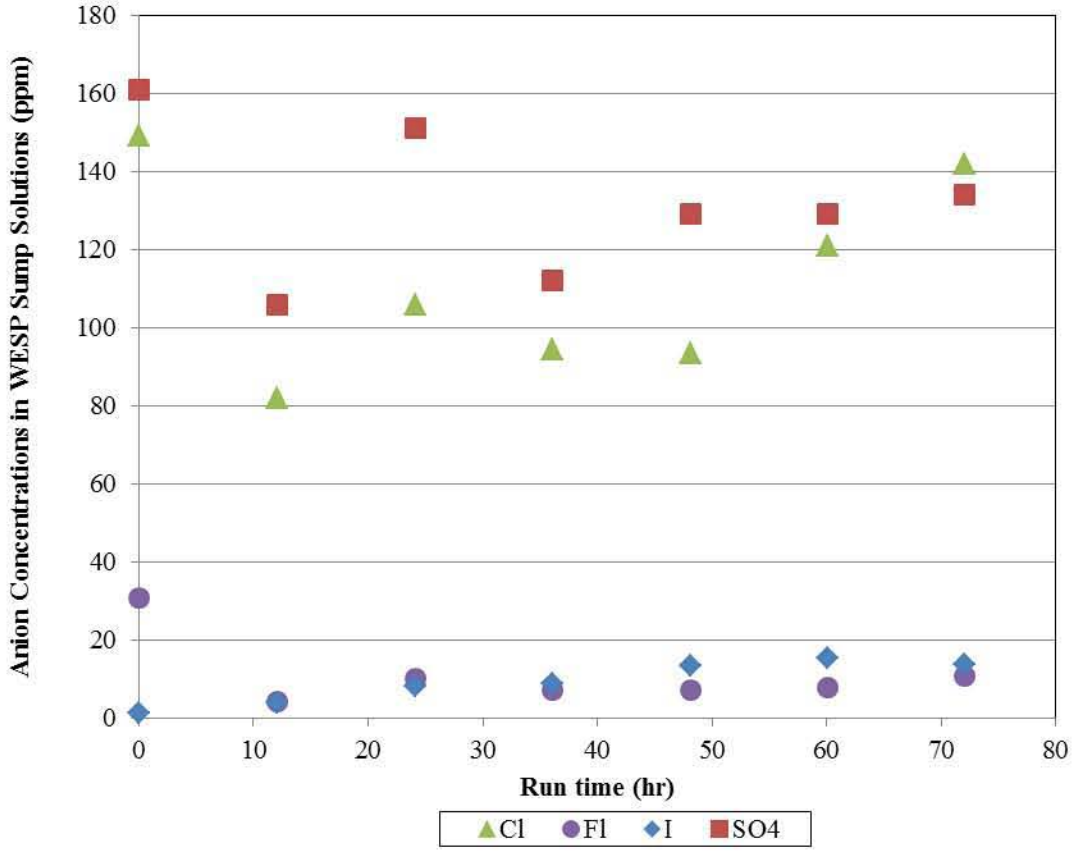


Figure 4.44.b. Anion concentrations in WESP solutions for Test 9.

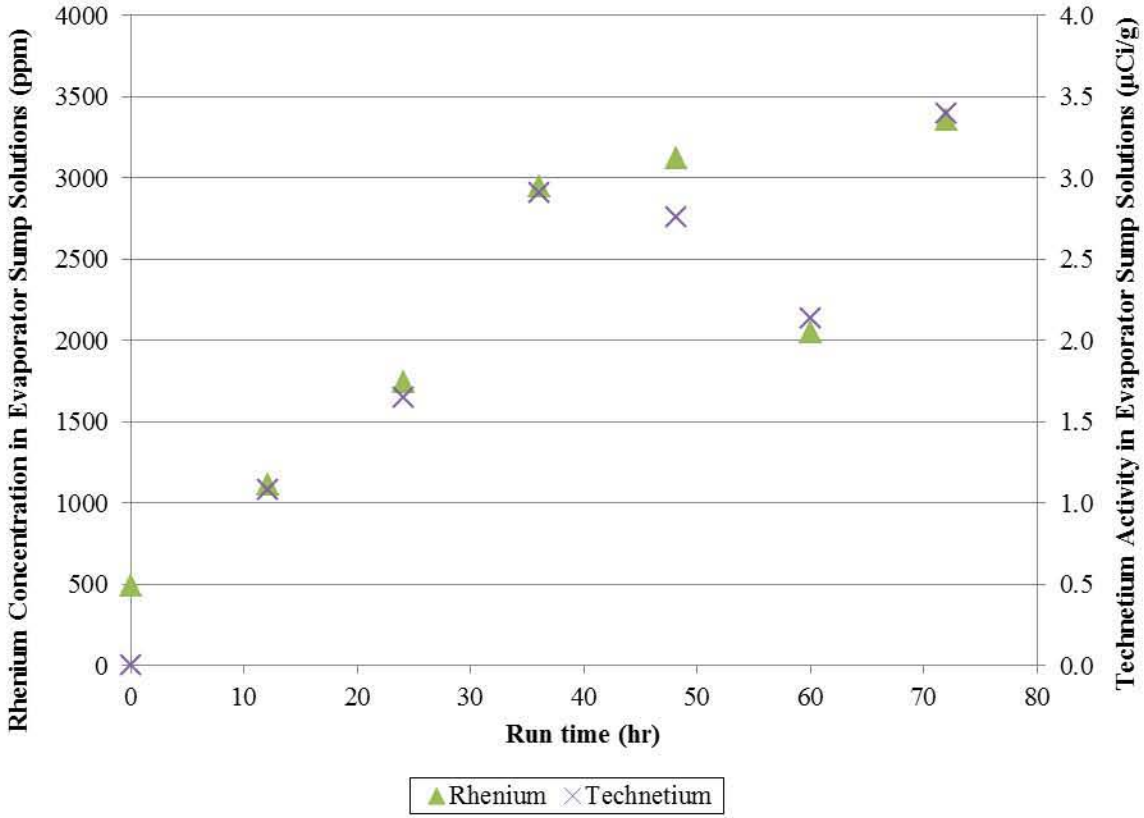


Figure 4.45.a. Technetium and rhenium concentrations in evaporator solutions for Test 9.

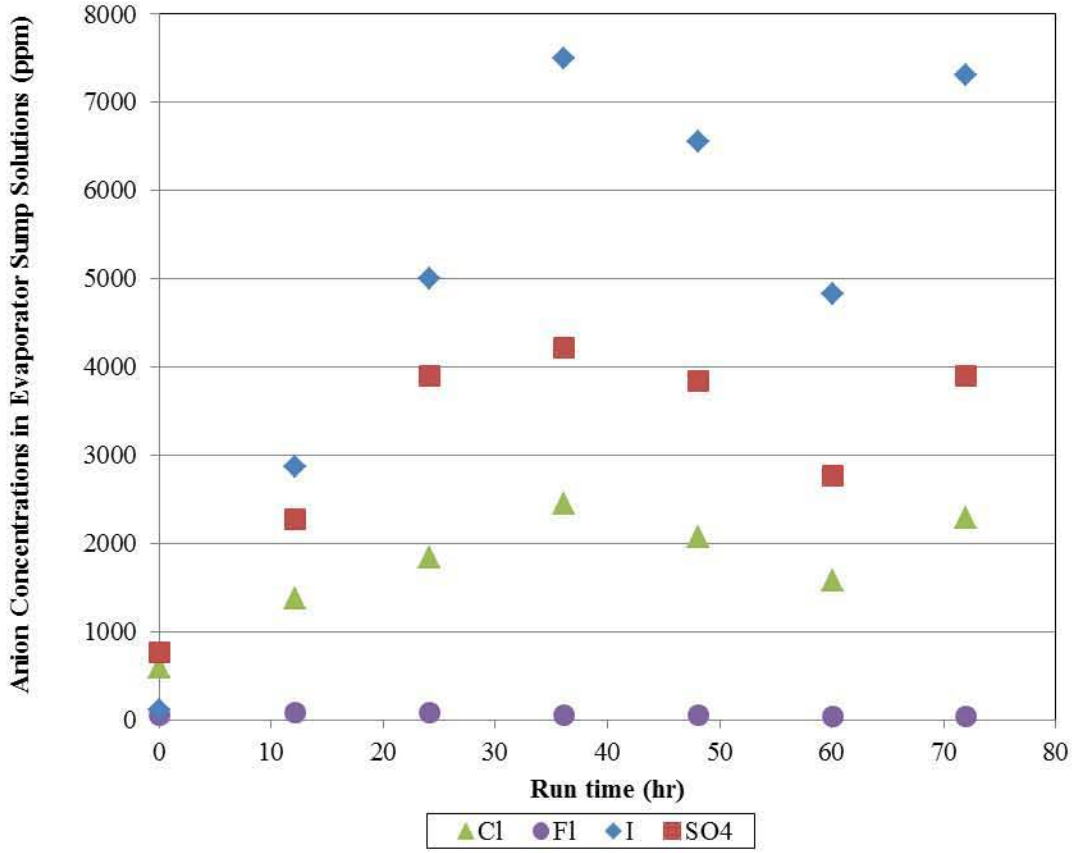


Figure 4.45.b. Anion concentrations in evaporator solutions for Test 9.

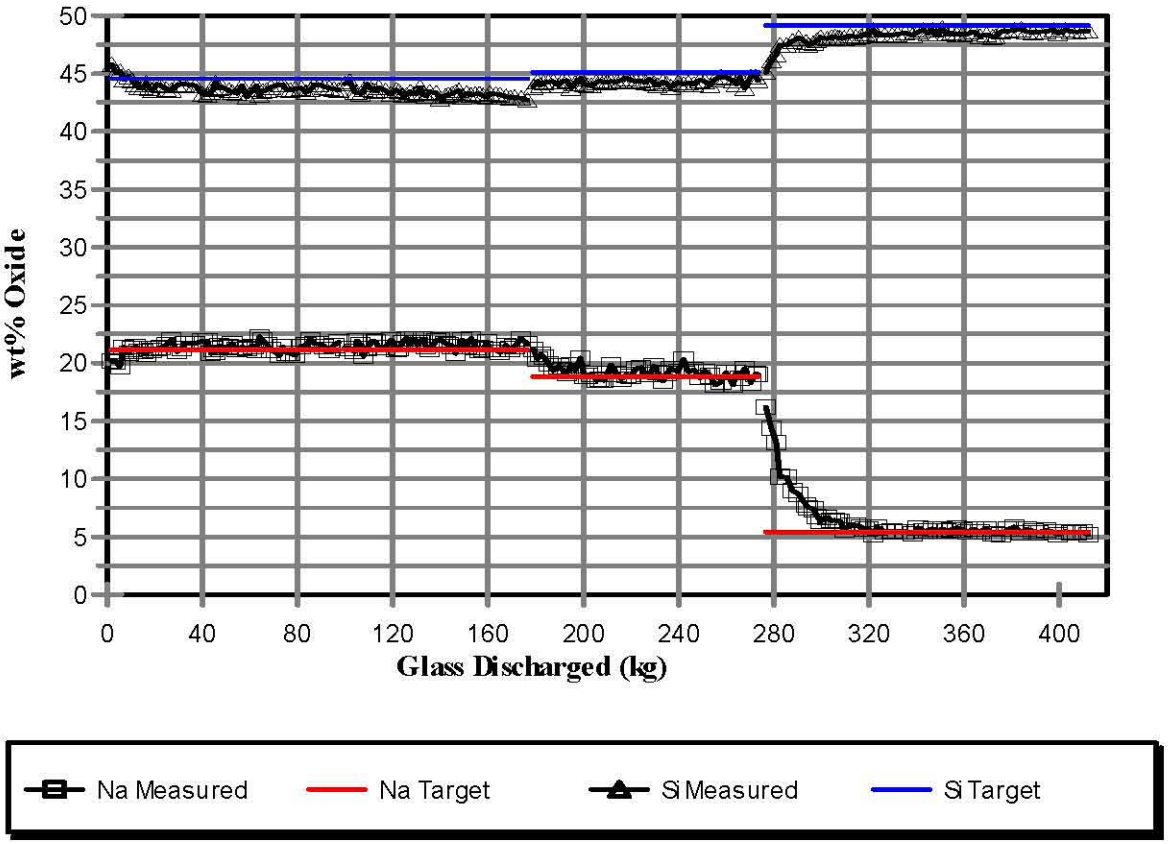


Figure 5.1.a. XRF analysis of sodium and silicon in product glasses, Tests 1-4.

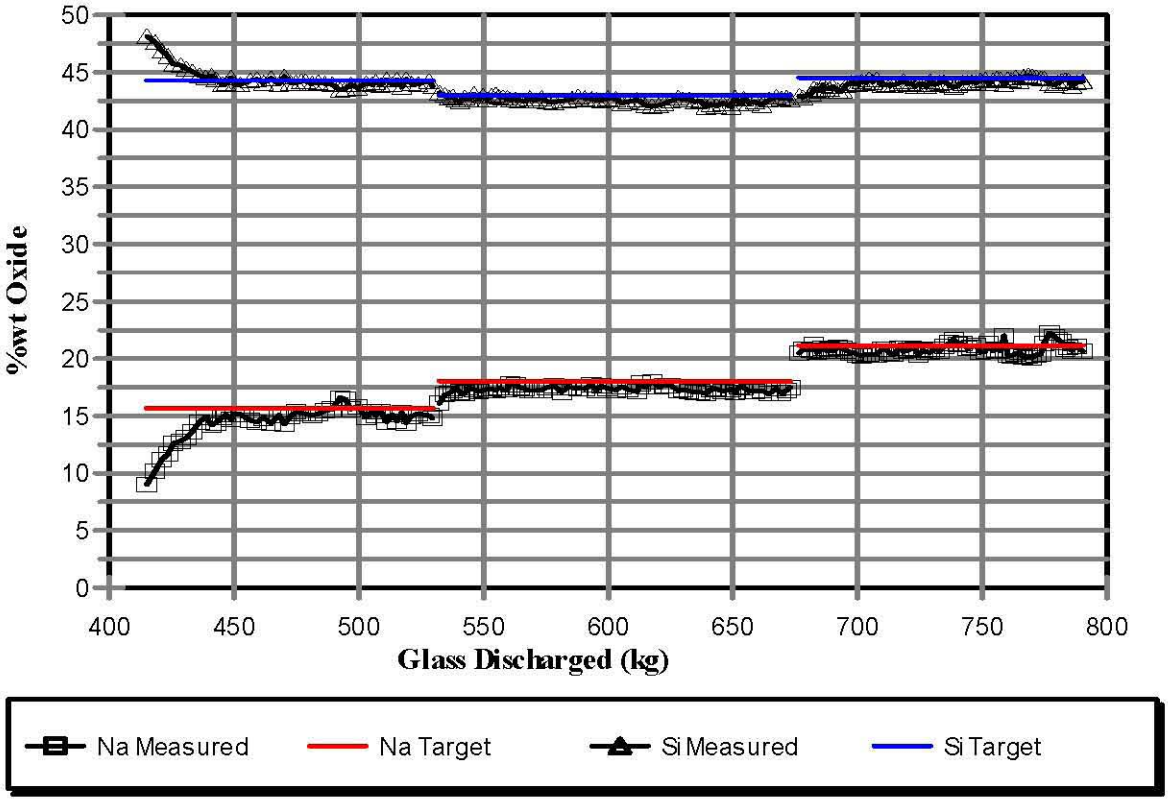


Figure 5.1.b. XRF analysis of sodium and silicon in product glasses, Tests 5-7.

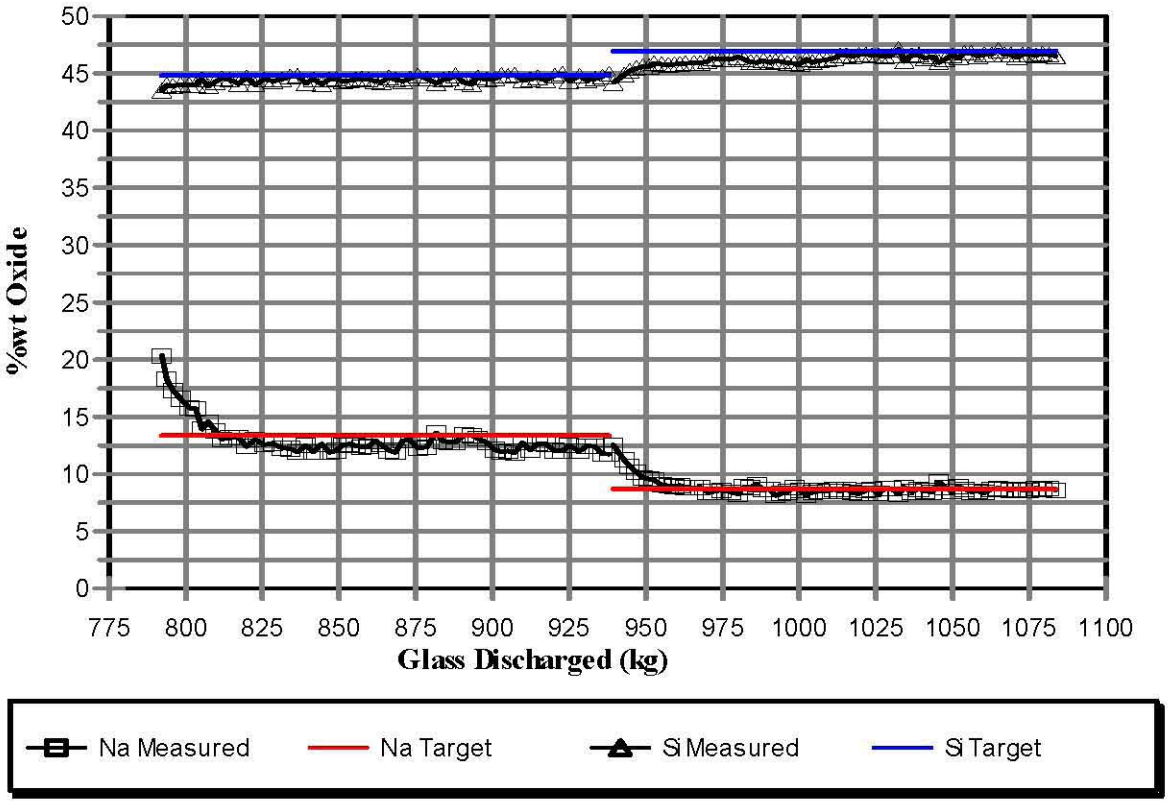


Figure 5.1.c. XRF analysis of sodium and silicon in product glasses, Tests 8-9.

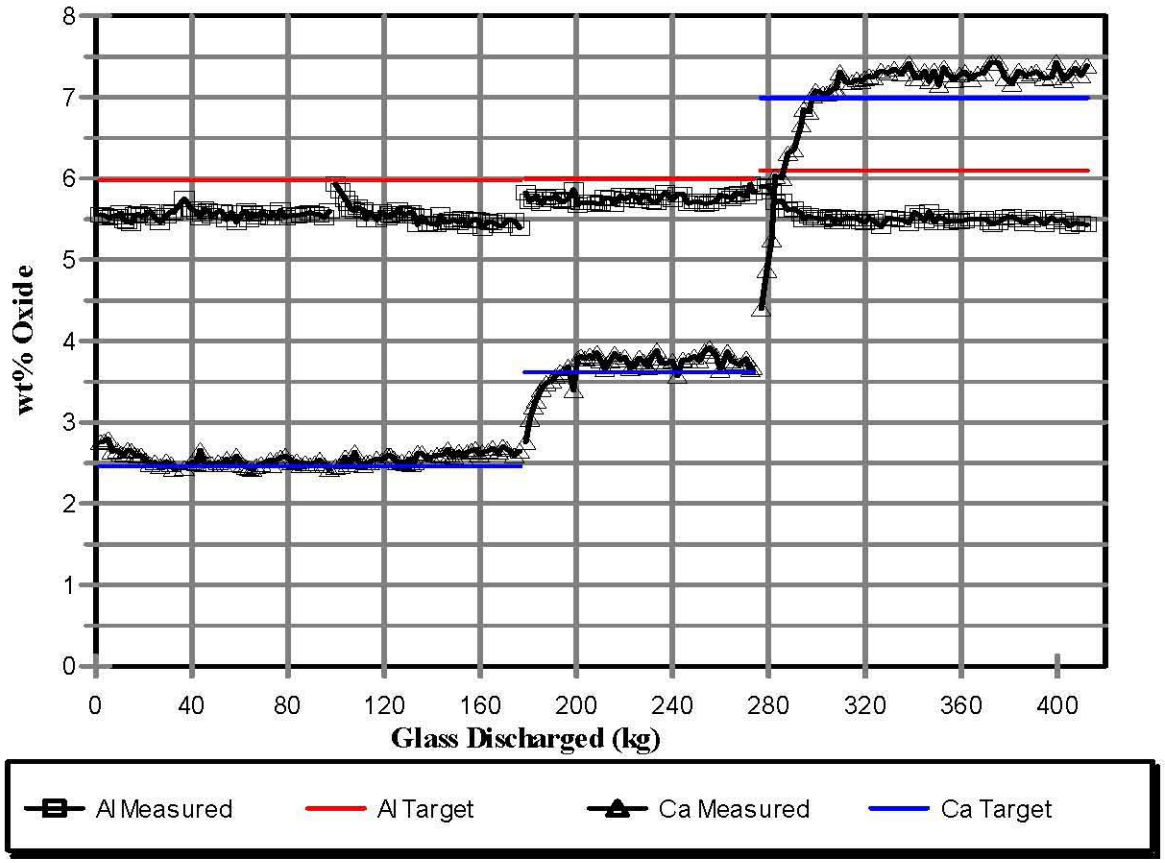


Figure 5.2.a. XRF analysis of aluminum and calcium in product glasses, Tests 1-4.

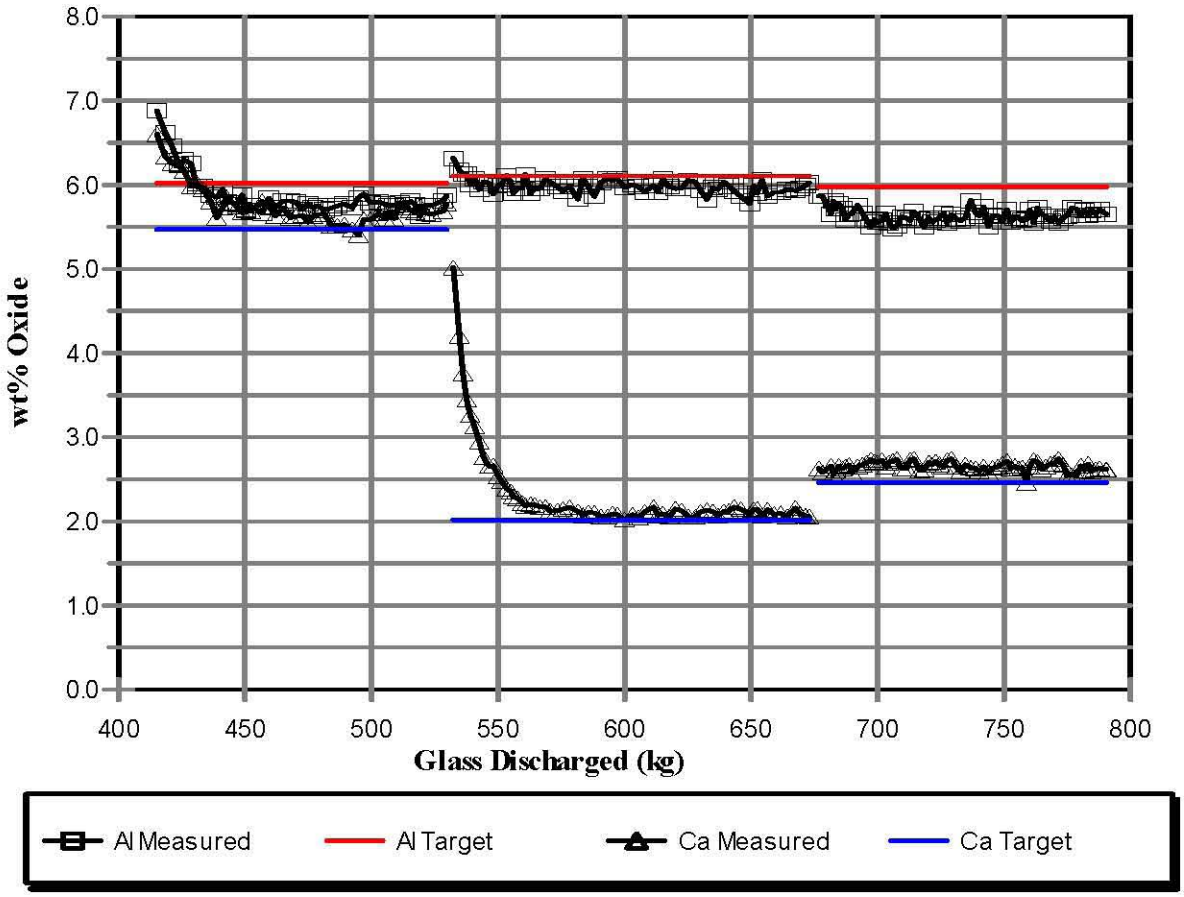


Figure 5.2.b. XRF analysis of aluminum and calcium in product glasses, Tests 5-7.

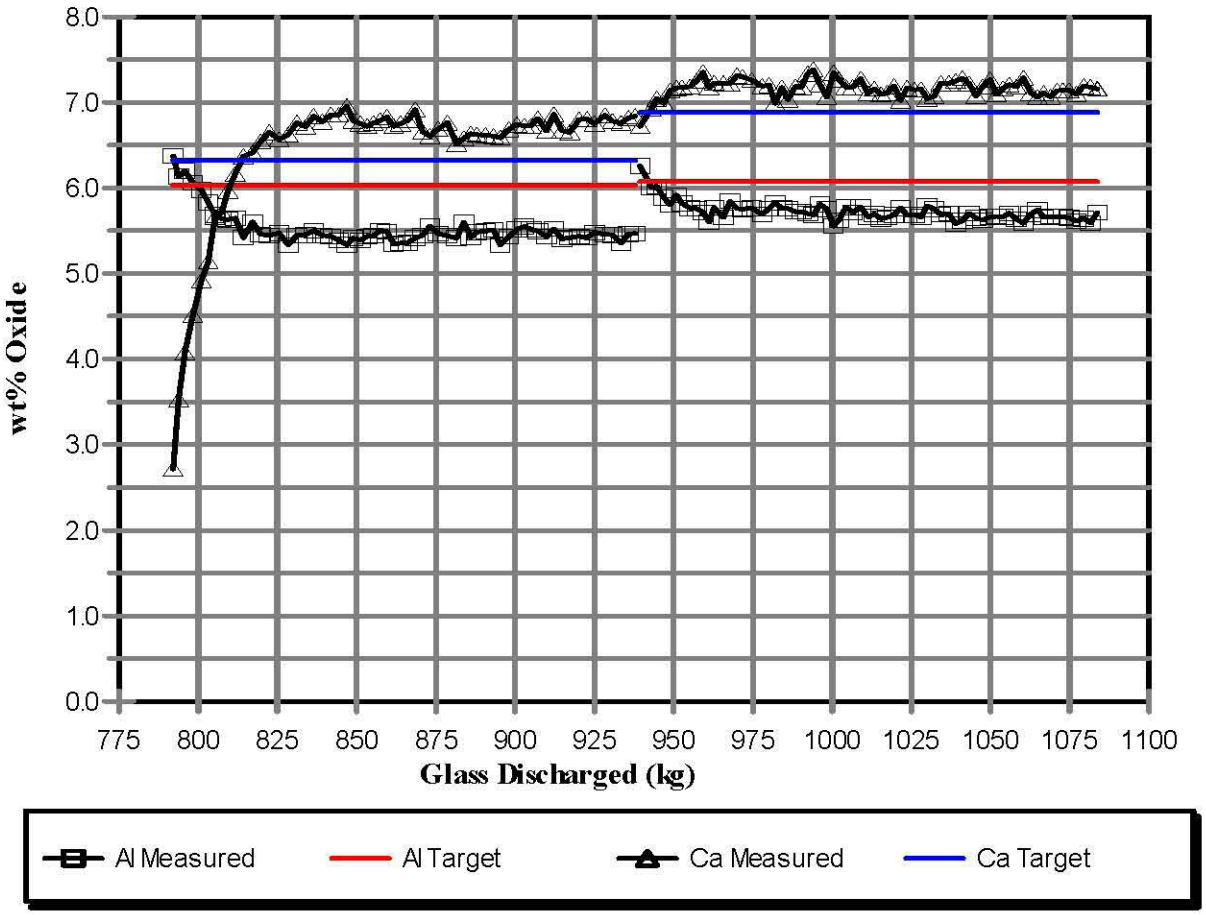


Figure 5.2.c. XRF analysis of aluminum and calcium in product glasses, Tests 8-9.

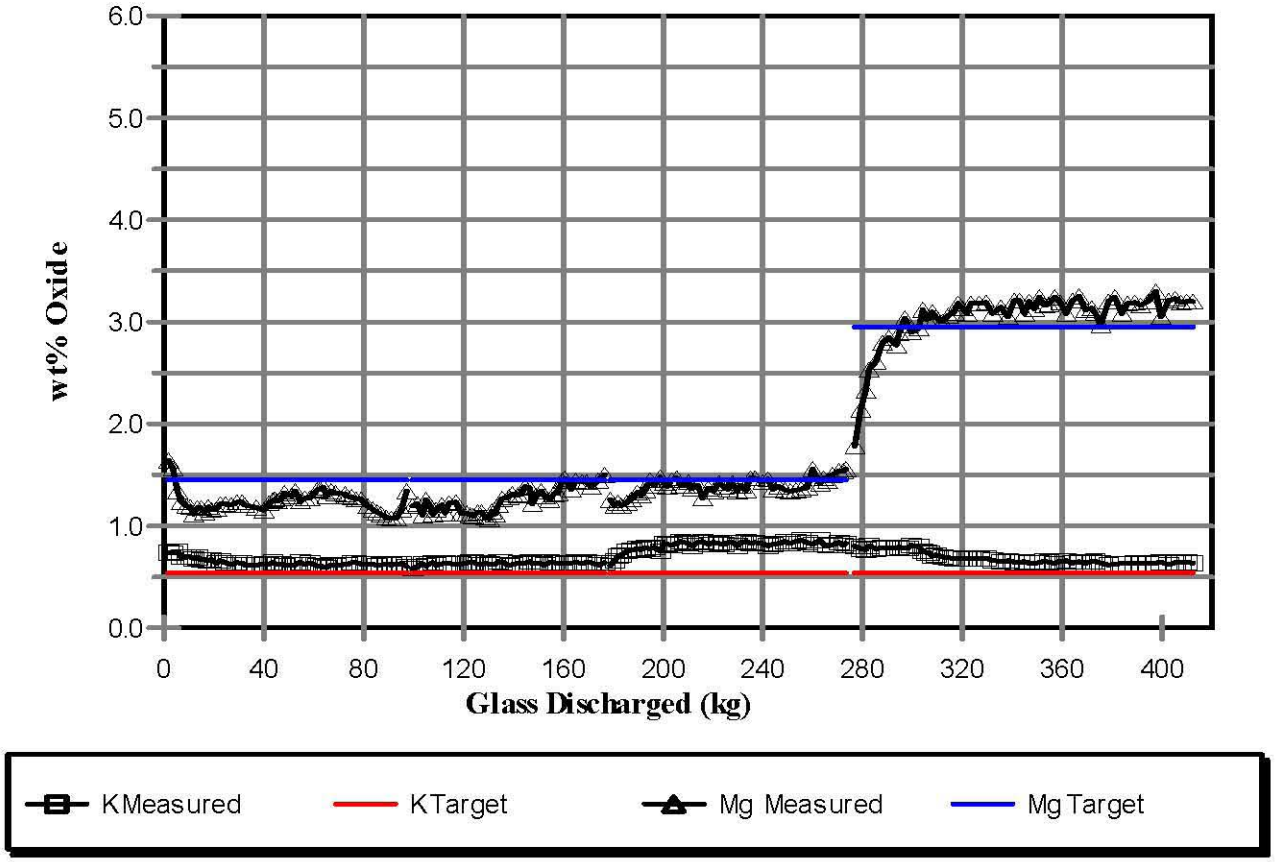


Figure 5.3.a. XRF analysis of potassium and magnesium in product glasses, Tests 1-4.

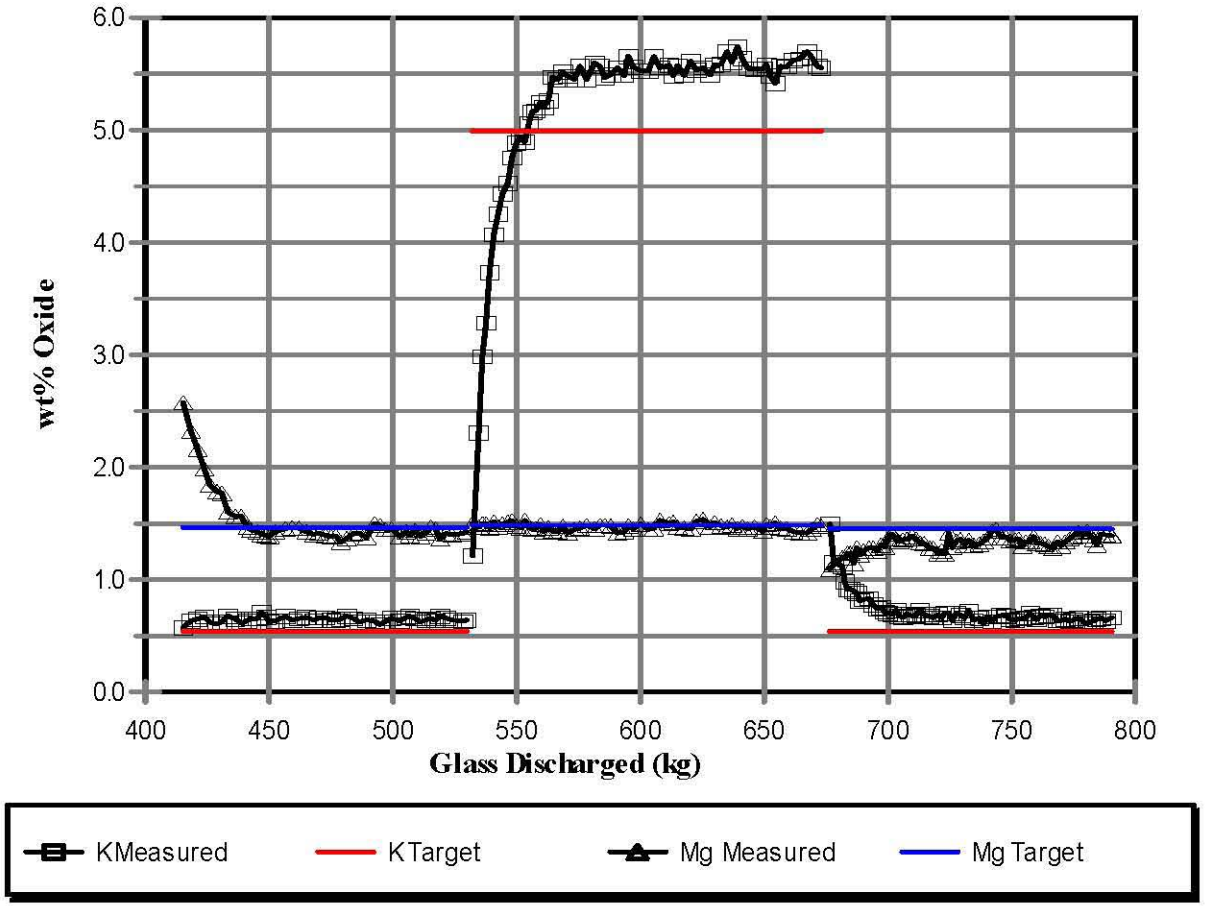


Figure 5.3.b. XRF analysis of potassium and magnesium in product glasses, Tests 5-7.

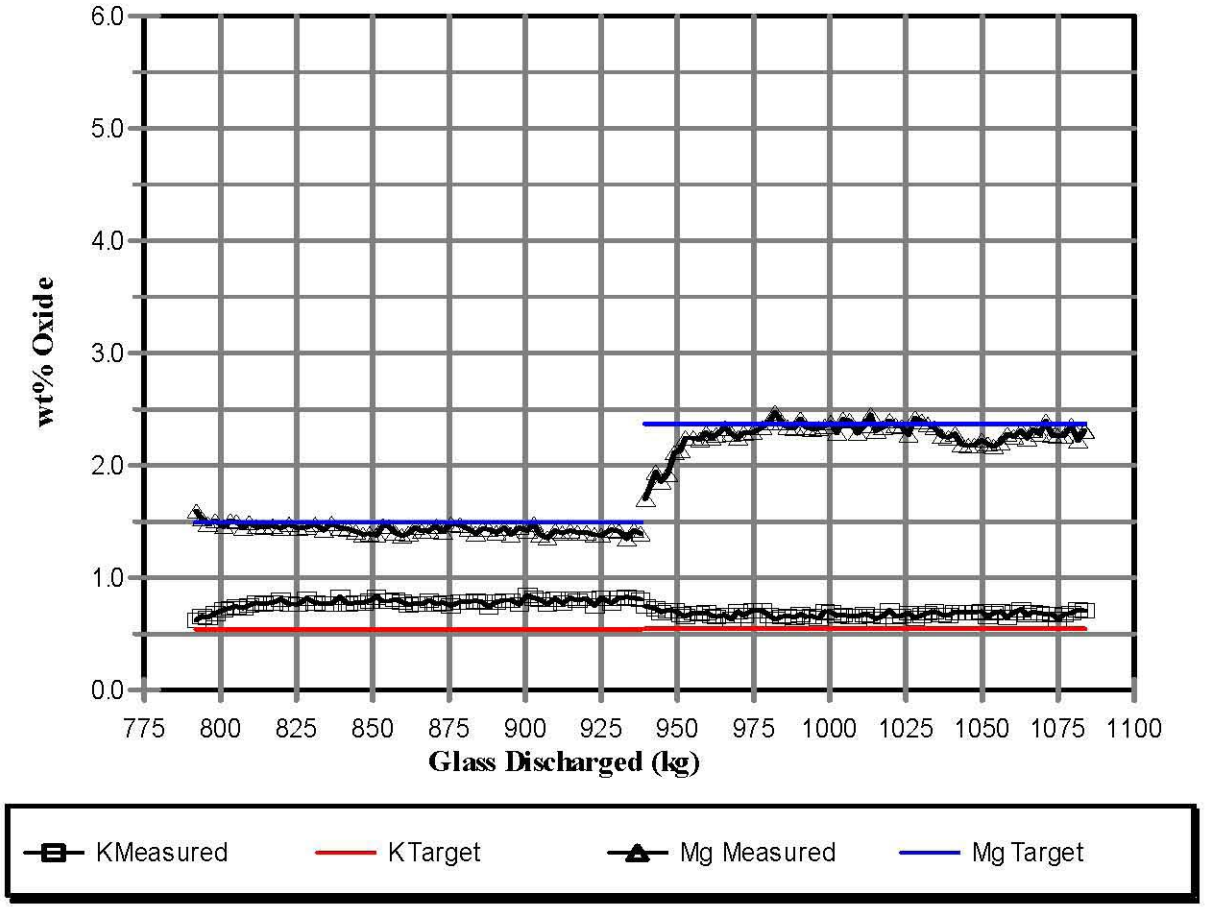


Figure 5.3.c. XRF analysis of potassium and magnesium in product glasses, Tests 8-9.

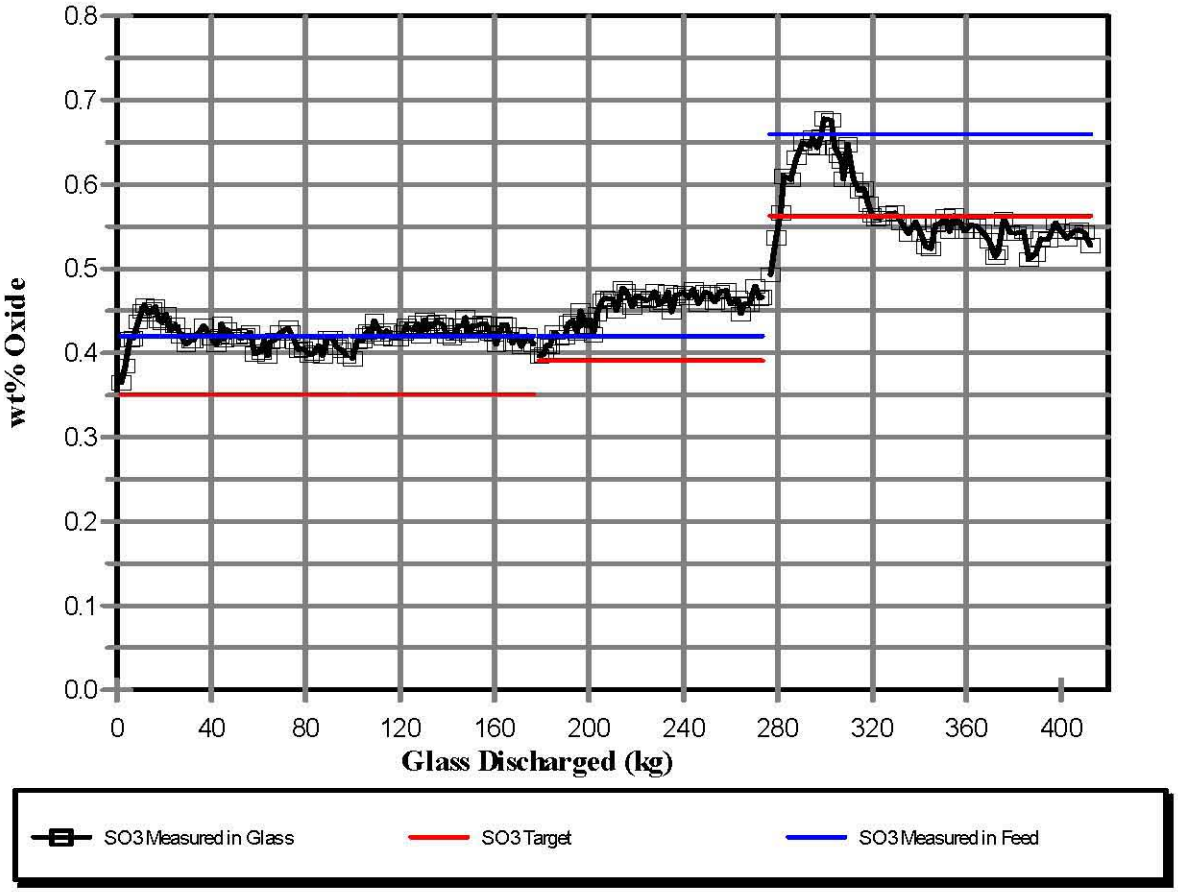


Figure 5.4.a. XRF analysis of sulfur in product glasses, Tests 1-4.

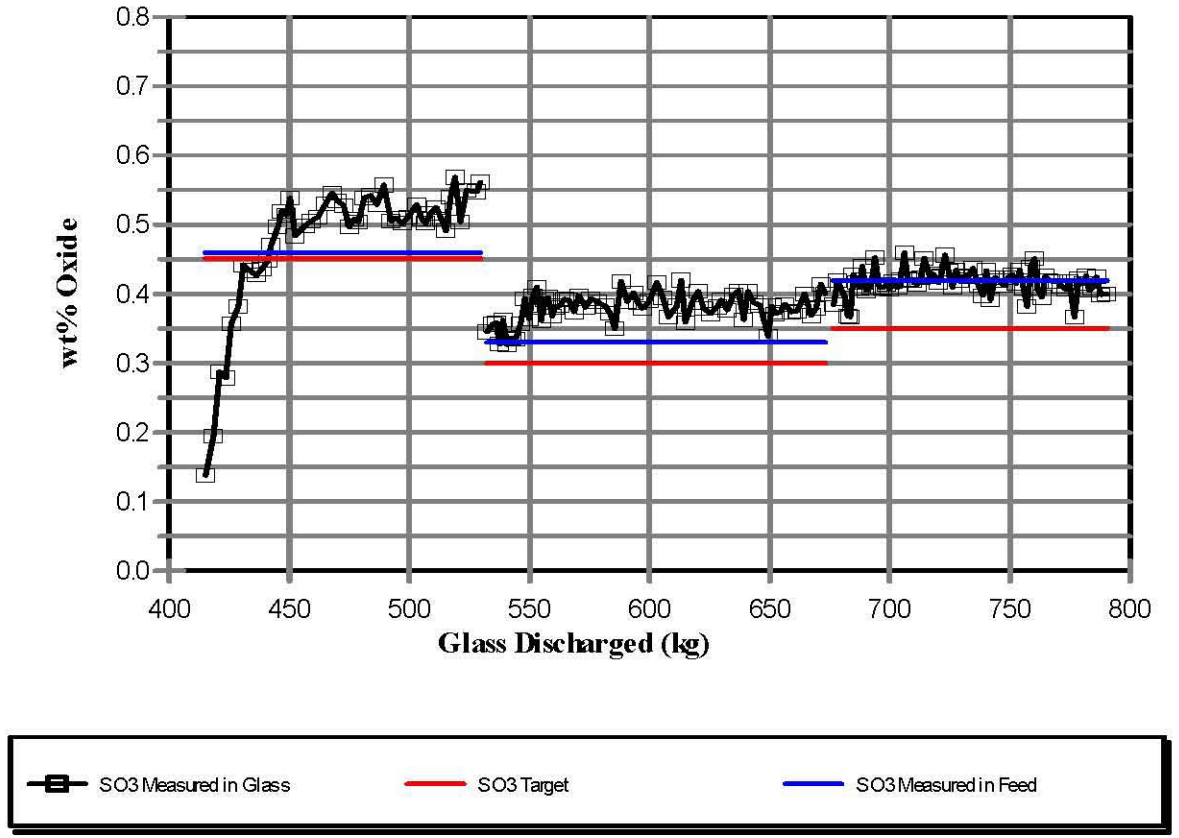


Figure 5.4.b. XRF analysis of sulfur in product glasses, Tests 5-7.

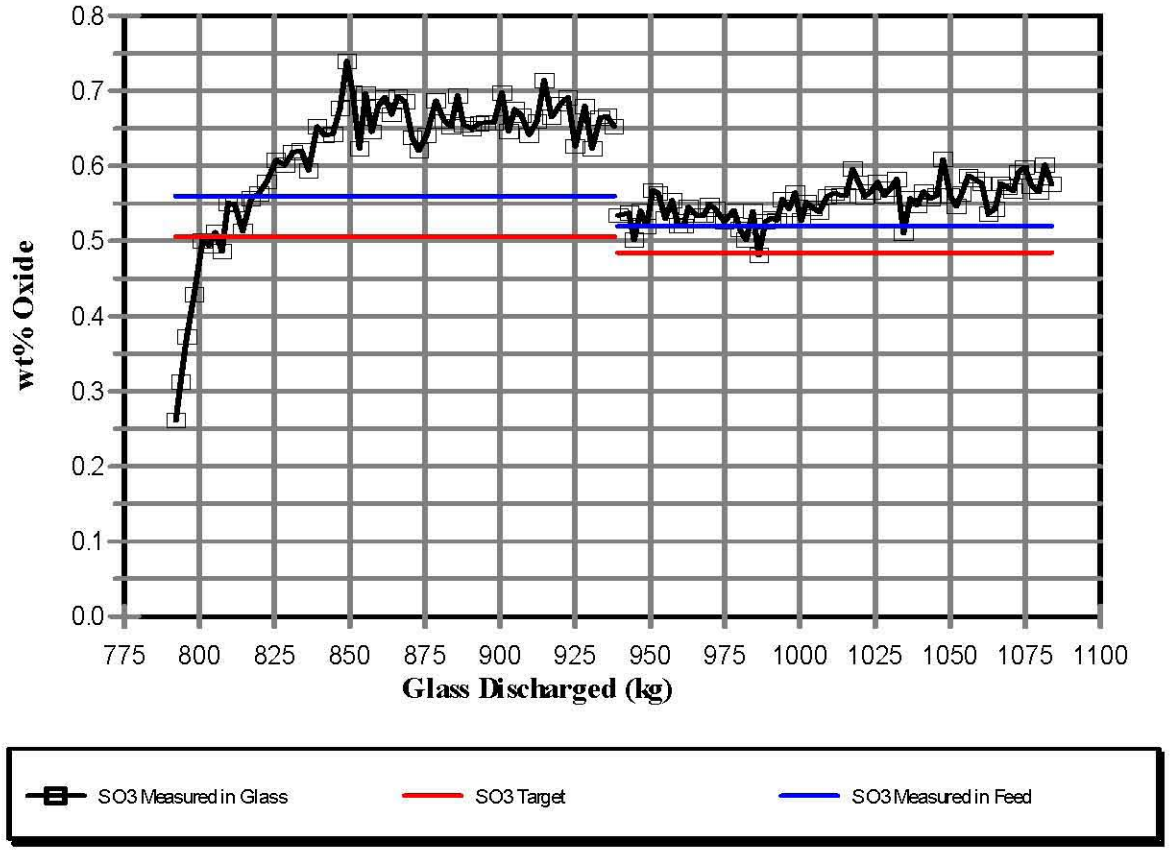


Figure 5.4.c. XRF analysis of sulfur in product glasses, Tests 8-9.

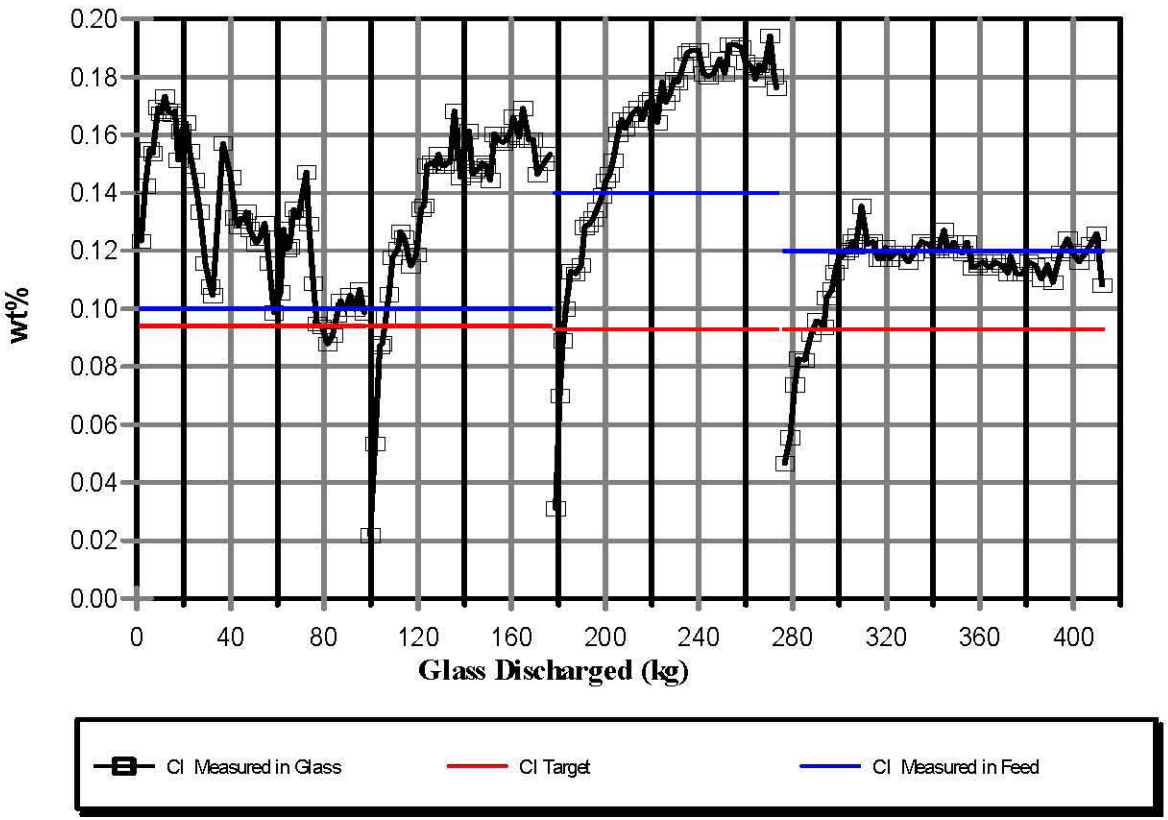


Figure 5.5.a. XRF analysis of chlorine in product glasses, Tests 1-4.

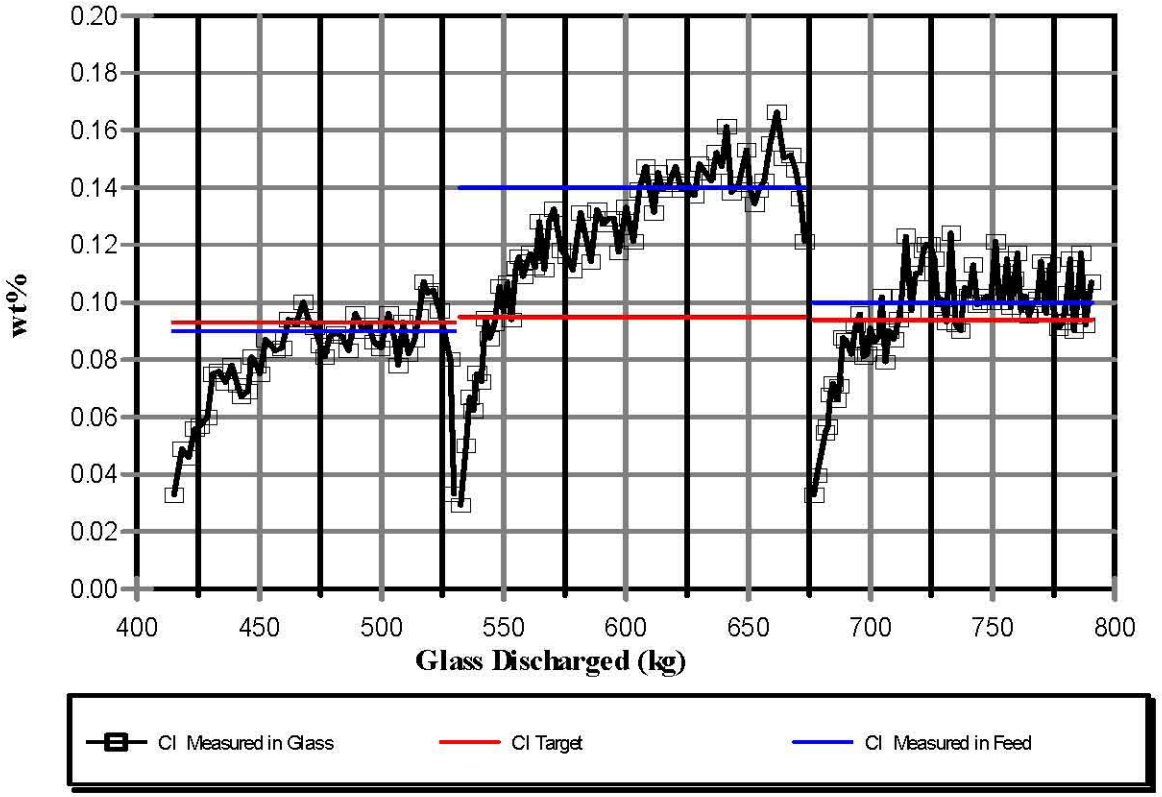


Figure 5.5.b. XRF analysis of chlorine in product glasses, Tests 5-7.

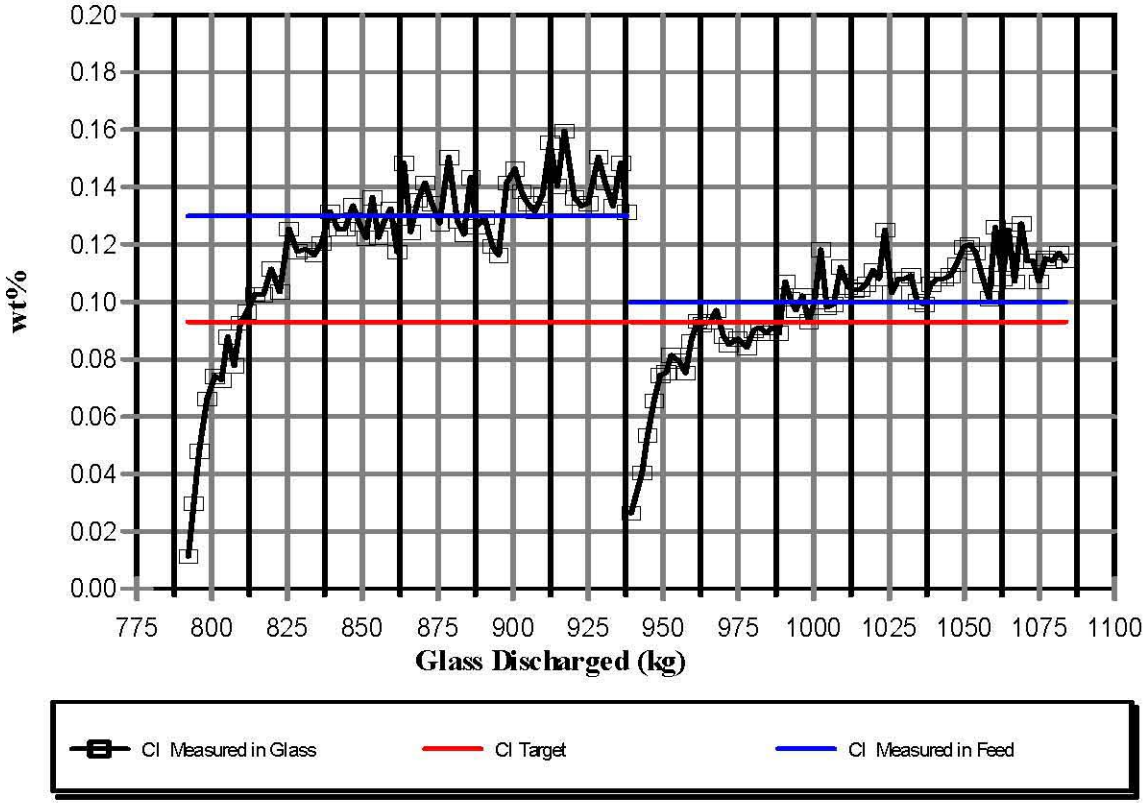


Figure 5.5.c. XRF analysis of chlorine in product glasses, Tests 8-9.

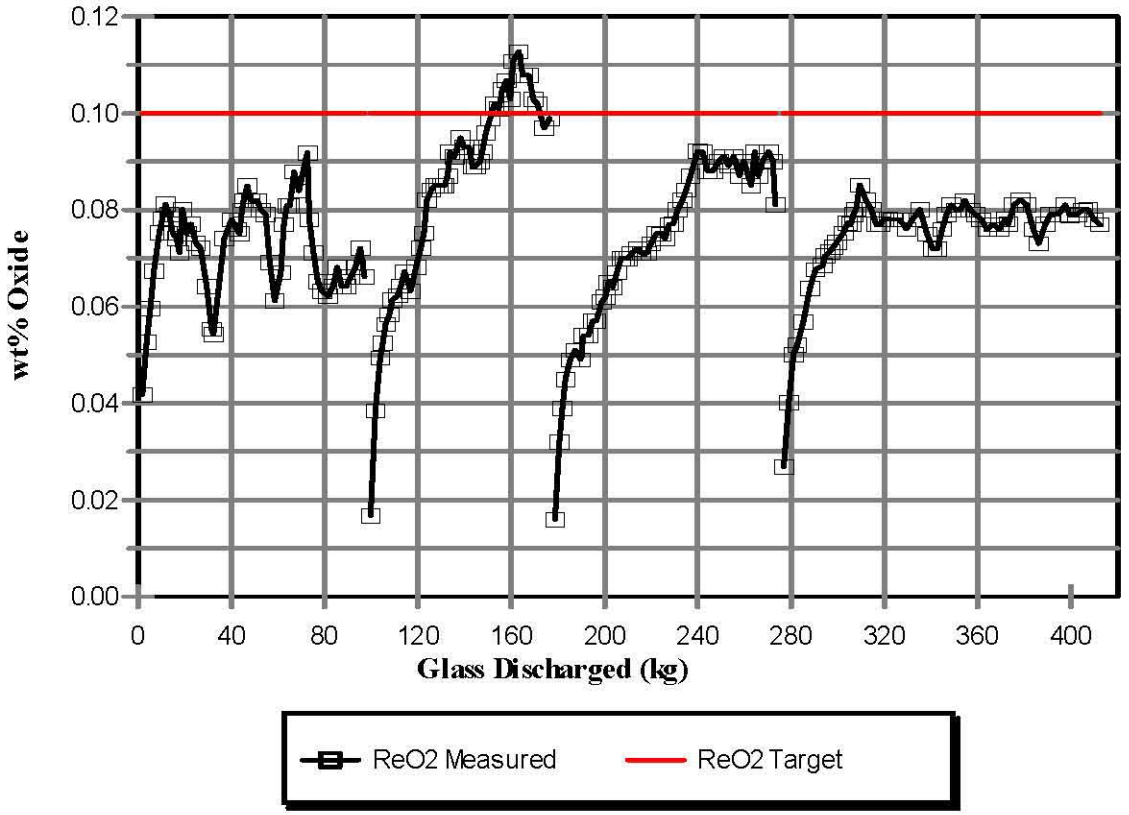


Figure 5.6.a. XRF analysis of rhenium in product glasses, Tests 1-4.

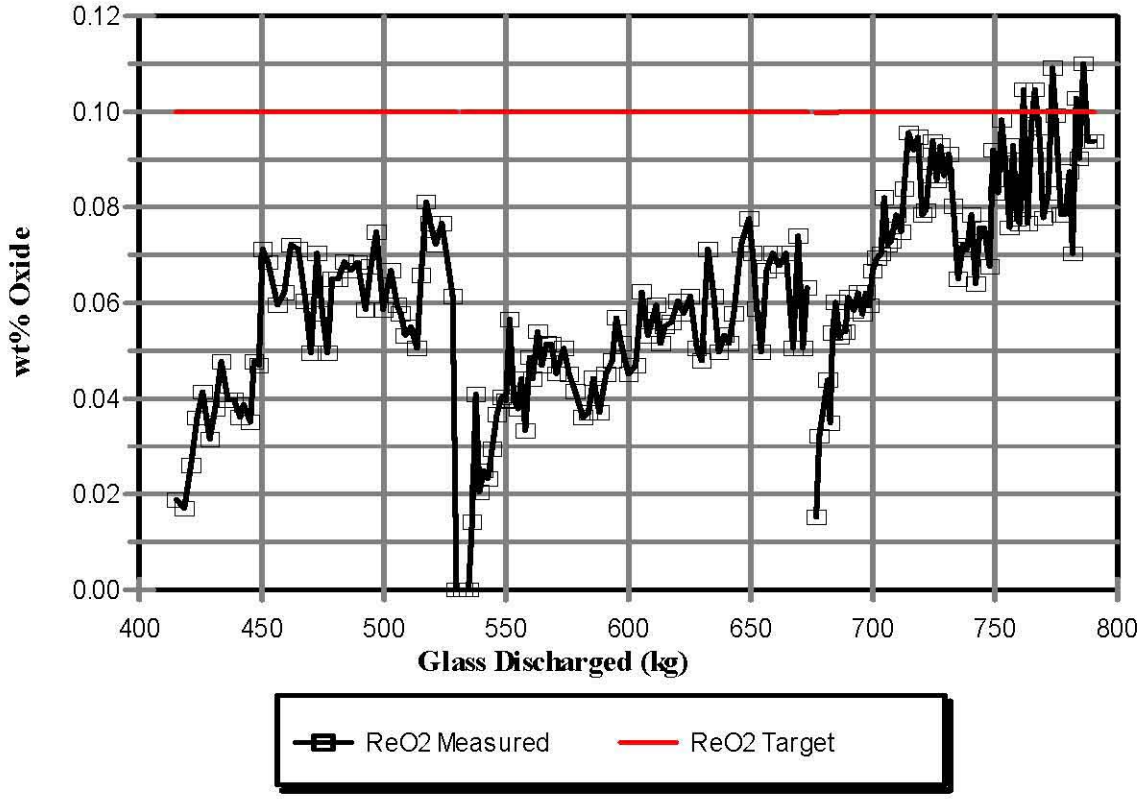


Figure 5.6.b. XRF analysis of rhenium in product glasses, Tests 5-7.

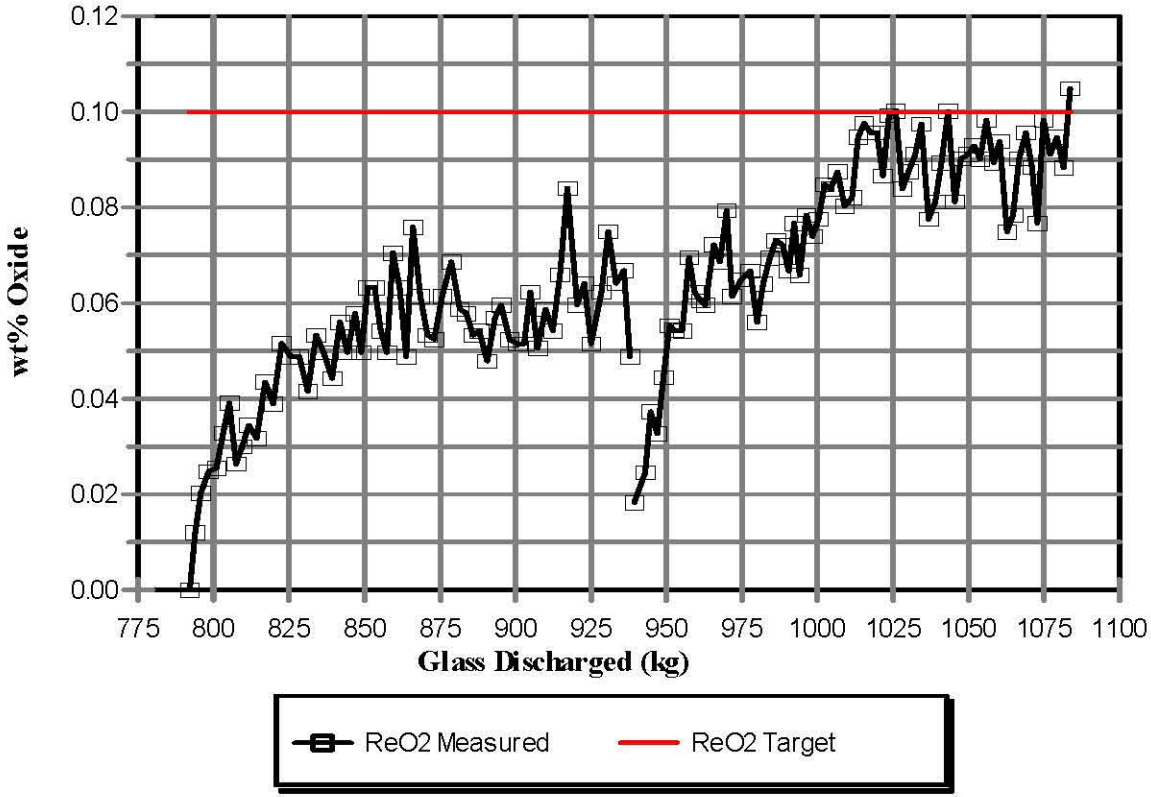


Figure 5.6.c. XRF analysis of rhenium in product glasses, Tests 8-9.

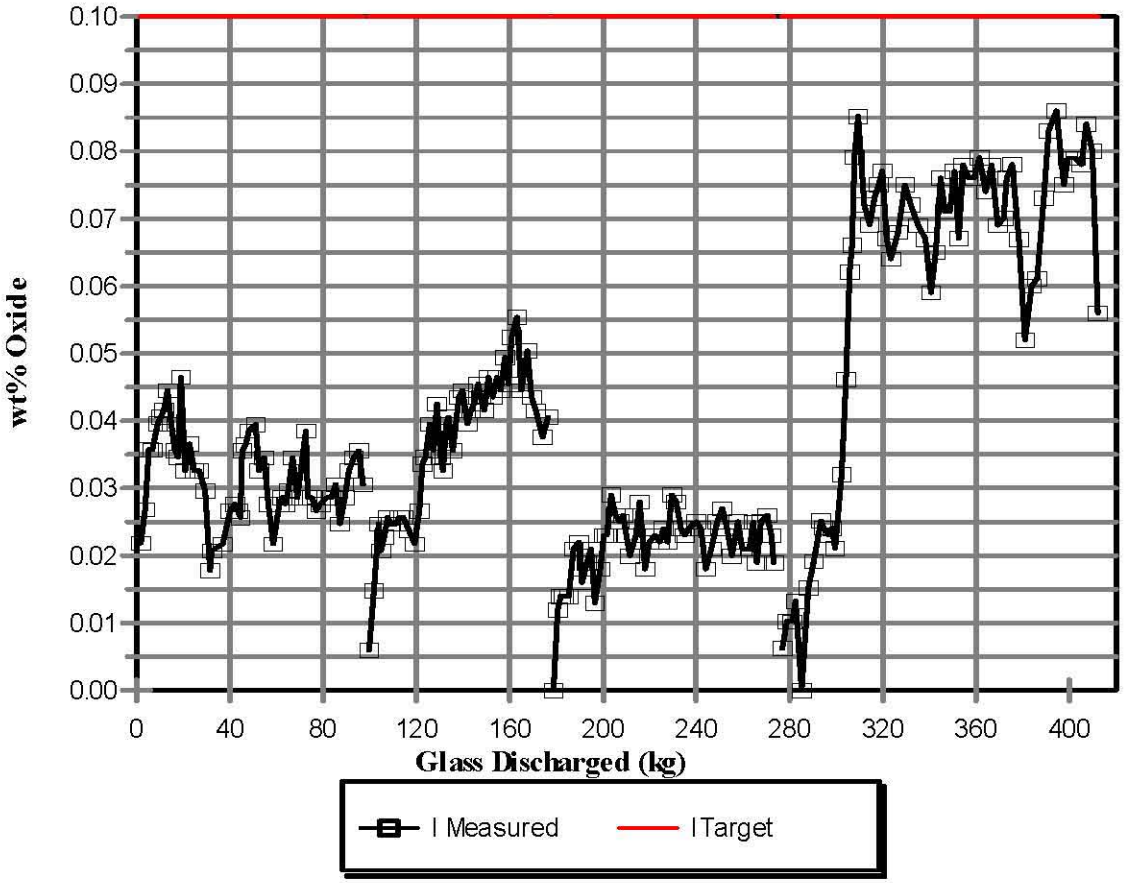


Figure 5.7.a. XRF analysis of iodine in product glasses, Tests 1-4.

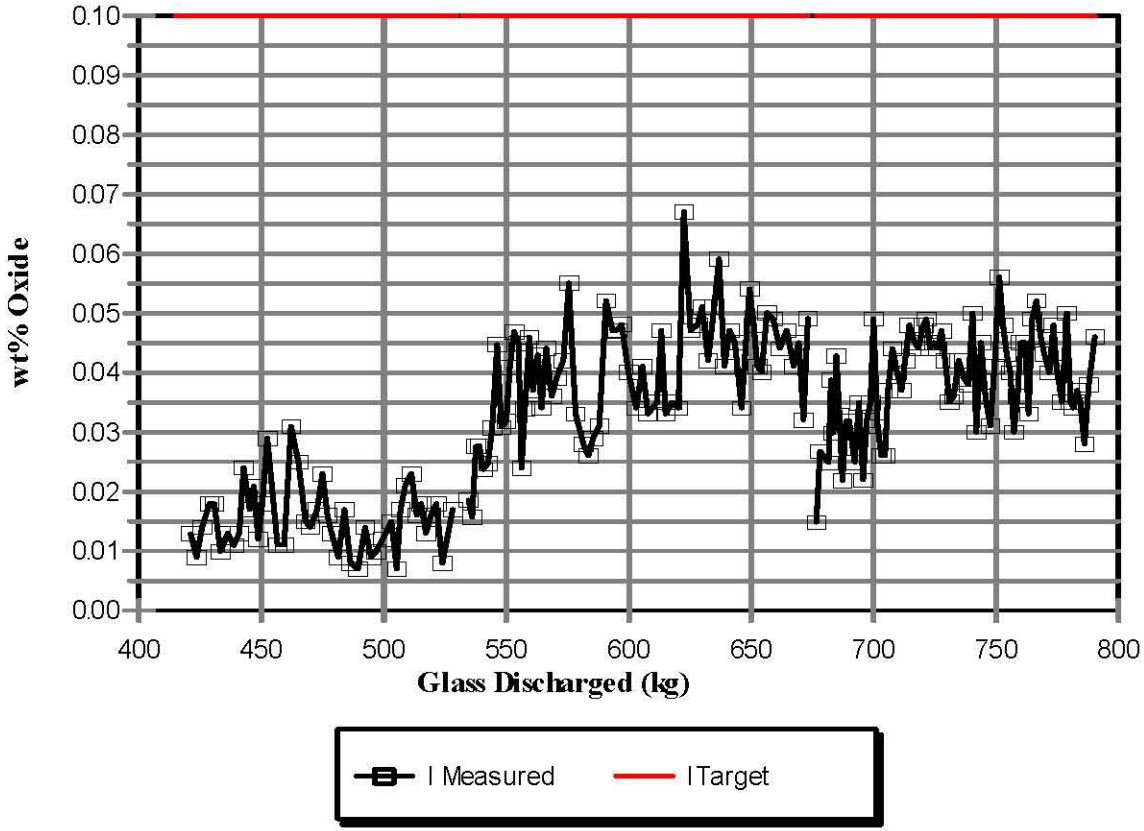


Figure 5.7.b. XRF analysis of iodine in product glasses, Tests 5-7.

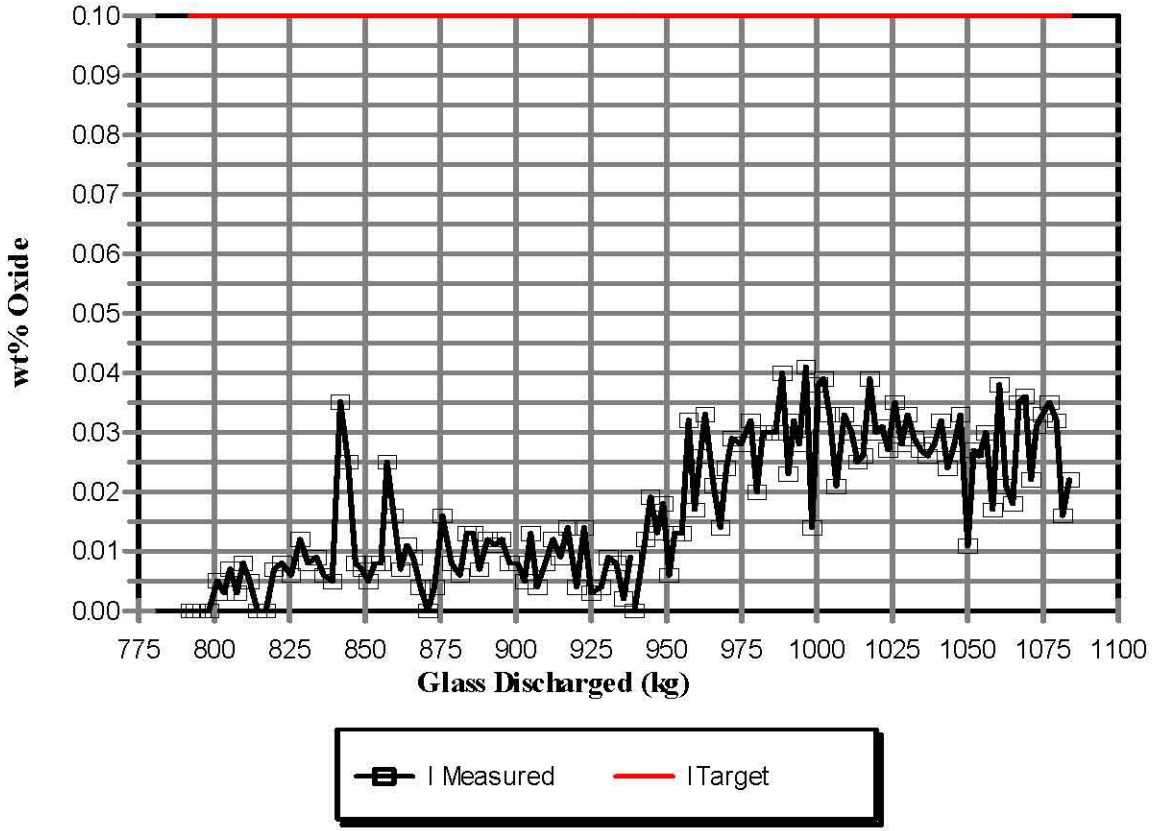


Figure 5.7.c. XRF analysis of iodine in product glasses, Tests 8-9.

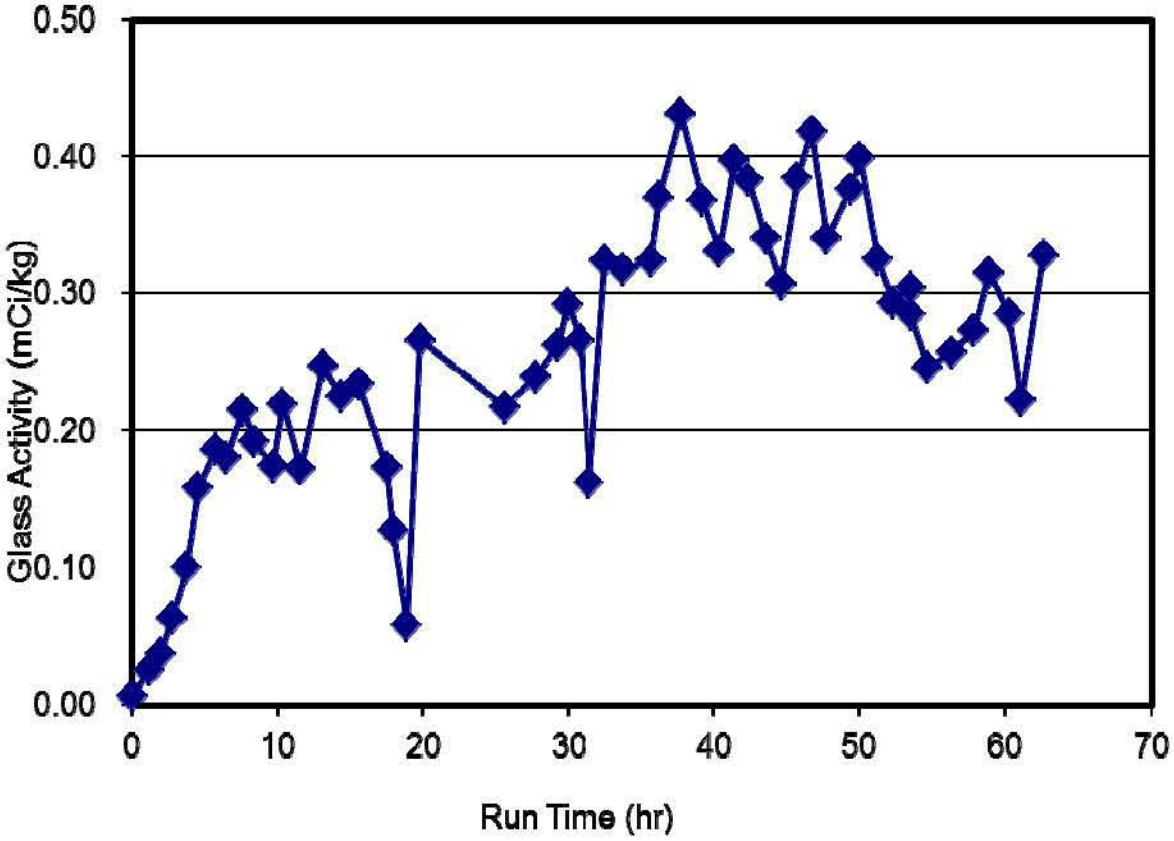


Figure 5.8.a Measured technetium concentration in glasses discharged during Test 1.

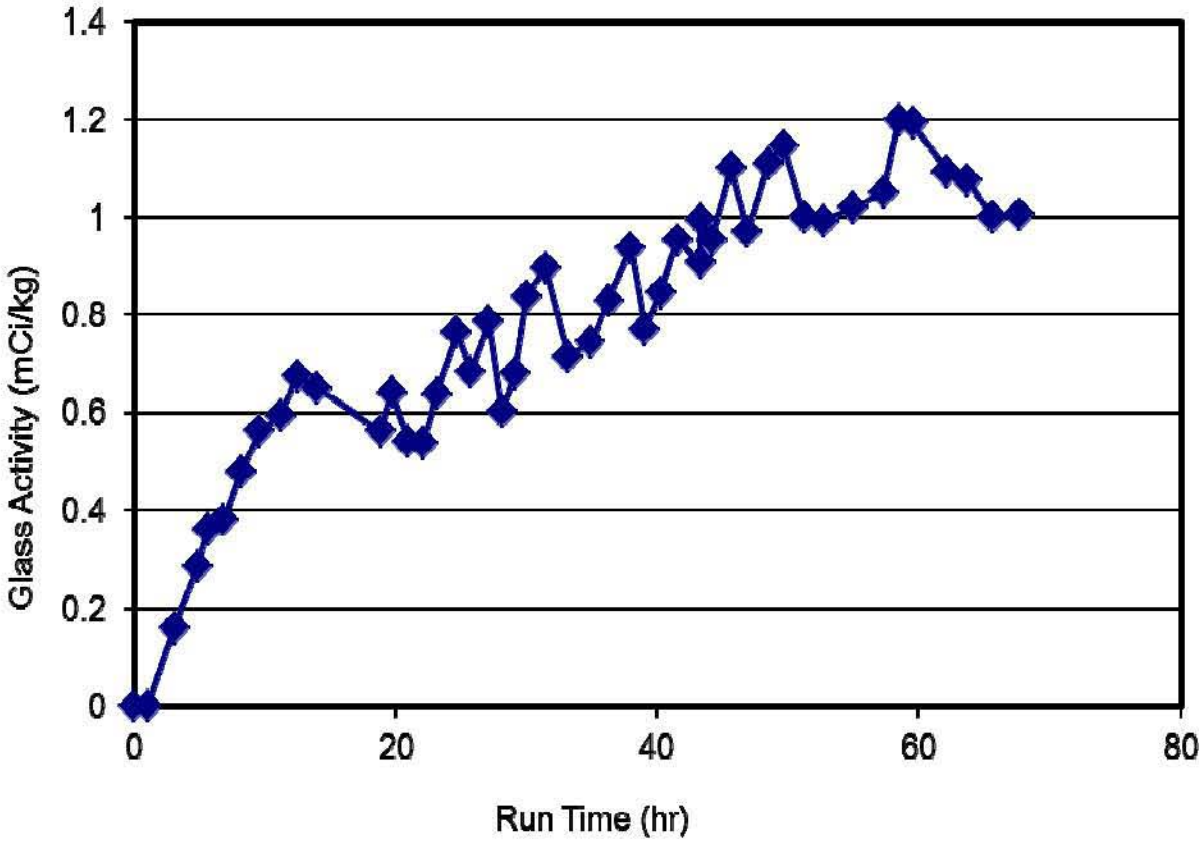


Figure 5.8.b Measured technetium concentration in glasses discharged during Test 2.

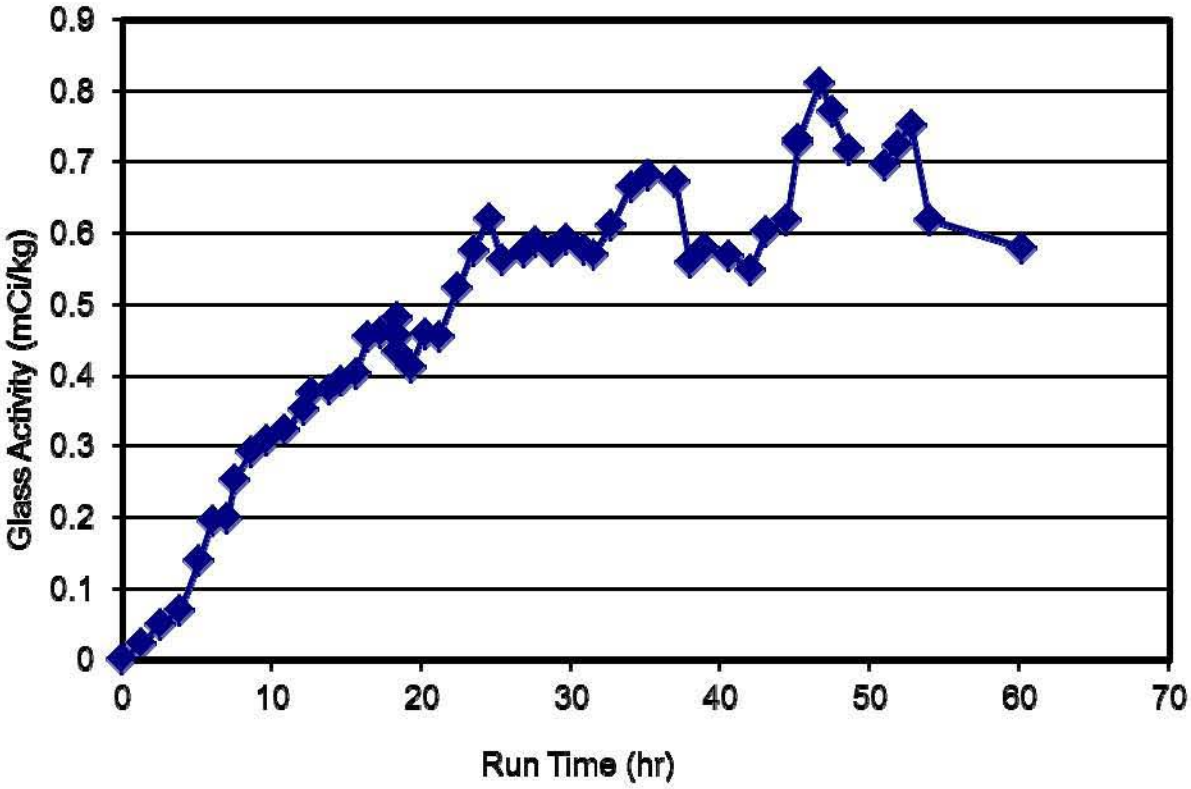


Figure 5.8.c. Measured technetium concentration in glasses discharged during Test 3.

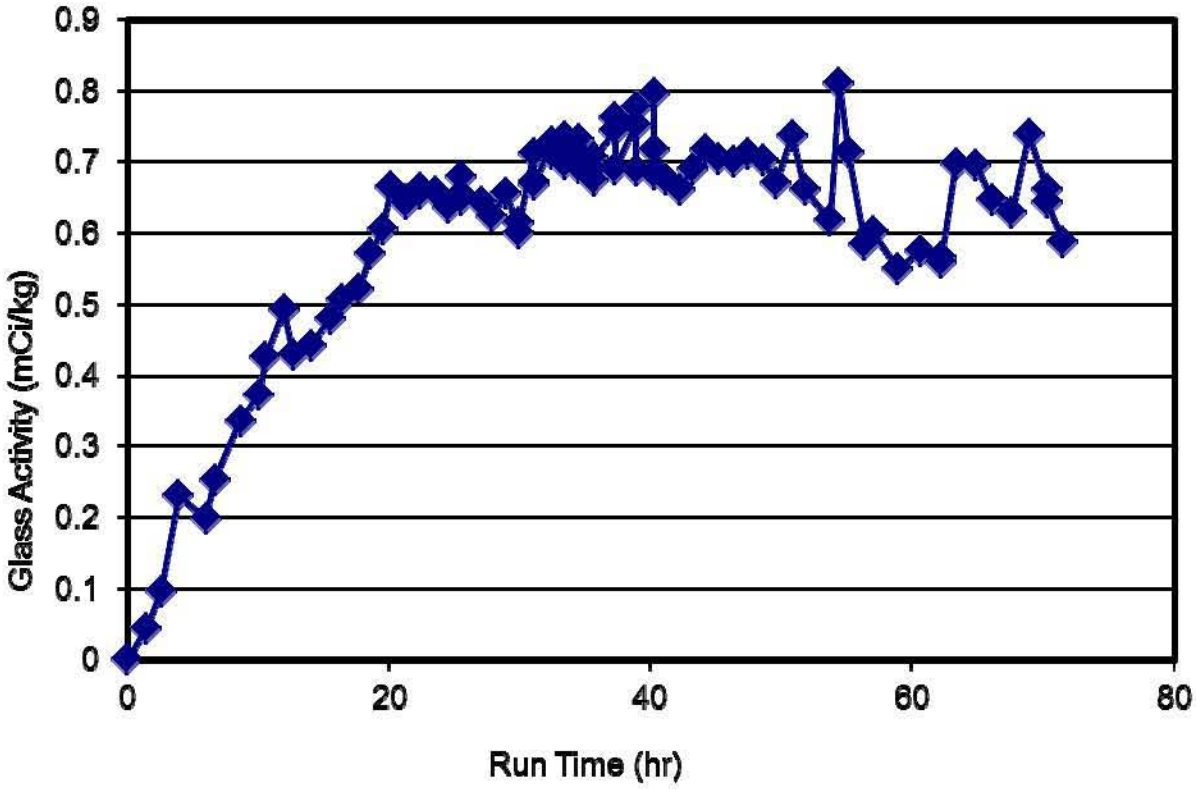


Figure 5.8.d. Measured technetium concentration in glasses discharged during Test 4.

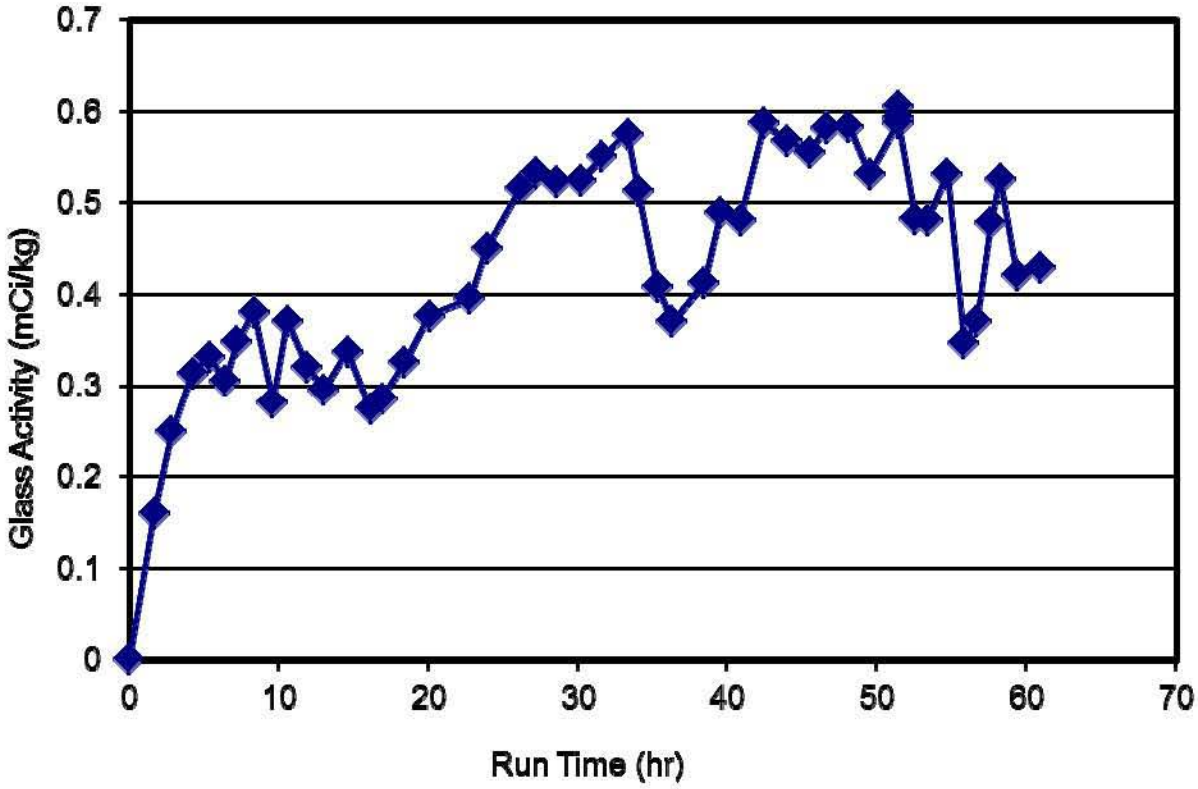


Figure 5.8.e. Measured technetium concentration in glasses discharged during Test 5.

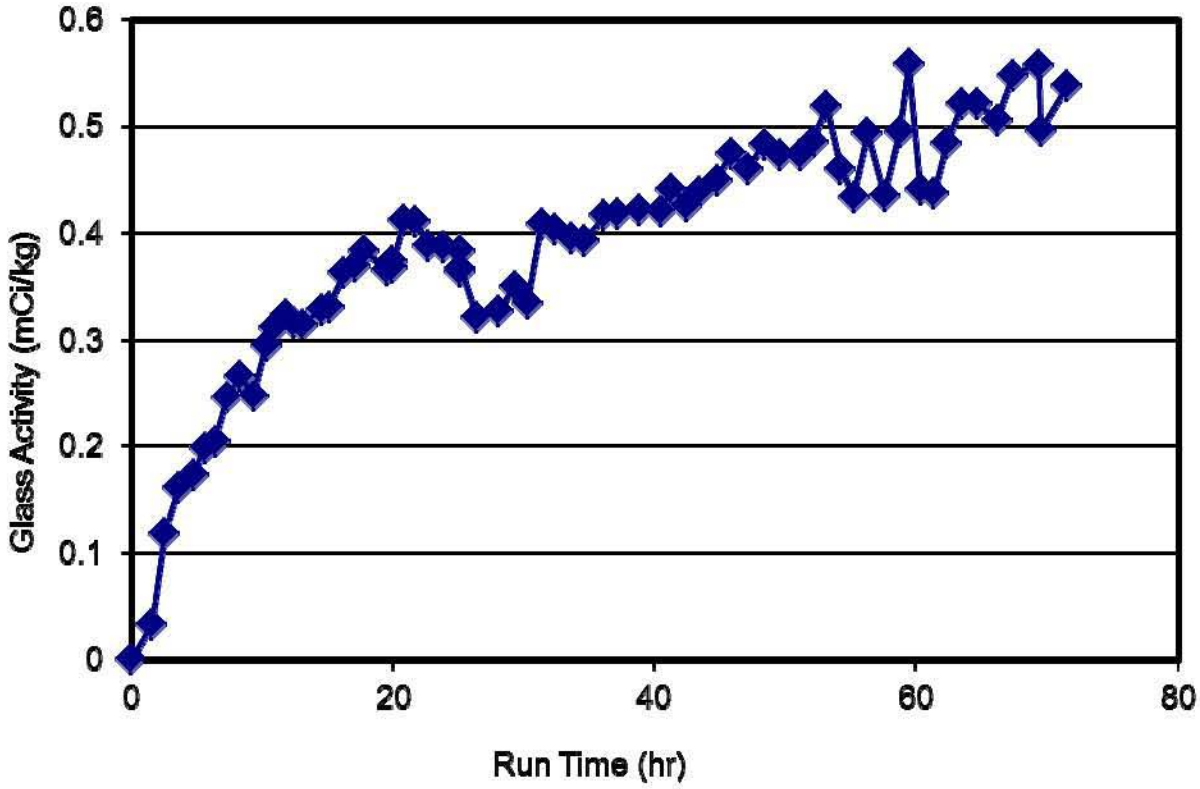


Figure 5.8.f. Measured technetium concentration in glasses discharged during Test 6.

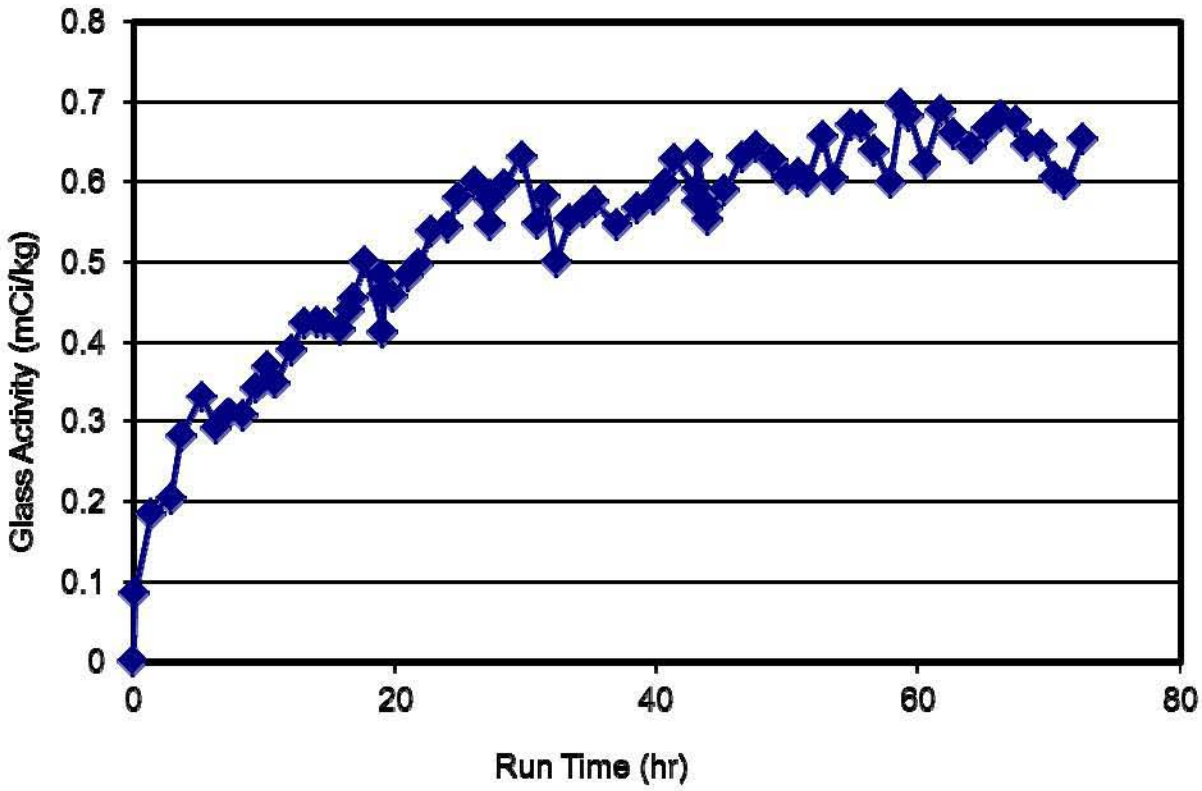


Figure 5.8.g. Measured technetium concentration in glasses discharged during Test 7.

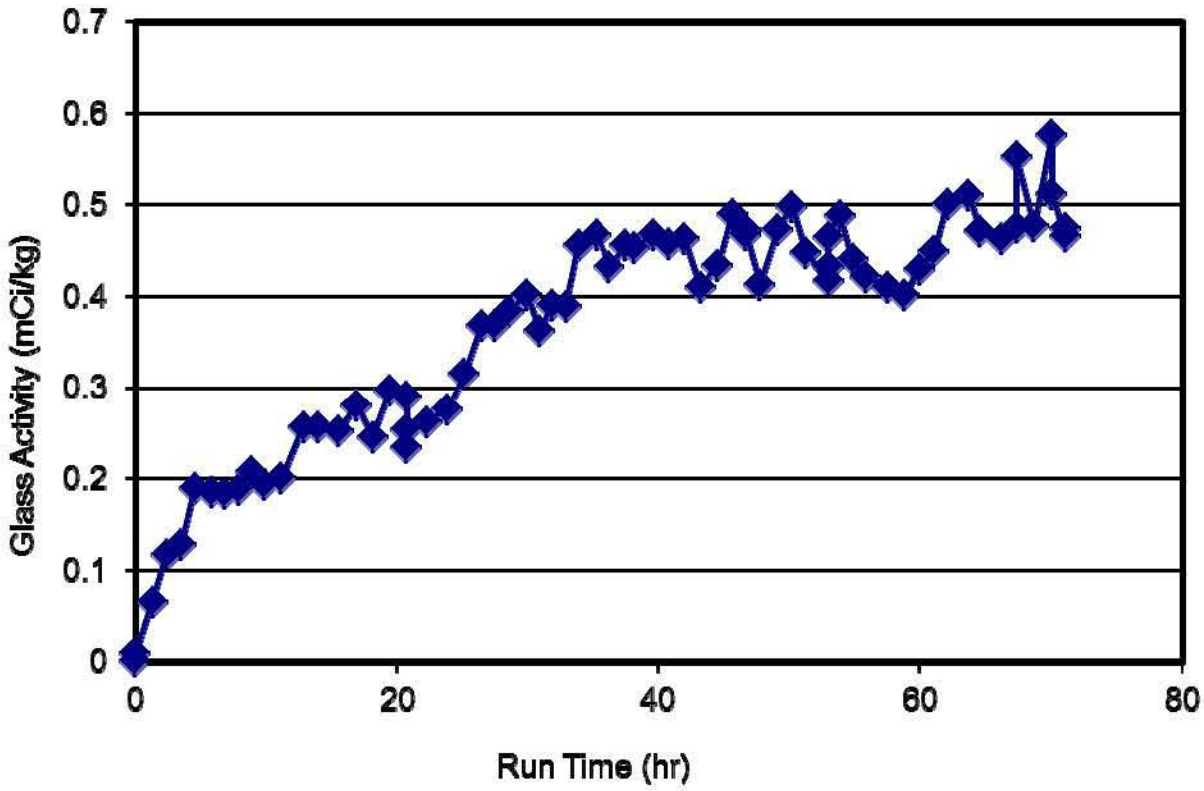


Figure 5.8.h. Measured technetium concentration in glasses discharged during Test 8.

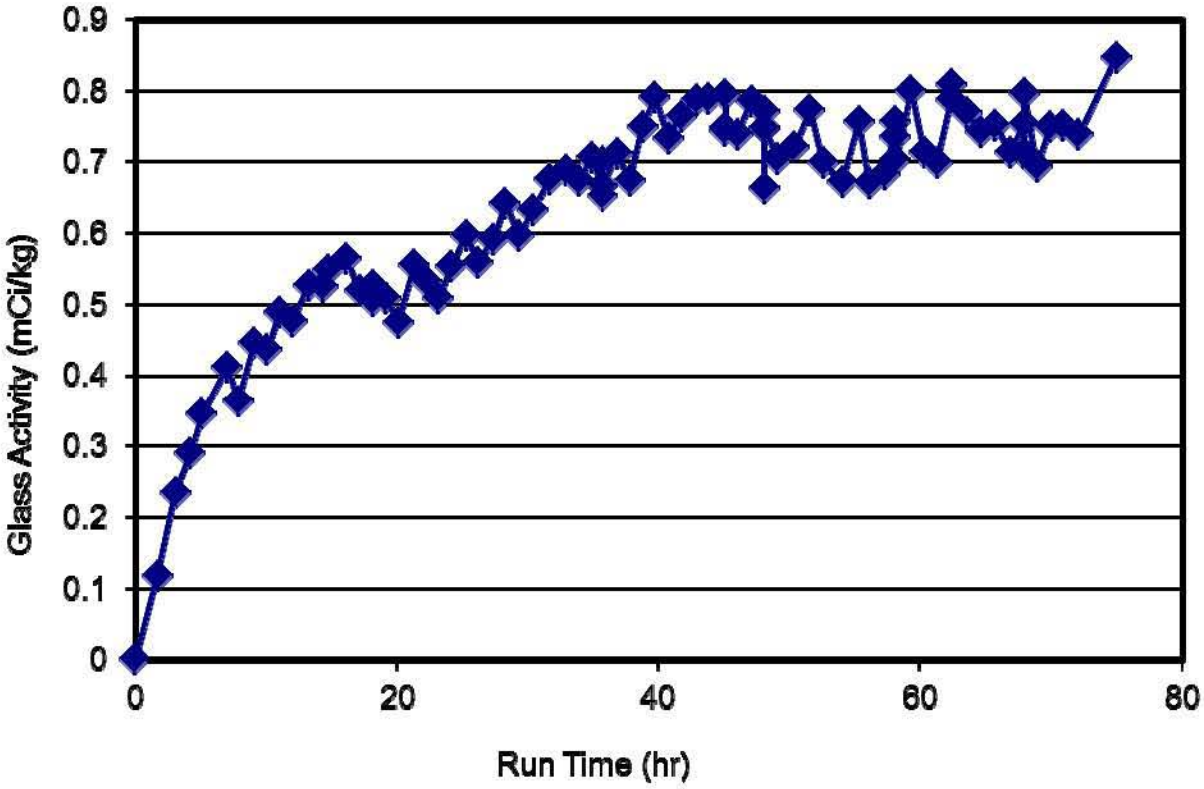


Figure 5.8.i. Measured technetium concentration in glasses discharged during Test 9.

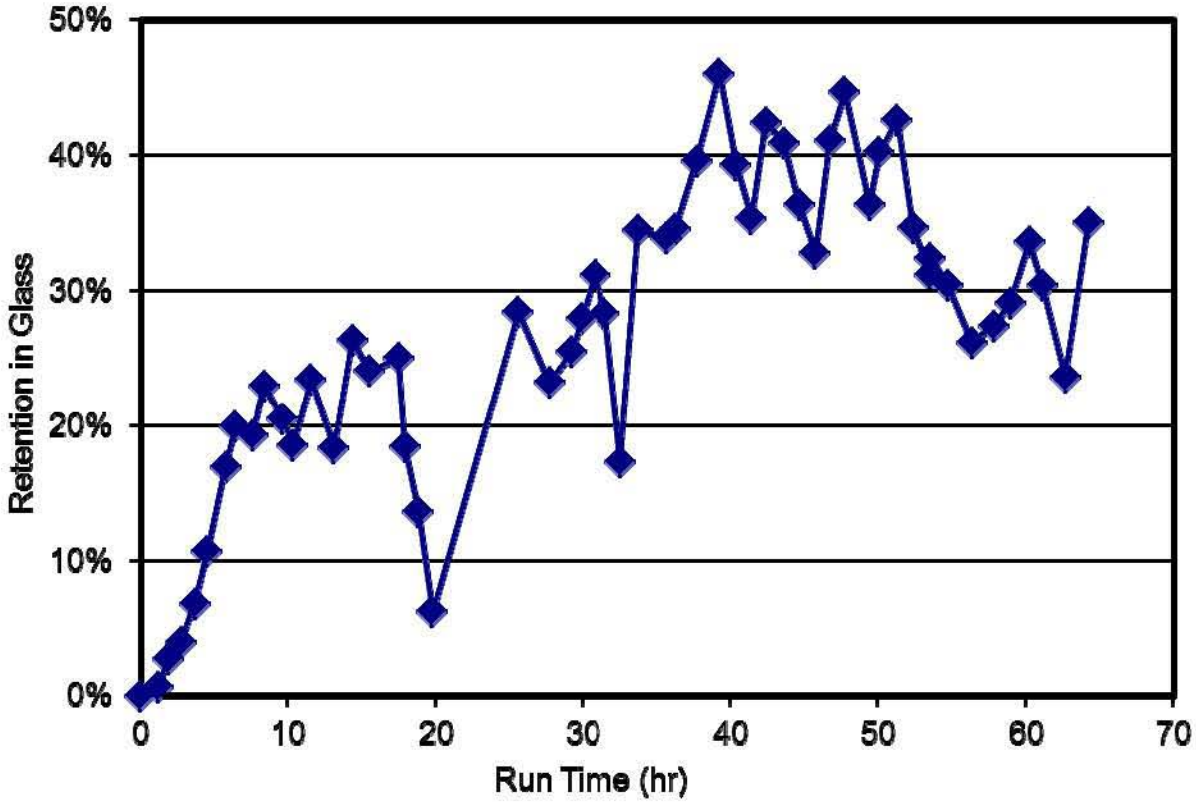


Figure 5.9.a. Percent of technetium fed to melter measured in glass during Test 1.

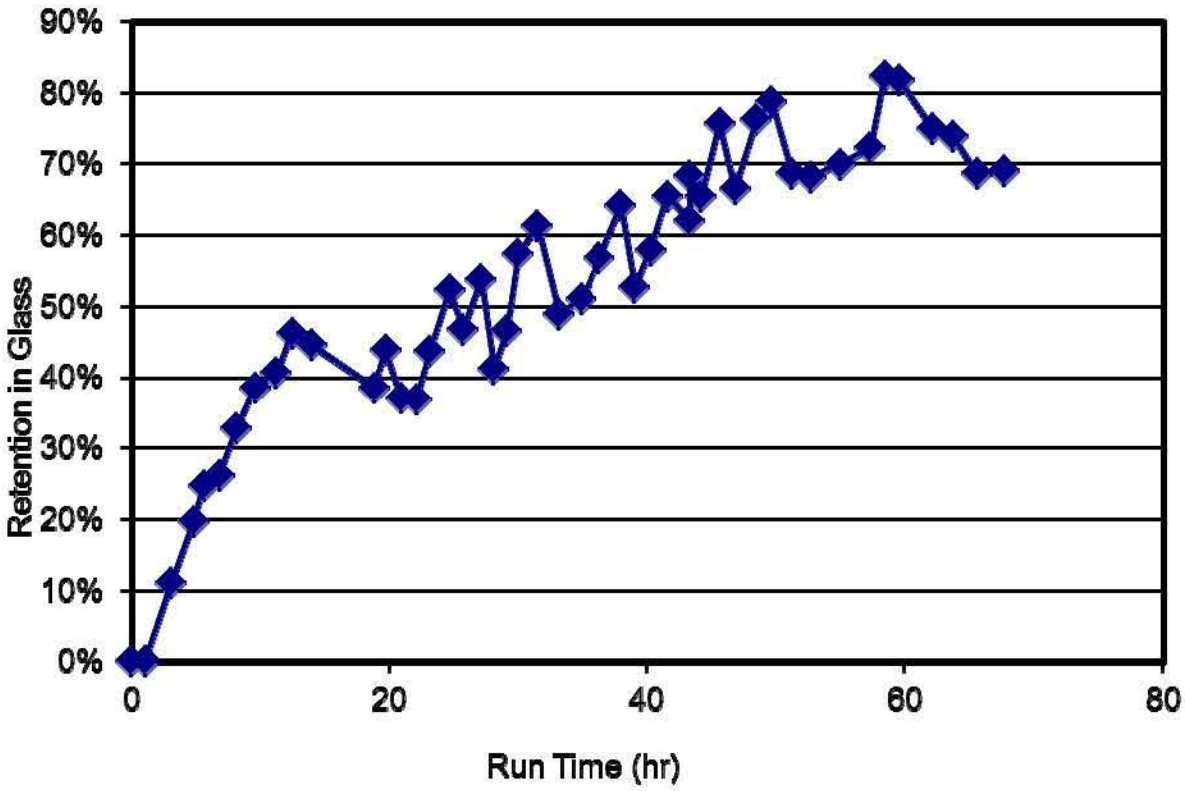


Figure 5.9.b. Percent of technetium fed to melter measured in glass during Test 2.

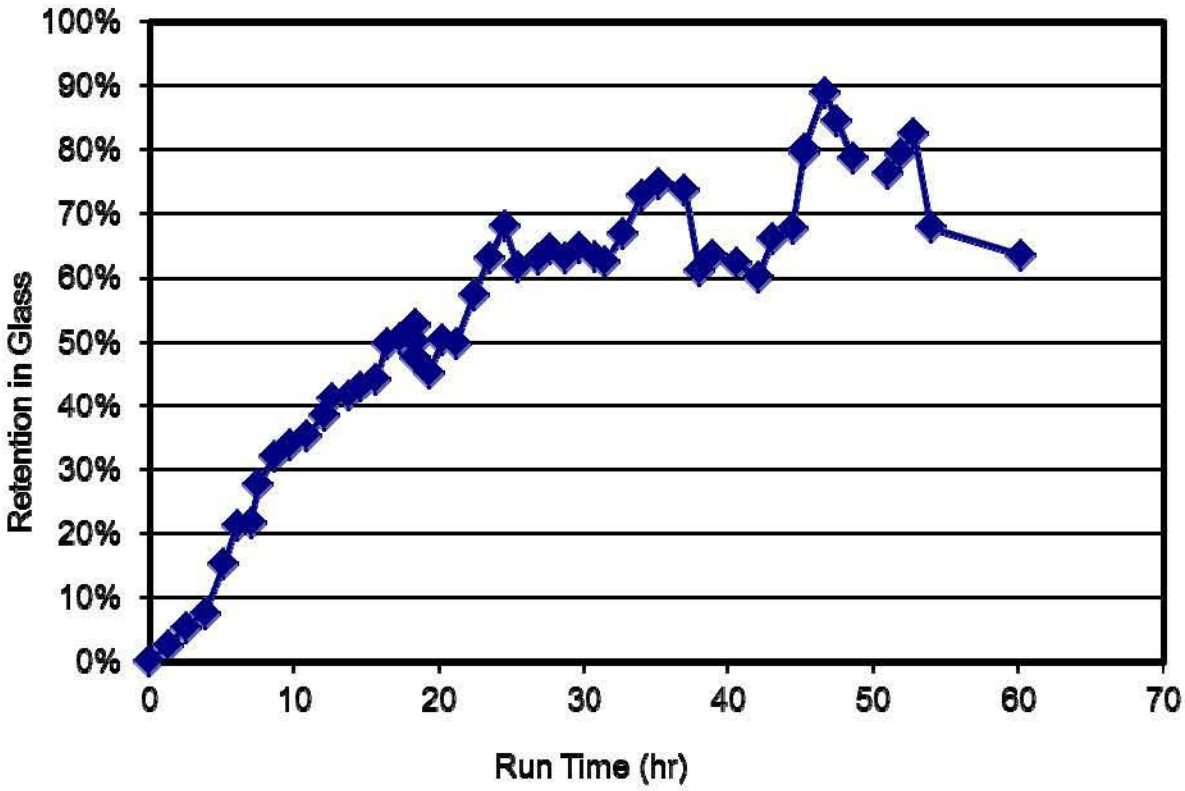


Figure 5.9.c. Percent of technetium fed to melter measured in glass during Test 3.

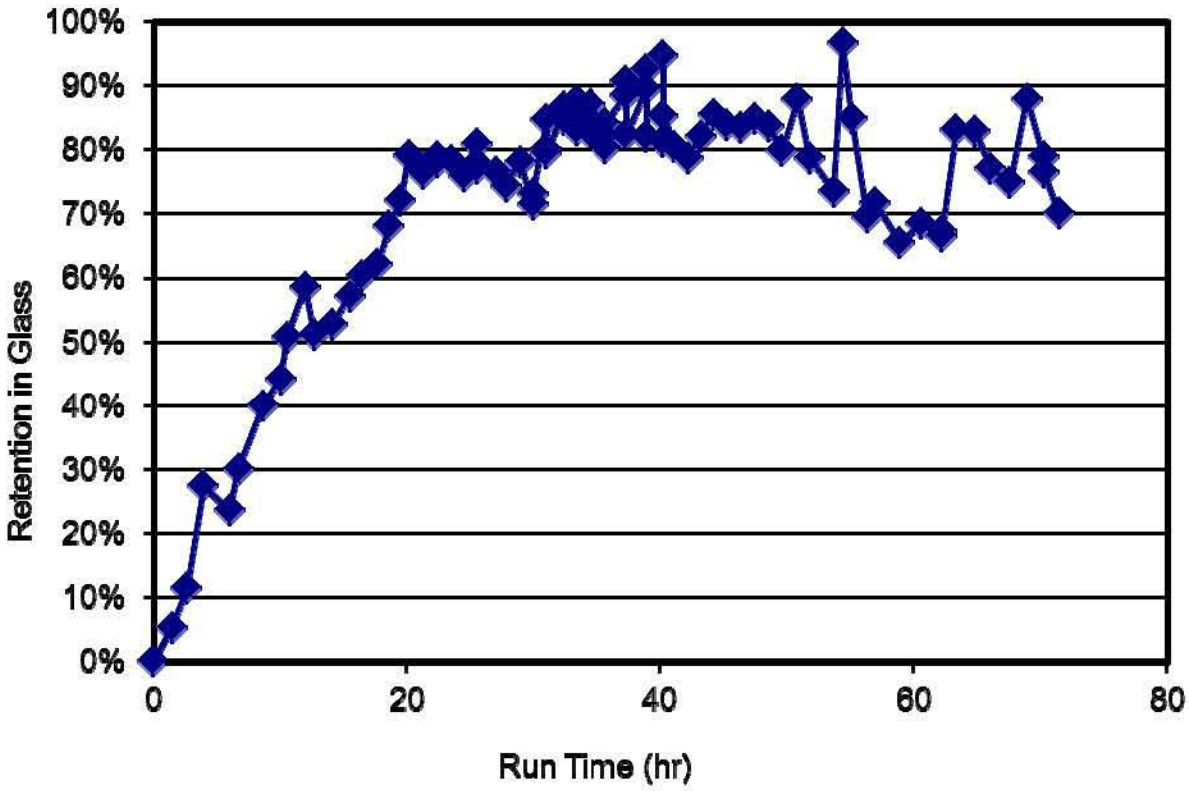


Figure 5.9.d. Percent of technetium fed to melter measured in glass during Test 4.

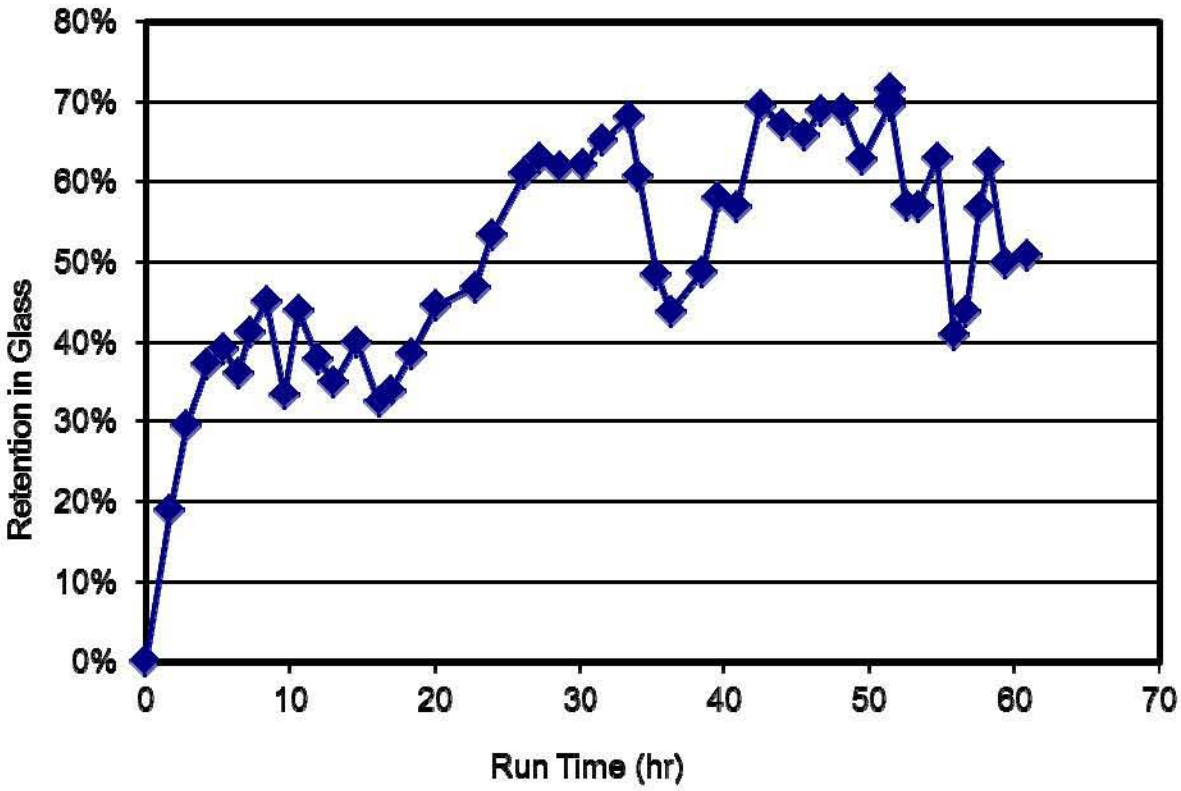


Figure 5.9.e. Percent of technetium fed to melter measured in glass during Test 5.

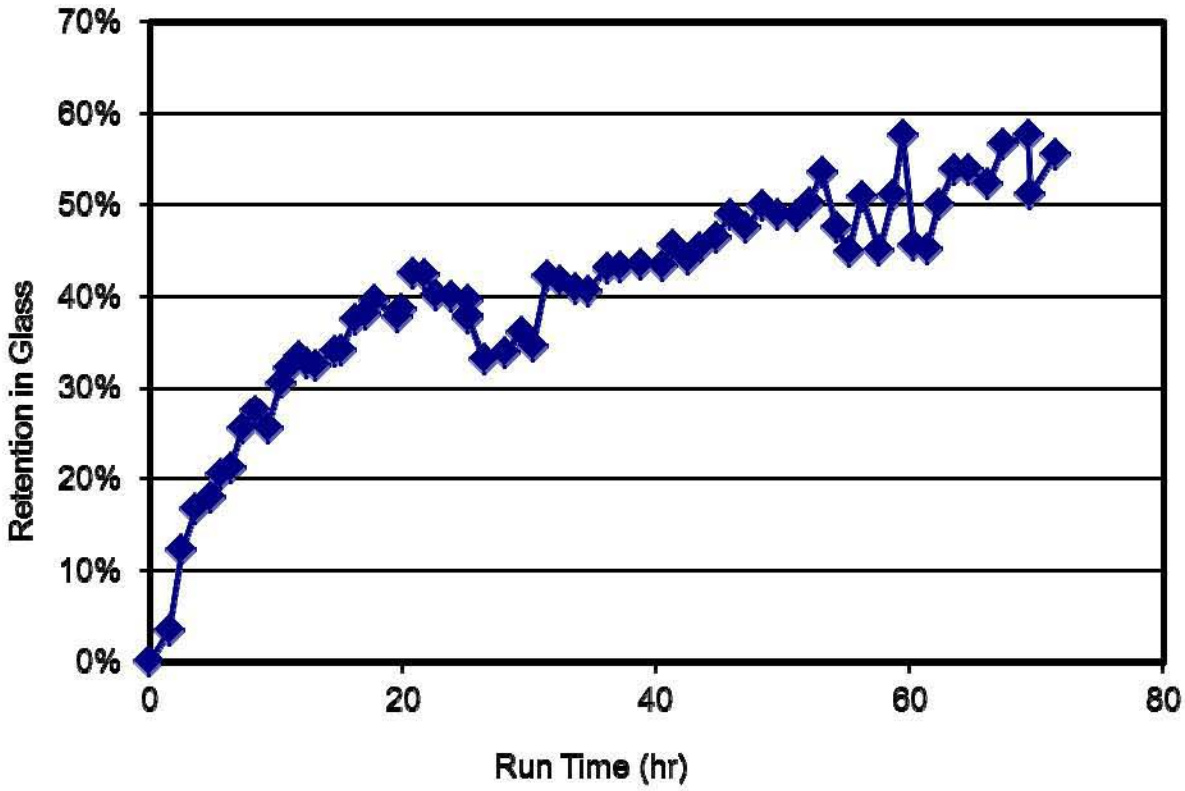


Figure 5.9.f. Percent of technetium fed to melter measured in glass during Test 6.

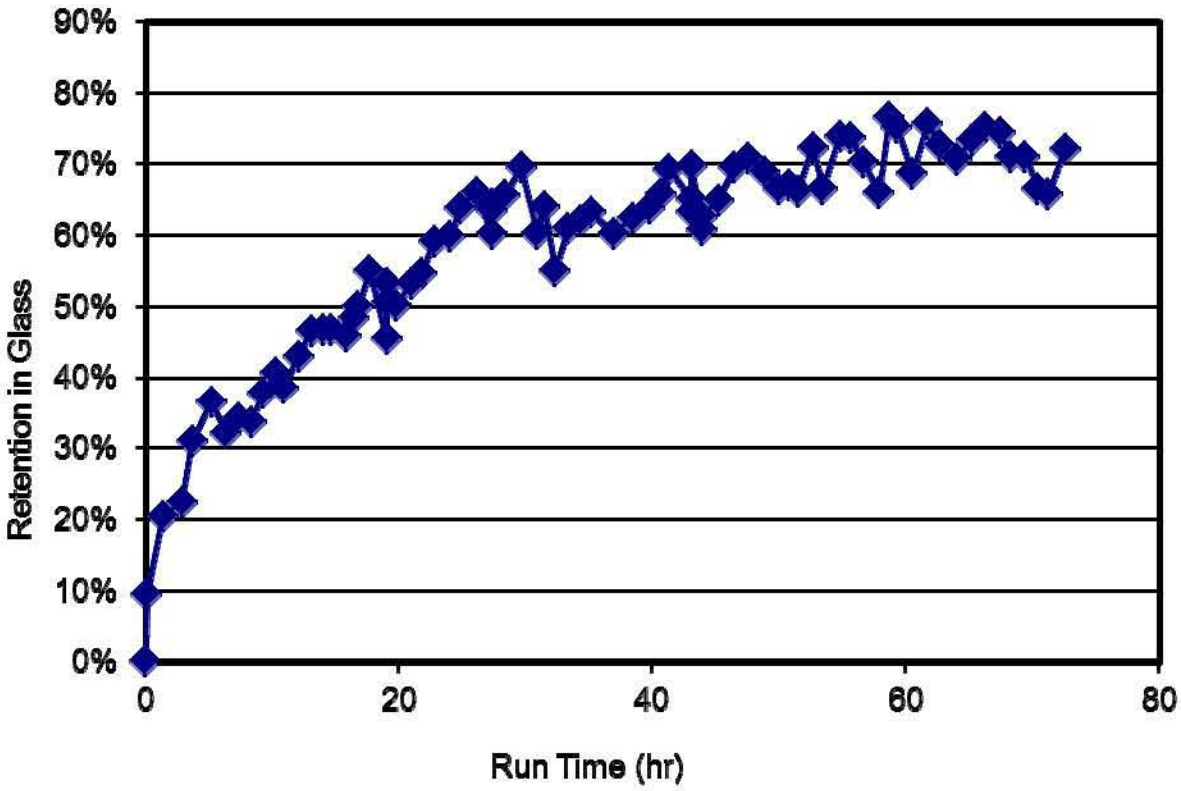


Figure 5.9.g. Percent of technetium fed to melter measured in glass during Test 7.

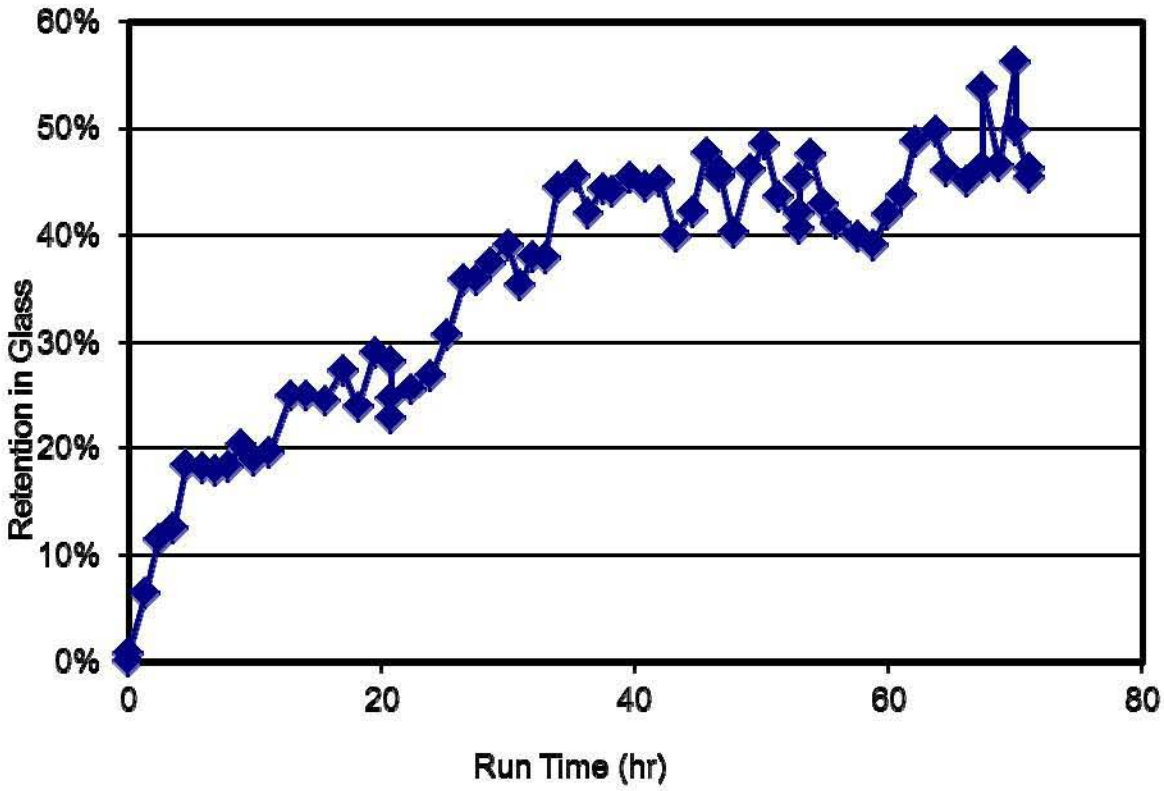


Figure 5.9.h. Percent of technetium fed to melter measured in glass during Test 8.

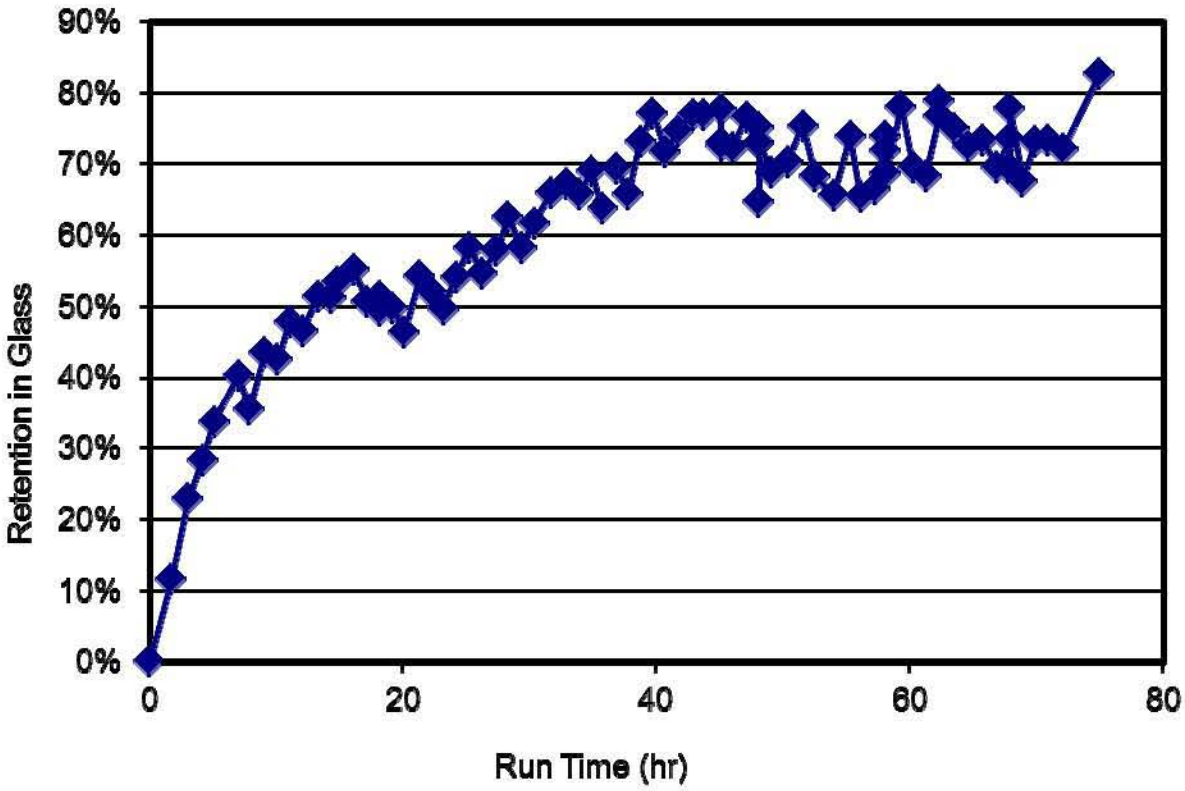


Figure 5.9.i. Percent of technetium fed to melter measured in glass during Test 9.



Figure 5.10. Secondary phase on dip sample taken after Test 6.

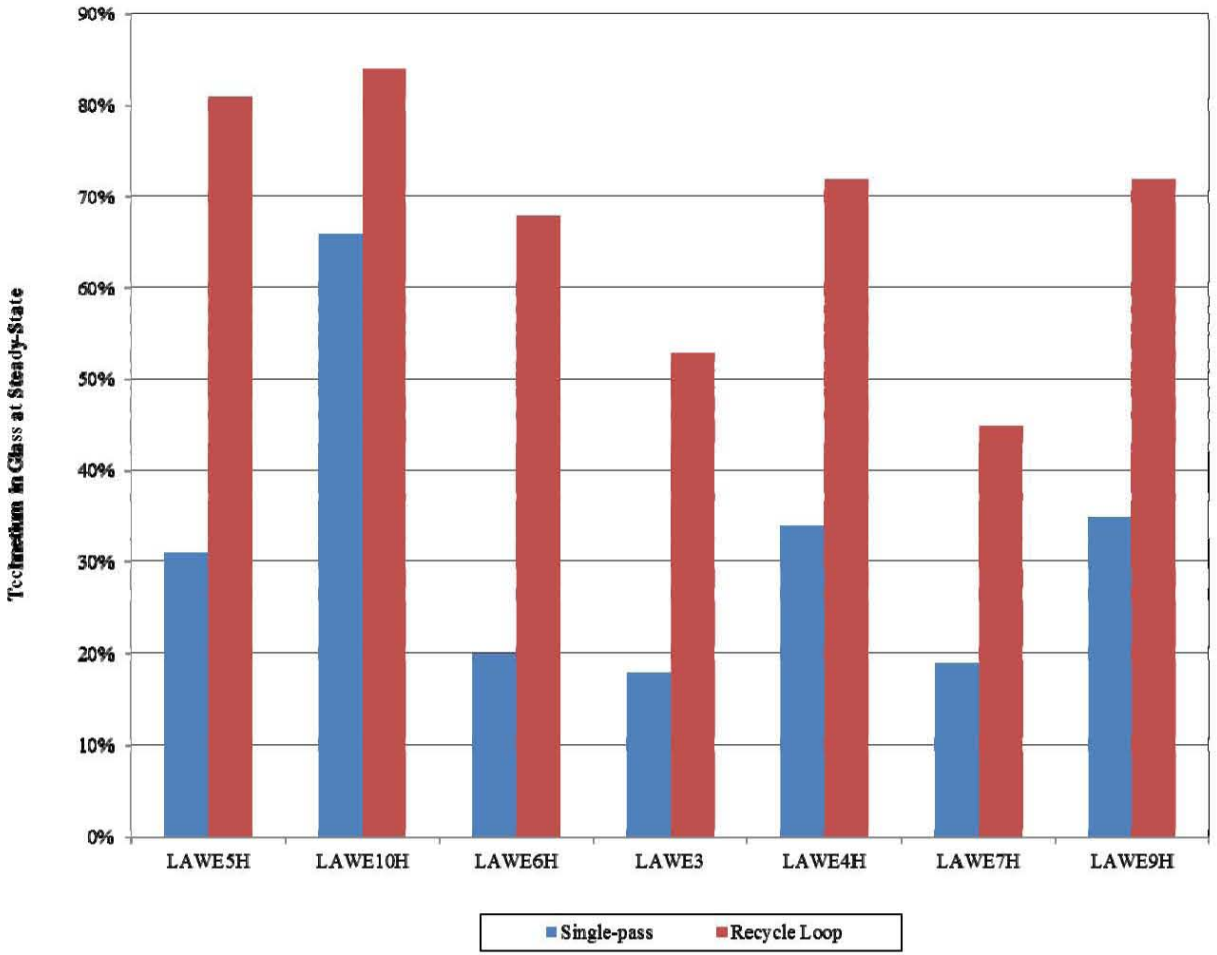


Figure 5.11. Measured steady-state technetium retention in glass for single-pass and recycle tests.

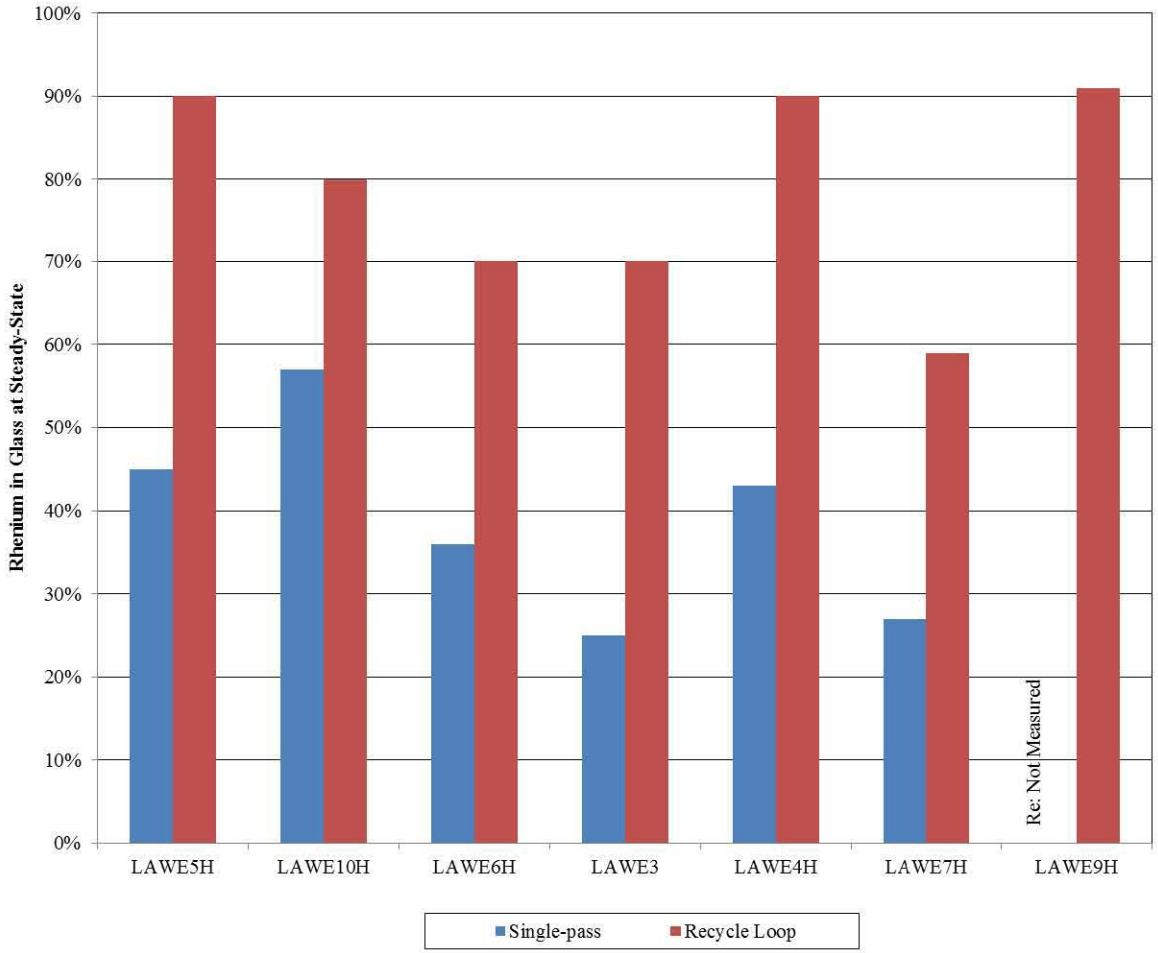


Figure 5.12. Measured steady-state rhenium retention in glass for single-pass and recycle tests.

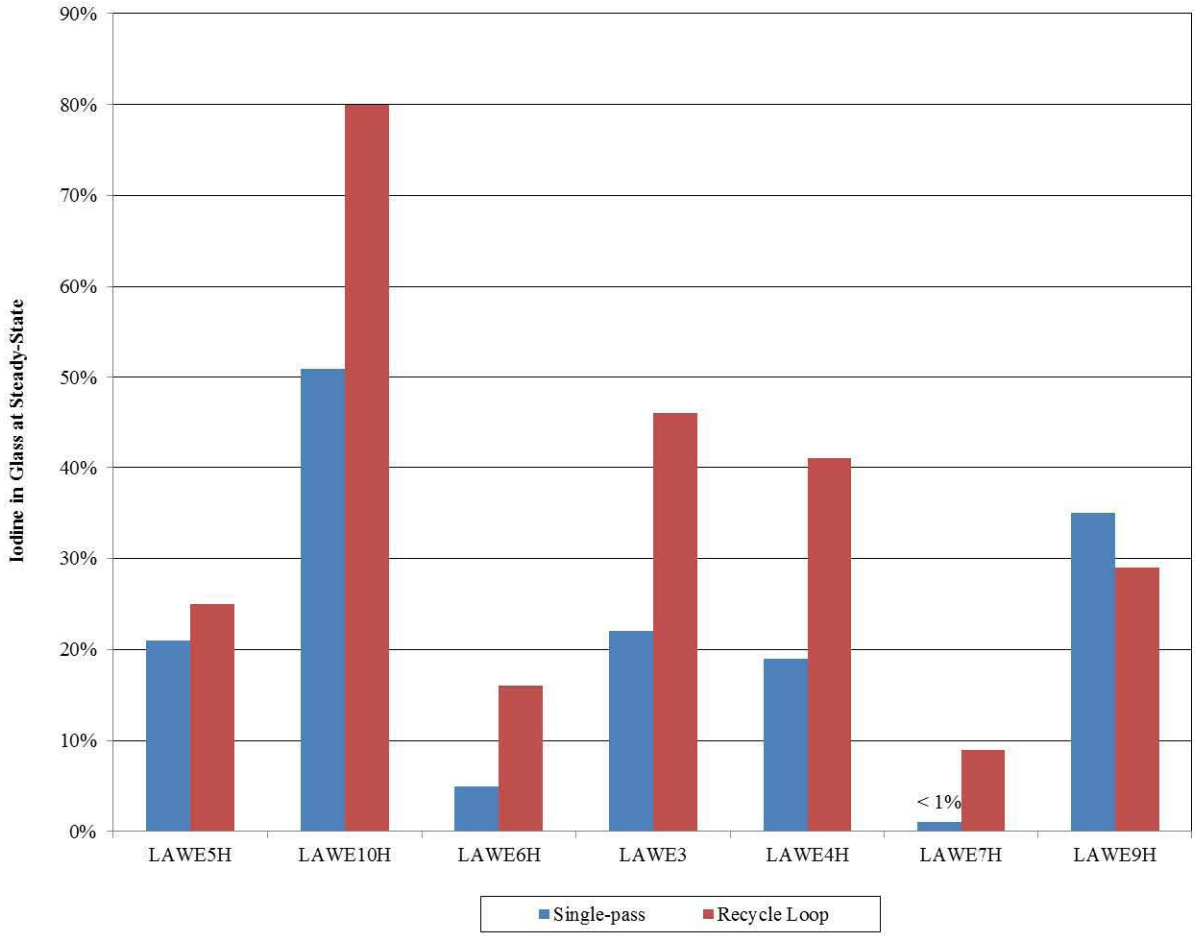


Figure 5.13. Measured steady-state iodine retention in glass for single-pass and recycle tests.

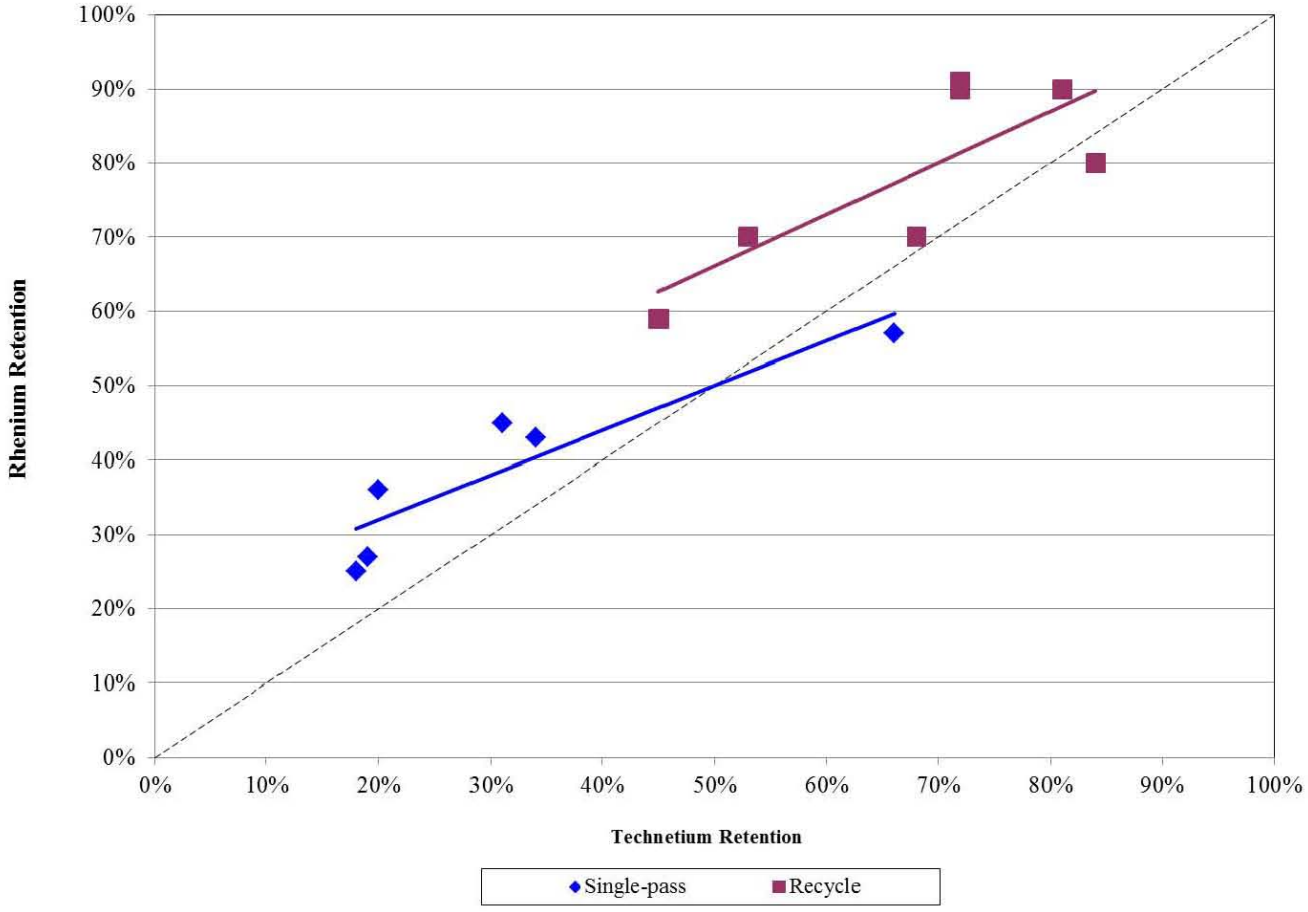


Figure 5.14. Relationship between technetium and rhenium retention in glass for single-pass and recycle tests. Dashed line illustrates 1:1 relationship.

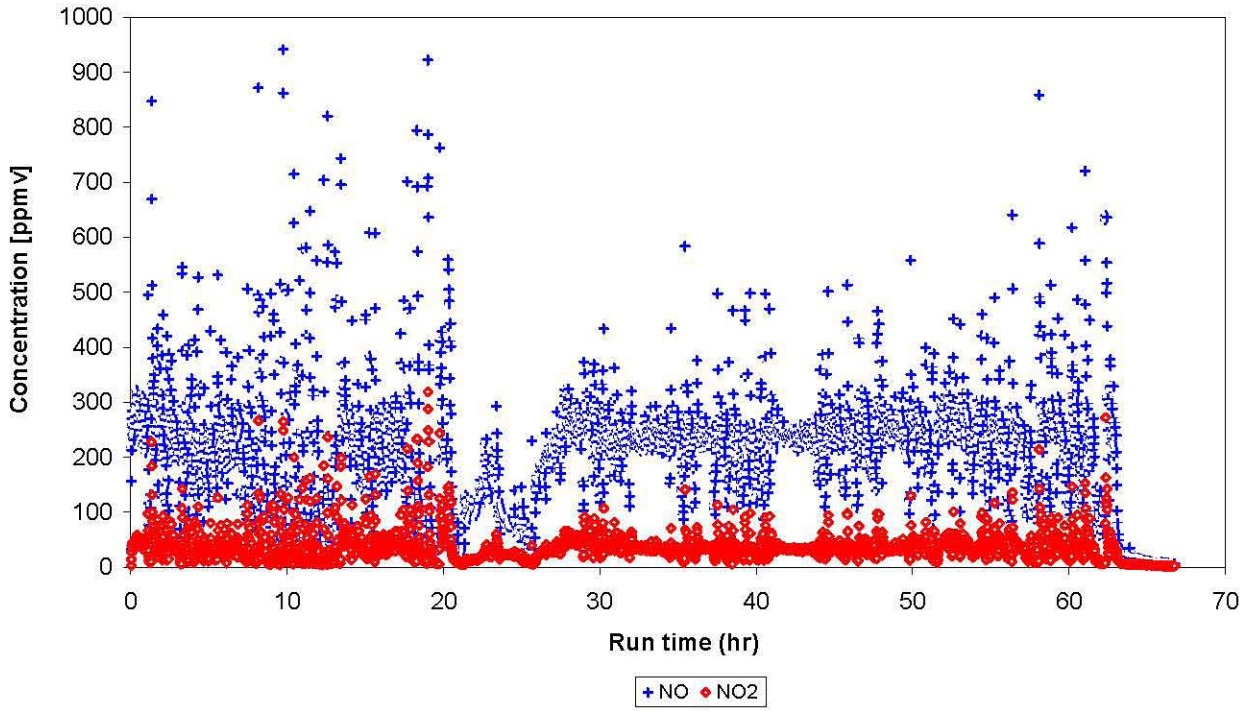


Figure 6.1.a. Nitrogen oxides concentrations in DM10 Off-gas system exhaust measured by FTIR during Test 1.

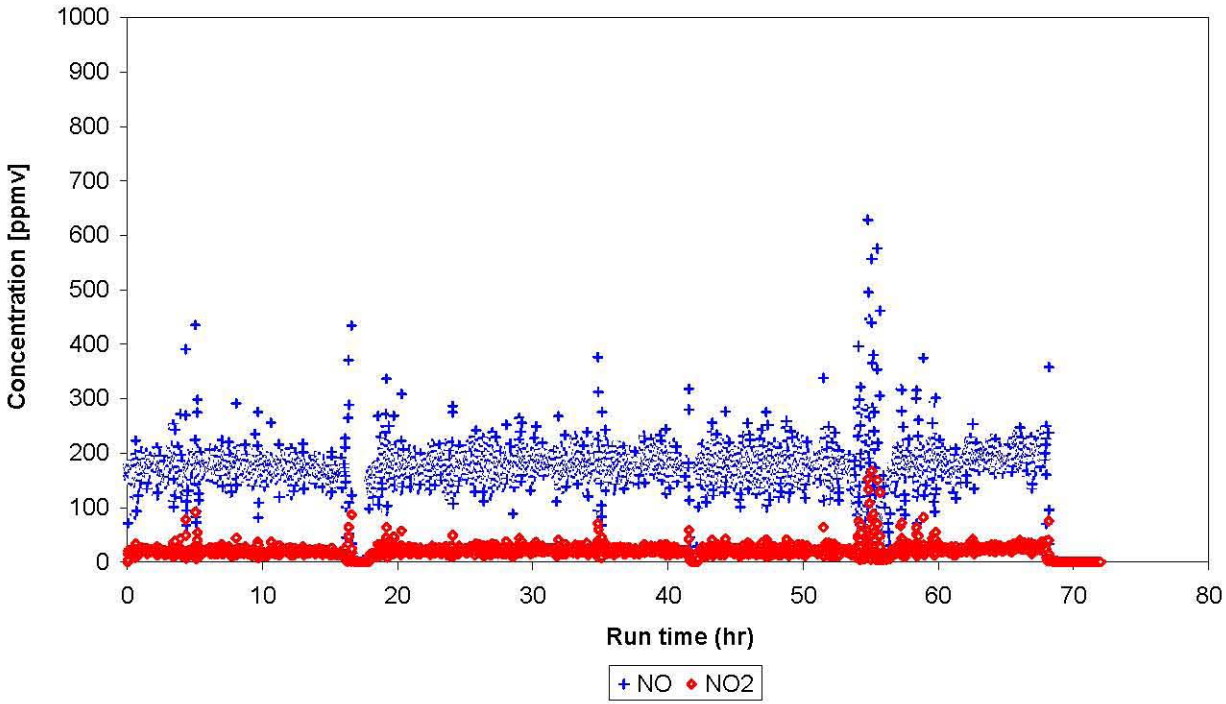


Figure 6.1.b. Nitrogen oxides concentrations in DM10 Off-gas system exhaust measured by FTIR during Test 2.

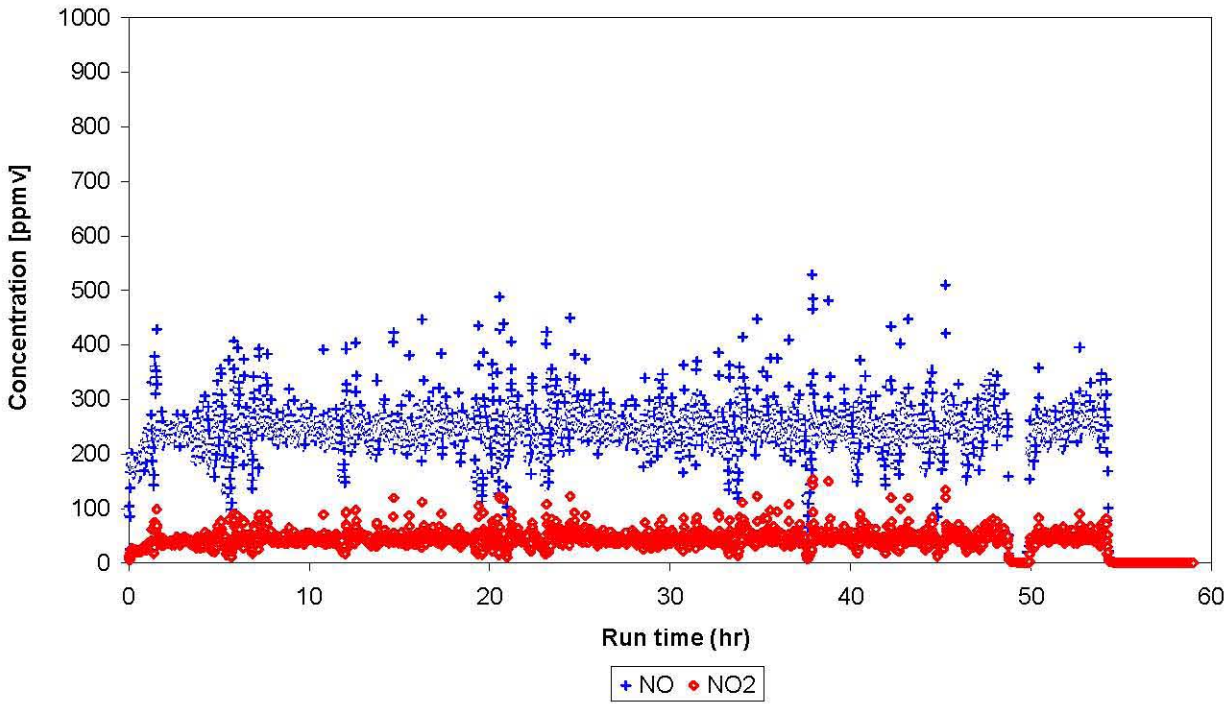


Figure 6.1.c. Nitrogen oxides concentrations in DM10 Off-gas system exhaust measured by FTIR during Test 3.

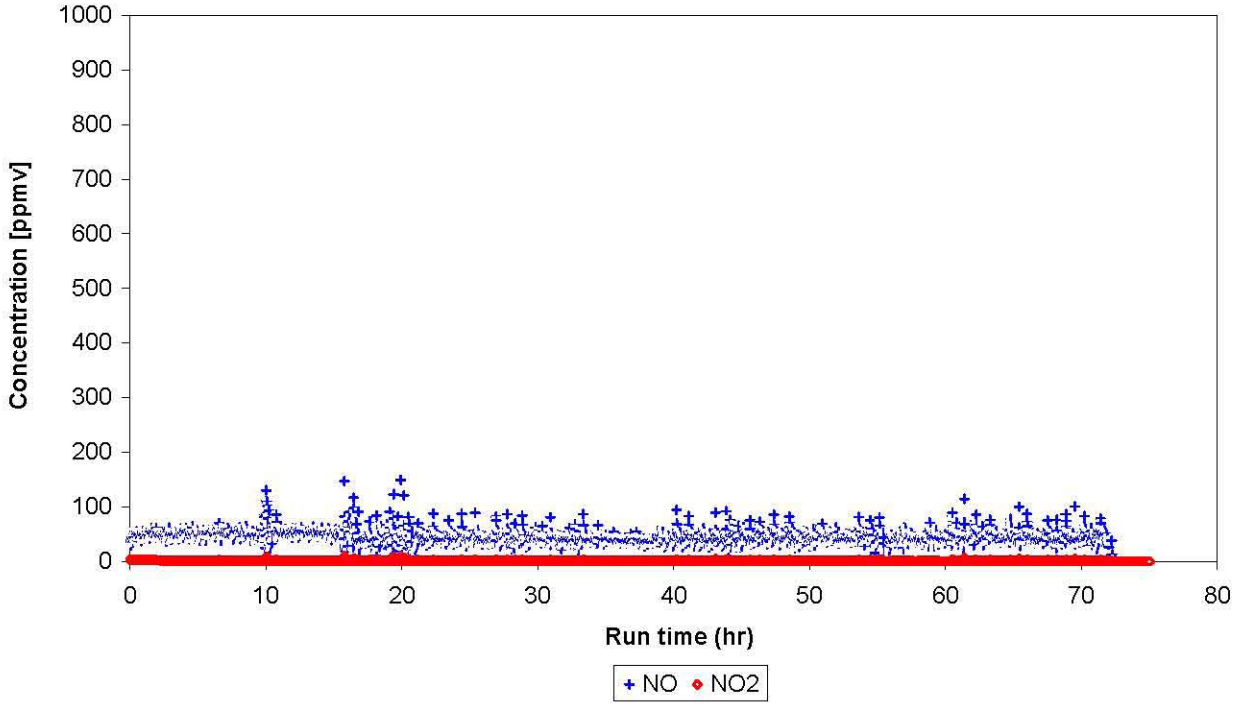


Figure 6.1.d. Nitrogen oxides concentrations in DM10 Off-gas system exhaust measured by FTIR during Test 4.

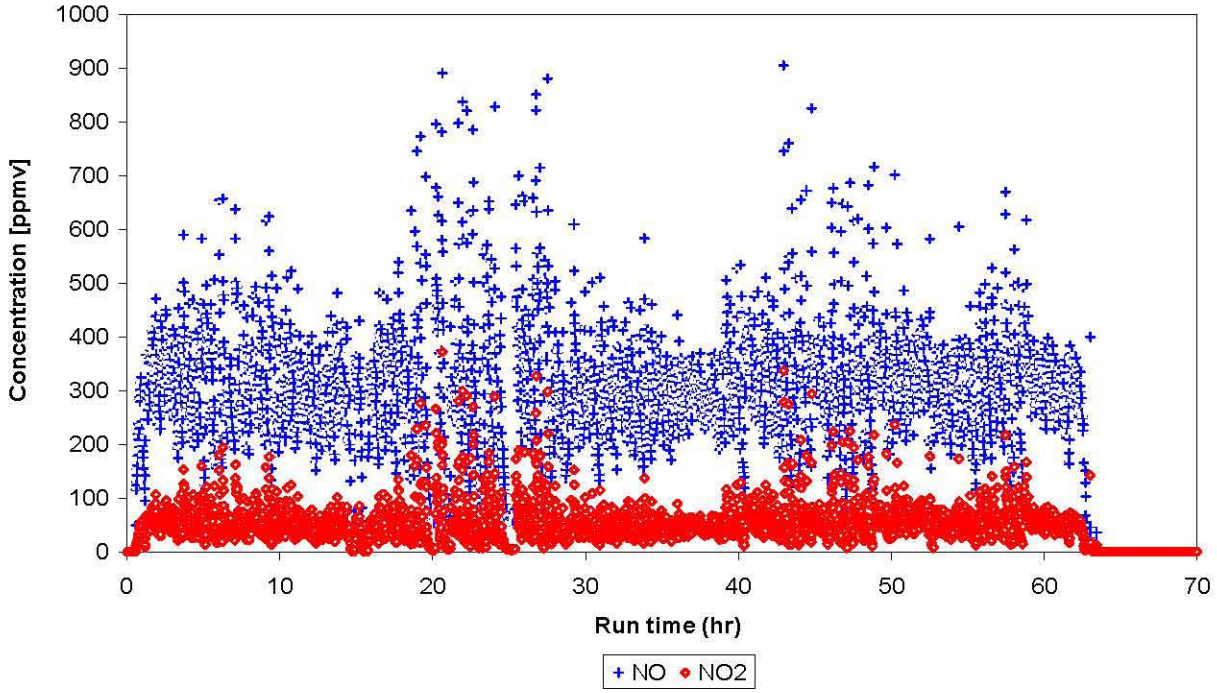


Figure 6.1.e. Nitrogen oxides concentrations in DM10 Off-gas system exhaust measured by FTIR during Test 5.

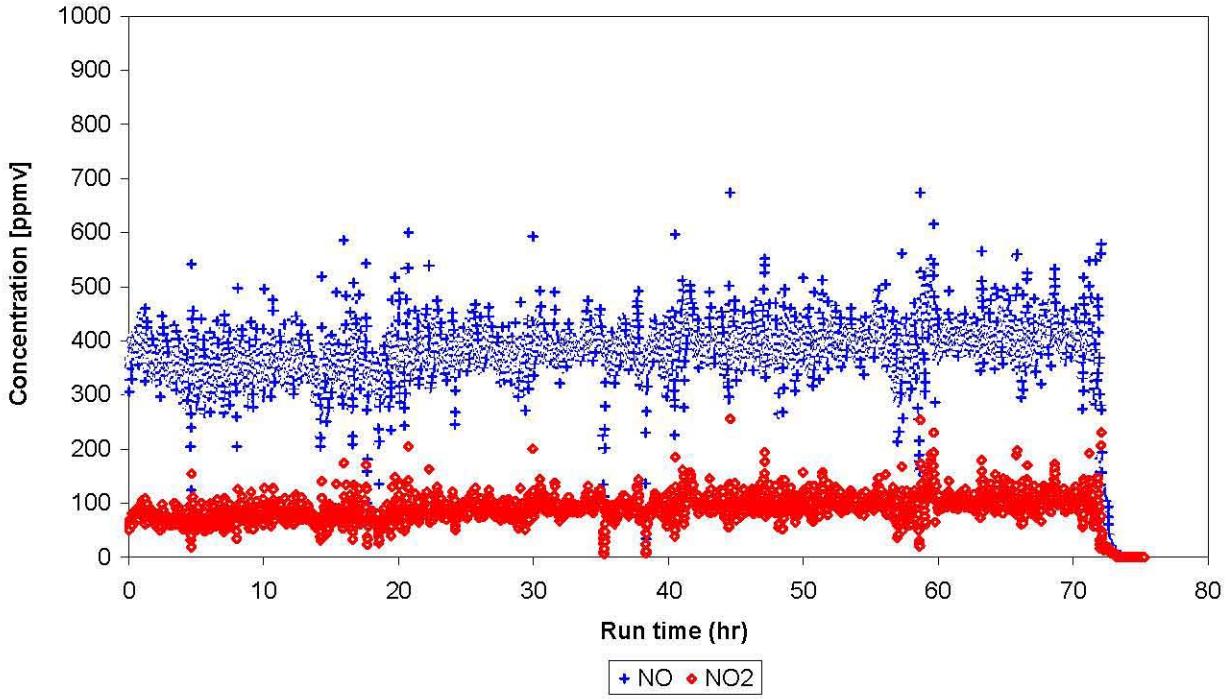


Figure 6.1.f. Nitrogen oxides concentrations in DM10 Off-gas system exhaust measured by FTIR during Test 6.

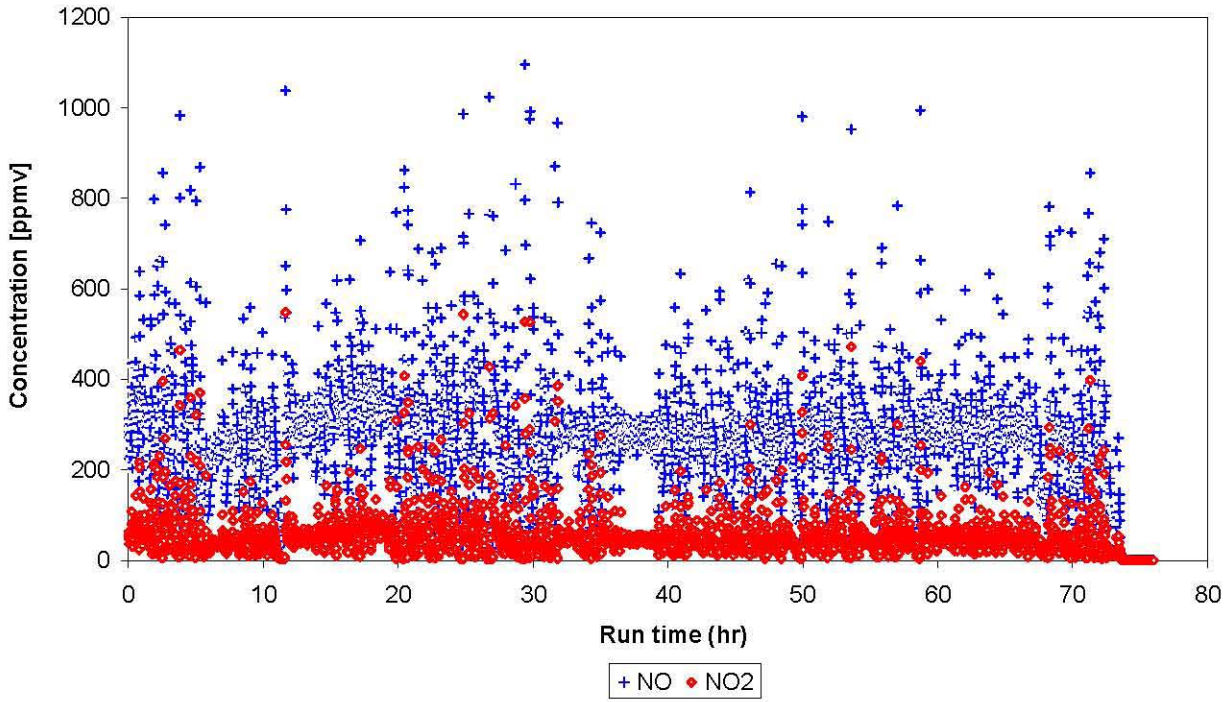


Figure 6.1.g. Nitrogen oxides concentrations in DM10 Off-gas system exhaust measured by FTIR during Test 7.

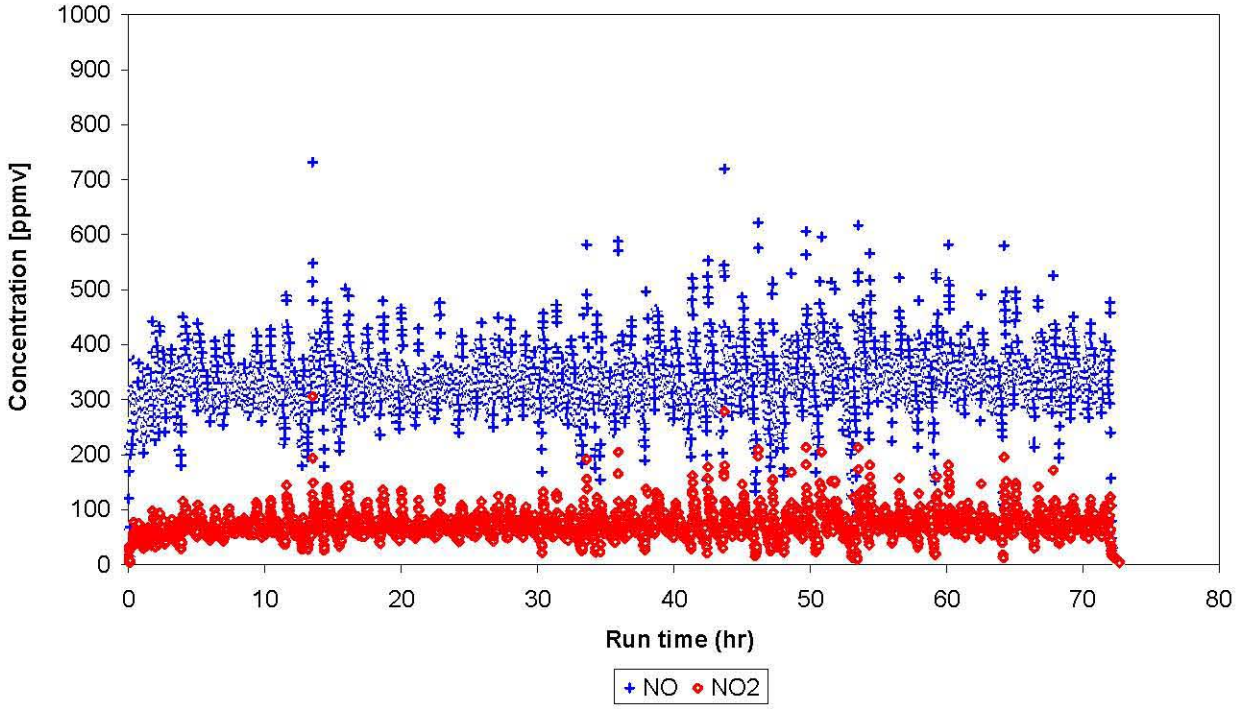


Figure 6.1.h. Nitrogen oxides concentrations in DM10 Off-gas system exhaust measured by FTIR during Test 8.

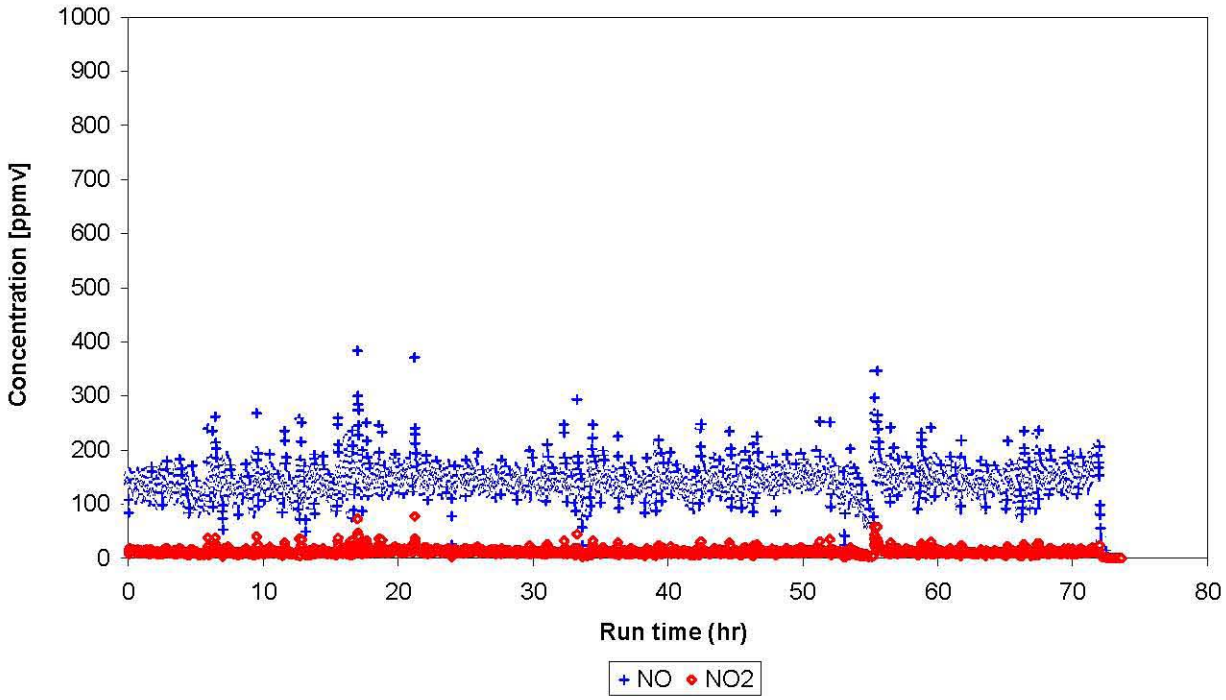


Figure 6.1.i. Nitrogen oxides concentrations in DM10 Off-gas system exhaust measured by FTIR during Test 9.

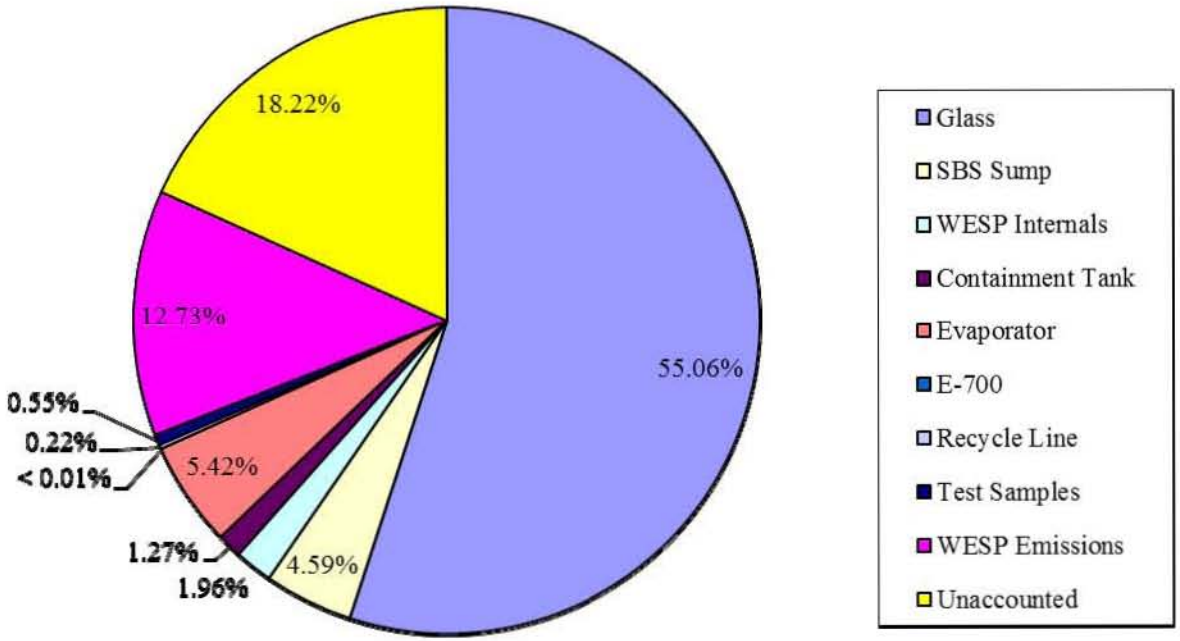


Figure 7.1.a. Technetium distribution for Test 2.

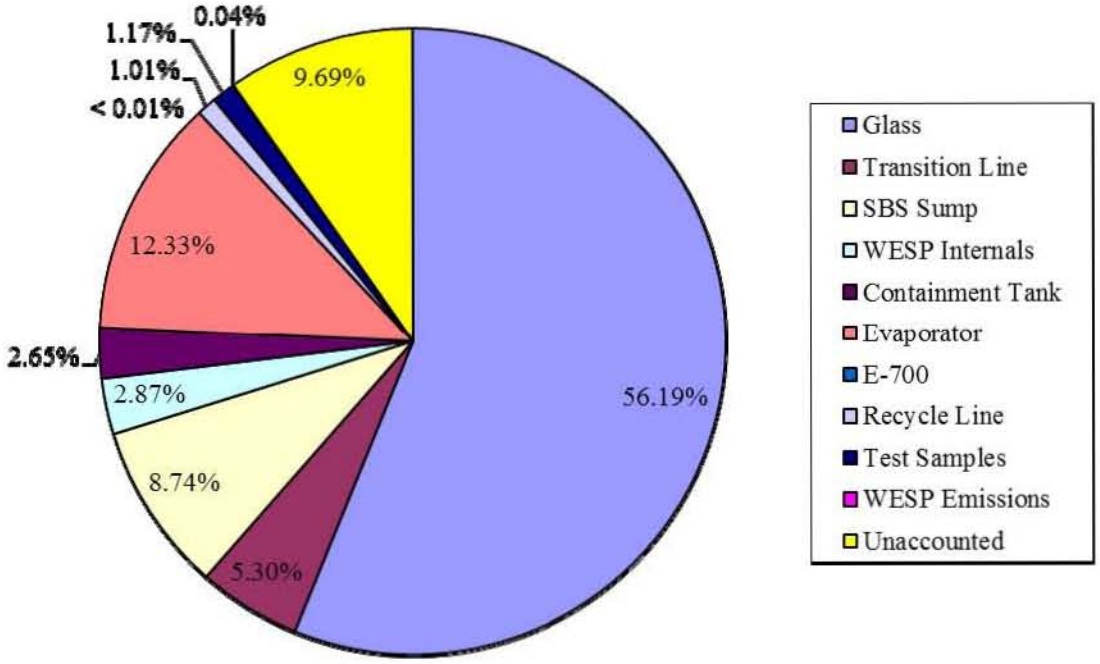


Figure 7.1.b. Technetium distribution for Test 3.

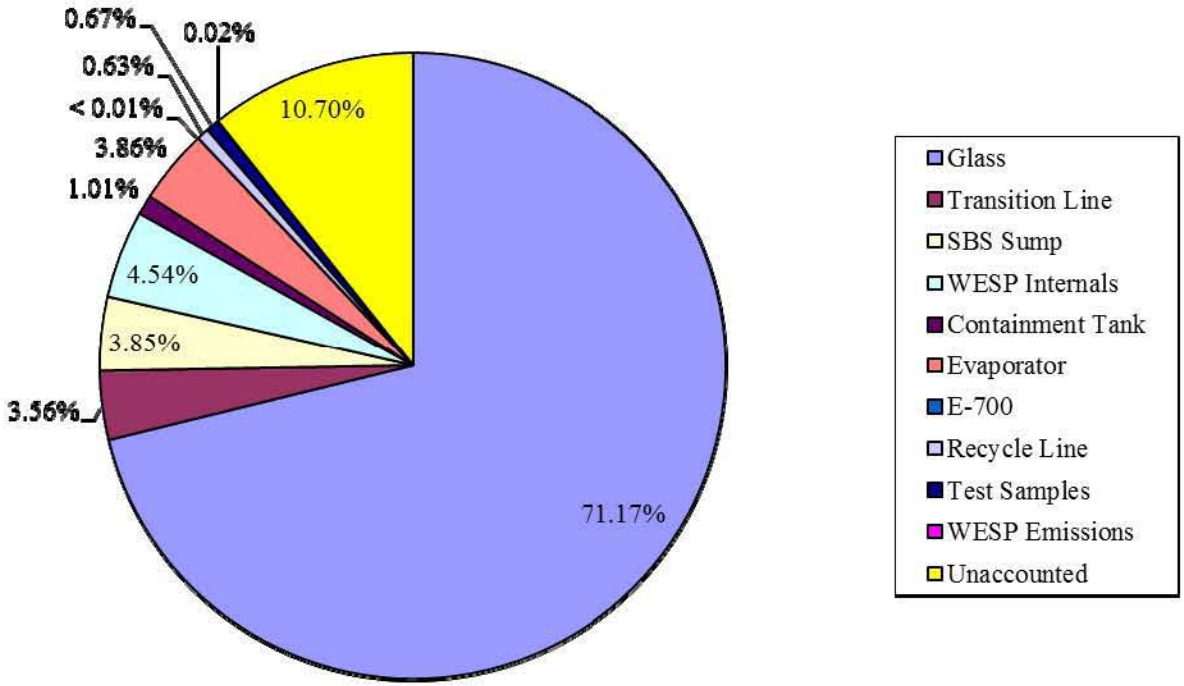


Figure 7.1.c. Technetium distribution for Test 4.

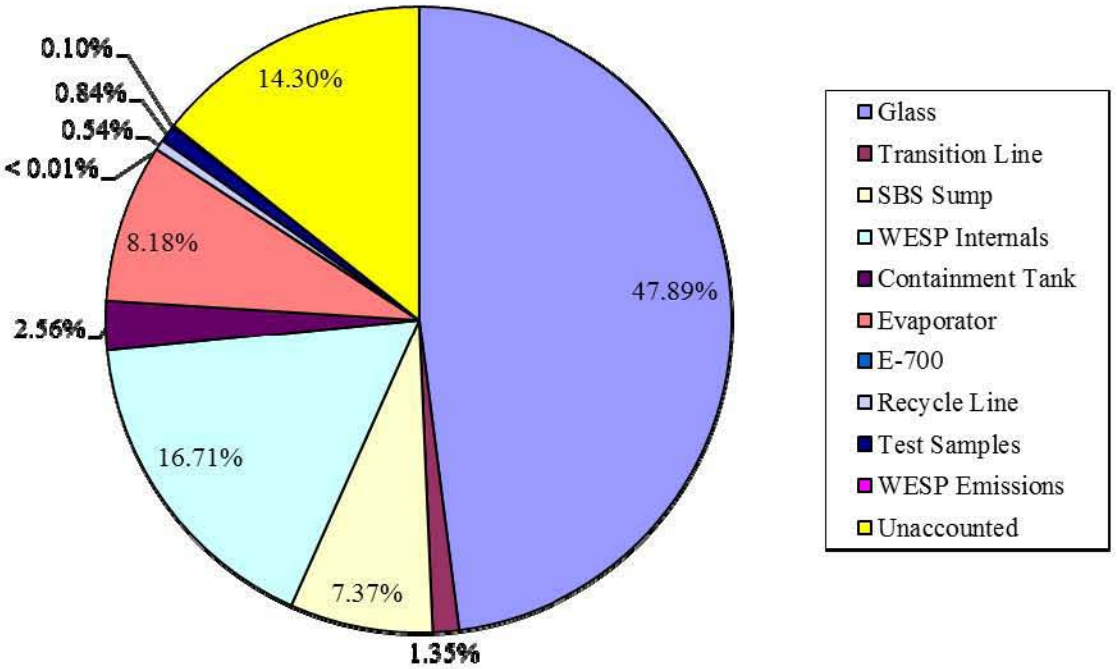


Figure 7.1.d. Technetium distribution for Test 5.

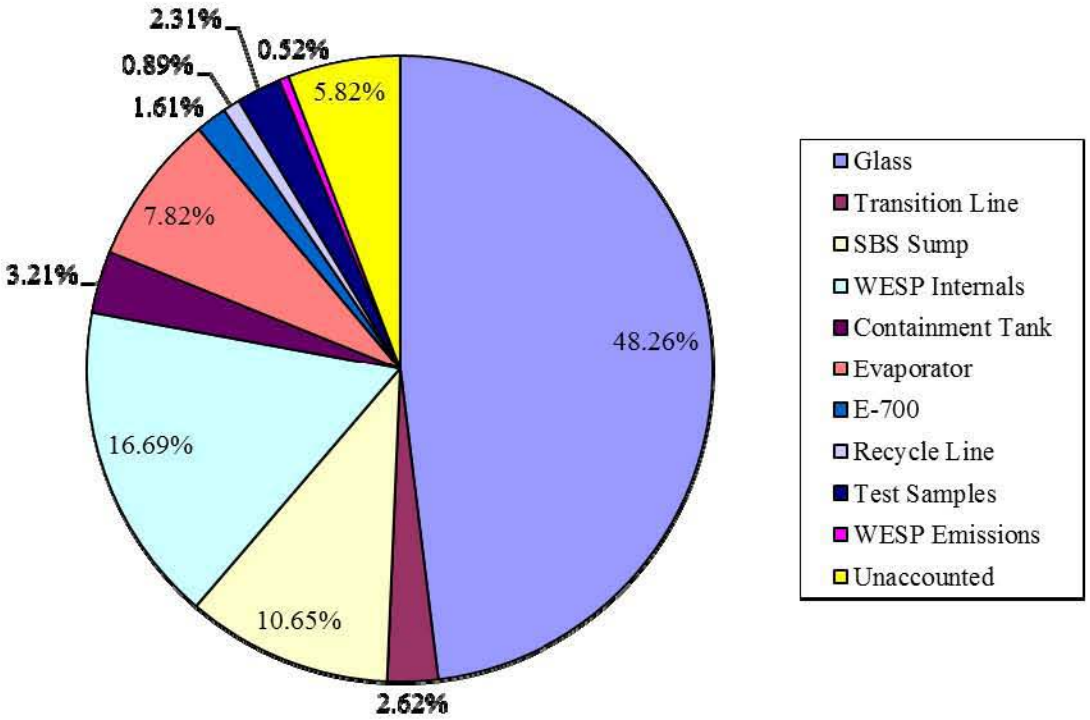


Figure 7.1.e. Technetium distribution for Test 6.

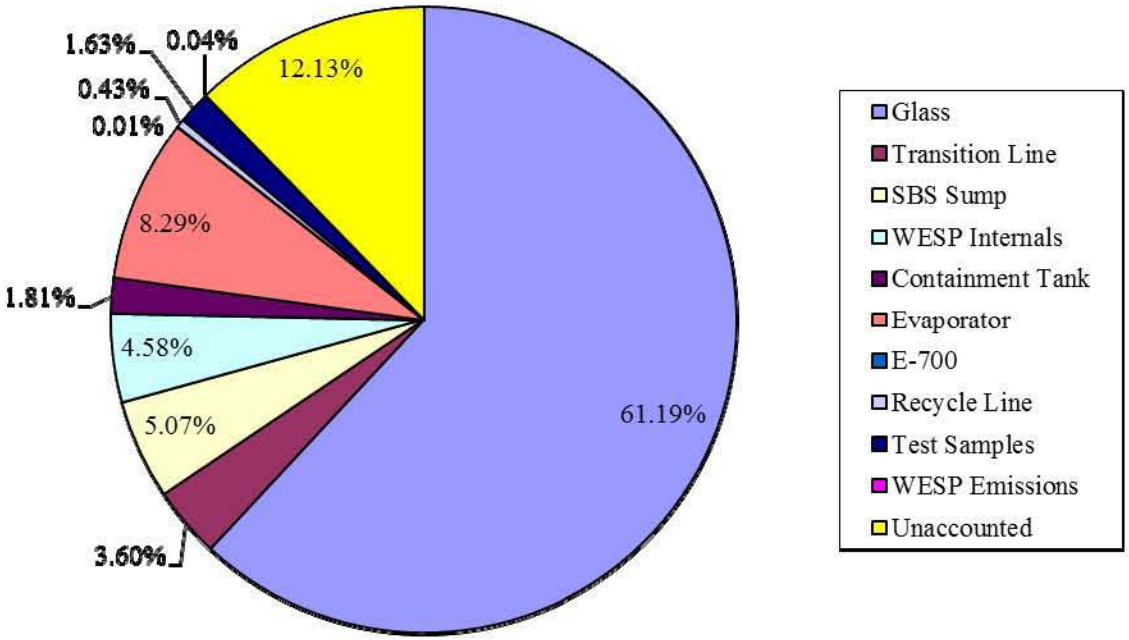


Figure 7.1.f. Technetium distribution for Test 7.

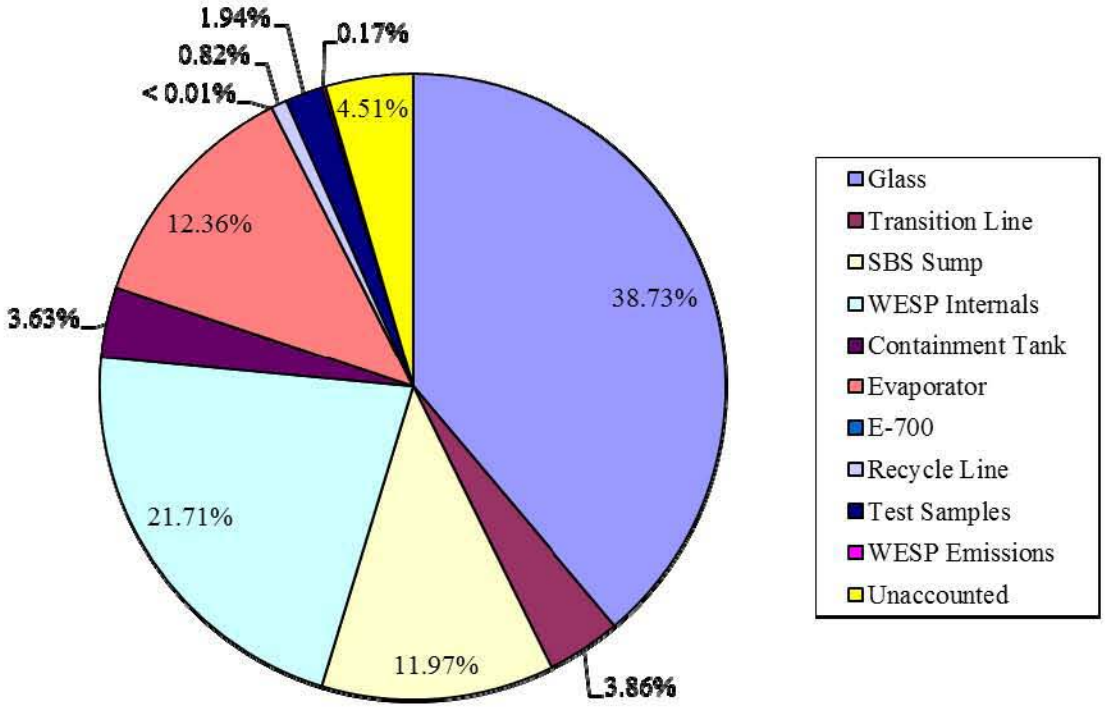


Figure 7.1.g. Technetium distribution for Test 8.

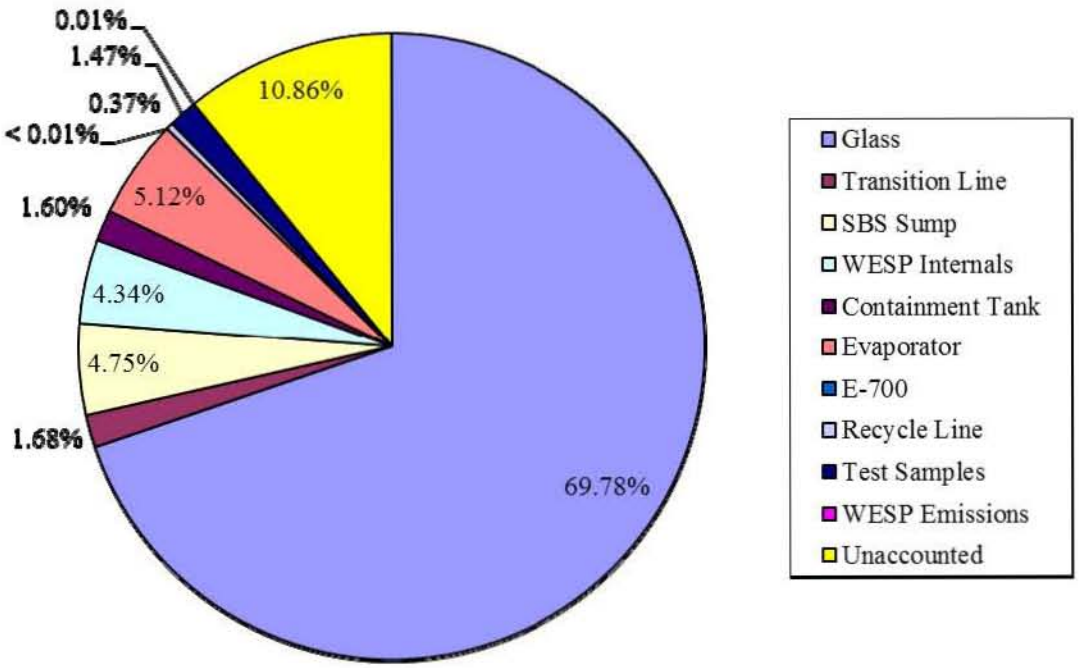


Figure 7.1.h. Technetium distribution for Test 9.

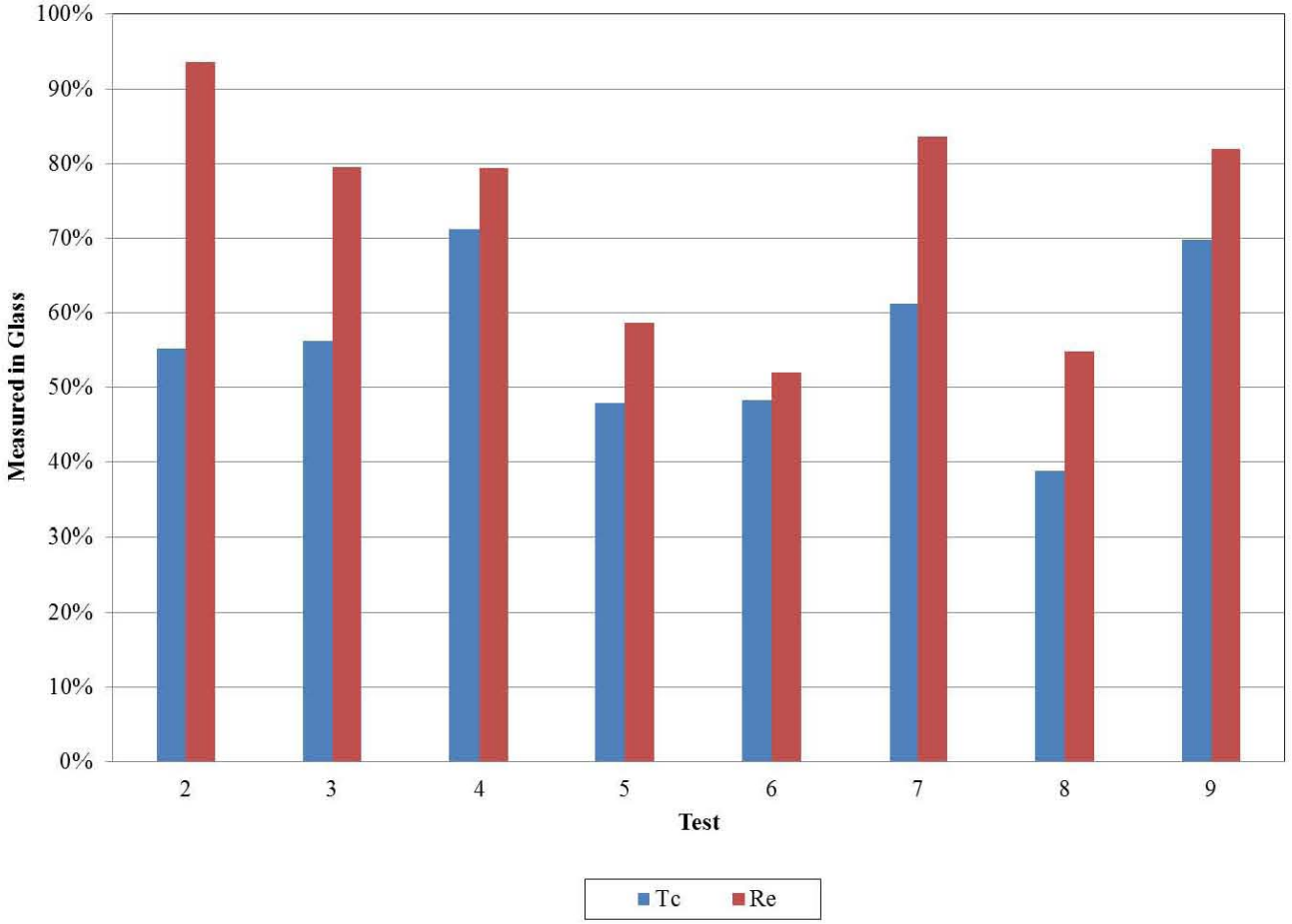


Figure 7.2. Technetium and rhenium measured in glass (cumulative).

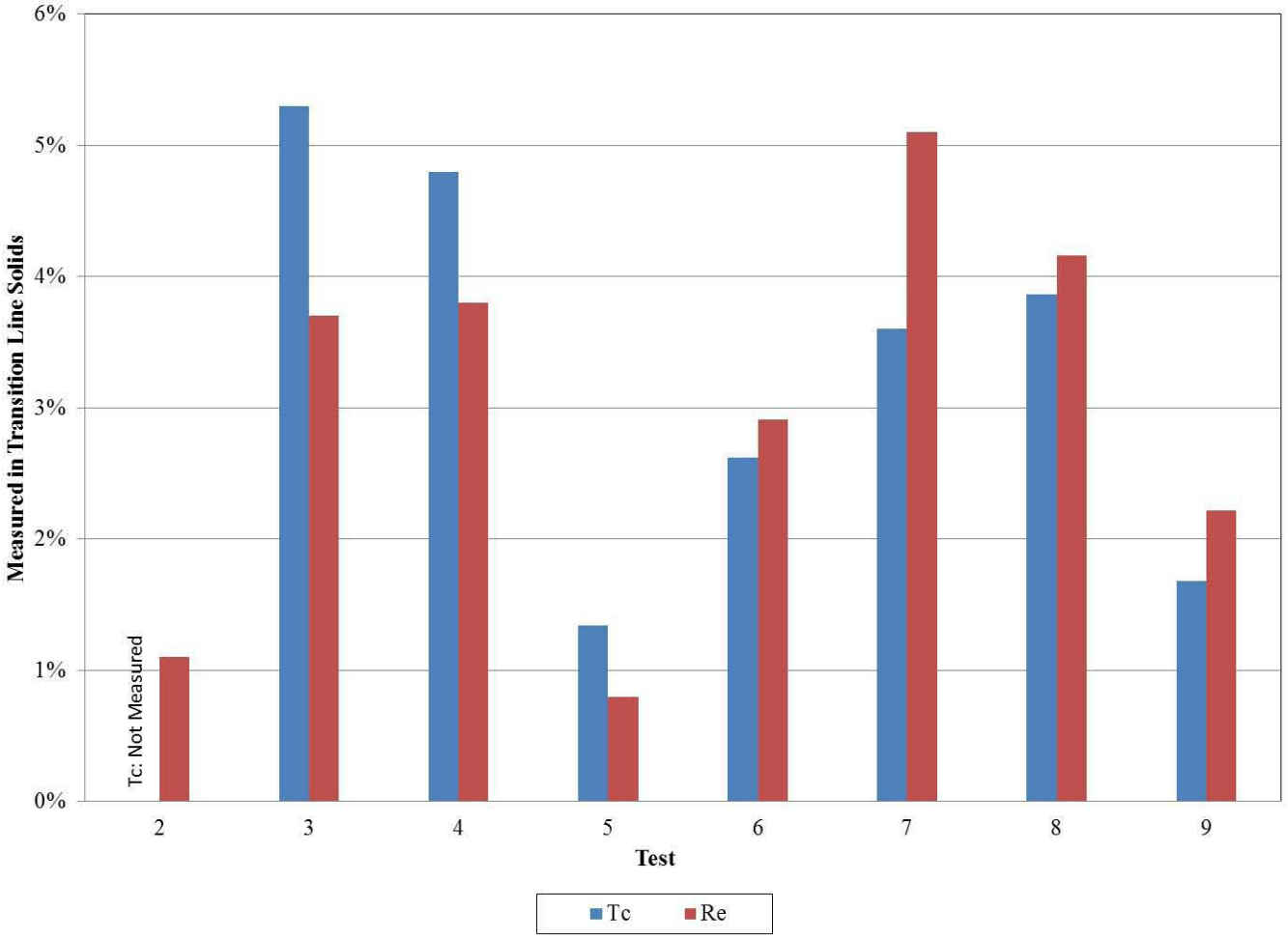


Figure 7.3. Technetium and rhenium measured in transition line deposits sampled at conclusion of tests.

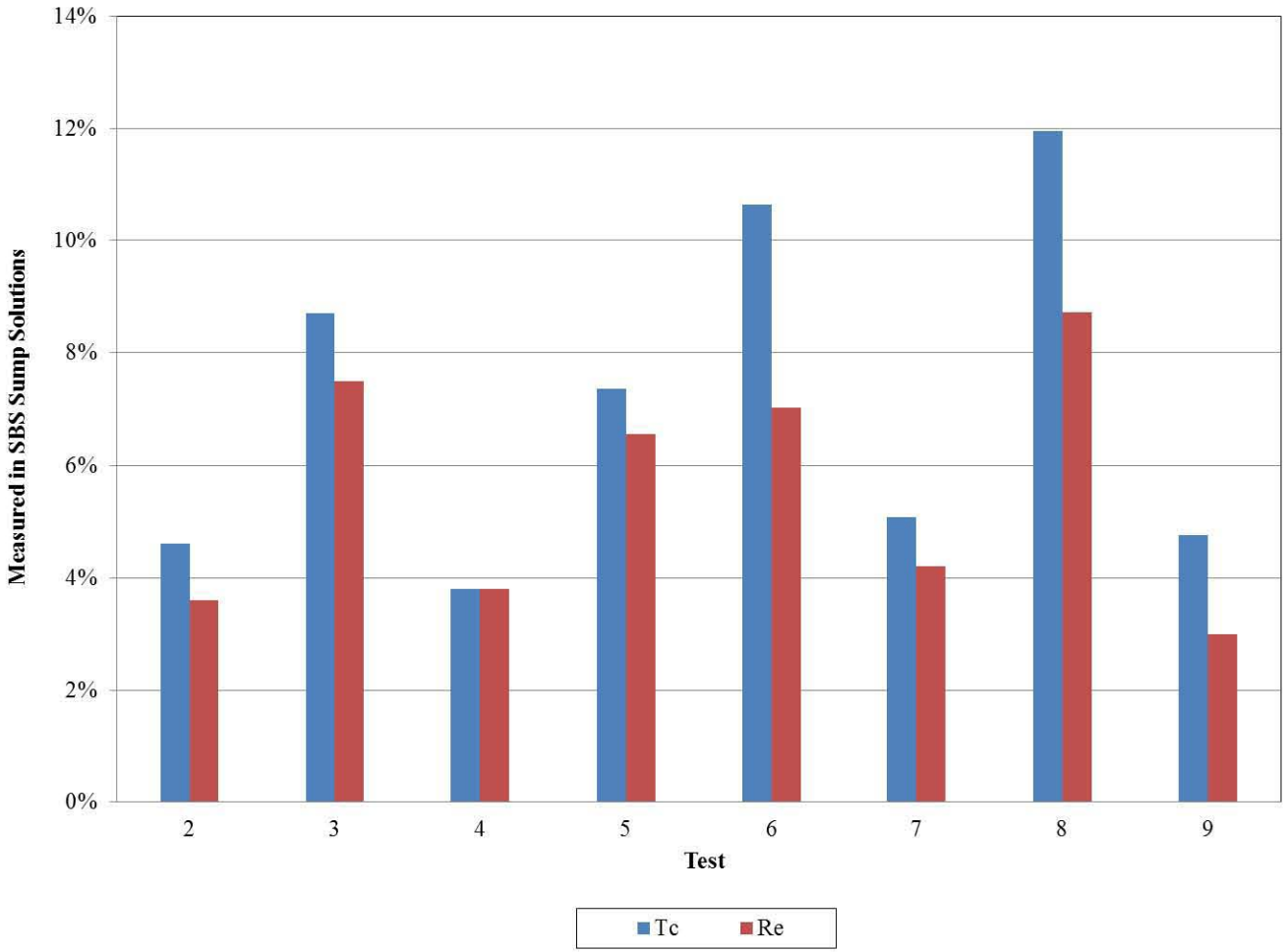


Figure 7.4. Technetium and rhenium measured in SBS sump solutions sampled at the conclusion of tests.

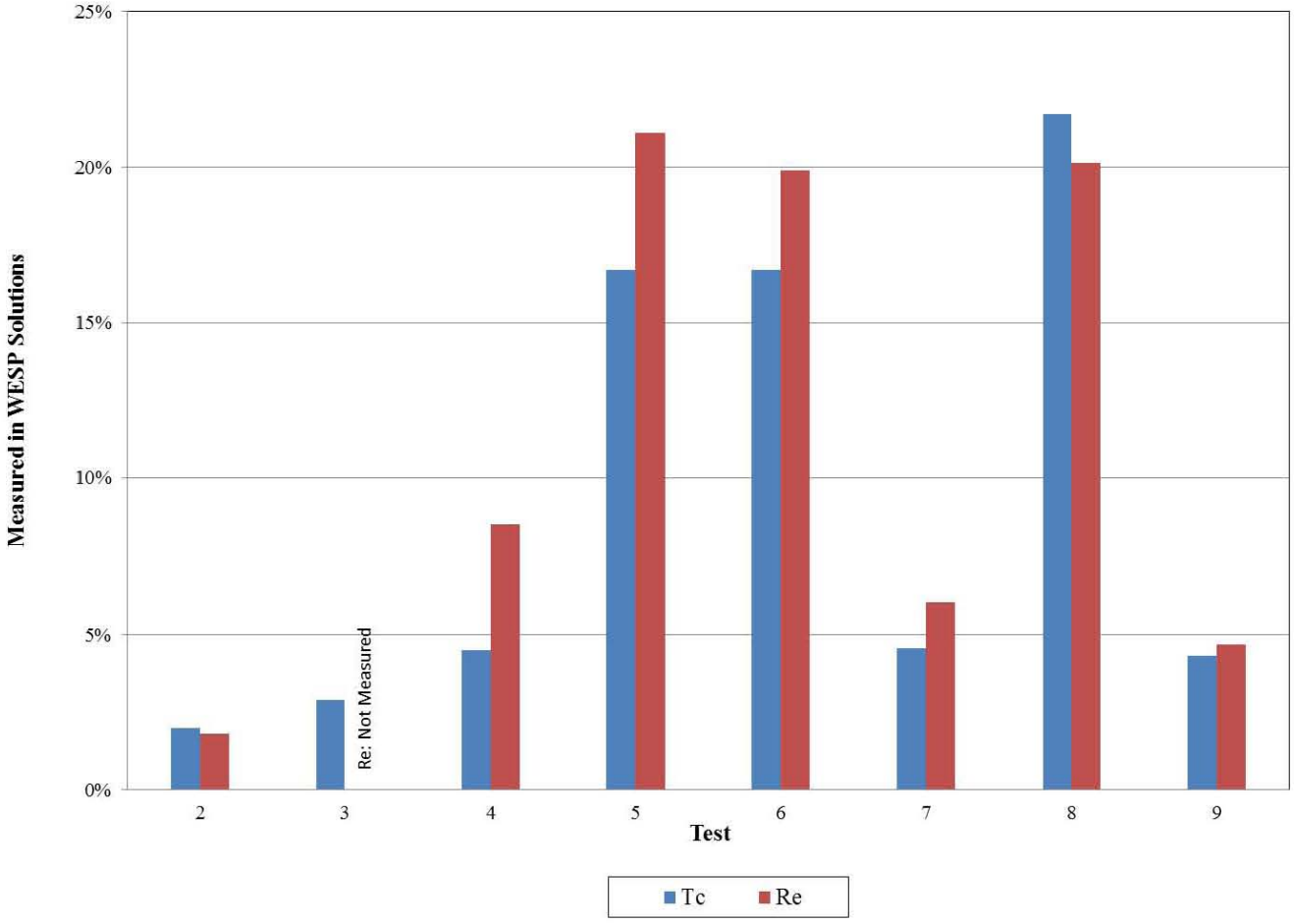


Figure 7.5. Technetium and rhenium measured in WESP solutions generated from deluges and rinses at the conclusion of tests.

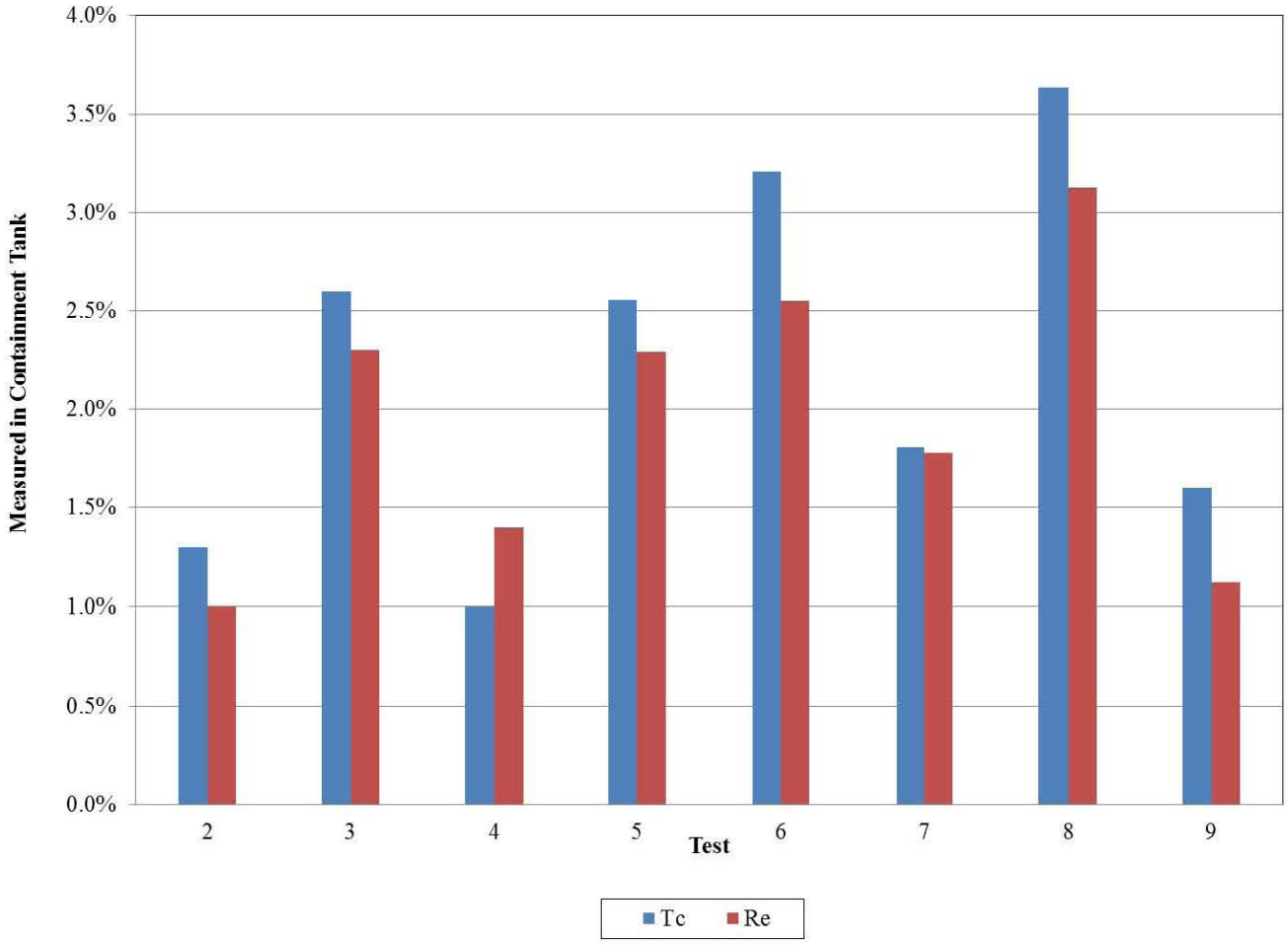


Figure 7.6. Technetium and rhenium measured in containment tank sampled at conclusion of tests.

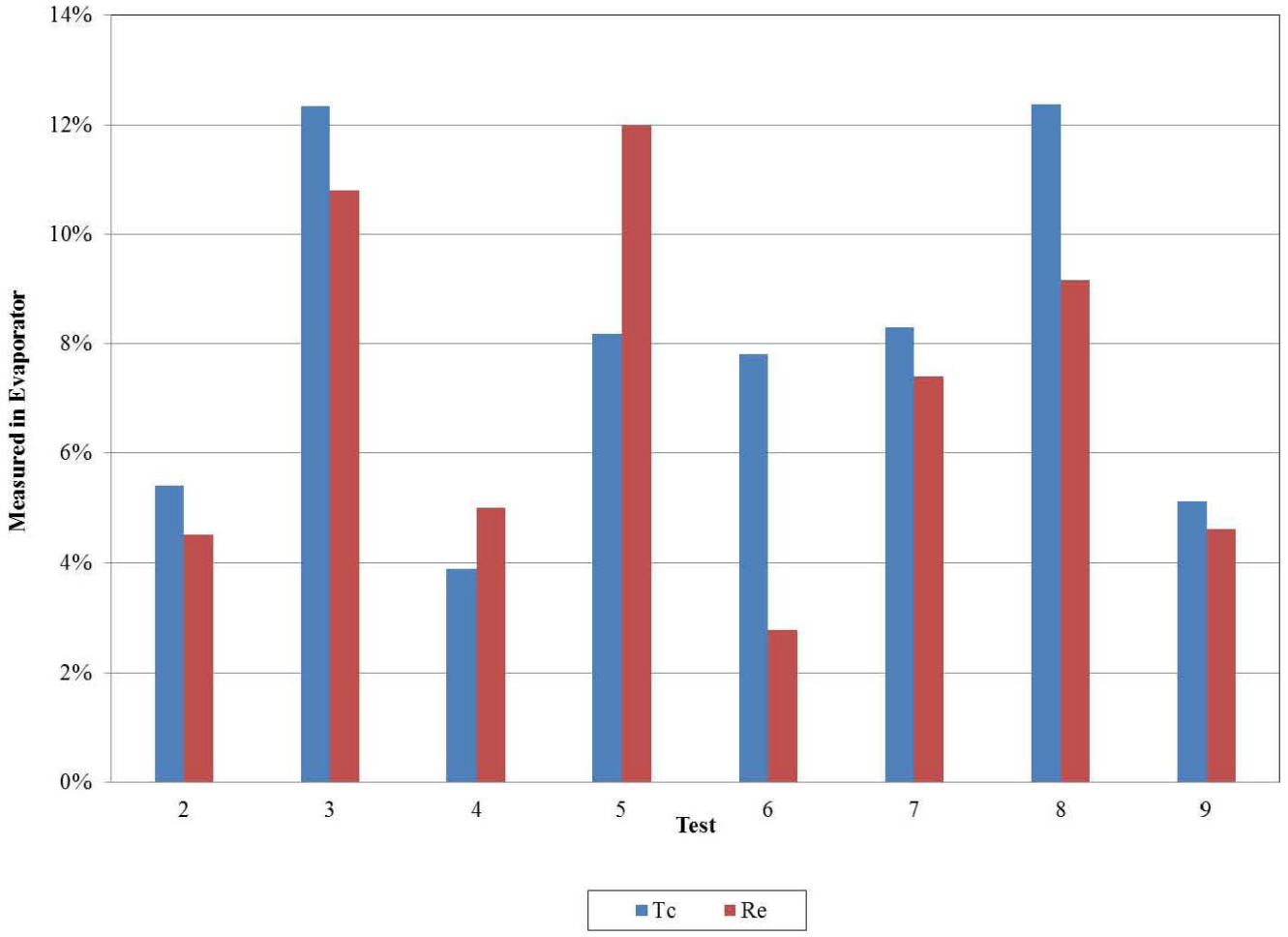


Figure 7.7. Technetium and rhenium measured in evaporator sampled at conclusion of tests.

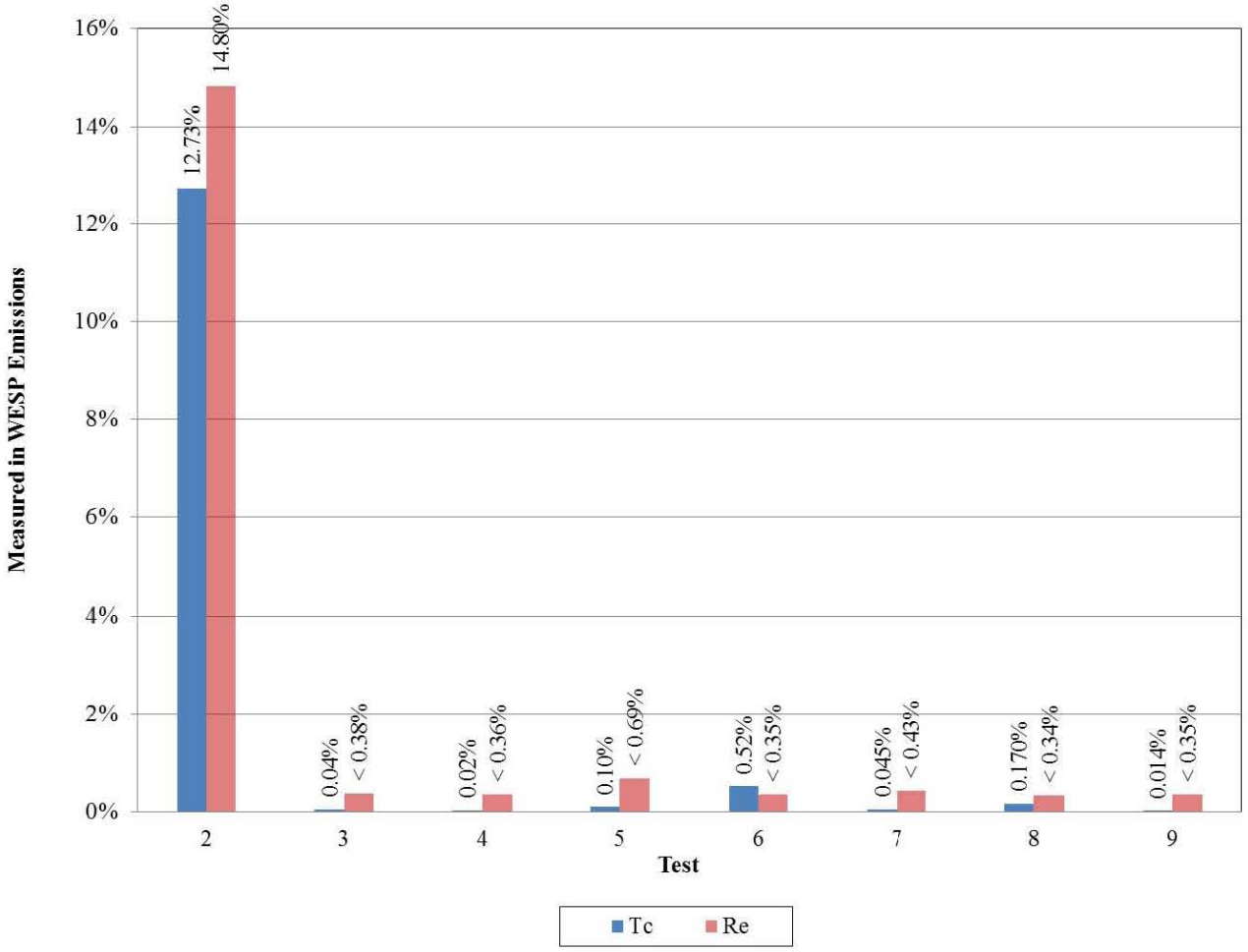


Figure 7.8. Technetium and rhenium measured in WESP emissions.

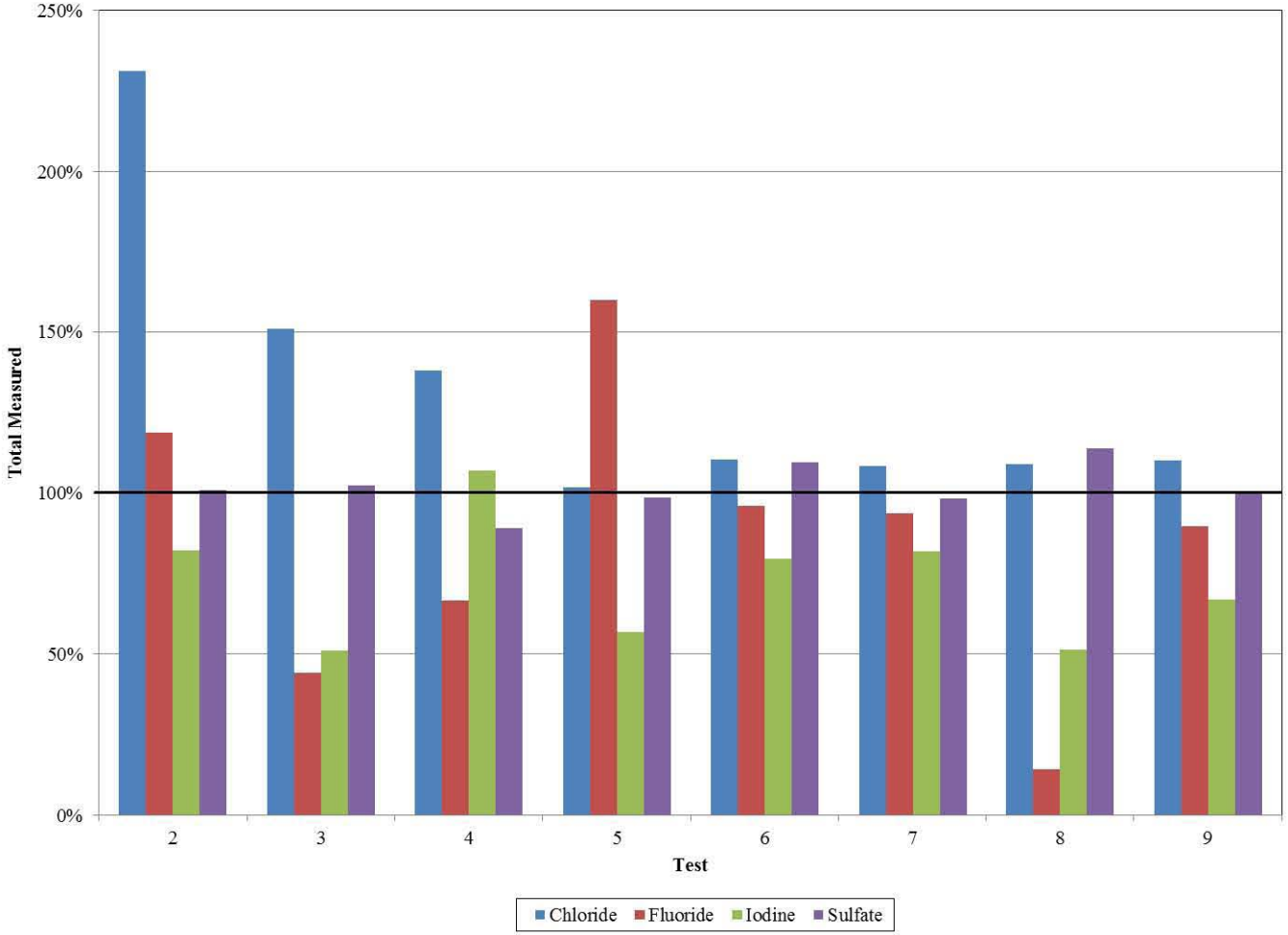


Figure 7.9. Total recovered halogens and sulfur.

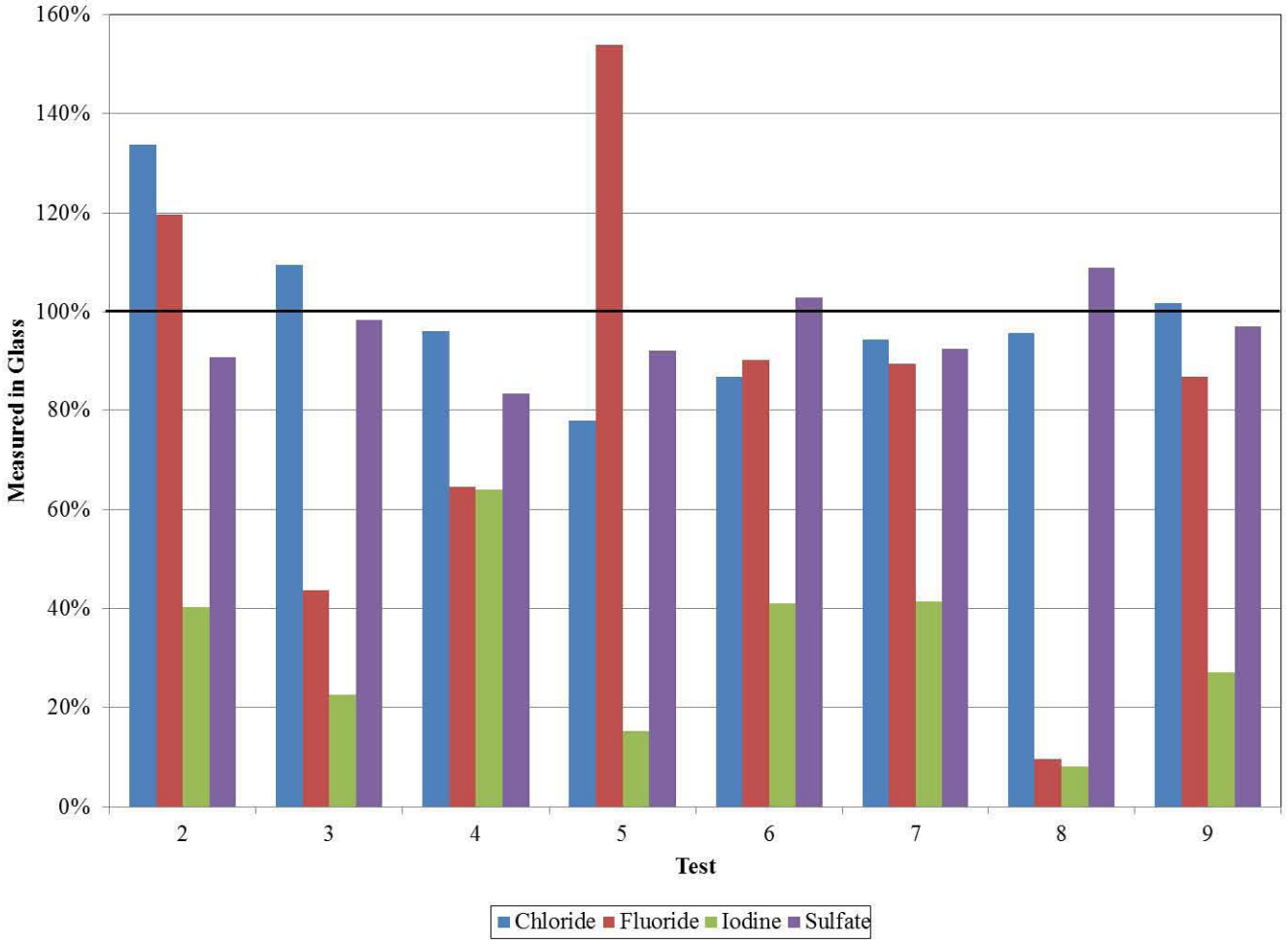


Figure 7.10. Halogens and sulfur measured in cumulative glass (cumulative).

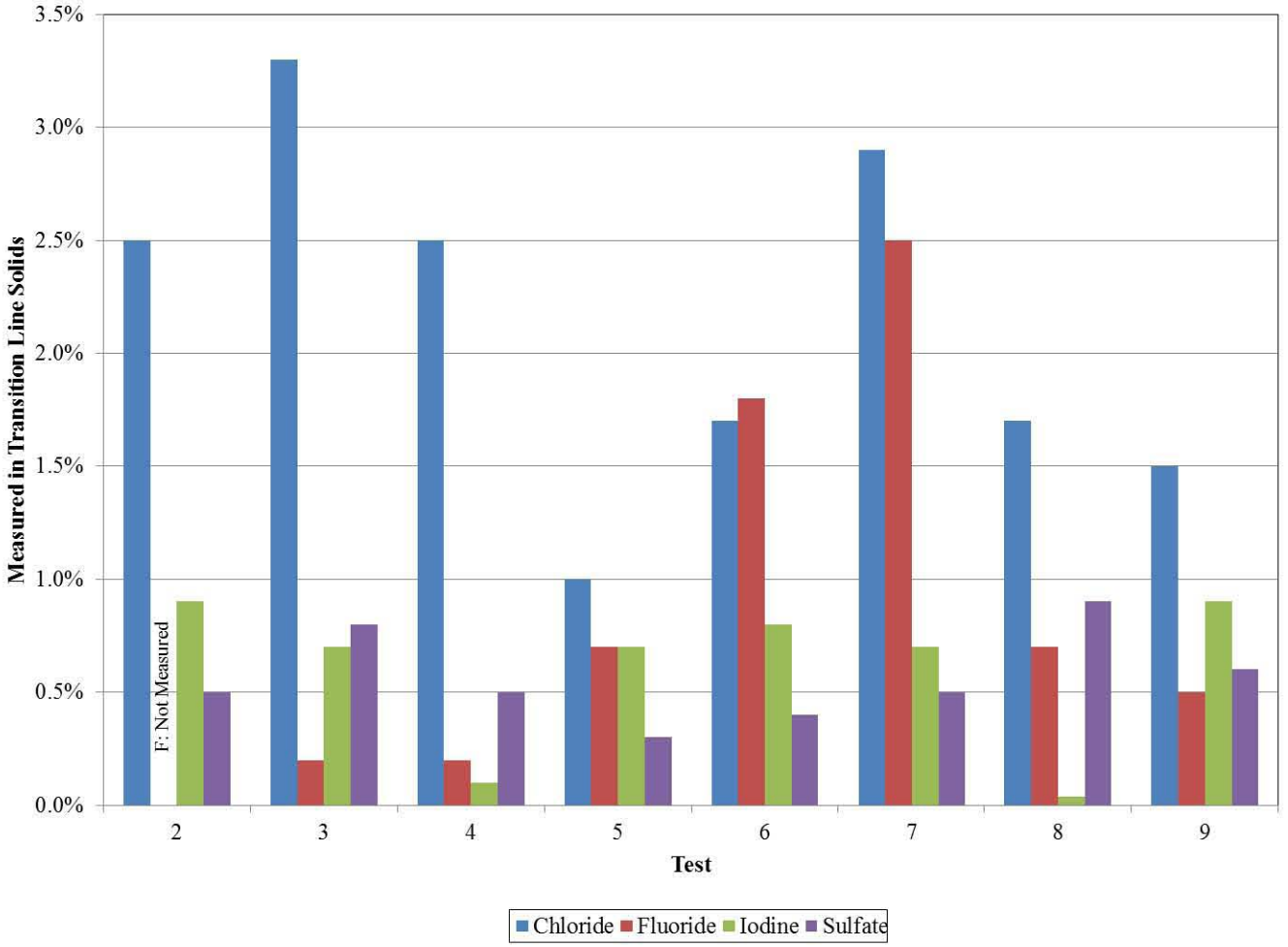


Figure 7.11. Halogens and sulfur measured in transition line deposits sampled at conclusion of tests.

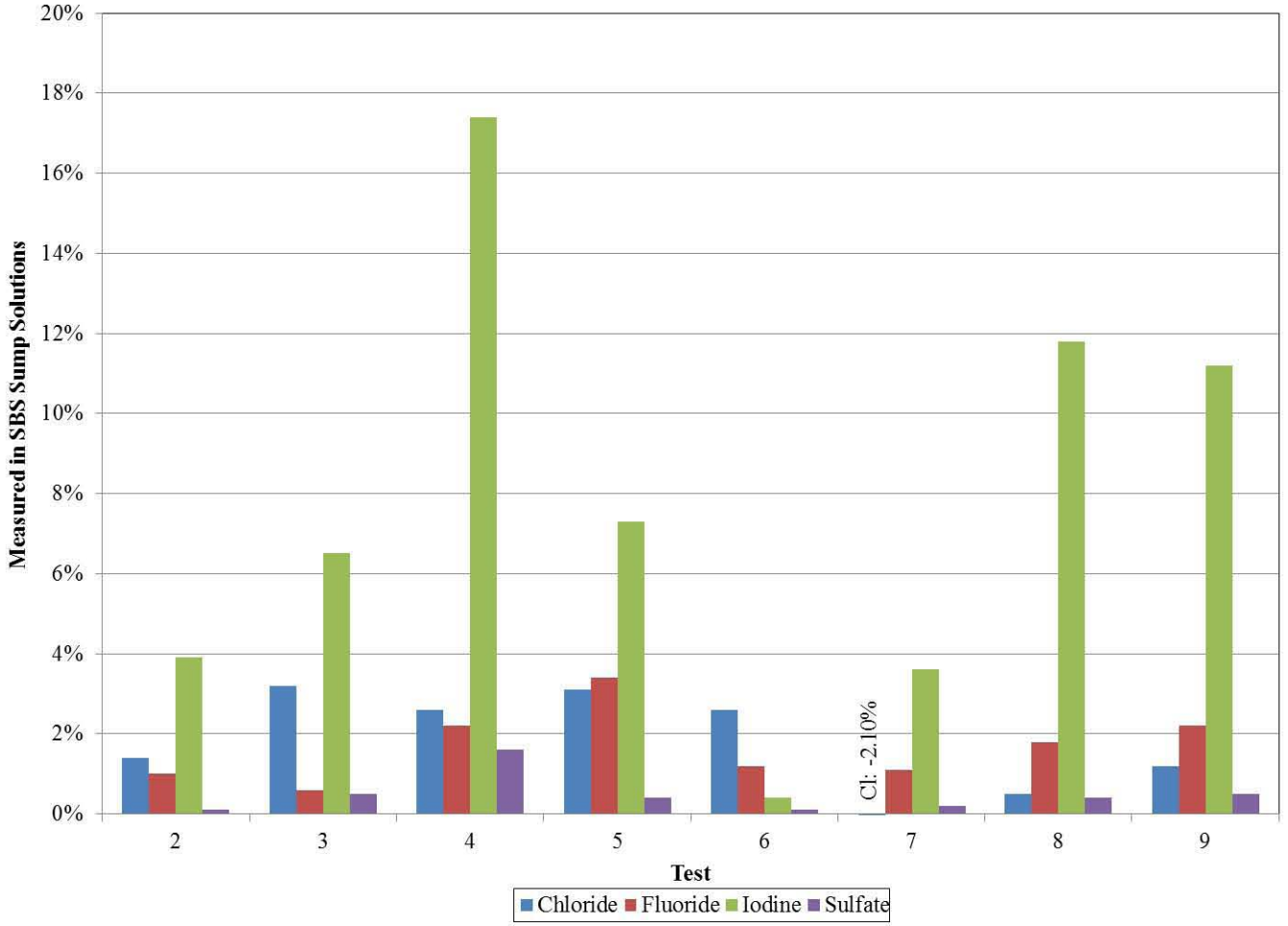


Figure 7.12. Halogens and sulfur measured in SBS sump solutions sampled at conclusion of tests.

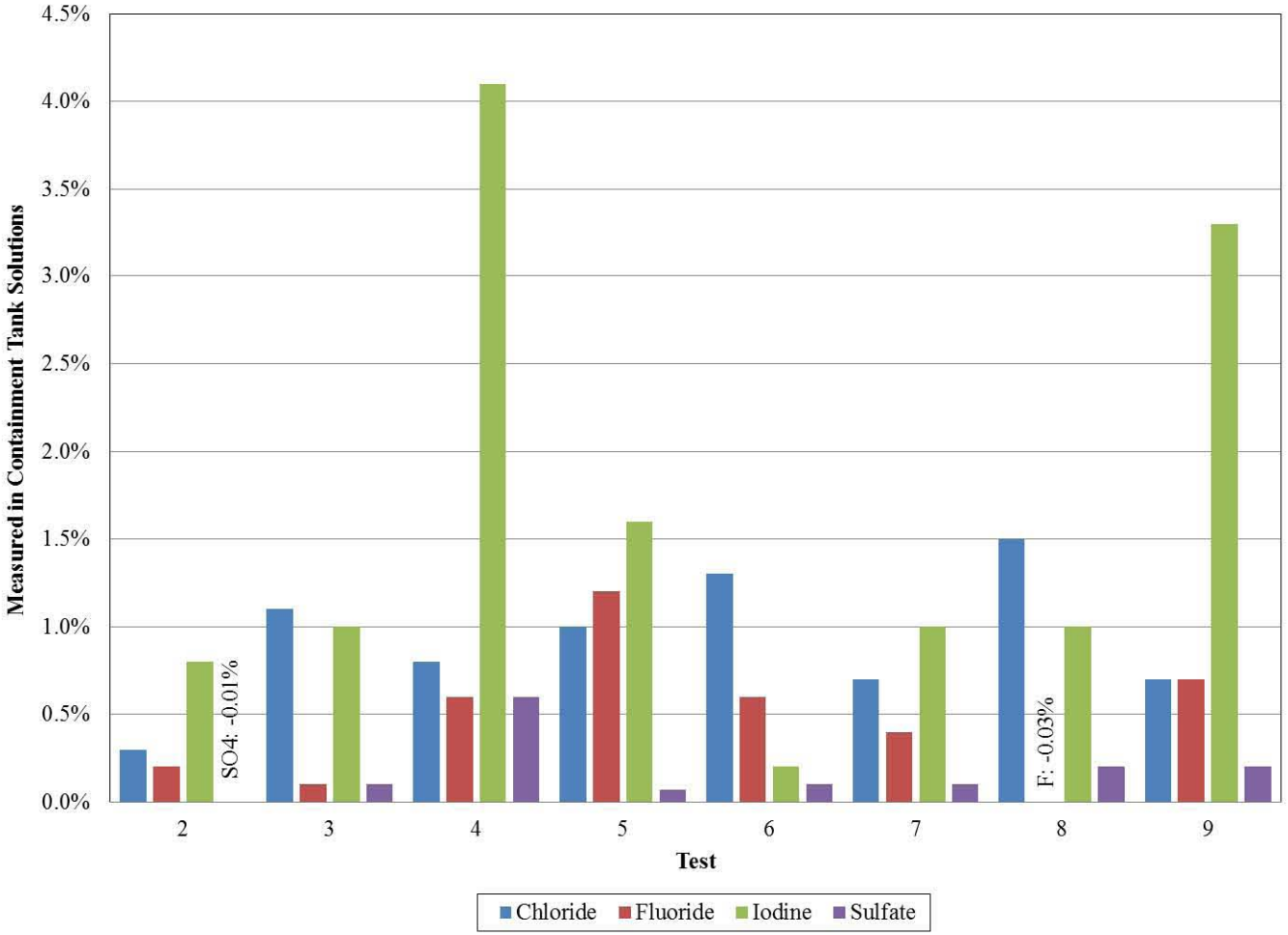


Figure 7.13. Halogens and sulfur measured in containment tank sampled at conclusion of tests.

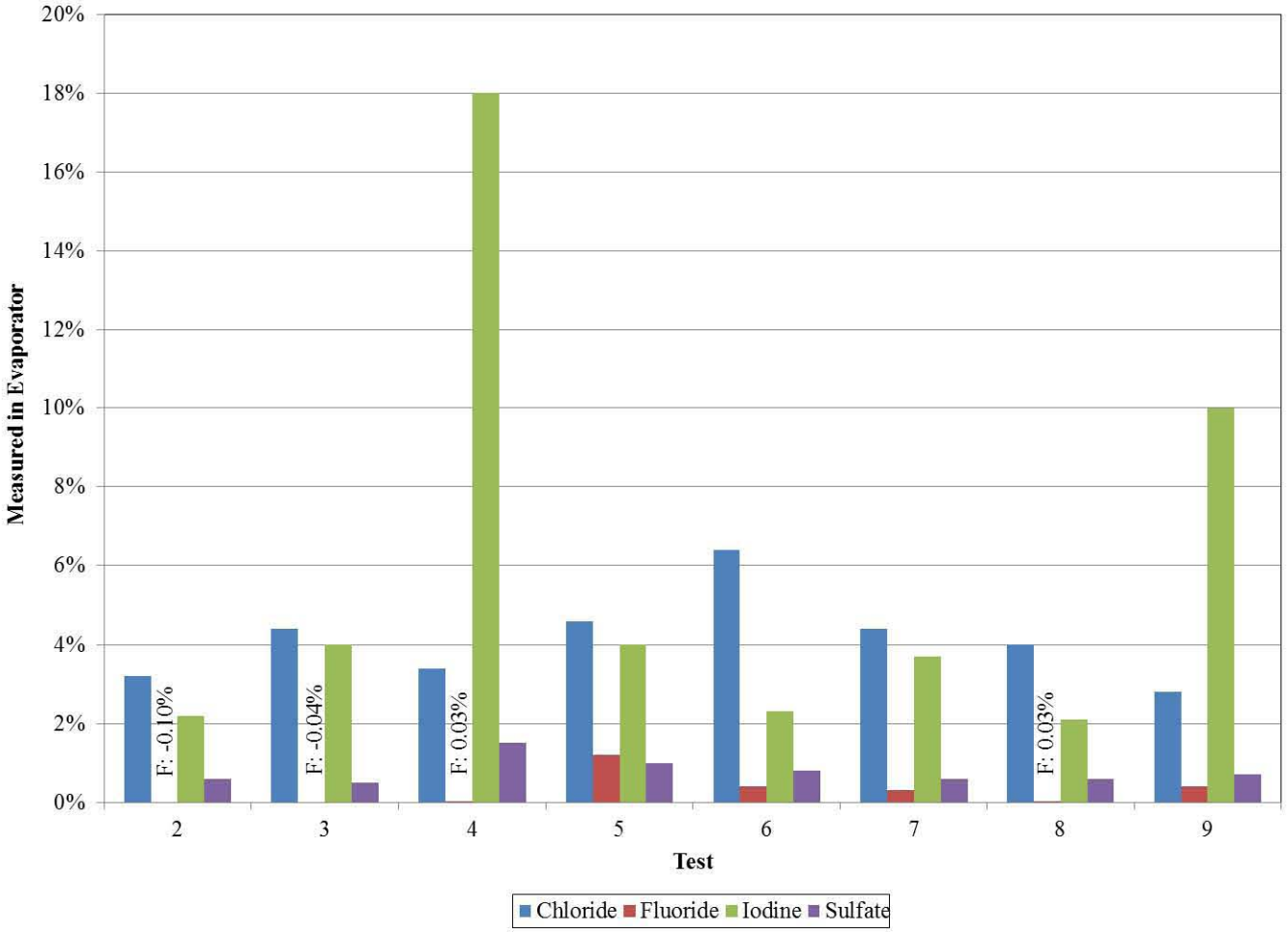


Figure 7.14. Halogens and sulfur measured in evaporator sampled at conclusion of tests.

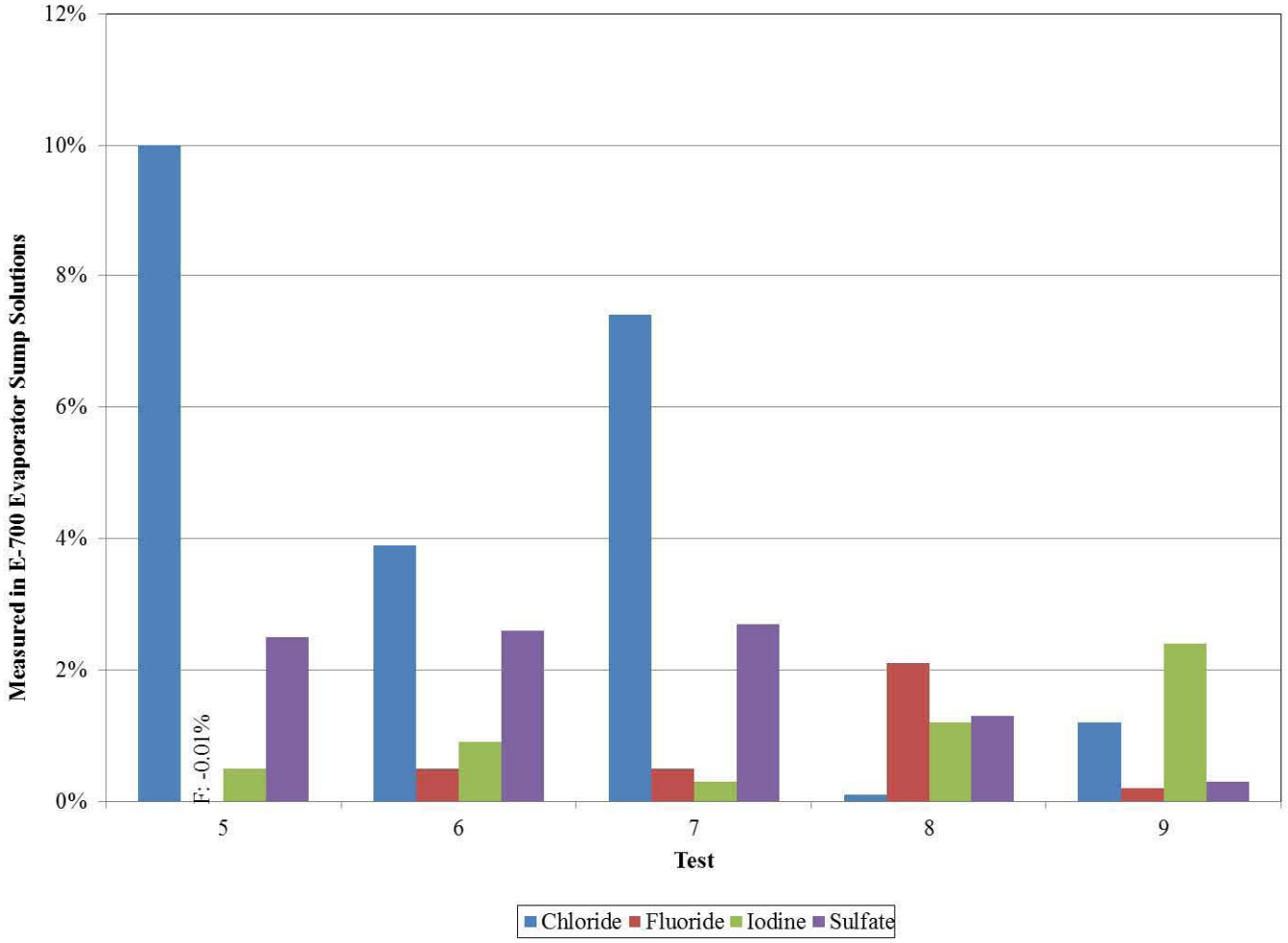


Figure 7.15. Halogens and sulfur measured in E-700 evaporator sampled at conclusion of tests.

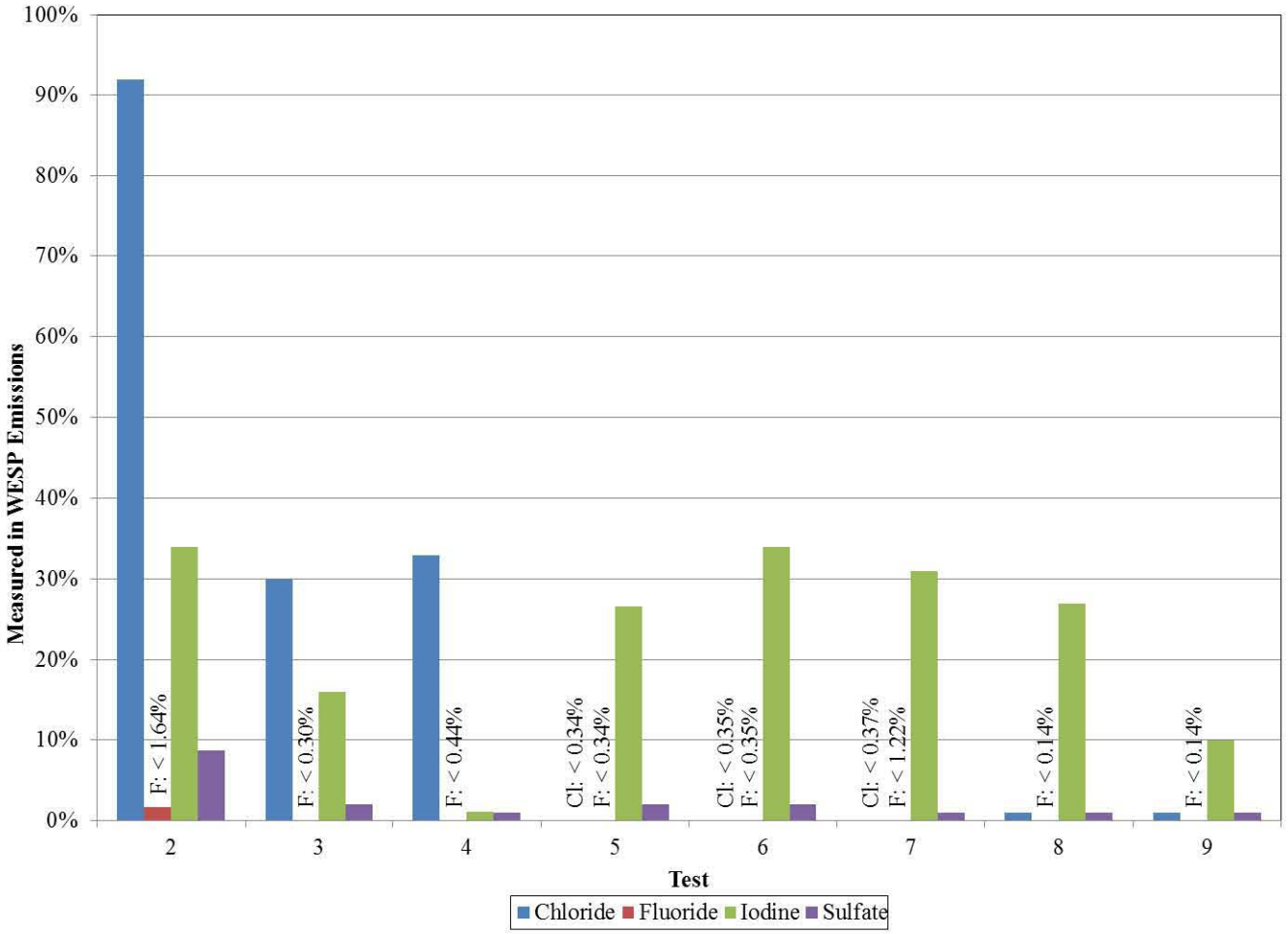


Figure 7.16. Halogens and sulfur measured in WESP emissions.

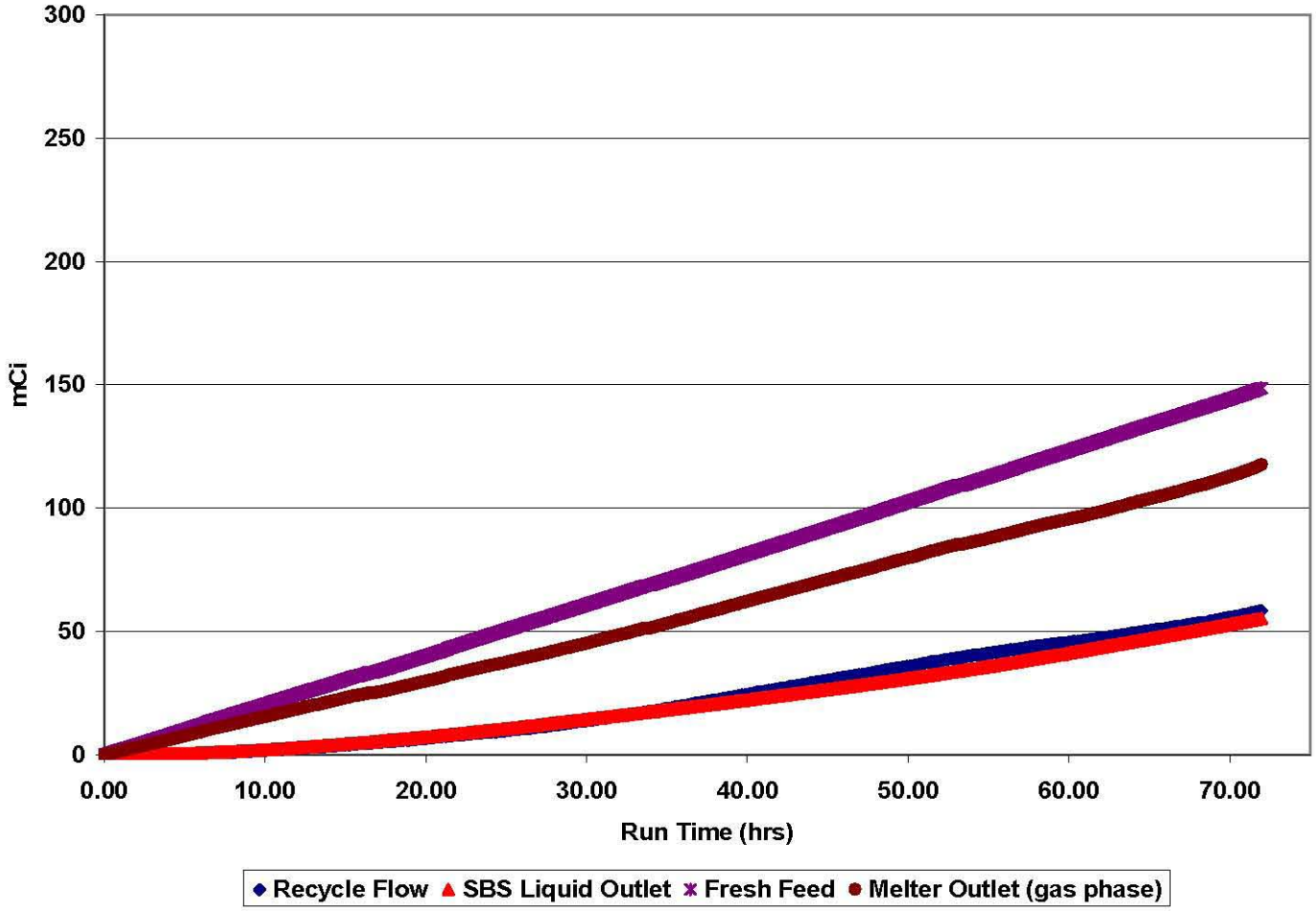


Figure 8.1. Flow of technetium through the system during Test 9.

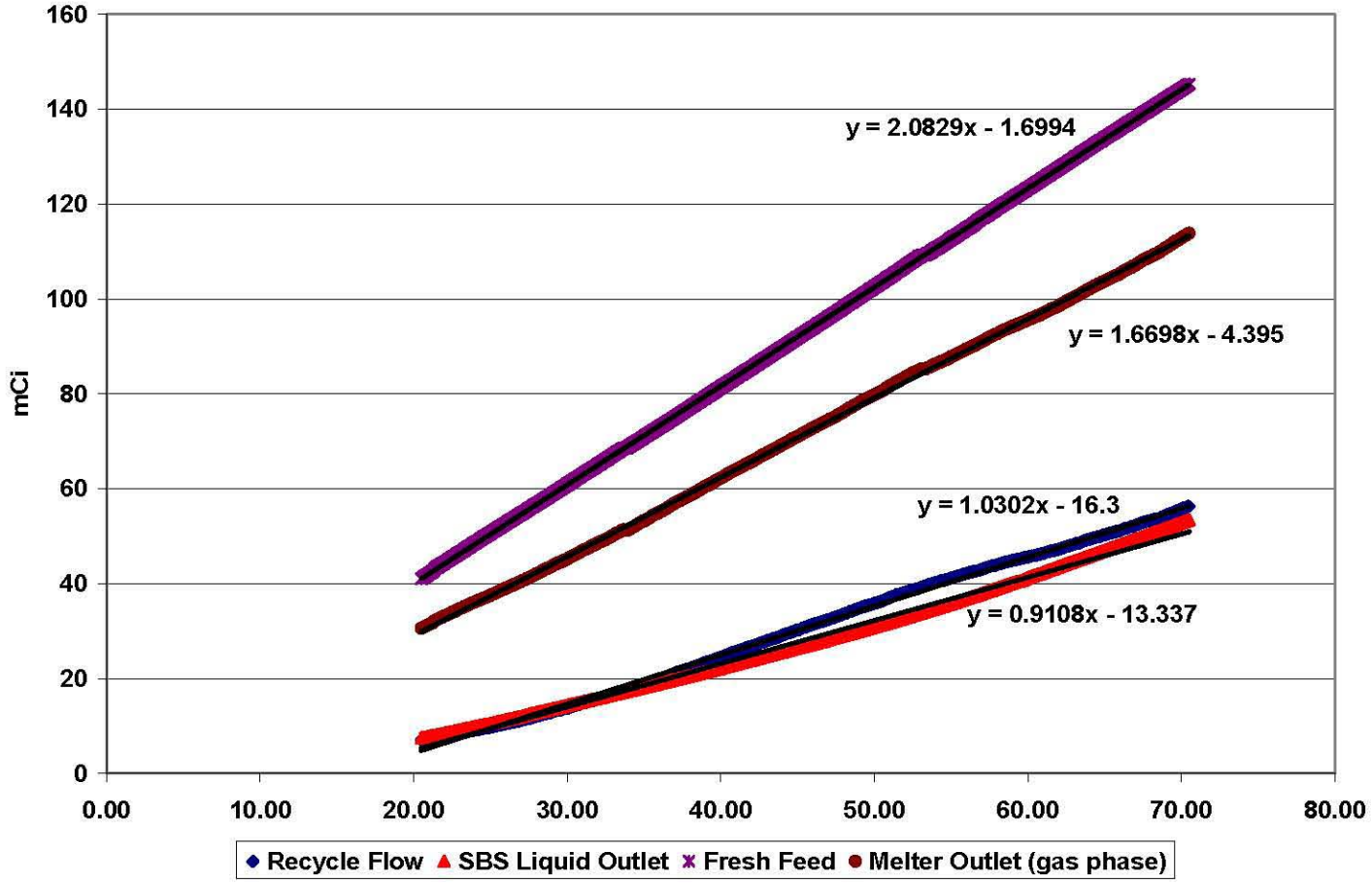


Figure 8.2. Flow of technetium through the system during Test 9, eliminating the initial transient portion of the test. A linear fit is added to the steady state portion of the test, where the slope of the curve is the flow rate of technetium.

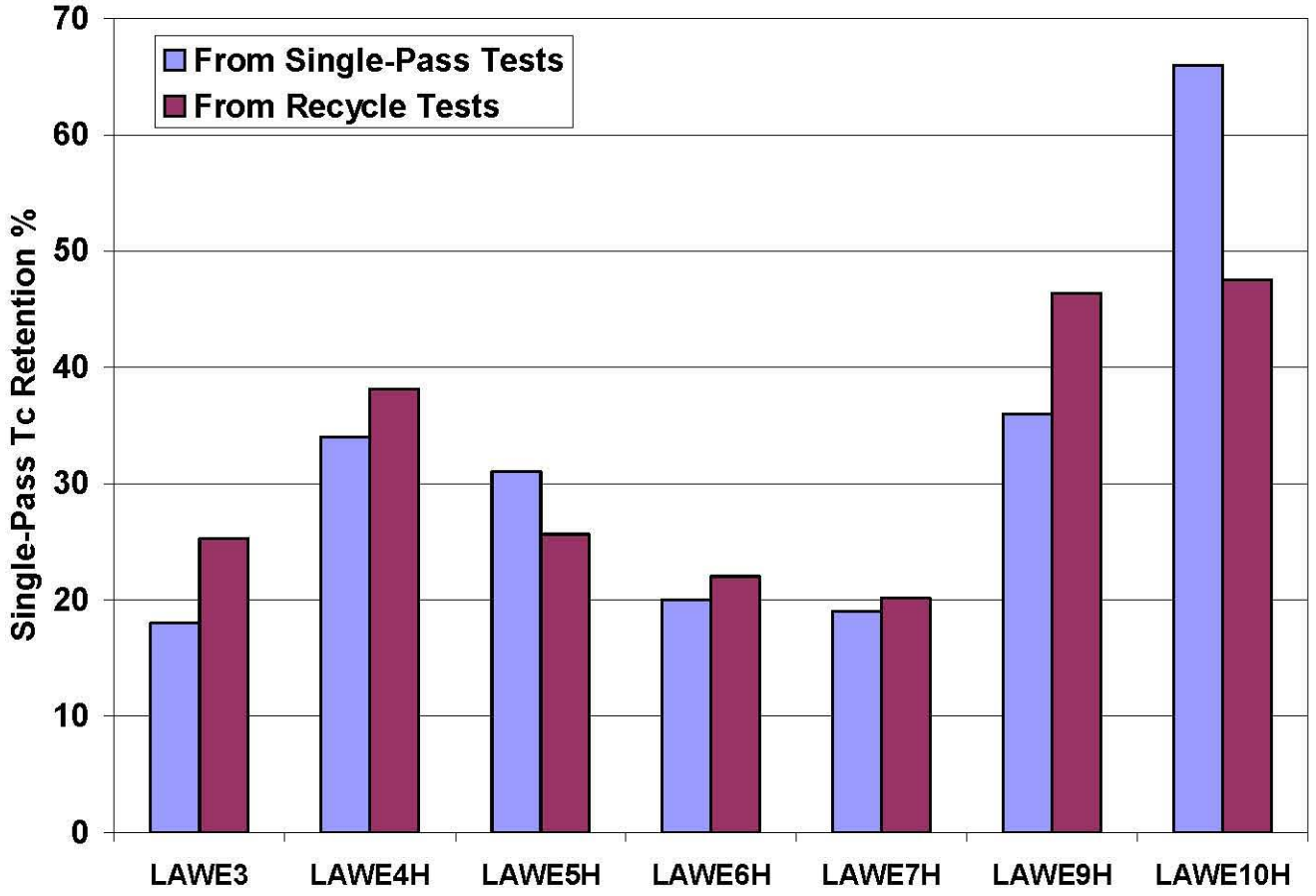


Figure 8.3. Comparison of single-pass technetium retentions in the melter determined on the DM10 melter systems with and without recycle.

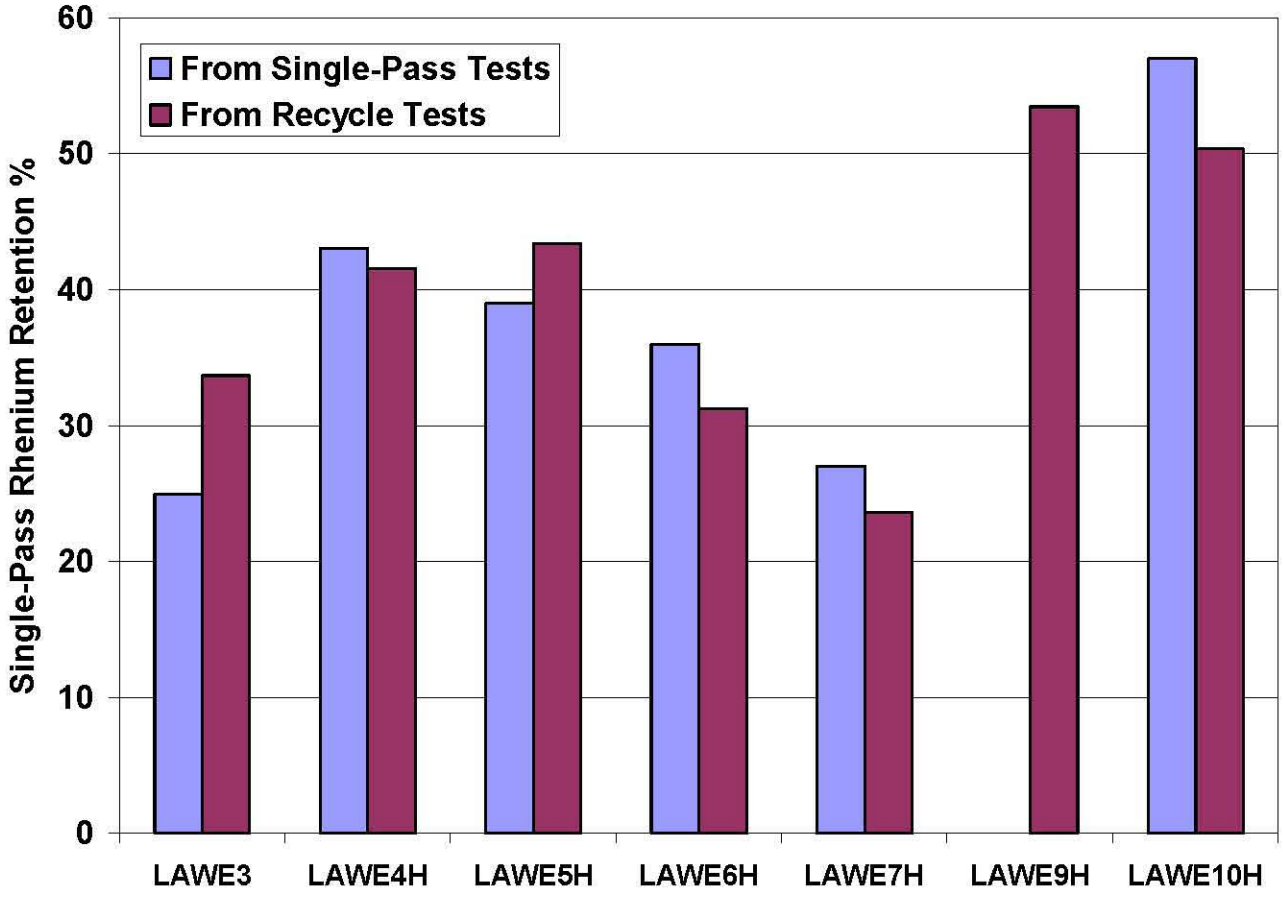


Figure 8.4. Comparison of single-pass rhenium retentions in the melter determined on the DM10 melter systems with and without recycle.

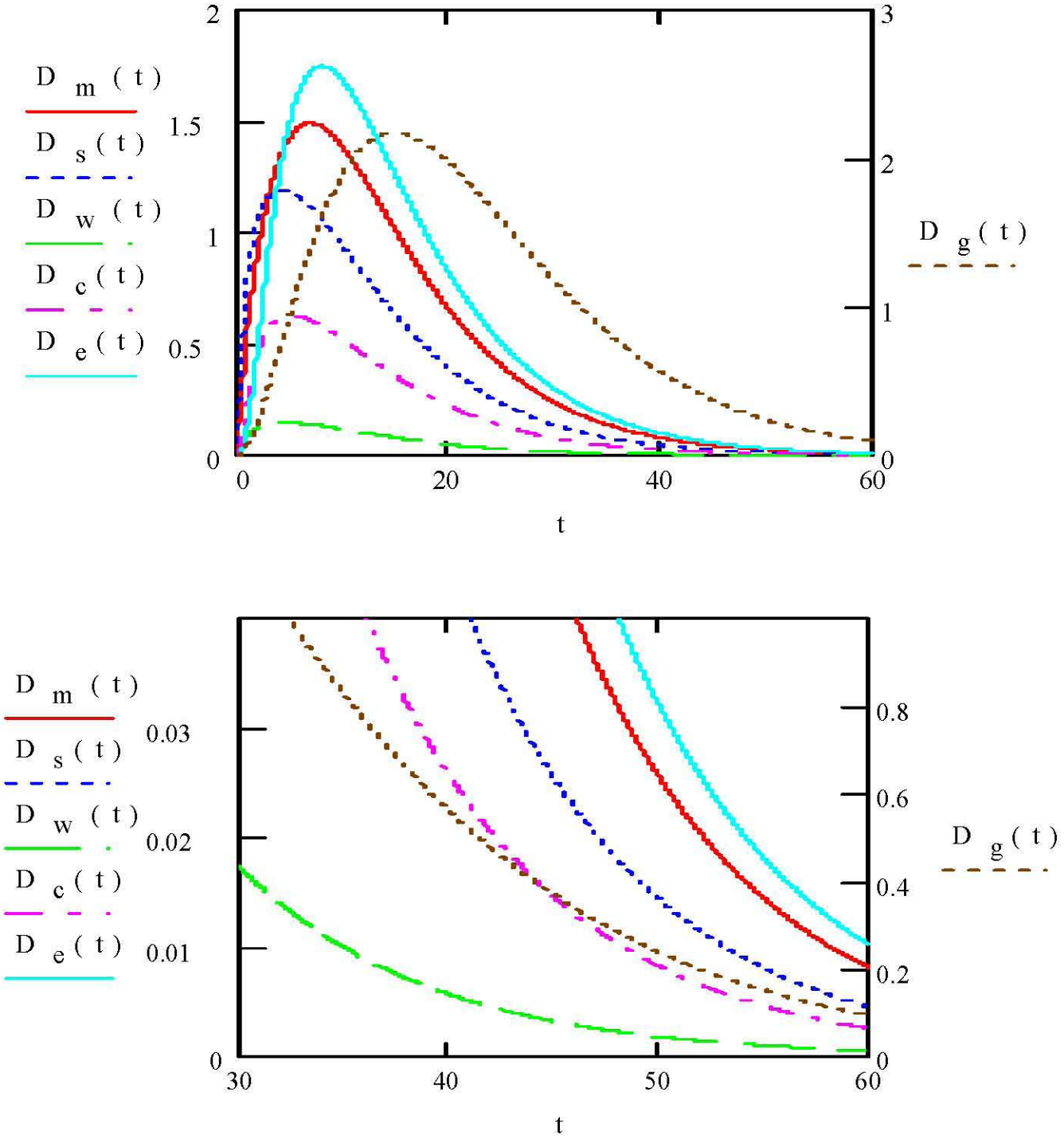


Figure 9.1. ^{99m}Tc activities (mCi) versus time (hours) calculated from DM10 process model. The subscripts in $D_i(t)$ refer to the various sumps as follows: m = melter; s=SBS; w=WESP; c=effluent collection tank; e=evaporator; g=cumulative in all discharged glass. Bottom figure is a blow-up of a portion of the top figure.

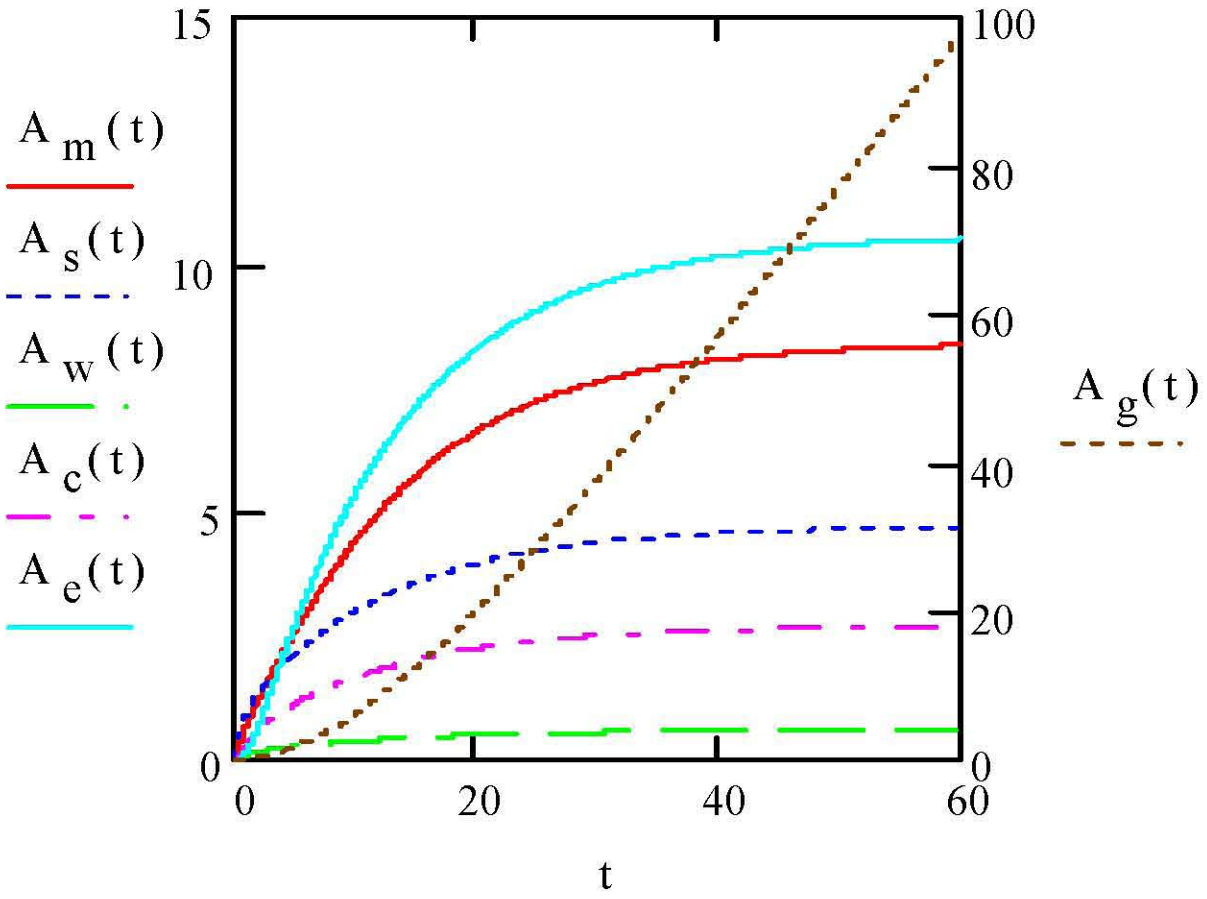


Figure 9.2. ^{99}Tc activities (mCi) versus time (hours) calculated from DM10 process model. Results are the same as for Figure 9.1 except that the half-life is now assumed to be very long compared to the test duration, so there is essentially no radioactive decay. The subscripts in $A_i(t)$ refer to the various sumps as follows: m = melter; s=SBS; w=WESP; c=effluent collection tank; e=evaporator; g=cumulative in all discharged glass.

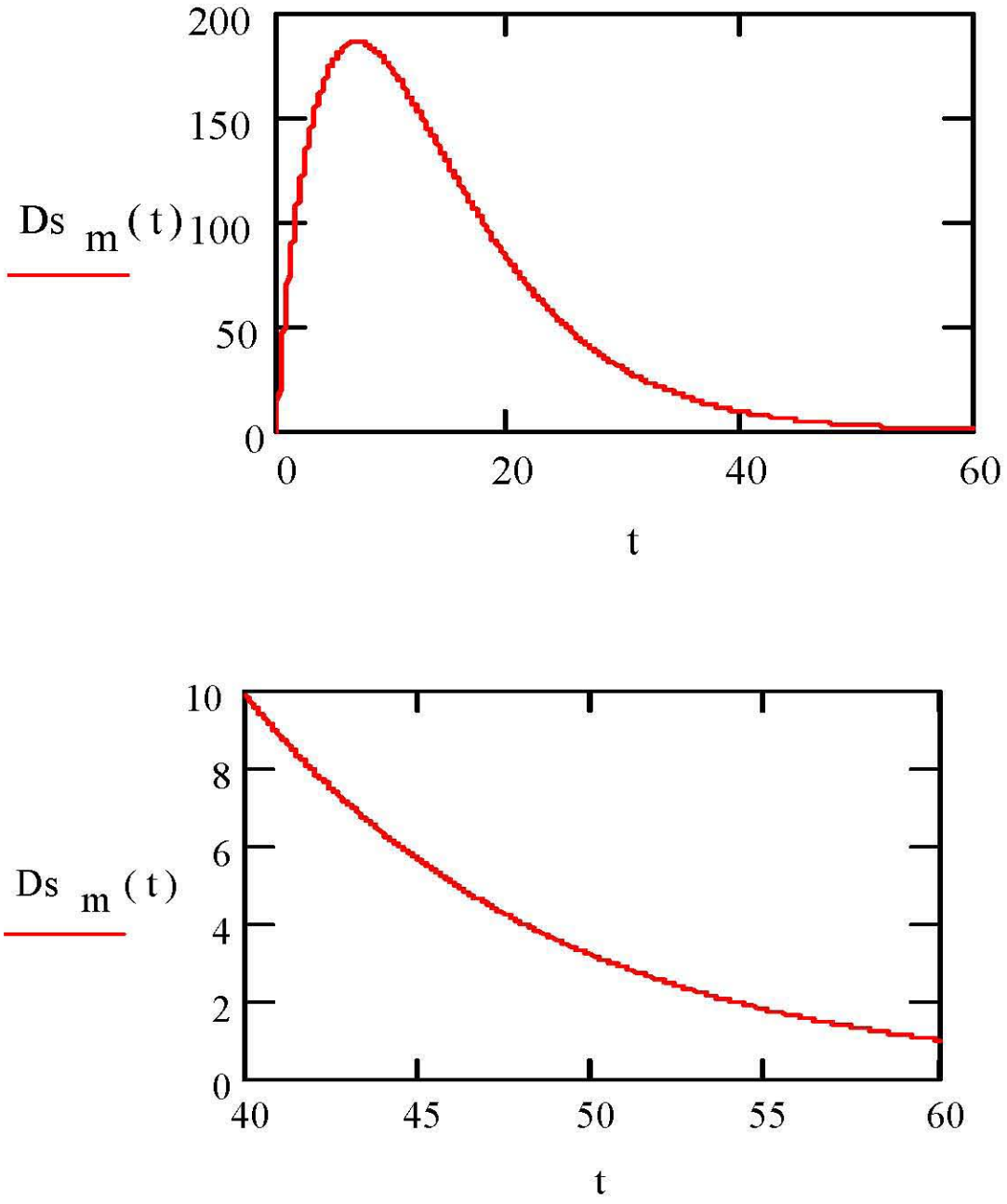


Figure 9.3. ^{99m}Tc specific activity (nCi/g) in discharged product glass versus time of discharge (hours) calculated from DM10 process model. Bottom figure is a blow-up of a portion of the top figure.

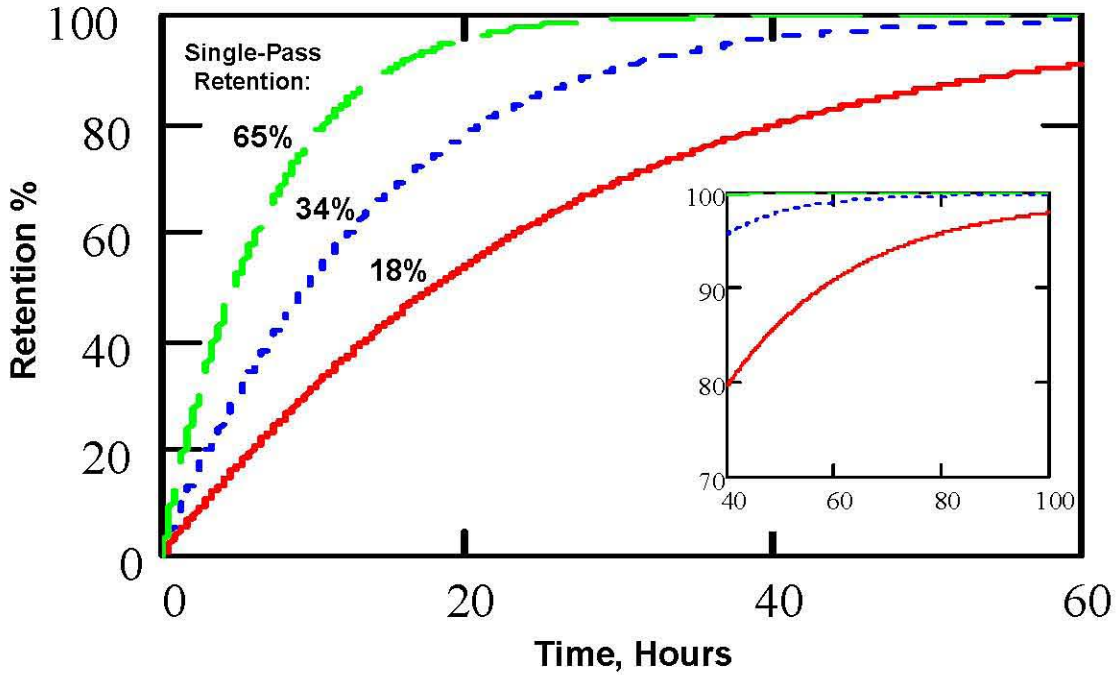


Figure 9.4.a. Percentage of ^{99m}Tc in the melter feed (excluding that in the recycle stream) that is retained in the discharged product glass versus time of discharge (hours) calculated from DM10 process model for three different single-pass retention values. Inset figure is a blow-up of a portion at longer times. Model uses parameters assumed during initial system design development.

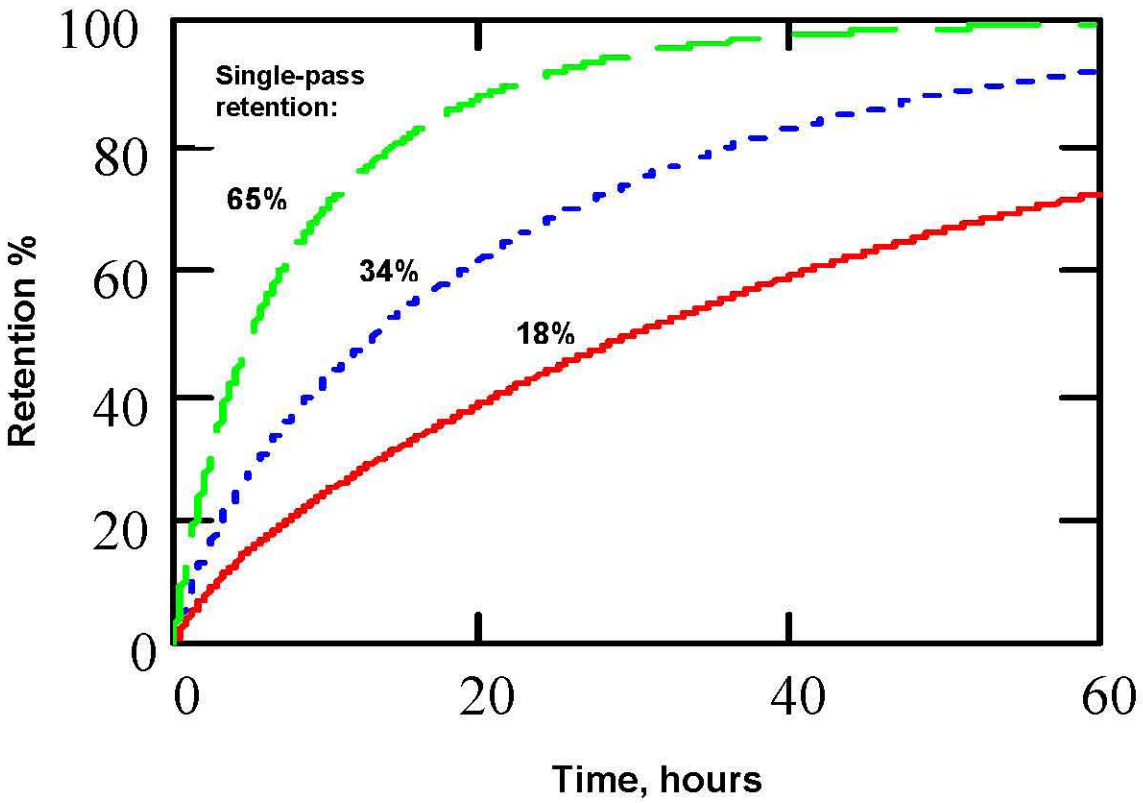


Figure 9.4.b. Percentage of ^{99m}Tc in the melter feed (excluding that in the recycle stream) that is retained in the discharged product glass versus time of discharge (hours) calculated from DM10 process model for three different single-pass retention values. Model uses as-built system design parameters.

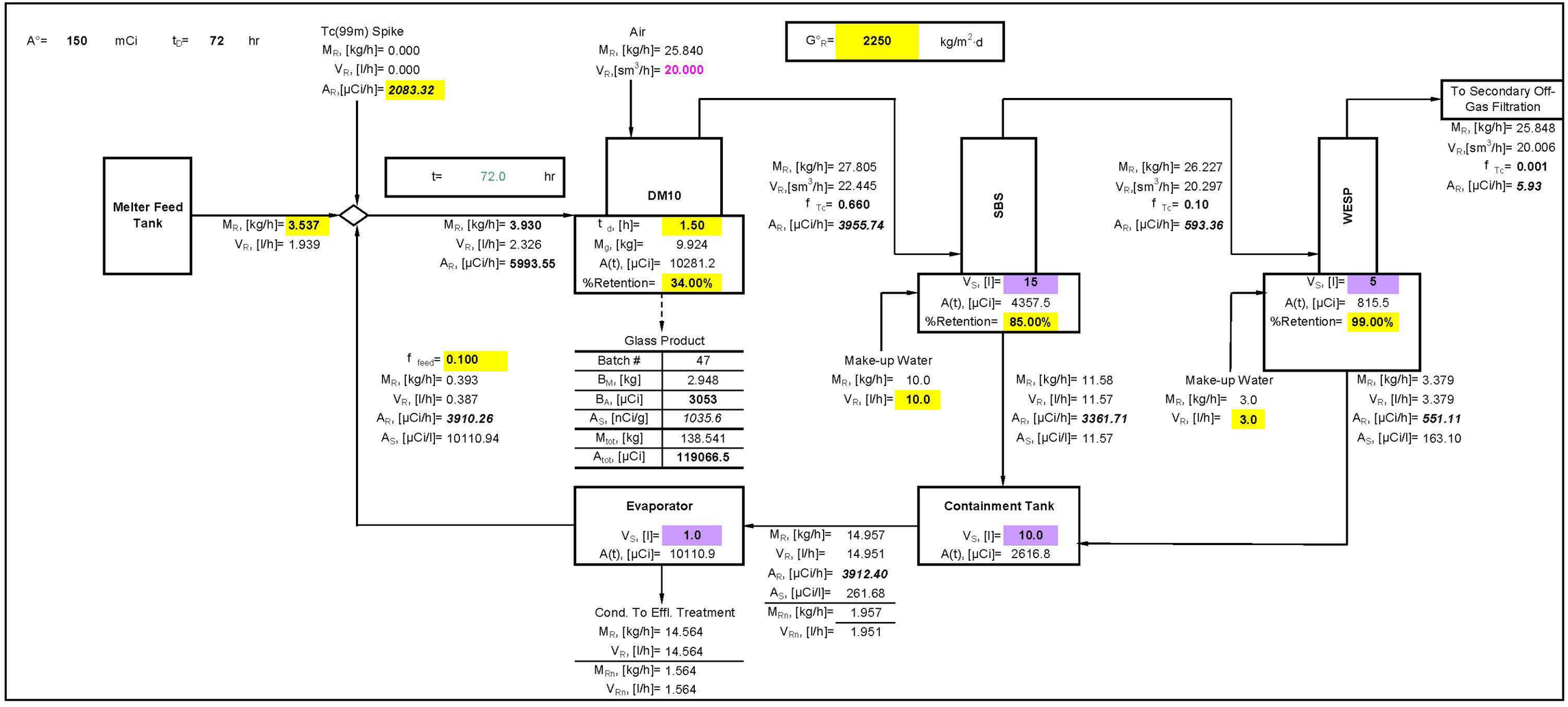


Figure 9.5.a DM10 model driver sheet with parameter values typical of those explored during system design.

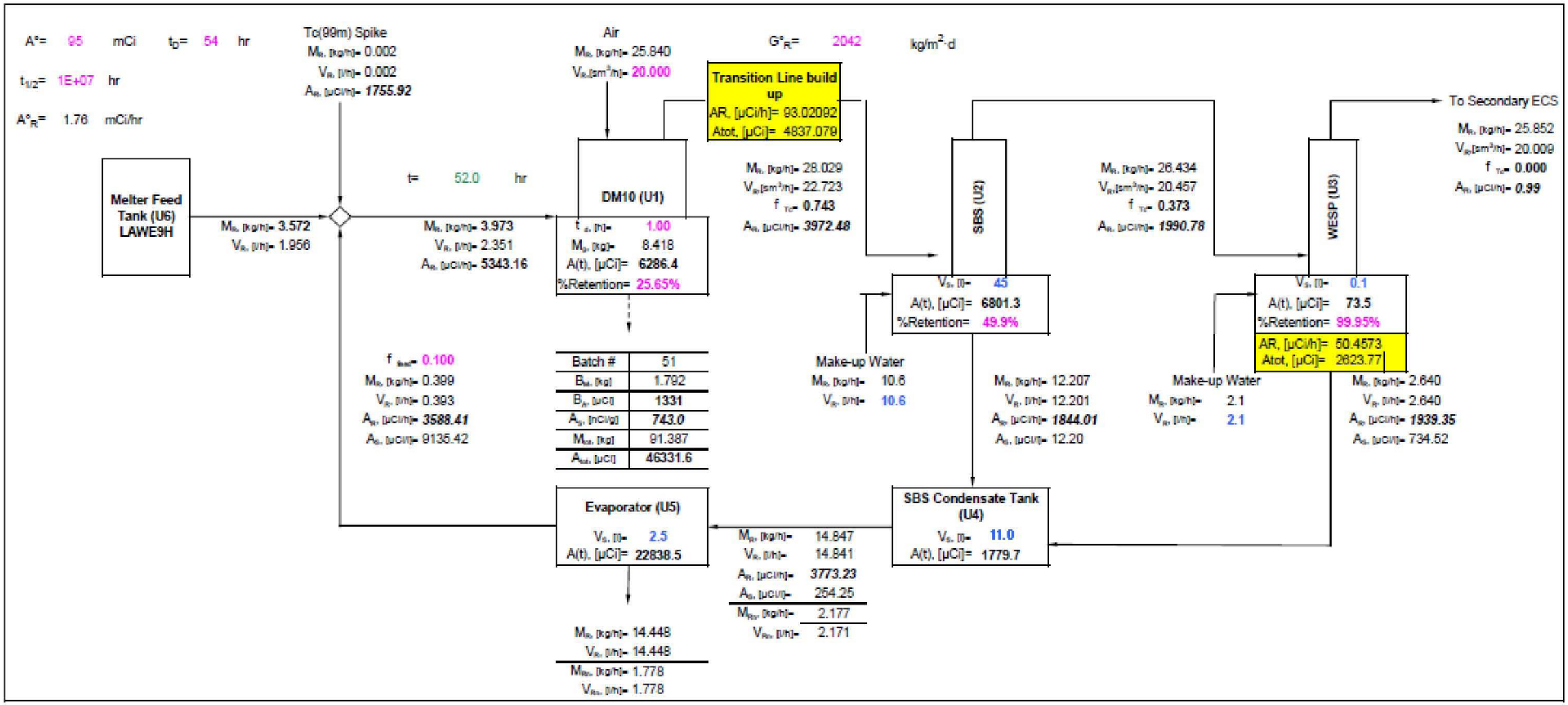


Figure 9.5.b DM10 model driver sheet with transition line and WESP holdup and Test 3 operating parameters.

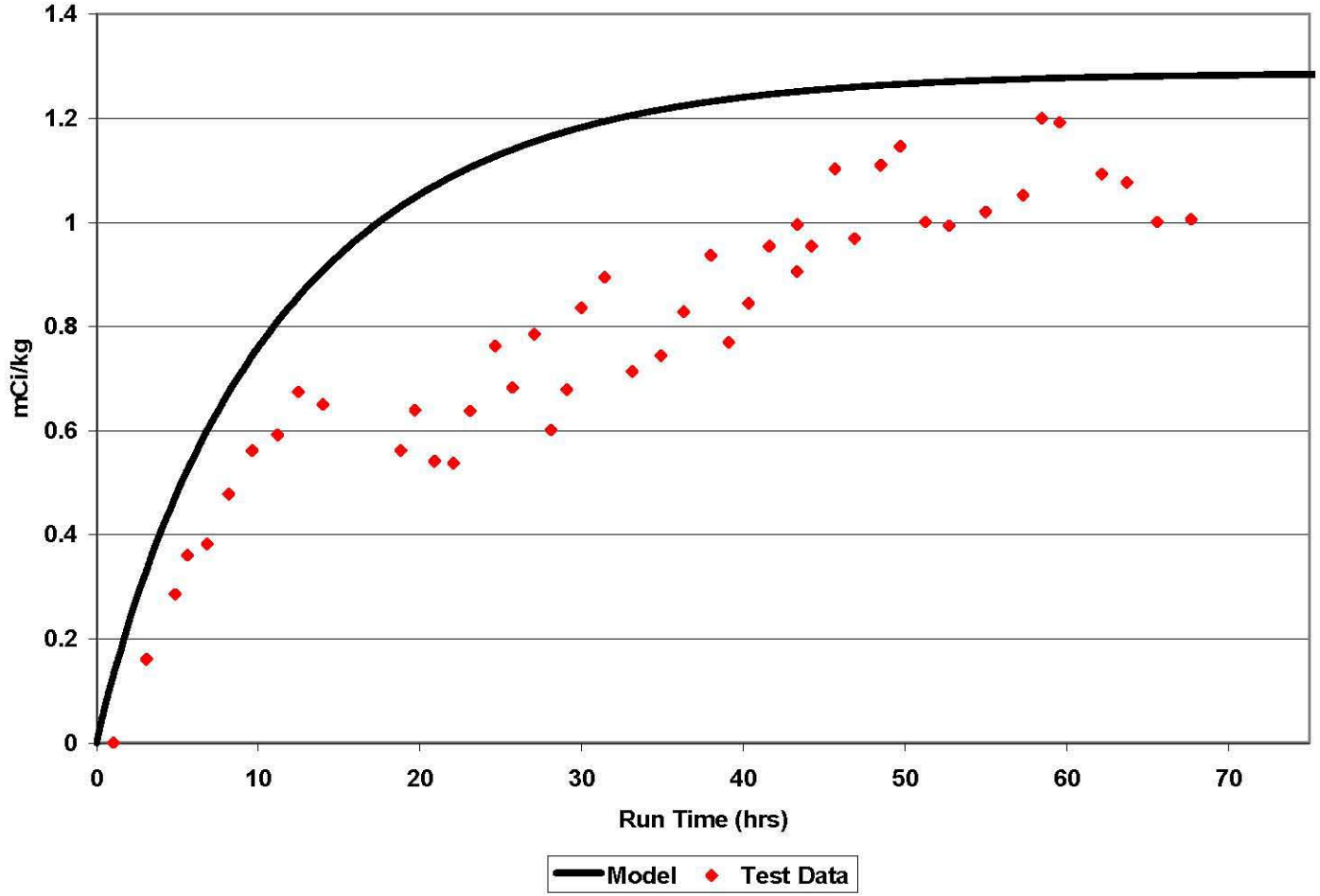


Figure 9.6.a. Technetium concentration in the glass during Test 2, the predicted concentrations and the concentrations in the discharged glass samples.

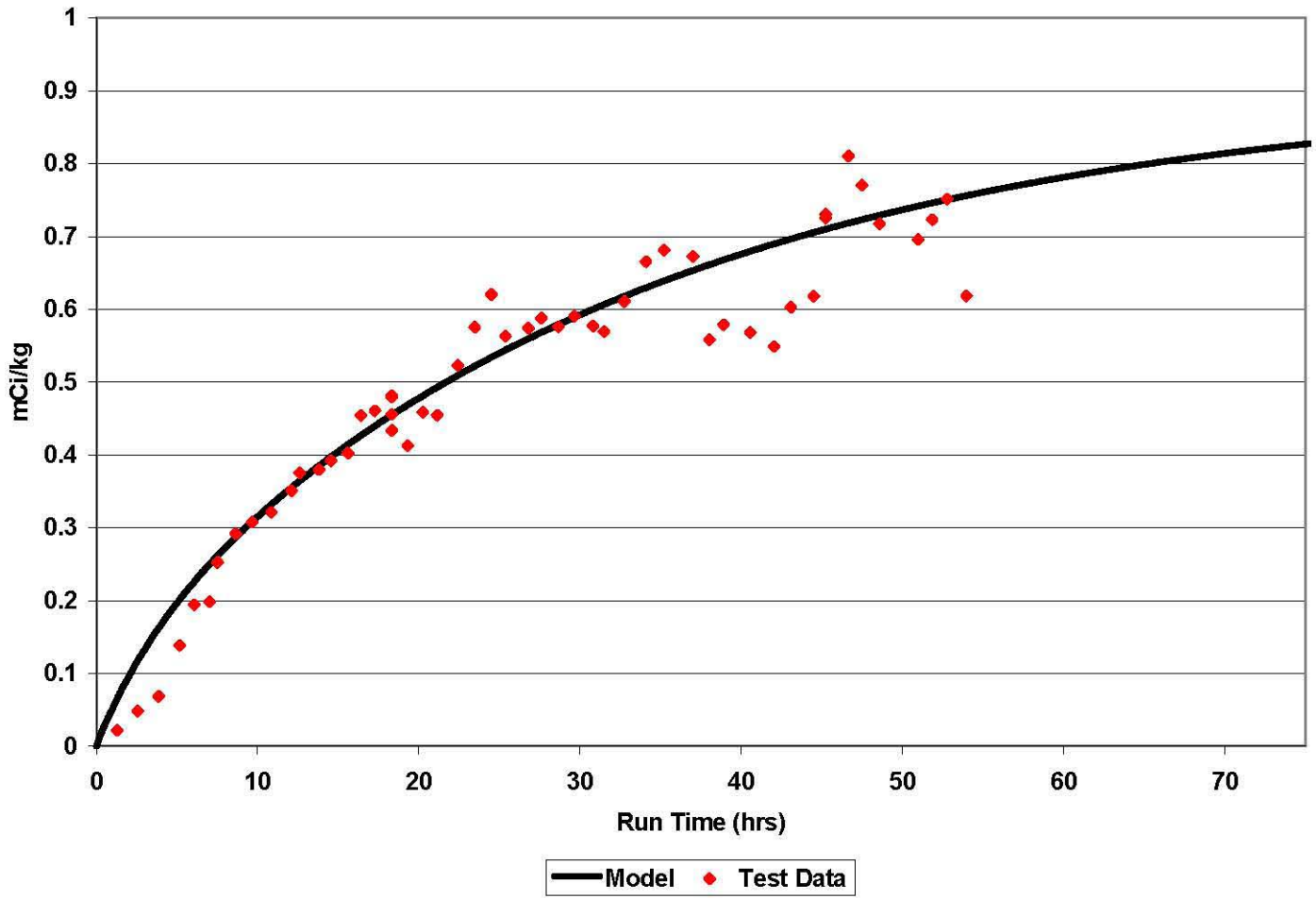


Figure 9.6.b. Technetium concentration in the glass during Test 3, the predicted concentrations and the concentrations in the discharged glass samples.

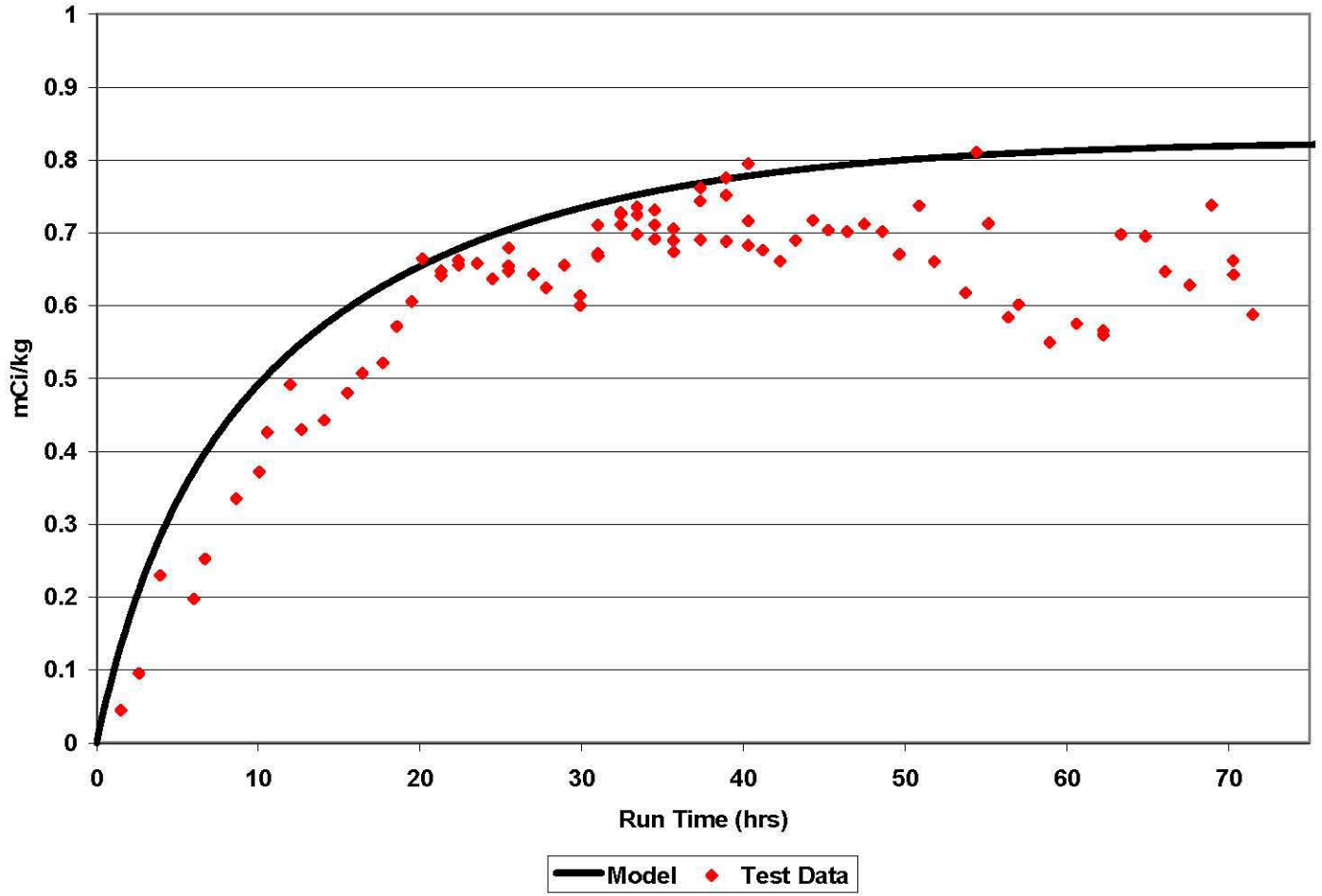


Figure 9.6.c. Technetium concentration in the glass during Test 4, the predicted concentrations and the concentrations in the discharged glass samples.

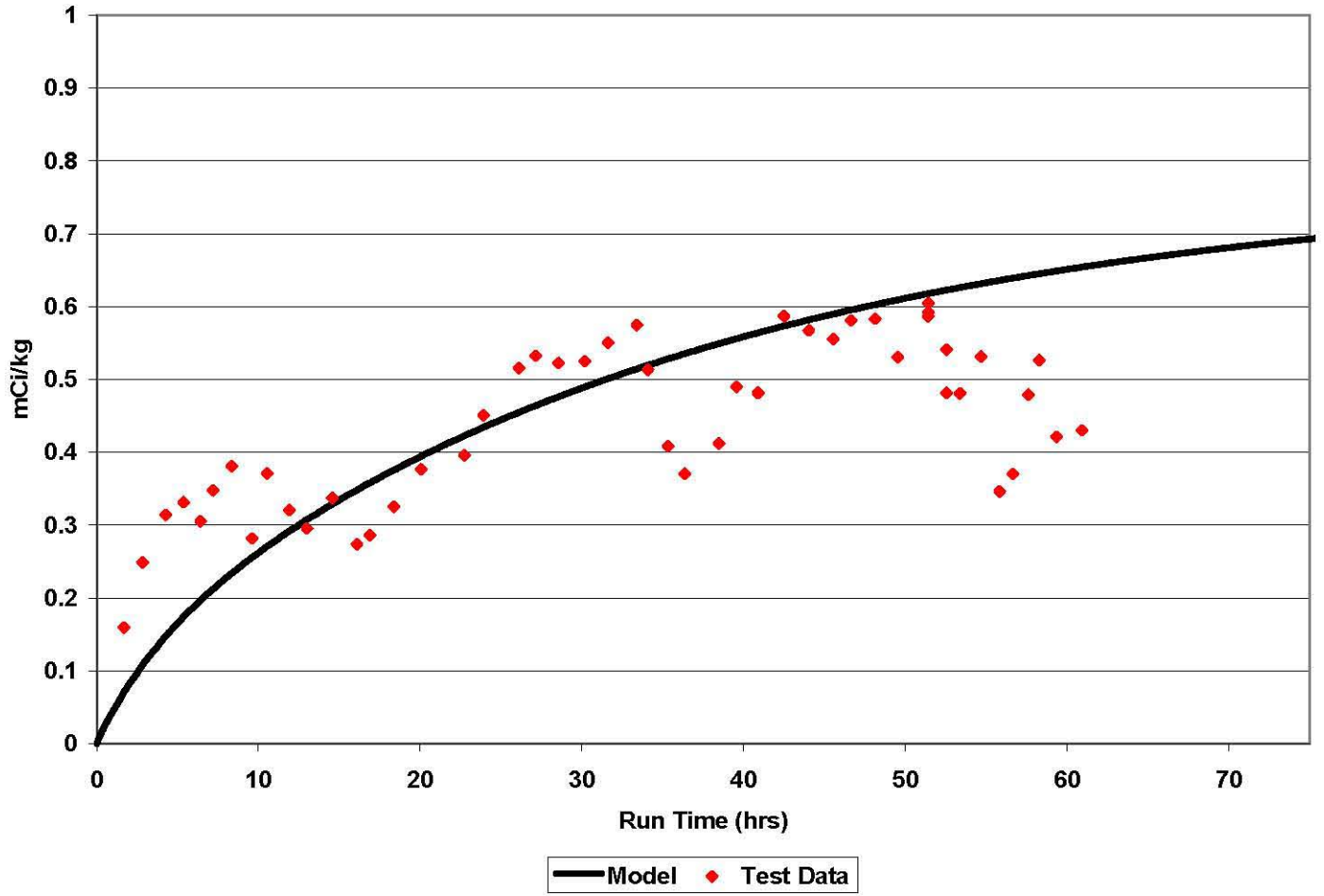


Figure 9.6.d. Technetium concentration in the glass during Test 5, the predicted concentrations and the concentrations in the discharged glass samples.

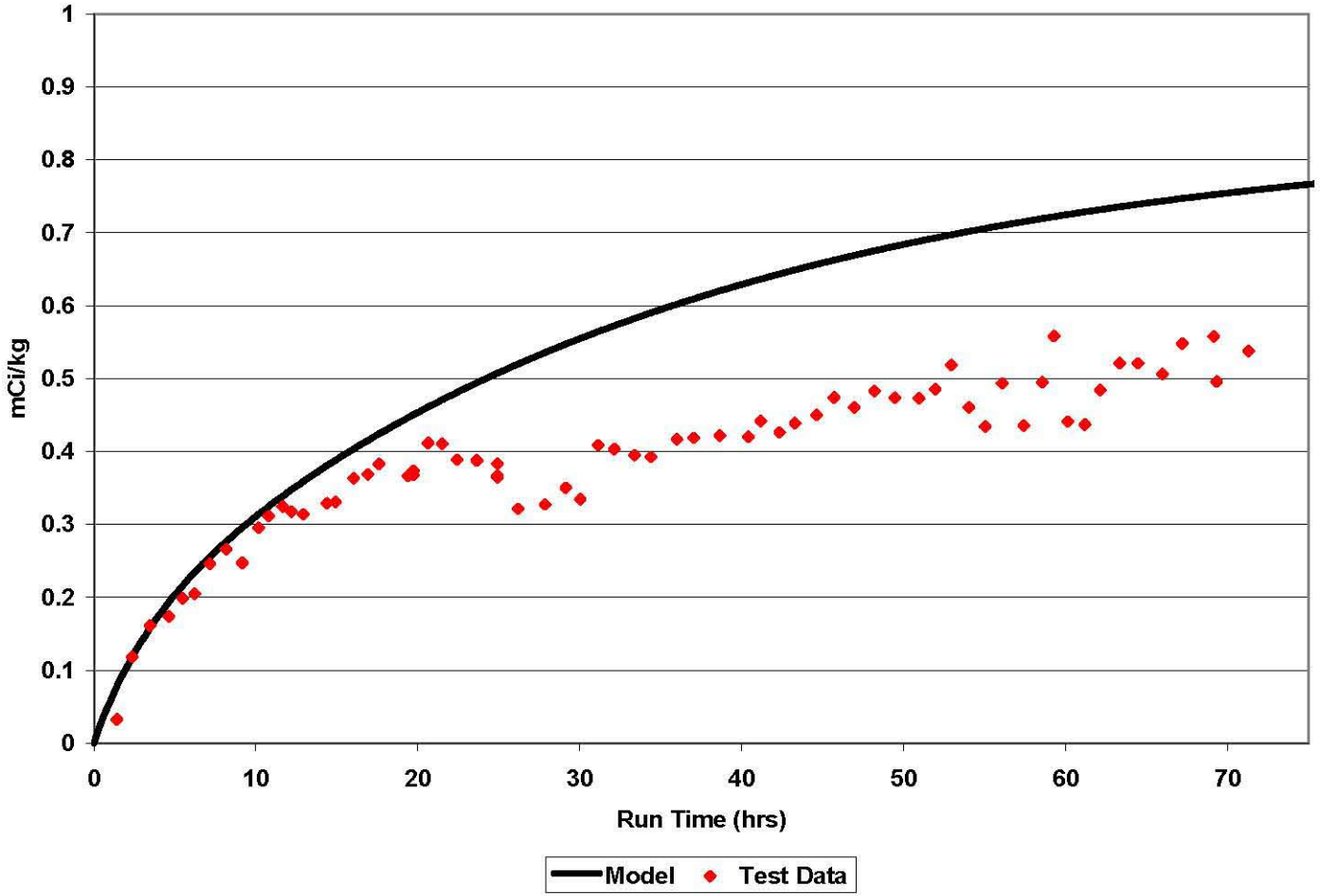


Figure 9.6.e. Technetium concentration in the glass during Test 6, the predicted concentrations and the concentrations in the discharged glass samples.

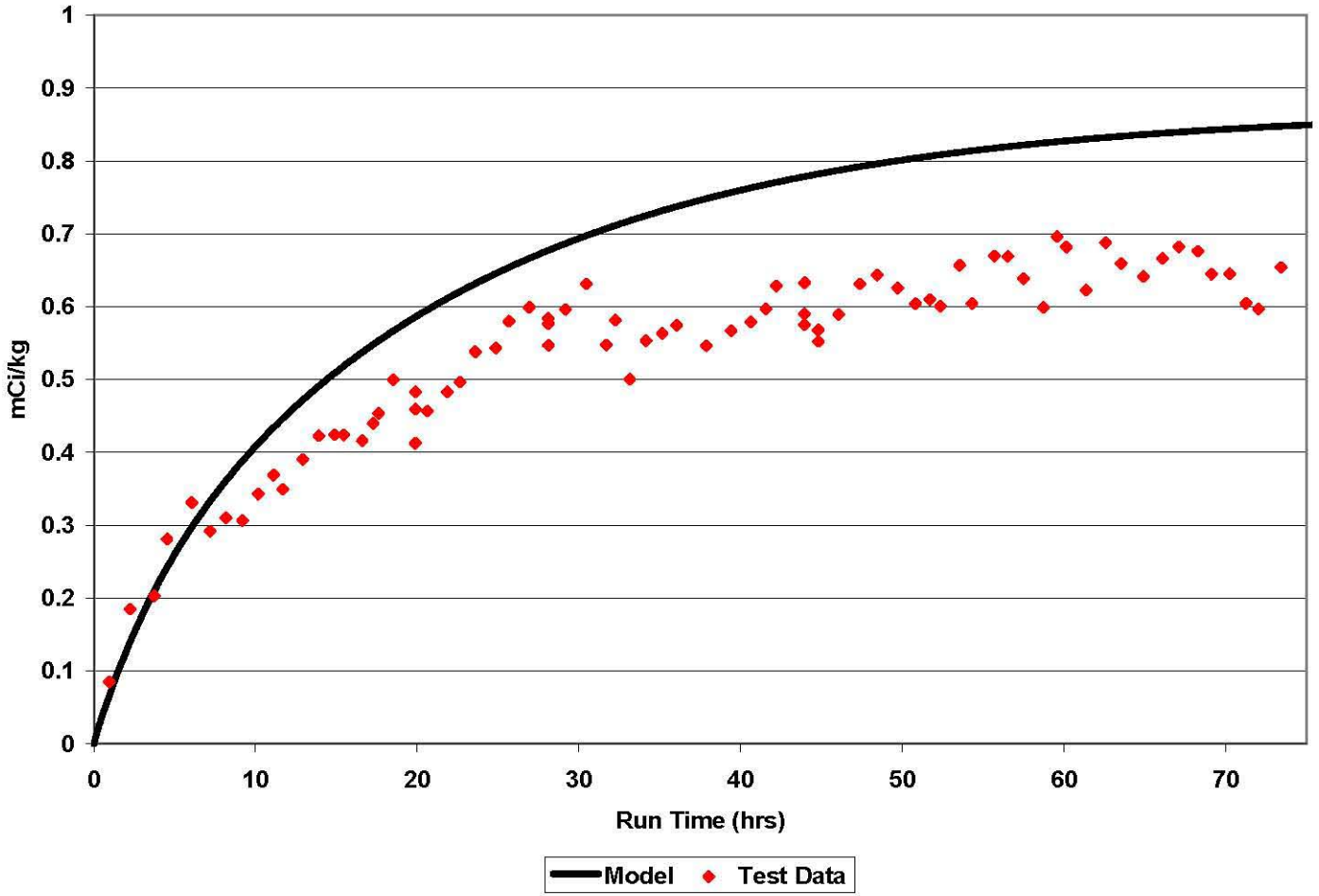


Figure 9.6.f. Technetium concentration in the glass during Test 7, the predicted concentrations and the concentrations in the discharged glass samples.

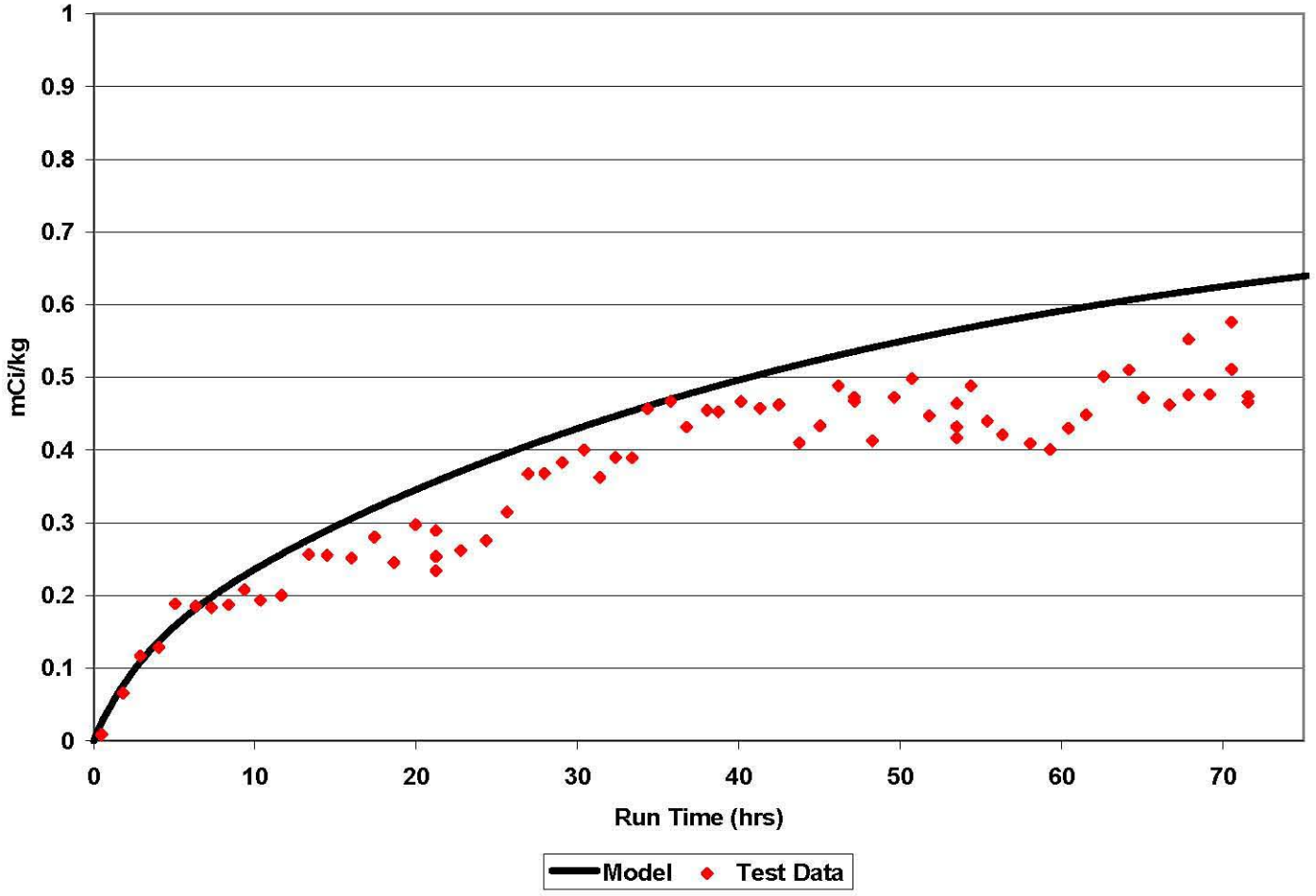


Figure 9.6.g. Technetium concentration in the glass during Test 8, the predicted concentrations and the concentrations in the discharged glass samples.

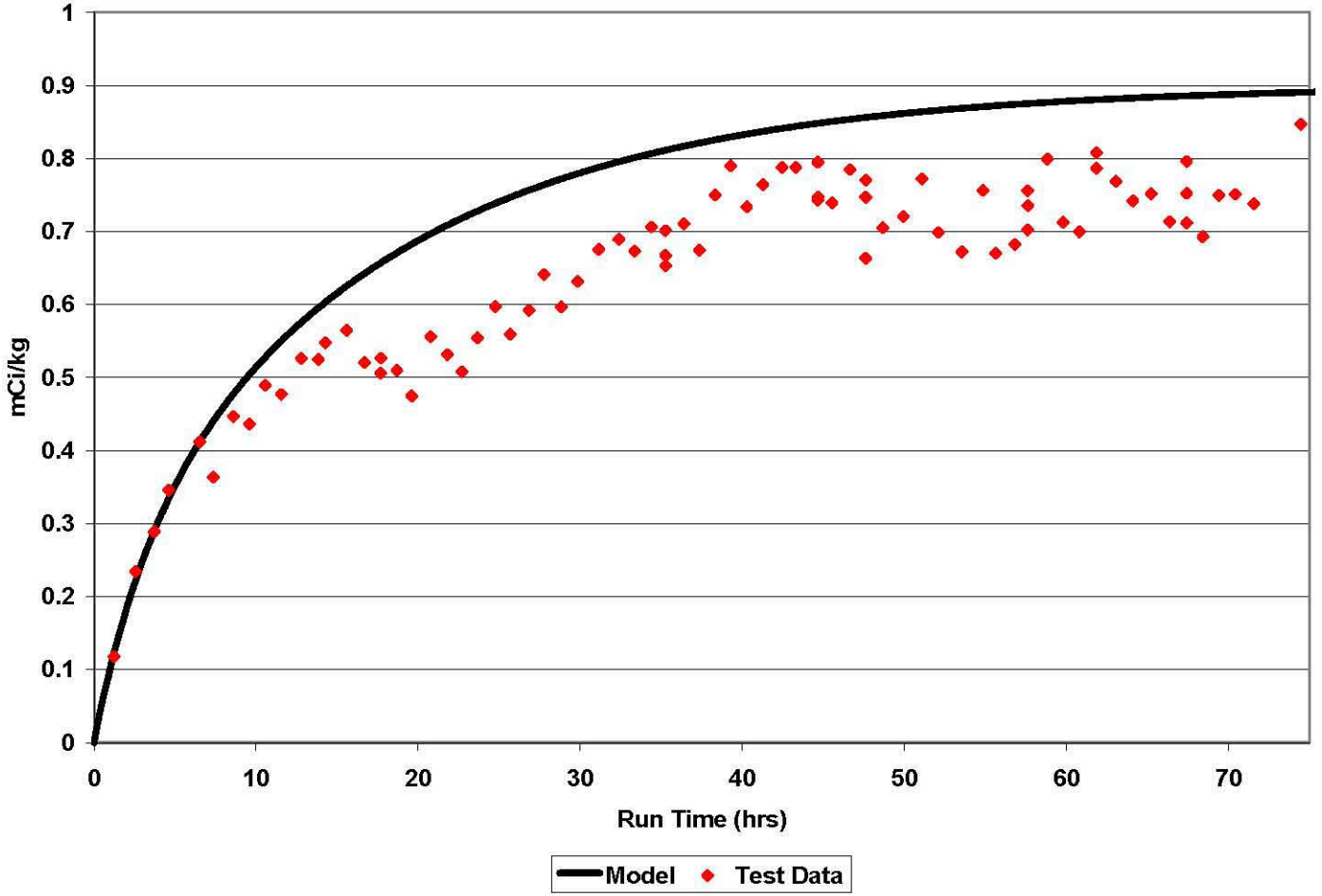


Figure 9.6.h. Technetium concentration in the glass during Test 9, the predicted concentrations and the concentrations in the discharged glass samples.

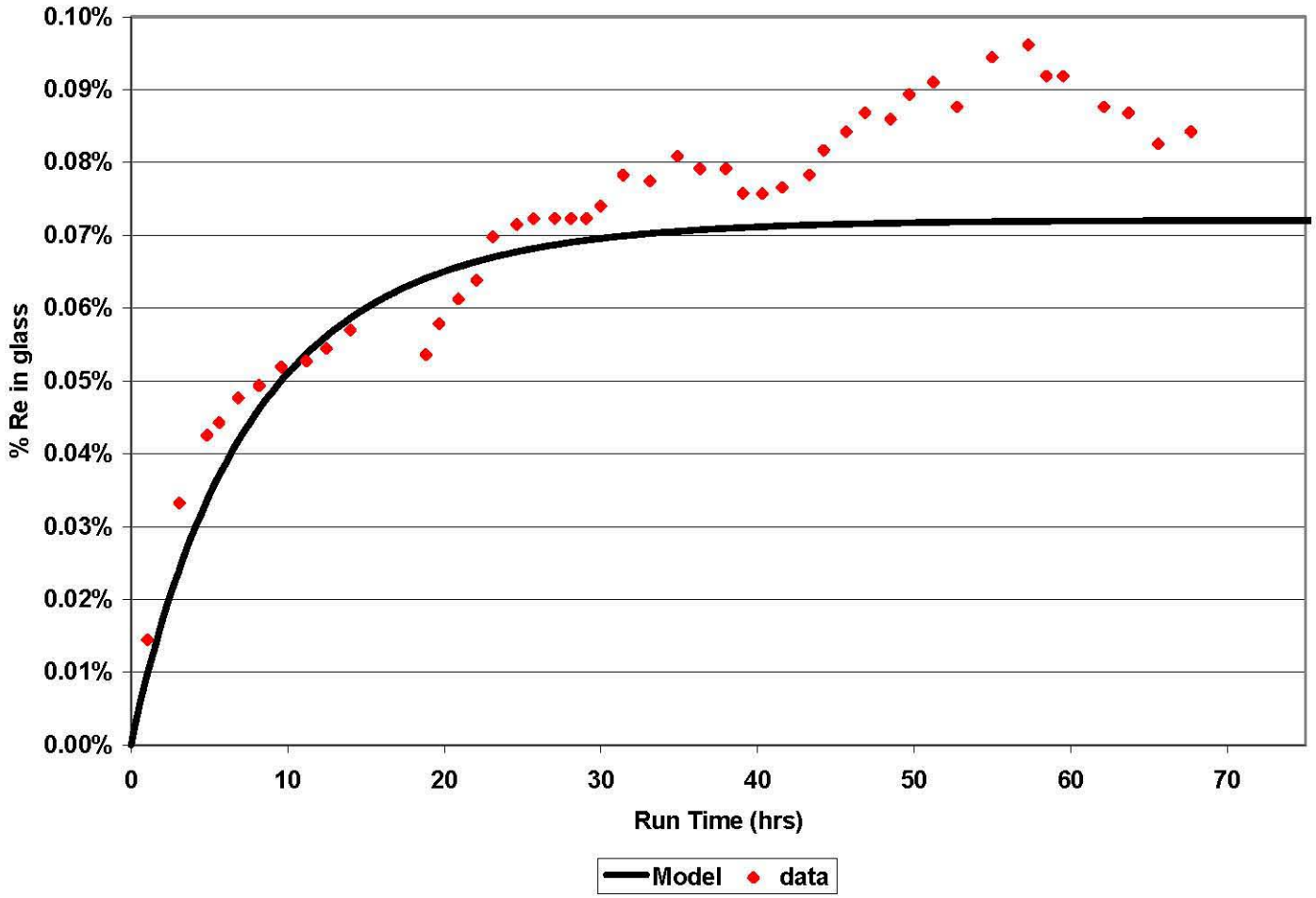


Figure 9.7.a. Rhenium weight percent in the glass during Test 2, the predicted concentrations and the concentrations in the discharged glass samples.

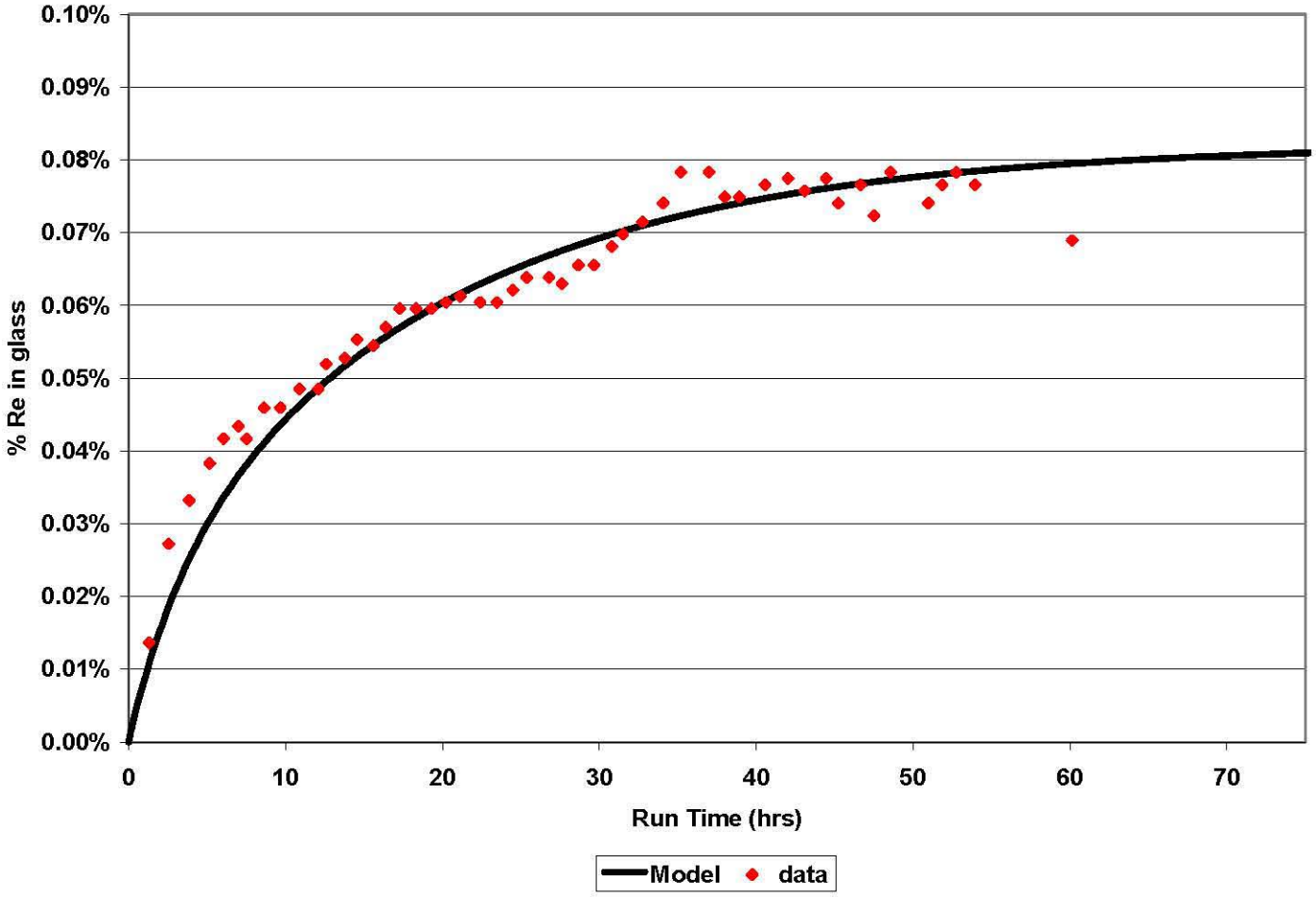


Figure 9.7.b. Rhenium weight percent in the glass during Test 3, the predicted concentrations and the concentrations in the discharged glass samples.

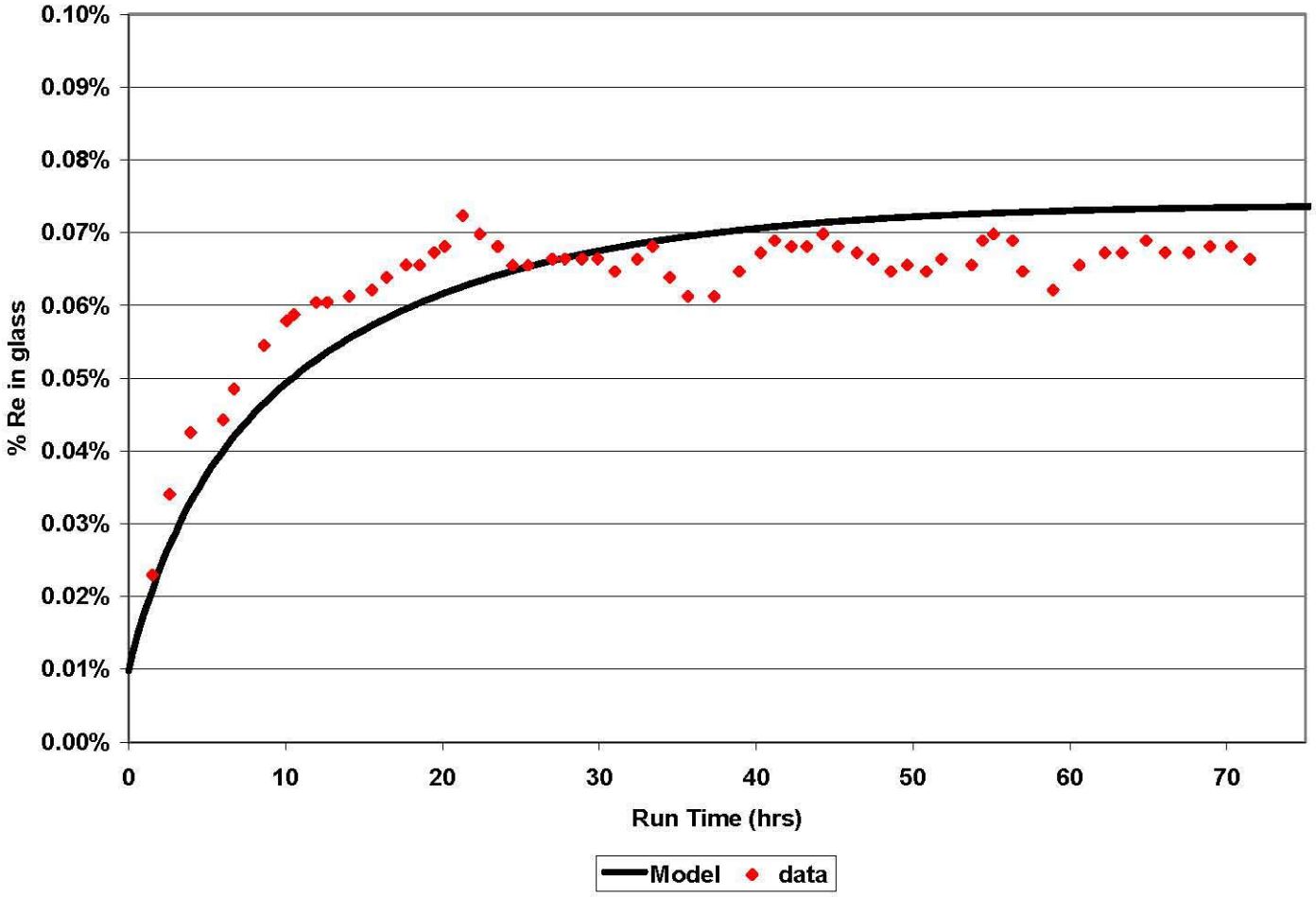


Figure 9.7.c. Rhenium weight percent in the glass during Test 4, the predicted concentrations and the concentrations in the discharged glass samples.

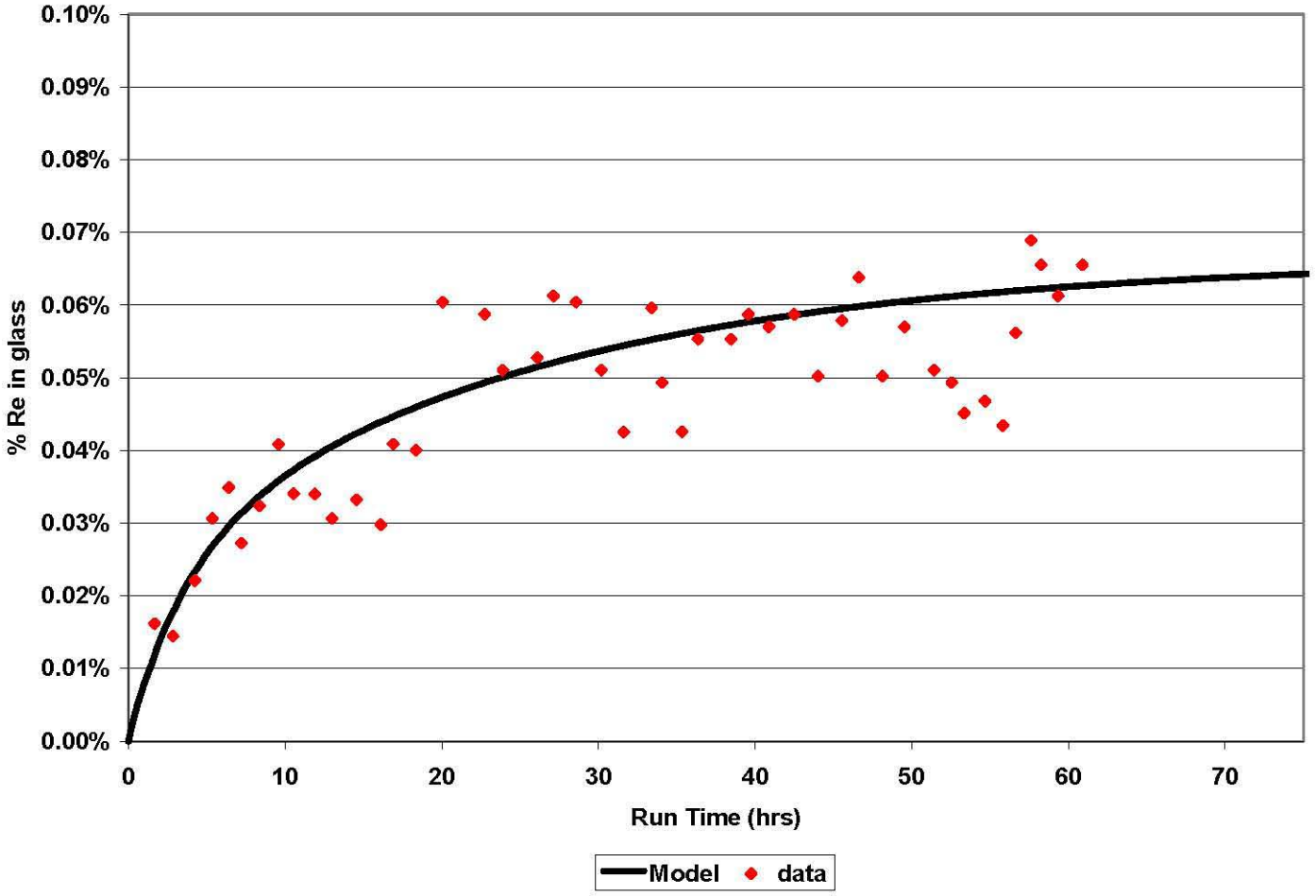


Figure 9.7.d. Rhenium weight percent in the glass during Test 5, the predicted concentrations and the concentrations in the discharged glass samples.

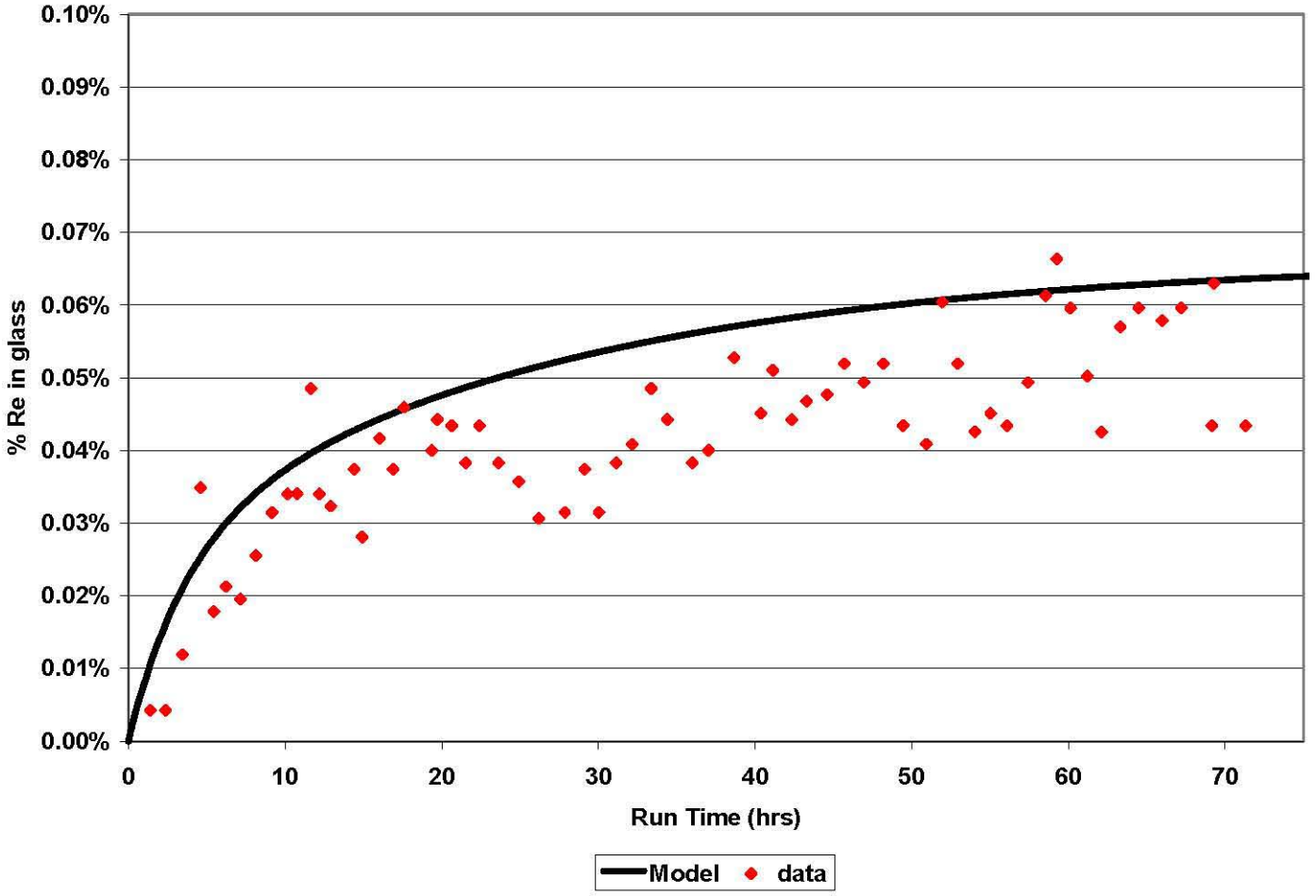


Figure 9.7.e. Rhenium weight percent in the glass during Test 6, the predicted concentrations and the concentrations in the discharged glass samples.

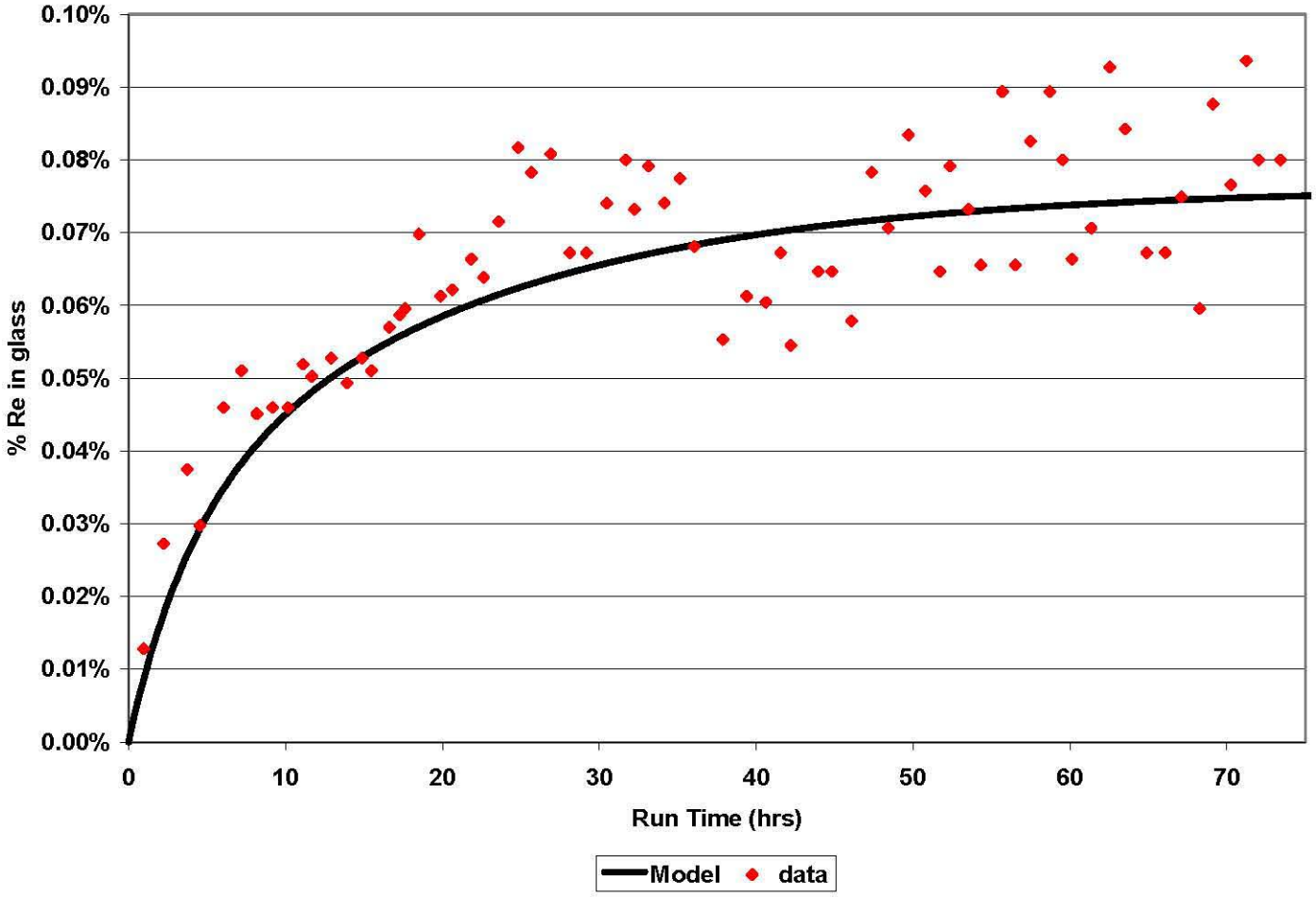


Figure 9.7.f. Rhenium weight percent in the glass during Test 7, the predicted concentrations and the concentrations in the discharged glass samples.

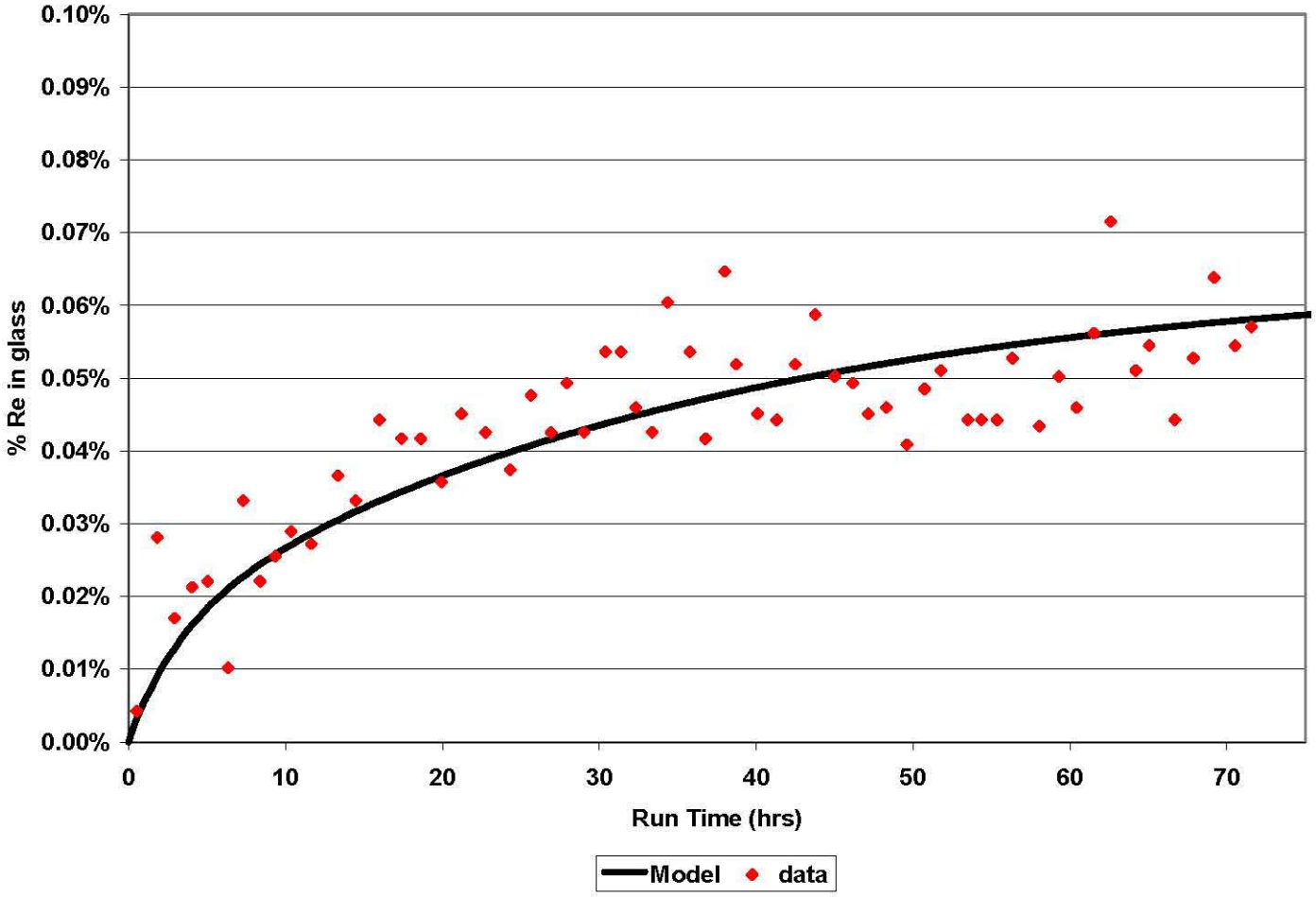


Figure 9.7.g. Rhenium weight percent in the glass during Test 8, the predicted concentrations and the concentrations in the discharged glass samples.

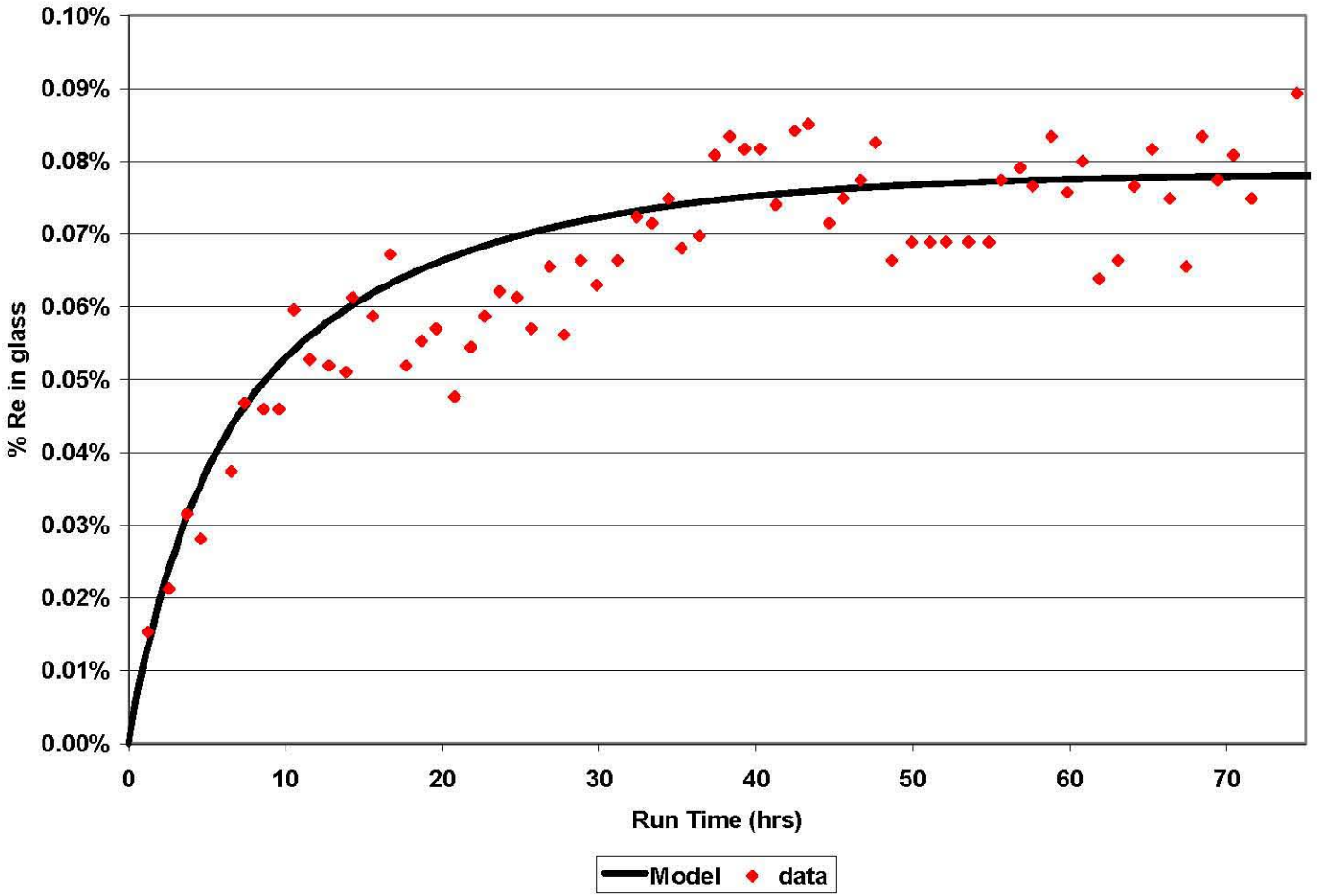


Figure 9.7.h. Rhenium weight percent in the glass during Test 9, the predicted concentrations and the concentrations in the discharged glass samples.

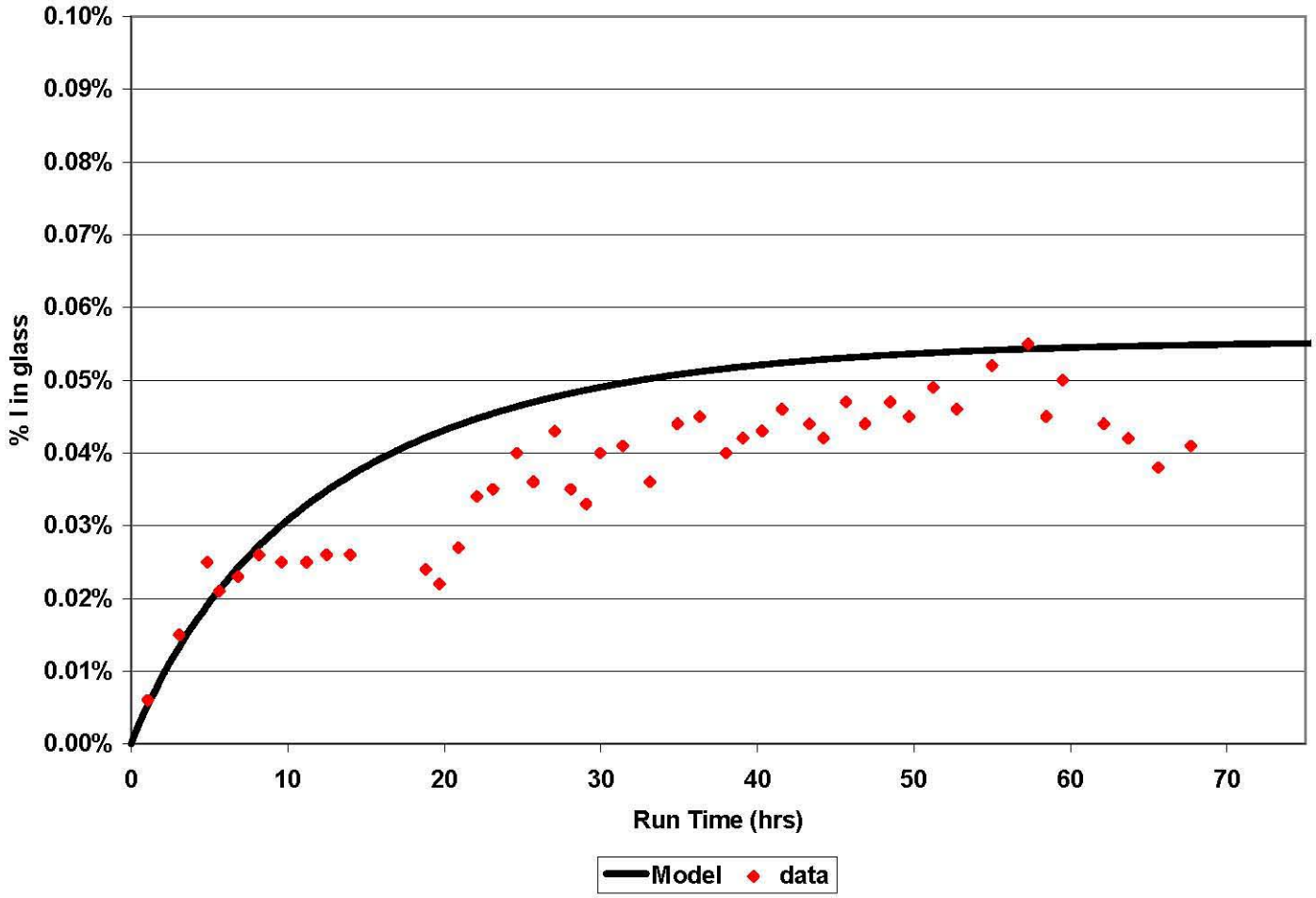


Figure 9.8.a. Iodine weight percent in the glass during Test 2, the predicted concentrations and the concentrations in the discharged glass samples.

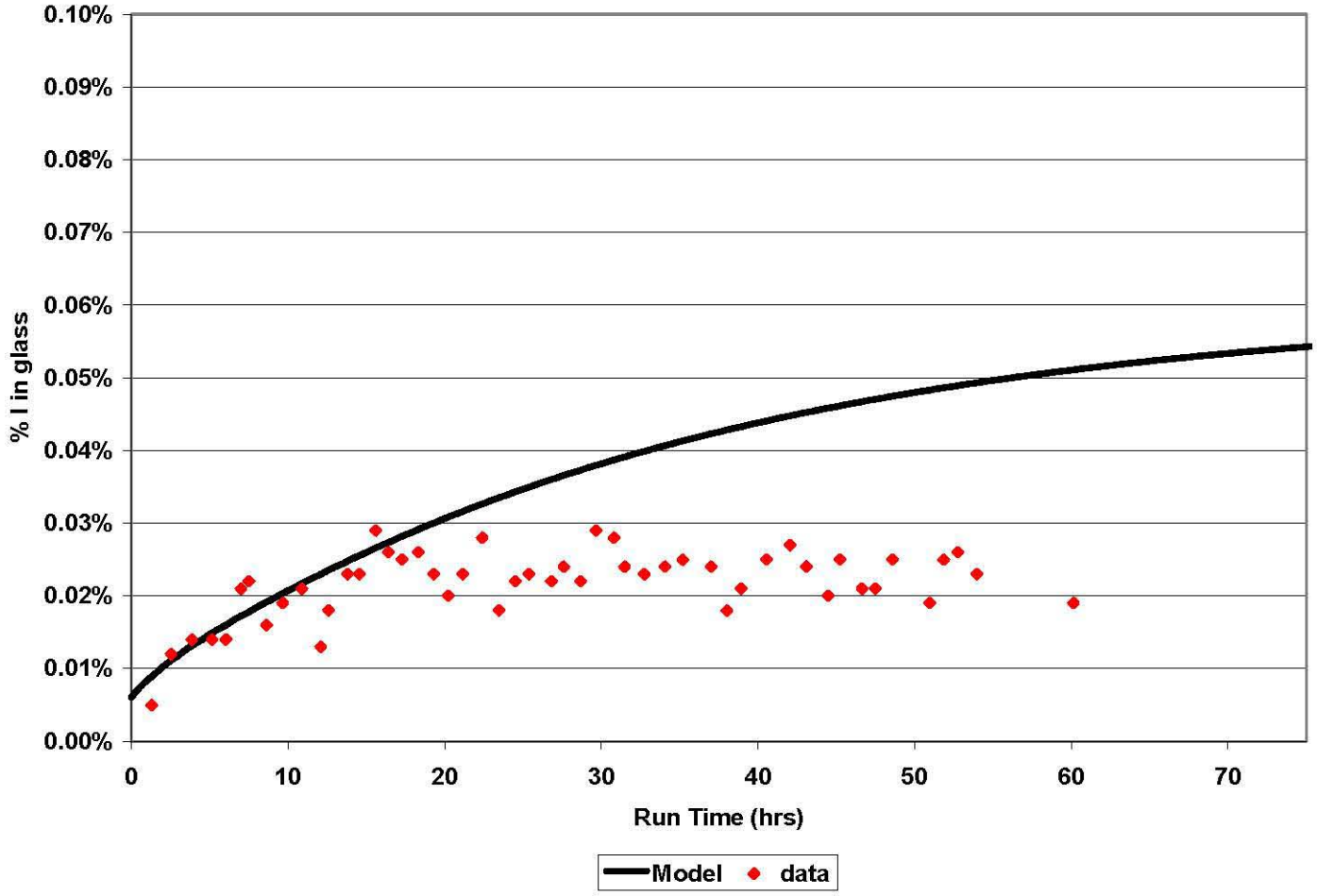


Figure 9.8.b. Iodine weight percent in the glass during Test 3, the predicted concentrations and the concentrations in the discharged glass samples.

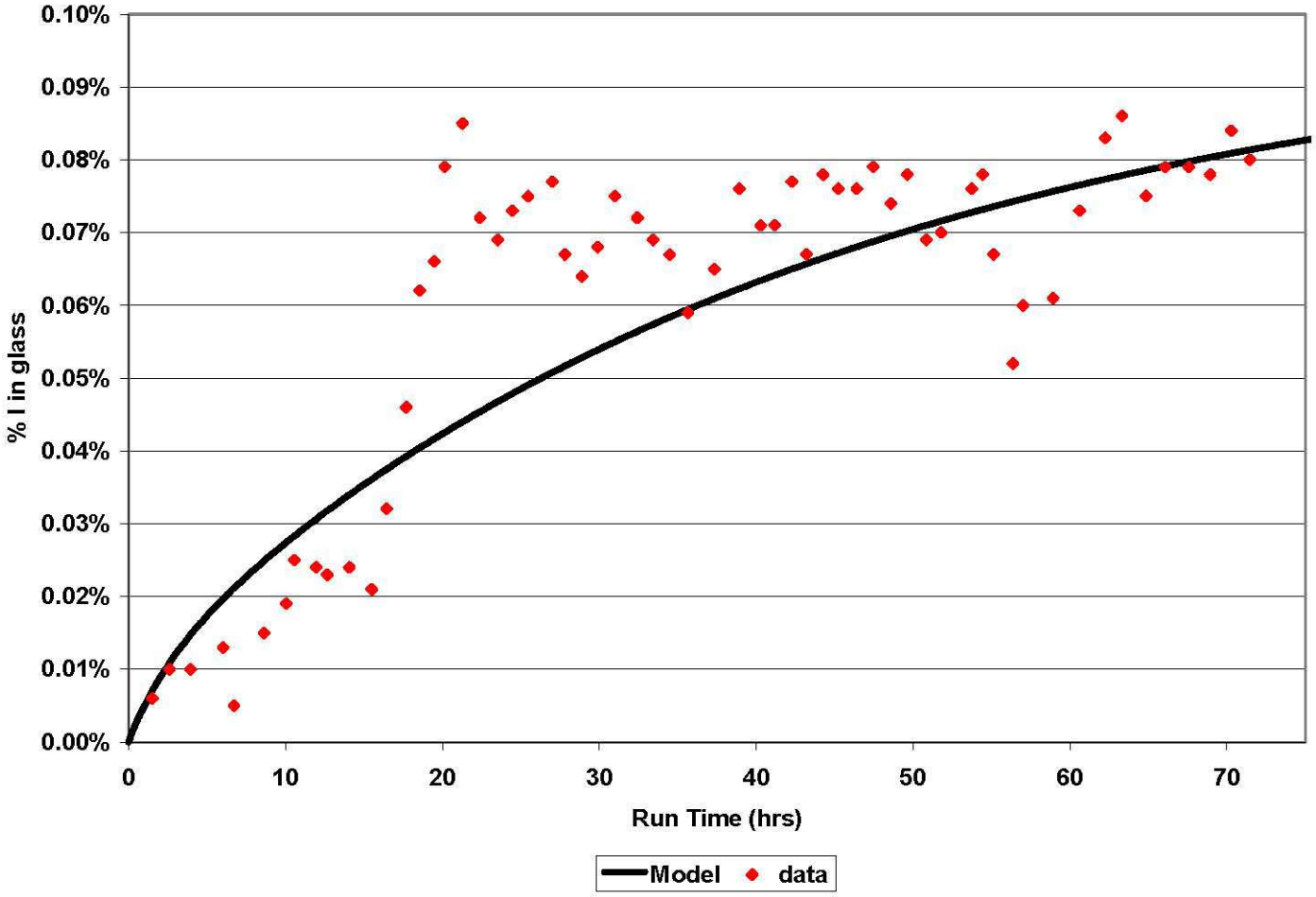


Figure 9.8.c. Iodine weight percent in the glass during Test 4, the predicted concentrations and the concentrations in the discharged glass samples.

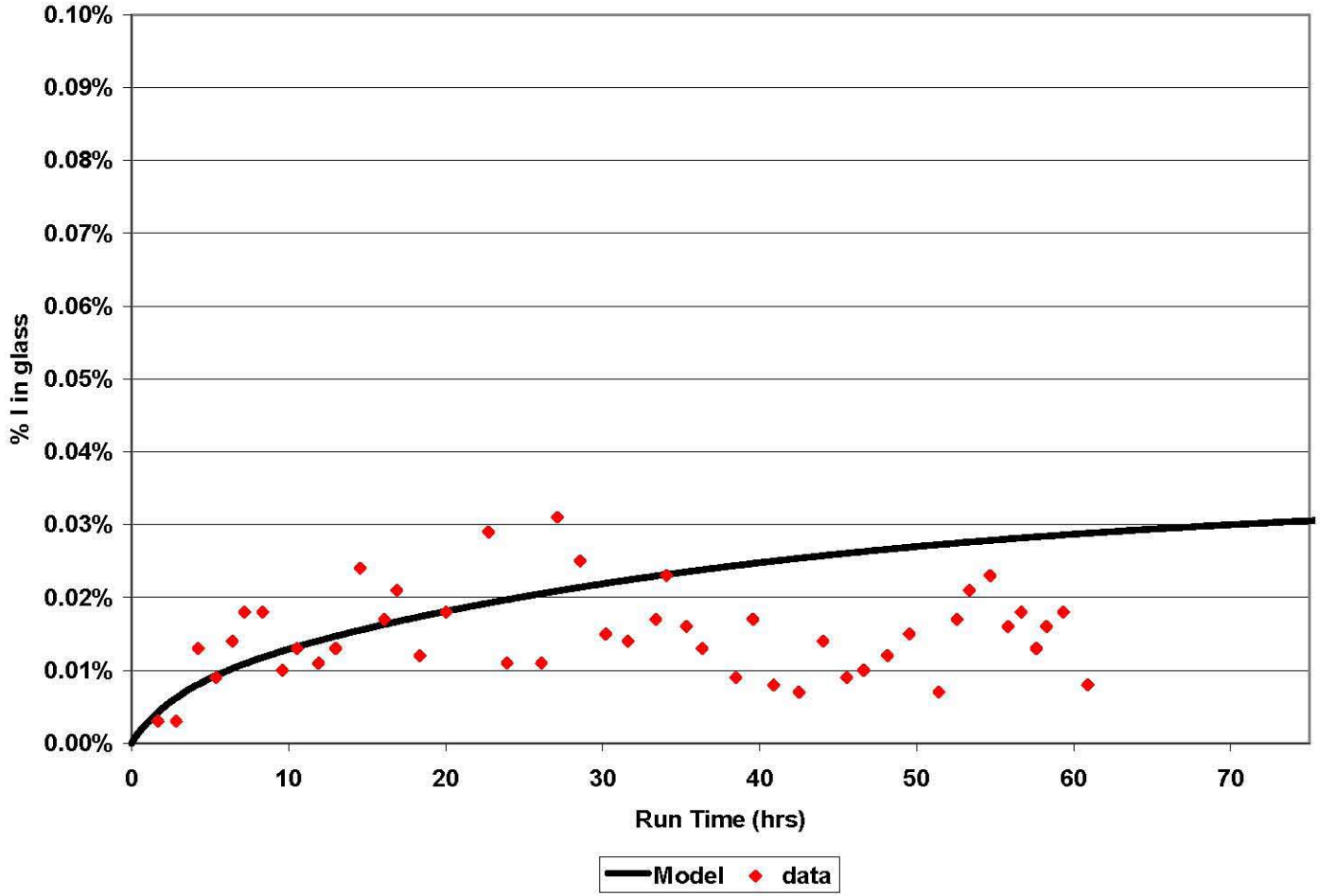


Figure 9.8.d. Iodine weight percent in the glass during Test 5, the predicted concentrations and the concentrations in the discharged glass samples.

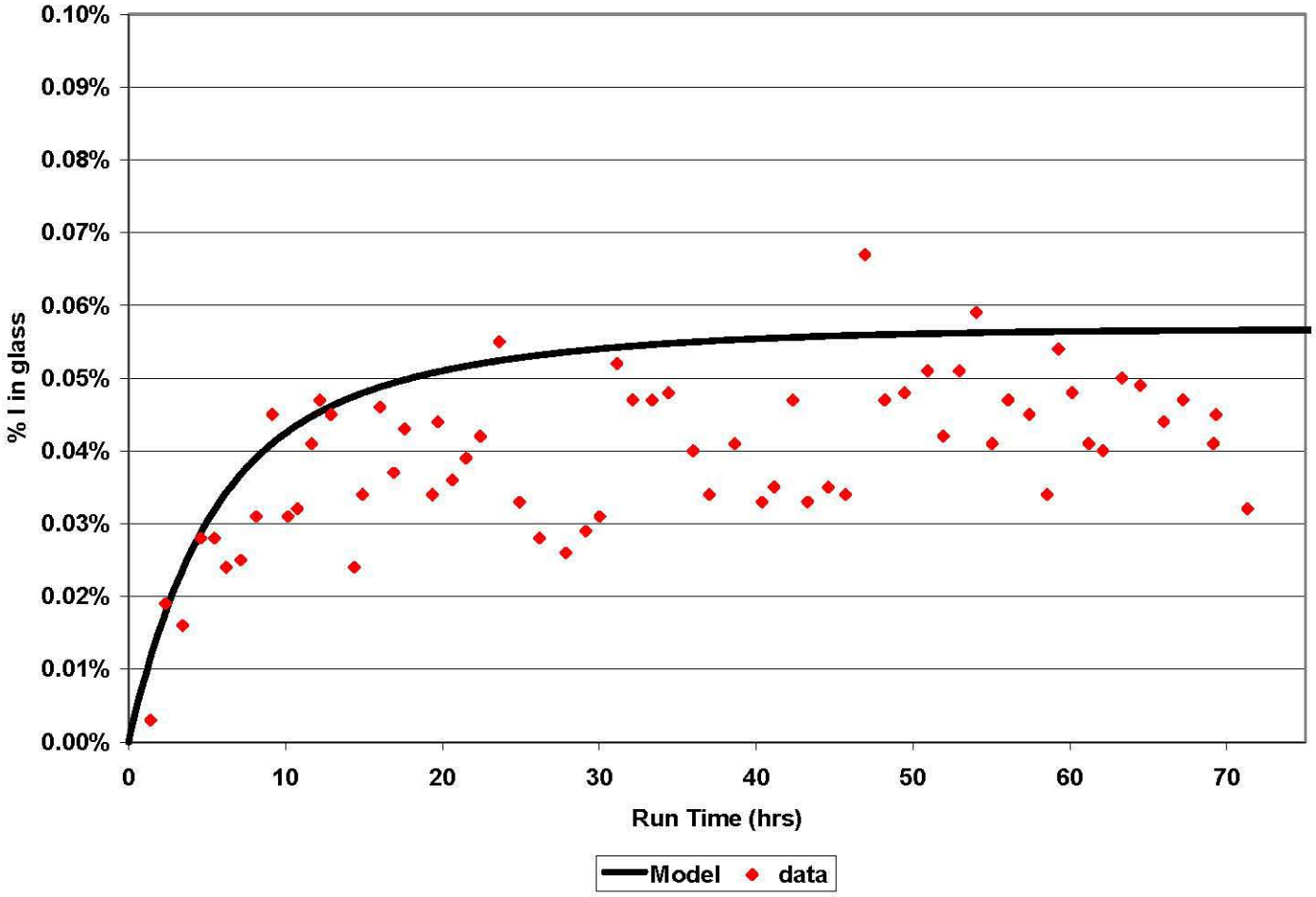


Figure 9.8.e. Iodine weight percent in the glass during Test 6, the predicted concentrations and the concentrations in the discharged glass samples.

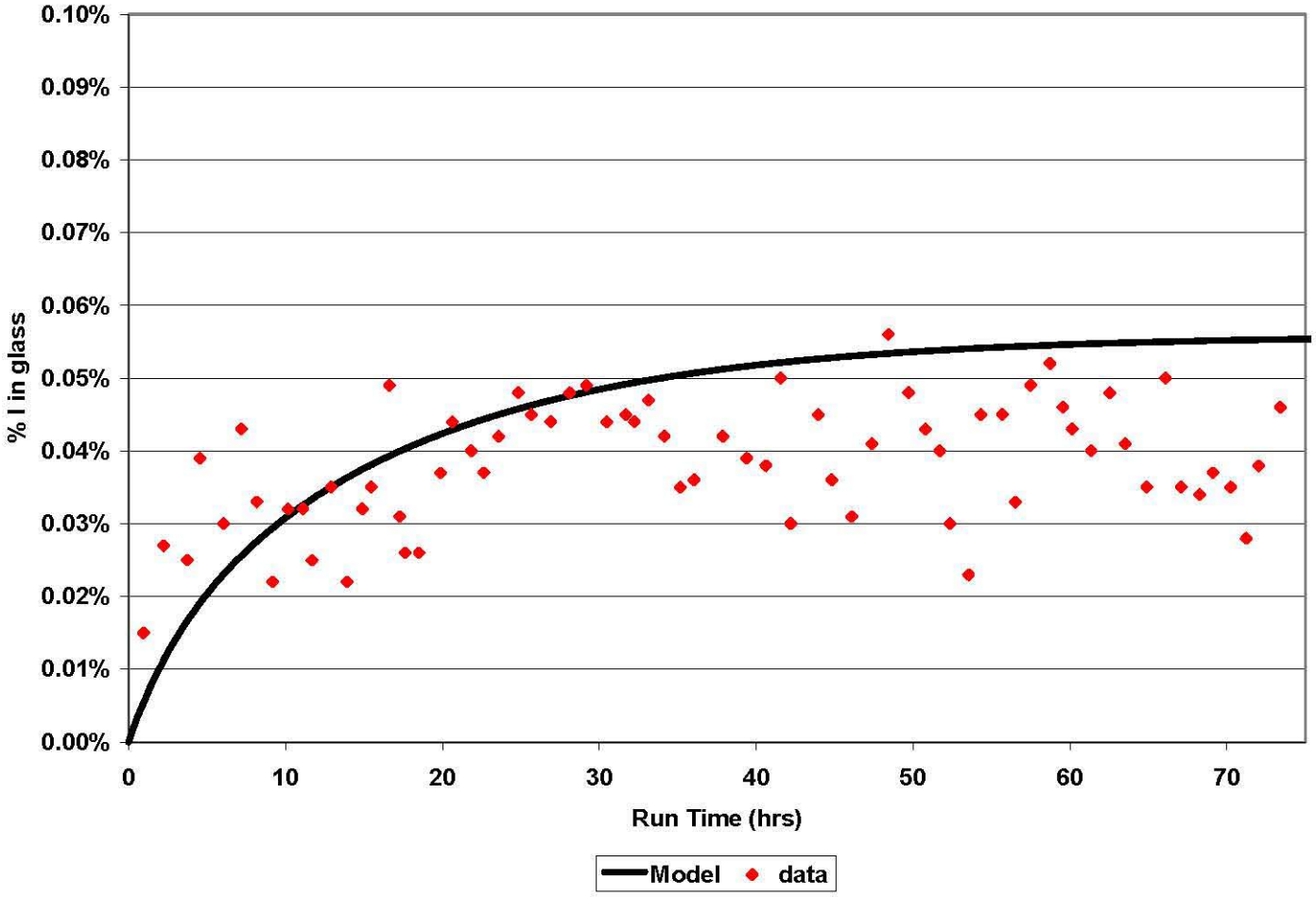


Figure 9.8.f. Iodine weight percent in the glass during Test 7, the predicted concentrations and the concentrations in the discharged glass samples.

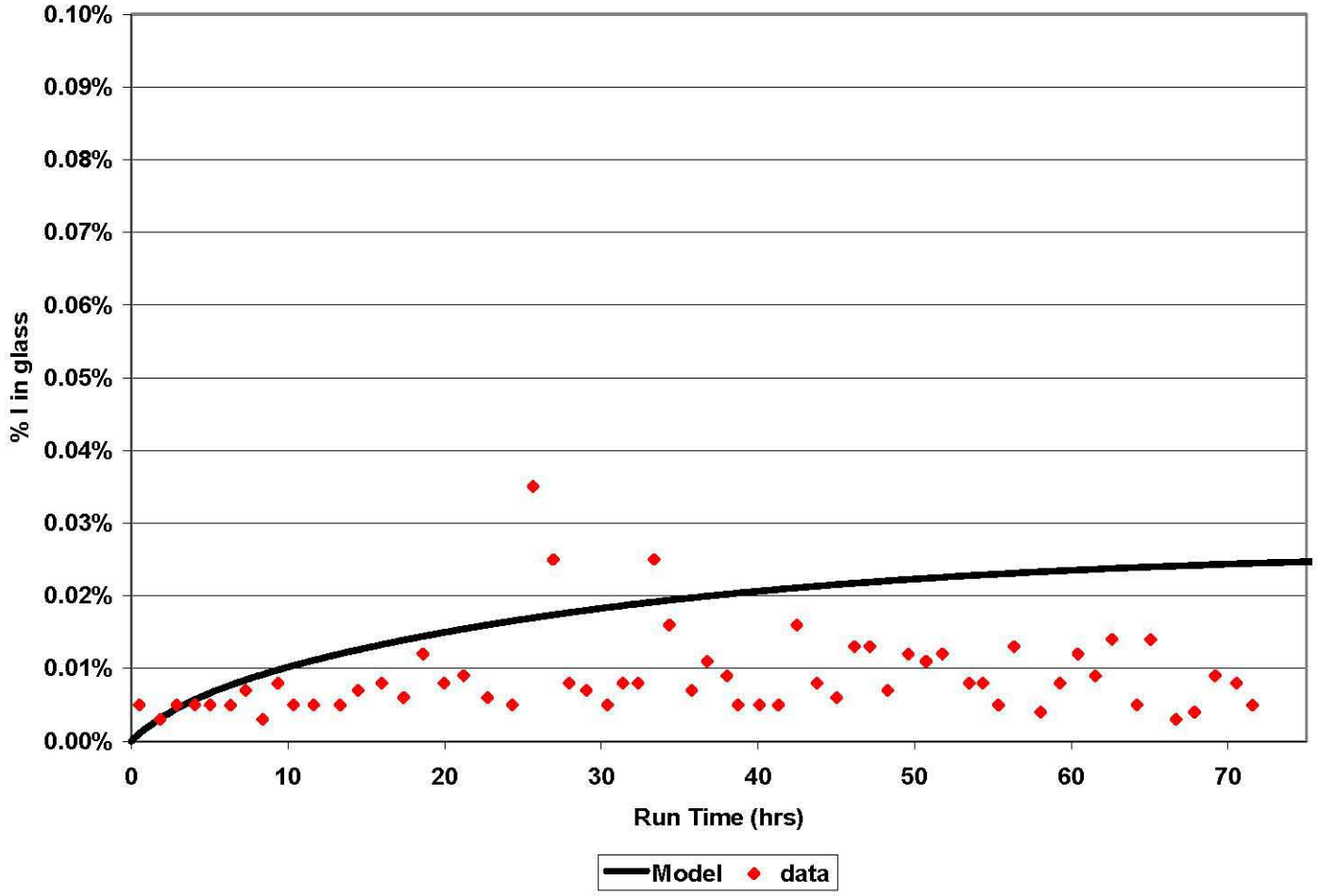


Figure 9.8.g. Iodine weight percent in the glass during Test 8, the predicted concentrations and the concentrations in the discharged glass samples.

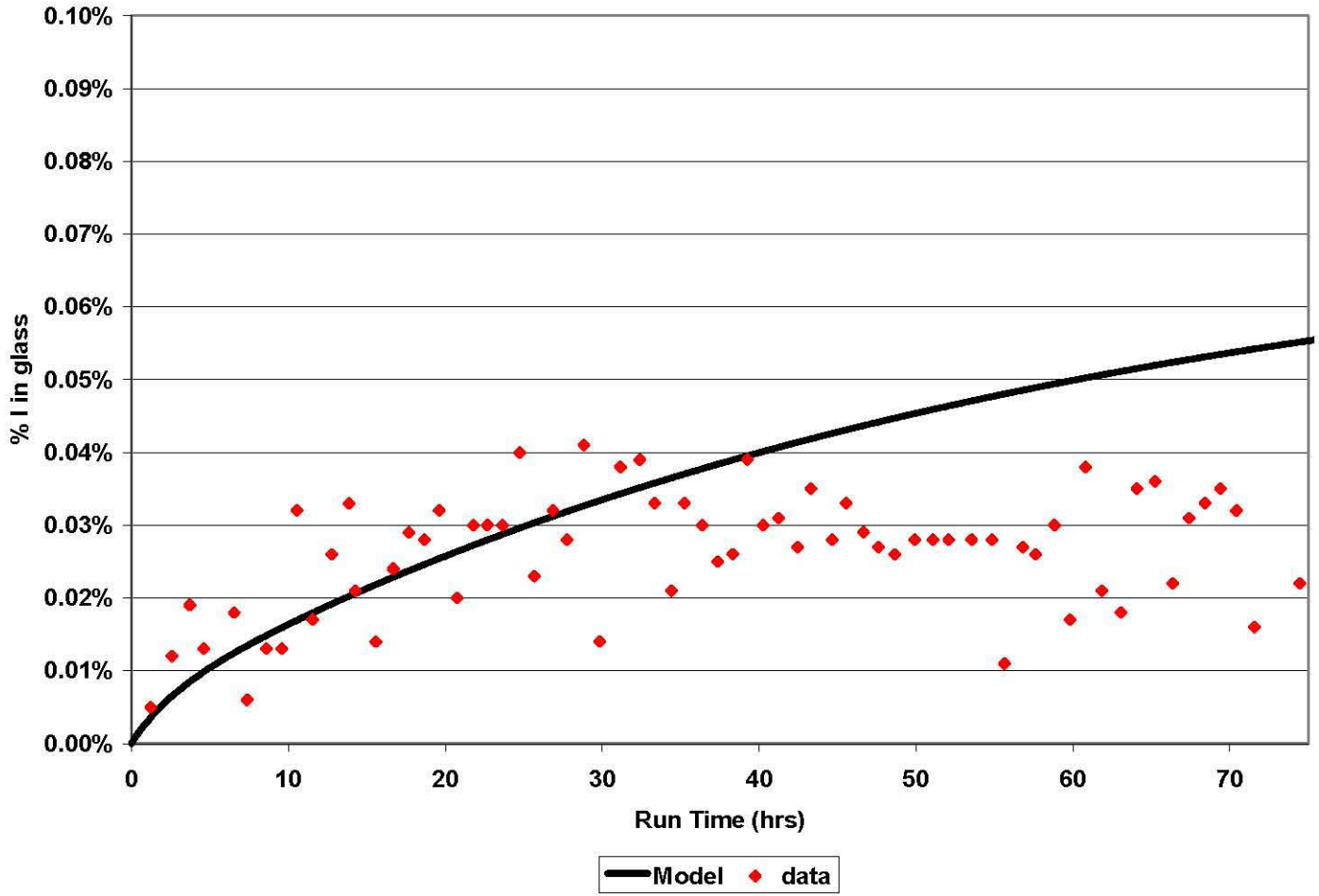


Figure 9.8.h. Iodine weight percent in the glass during Test 9, the predicted concentrations and the concentrations in the discharged glass samples.

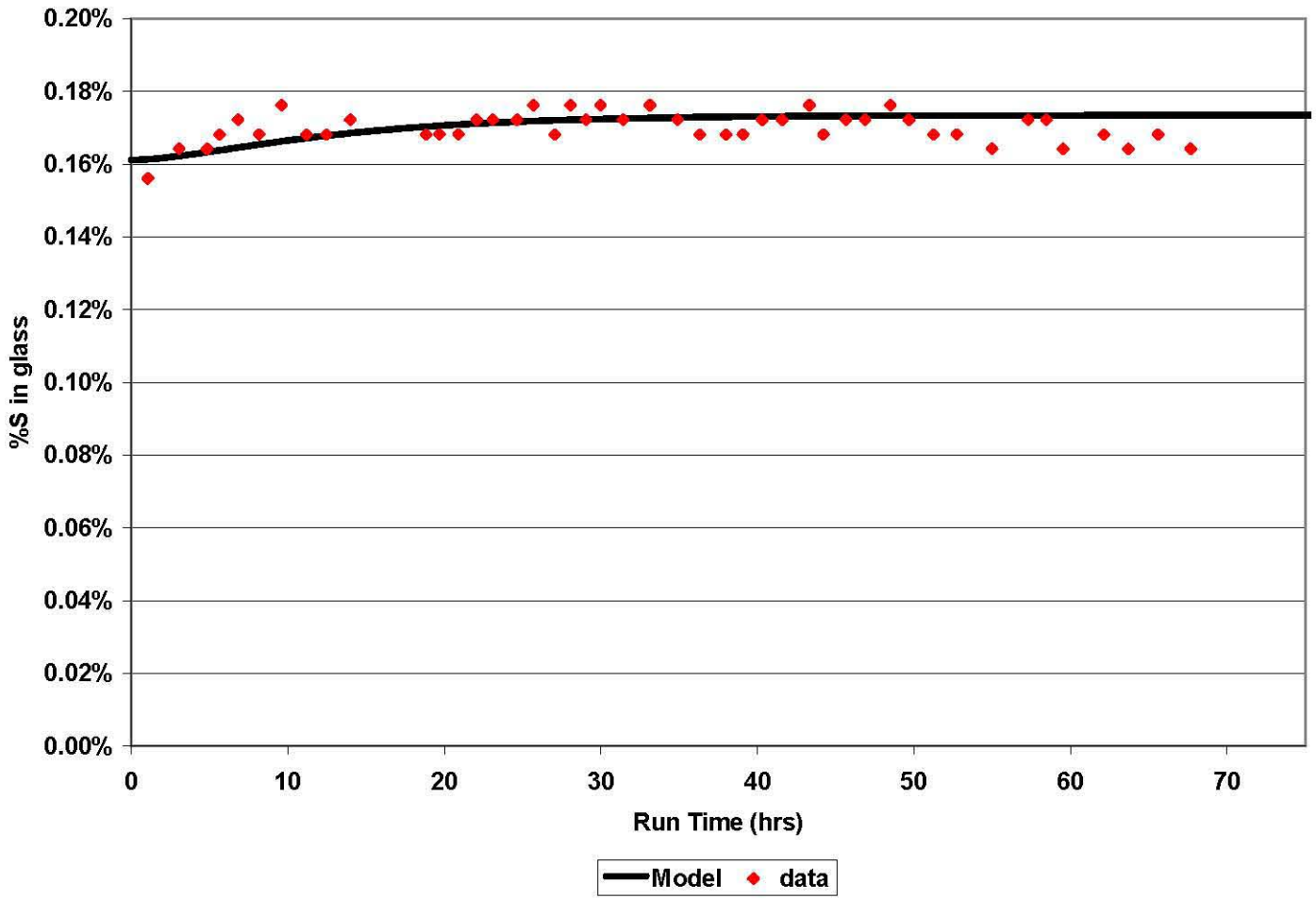


Figure 9.9.a. Sulfur weight percent in the glass during Test 2, the predicted concentrations and the concentrations in the discharged glass samples.

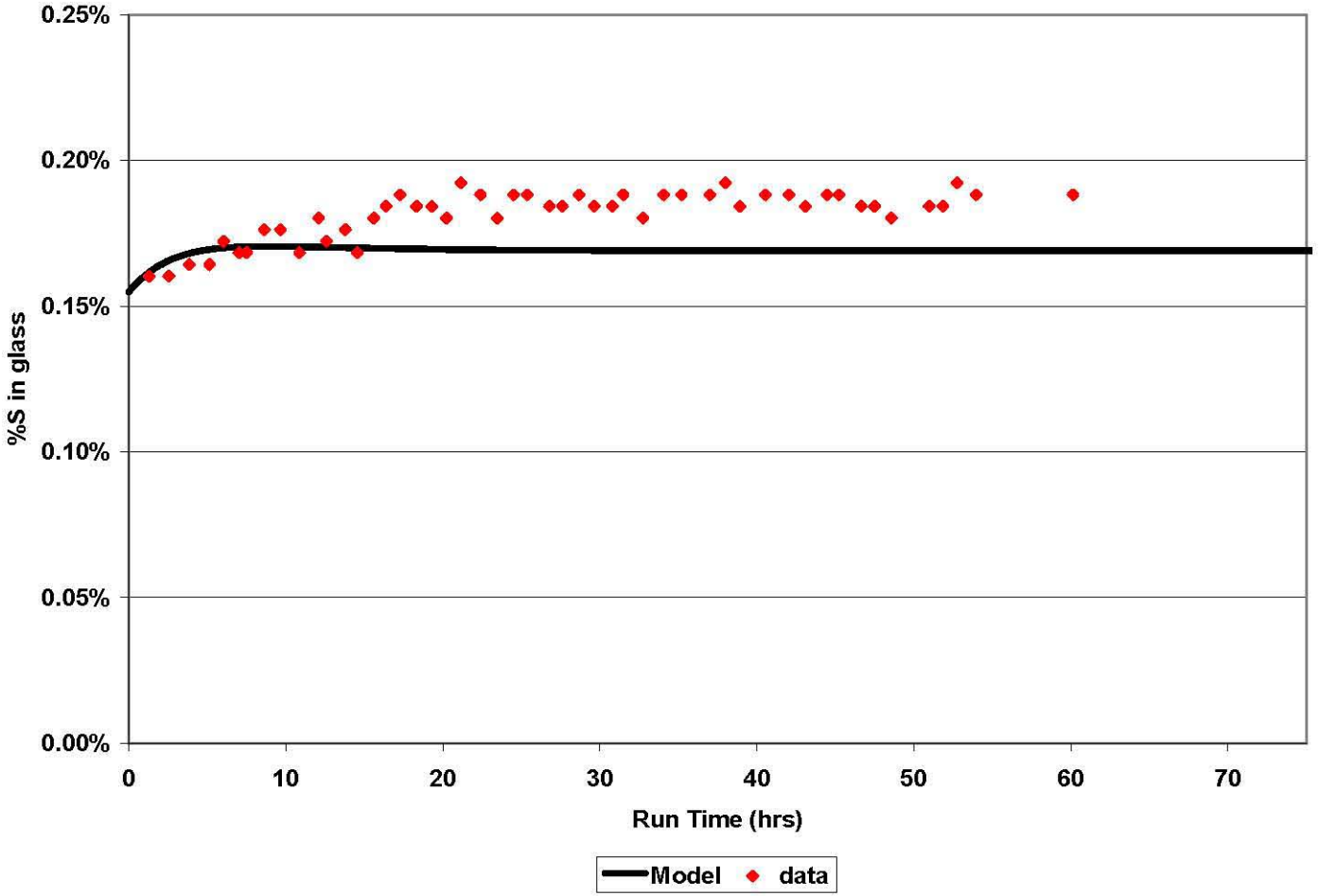


Figure 9.9.b. Sulfur weight percent in the glass during Test 3, the predicted concentrations and the concentrations in the discharged glass samples.

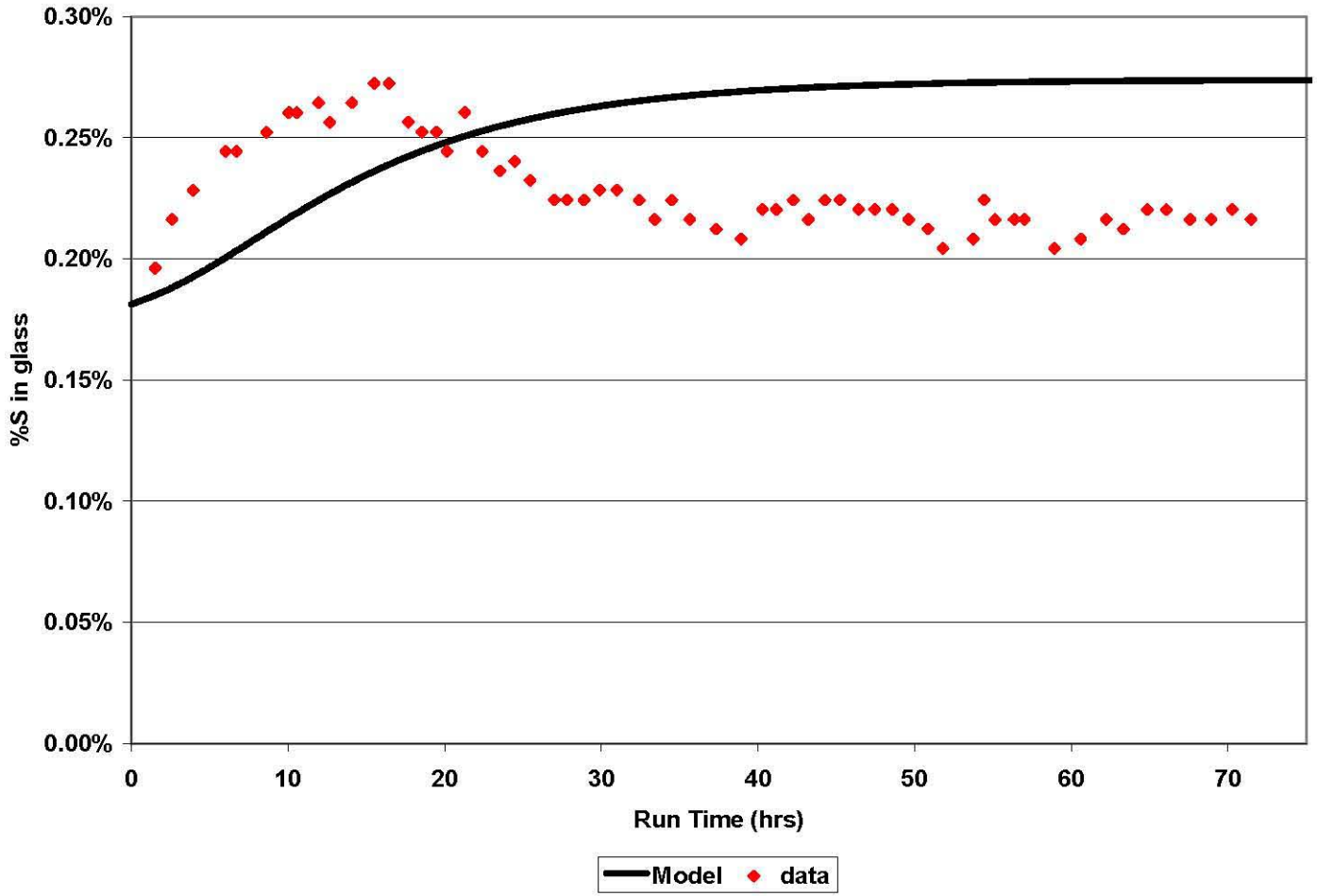


Figure 9.9.c. Sulfur weight percent in the glass during Test 4, the predicted concentrations and the concentrations in the discharged glass samples.

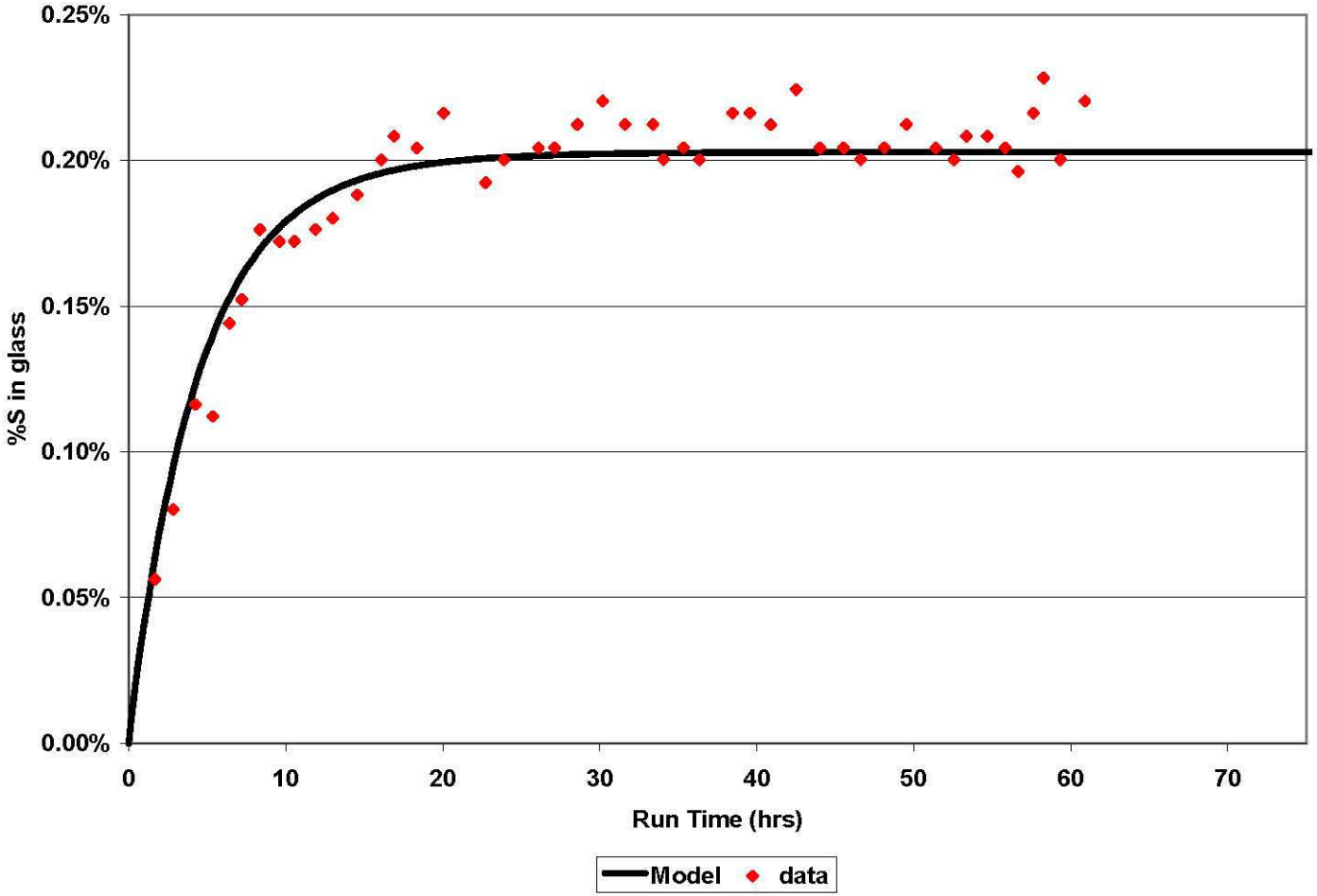


Figure 9.9.d. Sulfur weight percent in the glass during Test 5, the predicted concentrations and the concentrations in the discharged glass samples.

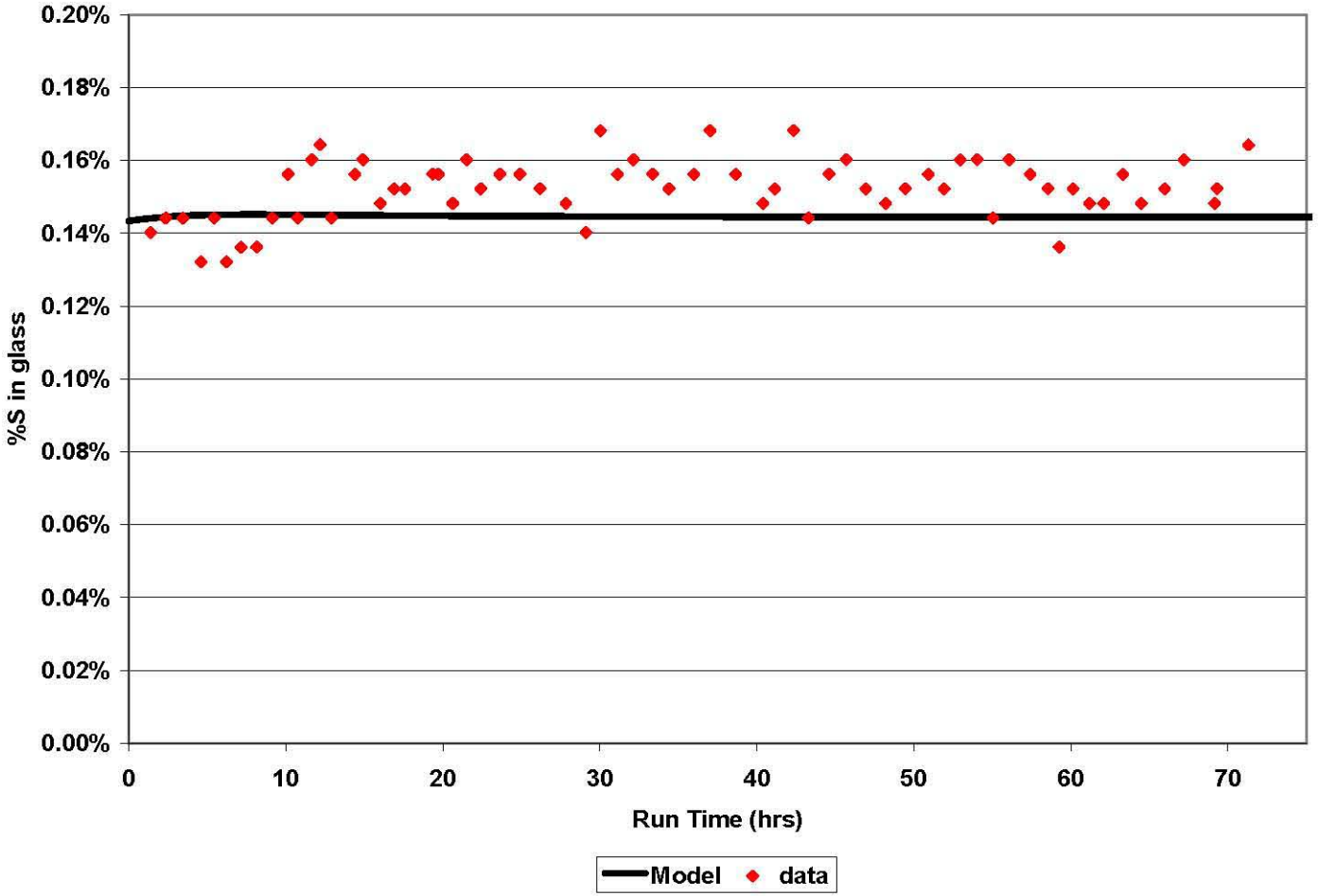


Figure 9.9.e. Sulfur weight percent in the glass during Test 6, the predicted concentrations and the concentrations in the discharged glass samples.

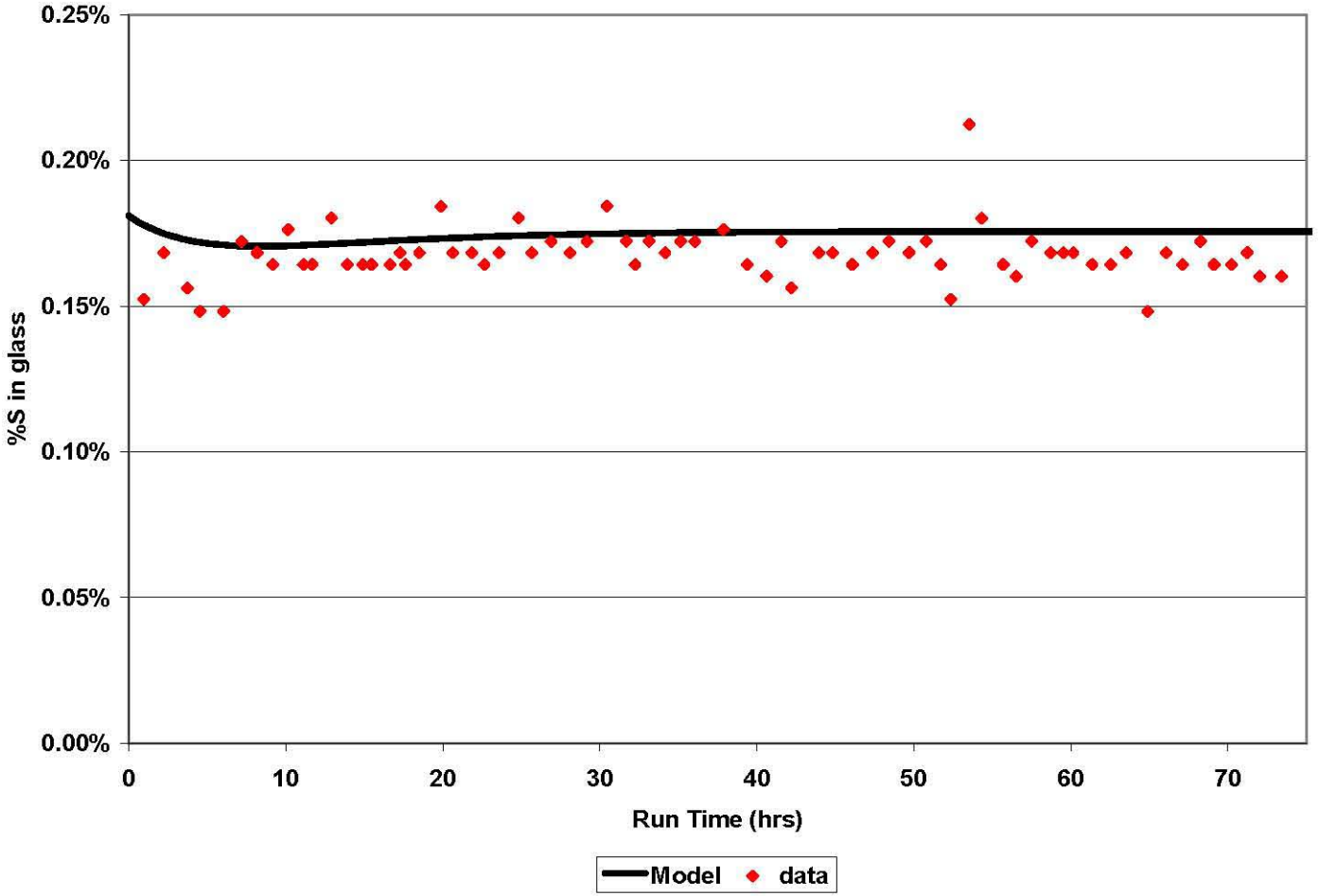


Figure 9.9.f. Sulfur weight percent in the glass during Test 7, the predicted concentrations and the concentrations in the discharged glass samples.

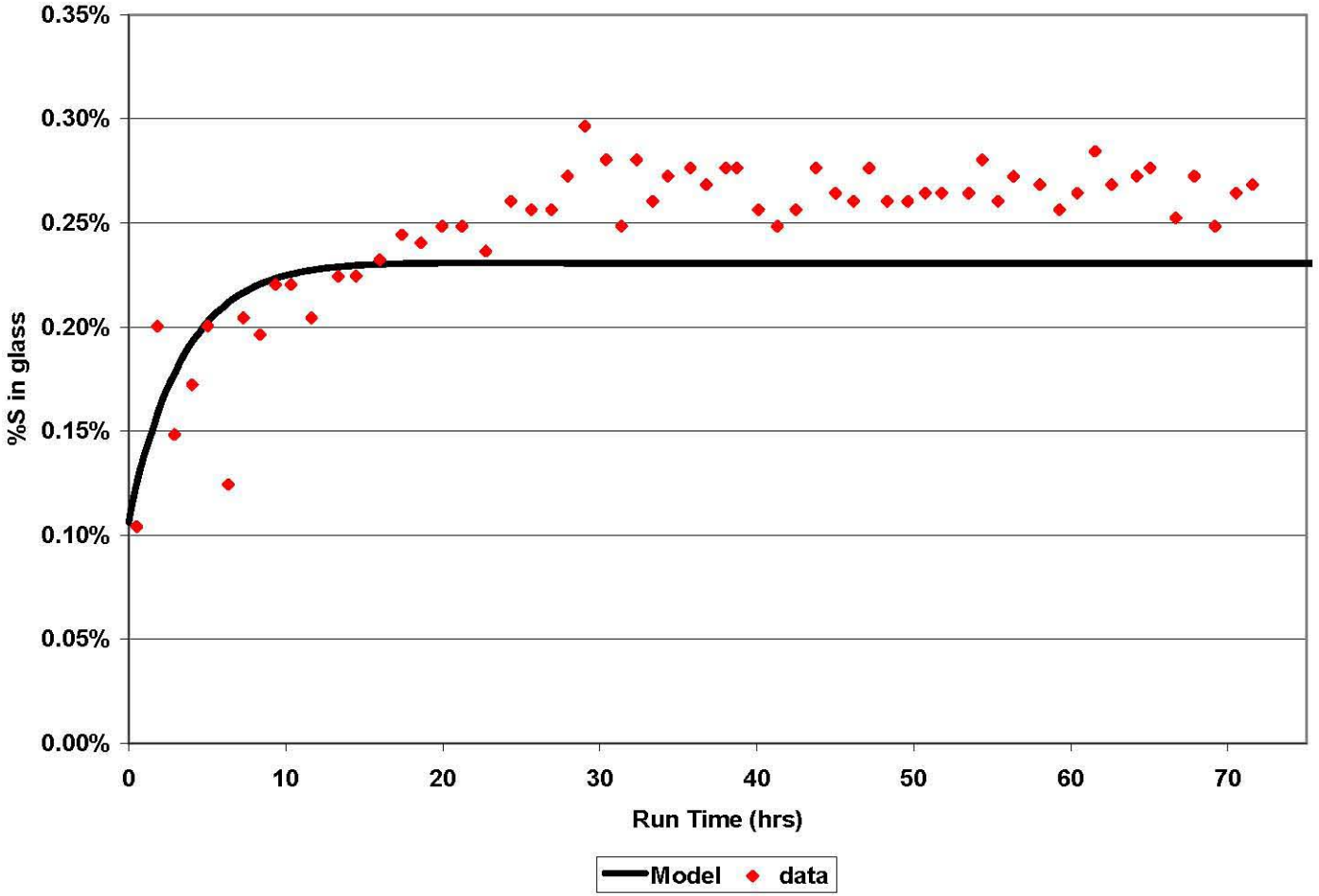


Figure 9.9.g. Sulfur weight percent in the glass during Test 8, the predicted concentrations and the concentrations in the discharged glass samples.

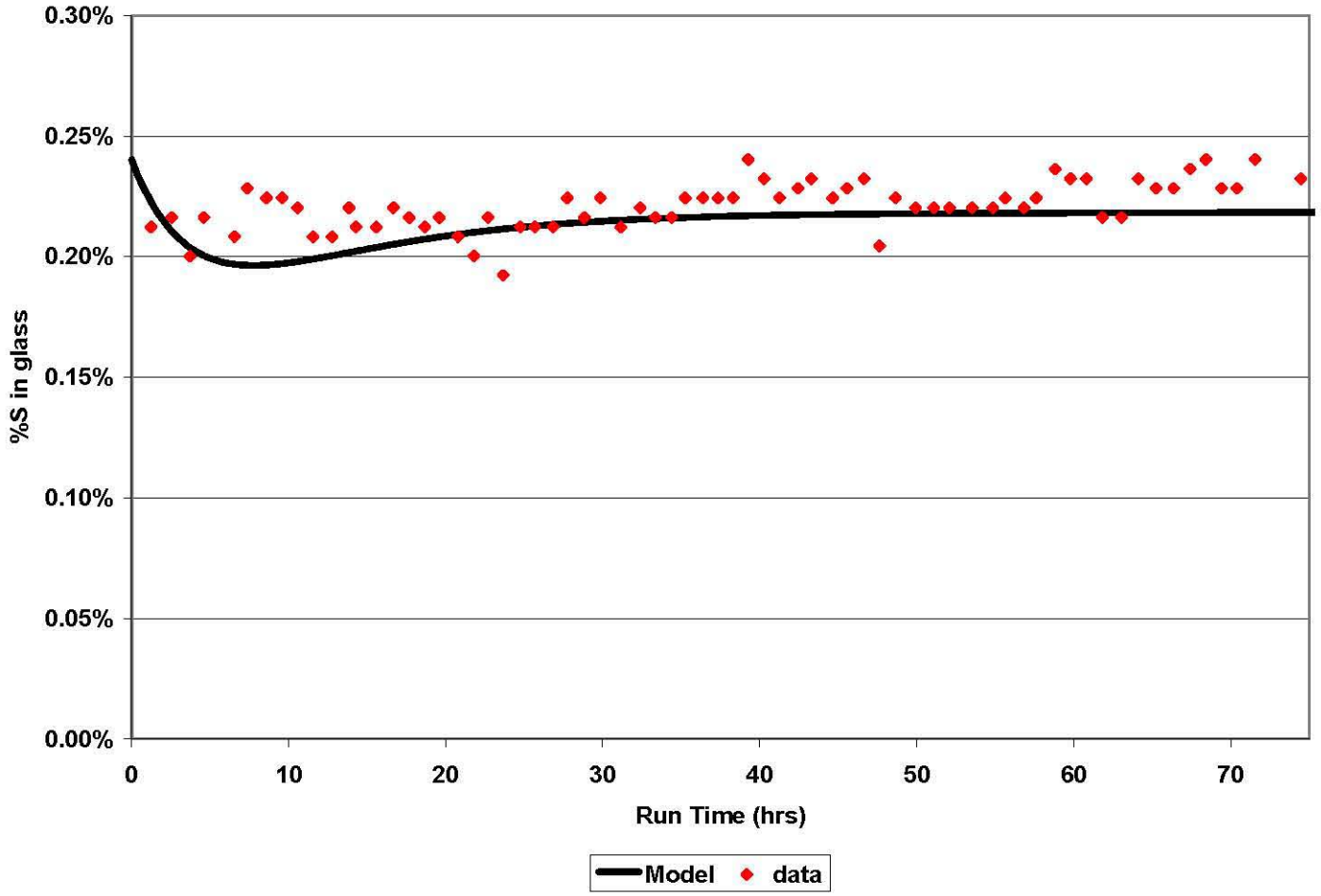


Figure 9.9.h. Sulfur weight percent in the glass during Test 9, the predicted concentrations and the concentrations in the discharged glass samples.

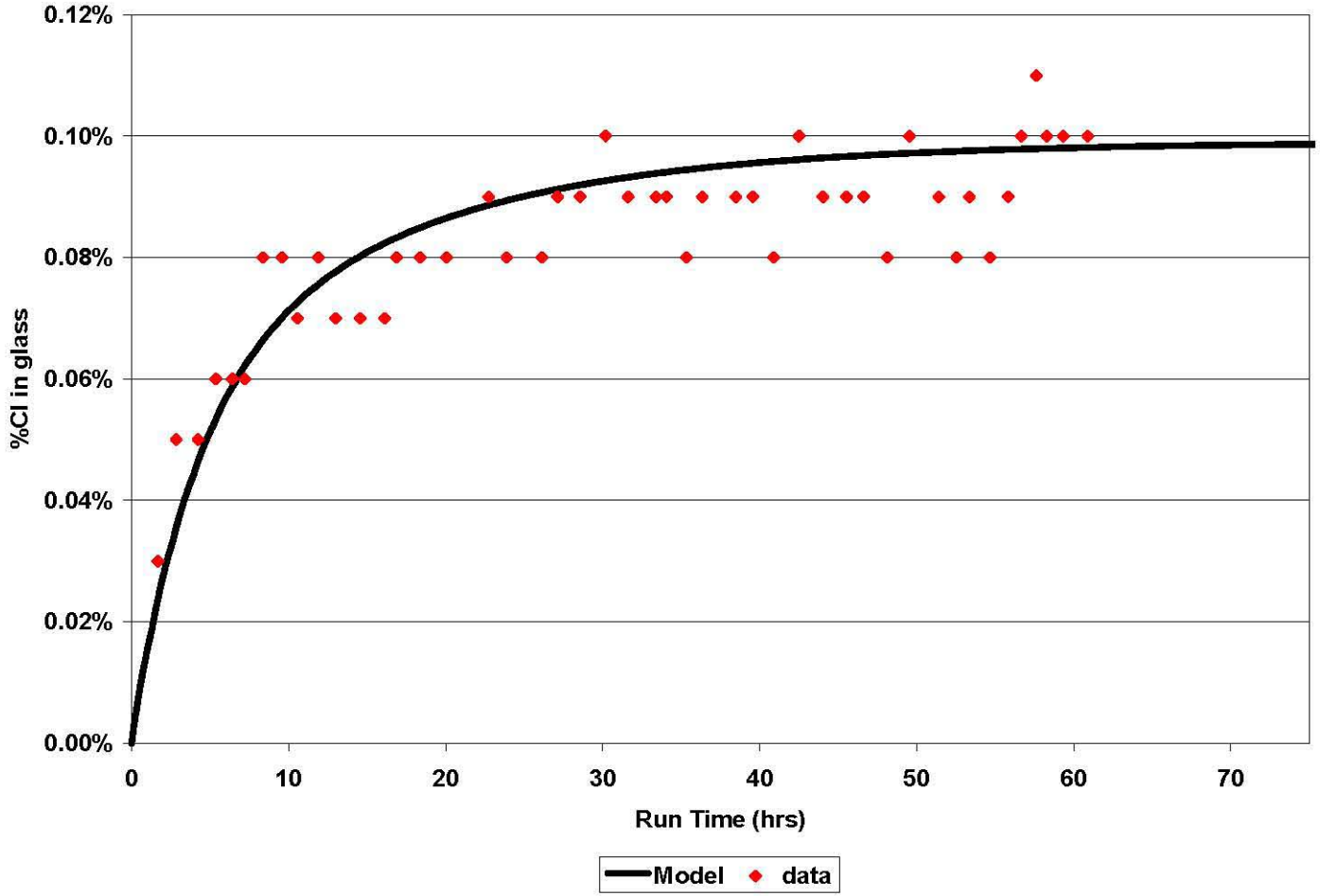


Figure 9.10.a. Chlorine weight percent in the glass during Test 5, the predicted concentrations and the concentrations in the discharged glass samples.

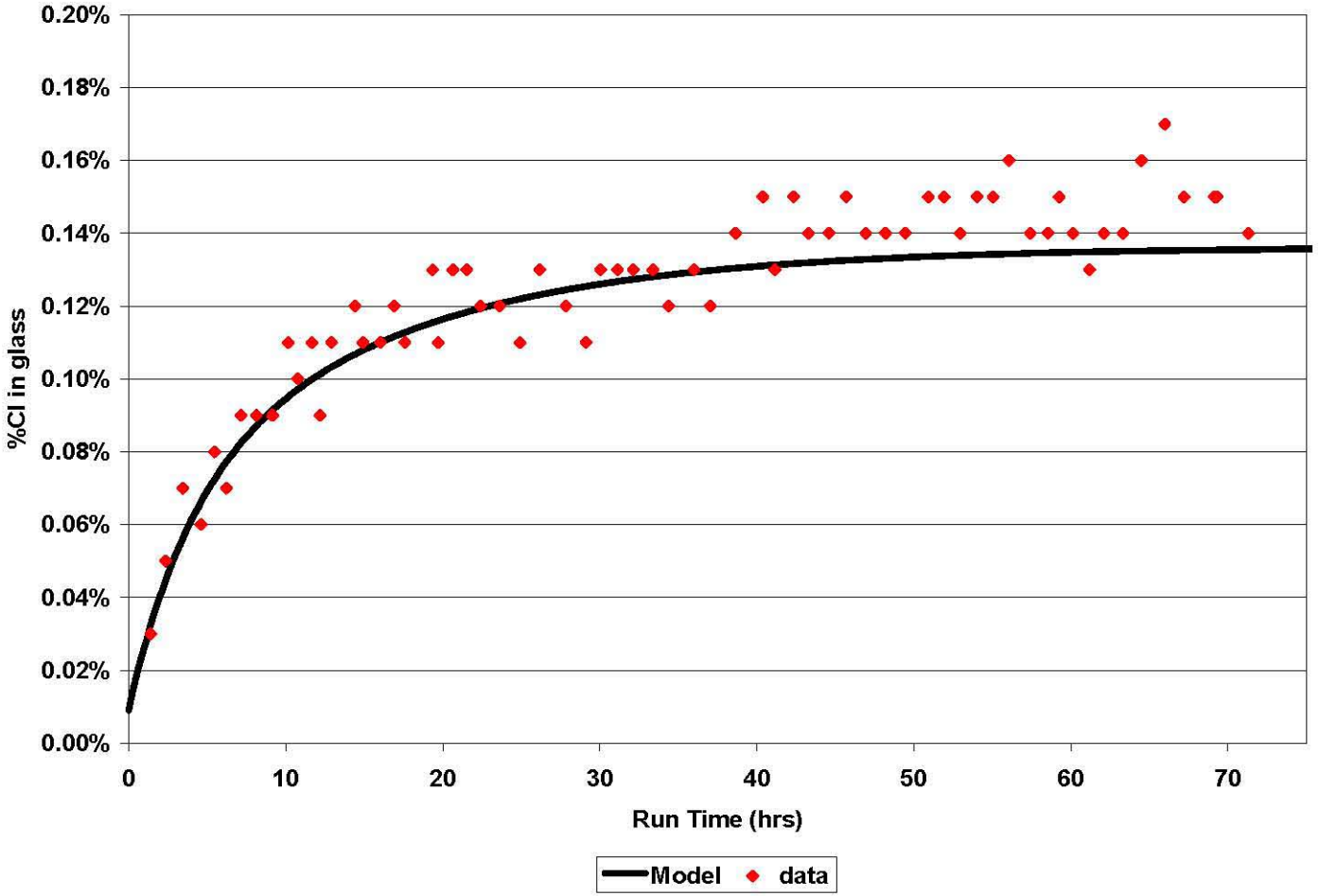


Figure 9.10.b. Chlorine weight percent in the glass during Test 6, the predicted concentrations and the concentrations in the discharged glass samples.

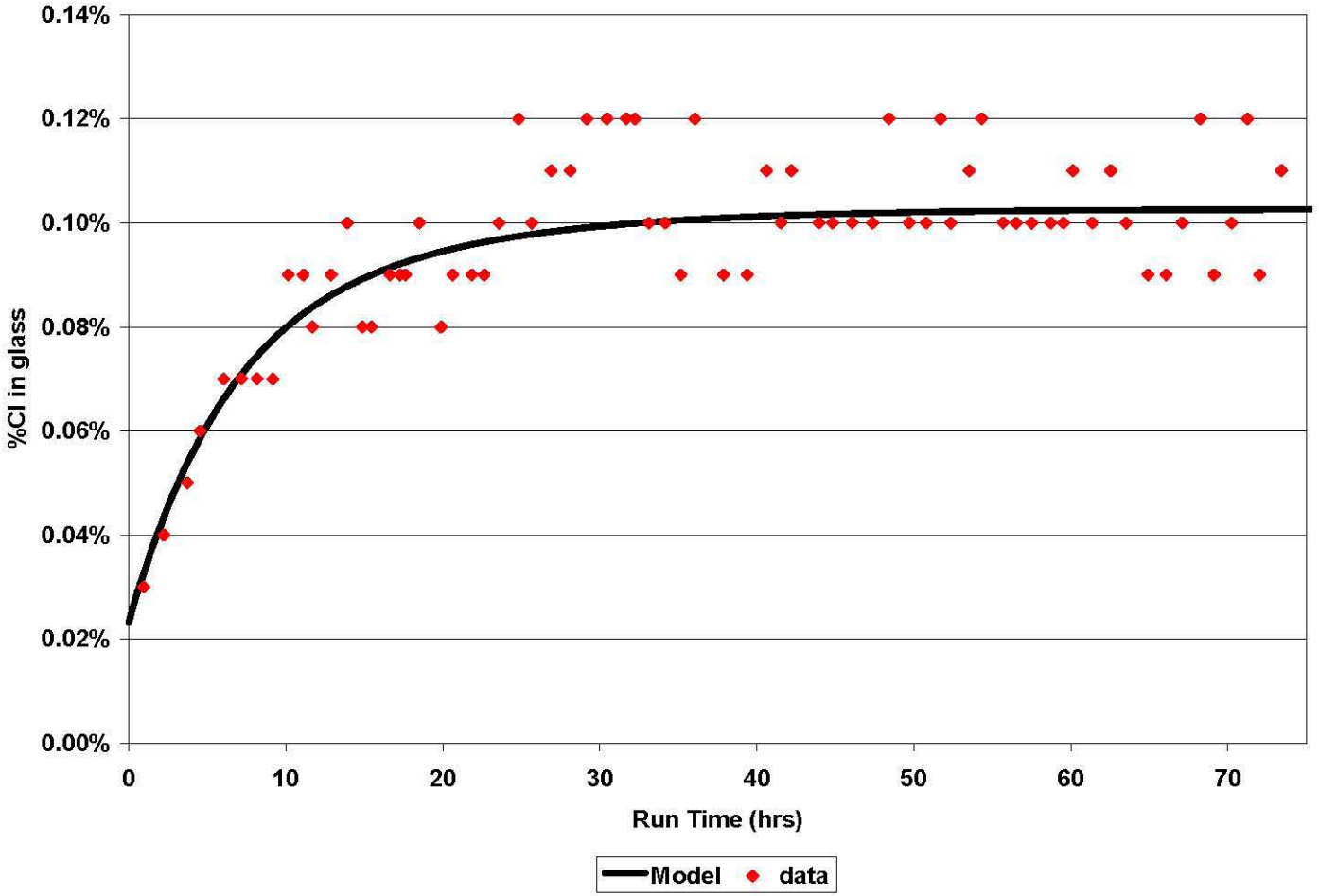


Figure 9.10.c. Chlorine weight percent in the glass during Test 7, the predicted concentrations and the concentrations in the discharged glass samples.

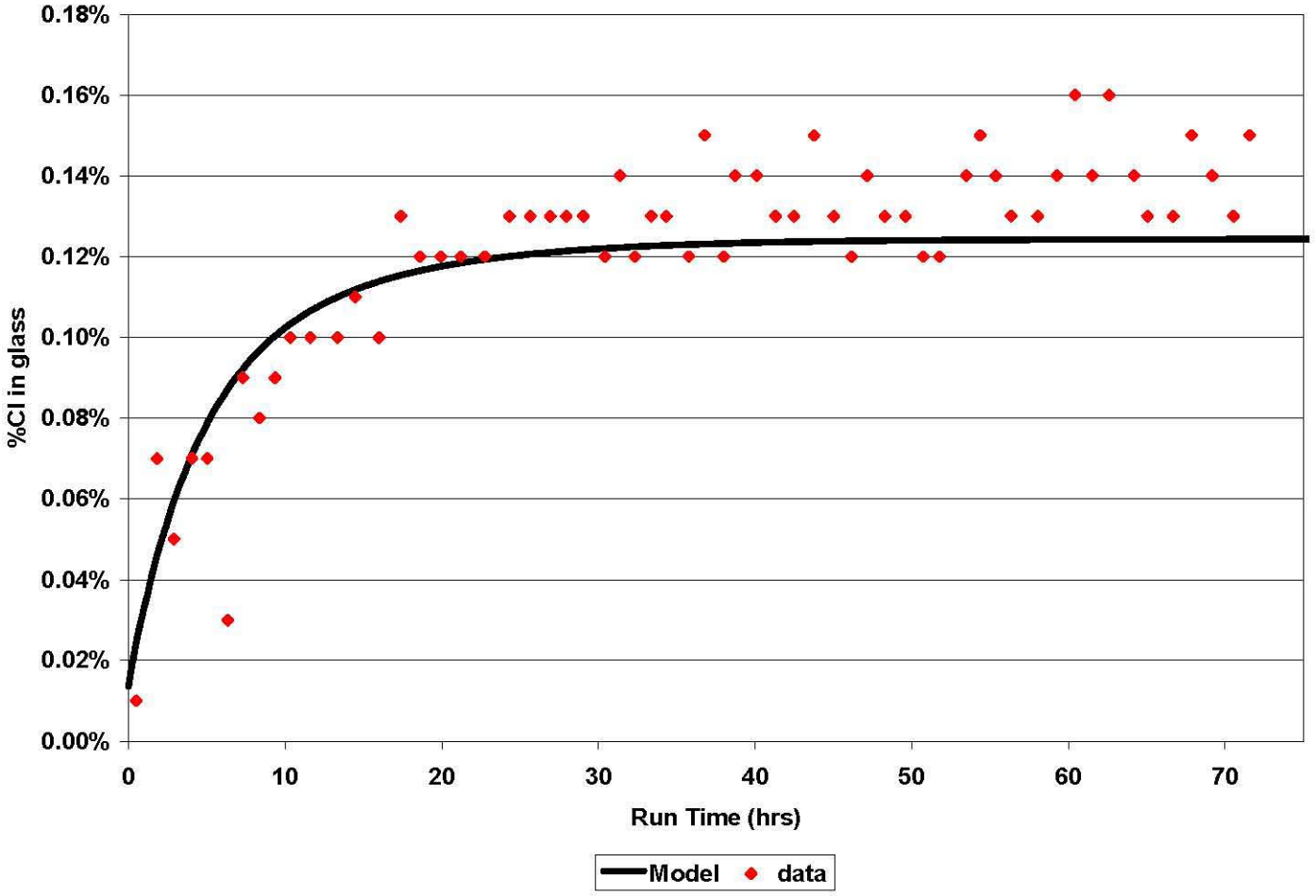


Figure 9.10.d. Chlorine weight percent in the glass during Test 8, the predicted concentrations and the concentrations in the discharged glass samples.

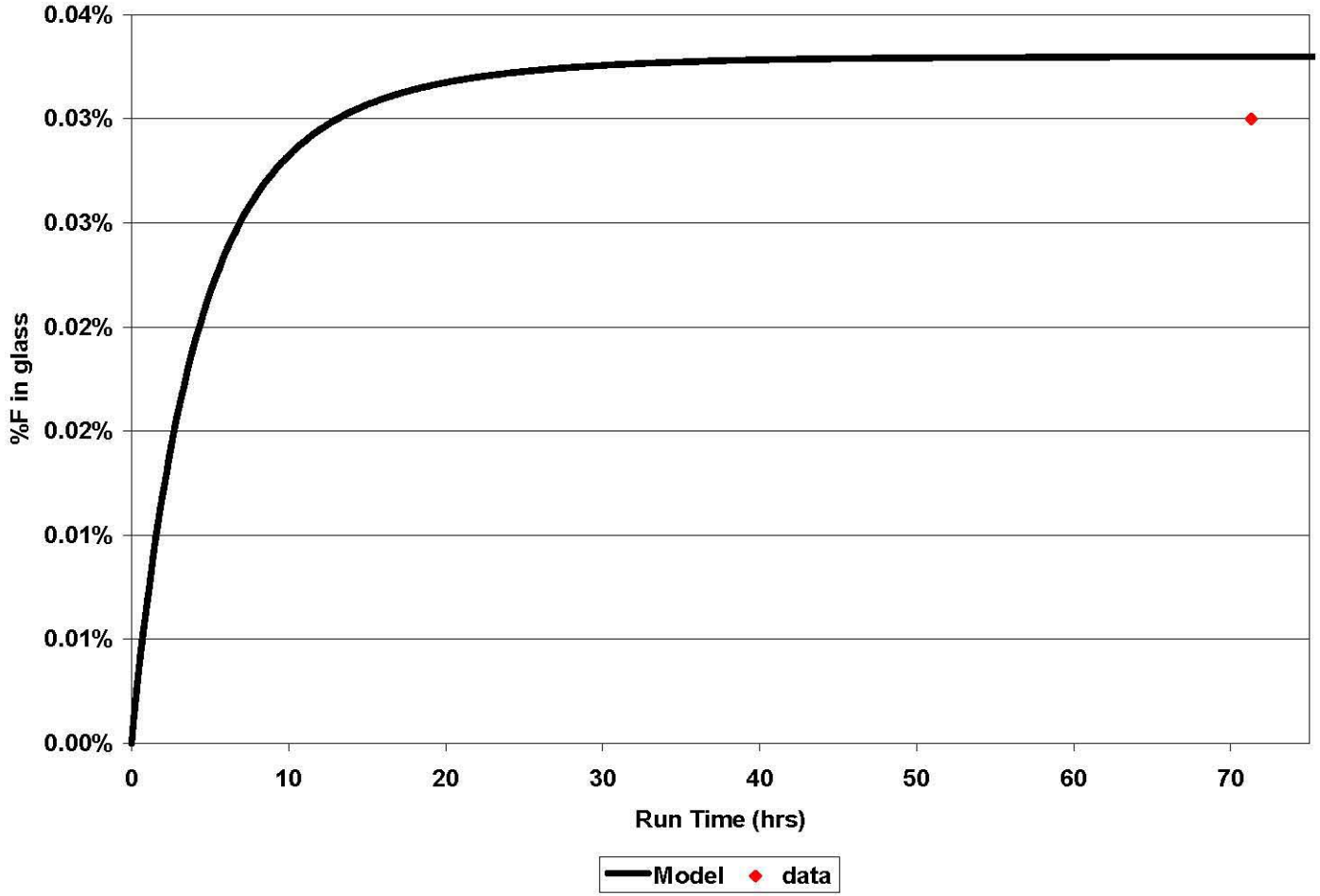


Figure 9.11.a. Fluorine weight percent in the glass during Test 6, the predicted concentrations and the concentrations in the discharged glass samples.

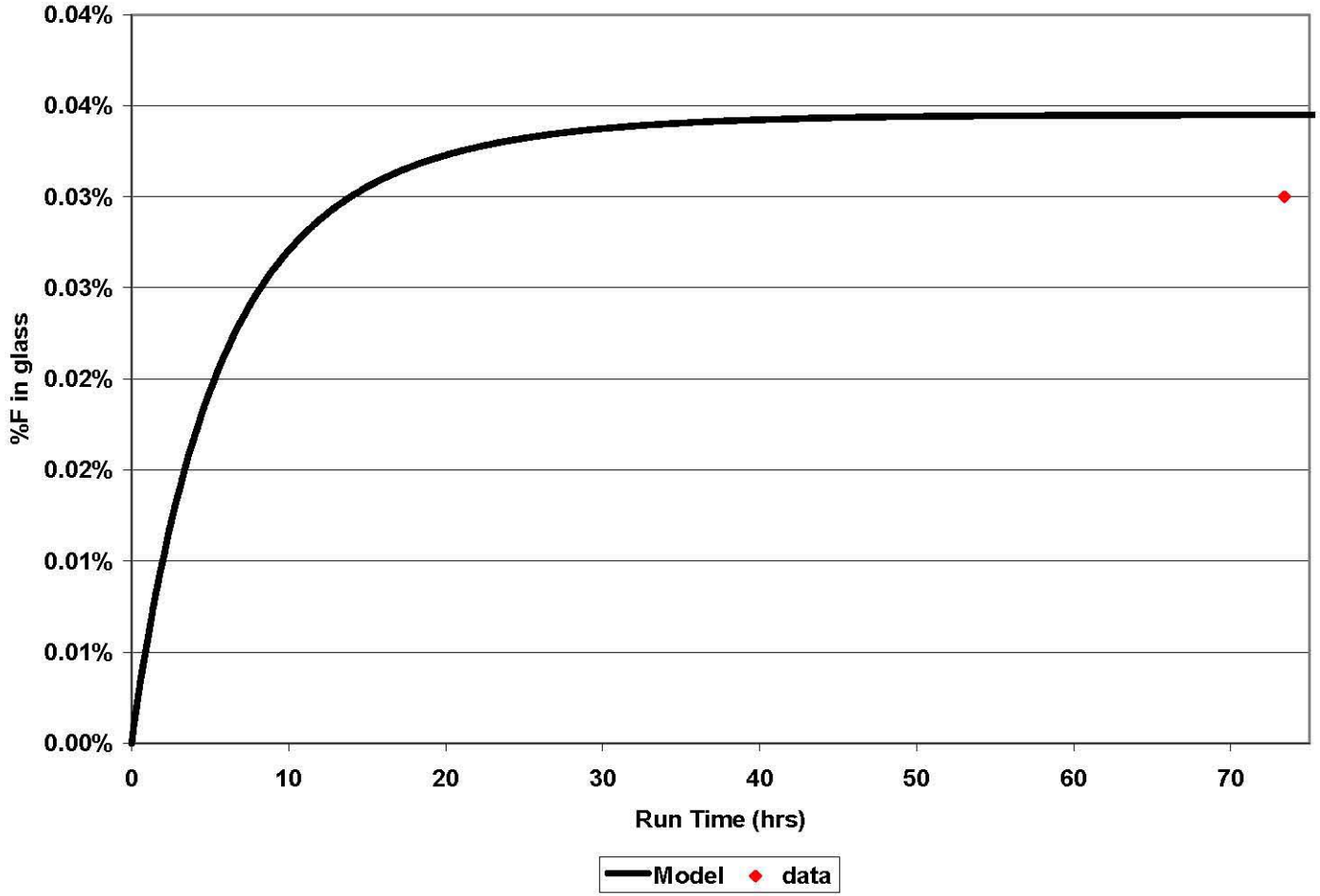


Figure 9.11.b. Fluorine weight percent in the glass during Test 7, the predicted concentrations and the concentrations in the discharged glass samples.

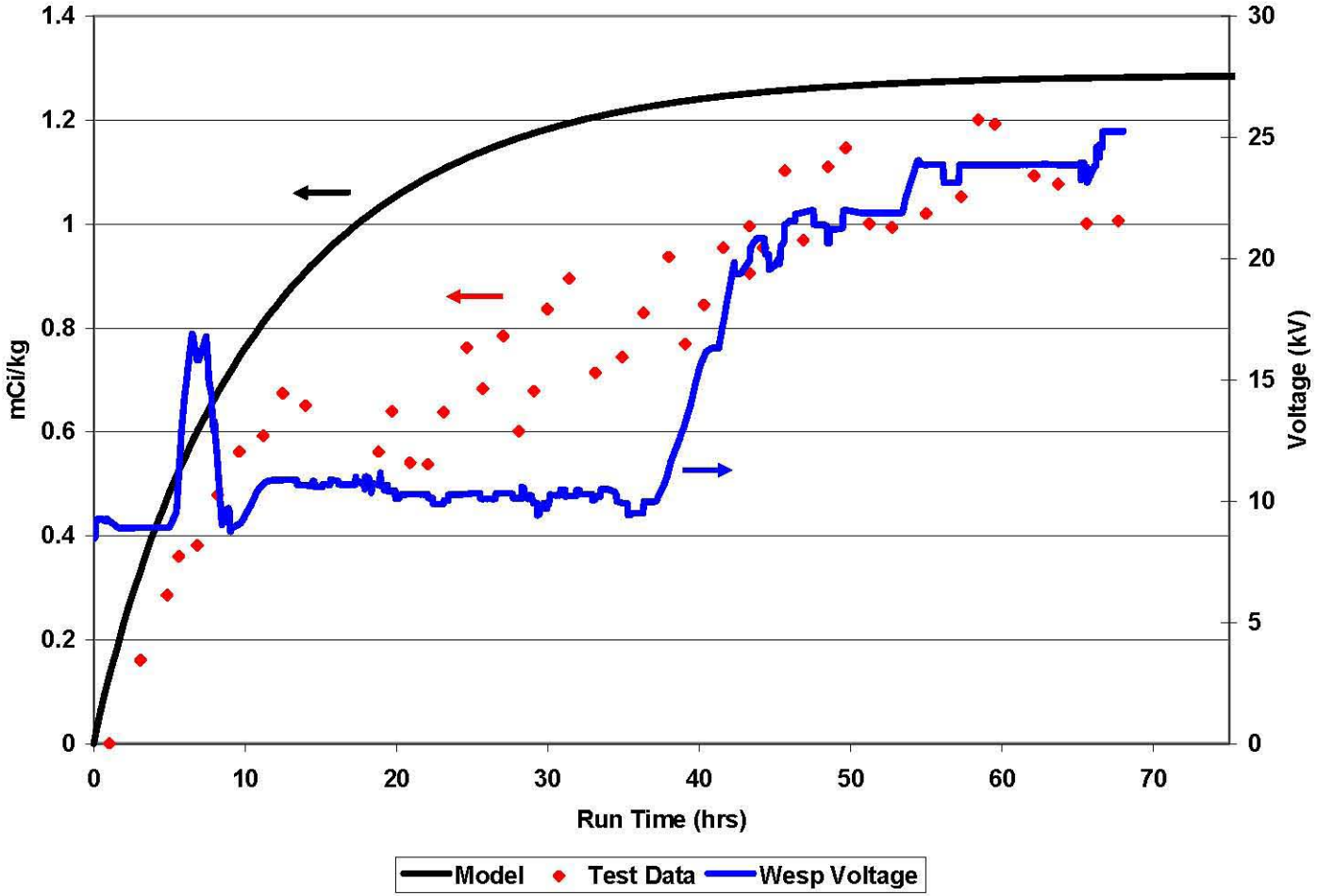


Figure 9.12. Technetium concentration in the glass for Test 2, both the model and discharge samples plotted with the WESP voltage.

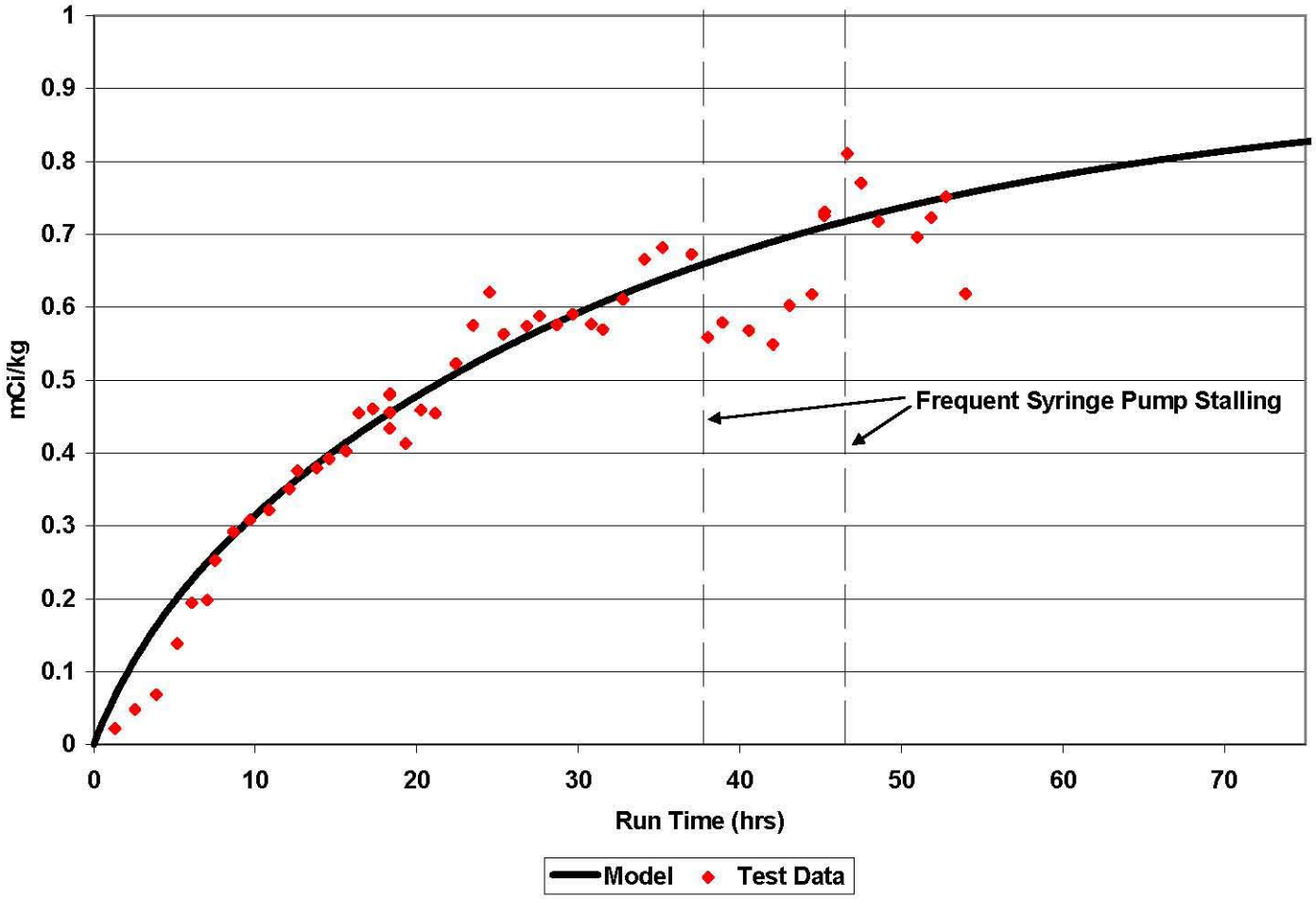


Figure 9.13. Technetium concentration in the glass for Test 3, both the model and discharge samples plotted with the syringe pump downtime indicated.

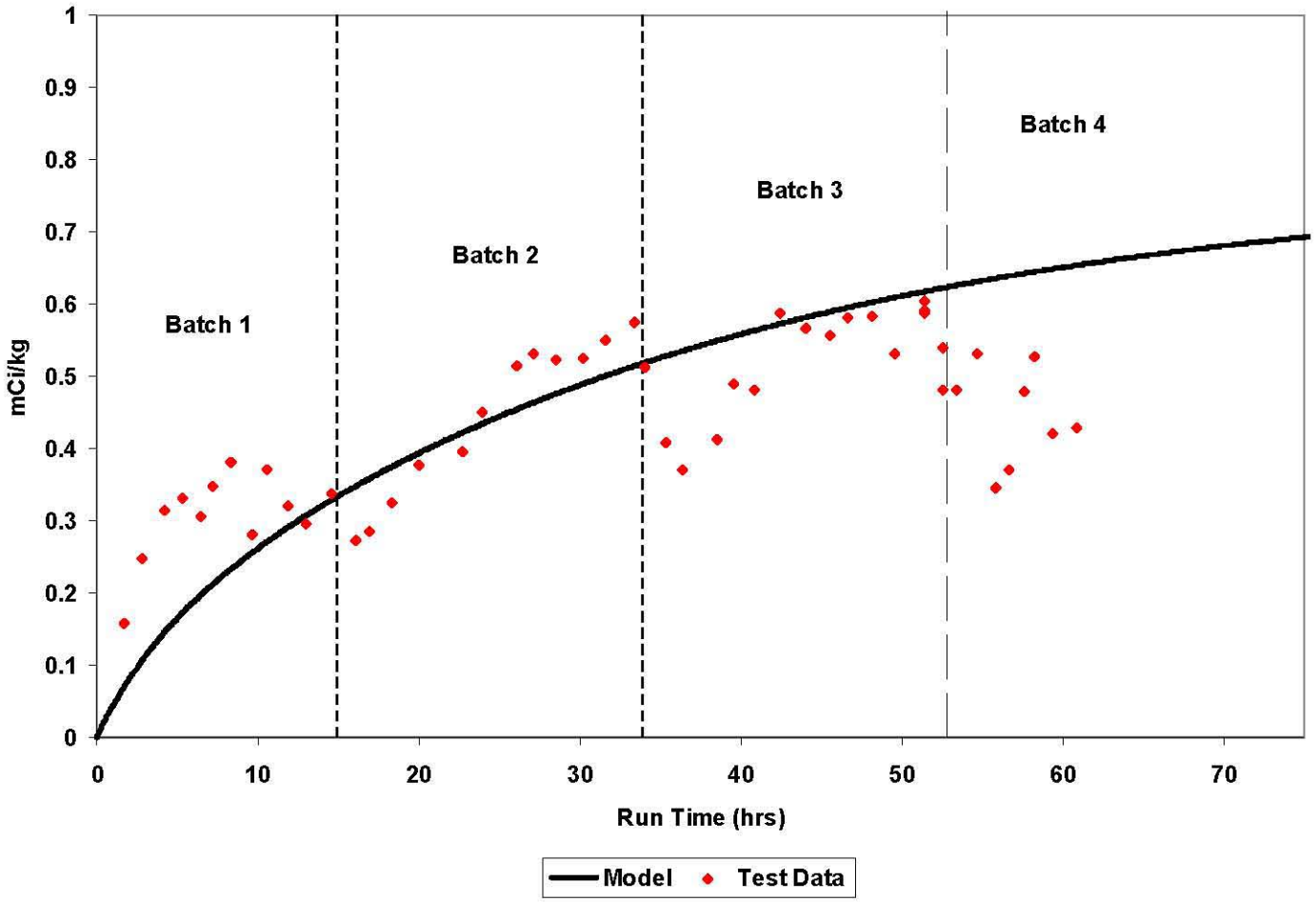


Figure 9.14. Technetium concentration in the glass for Test 5, both the model and discharge samples plotted with the feed batch additions and the feed concentration of technetium for each batch shown.

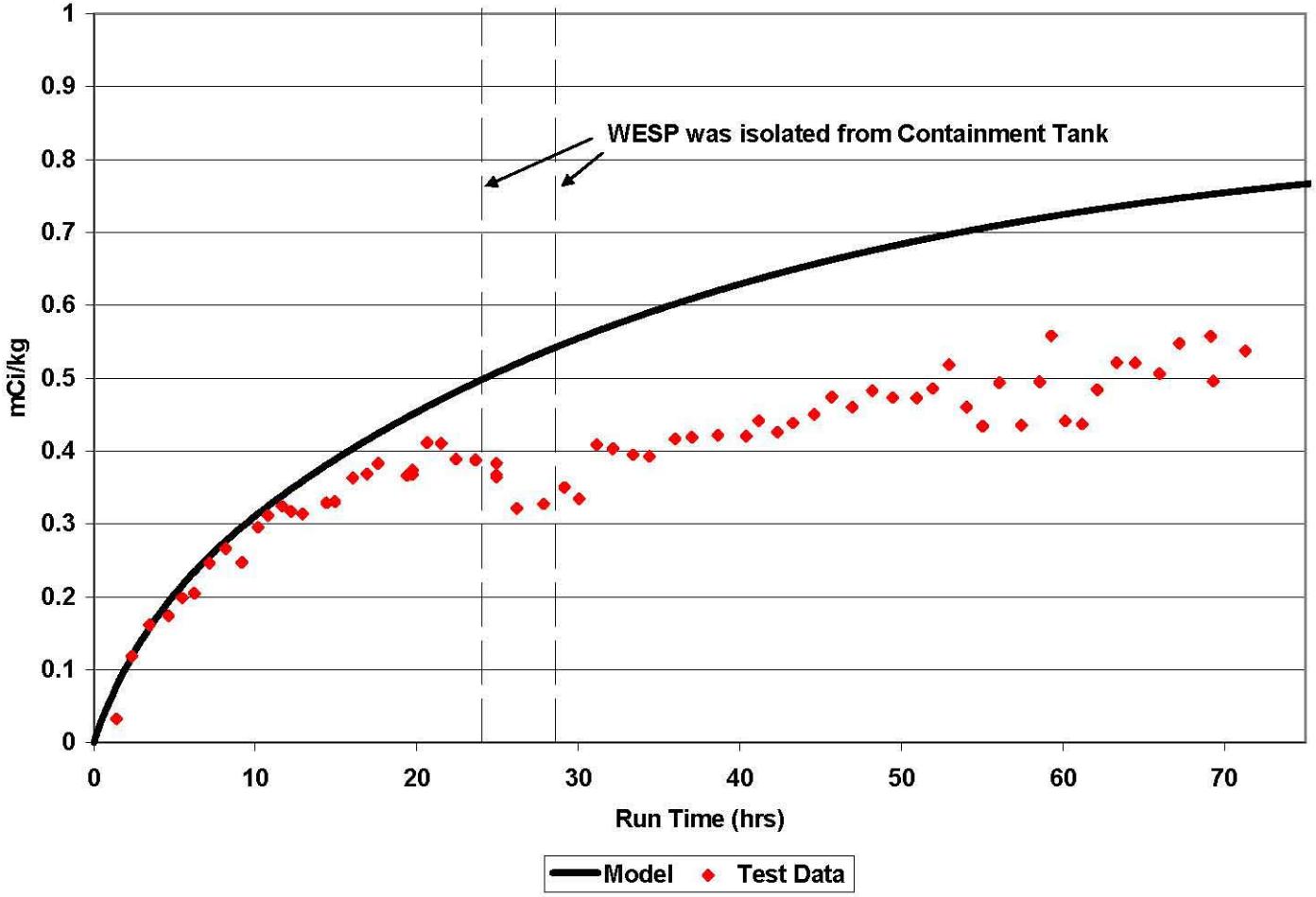


Figure 9.15. Technetium concentration in the glass for Test 6, both the model and discharge samples plotted with the time that the WESP was isolated from the Containment Tank highlighted.

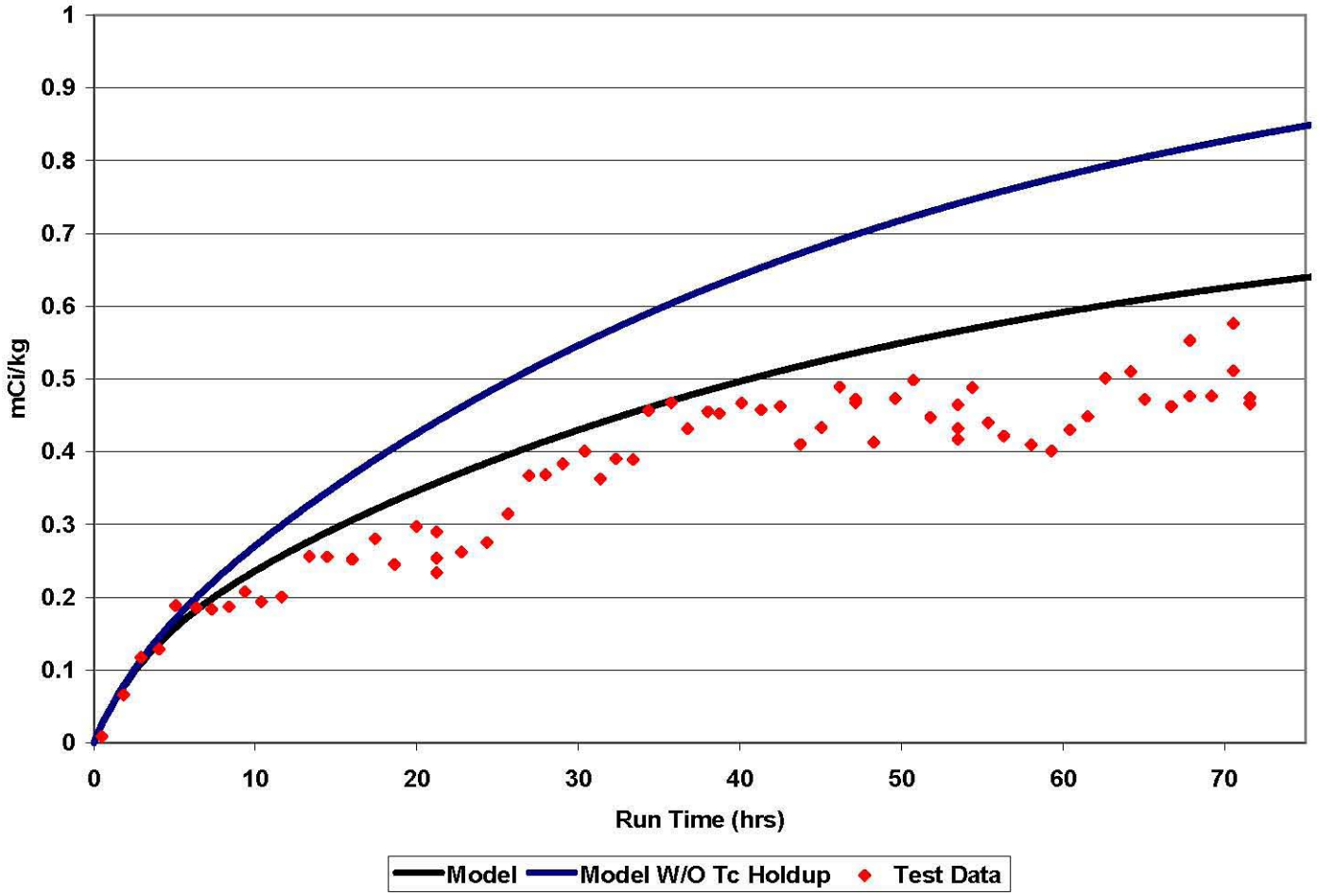


Figure 9.16. Test 8 technetium concentration in the glass with and without holdup in WESP and Transition Line.

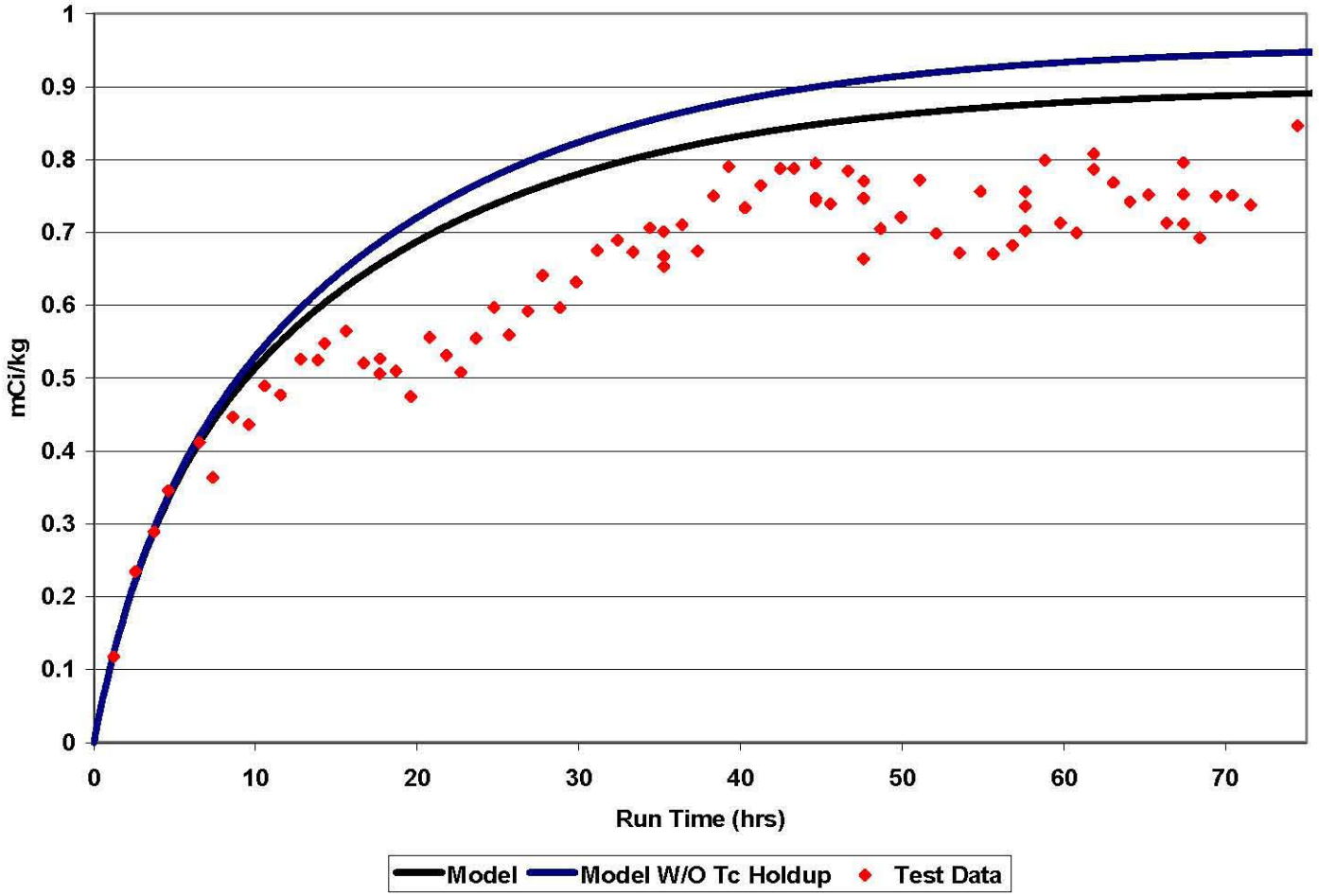


Figure 9.17. Test 9 technetium concentration in the glass with and without holdup in WESP and Transition Line.