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Dissolution Flowsheet for High Flux Isotope Reactor Fuel

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EXECUTIVE SUMMARY

As part of the Spent Nuclear Fuel (SNF) processing campaign, H-Canyon is planning to begin dissolving High Flux Isotope Reactor (HFIR) fuel in late FY17 or early FY18. Each HFIR fuel core contains inner and outer fuel elements which were fabricated from uranium oxide (U_3O_8) dispersed in a continuous Al phase using traditional powder metallurgy techniques. Fuels fabricated in this manner, like other SNF's processed in H-Canyon, dissolve by the same general mechanisms with similar gas generation rates and the production of H_2. The HFIR fuel cores will be dissolved and the recovered U will be down-blended into low-enriched U. HFIR fuel was previously processed in H-Canyon using a unique insert in both the 6.1D and 6.4D dissolvers. Multiple cores will be charged to the same dissolver solution maximizing the concentration of dissolved Al. The objective of this study was to identify flowsheet conditions through literature review and laboratory experimentation to safely and efficiently dissolve the HFIR fuel in H-Canyon.

Laboratory-scale experiments were performed to evaluate the dissolution of HFIR fuel using both Al 1100 and Al 6061 T6 alloy coupons. The Al 1100 alloy was considered a representative surrogate which provided an upper bound on the generation of flammable (i.e., H_2) gas during the dissolution process. The dissolution of the Al 6061 T6 alloy proceeded at a slower rate than the Al 1100 alloy and was used to verify that the target Al concentration in solution could be achieved for the selected Hg concentration. Mass spectrometry and Raman spectroscopy were used to provide continuous monitoring of the concentration of H_2 and other permanent gases in the dissolution offgas allowing the development of H_2 generation rate profiles. The H_2 generation rates were subsequently used to evaluate if a full HFIR core could be dissolved in an H-Canyon dissolver without exceeding 60% of the calculated lower flammability limit (LFL) for H_2 at a given Hg concentration.

Complete dissolution of the Al 1100 and Al 6061 T6 alloys up to a final Al concentration of 2 M was obtained using a 7 M HNO_3 solution containing a 0.002 M Hg catalyst. However, following the dissolutions, solids were observed in the solution. The solids were amorphous, but likely originated from the Si present in the alloys. No crystalline materials, such as $Al(NO_3)_3$ were observed. During the course of the dissolution experiments, it was determined that delaying the addition of Hg once the HNO_3 solution reached the boiling point can reduce the total offgas and H_2 generation rates. The delay in starting the Hg addition is not necessary for HFIR fuel dissolution, but could be useful in other research reactor dissolution campaigns.

The potential to generate flammable concentrations of H_2 in the offgas during a HFIR fuel dissolution was evaluated using the experimental data. The predicted H_2 concentration in the dissolver offgas stream was compared with 60% of the calculated H_2 LFL at 200 °C using several prototypical experiments. The calculations showed that a full HFIR core can be dissolved using nominally 0.002 M Hg to catalyze the dissolution. The margin between the predicted H_2 concentration and the calculated LFL was greater when the solution was allowed to boil for 45 min prior to initiating the Hg addition. When the Hg was increased to 0.004 M, the predicted H_2 concentration exceeded the calculated LFL early in the dissolution.

The dissolution experiments also demonstrated that additional Hg (beyond the initial 0.002 M) could be added as the Al concentration increases. The ability to add more Hg during a HFIR fuel dissolution could be beneficial if slow dissolution rates are observed at high Al concentrations. Experimental data were used to demonstrate that the predicted H_2 concentration in a dissolver was below 60% of the calculated LFL at 200 °C when 0.004 M Hg was used to catalyze the dissolution if the Al concentration is conservatively greater than 0.5 M. Data also show that the Hg concentration during a HFIR fuel dissolution can be increased from 0.002 to 0.008 M at an Al concentration of 1.3 M.

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LIST OF ABBREVIATIONS

B_4C	boron carbide
CVAA	cold vapor atomic absorption
HFIR	High Flux Isotope Reactor
ICPES	inductively-coupled plasma emission spectroscopy
LFL	lower flammability limit
MS	mass spectrometer
NIST	National Institute of Standards and Technology
SNF	Spent Nuclear Fuel
SRNL	Savannah River National Laboratory
SRP	Savannah River Plant
XRD	x-ray diffraction

1.0 Introduction

As part of the Spent Nuclear Fuel (SNF) processing campaign, H-Canyon is planning to begin dissolving High Flux Isotope Reactor (HFIR) fuel in late FY17 or early FY18.[1,2] Irradiated HFIR fuel is currently stored in the L-Area basin. During the HFIR campaign, 200 fuel cores will be processed. Each HFIR fuel core contains an inner and an outer fuel element (Figure 1-1).[3] The fuel cores are fabricated as concentric cylinders with the fuel plates located in the annulus between the inner and outer cylinders. The fuel plates project radially outward from the inner cylinder to the outer cylinder. The plates are curved in the shape of an involute to maintain constant spacing between adjacent plate surfaces.

Figure 1-1. Inner and Outer HFIR Fuel Elements

The HFIR fuel plates are fabricated from U_3O_8 and Al powders using a powder metallurgy process. Boron-10 (as boron carbide – B_4C) is also added to the U_3O_8 and Al powders as a burnable poison.[4] The dissolution behavior of fuel fabricated by powder metallurgy was previously assessed and found to exhibit similar dissolution behavior to fuels fabricated from traditional metallurgy techniques. Since fuels fabricated from traditional and powder metallurgical processes are both comprised of U-Al alloys (or other U compounds) dispersed in a continuous Al phase, each should dissolve by the same general mechanisms with similar gas generation rates including the production of H_2.[5]

The HFIR fuel cores will be dissolved in H-Canyon and the recovered U will be down-blended into low-enriched U. HFIR fuel was previously processed in H-Canyon using a unique insert in both the 6.1D and 6.4D dissolvers (Figure 1-2).[6] Multiple cores will be charged to the same dissolver solution. After the fuel is dissolved, the solution will be processed through Head End and centrifuged to remove particulate matter. After Head End treatment, the U will be recovered and purified by solvent extraction (1st and 2nd Uranium Cycles), and the waste processed for transfer to the H-Area Tank Farm. The relatively high Al content in the dissolved fuel limits the downstream processing due to issues associated with Al solubility.[7] The number of cores dissolved in a dissolver batch will be dependent on the final Al concentration in the solution. Typically, H-Canyon does not exceed approximately 1.7 M $Al(NO_3)_3$ in the dissolver (at 2 M HNO_3), but higher $Al(NO_3)_3$ concentrations ($\leq$2 M) were evaluated as part of this study.

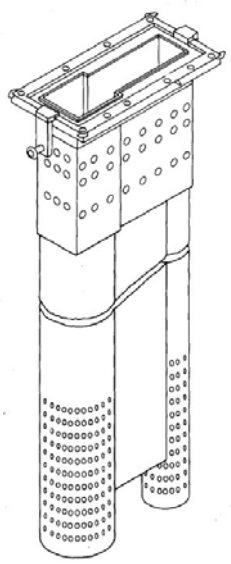

Figure 1-2. HFIR Insert

Bundles of SNF containing U-Al assemblies are currently dissolved using a Hg-catalyzed, HNO_3 flowsheet.[8,9] The Hg catalyst is added gradually after the dissolver has reached the solution boiling point to achieve a maximum catalyst concentration of 0.012 – 0.015 M; a Hg concentration of 0.002 M Hg was previously used to dissolve foreign and domestic research reactor fuels prior to implementation of the current flowsheets.[8]

The initial HNO_3 concentration is dependent on the amount of Al and U to be dissolved, targeting a final HNO_3 concentration of 0.5–1.0 M after completion of the dissolution of the last charge. Boric acid or $Gd(NO_3)_3$ may be used as a nuclear safety poison. Solids do not precipitate in surrogate dissolver solutions containing concentrations of B or Gd less than 2 g/L.[7]

1.1 Objectives

The objective of this study was to identify flowsheet conditions through literature review and laboratory experimentation to safely and efficiently dissolve the HFIR fuel in H-Canyon. During this task, we evaluated the generation of H_2 from the dissolution of the fuel to determine if a full HFIR core (inner and outer elements) can be charged to the dissolver without exceeding 60% of the lower flammability limit (LFL) of H_2 during the initial and subsequent charges. In addition, the downstream processing of the dissolver solution (including Head End and 1st Cycle operations) were evaluated to ensure any processing issues were identified and resolved.

2.0 Experimental Procedure

2.1 Surrogate Materials

The HFIR fuel cores contain both high purity Al (like Al 1100) and Al 6061 alloy.[3,4] High purity Al metal powder is mixed with U_3O_8 and B_4C to form the fissionable component of the fuel.[4] The Al 6061 alloy is used for the cladding and other components of the fuel.[3] The HFIR fuel does not contain any components within the core that serve primarily as structural components; mechanically, the elements are self-supporting. To provide dimensional stability, Al 6061 T6511 (tempered for stress relief) was selected for use in the outer side plates of the elements. Other Al 6061 components in the fuel are fabricated using Al 6061 alloy with a T6 temper.[3]

To select the surrogate materials to model the HFIR fuel during the flowsheet development, a series of scoping experiments were initially performed using both Al 1100 and Al 6061 T6 to characterize the offgas and measure the generation rate of H_2. The scoping experiments were also used to evaluate the effect of high Al concentrations on the dissolution rate of the two alloys. Based on these experiments, it was concluded that the offgas and H_2 generation rates were bounded by the dissolution of the Al 1100 alloy. The results from the scoping experiments are discussed in Section 3.2. The dissolution of the U_3O_8 in the fuel meat will generate a small amount of NO_2 gas (equation 1), but no H_2 is expected. Gray dissolved a mixture of UO_3 and U_3O_8 powders in dilute (2 M) HNO_3 and did not measure any H_2 in the offgas.[10]

$$U_3O_8 + 8HNO_3 \rightarrow 3UO_2(NO_3)_2 + 2NO_2 + 4H_2O \quad (1)$$

From the scoping experiments, it was concluded that the dissolution of the Al 6061 T6 alloy proceeds at a slower rate than the Al 1100 alloy and should be used to verify that the target Al concentration in solution can be achieved for a given concentration of Hg.

2.2 Al Alloy Dissolution

Three scoping experiments designed to select the surrogate materials for the HFIR flowsheet development and five experiments designed to define the process conditions were completed using Al 1100 and Al 6061 T6 alloys. A summary of the objective and dissolution conditions for each experiment are provided in Table 2-1. All experiments were performed at the boiling point of the solution.

Table 2-1. Al Alloy Dissolution Experiments

Exp. No.(1)	Type	Objective (Evaluate ...)	Al Alloy	Hg Conc. (M)	Target Al Conc. (M)
93	scoping	offgas generation and rate of dissolution	Al 6061 T6	0.002→0.004	1.6
94	scoping	offgas generation and rate of dissolution	Al 1100	0.002	1.7
95	scoping	effect of hold time on peak offgas rate	Al 1100	0.002	1.6
96	flowsheet	offgas generation rate at 0.002 M Hg	Al 1100	0.002	1.8
97	flowsheet	rate of dissolution at high Al conc.	Al 1100	0.002	2.0
98	flowsheet	offgas generation rate at 0.004 M Hg	Al 1100	0.004	2.0
99	flowsheet	rate of dissolution at high Al conc.	Al 6061 T6	0.002	2.0
101	flowsheet	increasing Hg from 0.002 to 0.008 M	Al 1100	0.002→0.008	0.6→2.0

(1) Experimental numbering sequence corresponds to data recording practices

2.2.1 Preparation of Al Coupons

The Al 1100 and Al-6061 T6 alloys used in the dissolution experiments were prepared by cutting corrosion coupons to the desired length. The coupons were lightly sanded, washed with soap and water, and then weighed and measured. The coupons were sanded to maximize reactivity as well as to generate consistent results. The coupons used for the majority of the experiments had a mass of approximately 6 g each with a surface area of approximately 5 cm^2. The masses, dimensions, and surface areas of the coupons used in the experiments are provided in Table 2-2. The surface areas are based on a 10 mm immersion depth along the length of each coupon in the HNO_3 solution. The calculations are illustrated by equation 2,

$$SA\ (cm^2) = 2(1\ cm)(t\ (cm)) + 2(1\ cm)(w\ (cm)) + (t(cm))(w\ (cm)) \quad (2)$$

where SA is the surface area of the immersed coupon, t is the thickness of the coupon, and w is the width of the coupon.

Table 2-2. Al Alloy Coupon Characteristics

Exp. No.[1]	Mass (g)	Length (cm)	Width (cm)	Thickness (cm)	Surface Area[2] (cm^2)
93	6.1670	2.428	1.497	0.633	5.208
94	6.0136	3.965	1.917	0.299	5.005
95	5.8068	3.985	1.913	0.284	4.937
96	6.2365	4.161	1.915	0.295	4.985
97	6.2365	4.090	1.905	0.290	4.942
98	6.2206	4.210	1.910	0.291	4.958
$99_{Day\ 1}$	7.1708	2.827	1.499	0.631	5.206
$99_{Day\ 2}$	0.8629	2.003	0.967	0.623	5.011
$101_{Day\ 1}$	1.7747	1.276	1.918	0.276	4.917
$101_{Day\ 2}$	4.6717	3.282	1.916	0.283	4.953

(1) Experiments 99 and 101 were performed over two days
(2) Surface areas were calculated for a 10 mm coupon immersion

2.2.2 Dissolving System

The vessel and offgas condenser used to perform the Al alloy dissolution experiments were fabricated from borosilicate glass by the SRNL Glass Shop. The dissolving vessel was made from a 300-mL round-bottom flask. Penetrations were added for a condenser, thermocouple, vessel purge, and Hg addition syringe pump. The bottom of the flask was flattened slightly to facilitate heating and agitation using a hot plate/stirrer with a magnetic stir bar. The solution temperature was controlled using an external thermocouple monitored by the hot plate. Online analysis of the offgas by mass spectrometry and Raman spectroscopy was performed to characterize the offgas and measure the offgas generation rate. The mass spectrometer (MS) sample line was connected above the condenser to an offgas sample port. A manometer, also connected to the offgas sample port, acts as a pressure relief device and provides a measurement of the pressure in the system. The offgas leaving the condenser subsequently passes through a cell containing a Raman probe and terminates in a bubbler (i.e., beaker containing 700 mL or 3.5 in of deionized water). The bubbler prevents air in-leakage from the vent side of the system. This configuration allows the offgas analyzers to measure the non-condensable gases such as H_2, N_2, O_2, Ar, NO, N_2O and NO_2 in real time during the experiment. A photograph of the equipment is shown in Figure 2-1.

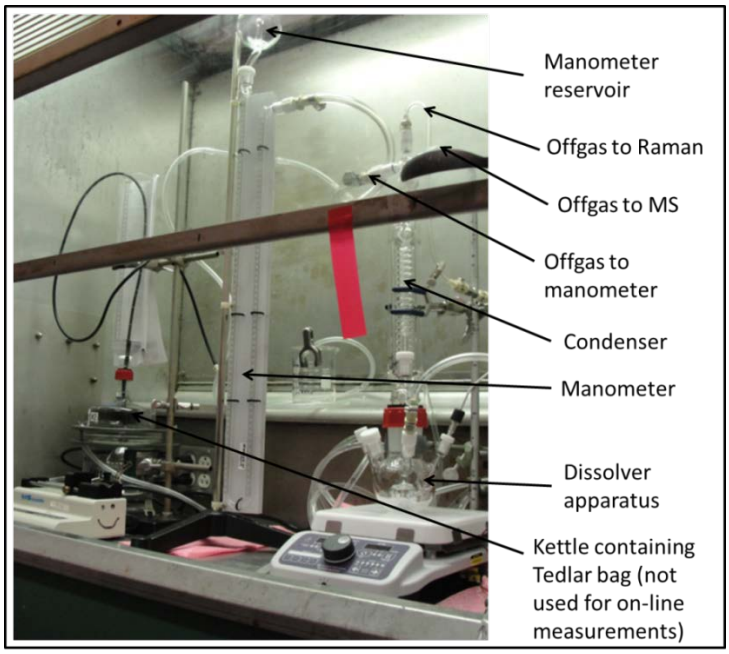

Figure 2-1. Dissolver Setup with Online MS and Raman Offgas Analyzers

2.2.2.1 Monitor Mass Spectrometer

The MS used during the dissolution experiments was a Monitor Instruments LAB 3000 Cycloidal MS. The Monitor MS samples a portion of the non-condensable offgas stream using vacuum and provides the volume percent of the gases in the sample based on calibration gas standards. The Monitor MS was calibrated using the gases listed in Table 2-3. The MS is controlled by a computer using Monitor v6.00 software.

To calculate offgas generation rates, an Ar tracer gas was metered into the system through a flow controller at a set rate (10 cm^3/min @ 70 °F, 1 atm). The total offgas rate was then calculated by dividing the set input rate by the measured Ar concentration in the offgas.

Table 2-3. Calibration Gases for MS and Raman Analyzers

Supplier	Gas	Ar	N_2	N_2O	NO_2	NO	O_2	H_2
		(%)	(%)	(%)	(%)	(%)	(%)	(%)
Air Liquide	20% N_2O-80% Ar	80.00	–	20.00	–	–	–	–
Liquid Technology	5% NO_2-20% O_2-75% Ar	74.89	–	–	4.98	–	20.13	–
Air Liquide	20% NO-80% Ar	80.00	–	–	–	20.00	–	–
Air Liquide	5% N_2-10% H_2-85% Ar	85.00	5.00	–	–	–	–	10.00
SRNL	Ar(1)	99.9	–	–	–	–	–	–
SRNL	N_2(1)		99.9	–	–	–	–	–
SRNL	Air(1)	0.94	78.03	–	–	–	20.99	–

(1) purity not measured; supplied from SRNL facility gases

Calibration of the MS is discussed in Appendix B.

2.2.2.2 Raman Spectrometer

The Raman spectrometer non-intrusively analyzes the offgas through a quartz window using the excitation of a laser passing through a fixed portion of the offgas stream. The Raman scattering technique identifies and measures the concentration of gases in the offgas stream. The Raman spectrometer was also calibrated using the standard gases shown in Table 2-3. The Raman spectrometer measures the concentrations of the offgas species approximately every 12-13 seconds. Since the Raman spectrometer directly measures the concentrations in the offgas stream, there is zero dead time between the offgas concentration measurement and the reading other than the analysis time of 12-13 seconds. The Raman spectrometer was controlled by and data was logged using a computer running EZRamanReader v8.3.9 software and an Excel spreadsheet.

To calculate offgas generation rates in experiments in which only the Raman spectrometer was used to characterize the offgas, a CO_2 tracer gas was metered into the system through a flow controller at a set rate (20, 30, or 50 cm^3/min @ 70 °F, 1 atm). The total offgas rate was then calculated by dividing the set input rate by the measured CO_2 concentration in the offgas.

Calibration of the Raman spectrometer and treatment of the data is discussed in Appendix F.

2.2.3 Dissolution Experiments

Prior to performing a dissolution experiment, the dissolving system was checked for leaks by connecting a Tedlar® bag inside a glass kettle filled with water (Figure 2-1.) to the dissolver and adding sufficient Ar, N_2, or CO_2 to the bag to generate a column of water 18-28 cm tall. The Tedlar® bag system was then closed and monitored for any observable decrease in the water column height over approximately 3 min. After the system integrity was confirmed, the experiment was started.

To perform a dissolution, the Al alloy coupon was initially placed in a perforated glass basket. The basket was lowered until the coupon was immersed 10 mm lengthwise into a 7 M HNO_3 dissolving solution at room temperature. The solution was then heated to boiling. Chilled water (at 3 °C) was circulated through the condenser during the dissolution to remove water vapor from the offgas stream prior to analysis by the MS and before the gas flowed through the Raman cell. Once the solution reached boiling, either the Hg solution was added right away or there was a hold time before starting the Hg addition to reduce the initial offgas surge. The initial volume of HNO_3 and the volume of the Hg solution added (Table 2-4) were based on the mass of the Al coupon and the target Al and Hg concentrations following the dissolution.

Table 2-4. Dissolving Solution Volume and Composition

Exp. No.	Initial Volume	Hg Solution Volume	Target Hg Concentration	Target Al Concentration
	(mL)	(mL)	(M)	(M)
93	130	1.55	0.002→0.004	1.6
94	130	1.55	0.002	1.7
95	130	1.55	0.002	1.6
96	114	1.35	0.002	1.8
97	124	1.48	0.002	2.0
98	114	2.75	0.004	2.0
99	128	1.55	0.002	2.0
101	114	5.70	0.002→0.008	0.6→2.0

During the dissolution of both Al 1100 and Al 6061 alloys, it was found that holding the coupon in the boiling HNO_3 solution for 45 min significantly reduced the initial surge of offgas; therefore, this practice

was used for subsequent dissolution experiments. The reduced reactivity of the Al coupons was likely due to the passivation of the surface by the HNO_3 solution during the hold time.

To emulate the Hg addition performed in the 6.4D dissolver,[11] the time of the Hg addition relative to total fuel dissolution time was scaled in an effort to match the Hg addition to the increasing concentration of Al in solution. It was assumed that the 6.4 D dissolver takes about 36 h to dissolve a charge of fuel and 6 h of that time is used to add 0.012 M Hg. Therefore, one-sixth of the total dissolution time is used for adding Hg. For the lab scale experiments, approximately 76 min were needed to dissolve the Al-1100 alloy coupons starting with 7 M HNO_3 (with the Al concentration increasing to approximately 1.6 M). Therefore on the lab scale the Hg was added over 76/6 or 12.67 min. The Hg solution for the dissolution of the Al alloys was obtained from H-Canyon Tank 201 and contained 4.31 wt % $Hg(NO_3)_2$ (0.169 M Hg) and 37.79 wt % (7.64 M) HNO_3. Therefore, on the lab scale, 10 mL of the Hg solution would be added to 130 ml of HNO_3 solution giving an effective Hg addition rate of 10 mL/12.67 minutes or 0.79 mL/min (47.4 mL/h).

During the experiments, samples of the final dissolving solutions were collected for analysis. Samples were submitted to SRNL Analytical Development to measure the HNO_3 (free acid), Hg, and metals concentrations in reagents and in final dissolving solutions. The free acid, Hg, and metals concentrations were determined by titration, cold vapor atomic absorption (CVAA) spectroscopy, and inductively-coupled plasma emission spectroscopy (ICPES), respectively. Some final dissolution solutions (Experiments 96, 97, 99) were filtered and the filtered solids were examined by x-ray diffraction (XRD) analysis. Samples of the initial 7 M HNO_3 dissolving solution were also submitted for free acid analysis. Samples of the H-Canyon Hg solution were submitted for free acid and Hg analysis. The analyses were used as checks on the concentrations since the initial and final volumes of the dissolver solutions were measured as well as the mass of Al added to each solution.

2.3 Quality Assurance

Requirements for performing reviews of technical reports and the extent of review are established in manual E7, 2.60. SRNL documents the extent and type of review using the SRNL Technical Report Design Checklist contained in WSRC-IM-2002-00011, Rev. 2.

3.0 Results and Discussion

3.1 Review of Past HFIR Fuel Dissolution Campaigns

The dissolution and recovery of highly enriched U from HFIR fuel was previously performed at the SRS. The fuel was first dissolved under a Test Authorization in the late 1960's.[12] Between May 1969 and November 1972, 68 HFIR cores were dissolved in H-Canyon.[13] Another 176 cores were dissolved in 11 campaigns between April 1976 and May 1988.[14] The previous processing experience documented in SRP Works Technical Monthly Reports was reviewed to identify the range of conditions which were successfully used to dissolve the fuel. Of particular interest were the concentrations of Hg which were used to catalyze the fuel dissolutions.

HFIR fuel dissolution data from H-Canyon campaigns performed between September 1972 and September 1980 are summarized in Table 3-1.[15] During these campaigns, the Hg concentration was held constant at 0.004 M. A less complete data set for dissolution campaigns performed between April 1976 and May 1988 are provided in Table 3-2.[14] The HFIR fuel dissolutions were performed in the 6.1D dissolver except between August 1980 and February 1982 when the 6.4D dissolver was used.

Table 3-1. HFIR Fuel Dissolution Data using 0.004 M Hg

Date	^{235}U (inner)	^{235}U (outer)	^{235}U[(1)]	Reflux Time	Assembly Exposure		Initial HNO_3	Volume
					Inner	Outer		
	(kg)	(kg)	(kg)	(h)	(MWD)	(MWD)	(M)	(L)
Sep-72	2.597	6.805	9.402	14-16	800	1550	-	-
Apr-74	2.622	6.872	9.494	16-17	571	1682	-	-
May-74	2.622	6.872	9.494	16-20	571	1682	-	-
Jun-74	2.622	6.872	9.494	16-20	582	1498	-	-
Jul-74	2.622	6.872	9.494	16-18	557	1528	-	-
May-76	2.622	6.872	9.494	16-20	562	1637	3.35	-
Jun-76	2.622	6.872	9.494	16-18	556	1685	3.35	6525
Jul-76	2.622	6.872	9.494	16-21	552	1656	3.35	6525
Aug-76	2.622	6.872	9.494	16-22[(2)]	580	1718	3.35	6525
Aug-77	2.622	6.872	9.494	16-21[(2)]	526	1514	3.5	6525
Aug-80	2.622	6.872	9.494	20-28	537	1554	2	13000[(3)]
Sep-80	2.622	6.872	9.494	20-28	537	1554	2	13000[(3)]

(1) Prior to irradiation
(2) Includes 5 h dissolution for heal cleanout prior to low enriched U campaign
(3) 6.4D dissolver

Table 3-2. Dissolution of HFIR Fuel in H-Canyon Dissolvers

Date	Vessel	Al Charge	Hg
		(kg)	(M)
Apr-76 – Feb-82	6.4D	135.3	0.00400
July-83 – Nov-83	6.1D	134.6	0.00400
Dec-83 – Feb-84	6.1D	134.6	0.00700
Mar-84	6.1D	134.6	0.01000
Jan-86 – Mar-86	6.1D	134.6	0.00700
Apr-86	6.1D	134.7	0.00350
May-86	6.1D	134.7	0.00175
Jun-86	6.1D	134.7	0.00350
May-88	6.1D	135.5	0.00350

The data in Table 3-1 show that dissolution (i.e., reflux) times for a single HFIR core (per batch) ranged from 14 to 28 h when 0.004 M Hg was used as the catalyst concentration. However, a majority of the dissolutions were completed in 20 h or less. If 0.002 M Hg is used to catalyze the dissolution, the dissolution time could double assuming the fuel dissolution rate is proportional to the Hg concentration. Therefore, an estimate of the dissolution time for the initial HFIR core is 28 to 40 hr. The dissolution times of subsequent cores using the same dissolving solution would be expected to increase as the Al concentration in the dissolver also increases.

3.2 Selection of Surrogate Materials for Dissolution Studies

To establish which Al alloy provides a bounding estimate for the generation of H_2 during the flowsheet development for HFIR fuel, dissolution experiments were performed using both Al 1100 and Al 6061 T6 alloys. As noted in Section 2.1, the dissolution of the U_3O_8 in the HFIR fuel meat does not need to be evaluated. Dissolution of U_3O_8 will generate a small amount of NO_2 gas (equation 1), but no H_2 is expected. In the experimental work, both Al alloys were dissolved using the equipment described in Section 2.2.2 using a solution containing 7 M HNO_3. The Hg concentration was adjusted to 0.002 M. The offgas generation rates and gas concentrations were measured using the MS during dissolution of both alloys. The H_2 generation rate per unit surface area is plotted as a function of the dissolved Al concentration in Figure 3-1 for both alloys. The concentration of Al in the dissolving solution as a function of time was estimated using the method described by Almond et al.[8] The plot shows that the dissolution of the Al 1100 alloy is bounding in terms of the H_2 generation rate when compared to the dissolution of the Al 6061 T6 alloy. Based on these results, data from the dissolution of Al 1100 were used to evaluate the H_2 generation rate from the dissolution of HFIR fuel.

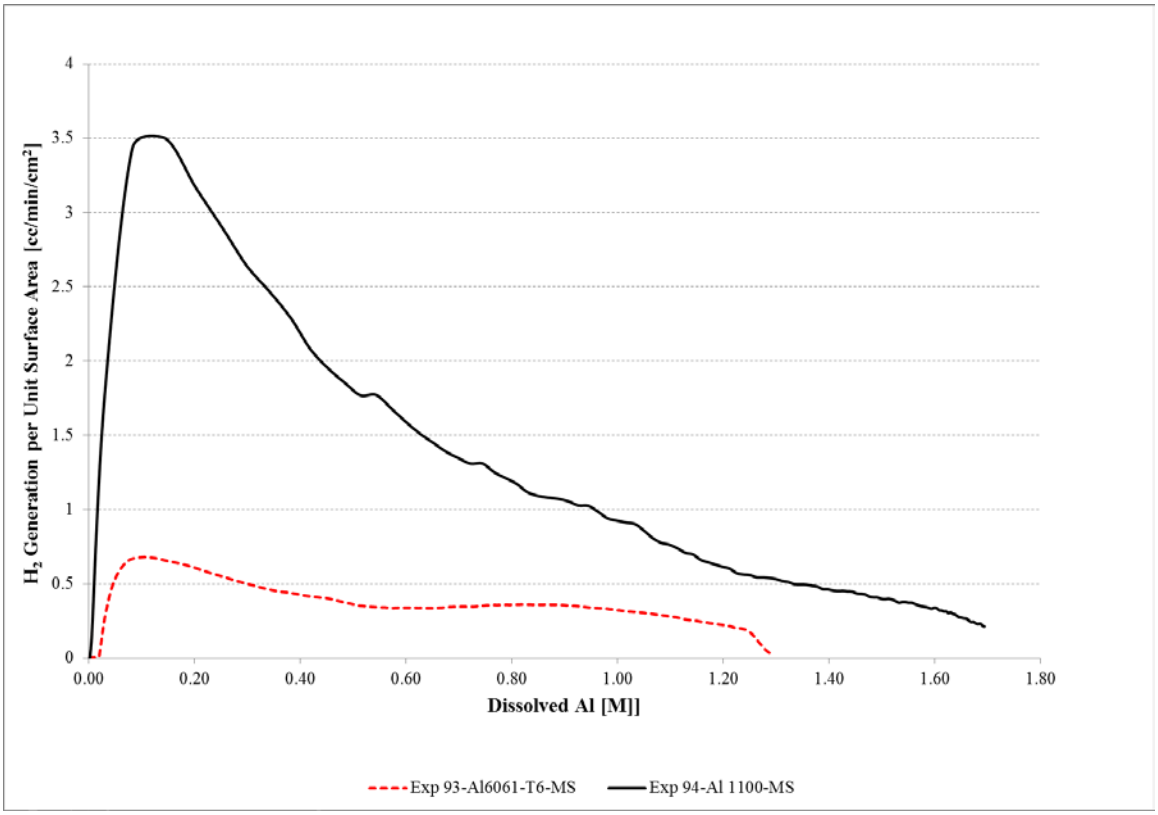

Figure 3-1. H_2 generation Rate during the Dissolution of Al 1100 and Al 6061 T6 Alloys

During the dissolution of the Al alloys, it was observed that holding the coupon in the boiling HNO_3 solution for 45 min prior to starting the Hg addition significantly reduced the initial surge of offgas and the H_2 generation rate. In Experiment 94, Al 1100 was dissolved in 7 M HNO_3 where the addition of 0.002 M Hg was initiated immediately after reaching boiling. In Experiment 95, Al 1100 was dissolved in 7 M HNO_3 and the addition of 0.002 M Hg was initiated 45 min after the solution reached the boiling point. The H_2 generation rates for the two experiments are shown in Figure 3-2 and demonstrate that holding the Al at the solution boiling point for 45 min then starting the Hg addition reduces the H_2 generation rate especially during the peak H_2 generation at the beginning of the dissolution.

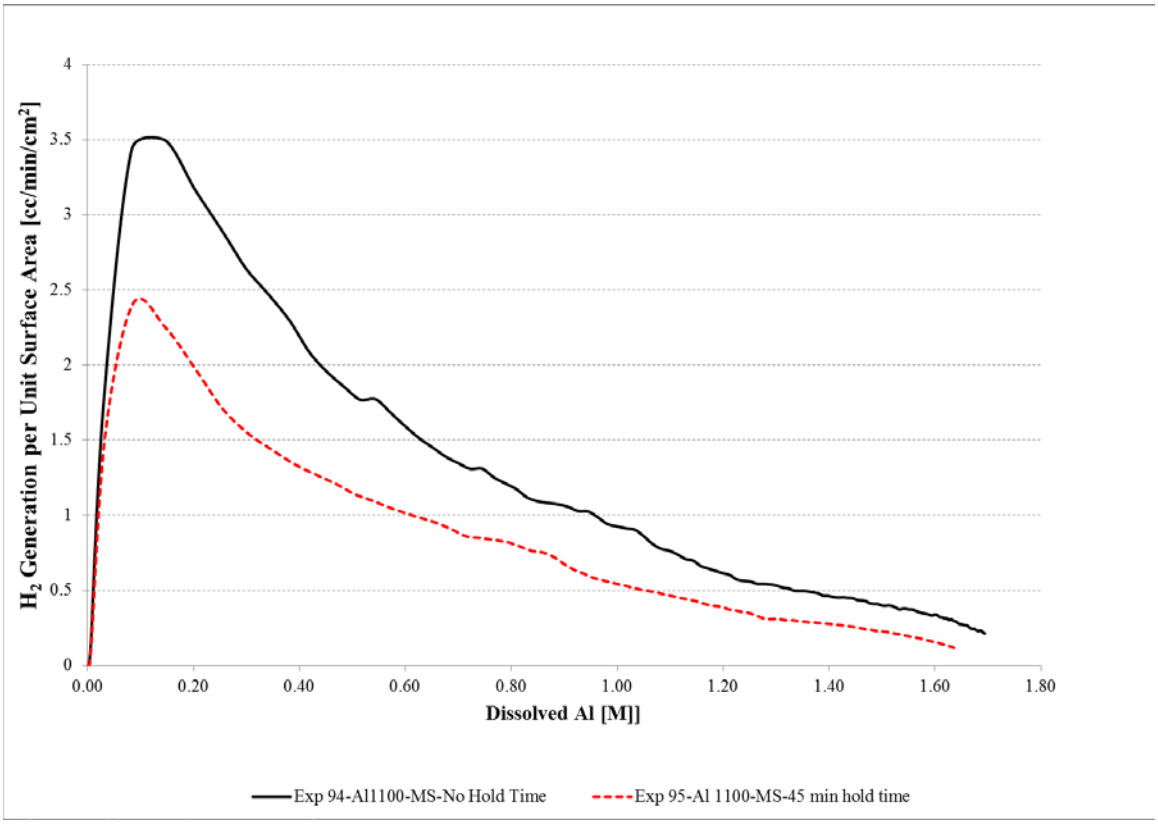

Figure 3-2. Effect of Hold Time on H_2 Generation Rate

3.3 Flowsheet Development

3.3.1 Maximum Dissolved Al Concentration

Three experiments were performed using the Al 1100 and Al 6061 T6 alloys with high (e.g., 1.8-2.0 M) targeted Al end points to evaluate the rate of dissolution and to determine if there were any solubility issues following dissolution. Experiments 96 and 97, performed with the Al 1100 alloy, targeted final Al concentrations of 1.8 and 2.0 M, respectively. Experiment 99 was performed with Al 6061 T6 alloy and targeted a final Al concentration of 2.0 M. The H_2 generation curves (which illustrate the extent of dissolution) for the three experiments are plotted as a function of time in Figure 3-3. Time zero for each curve represents the start of the Hg addition. The figure shows that the Al 1100 alloy dissolves at about twice the rate of the Al 6061 T6 alloy. Complete dissolution of the Al coupon was achieved in each experiment. However, following the dissolution experiments, solids were observed in the solution. Analysis of the solids by XRD showed only amorphous material (Figure 3-4). No crystalline materials, such as $Al(NO_3)_3$ were observed. This result is consistent with several previous Al 1100 dissolution experiments in which unidentifiable amorphous solids were recovered from the dissolving solution by filtration. In other experiments, undissolved solids were identified by XRD as elemental Si.[8] Amorphous and silicon-containing solids from the dissolution of HFIR fuel in an H-Canyon dissolver should be easily removed by the Head End centrifuge using the standard gelatin strike process.

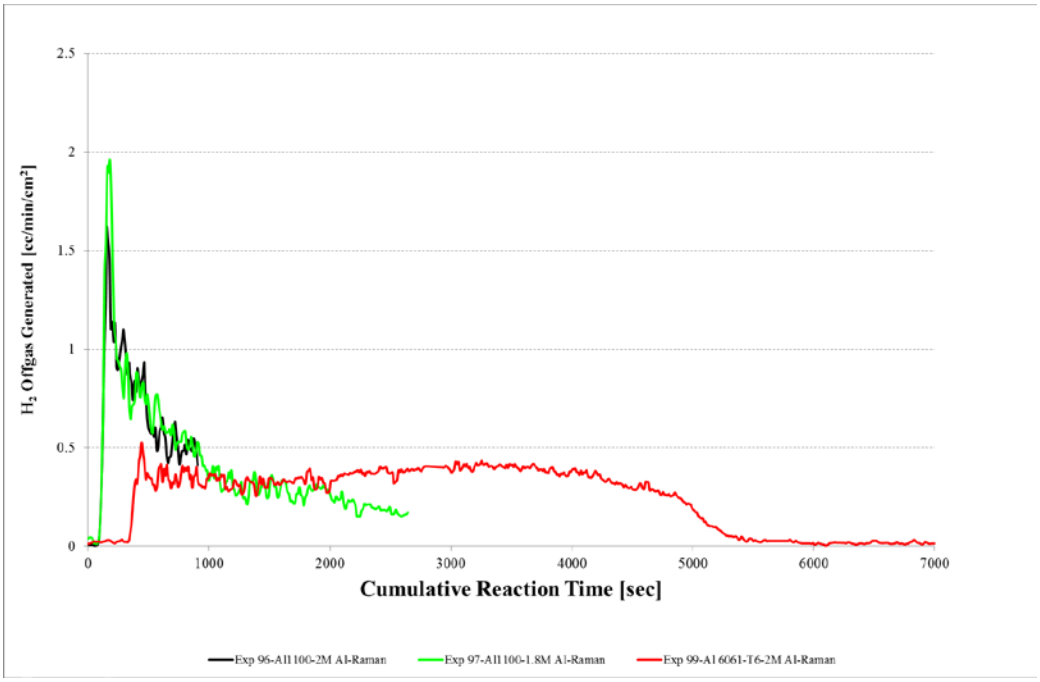

Figure 3-3. H_2 Generation Rate for Experiments Targeting High Concentrations of Al

3.3.2 Flammable Gas Generation

The rate of flammable gas generation from the HFIR fuel is proportional to the surface area exposed to the dissolving solution. The surface areas of the fuel and carriers used to transport the fuel elements were calculated by Laurinat.[16] The surface area calculations were completed by taking into account that closely spaced internal surfaces will be blanketed by product gases generated during a dissolution, therefore, these surfaces are not exposed to the dissolving acid. In previous work, Caracciolo[17] demonstrated that the dissolution rate for two concentric fuel tubes containing a 16 wt % U-Al alloy was essentially the same as for a single tube of the same alloy. This result indicated that the outside surface area of the outer tube controlled the dissolution rate.

To estimate the concentration of H_2 in the offgas during the dissolution of HFIR fuel, experiments were performed using both Al 1100 and Al 6061 T6 alloys. Preliminary experiments demonstrated that the dissolution of the Al 1100 alloy was bounding in terms of the H_2 generation rate when compared to the dissolution of the Al 6061 T6 alloy. Experiments 96, 97, and 98 were performed to measure the H_2 generation rate for Al 1100 at nominally 0.002 M Hg and for an increased concentration of 0.004 M. In these experiments, the Hg addition was not started until the solution boiled for 45 min. This methodology was used to reduce the initial surge of offgas when Hg is added to the dissolving solution. In each case, 7 M HNO_3 was used as the dissolving solution.

The H_2 generation rates for Experiments 94, 96, 97, and 98 are plotted as a function of the dissolved Al concentration in Figure 3-5. The H_2 generation rates were calculated from the measured offgas generation rates, measured H_2 concentrations, and the measured surface area of the Al 1100 coupons. The concentration of Al in the dissolving solution as a function of time was estimated using the method described by Almond et al.[8] The figure shows that the H_2 generation rates surge after the start of the Hg addition and the rate for Experiment 98 (0.004 M Hg) is approximately twice the values for Experiments 96 and 97 (0.002 M Hg) based on the Raman data.

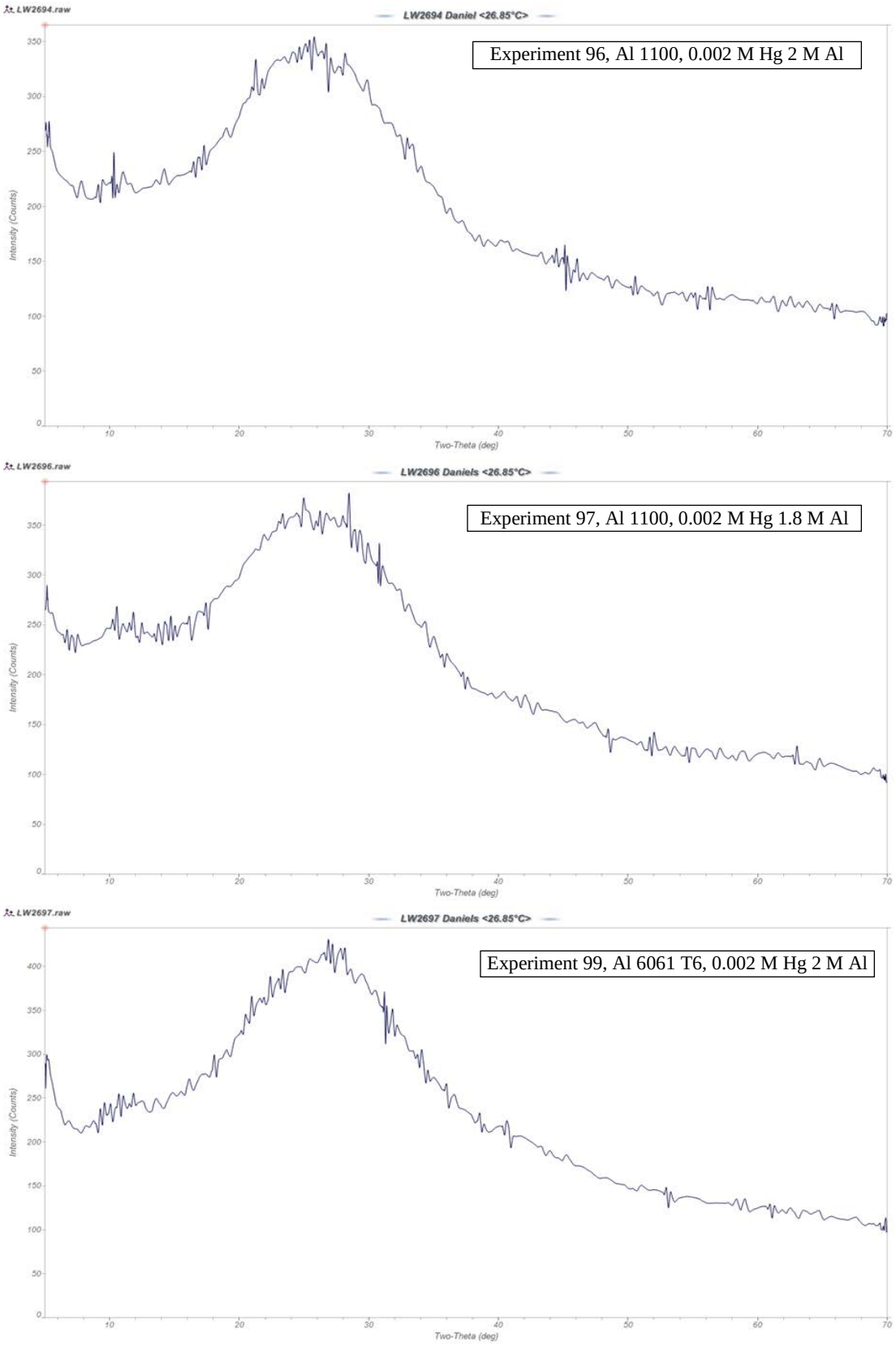

Figure 3-4. XRD Results for Solids Generated During Al Alloy Dissolutions

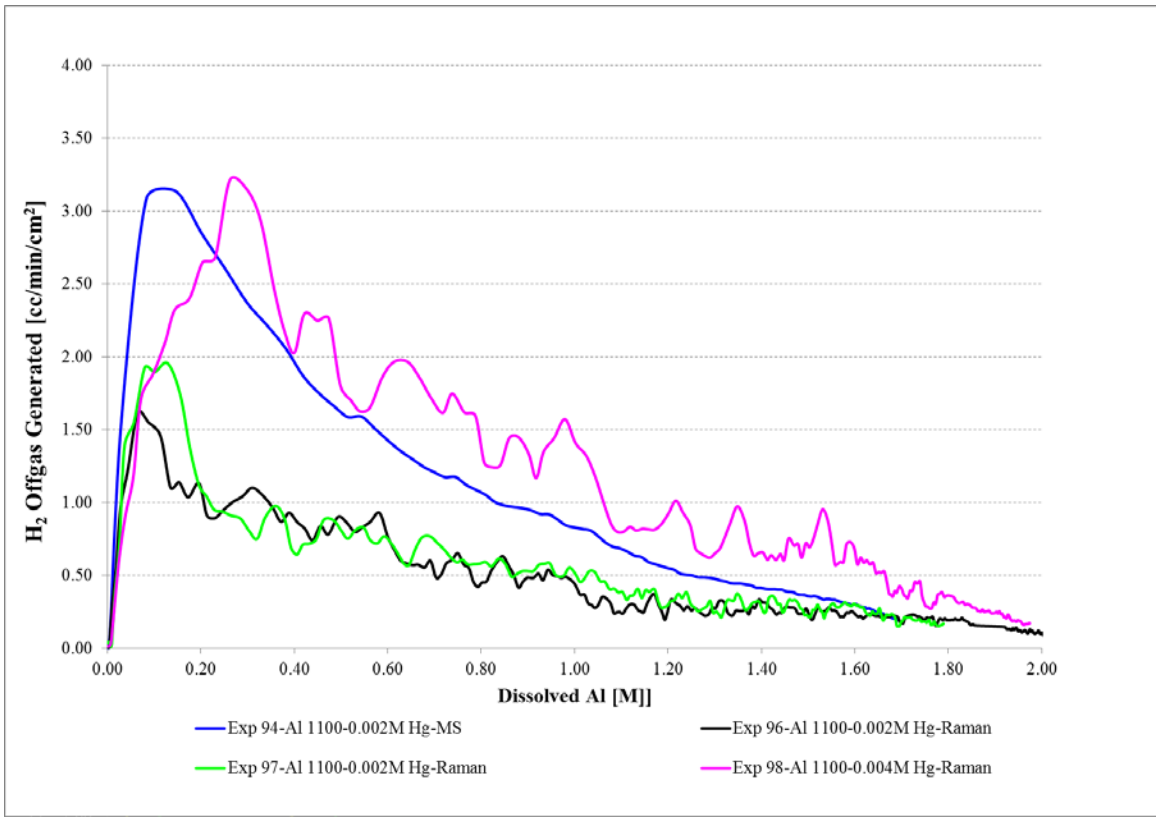

Figure 3-5. H_2 Generation Rate from the Dissolution of Al 1100 Alloy

The criterion of not exceeding 60% of the H_2 LFL in the dissolver offgas (at 200 °C) was used for the fuel dissolution calculations in this report and is consistent with the criterion used by Almond et al. in a previous study.[8] When automatic instrumentation with safety interlocks is provided, the combustible concentration is permitted to be maintained at or below 60% of the LFL.[18] The H_2 LFL at 200 °C is required due to the I_2 reactor in the offgas stream of the H-Canyon dissolvers which operates at this temperature. Lower flammability limit data reported by Scott et al.[19] for air, H_2, NO, and N_2O mixtures were used to calculate the LFL for comparison to the H_2 concentrations calculated for an H-Canyon dissolver. Three data sets for NO:N_2O ratios of 2.57, 1.00, and 0.33 are shown in Appendix A. The H_2 LFL data in Appendix A were correlated using a second order polynomial to allow interpolation at varying concentrations of air (Table 3-3).

Table 3-3. Correlations for H_2 LFL Data

NO:N_2O Ratio(1) (vol %/vol %)	Correlation
$x \geq 2.57$	H_2 LFL (vol %) = $6.038 + 3.174\times10^{-2}$(Air vol %) - 5.401×10^{-4}(Air vol %)^2
$1 \leq x < 2.57$	H_2 LFL (vol %) = $3.425 + 1.207\times10^{-1}$(Air vol %) - 1.186×10^{-3}(Air vol %)^2
$x < 1$	H_2 LFL (vol %) = $5.479 - 1.067\times10^{-3}$(Air vol %) - 1.400×10^{-4}(Air vol %)^2

(1) x is defined as the NO:N_2O ratio

The NO:N_2O volume ratios for dissolution experiments 94, 96, 97, and 98, which were used to estimate the H_2 LFL in the offgas during dissolution of HFIR fuel, are shown in Figure 3-6. The LFL data for H_2 provided in Appendix A show that higher NO:N_2O ratios result in higher values for the H_2 LFL. The NO:N_2O data shown for Experiment 94 in Figure 3-6 are based on offgas analyses performed using the

MS and have higher values when compared to data from the experiments in which the offgas analysis was performed by Raman spectroscopy. It is unclear why the ratios measured by the MS are higher than the ratios measured by Raman spectroscopy for experiments performed using similar conditions; however, the lower NO:N_2O ratios will result in lower values of the H_2 LFL which is a conservative bias.

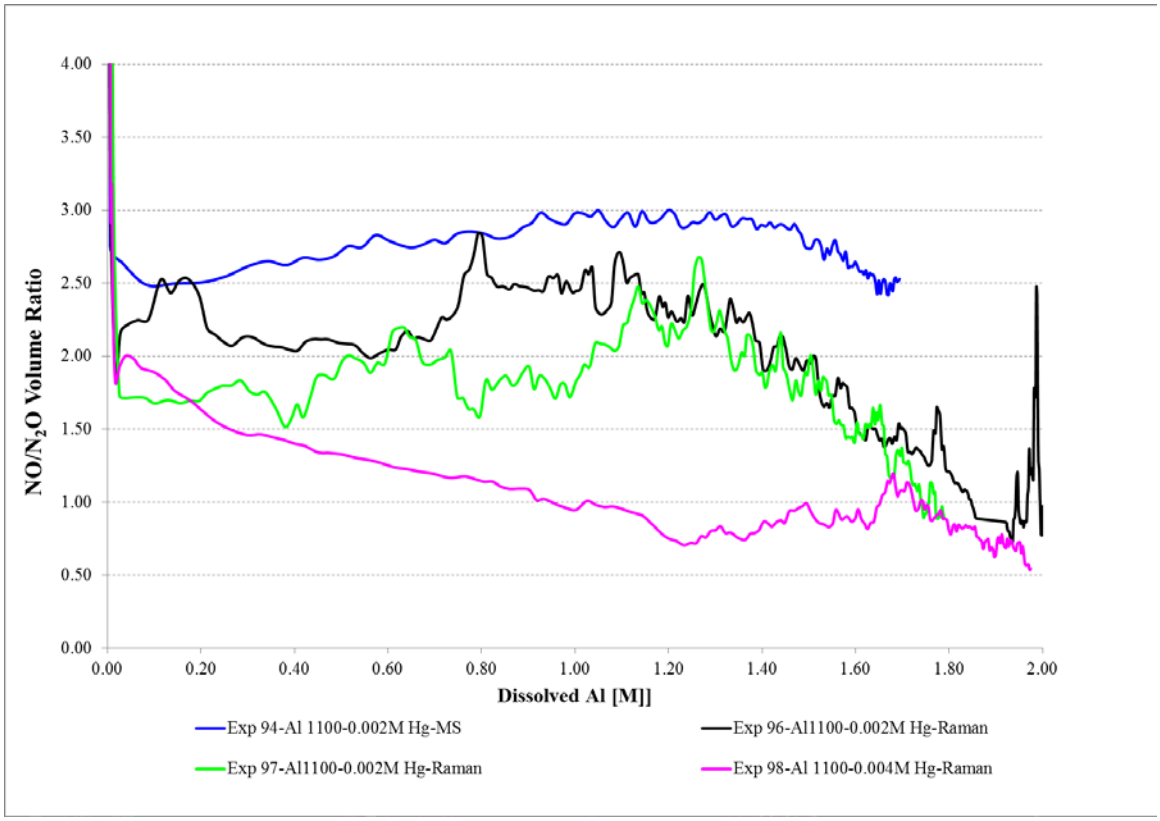

Figure 3-6. NO:N_2O Volume Ratio from the Dissolution of Al 1100 Alloy

The maximum concentration of H_2 calculated during the dissolution of HFIR fuel must be compared to the appropriate percentage of the LFL for H_2 at the maximum temperature of the offgas. Since the offgas from the H-Canyon dissolvers flow through the iodine reactor, which operates at 200 °C, the LFL for H_2 must be corrected for the increase in temperature. The LFL is corrected using equation 3,[20]

$$LFL_T = LFL_{ref}\left(1 - A(T\text{-}T_{ref})\right) \quad (3)$$

where LFL_T is the LFL at temperature T, LFL_{ref} is the LFL at the reference temperature, A is an empirical coefficient (Zabetakis attenuation factor) equal to 0.0011, and T is the temperature at which the LFL is evaluated. For the H_2 LFL data provided in Appendix A, which were measured at 28 °C, equation 3 can be simplified to equation 4 for use at 200 °C.

$$LFL_{200\ ^oC} = LFL_{28\ ^oC}\left(0.811\right) \quad (4)$$

The H_2 generation rates calculated for Experiments 94, 96, 97, and 98 (Figure 3-5) were used to predict the H_2 concentration in the offgas stream from an H-Canyon dissolver. The experiments were performed using 0.002 to 0.004 M Hg and targeted a final Al concentration of 1.8 to 2 M. The offgas generation rate for a HFIR core was based on the outer surface area of the inner and outer elements and the carriers since

the fuel and carriers will be completely immersed in the dissolver. For complete immersion of the fuel, the exposed surface area for one HFIR core (and carriers) is 23.408 ft^2.[16]

To estimate the H_2 concentration in the dissolver offgas stream, the total offgas generation rate was initially predicted for a single HFIR core (including the inner and outer element carriers) (equation 5).

$$\text{Predicted Offgas Rate (SCFM)} = \text{Measured Offgas Rate} \left(\frac{\text{SCFM}}{\text{ft}^2}\right) \left(23.408\ \text{ft}^2\right) \quad (5)$$

The predicted H_2 generation rate for a HFIR core was calculated in a similar manner (equation 6) by scaling-up the H_2 generation rate calculated from the experimental data (Figure 3-5).

$$\text{Predicted } H_2 \text{ Offgas Rate (SCFM)} = \text{Measured } H_2 \text{ Offgas Rate} \left(\frac{\text{SCFM}}{\text{ft}^2}\right) \left(23.408\ \text{ft}^2\right) \quad (6)$$

The predicted H_2 concentration in the dissolver offgas stream was subsequently calculated from the predicted H_2 offgas rate, the predicted (total) offgas rate, and the volumetric flow rate of air used to sparge (i.e., mix) the solution and purge the dissolver (equation 7). A dissolver sparge/purge rate of 40 SCFM was used for all calculations.

$$\text{Predicted } H_2 \text{ Conc (vol \%)} = \frac{\text{Predicted } H_2 \text{ Offgas Rate (SCFM)}}{\text{Predicted Offgas Rate (SCFM)} + 40\ \text{SCFM}} \left(\frac{100\ \text{vol \%}}{1}\right) \quad (7)$$

The predicted H_2 concentration (with air dilution) in the dissolver offgas stream is compared with 60% of the calculated H_2 LFL at 200 °C in Figure 3-7, Figure 3-8, Figure 3-9, and Figure 3-10 for Experiments 94, 96, 97, and 98, respectively, to determine if a full HFIR core can be charged to the dissolver without exceeding the calculated LFL. The comparisons of the predicted H_2 concentration to 60% of the LFL show that a full HFIR core can be dissolved using nominally 0.002 M Hg to catalyze the dissolution (Figure 3-7, Figure 3-8, and Figure 3-9). It should be noted that the margin between the predicted H_2 concentration and the calculated LFL is greater when the dissolving solution was allowed to boil for 45 min prior to initiating the Hg addition (Figure 3-8 and Figure 3-9). The comparison of the predicted H_2 concentration to 60% of the LFL for Experiment 98 (Figure 3-10), which was performed using 0.004 M Hg to catalyze the dissolution, shows that the predicted H_2 concentration exceeds the calculated LFL early in the dissolution (between approximately 0.15 and 0.5 M Al). However, the predicted H_2 concentration would not exceed the LFL if only an outer HFIR element was dissolved; although, this processing option is not very appealing since only outer (or inner) elements could be dissolved until the Al concentration exceeded approximately 0.5 M.

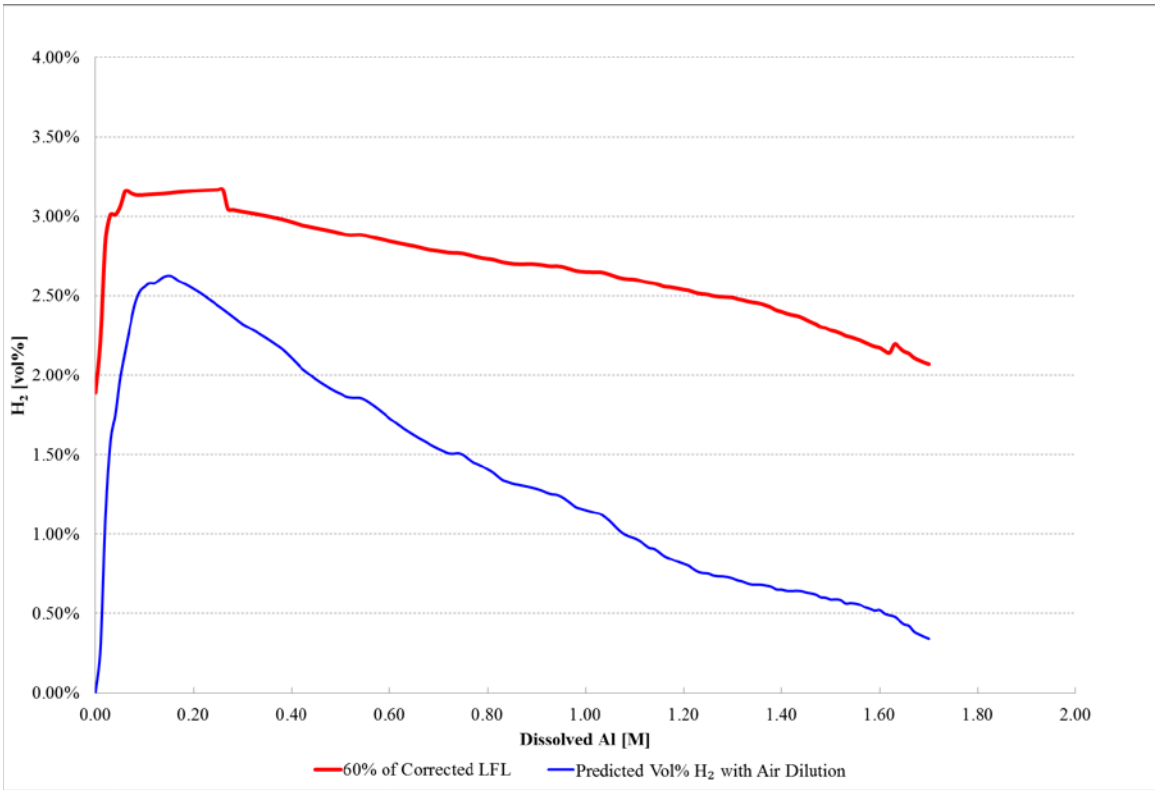

Figure 3-7. H_2 LFL Comparison for Exp. 94 – 7 M HNO_3, 0.002 M Hg, and No Hold Time

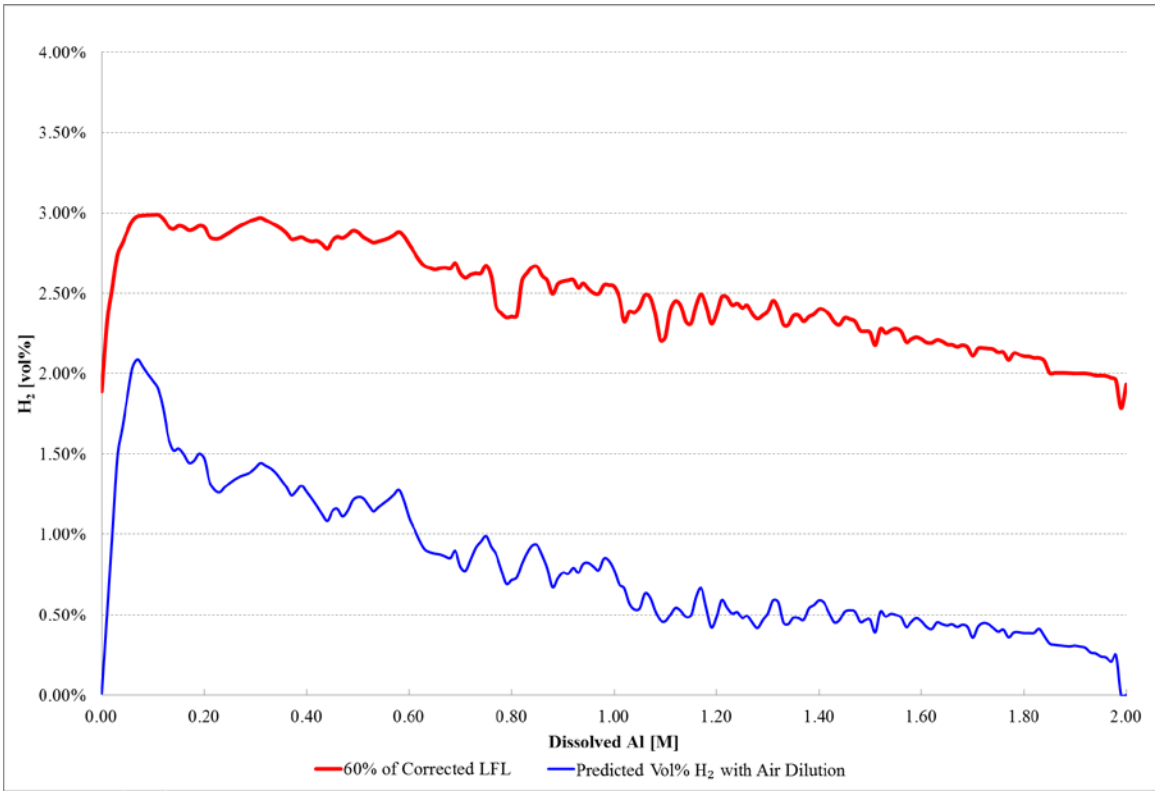

Figure 3-8. H_2 LFL Comparison for Exp. 96 – 7 M HNO_3, 0.002 M Hg, and 45 min Hold Time

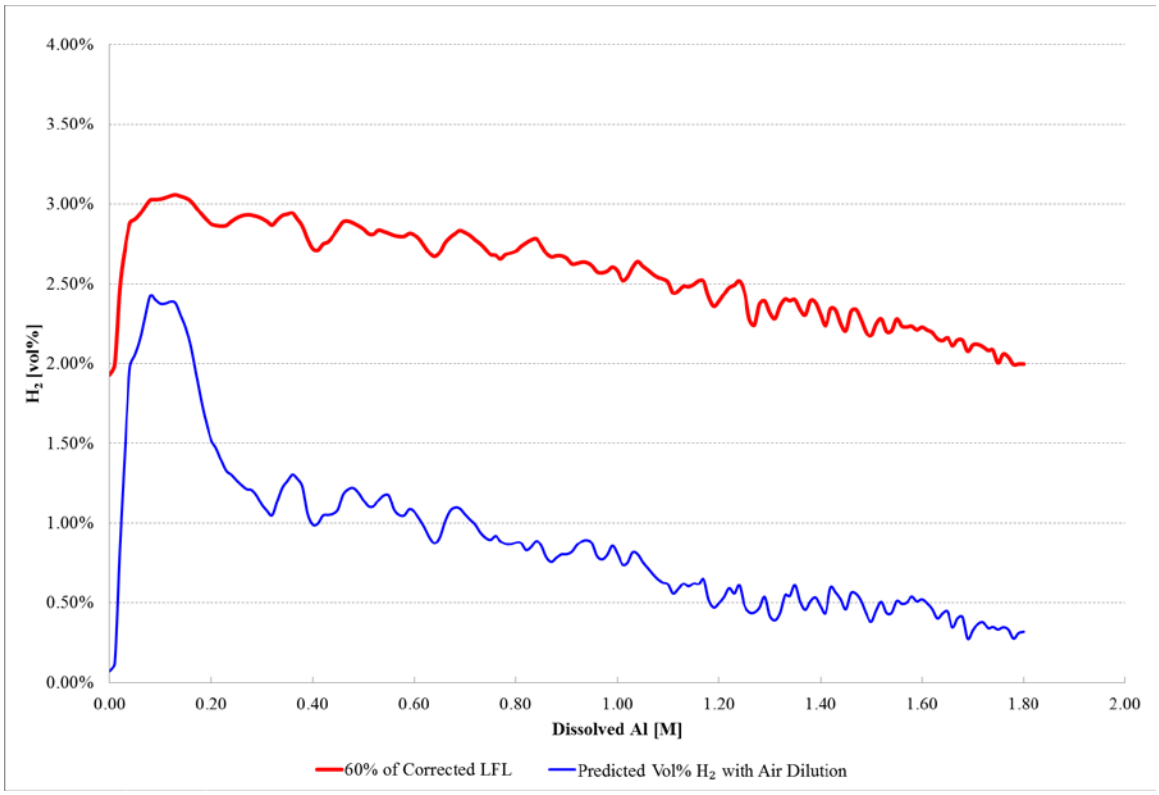

Figure 3-9. H_2 LFL Comparison for Exp. 97 – 7 M HNO_3, 0.002 M Hg, and 45 min Hold Time

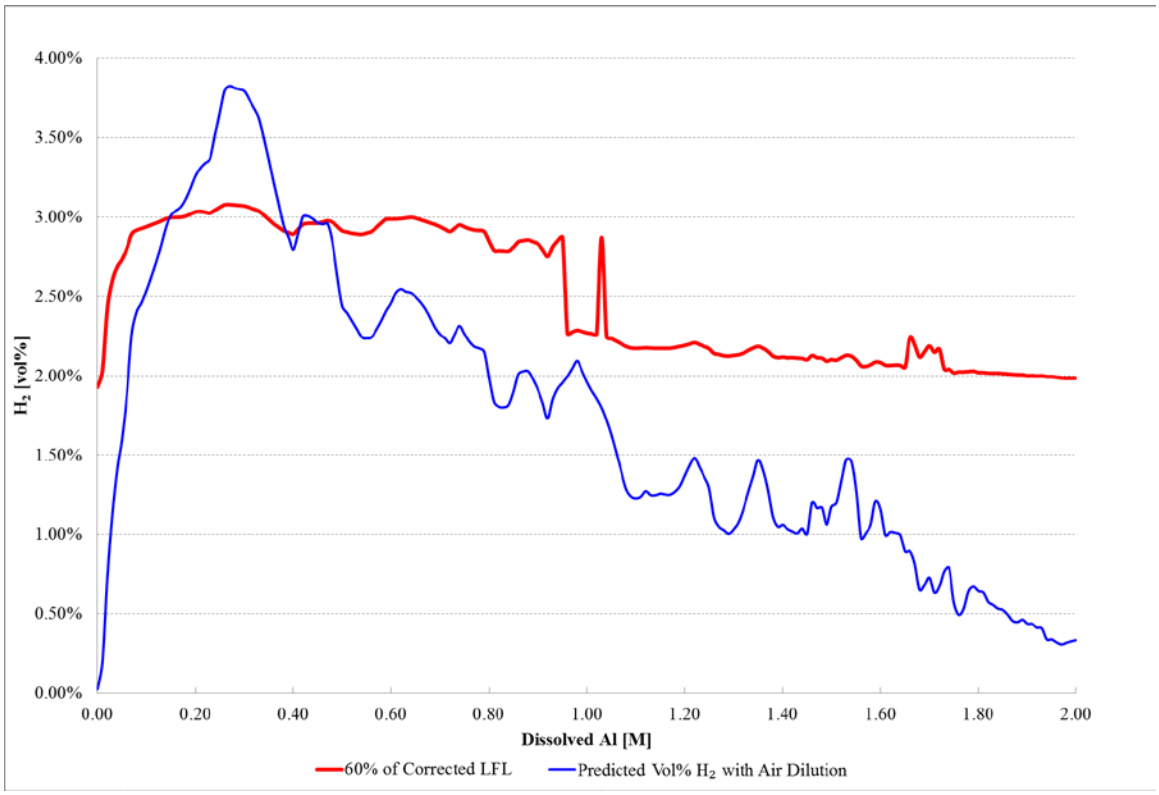

Figure 3-10. H_2 LFL Comparison for Exp. 98 – 7 M HNO_3, 0.004 M Hg, and 45 min Hold Time

The uncertainties associated with the calculations performed to determine if a complete HFIR core could be charged to an H-Canyon dissolver (at a given Hg concentration) were not evaluated; however, the uncertainties associated with the offgas analyses were examined. The MS was calibrated using NIST-traceable standards before each experiment and the calibration gases checked prior to starting the experiment. The 2σ value or twice the standard deviation for the MS H_2 analysis was <1 vol % (see Appendix B). A summary of the 2σ uncertainties for all calibrated gases is provided in Table 3-4. The 2σ uncertainties for the O_2 and NO_2 concentrations are artificially low due to adjustments to the MS calibration matrix so the 2σ values were conservatively assumed to be < 3 vol % like the NO and N_2O gases.

Table 3-4. Two Sigma Uncertainties for Gas Concentrations Measured by Mass Spectrometry

Gas	2σ Uncertainty (vol %)
H_2	0.38
N_2	0.34
NO	2.14
O_2	0.67*
Ar	0.36
N_2O	1.93
NO_2	0.30*

* Assumed value of <3 vol %

The Raman spectrometer was also calibrated using the NIST-traceable standards and calibration gases checked before each experiment. The 2σ value or twice the standard deviation for the Raman spectrometer H_2 analysis is <2 vol % (see Appendix F). A summary of the 2σ uncertainties for all calibrated gases is provided in Table 3-5.

Table 3-5. Two Sigma Uncertainties for Gas Concentrations Measured by Raman Spectroscopy

Gas	2σ Uncertainty (vol %)
CO_2	3.36
N_2	3.07
O_2	1.44
H_2	1.39

To understand how small uncertainties in the offgas measurements performed by Raman spectroscopy affected the calculations performed to determine if a complete HFIR core could be charged to a dissolver, the measured H_2 concentrations in Experiments 96 and 97 were assumed to be inflated by 1.8 vol% (>2σ uncertainty) and the predicted H_2 concentrations were still less than 60% of the calculated LFL for all Al concentrations (Figure 3-11 and Figure 3-12). In Experiment 94, the H_2 concentrations measured by the MS were inflated by 0.6 vol % (>2σ uncertainty) and the predicted H_2 concentrations were also still less than the LFL (Figure 3-13). In addition, several aspects of the calculations have built-in conservatisms which further address the uncertainty in the calculations. The calculated H_2 concentration in the offgas stream is compared to 60% of the LFL which provides a layer of conservatism. The saturated water vapor in the offgas stream is ignored and would further dilute the H_2 concentration. Given the conservative nature of the experimental design and the calculations performed, the conclusion that a complete HFIR core can be charged to an H-Canyon dissolver using nominally 0.002 M Hg to catalyze the dissolution adequately incorporates the many uncertainties associated with the experimental and modeling work.

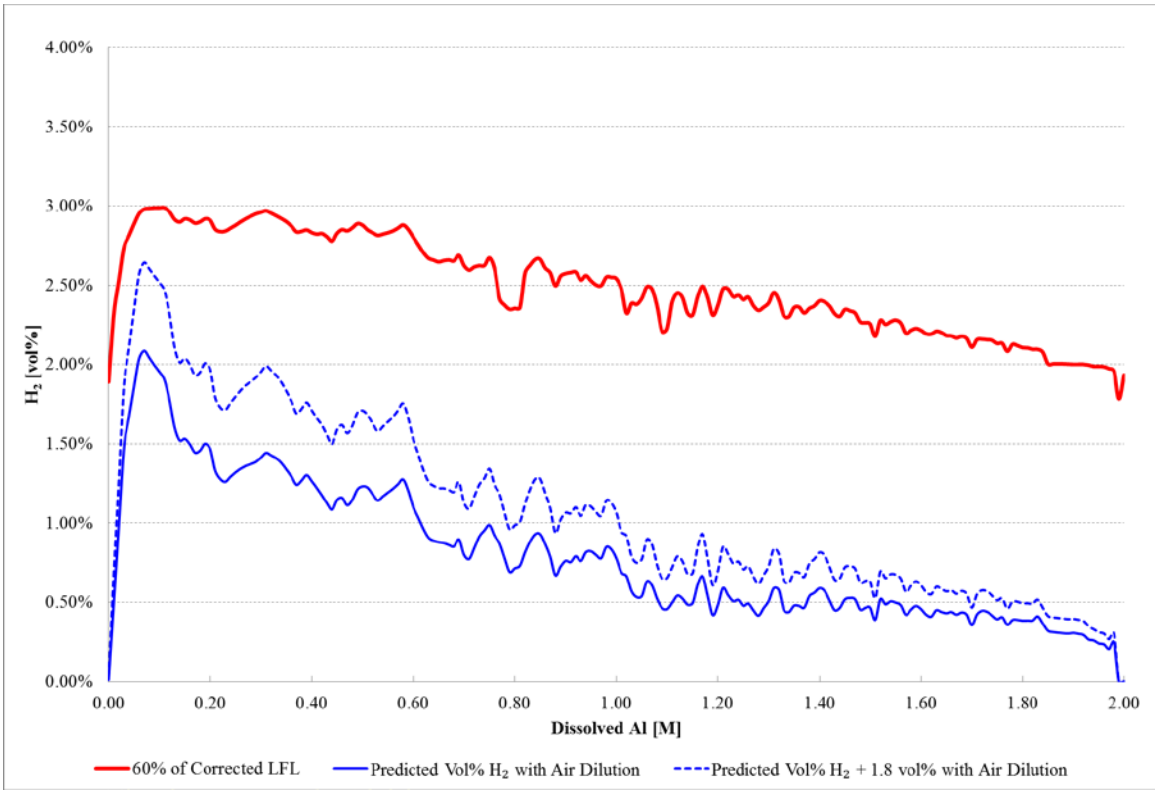

Figure 3-11. H_2 LFL Comparison for Exp. 96 with Predicted H_2 Increased by 1.8 vol %

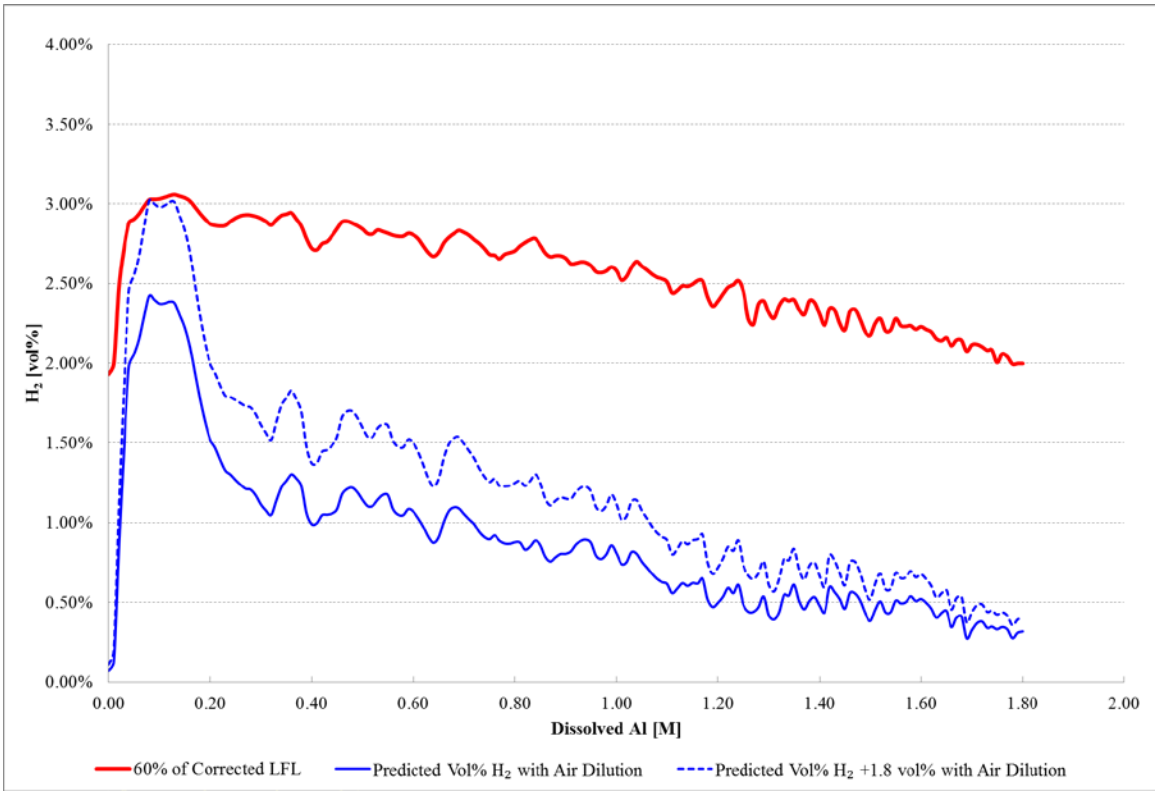

Figure 3-12. H_2 LFL Comparison for Exp. 97 with Predicted H_2 Increased by 1.8 vol %

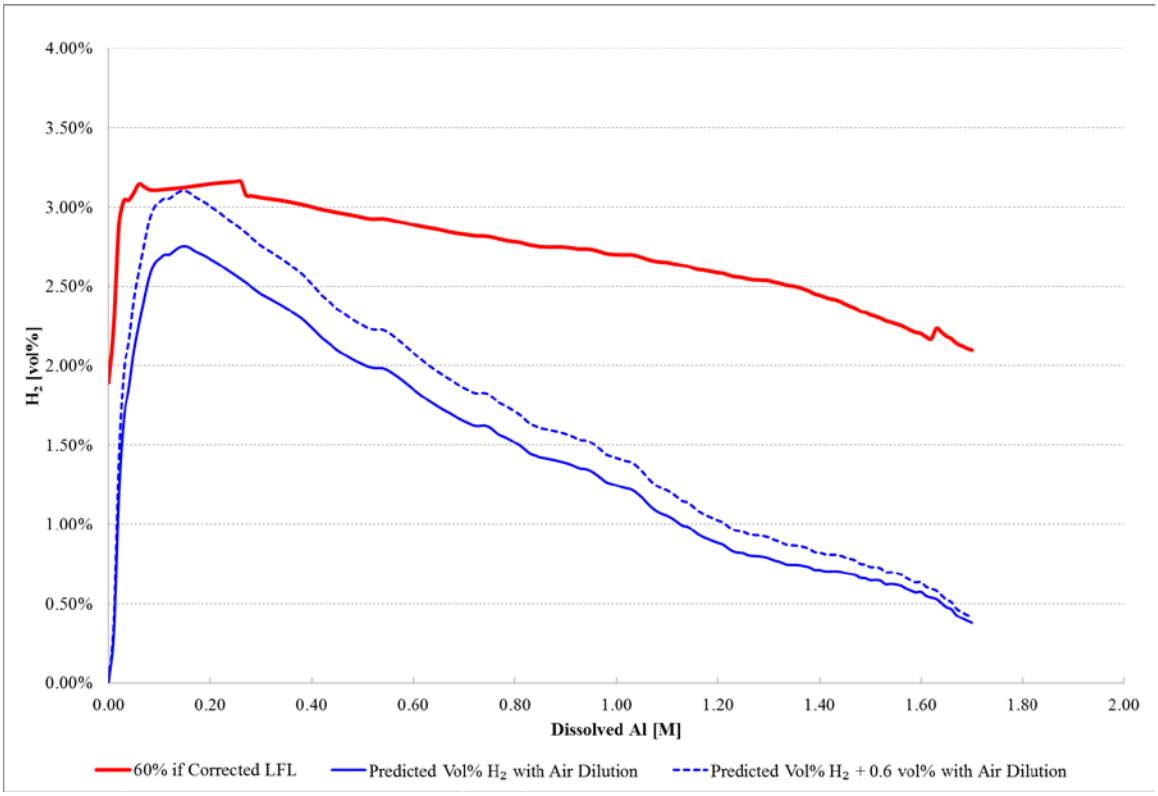

Figure 3-13. H_2 LFL Comparison for Exp. 94 with Predicted H_2 Increased by 0.6 vol %

3.3.3 Adding More Hg during HFIR Fuel Dissolution

A series of Al 1100 alloy dissolution experiments was performed to investigate the effects of higher Hg concentrations on the H_2 generation rate. In Experiment 97, the Al-1100 alloy was dissolved in 7 M HNO_3 by metering in 0.002 M Hg 45 min after the solution began to boil. The H_2 generation rate for Experiment 97 is shown in Figure 3-14. The Al 1100 alloy dissolution performed in Experiment 98 was a repeat of Experiment 97 except 0.004 M Hg was metered into the solution at the same rate. Doubling the Hg concentration used to catalyze the dissolution results in an approximate doubling of the H_2 generation rate (Figure 3-14). Experiment 101 was performed to evaluate the addition of more Hg during an Al 1100 alloy dissolution (Figure 3-14). The ability to add more Hg during a HFIR fuel dissolution could be beneficial if slow dissolution rates are observed at high Al concentrations.

Experiment 101 was performed over 2 days. During the first day, an Al 1100 coupon was dissolved to reach approximately 0.6 M Al in the solution. On the next day, a second Al 1100 coupon was dissolved to reach approximately 2 M Al. During the second day, another Hg addition was made when the Al concentration reached approximately 1.3 M to increase the Hg concentration to 0.008 M. The initial plan was to add more Hg at 0.6 M Al, but the coupon started dissolving once the system got close to boiling since 0.002 M Hg was already present in the solution. The rise in the H_2 generation rate during the second day at approximately 0.85 M Al was due to a change in the CO_2 tracer gas flow rate from 30 to 50 cm^3/min to prevent the offgas from diluting the tracer gas concentration below detection. The H_2 generation rate returned to a consistent level after the CO_2 flow rate change worked its way through the dissolving system. The second rise in the offgas generation around 1.3 M Al was due to the second addition of Hg to bring the concentration from 0.002 M to 0.008 M.

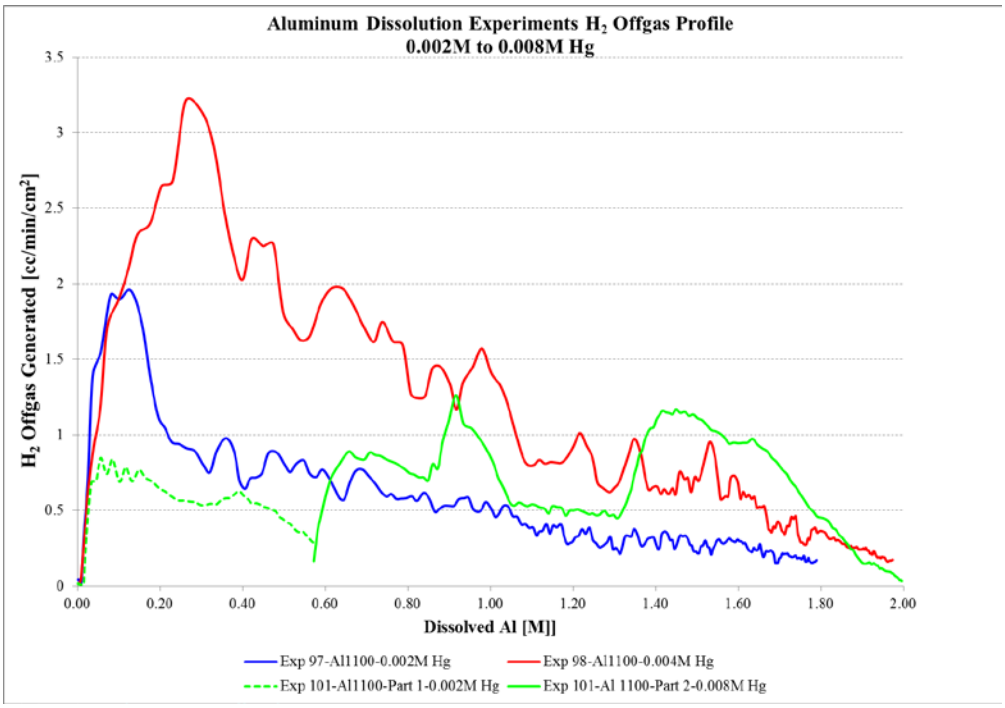

Figure 3-14. Effect of Adding Additional Hg During Al 1100 Alloy Dissolution

The predicted H_2 concentrations for Experiments 101 are compared to 60% of the calculated H_2 LFL at 200 °C in Figure 3-15 to illustrate that the Hg concentration can be increased from 0.002 to 0.008 M at Al concentrations greater than 1.3 M during a HFIR fuel dissolution. In addition, Figure 3-10 shows that the Hg concentration during a HFIR fuel dissolution can be conservatively increased from 0.002 to 0.004 M at Al concentrations greater than 0.5 M.

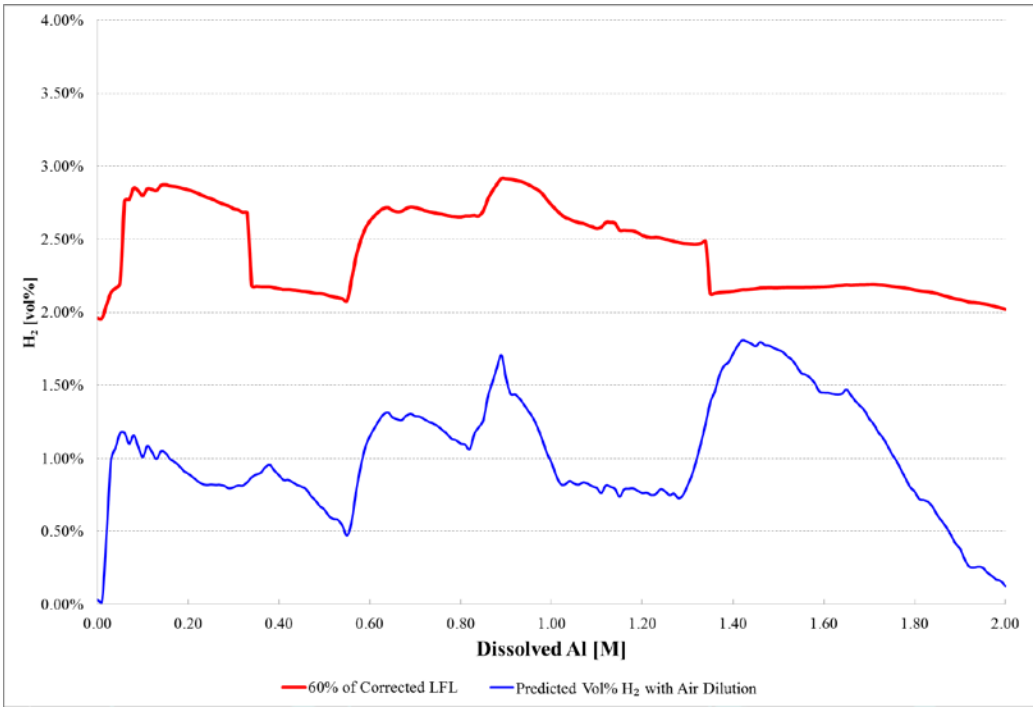

Figure 3-15. H_2 LFL Comparison for Exp. 101 – 7 M HNO_3 and 0.002 to 0.008 M Hg at 1.3 M Al

3.4 Downstream Processing of HFIR Fuel

Following dissolution of the HFIR fuel, the solution will be processed through Head End and the 1st and 2nd Cycles of solvent extraction to recover the enriched U for subsequent down-blending for use as commercial reactor fuel. No issues associated with the processing of the enriched U solutions through Head End and solvent extraction are anticipated. The dissolution of the HFIR fuel will generate undissolved solids such as transition metal fission products (e.g., Zr, Mo, Ru, Tc, Pd, and Ag) and Si (as SiO_2) present in the Al alloys and produced from the transmutation of Al during fuel irradiation. These solids should be easily removed by the Head End centrifuge using the standard gelatin strike process. Once the solution is clarified, purification by solvent extraction should proceed in the same manner as other enriched U feedstocks. High and low activity waste generated from the processing will be neutralized and prepared for disposal using existing SRS facilities. No issues are anticipated.

4.0 Conclusions

To achieve complete dissolution of a HFIR core and the associated carriers, a Hg-catalyzed HNO_3 dissolution flowsheet was demonstrated. In laboratory experiments, Al 1100 and Al 6061 T6 alloys were dissolved starting with a 7 M HNO_3 solution. A Hg catalyst concentration of 0.002 M was sufficient to dissolve Al alloy coupons up to a final Al concentration of 2 M. Complete dissolution of the Al coupons was achieved; however, following the dissolutions, solids were observed in the solution. The solids were amorphous by XRD, but likely originated from the Si present in the alloys. No crystalline materials, such as $Al(NO_3)_3$ were observed. During the course of the experiments, it was determined that delaying the addition of Hg once the HNO_3 solution reaches boiling can reduce the total offgas and H_2 generation rates. The delay in starting the Hg addition is not necessary for HFIR fuel dissolution, but could be useful in other research reactor dissolution campaigns.

The potential to generate flammable concentrations of H_2 in the offgas during a HFIR fuel dissolution was evaluated using the experimental data. The predicted H_2 concentration (with air dilution) in the dissolver offgas stream was compared with 60% of the calculated H_2 LFL at 200 °C using several prototypical experiments. The calculations showed that a full HFIR core can be dissolved using nominally 0.002 M Hg to catalyze the dissolution. The margin between the predicted H_2 concentration and the calculated LFL was greater when the dissolving solution was allowed to boil for 45 min prior to initiating the Hg addition. When the Hg concentration was increased to 0.004 M, the predicted H_2 concentration exceeded 60% of the calculated LFL early in the dissolution.

The Al alloy dissolution experiments also demonstrated that additional Hg (beyond the initial 0.002 M) could be added as the Al concentration increases. The ability to add more Hg during a HFIR fuel dissolution could be beneficial if slow dissolution rates are observed at high Al concentrations. Experimental data were used to demonstrate that the predicted H_2 concentration in a dissolver was below 60% of the calculated LFL at 200 °C when 0.004 M Hg is used to catalyze the dissolution if the Al concentration is conservatively greater than 0.5 M. Data also show that the Hg concentration during a HFIR fuel dissolution can be increased from 0.002 to 0.008 M at an Al concentration of 1.3 M.

5.0 Flowsheet Recommendations

Flowsheet recommendations were developed for the dissolution of a full HFIR fuel core and the Al carriers used to transport and charge the inner and outer elements to either the 6.4D or 6.1D dissolver. The process conditions required to ensure that the predicted H_2 concentration in the offgas from a dissolution is less than 60% of the H_2 LFL at 200 °C are summarized below.

- The flowsheet analysis assumes complete immersion of the HFIR fuel in the dissolver solution.
- A dissolver air sparge/purge flow rate of at least 40 SCFM is required.

- The initial HNO_3 concentration shall be based on the mass of Al and U charged to the dissolver. The concentration is typically 5 to 7.5 M.
- A Hg concentration of nominally 0.002 M shall be used to catalyze the dissolution of the HFIR fuel. The Hg shall be metering into the 6.4D dissolver as described in Procedure 221-H-4101.[11] A similar Hg addition rate shall be used for the 6.1D dissolver.
- The HNO_3 concentration in the dissolver solution following the dissolution of a batch of HFIR fuel (containing up to 5 full cores) shall be greater than 0.5 M.

Variations in the Hg concentration added to the dissolver shall not exceed ±25% of the required concentration (0.0020±0.0005). Additional Hg may be added to the dissolver at the same rate used to establish the initial concentration to increase the rate of dissolution as described in Section 3.3.3 of this report. Based on previous dissolution campaigns, the HFIR flowsheet should result in an estimated dissolution time of 28 to 40 h for the initial core. The dissolution times of subsequent cores using the same dissolving solution would be expected to increase as the Al concentration in the dissolver also increases.

6.0 References

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Appendix A. Lower Flammability of H_2

Lower flammability data reported by Scott et al.[19] for air, H_2, NO, and N_2O mixtures were used to calculate the LFL for comparison to the H_2 concentrations calculated for an H-Canyon dissolver. Three data sets for NO:N_2O ratios of 2.57, 1.00, and 0.33 are shown in Table A-1. The H_2 LFL data in Table A-1 marked with an asterisk did not propagate a flame.

Table A-1. Lower Flammability Limits for H_2 (1 atm and 28 °C)

	NO:NO_2 = 2.57	**NO:NO_2 = 1.00**	**NO:NO_2 = 0.33**
Air	**H_2 LFL**	**H_2 LFL**	**H_2 LFL**
(vol %)	**(vol %)**	**(vol %)**	**(vol %)**
1.5	6.2	-	-
4.6	6.4	-	-
6.2	5.9*	-	-
21.7	6.4	-	-
34.5	6.1*	-	-
52.6	7.2	-	-
60.8	5.5*	-	-
66.8	6.6	-	-
74.1	4.3*	-	-
28.7	-	6.3	-
40.6	-	5.1	-
54.2	-	7.0	-
57.1	-	6.9*	-
61.3	-	6.9	-
68.9	-	6.3	-
81.2	-	4.2*	-
33.5	-	-	5.3
45.7	-	-	4.5*
50.3	-	-	6.3
52.0	-	-	4.5*
59.4	-	-	5.6
62.5	-	-	4.1*

* Did not propagate flame

The H_2 LFL data in Table A-1 were correlated using a second order polynomial to allow interpolation at varying concentrations of air. The correlations including parameters for the polynomials are shown in Figures A-1 to A-3 for NO:NO_2 ratios of 2.57, 1.00, and 0.33, respectively.

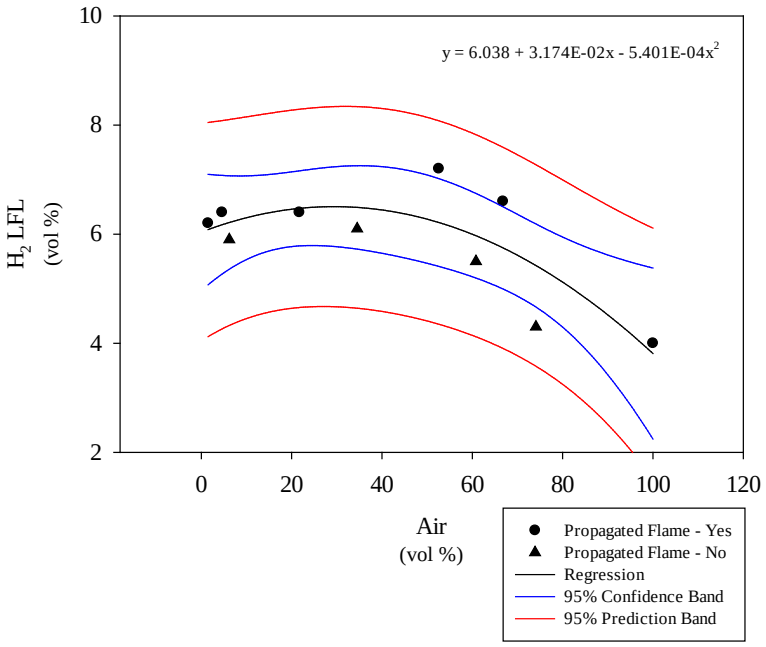

Figure A-1. Lower Flammability of H_2 ($NO:NO_2$ = 2.57)

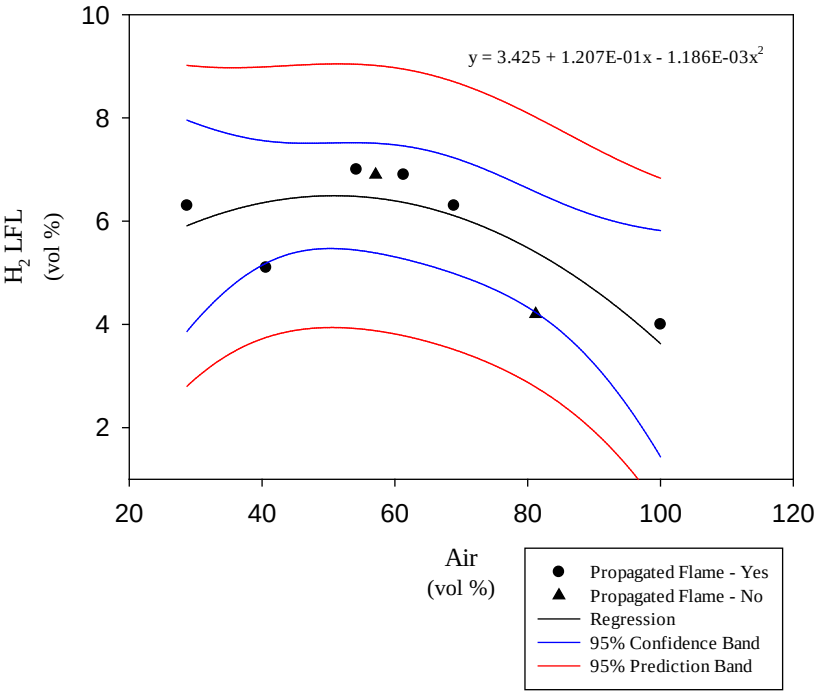

Figure A-2. Lower Flammability of H_2 ($NO:NO_2$ = 1.00)

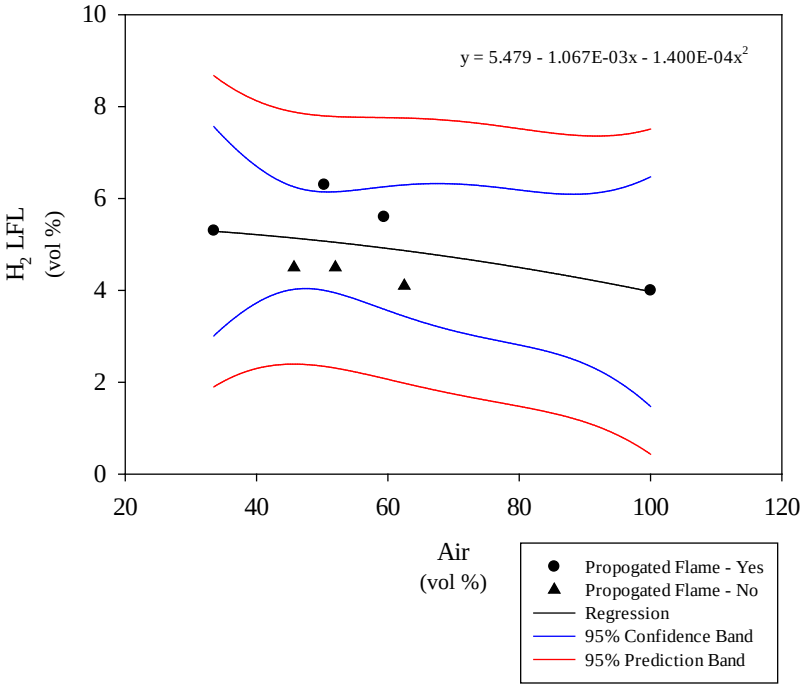

Figure A-3. Lower Flammability of H_2 ($NO:NO_2$ = 0.33)

Appendix B. Monitor MS Calibration and Sampling Method

The Monitor MS was calibrated using a set of calibration gases as shown in Table 2-3 before the start of each dissolution experiment. The calibration gases were then sampled back through the MS to check the calibration. If the calibration checks were off for particular gases, the MS calibration matrix was adjusted for those gases after the run. For the Al dissolution performed in Experiments 93, 94, and 95, the calibration checks with the adjusted MS calibration matrix are shown in Table B-1. The calibration check tells us if the calibration was successful and provides an indication of the variance of the measurements since the calibration gas is read for several samples. Due to rounding to the nearest hundredth, the numbers in the table may not sum to 100 but all the decimals were carried in the calculations performed in this report.

Table B-1. Pre-run Check of Calibration Gases for Al Dissolution Experiments 93-95

Gas Description	H_2 (%)	N_2 (%)	NO (%)	O_2 (%)	Ar (%)	N_2O (%)	NO_2 (%)
20% N_2O-80% Ar	0.01	0.00	0.1	0.00	80.28	19.45	0.17
	0.01	0.00	0.06	0.00	79.96	19.76	0.21
	0.01	0.00	0.06	0.00	80.05	19.76	0.13
	0.01	0.00	0.03	0.00	80.00	19.78	0.18
	0.01	0.00	0.31	0.00	80.1	19.33	0.25
	0.02	0.00	0.32	0.00	80.1	19.28	0.29
	0.02	0.00	0.31	0.00	80.05	19.36	0.26
	0.01	0.00	0.33	0.00	80.21	19.17	0.28
	0.02	0.16	0.44	0.00	80.66	18.47	0.25
	0.01	0.15	0.43	0.00	80.59	18.61	0.21
	0.02	0.16	0.43	0.00	80.55	18.56	0.29
	0.02	0.16	0.43	0.00	80.66	18.47	0.27
4.98% NO_2-20.13% O_2-74.89% Ar	0.01	0.28	0.04	19.83	74.81	0.00	5.03
	0.01	0.28	0.02	19.74	74.89	0.01	5.06
	0.01	0.28	0.01	19.71	74.88	0.00	5.11
	0.01	0.28	0.00	19.81	74.74	0.00	5.16
	0.01	0.29	0.08	20.44	73.88	0.13	5.16
	0.02	0.29	0.09	20.57	73.81	0.13	5.09
	0.02	0.29	0.08	20.55	73.80	0.14	5.12
	0.01	0.29	0.08	20.57	73.76	0.13	5.15
	0.04	0.33	0.15	20.44	73.90	0.10	5.03
	0.02	0.34	0.09	20.26	74.01	0.10	5.18
	0.02	0.33	0.09	20.31	74.00	0.10	5.15
	0.02	0.34	0.08	20.27	74.00	0.10	5.20
20% NO-80% Ar	0.03	0.08	19.77	0.00	79.96	0.02	0.13
	0.01	0.07	19.85	0.00	79.98	0.01	0.07
	0.01	0.07	19.81	0.00	80.00	0.02	0.09
	0.01	0.07	19.88	0.00	79.95	0.02	0.07
	0.02	0.13	20.77	0.00	78.70	0.17	0.2
	0.02	0.13	20.77	0.00	78.77	0.16	0.16
	0.01	0.13	20.95	0.00	78.64	0.15	0.12
	0.02	0.13	20.92	0.00	78.65	0.16	0.14
	0.02	0.13	21.5	0.00	78.06	0.12	0.17
	0.01	0.12	21.57	0.00	78.07	0.11	0.12
	0.01	0.12	21.68	0.00	77.98	0.11	0.09

Gas Description	H_2 (%)	N_2 (%)	NO (%)	O_2 (%)	Ar (%)	N_2O (%)	NO_2 (%)
5% N_2-10% H_2-85% Ar	0.01	0.12	21.79	0.00	77.79	0.12	0.16
	9.75	5.08	0.01	0.00	85.15	0.00	0.01
	9.72	5.06	0.00	0.00	85.19	0.00	0.02
	9.73	5.06	0.00	0.00	85.20	0.00	0.01
	10.20	5.01	0.00	0.00	84.77	0.00	0.01
	10.17	5.17	0.01	0.00	84.45	0.12	0.09
	10.19	5.18	0.02	0.00	84.51	0.10	0.00
	10.25	5.20	0.01	0.00	84.38	0.11	0.05
	10.20	5.18	0.01	0.00	84.49	0.11	0.01
	9.91	5.20	0.00	0.00	84.75	0.09	0.05
	9.92	5.20	0.00	0.00	84.76	0.09	0.03
	10.01	5.24	0.00	0.00	84.68	0.07	0.00
	10.08	5.27	0.00	0.00	84.53	0.08	0.05
100% Ar	0.00	0.06	0.00	0.00	99.94	0.00	0.00
	0.01	0.04	0.00	0.00	99.91	0.00	0.04
	0.01	0.02	0.00	0.00	99.96	0.00	0.01
	0.00	0.02	0.00	0.00	99.98	0.00	0.00
	0.01	0.04	0.00	0.00	99.82	0.11	0.02
	0.02	0.03	0.00	0.00	99.79	0.11	0.05
	0.02	0.04	0.00	0.00	99.77	0.12	0.06
	0.02	0.04	0.00	0.00	99.74	0.12	0.09
	0.01	0.06	0.01	0.00	99.84	0.06	0.02
	0.02	0.05	0.00	0.00	99.76	0.07	0.10
	0.02	0.05	0.00	0.00	99.73	0.08	0.12
	0.01	0.05	0.01	0.00	99.87	0.06	0.00
100% N_2	0.01	99.99	0.00	0.00	0.00	0.00	0.00
	0.01	99.99	0.00	0.00	0.00	0.00	0.00
	0.01	99.98	0.00	0.00	0.00	0.00	0.01
	0.01	99.99	0.00	0.00	0.00	0.00	0.00
	0.01	99.85	0.01	0.00	0.00	0.11	0.01
	0.02	99.87	0.01	0.00	0.00	0.11	0.00
	0.02	99.82	0.00	0.00	0.00	0.11	0.04
	0.02	99.82	0.00	0.00	0.00	0.12	0.04
	0.01	99.90	0.01	0.00	0.00	0.08	0.00
	0.02	99.91	0.01	0.00	0.00	0.07	0.00
	0.01	99.91	0.01	0.00	0.00	0.07	0.00
	0.01	99.89	0.01	0.00	0.00	0.07	0.02
Air (78.0% N_2-21.0% O_2-0.9% Ar)	0.01	79.46	0.00	20.25	0.22	0.06	0.00
	0.01	79.48	0.00	20.22	0.20	0.07	0.02
	0.01	79.48	0.01	20.25	0.19	0.06	0.00
	0.01	79.52	0.00	20.24	0.14	0.07	0.02
	0.02	78.06	0.00	21.67	0.00	0.16	0.07
	0.02	78.17	0.01	21.64	0.00	0.15	0.01
	0.02	78.15	0.01	21.67	0.00	0.15	0.00
	0.02	78.25	0.01	21.52	0.00	0.15	0.06
	0.39	79.92	0.00	19.54	0.00	0.14	0.02
	0.08	80.11	0.00	19.57	0.00	0.14	0.10
	0.03	80.17	0.00	19.58	0.00	0.14	0.09
	0.01	80.27	0.00	19.57	0.00	0.13	0.01

To estimate the variability of the MS concentration measurements, the pre-run check values in Table B-1 were compared to the standard or calibrated values across Experiment 93, 94, and 95. The standard deviations of the measured concentrations with respect to the known calibrated concentrations for the data were calculated. The standard deviations were then doubled to get a measure of the variability in the MS measurements. Table B-2 shows the standard deviation of the measured concentrations with respect to the calibrated values. For the H_2, N_2, and Ar gases, the 2σ value or twice the standard deviation is <1 vol %. For the NO and N_2O gases, the 2σ value is <3 vol %. The 2σ value for O_2 and NO_2 gases are artificially low due to adjustments to the MS calibration matrix so the 2σ values were conservatively assumed to be < 3 vol % like the NO and N_2O gases.

Table B-2. Standard Deviation of MS Concentrations with Respect to Calibrated Values

Gas	Standard Deviation (σ)	2*Standard Deviation (2σ)
	(vol %)	(vol %)
H_2	0.19	0.38
N_2	0.17	0.34
NO	1.07	2.14
O_2	0.33	0.67
Ar	0.18	0.36
N_2O	0.97	1.93
NO_2	0.15	0.30

Once the calibration is complete, the system is purged with 100% Ar while the Monitor MS is sampling the system offgas. By checking the calibration gases after calibration and purging the system with 100% Ar, a set of baseline or zero values for the offgas concentrations can be collected and analyzed. The baseline values for Experiment 93, 94, 95 are shown in Table B-3. These baseline values represent zero or 100% concentrations within the accuracy of the Monitor MS. In other words, the raw N_2, N_2O, NO_2, NO, O_2, and H_2 MS readings are re-baselined by subtracting off the average baseline values like shown in Table B-3 through Table B-5. The raw Ar MS reading is re-baselined to 100% by dividing by the average baseline value shown in Table B-3 while limiting the maximum to 100%. The re-baselined values are then re-normalized to ensure that the sum of the re-baselined values is 100% because the MS is setup so that all the measured gases sum to 100%. The total offgas flow is then calculated by dividing the Ar tracer flow coming into the system by the re-baselined normalized Ar concentration as shown in Table B-6. The offgas flow rates and re-baselined normalized MS offgas concentrations for Experiment 93, 94, and 95 are shown in Appendices C, D, and E, respectively.

Table B-3. Monitor MS Baseline Offgas Concentrations for Experiment 93

Sample	H_2	N_2	NO	O_2	Ar	N_2O	NO_2
	(%)	(%)	(%)	(%)	(%)	(%)	(%)
1	0.01	0.04	0.00	0.00	99.82	0.11	0.02
2	0.02	0.03	0.00	0.00	99.79	0.11	0.05
3	0.02	0.04	0.00	0.00	99.77	0.12	0.06
4	0.02	0.04	0.00	0.00	99.74	0.12	0.09
Average	0.02	0.03	0.00	0.00	99.78	0.11	0.05
Re-baseline	100	0	0	0	0	0	0

Table B-4. Monitor MS Baseline Offgas Concentrations for Experiment 94

Sample	H_2	N_2	NO	O_2	Ar	N_2O	NO_2
	(%)	(%)	(%)	(%)	(%)	(%)	(%)
1	0.01	0.06	0.01	0.00	99.84	0.06	0.02
2	0.02	0.05	0.00	0.00	99.76	0.07	0.10
3	0.02	0.05	0.00	0.00	99.73	0.08	0.12
4	0.01	0.05	0.01	0.00	99.87	0.06	0.00
Average	0.02	0.05	0.00	0.00	99.80	0.07	0.06
Re-baseline	100	0	0	0	0	0	0

Table B-5. Monitor MS Baseline Offgas Concentrations for Experiment 95

Sample	H_2	N_2	NO	O_2	Ar	N_2O	NO_2
	(%)	(%)	(%)	(%)	(%)	(%)	(%)
1	0.00	0.06	0.00	0.00	99.94	0.00	0.00
2	0.01	0.05	0.00	0.00	99.91	0.00	0.04
3	0.01	0.02	0.00	0.00	99.96	0.00	0.01
4	0.00	0.02	0.00	0.00	99.98	0.00	0.00
Average	0.01	0.04	0.00	0.00	99.95	0.00	0.01
Re-baseline	100	0	0	0	0	0	0

Table B-6. Monitor MS Tracer Gas Flow Rates

Experiment	Ar Flow
	(cm^3/min)
93	10
94	10
95	20

At the end of the dissolution experiment, the H_2 calibration gas is re-sampled by the MS to see if the instrument is still reading the offgas concentrations accurately. Table B-7 through Table B-9 show multiple samples of the H_2 calibration gas read by the Monitor MS. Comparing the pre- and post-run calibration checks of the H_2 calibration gas shows that the Monitor MS is reading offgas concentrations accurately and the offgas concentrations measured during the experiment are valid.

Table B-7. Post-run Check of Calibration Gas for Experiment 93

Gas	H_2	N_2	NO	O_2	Ar	N_2O	NO_2
	(%)	(%)	(%)	(%)	(%)	(%)	(%)
5% N_2-10% H_2-85% Ar	11.52	4.87	0.01	0.00	83.61	0.00	0.00
	11.62	4.96	0.00	0.00	83.41	0.00	0.01
	11.65	4.98	0.01	0.00	83.37	0.00	0.00
	11.60	4.95	0.00	0.00	83.44	0.00	0.00

Table B-8. Post-run Check of Calibration Gas for Experiment 94

Gas	H_2	N_2	NO	O_2	Ar	N_2O	NO_2
	(%)	(%)	(%)	(%)	(%)	(%)	(%)
5% N_2-10% H_2-85% Ar	9.49	4.67	0.00	0.00	85.84	0.00	0.00
	9.47	4.65	0.00	0.00	85.88	0.00	0.00
	9.52	4.67	0.00	0.00	85.81	0.00	0.00
	9.51	4.66	0.00	0.00	85.83	0.00	0.00

Table B-9. Post-run Check of Calibration Gas for Experiment 95

Gas	H_2	N_2	NO	O_2	Ar	N_2O	NO_2
	(%)	(%)	(%)	(%)	(%)	(%)	(%)
5% N_2-10% H_2-85% Ar	10.32	4.99	0.00	0.00	84.68	0.00	0.00
	10.30	4.99	0.01	0.00	84.71	0.00	0.00
	10.37	5.02	0.01	0.00	84.61	0.00	0.00
	10.39	5.03	0.00	0.00	84.54	0.00	0.04

Appendix C. MS Offgas Data for Experiment 93

Table C-1. Re-Baselined Normalized MS Offgas Concentration Data for Experiment 93

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	Ar	Total Offgas Flow	H_2	N_2	NO	O_2	N_2O	NO_2
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
13	0.0008	69.95	4.297	0.70	3.76	93.00	0.00	0.30	2.25
36	0.0015	69.52	4.384	0.70	3.63	93.04	0.00	0.30	2.34
60	0.0023	69.13	4.466	0.71	3.58	93.06	0.00	0.31	2.34
83	0.0030	68.85	4.524	0.72	3.50	93.27	0.00	0.27	2.24
107	0.0039	68.59	4.579	0.71	3.65	93.10	0.00	0.28	2.26
130	0.0046	68.23	4.657	0.71	3.53	93.36	0.00	0.27	2.13
154	0.0055	67.88	4.733	0.72	3.45	93.33	0.00	0.26	2.24
178	0.0063	67.60	4.793	0.72	3.40	93.36	0.00	0.24	2.28
201	0.0071	67.22	4.877	0.71	3.16	93.77	0.00	0.24	2.12
225	0.0080	66.88	4.953	0.71	3.08	93.94	0.00	0.24	2.02
248	0.0089	66.41	5.059	0.72	2.98	94.05	0.00	0.23	2.02
272	0.0098	65.96	5.161	0.72	2.91	94.18	0.00	0.24	1.94
295	0.0107	65.52	5.263	0.70	2.85	94.28	0.00	0.27	1.90
319	0.0116	64.91	5.406	0.71	2.83	94.18	0.00	0.28	2.00
342	0.0125	64.40	5.527	0.69	2.72	94.49	0.00	0.30	1.81
366	0.0135	63.88	5.653	0.69	2.72	94.35	0.00	0.31	1.93
389	0.0145	63.35	5.784	0.69	2.67	94.41	0.00	0.33	1.90
413	0.0155	62.88	5.903	0.68	2.61	94.57	0.00	0.36	1.78
437	0.0166	62.44	6.015	0.66	2.58	94.76	0.00	0.35	1.64
460	0.0176	61.78	6.187	0.65	2.27	95.05	0.00	0.37	1.65
484	0.0188	60.55	6.517	0.63	1.47	96.03	0.00	0.46	1.40
507	0.0201	53.24	8.783	1.02	0.33	87.00	0.00	10.15	1.51
531	0.023	29.68	23.688	1.93	0.00	68.55	0.00	28.19	1.33
556	0.031	13.06	66.597	2.27	0.00	62.89	0.00	33.58	1.26
580	0.048	7.87	117.017	2.30	0.00	61.77	0.00	34.62	1.31
604	0.071	6.38	146.842	2.30	0.00	61.80	0.00	34.61	1.29
628	0.098	6.13	153.104	2.31	0.00	62.12	0.00	34.32	1.25
651	0.123	6.30	148.722	2.36	0.00	62.43	0.00	33.97	1.23
675	0.149	6.63	140.744	2.42	0.00	62.49	0.00	33.87	1.22
699	0.173	7.03	132.212	2.50	0.00	62.69	0.00	33.62	1.19
723	0.196	7.48	123.642	2.58	0.00	62.54	0.00	33.71	1.18
747	0.217	7.99	115.181	2.65	0.00	62.49	0.00	33.72	1.14

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	**Est. Al Conc.**	**Ar**	**Total Offgas Flow**	**H_2**	**N_2**	**NO**	**O_2**	**N_2O**	**NO_2**
(sec)	**(M)**	**(vol %)**	**(cm^3/min)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**
771	0.237	8.46	108.195	2.71	0.00	62.30	0.00	33.82	1.17
795	0.256	8.96	101.595	2.79	0.00	62.20	0.00	33.89	1.12
819	0.273	9.59	94.282	2.90	0.00	62.12	0.00	33.80	1.18
843	0.289	10.18	88.250	3.00	0.00	62.17	0.00	33.76	1.08
867	0.304	10.69	83.549	3.07	0.00	61.86	0.00	33.94	1.12
891	0.319	11.18	79.475	3.14	0.00	61.82	0.00	33.89	1.14
914	0.332	11.62	76.080	3.20	0.00	61.66	0.00	34.06	1.09
938	0.345	12.02	73.172	3.25	0.00	61.52	0.00	34.15	1.08
962	0.358	12.42	70.534	3.31	0.00	61.49	0.00	34.12	1.08
986	0.370	12.82	67.993	3.40	0.00	61.41	0.00	34.07	1.12
1010	0.382	13.25	65.478	3.47	0.00	61.44	0.00	33.98	1.12
1034	0.394	13.63	63.354	3.53	0.00	61.31	0.00	34.09	1.06
1058	0.405	14.08	61.009	3.59	0.00	61.01	0.00	34.26	1.13
1082	0.415	14.52	58.860	3.68	0.00	60.94	0.00	34.26	1.12
1106	0.426	14.91	57.079	3.75	0.00	60.62	0.00	34.47	1.16
1130	0.436	15.23	55.662	3.81	0.00	60.57	0.00	34.51	1.11
1154	0.445	15.61	54.064	3.89	0.00	60.74	0.00	34.22	1.15
1177	0.454	16.05	52.301	3.95	0.00	60.81	0.00	34.10	1.14
1201	0.463	16.47	50.700	3.99	0.00	60.73	0.00	34.12	1.16
1225	0.472	16.97	48.929	4.06	0.00	60.90	0.00	33.87	1.18
1249	0.481	17.41	47.437	4.09	0.00	60.63	0.00	34.10	1.17
1273	0.489	17.84	46.051	4.15	0.00	60.62	0.00	34.04	1.18
1297	0.497	18.27	44.731	4.20	0.00	60.68	0.00	33.97	1.15
1321	0.505	18.68	43.520	4.24	0.00	60.60	0.00	33.98	1.18
1345	0.513	19.07	42.451	4.32	0.00	60.64	0.00	33.89	1.15
1369	0.520	19.45	41.402	4.38	0.00	60.59	0.00	33.87	1.15
1393	0.527	19.79	40.520	4.45	0.00	60.47	0.00	33.90	1.18
1417	0.534	20.17	39.587	4.54	0.00	60.51	0.00	33.85	1.11
1440	0.541	20.49	38.812	4.61	0.00	60.22	0.00	33.99	1.18
1464	0.548	20.86	37.941	4.69	0.00	60.15	0.00	33.94	1.22
1488	0.555	21.12	37.349	4.76	0.00	59.89	0.00	34.07	1.28
1512	0.561	21.41	36.716	4.80	0.00	59.80	0.00	34.12	1.28
1536	0.568	21.63	36.230	4.84	0.00	59.69	0.00	34.21	1.25
1560	0.574	21.83	35.809	4.92	0.00	59.83	0.00	34.00	1.25
1584	0.580	22.02	35.411	4.99	0.00	59.66	0.00	34.02	1.33
1608	0.587	22.24	34.974	5.04	0.00	59.64	0.00	34.07	1.25
1632	0.593	22.45	34.551	5.12	0.03	59.56	0.00	33.99	1.30

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	**Est. Al Conc.**	**Ar**	**Total Offgas Flow**	**H_2**	**N_2**	**NO**	**O_2**	**N_2O**	**NO_2**
(sec)	**(M)**	**(vol %)**	**(cm^3/min)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**
1656	0.599	22.64	34.161	5.18	0.00	59.45	0.00	34.06	1.31
1680	0.605	22.89	33.693	5.24	0.02	59.44	0.00	34.02	1.27
1703	0.611	23.12	33.246	5.31	0.07	59.58	0.00	33.78	1.25
1727	0.616	23.30	32.925	5.34	0.00	59.30	0.00	34.14	1.22
1751	0.622	23.46	32.631	5.40	0.02	59.16	0.00	34.15	1.28
1775	0.628	23.68	32.226	5.45	0.01	59.16	0.00	34.24	1.13
1799	0.634	23.82	31.981	5.49	0.00	59.07	0.00	34.26	1.18
1822	0.639	23.97	31.724	5.54	0.02	58.98	0.00	34.17	1.30
1846	0.645	24.07	31.539	5.56	0.00	58.62	0.00	34.58	1.24
1870	0.650	24.26	31.226	5.63	0.00	58.63	0.00	34.49	1.26
1894	0.656	24.39	31.000	5.69	0.00	58.60	0.00	34.51	1.19
1918	0.661	24.55	30.726	5.76	0.00	58.48	0.00	34.57	1.19
1942	0.667	24.67	30.537	5.85	0.00	58.38	0.00	34.53	1.24
1965	0.672	24.80	30.327	5.91	0.00	58.29	0.00	34.59	1.21
1989	0.677	24.91	30.140	5.97	0.01	58.27	0.00	34.54	1.21
2013	0.683	25.02	29.975	6.02	0.00	58.19	0.00	34.57	1.22
2037	0.688	25.11	29.821	6.06	0.01	58.12	0.00	34.54	1.26
2061	0.693	25.22	29.651	6.11	0.01	58.17	0.00	34.47	1.24
2084	0.698	25.37	29.420	6.14	0.03	58.27	0.00	34.38	1.17
2108	0.703	25.41	29.351	6.16	0.00	57.99	0.00	34.68	1.17
2132	0.709	25.57	29.103	6.20	0.00	58.04	0.00	34.66	1.09
2156	0.714	25.61	29.044	6.24	0.00	57.93	0.00	34.61	1.22
2180	0.719	25.79	28.775	6.27	0.00	57.93	0.00	34.61	1.19
2204	0.724	25.92	28.586	6.34	0.00	57.82	0.00	34.74	1.10
2228	0.729	26.07	28.362	6.45	0.07	57.54	0.00	34.62	1.33
2251	0.734	26.27	28.072	6.54	0.18	57.48	0.00	34.45	1.35
2275	0.739	26.37	27.926	6.60	0.22	57.33	0.00	34.42	1.43
2299	0.744	26.54	27.681	6.70	0.28	57.34	0.00	34.20	1.48
2323	0.749	26.69	27.469	6.76	0.25	56.96	0.00	34.57	1.46
2347	0.754	26.78	27.348	6.78	0.23	56.61	0.00	34.87	1.51
2371	0.758	26.91	27.157	6.88	0.28	56.58	0.00	34.74	1.52
2394	0.763	27.07	26.945	6.91	0.30	56.62	0.00	34.73	1.44
2418	0.768	27.15	26.829	6.95	0.32	56.50	0.00	34.73	1.50
2442	0.773	27.28	26.661	6.98	0.30	56.48	0.00	34.77	1.47
2466	0.777	27.38	26.516	7.04	0.37	56.57	0.00	34.45	1.57
2490	0.782	27.53	26.318	7.13	0.46	56.93	0.00	33.98	1.51
2513	0.786	27.66	26.149	7.14	0.40	56.60	0.00	34.34	1.51

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	**Est. Al Conc.**	**Ar**	**Total Offgas Flow**	**H_2**	**N_2**	**NO**	**O_2**	**N_2O**	**NO_2**
(sec)	**(M)**	**(vol %)**	**(cm^3/min)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**
2537	0.791	27.80	25.975	7.21	0.46	56.76	0.00	34.05	1.52
2561	0.796	27.95	25.783	7.27	0.49	56.87	0.00	33.92	1.45
2585	0.800	28.02	25.686	7.30	0.45	56.54	0.00	34.18	1.53
2609	0.805	28.10	25.583	7.35	0.45	56.46	0.00	34.22	1.53
2633	0.809	28.27	25.367	7.42	0.48	56.45	0.00	34.08	1.57
2657	0.814	28.38	25.241	7.45	0.47	56.33	0.00	34.16	1.58
2681	0.818	28.54	25.044	7.48	0.44	56.11	0.00	34.41	1.56
2705	0.823	28.69	24.855	7.57	0.47	56.27	0.00	34.25	1.44
2729	0.827	28.81	24.713	7.60	0.49	56.05	0.00	34.30	1.57
2753	0.831	28.99	24.492	7.64	0.51	55.92	0.00	34.41	1.52
2777	0.836	29.12	24.342	7.70	0.50	55.95	0.00	34.33	1.52
2801	0.840	29.29	24.138	7.76	0.51	55.95	0.00	34.28	1.49
2825	0.844	29.39	24.028	7.79	0.48	55.62	0.00	34.54	1.57
2849	0.849	29.50	23.901	7.83	0.42	55.57	0.00	34.65	1.53
2872	0.853	29.66	23.712	7.92	0.55	55.70	0.00	34.23	1.60
2896	0.857	29.77	23.596	7.97	0.57	55.71	0.00	34.14	1.61
2920	0.861	29.92	23.422	8.00	0.56	55.79	0.00	34.20	1.44
2944	0.865	29.96	23.375	8.02	0.56	55.69	0.00	34.15	1.58
2968	0.869	30.02	23.306	8.04	0.53	55.59	0.00	34.26	1.57
2992	0.873	30.09	23.234	8.07	0.53	55.59	0.00	34.26	1.55
3016	0.878	30.27	23.034	8.10	0.60	55.77	0.00	33.96	1.57
3040	0.882	30.33	22.966	8.13	0.61	55.77	0.00	33.90	1.60
3064	0.886	30.44	22.847	8.16	0.64	55.82	0.00	33.85	1.53
3088	0.890	30.53	22.759	8.16	0.66	55.58	0.00	34.03	1.57
3112	0.894	30.61	22.665	8.15	0.60	55.53	0.00	34.12	1.60
3136	0.898	30.70	22.571	8.19	0.60	55.52	0.00	34.06	1.63
3160	0.902	30.86	22.402	8.21	0.65	55.46	0.00	34.05	1.63
3184	0.906	31.01	22.249	8.25	0.58	55.27	0.00	34.36	1.53
3208	0.910	31.23	22.023	8.33	0.68	55.46	0.00	33.90	1.62
3232	0.914	31.35	21.902	8.35	0.65	55.29	0.00	34.09	1.63
3256	0.917	31.55	21.693	8.38	0.71	55.48	0.00	33.85	1.57
3280	0.921	31.71	21.540	8.40	0.65	55.43	0.00	33.95	1.57
3303	0.925	31.84	21.405	8.44	0.66	55.37	0.00	33.97	1.56
3327	0.929	32.08	21.174	8.47	0.64	55.31	0.00	34.04	1.54
3351	0.932	32.20	21.055	8.47	0.64	54.93	0.00	34.31	1.64
3375	0.936	32.41	20.854	8.51	0.66	54.87	0.00	34.39	1.57
3399	0.940	32.54	20.729	8.58	0.70	54.95	0.00	34.27	1.50

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	Ar	Total Offgas Flow	H_2	N_2	NO	O_2	N_2O	NO_2
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
3423	0.943	32.65	20.630	8.55	0.66	54.61	0.00	34.49	1.69
3447	0.947	32.76	20.528	8.57	0.64	54.59	0.00	34.55	1.64
3471	0.951	32.87	20.418	8.59	0.64	54.64	0.00	34.48	1.66
3495	0.954	32.98	20.317	8.62	0.69	54.85	0.00	34.29	1.55
3519	0.958	33.09	20.217	8.64	0.78	54.86	0.00	34.10	1.61
3543	0.962	33.17	20.144	8.65	0.74	54.89	0.00	34.23	1.50
3567	0.965	33.28	20.052	8.65	0.76	54.77	0.00	34.24	1.58
3591	0.969	33.45	19.891	8.71	0.85	55.02	0.00	33.73	1.69
3615	0.972	33.52	19.834	8.69	0.73	54.83	0.00	34.13	1.62
3639	0.976	33.67	19.699	8.69	0.79	54.86	0.00	34.10	1.56
3663	0.979	33.77	19.608	8.71	0.86	54.82	0.00	34.05	1.55
3687	0.983	33.94	19.468	8.69	0.84	54.49	0.00	34.23	1.75
3711	0.986	34.08	19.342	8.72	0.86	54.46	0.00	34.24	1.72
3734	0.989	34.27	19.178	8.75	0.85	54.56	0.00	34.18	1.66
3758	0.993	34.42	19.054	8.81	0.86	54.60	0.00	34.08	1.65
3782	0.996	34.70	18.822	8.83	0.85	54.40	0.00	34.24	1.67
3806	0.999	34.98	18.585	8.92	0.93	54.60	0.00	33.94	1.61
3830	1.003	35.13	18.468	8.93	0.89	54.40	0.00	34.15	1.63
3854	1.006	35.25	18.368	8.93	0.91	54.12	0.00	34.41	1.63
3878	1.009	35.38	18.263	8.95	0.89	54.06	0.00	34.43	1.67
3902	1.012	35.49	18.175	8.99	0.90	53.96	0.00	34.42	1.73
3926	1.016	35.63	18.068	9.01	0.91	54.02	0.00	34.43	1.63
3950	1.019	35.86	17.884	9.07	1.05	54.16	0.00	34.12	1.60
3974	1.022	35.94	17.822	9.09	0.97	54.04	0.00	34.20	1.71
3998	1.025	36.11	17.693	9.13	1.00	54.08	0.00	34.07	1.72
4022	1.028	36.25	17.584	9.15	1.03	54.07	0.00	34.00	1.74
4046	1.031	36.36	17.506	9.13	1.01	53.89	0.00	34.34	1.62
4070	1.035	36.43	17.451	9.14	1.04	53.90	0.00	34.35	1.57
4094	1.038	36.62	17.310	9.17	1.01	53.98	0.00	34.16	1.68
4118	1.041	36.72	17.232	9.17	1.07	54.13	0.00	33.95	1.68
4142	1.044	36.88	17.111	9.20	1.10	54.25	0.00	33.89	1.57
4166	1.047	36.94	17.070	9.23	1.13	54.31	0.00	33.74	1.59
4190	1.050	37.24	16.853	9.26	1.16	54.29	0.00	33.60	1.70
4214	1.053	37.35	16.772	9.28	1.21	54.39	0.00	33.44	1.68
4238	1.056	37.50	16.667	9.27	1.18	54.12	0.00	33.75	1.68
4262	1.059	37.77	16.477	9.31	1.21	54.32	0.00	33.56	1.60
4286	1.062	37.94	16.360	9.35	1.29	54.20	0.00	33.53	1.63

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	Ar	Total Offgas Flow	H_2	N_2	NO	O_2	N_2O	NO_2
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
4310	1.065	38.09	16.253	9.35	1.39	54.05	0.00	33.45	1.76
4334	1.067	38.25	16.144	9.39	1.26	54.17	0.00	33.48	1.70
4358	1.070	38.34	16.084	9.38	1.20	53.92	0.00	33.70	1.80
4382	1.073	38.57	15.924	9.43	1.26	54.16	0.00	33.50	1.65
4406	1.076	38.77	15.790	9.48	1.41	54.42	0.00	33.02	1.67
4430	1.079	38.80	15.771	9.44	1.30	54.17	0.00	33.47	1.62
4454	1.081	39.08	15.587	9.50	1.34	54.12	0.00	33.42	1.62
4478	1.084	39.25	15.480	9.49	1.39	53.95	0.00	33.48	1.70
4502	1.087	39.39	15.384	9.50	1.38	53.85	0.00	33.43	1.84
4526	1.090	39.51	15.311	9.51	1.48	53.80	0.00	33.42	1.79
4550	1.092	39.70	15.186	9.54	1.51	53.92	0.00	33.37	1.66
4574	1.095	39.83	15.104	9.55	1.41	53.85	0.00	33.42	1.77
4598	1.098	39.90	15.063	9.55	1.39	53.57	0.00	33.67	1.82
4622	1.100	40.17	14.895	9.58	1.55	53.78	0.00	33.40	1.69
4646	1.103	40.39	14.758	9.58	1.42	53.81	0.00	33.52	1.67
4670	1.106	40.62	14.616	9.62	1.44	53.81	0.00	33.36	1.78
4694	1.108	40.94	14.426	9.63	1.53	53.96	0.00	33.23	1.65
4718	1.111	41.06	14.355	9.65	1.50	53.74	0.00	33.26	1.85
4742	1.113	41.33	14.195	9.65	1.50	53.47	0.00	33.70	1.68
4766	1.116	41.53	14.078	9.66	1.58	53.60	0.00	33.39	1.77
4790	1.118	41.71	13.978	9.68	1.62	53.56	0.00	33.43	1.71
4814	1.121	41.76	13.946	9.63	1.72	53.22	0.00	33.56	1.87
4838	1.123	41.96	13.835	9.67	1.54	53.44	0.00	33.68	1.66
4862	1.126	42.09	13.759	9.70	1.56	53.52	0.00	33.46	1.75
4886	1.128	42.26	13.666	9.73	1.64	53.76	0.00	33.16	1.71
4910	1.131	42.27	13.656	9.76	1.64	53.67	0.00	33.21	1.72
4934	1.133	42.46	13.553	9.73	1.60	53.57	0.00	33.38	1.71
4958	1.135	42.59	13.479	9.74	1.69	53.69	0.00	33.10	1.78
4982	1.138	42.78	13.375	9.79	1.77	53.77	0.00	32.95	1.72
5006	1.140	43.07	13.219	9.81	1.81	53.98	0.00	32.68	1.71
5030	1.142	43.15	13.173	9.77	1.81	53.71	0.00	32.89	1.82
5054	1.145	43.33	13.081	9.78	1.76	53.82	0.00	32.85	1.79
5078	1.147	43.50	12.989	9.79	1.80	53.79	0.00	32.85	1.76
5102	1.149	43.66	12.906	9.80	1.86	53.89	0.00	32.72	1.73
5126	1.152	43.76	12.852	9.78	1.89	53.85	0.00	32.69	1.79
5149	1.154	43.90	12.777	9.81	1.93	54.02	0.00	32.49	1.75
5173	1.156	44.07	12.693	9.82	2.02	54.15	0.00	32.24	1.77

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	Ar	Total Offgas Flow	H_2	N_2	NO	O_2	N_2O	NO_2
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
5197	1.158	44.17	12.639	9.82	1.95	53.95	0.00	32.49	1.79
5221	1.161	44.30	12.571	9.79	2.00	53.93	0.00	32.56	1.73
5245	1.163	44.47	12.487	9.84	2.01	54.01	0.00	32.49	1.66
5269	1.165	44.57	12.436	9.83	2.05	54.08	0.00	32.20	1.84
5293	1.167	44.80	12.321	9.85	2.09	54.18	0.00	32.19	1.70
5318	1.170	44.90	12.271	9.85	2.04	54.18	0.00	32.17	1.76
5342	1.172	45.05	12.199	9.86	2.10	54.14	0.00	32.04	1.87
5366	1.174	45.20	12.126	9.86	2.09	54.19	0.00	31.96	1.90
5390	1.176	45.35	12.053	9.92	2.23	54.41	0.00	31.55	1.90
5414	1.178	45.46	11.995	9.90	2.13	54.07	0.00	32.14	1.76
5438	1.180	45.57	11.943	9.89	2.28	54.09	0.00	31.98	1.77
5462	1.182	45.72	11.874	9.90	2.24	54.07	0.00	32.06	1.73
5486	1.184	45.81	11.828	9.87	2.22	53.93	0.00	32.11	1.86
5510	1.187	46.05	11.714	9.92	2.23	54.10	0.00	31.96	1.79
5533	1.189	46.12	11.682	9.93	2.30	54.04	0.00	31.88	1.85
5558	1.191	46.28	11.606	9.91	2.35	54.05	0.00	31.87	1.82
5582	1.193	46.43	11.538	9.94	2.42	54.22	0.00	31.70	1.71
5605	1.195	46.57	11.472	9.96	2.49	54.29	0.00	31.48	1.79
5629	1.197	46.69	11.416	9.90	2.42	54.14	0.00	31.71	1.82
5653	1.199	46.90	11.324	9.95	2.56	54.70	0.00	31.01	1.78
5677	1.201	47.11	11.225	9.95	2.50	54.60	0.00	31.08	1.87
5701	1.203	47.25	11.163	9.89	2.53	54.34	0.00	31.32	1.93
5725	1.205	47.51	11.046	9.83	2.58	54.25	0.00	31.46	1.88
5749	1.207	47.80	10.920	9.84	2.58	54.30	0.00	31.38	1.90
5773	1.209	47.95	10.854	9.85	2.68	54.33	0.00	31.30	1.84
5797	1.211	48.08	10.799	9.82	2.83	54.38	0.00	31.16	1.81
5821	1.211	48.30	10.703	9.80	2.71	54.29	0.00	31.29	1.90
5845	1.211	48.16	10.766	9.77	3.33	53.70	0.00	31.03	2.17
5869	1.211	47.90	10.879	9.66	4.25	52.90	0.00	30.86	2.33
5893	1.211	47.85	10.899	9.64	5.11	52.57	0.00	30.38	2.30
5917	1.221	48.12	10.780	9.70	4.81	53.10	0.00	30.32	2.08
5941	1.221	48.61	10.572	9.80	3.94	54.01	0.00	30.36	1.89
5965	1.221	49.12	10.357	9.88	3.29	54.88	0.00	30.09	1.85
5989	1.221	49.38	10.250	9.92	3.15	54.87	0.00	30.19	1.87
6013	1.228	49.54	10.185	9.90	3.12	54.82	0.00	30.38	1.78
6037	1.229	49.93	10.026	9.91	3.32	54.91	0.00	29.91	1.95
6061	1.231	50.41	9.838	9.88	3.42	55.03	0.00	29.74	1.93

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	**Est. Al Conc.**	**Ar**	**Total Offgas Flow**	**H_2**	**N_2**	**NO**	**O_2**	**N_2O**	**NO_2**
(sec)	**(M)**	**(vol %)**	**(cm^3/min)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**
6085	1.233	50.87	9.659	9.92	3.64	55.06	0.00	29.40	1.98
6109	1.234	51.39	9.459	9.90	3.65	55.36	0.00	29.16	1.93
6133	1.236	52.14	9.178	9.94	3.85	55.70	0.00	28.58	1.94
6157	1.238	52.73	8.963	9.89	4.04	55.76	0.00	28.40	1.90
6181	1.239	53.42	8.718	9.88	4.09	55.77	0.00	28.21	2.04
6205	1.241	54.19	8.453	9.81	4.21	55.74	0.00	28.19	2.06
6229	1.242	55.14	8.134	9.83	4.36	56.33	0.00	27.51	1.97
6253	1.244	55.68	7.959	9.76	4.55	56.36	0.00	27.19	2.14
6277	1.245	56.72	7.630	9.71	4.63	56.54	0.00	26.84	2.28
6301	1.246	57.64	7.349	9.61	4.80	56.78	0.00	26.80	2.02
6325	1.248	58.35	7.137	9.53	4.95	56.75	0.00	26.51	2.27
6349	1.249	59.34	6.851	9.42	5.00	56.96	0.00	26.23	2.39
6373	1.250	60.09	6.643	9.40	5.43	57.42	0.00	25.34	2.41
6397	1.251	60.72	6.468	9.27	5.60	57.45	0.00	25.27	2.40
6421	1.252	61.60	6.233	9.18	5.67	57.61	0.00	25.24	2.30
6445	1.254	62.37	6.033	9.09	5.82	58.07	0.00	24.50	2.53
6469	1.255	63.16	5.833	8.95	5.95	58.24	0.00	24.47	2.39
6493	1.256	63.64	5.713	8.83	6.21	58.24	0.00	24.24	2.49
6516	1.257	64.71	5.453	8.76	6.36	58.83	0.00	23.44	2.61
6541	1.258	65.12	5.356	8.62	6.60	58.78	0.00	23.36	2.64
6564	1.258	65.82	5.194	8.54	6.91	59.18	0.00	22.87	2.51
6589	1.259	66.33	5.076	8.46	7.16	59.39	0.00	22.36	2.63
6615	1.260	67.94	4.718	8.36	7.30	59.64	0.00	22.16	2.53
6638	1.261	68.49	4.600	8.17	7.43	59.79	0.00	22.18	2.43
6662	1.262	69.20	4.450	8.06	7.56	60.17	0.00	21.86	2.36
6686	1.263	69.87	4.313	7.89	7.69	60.19	0.00	21.91	2.32
6709	1.263	70.24	4.237	7.78	7.97	60.13	0.00	21.47	2.66
6733	1.264	70.80	4.125	7.64	8.01	60.44	0.00	21.42	2.49
6756	1.265	71.32	4.022	7.53	8.36	60.61	0.00	21.14	2.36
6780	1.266	71.86	3.915	7.46	8.59	61.18	0.00	20.51	2.27
6804	1.266	72.21	3.849	7.34	8.90	61.17	0.00	20.16	2.42
6827	1.267	72.67	3.761	7.21	9.12	61.59	0.00	19.83	2.25
6851	1.268	73.16	3.669	7.06	9.09	61.47	0.00	19.73	2.65
6875	1.268	73.63	3.581	6.94	9.38	61.83	0.00	19.26	2.59
6898	1.269	74.08	3.499	6.81	9.65	61.99	0.00	18.98	2.57
6922	1.269	74.49	3.425	6.70	9.84	62.31	0.00	18.50	2.65
6946	1.270	74.75	3.377	6.57	10.16	62.08	0.00	18.44	2.74

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	Ar	Total Offgas Flow	H_2	N_2	NO	O_2	N_2O	NO_2
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
6969	1.271	75.22	3.295	6.49	10.30	62.60	0.00	17.87	2.74
6993	1.271	75.45	3.254	6.39	10.73	62.53	0.00	17.56	2.80
7017	1.272	75.94	3.169	6.24	10.83	62.92	0.00	17.19	2.82
7040	1.272	76.17	3.128	6.11	11.20	62.88	0.00	16.80	3.01
7064	1.273	76.58	3.058	6.00	11.35	63.58	0.00	16.37	2.70
7088	1.273	76.84	3.013	5.90	11.68	63.59	0.00	16.23	2.59
7111	1.274	77.23	2.948	5.81	11.75	63.97	0.00	15.92	2.55
7135	1.274	77.49	2.906	5.68	12.08	63.75	0.00	15.86	2.63
7159	1.275	77.87	2.841	5.56	12.13	64.16	0.00	15.33	2.82
7182	1.275	78.05	2.812	5.46	12.57	64.07	0.00	14.97	2.93
7206	1.276	78.31	2.770	5.35	12.75	64.44	0.00	14.66	2.81
7230	1.276	78.62	2.719	5.24	13.07	64.64	0.00	14.21	2.85
7253	1.277	79.11	2.640	5.10	13.13	65.47	0.00	13.61	2.69
7277	1.277	79.47	2.584	4.93	13.21	65.88	0.00	13.37	2.60
7301	1.277	79.27	2.615	4.71	14.69	63.72	0.00	12.72	4.16
7324	1.277	76.68	3.041	4.62	19.46	56.93	0.00	14.96	4.02
7348	1.277	76.71	3.037	4.85	20.31	56.34	0.00	14.37	4.13
7372	1.277	77.30	2.937	4.89	19.94	57.31	0.00	13.85	4.01
7395	1.277	77.76	2.861	4.91	19.63	57.92	0.00	13.35	4.18
7419	1.277	78.14	2.798	4.88	19.98	58.16	0.00	12.86	4.13
7443	1.277	78.28	2.774	4.78	21.33	57.00	0.00	12.43	4.46
7466	1.277	78.28	2.775	4.65	24.21	55.08	0.00	11.99	4.07
7490	1.277	78.11	2.802	4.47	28.15	51.74	0.00	11.42	4.22
7514	1.277	77.72	2.867	4.30	33.22	47.91	0.00	10.91	3.66
7537	1.277	77.22	2.950	4.11	38.87	43.52	0.00	10.31	3.20
7561	1.277	76.47	3.077	3.86	44.63	38.88	0.00	9.57	3.06
7585	1.277	75.63	3.223	3.66	50.42	34.23	0.00	9.13	2.57
7608	1.277	74.58	3.408	3.28	59.20	27.91	0.00	7.74	1.87
7632	1.277	71.57	3.973	2.30	73.44	16.35	0.00	5.90	2.01
7656	1.277	67.35	4.847	1.73	81.93	9.17	0.00	4.83	2.34
7679	1.277	61.87	6.164	1.34	87.28	5.06	0.00	3.74	2.58
7703	1.277	56.63	7.657	1.09	89.92	3.17	0.00	3.04	2.78
7727	1.277	51.29	9.497	0.91	88.81	2.14	3.07	2.45	2.63
7750	1.277	46.93	11.307	0.74	87.99	1.57	5.57	1.99	2.14
7774	1.277	43.54	12.969	0.63	87.26	1.24	7.33	1.74	1.80
7797	1.277	41.19	14.280	0.57	86.84	1.06	8.52	1.53	1.49
7821	1.277	39.31	15.436	0.52	86.31	0.90	9.44	1.41	1.41

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	**Est. Al Conc.**	**Ar**	**Total Offgas Flow**	**H_2**	**N_2**	**NO**	**O_2**	**N_2O**	**NO_2**
(sec)	**(M)**	**(vol %)**	**(cm^3/min)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**
7845	1.277	41.28	14.222	0.64	85.81	1.18	7.91	2.21	2.26
7869	1.277	39.65	15.221	0.68	85.47	1.06	8.91	1.80	2.09
7892	1.277	39.99	15.006	0.72	84.87	1.06	8.36	2.22	2.78
7916	1.277	39.26	15.468	0.76	84.89	0.98	8.78	2.04	2.55
7939	1.277	38.39	16.050	0.74	84.99	0.85	9.26	1.86	2.30
7963	1.277	37.72	16.514	0.71	85.10	0.75	9.65	1.71	2.08
7986	1.277	37.19	16.892	0.68	85.16	0.68	9.96	1.60	1.92
8010	1.277	36.7951	17.177	0.66	85.11	0.61	10.22	1.52	1.88
8033	1.277	36.52	17.384	0.65	85.20	0.57	10.40	1.43	1.75
8056	1.277	36.39	17.477	0.62	85.36	0.54	10.53	1.38	1.57
8080	1.277	36.36	17.504	0.60	85.41	0.51	10.64	1.34	1.49
8103	1.280	36.41	17.464	0.60	85.52	0.50	10.70	1.28	1.40
8127	1.283	36.45	17.432	0.57	85.69	0.47	10.79	1.20	1.27
8151	1.286	36.55	17.362	0.53	85.92	0.44	10.90	1.09	1.13
8174	1.289	36.96	17.053	0.49	86.08	0.41	10.89	1.03	1.09
8198	1.292	37.34	16.778	0.46	86.45	0.40	10.87	0.94	0.88
8221	1.295	37.70	16.527	0.46	86.66	0.40	10.74	0.94	0.80
8245	1.298	38.42	16.027	0.46	86.85	0.39	10.59	0.91	0.80
8268	1.301	39.17	15.529	0.46	87.19	0.41	10.37	0.90	0.67
8291	1.303	40.04	14.978	0.46	87.32	0.39	10.12	0.92	0.78
8315	1.306	41.12	14.317	0.46	87.72	0.40	9.86	0.91	0.66
8339	1.309	42.09	13.759	0.48	87.92	0.40	9.56	0.94	0.71
8362	1.311	42.89	13.314	0.50	88.24	0.42	9.26	0.97	0.61
8386	1.313	43.28	13.106	0.57	88.30	0.44	8.90	1.12	0.66
8409	1.315	44.21	12.617	0.67	88.34	0.48	8.39	1.32	0.80
8553	1.328	45.83	11.819	0.42	88.70	0.42	7.79	1.61	1.05
8578	1.330	51.44	9.441	0.81	90.77	0.57	5.04	1.67	1.14
8601	1.332	55.30	8.082	0.93	92.18	0.71	3.52	1.77	0.88
8625	1.333	56.64	7.655	1.00	92.65	0.77	2.78	1.84	0.96
8649	1.335	57.88	7.279	1.03	93.41	0.85	1.97	1.88	0.86
8672	1.336	59.01	6.947	1.10	93.65	0.90	1.18	2.05	1.12
8696	1.337	60.46	6.539	1.13	94.31	0.99	0.27	2.10	1.19
8719	1.338	61.83	6.174	1.15	94.51	1.08	0.00	2.16	1.09
8742	1.339	62.91	5.895	1.19	94.18	1.19	0.00	2.21	1.23
8766	1.340	63.97	5.631	1.23	93.88	1.32	0.00	2.23	1.35
8789	1.341	65.19	5.341	1.24	93.89	1.46	0.00	2.27	1.14
8813	1.342	66.25	5.095	1.27	93.35	1.59	0.00	2.37	1.42

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	Ar	Total Offgas Flow	H_2	N_2	NO	O_2	N_2O	NO_2
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
8836	1.343	67.19	4.882	1.31	93.03	1.75	0.00	2.41	1.50
8860	1.344	68.26	4.650	1.31	92.74	2.01	0.00	2.46	1.47
8883	1.344	69.02	4.488	1.36	92.34	2.22	0.00	2.49	1.59
8906	1.345	69.82	4.322	1.38	91.80	2.44	0.00	2.47	1.90
8930	1.346	71.23	4.039	1.39	91.66	2.89	0.00	2.51	1.55
8953	1.347	71.79	3.930	1.40	91.08	3.16	0.00	2.58	1.78
8977	1.347	72.73	3.749	1.43	90.26	3.56	0.00	2.64	2.12
9000	1.3479	73.40	3.625	1.44	89.46	3.95	0.00	2.66	2.48
9024	1.3485	74.10	3.494	1.46	89.24	4.43	0.00	2.67	2.20
9047	1.349	74.59	3.407	1.50	88.43	4.89	0.00	2.70	2.48
9071	1.350	75.20	3.298	1.51	87.67	5.38	0.00	2.67	2.76
9094	1.350	75.83	3.187	1.51	87.05	6.05	0.00	2.67	2.72
9118	1.351	76.49	3.074	1.49	86.14	6.88	0.00	2.78	2.71
9141	1.351	76.90	3.004	1.54	85.49	7.57	0.00	2.77	2.64
9165	1.352	77.44	2.914	1.50	84.51	8.37	0.00	2.72	2.89
9188	1.352	77.96	2.827	1.55	83.35	9.53	0.00	2.77	2.80
9212	1.353	78.36	2.762	1.54	82.52	10.46	0.00	2.80	2.69
9235	1.353	78.76	2.697	1.52	81.92	11.47	0.00	2.75	2.34
9518	1.5244	82.19	2.166	1.87	69.41	24.14	0.00	2.43	2.15
9541	1.5248	82.46	2.128	1.60	68.24	25.49	0.00	2.44	2.23
9565	1.5252	82.62	2.103	1.53	67.17	26.29	0.00	2.32	2.69
9589	1.5255	82.72	2.089	1.54	66.42	27.11	0.00	2.39	2.54
9612	1.5259	82.82	2.074	1.53	66.18	27.65	0.00	2.44	2.20
9636	1.5263	83.02	2.045	1.50	64.73	28.77	0.00	2.35	2.65
9659	1.5266	83.30	2.005	1.48	64.05	29.89	0.00	2.32	2.26
9683	1.5270	83.45	1.983	1.47	63.17	30.70	0.00	2.35	2.31
9707	1.5273	83.46	1.982	1.47	62.79	31.11	0.00	2.34	2.28
9730	1.5277	83.69	1.948	1.46	61.87	32.31	0.00	2.28	2.09
9754	1.5280	83.65	1.954	1.45	60.93	32.58	0.00	2.31	2.74
9777	1.5283	83.84	1.927	1.46	59.97	33.57	0.00	2.20	2.79
9801	1.5287	83.91	1.918	1.44	59.32	34.31	0.00	2.30	2.62
9824	1.5290	84.10	1.891	1.46	58.45	35.21	0.00	2.24	2.65
9848	1.5293	84.13	1.887	1.46	57.39	35.86	0.00	2.22	3.07
9871	1.5296	84.29	1.863	1.45	57.07	36.65	0.00	2.16	2.66
9895	1.5300	84.24	1.871	1.45	56.38	36.76	0.00	2.24	3.17
9919	1.5303	84.49	1.836	1.40	55.69	38.10	0.00	2.10	2.72
9942	1.5306	84.47	1.839	1.40	55.49	38.47	0.00	2.12	2.52

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	**Est. Al Conc.**	**Ar**	**Total Offgas Flow**	**H_2**	**N_2**	**NO**	**O_2**	**N_2O**	**NO_2**
(sec)	**(M)**	**(vol %)**	**(cm^3/min)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**
9966	1.5309	84.51	1.833	1.46	54.32	38.90	0.00	2.13	3.20
9990	1.5313	84.70	1.807	1.43	53.74	40.03	0.00	2.11	2.68
10013	1.5316	84.75	1.800	1.41	53.52	40.39	0.00	2.07	2.61
10037	1.5319	84.79	1.793	1.46	52.47	41.20	0.00	2.07	2.80
10060	1.5322	84.81	1.791	1.39	52.34	41.67	0.00	1.99	2.62
10084	1.5325	84.80	1.793	1.42	51.18	41.98	0.00	2.04	3.38
10108	1.5328	84.90	1.778	1.40	51.09	42.70	0.00	1.96	2.85
10131	1.5331	85.00	1.764	1.38	50.22	43.61	0.00	1.89	2.89
10155	1.5334	85.08	1.754	1.38	49.56	44.39	0.00	1.86	2.82
10178	1.5337	85.22	1.734	1.36	48.85	45.12	0.00	1.82	2.85
10202	1.5341	85.14	1.746	1.38	48.65	44.96	0.00	1.92	3.10
10226	1.5344	85.22	1.734	1.36	47.79	45.78	0.00	1.89	3.19
10249	1.5347	85.27	1.727	1.32	47.69	45.92	0.00	1.89	3.18
10273	1.5350	85.30	1.724	1.35	47.14	46.43	0.00	1.94	3.14
10297	1.5353	85.23	1.734	1.40	46.76	46.37	0.00	1.88	3.58
10320	1.5356	85.34	1.717	1.37	46.27	47.30	0.00	1.90	3.16
10344	1.5359	85.40	1.709	1.34	45.76	47.95	0.00	1.79	3.16
10367	1.5362	85.47	1.701	1.35	45.15	48.40	0.00	1.80	3.30
10391	1.5365	85.53	1.692	1.34	44.64	49.20	0.00	1.77	3.04
10415	1.5368	85.49	1.697	1.33	44.46	49.10	0.00	1.74	3.37
10438	1.5370	85.57	1.687	1.34	43.77	49.68	0.00	1.75	3.46
10462	1.5373	85.58	1.685	1.31	43.75	49.84	0.00	1.73	3.36
10486	1.5376	85.64	1.677	1.31	43.35	50.55	0.00	1.77	3.01
10509	1.5379	85.55	1.690	1.32	43.06	50.70	0.00	1.72	3.20
10533	1.5382	85.64	1.676	1.33	42.35	51.38	0.00	1.66	3.28
10556	1.5385	85.72	1.666	1.30	41.90	51.99	0.00	1.67	3.14
10580	1.5388	85.70	1.668	1.28	41.55	52.02	0.00	1.61	3.54
10604	1.5391	85.70	1.668	1.33	41.06	52.31	0.00	1.63	3.67
10627	1.5394	85.74	1.663	1.32	41.14	52.71	0.00	1.59	3.25
10651	1.5397	85.87	1.646	1.27	40.96	53.33	0.00	1.61	2.83
10675	1.5400	85.77	1.659	1.29	40.17	53.26	0.00	1.61	3.67
10699	1.5403	85.84	1.650	1.25	40.16	53.88	0.00	1.54	3.16
10722	1.5405	85.81	1.654	1.28	39.89	53.91	0.00	1.59	3.33
10746	1.5408	85.81	1.653	1.30	39.21	54.14	0.00	1.54	3.80
10770	1.5411	85.89	1.642	1.29	38.87	54.61	0.00	1.55	3.68
10794	1.5414	85.89	1.643	1.25	38.86	54.72	0.00	1.53	3.64
10818	1.5417	85.98	1.630	1.27	38.65	55.42	0.00	1.49	3.17

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	**Est. Al Conc.**	**Ar**	**Total Offgas Flow**	**H_2**	**N_2**	**NO**	**O_2**	**N_2O**	**NO_2**
(sec)	**(M)**	**(vol %)**	**(cm^3/min)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**
10841	1.5420	85.98	1.631	1.26	38.72	55.53	0.00	1.47	3.01
10865	1.5423	85.98	1.631	1.28	38.00	55.50	0.00	1.53	3.68
10889	1.5426	85.96	1.633	1.26	37.84	55.81	0.00	1.49	3.60
10913	1.5429	86.03	1.623	1.26	37.92	56.14	0.00	1.46	3.22
10936	1.5431	86.06	1.619	1.28	37.33	56.49	0.00	1.41	3.49
10960	1.5434	86.11	1.613	1.26	37.08	56.79	0.00	1.46	3.41
10984	1.5437	85.94	1.636	1.26	36.99	56.17	0.00	1.51	4.07
11008	1.5440	86.09	1.615	1.21	36.76	57.28	0.00	1.38	3.37
11031	1.5443	86.03	1.624	1.29	36.52	57.10	0.00	1.40	3.68
11055	1.5446	86.11	1.613	1.25	36.32	57.67	0.00	1.31	3.46
11079	1.5449	86.13	1.611	1.21	35.86	57.77	0.00	1.30	3.87
11103	1.5451	86.18	1.604	1.22	36.14	58.16	0.00	1.35	3.14
11126	1.5454	86.18	1.603	1.23	35.51	58.39	0.00	1.36	3.51
11150	1.5457	86.14	1.609	1.22	35.66	58.30	0.00	1.31	3.51
11174	1.5460	86.21	1.600	1.20	35.39	58.82	0.00	1.29	3.30
11198	1.5463	86.15	1.607	1.20	35.44	58.51	0.00	1.30	3.56
11221	1.5465	86.20	1.601	1.22	34.86	58.62	0.00	1.30	3.99
11245	1.5468	86.14	1.608	1.23	35.32	58.52	0.00	1.35	3.57
11269	1.5471	86.24	1.595	1.22	34.80	58.98	0.00	1.29	3.71
11293	1.5474	86.15	1.607	1.26	34.83	58.66	0.00	1.35	3.90
11317	1.5477	86.29	1.589	1.20	34.70	59.60	0.00	1.28	3.22
11340	1.5479	86.26	1.592	1.17	34.32	59.50	0.00	1.25	3.75
11364	1.5482	86.28	1.591	1.19	34.35	59.87	0.00	1.22	3.37
11388	1.5485	86.41	1.572	1.15	34.09	60.52	0.00	1.21	3.03
11412	1.5488	86.29	1.588	1.21	34.01	59.84	0.00	1.25	3.68
11435	1.5491	86.24	1.595	1.19	34.01	59.80	0.00	1.22	3.78
11459	1.5493	86.30	1.587	1.20	33.86	60.33	0.00	1.26	3.34
11483	1.5496	86.26	1.593	1.22	33.72	60.05	0.00	1.27	3.74
11507	1.5499	86.27	1.592	1.21	33.47	60.01	0.00	1.20	4.12
11531	1.5502	86.36	1.579	1.19	33.35	60.82	0.00	1.21	3.44
11554	1.5505	86.31	1.586	1.20	33.57	60.76	0.00	1.17	3.30
11578	1.5507	86.38	1.576	1.17	33.27	61.34	0.00	1.12	3.11
11601	1.5510	86.36	1.580	1.18	33.07	61.19	0.00	1.16	3.40
11625	1.5513	86.31	1.587	1.21	32.97	60.88	0.00	1.09	3.85
11649	1.5516	86.32	1.585	1.18	32.98	61.05	0.00	1.15	3.64
11672	1.5518	86.30	1.587	1.18	33.32	60.91	0.00	1.22	3.37
11696	1.5521	86.32	1.585	1.17	32.95	61.11	0.00	1.10	3.67

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	**Est. Al Conc.**	**Ar**	**Total Offgas Flow**	**H_2**	**N_2**	**NO**	**O_2**	**N_2O**	**NO_2**
(sec)	**(M)**	**(vol %)**	**(cm^3/min)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**
11720	1.5524	86.29	1.589	1.18	32.87	61.00	0.00	1.21	3.74
11743	1.5527	86.33	1.583	1.17	32.71	61.59	0.00	1.09	3.43
11767	1.5530	86.34	1.582	1.17	32.63	61.67	0.00	1.10	3.43
11791	1.5532	86.37	1.579	1.15	32.48	61.59	0.00	1.08	3.70
11815	1.5535	86.42	1.571	1.15	32.66	62.01	0.00	1.06	3.12
11839	1.5538	86.38	1.577	1.18	32.30	61.98	0.00	1.06	3.47
11862	1.5541	86.41	1.573	1.18	32.04	61.93	0.00	1.10	3.75
11886	1.5543	86.45	1.567	1.14	32.23	62.12	0.00	1.05	3.46
11910	1.5546	86.51	1.559	1.15	32.06	62.53	0.00	1.04	3.21
11934	1.5549	86.35	1.581	1.15	31.91	62.00	0.00	1.07	3.87
11958	1.5552	86.51	1.559	1.14	31.59	62.45	0.00	1.06	3.75
11981	1.5554	86.55	1.554	1.15	31.83	62.64	0.00	0.98	3.40
12005	1.5557	86.48	1.564	1.19	31.72	62.12	0.00	1.05	3.93
12029	1.5560	86.57	1.552	1.14	31.44	62.65	0.00	1.09	3.68
12053	1.5563	86.50	1.561	1.17	31.78	62.35	0.00	1.05	3.66
12077	1.5565	86.48	1.563	1.17	31.57	62.61	0.00	1.00	3.65
12100	1.5568	86.52	1.558	1.13	31.71	62.60	0.00	1.02	3.55
12124	1.5571	86.47	1.564	1.13	31.59	62.61	0.00	1.01	3.67
12148	1.5574	86.45	1.568	1.12	31.49	62.52	0.00	1.01	3.86
12172	1.5576	86.45	1.567	1.11	31.88	62.69	0.00	1.00	3.32
12196	1.5579	86.48	1.564	1.16	31.39	62.58	0.00	1.00	3.87
12219	1.5582	86.45	1.568	1.14	31.80	62.36	0.00	1.04	3.66
12243	1.5585	86.42	1.571	1.09	31.44	62.25	0.00	1.01	4.20
12267	1.5587	86.32	1.584	1.09	31.86	61.45	0.00	1.01	4.59
12291	1.5590	85.36	1.715	1.22	36.99	55.57	0.00	1.87	4.34
12315	1.5593	85.25	1.730	1.30	37.71	54.65	0.00	2.08	4.27
12338	1.5596	85.86	1.648	1.25	34.91	58.41	0.00	1.51	3.91
12362	1.5599	86.43	1.570	1.16	31.97	62.34	0.00	1.04	3.49
12386	1.5602	86.55	1.554	1.15	30.87	63.14	0.00	1.00	3.84
12410	1.5605	86.58	1.550	1.18	30.60	63.43	0.00	1.02	3.77
12434	1.5607	86.65	1.540	1.18	30.26	63.67	0.00	1.16	3.74
12457	1.5610	86.63	1.543	1.22	30.18	63.57	0.00	1.34	3.69
12481	1.5613	86.59	1.548	1.30	30.18	63.59	0.00	1.60	3.33
12505	1.5616	86.57	1.552	1.33	30.41	63.08	0.00	1.76	3.41
12529	1.5618	86.38	1.577	1.44	30.18	62.29	0.00	2.06	4.03
12552	1.5621	86.37	1.578	1.54	30.50	62.13	0.00	2.25	3.57
12576	1.5624	86.39	1.575	1.55	30.48	61.80	0.00	2.46	3.70

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	Ar	Total Offgas Flow	H_2	N_2	NO	O_2	N_2O	NO_2
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
12600	1.5627	86.36	1.579	1.62	30.29	61.81	0.00	2.59	3.70
12624	1.5629	86.44	1.569	1.66	30.30	61.92	0.00	2.64	3.49
12648	1.5632	86.43	1.569	1.70	29.90	62.16	0.00	2.75	3.49
12671	1.5635	86.44	1.568	1.75	29.84	62.04	0.00	2.86	3.51
12695	1.5638	86.44	1.568	1.79	29.24	62.06	0.00	2.99	3.92
12719	1.5640	86.54	1.555	1.77	29.56	62.34	0.00	2.93	3.40
12743	1.5643	86.48	1.563	1.86	29.49	61.75	0.00	3.04	3.86
12766	1.5646	86.49	1.562	1.88	29.56	61.85	0.00	3.08	3.64
12790	1.5649	86.49	1.562	1.87	29.53	61.84	0.00	3.04	3.71
12814	1.5651	86.66	1.539	1.87	29.26	62.62	0.00	2.93	3.31
12838	1.5654	86.66	1.540	1.89	29.38	62.43	0.00	2.98	3.32
12862	1.5657	86.66	1.540	1.91	29.36	62.68	0.00	2.89	3.16
12885	1.5659	86.69	1.535	1.90	29.01	62.62	0.00	2.86	3.61
12909	1.5662	86.74	1.529	1.86	29.03	62.71	0.00	2.82	3.58
12933	1.5665	86.74	1.529	1.88	29.41	62.70	0.00	2.80	3.21
12957	1.5668	86.81	1.520	1.89	29.13	62.70	0.00	2.78	3.50
12981	1.5670	86.84	1.515	1.85	29.32	62.94	0.00	2.63	3.25
13004	1.5673	86.80	1.520	1.86	28.96	62.49	0.00	2.76	3.93
13028	1.5676	86.93	1.503	1.80	29.37	62.99	0.00	2.56	3.27
13052	1.5678	86.87	1.511	1.82	28.82	62.95	0.00	2.59	3.82
13076	1.5681	86.94	1.502	1.80	29.35	62.87	0.00	2.53	3.46
13099	1.5683	87.05	1.488	1.71	29.08	63.38	0.00	2.42	3.42
13123	1.5686	87.10	1.481	1.72	29.31	63.72	0.00	2.38	2.88
13147	1.5689	86.95	1.500	1.73	29.42	62.54	0.00	2.45	3.86
13171	1.5691	87.02	1.492	1.75	29.40	62.92	0.00	2.31	3.62
13195	1.5694	87.11	1.479	1.71	29.43	63.11	0.00	2.30	3.45
13218	1.5696	87.15	1.474	1.68	29.36	63.36	0.00	2.24	3.37
13242	1.5699	87.06	1.486	1.70	29.64	62.86	0.00	2.18	3.61
13266	1.5702	87.11	1.479	1.65	29.58	63.19	0.00	2.08	3.50
13289	1.5704	87.13	1.477	1.60	29.85	63.10	0.00	2.05	3.40
13313	1.5707	87.08	1.484	1.62	29.82	63.00	0.00	2.01	3.55
13337	1.5710	87.05	1.488	1.59	30.20	62.66	0.00	1.95	3.60
13361	1.5712	87.11	1.480	1.58	30.27	62.74	0.00	1.93	3.49
13385	1.5715	87.10	1.481	1.54	29.96	63.03	0.00	1.85	3.62
13408	1.5717	87.12	1.479	1.57	30.29	62.78	0.00	1.85	3.51
13432	1.5720	87.18	1.470	1.53	30.06	63.38	0.00	1.75	3.29
13456	1.5723	87.23	1.464	1.48	30.20	63.23	0.00	1.74	3.35

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	Ar	Total Offgas Flow	H_2	N_2	NO	O_2	N_2O	NO_2
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
13480	1.5725	87.15	1.474	1.50	30.62	62.36	0.00	1.75	3.76
13504	1.5728	87.19	1.469	1.47	30.70	62.80	0.00	1.78	3.26
13527	1.5730	87.10	1.480	1.51	30.74	62.49	0.00	1.66	3.60
13551	1.5733	87.19	1.469	1.48	30.69	62.76	0.00	1.63	3.43
13575	1.5735	87.10	1.481	1.47	30.74	62.56	0.00	1.59	3.64
13599	1.5738	87.21	1.467	1.42	31.17	62.82	0.00	1.62	2.96
13622	1.5741	87.19	1.469	1.43	31.10	62.49	0.00	1.49	3.49
13646	1.5743	87.29	1.456	1.41	30.83	63.32	0.00	1.44	3.00
13670	1.5746	87.16	1.473	1.36	31.19	62.37	0.00	1.51	3.57
13694	1.5748	87.24	1.462	1.37	30.96	62.80	0.00	1.42	3.46
13718	1.5751	87.19	1.470	1.37	31.23	62.71	0.00	1.47	3.23
13742	1.5754	87.28	1.458	1.32	31.17	63.65	0.00	1.26	2.61
13765	1.5756	87.22	1.466	1.36	31.05	62.84	0.00	1.35	3.41
13789	1.5759	87.23	1.464	1.33	31.03	62.67	0.00	1.36	3.61
13813	1.5761	87.21	1.467	1.31	31.67	62.49	0.00	1.27	3.26
13837	1.5764	87.30	1.455	1.31	31.39	63.01	0.00	1.28	3.01
13861	1.5766	87.12	1.478	1.32	31.73	62.33	0.00	1.27	3.35
13884	1.5769	87.22	1.466	1.27	31.59	62.81	0.00	1.20	3.14
13908	1.5772	87.26	1.460	1.34	31.34	62.92	0.00	1.18	3.22
13932	1.5774	87.26	1.460	1.30	31.75	62.64	0.00	1.23	3.09
13956	1.5777	87.22	1.465	1.29	31.33	62.61	0.00	1.18	3.59
13979	1.5779	87.17	1.472	1.28	31.98	62.47	0.00	1.11	3.16
14003	1.5782	87.24	1.463	1.24	31.71	62.57	0.00	1.11	3.37
14027	1.5784	87.17	1.472	1.25	32.04	61.98	0.00	1.15	3.57
14051	1.5787	87.10	1.481	1.25	31.96	61.85	0.00	1.14	3.79
14075	1.5790	87.16	1.473	1.22	31.72	62.65	0.00	1.01	3.40
14098	1.5792	87.08	1.484	1.22	31.83	62.13	0.00	1.02	3.80
14122	1.5795	87.23	1.464	1.24	31.81	62.86	0.00	0.95	3.14
14146	1.5797	87.07	1.485	1.23	31.99	62.48	0.00	1.04	3.26
14170	1.5800	87.15	1.475	1.21	32.17	62.43	0.00	0.92	3.27
14193	1.5803	87.15	1.475	1.19	32.27	62.12	0.00	1.00	3.41
14217	1.5805	87.19	1.469	1.17	32.62	62.75	0.00	0.81	2.64
14241	1.5808	87.14	1.476	1.19	32.65	62.33	0.00	0.98	2.86
14265	1.5810	87.21	1.467	1.17	32.73	62.12	0.00	0.93	3.05
14288	1.5813	87.18	1.470	1.21	32.37	62.21	0.00	0.93	3.28
14312	1.5816	87.22	1.466	1.17	32.63	62.33	0.00	0.86	3.01
14336	1.5818	87.21	1.467	1.18	32.19	62.16	0.00	0.93	3.54

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	Ar	Total Offgas Flow	H_2	N_2	NO	O_2	N_2O	NO_2
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
14360	1.5821	87.16	1.473	1.15	32.48	62.25	0.00	0.82	3.29
14383	1.5823	87.05	1.487	1.19	32.70	61.83	0.00	0.90	3.38
14407	1.5826	87.17	1.472	1.12	32.69	61.95	0.00	0.86	3.38
14431	1.5828	87.12	1.478	1.19	33.29	61.54	0.00	0.86	3.12
14455	1.5831	87.18	1.470	1.16	33.06	61.75	0.00	0.90	3.13
14478	1.5834	87.28	1.458	1.14	32.62	62.51	0.00	0.79	2.94
14502	1.5836	87.23	1.464	1.14	32.71	62.05	0.00	0.87	3.23
14525	1.5839	87.27	1.459	1.16	32.53	62.39	0.00	0.80	3.12
14549	1.5841	87.31	1.453	1.12	32.87	62.30	0.00	0.75	2.96
14573	1.5844	87.28	1.457	1.06	32.74	62.29	0.00	0.72	3.19
14597	1.5846	87.24	1.462	1.10	32.96	62.14	0.00	0.73	3.07
14621	1.5849	87.23	1.464	1.11	33.20	62.09	0.00	0.78	2.83
14645	1.5852	87.17	1.471	1.09	33.21	61.95	0.00	0.76	3.00
14668	1.5854	87.20	1.468	1.06	33.18	62.66	0.00	0.62	2.48
14692	1.5857	87.30	1.454	1.07	33.30	62.69	0.00	0.57	2.37
14716	1.5859	87.10	1.481	1.10	32.67	61.96	0.00	0.65	3.61
14740	1.5862	87.21	1.467	1.08	33.23	62.14	0.00	0.64	2.91
14763	1.5864	87.11	1.480	1.11	32.96	61.55	0.00	0.70	3.68
14787	1.5867	87.20	1.468	1.13	33.43	61.97	0.00	0.64	2.83
14811	1.5870	87.23	1.463	1.15	32.92	62.10	0.00	0.65	3.18
14835	1.5872	87.26	1.459	1.08	33.34	61.94	0.00	0.71	2.93
14858	1.5875	87.20	1.468	1.10	33.33	62.07	0.00	0.70	2.80
14882	1.5877	87.26	1.460	1.09	33.31	62.02	0.00	0.68	2.89
14906	1.5880	87.21	1.466	1.07	33.07	62.08	0.00	0.57	3.20
14930	1.5883	87.15	1.474	1.10	33.43	61.73	0.00	0.70	3.05
14954	1.5885	87.13	1.477	1.13	33.19	61.44	0.00	0.65	3.59
14977	1.5888	87.16	1.474	1.09	33.11	61.52	0.00	0.64	3.64
15001	1.5890	87.14	1.476	1.08	33.42	61.70	0.00	0.65	3.15
15025	1.5893	87.12	1.479	1.12	33.02	61.62	0.00	0.69	3.55
15049	1.5896	87.27	1.459	1.05	33.20	61.91	0.00	0.59	3.25
15072	1.5898	87.30	1.454	1.02	33.41	62.16	0.00	0.52	2.89
15096	1.5901	87.24	1.463	1.09	33.15	61.70	0.00	0.61	3.45
15120	1.5903	87.25	1.461	1.07	33.24	61.78	0.00	0.63	3.28
15143	1.5906	87.35	1.448	1.07	33.26	62.38	0.00	0.54	2.75
15167	1.5908	87.35	1.448	1.04	33.19	62.32	0.00	0.56	2.89
15191	1.5911	87.24	1.462	1.07	32.69	61.95	0.00	0.60	3.69
15214	1.5913	87.34	1.450	1.05	33.32	62.33	0.00	0.51	2.79

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	**Est. Al Conc.**	**Ar**	**Total Offgas Flow**	**H_2**	**N_2**	**NO**	**O_2**	**N_2O**	**NO_2**
(sec)	**(M)**	**(vol %)**	**(cm^3/min)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**
15238	1.5916	87.26	1.460	1.07	33.17	61.80	0.00	0.57	3.40
15261	1.5918	87.34	1.449	1.06	33.34	62.45	0.00	0.53	2.63
15285	1.5921	87.31	1.454	1.06	33.40	61.99	0.00	0.51	3.04
15309	1.5924	87.26	1.460	1.02	33.34	62.01	0.00	0.50	3.14
15332	1.5926	87.35	1.448	1.05	33.28	62.12	0.00	0.53	3.01
15356	1.5929	87.26	1.460	1.09	33.18	61.81	0.00	0.56	3.36
15380	1.5931	87.30	1.455	1.07	33.12	62.40	0.00	0.46	2.96
15403	1.5934	87.30	1.455	1.02	33.12	62.16	0.00	0.50	3.20
15427	1.5936	87.27	1.459	1.05	33.56	61.84	0.00	0.53	3.02
15451	1.5939	87.28	1.457	1.06	33.34	61.80	0.00	0.55	3.25
15475	1.5941	87.39	1.442	1.02	33.79	62.20	0.00	0.50	2.50
15498	1.5944	87.39	1.443	1.06	33.00	62.19	0.00	0.49	3.26
15522	1.5946	87.34	1.450	1.04	33.19	62.05	0.00	0.48	3.24
15546	1.5949	87.34	1.449	1.06	33.34	62.00	0.00	0.45	3.15
15570	1.5952	87.39	1.443	1.03	33.32	62.27	0.00	0.45	2.92
15594	1.5954	87.32	1.452	1.10	32.95	61.46	0.00	0.59	3.90
15617	1.5957	87.32	1.452	1.06	33.35	61.89	0.00	0.49	3.20
15641	1.5959	87.31	1.453	1.06	33.07	62.08	0.00	0.48	3.31
15665	1.5962	87.40	1.441	1.05	33.18	62.46	0.00	0.44	2.88
15689	1.5964	87.27	1.459	1.07	32.97	62.05	0.00	0.54	3.37
15712	1.5967	87.32	1.452	1.04	33.11	62.07	0.00	0.49	3.30
15736	1.5969	87.29	1.456	1.04	32.92	62.03	0.00	0.40	3.61
15760	1.5972	87.36	1.447	1.03	32.82	62.35	0.00	0.47	3.34
15784	1.5974	87.31	1.454	1.04	33.12	62.17	0.00	0.41	3.27
15808	1.5977	87.30	1.455	1.06	33.04	62.02	0.00	0.49	3.39
15832	1.5980	87.36	1.447	1.05	33.30	62.11	0.00	0.48	3.06
15855	1.5982	87.40	1.441	1.07	33.13	61.84	0.00	0.47	3.49
15879	1.5985	87.38	1.444	1.05	33.37	62.13	0.00	0.41	3.04
15903	1.5987	87.46	1.434	1.01	33.21	62.56	0.00	0.40	2.82
15926	1.5990	87.48	1.431	1.03	33.08	62.47	0.00	0.35	3.07
15950	1.5992	87.46	1.434	1.04	33.23	62.75	0.00	0.31	2.67
15974	1.5995	87.41	1.441	1.03	33.22	62.03	0.00	0.51	3.21
15998	1.5997	87.37	1.445	1.03	33.38	61.95	0.00	0.41	3.22
16021	1.6000	87.47	1.432	1.05	33.14	62.10	0.00	0.46	3.25
16045	1.6002	87.45	1.435	1.04	33.47	62.38	0.00	0.44	2.67
16069	1.6005	87.46	1.434	1.07	33.27	62.32	0.00	0.36	2.97
16093	1.6007	87.54	1.424	1.03	32.97	62.56	0.00	0.40	3.03

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	Ar	Total Offgas Flow	H_2	N_2	NO	O_2	N_2O	NO_2
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
16117	1.6010	87.46	1.433	1.01	33.25	62.26	0.00	0.35	3.13
16141	1.6012	87.41	1.440	1.02	33.21	61.88	0.00	0.43	3.45
16164	1.6015	87.47	1.433	1.05	33.17	62.39	0.00	0.40	2.98
16188	1.6017	87.41	1.441	1.07	32.88	62.04	0.00	0.40	3.60
16211	1.6020	87.42	1.438	1.03	33.15	62.68	0.00	0.35	2.79
16235	1.6022	87.50	1.428	1.01	33.14	62.71	0.00	0.30	2.85
16258	1.6025	87.53	1.425	1.00	32.79	62.94	0.00	0.33	2.94
16282	1.6027	87.50	1.429	1.01	33.06	62.67	0.00	0.31	2.94
16306	1.6030	87.44	1.436	1.03	32.93	62.41	0.00	0.31	3.33
16330	1.6033	87.35	1.448	1.03	33.08	62.10	0.00	0.37	3.42
16354	1.6035	87.38	1.444	1.05	33.09	62.38	0.00	0.35	3.13
16377	1.6038	87.52	1.426	1.02	33.22	62.82	0.00	0.27	2.67
16401	1.6040	87.37	1.445	1.01	33.24	62.01	0.00	0.40	3.34
16425	1.6043	87.33	1.451	1.04	33.55	61.82	0.00	0.39	3.19
16448	1.6045	87.38	1.444	1.05	32.94	62.20	0.00	0.39	3.42
16472	1.6048	87.45	1.435	1.01	33.38	62.29	0.00	0.34	2.97
16496	1.6050	87.37	1.446	1.01	33.15	61.99	0.00	0.36	3.49
16520	1.6053	87.43	1.438	1.03	33.46	61.93	0.00	0.35	3.23
16544	1.6055	87.51	1.427	1.02	33.27	62.63	0.00	0.29	2.80
16568	1.6058	87.51	1.427	0.98	33.57	63.01	0.00	0.17	2.27
16591	1.6060	87.54	1.423	1.02	33.41	62.63	0.00	0.35	2.59
16615	1.6063	87.54	1.424	1.00	33.37	62.86	0.00	0.29	2.48
16639	1.6065	87.49	1.430	1.01	33.31	61.81	0.00	0.34	3.52
16662	1.6068	87.43	1.438	1.06	33.19	62.16	0.00	0.31	3.29
16686	1.6070	87.49	1.429	0.99	33.34	62.66	0.00	0.29	2.72
16710	1.6073	87.57	1.420	1.02	33.00	62.78	0.00	0.23	2.97
16734	1.6075	87.56	1.420	1.01	32.84	62.92	0.00	0.20	3.03
16757	1.6078	87.60	1.415	0.98	33.26	62.30	0.00	0.29	3.17
16781	1.6080	87.64	1.410	0.99	33.23	62.92	0.00	0.20	2.66
16805	1.6083	87.59	1.417	0.97	33.29	62.39	0.00	0.21	3.14
16829	1.6085	87.56	1.421	1.03	33.13	62.46	0.00	0.26	3.13
16852	1.6088	87.40	1.442	1.03	33.40	61.87	0.00	0.26	3.45
16876	1.6090	87.54	1.424	1.04	33.40	62.46	0.00	0.26	2.84
16900	1.6093	87.53	1.425	1.03	33.47	62.45	0.00	0.31	2.74
16923	1.6095	87.59	1.417	1.02	32.94	62.62	0.00	0.23	3.19
16947	1.6098	87.61	1.414	0.96	32.80	63.27	0.00	0.20	2.78
16971	1.6100	87.47	1.432	1.02	33.08	62.41	0.00	0.25	3.24

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	Ar	Total Offgas Flow	H_2	N_2	NO	O_2	N_2O	NO_2
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
16995	1.6103	87.46	1.434	1.00	32.73	62.48	0.00	0.32	3.47
17018	1.6105	87.51	1.427	1.01	33.05	62.72	0.00	0.18	3.04
17042	1.6108	87.52	1.426	1.00	32.94	62.26	0.00	0.21	3.60
17066	1.6110	87.55	1.422	1.02	33.38	62.98	0.00	0.23	2.38
17090	1.6113	87.54	1.423	1.00	33.17	62.30	0.00	0.20	3.33
17114	1.6115	87.51	1.427	1.05	33.11	62.38	0.00	0.30	3.16
17137	1.6118	87.62	1.414	1.05	33.15	62.97	0.00	0.17	2.66
17161	1.6120	87.59	1.417	1.04	33.36	62.42	0.00	0.26	2.92
17184	1.6123	87.57	1.419	0.98	32.92	62.54	0.00	0.25	3.30
17208	1.6125	87.49	1.430	1.03	33.28	62.21	0.00	0.29	3.19
17232	1.6128	87.66	1.408	1.03	33.12	62.45	0.00	0.26	3.14
17256	1.6130	87.71	1.402	1.02	33.33	62.54	0.00	0.16	2.96
17280	1.6133	87.57	1.420	1.01	32.96	61.94	0.00	0.31	3.78
17303	1.6135	87.72	1.399	1.02	32.88	62.56	0.00	0.29	3.25
17327	1.6138	87.66	1.408	0.99	33.01	62.54	0.00	0.20	3.26
17351	1.6140	87.68	1.405	0.96	33.25	62.79	0.00	0.16	2.84
17374	1.6142	87.79	1.391	1.02	32.81	62.73	0.00	0.18	3.26
17398	1.6145	87.87	1.380	0.96	32.96	62.93	0.00	0.15	3.00
17422	1.6147	87.76	1.394	1.03	33.08	62.50	0.00	0.28	3.11
17445	1.6150	87.74	1.398	0.99	33.07	62.46	0.00	0.24	3.25
17472	1.6153	87.75	1.396	0.97	33.02	62.76	0.00	0.16	3.09
17496	1.6155	87.69	1.404	0.99	33.32	62.12	0.00	0.27	3.31
17520	1.6158	87.77	1.394	0.98	33.26	63.02	0.00	0.16	2.58
17544	1.6160	87.62	1.413	1.02	33.28	62.25	0.00	0.23	3.22
17568	1.6163	87.80	1.390	1.01	32.87	62.96	0.00	0.16	3.00
17591	1.6165	87.63	1.411	1.05	32.64	62.27	0.00	0.28	3.75
17615	1.6167	87.65	1.409	1.04	32.85	62.48	0.00	0.16	3.47
17639	1.6170	87.76	1.395	1.01	33.27	62.95	0.00	0.20	2.57
17663	1.6172	87.70	1.402	1.06	33.29	62.28	0.00	0.20	3.16
17686	1.6175	87.75	1.395	0.98	33.16	62.91	0.00	0.16	2.78
17710	1.6177	87.75	1.396	1.05	32.81	62.80	0.00	0.19	3.16
17734	1.6180	87.71	1.401	1.00	33.01	62.93	0.00	0.14	2.93
17758	1.6182	87.82	1.387	0.96	32.75	63.15	0.00	0.16	2.98
17781	1.6185	87.74	1.397	0.99	32.57	62.88	0.00	0.20	3.36
17805	1.6187	87.79	1.391	0.99	32.80	63.23	0.00	0.19	2.79
17829	1.6189	87.74	1.398	0.99	32.97	62.69	0.00	0.19	3.16
17853	1.6192	87.77	1.393	1.02	32.82	62.96	0.00	0.18	3.01

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	**Est. Al Conc.**	**Ar**	**Total Offgas Flow**	**H_2**	**N_2**	**NO**	**O_2**	**N_2O**	**NO_2**
(sec)	**(M)**	**(vol %)**	**(cm^3/min)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**
17876	1.6194	87.76	1.395	0.99	33.10	62.99	0.00	0.20	2.72
17900	1.6197	87.83	1.386	1.01	33.23	63.12	0.00	0.17	2.47
17924	1.6199	87.76	1.395	1.00	32.82	62.89	0.00	0.16	3.12
17948	1.6202	87.79	1.391	0.99	32.66	63.00	0.00	0.14	3.21
17972	1.6204	87.84	1.385	0.99	32.76	63.45	0.00	0.15	2.66
17996	1.6207	87.89	1.378	0.98	32.52	63.39	0.00	0.13	2.99
18019	1.6209	87.90	1.377	1.00	32.46	63.44	0.00	0.13	2.97
18043	1.6211	87.87	1.381	1.00	32.52	62.81	0.00	0.18	3.49
18067	1.6214	87.83	1.386	1.00	32.81	62.87	0.00	0.18	3.15
18091	1.6216	87.79	1.391	1.01	32.96	62.84	0.00	0.15	3.04
18115	1.6219	87.87	1.380	1.02	32.69	62.71	0.00	0.20	3.38
18138	1.6221	87.93	1.373	1.02	32.79	63.11	0.00	0.19	2.89
18162	1.6224	88.00	1.364	1.04	32.33	63.59	0.00	0.18	2.86
18186	1.6226	88.00	1.364	1.00	32.43	63.78	0.00	0.11	2.68
18209	1.6228	87.98	1.366	1.02	32.46	63.15	0.00	0.20	3.17
18233	1.6231	88.07	1.355	0.97	32.21	63.76	0.00	0.00	3.05
18257	1.6233	87.89	1.378	0.99	32.24	63.43	0.00	0.07	3.28
18281	1.6236	87.95	1.370	1.01	32.26	63.43	0.00	0.09	3.21
18304	1.6238	87.90	1.376	1.03	32.09	63.33	0.00	0.17	3.38
18328	1.6240	88.08	1.354	1.00	32.50	63.59	0.00	0.01	2.90
18351	1.6243	87.93	1.373	0.97	31.94	63.75	0.00	0.06	3.29
18375	1.6245	88.06	1.356	0.94	32.13	64.26	0.00	0.00	2.66
18398	1.6247	87.98	1.366	0.98	32.32	63.52	0.00	0.07	3.11
18422	1.6250	88.07	1.354	0.97	31.99	63.86	0.00	0.09	3.09
18446	1.6252	87.96	1.369	1.02	32.03	63.57	0.00	0.17	3.21
18469	1.6255	87.95	1.370	0.99	32.12	63.55	0.00	0.20	3.14
18493	1.6257	87.88	1.380	1.02	32.16	63.07	0.00	0.14	3.61
18517	1.6259	87.90	1.376	1.01	31.91	63.50	0.00	0.09	3.49
18541	1.6262	88.03	1.359	1.03	32.22	63.90	0.00	0.09	2.77
18564	1.6264	87.98	1.366	1.01	31.97	64.02	0.00	0.06	2.94
18588	1.6267	87.88	1.380	1.03	31.82	63.51	0.00	0.08	3.57
18612	1.6269	87.94	1.372	1.00	31.88	64.03	0.00	0.10	2.99
18635	1.6271	87.80	1.390	1.02	31.79	63.80	0.00	0.01	3.38
18659	1.6274	87.90	1.377	1.01	31.96	63.96	0.00	0.05	3.02
18683	1.6276	87.87	1.381	1.00	31.71	63.78	0.00	0.11	3.40
18706	1.6279	88.01	1.363	0.98	31.73	64.46	0.00	0.05	2.79
18730	1.6281	87.85	1.383	1.00	32.08	64.23	0.00	0.10	2.59

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	**Est. Al Conc.**	**Ar**	**Total Offgas Flow**	**H_2**	**N_2**	**NO**	**O_2**	**N_2O**	**NO_2**
(sec)	**(M)**	**(vol %)**	**(cm^3/min)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**
18753	1.6283	87.81	1.388	1.00	31.80	63.95	0.00	0.00	3.25
18777	1.6286	87.85	1.383	1.01	31.74	64.02	0.00	0.10	3.13
18800	1.6288	88.03	1.360	1.00	31.59	64.69	0.00	0.09	2.64
18824	1.6291	87.97	1.367	1.01	31.94	64.20	0.00	0.05	2.80
18848	1.6293	87.95	1.370	1.03	31.29	64.23	0.00	0.05	3.41
18872	1.6296	88.01	1.362	0.99	31.46	64.62	0.00	0.00	2.93
18896	1.6298	88.05	1.357	1.00	31.50	64.43	0.00	0.03	3.04
18919	1.6300	88.17	1.341	1.00	31.41	65.18	0.00	0.02	2.39
18943	1.6303	88.06	1.356	1.00	31.46	64.61	0.00	0.02	2.90
18966	1.6305	87.96	1.369	1.07	31.00	64.46	0.00	0.03	3.45

Appendix D. MS Offgas Data for Experiment 94

Table D-1. Re-Baselined Normalized MS Offgas Concentration Data for Experiment 94

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	Ar	Total Offgas Flow	H_2	N_2	NO	O_2	N_2O	NO_2
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
17	0.0005	76.60	3.055	0.43	12.06	80.19	0.00	0.44	6.87
41	0.0010	76.66	3.045	0.44	11.86	80.55	0.00	0.43	6.73
64	0.0015	76.33	3.100	0.43	11.82	80.78	0.00	0.47	6.50
88	0.002	76.18	3.127	0.43	9.02	83.96	0.00	0.38	6.21
111	0.003	72.52	3.790	0.44	5.30	80.37	0.00	6.37	7.51
136	0.006	21.72	36.031	1.91	3.13	59.92	0.00	21.78	13.27
160	0.030	3.75	256.375	3.40	3.42	56.44	0.00	21.33	15.42
184	0.083	2.48	393.207	4.37	3.63	54.32	0.00	21.82	15.86
208	0.146	2.64	369.473	4.74	3.71	54.47	0.00	21.80	15.29
232	0.203	2.95	328.434	4.83	3.74	54.61	0.00	21.79	15.04
256	0.254	3.23	299.635	4.83	3.75	55.33	0.00	21.72	14.37
279	0.299	3.53	272.950	4.84	3.80	56.10	0.00	21.45	13.80
303	0.342	3.79	253.651	4.87	3.85	57.12	0.00	21.54	12.62
327	0.382	4.10	234.115	4.90	3.87	57.28	0.00	21.83	12.13
351	0.419	4.49	212.929	4.90	3.91	57.67	0.00	21.55	11.97
375	0.453	4.74	200.852	4.86	3.89	57.78	0.00	21.71	11.76
399	0.485	4.98	190.764	4.86	3.93	57.95	0.00	21.58	11.68
422	0.514	5.25	180.341	4.91	4.00	58.52	0.00	21.25	11.32
446	0.544	5.22	181.526	4.89	4.00	58.52	0.00	21.31	11.28
470	0.573	5.50	171.895	4.89	4.05	59.33	0.00	20.97	10.76
494	0.600	5.74	164.181	4.85	4.07	59.09	0.00	21.15	10.85
518	0.627	5.97	157.549	4.80	4.06	59.08	0.00	21.40	10.65
542	0.652	6.16	152.370	4.76	4.05	59.02	0.00	21.51	10.65
566	0.677	6.42	145.645	4.77	4.10	59.14	0.00	21.37	10.61
589	0.699	6.55	142.582	4.73	4.12	59.48	0.00	21.26	10.40
613	0.722	6.71	138.952	4.72	4.14	59.36	0.00	21.40	10.38
637	0.745	6.74	138.421	4.74	4.20	60.02	0.00	21.17	9.87
661	0.767	6.97	133.458	4.69	4.22	59.97	0.00	21.01	10.10
685	0.789	7.20	128.942	4.70	4.24	60.19	0.00	21.11	9.76
709	0.810	7.32	126.641	4.64	4.23	60.01	0.00	21.16	9.96
732	0.829	7.58	121.863	4.60	4.24	59.83	0.00	21.30	10.03
756	0.849	7.74	119.196	4.59	4.27	60.03	0.00	21.37	9.73

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	**Est. Al Conc.**	**Ar**	**Total Offgas Flow**	**H_2**	**N_2**	**NO**	**O_2**	**N_2O**	**NO_2**
(sec)	**(M)**	**(vol %)**	**(cm^3/min)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**
780	0.869	7.79	118.367	4.57	4.31	60.32	0.00	21.30	9.49
804	0.888	7.76	118.829	4.52	4.34	60.55	0.00	21.01	9.58
828	0.907	7.84	117.562	4.50	4.38	61.01	0.00	20.94	9.17
852	0.926	8.00	114.962	4.48	4.44	61.42	0.00	20.59	9.08
876	0.945	7.96	115.556	4.44	4.47	61.36	0.00	20.85	8.88
899	0.963	8.20	112.023	4.41	4.50	61.20	0.00	21.00	8.89
923	0.981	8.49	107.746	4.38	4.51	61.29	0.00	21.09	8.74
947	0.999	8.59	106.449	4.36	4.59	61.63	0.00	20.70	8.72
971	1.016	8.61	106.146	4.31	4.62	61.81	0.00	20.75	8.52
995	1.034	8.61	106.175	4.26	4.65	61.75	0.00	20.87	8.48
1018	1.050	8.89	102.498	4.20	4.70	62.00	0.00	20.67	8.42
1042	1.066	9.22	98.427	4.12	4.71	61.72	0.00	21.11	8.34
1066	1.082	9.40	96.345	4.04	4.71	61.61	0.00	21.36	8.29
1090	1.098	9.44	95.922	3.99	4.76	61.97	0.00	21.05	8.23
1114	1.114	9.66	93.545	3.96	4.85	62.29	0.00	20.88	8.02
1138	1.129	9.85	91.563	3.88	4.80	61.72	0.00	21.37	8.23
1161	1.143	9.97	90.316	3.87	4.90	62.54	0.00	20.89	7.80
1185	1.158	10.35	86.608	3.83	4.86	62.26	0.00	21.30	7.75
1209	1.172	10.44	85.814	3.76	4.85	62.21	0.00	21.32	7.86
1233	1.186	10.60	84.325	3.74	4.88	62.43	0.00	21.15	7.80
1257	1.199	10.80	82.617	3.72	4.94	62.72	0.00	20.90	7.72
1280	1.212	10.90	81.759	3.69	4.94	62.72	0.00	21.07	7.58
1304	1.225	11.27	78.715	3.65	4.92	62.25	0.00	21.55	7.63
1328	1.238	11.39	77.761	3.63	4.93	62.23	0.00	21.58	7.63
1352	1.251	11.51	76.884	3.64	4.99	62.69	0.00	21.48	7.20
1376	1.263	11.76	75.044	3.63	5.02	62.46	0.00	21.44	7.44
1400	1.276	11.82	74.601	3.65	5.06	62.72	0.00	21.35	7.22
1424	1.288	11.86	74.282	3.64	5.14	63.06	0.00	21.12	7.04
1448	1.300	11.93	73.831	3.61	5.14	62.81	0.00	21.39	7.04
1472	1.312	12.21	71.902	3.62	5.23	63.02	0.00	21.27	6.87
1495	1.323	12.36	70.890	3.62	5.28	62.98	0.00	21.21	6.90
1519	1.335	12.66	68.989	3.61	5.31	62.59	0.00	21.65	6.83
1543	1.346	12.75	68.413	3.63	5.42	62.75	0.00	21.60	6.60
1567	1.357	12.93	67.366	3.68	5.53	62.81	0.00	21.32	6.65
1591	1.368	13.26	65.404	3.73	5.63	62.83	0.00	21.37	6.44
1615	1.379	13.58	63.631	3.79	5.74	62.66	0.00	21.33	6.48
1638	1.388	14.10	60.937	3.82	5.82	62.29	0.00	21.69	6.38

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	Ar	Total Offgas Flow	H_2	N_2	NO	O_2	N_2O	NO_2
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
1662	1.398	14.34	59.745	3.89	5.95	62.36	0.00	21.50	6.29
1686	1.408	14.68	58.120	3.93	6.09	62.17	0.00	21.51	6.30
1710	1.417	15.01	56.634	3.99	6.21	62.28	0.00	21.36	6.16
1734	1.427	15.10	56.232	4.04	6.30	62.07	0.00	21.55	6.05
1758	1.436	15.45	54.727	4.11	6.43	61.95	0.00	21.35	6.15
1782	1.444	15.72	53.621	4.18	6.58	62.04	0.00	21.39	5.81
1806	1.453	16.36	51.122	4.27	6.68	61.68	0.00	21.43	5.94
1829	1.461	16.71	49.830	4.35	6.83	61.65	0.00	21.48	5.70
1853	1.469	17.03	48.733	4.40	6.97	61.55	0.00	21.18	5.89
1877	1.477	17.74	46.372	4.47	7.06	61.15	0.00	21.35	5.97
1901	1.484	18.06	45.385	4.52	7.19	60.84	0.00	21.51	5.95
1925	1.492	18.18	44.999	4.55	7.27	60.40	0.00	21.95	5.83
1949	1.499	18.74	43.364	4.62	7.41	60.23	0.00	22.00	5.74
1973	1.506	19.08	42.406	4.69	7.59	60.26	0.00	21.96	5.49
1996	1.513	19.24	41.964	4.77	7.80	60.26	0.00	21.58	5.60
2020	1.519	19.69	40.789	4.85	7.95	60.14	0.00	21.49	5.57
2044	1.526	20.19	39.540	4.88	8.06	59.82	0.00	21.70	5.55
2068	1.532	20.70	38.307	4.89	8.13	59.20	0.00	22.24	5.54
2092	1.539	20.86	37.936	4.99	8.32	59.54	0.00	21.75	5.40
2116	1.545	21.05	37.506	5.05	8.43	59.17	0.00	21.93	5.42
2139	1.551	21.51	36.497	5.13	8.63	59.36	0.00	21.49	5.39
2163	1.557	21.72	36.046	5.19	8.81	59.55	0.00	21.31	5.14
2187	1.562	22.18	35.081	5.21	8.85	58.97	0.00	21.70	5.28
2211	1.568	22.67	34.115	5.25	8.96	58.66	0.00	21.76	5.37
2235	1.574	23.14	33.222	5.29	9.05	58.35	0.00	21.96	5.35
2258	1.579	23.63	32.325	5.38	9.23	58.64	0.00	21.58	5.17
2282	1.584	23.86	31.913	5.40	9.28	57.85	0.00	22.19	5.28
2306	1.589	24.37	31.032	5.47	9.45	57.69	0.00	22.03	5.37
2330	1.594	25.02	29.970	5.55	9.60	57.64	0.00	22.04	5.17
2354	1.599	24.89	30.184	5.63	9.79	57.64	0.00	21.78	5.16
2378	1.604	25.28	29.555	5.70	9.92	57.32	0.00	21.93	5.13
2402	1.609	26.27	28.063	5.75	9.98	57.00	0.00	22.10	5.17
2426	1.613	26.59	27.603	5.82	10.12	56.78	0.00	21.98	5.29
2450	1.618	27.15	26.835	5.87	10.20	56.66	0.00	22.13	5.14
2474	1.622	27.38	26.529	5.93	10.43	56.72	0.00	21.91	5.01
2497	1.626	28.21	25.448	5.97	10.50	56.25	0.00	22.21	5.07
2521	1.630	28.17	25.494	6.05	10.72	56.37	0.00	21.95	4.92

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	**Est. Al Conc.**	**Ar**	**Total Offgas Flow**	**H_2**	**N_2**	**NO**	**O_2**	**N_2O**	**NO_2**
(sec)	**(M)**	**(vol %)**	**(cm^3/min)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**
2545	1.635	28.93	24.560	6.09	10.82	56.09	0.00	21.94	5.06
2569	1.639	29.19	24.257	6.08	11.08	55.85	0.00	21.86	5.13
2593	1.642	29.96	23.378	6.11	11.18	55.66	0.00	22.20	4.86
2617	1.646	30.67	22.600	6.10	11.15	54.95	0.00	22.66	5.15
2640	1.650	31.04	22.215	6.18	11.37	55.39	0.00	22.00	5.06
2664	1.653	31.28	21.965	6.16	11.39	54.74	0.00	22.54	5.16
2688	1.657	31.71	21.535	6.24	11.60	55.12	0.00	22.04	4.99
2712	1.660	32.01	21.240	6.30	11.80	55.23	0.00	21.85	4.82
2736	1.664	32.93	20.368	6.30	11.94	54.75	0.00	21.81	5.19
2760	1.667	33.55	19.808	6.25	12.11	54.25	0.00	22.35	5.04
2784	1.670	33.97	19.434	6.27	12.34	53.96	0.00	22.29	5.15
2807	1.673	33.99	19.424	6.33	12.76	54.24	0.00	21.70	4.97
2831	1.677	34.68	18.831	6.32	13.11	53.76	0.00	21.69	5.12
2855	1.680	35.06	18.525	6.29	13.49	53.32	0.00	21.80	5.10
2879	1.683	35.63	18.069	6.35	13.87	53.48	0.00	21.18	5.13
2903	1.686	34.93	18.631	6.27	13.72	53.83	0.00	21.20	4.98
2927	1.689	35.77	17.959	6.34	13.89	53.36	0.00	21.24	5.17
2951	1.691	36.91	17.093	6.35	14.30	53.03	0.00	21.07	5.24
2975	1.694	37.27	16.833	6.36	14.89	52.88	0.00	20.91	4.96

Appendix E. MS Offgas Data for Experiment 95

Table E-1. Re-Baselined Normalized MS Offgas Concentration Data for Experiment 95

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	Ar	Total Offgas Flow	H_2	N_2	NO	O_2	N_2O	NO_2
(sec)	(M)	(vol)	(cm^3/min)	(vol)	(vol)	(vol)	(vol)	(vol)	(vol)
0	0.0000	88.75	2.536	1.20	9.70	84.78	0.00	0.71	3.61
24	0.0012	88.89	2.500	1.20	9.66	85.03	0.00	0.80	3.32
47	0.0018	88.82	2.518	1.17	10.36	84.82	0.00	0.59	3.06
71	0.0024	88.69	2.551	1.21	10.50	83.54	0.00	0.79	3.96
95	0.003	88.83	2.515	1.19	10.59	84.45	0.00	0.72	3.05
118	0.004	88.62	2.568	1.21	7.55	85.95	0.00	1.86	3.42
142	0.007	42.70	26.839	3.15	2.82	53.50	0.00	38.23	2.31
167	0.033	10.13	177.469	4.30	3.23	55.08	0.00	34.90	2.50
191	0.086	7.45	248.312	4.79	3.33	53.00	0.00	34.83	4.05
215	0.146	7.67	240.620	4.63	3.29	51.85	0.00	34.79	5.44
239	0.202	8.26	222.208	4.40	3.26	50.51	0.00	35.35	6.49
263	0.255	9.01	202.076	4.18	3.24	49.43	0.00	35.95	7.20
287	0.303	9.50	190.430	4.01	3.20	48.65	0.00	36.51	7.63
311	0.348	10.05	179.077	3.96	3.22	48.10	0.00	37.12	7.60
335	0.391	10.57	169.167	3.91	3.28	47.91	0.00	37.25	7.66
359	0.431	11.09	160.280	3.91	3.33	48.02	0.00	37.07	7.67
383	0.469	11.67	151.350	3.94	3.37	47.83	0.00	37.25	7.61
407	0.505	12.31	142.478	3.94	3.36	47.52	0.00	37.45	7.72
431	0.540	12.85	135.619	3.98	3.43	47.92	0.00	36.94	7.72
455	0.572	13.44	128.822	4.02	3.45	48.08	0.00	36.65	7.79
479	0.603	14.01	122.742	4.07	3.52	48.78	0.00	35.79	7.84
503	0.633	14.34	119.460	4.04	3.50	48.76	0.00	35.98	7.72
527	0.662	14.73	115.794	4.03	3.53	48.89	0.00	35.66	7.89
551	0.689	15.28	110.863	4.02	3.57	48.94	0.00	35.66	7.81
575	0.716	15.76	106.926	3.96	3.54	48.67	0.00	35.90	7.92
599	0.742	15.94	105.483	3.97	3.59	49.18	0.00	35.37	7.89
623	0.768	16.29	102.782	4.02	3.64	49.30	0.00	35.32	7.72
647	0.792	16.77	99.243	4.09	3.73	49.31	0.00	35.19	7.68
671	0.816	17.43	94.712	4.13	3.74	49.19	0.00	35.20	7.73
695	0.839	18.13	90.288	4.17	3.76	49.60	0.00	34.85	7.62
719	0.861	18.53	87.919	4.22	3.84	50.56	0.00	33.78	7.61
743	0.882	19.29	83.694	4.24	3.82	51.09	0.00	33.10	7.75
767	0.902	20.59	77.150	4.29	3.87	52.00	0.00	32.01	7.82

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	**Est. Al Conc.**	**Ar**	**Total Offgas Flow**	**H_2**	**N_2**	**NO**	**O_2**	**N_2O**	**NO_2**
(sec)	**(M)**	**(vol)**	**(cm^3/min)**	**(vol)**	**(vol)**	**(vol)**	**(vol)**	**(vol)**	**(vol)**
791	0.920	21.51	72.971	4.29	3.76	52.39	0.00	31.68	7.89
815	0.938	22.28	69.772	4.32	3.73	53.45	0.00	30.68	7.82
839	0.954	22.96	67.104	4.30	3.72	53.88	0.00	30.07	8.02
863	0.971	23.49	65.130	4.32	3.74	54.64	0.00	29.46	7.84
887	0.986	23.84	63.890	4.28	3.73	54.84	0.00	29.31	7.83
911	1.002	24.16	62.778	4.26	3.75	55.06	0.00	29.19	7.74
935	1.017	24.60	61.296	4.26	3.83	55.37	0.00	28.65	7.89
959	1.032	24.86	60.456	4.20	3.77	55.15	0.00	29.10	7.78
983	1.047	25.12	59.609	4.17	3.77	55.23	0.00	29.13	7.69
1007	1.061	25.40	58.748	4.16	3.82	55.67	0.00	28.82	7.53
1031	1.076	25.64	58.002	4.13	3.89	55.93	0.00	28.43	7.61
1056	1.090	25.92	57.164	4.07	3.89	55.83	0.00	28.61	7.60
1079	1.104	26.06	56.733	4.03	3.91	55.98	0.00	28.45	7.64
1103	1.118	26.25	56.193	3.96	3.92	55.82	0.00	28.78	7.52
1128	1.132	26.57	55.279	3.93	3.99	56.02	0.00	28.59	7.47
1152	1.145	26.70	54.903	3.88	4.01	56.05	0.00	28.46	7.59
1176	1.159	27.16	53.637	3.84	4.07	56.25	0.00	28.28	7.56
1200	1.172	27.52	52.668	3.78	4.06	56.22	0.00	28.40	7.53
1224	1.185	27.76	52.045	3.75	4.10	56.13	0.00	28.57	7.45
1248	1.197	27.93	51.607	3.73	4.16	56.26	0.00	28.37	7.48
1271	1.209	28.46	50.267	3.69	4.18	56.08	0.00	28.55	7.50
1295	1.222	28.70	49.687	3.65	4.16	56.03	0.00	28.78	7.38
1319	1.234	29.06	48.813	3.63	4.19	56.07	0.00	28.56	7.54
1343	1.246	29.34	48.158	3.62	4.30	56.67	0.00	28.00	7.42
1368	1.258	29.93	46.827	3.58	4.29	56.33	0.00	28.33	7.47
1391	1.269	30.90	44.728	3.57	4.42	56.45	0.00	28.13	7.44
1415	1.279	31.62	43.250	3.56	4.47	55.97	0.00	28.47	7.53
1439	1.290	32.01	42.472	3.59	4.62	56.07	0.00	28.30	7.42
1463	1.300	31.99	42.527	3.61	4.71	56.03	0.00	28.21	7.44
1488	1.311	32.23	42.048	3.59	4.73	55.93	0.00	28.29	7.46
1511	1.321	32.26	41.998	3.54	4.71	55.84	0.00	28.61	7.30
1536	1.332	32.12	42.260	3.52	4.73	55.67	0.00	28.65	7.43
1560	1.342	32.40	41.726	3.50	4.74	55.88	0.00	28.46	7.42
1584	1.352	32.58	41.397	3.48	4.74	55.78	0.00	28.73	7.26
1608	1.362	32.87	40.850	3.48	4.79	55.86	0.00	28.47	7.39
1632	1.372	33.04	40.532	3.49	4.75	55.56	0.00	28.82	7.39
1656	1.382	33.37	39.928	3.49	4.83	55.79	0.00	28.67	7.23
1680	1.392	33.56	39.589	3.49	4.83	55.47	0.00	28.95	7.26

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	**Est. Al Conc.**	**Ar**	**Total Offgas Flow**	**H_2**	**N_2**	**NO**	**O_2**	**N_2O**	**NO_2**
(sec)	**(M)**	**(vol)**	**(cm^3/min)**	**(vol)**	**(vol)**	**(vol)**	**(vol)**	**(vol)**	**(vol)**
1704	1.402	33.95	38.904	3.52	4.92	55.58	0.00	28.85	7.13
1728	1.411	34.48	38.000	3.53	5.00	55.40	0.00	28.83	7.23
1752	1.420	34.96	37.212	3.58	5.14	55.53	0.00	28.52	7.23
1776	1.429	35.50	36.334	3.60	5.25	55.39	0.00	28.67	7.09
1800	1.438	35.98	35.583	3.62	5.34	54.94	0.00	28.82	7.28
1824	1.447	36.54	34.739	3.65	5.52	55.09	0.00	28.54	7.19
1848	1.455	37.28	33.641	3.67	5.66	54.86	0.00	28.56	7.24
1872	1.463	37.76	32.962	3.69	5.76	54.56	0.00	28.74	7.26
1896	1.471	38.54	31.890	3.70	5.86	54.50	0.00	28.91	7.03
1920	1.479	38.84	31.497	3.72	5.99	54.09	0.00	28.87	7.34
1944	1.487	39.62	30.476	3.76	6.13	54.09	0.00	28.79	7.22
1968	1.494	40.38	29.530	3.80	6.22	53.82	0.00	28.88	7.28
1992	1.501	40.71	29.133	3.85	6.34	53.83	0.00	28.74	7.24
2016	1.508	41.30	28.431	3.89	6.49	53.91	0.00	28.58	7.13
2040	1.515	42.01	27.613	3.91	6.58	53.52	0.00	28.76	7.23
2064	1.522	42.70	26.836	3.94	6.66	53.48	0.00	28.73	7.20
2088	1.528	43.43	26.047	3.97	6.76	53.28	0.00	28.83	7.16
2112	1.535	43.80	25.667	4.01	6.85	53.09	0.00	28.96	7.09
2136	1.541	44.86	24.583	4.05	6.99	52.88	0.00	28.82	7.26
2160	1.547	45.50	23.953	4.05	6.99	52.22	0.00	29.31	7.44
2184	1.553	46.37	23.130	4.11	7.16	52.48	0.00	28.99	7.26
2208	1.558	46.98	22.574	4.15	7.30	52.53	0.00	28.82	7.19
2232	1.564	47.50	22.108	4.17	7.44	52.25	0.00	28.81	7.33
2256	1.569	48.39	21.333	4.19	7.49	52.12	0.00	28.99	7.21
2280	1.574	48.94	20.869	4.21	7.62	52.05	0.00	28.74	7.37
2304	1.579	49.68	20.259	4.22	7.73	52.03	0.00	28.70	7.31
2328	1.584	50.44	19.654	4.25	7.80	51.76	0.00	28.71	7.48
2352	1.589	51.32	18.972	4.28	7.92	51.88	0.00	28.60	7.32
2376	1.593	51.76	18.639	4.27	8.07	51.59	0.00	28.64	7.43
2400	1.598	52.79	17.885	4.29	8.12	51.31	0.00	28.82	7.46
2424	1.602	53.35	17.490	4.34	8.28	51.56	0.00	28.41	7.42
2448	1.607	54.09	16.978	4.33	8.45	51.27	0.00	28.52	7.42
2472	1.611	54.86	16.458	4.36	8.54	51.04	0.00	28.60	7.47
2496	1.615	55.59	15.975	4.37	8.59	50.56	0.00	28.79	7.69
2520	1.618	56.62	15.325	4.42	8.82	51.16	0.00	28.11	7.50
2544	1.622	57.33	14.885	4.41	8.82	50.66	0.00	28.31	7.80
2568	1.626	57.83	14.585	4.41	9.04	50.71	0.00	28.04	7.80
2592	1.629	58.72	14.057	4.42	9.04	50.66	0.00	28.28	7.60

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	**Est. Al Conc.**	**Ar**	**Total Offgas Flow**	**H_2**	**N_2**	**NO**	**O_2**	**N_2O**	**NO_2**
(sec)	**(M)**	**(vol)**	**(cm^3/min)**	**(vol)**	**(vol)**	**(vol)**	**(vol)**	**(vol)**	**(vol)**
2616	1.633	59.45	13.643	4.45	9.28	50.81	0.00	27.74	7.72
2640	1.636	60.44	13.091	4.44	9.46	50.75	0.00	27.68	7.67

Appendix F. Raman Calibration and Sampling Method

The Raman spectrometer was calibrated using a set of calibration gases as shown in Table 2-3. Due to the nature of the Raman technique, the instrument only needs to be calibrated once for the intensities (or quantities) of the calibration gases. The wavelengths for the various calibration gases are known and also remain fixed. As an additional check before and after each experiment, air, 99.9 vol % CO_2, and/or a 2.67 vol % H_2 gas (balance Ar) were analyzed using the Raman cell to ensure the calibration was still good. If the calibration checks were off for these gases, the Raman calibration model was adjusted for those gases after the run. For the Al dissolutions performed in Experiments 96 and 97, the calibration checks are shown in Table F-2. The calibration check tells us if the calibration was successful and provides an indication of the variance of the measurements since the calibration gas is analyzed for several samples.

The Raman readings should be positive and sum to 100% except for the 2.67 vol % H_2 gas which is 97.33 vol % Ar (which is not detected by the Raman spectrometer). Due to the noise in the Raman signal, any raw readings that are less than zero are fixed to zero and then all the gas readings for H_2, NO_2, N_2, O_2, N_2O, NO, CO_2, CO, H_2O and NH_3 are normalized to 100% except for the 2.67 vol % H_2 gas. These fixed and normalized Raman readings are the values reported in Table F-2 except for the 2.67 vol % H_2 gas where the raw readings are provided. Due to rounding to the nearest hundredth, the numbers in the table may not sum to 100 vol % but all the decimal places were carried in the calculations performed for this report.

The total offgas flow is calculated from the fixed normalized sum of the CO_2 and CO concentrations divided into the CO_2 tracer flow rate coming into the system as shown in Table F-1. The noise in the concentrations measured by the Raman spectrometer propagates into the total offgas flow rate so moving averages of the total offgas flow rates were performed using equation F-1:

$$\text{Offgas flow rate}_{t_i}(\text{cm}^3/\text{min}) = \frac{\sum_{k=t_{i-1}}^{t_{i+1}} \text{Offgas flow rate}_k}{3} \quad \text{(F-1)}$$

where Offgas flow rate = offgas generated by the dissolution in cm^3/min
t_i = time at integer time step i
k= integer time step t_{i-1}, t_i, and t_{i+1}.

The moving average offgas flow rates and fixed normalized moving average Raman offgas concentrations for Experiment 96, 97, 98 and 101 are shown in Appendix G, H, I, and J, respectively.

Table F-1. Raman Tracer Gas Flow Rates

Experiment	CO_2 Flow (cm^3/min)
96	20
97	20
98	20
$101_{Day\ 1}$	20
$101_{Day\ 2}$	30,50

Table F-2. Pre-run Check of Calibration Gases for Al Dissolution Experiments 96-97

Gas Description	Exp.	H_2 (%)	NO_2 (%)	N_2 (%)	O_2 (%)	N_2O (%)	NO (%)	CO_2 (%)	CO (%)	H_2O (%)	NH_3 (%)
99.9% CO_2	96	0.00	0.18	0.29	0.51	0.00	0.00	98.28	0.34	0.40	0.00
	96	0.00	0.27	0.00	0.61	0.00	0.18	98.15	0.09	0.39	0.32
	96	0.07	0.24	0.14	0.49	0.00	0.00	98.49	0.00	0.37	0.19
	96	0.08	0.24	0.00	0.00	0.00	0.64	98.18	0.25	0.49	0.11
	96	0.00	0.23	0.00	1.25	0.00	0.00	97.49	0.09	0.87	0.06
	96	0.00	0.23	0.00	1.09	0.00	0.00	97.72	0.50	0.44	0.01
	96	0.23	0.30	0.14	0.47	0.00	0.20	98.29	0.09	0.27	0.00
	96	0.00	0.25	0.00	0.37	0.00	0.23	98.21	0.16	0.68	0.10
	97	0.00	0.24	0.00	0.40	0.00	0.00	98.62	0.26	0.49	0.00
	97	0.00	0.29	0.28	0.70	0.00	0.04	98.05	0.00	0.58	0.07
	97	0.21	0.28	0.04	0.78	0.00	0.00	98.45	0.00	0.19	0.06
	97	0.00	0.25	0.22	0.00	0.00	0.15	98.01	0.55	0.64	0.18
	97	0.23	0.24	0.00	0.65	0.00	0.00	98.64	0.00	0.24	0.00
	97	0.07	0.21	0.05	0.48	0.00	0.00	98.60	0.06	0.53	0.00
	97	0.17	0.29	0.37	0.39	0.00	0.04	98.42	0.00	0.32	0.00
	97	0.00	0.23	0.00	0.66	0.00	0.01	98.46	0.29	0.35	0.00
Air (78.0% N_2-21.0% O_2-0.9% Ar)	96	0.07	0.02	76.00	20.13	0.11	0.21	2.40	0.25	0.80	0.00
	96	0.00	0.01	76.10	21.16	0.17	0.00	1.95	0.12	0.44	0.06
	96	0.18	0.02	75.40	20.95	0.00	0.02	2.81	0.26	0.37	0.00
	96	0.00	0.07	76.59	20.40	0.01	0.00	1.95	0.34	0.64	0.00
	96	0.32	0.01	76.66	20.56	0.00	0.00	1.74	0.00	0.71	0.00
	96	0.00	0.00	76.55	20.36	0.00	0.48	1.89	0.12	0.60	0.00
	96	0.02	0.00	75.40	19.99	0.00	0.36	2.99	0.00	0.87	0.37
	96	0.12	0.03	76.67	20.27	0.07	0.01	2.08	0.00	0.74	0.00
	97	0.21	0.35	77.04	20.59	0.22	0.00	0.63	0.00	0.76	0.20
	97	0.00	0.35	77.09	20.63	0.00	0.00	1.15	0.07	0.67	0.04
	97	0.05	0.36	77.52	20.66	0.00	0.00	0.89	0.00	0.51	0.00
	97	0.37	0.34	76.83	20.00	0.01	0.00	0.54	0.00	1.06	0.85
	97	0.00	0.37	77.20	20.38	0.01	0.13	0.89	0.00	0.75	0.28
	97	0.00	0.36	76.20	20.41	0.08	0.93	1.23	0.00	0.72	0.07
	97	0.14	0.31	77.12	19.46	0.00	0.19	1.29	0.85	0.48	0.15
	97	0.51	0.37	77.03	20.34	0.03	0.09	0.85	0.53	0.08	0.16
2.67% H_2-97.33% Ar	96	3.24	0	0	0	0	0	0	0	0	0
	96	3.18	0	0	0	0	0	0	0	0	0
	96	3.33	0	0	0	0	0	0	0	0	0
	96	3.48	0	0	0	0	0	0	0	0	0
	96	3.52	0	0	0	0	0	0	0	0	0
	96	3.38	0	0	0	0	0	0	0	0	0
	96	3.37	0	0	0	0	0	0	0	0	0
	96	3.47	0	0	0	0	0	0	0	0	0
	97	3.54	0	0	0	0	0	0	0	0	0
	97	3.22	0	0	0	0	0	0	0	0	0
	97	3.02	0	0	0	0	0	0	0	0	0
	97	3.34	0	0	0	0	0	0	0	0	0
	97	3.58	0	0	0	0	0	0	0	0	0
	97	3.39	0	0	0	0	0	0	0	0	0
	97	3.30	0	0	0	0	0	0	0	0	0
	97	3.25	0	0	0	0	0	0	0	0	0

To estimate the variability of the concentrations measured by Raman spectroscopy, the pre-run check values of Table F-2 were compared to the standard values across Experiments 96 and 97. The standard deviations of the measured concentrations with respect to the calibrated concentrations for the data were calculated. These standard deviations were then doubled to get an idea of the variability in the Raman spectroscopy concentration measurements. Table F-3 shows the standard deviation of the measured concentrations with respect to their calibrated values. For the H_2 and O_2 gases, the 2σ values or twice the standard deviation is <2 vol%. The 2σ values for O_2 and N_2 are < 4 vol %.

Table F-3. Standard Deviation of Raman Concentrations with Respect to Calibrated Values

Gas	Standard Deviation (σ)	2*Standard Deviation (2σ)
	(vol %)	(vol %)
CO_2	1.68	3.36
N_2	1.54	3.07
O_2	0.72	1.44
H_2	0.70	1.39

Appendix G. Raman Offgas Data for Experiment 96

As discussed in Appendix F, the Raman readings should be positive and sum to 100% except in cases where there is significant Ar present. Due to the noise in the Raman signal, any raw readings that are less than zero are fixed to zero and then all the gas readings for H_2, NO_2, N_2, O_2, N_2O, and NO are normalized to 100 vol %. Even with these corrections, the Raman readings have noise in them. To reduce this noise, moving averages of the fixed and normalized readings were performed using equation G-1:

$$\text{Gas}_{t_i}(\text{vol\%}) = \frac{\sum_{k=t_{i-2}}^{t_{i+2}} \text{Gas}_k}{5} \quad \text{(G-1)}$$

where Gas = H_2, NO_2, N_2, O_2, N_2O, NO concentrations (vol%)
t_i = time at integer time step i
k= integer time step t_{i-2}, t_{i-1}, t_i, t_{i+1}, and t_{i+2}.

These moving averages do not eliminate all the noise but smooth the values so comparisons and calculations can be performed. The fixed, normalized, and moving average Raman gas concentrations are reported in Table G-1. Due to rounding to the nearest hundredth, the numbers in the table may not sum to 100 vol % but all the decimal places were carried in the calculations performed for this report.

Table G-1. Fixed Normalized Moving Average Raman Data for Experiment 96

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
8	0.001	87.86	2.764	1.08	5.54	2.19	3.16	0.27	87.75
19	0.001	88.20	2.675	1.13	5.56	2.96	3.48	0.27	86.60
30	0.002	88.17	2.684	1.45	5.74	2.13	3.71	0.27	86.70
42	0.002	88.19	2.679	1.02	5.84	2.96	3.73	0.15	86.29
53	0.003	88.04	2.716	0.78	5.75	4.29	4.14	0.10	84.95
64	0.003	87.84	2.769	0.75	6.08	5.75	4.69	0.70	82.04
76	0.004	86.83	3.035	1.29	7.08	4.51	4.96	7.61	74.56
87	0.004	77.93	6.347	1.99	7.85	4.41	4.11	13.43	68.22
98	0.006	62.42	15.134	3.19	8.52	3.90	3.52	18.50	62.37
110	0.010	42.98	31.820	4.77	9.42	3.13	3.35	22.96	56.37
121	0.018	32.21	44.030	6.08	10.24	2.08	2.91	27.39	51.30
132	0.028	23.88	70.419	6.76	10.94	2.43	2.52	24.46	52.88
144	0.044	20.02	88.510	6.92	11.88	3.15	3.71	23.10	51.24
155	0.064	14.66	117.679	6.84	13.20	3.71	3.53	22.40	50.32
166	0.088	14.35	120.417	6.42	14.32	3.70	3.81	22.06	49.68
178	0.114	14.31	120.758	6.01	15.58	3.91	3.40	20.18	50.93
189	0.135	17.66	97.690	5.63	16.19	3.90	3.44	20.63	50.21
201	0.153	16.96	105.307	5.39	16.75	3.58	2.36	20.44	51.47

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
212	0.173	18.19	97.072	5.32	16.91	3.65	2.41	20.32	51.39
224	0.196	16.35	106.397	5.31	17.44	3.75	2.21	20.87	50.44
235	0.213	18.55	88.087	5.17	17.32	3.80	2.65	22.25	48.80
246	0.230	18.38	89.032	5.01	17.33	3.80	2.88	22.54	48.44
258	0.248	17.63	94.805	4.98	17.23	4.30	2.82	22.80	47.87
269	0.267	16.43	102.859	4.85	17.29	3.86	3.19	23.04	47.77
281	0.289	15.28	110.891	4.69	16.88	3.70	3.10	22.89	48.75
292	0.310	14.77	115.891	4.74	16.77	3.79	3.17	22.85	48.67
304	0.335	16.23	106.461	4.87	16.98	3.79	3.32	23.03	48.00
315	0.355	17.40	98.291	4.88	16.91	3.31	3.88	23.16	47.87
327	0.372	18.73	87.065	4.98	16.96	3.33	3.17	23.37	48.20
338	0.389	18.08	90.687	5.12	17.00	3.22	3.72	23.29	47.65
349	0.406	19.14	85.583	5.05	17.03	2.68	3.75	23.53	47.97
361	0.423	18.98	86.654	4.71	16.94	2.59	3.51	23.32	48.93
372	0.439	20.74	78.195	4.73	16.88	2.80	3.43	23.15	49.00
384	0.456	18.55	91.242	4.59	16.86	3.21	3.42	23.09	48.84
395	0.473	18.90	88.930	4.39	16.86	3.05	3.12	23.30	49.28
407	0.493	16.82	99.423	4.52	16.90	3.29	3.40	23.24	48.64
418	0.511	18.29	89.736	4.82	16.73	3.22	3.62	23.21	48.40
430	0.530	19.28	84.557	4.72	16.78	2.94	4.13	23.22	48.21
442	0.546	19.02	86.442	4.80	16.68	2.50	4.96	23.51	47.56
453	0.563	18.44	89.709	4.83	16.67	2.55	4.84	23.80	47.31
465	0.583	17.12	97.030	4.77	16.60	2.61	4.58	23.64	47.80
476	0.600	20.11	82.435	4.62	16.70	2.94	4.74	23.31	47.69
488	0.616	22.83	70.893	4.67	16.63	2.90	4.56	23.38	47.87
499	0.627	23.86	64.920	4.63	16.59	3.08	4.47	22.75	48.47
511	0.641	24.55	62.923	4.61	16.51	2.97	5.09	22.32	48.49
522	0.654	25.14	61.293	4.65	16.50	3.20	5.13	22.57	47.95
534	0.665	24.66	63.872	4.49	16.49	2.75	5.18	22.71	48.39
546	0.679	25.37	62.099	4.46	16.78	2.24	4.80	23.03	48.69
557	0.692	23.64	67.523	4.44	16.99	1.96	5.06	23.01	48.54
569	0.704	26.82	55.501	4.36	17.02	2.00	4.83	22.52	49.28
580	0.715	26.42	56.487	4.50	16.87	1.94	4.71	22.04	49.94
592	0.725	25.63	59.872	4.86	17.01	1.95	4.56	22.03	49.59
603	0.738	26.53	57.807	5.23	16.68	2.66	4.62	21.61	49.19
615	0.750	24.36	64.953	5.01	16.62	2.67	4.27	21.33	50.10
627	0.762	27.29	55.124	5.22	16.73	2.88	4.69	19.85	50.63

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
638	0.774	27.14	55.436	4.96	16.73	2.99	5.58	19.40	50.34
650	0.783	29.97	46.748	4.88	16.27	3.28	5.72	18.91	50.95
662	0.793	30.20	46.233	4.56	16.12	4.60	5.66	17.97	51.10
673	0.802	29.71	47.330	4.76	15.91	4.87	5.61	18.01	50.84
685	0.812	29.46	47.887	4.78	15.56	4.67	4.76	19.70	50.53
697	0.821	27.02	55.124	4.81	15.59	4.06	4.19	20.16	51.19
708	0.833	25.13	60.684	4.82	15.58	3.78	4.51	20.49	50.81
720	0.846	23.21	66.195	4.76	15.69	2.35	4.74	20.83	51.62
732	0.860	26.33	57.536	4.87	15.66	2.26	4.93	20.90	51.38
743	0.870	27.33	54.302	4.63	15.96	2.27	4.41	20.82	51.92
755	0.880	30.54	46.149	4.51	15.93	2.67	4.15	20.90	51.85
767	0.890	28.20	52.042	4.41	15.86	2.93	3.87	20.98	51.95
778	0.899	27.65	53.729	4.51	15.84	2.99	3.73	21.02	51.91
790	0.912	27.22	54.528	4.42	15.70	2.93	3.72	21.23	52.00
802	0.923	27.14	54.781	4.68	15.45	2.46	4.85	21.02	51.54
813	0.932	29.88	48.075	4.85	15.29	2.15	4.99	21.10	51.61
825	0.943	27.50	54.060	4.98	15.28	2.10	4.94	20.51	52.19
837	0.953	30.41	46.998	5.34	15.31	1.64	5.03	20.56	52.12
849	0.964	30.66	46.543	5.31	15.23	1.67	4.69	20.57	52.53
860	0.971	30.75	46.273	5.21	15.41	1.75	4.38	21.34	51.91
872	0.981	28.21	52.158	5.22	15.47	1.79	4.40	20.82	52.31
884	0.993	28.88	51.046	5.08	15.35	2.01	4.21	21.33	52.03
895	1.002	29.15	50.239	4.77	15.23	2.30	4.35	21.28	52.06
907	1.012	32.74	42.614	4.81	15.37	2.38	4.24	21.15	52.06
919	1.021	32.17	43.550	4.70	15.02	3.03	4.52	20.25	52.47
931	1.029	35.36	36.605	4.71	15.06	2.80	4.34	20.52	52.57
943	1.037	35.25	36.783	4.50	15.37	2.58	4.46	20.25	52.83
954	1.043	36.11	35.389	4.36	15.88	2.59	4.37	21.80	51.00
966	1.051	33.96	39.590	4.17	15.80	2.21	4.94	22.11	50.77
978	1.059	30.93	45.740	4.29	16.00	1.73	4.90	22.23	50.85
990	1.070	31.90	44.407	4.23	15.93	1.77	5.02	22.00	51.06
1001	1.078	35.71	37.901	4.46	15.79	1.91	4.26	21.86	51.72
1013	1.084	39.90	30.124	4.45	15.26	1.87	4.16	20.53	53.74
1025	1.090	39.56	30.576	4.49	15.23	2.24	3.97	20.02	54.05
1037	1.097	38.68	31.728	4.37	15.03	2.81	3.91	19.91	53.97
1049	1.103	37.91	32.760	4.05	14.84	3.32	3.99	20.30	53.50
1061	1.110	35.17	37.468	4.03	14.67	3.27	4.58	20.96	52.50

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
1072	1.118	32.40	42.448	3.93	14.57	3.56	4.30	20.82	52.82
1084	1.127	33.24	41.322	4.05	14.38	3.46	4.63	20.66	52.82
1096	1.135	36.13	36.423	4.04	14.49	2.94	4.50	20.80	53.24
1108	1.142	39.93	30.104	4.68	15.10	3.33	4.21	21.19	51.49
1120	1.148	40.72	29.172	4.70	15.03	3.16	4.06	21.26	51.80
1132	1.154	37.75	34.254	4.79	15.03	3.45	3.95	21.92	50.87
1143	1.161	33.78	40.945	4.63	15.00	3.45	3.62	22.44	50.86
1155	1.171	30.20	46.315	4.47	15.03	3.47	3.37	22.62	51.04
1167	1.180	34.51	39.630	4.16	14.53	2.74	2.98	22.17	53.42
1179	1.187	37.97	33.561	4.09	15.00	3.49	3.12	22.24	52.05
1191	1.193	42.02	27.697	3.94	14.82	2.99	3.35	22.25	52.64
1203	1.199	37.76	34.268	4.05	14.80	3.29	3.35	22.82	51.68
1215	1.206	32.88	44.278	4.20	14.55	3.79	3.17	22.47	51.81
1227	1.218	32.43	44.765	3.84	14.44	4.11	3.54	22.88	51.20
1239	1.227	33.18	43.237	3.74	14.07	3.52	3.09	23.19	52.40
1251	1.234	35.89	36.562	3.98	14.12	3.74	3.12	23.21	51.84
1262	1.242	32.29	41.967	3.82	14.07	3.26	3.27	22.14	53.43
1274	1.250	34.52	38.438	3.76	13.88	3.40	3.96	22.86	52.13
1286	1.258	33.22	41.169	3.73	13.79	3.42	3.98	22.41	52.66
1299	1.267	36.72	35.890	3.88	13.69	3.68	4.30	21.55	52.91
1311	1.275	37.57	34.842	3.71	13.44	3.53	5.36	21.17	52.80
1322	1.280	38.36	33.105	3.74	13.53	3.93	5.05	21.46	52.29
1334	1.287	37.91	33.637	3.88	13.99	3.84	4.82	22.27	51.20
1346	1.295	35.67	36.711	4.23	13.87	4.30	4.86	22.71	50.03
1358	1.302	35.58	36.882	4.15	13.67	4.25	4.36	23.46	50.11
1370	1.310	32.11	42.542	4.27	14.08	4.17	3.16	23.32	51.00
1382	1.319	35.11	38.641	4.59	14.25	4.19	2.99	23.34	50.64
1394	1.327	39.89	31.875	4.39	13.80	4.24	2.69	22.66	52.21
1406	1.332	41.06	29.586	4.33	13.98	3.69	2.68	22.20	53.13
1418	1.339	41.66	28.993	4.31	14.05	3.65	3.36	22.44	52.20
1430	1.345	37.76	34.071	4.21	13.77	4.01	3.50	23.06	51.45
1442	1.351	37.47	34.600	4.14	13.68	4.18	3.71	22.78	51.51
1454	1.360	37.32	34.738	4.11	13.66	4.16	3.59	23.04	51.44
1466	1.366	37.25	34.873	4.25	13.67	4.05	4.28	22.57	51.18
1478	1.373	41.42	29.266	4.44	13.55	4.15	4.39	22.29	51.18
1490	1.380	37.65	34.167	4.72	13.67	3.80	4.72	22.70	50.40
1502	1.386	38.39	32.919	4.66	13.34	3.86	4.90	23.56	49.68

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
1515	1.394	34.45	38.101	4.89	13.26	3.13	5.06	23.82	49.84
1527	1.402	34.55	37.926	4.63	13.18	3.24	4.81	25.49	48.64
1539	1.410	34.93	37.356	4.62	13.24	3.09	4.41	25.69	48.95
1551	1.418	36.01	35.597	4.40	13.00	3.12	4.22	25.39	49.88
1563	1.425	36.69	34.521	4.24	13.05	3.00	4.44	24.58	50.68
1575	1.432	40.24	30.471	4.24	13.07	3.39	4.79	24.27	50.24
1587	1.438	40.27	30.425	4.51	12.89	3.06	4.54	23.91	51.09
1600	1.444	40.55	30.020	4.52	12.73	3.27	4.72	23.86	50.90
1612	1.451	36.88	34.237	4.62	12.89	3.35	4.46	24.52	50.16
1624	1.458	37.73	33.070	4.76	12.81	3.30	4.51	25.49	49.14
1636	1.465	38.15	32.470	4.78	12.82	3.50	4.41	25.58	48.91
1648	1.471	38.72	31.661	4.84	12.88	4.52	4.83	24.44	48.49
1660	1.478	42.67	27.757	4.79	12.94	4.39	5.16	24.59	48.13
1673	1.484	42.66	27.777	4.75	12.96	4.52	5.99	24.60	47.17
1685	1.489	43.37	26.850	4.95	12.98	4.49	5.77	24.72	47.10
1697	1.495	39.55	30.598	4.99	13.22	4.38	5.84	24.10	47.48
1709	1.502	44.60	25.683	5.09	13.34	4.07	5.69	24.30	47.51
1721	1.506	49.27	21.436	5.16	13.24	3.97	5.69	24.32	47.62
1734	1.510	49.10	21.657	5.15	12.95	3.92	5.44	24.15	48.39
1746	1.515	44.53	25.945	5.12	13.03	3.66	4.89	24.57	48.74
1758	1.522	40.68	29.237	5.40	13.04	3.68	5.09	26.20	46.59
1770	1.527	42.76	26.917	5.30	12.69	3.63	4.73	27.43	46.22
1782	1.533	43.19	26.391	5.35	12.62	4.07	4.60	27.62	45.74
1795	1.538	42.36	27.348	5.30	12.51	4.43	4.37	27.38	46.00
1807	1.544	40.56	29.317	5.35	12.37	4.80	5.11	27.30	45.06
1819	1.551	41.26	28.524	5.10	12.08	4.43	5.02	26.88	46.50
1831	1.556	41.89	27.796	5.23	12.06	4.17	5.42	26.79	46.33
1844	1.562	42.71	26.831	5.13	12.35	4.20	5.65	25.49	47.17
1856	1.568	47.54	22.962	5.27	12.50	4.14	5.47	26.09	46.53
1868	1.572	47.73	22.749	5.34	12.53	4.46	4.99	25.81	46.87
1880	1.576	48.63	21.819	5.53	12.43	4.76	5.29	25.66	46.33
1893	1.582	44.07	25.409	5.37	12.52	5.03	5.29	25.79	45.99
1905	1.587	44.58	24.865	5.42	12.34	4.71	4.67	27.52	45.34
1917	1.592	44.48	24.963	5.67	12.29	4.77	4.53	27.50	45.25
1930	1.598	45.23	24.231	5.62	12.18	4.39	4.85	27.93	45.02
1942	1.603	45.54	23.921	5.25	12.67	5.08	3.90	29.18	43.91
1954	1.608	46.82	22.757	5.28	12.72	4.89	3.77	29.61	43.72

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
1967	1.613	46.97	22.623	5.43	12.74	5.29	3.85	29.58	43.11
1979	1.617	47.83	21.825	5.22	12.66	5.54	4.53	29.51	42.54
1991	1.622	46.42	23.122	5.21	12.64	5.95	4.14	29.69	42.37
2004	1.627	46.09	23.430	5.38	12.12	5.60	4.45	28.71	43.73
2016	1.632	45.51	23.960	5.53	11.95	6.07	3.97	28.73	43.75
2028	1.637	46.09	23.397	5.53	11.92	6.21	4.06	28.90	43.38
2041	1.642	46.51	23.001	5.41	12.02	6.70	3.48	28.91	43.48
2053	1.647	47.35	22.257	5.55	12.13	6.32	3.89	29.31	42.81
2065	1.651	47.91	21.751	5.67	12.05	6.97	3.98	29.44	41.89
2078	1.656	48.49	21.249	5.63	11.95	6.88	4.43	29.21	41.89
2090	1.661	47.74	21.914	5.78	12.18	6.85	4.28	29.79	41.12
2102	1.665	48.98	20.914	5.70	12.06	6.16	4.03	30.11	41.93
2115	1.670	48.90	20.977	5.75	11.78	6.55	3.91	29.64	42.37
2127	1.674	49.11	20.790	5.80	11.87	6.40	3.62	29.65	42.66
2139	1.678	48.08	21.604	5.76	11.93	6.77	3.38	30.06	42.10
2152	1.683	47.93	21.733	5.78	11.66	6.41	3.15	29.80	43.20
2164	1.688	49.06	20.787	5.90	11.66	6.23	3.49	29.97	42.75
2177	1.692	49.03	20.808	5.71	12.07	6.62	3.43	28.43	43.74
2189	1.697	54.21	17.418	5.78	12.07	6.38	3.83	28.73	43.20
2201	1.700	54.27	17.370	5.79	12.11	6.48	3.64	28.67	43.31
2214	1.703	54.80	16.935	5.63	11.97	7.27	3.82	28.59	42.72
2226	1.707	49.84	20.137	5.83	11.94	8.00	3.80	28.52	41.91
2239	1.712	49.45	20.449	6.01	11.67	7.73	3.49	30.34	40.76
2251	1.716	49.21	20.642	6.08	11.63	7.60	3.37	30.41	40.90
2264	1.721	49.41	20.478	6.23	11.53	7.15	4.18	30.43	40.48
2276	1.725	49.57	20.350	6.32	11.51	6.89	4.54	30.10	40.63
2289	1.730	49.63	20.300	6.19	11.45	6.66	4.47	29.98	41.24
2301	1.734	49.68	20.261	5.99	11.33	6.73	4.80	30.15	41.00
2314	1.738	49.62	20.310	5.95	11.30	7.35	4.77	30.07	40.56
2326	1.743	50.37	19.728	5.87	11.40	7.64	4.41	30.39	40.28
2339	1.747	51.19	19.084	5.85	11.35	7.57	4.57	30.62	40.04
2351	1.751	51.64	18.736	5.95	11.39	7.85	4.71	30.79	39.31
2363	1.755	51.45	18.877	6.23	11.44	7.85	4.68	30.97	38.84
2376	1.759	51.43	18.888	6.06	11.39	8.03	5.10	30.79	38.63
2389	1.763	51.62	18.743	6.26	11.31	7.66	4.65	30.69	39.44
2401	1.767	51.84	18.584	6.44	11.72	8.68	3.82	27.84	41.51
2414	1.771	58.80	14.893	6.32	11.66	8.66	4.43	27.87	41.06

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
2426	1.774	59.33	14.503	5.93	11.18	8.79	4.28	26.34	43.48
2439	1.776	57.91	15.649	6.08	11.20	9.20	3.63	26.55	43.34
2451	1.781	51.62	18.860	5.94	11.04	9.91	3.97	26.64	42.50
2464	1.785	51.16	19.194	5.84	10.62	9.25	4.46	29.59	40.24
2476	1.789	52.84	17.859	6.03	10.55	9.57	3.73	29.44	40.68
2489	1.793	52.59	18.031	6.32	11.03	9.90	3.75	31.00	37.99
2501	1.796	53.41	17.449	6.20	10.97	9.32	4.21	31.36	37.95
2514	1.800	53.82	17.165	6.30	11.03	9.17	4.48	31.25	37.78
2526	1.804	54.08	16.983	6.35	11.04	9.33	4.41	31.34	37.53
2539	1.807	54.11	16.962	6.43	11.04	9.21	4.93	31.56	36.83
2552	1.811	53.91	17.098	6.35	10.90	9.50	5.68	31.67	35.90
2564	1.815	54.15	16.938	6.68	10.95	9.46	5.23	31.74	35.93
2577	1.819	54.63	16.620	6.53	10.89	9.75	5.01	31.86	35.96
2589	1.822	54.95	16.400	6.61	10.81	10.10	5.13	31.86	35.49
2602	1.826	54.81	16.493	6.63	10.87	10.60	4.14	32.48	35.29
2615	1.829	54.65	16.599	7.02	11.00	10.39	3.07	33.08	35.43
2627	1.833	55.45	16.079	6.76	10.82	10.74	3.44	32.72	35.52
2640	1.836	55.77	15.867	6.70	10.86	10.65	3.01	33.10	35.69
2652	1.840	56.43	15.450	6.65	10.88	10.68	2.76	33.36	35.66
2665	1.843	56.71	15.278	6.56	10.99	10.71	3.18	33.90	34.67
2678	1.846	57.56	14.748	6.20	11.03	10.56	3.61	34.02	34.59
2690	1.849	58.14	14.403	6.18	11.09	10.94	3.23	34.68	33.89
2703	1.853	57.98	14.500	6.33	11.01	11.76	3.67	34.45	32.78
2716	1.856	57.82	14.601	6.04	10.87	12.67	3.80	34.92	31.71
2728	1.859	58.31	14.324	6.09	10.68	13.40	4.11	34.79	30.93
2986	1.921	59.43	13.680	5.98	10.57	14.71	3.71	34.89	30.14
2998	1.924	61.12	12.726	5.98	10.34	15.86	3.83	34.84	29.15
3010	1.926	60.85	12.875	5.66	10.33	16.25	3.65	35.56	28.56
3021	1.929	61.17	12.703	5.79	10.35	16.21	3.21	35.82	28.63
3032	1.931	60.90	12.844	5.75	10.50	16.51	2.60	36.69	27.95
3044	1.934	62.24	12.142	5.82	10.57	16.04	2.52	37.21	27.84
3055	1.936	63.12	11.698	5.96	10.73	15.77	2.69	37.67	27.18
3066	1.938	63.56	11.470	6.73	11.31	17.10	2.56	33.12	29.19
3077	1.940	65.02	10.798	6.58	11.30	17.15	3.33	32.59	29.05
3089	1.942	64.29	11.168	6.55	11.08	16.33	3.95	31.57	30.51
3100	1.944	64.06	11.287	6.94	11.57	17.86	4.67	27.19	31.77
3111	1.947	64.64	11.044	6.97	11.45	17.61	4.58	26.96	32.43

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
3122	1.949	64.71	11.007	6.14	10.96	16.28	4.41	31.93	30.29
3134	1.951	65.43	10.645	6.14	11.11	16.68	4.15	32.70	29.22
3145	1.953	63.57	11.469	6.02	11.17	17.33	3.70	33.31	28.47
3156	1.955	64.32	11.093	6.06	11.18	17.79	2.99	33.07	28.91
3168	1.957	66.62	10.089	6.05	11.22	18.00	2.76	33.16	28.80
3179	1.959	66.19	10.298	6.30	11.14	19.57	2.48	33.05	27.45
3190	1.961	65.69	10.550	6.03	10.98	19.59	2.38	32.79	28.22
3201	1.963	63.43	11.535	6.05	10.83	19.60	3.01	32.30	28.21
3213	1.966	63.41	11.546	5.86	10.59	20.46	3.35	32.01	27.73
3224	1.968	65.58	10.545	5.89	11.29	22.35	3.71	27.71	29.05
3235	1.970	67.79	9.580	5.83	11.21	20.86	4.40	27.42	30.28
3247	1.972	68.37	9.297	6.57	11.88	22.12	4.76	23.10	31.57
3258	1.973	69.15	8.982	7.63	12.29	22.91	3.95	24.28	28.93
3269	1.975	67.99	9.465	7.67	12.52	22.29	4.28	24.12	29.12
3281	1.977	70.57	8.368	7.65	12.39	21.38	4.33	24.30	29.95
3292	1.979	70.53	8.385	7.66	12.44	21.67	4.57	24.69	28.97
3303	1.980	69.66	8.779	7.73	12.36	22.05	4.39	24.84	28.62
3315	1.982	69.18	8.968	6.67	12.79	22.63	4.90	19.09	33.92
3326	1.984	69.67	8.779	6.82	12.97	22.72	5.14	19.27	33.09
3337	1.985	72.87	7.458	7.20	12.94	23.20	5.63	18.55	32.48
3349	1.987	73.01	7.401	7.66	13.83	25.17	4.93	13.94	34.46
3360	1.988	72.72	7.513	7.94	14.21	24.64	4.85	14.13	34.24
3372	1.990	72.48	7.599	7.81	13.38	23.91	5.16	18.60	31.14
3383	1.991	70.49	8.448	7.50	12.45	22.58	4.78	23.10	29.60
3394	1.993	68.36	9.349	7.24	12.63	23.33	4.12	23.66	29.02
3406	1.995	68.34	9.354	6.81	11.79	20.76	4.78	28.28	27.58
3417	1.997	68.96	9.073	6.07	11.00	18.69	4.45	33.59	26.20
3429	1.998	69.61	8.782	6.12	11.10	17.94	3.59	34.49	26.75
3440	2.000	67.15	9.786	6.16	11.71	18.99	4.23	29.87	29.05
3451	2.002	69.10	8.997	5.61	10.99	17.99	4.46	34.36	26.60
3463	2.004	68.88	9.091	6.27	12.08	20.85	3.92	29.32	27.56

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Appendix H. Raman Offgas Data for Experiment 97

As discussed in Appendix F, the Raman readings should be positive and sum to 100% except in cases where there is significant Ar present. Due to the noise in the Raman signal, any raw readings that are less than zero are fixed to zero and then all the gas readings for H_2, NO_2, N_2, O_2, N_2O, and NO are normalized to 100 vol %. Even with these corrections, the Raman readings have noise in them. To reduce this noise, moving averages of the fixed and normalized readings were performed using equation G-1.

These moving averages do not eliminate all the noise but smooth the values so comparisons and calculations can be performed. The fixed, normalized, and moving average Raman gas concentrations are reported in Table G-1. Due to rounding to the nearest hundredth, the numbers in the table may not sum to 100 vol % but all the decimal places were carried in the calculations performed for this report.

Table H-1. Fixed Normalized Moving Average Raman Data for Experiment 97

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
2	0.001	77.62	5.785	3.40	13.51	1.53	4.46	0.43	76.67
13	0.002	77.44	5.846	3.80	13.54	1.61	5.26	0.43	75.35
24	0.003	77.92	5.677	3.79	13.54	1.61	5.27	0.47	75.31
35	0.004	77.17	5.919	3.43	13.88	1.49	5.26	0.41	75.53
47	0.005	77.27	5.883	1.45	13.39	2.54	4.38	0.26	77.99
58	0.006	77.39	5.845	1.30	13.14	2.09	4.22	0.26	78.99
69	0.008	77.56	5.787	0.91	12.90	1.60	4.11	0.32	80.16
80	0.009	77.45	5.824	1.64	12.68	1.82	3.80	5.80	74.26
92	0.010	70.98	8.765	2.91	12.06	2.29	3.22	11.45	68.08
103	0.011	55.99	20.288	3.81	11.47	2.10	3.67	16.94	62.01
114	0.016	39.03	36.850	5.27	11.06	2.64	3.12	22.36	55.56
126	0.026	27.53	54.390	6.54	11.01	2.75	3.14	28.04	48.52
137	0.037	20.22	93.209	7.36	10.95	3.18	3.11	27.79	47.61
148	0.057	17.79	102.797	7.44	11.42	2.74	3.25	27.64	47.50
160	0.080	14.07	130.602	7.29	12.20	2.22	3.40	27.58	47.31
171	0.101	13.94	132.625	7.06	13.19	2.25	3.43	27.67	46.40
182	0.129	12.52	142.597	6.78	14.02	2.77	3.32	27.07	46.03
194	0.156	13.31	132.931	6.47	15.22	2.90	3.62	26.80	45.00
205	0.177	15.56	109.729	6.17	16.32	2.96	3.68	26.29	44.58
216	0.196	17.99	95.048	5.82	17.26	3.20	4.00	25.88	43.84
228	0.212	18.30	92.080	5.60	17.93	3.35	4.49	24.99	43.64
239	0.228	18.39	91.547	5.15	18.67	3.24	4.36	24.71	43.87
250	0.246	16.73	100.205	4.63	19.05	2.95	4.33	24.68	44.36
262	0.265	16.18	105.707	4.26	19.21	3.37	4.77	24.43	43.95
273	0.285	16.29	105.017	4.20	19.55	3.58	4.23	24.14	44.29

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
284	0.304	17.20	99.721	3.98	19.89	3.77	4.45	24.62	43.30
296	0.321	17.95	92.604	4.02	19.84	3.93	5.26	24.44	42.51
307	0.337	16.48	104.164	4.26	19.90	4.03	5.40	24.11	42.29
319	0.360	15.70	108.608	4.45	20.77	3.74	5.65	24.75	40.65
330	0.379	18.91	92.293	4.75	21.48	3.48	6.35	25.41	38.54
341	0.393	21.55	74.873	4.56	21.93	3.37	5.09	25.30	39.75
353	0.406	23.16	66.693	4.78	22.49	3.42	4.13	24.41	40.77
364	0.418	21.36	73.875	4.76	22.91	3.87	4.65	24.72	39.08
376	0.433	20.76	76.674	4.63	22.29	3.67	4.56	23.93	40.92
387	0.447	18.89	86.529	4.28	21.69	3.65	4.26	23.14	42.98
398	0.463	17.10	98.972	4.40	21.43	3.43	5.98	22.54	42.21
410	0.484	18.23	94.124	4.62	21.65	2.84	7.24	22.37	41.28
421	0.501	19.22	88.215	4.53	21.23	1.94	8.28	21.63	42.39
433	0.515	20.07	81.297	4.58	21.30	1.85	8.72	21.15	42.40
444	0.531	18.66	87.606	4.58	21.53	2.10	9.00	21.03	41.76
456	0.548	19.36	84.413	4.86	21.89	1.85	7.96	21.48	41.96
467	0.562	19.79	81.655	4.50	21.61	1.71	7.95	22.25	41.98
479	0.578	20.00	80.518	4.43	21.71	1.78	6.93	22.03	43.13
490	0.593	19.09	84.846	4.49	22.07	1.60	6.79	22.08	42.99
502	0.609	20.19	79.336	4.45	22.31	1.21	7.10	20.53	44.40
513	0.623	22.56	70.396	4.52	22.19	1.27	8.01	20.04	43.96
525	0.635	23.99	64.063	4.47	22.32	1.34	7.63	20.11	44.13
536	0.646	24.02	63.916	4.44	22.53	1.23	8.15	20.31	43.34
548	0.659	21.32	74.625	4.52	22.33	1.13	8.20	20.51	43.31
559	0.673	19.73	81.868	4.60	21.99	0.87	7.55	21.94	43.04
571	0.690	18.70	86.964	4.38	22.02	0.63	7.58	22.22	43.17
582	0.706	19.31	83.789	4.28	21.96	0.72	7.76	21.95	43.33
594	0.722	20.75	77.099	4.33	21.84	1.03	7.24	21.91	43.65
605	0.735	21.57	72.916	4.24	21.86	1.13	6.87	21.69	44.20
617	0.748	23.60	65.558	4.46	23.00	2.26	7.79	23.00	39.48
628	0.760	23.82	64.759	4.65	23.02	2.60	7.50	22.91	39.32
640	0.772	24.55	61.765	4.61	23.19	3.05	7.29	23.41	38.45
651	0.783	23.06	66.774	4.28	23.28	2.64	7.82	23.49	38.49
663	0.796	23.08	66.705	4.31	23.19	2.69	7.92	23.93	37.96
675	0.809	21.87	71.985	4.07	22.02	1.88	6.80	23.00	42.23
686	0.822	21.01	75.917	3.67	22.00	1.98	7.50	23.40	41.45
698	0.838	20.03	79.928	3.82	21.76	1.52	7.93	22.93	42.04

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
709	0.852	22.12	71.738	3.97	21.63	2.28	7.60	22.51	42.02
721	0.865	24.34	63.148	3.84	21.87	2.78	7.84	22.73	40.93
732	0.875	24.10	64.300	3.92	21.86	2.60	8.54	22.39	40.69
744	0.889	23.99	64.637	4.06	21.84	2.65	8.03	21.93	41.48
756	0.902	24.92	62.205	4.21	22.38	2.42	7.95	21.52	41.52
768	0.912	26.01	57.548	4.57	22.78	2.36	7.92	22.47	39.91
780	0.923	25.37	59.656	4.75	22.85	1.76	7.64	21.98	41.01
792	0.936	25.22	60.021	4.79	22.82	2.03	7.87	21.99	40.49
804	0.947	25.58	58.755	4.91	22.98	1.83	7.81	22.49	39.98
816	0.958	27.36	53.573	4.71	22.63	2.51	7.65	23.06	39.44
828	0.969	27.74	52.681	4.61	22.29	2.59	7.54	22.42	40.56
840	0.978	27.56	53.311	4.67	21.92	3.21	7.58	22.29	40.33
852	0.989	26.31	56.699	4.84	22.85	2.98	7.02	22.90	39.40
865	1.002	27.97	53.508	4.71	22.51	3.26	6.87	22.16	40.48
877	1.011	30.25	47.268	4.78	22.07	3.15	6.44	22.10	41.47
890	1.020	29.41	50.156	4.67	21.95	3.10	5.70	21.93	42.65
902	1.031	26.44	56.770	4.61	21.95	2.92	5.70	22.16	42.66
914	1.043	24.63	61.457	4.22	20.92	3.52	5.97	21.16	44.21
926	1.054	27.18	54.091	4.23	20.78	3.39	5.75	21.34	44.51
938	1.065	26.92	54.904	4.12	21.20	3.14	6.16	21.23	44.16
950	1.075	29.41	48.872	4.11	21.42	3.22	6.18	21.26	43.80
962	1.085	28.60	50.754	4.00	21.66	3.76	5.96	21.28	43.35
974	1.094	29.70	47.656	3.99	21.82	3.66	5.63	21.15	43.74
985	1.103	30.09	46.966	4.07	22.91	4.18	5.97	19.58	43.28
997	1.112	34.16	39.759	4.14	22.75	4.14	5.25	19.73	43.99
1009	1.118	33.26	42.232	4.21	22.59	3.92	5.12	19.37	44.80
1020	1.126	33.36	42.058	4.29	22.52	3.04	4.74	19.31	46.11
1032	1.135	29.64	48.400	4.18	22.38	2.73	4.62	19.00	47.08
1044	1.144	32.87	41.289	4.15	21.16	2.26	3.86	20.40	48.18
1056	1.152	30.17	47.352	4.18	20.82	2.78	4.03	20.15	48.04
1067	1.160	29.91	47.984	4.00	21.00	2.69	4.42	20.26	47.63
1079	1.171	30.22	47.508	4.23	21.33	3.48	4.89	20.20	45.87
1091	1.179	34.09	39.613	4.02	21.69	3.85	4.67	20.70	45.08
1103	1.186	37.43	33.463	4.12	21.49	4.12	6.06	20.04	44.17
1115	1.192	36.76	34.546	4.07	22.22	3.81	5.94	20.68	43.29
1126	1.198	36.22	35.335	4.10	21.96	3.81	5.38	21.08	43.67
1138	1.206	32.98	41.234	3.89	21.45	3.06	5.29	20.58	45.73

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
1150	1.214	34.00	39.640	4.15	20.96	2.81	5.67	20.92	45.50
1162	1.222	31.13	45.437	4.09	21.31	1.97	4.26	21.91	46.47
1174	1.230	31.14	45.405	3.77	20.93	2.16	4.41	21.64	47.08
1185	1.240	29.51	48.118	3.96	20.78	2.50	4.82	21.17	46.77
1197	1.248	32.39	42.297	3.56	19.94	2.69	5.00	20.67	48.15
1209	1.256	33.45	39.978	3.51	20.26	3.17	5.08	18.90	49.08
1221	1.264	36.14	35.865	3.54	20.28	3.70	5.39	18.25	48.85
1233	1.271	37.78	33.649	3.87	19.76	3.67	5.53	18.33	48.84
1244	1.276	36.78	35.846	3.78	20.33	3.06	5.40	18.97	48.46
1256	1.283	37.77	34.715	4.15	20.93	3.23	4.93	19.90	46.86
1268	1.291	36.09	36.999	4.36	20.42	3.12	4.53	21.24	46.33
1280	1.297	39.51	30.928	3.90	20.29	3.36	4.54	21.44	46.47
1292	1.303	39.18	31.285	3.99	20.57	3.55	4.19	20.93	46.77
1304	1.309	41.13	28.687	4.05	19.90	3.97	4.23	20.48	47.37
1316	1.314	41.75	27.918	3.77	19.72	3.75	5.18	20.74	46.85
1327	1.319	37.85	33.869	3.73	19.84	3.09	5.04	21.48	46.81
1339	1.326	35.08	37.832	4.30	19.95	2.78	5.25	21.70	46.02
1351	1.335	35.29	37.584	4.35	19.87	3.13	5.33	22.75	44.57
1363	1.341	35.74	36.680	4.43	19.71	3.33	5.14	23.22	44.17
1375	1.348	35.12	37.844	4.93	20.23	3.77	3.97	22.92	44.17
1387	1.356	37.00	35.928	4.66	20.01	4.67	4.79	21.76	44.11
1399	1.363	41.10	30.188	4.57	19.52	5.15	4.13	22.19	44.45
1411	1.367	41.73	29.008	4.48	19.24	4.96	4.34	21.32	45.66
1423	1.374	39.30	31.584	4.39	19.08	4.61	4.27	21.52	46.13
1435	1.380	35.35	37.036	4.14	18.67	3.98	4.58	22.29	46.33
1447	1.387	36.16	35.688	4.42	18.84	3.85	3.87	23.79	45.24
1459	1.395	35.66	36.347	4.39	19.53	3.49	4.15	23.82	44.61
1470	1.401	41.15	29.478	4.64	19.76	2.92	3.92	23.79	44.97
1482	1.406	45.36	24.659	4.88	19.96	3.21	4.92	24.03	43.00
1494	1.410	44.82	25.423	4.95	19.59	3.93	4.74	23.89	42.90
1506	1.415	39.37	32.212	5.26	19.47	2.82	5.35	23.18	43.91
1518	1.423	38.16	33.320	5.35	18.57	2.81	5.42	23.08	44.77
1530	1.429	38.20	33.257	5.11	18.30	3.35	5.23	23.45	44.56
1542	1.435	41.99	28.006	5.36	18.45	3.05	4.48	22.41	46.24
1554	1.441	44.23	26.079	5.75	18.75	2.62	4.68	21.60	46.60
1566	1.445	48.17	21.701	5.65	19.20	3.65	3.75	23.13	44.61
1578	1.449	47.60	22.311	5.65	19.30	3.71	3.58	23.35	44.41

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
1590	1.453	43.63	26.167	5.51	19.05	3.41	3.47	23.99	44.58
1602	1.459	39.04	31.557	5.23	18.71	3.48	3.21	25.06	44.32
1614	1.466	38.03	32.777	4.96	18.37	3.76	3.19	25.81	43.91
1626	1.472	38.23	32.524	5.06	17.58	3.52	3.38	24.87	45.60
1638	1.478	40.24	29.715	5.19	18.64	3.68	3.33	25.08	44.07
1650	1.484	46.10	24.479	5.53	18.78	3.80	3.88	24.90	43.12
1662	1.488	46.28	24.258	5.45	18.81	4.17	4.24	23.85	43.48
1674	1.492	49.81	20.925	5.42	19.10	4.17	3.98	23.28	44.05
1687	1.497	48.65	21.688	5.25	19.13	4.01	4.28	23.43	43.90
1699	1.501	49.11	21.156	5.06	18.08	4.22	4.12	23.08	45.43
1711	1.505	47.94	22.101	4.88	17.82	4.54	4.51	22.73	45.53
1723	1.510	43.56	26.169	4.99	17.41	4.67	4.68	23.65	44.60
1735	1.515	43.09	26.712	4.94	17.20	4.89	5.04	24.80	43.12
1747	1.520	41.27	28.483	5.21	17.10	5.29	4.90	23.84	43.66
1759	1.526	46.21	24.039	5.36	16.90	5.14	5.64	24.22	42.74
1771	1.530	47.09	23.044	5.41	17.16	4.70	5.43	23.55	43.75
1783	1.534	51.43	19.387	5.29	17.32	4.45	5.25	23.80	43.89
1795	1.538	47.75	22.421	5.40	17.16	3.78	5.12	24.25	44.30
1808	1.543	45.75	24.854	5.27	17.02	3.60	5.10	25.25	43.75
1820	1.548	41.58	28.340	5.20	17.08	3.44	4.98	25.35	43.96
1832	1.554	41.58	28.336	5.39	16.94	3.87	4.74	26.96	42.10
1844	1.559	44.13	25.341	5.61	16.97	3.61	4.58	27.29	41.93
1857	1.564	44.88	24.567	5.67	16.93	3.96	4.84	26.78	41.82
1869	1.569	44.60	24.867	5.75	16.91	3.74	5.41	26.98	41.21
1881	1.574	44.24	25.228	5.98	16.71	3.67	5.60	26.94	41.11
1893	1.579	43.89	25.575	6.11	17.06	3.71	6.01	27.51	39.60
1905	1.584	45.60	23.940	6.23	16.93	3.96	6.25	27.19	39.44
1917	1.588	45.75	23.779	6.16	16.76	4.25	6.73	27.09	39.01
1929	1.593	45.91	23.625	6.09	16.66	4.51	6.96	26.87	38.92
1942	1.598	44.45	24.999	6.07	16.73	4.33	6.84	27.41	38.63
1954	1.603	44.94	24.525	5.96	16.17	3.52	6.56	26.63	41.16
1966	1.608	45.28	24.185	6.03	16.38	3.39	7.13	27.17	39.91
1978	1.612	46.39	23.118	6.02	16.51	3.43	7.01	27.21	39.81
1990	1.617	46.56	22.960	6.12	16.66	3.44	6.38	27.67	39.73
2002	1.621	47.06	22.503	5.71	16.26	3.96	9.34	25.54	39.19
2015	1.626	50.20	20.155	5.78	16.12	4.54	9.47	25.50	38.58
2027	1.630	50.37	20.003	5.71	15.92	4.55	9.07	25.52	39.22

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
2039	1.633	51.06	19.416	5.71	15.99	4.54	8.43	25.93	39.41
2051	1.637	48.67	21.112	5.93	16.01	4.86	9.28	24.15	39.76
2064	1.642	53.18	17.958	6.58	16.16	5.12	5.72	26.22	40.19
2076	1.645	52.80	18.278	6.36	15.78	5.37	4.49	25.98	42.01
2088	1.648	51.43	19.490	6.14	15.87	5.69	4.26	26.54	41.49
2100	1.653	48.09	21.672	6.32	15.90	5.77	4.61	25.28	42.13
2112	1.657	52.51	18.688	5.99	15.80	5.16	3.97	27.29	41.79
2125	1.660	54.33	17.114	5.55	15.85	5.32	3.85	27.55	41.88
2137	1.663	54.04	17.347	5.75	16.50	5.75	4.37	28.97	38.65
2149	1.667	50.65	19.495	5.90	16.56	5.80	4.20	29.19	38.35
2162	1.671	50.87	19.330	5.84	16.42	5.73	4.10	31.14	36.77
2174	1.675	50.80	19.384	5.82	16.32	6.30	3.88	31.19	36.49
2186	1.679	50.96	19.260	6.07	16.18	6.14	4.39	30.98	36.24
2198	1.683	50.75	19.420	5.80	16.11	6.15	4.88	30.73	36.33
2211	1.687	52.57	18.085	5.64	16.29	6.47	5.08	28.60	37.92
2223	1.690	57.71	15.136	5.00	16.21	6.68	4.80	28.56	38.75
2235	1.693	58.26	14.725	5.17	16.18	7.13	4.24	28.73	38.56
2248	1.696	57.37	15.341	4.92	16.41	6.96	3.78	29.32	38.61
2260	1.699	53.41	17.467	5.15	16.06	6.79	3.68	28.79	39.54
2272	1.702	52.91	17.845	5.24	15.40	6.40	3.93	30.37	38.66
2285	1.706	53.26	17.592	6.05	15.28	6.08	4.06	30.21	38.32
2297	1.710	52.95	17.801	5.81	15.19	6.00	5.24	29.96	37.81
2309	1.713	53.73	17.224	6.12	14.85	6.04	5.84	29.40	37.74
2322	1.717	53.90	17.107	6.13	15.10	6.03	6.05	29.86	36.83
2334	1.720	54.32	16.828	6.29	15.43	6.56	6.17	30.53	35.03
2346	1.723	55.64	15.967	6.16	15.51	6.87	6.24	30.80	34.41
2359	1.726	56.44	15.443	6.27	15.57	6.37	5.66	31.14	35.00
2371	1.729	56.44	15.442	6.11	15.69	6.51	5.21	31.63	34.85
2383	1.732	55.89	15.786	6.00	15.46	6.62	5.31	32.05	34.55
2396	1.736	55.50	16.036	6.10	15.24	5.73	5.58	31.77	35.58
2408	1.739	55.79	15.854	6.27	15.52	6.45	5.99	32.33	33.44
2421	1.742	56.76	15.261	5.91	15.71	7.02	6.44	32.84	32.08
2433	1.745	57.93	14.532	6.29	15.95	7.18	7.13	33.49	29.95
2445	1.748	58.55	14.158	6.46	15.99	7.07	6.75	33.18	30.54
2458	1.751	58.29	14.315	6.37	15.97	7.29	6.48	33.24	30.64
2470	1.754	58.18	14.377	6.08	15.63	6.61	6.10	33.10	32.47
2483	1.757	58.05	14.455	6.46	15.37	6.18	6.11	33.02	32.86

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	**Est. Al Conc.**	**CO_2 and CO**	**Total Offgas Flow**	**H_2**	**NO_2**	**N_2**	**O_2**	**N_2O**	**NO**
(sec)	**(M)**	**(vol %)**	**(cm^3/min)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**
2495	1.759	57.73	14.647	6.72	15.69	5.98	6.10	30.73	34.78
2507	1.762	62.70	12.317	6.57	15.55	5.56	6.95	30.63	34.74
2520	1.765	62.83	12.240	6.58	15.51	5.87	7.04	30.78	34.23
2532	1.767	63.80	11.673	6.98	15.83	5.81	6.90	31.35	33.13
2545	1.770	60.28	13.208	6.97	15.77	5.75	6.53	31.39	33.59
2557	1.772	60.87	12.870	6.43	15.54	5.90	6.99	34.15	31.00
2570	1.775	62.06	12.244	6.44	15.58	6.02	6.82	34.54	30.60
2582	1.777	61.69	12.433	6.16	15.57	5.84	6.78	34.64	31.00
2595	1.780	62.00	12.264	6.15	15.35	5.54	7.46	34.30	31.22
2607	1.782	61.77	12.384	6.26	15.35	6.21	7.57	34.02	30.59
2620	1.785	61.56	12.495	6.36	15.04	6.10	6.52	33.47	32.52
2632	1.787	61.83	12.353	6.50	15.15	5.92	6.02	34.54	31.87
2645	1.790	60.98	12.803	6.63	15.17	5.82	6.19	34.99	31.20

Appendix I. Raman Offgas Data for Experiment 98

As discussed in Appendix F, the Raman readings should be positive and sum to 100% except in cases where there is significant Ar present. Due to the noise in the Raman signal, any raw readings that are less than zero are fixed to zero and then all the gas readings for H_2, NO_2, N_2, O_2, N_2O, and NO are normalized to 100 vol %. Even with these corrections, the Raman readings have noise in them. To reduce this noise, moving averages of the fixed and normalized readings were performed using equation G-1.

These moving averages do not eliminate all the noise but smooth the values so comparisons and calculations can be performed. The fixed, normalized, and moving average Raman gas concentrations are reported in Table I-1. Due to rounding to the nearest hundredth, the numbers in the table may not sum to 100 vol % but all the decimal places were carried in the calculations performed for this report.

Table I-1. Fixed Normalized Moving Average Raman Data for Experiment 98

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
4	0.001	78.40	5.546	1.24	13.66	1.92	6.48	8.11	68.60
15	0.002	78.22	5.600	1.19	12.76	1.61	6.20	14.90	63.34
27	0.004	78.02	5.672	1.28	12.51	1.32	4.54	15.66	64.69
38	0.005	78.20	5.618	1.70	13.01	1.86	4.79	8.94	69.71
50	0.006	78.23	5.609	2.40	12.41	1.68	4.04	14.66	64.81
61	0.007	76.34	6.360	2.76	11.62	1.37	3.96	20.40	59.89
73	0.009	67.42	10.461	3.42	11.36	2.01	3.71	19.03	60.47
84	0.012	53.97	18.868	4.55	10.29	2.11	3.69	23.38	55.99
95	0.017	40.87	32.233	5.27	9.32	1.90	3.08	28.48	51.96
107	0.026	29.86	51.773	6.06	8.76	2.55	2.50	27.35	52.77
118	0.039	23.87	65.473	6.97	8.35	2.97	2.03	26.54	53.15
130	0.056	20.87	75.981	7.73	8.20	3.23	1.81	26.49	52.54
141	0.072	17.81	101.001	8.40	8.20	3.40	1.57	26.86	51.57
153	0.098	16.54	107.388	8.71	8.10	3.91	2.07	26.69	50.52
164	0.124	15.37	114.632	9.09	7.96	4.24	2.11	26.99	49.61
175	0.144	14.92	122.086	9.43	7.88	4.09	2.22	27.65	48.73
187	0.176	14.72	123.372	9.65	7.81	4.14	2.55	28.09	47.76
198	0.204	13.50	135.208	9.71	7.79	4.07	2.59	28.90	46.94
210	0.230	13.75	130.870	10.15	7.81	3.87	2.19	29.74	46.23
221	0.262	11.64	152.469	10.44	7.87	3.50	2.54	30.27	45.39
233	0.298	12.04	147.849	10.56	7.93	3.54	2.35	30.73	44.90
244	0.328	12.94	136.113	10.68	7.96	3.62	2.05	30.71	44.98
256	0.357	15.26	113.227	10.80	8.03	3.77	2.27	30.76	44.38
267	0.379	16.64	102.107	10.54	8.11	3.74	2.56	30.95	44.10
279	0.400	17.12	97.603	10.31	8.21	3.76	2.65	31.27	43.81

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	**Est. Al Conc.**	**CO_2 and CO**	**Total Offgas Flow**	**H_2**	**NO_2**	**N_2**	**O_2**	**N_2O**	**NO**
(sec)	**(M)**	**(vol %)**	**(cm^3/min)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**
290	0.422	15.35	112.805	10.08	8.27	4.10	2.93	31.26	43.36
302	0.450	15.30	113.152	9.85	8.43	3.96	3.27	31.82	42.67
313	0.474	14.81	117.849	9.52	8.56	4.15	3.25	31.89	42.63
325	0.499	16.62	102.324	8.73	8.79	4.33	3.50	32.05	42.61
336	0.521	17.30	98.491	8.56	8.99	4.25	3.48	32.33	42.39
348	0.541	17.39	97.560	8.26	9.16	4.10	3.72	32.54	42.23
359	0.562	16.72	102.125	8.03	9.31	3.94	4.21	32.57	41.94
371	0.588	14.44	119.599	7.70	9.39	3.68	5.52	32.54	41.17
382	0.613	14.39	120.165	8.11	9.51	3.57	5.55	32.71	40.55
394	0.643	14.00	123.319	7.91	9.69	3.43	5.59	32.97	40.41
405	0.667	14.67	116.593	7.91	9.98	3.31	5.44	33.21	40.15
417	0.693	15.43	109.735	7.75	10.24	3.66	4.99	33.37	39.99
429	0.718	16.70	100.828	7.94	10.56	3.82	4.03	33.85	39.80
440	0.738	15.79	110.617	7.83	10.82	3.89	3.88	33.95	39.61
452	0.764	16.94	103.377	7.76	11.04	3.74	3.87	33.80	39.80
463	0.788	17.16	102.164	7.74	11.27	4.01	3.73	33.98	39.28
475	0.807	19.92	80.468	7.85	11.46	3.78	3.61	34.25	39.05
486	0.823	20.01	80.002	7.71	11.66	3.80	3.49	34.26	39.10
498	0.841	20.08	79.644	7.83	11.85	3.89	3.12	34.80	38.50
510	0.860	18.42	89.973	7.95	11.86	4.29	3.38	34.70	37.83
521	0.880	18.19	91.172	7.88	12.09	4.25	3.14	34.72	37.92
533	0.902	19.38	86.002	7.69	12.26	4.38	3.44	34.65	37.58
544	0.918	21.46	73.819	7.85	12.54	4.70	3.47	35.47	35.97
556	0.934	19.59	88.167	7.57	12.52	4.97	3.82	35.15	35.96
568	0.956	17.72	97.202	7.36	12.88	4.90	3.77	35.71	35.38
579	0.979	15.80	108.156	7.21	12.83	5.17	4.14	36.00	34.65
591	1.002	16.96	98.106	7.12	12.86	6.28	3.79	35.90	34.05
603	1.025	17.39	95.539	6.85	12.73	6.21	3.66	35.13	35.41
614	1.044	18.98	86.078	6.78	13.06	6.14	3.79	35.43	34.81
626	1.063	21.55	73.909	6.66	13.17	6.61	3.56	35.58	34.41
638	1.078	23.87	64.543	6.54	13.31	6.09	4.10	35.49	34.47
649	1.091	24.99	60.117	6.61	13.57	4.80	4.46	35.92	34.64
661	1.105	24.94	60.261	6.59	13.79	4.43	4.72	36.14	34.33
673	1.119	24.58	61.391	6.74	13.97	4.21	4.63	36.44	34.02
684	1.132	24.90	60.339	6.65	14.06	4.11	4.72	36.64	33.82
696	1.145	24.95	60.155	6.76	14.04	4.50	4.85	36.63	33.23
708	1.159	24.97	60.092	6.74	14.07	4.86	4.97	37.16	32.20

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
719	1.172	24.86	60.438	6.69	14.11	5.17	5.04	37.74	31.25
731	1.186	23.90	63.960	6.60	14.17	5.34	5.45	38.37	30.05
743	1.201	23.02	67.148	6.82	14.18	4.97	6.09	38.81	29.13
755	1.217	21.40	73.678	6.81	14.47	4.74	5.76	39.33	28.88
766	1.233	23.61	66.624	6.91	14.73	4.59	6.15	39.64	27.97
778	1.248	25.74	59.971	7.00	14.83	3.95	6.29	39.45	28.48
790	1.259	29.06	48.864	6.95	15.18	3.74	6.04	39.60	28.50
802	1.270	29.66	47.480	6.82	15.35	3.63	5.55	38.83	29.83
813	1.280	30.96	44.683	7.03	15.45	3.33	5.66	38.94	29.59
825	1.290	30.97	44.670	6.90	15.30	3.34	5.52	38.25	30.68
837	1.300	30.23	46.393	6.95	15.32	3.55	5.45	38.03	30.71
849	1.311	29.63	47.587	7.14	14.95	3.61	5.54	37.45	31.31
860	1.321	28.01	51.906	7.25	14.89	4.11	5.65	38.05	30.05
872	1.333	25.83	59.057	7.22	14.77	4.23	5.52	38.10	30.17
884	1.348	23.75	64.569	7.48	15.10	4.16	5.32	38.67	29.26
896	1.364	26.72	57.590	7.56	15.22	4.04	5.69	38.72	28.77
907	1.374	30.45	47.084	7.60	15.10	3.98	6.03	37.72	29.56
919	1.383	32.81	41.011	7.70	15.16	4.16	6.39	37.22	29.36
931	1.393	31.81	42.916	7.54	15.22	4.03	6.71	36.77	29.73
943	1.403	31.85	42.827	7.62	14.89	3.79	7.21	35.62	30.87
955	1.413	33.50	39.977	7.55	14.80	4.17	6.86	35.91	30.71
966	1.421	32.14	43.248	7.34	15.11	4.49	6.69	36.21	30.16
978	1.431	34.32	39.906	7.55	15.09	3.95	6.52	35.86	31.02
990	1.441	33.82	40.683	7.89	15.07	4.16	6.20	35.54	31.14
1002	1.449	34.97	37.851	7.94	15.00	4.42	5.83	35.95	30.87
1014	1.458	30.66	46.071	8.13	15.10	4.89	6.05	33.95	31.88
1026	1.470	35.28	40.684	8.60	14.95	4.53	5.70	34.07	32.15
1038	1.478	35.22	40.809	8.70	15.03	4.40	5.30	33.93	32.64
1050	1.486	38.07	34.704	8.89	15.01	4.65	5.41	33.48	32.56
1061	1.495	33.80	39.540	9.06	15.11	4.61	5.73	32.86	32.63
1073	1.503	35.56	36.254	9.49	14.98	4.02	5.57	33.95	31.99
1085	1.511	34.43	38.271	9.75	15.06	4.37	5.76	34.33	30.74
1097	1.521	31.86	43.284	9.79	14.89	5.06	6.16	34.44	29.67
1109	1.531	29.66	47.596	9.94	15.04	5.46	6.66	34.00	28.90
1121	1.543	33.40	42.111	10.23	15.35	5.67	6.31	34.10	28.34
1133	1.551	38.41	33.978	10.26	15.42	5.87	6.29	33.47	28.68
1145	1.557	41.83	27.926	10.19	15.57	5.63	6.36	31.96	30.30

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
1156	1.563	42.77	26.964	10.68	16.01	5.83	6.34	31.79	29.36
1168	1.570	42.53	27.219	10.84	16.21	5.45	6.08	32.65	28.77
1180	1.576	42.13	27.764	10.54	15.99	5.50	6.04	32.73	29.19
1192	1.582	37.35	34.401	10.34	16.03	5.63	6.06	32.54	29.40
1204	1.591	37.67	34.061	10.62	16.01	5.79	5.62	33.17	28.80
1216	1.599	38.33	33.180	10.21	16.07	5.33	5.32	33.40	29.66
1228	1.606	41.19	28.639	9.96	15.83	5.59	4.95	32.61	31.05
1240	1.612	40.09	29.887	10.34	16.33	6.10	4.98	33.04	29.21
1252	1.619	41.60	28.181	10.35	16.41	6.13	4.90	33.55	28.65
1264	1.626	40.57	29.582	10.14	16.58	6.80	5.38	33.61	27.51
1276	1.632	41.75	28.249	10.11	16.37	7.00	5.45	32.84	28.23
1288	1.639	41.08	28.960	10.09	16.53	6.98	5.31	32.74	28.36
1300	1.645	43.50	25.988	9.89	16.15	6.57	5.17	31.68	30.54
1312	1.651	43.37	26.131	9.95	16.21	6.21	5.30	31.40	30.93
1324	1.657	43.74	25.723	10.04	16.00	5.94	4.87	30.87	32.29
1336	1.663	44.05	25.418	10.31	16.26	6.31	5.64	29.73	31.76
1348	1.669	48.43	21.864	10.25	16.29	6.63	6.22	28.26	32.35
1360	1.673	52.72	18.370	10.11	16.35	6.49	6.22	28.54	32.29
1372	1.677	53.28	17.840	10.29	16.66	6.84	6.18	27.67	32.36
1384	1.681	54.06	17.371	10.14	16.61	7.01	6.43	27.24	32.57
1396	1.685	50.73	19.916	9.78	16.54	6.95	5.67	28.94	32.12
1408	1.690	51.12	19.566	9.72	16.66	6.32	4.48	30.77	32.06
1420	1.695	47.49	22.124	9.53	16.49	6.43	4.52	30.37	32.65
1432	1.700	47.46	22.156	9.24	16.41	6.73	4.89	30.15	32.58
1444	1.705	50.86	19.720	9.24	16.51	6.42	4.56	30.45	32.83
1456	1.709	51.12	19.496	9.04	16.32	6.32	4.58	29.88	33.86
1468	1.713	51.87	18.829	9.06	16.05	6.65	5.33	29.53	33.38
1481	1.719	48.28	21.433	9.18	16.33	6.59	5.13	30.08	32.70
1493	1.724	48.66	21.122	9.30	15.87	6.83	4.56	31.56	31.89
1505	1.728	46.28	23.488	9.63	16.01	7.06	5.42	31.82	30.06
1517	1.734	47.35	22.598	9.75	15.87	7.40	5.20	31.64	30.14
1529	1.739	47.19	22.726	10.06	16.15	7.64	5.15	30.32	30.68
1541	1.744	54.01	17.404	10.19	16.02	8.31	5.26	30.00	30.21
1553	1.748	53.88	17.502	9.10	16.61	8.26	5.54	30.99	29.51
1565	1.751	55.19	16.517	8.71	16.47	8.02	4.84	31.26	30.70
1577	1.756	51.45	18.901	7.55	16.71	7.87	4.77	32.02	31.07
1589	1.760	51.97	18.506	7.36	16.58	7.87	4.92	33.66	29.61

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
1602	1.765	51.23	19.040	7.19	16.62	7.68	5.10	33.80	29.62
1614	1.769	51.87	18.561	8.43	16.26	8.13	5.19	32.68	29.31
1626	1.773	51.89	18.550	8.19	15.84	8.61	6.26	31.97	29.13
1638	1.777	50.92	19.329	9.44	15.47	8.68	6.46	31.24	28.72
1650	1.782	49.92	20.097	9.28	15.31	9.07	5.87	31.07	29.40
1662	1.787	49.98	20.048	9.54	15.40	9.59	6.02	31.50	27.96
1674	1.791	51.62	18.780	9.30	15.45	9.33	5.68	31.93	28.31
1687	1.796	53.03	17.720	10.11	15.59	9.37	5.06	31.93	27.93
1699	1.800	52.84	17.867	10.12	15.79	9.99	5.37	32.48	26.25
1711	1.804	53.21	17.608	10.17	15.66	9.98	6.29	32.52	25.39
1723	1.808	52.87	17.849	9.94	15.42	9.80	5.77	32.20	26.87
1735	1.812	53.27	17.553	9.91	15.30	10.33	5.51	31.88	27.06
1747	1.816	53.71	17.262	9.45	15.67	10.19	5.34	32.95	26.39
1760	1.820	54.58	16.668	9.32	15.36	9.95	5.67	32.33	27.36
1772	1.824	54.31	16.866	9.13	15.49	10.31	5.29	32.60	27.18
1784	1.828	54.17	16.958	9.22	15.38	10.47	5.48	32.63	26.81
1796	1.832	53.58	17.356	9.12	15.21	10.63	5.87	32.38	26.80
1808	1.836	54.27	16.863	8.84	14.90	11.39	5.85	32.03	26.99
1821	1.840	54.06	16.997	8.89	15.09	11.33	5.05	32.60	27.04
1833	1.844	54.65	16.602	9.04	14.97	11.14	4.74	32.76	27.35
1845	1.848	54.92	16.421	8.90	15.05	11.17	5.05	32.80	27.04
1857	1.851	55.23	16.217	8.63	15.15	11.21	5.33	32.88	26.80
1870	1.855	55.61	15.969	8.65	15.25	10.84	5.17	32.81	27.29
1882	1.859	56.00	15.718	8.75	15.41	11.29	6.01	33.12	25.42
1894	1.863	56.75	15.251	8.45	15.37	11.66	6.61	32.91	25.01
1906	1.866	56.76	15.244	8.36	15.33	11.76	6.88	33.07	24.61
1919	1.870	57.37	14.866	8.44	15.22	12.05	6.67	33.27	24.35
1931	1.873	56.99	15.097	8.77	15.28	12.59	6.84	33.63	22.90
1943	1.877	57.68	14.682	8.48	15.15	12.37	6.05	33.52	24.43
1956	1.880	57.68	14.682	8.59	15.18	12.41	5.74	33.46	24.63
1968	1.884	57.69	14.676	8.58	15.21	12.56	5.00	33.55	25.10
1980	1.887	57.52	14.775	8.72	15.73	12.94	4.67	34.69	23.24
1992	1.890	58.69	14.112	8.67	15.77	12.19	4.22	35.00	24.16
2005	1.894	59.69	13.519	8.84	15.77	12.75	4.18	34.76	23.70
2017	1.897	60.14	13.262	9.11	16.01	13.17	3.89	35.58	22.24
2029	1.900	60.14	13.259	9.10	15.84	13.16	4.14	35.27	22.50
2042	1.903	59.88	13.406	9.26	15.30	12.02	4.19	34.03	25.20

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	**Est. Al Conc.**	**CO_2 and CO**	**Total Offgas Flow**	**H_2**	**NO_2**	**N_2**	**O_2**	**N_2O**	**NO**
(sec)	**(M)**	**(vol %)**	**(cm^3/min)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**	**(vol %)**
2054	1.906	59.71	13.504	8.85	15.01	12.90	4.57	33.32	25.37
2066	1.909	59.08	13.855	9.12	15.03	12.60	4.95	33.92	24.38
2079	1.913	59.43	13.655	8.54	14.82	12.05	5.56	33.19	25.84
2091	1.916	59.88	13.404	8.77	15.50	12.70	4.62	33.92	24.49
2103	1.919	61.79	12.412	8.58	15.48	13.39	4.55	34.22	23.78
2116	1.922	61.99	12.300	8.69	15.29	13.13	4.78	34.36	23.75
2128	1.925	61.43	12.619	8.12	15.09	13.07	4.86	33.61	25.25
2140	1.928	59.58	13.574	8.50	15.35	12.92	4.59	34.48	24.16
2153	1.931	60.40	13.150	8.12	14.79	12.09	5.68	34.16	25.16
2165	1.934	61.37	12.612	7.75	14.78	12.11	6.00	34.23	25.13
2178	1.937	62.11	12.206	7.61	15.15	12.48	5.48	34.94	24.33
2190	1.940	62.12	12.199	7.78	15.19	12.53	5.09	35.39	24.02
2202	1.943	62.19	12.162	7.75	15.03	13.17	5.48	35.16	23.41
2215	1.946	62.61	11.949	7.60	14.63	13.18	5.41	34.55	24.63
2227	1.948	61.61	12.475	7.69	14.65	13.08	5.01	34.54	25.05
2240	1.952	61.98	12.282	7.63	14.56	13.06	5.64	34.27	24.85
2252	1.954	62.18	12.181	7.66	14.94	13.53	5.87	35.11	22.89
2264	1.957	63.96	11.277	7.71	14.97	12.72	5.00	35.09	24.52
2277	1.960	65.26	10.659	7.65	15.61	12.37	4.45	36.44	23.48
2289	1.962	66.00	10.306	7.79	15.78	12.87	4.98	37.17	21.42
2302	1.965	66.03	10.291	8.01	15.84	13.00	4.48	37.40	21.27
2314	1.967	65.63	10.473	8.01	15.70	12.95	4.35	37.51	21.47
2327	1.970	65.68	10.452	7.93	15.56	12.54	5.28	37.30	21.39
2339	1.972	65.69	10.446	8.20	15.39	13.13	6.12	37.16	20.00
2352	1.975	65.77	10.212	8.40	15.67	11.54	6.26	37.63	20.49

Appendix J. Raman Offgas Data for Experiment 101

As discussed in Appendix F, the Raman readings should be positive and sum to 100% except in cases where there is significant Ar present. Due to the noise in the Raman signal, any raw readings that are less than zero are fixed to zero and then all the gas readings for H_2, NO_2, N_2, O_2, N_2O, and NO are normalized to 100 vol %. Even with these corrections, the Raman readings have noise in them. To reduce this noise, moving averages of the fixed and normalized readings were performed using equation G-1.

These moving averages do not eliminate all the noise but smooth the values so comparisons and calculations can be performed. The fixed, normalized, and moving average Raman gas concentrations are reported in Table J-1. Due to rounding to the nearest hundredth, the numbers in the table may not sum to 100 vol % but all the decimal places were carried in the calculations performed for this report.

Since the CO_2 tracer gas was changed during this experiment, Table J-1 lists the tracer gas flow rates with respect to the cumulative reaction times.

Table J-1. Experiment 101 Raman Tracer Gas Flow Rates

Cumulative Reaction Time	CO_2 Flow
	(cm^3/min)
3-779	20
787-1133	30
1144-2662	50

Table J-2. Fixed Normalized Moving Average Raman Data for Experiment 101

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
3	0.001	79.63	5.117	1.64	3.89	4.08	3.57	48.88	37.94
14	0.002	81.01	4.706	1.28	3.89	4.42	3.76	49.15	37.51
26	0.003	81.16	4.657	1.28	3.89	4.60	3.70	48.67	37.86
37	0.003	81.06	4.688	1.54	4.15	4.61	3.59	48.76	37.34
48	0.004	79.83	5.053	1.09	4.18	4.74	4.26	48.42	37.31
59	0.005	79.93	5.021	0.96	3.94	3.25	3.79	46.24	41.82
71	0.006	80.39	4.880	0.92	3.93	3.12	3.23	46.16	42.65
82	0.007	80.34	4.895	1.16	3.91	2.88	2.43	47.20	42.42
93	0.008	80.33	4.898	0.88	3.63	3.18	2.08	47.52	42.70
104	0.009	80.07	4.978	0.92	3.60	3.23	2.19	47.73	42.33
116	0.010	80.17	4.946	0.86	3.50	4.05	2.48	46.96	42.15
127	0.010	80.26	4.920	0.87	3.43	3.80	2.28	47.79	41.84
138	0.011	80.24	4.926	0.62	3.39	3.30	2.18	48.11	42.40
149	0.012	80.49	4.848	0.69	3.29	2.53	1.83	48.28	43.38
161	0.013	80.28	4.913	0.64	3.00	2.74	1.39	47.98	44.25

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
172	0.014	80.35	4.891	0.91	2.93	1.91	1.56	48.51	44.18
183	0.015	79.90	5.032	1.77	3.09	2.03	2.19	47.90	43.01
195	0.016	73.77	7.547	3.09	3.02	2.73	2.37	46.96	41.83
206	0.017	62.41	13.684	4.20	2.98	3.42	2.72	46.21	40.48
217	0.020	47.41	24.455	5.43	2.98	3.64	2.71	45.48	39.75
229	0.026	36.40	37.211	6.41	2.78	4.43	2.35	44.68	39.34
240	0.034	28.27	53.431	6.32	2.41	5.00	1.95	43.71	40.62
251	0.045	25.70	58.861	5.81	2.19	5.06	4.08	42.11	40.75
263	0.057	21.66	76.703	5.44	2.08	5.07	4.03	41.33	42.06
274	0.070	22.26	74.331	4.90	2.01	4.71	3.94	41.08	43.35
285	0.085	18.43	92.385	4.47	1.94	4.69	3.95	40.21	44.74
297	0.102	20.80	79.633	4.26	1.84	4.68	3.64	39.88	45.70
308	0.117	18.63	90.478	4.27	1.82	4.85	1.27	40.53	47.26
320	0.132	19.39	85.037	4.01	1.76	4.85	1.25	40.60	47.52
331	0.149	17.43	94.799	3.99	1.66	4.81	1.29	40.44	47.80
342	0.165	17.88	91.941	3.83	1.59	4.76	1.35	40.70	47.78
354	0.182	18.06	90.825	3.72	1.49	4.51	1.43	40.93	47.91
365	0.198	18.43	88.542	3.60	1.40	4.39	1.45	41.14	48.02
376	0.213	18.79	86.500	3.55	1.30	4.44	1.35	41.41	47.95
388	0.230	19.38	83.348	3.48	1.24	4.49	1.25	41.98	47.56
399	0.244	19.98	80.149	3.47	1.18	4.22	1.01	42.49	47.62
411	0.259	20.40	78.052	3.56	1.15	4.19	1.04	42.87	47.18
422	0.272	21.03	75.255	3.65	1.12	4.16	0.93	43.01	47.14
434	0.286	21.62	72.583	3.75	1.10	3.98	0.96	43.43	46.78
445	0.298	21.94	71.168	3.70	1.08	4.06	0.97	43.61	46.58
456	0.311	22.68	68.421	3.86	1.08	4.39	1.00	43.73	45.94
468	0.324	23.01	67.118	3.99	1.06	4.56	0.87	43.89	45.63
479	0.335	23.64	64.646	4.09	1.07	4.95	1.00	44.13	44.76
491	0.347	23.74	64.318	4.34	1.09	4.86	1.07	44.26	44.37
502	0.358	24.50	61.701	4.63	1.11	5.08	1.09	44.37	43.72
514	0.370	24.76	60.798	4.71	1.10	4.86	1.20	44.50	43.62
525	0.380	24.80	60.677	4.94	1.12	5.07	1.28	44.67	42.93
537	0.392	24.71	60.950	5.07	1.13	4.90	1.31	44.83	42.77
548	0.403	25.59	58.271	5.04	1.13	5.15	1.25	45.04	42.39
560	0.413	26.29	56.166	5.01	1.13	4.98	1.31	45.24	42.32
571	0.423	27.14	53.701	4.98	1.16	5.30	1.22	45.40	41.93
583	0.433	26.93	54.277	4.97	1.14	5.13	1.18	45.63	41.95

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
594	0.442	27.29	53.329	4.96	1.16	5.08	1.36	45.71	41.73
606	0.453	27.60	52.539	4.90	1.18	5.44	1.45	45.48	41.56
617	0.462	28.14	51.076	4.97	1.21	5.57	1.41	45.43	41.41
629	0.471	28.53	50.121	4.93	1.25	5.72	1.51	45.39	41.20
640	0.480	28.81	49.445	4.91	1.31	6.05	1.30	45.22	41.21
652	0.489	29.78	47.204	4.78	1.31	6.12	1.03	45.41	41.36
663	0.497	30.43	45.770	4.77	1.35	5.85	1.09	46.04	40.90
675	0.506	30.41	45.810	4.54	1.36	5.84	1.20	46.39	40.68
687	0.514	30.94	44.756	4.53	1.34	5.65	1.23	46.55	40.70
698	0.522	31.50	43.664	4.39	1.32	5.36	1.50	46.61	40.82
710	0.530	33.09	40.469	4.43	1.33	5.46	1.49	46.52	40.77
721	0.537	33.76	39.275	4.46	1.29	5.79	1.32	46.06	41.08
733	0.544	34.37	38.193	4.67	1.28	6.05	1.32	45.62	41.06
744	0.551	35.07	37.046	4.58	1.30	6.12	1.19	45.70	41.10
756	0.558	36.01	35.602	4.53	1.31	6.33	1.24	45.95	40.64
768	0.565	37.52	33.358	4.46	1.33	6.26	1.44	46.11	40.41
779	0.570	38.23	32.093	4.43	1.35	5.89	1.34	46.45	40.55
787	0.572	69.60	13.323	6.13	4.93	7.40	4.04	49.23	28.27
799	0.575	63.28	17.679	6.54	4.20	6.96	3.21	44.46	34.63
810	0.578	57.47	22.632	6.59	3.46	7.61	2.45	40.38	39.51
821	0.582	51.18	29.164	6.58	3.02	7.70	1.76	37.91	43.02
833	0.588	46.43	34.969	6.41	2.64	7.85	1.55	35.43	46.12
844	0.594	42.13	41.550	6.37	2.37	8.67	1.54	33.24	47.81
856	0.602	38.61	48.297	6.41	2.16	9.11	1.54	31.58	49.20
867	0.611	35.43	54.959	6.36	2.01	8.76	1.58	30.50	50.80
879	0.621	33.30	60.185	6.27	1.88	8.57	1.82	29.62	51.84
890	0.631	31.92	64.109	6.24	1.74	8.46	1.68	29.07	52.81
902	0.643	30.53	68.379	6.23	1.63	7.72	1.51	29.17	53.74
913	0.655	29.84	70.549	6.25	1.59	7.47	1.24	30.02	53.43
925	0.667	30.94	67.342	6.27	1.51	7.23	1.27	30.10	53.61
936	0.678	31.25	66.286	6.29	1.43	6.88	1.13	30.11	54.16
948	0.689	31.07	66.904	6.21	1.38	6.63	1.10	30.32	54.35
959	0.701	29.77	70.795	6.19	1.36	6.48	1.26	30.31	54.41
971	0.714	29.98	70.121	6.13	1.28	6.26	1.27	29.55	55.52
982	0.725	30.29	69.044	6.18	1.24	5.89	1.20	29.55	55.95
994	0.737	30.94	67.014	6.22	1.21	5.79	1.07	29.79	55.92
1005	0.748	31.16	66.322	6.18	1.15	5.63	1.07	29.96	56.01

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
1017	0.760	31.58	65.012	6.20	1.11	5.27	0.98	30.20	56.24
1029	0.771	31.76	64.470	6.10	1.07	4.95	1.03	30.33	56.53
1040	0.782	32.14	63.359	6.04	1.07	4.96	1.04	30.51	56.37
1052	0.793	32.39	62.619	5.90	1.05	4.91	1.08	30.45	56.61
1063	0.803	32.52	62.249	5.87	1.05	5.04	1.15	29.93	56.95
1075	0.814	32.62	61.973	5.75	1.03	6.18	1.15	29.60	56.28
1086	0.824	32.26	63.043	5.65	1.03	6.22	1.10	29.62	56.38
1098	0.836	32.34	62.827	5.51	1.00	6.37	1.05	29.74	56.33
1109	0.846	32.07	63.607	6.30	1.00	6.24	1.24	29.37	55.85
1121	0.857	32.56	62.141	6.19	0.99	6.17	1.02	29.97	55.66
1133	0.868	32.59	75.575	6.22	1.02	5.29	0.95	30.36	56.15
1144	0.882	33.06	87.511	6.13	1.02	5.07	0.98	30.66	56.14
1156	0.900	32.77	102.660	6.10	1.03	4.89	0.98	30.66	56.34
1167	0.917	32.90	102.067	5.21	1.06	5.05	1.06	30.98	56.64
1179	0.935	33.46	99.680	5.19	1.09	4.89	1.28	31.01	56.55
1191	0.952	34.19	96.308	5.04	1.13	4.92	1.46	31.00	56.45
1202	0.968	35.48	91.143	4.97	1.17	5.19	1.56	31.11	56.01
1214	0.984	36.85	86.166	4.73	1.25	5.02	1.82	31.29	55.89
1225	0.997	39.18	77.805	4.56	1.34	4.85	1.76	31.81	55.68
1237	1.010	41.48	70.833	4.47	1.41	5.02	1.62	32.17	55.31
1249	1.022	43.15	66.036	4.18	1.49	5.30	1.46	32.57	54.99
1260	1.033	44.51	62.335	4.22	1.60	5.08	1.37	32.82	54.91
1272	1.044	45.21	60.641	4.51	1.64	5.23	1.06	33.23	54.33
1284	1.054	45.88	58.998	4.52	1.66	5.35	0.84	33.27	54.36
1295	1.064	46.36	57.846	4.53	1.71	5.25	0.87	33.45	54.20
1307	1.074	46.62	57.247	4.67	1.74	4.84	0.98	33.91	53.86
1319	1.084	47.26	55.812	4.72	1.72	4.99	1.04	33.87	53.64
1330	1.093	47.66	54.920	4.68	1.73	5.27	1.04	33.99	53.29
1342	1.103	48.40	53.324	4.76	1.70	5.17	1.14	34.33	52.89
1354	1.112	48.32	53.494	4.45	1.63	9.10	1.14	33.03	50.66
1365	1.121	46.59	57.754	4.52	1.59	9.29	1.29	32.76	50.55
1377	1.132	46.51	57.916	4.47	1.58	9.55	1.42	32.85	50.14
1389	1.143	46.62	57.697	4.42	1.54	9.49	1.62	32.59	50.35
1401	1.152	48.89	52.286	4.41	1.55	9.50	1.73	32.65	50.17
1412	1.161	48.88	52.300	4.72	1.59	5.34	1.89	34.08	52.39
1424	1.170	49.04	51.952	4.77	1.57	5.23	1.79	34.19	52.45
1436	1.179	48.95	52.152	4.82	1.58	5.47	1.61	34.48	52.03

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
1447	1.188	49.43	51.172	4.82	1.61	5.43	1.28	34.97	51.91
1459	1.197	50.15	49.732	4.84	1.60	5.17	1.27	35.05	52.05
1471	1.205	50.96	48.130	4.89	1.61	5.36	1.32	35.51	51.32
1483	1.214	51.19	47.671	4.99	1.60	5.42	1.35	35.76	50.88
1494	1.222	51.44	47.203	4.92	1.56	5.26	1.47	35.77	51.02
1506	1.230	51.29	47.491	4.92	1.53	5.07	1.78	35.85	50.86
1518	1.239	51.43	47.228	5.16	1.54	5.21	1.67	36.04	50.40
1530	1.247	51.77	46.604	5.25	1.50	5.34	1.48	35.81	50.62
1542	1.255	52.12	45.937	5.05	1.50	5.77	1.42	35.79	50.48
1553	1.263	52.26	45.670	5.05	1.50	5.65	1.25	35.96	50.60
1565	1.271	52.80	44.735	5.21	1.50	5.61	1.17	36.07	50.44
1577	1.279	53.05	44.279	5.03	1.49	5.86	1.15	36.24	50.23
1589	1.286	53.48	43.513	5.17	1.50	5.55	1.19	36.92	49.67
1601	1.294	53.25	43.896	5.43	1.50	5.17	1.20	37.53	49.17
1612	1.301	53.63	43.240	5.91	1.50	5.11	1.29	37.83	48.36
1624	1.309	53.61	43.263	6.32	1.51	5.31	1.53	38.54	46.78
1636	1.317	53.67	43.156	6.92	1.54	5.18	1.63	39.36	45.37
1648	1.325	53.59	43.295	7.46	1.54	5.44	1.73	39.66	44.16
1660	1.332	53.13	44.139	8.19	1.53	5.49	1.69	40.26	42.84
1672	1.340	52.80	44.709	8.75	1.51	5.52	1.75	40.77	41.70
1683	1.348	52.16	45.861	9.32	1.53	5.23	1.85	41.07	41.02
1695	1.356	52.08	46.012	9.67	1.53	5.32	2.07	41.20	40.22
1707	1.364	51.16	47.753	10.04	1.55	5.49	2.12	41.33	39.46
1719	1.373	50.80	48.441	10.35	1.61	5.56	2.02	41.50	38.97
1731	1.382	50.27	49.458	10.44	1.61	5.65	1.89	42.04	38.37
1743	1.390	50.16	49.677	10.47	1.60	6.24	1.56	42.09	38.04
1755	1.399	49.43	51.173	10.69	1.59	6.35	1.52	42.10	37.76
1767	1.409	48.74	52.603	10.68	1.55	6.45	1.14	42.61	37.56
1778	1.417	48.03	54.111	10.63	1.53	6.26	1.23	42.96	37.39
1790	1.427	48.05	54.071	10.53	1.54	6.59	1.28	42.78	37.29
1802	1.437	47.60	55.063	10.30	1.54	6.45	1.53	43.03	37.16
1814	1.447	47.13	56.132	10.03	1.53	6.80	1.43	43.19	37.02
1826	1.457	46.06	58.557	9.90	1.55	6.90	1.62	43.26	36.77
1838	1.467	46.13	58.408	9.72	1.55	7.15	1.96	43.13	36.49
1850	1.478	45.82	59.142	9.66	1.56	6.86	2.09	43.56	36.27
1862	1.488	46.31	57.991	9.62	1.56	7.22	1.62	44.05	35.94
1874	1.499	45.77	59.272	9.48	1.57	7.08	1.67	44.57	35.63

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
1886	1.509	45.83	59.129	9.29	1.57	7.25	1.72	44.88	35.30
1898	1.520	45.58	59.696	9.11	1.58	7.83	1.57	44.96	34.94
1910	1.531	45.77	59.253	8.92	1.56	8.09	1.24	45.10	35.10
1922	1.541	45.76	59.266	8.62	1.56	8.28	1.49	44.95	35.10
1934	1.552	45.59	59.681	8.50	1.55	8.61	1.55	44.66	35.14
1946	1.562	45.55	59.774	8.36	1.54	8.96	1.70	44.31	35.14
1958	1.573	45.39	60.156	8.09	1.51	9.07	1.56	44.29	35.48
1970	1.584	45.27	60.454	7.73	1.49	9.75	1.79	43.93	35.30
1982	1.595	44.96	61.201	7.68	1.46	9.94	1.86	43.75	35.31
1994	1.606	44.80	61.600	7.60	1.42	10.43	1.77	43.56	35.21
2006	1.617	44.09	63.428	7.40	1.39	10.77	1.62	43.62	35.20
2018	1.628	43.87	63.984	7.35	1.35	11.45	1.34	43.65	34.85
2030	1.640	43.41	65.204	7.40	1.35	11.83	1.27	43.94	34.22
2042	1.651	43.73	64.349	7.22	1.33	12.84	1.15	44.07	33.40
2054	1.663	43.33	65.417	6.91	1.31	13.78	1.01	43.97	33.04
2066	1.674	43.33	65.406	6.76	1.28	14.41	0.78	43.93	32.85
2078	1.686	43.13	65.939	6.38	1.26	14.99	1.08	43.78	32.51
2090	1.698	43.03	66.200	6.13	1.24	15.61	1.16	43.42	32.44
2102	1.710	43.36	65.331	5.86	1.25	16.09	1.22	43.08	32.51
2114	1.722	43.66	64.567	5.70	1.24	16.35	1.22	43.21	32.29
2126	1.733	44.53	62.293	5.47	1.24	16.86	1.42	43.32	31.69
2138	1.744	45.02	61.073	5.30	1.28	17.12	1.30	43.51	31.50
2150	1.755	45.64	59.557	5.04	1.28	17.60	1.15	43.84	31.08
2162	1.765	46.33	57.943	4.80	1.27	17.67	1.41	44.20	30.65
2174	1.775	47.21	55.952	4.59	1.29	18.00	1.38	44.56	30.19
2186	1.785	48.35	53.446	4.58	1.33	18.29	1.30	44.58	29.92
2198	1.794	49.06	51.930	4.38	1.33	18.75	1.46	44.81	29.27
2211	1.804	49.71	50.583	4.42	1.34	18.94	1.65	44.83	28.81
2223	1.813	50.09	49.823	4.42	1.38	19.11	1.56	45.01	28.53
2235	1.822	50.93	48.195	4.40	1.41	19.51	1.63	45.11	27.95
2247	1.830	51.86	46.434	4.13	1.41	19.59	1.87	45.30	27.71
2259	1.839	53.08	44.229	4.18	1.42	19.74	1.73	45.42	27.50
2271	1.846	54.30	42.115	4.02	1.47	19.63	1.84	46.00	27.03
2283	1.854	55.38	40.302	3.95	1.56	20.19	1.86	44.94	27.51
2295	1.861	56.62	38.344	3.82	1.58	20.03	1.88	45.46	27.23
2307	1.867	57.64	36.774	3.70	1.62	20.55	1.82	46.26	26.05
2320	1.874	58.83	35.005	3.47	1.65	20.69	1.81	46.28	26.10

		Tracer	Offgas Flow and Concentrations without tracers and water						
Cumulative Reaction Time	Est. Al Conc.	CO_2 and CO	Total Offgas Flow	H_2	NO_2	N_2	O_2	N_2O	NO
(sec)	(M)	(vol %)	(cm^3/min)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)	(vol %)
2332	1.880	59.09	34.620	3.44	1.65	21.15	1.67	46.43	25.66
2344	1.886	59.84	33.570	3.06	1.64	20.79	1.47	48.04	25.00
2356	1.892	60.73	32.371	2.82	1.68	21.27	1.44	47.97	24.81
2368	1.898	62.11	30.522	2.67	1.68	21.59	1.43	47.75	24.89
2380	1.903	62.91	29.478	2.52	1.70	21.74	1.48	47.88	24.69
2393	1.909	63.04	29.312	2.49	1.72	22.01	1.29	48.00	24.48
2405	1.914	63.30	28.991	2.58	1.75	22.40	1.33	48.27	23.67
2417	1.919	63.68	28.532	2.72	1.74	22.39	1.49	47.85	23.81
2429	1.924	64.46	27.572	2.56	1.77	22.06	1.77	47.64	24.20
2441	1.929	64.82	27.141	2.76	1.80	22.15	1.92	47.78	23.59
2454	1.934	65.32	26.546	2.57	1.81	22.03	2.13	47.76	23.69
2466	1.939	65.72	26.085	2.54	1.83	22.15	2.21	47.67	23.60
2478	1.944	66.70	24.970	2.29	1.86	22.00	2.29	48.37	23.20
2490	1.948	67.14	24.476	2.39	1.91	21.77	2.15	48.69	23.10
2503	1.953	68.23	23.302	2.31	1.98	21.72	2.22	49.17	22.60
2515	1.957	68.80	22.694	2.20	2.03	21.48	2.51	49.41	22.37
2527	1.961	69.76	21.674	2.23	2.09	21.34	2.57	49.65	22.12
2540	1.965	70.37	21.066	2.25	2.16	21.43	2.66	50.04	21.47
2552	1.969	71.39	20.050	2.31	2.18	21.74	2.99	50.44	20.33
2564	1.972	72.12	19.334	2.21	2.24	21.43	3.04	50.51	20.57
2576	1.975	72.71	18.769	2.19	2.30	21.02	2.98	51.05	20.45
2589	1.979	73.32	18.202	1.97	2.41	20.67	3.07	51.84	20.05
2601	1.982	74.61	17.037	1.90	2.44	20.57	2.76	51.91	20.41
2613	1.985	75.40	16.323	1.79	2.46	19.83	2.66	52.72	20.54
2625	1.988	76.44	15.417	1.63	2.52	19.41	2.85	53.24	20.34
2638	1.991	77.00	14.943	1.25	2.62	18.53	2.93	54.11	20.56
2650	1.994	78.09	14.031	1.33	2.69	17.98	2.97	55.09	19.93
2662	1.996	78.34	13.380	1.19	2.87	16.63	3.27	56.86	19.18

Distribution:

T. B. Brown, 773-A
M. E. Cercy, 773-42A
D. A. Crowley, 773-43A
D. E. Dooley, 773-A
A. P. Fellinger. 773-42A
S. D. Fink, 773-A
C. C. Herman, 773-A
D. T. Hobbs, 773-A
E. N. Hoffman, 999-W
J. E. Hyatt, 773-A
K. M. Kostelnik, 773-42A
B. B. Looney, 773-42A
D. A. McGuire, 773-42A
T. O. Oliver, 773-42A
F. M. Pennebaker, 773-42A
G. N. Smoland, 773-42A
B. J. Wiedenman, 773-42A
W. R. Wilmarth, 773-A
S. J. Roberson II, 704-2H
K. P. Burrows, 704-24
P. M. Palmer, 704-2H
C. M. Hadden, 704-2H
W. H. Clifton Jr, 704-2H
A. C. Carraway, 211-18H
T. L. Tice, 221-H
J. B. Schaade, 703-H
R. T. Burns, 221-H
S. A. Yano, 704-2H
J. R. Lint, 704-2H
A. D. Meredith, 704-2H
K. J. Usher, 704-2H
Records Administration (EDWS)